Jurnal Ilmu dan Teknologi Kelautan Tropis Vol. 11 No. 1, Hlm. 123-130, April 2019
p-ISSN : 2087-9423 http://journal.ipb.ac.id/index.php/jurnalikt
e-ISSN : 2620-309X DOI: http://dx.doi.org/10.29244/jitkt.v11i1.24775

THE EFFECT OF OCEANOGRAPHIC FACTORS ON SKIPJACK TUNA FAD VS FREE SCHOOL CATCH IN THE BONE BAY, INDONESIA: AN IMPORTANT STEP TOWARD FISHING MANAGEMENT

PENGARUH FAKTOR-FAKTOR OSEANOGRAFI PADA RUMPON DAN DAERAH KAWANAN CAKALANG DI TELUK BONE, INDONESIA: TAHAPAN TERPENTING DALAM PENGELOLAAN PERIKANAN

Mukti Zainuddin[1]*, Safruddin[1], Aisjah Farhum[1], Muhammad Ridwan[2], Andi Rani Sahni Putri[1], and Rachmat Hidayat[1]
[1]Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar
[2]Fisheries Agribusiness Department, National Agricultural Polytechnic, Pangkep, Indonesia
*E-mail: muktizunhas@gmail.com

ABSTRACT

The aims of this study were to compare skipjack catch between FAD and free school fishing grounds and to describe the effect of the oceanographic factors on either skipjack tuna Fish Aggregating Device (FAD) or free school. We used a field survey method for collecting the skipjack catch and the fishing positions for both near FAD and free school areas. Remotely sensed satellite data of sea surface temperature (SST) and chlorophyll-a concentration (Chl-a) were also used to extract the oceanographic data corresponding with both the fishing locations. To find out the vital oceanographic factors, we examined the characteristics of the oceanographic variables and skipjack catch using t-test. Results indicated that the fishing operations of skipjack tuna at FAD tended to locate areas of relatively higher Chl-a than at free school locations. We also found that skipjack tuna catch was higher near the FAD than the other area, where the Chl-a was the most significant factor that affected the difference. This study suggests that the number of skipjack tuna FAD in the coastal waters of Bone Bay should be calculated accurately to ensure and support the tuna fishing management in that study area.

Keywords: FAD, free school, skipjack tuna, oceanographic factors, fishing management

ABSTRAK

Penelitian ini bertujuan untuk membandingkan tangkapan cakalang antara rumpon dan daerah kawanan ikan, serta untuk menggambarkan pengaruh faktor-faktor oseanografi baik pada rumpon maupun daerah kawanan cakalang. Pengumpulan data tangkapan menggunakan metode survei lapangan pada daerah tangkapan yang dekat dengan rumpon dan daerah kawanan ikan. Data satelit penginderaan jauh pada suhu permukaan laut (SPL) dan konsentrasi klorofil-a (Chl-a) juga digunakan untuk mengekstraksi data oseanografi yang sesuai dengan kedua lokasi penangkapan. Untuk mengetahui faktor-faktor penting dalam oseanografi, juga dilihat karakteristik dari variabel oseanografi dan daerah tangkapan cakalang menggunakan uji-t. Hasil penelitian menunjukkan bahwa operasi penangkapan cakalang di daerah rumpon cenderung menemukan Chl-a yang relatif lebih tinggi daripada di daerah kawanan ikan. Hasil tangkapan cakalang lebih tinggi di dekat rumpon daripada daerah lain. Hal ini dikarenakan perbedaan nilai Chl-a merupakan faktor oseanografi yang berpengaruh paling signifikan. Penelitian ini memberikan gambaran bahwa jumlah rumpon cakalang di perairan pantai Teluk Bone harus diperhitungkan kembali untuk memastikan dan mendukung pengelolaan penangkapan cakalang di wilayah studi.

Kata kunci: *rumpon, daerah kawanan, cakalang, faktor oseanografi, pengelolaan perikanan*

I. INTRODUCTION

Skipjack tuna is the most important species targeting by local fishers in the Bay of Bone, South Sulawesi, Indonesia. The distribution and abundance of this species are markedly influenced by oceanographic factors such as distributions of SST and chlorophyll-a (hereafter Chl-a) density (Zainuddin, 2011). Skipjack migration route and its habitat in the western North Pacific Ocean corresponds to the movement of optimum ranges of the oceanographic features (Mugo *et al*., 2010). The effect of the 29°C SST isotherm is a reasonable proxy to detect the region of highest skipjack CPUEs (frontal area) in the western Pacific Ocean (Lehodey *et al*., 1997). The highest skipjack CPUEs off the southern Brazilian coast occur in waters of SST 22°-26.5°C, although that relationship varied seasonally (Andrade, 2003).

