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Spatial and Temporal Analysis of Oceanographic Parameters and Their Relationship with Upwelling Phenomena in Seram Sea and Buru Island Waters

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ABSTRACT

The waters of the Seram Sea and Buru Island are comparatively rich in resources and productivity. However, many fishermen continue to rely on intuition or instinct to locate fishing spots. Therefore, understanding the significance of oceanographic parameters as indicators of water's primary productivity is crucial. This study utilizes data from January 2010 to December 2020, including oceanographic parameters such as sea surface temperature (SST) and chlorophyll-a concentration from AQUA-MODIS satellite imagery, wind data from ECMWF reanalysis, and fish catch data from Fishing Spot Galala-Hative Kecil.The research aimed to examine the variability of sea surface temperature, chlorophyll-a, and surface winds, and their relationship with the upwelling phenomenon in Seram Sea waters and Buru Island. Data were processed spatially using script methods in the Grads 2.2.1 application and temporally using statistical methods in MS Excel, followed by correlation analysis using Pearson correlation.The results indicate that sea surface temperature, chlorophyll-a, and winds exhibit greater variability from May to August. Upwelling potential in these waters occurs from June to August and continues through September and October, characterized by strong upwelling. This is evidenced by low sea surface temperatures ranging from 26°C to 27.7°C, chlorophyll-a concentrations ranging from 0.5 to 1.2mg/l, and wind speeds during this period ranging from 3.9 to 6.4m/s. Additionally, correlation tests reveal that sea surface temperature and chlorophyll-a in the study area from May to August have a linear correlation with fish catch (CPUE), with values of 0.52 and 0.56, respectively.

INTRODUCTION

Geographically, Indonesia is situated in the tropical region, stretching between 95° E – 141° E and 6° N – 11° S, with the majority of its area comprised of the sea (70%), known as the "maritime continent" **(Ramage, 1971)**. With a maritime area covering 3.25

million km^2 and a Zone Exclusive Economic (ZEE) spanning 2.55 million km^2, Indonesia heavily relies on life above and below the ocean. One of the human activities closely related to the sea is fishing. This is due to the abundant biodiversity potential (fish) in the Indonesian waters. In determining fishing grounds, fishermen tend to rely on intuition or instincts passed down from ancestors. As a result, they have not been able to develop fishing operation plans due to changes in oceanographic conditions or weather that significantly affect changes in fish catch potential **(Kumaat *et al.*, 2018)**. Meanwhile, oceanographic conditions can be used as indicators of the fertility of waters by understanding the variability of oceanographic parameters, such as sea surface temperature, chlorophyll-a, and wind. Observations of sea surface temperature and chlorophyll-a distribution as indicators of the primary productivity level of water can be conducted not only directly through *in situ* measurements but also indirectly through satellite image observations **(Amri *et al.*, 2005**). This is supported by the study of **Insanu *et al*. (2013)** who postulated that marine parameters obtained using remote sensing data will be faster, more effective, efficient, and able to cover a wider coverage area.

Upwelling is an oceanographic phenomenon triggered by strong winds, characterized by low sea surface temperatures, and typically resulting in the upward movement of nutrient-rich water masses to the ocean surface **(Setianto *et al.*, 2019)**. Monitoring of upwelling phenomena using satellite imagery has been conducted in several locations, such as observations of upwelling in the waters from South East Java to South Lombok by **Raditya *et al*. (2013)**, utilizing Aqua MODIS level 3 imagery as a provider of sea surface temperature information over 4 years (2007 – 2011). Next, the upwelling phenomenon has been monitored through satellite image data comparison between EOS Aqua/Terra Modis and NOAA AVHRR **(Sunarernanda *et al.*, 2016)**. The study found that upwelling in these waters is influenced by wind pressure generated by the southeast season winds. The objectives of this study were to identify the variability of sea surface temperature and chlorophyll-a during upwelling events and to detect the distribution patterns of upwelling in the southern waters of Java over this period. Parameters used to determine upwelling included sea surface temperature, chlorophyll-a, geostrophic currents, sea surface height, and wind.

MATERIALS AND METHODS

1. Study area and sampling

The study area is located in the Seram waters and Buru island (Fig. 1) with geographical coordinates between 2-7°S and 125-132°E.

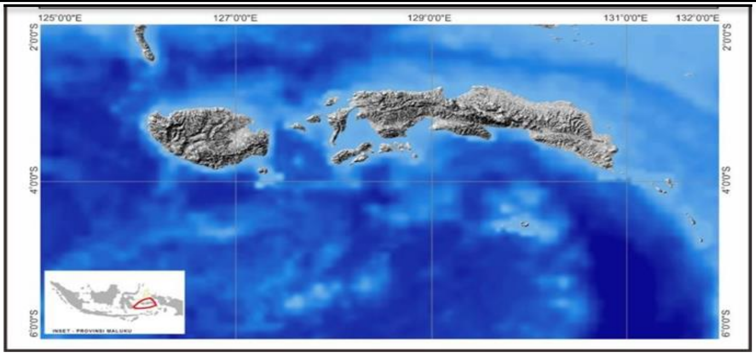


Fig. 1. Research site **(Titaley *et al.*, 2024)**

The data used in this study are sea surface temperature, chlorophyll-a, wind distribution and fish catch results. Here is a detailed description of the collection methods for each dataset:

- Sea surface temperature and chlorophyll-a data were extracted from near real-time AQUA MODIS satellite imagery. The data used are daily averages with a 4km level 4 and a resolution of 0.250 x 0.250, downloaded from the Marine Copernicus website (https://resources.marine.copernicus.eu/) for the period extending from January 2010 to December 2020.
- The wind data were obtained from daily mean reanalysis data downloaded from the NOAA website (https://ncdc.noaa.gov/). The data have a spatial resolution of 0.25 x 0.25 and consist of zonal (U) and meridional (V) component data at a height of 10 meters. The data cover the period from December 2016 to November2020.
- The fish catch data include details such as vessel name, FAD (Fish Aggregating Device) position, vessel type, fishing gear units, total catch by fish species, and so forth. These data were obtained from PPP-Galala Ambon for the period from 2016 to 2020.

