Sea surface temperature and chlorophyll-a condition of skipjack tuna (*Katsuwonus Pelamis*) catching area in Ternate Island marine waters

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**Abstract.** Skipjack tuna is one pelagic fish that always migrates for a condition with relevant oceanographic factors for their survival, particularly for optimum sea surface temperature and chlorophyll-a. This study conducted with the experimental fishing method from June - November 2018 in the waters of Ternate Island in observation of the optimal condition of oceanographic factors, mainly SST and Chlorophyll-a in the distribution of skipjack tuna. Employing a polynomial regression analysis, the research results show that the sea surface temperature and chlorophyll-a parameters are strictly related to the distribution of the amount of skipjack tuna caught with correlation coefficient value (r) respectively of 0.646 for sea surface temperature and 0.565 for chlorophyll-a. The optimum temperature for the skipjack tuna in the waters of Ternate Island according to the research results ranges from 27.0 °C - 30.9 °C, while the optimum condition of chlorophyll-a is higher than 0.2 mg/m³ - 0.35 mg/m³, and it seems that every increment of chlorophyll-a content in water indicates an increase of the amount of skipjack tuna catch.

1. Introduction

The Waters of Ternate Island located on the Indonesian cross flow (*ARLINDO*) mass movement path. Thus, it is productive of pelagic fish potentials, both big pelagic fishes such as yellowfin tuna, bigeye tuna, and skipjack tuna and small pelagic fishes such as *Sardinella Lemuru, Mackerel Scads, Mackerel Tuna, Yellow Strip Scad*, and other fishes. As part of big pelagic fishes, skipjack tuna or *Katsuwonus pelamis* as seen in Figure 1 is a fish with higher exploitation rate than any other fishes in Ternate Island seawaters of up to 403,341.0 kg/year. This exploitation level is only 46.89% of available sustainable potential or classified low compared to real viable possibility about 860,180.43 tons/year [1].

Skipjack tuna production can optimize when its catching area distribution predicted before the fishing operation. The distribution and abundance of biological resources in water cannot separate from condition and variation of oceanographic parameters [2]. Catching area distribution predicted through a biophysical state study of oceanographic factors, including sea surface temperature and chlorophyll-a concentration, in which, almost all fish populations in the sea life in an optimum range of temperature and chlorophyll-a [3]. The environmental condition fluctuation significantly affects seasonal migration and the presence of fishes in a location [4]. Skipjack tuna’s spatial and temporal distribution is significantly affected by oceanographic factors condition [5].
Sea surface temperature significantly contributes to fish growth, mobility and activity, migration, distribution, abundance, maturation, egg fecundity, and hatching and fish larva survival ability [6]. Sea surface temperature is taken as an indicator to predict organism presence in the water body, mainly fishes since most organisms are poikilothermic [7]. Chlorophyll-a is a parameter used to determine primary productivity in the sea, in which chlorophyll-a concentration indicates phytoplankton and zooplankton presence with their essential role as sea organism producer including fishes in the food chain [8]. The distribution of chlorophyll-a concentration in the sea varied geographically and based on water body depth resulted from the difference in sunlight intensity, and nutrients existed level.

Figure 1. Skipjack Tuna (*Katsuwonus pelamis*)

Complete and accurate information about the characteristics of oceanographic factors, particularly the sea surface temperature and chlorophyll-a of the water body is highly required for optimal and sustainable resources management. Therefore, to improve optimal skipjack tuna exploitation, optimum condition information of sea surface temperature and chlorophyll-a required for reference in determining productive catching area.

2. Materials and Methods
This study conducted for six months (June-November, 2018) in Ternate Island seawaters with the fishing base at PPN Ternate. The materials and instruments used consists of *skipjack tuna* for type and weight identification, seawater sample for chlorophyll-a analysis, *Aqua Modis* level 3 satellite image, pole and line vessel unit, weighing scale, digital thermometer, bottle for seawater sample, GPS, and fishfinder.

