# GAM (Generalized Additive Model) Analysis for Predicting Potential Area of Lemuru in Bali Strait

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## Abstract

Lemuru is a potential fish in the Bali strait with 80% of the total catch. The fishing process is determined by the efficiency and effectiveness of improving the fishing area. However, the lack of awareness of fishing areas by fishermen tend to be less optimal, waste of time and fuel. One of the alternatives is to use remote sensing data. Fishing areas information can be obtained through oceanographic parameters. Sea surface temperature and chlorophyll-a are main factor determined fishing areas. This study aims to predict the fishing area of S. lemuru using GAM (Generalized Additive Model) analysis, the results of this model can show a range of oceanographic factors that significantly explain high fishing related to marine environmental parameters. Fishing data and coordinates were obtained from PPP Muncar, Banyuwangi on May 2021. Data used is from fishing data around two years in Bali strait. The optimum value of chlorophyll-a Lemuru fishing is at 0.1- 1.2 mg $m^{-3}$ and sea surface temperatures around 27 - 31°C. According to GAM statistical modelling, the most appropriate fishing area was data combination among data fishing, sea surface temperature of AIC and CDE AIC around 23044.21, and CDE 8.18%. The whole area of Bali strait is Lemuru fish distribution yet located in different areas each season such as west season at latitude (-8.26°)-(-8.59°) longitude (114.466°)-(114.449°), east season at latitude (-8.74°)-(-8.70°) longitude (114.299°)-(114.187°), while in transition season 1 at latitude (-8.50°)-(-8.78°) longitude (114.819°)-(115.070°) and season 2 at latitude (-8.27°)-(-8.56°) longitude (114.742°)-(114.819°).

**Keywords**: Bali Strait, Fishing Area, GAM, Lemuru

## INTRODUCTION

Fishing area awareness is very important to improve the efficiency and effectiveness of fishing. Information on fishing areas can be obtained through oceanographic parameters. One of the alternatives which provide the best solution to determine fishing areas is combined SIG (Geographic Information System) capabilities and remote sensing [1]. The lack of knowledge of fishermen toward fishing areas can cause negatives to impact such as less optimal fishing, waste of time and fuel. In the process, fishermen still use traditional methods such as relying on fishing habits [2].

Bali strait waters are geographically located between Java and Bali Island around 900 miles2. According to fishery marine statistical in 2017, this is one of the waters who has higher potential fishing in Indonesia produces 100 tons per year which most of them Pelagic. The potential Pelagic who has higher economic are Scad, Tuna, and Lemuru fish [3]. Lemuru is a small pelagic resource that is the main commodity in Bali Strait waters [4] around 80%.

Oceanographic parameters are one of the factors that influence the variability of fishing, such as chlorophyll-a [1]. Chlorophyll-a is one indicator of the abundance of phytoplankton in waters. Primary productivity of waters can be seen from the abundance of phytoplankton that carries out the process of photosynthesis to produce organic products, while primary productivity is used as a health reference of an environment and the richness of various marine resources [5].

The dynamic relationship of oceanographic influence and fishing (field conditions) are not linear, however it is necessary to use a

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statistical approach that does not require data linearity, therefore GAM is used. GAM (generalized additive model) is a statistical approach that is widely used to predict the environmental/habitat relationship of fish without requiring data linearity. The GAM (generalized additive model) statistical approach has been used in various seas in Indonesia with better accuracy in estimating fish distribution areas. The GAM model was used to measure the effect of oceanographic variables on the distribution and abundance of fish. Determination of potential fishing areas precisely and accurately is used field data (fishing data by fishermen) and satellite image data. Satellite image data is used to quickly assess potential fishing areas over a large area [6].

From the various explanations above, it is known that it is necessary to conduct research on the distribution of Lemuru according to oceanographic parameters using geographic information systems or remote sensing used the Generalized Addictive Models (GAM) method to determine the relationship between Lemuru fishing and oceanographic parameters that occur in the Bali strait.

## OBJECT AND METHOD

### Research Areas and Data Sources

The study area of this research is located in Bali Strait. The Bali Strait are geographically located between the Java and Bali Island with an area of up to 900 miles square which can be seen in Figure 1. Acquisition of data fishing obtained from the Muncar Fishery Port located in Kedungrejo Village, Kec. Muncar, Banyuwangi Regency.

Some paths used in mapping the distribution of Lemuru fishing areas are based on geographic information systems in Bali Strait are the first to download SNPP-VIIRS satellite image data, to map Chl-a and sea surface temperatures. SNPP-VIIRS data is high quality remote sensing data [7]. The satellite image data is then processed by using the application of SeaDAS 7.2, Er-Mapper, Arcgis 10.3 with the output of a distribution map of the potential area for lemuru fishing and a map of the distribution of oceanographic parameters. The variability analysis oceanographic data will be used to determine the optimum parameter values for Lemuru. After obtaining the oceanographic parameter values, it will be processed by coordinate point data for fishermen's fishing (obtained from PPN Muncar) to predict the GAM statistical approach which will be processed using the Rstudio application to model GAM and plot GAM in the form of a smoothing curve. In general, GAM uses a smoothing curve to model the relationship between fishing (response variable) and oceanographic variables, which in this case are called predictive variables [8].

