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THE IMPACT OF OCEANOGRAPHIC PARAMETERS CHANGES ON THE DISTRIBUTION AND ABUNDANCE OF SKIPJACK TUNA *Katsuwonus pelamis* IN MAKASSAR STRAIT

DAMPAK PERUBAHAN PARAMETER OSEANOGRAFI TERHADAP DISTRIBUSI DAN KELIMPAHAN CAKALANG **Katsuwonus pelamis** *DI SELAT MAKASSAR*

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ABSTRACT

This study aimed to identify the changes of oceanographic parameters and to analyze the effects of the parameter changes on the distribution and abundance of skipjack tuna captured by purse seine fishing gear operated in Coastal Waters of Makassar Strait. This study collected fishing and field oceanographic data from May to October 2017. A survey method was used to obtain primary data (skipjack catch per unit effort/CPUE) and secondary data including sea surface temperature (SST) and Chl-a level 3 with a monthly temporal and spatial resolution of 4 km from 2007-2017, interview, and study literature. The data were processed by using SeaDAS and ArcGIS software packages and were analyzed by anomalies, standard deviation, and Generalized Additive Models (GAMs) analyses. The results showed there were anomalies for both SST and Chl-a near study area reflecting the significant changes in the oceanographic conditions. The changes for both SST and Chl-a were 1.5ºC and -0.97 mg.m^{-3} respectively. This study suggests that the Chl-a parameter has more significant effects on skipjack tuna distribution and CPUE than SST. Understanding of the areas of the oceanographic changes strongly supports the available habitat for the fishing operation and conservation.

Keywords: skipjack tuna, sst anomaly, chlorophyll-a anomaly, coastal waters of Makassar Strait

ABSTRAK

Penelitian ini bertujuan untuk mengidentifikasi daerah potensial penangkapan yang mengalami perubahan parameter oseanografi dan menganalisis pengaruh tersebut terhadap distribusi dan kelimpahan cakalang yang ditangkap dengan armada kapal purse seine yang beroperasi di perairan pesisir Selat Makassar. Data yang digunakan pada penelitian ini adalah data tangkapan dan parameter oseanografi dari Mei hingga Oktober 2017. Metode survei digunakan untuk memperoleh data primer (CPUE cakalang) dan data sekunder diantaranya suhu permukaan laut (SST) dan klorofil-a level 3 dengan resolusi temporal bulanan dan resolusi spasial 4 km dari 2007-2017, wawancara, dan studi literatur. Pengolahan data dilakukan dengan menggunakan perangkat lunak SeaDAS dan ArcGIS dan dianalisis menggunakan analisis anomali parameter oseanografi, standar deviasi, dan GAMs (Generalized Additive Models). Hasil penelitian menunjukkan bahwa terdapat anomali parameter oseanografi SST dan Chl-a di sekitar area penelitian yang cukup signifikan, dengan nilai anomali masing-masing pada SST dan Chl-a sebesar 1,5ºC and -0,97 mg.m^{-3}. Penelitian ini berimplikasi pada pentingnya pengetahuan tentang perubahan daerah potensial penangkapan untuk mendukung keberadaan habitat yang layak bagi usaha pengelolaan dan konservasi ikan cakalang di daerah studi.

Kata kunci: *cakalang, anomali sst, anomali klorofil-a, CPUE, perairan pesisir Selat Makassar*

I. INTRODUCTION

Global climate change has a significant impact on marine life in many aspects. Some research has proved how the oceanographic parameters changes such as sea surface temperature (Southward *et al*., 1995; Andrade and Garcia, 1999; Jung *et al*., 2013) affected whether it's plankton or the fish, including skipjack tuna. This is because mostly all of the sea organisms are poikilotherms.

Skipjack is included on top 10 species that contributes to global catch and is one of the most important species of commercial fish. Currently, tuna harvest that comes from the Pacific Ocean is 3.2 of million tones, and it is dominated by skipjack tuna (Lehodey *et al*., 1997; Mugo *et al*., 2010; Jufri *et al*., 2014). On a national scale, the commodity production growth of big pelagic fish especially for skipjack was recorded on 3.63% in the year 2007-2011 (Nelwan *et al*., 2012).

