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Hotspots of Bony Flying fish (H. Oxycephalus) Distribution Constrained by Physical Oceanographic Condition in the central of Makassar Strait during Boreal Winter

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Abstract— *This study performed descriptive and qualitative approach to identify favourable Bony Flyingfish (H. Oxycephalus) distribution using primary data from gillnet flyingsih catches and multisensors satellites oceanography of sea surface temperature (SST) and chlorophill-a (Chl-a) during boreal winter of 2016 (September 2016 – February 2017) in the central of Makassar strait. Emperical Cumulative Distribution Function (ECDF) has been used to analyze the suitability of physical oceanographic parameters with Bony Flyingfish catch. The results show that during boreal winter transition (September to October 2016) hotspot of Bony flyingfish distributed in the coastal water off of Pinrang region and then moved to the north at the frontal water between coastal and off Majene region during the rest of boreal winter (November 2016 – February 2017) with corresponding SST and Chl-a of 29.5 – 31.0C and 0.1 – 0.9 mg/m m3., respectivelly. ECDF analysis indicated that SST has stronger association than Chl-a contributed on the increase of Bony flyingfsih catch in the hotspots areas. The movement of hotspot from off water of Pinrang in September at the south of central Makassar to the north in the off water of Majene during the peak of boreal winter was analysed due to the Indonesian throughflow generated eddy which is still stronger during transition boreal winter and became favourable condition for the hotspot of flyingfish in the Pinrang water.*

Keywords— ***physical oceanographic parameters, Bony flyingfish (H. Oxycephalus), Indonesian throughflow generated eddy.***

I. INTRODUCTION

Flyingfish catches in Majene water in the central of Makassar strait generaly use Gillnet as fishing gear. This technique is considered having high selectibility to ensure sustainable flyingfish catches ([1],[2]).

Based on several studies of catches of flyingfished types in the Indonesian waters, [3] found that Makassar strait and Flores sea have 11 types and then central Maluku (Ambon and surrounding waters) 8 types.

Flyingfish (H. *oxycephalus*) is most dominant catch using gillnet in the Majene water, central of Makassar strait [2]. H. *oxycephalus* species are most dominant catched in Naku water, south of Ambon island [4], in the Seram water [5], and also in the south china sea water associated with Kuroshio current [6].

Satellite oceanography is a remote sensing technology that is now efficiently exploiting ocean and fisheries aspects in term of natural resources management. This technology could monitor all physical aspects in the sea regionally and synoptically, so that useful for any benefit to look for favourable conditions of fishing catches and many purposes such as biological hotspots [7] a potential area favourable for fishing catches associated with certain conducice oceanographic conditions (upwelling, front and eddy).

In physical perspective, the Makassar strait is the main pathways on the Indo-Pacific feature what so called the Indonesian throughflow (ITF) [8]. This strait is known with very dinamic water affected by water masses and current exchanges between Pacific and Indian Ocean, the ITF, and monsoonal current) [9]. Interctions between two different monsoon (wet and dry) and the ITF will influence current circulation and variability of SST and Chl-a in the Makassar strait [10], besides the regional climate change could affect the structure and transformation of physical and chemical properties in this region [11].

Dynamics of physical oceanographic processes will impact on pelagic fish distribution in some certain waters and will find favourable contion for spawning, migration

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and protection [12]. [13] showed that flyingfish is associated with favourable SST, so that accurate prediction of high potential catch of flyingfish (H. *oxycephalus*) could be implemented using other oceanograhic parameters, such as Chlorphyll-a, current, and salinity. Meanwhile traditional fishermen still do fishing with intuitive feeling without any support of this technology using satellite remote sensing.

Flyingfish data from Majene local government fisheries deparmentt (Dinas during last decade showed catch decreasing trend. One factor is our less knowledge on the hotspot diribution of flyingfish changing by season and regional climate variations. In the Makassar strait. This study is intending to use descriptive and qualitative method applying multisensor satellite remote sensing of SST and Chl-a together with flyingfsih (H. *oxycephalus*) catch to see the hotspot areas during the boreal winter in the central of Makassar Strait.

II. DATA AND METHODS

Descriptive and qualitative method will be applied to use mutisensor satellite oceanography that can derive sea surface temperature and chlorphyll-a, and will be related to flyingfish catches using emperical cumulative distribution funtion analysis. All the data are set from September 2016 until February 2017 to accommodate boreal winter.