Data sampling is performed two times per fishing trip (1 trip = 3-days fishing) with the experimental fishing method using pole and line vessel. The data of fishes caught type and weight obtained during weighing at PPN Ternate (fishing base), while the fishing position and sea surface temperature data obtained during the fishing process. Meanwhile, the chlorophyll-a data obtained from analysis result on seawater samples from each fishing operation. Besides, sea surface temperature and chlorophyll-a data obtained from extracting the *Aqua Modis* image are used as comparative data for full area coverage. The relationship between catch and sea surface temperature and chlorophyll-a were analyzed using a polynomial regression with the following formula.

\[
Y = aX^2 + bX + c
\]

Where:
- \(Y\) = Catch,
- \(X\) = SST and Chlorophyll-a, and
- \(a, b, c\) = Constant

The optimum value of sea surface temperature and chlorophyll-a of skipjack tuna distribution in Ternate Island sea waters is determined with an analysis on the distribution of skipjack tuna catching
frequency and the sea surface temperature and chlorophyll-a parameters, and further chart plotted then descriptive analysis. The Sturgess model [9] is employed to determine the frequency distribution, as follows: 1) the number of the class is defined with the formula: \( K = 1 + (3.3 \log N) \), where \( K \): Number of Classes, \( \log \): logarithm, \( N \): number of observation data; 2) the class interval is determined with the formula: \( I = R/K \), where \( P \): Class interval, \( R \): interval, \( K \): Number of Classes; 3) it is to determine the lowest value as the lower class limit, to add the class interval to the lower class limit to obtain the next class limit until the final class limit.

3. Results and Discussions

3.1. Skipjack Tuna Production in June

The fishery resources are quite substantial, consisting of pelagic and demersal fishes, with skipjack tuna is mostly exploited by pole and line fishermen [10]. Figure 2 shows the catch data from June-November, 2018 accumulated from 2 pole and line vessels with a three-days fishing model. Based on Figure 2 the highest production in August 2018 of 9,025.4 kg, and the lowest production in October 2018 of 4,112.0 kg, with a monthly production average of 5,145.701 tons/month and the total output during this study period of 30,874.204 kg accumulated from 2 pole and line vessels.

![Figure 2. Skipjack Tuna catch from June-November 2018](image)

3.2. Catching Area

The skipjack tuna catching area during research is distributed in the west to south of waters of Ternate Island, precisely at the coordinates 00°42'13" N - 00°50'20" N and 127°08'40" E - 127°18'54" E as seen in Figure 3 at 1 - 3 nautical miles from Ternate Island. The catching area position is plotted using GPS during fishing operation for 237 trips, and this catching area seems to shift from June to November 2018. The reason for this dynamic shift of catching area is expectedly skipjack tuna's live migration based on a change of ARLINDO (Indonesian Through Flow) mass movement. The ARLINDO mass movement from North Molucca Sea to the Seram Sea is the result of monsoon wind flow [11]. This ARLINDO movement expectedly influences the shift in skipjack tuna catching area in the waters of Ternate Island from west to south dynamically following ARLINDO mass movement for an appropriate condition of oceanographic factors for their survival.

3.3. SST and Chlorophyll-a Condition on Number of Skipjack Tuna Catch

The oceanographic factors play an essential role in the distribution and abundance of fish resources, in which information of the optimum range of sea surface temperature and chlorophyll-a may be taken as a starting point to determine productive catching area known as the optimum fish catching zone [12].
3.4. Sea Surface Temperature (SST)

Besides an indicator of climate change phenomena, the temperature is also an oceanographic factor which plays an essential role in organisms' life by influencing their metabolic activity and also plays a role in sea organisms' development. Sea surface temperature also characterizes the mass of seawater and its relation to seawater layer condition, which used to analyze any existing phenomena in the sea [13]. The sea surface temperature of catching area in Ternate Island sea waters from June to November 2018 ranges from 26.0-32.70°C, with an average of 28.14°C. The SST in June, July, August, September, and November considerably fluctuate with an average ranging from 29.04°C - 29.47°C. The SST fluctuation also leads to variation in skipjack tuna daily catch, and it seems when increases, the trap also increases, and vice versa, as seen in Figure 3.

![Figure 3. Skipjack Tuna catching area](image)

The SST analysis result with skipjack tuna distribution by employing a polynomial regression analysis is a close relationship with regression model $Y = -5.9862X^2 + 352.79X - 5057.8$ and correlation coefficient value ($r$) of 0.646 as seen in Figure 5. The close relationship between SST and skipjack tuna

![Figure 4. The SST fluctuation in Skipjack Tuna catch](image)
catch is temperature factor influences fishes’ distribution and metabolism activities, in which fishes are significantly sensitive to temperature change even if only 0.03°C, while the higher unstable temperature will reduce fishes’ feeding speed [14]. Skipjack tuna (Katsuwonus pelamis) is sensitive to temperature change, particularly during feeding, concerning a particular habit.

