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Estimating potential fishing zones for Skipjack Tuna (*Katsuwonus pelamis*) Abundance in Southern Makassar Strait

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Abstract. This study aims to estimate potential fishing zones by estimating the abundance of skipjack fish in the Makassar Strait using satellite data and Geographic Information Systems (GIS) techniques. The data used consists of catch coordinates, skipjack catches, oceanographic data from satellite imagery with high-resolution Spectra-Resolution Imaging Spectroradiometer (MODIS) Aqua data (sea surface temperature, chlorophyll-a), Etopo1 for depth, and Aviso for the current speed. The prediction of skipjack tuna abundance is calculated by the Generalized Additive Model (GAM) prediction function to determine the best parameters seen from the AIC and GCV value, then mapped using geographic information system techniques by using the multi-regression formula. The results showed that the most potential fishing ground for skipjack tuna in the Makassar Strait was in March 2018 with an estimated abundance of more than 477 fish km^{-2} at coordinates 118.1297 east longitude and -3.3814 southern latitude. We suggest that efforts to catch Skipjack Tuna are directed to this area for more profitable catches.

1. Introduction

Makassar Strait waters have abundant and diverse fish resources and are included in the Fishing management area (FMA)-713. The potential for tuna fishing recorded in 2016 was 419,342 tons in the WPP-NRI 713 region; one of them is skipjack [1]. Skipjack tuna is also a species that dominates the world fish market and is a target of the international market [2-3]. Skipjack tuna has a broad migration pattern and mostly located in the equatorial region [4]. Even many industrial fleets target tuna fish production [3,5]. The existence of skipjack tuna is closely related to environmental factors dynamics, especially the location of foraging grounds [6-7]. Many environmental factors are associated with skipjack tuna's movement, such as sea surface temperature, currents, chlorophyll-a, depth, and other environmental factors [8-9].

Skipjack tuna resources in the waters of the Makassar Strait south have shown an increase in exploitation. Increased fishing such as the amount of effort and reduced efficiency of fishing gear can reduce production and not selectively catch the size of the skipjack tunas. Based on data from the South Sulawesi Maritime and Fisheries Service, skipjack tuna production from seven regencies and cities on the Makassar Strait coast in the past six years showed an average increase in production of 3.47% from

IOP Conf. Series: Earth and Environmental Science **564** (2020) 012082 doi:10.1088/1755-1315/564/1/012082

3,580.5 tons in 2008 to 4,201, 7 tons in 2012 [10]. The results of the Y '/ R analysis show that there has been a decline in the catch of skipjack tuna in the south Makassar Straits beside this, to improve the catch need to be reduced the number of fishing effort units and expansion of fishing areas as well as management control over the characteristics of ships and fishing gear fisheries used [10]. With the potential and ease of obtaining satellite imagery data, the use of geographic information systems (GIS) as a source of information about fishing potential and estimation of fish stocks in water. Besides, the depiction of the condition of the earth's surface using satellite imagery is much more efficient because the satellite imagery can observe the situation on the surface of the earth in an extensive range [11]. One of the ways that can do to help policymakers, in this case, the government authorities are the information needed about the abundance of fish in the waters of the Makassar Strait as a reference in making decisions in the management of fish resources. Therefore, research on Estimating Potential Fishing Zones for Skipjack Tuna (*Katsuwonus pelamis*) Abundance in Southern Makassar Strait must to conducted. The point of this research is to predict the area of skipjack fishing based on the best model of GAMs.

2. Research methods

2.1. Study are and material

This research was conducted in Makassar Strait by following purse seine fishing gear capture operations. Research time between March to July 2018. The sample points used in this study were 81 points. The point uses acts as a reference to predict fish abundance in the Makassar.

Additional data used were obtained through observation of the Aqua Satellite Image (MODIS) by Ocean Color (https://oceancolor.gsfc.nasa.gov/) for sea surface temperature and chlorophyll-a, while for current were taken from the AVISO Altimetry site (https://las.aviso.altimetry.fr/las/UI.vm) and depth data from Etopo1 (https://www.ngdc.noaa.gov/mgg/global/).

