Analysis of the relationship between chlorophyll-a and sea surface temperature on marine capture fisheries production in Indonesia: 2018

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Abstract. Fishery production in Indonesia is still relatively high, dominated by the marine capture fisheries. Oceanographic dynamics can affect the high and low levels of marine fishery production. Sea surface temperature and chlorophyll-a are oceanographic parameters that are often used as indicators for determining fishing areas, especially pelagic fish which are associated with ocean fertility. This study aims to identify the effect of chlorophyll-a and sea surface temperature (SST) on the production of fish catches in Indonesia: 2018. Data on marine capture fisheries production (skipjack, mackerel tuna, tuna and shrimp) in 2018 were obtained from the Ministry of Marine Affairs and Fisheries (KKP). Data of Chlorophyll-a and sea surface temperature (SST) are satellite observations from Marine Copernicus. The relationship between chlorophyll-a and sea surface temperature (SST) with marine capture fisheries production was analyzed using logistic regression analysis. The results showed that chlorophyll-a significantly affected the yield of skipjack and tuna in Indonesia with coefficients of \(-5.7066\) and \(-4.3760\), respectively. A higher concentration of chlorophyll-a had the possibility to produce high fish production of 0.0033 times than an area with a lower concentration of chlorophyll-a.

Keywords: chlorophyll-a, logistic regression, oceanographic, sea surface temperature

1. Introduction
Indonesia is an archipelagic country that has very potential aquatic resources. These potential aquatic resources that managed properly can become a pillar of strategic economic development, one of which is the fishery industry. The fisheries industry is one industry that has a significant enough contribution to Indonesia's Gross Domestic Product (GDP), and its contribution to Indonesia's GDP always increases from year to year. It can be seen from the percentage of the fishery industry's contribution to Indonesia's GDP from 2.09% in 2010 and continues increasing to 2.80% in 2020 [1].

A study conducted by the Indonesian Institute of Sciences with the Coordinating Ministry for Maritime Affairs [2], Indonesia's maritime GDP in 2018 reached Rp 1084 trillion with a contribution of 10.14% to the national GDP. The fisheries cluster has the second-largest contribution to maritime GDP, which is 26.33% in 2018 and has increased compared to its contribution in 2010, 22.59%. It shows that
fisheries are an essential industry to pay attention to, especially considering the state and contribution of marine capture fisheries in Indonesia.

The Indonesian fishery industry is divided into two: the aquaculture industry and the marine capture fisheries industry. The aquaculture industry includes marine aquaculture, ponds, floating net cages, and rice fields. While the marine capture fisheries industry is an industry that generally utilizes catches from the sea. FAO data shows that Indonesia ranks second after China with a production value of marine capture fisheries in 2014 of 6.48 million tons or contributes 7.38% to marine capture fisheries globally. The primary commodities are skipjack, mackerel tuna, tuna, and shrimp [2]. Indonesia’s marine capture fisheries production in 2016 reached 185,119 tons, with a contribution of 58.36% to the national fishery production (BPS, 2016). It shows that the marine capture fisheries industry is significantly contributing of fishery production in Indonesia, so the increase and development of marine capture fisheries production are very significant to do. The increase and development of marine capture fisheries production are influence by several factors, one of which is determining fishing ground [3].

The fishing ground is a water area with the potential for fishing with high success and is used properly. Determination of a good fishing ground can optimize the fishing process to increase successful fishing activities [4]. Previous studies [3], [5] show that oceanographic factors influence the determination of fishing ground. Oceanographic factors that are often used to determine fishing ground are chlorophyll-a and sea surface temperature (SST).

The distribution of chlorophyll-a and SST in Indonesian waters is quite varied. The Java Sea has chlorophyll-a concentrations ranging from 0.15-0.22 mg/m³ with a monthly average of SST ranging from 27.9-31.4°C [6]. Then, the Makassar Strait has chlorophyll-a and a temperature distribution in the range of 0.09-1.782 mg/m³ and 25.7-30.89°C [7]. Meanwhile, the southern Halmahera waters have chlorophyll-a 0.1-0.35 mg/m³ and a temperature range of 29-31.5°C [8]. The difference between Chlorophyll-a and SST causes fish to vary, especially pelagic fish [9]. Variations of Chlorophyll-a and SST are thought to cause different condition of marine capture fisheries production results, especially pelagic fish such as skipjack, mackerel tuna, and tuna. Thus, this study will identify the relationship between chlorophyll-a and SST with the condition of marine capture fisheries production in Indonesia: 2018.