Primarily targeting schools of skipjack *Katsuwonus pelamis* and yellowfin *Thunnus albacares* in the Bone Bay, FAD-related purse seining and pole and lining are nowadays a technologically excellent fishery that augments their catch. In this area, the FAD is used to aggregate skipjack schools before conducting the fishing operation. The reasons why fish have developed such behavioral trait and food chain process are still open to exploring, and several hypotheses have been proposed to explain the responsible mechanisms (Fréon and Dagorn, 2000).

A combined satellite remote sensing (SRS) and geographic information system (GIS) provides a powerful tool to detect potentially skipjack tuna habitat. The skipjack habitat has been proved to correspond with several oceanographic factors such as surface temperature, salinity, and thermal fronts and Chl-a (Andrade, 2003; Mugo *et al.,* 2010; Zainuddin *et al*., 2017).

SST and Chl-a derived from satellite data are determinant factors in predicting tuna forage and their habitat in Western North Pacific Ocean (Lehodey *et al*., 1998). Therefore, the objectives of this study are to compare skipjack catch between FAD and free school fishing grounds and to describe the effect of the oceanographic factors on either skipjack tuna Fish Aggregating Device (FAD) or free school in the Bone Bay, Indonesia.

II. RESEARCH METHODS

We used a survey method by collecting satellite data together with catch data. The physical and biological environmental satellite data used to describe the oceanographic conditions at the fishing ground were SST and Chl-a data derived from Aqua/MODIS. The NASA distributes *Standard Mapped Image* (SMI) level 3 binary data with HDF (*Hierarchical Data Format*) format (http:www). We used the satellite data with monthly temporal resolution, Mei-August 2017, and 0.044° of longitude and latitude spatial resolution. We processed the data using SEADAS (*SeaWiFS Data Analysis System*) software package to get image data throughout the study area. The pole and line fishery data consisted of fishing ground position in latitude and longitude, SST fishing boat and daily CPUE data. We compiled the daily data into monthly to match the satellite data temporal resolution. The oceanographic data were linked to fishery data to estimate and extract SST and Chl-a at and around fishing grounds.

In this study, firstly we plotted the fishing data on SST and Chl-a image map to understand the spatial and temporal distribution pattern of skipjack fishing grounds relative to the oceanographic conditions near FAD and free school locations. We examined several variables including the skipjack catches, SST and Chl-a between around the FAD and free school positions using t-test. Using generalized additive models (GAMs), we then investigated the effects of the oceanographic conditions of both SST and Chl-a on catch data in R-software package. All images produced in this study were mapped using ArcGIS 10.3 software package.

III. RESULTS AND DISCUSSION

Based on the dataset from Mei to August 2017, the relationship between skipjack fishing sets and SST in surrounding FAD showed that most of the fishing efforts were found in areas of 29.0-31.5°C SST (Fig.1:upper). However, the highest frequency tended to center at 30.53ºC SST. Fishing sets concerning Chl-a performed that most top catches occurred near FAD areas of chl-a varied from 0.30-0.35 mg/m^{-3} (Fig.1: lower). The highest fishing sets of high catch data tended to concentrate near 0.34 mg m^{-3}.

During the period of study, distribution of skipjack fishing around the free school locations performed that the fishing sets mainly occurred in areas of 29.0-29.75ºC SST (Fig.2: upper).

