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Mapping the Gravity Center of Fishing Ground on Skipjack Tuna Distribution in Bone Gulf-Flores Sea

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Abstract**—** *Bone Gulf and Flores Sea in the Fisheries Management Area 713 (WPP 713) are known as one of the best skipjack tuna fishing areas in Indonesia, where skipjack tuna is an export commodity and has high economic value. The potential of skipjack tuna is based on the spatial-temporal pattern of oceanographic conditions. The distribution of skipjack tuna can be predicted by the biophysical conditions of the environment. Sea surface temperature and chlorophyll-a are biophysical parameters that greatly affect the distribution of skipjack tuna and are often used to predict potential fishing grounds. The study used skipjack fisheries data from April to July in 2017 to 2019 and remote sensing satellite data on sea surface temperature and chlorophyll-a from Aqua / MODIS. This study aims to determine the gravity center of skipjack tuna fishing ground in Bone-Flores Sea using the Generalized Additive Model (GAM). The distribution of skipjack tuna was found to be significantly related (p <0.0001) with preferred range of sea surface temperature at 29.02–31.03 °C and concentration of chlorophyll-a at 0.14–0.44 mg/m3. The gravity center of fishing ground from April shows that skipjack tuna shift to the north in May and June, then back to the south in July. This study dedicated on providing scientific information regarding the gravity center of skipjack tuna fishing ground in Gulf Bone-Flores Sea, as well as the applicability of remote sensing in contributing to optimalization and sustainable utilization of skipjack fisheries resource.*

Keywords**— *skipjack tuna, sea surface temperature, chlorophyll-a, gravity center of fishing grounds, remote sensing.***

I. INTRODUCTION

The Bone Gulf and Flores Sea in the Indonesia's Fisheries Management Area 713 are known as one of the best skipjack fishing areas in Indonesia [1], where skipjack is an export commodity with high economic value. This is evidenced by the various fishing gear fleets operating to exploit skipjack (*Katsuwonus pelamis*) such as purse seine, huhate (*pole and line*), hand line and trolling line.

The potential of skipjack tuna is influenced by spatial-temporal oceanographic conditions. The biophysical environment in Bone Gulf is certainly different from the biophysical environment in the Flores Sea. The availability of food both in quantity and quality affects the predation rate and is an important variable for the skipjack population. The distribution of fish can be predicted according to the biophysical conditions of the environment. Concentration of chlorophyll-a and sea surface temperature are biophysical parameters that greatly affect in fish distribution and are often used to predict potential fishing grounds [3, 6]

Several studies have shown that the distribution, migration and movement patterns of skipjack tuna are strongly influenced by oceanographic factors. Fish migrate due to changes in several environmental factors such as temperature, salinity and currents, efforts to find water areas where there is sufficient food and efforts to find spawning areas [5]. Sea surface temperature and chlorophyll-a have a significant effect on the catch per unit effort (CPUE) variation of skipjack tuna. The skipjack tuna distribution pattern is associated with variables changes that reflect their preferred oceanographic. [8]

Thus from various studies show environmental biophysical conditions affect to distribution pattern of skipjack tuna, this study aim to determine the gravity center and distribution of skipjack fishing ground.

The contribution of this study is for the availability of scientific information regarding the gravity center of skipjack fishing ground in Bone Gulf-Flores Sea. As well as the results of this study can be used for optimalization and sustainable utilization of skipjack fishery resources.

II. MATERIALS AND METHODS

This research was conducted from April to July 2019, taking locations in two districts, Luwu Regency with fishing ground in Gulf Bone also Sinjai Regency with fishing ground in the Flores Sea (Fig. 1). Data processing was carried out at the Laboratory of Fisheries and Geospatial Information Systems, Faculty of Marine and Fisheries Sciences, Hasanuddin University.