The environment changes to the marine ecosystem are affected by the distribution and fish abundance (Perry *et al*., 2005; Deutsch *et al*., 2015). Skipjack from all around the world is very dependent on strong variations connected to the dynamics of the environmental conditions (Sund *et al*., 1981), as the abundance and distribution of skipjack in South Sulawesi water affected by some of the sea environments (Safruddin and Zainuddin, 2008).

The relation on SST and skipjack, and available fishing data is a common parameter that is used to predict the availability of tuna on an area (Barkley *et al*., 1978; Evans *et al*., 1980; Andrade and Garcia, 1999). The impact of SST changes on tuna distribution related to El-Nino Southern Oscillation phenomenon in the western Pacific also clearly described on Lehodey *et al*. (1997) where the tagged skipjack is moved into the study area during La-Nina period and moved out during the El-Nino period.

Chlorophyll-a is also one of the parameters that take a significant role on availability and abundance of fish on the area. By predicting the amount of chlorophyll-a paired with the fishing data, we can inspect how does the thing possibly affected an area to form the catch area. For example, Sartimbul *et al*. (2010) predicted the distribution of *Sardinella lemuru* using chlorophyll-a and fishing data in Bali Strait. Also, the potential catch area characteristic of skipjack in Bone Gulf identified on chlorophyll-a concentration on 0.125 and 0.213 mg.m^{-3} (Zainuddin *et al*., 2015).

The complexity, uniqueness, and the dynamic of Indonesian Waters make the observed satellite data of oceanographic condition is one of our technology choices to research by near real-time (NRT) and continuously (Wibawa *et al*., 2012). Moreover, the research about population and abundance of skipjack tuna in Makassar Strait is still rare. This is why satellite-based research is essential to do, and furthermore, it will support the next observation for Indonesian Waters to become a sustainable fishing area of skipjack tuna.

II. MATERIAL AND METHODS

2.1. Study Area

This study was conducted in Makassar Strait (2ºN-6ºS and 116-121ºE) where the skipjack tuna vessels operate in several areas including Barru district. Makassar Strait according to Gordon *et al.* (1999) is affected by Indonesia throughflow that composed mostly of North Pacific thermocline and intermediate water flowing through the strait and this throughflow may also affect the oceanographic parameters in that area.

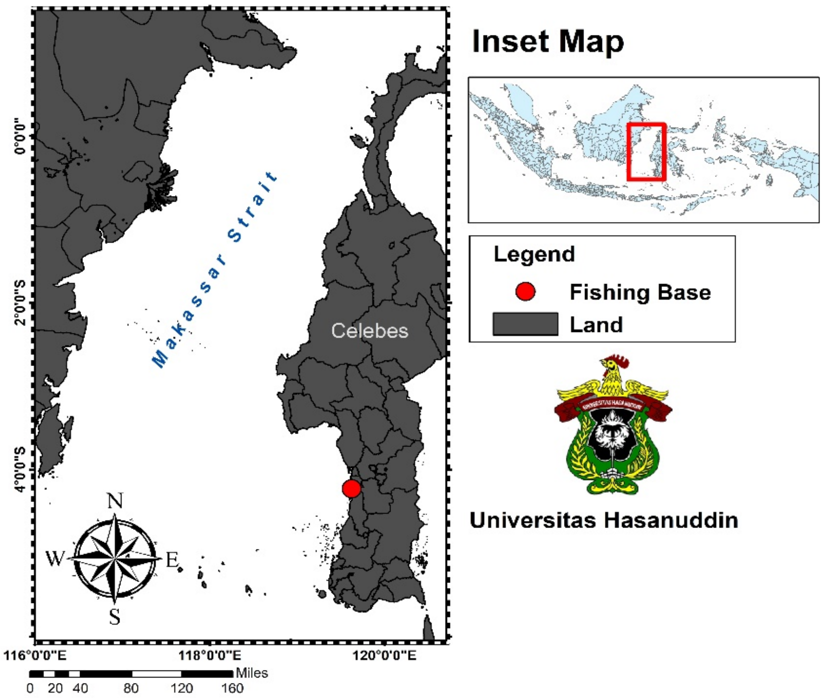


Figure 1. The study location map in the Makassar Strait.

2.2. Fishery Data

Skipjack tuna catch data obtained from local purse seiners that mostly all based in Siddo, Barru District, South Sulawesi. 78 points of fishing sets taken from May to October 2017.