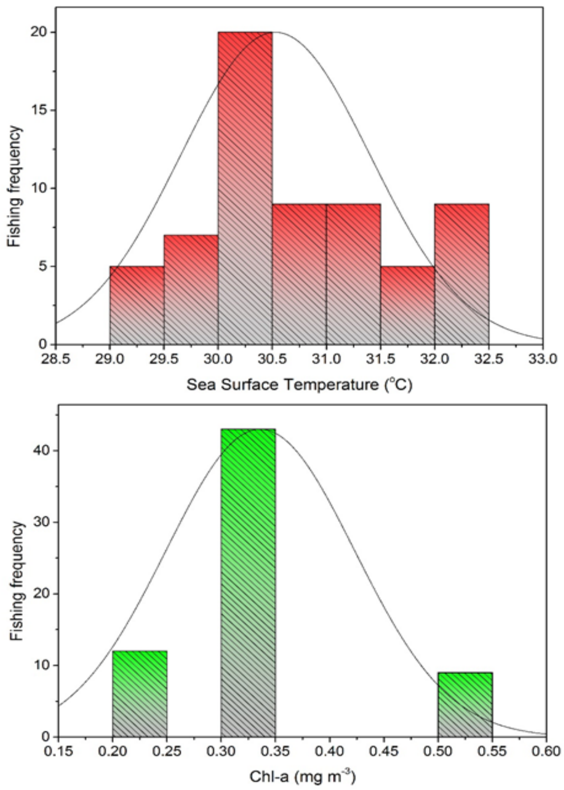


Figure 1. The histogram relationship between skipjack pole and line fishing frequency and SST (upper) and Chl-a (lower) derived from MODIS near the FAD areas in the Bone Bay.

The fishing efforts mostly aggregated at 30.35ºC. In the free school areas, the fishing sets were predominantly found in the waters of 0.20-0.34 mg m^{-3} (Fig.2: lower). The greatest fishing operations tended to concentrate near 0.23 mg m^{-3}.

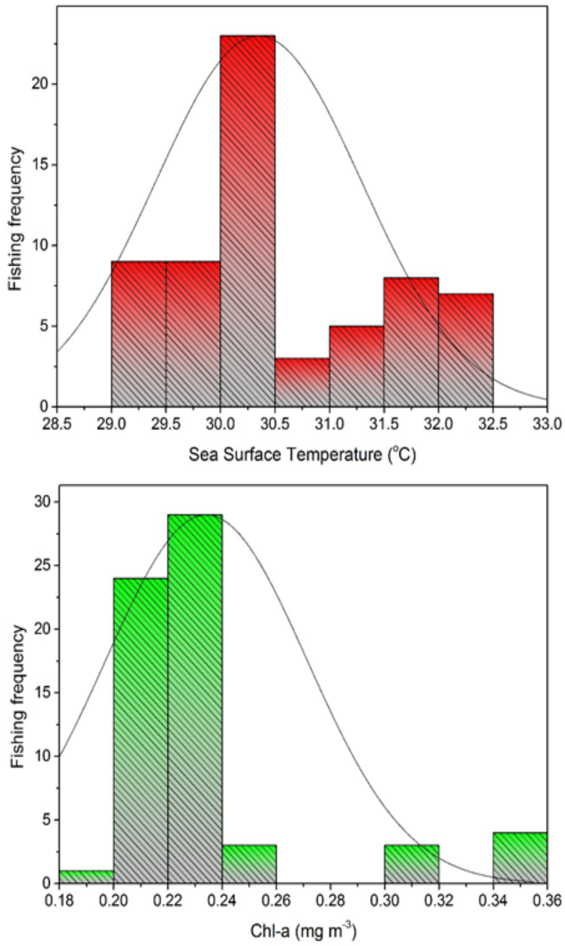


Figure 2. The histogram relationship between skipjack pole and line fishing frequency and SST (upper) and Chl-a (lower) derived from MODIS near the free school fishing grounds in the Bone Bay.

GAM plots could be interpreted as the individual effect of each predictor variable on CPUE as a rug plot (Figure 3). Rug plots on the horizontal axis represent observed data points, and the fitted function is shown by the thick line. The dashed line indicates the 95% confidence bands.

In the areas of surrounding FAD, both SST and Chl-a had positive effects on skipjack CPUE. It is essential to see that skipjack CPUE increases significantly with Chl-a from 0.25 to 0.35 mg m^{-3} and SST from 30 to 31.5°C. The SST and Chl-a values outside the preferred oceanographic ranges are unclear because the reduced density of fishery data points leads to larger standard error ranges (wider confidence bands).