2. Materials and Methods

The data used in this study is data of 2018, namely marine capture fishery production data (skipjack, mackerel tuna, tuna, and shrimp) as response variables and chlorophyll-a and SST data as predictor variables. Marine capture fisheries production data is secondary data obtained from the Ministry of Marine Affairs and Fisheries (KKP).

Marine capture fisheries production data is annual data in tons categorized into high and low based on the average production value of each type of fish. Chlorophyll-a and SST are satellite observation data subjected to geometric and radiometric corrections and field data verification obtained from E.U. Copernicus Marine Service Information (https://resources.marine.copernicus.eu/products accessed on 2 May 2021). The chlorophyll data has monthly temporal resolution and 0.25°×0.25° spatial resolution. SST data has monthly temporal resolution and 0.05°×0.05° spatial resolution. The values of chlorophyll-a and SST were analyzed by averaging values spatially in 34 provinces with the furthest distance of 0.5°-1° or 55-111 km from the coast. It is expected to be able to interpret the value of chlorophyll-a and SST in each province.

The chlorophyll data has monthly temporal resolution and 0.25°×0.25° spatial resolution. SST data has monthly temporal resolution and 0.05°×0.05° spatial resolution. The SST uses satellite data provided by GHRSSST (Group for High-Resolution Sea Surface Temperature) using field observations to determine the SST data. The values of chlorophyll-a and SST were analyzed by averaging values spatially in 34 provinces with a distance of 0.5°-1° or 55-111 km from the coast of each province using the following equation [27]:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$  

(1)
where $\bar{x}$ is the average value, $x_i$ is the value of the $i$-th sample and $n$ is the amount of data. The distance is expected to be able to interpret the value of chlorophyll-a and SST in each province.

The analytical method used in this research is descriptive and inferential analysis. The descriptive analysis can overview in general condition of fish production (skipjack, mackerel tuna, tuna, and shrimp), chlorophyll-a, and SST conditions in Indonesia: 2018. Meanwhile, the inferential analysis conducted using logistic regression can provide conclusions related to variables that affect the high and low condition of fish production (skipjack, mackerel tuna, tuna, and shrimp) in Indonesia: 2018.

The logistic regression analysis was carried out to examine the relationship between each independent variable (chlorophyll-a and SST) with each variable of marine capture fisheries production conditions (skipjack, mackerel tuna, tuna, and shrimp). So that there are 4 (four) logistic regression models that were formed in this study. The logistic regression analysis was used in this study because the response variables were formed into categorical variables, namely “high” and “low” based on the average production value. The regions (provinces) with production values higher than or equal to the average production values are categorized as “high” production conditions, while the regions with production values lower than the average production values are categorized as “low” production conditions. Referring to the research of [10], the first step in logistic regression analysis is to create a logistic regression model. This study uses a significance level of 5 (five) percent, with a logistic regression model as in the following equation [26]:

$$\log \left( \frac{p(X)}{1-p(X)} \right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2$$

The marine capture fisheries production conditions is categorized into high ($X=1$) and low ($X=0$) which is denoted by $p(X)$, that is a logistic probability which is formulated by the following equation:

$$p(X) = \frac{e^{(\beta_0 + \beta_1 X_1 + \beta_2 X_2)}}{1 + e^{(\beta_0 + \beta_1 X_1 + \beta_2 X_2)}}$$

The chlorophyll-a is denoted by $X_1$ and SST is denoted by $X_2$ with $\beta_0$, $\beta_1$, and $\beta_2$ being the parameters in the logistic regression model. The null hypothesis for the significance test are $\beta_1 = 0$ (The chlorophyll-a have no effect on marine capture fisheries production conditions) and $\beta_2 = 0$ (The SST has no effect on marine capture fisheries production conditions), while the alternative hypothesis are $\beta_1 \neq 0$ (The chlorophyll-a have effect on marine capture fisheries production conditions) and $\beta_2 \neq 0$ (The SST has effect on marine capture fisheries production conditions). The decision to reject the null hypothesis in that significance test is when the p-value of the significance test results is less than the predetermined significance level (p-value < 0.05).