2. Methods

2.1 Sea surface temperature and chlorophyll-a

Spatial and temporal distribution of sea surface temperature and chlorophyll-a were determined by interpreting AQUA-MODIS images that have been downloaded and mapped. The downloaded data in netcdf format (.nc) were extracted using two methods: first, using ODV application to convert netcdf data format into a text spreadsheet format (.txt) for easy display and analysis in Microsoft Excel temporally. Secondly, using QGIS application to display sea surface temperature and chlorophyll-a data in the form of maps and analyze them spatially. Graphs and tables were utilized to display the monthly distribution values of sea surface temperature and chlorophyll-a based on station points or sample areas. Subsequently, interpretation was carried out regarding the variability of sea surface temperature and chlorophyll-a parameters, and the identification of potential upwelling strength based on the upwelling criteria outlined in the study of **Lumban Gaol *et al*. (2018)**.

2.2 Wind distribution

The downloaded data were extracted using Ferret v6.842 software with a simple scripting or programming language to access the wind direction and speed components *u* and *v*. The programming language employed enables cropping according to the coordinates of the research location, compiling reanalysis data for average seasonal periods of 5 years, and generating images in (.png) format. Spatial interpretation was conducted to discern the variability of wind patterns in the waters surrounding Seram sea waters and Buru Islands. Data were further selected based on coordinates, then grouped and averaged monthly for the period from 2016 to 2020 using a simple average formula. Before obtaining the average wind speed value from the zonal (u) and meridional (v) components, the wind resultant value was calculated as follows, based on the method described by **Utami *et al*. (2018)**:

$$C = \sqrt{(u)^2 + (v)^2}$$

C : resultant wind speed (m/s)
u : wind speed in the East-West direction
v: wind speed in the North-South direction

Graphical tables were employed to display the monthly average wind speed based on sample regions. Temporal interpretation was conducted to discern the variability of wind speed.

2.3 Catch productivity

According to **King (1995)** as cited in **Purnamaningtyas *et al*. (2006)**, the analysis of catch productivity indicators used is the catch per unit effort (CPUE) with the formula:

$$CPUE = \frac{Ci}{Ei}$$

CPUE: catch per unit effort (kg/trip)
Catch (C_i): catch in month i (kg)
Effort (E_i): effort in month i (trips/month)

2.4 Correlation test between parameters

The correlation test aims to observe fluctuations and measure the strength of relationships between variables. After identifying the variability in sea surface temperature, chlorophyll-a, and wind distribution in each sample area, the relationships among these parameters and fish catch and CPUE were analyzed using the Pearson correlation method.

According to **Hasan (2003)**, the general formula for correlation (Pearson Product Moment) is presented as follows:

$$r = \frac{n\sum\sum_{i=1}^{n} x_i y_i - (\sum_1^n x_i)(\sum_1^n y_i)}{\sqrt{n\sum_1^n x_i^2 - (\sum x_i)^2} - n\sum_1^n y_i^2 - (\sum y_i)^2}$$

r : correlation coeficient/*Pearson*
x_i : Ocenographic Parameters (Sea Surface Temperature, Chlorophyll-a and Wind)
y_i : Fish Catch/CPUE

RESULTS AND DISCUSSION

Sea surface temperature distribution by monthly period

The research sample areas were randomly selected, comprising 10 sample points. It is assumed that sample area 1 (1-5 points) represents the northern part of the research area, while sample area 2 (6-10 points) represents the southern part of the research area, as shown in Table (1).

Table 1. Sample area coordinate

Sample area	Latitude	Longitude
1	2.27^{0}S – 3.35^{0}S	125.03^{0}E – 126.48^{0}E
2	2.27^{0}S – 3.35^{0}S	126.52^{0}E – 127.65^{0}E
3	2.27^{0}S – 3.35^{0}S	127.65^{0}E – 128,90^{0}E
4	2.27^{0}S – 2.98^{0}S	129.06^{0}E – 130.19^{0}E
5	2.27^{0}S – 3.31^{0}S	130.31^{0}E – 130.90^{0}E
6	3.35^{0}S – 4.31^{0}S	125.77^{0}E – 126.73^{0}E
7	3.19^{0}S – 4.31^{0}S	127.60^{0}E – 128.06^{0}E
8	3.19^{0}S – 4.31^{0}S	128.10^0 E – 128.94^{0}E
9	3.31^{0}S – 4.31^{0}S	129.48^{0}E – 130.35^{0}E
10	3.65^{0}S – 4.31^{0}S	130.40^{0}E – 131.44^{0}E

Generally, the average of sea surface temperature (SST) variability over a 10-year period (2010-2020) in Seram Sea waters and Buru Islands (Table 2) reveals a range between 26.4 & 31.3°C.