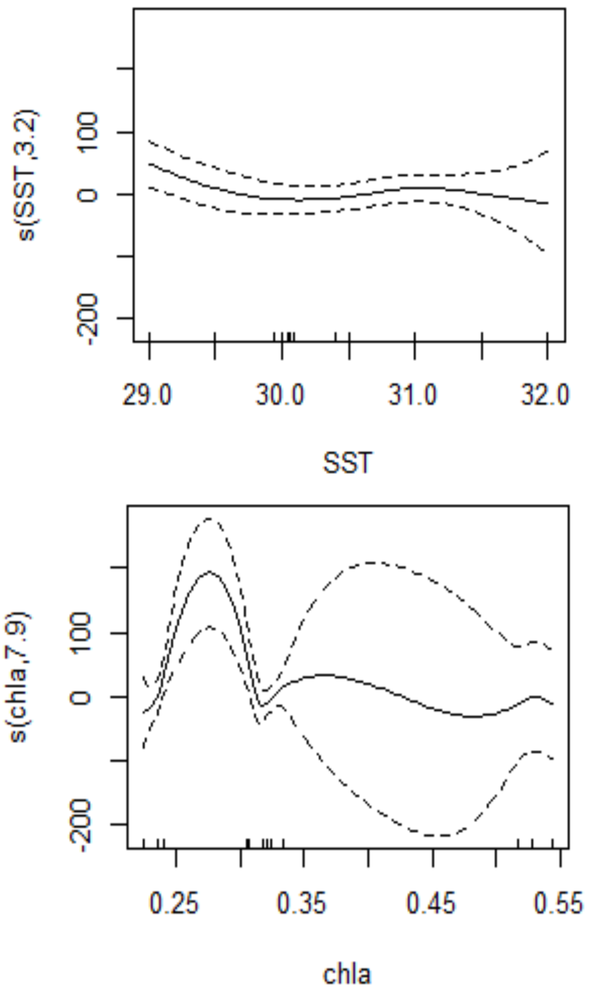


Figure 3. The generalized additive model derived the effect of SST (left) and Chl-a (right) on nominal skipjack CPUE deviance near FAD locations. Both independent variables are included in the

GAM. Dashed lines indicate 95% confidence bands.

In the areas of free school fishing grounds, it seems that both SST and Chl-a had adverse effects on skipjack CPUE. It is clear that skipjack CPUEs tended to be low when SST increase from 30 to 32°C (Figure 4).

However, Chl-a had a good effect on skipjack CPUEs when Chl-a ranged from 0.20 to 0.25 mg m^{-3}. The skipjack pole and liners appeared to increase fishing efforts in the waters of 30.0-30.5°C SST and 0.20 to 0.25 mg m^{-3} chlorophyll-a concentration.

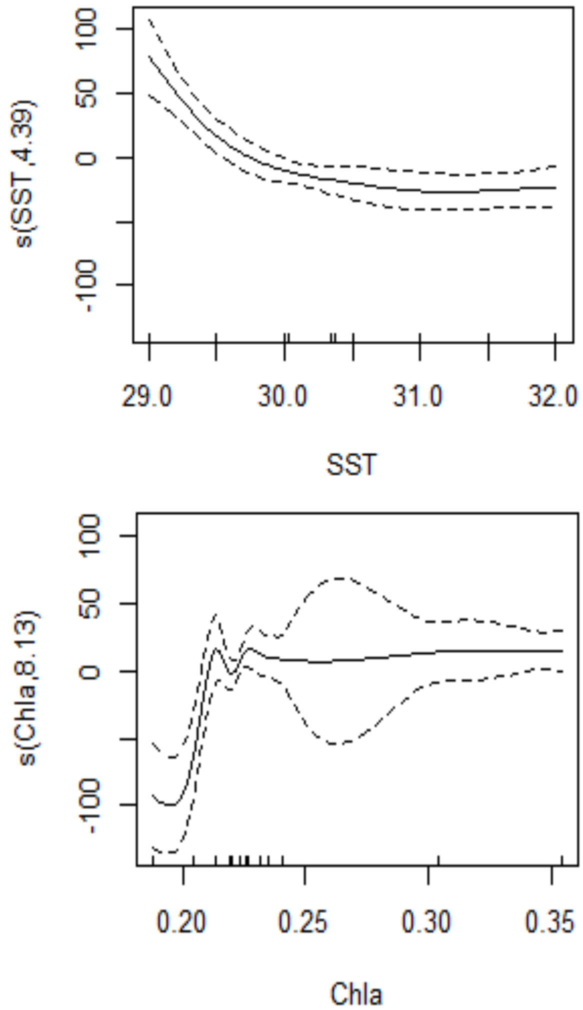


Figure 4. The generalized additive model derived the effect of SST (left) and Chl-a (right) on nominal skipjack CPUE deviance in the

free school fishing grounds. Both independent variables are included in the GAM. Dashed lines indicate 95% confidence bands.

