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To cite this article: R Hidayat and M Zainuddin 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **241** 012011

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Detection of cyclonic and anti-cyclonic eddy in relation to potential Skipjack Tuna fishing ground in Makassar Strait

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Abstract. Makassar Strait is one of best fishing ground in Indonesia. The distribution of skipjack tuna can be detected with oceanography factor. The purpose of this study was to determine the characteristics of eddies which has a relationship to chlorophyll-a in determining the skipjack tuna habitat. The study used geostrophic current data from AVISO which consisted of U (zonal component) and V (meridian component), chlorophyll-a data with spatial resolution of 4 km together with skipjack tuna catch. This research took place in May – July 2017. We used the satellite data of geostrophic current to identify the eddy fields. The results showed eddy intensity in Makassar Strait took place approximately 6-7 days until new eddy appeared. Two types of eddy (cyclonic and anti-cyclonic) were found in Makassar Strait waters. The cyclonic eddy location was appeared in Barru and Palu waters while the anti-cyclonic eddy was detected in the south of Makassar Strait. In addition, the distribution of chlorophyll-a in cyclonic eddy was higher than in anti-cyclonic eddy fields. We found that the occurrence of cyclonic and anti-cyclonic eddies are an important step toward defining skipjack tuna habitat which in turn, play an essential role for fishing operation and management.

1. Introduction

The Makassar Strait has quite dynamic water conditions. The mass of water in the Makassar Strait waters is influenced by the activities of [11](#) Indonesian crossing [\[2\]](#). This current is the result of the difference in sea water levels that occur from the Pacific Ocean to the Indian Ocean [\[3\]](#). Some important phenomenon occurs as a result of this current activity. The Makassar Strait is also one of the locations on WPP-NRI 713 which has great potential. The potential for tuna fishing recorded in 2016 was 419,342 tons in the WPP-NRI 713 region [\[7\]](#). Tuna spesies, especially skipjack tuna, are in great demand by the public. Skipjack tuna fisheries are strongly influenced by environmental factors. Some environmental factors are the main factor in determining capture hotspots [\[5\]](#); [\[11\]](#); [\[16\]](#); [\[18\]](#). Determination of pelagic fish hotspots is a way to predict the presence of fish that can be used as fishing points [\[17\]](#).

Determination of Pelagic Hotspots involves many oceanography factors which are believed to be the best predictors for detecting fish in the ocean [\[1\]](#). Eddy is one of the oceanography factors that can determine the habitat characteristics of pelagic fish, especially skipjack tuna [\[4\]](#). Eddy is an [8](#) extraction of current parameters that has strong links with other oceanography parameters, especially sea surface temperature and chlorophyll-a [\[8\]](#). The use of sea surface temperature and chlorophyll is done by determining the front line of the two parameters, this can produce pelagic hotspot index which can be



tested spatially and temporally to get accurate predictions [18]. The average range of sea surface temperature that has a strong relationship with skipjack tuna fishing ranged from 28 - 31.5 °C with horizontal changes of 0.0 to 0.7 °C while the chlorophyll-a distribution was between 0.15 - 0.35 mg m⁻³ [18]; [15]. In addition to eddy kinetic energy, sea surface temperature, and chlorophyll-a, the determination of hotspots by analyzing oceanographic factors is thought to have a relationship with his work on El-Nino and La-Nina for years. This event is seen to affect the distribution of several oceanographic factors such as increasing and decreasing sea surface temperatures at the point where El-Nino and La-Nina occur. In addition, chlorophyll-a concentration will increase when El-Nino occurs and decreases when La-Nina occurs [14]. Indirectly the temperature rise will affect the eddy rotation [8]. Eddy can also cause upwelling and downwelling in line with the occurrence of El-Nino and La-Nina [12]. Events of upwelling and downwelling will also have a large effect on the level of nutrient fertility in the area of occurrence [6]. With a wide area and oceanographic data that very much feels very difficult to predict the existence of fish using the observation method, the use of data through remote sensing facilities that are currently developing is very effective in supporting the determination of pelagic fish hotspots, especially skipjack fish [10].

2. Material and methods

2.1. Study area

The research was conducted in May - July 2017 located in the waters of Barru, Makassar Strait, South Sulawesi by following the purse seine fishing operation in Siddo Village, Soppeng Riaja Sub-district, Barru Regency.

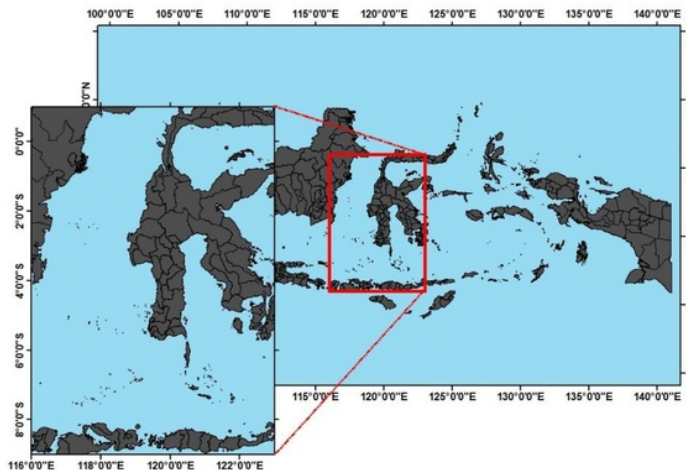


Figure 1. Study area.