2.2.1. Remotely Sensed Environmental Data

Monthly satellite data were compiled for sea surface temperature (SST) and chlorophyll-a with a spatial resolution of 4 km from 2007 until 2017 using were downloaded from NASA Ocean Color (http://oceancolor.gsfc.nasa.gov) sites respectively, and composited into images using SEADAS version 7.2. All the data were processed into ArcGIS 10.5 using and were interpolated into map images.

2.2.2. Plotting Fishery Data to Remotely Sensed Environment Data

As much as 78 points of skipjack field catch data from purse seiners were matched to corresponding images for SST and chlorophyll-a, using SEADAS 7.2 to extract the values to latitude and longitude positions. The result was a matrix that used to fit GAMs.

2.2.3. Generalized Additive Models

GAMs were constructed in R software version 3.4.2 using the gam function of the mgcv package, with CPUE as the response variable and SST and chlorophyll-a as predictor variables using the formula below.

$$x = \alpha + s(SST) + s\,(\text{Chlorophyll-a}) + \varepsilon \quad (1)$$

Information: α is the modal constant, s is smoothing function from predictor variable, and ε is random error. GAM graphic analysis output can show whether the parameters observed were significant to skipjack catch or not.

2.2.4. Standard Deviation

Standard deviation is the measurement of how to quantify the average deviation distance of measured from its average data. For this analyses, we used the formula below.

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}, \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Information: s is standard deviation, x_1, x_2, ... x_N is sampling data, and $\bar{x}$ is sample average. The output of this was drawn on the graphic map and shown the vulnerability level of a region with the oceanographic parameters anomaly.

III. RESULTS AND DISCUSSION

The gas house concentration that is getting bigger in the atmosphere caused the average of global temperature increased ~0.2°C each decade for the last 30 years with most of the energy is being absorbed by the ocean. On June to August 2009, SST is reaching 0.58°C above the average SST that has been written for 20 centuries, which is on 16.4°C (Guldberg and Bruno, 2010).

SST and Chlorophyll-a anomalies can be seen from 12 maps for each parameter below that monthly represented from 2007 until 2017. The monthly satellite data of 4 km spatial resolution from SEADAS was processed in ArcGIS by using interpolation tool.

The monthly trend of SST for the last ten years was revolved around -2.70 until 2.98°C (Figure 2). Commonly the trend is rising from previous years as we can see by mostly of the months. The most visible area of this changes is southern of Makassar Strait. It is corresponding to the statement of Muhling *et al.* (2015) that said the sea surface temperature is increasing in some part of the world and fish distribution is shifting more and more.