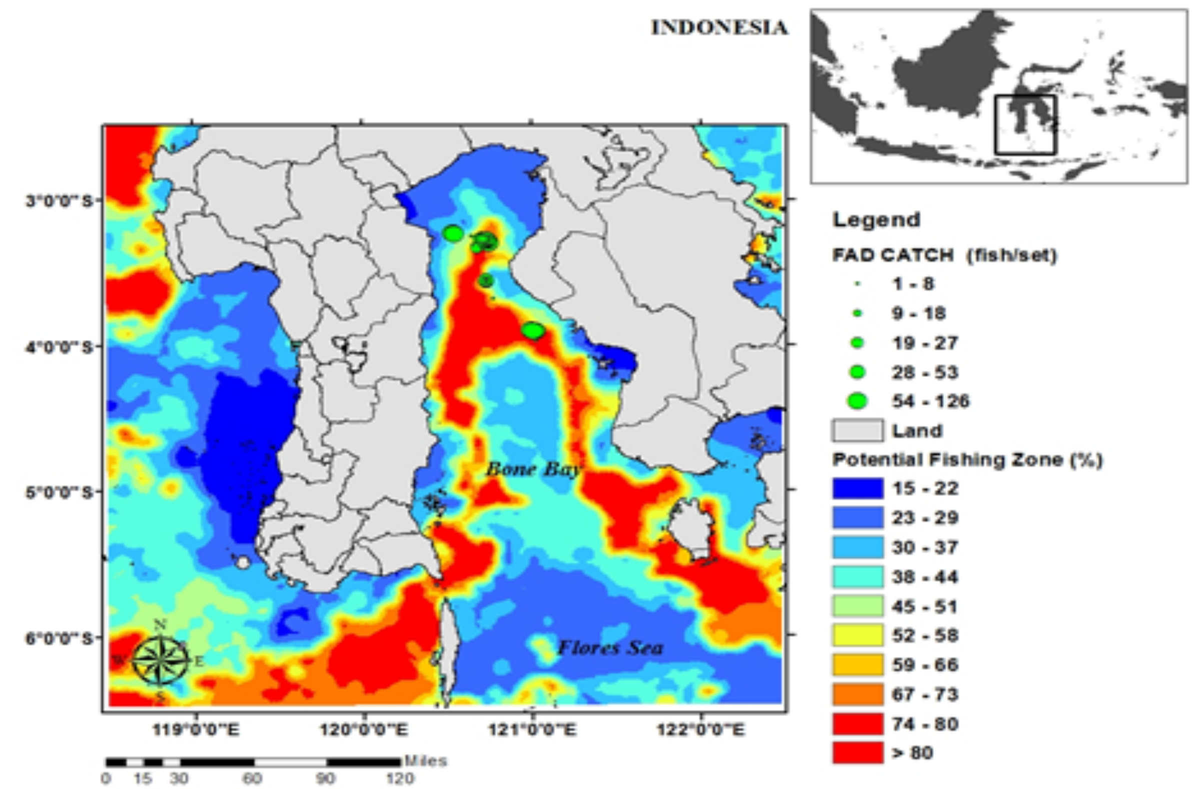
The mean SST of surrounding FAD was higher than that of free school fishing grounds (Table 1). Using T-test, the difference of SST between both locations was not statistically significant. While the mean Chl-a concentration near FAD areas was significantly higher than that free school locations, it interesting to note that skipjack tuna catches near FAD fishing grounds were considerably greater than those free schools fishing locations.

Spatial distribution of skipjack pole and liner in the Bone Bay mostly occurred in areas of preferred SST and Chl-a (potential fishing zones) (Figure 5). It clearly shows that the high catch of fishing sets near FAD have a wide latitudinal band than those in the free school areas. This study found that spatial distribution of skipjack tuna fishing efforts either near FAD or free school locations tended to be random. The several distributions of both FAD and free school fishing sets also appeared to inhabit the same locations within the study area.

Table 1. Performance of fishery and oceanographic factors in areas of FAD and free school fishing ground using T-Test.