Furthermore, a fit model test was conducted to determine whether the model was appropriate in explaining the variables of marine capture fisheries production conditions. The fit model test uses the Hosmer and Lameshow test, with the null hypothesis that the model is by the data used (model fit) and the alternative hypothesis is that the model does not fit. The model is said to be fit if the test results show p-value > alpha 0.05 percent. After the model is said to be fit, the summary of the logistic regression model results that have been made can conclude with a certain level of confidence.

3. Results and Discussion

The distribution of chlorophyll-a in Indonesian waters in 2018 ranged from 0.130–2.069 mg/m$^3$ with an average of 0.565 mg/m$^3$ (Figure 1). The highest chlorophyll concentrations were recorded in the waters of East Sumatera, Coastal Kalimantan, Coastal Java, and Southwest Papua. Meanwhile, low chlorophyll-a concentrations were recorded in Southeast Nusa Tenggara Timur and Tomini Bay. The difference in the spatial distribution of chlorophyll-a concentrations is caused by physical oceanographic processes that occur in every region in Indonesia, especially upwelling and run-off processes from rivers. The high concentration of chlorophyll-a in the waters of East Sumatera, Coastal Kalimantan is thought to be due to input from the river in the form of dissolved organic matter incorporated in the river flow to the coast with high chlorophyll-a content [11].
The distribution of SST in Indonesian waters: 2018 ranged from 26.5-30.5°C with an average of 28.98°C (Figure 2). The highest SST was recorded in Tomini Bay, North Sulawesi to the Makassar Strait, Malacca Strait, Aceh, North Sumatra, and North Papua. Meanwhile, the lowest SST was recorded in South Java, namely South DIY, Central Java, East Java, and Bali. The difference in the spatial distribution of SST is caused by physical oceanographic processes that occur in each region in Indonesia. SST is an essential factor in knowing potential areas to become fishing grounds. Fish populations in the sea mostly have an optimum temperature range for adaptation and survival [23]. The optimum temperature range is an indirect indicator of the presence of fish.

Figure 3 shows that the production conditions of marine capture fisheries (skipjack, mackerel tuna, tuna, and shrimp) in 2018 for each province in Indonesia. Overall, the total production of skipjack, mackerel tuna, tuna, and shrimp was 1 696 197 tons, with the contribution 30.11%, 32%, 24.11%, and 13.78%, respectively. Figure 3A shows the condition of skipjack production in all provinces of Indonesia. The average skipjack production is 15 020 tons, with the highest capture fisheries conditions
in 10 provinces (Aceh, North Sumatra, West Sumatra, DKI Jakarta, North Sulawesi, South Sulawesi, Southeast Sulawesi, Maluku, North Maluku, and Papua). Figure 3B shows the conditions of mackerel tuna production with an average production of 15,964 tons. Provinces with the highest tuna production are in 15 provinces (Aceh, West Sumatra, Central Java, East Java, Bali, NTB, NTT, West Kalimantan, South Kalimantan, North Sulawesi, South Sulawesi, Southeast Sulawesi, Maluku, North Maluku and West Papua). Figure 3C shows the condition of tuna production with an average of 12,029 tons. Provinces with the highest tuna production are in 11 provinces (Aceh, West Sumatra, DKI Jakarta, Bali, NTB, South Sulawesi, Gorontalo, Maluku, North Maluku, and West Papua). Figure 3D shows the condition of shrimp production with an average production of 6,874 tons. Provinces with the highest shrimp production are in 13 provinces (North Sumatra, West Sumatra, Jambi, South Sumatra, Bengkulu, Bangka Belitung Islands, West Java, Central Java, East Java, West Kalimantan, South Kalimantan, East Kalimantan, and Central Sulawesi).