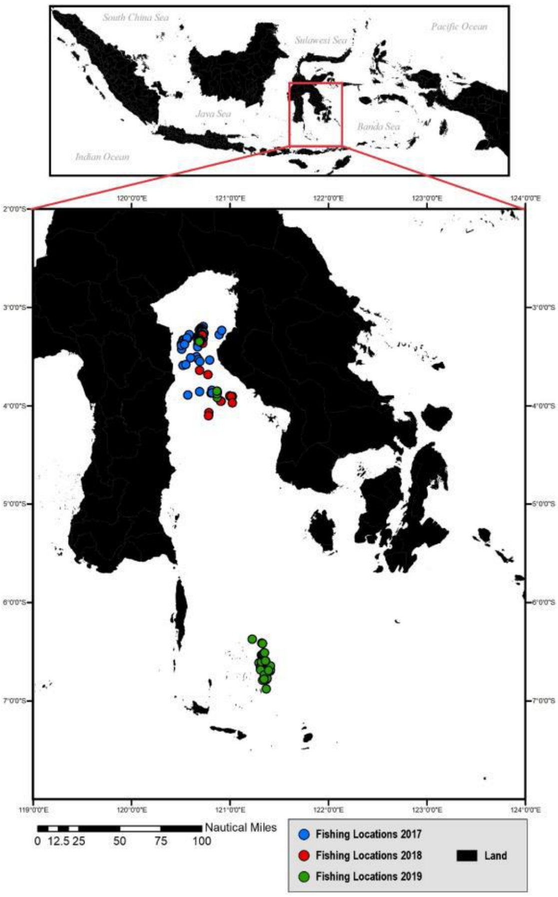

Fig.1: Map of study area in Bone Gulf and Flores Sea showing fishing location points from April to July 2017 to 2019.

a. Fishery data

Monthly catch data were collected from field surveys around the waters of Gulf Bone-Flores Sea from April to July 2019. As well as supporting data from previous studies, April to July in 2017 to 2018. The data obtained included catch per unit effort (CPUE) and fishing location (longitude and latitude).

b. Satellite remote sensing data

Sea surface temperature and chlorophyll-a subset data by Aqua/MODIS (Moderate Resolution Imaging Spectroradiometer) satellite measurements were used. The subset data were distributed by NASA Ocean Color on the website (http://oceancolor.gsfc.nasa.gov/). The data set is level 3 (4 km) monthly data from April to July 2017 to 2019 which coincides with the time of fish catch data to obtain sea surface temperature and chlorophyll-a values. Data sets are also used to obtain skipjack optimum oceanographic conditions and also to develop predictive models by Generalized Additive Model (GAM)

c. Generalized Additive Model (GAM) Analysis

Skipjack distribution and oceanographic variables have been shown to have a non-linear relationship optimal range of sea surface temperature and chlorophyll-a would be suitable for fish, whereas if the chlorophyll-a concentration and sea surface temperature were lower or higher than the optimal ranges, it would indicate a mismatch. [2]

The responses distribution in GAM is not limited to just the normal distribution, but the variables included in the exponential group can be analyzed using this model. The additive model itself is an extension of ordinary linear regression by replacing linear functions with additive functions that do not have a rigid shape, so that this model can be used even though the relationship between the response and predictor variables is not linear. Based on the characteristics of the catch data obtained, the GAM analysis was chosen as the most appropriate analysis to determine the relationship between fish distribution and sea surface temperature and chlorophyll-a concentration [2]

GAM analysis was carried out on CPUE, chlorophyll-a concentration, and sea surface temperature data at the fishing location using the following formula:

$$y = \alpha + s(x_i) + s(x_2) + \ldots + \varepsilon$$

where y is the CPUE value, α is the constant, s is the smooth spline function of the predictor variables (sea surface temperature and chlorophyll-a), x is the predictor variable, namely sea surface temperature (x_i) and chlorophyll-a (x_2), and ε is random error

d. Gravity center of fishing ground

To determine the gravity center of skipjack fishing ground in study area, the fishing location data were plotted on the average distribution of sea surface temperature and chlorophyll-a images from April to July. The satellite data were then extracted for each pixel corresponding to the fishing locations. The GAM results which are the relationship between oceanographic variables derived from satellites and skipjack tuna CPUE at all fishing positions produce CPUE predictive values. This predictive value along the fishing positions were used to determine the center gravity of fishing ground. The monthly center gravity fishing ground were mapped using ArcGIS 10.2 software. The center of gravity of the fishing area is obtained by the following formula [4,8]:

$$GC_{ij} = \frac{\sum L_{ij}\, CPUE_{ij}}{\sum CPUE_{ij}}$$

Where, GC_{ij} is the monthly gravity centre of fishing grounds at longitude and latitude position, L_{ij} is the latitude and longitude of fishing point, and $CPUE_{ij}$ is the catch per effort (fish/fishing set) at position ij.