Table 2. SST value in sample area and research time

Samplearea	**Station point**	**Month (^0C)**											
		12	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
I	1	30.40	29.39	29.71	29.71	30.13	30.03	28.88	27.93	26.88	26.66	27.34	28.62
	2	30.23	29.66	29.83	29.83	30.21	29.96	29.31	28.57	26.79	26.55	27.33	29.12
	3	30.34	29.38	29.67	29.67	30.13	30.00	29.88	27.99	26.92	26.71	27.39	28.61
	4	30.40	29.39	29.68	29.68	30.16	30.02	29.90	28.01	26.99	26.72	27.42	28.62
	5	30.38	29.34	29.66	29.66	30.14	30.03	28.92	28.05	26.98	26.77	27.45	28.66
II	6	30.40	29.73	29.83	29.83	30.34	29.97	30.36	28.50	26.70	26.49	27.22	29.02
	7	30.27	29.61	29.82	29.82	30.23	30.03	30.34	28.55	26.80	26.58	27.33	29.13
	8	30.20	29.59	29.77	29.77	30.10	30.01	30.32	28.57	26.86	26.62	27.43	29.20
	9	30.29	29.75	29.85	29.85	30.29	29.97	30.34	28.51	26.66	26.44	27.19	29.13
	10	30.36	29.40	29.64	29.64	30.07	30.03	29.96	28.11	27.01	26.78	27.45	28.65

Based on monthly average data over a 10-year period (January 2010-December 2020), SST values remain stable during the second transition season (September-November). SST increases during the west season (December-February) and first transition seasons (Maret-Mei), and decreases during the east season (June-August). Analysis of satellite imagery of SST during the west season, first transition, east season, and second transition seasons (Fig.2) indicates spatial and temporal fluctuations in SST. During the west season (Fig. 2a), SST ranges from 29 to 31°C, evenly distributed across the Maluku Sea. December marks the beginning of the west season. The First transition season (Fig. 2b) shows similar SST distribution to the west season, but with a 2°C decrease. March marks the beginning of the first transition season. June marks the beginning of the east season (Fig. 2c), characterized by lower SST values ranging from 26 to 29°C, predominantly in the east season due to the movement of relatively warmer water masses. September marks the beginning of the second transition season (Fig. 2d), with SST distribution similar to the east season, but with more widespread coverage compared to the east season.

During the west season, the apparent position of the sun is in the southern hemisphere, so the heat received is less than that recorded during the eastern season **(Hestiningsih *et al.*, 2017)**. This means that the distribution of sea surface temperatures in the Northern Hemisphere tends to be cooler compared to the Southern Hemisphere. This is indicated by the relatively low distribution values in the east season (Fig. 2c). During the eastern season, the water temperature is lower because it is influenced by cold water masses.The sea surface temperature conditions during the eastern season and the second transition period (Fig. 2c, d) generally show an increase. This is due to the position of the sun being in the Northern Hemisphere, allowing an optimal sunlight penetration to be received by the sea surface. The observed decrease in sea surface temperature (SST) values in the eastern part of the Seram Sea, compared to the western part, is likely associated with the upwelling phenomenon. This process allows the transport of warm or cold water masses from other areas, affecting sea surface temperature values **(Meilani, 2016)**. The strong eastern wind speeds push water masses from the Maluku Sea toward the west. As a result, the temperature in the eastern part of the Seram Sea waters decreases because cold water masses from the depths rise to the surface.

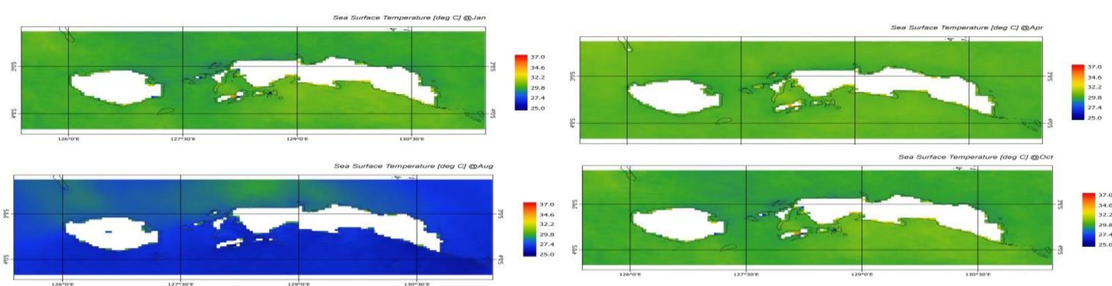
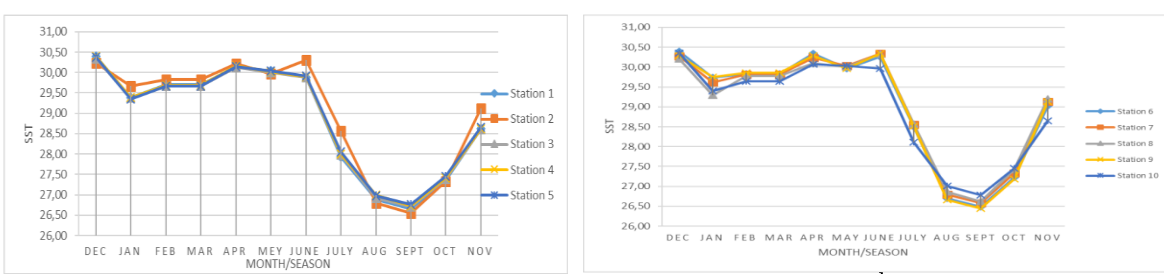


Fig. 2. Chlorophyll-a value in season (a) West, (b) Transition I, (c) East, (d)Transition II



a b

Fig. 3. Variability of sea surface temperature values for **(a)** Sample area 1 **(b)** Sample area 2

In general, the sea surface temperature values in sample area 1 range between 26.77 and 30.00°C, with the warmest temperatures remaining relatively stable during the December-Januari-February and March-April-Mey periods. The temperature values decrease during the July-August-September-October period and increase during the March-April-May period. The pattern of sea surface temperature fluctuations in sample area 1 is presented in a graph, as shown in Fig (3). This is suspected to be related to the upwelling phenomenon. This process allows the transport of warm or cold water masses from other areas, affecting sea surface temperature values **(Meilani, 2016)**. The strong eastern wind speeds push water masses from the Maluku Sea toward the west. As a result, the temperature in the eastern part of the Seram Sea waters decreases because cold water masses from the depths rise to the surface.