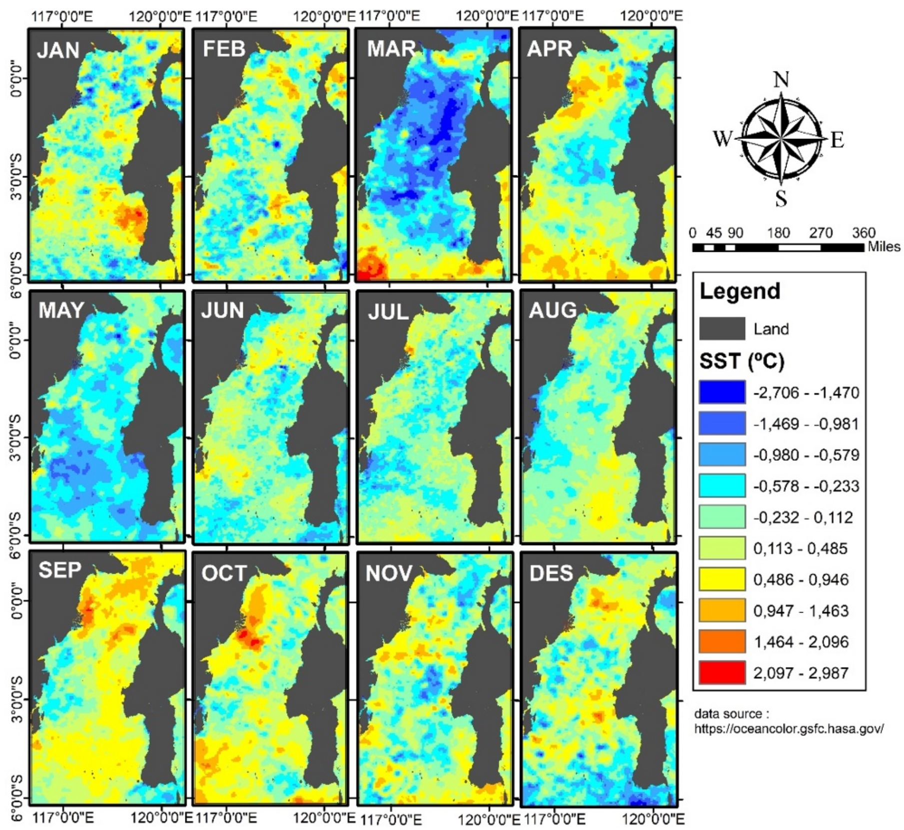


Figure 2. Monthly sea surface temperature anomalies trend in Makassar Strait from 2007 until 2017.

The monthly trend of chlorophyll-a for the last ten years was revolved around -1.95 until 1.96 mg.m^{-3} (Figure 3). On January to April, the chlorophyll-a were tended to be decreasing on -0.54 until -0.23 mg.m^{-3} while from May to August were increasing until 0.43 mg.m^{-3}. On September to October, the chlorophyll-a concentration tended to be decreasing and in December was increasing again.

Seventy-eight of fishing points were plot and extracted from ArcGIS by using a tool of extraction (value to points) to get the latitude and longitude positions. From our field fishing data that taken from May to October 2017, we obtained data catch as follows: 3665 fishes in May, 5074 fishes in June, 6547 in July 2300 fishes in September, and 8450 fishes in October.