III. RESULTS AND DISCUSSION

During April to July in 2017 to 2019, skipjack tuna were found in the study area at temperatures range from 29.02 - 31.03 ° C and chlorophyll-a concentrations 0.14 - 0.44 mg/m^3. The highest fishing frequency was at sea surface temperature range of 29.5 - 30 °C with a proportion of 50.21% (Fig. 3a) and chlorophyll-a concentration of 0.3-0.35 mg/m^3 with a proportion of 28.45% (Fig. 3b). The highest average catch was at a temperature of 30.24 ± 0.12 °C as many as 68 fishes (Fig. 3c) and a chlorophyll-a concentration 0.24 ± 0.02 mg/m^3 as many as 61 fishes (Fig.3d).

The variation of sea surface temperature in April is relatively higher than the following months, ranging from 29.38 °C to 32.60 °C and continues to decline every month. The sea surface temperature in Bone Gulf tends to be higher than the sea surface temperature in the Flores Sea (Fig. 3), this is due to the influence of cold water masses from the current circulation system and the occurrence of upwelling and downwelling. In contrast to the distribution of chlorophyll-a concentrations, the variation in April was relatively lower than in the following months, which ranged from 0.08 to 1.88 mg / m3 and continued to increase in concentration every month (Fig. 4).

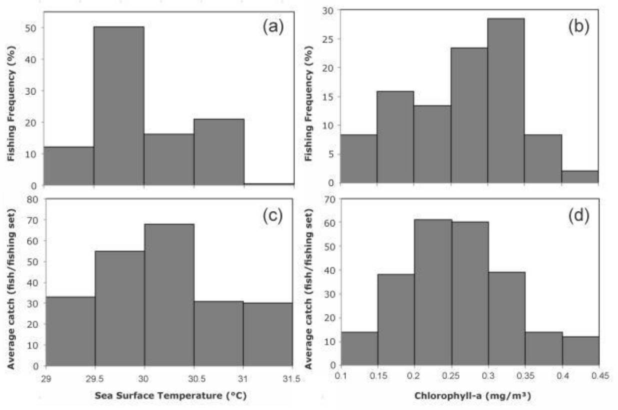

Fig.2: (a) The fishing frequency of skipjack tuna in sea surface temperature range; (b) The fishing frequency of skipjack tuna in chlorophyll-a range; (c) Average catch of skipjack tuna in sea surface temperature range; (d) Average catch of skipjack tuna in chlorophyll-a range in Gulf Bone-Flores Sea

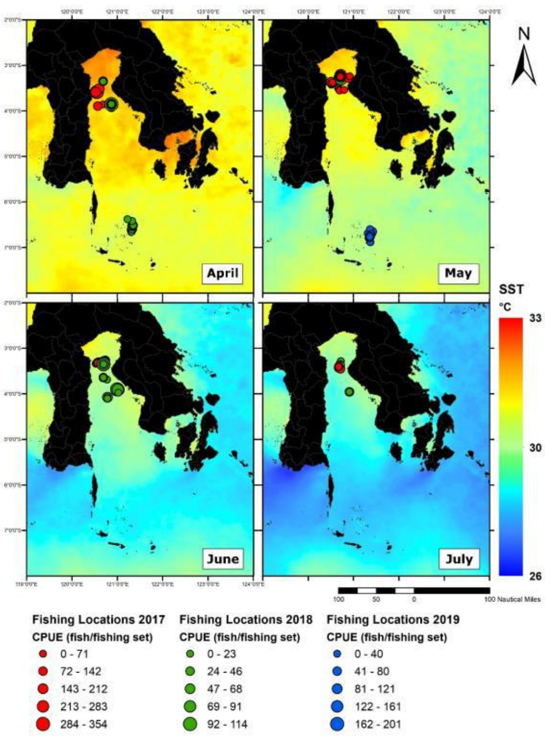

Fig.3: Map of average sea surface temperature distribution in Bone Gulf and Flores Sea