Furthermore, the sea surface temperature values in the sample area 2 range between 28.30 and 29.70°C, with temperatures relatively fluctuating during the June-July-August and September-October-November periods. The sea surface temperature values decrease during the December-January-February period and increase during the March-April-May period. The pattern of sea surface temperature fluctuations in sample area 2 is presented in a graph, as shown in Fig. (3). Based on the above explanation, the fluctuation in temperature values between the station points shows that the average range in sample area 1 tends to be warmer compared to sample area 2. Basically, sea surface temperatures in Indonesia are influenced by monsoon winds, therefore the distribution of sea surface temperatures will follow the seasonal change patterns **(Sunarernanda *et al*., 2017)**. The fluctuation of sea surface temperature values in sample area 2 (Table 2, Fig.3), particularly during the June-July-August and September-October-November periods, is suspected to be influenced by strong monsoon winds that push water masses in the area. This condition causes the rise of water masses from the sea floor, which have cooler temperatures, to the surface. The rise of water masses from the sea floor to the surface requires time (time lag) to fill the void of water masses at the sea surface. This time lag causes lower sea surface temperatures **(Hestiningsih *et al*., 2017)**.

Chlorophyll distribution by monthly period

The variability of the average chlorophyll-a concentration distribution over ten years (2010-2020) in the Seram sea waters and Buru Island (Table 3) tends to show relatively low and homogeneous values ranging from <0.21 to 1.2mg/m^3 in each month period. Data were collected from December to November because the data analysis was categorized by seasons: west season (December-February), transition season 1 (March-May), east season (June-August), and transition season 2 (September-November). During the west season (Dec-Feb) and the first transition period, high concentrations were predominantly found in coastal areas (Fig. 4a, b). This is suspected to be influenced by runoff from the land as a result of high rainfall during this season.

Table 3. Chlorophill-avalue in sample area and research time

Sample area	Station point	Month (mg/m^3)											
		12	1	2	3	4	5	6	7	8	9	10	11
I	1	0.26	0.27	0.23	0.23	0.25	0.35	0.48	0.53	0.57	0.51	0.38	0.32
	2	0.30	0.31	0.27	0.26	0.28	0.37	0.51	0.56	0.65	0.52	0.40	0.34
	3	0.30	0.31	0.27	0.26	0.28	0.37	0.51	0.56	0.65	0.52	0.40	0.34
	4	0.32	0.31	0.27	0.27	0.27	0.34	0.46	0.50	0.85	0.39	0.35	0.33
	5	0.29	0.32	0.26	0.29	0.32	0.44	0.55	0.57	0.70	0.51	0.41	0.35
II	6	0.22	0.23	0.22	0.22	0.24	0.40	0.72	0.79	1.01	0.78	0.48	0.31
	7	0.21	0.21	0.21	0.21	0.21	0.34	0.66	0.63	1.20	0.61	0.42	0.29
	8	0.21	0.21	0.21	0.21	0.21	0.38	0.63	0.75	0.76	0.67	0.42	0.30
	9	0.22	0.24	0.22	0.22	0.23	0.39	0.69	0.78	0.81	0.69	0.43	0.31
	10	0.20	0.23	0.22	0.21	0.23	0.37	0.71	0.81	1.00	0.75	0.44	0.29

Based on the distribution of chlorophyll-a concentration during the east season and the second transition period, high concentrations are predominantly found in the eastern-southeastern waters of Seram Sea waters (Fig.4c, d). The high concentration of chlorophyll-a in the eastern-southeastern waters of the research area is due to the upwelling phenomenon, which is marked by low sea surface temperatures in the area.

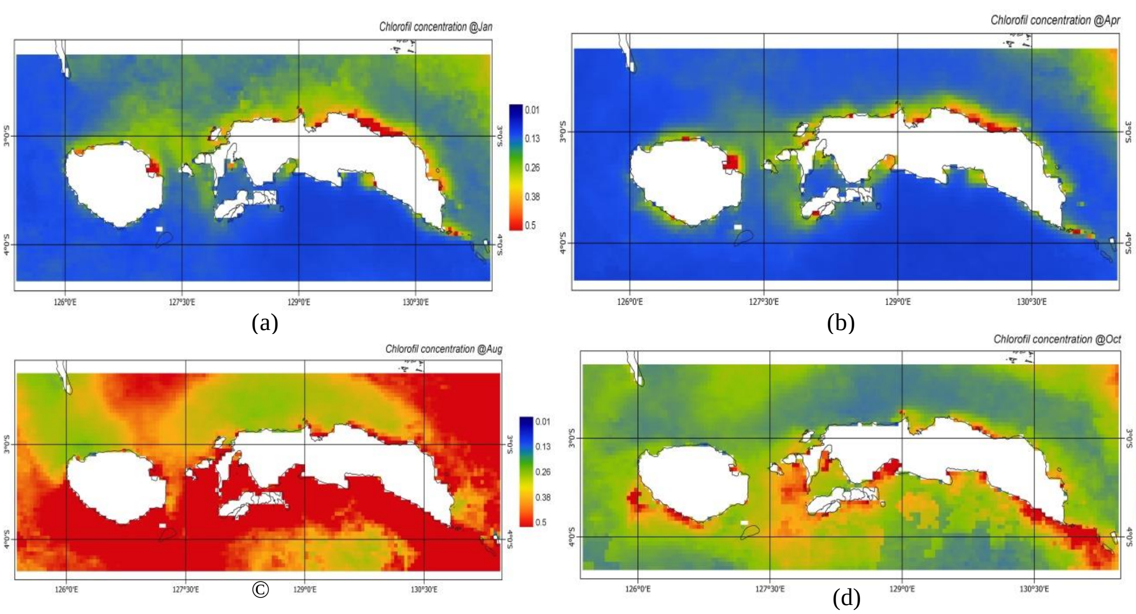
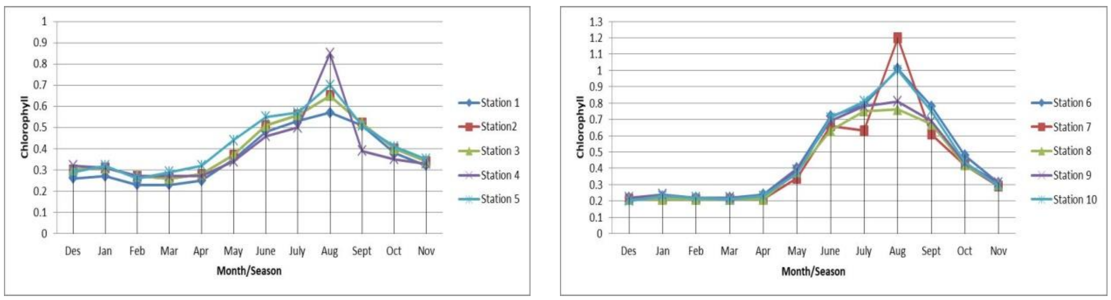