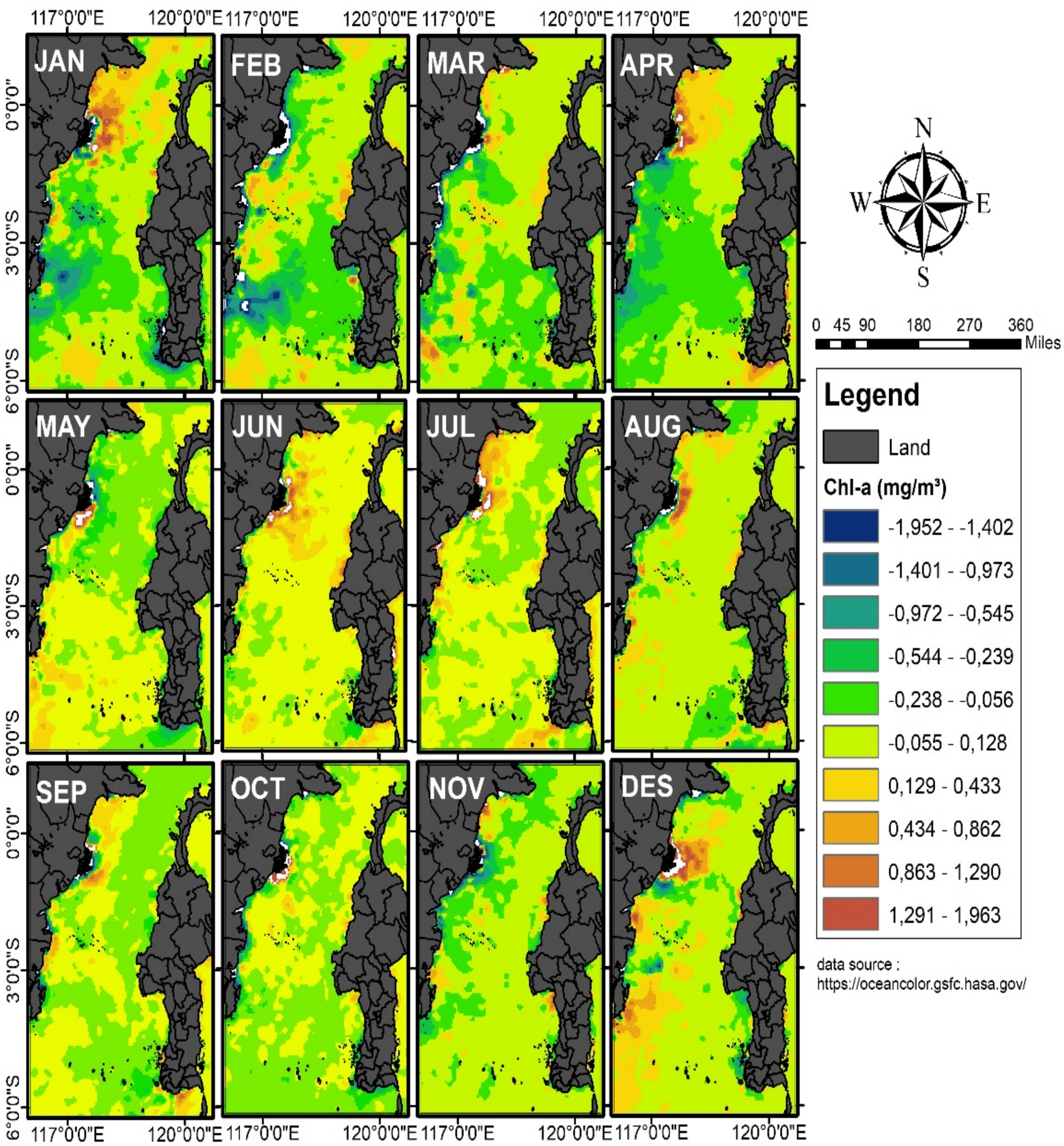
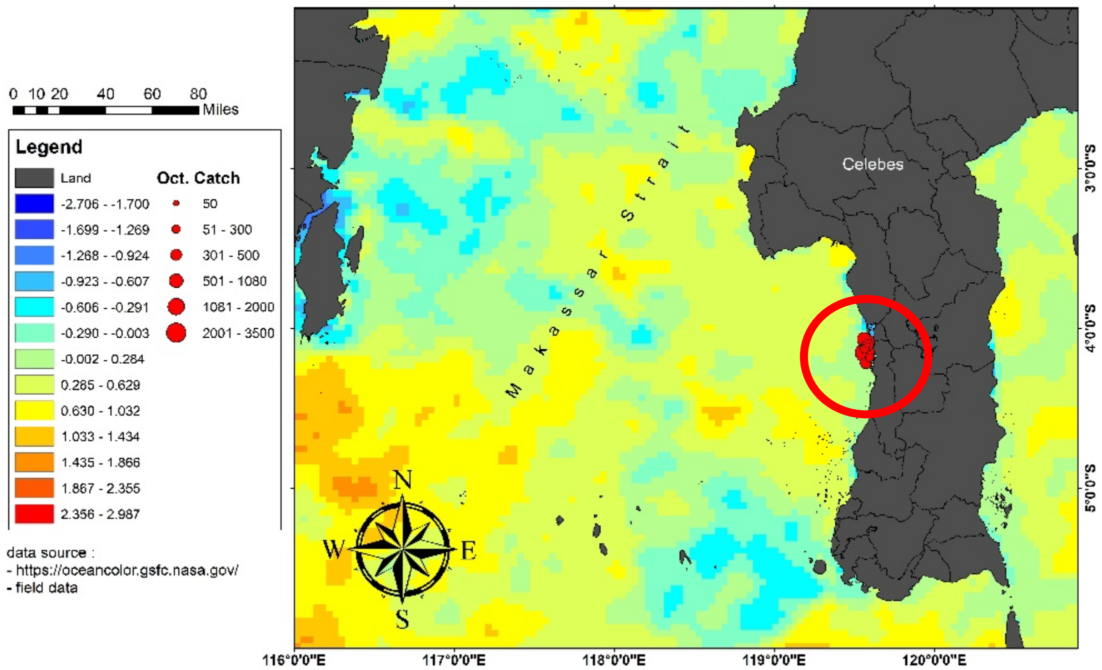
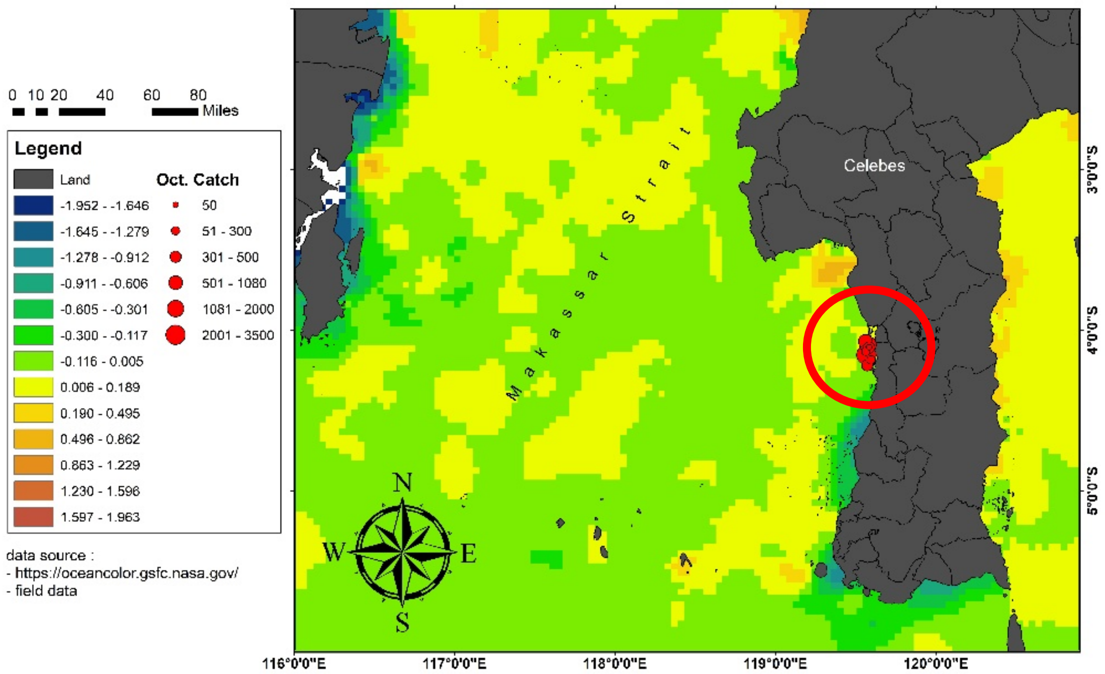