Furthermore, Figure 5 shows a hyperbolic trend line explaining skipjack tuna caught distribution with sea surface temperature, in which it seems that there are the SST and skipjack tuna catch fluctuation, starting from 26.0°C and reaches its peak at 29.0 - 30.0°C, which later declines at over 30°C. This fluctuation is then analyzed for the optimum temperature frequency distribution in skipjack tuna catch, as seen in Figure 6. The analysis result shows that the optimum temperature for fishes catching ranges from 27.0°C - 30.9°C. This optimum temperature distribution in line with some previous result research in several other locations, as seen in Table 1.

| Researcher           | Year | Location                                      | SST Value    |
|----------------------|------|-----------------------------------------------|--------------|
| Syahdan et al.       | 2007 | Sulawesi Tenggara, Indonesia                  | 25°C - 32°C  |
| Zainuddin            | 2011 | Bone Gulf, Indonesia                          | 295°C - 31.5°C|
| Zainuddin et al.     | 2013 | Bone Gulf and Flores Sea, Indonesia           | 28.5°C - 30.5°C|
| Rintaka              | 2015 | Maluku Northern Water – Papua, Indonesia      | 27.5°C - 30°C|
| Fajrianti et al.     | 2016 | Bone Gulf, Indonesia                          | 29.5°C - 31.5°C|
| Zainuddin et al.     | 2016 | Bone Gulf, Indonesia                          | 29.5°C - 31.5°C|
| This Research        | 2018 | Ternate Water, Indonesia                      | 27°C - 30.9°C|

The relatively equal optimum temperature of each area will affect fishes' distribution, mainly pelagic fishes with swimming layer depending on sea surface temperature [13].

![Figure 5. The relationship between SST and Skipjack Tuna Catch](image)

![Figure 6. Distribution of Skipjack Tuna Catch and SST Factor](image)

### 3.5 Chlorophyll-a

Phytoplankton existing in photic zone contains chlorophyll-a useful for photosynthesis, in which chlorophyll-a can absorb blue and green lights. Therefore, phytoplankton existence detected based on chlorophyll-a ability [8]. The chlorophyll-a concentration in fishes catching area ranges from 0.195 mg/m³ - 0.357 mg/m³, with an average of 0.33 mg/m³. Meanwhile, Figure 7 shows the higher fluctuating chlorophyll-a concentration from June to November 2018, in which an increase and decrease of chlorophyll-a concentration affects the increase and decrease of skipjack tuna catch. This chlorophyll-a concentration is closely related to the skipjack tuna catch distribution with correlation coefficient.
value \( r = 0.565 \), and the polynomial regression model formed is \( Y = -1595.6X^2 + 1166.5X - 67.446 \) as seen in Figure 8. The water body with high chlorophyll-a content has much phytoplankton content and preferred to by fishes. Therefore, chlorophyll-a took as a fecundity indication of water body about catching activity productivity [15].

![Figure 7. Chlorophyll-a Fluctuation on Skipjack Tuna Catch](image)

The food chain factor also becomes a reason for the close relationship between chlorophyll-a and skipjack tuna catch. Ternate Island seawater is a catching area of pelagic fishes like Sardinella Lemuru, Mackerel Scads, Mackerel Tuna, and Yellow Strip Scad. The optimum temperature and food factor play more role in distribution effect of Sardinella Lemuru. Moreover, Sardinella Lemuru prefers an area with high chlorophyll-a content [16]. Besides, Sardinella Lemuru is the prey of skipjack tuna. Therefore, the existence of chlorophyll-a, sardinella lemuru, and small pelagic fishes may become an indicator of skipjack tuna presence in the catching area.

![Figure 8. The relationship between Chlorophyll-a and Skipjack Tuna Catch](image)

![Figure 9. Distribution of Skipjack Tuna Catch and Chlorophyll-a Concentration (mg/m³)](image)

Meanwhile, Figure 9 shows the optimum chlorophyll-a concentration for skipjack tuna catch distribution in Ternate Island seawater ranges from 0.2 mg/m³-0.35mg/m³. Almost the same value is also obtained by Zainuddin (2011) in the sea of Bone Gulf ranging from 0.15 mg/m³-0.40 mg/m³ and Putri et al. (2018) in Bone Gulf ranging from 0.15 mg/m³-0.27 mg/m³ [17].
4. Conclusions
The study results show that SST and chlorophyll-a concentration are closely related to skipjack tuna catch distribution with the correlation coefficient values (r) of oceanographic factors are respectively 0.646 for SST and 0.565 for chlorophyll-a concentration. The optimum SST and chlorophyll-a concentration for skipjack tuna distribution are 27.0°C-30.9°C and 0.2 mg/m³–0.35mg/m³ respectively.

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