Fig. 4. Chlorophyll-a value in season (a) West, (b) Transition I, (c) East, (d)Transition II

The chlorophyll-a concentration values in the waters of research area for sample area 2 range from 0.21to 1.2mg/m^3, with an increasing fluctuation pattern during the periods of June-July-August and September-October-November **(Titaley *et al*, 2024)**. The chlorophyll-a concentration values begin to decrease during the period of December-January-February and March-April-May. The fluctuation pattern of chlorophyll-a concentration values in sample area 2 is presented in a graph form, as shown in Fig. (5). Based on the explanation above, the fluctuation of chlorophyll-a concentration values among station points indicates that the range of average values in sample area 1 tends to be lower than in sample area 2.



(a) (b)

Fig. 5. Variability of sea surface temperature values for (a) Sample area 1 (b) Sample area 2

The fluctuating concentration of chlorophyll-a in sample area 2 (Table 3 & Fig. 4) is suspected to be influenced by several factors, such as wind speed over the water and rainfall as a result of the interaction between the ocean and the land. The increase in chlorophyll-a concentration during the western season is due to the movement of winds from the Pacific Ocean carrying water vapor or moist air masses, leading to increased rainfall in the Seram Sea waters and Buru island. This condition results in generally high chlorophyll-a concentrations in the coastal waters attributed to the high nutrient supply from the land through river runoff, which decreases toward the open sea **(Meilani, 2016)**.

On the other hand, the increase in chlorophyll-a concentration during the eastern season is ascribed to strong monsoon winds pushing the water masses in the area. The strong winds blowing over the sea surface push the surface water, creating a void. Water from below then rises to fill this void, bringing cooler temperatures and lots of nutrients **(Setianto *et al.*, 2020)**.

Surface wind speed

In general, the wind speed values in the waters around the Seram Sea waters and Buru Island do not show significant differences, both on the west and east sides. This is because the wind measurements are taken at a height of 10 meters above sea level. According to

Wahid (2018), at a height of 10 meters and above, the wind is considered to be approaching stability because the gradient values become smaller. Therefore, the explanation for the variability in wind speed values in the Seram Sea waters and Buru island will be based on the study period. Based on the average monthly data over a 5-year period (December 2016 - November 2020), the surface wind speed values in the Seram Sea waters and Buru Island were obtained according to station points and study periods (Table 4 & Fig. 6). Generally, the wind speed values in the Seram Sea waters range from 2.32 to 6.38m/s, with a fluctuating pattern increasing during the periods of December-January-February and June-July-August. Wind speed appears to decrease during the periods of March-April-May and September-October-November. The fluctuating pattern of wind speed in the Seram sea waters and Buru island waters is presented in a graphical form, as shown in Fig. (6).

Table 4. Surface wind speed in sample area and research time

Station point	**Month (m/s)**											
	12	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	1.45	2.12	2.28	1.03	0.78	1.88	1.86	1.52	1.35	0.86	0.41	1.65
2	1.49	2.45	2.54	0.84	0.94	1.99	2.05	1.70	1.56	1.00	0.41	1.54
3	1.36	1.45	1.48	0.40	0.99	1.90	2.07	1.77	1.57	1.08	0.49	0.75
4	2.32	1.82	2.03	0.28	2.37	4.14	4.28	3.70	3.43	2.39	1.24	0.96
5	2.88	3.13	3.28	0.63	3.57	5.52	5.50	4.80	4.59	3.42	2.00	1.41
6	2.88	3.98	3.91	0.98	4.16	5.94	5.85	5.09	4.92	3.80	2.37	1.45
7	3.24	4.68	4.39	1.32	4.70	6.28	6.14	5.31	5.17	4.08	2.61	1.39
8	3.52	5.20	4.69	1.68	5.21	6.58	6.38	5.52	5.40	4.30	2.82	1.27
9	3.76	5.60	4.84	2.00	5.72	6.83	6.59	5.74	5.64	4.48	2.95	1.13
10	3.90	5.94	4.93	2.16	5.74	6.73	6.47	5.66	5.62	4.43	2.93	1.00

Wind always blows from areas with high air pressure (maximum) to areas with lower air pressure (minimum) **(Tjasyono, 2006 as cited in Sultan, 2018)**. This indicates that the greater the difference in air pressure, the stronger the wind speed will be. Among the months experiencing an increase in wind speed, August stands out as having the highest wind speed values. August falls within the eastern season, which is known for having the highest wind speeds compared to other seasons **(Utami *et al.*, 2018)**. The relatively high wind speed values during the eastern season result in a greater potential for upwelling events in the Seram Sea waters and Buru island.