Figure 3. Monthly chlorophyll-a anomalies trend in Makassar Strait from 2007 until 2017.



a)

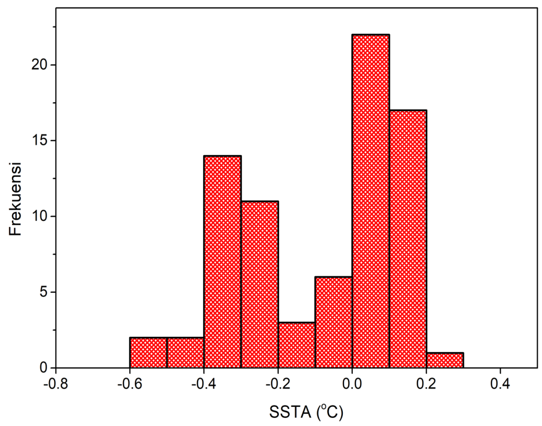


b)

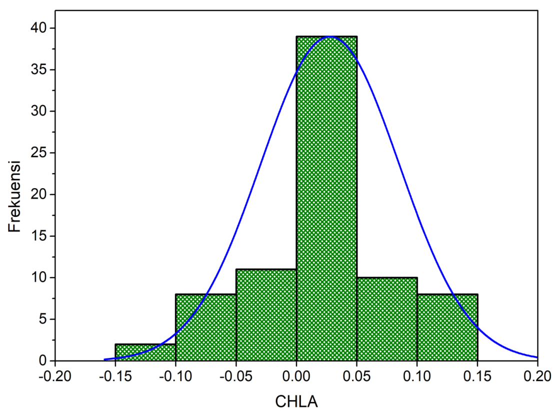
Figure 4. Spatial distribution of skipjack tuna catches by purse seine displayed as dots in October 2017 overlain on (a) sea surface temperature; (b) chlorophyll-a anomaly images.

Sea surface temperature anomaly in October 2017 (Figure 4a) has the anomaly variation range on 2.70 to 2.98ºC. The catches were gathered in the north of Barru Waters. Fishing spots had the SST anomalies around -0.60 to 1.03ºC and the catches range is from 50 to 3500 fishes. Meanwhile for chlorophyll-a anomaly (Figure 4b) has the anomaly variation range on -1.95 to 1.96 $mg.m^{-3}$. The catches were gathered on fishing spots that had the chlorophyll-a anomalies around -0.60 to 0.005 $mg.m^{-3}$.