showing fishing locations on April to July in 2017 to 2019

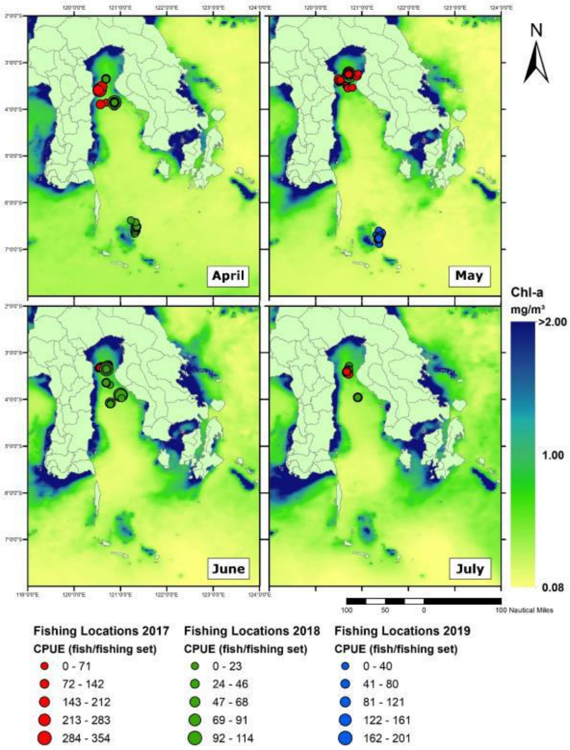

Fig.4: Map of average concentration of chlorophyll-a distribution in Bone Gulf and Flores Sea showing fishing locations on April to July in 2017 to 2019

The GAM plot can be interpreted as the individual effect of each predictor variable (sea surface temperature and chlorophyll-a) to CPUE value. The x-axis shows the predictor variables, sea surface temperature (Fig. 5a) and chlorophyll-a (Fig. 5b) and the y-axis shows the contribution of the smoother to responses value, CPUE. The percentage value is higher if the GAM function developed is above the zero axis which indicates the strong influence of a parameter and if it is below the 0 axis it indicates the weak effect of a parameter on skipjack tuna. The GAM plot on the horizontal axis represents the observed catch data points. The function indicated by the thick line and gray shade represents the 95% confidence interval (Fig. 5). Based on the results of GAM analysis in this study, it shows that sea surface temperature and chlorophyll-a concentration have a significant effect (p <0.0001) on the CPUE value of skipjack tuna (Table 1).

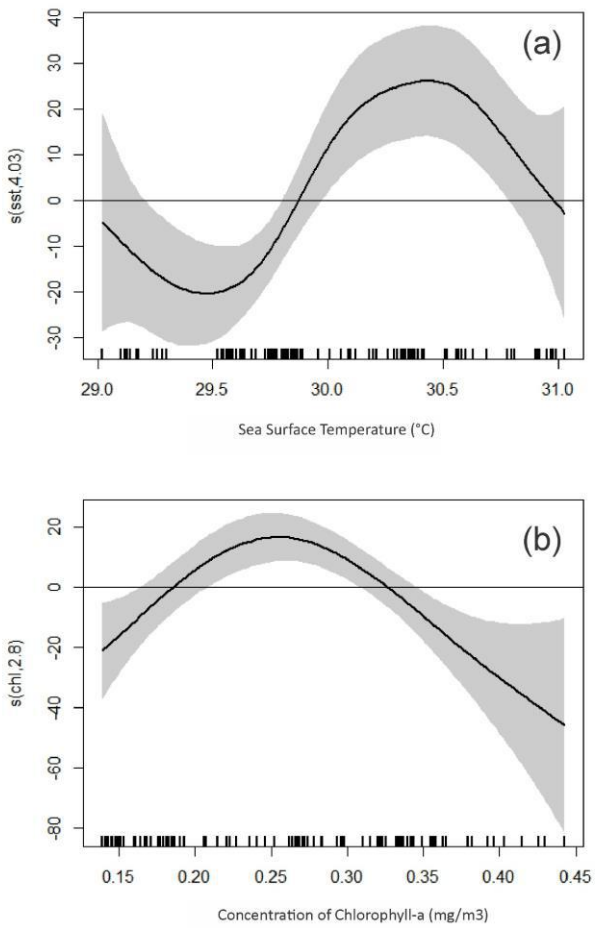

Fig.5: GAM analysis of skipjack tuna catch against: (a) sea surface temperature and (b) concentration of chlorophyll-a. Distribution of relative density data is shown on the x-axis.