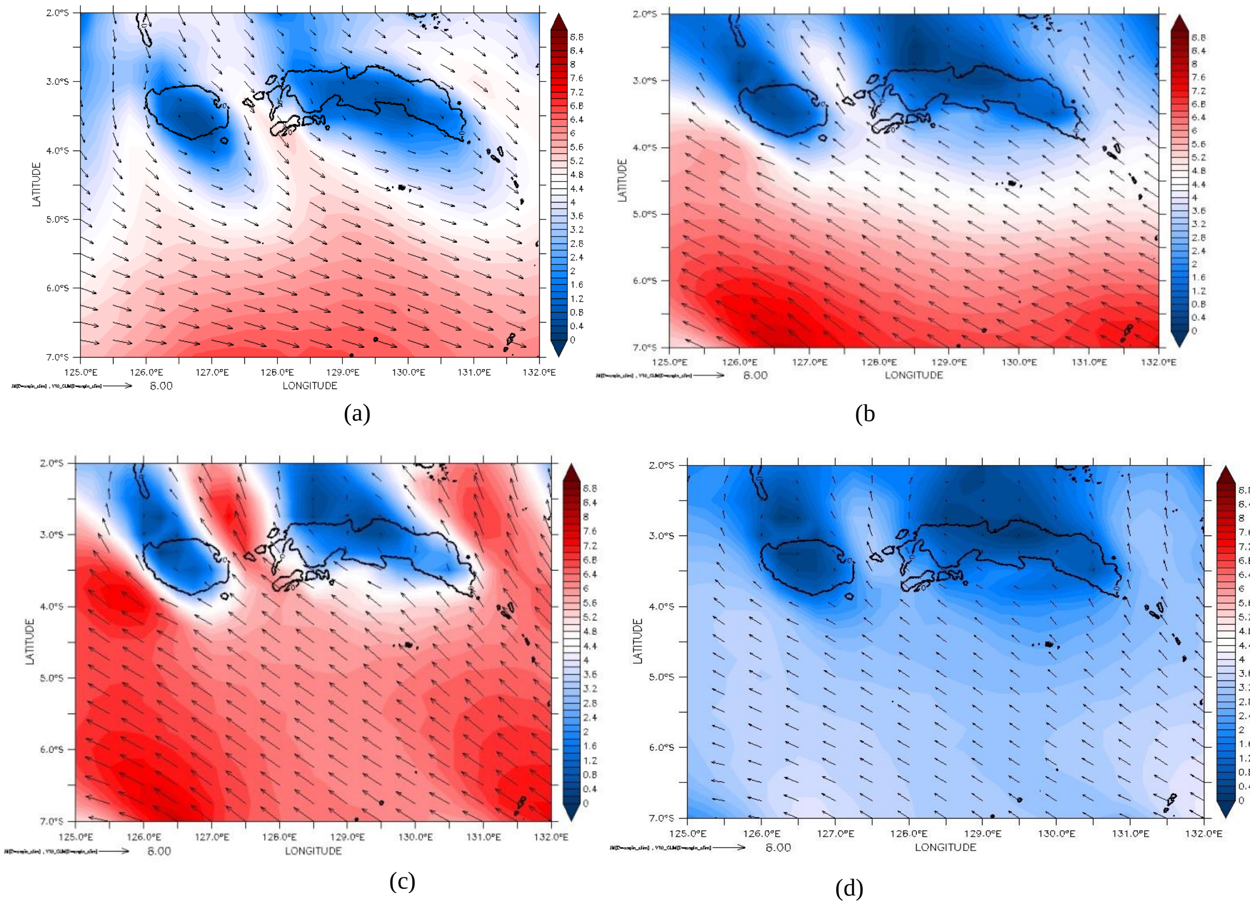


Fig. 6. Surface wind speed in season (a) West, (b) Transition I, (c) East, (d)Transition II

Identifying upwelling potential using sea surface temperature and chlorophyll-a

Upwelling is when cooler and denser seawater from the ocean floor moves up toward the surface due to the influence of wind movement on the sea surface. This movement typically brings essential nutrients needed for phytoplankton growth near the ocean surface, becoming a food source for marine life **(Rizqi, 2016 as cited in Putra *et al.*, 2017)**. The potential occurrence of upwelling has a positive impact on marine environments, as nutrients from deeper layers rise to the surface, enriching the water. This condition improves further if the water surface receives sufficient sunlight, enhancing primary productivity **(Putra *et al*, 2017)**.

Based on monthly average data over a 10-year period (January2010–December2020), a compilation of sea surface temperature and chlorophyll-a concentration data grouped by seasonal periods was obtained (Figs.7, 8). The process of determining upwelling potential and its criteria is based on the average range of sea surface temperature and chlorophyll-a concentration values.

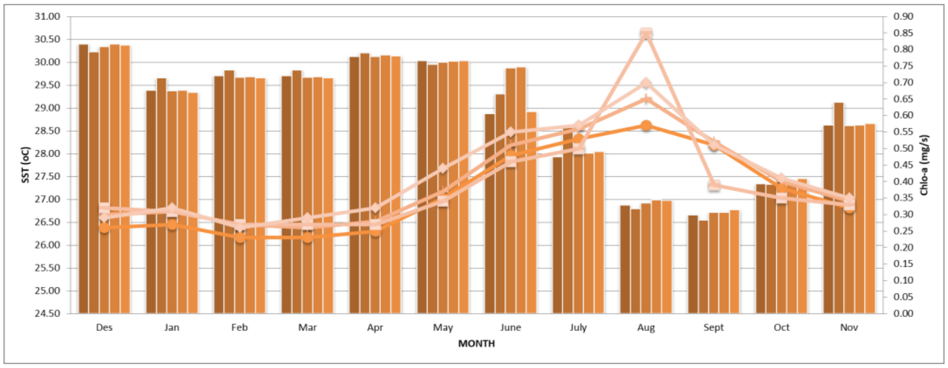


Fig. 7. Upwelling potential based on sea surface temperature and chlorophyll-a concentration parameters for sample area 1