2.2. Material

In this study using two main data namely current and chlorophyll-a. Flow data used is daily data obtained from AVISO (<https://las.aviso.altimetry.fr/las/UI.vm>). While for chlorophyll use monthly data from Aqua-MODIS with the 4km resolution provided by Ocean Color (<https://oceancolor.gsfc.nasa.gov/>). In addition to satellite image data, this study also uses catch data of 60 fishing ground points for 3 months of study (May - July 2017) as a validation of the presence of eddy with chlorophyll-a intensity. The software used in this study, among others, SeaDAS to cut and extract chlorophyll data, ArcGIS to create visualizations of cyclonic and anti-cyclonic eddies appearance maps and chlorophyll-a distribution maps to be contacted with the presence of eddy. Then use OriginLab in making graphics.

2.3. Eddies spatial distribution

Geostrophic are obtained from data processing and identify vortex by observing whether there is a circular pattern in the vector plot. Can be concluded as a vortex when a circular pattern is plotted in a vector out or separated from the mainstream. To strengthen the analysis, overly chlorophyll-a data is needed to verify the presence of nutrient anomalies in the area of eddy occurrence. Besides that, the point of catching skipjack fish will also prove the connection of eddy to the tuna fishing area in the Makassar Strait.

The direction of rotation is analyzed clockwise which indicates the occurrence of cyclonic and vice versa anti-cyclonic eddies. The core of Eddies is determined by identifying the midpoint of the circular current visually. The average geostrophic velocity at the vortex can be calculated using the Pythagorean formula:

$$c = (u^2+v^2)^{1/2} \quad (1)$$

Where:

c = The resultant speed of geostrophic current (cm/s)

u = Geostrophic current U component (cm/s)

v = Geostrophic current V component (cm/s)

In looking at the relationship of the vortex with chlorophyll-concentration as an indicator of the phenomenon of upwelling and downwelling. Chlorophyll-a concentrations in each month (May - July 2017) that occur in the formation of the vortex are analyzed with the surrounding area. When dizziness is formed or not formed and the relationship between chlorophyll-a concentration and vortex direction.

3. Results and Discussion

3.1. Eddies spatial distribution

Based on the results of data visualization, the geostrophic currents in the daily dataset, it is known that for 92 days on May - July 2017 the incidence of eddy occurred almost every day in the Makassar Strait. While for monthly datasets, there is 6 times eddy which is divided into 4 cyclonic and 2 anti-cyclonic. Although in the visualization there is some eddy that is not perfectly formed.

3.2. Eddies temporal distribution with daily dataset

We show examples of temporal resolution from eddy distribution that occurs in the Makassar Strait. The existence of eddy is spread in Barru waters, Palu waters and south strait of Makassar waters. There are 33 cyclonic (red circles) and 19 anti-cyclonic (blue circles) perfect eddies [Figure 2]. In this incident, we did not identify eddy whose vortex was not perfect. Shown for temporal resolution, the presence of eddy with approximately the same area lasts 6-7 days.

3.3. Eddies temporal distribution with monthly dataset

Identification of eddy events using monthly data shows there are 7 eddy events in the Makassar Strait, From 7 events, 5 of them were cyclonic eddy [Figure 3]. Monthly data used is a composite result of daily data each month (May - July 2017). The distribution of eddy events using monthly data also shows eddy scattered in the Barru Waters, Palu Waters and the Southern Waters of the Makassar Strait.



Figure 2. Temporal distribution eddies (cyclonic and anti-cyclonic) first day to the 30th day in May 2017.

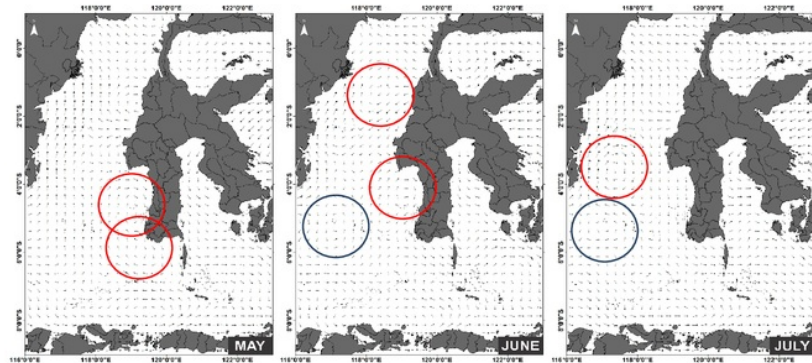


Figure 3. Temporal distribution eddies (cyclonic and anti-cyclonic) use monthly dataset May - July 2017.