Table 1. GAM analysis of sea surface temperature and chlorophyll-a on skipjack tuna CPUE

	edf	Ref.df	F	p-value
s(SPL)	4.029	4.943	6.407	0.0000167
s(Chl-a)	2.797	3.516	7.015	0.0000845
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				

A strong relationship was observed in the sea surface temperature range of 29.7 - 30.9 °C (Fig. 5a) and chlorophyll-a concentrations of 0.17 - 0.33 mg/m^3 (Fig. 5b). This is evidenced by the distribution of the highest relative density of catch data (catch frequency) and the highest catch in this range. The results are also consistent with the average catch and fishing frequency shown in Fig. 2.

The results obtained were the same as the results of research on skipjack tuna in the Coral Triangle area [7] that the distribution and dynamics of skipjack tuna habitat hotspots in Bone-Flores Sea is in the temperature range of 29.5-31.5 °C with a concentration of 0.15-0.35 mg/m^3.

The determining of gravity center of skipjack fishing ground shown that from April to July all of the gravity center were in Bone Gulf. The results of the GAM prediction also show that all the center points of gravity obtained are in the appropriate conditions for the skipjack tuna parameters (Fig. 6).

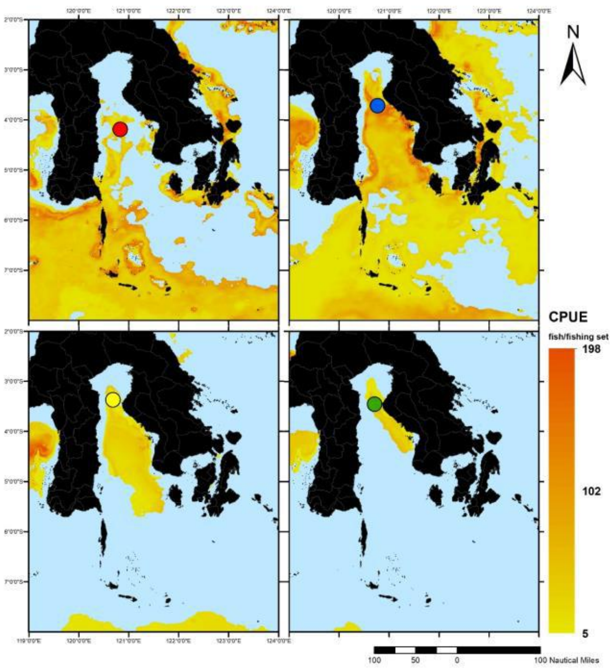

Fig.3: Map of skipjack tuna gravity center fishing ground overlay on GAM predictive raster from April to July

Figure 6 shows that in April, the gravity center point is 4°11'13.5"S, 120°49'50.6"E which shows that gravity center is in between the waters of Wajo Regency and Kolaka Regency. In May, the gravity center point is at 3°42'40.4"S, 120°46'18.5"E which indicates gravity center is in the waters of North Kolaka Regency. In June, the gravity center point is at 3°21'45.1"S, 120°41'07.0"E which indicates the gravity center is between the waters of Luwu Regency and North Kolaka Regency. In July, the gravity center point is at 3°27'08.9"S, 120°42'44.5"E which indicates gravity center is in North Kolaka Regency. By the results of determining the gravity center of fishing grounds, the distribution direction can be seen (Fig. 7) that from April, gravity center of skipjack tuna fishing ground shift to north in May and June, then returns to south in July.