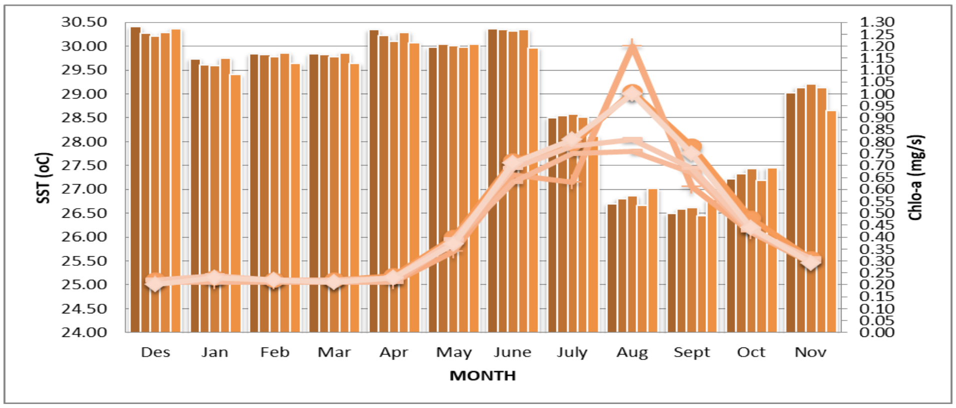


Fig. 8. Upwelling potential based on sea surface temperature and chlorophyll-a concentration parameters for sample area 2

Fig. (7) shows a decrease in temperature and an increase in chlorophyll-a across all points in sample area 1 from the first transition period to the eastern season. This indicates a strong potential for upwelling in that area. Fig. (8) depicts fluctuations in temperature and chlorophyll-a throughout the seasons. This suggests a strong potential for upwelling in that area. Therefore, the upwelling potential tends to be higher during the eastern season in sample area 2.

Relationship between sea surface temperature, chlorophyll-a, and wind on the upwelling phenomenon

Table 5. Distribution of SST, chlorophyll-a and wind sample area 1

Upwelling	SST		Chlorophyll-a		Wind	
	Max	Min	Max	Min	Max	Min
Weak	> 29.0	29.0	0.43	<0.43	3.6	< 3.6
Medium	28.9	27.44	0.64	0.44	4.50	3.6
Strong	27.9	26.50	0.80	0.65	5.50	4.50
Very Strong	26.55	< 26.55	> 0.85	0.85	>5.52	5.52

Table 6. Distribution of SST, chlorophyll-a and wind sample area 2

Upwelling	SST (^{0}C)		Chlorophyll-a (mg/m^3)		Wind (m/s)	
	Max	Min	Max	Min	Max	Min
Weak	> 29.0	28.9	0.55	<0.50	3.6	< 3.6
Medium	28.8	27.45	0.7	0.55	4.50	3.6
Strong	27.5	26.50	0.9	0.7	5.50	4.50
Very strong	26.44	< 26.44	> 1.0	1.0	>5.52	5.52

Overall, the analysis indicates a strong correlation between sea surface temperature, chlorophyll-a concentration, and surface wind speed in the study area. In sample areas 1 and 2, there are signs of upwelling characterized by low sea surface temperatures, high chlorophyll-a concentrations, and high wind speeds during June, July, and August. However, spatially, the southern part of the Seram Sea waters and Buru Island (sample area 2) tends to experience more intense upwelling compared to sample area 1. During the eastern season, high concentrations of chlorophyll-a are observed on the eastern side of the Seram Sea waters and Buru island reaching values of 1.0mg/m^3, the sea surface temperatures in this area are relatively low, ranging from 26.4 to 27.5°C, and are accompanied by wind speeds of 5.52m/s. These conditions suggest the presence of upwelling, which aligns with the findings of **Natalia *et al.* (2016)**. They noted that upwelling is indicated by lower sea surface temperatures, higher chlorophyll-a concentrations, and strong wind speeds.

Catch productivity

Based on secondary data obtained from Fish Spot Galala for the years 2016-2010, fish catch production in the waters of the Seram Sea and Buru island fluctuated monthly during this period (Fig. 9). The highest recorded fish catch was in October 2018, with a total catch of 77,503kg, while the lowest recorded fish catch was in September 2020, with a total catch of 3,029kg. The average fish catch during the years 2016-2020 was 1,521,885kg

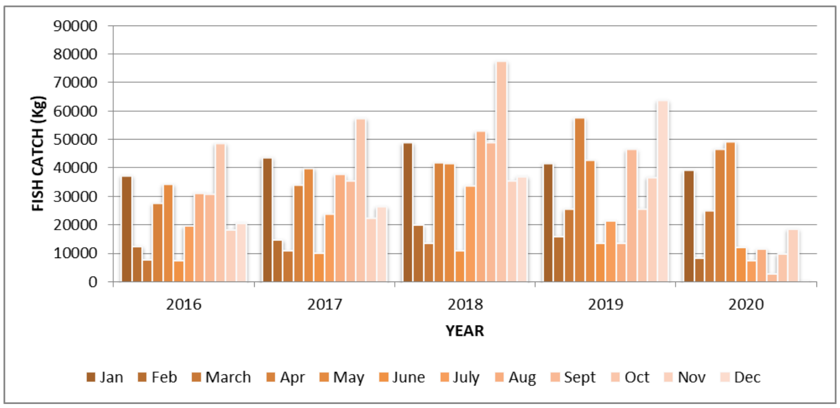


Fig. 9. Fish catch

The fish catch in the waters of Seram Sea and Buru island showed a low trend in 2016, then started to increase in the following years until 2018. However, there was a significant decrease in 2016 to 2020.