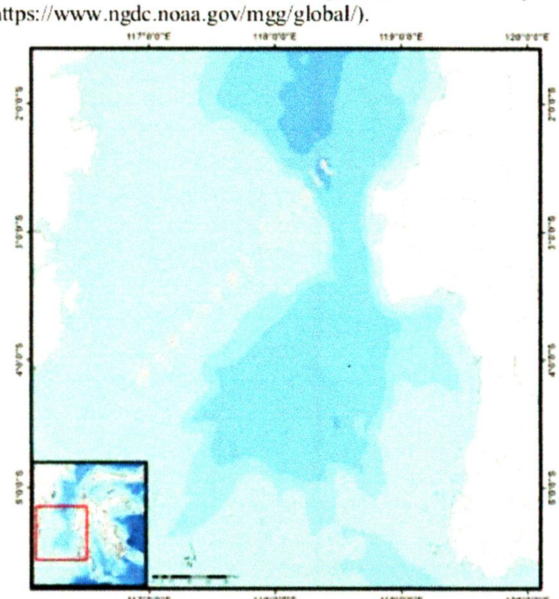

Figure 1. Study Area in Makassar Strait

2.2. Methods

2.2.1. Determination of the optimal model as a reference for prediction skipjack tuna abundance.
The method used a generalize additive model (GAM) to see the effect of multi oceanography parameters on catch [12-13]. To apply this model, we used R software with the formula:

$$g(\mu_i) = \alpha^0 + s_1\,(SPL) + s_2(CHL) + s_3(Current) + s_4(Depth) + \varepsilon \qquad (1)$$

Where:
g = spline smooth function,
μ_i = response variable
α^0 = constant coefficient
s_n = smoothing function of the predictor variable
ε = standard error

The analysis continues by looking at the value of Akaike Information Criteria (AIC) and Generalized Cross-Validation (GCV). A witch will be used to determine the optimal model.

2.2.2. Skipjack tuna abundance prediction.
The next step is finding the intercept and slope values for each test parameter that is doing by T-test analysis. After obtaining the intercept and slope values, the selected model will be used to predict fish abundance using multiple regression. The prediction made using the raster calculator facility in the ArcGIS program to manage data using multiple regression. The formula is as follows:

$$y = a + b_1X_1 + b_2X_2 + \cdots + b_nX_n + \varepsilon \qquad (2)$$

Where:
y = dependent variable,
a = intercept
b_n = slope
X_n = independent (explanatory) variable
ε = standard error

Determination of capture points utilizing the spatial techniques of analysts in ArcGIS software. The results of the multiple regression analysis are the basis for determining the fishing point in the Makassar Strait.

3. Result and discussion

3.1. The optimal model as a reference for prediction skipjack tuna abundance.
In this study, we used four oceanographic parameters (sea surface temperature, Chlorophyll-a, Flow, and depth). Sea surface temperature is the main parameter in marine life. In addition to being able to determine fish sea surface temperature also affects the metabolic rate and fish reproduction cycle [6,14] while Chlorophyll-a is a factor that can reference the fertility of the waters by assuming the amount of phytoplankton in the waters [15]. Ocean currents and depth are closely related to fish migration at sea. Currents that occur in the Makassar Strait are the result of differences in seawater levels that occur from the Pacific Ocean to the Indian Ocean [16], known as Indonesian throughflow [17] and depth can describe the swimming layer of the skipjack tuna as the object of the research.

Before creating the model, we first examine the effect of these oceanographic parameters on catches with GAM analysis. We get a positive effect relationship about catch like Figure 2, and The analysis can be continued by looking at the AIC and GCV values. AIC is widely used as an initial parameter of forecasting because it can explain the suitability of the model with the forecast sample [18] while GCV is the value that comes out of the selection of the best regression component for forecasting [19].

From the results, we compared ten models (table 1) to choose the best model. Table 1 shows ten models resulting from a combination of sea surface temperature, Chlorophyll-a, Current, and depth to get the best model.