The marine capture fishery production condition is thought to be influenced by oceanographic factors related to the optimum conditions of the waters for the sustainability of fishery production. It will be different for each species. Shrimp has optimum temperature conditions ranging from 27-30.2°C [12] and chlorophyll-a concentrations ranging from 0.2-0.9 mg/m³ [13]. Tuna has optimum temperature conditions ranging from 30-31°C, and chlorophyll-a concentrations ranged from 0.2-0.3 mg/m³ [14]. Cakalang has optimum temperature conditions ranging from 29-31.5°C, and chlorophyll-a concentrations ranged from 0.15-0.4 mg/m³ [15]. Mackerel tuna has optimum temperature ranged from 29-30.5°C, and the concentration of chlorophyll-a ranged from 0.2-0.4 mg/m³ [6].

**Figure 3.** Condition of Marine Capture Fisheries in Indonesia: 2018 (A) Skipjack (B) Mackerel Tuna (C) Tuna (D) Shrimp (1= high; 0 = low).

KKP data in 2018 shows that three provinces, namely Aceh, South Kalimantan, and North Sulawesi, have the highest marine capture fisheries production. Aceh Province recorded the highest production of mackerel tuna (*Euthynnus* sp) of 75,142 tons. South Kalimantan Province recorded the highest production of shrimp of 34,923 tons, and North Sulawesi Province recorded the highest production of tuna and skipjack (*Katsuwonus pelamis*) 108,147 tons and 79,197 tons, respectively. The distribution of chlorophyll-a and SST, which has the highest total marine capture fisheries production, is shown in Figure 4.
Figure 4. Distribution of Chlorophyll-a and SST with The Highest Marine Capture Fisheries Production Conditions (A) SST in Aceh (B) Chlorophyll-a in Aceh (C) SST in South Kalimantan (D) Chlorophyll-a in South Kalimantan (E) SST in North Sulawesi (F) Chlorophyll-a in North Sulawesi.
Aceh Province has an average SST value of 29.49°C and an average chlorophyll-a concentration of 0.156 mg/m³ (Figures 4A and 4B). Aceh’s waters are relatively warm throughout the year, especially in the eastern, which is very suitable for tuna habitat. [16], specifically in his research, stated that SST 27-30.1°C and chlorophyll-a concentrations ranging from 0.26-0.33 mg/m³ strongly support commercial fisheries, especially tuna in the northern waters of Aceh. The average chlorophyll-a concentration in Aceh province is 0.156 mg/m³, not in the range of 0.26-0.33 mg/m³. However, on a monthly average (October-February), chlorophyll-a in Aceh is very suitable for habitat tuna, ranging from 0.276 to 0.301 mg/m³. It is because Aceh’s waters are very dynamic and are influenced by the monsoon. Tuna is also an active swimmer, so there is often a strong current. The waters of Aceh, especially the eastern region, are the most suitable location because these waters are a strait that is identical to the relatively strong ocean currents.

South Kalimantan Province has an average SST value of 29.18°C and an average chlorophyll-a concentration of 0.765 mg/m³ (Figures 4C and 4D). SST conditions is still in the optimal shrimp range, and this is because the average value of SST is still in a suitable temperature range for shrimp or lobster adaptation, which is around 20-30°C [17]. [12] explicitly describes the adaptation temperature for shrimp to keep growing, ranging from 27-30.2°C. The chlorophyll-a in South Kalimantan is also suitable for developing shrimp or lobster, which is still around 0.3-0.85 mg/m³ [18]. The relatively high chlorophyll-a concentration in South Kalimantan throughout the year could be due to the input of nutrients from rivers to the coast.

North Sulawesi Province has an average SST value of 29.33°C and an average chlorophyll-a concentration of 0.130 mg/m³ (Figures 4E and 4F). The waters of North Sulawesi in the northern waters are warm all year, and the eastern waters are relatively calmer for skipjack and tuna habitats. [19] states that a suitable skipjack habitat is in waters with temperatures ranging from 29.5-31.1°C and chlorophyll-a concentrations ranging from 0.1-0.23 mg/m³. Meanwhile, tuna has a habitat in waters with temperatures ranging from 25.63-29.17°C and chlorophyll-a concentrations ranging from 0.077-1.17 mg/m³ [20]. Tuna and skipjack are also active swimming fish. The relatively warm SST is considered suitable for physiological adaptations for fish to swim quickly to capture prey. In addition, a high concentration of chlorophyll-a can be a good indicator to show the level of primary productivity. An increase in primary productivity will cause small fish to accumulate, which becomes food for tuna and skipjack. in which small fish that are prey for tuna and skipjack tuna accumulate.