3.4. Eddies temporal distribution with monthly dataset in relation with chlorophyll-a

Data overlays between eddy fish, chlorophyll-a and tuna fish skipjack show appropriate results. Distribution of skipjack tuna (60 catch points) from May to July 2017 is in the eddy event area. Also seen if the chlorophyll-a concentration is consistently higher in the vortex area [9].

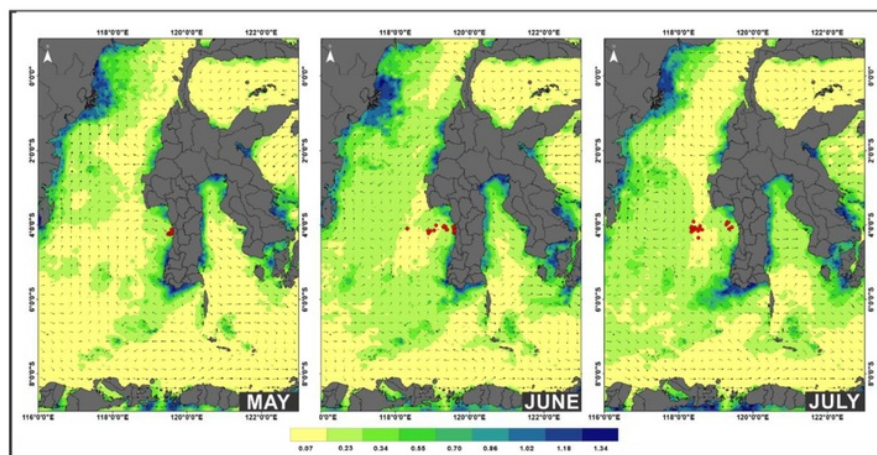


Figure 4. Temporal distribution eddies (cyclonic and anti-cyclonic) use monthly dataset in relation with chlorophyll-a May - July 2017.

Figure 4 also shows, especially in July 2017 the fishing area is quite far from the sea. This incident could be one of the references in determining fishing areas in fisheries management. The area where eddy occurs is a good fishing hotspot. Eddy can be an indication of an upwelling which is one indicator of the increase in nutrients from the bottom of the waters. Increase in nutrients in the surface of the water can be a factor in the presence of fish in the waters.

3.5. Chlorophyll-a distribution

Chlorophyll-a distribution in the study area extracted from the capture point indicates that more than 30% of the 60 catchment catches data is between 0.20 - 0.25 mg m⁻³, in line with the results stated previously which states if the chlorophyll-a distribution which is suitable for catching skipjack fish in

FMA 713 which ranges from 0.15 to 0.35 mg m⁻³ [18]. As for this relationship with eddy distribution. Seen [Figure 4] almost all of the capture points are in areas where eddy occurs. This shows that eddy shows can be an indicator or capture hot spots in waters other than sea surface temperatures.

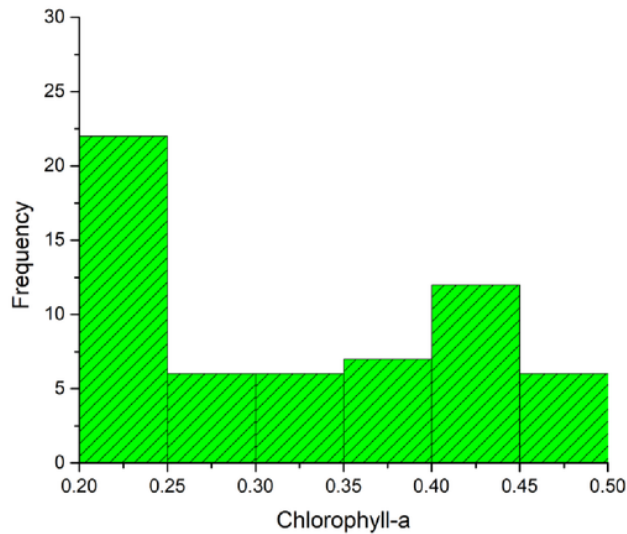


Figure 5. Chlorophyll-a distribution May to July 2017.

The chlorophyll-a distribution extracted from the point of capture tends to have a small value of 0.20 - 0.25 mg m⁻³. This is because skipjack tuna is a top predator which means it is not directly related to chlorophyll-a but will be associated with small pelagic fish [13].

4. Conclusions

Spatially the emergence of the eddy in the Makassar Strait is scattered around Barru waters, Palu waters and southern part of the Makassar Strait waters. Temporally using daily data, the appearance of eddy lasts 6-7 days in an area that is almost the same as the intensity of appearance almost every day. While using monthly data as much as 7 occurrences of eddy during the study. The occurrence of the eddy is directly related to skipjack tuna fishing ground and can be a reference for the fishing area for fisheries management.

Acknowledgements

This study is funded by scholarship program of Ministry of Research, Technology and Higher Education of the Republic of Indonesia (PMDSU research Grant), the National Competitive Research Grant (PTUPT 2018). We wish to thank the Skipjack Spot Hunter team.

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