2.1 Research Area

In order to get flyingfish catch data, we determine Somba in Sendana, one of the coastal sub-districts in Majene Regency, West Sulawesi Province, as the fishing base . The research area is located at coordinates 03° 22' 51.8" S and 118° 50' 47.8" E. The fishing area of drifting gillnets for the capture of H *oxycephalus* is in the central of Makassar Strait, in area with coordinates of 2° 57' 50.40 "- 3° 53' 45.60" S; 118° 7' 4.8" - 118° 46' 19.20" E and 3° 53’ 28.68”- 4° 16’ 48.24”S; 119° 6’ 43.08” – 119° 20’ 48.43”E as shown in Figure 1.

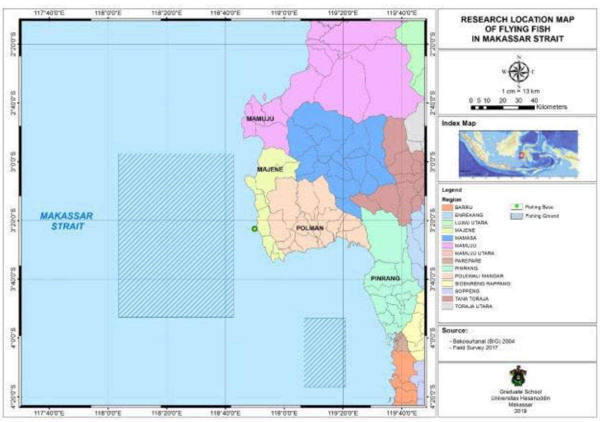

Fig.1: Fishing area of drifting gillnet in the central of Makassar Strait

2.2 DATA

This study utilizes primary data of gillnet flyingfish catch (H. *oxycephalus*) per trip (Catch Per Unit Effort/CPUE) and secondary data of monthly sea surface temperature (SST) and monthly chlorophyll-a (Chl-a) from Aqua/MODIS satellite images. All the image data are free cloud coverage and had been atmospheric and geometrically corrected. The SST and Chl-a data are taken from the MODIS web (www.oceancolor.gsfc.nasa.gov). Catch data are analysied by counting weight per hauling that can represent catch fluctuation spatially and temporally before further analysis to see the relation with SST and Chl-a. In order to increase the quality of flyingfish catch data, interview had been applied to the fishermen.

2.3 Empirical Comulatif Distribution Function (ECDF)

The study applies emperical cumulative distribution function (ECDF) method to see the relationship between oceanographic parameters (SST and Chl-a) and highest flyingfish catch (CPUE) using 3 functions [14,15] as follow:

$$f(x) = \frac{1}{n}\sum_{t=1}^{n} l(xi) \quad \text{.................} \quad (1)$$

With indicator function

$$l(xi) = \begin{cases} 1, if\,(xi \le t) \\ 0, otherwise \end{cases}$$

$$g(t) = \frac{1}{n}\sum_{t=1}^{n} \frac{yi}{y} l(xi) \quad \text{...........................} \quad (2)$$

$$D(t) = \max\left| f(t) - g(t) \right| \quad \text{..................} \quad (3)$$

where:

f (t)	:	Emperical cumulative frequency distribution function
g (t)	:	Catch-weighted cumulative distribution function
l (xi)	:	Indication function
D (t)	:	Absolute value of the difference between two curves f (t) and g (t) at any point t and assessed by standard Kolmogov-Smirnov test
n	:	The number of fishing trips
xi	:	The measurement for satellite-derived oceanographic variables in a fishing trip.
t	:	An index, ranging the ordered observation

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from lowest and highest value of oceanographic variables.

yi : The CPUE in a fishing trip i and averaged estimate of all CPUE fishing trips.

max : Certain number of variable where difference between 2 curves $|g(t)\text{-}f(t)|$) is maximum.

III. RESULTS AND DISCUSSIONS

3.1 RESULTS

Flyingfish CPUE in the research area during boreal winter (September 2016 – February 2017) indicated abundant hotspot around off of Pinrang water in September 2016 and spread to the north around Majene water in October 2016 with catches in the ranges of 65 kg and 107.89 kg, respectively (Fig. 2a and 2b). During November 2016 – February 2017, the flyingfish CPUE reduced significantly and located in the off water of Majene with catch around 86 kg. In general, flyingfish CPUE has the highest catch during transtion period of boreal winter in September and October compared to the rest of boreal winter during November 2016 – February 2017.