Figure 5 shows the BarPlot of capture fisheries production conditions (skipjack, mackerel tuna, Tuna, and Shrimp) with chlorophyll-a and SST.

**Figure 5.** BarPlot of Marine Capture Fisheries Production Conditions (Skipjack, Mackerel Tuna, Tuna, and Shrimp) with (A) Chlorophyll-a and (B) SST.

In general, Figure 5A shows the difference in the average value of chlorophyll-a in each type of capture fisheries production, both skipjack, mackerel tuna, tuna, and shrimp. In contrast, Figure 5B shows no difference in the average value of SST for each type of capture fisheries production, both skipjack,
mackerel tuna, and shrimp. It gives an initial assumption that chlorophyll-a affects the condition of marine capture fisheries, while SST is thought not to affect. Therefore, further analysis (inferential) was carried out to examine the effect of chlorophyll-a and SST on the production conditions of marine capture fisheries (skipjack, mackerel tuna, tuna, and shrimp) using logistic regression analysis.

Model suitability test using Hosmer and Lameshow test for each logistic regression model for marine capture fisheries production conditions (skipjack, mackerel tuna, tuna, and shrimp) showed a p-value > alpha 0.05 %, so all models were said to be fit. The test results are shown in Table 1.

Table 1. Model suitability test using Hosmer and Lameshow test for each logistic regression model for marine capture fisheries production conditions (skipjack, mackerel tuna, tuna, and shrimp).

| Test Result | Skipjack | Mackerel Tuna | Tuna | Shrimp |
|-------------|----------|----------------|------|--------|
| X-squared   | 4.5303   | 9.1979         | 7.0137 | 8.0837 |
| df          | 8        | 8              | 8    | 8      |
| p-value     | 0.8064   | 0.3259         | 0.5352 | 0.4253 |

Because all logistic regression models are said to be fit, a summary of the logistic regression analysis results can be used to conclude the tests carried out. The logistic regression analysis results for the production conditions of skipjack and tuna indicate that chlorophyll-a has a significant effect on the production conditions. All logistic regression models are said to be fit, so that a summary of the logistic regression analysis results can be concluded. The logistic regression analysis results for skipjack and tuna production conditions indicate that chlorophyll-a has a significant effect on the production conditions. In contrast, the results of logistic regression analysis for the production conditions of tuna and shrimp showed that none of the variables had a significant influence. It is shown in Table 2 with a 95% confidence level, there is sufficient evidence to state that the chlorophyll-a variable affects the production conditions of skipjack tuna. Meanwhile, with a 90% confidence level, there is sufficient evidence to state that the chlorophyll-a variable affects the production conditions of tuna.

Table 2. Summary of logistic regression analysis results for marine capture fisheries production conditions (skipjack, mackerel tuna, tuna, and shrimp).

| Marine Capture Fisheries Production | Coefficient | Estimate | Pr (>|z|) |
|-------------------------------------|-------------|----------|----------|
| Skipjack                            | Intercept   | -8.0399  | 0.7973   |
|                                     | Chlorophyll-a | -5.7066  | 0.0425*  |
|                                     | SST         | 0.3352   | 0.7547   |
| Mackerel Tuna                       | Intercept   | 6.904    | 0.759    |
|                                     | Chlorophyll-a | -1.4731  | 0.156    |
|                                     | SST         | -0.2247  | 0.772    |
| Tuna                                | Intercept   | 18.4672  | 0.4993   |
|                                     | Chlorophyll-a | -4.376   | 0.0888   |
|                                     | SST         | -0.6013  | 0.519    |
| Shrimp                              | Intercept   | -33.3262 | 0.237    |
|                                     | Chlorophyll-a | 0.4373   | 0.538    |
|                                     | SST         | 1.1234   | 0.247    |

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Chlorophyll-a is an important oceanographic parameter to determine the presence of fish [21]. Chlorophyll-a is indirectly related to water fertility related to productivity; namely, chlorophyll-a becomes the first food chain for small fish and then becomes food for large fish (skipjack and tuna) [24].
The parameters that control the distribution of chlorophyll-a are light intensity and nutrients. Another factor that affects marine capture fisheries production conditions is the time lag between chlorophyll-a and large pelagic fish [22]. An increase in chlorophyll-a will not directly follow the increase in fishery production. It is due to the existence of a food pyramid system or food chain. The process of a food chain from phytoplankton to being used by large fish will take time. It is what makes the process of increasing chlorophyll-a indirectly increase fishery production [25].