No	Variable	Mean FAD	Mean Free Schools	T-test value	P-Value	Significant
1	SST	30.528°C	30.349°C	1.72	0.242	-
2	Chl-a	0.336 mg m^{-3}	0.234 mg m^{-3}	11.53	0.000	**
3	Catch	29 fish/set	15 fish/set	2.291	0.024	**

** Significant at α=5%



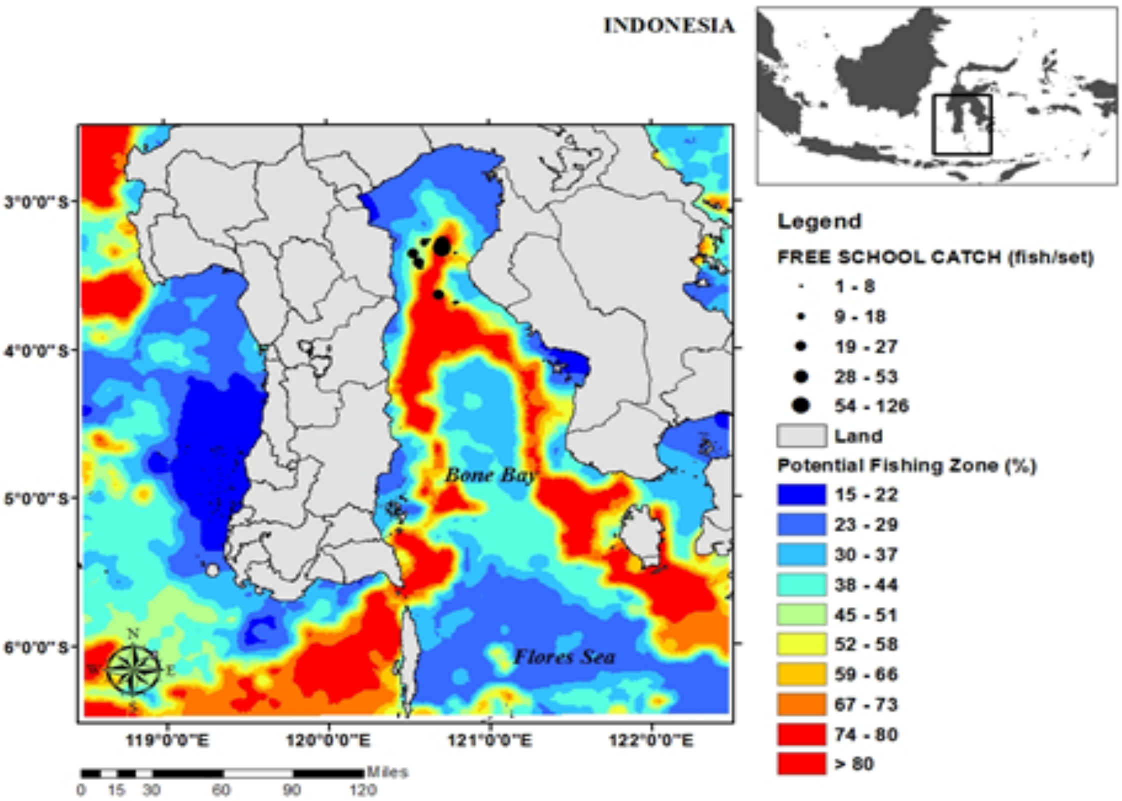


Figure 5. Spatial distribution of skipjack fishing sets near FAD (upper) and free school fishing ground (lower) displayed as dots overlain on potential fishing zone map from May to August.

IV. CONCLUSIONS

In the surrounding FAD locations, skipjack tuna CPUEs are significantly higher than in the free school areas. Our evidence shows that the increasing catch rate near FAD corresponds to the enhancement of Chl-a around that area. Hence, this study suggested that spatial dynamics of skipjack tuna schools corresponded well with the specific area of the warm water SST and relatively high Chl-a concentration. These conditions in surrounding FAD provide enhanced feeding opportunity for skipjack tuna to assemble. It also implies that the Chl-a and SST signatures are capable of detecting potential fish schools or skipjack tuna habitats.

Chl-a is a key in affecting the abundance of skipjack tuna near FAD fishing ground. Chl-a is a good indicator for detecting tuna habitat and migration route. Around FAD locations, Chl-a has a positive effect on skipjack CPUE especially from 0.25-0.35 mg m^{-3}, indicating this factor provides an essential indication of tuna school location in the Bone Bay. A good feeding ground well forms near FAD and leads to significantly increase CPUE particularly in the southeast monsoon (May-August). During this period, the potential skipjack schools were accessible for fishery activities where the skipjack schools were mostly found.