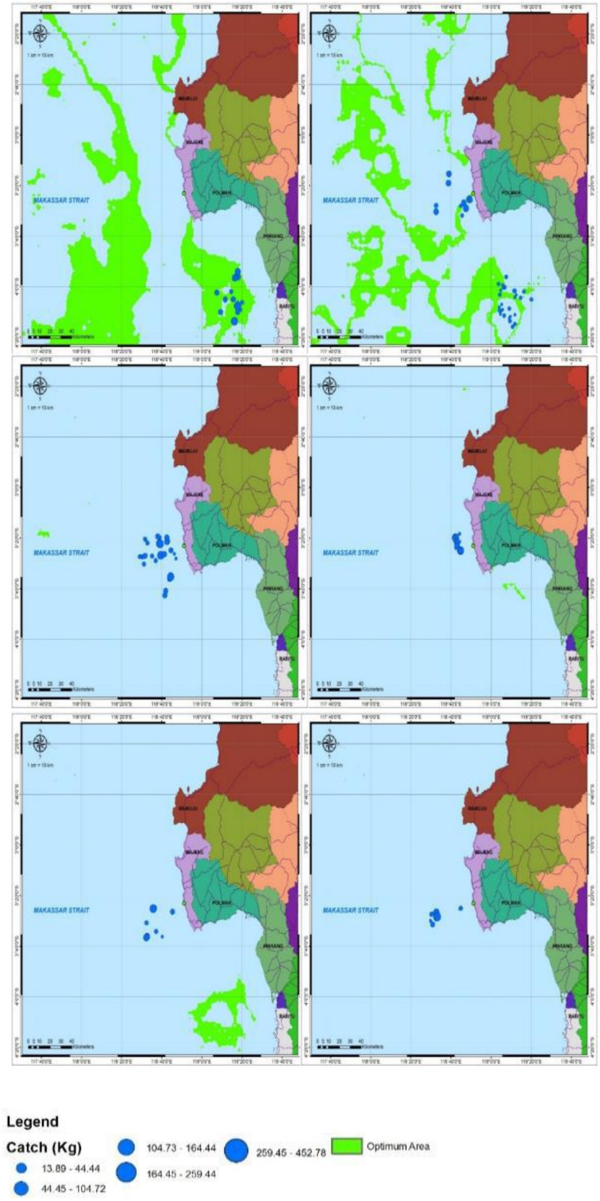

Fig.2: Distribution of optimum area (green zone) and catch of flyingfish (H. oxycephalus) (kg) in September 2016 - February 2017

Sea surface temperature (SST) distribution during boreal winter (September 2016 – February 2017) was dominated by high SST feature stronger in September and October 2016 in the range of 30.5 – 31^{0}C and decreased significantly around the main pathway of the Indonesian throughflow (ITF) from November 2016 until February 2017, in the range of 29.0 – 29.30 ^{0}C. Figure 3 shows the SST distribution superimpose with the flyingfish catch during boreal winter in the central of Makassar strait

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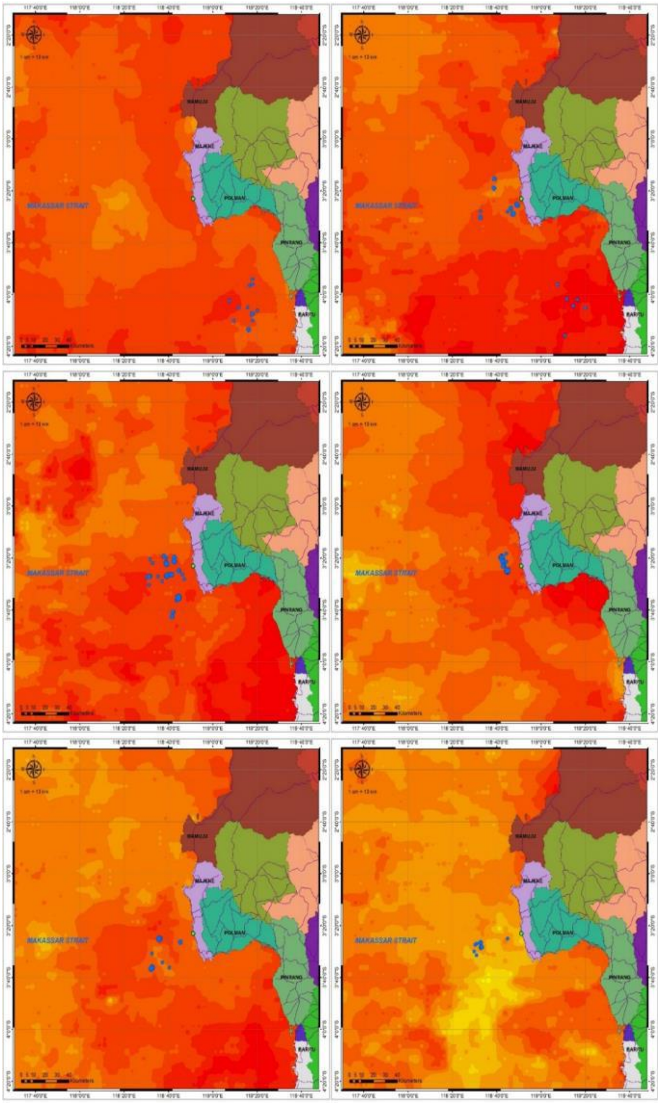