Furthermore, the odds ratio was used to see the magnitude of the effect of the chlorophyll-a variable on the production conditions of skipjack and tuna capture fisheries (Table 3).

| Test Result | Skipjack | Tuna |
|-------------|----------|------|
| Intercept   | 0.0003   | 1.04767e+08 |
| Chlorophyll-a| 0.0033  | 1.26000e+02 |
| SST         | 1.3982   | 5.48100e+01 |

The intercept value of 0.0003 for skipjack production conditions in Table 3 means that when the other independent variables are 0, the skipjack production conditions will have a chance of $e^{(-0.0399)} = 0.0003$ or 0.03 percent to produce high production conditions. Meanwhile, the odds ratio for chlorophyll-a indicates that if there is a province with higher chlorophyll-a, that area has the opportunity to produce 0.0033 times higher fish production compared to other areas with lower chlorophyll-a. Then the results of the odds ratio for the production conditions of tuna have a very small value, so to interpret as in the case of skipjack production conditions is complex and not done.

4. Conclusion
The relationship between chlorophyll-a and SST with production conditions of marine capture fisheries (skipjack, mackerel tuna, tuna, and shrimp) was analyzed using logistic regression analysis. The results showed that chlorophyll-a had a significant effect on marine capture fisheries production conditions of skipjack and tuna capture in Indonesia with coefficients of -5.7066 and -4.3760, respectively and the odds ratio 0.0033 for skipjack. The odds ratio value indicates that areas with higher chlorophyll-a have the opportunity to produce high skipjack production of 0.0033 times compared to areas with lower chlorophyll-a.

References
[1] Badan Pusat Statistik 2021 Statistik Pertumbuhan Ekonomi Indonesia Triwulan IV-2020 www.bps.go.id 36 1–12
[2] Kementerian Koordinator Bidang Kemaritiman dan Investasi 2020 Rencana Strategis Kementerian Koordinator Bidang Kemaritiman dan Investasi Tahun 2020-2024 (Jakarta: Kementerian Koordinator Bidang Kemaritiman dan Investasi) pp 1–16
[3] Mujib Z, Boesono H and Fitri A D P F 2013 Pemetaan sebaran ikan tongkol (Euthynnus sp.) dengan data klorofil-a citra modis pada alat tangkap payang (Danish-seine) Jurnal of Fisheries Resources Utilization Management and Technology 2(2) 150-160
[4] Simbolon D and Girsang H S 2009 Hubungan antara kandungan klorofil-a dengan hasil tangkapan tongkol di daerah penangkapan ikan perairan Pelabuhanratu Jurnal Peneliti Perikanan Indonesia 15(4) 297-305
[5] Gaol J L, Wudianto, Pasaribu B P, Manurung D and Endriani R 2010 The fluctuation of chlorophyll-a concentration derived from satellite imagery and catch of oily sardine (Sardinella lemuru) in Bali Strait Remote Sens. Earth Sci. 1(1) 24–30
[6] Putra E, Gaol J L and Siregar V P 2012 Relationship chlorophyll-a concentration and sea surface temperature with primary pelagic fish catches in Java Sea from modis satellite images Jurnal Teknologi Perikanan dan Kelautan 3(2) 1–10 (in Bahasa Indonesia)

[7] Nababan B, Rosyadi N, Manurung D, Natih N M and Hakim R 2016 The seasonal variability of sea surface temperature and chlorophyll-a concentration in the South of Makassar Strait Procedia Environ. Sci. 33 583–599

[8] Tangke U, Karuwal J C, Zainuddin M and Mallawa A, 2015 Distribution of sea surface temperature and chlorophyll-a and the effect on the catches of yellowfin tuna (Thunnus albacares) in the Southern Halmahera Sea waters Jurnal IPTEKS PSP 2(3) 248–260 (in Bahasa Indonesia)

[9] Cahya C N, Setyohadi D and Surinati D 2016 The influence of oceanographic parameters on fish distribution Oseana 41(4) 1–14

[10] Widiantara A and Yuhan R J 2019 Pengaruh variabel sosial ekonomi terhadap perkawinan usia anak pada wanita di Indonesia tahun 2017 Stat. J. Theor. Stat. Its Appl. 19(2) 139–149.