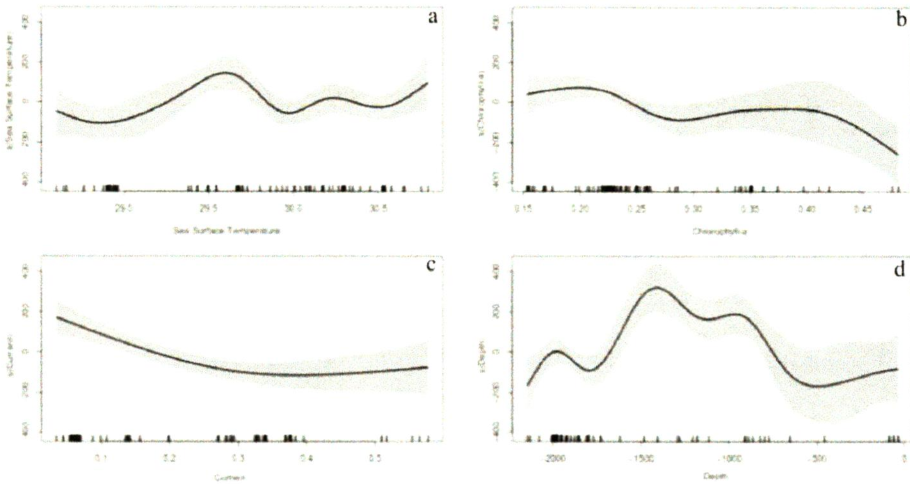

Figure 2. GAM effect of the four oceanographic variables on CPUE, from the model constructed with: (a) Sea Surface Temperature, (b) Chlorophyll-a, (c) Current and (d) Depth. The grey-shaded area indicates the 95% confidence intervals; the solid line shows the fitted GAM function, which describes the effect that a predictor variable has on the response variable (CPUE). The rug plot on the x-axis shows the relative density of data points.

Table 1. GAMs fitted in the model selection process (N = 81). The model, predictor terms used, the estimated degrees of freedom, Akaike information criterion (AIC) value, and Generalized Cross-Validation (GCV). The 'best' model was selected based on the significance of predictor terms, reduction of AIC, and GCV.

No.	Model	N	GCV	AIC
1	SST + CHL	81	19443	1029.88
2	SST + DPT	81	13527	998.049
3	SST + CRN	81	17319	1021.935
4	CHL + DPT	81	11462	985.876
5	CHL + CRN	81	14987	1009.457
6	DPT + CRN	81	12459	994.32
7	SST + CHL + DPT	81	10671	974.896
8	SST + CHL + CRN	81	13712	1000.586
9	CHL + DPT + CRN	81	10886	981.313
10	SST + CHL + DPT + CRN	81	9299	963.246

* SST = Sea Surface Temperature
CHL = Chlorophyll-a
CRN = Current
DPT = Depth

We can see from the AIC and GCV values from the 10th model. The most significant model is to use a combination of sea surface temperature, Chlorophyll-a, Current, and depth. AIC Value obtained were 963.246 and GCV is 9299, with a total sample of 81 catch point.

3.2. The optimal model as a reference for prediction skipjack tuna abundance.
The value of AIC and GCV is the basis for making a multi-regression model used to predict fishing grounds. In multi regression, we need intercept and slope values for each parameter. Therefore a t-test was performed to determine the value of the intercept and slope (Table 2).

Table 2. T-test Result

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-6045.847	1736.446		-3.482	.001
	SST	253.234	65.860	.496	3.845	.000
	CHL	-1224.172	682.240	-.295	-1.794	.077
	DEPTH	.264	.104	.567	2.549	.013
	CURRENT	-2374.808	493.893	-1.002	-4.808	.000

a. Dependent Variable: CATCH

These coefficient values used to determine the proportion of sea surface temperature (X_1), chlorophyll-a (X_2), current (X_3), velocity, and depth (X_4). so the formula is formed as below :

$$y = (-6045.847) + 253.234(SST) - 1224.172(CHL) + 0.264(DEPTH) - 2374.808(CURRENT) + \varepsilon \quad (3)$$

It means that any decrease or increase in the parameter has an impact on the slope value. At sea surface temperature, each increase of 1° C will increase the 253 population, while for chlorophyll-a, every increase of 1 mg m^{-3} will decrease in population by 1224 and so on. Visually the results of the analysis of multiple regressions are shown in figure 3. In the picture shown below, the Makassar Strait area has a large population potential. The visible abundance of fish evenly distributed in the southern part of the Makassar strait from March to July. This is because March to July is still in the same season.

The determination of the fishing point is obtained from the optimal value parameter combined to form a capture zone. The fishing zone is then extracted to the catch point using spatial analysis techniques (figure 3). From this combination of techniques, a potential map with a catch point in the south of the Makassar Strait is formed. The combination of fishing point predictions and the prediction of skipjack fish abundance can determine the potential fishing area. The highest potential catch is at the prediction fishing point that is equal to 477 fish km^{-2} at coordinates 118.1297 east longitude and -3.3814 southern latitude. This potential was predicted in March 2018 (figure 4).