Fig.3: Distribution of SST (°C) and catch of flying fish (H. oxycephalus) (kg) in September 2016-February 2017

Chlorophyll-a (Chl-a) concentration during boreal winter (September 2016 – February 2017) revealed less productivity in most central of Makassar strait, except in the coastal region around Majene bay duriing September – October 2016 in the range of 0.1 - 0.9 . mg.m^{-3}. Chl-a expanded broadly along the main pathway of ITF and coastal areas in the west Sulawesi province with Chl-a concentration increase in the range of 0.1 – 1.3 . mg.m^{-3}. Figure 4 introduces the Chl-a concentration superimpose with the flyingfish catch during boreal winter in the central of Makassar strait.

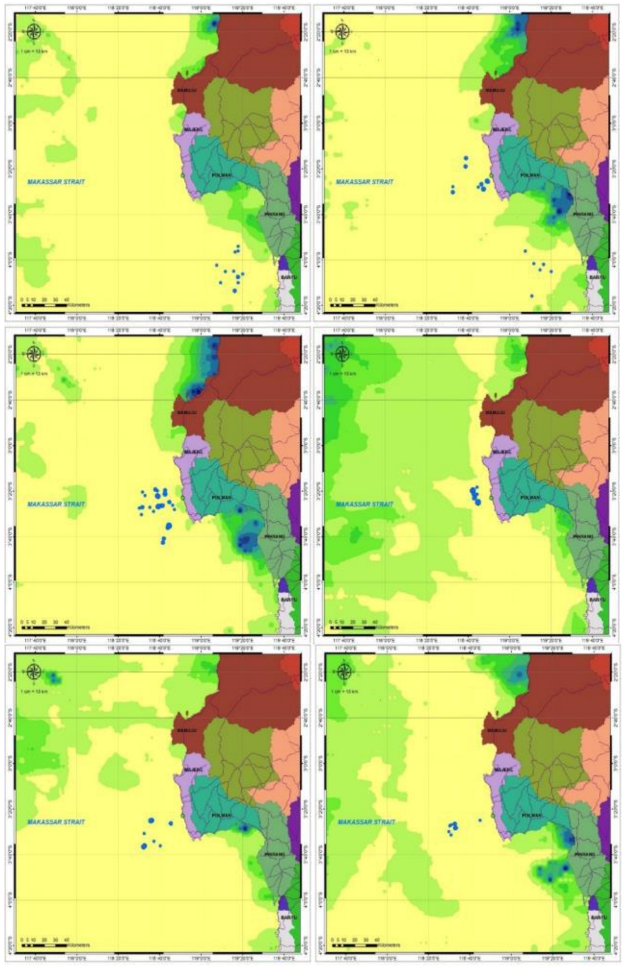

Fig.4: Distribution of CHL-a (mg.m^{-3}) and catch of flying fish (H. oxycephalus) (kg) in September 2016-February 2017

3.2 DISCUSSIONS

High flyingfish CPUE occured in September and October 2016 located off Pinrang water surrounding with relatively homogeneous high temperature distribution in that region. In the following month at the rest of boreal winter during November 2016 – February 2017, the flyingfish CPUE moved to the north in the central of Makassar strait around off Majene water where the hotspots associated with frontal areas. The high flyingfish catch is likely favorable on higher temperature in the range of 30.5 – 31^{0}C during September – October 2016 in the off Pinrang water and reduces to less temperature in the range of 29.5 – 30^{0}C in the rest of boreal winter during November 2016 – February 2017 constrained by frontal areas oround the hotspots in the Majene water.

Less Chl-a concentration during September – October 2016 infers that high flyingfish CPUE during that transition period to boreal winter does not favorable to high flyingfish catch off the Pinrang water. Frontal region revealed by SST distribution around hotspots consistent also seen on the Chl-a distribution during the rest of boreal winter from November 2016 until February 2017 around Majene water.