[11] Susanto R D, Moore T S and Marra J 2006 Ocean color variability in the Indonesian seas during the SeaWiFS era geochemistry Geophys. Geosystems 7(5) 1–16

[12] Settijnaningsih L, Gunandi B and Supriyono E 2019 The polyculture based aquaponic system of freshwater Prawn (Macrobrachium rosenbergii (de Man 1879)) and Kissing Goramy (Helostoma temminckii Cuvier, 1829) Jurnal Ilmu-Ilmu Hayati 18(2) 135-144 (in Bahasa Indonesia)

[13] Junaidi M, Cokrowati N, Diniarti N, Dwi H S B and Fitriani M L 2021 Hubungan suhu permukaan laut dan klorofil-a dengan hasil tangkapan benih lobster di perairan selatan pulau Lombok Jurnal Rekayasa 14(1) 57–67

[14] Safruddin, Zainuddin M and Tresnati J 2019 The fishing ground of large pelagic fish during the southeast monsoon in Indonesian fisheries management area-713 IOP Conf. Ser. Earth Environ. Sci. 370(1) 012045

[15] Zainuddin M 2011 Skipjack tuna in relation to sea surface temperature and chlorophyll-a concentration of Bone Bay using remotely sensed satellite data JITKT 3(1) 82-90 (in Bahasa Indonesia)

[16] Muklis M, Gaol J L and Simbolon D 2009 Potensial fishing ground mapping of skipjack and frigate tuna in North Nanggroe Aceh Darussalam waters JITKT 1(1) 24-32 (in Bahasa Indonesia)

[17] Pratiwi R 2013 Lobster komersial (Panulirus spp.) Oseana 38 55–68

[18] Syahdan M, Atmadipoera A S, Budi S and Jonson L 2014 Variability of surface chlorophyll-a in the Makassar Strait – Java Sea, Indonesia J. Sci. Basic Appl. Res. 2 103–116

[19] Fauzan F M, Zainuddin M and Marimba A A 2018 Mapping of skipjack tuna (Katsuwonus pelamis) fishing ground using geographic information system technically at Tolitoli Costal water central of Celebes Jurnal IPTEKS PSP 5(10) 149–165 (in Bahasa Indonesia)

[20] Kumaat J C and Rampengan M M F 2018 Tuna fishing ground modeling based on geographic information system in bitung sea waters Journal of Environment and Earth Science 8(11) 46–51

[21] Adnan 2010 Analisis suhu permukaan laut dan klorofil-a data inderaja hubungannya dengan hasil tangkapan ikan tongkol (Euthynnus affinis) di perairan Kalimantan Timur Jurnal Amanisal. PSP FPIK Unpatti 1(1) 1–12

[22] Demena Y E, Miswar E and Musman M 2017 The determination of potential fishing area of skipjack tuna (Katsuwonus pelamis) using satellite imagery in the waters of south Jayapura, Jayapura City JIM FKP Unsyiah 2 194–199 (in Bahasa Indonesia)

[23] Laevastu T and Hela I 1970 Fisheries oceanography fishing (London: News Book Ltd)

[24] Maulana A, Triarso I and Sardiyatmo 2016 Aplication of Geografic Information System in the fishing area determination of Skipjack Tuna (Katsuwonus pelamis) at Sadeng Seawaters,
Yogyakarta Journal of Fisheries Resources Utilization Management and Technology 6(3) 27-36 (in Bahasa Indonesia)

[25] Kämpf J and Chapmant P 2016 Upwelling system of the world: a scientific journey to the most productive marine ecosystem (Switzerland: Springer International Publishing)
[26] James G, Witten D, Hastie T and Tibshirani R 2013 An introduction to statistical learning (New York: Springer Ltd)
[27] Emery WJ and Thomson R E 1998 Data analysis methods in physical oceanography (Britain: BPC Weatons).