The spatial distribution of both FAD and free school fishing ground should be managed optimally. The FAD fishing grounds are distributed and located near the shore of potential fishing zones (PFZ), whereas the free school fishing areas are plotted in offshore (Deep-Sea) of the PFZ. Therefore, this study supports the application of fishing management and conservation in the Bone Bay by effectively distributing the location of FAD and free school fishing grounds. Certainly, the number of fishing effort for both FAD and free school should take into account the total allowable catch (TAC) for skipjack within this area.

ACKNOWLEDGMENTS

We are greatly indebted to Rachmat Hidayat and Andi Rani Sahni Putri for all assistance in collecting the pole and line fishery data during four months scientific survey in Bone Bay. We also appreciate the use of AQUA-MODIS SST and chlorophyll-a data sets, downloaded from the ocean color portal (http://oceancolor.gsfc.nasa.gov). This work was partly supported to MZ. by the Internal Competition Research Grant under BMIS Hasanuddin University. This study was also partly supported by the PTUPT National Research Grant, Kemenristek DIKTI Indonesia. Acknowledgments to also the CCMRS IPB for choosing this article to be published through The 2nd International Conference on Integrated Coastal Management and Marine Biotechnology 2018 (ICMMBT 2018).

REFERENCES

Andrade, H.A. 2003. The relationship between the Skipjack tuna (*Katsuwonus pelamis*) fishery and seasonal temperature variability in the south-western Atlantic. *Fish. Oceanogr.*, 12:10-18.

Fréon, P. and L. Dagorn. 2000. Review of fish associative behavior: towards a generalization of the meeting point hypothesis. *Rev. Fish Biol. Fish.,* 10:183–207.

Lehodey, P., M. Bertignac, J. Hampton, A. Lewis, and J. Picaut. 1997. El niño southern oscillation and tuna in the western Pacific. *Nature,* 389:715-718.

Mugo, R., S. Saitoh, A. Nihira, and T. Kuroyama. 2010. Habitat characteristics of skipjack tuna (Katsuwonus pelamis) in the western North Pacific: a remote sensing perspective. *Fish. Oceanogr.*, 19(5) 382-396.

Polovina, J.J., E. Howel, D.R. Kobayashi, and M.P. Seki. 2001. The transition zone chlorophyll front, a dynamic global feature defining migration and forage habitat for marine resources. *Progress in Oceanogr.*, 49:469-483.

Ramos, A.G., J. Santiago, P. Sangra, and Canton. 1996. An application of satellite-derived sea surface temperature data to the skipjack (Katsuwonus pelamis Linnaeus,1758) and albacore tuna (Thunnus alalunga Bonaterre,1788) fisheries in the north-east Atlantic. *Int. J. Remote Sensing*, 17:749-759.

Zainuddin, M. 2011. Skipjack Tuna In relation to oceanographic conditions of bone bay using remotely sensed satellite data. *J. Ilmu Dan Teknologi Kelautan Tropis,* 3(1):82-90. http://dx.doi.org/10.29244/jitkt.v3i1.7837.

Zainuddin, M., K. Saitoh, and S. Saitoh. 2004. Detection of potential fishing ground for albacore tuna using synoptic measurements of ocean color and thermal remote sensing in the northwestern North Pacific. *Geophys. Res. Let.,* 31:L20311. http://dx.doi.org/10.1029/2004GL021000.

Zainuddin, M., K. Saitoh, and S. Saitoh. 2008. Albacore tuna fishing ground in relation to oceanographic conditions of northwestern North Pacific using remotely sensed satellite data. *Fish. Oceanogr.,* 17(2):61-73.

Zainuddin, M., A. Farhum, S. Safruddin, M.B. Selamat, S. Sudirman, and N. Nurdin. 2017. Detection of pelagic habitat hotspots for skipjack tuna in the Gulf of Bone-Flores Sea, southwestern Coral Triangle tuna, Indonesia. *PLoS ONE,* 12(10): e0185601. https://doi.org/10.1371/journal.pone.0185601.

Received : 02 January 2019
Reviewed : 18 January 2019
Accepted : 23 March 2019