Figure 5 shows ECDF analysis to identify oceanographic variable of SST favorable to potential high flyingfish catch in the central Makassar strait. The cumulative dustribution curved fifference between two functions has confident level of 95%. The result suppoted the qualtitative analysis on the stronger association of high flyingfish CPUE with the SST in the range 29.5 – 31.0 ^{0}C as shown on Fig. 5 for September 2016 ECDF analysis.

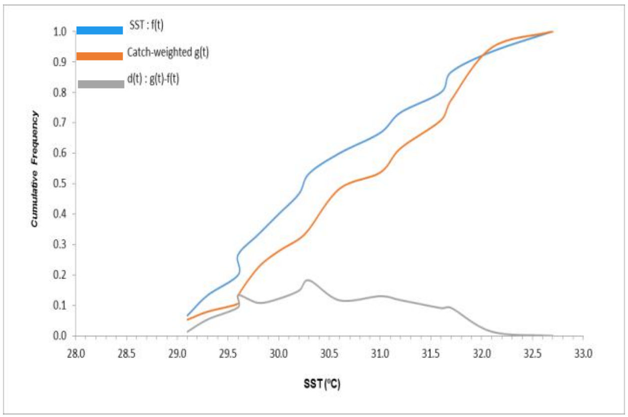

Fig.5: Empirical Cumulative Distribution Function for the SST as weighted by flyingfish catch and also absolute difference of the two curved functions in September 2016.

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High flyingfish CPUE in September and October 2016 was associated with high temperature and had stronger favourable condition with SST compare to Chl-a (ECDF analysis figure is not shown). What cause this strong relatioship occurred around off Pinrang water compare to the less flyingfish CPUE around Majene water during the rest boreal winter from November 2016 until February 2017. Figure 6 is taken from Metzger et. al., 2010 performing mean current system during 2004-2005 simulated by HYCOM in the Makassar strait. There is eddy around hotspot in the off Pinrang water. It is analysed that the high flyingfish catch during September was due to eddy in that associated region.

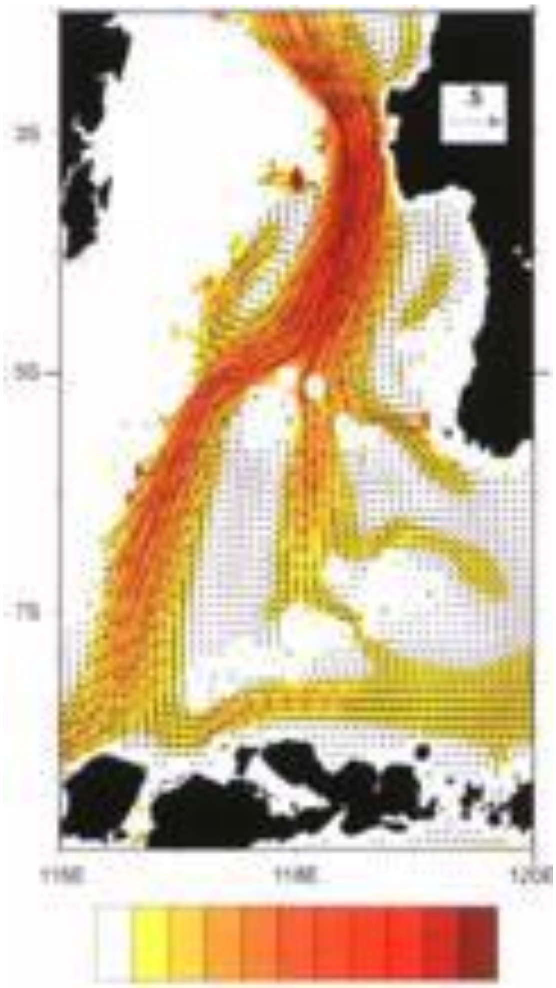

Fig.6: HYCOM mean simulated circulation in the Makassar strait during 2004-2005 (Fig. Taken from [16]).

IV. CONCLUSION

There are two prominent hotspots for the potential flyingfish catches in the central of Makassar strait: firstly in the coastal water off Pinrang region during boreal winter transition (September to October 2016) and secondly in the Majene water during the rest of boreal winter from November 2016 until February 2017. High potential flyingfish catch in the coastal water off Pinrang region was analysed due to eddy in that region, meanwhile around Majene water caused by frontogenegis as shown by SST and Chl-a in the renges of 29.5 – 310C and 0.1 – 0.9 mg.m-3. ECDF analysis indicated that SST has stronger association compare to Chl-a on the increase of flyingfish catch.

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