From the graphic based on sea surface temperature (SST) anomaly (Figure 5a), skipjack caught on anomaly between -0.6 to 0.3ºC, and the highest catch frequency was on 0 to 0.2ºC. The graphic didn't form a normal curve.



a)

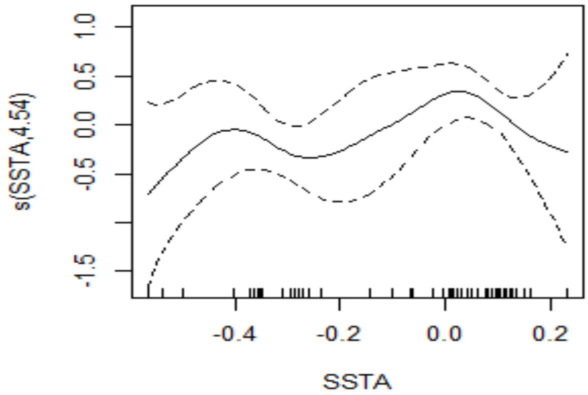


b)

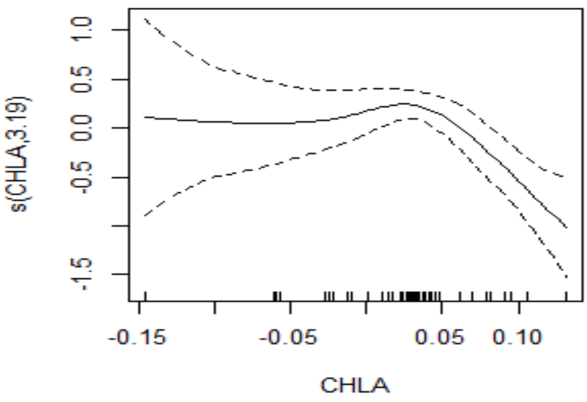
Figure 5. Histograms of catch frequency and environmental variables anomalies showing (a) sea surface temperature; (b) chlorophyll-a.

The relation between skipjack catches, and chlorophyll-a anomaly (Figure 5b) was on -0.15 – 0.15 $mg.m^{-3}$. The highest catch frequency was on range 0 to 0.10 $mg.m^{-3}$, and we can see the graphic formed in a normal curve.

The significance graphic of sea surface temperature anomaly with skipjack catch (Figure 6a) was on -0.4 to -0.2, and 0.0 to 0.2 ºC. While the predictor line was narrow on the same anomaly range with skipjack. According to the chlorophyll-a significance value graphic (Figure 5b) skipjack tuna distributed on a high number in anomaly range from 0 to 0.05 $mg.m^{-3}$. It is parallel with the predictor line where the significant impact is on the same scale.



a)



b)

Figure 6. The significance value of data catches to oceanographic parameters anomalies for (a) sea surface temperature; (b) chlorophyll-a.

The abundance of skipjack can be seen from the total catch of field data. According to the total catch, an increasing number of catch happened from May to July, while on the catch in September was decreasing. Then on October, there was a significantly increased number of the total catch. The distribution of skipjack can be seen from the obtained catch on fishing spots. In May, there were a lot of Skipjack in the north of Barru Waters with the abundance of 400 fish/haul. In June, there were a lot of Skipjack caught in the west of Barru Waters (more or less 119ºE) while on July were on 118º to 119ºE with the abundance of 620 fish/haul. On September the school were concentrated in the north of Barru Waters and the same location in October but tended to be wider to around Pare-pare Waters with the abundance of 3500 fish/haul.

The result also shows that the highest CPUEs of Skipjack associated with relatively higher standard deviation values. We found that the catches were mostly available on standard deviation range of 1.5 – 2.3. This fact means the changes of geophysical oceanographic parameters imply significantly on the highest catches.

On the previous research (Mallawa *et al.,* 2016) said that the purse seine catches in Makassar Strait was been the highest on the transition season period from west season to east season (April to June) and also on east season period (July to October). Based on the result of anomalies trend map specially to SST were correspond to Jung *et al.* (2013) that predict in 2030 the sea surface temperature will tend to be warmer from the previous time particularly in tropical area so that the distribution of tropical fishes will be shifted on the area that will more appropriate to their temperature body. The increasing of ocean temperature will also affect the physiology, and the habit of many marine species (Drinkwater *et al.,* 2010) for example like the metabolism will be work faster, the growth and needs of food will change, and also body activities.

IV. CONCLUSIONS

We conclude that according to anomalies map, there were oceanographic parameters changes in Makassar Strait include Barru Waters where the area is used as the fishing ground to local fisherman. The oceanographic changes had significant impact on the distribution and abundance of skipjack tuna.

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