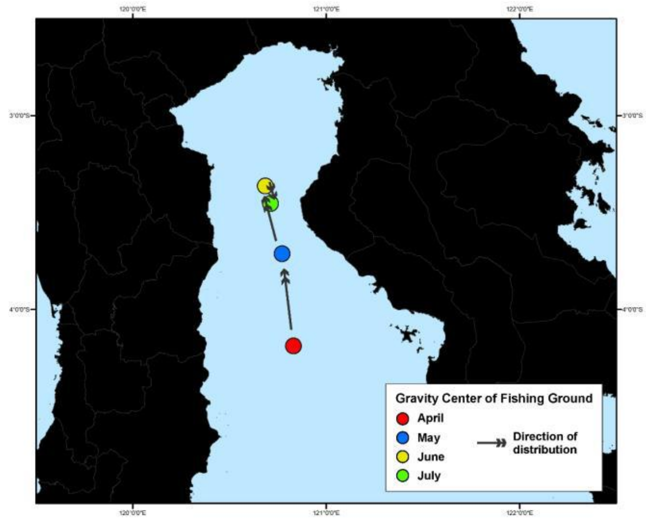

Fig.4: Direction of skipjack tuna gravity center movement estimated by GAM from April to July

Research which found that the movement pattern of skipjack tuna in the Makassar Strait during January-May depicts a shift in clockwise distribution. Skipjack tuna move from offshore to the Makassar Strait in January and then during February-March the movement continues towards the offshore area of Barru-Parepare-Pinrang Regency in the southeastern Makassar Strait. Then, during April-May the fish concentration moved westward to the offshore area and then began moving north to the waters off Mamuju Regency.[8]

These findings suggest that the pattern of skipjack distribution may be related to the dynamic movement of the preferred oceanographic conditions in terms of sea surface temperature and chlorophyll-a concentration.

IV. CONCLUSION

Based on the results and discussion of this research study, it can be concluded that the center of gravity of the fishing ground shows that the direction of distribution of skipjack tuna from April moves northward in May and June, then returns south in July.

V. SUGGESTIONS

Suggestions for the continuation of this research is further research is needed on the gravity center of skipjack fishing ground in the span of the year so that the movement pattern of skipjack tuna can be seen more obviously.

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REFERENCES

[1] Gordon A. L. 2005. Oceanography of the Indonesian Seas and their throughflow. *Oceanography Special Issue: The Indonesian Seas Vol 18 No. 4, p 14–27*

[2] Istnaeni Z. D. & Zainuddin M. 2019. The Impact of Oceanographic Parameters Changes on the Distribution and Abundance of Skipjack Tuna Katsuwonus Pelamis in Makassar Strait. *Journal of Tropical Marine Science and Technology. 11 171–80*

[3] Lanz, E., Manuel, N.M., Juana, L.M., Dworak, J.A., 2009. Small pelagic fish catches in the Gulf of California associated with sea surface temperature and chlorophyll. *CalCOFI Rep. 50, 134–146.*

[4] Lehodey P., Bertignac M., Hampton J., Lewis and Picaut J. 1997. El Nino Southern Oscillation and Tuna in the Western Pacific Nature 389 715–8.

[5] Simbolon, D., R. Irnawati, L. P. Sitanggang, D. Ernaningsih, M. Tadjuddah, V. EN Manoppo, Karnan, dan Mohamad. 2009. Formation Fishing Ground. *Bogor: Department of Resource Utilization. Faculty of Fisheries and Marine Science. Bogor Agricultural Institute.*

[6] Zainuddin, M., 2011. Skipjack Tuna in relation to sea surface temperature and chlorophyll-a concentration of Bone Bay using remotely sensed satellite data. *Journal of Tropical Marine Science and Technology. 3 (1), 82–90*

[7] Zainuddin, M., Farhum, A., Safruddin, S., Selamat, M. B., Sudirman, S., Nurdin, N., Syamsuddin, M., Ridwan, M., Saitoh, S.I. 2017. Detection of pelagic habitat hotspots for skipjack tuna in the Gulf of Bone-Flores Sea, southwestern Coral Triangle tuna, Indonesia. *PLoS ONE Vol. 12:10 p 1-19.*

[8] Zainuddin, M. Amir, M. I.Bone, A. Farhum, S. A. Hidayat, R. Putri, A. R.S. Mallawa, A. Safruddin. Ridwan, M. 2019. Mapping distribution patterns of skipjack tuna during January-May in the Makassar Strait. *IOP Conference Series: Earth and Environmental Science Vol 370:1*