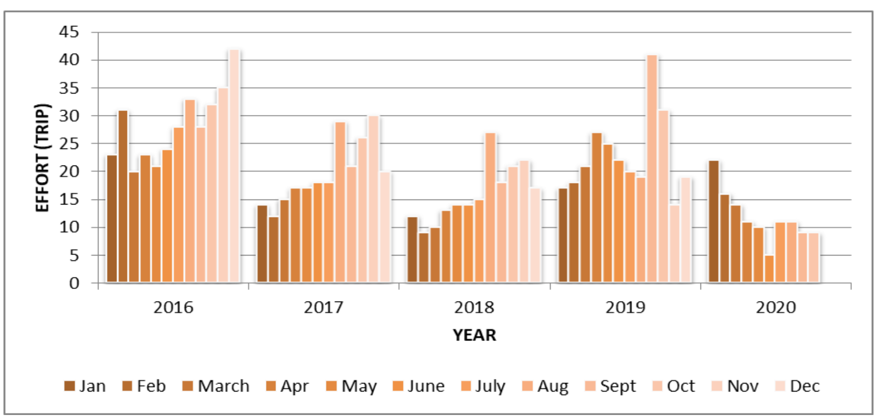


Fig. 10. Effort fish catch 2016-2020

Based on secondary data obtained from Fish Spot Galala for the years 2016-2020, it is known that fishing in the waters of the Seram Sea waters and Buru island predominantly uses boats with a capacity of 10-99 GT and purse seine fishing gear. The number of fishing trips or efforts in these waters varied considerably (Fig. 10). The highest effort was recorded in December 2016, with 42 trips, while the lowest effort was recorded in June 2020, with 5 trips. The average effort or number of trips during the years 2016-2020 was 20 trips. During the period from 2016 to 2020, there was a significant decrease in the number of trips in 2018 compared to other years. This condition could be influenced by many factors, including knowledge components about behavior, fishing gear, fishing boats, fishing techniques, fish sources in a particular water area (fishing ground), and fishing aids (instrumentation) **(Ayodhyoa, 1981 as cited in Dewanti *et al.*, 2018)**. However, one possible reason for the field conditions might be the incomplete recording of fish production data. This can be due to internal or external factors, such as data that have not yet been transferred to softcopy reports or fishermen who do not immediately report their catch to the relevant authorities. This situation can affect the quality of the data used in the research, making it unbalanced when compared to the data recorded in other periods.

Catch per unit effort (CPUE)

Fishery production in a region can be assessed for increases or decreases based on CPUE results. The average monthly CPUE values in the waters of the Seram Sea waters and Buru Island show considerable fluctuation (Fig. 11). The highest CPUE was recorded in May 2020 at 4932.37kg/trip, while the lowest CPUE was recorded in June 2016 at 313.12kg/trip. The average CPUE during the period from 2016 to 2020 was recorded as 907.078 for 2016; in 2017 it was 1553.43, while for 2018, it was recorded as 2424.38; for 2019 an average of 1567.063 was recorded, and finally for 2020, the average was 1894.53kg/trip.

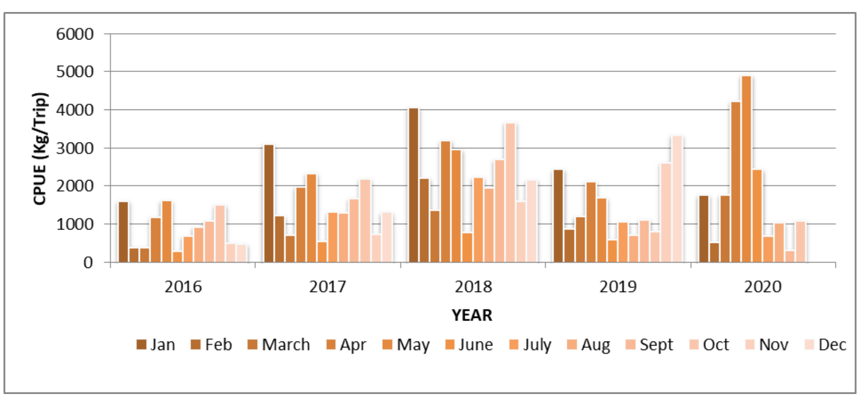


Fig. 11. CPUE 2016-2020

Correlation test between parameters

The summary of Pearson correlation coefficients (*r*) for sea surface temperature, chlorophyll-a, and wind against fish catch and CPUE is presented in Table (7). The correlation test results show that the sea surface temperature (SST) in sample area 2 has a positive linear relationship with catch per unit effort (CPUE), with a correlation coefficient (r) of 0.52. Meanwhile, the significant correlation coefficient for sea surface temperature in sample area 2 with CPUE is because the high and low CPUE values are related to dominant catch data in the western waters of the Seram Sea waters and Buru Island. This also explains how the correlation values of chlorophyll-a are influenced by the catch data.

Table 7. Pearson correlation test between parameter**s**

Correlation (*r*)	**Sea Surface Temperature**		**Chlorophyll -a**		**Wind**
	Sample area 1	**Sample area 2**	**Sample area 1**	**Sample area 2**	
Fish catch	0.27	-0.36	0.39	-0.47	-0.56
CPUE	-0.14	-0.52	0.43	0.56	0.66

CONCLUSION

1. Results of the analysis of the variability distribution of sea surface temperature, chlorophyll-a, and wind spatially show a distribution of values that varies and is homogeneous in each seasonal period. Temporally, for sample areas 1 and 2 during the west season-transition I period, the pattern is almost the same, while for sample area 2 during the east season-transition II period, the pattern is more significant.
2. The potential for upwelling during 2010-2019 occurred from the east monsoon to the second transition season in sample region 1, and throughout the seasons in sample region 2. Both regions experienced strong upwelling.
3. The correlation test results indicate a significant negative correlation between sea surface temperature and catch yields, meaning that as sea surface temperature decreases, catch yields increase. Conversely, there is a significant positive correlation between chlorophyll-a levels and catch yields or CPUE, indicating that higher chlorophyll-a levels correspond to higher catch yields. This relationship is due to the variability in CPUE being linked to dominant catch data in the southern waters of the Seram Sea and Buru Island.

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