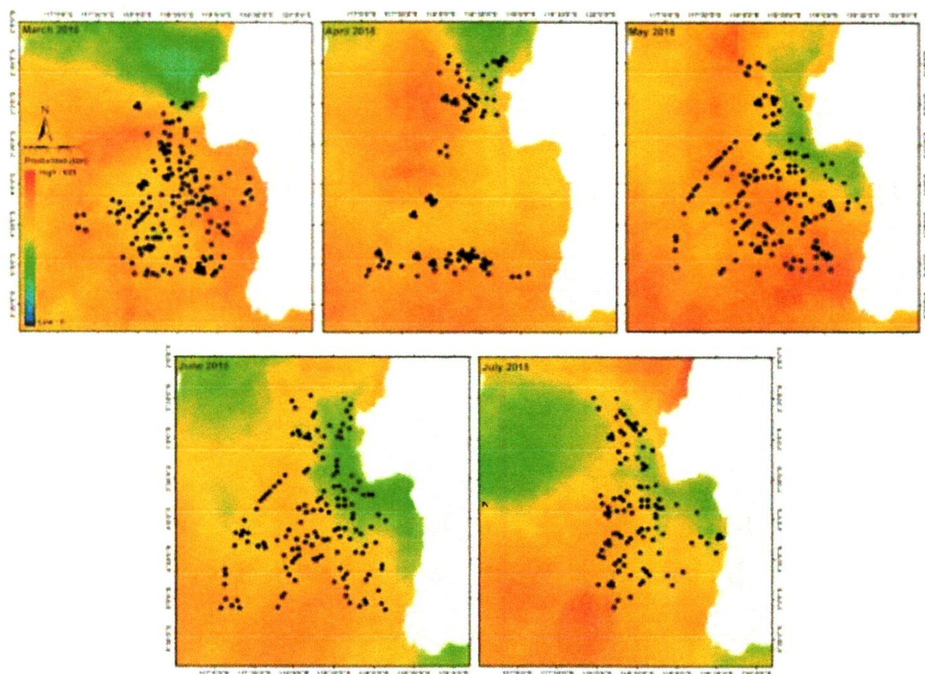

Figure 3. The prediction of the distribution of fishing points and abundance skipjack tuna from March to July 2018.

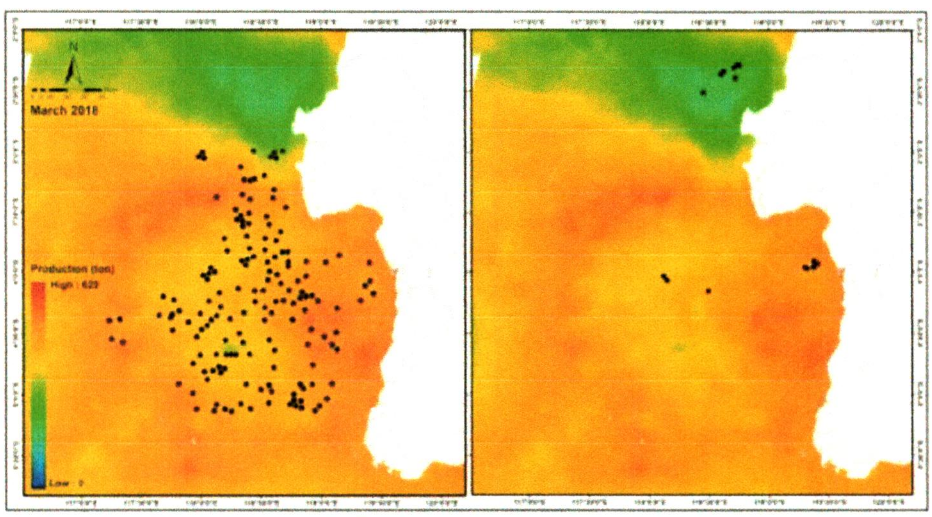

Figure 4. The Prediction of fish abundance in March 2018 (left), actual fishing data (right).

Although outside of the research objective, figure 4 showed that the catch point prediction results (left) have similarities with the actual catch point data (right). This finding can indirectly be a reference to make widespread regional predictions not only on fish abundance but also potential fishing positions.

4. Conclusions

Predictions of fish abundance in early 2018 (March - July) show that the highest abundance occurred in March with 477 fish / km2. The results of the prediction of fishing point can be a reference in the utilization of skipjack fisheries in the Makassar Strait.

Acknowledgments

We recognize the use of Aqua Satellite Image (MODIS) by Ocean Color (https://oceancolor.gsfc.nasa.gov/) for sea surface temperature and chlorophyll-a, while for current were taken from the AVISO Altimetry site (https://las.aviso.altimetry.fr/las/UI.vm) and depth data from Etopo1 (https://www.ngdc.noaa.gov/mgg/global/). This study was funded under the scholarship program of the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia (PMDSU research Grant No. 1739/UN4.21/PL.01.10/2019). We also wish to thank the Skipjack Spot Hunter team.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9