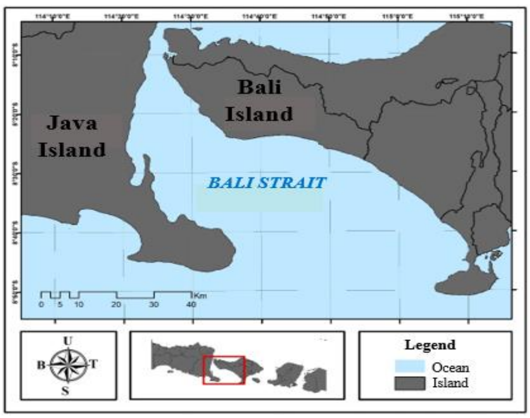


**Figure 1.** Research Location Map

**Image Processing**

Image data processed by oceanographic data, namely chlorophyll-a/CHL-a data and sea surface temperature/SST. To download CHL-a and SPL image data, the data taken is monthly data which is then processed for analysis. The flow satellite image processing data can be seen in

**Catch per Units Effort (CPUE)**

Catch per Unit Effort (CPUE) is a method to find out the ups and downs of fishery production which is averaged annually determined by amount of production. Determination of CPUE of Lemuru can be determined by the fishing formula (fishing Lemuru result) divided by effort (effort of fishing Lemuru fish) [9]. Based on the Schaefer method, the CPUE formula is as follows [10]

$$CPUE = \frac{Catch}{Effort}$$

Description:
Catch = Total catch (kg)
Effort = Total catch effort (trip)
CPUE = Catch per unit effort (kg/trip)

**GAM (Generalized Additive Model)**

All oceanographic data obtained from satellite imagery along with capture data are used as input data in the generalized additive model (GAM). This model examines the mechanism of the relationship between fish catches and oceanographic parameters. The results of this model can show a range of significant oceanographic factors explaining high fishing relate to marine environmental parameters. Oceanographic data that are input to the GAM model include SST and Chlorophyll-a concentrations. The GAM model can be seen in the equation where g is a relationship function, xi is the vector of oceanographic predictor variables (SPL and chlorophyll), μ x)( is an additive predictor, μ is the average response variable, à is the intercept constant, p is the number of fishing trip/setting and f i is the non-parametric function to i. This model determined the optimum oceanographic level where the predicted catch is higher [11].

$$g\ (mui) = bo + s_1(x1i) + s_2(x2i) + s_3(x3i)$$

Description:
g = spline smooth function
mui = response variable
bo = constant coefficient

**RESULT AND DISCUSSION**

**Oceanographic Parameters**

Several oceanographic parameters that have been processed, the distribution of oceanographic data at the point of capture of lemuru (S. Lemuru) shows an increase and decrease in the dynamic distribution of oceanographic values. Oceanographic parameters play an important role in knowing or studying the abundance and distribution of fish resources [12]. Oceanographic data processing obtained from SNPP satellite recording using the VIIRS sensor which can be accessed from the web https://oceancolor.gsfc.nasa.gov/l3/

**1) Chlorophyll-a**

Chlorophyll-a is included in the factors can affect the distribution of fish, so to know the distribution of fish, information on the value of chlorophyll-a is needed in the studied waters. One indicator of the abundance of phytoplankton in the waters is chlorophyll-a [5]. One of the ways to obtain chlorophyll-a information is to record satellite images which can simplify, speed up and also minimize costs for field data retrieval. From the data processing of Chlorophyll-a in the Bali Strait, it can be concluded that the average value of Chlorophyll-a in the Bali Strait can be seen in Figure 2(a). With the results of the highest average chlorophyll value in 2019 occurred in the East Season with a chlorophyll-a value of 1 .53 mg/m3 and the lowest was in the Transitional Season 2 of 0.49 mg/m3 while in 2020 the highest chlorophyll value occurred in the East Season, which was 1.30 mg/m3 and the lowest was in the West Season of 0.15. mg/m3.

**2) Sea Surface Temperature**

Sea Surface Temperature affects the distribution of fish besides chlorophyll-a Sea Surface Temperature affects the distribution of primary production in waters. Nevertheless, it is necessary to obtain information on the distribution of the sea surface temperature in the Bali Strait, sea surface temperature information can be obtained from recording satellite images which can simplify, speed up and also minimize costs for retrieval of field data. From the data processing of Sea Surface Temperature, it can be concluded that the average value in Bali Strait can be seen in Figure 2(b). With the results of the highest average sea surface temperature in 2019 occurring in the West Season with a sea surface temperature value of 30 .03℃ and the lowest was in East Season 2 of 24.80℃ while in 2020 the highest chlorophyll value occurred in Transitional Season 1 which was 29.31℃ and the lowest was in East Season of 26.79℃. This happens due to monthly and seasonal variations in SPL also shows different values for each region in Indonesia [13]. Sea surface temperature is very influential on the life of marine organisms such as the influence of metabolism and also their breeding. Indications of the quality of a waters can be seen from the SST, with satellite rocks [14].

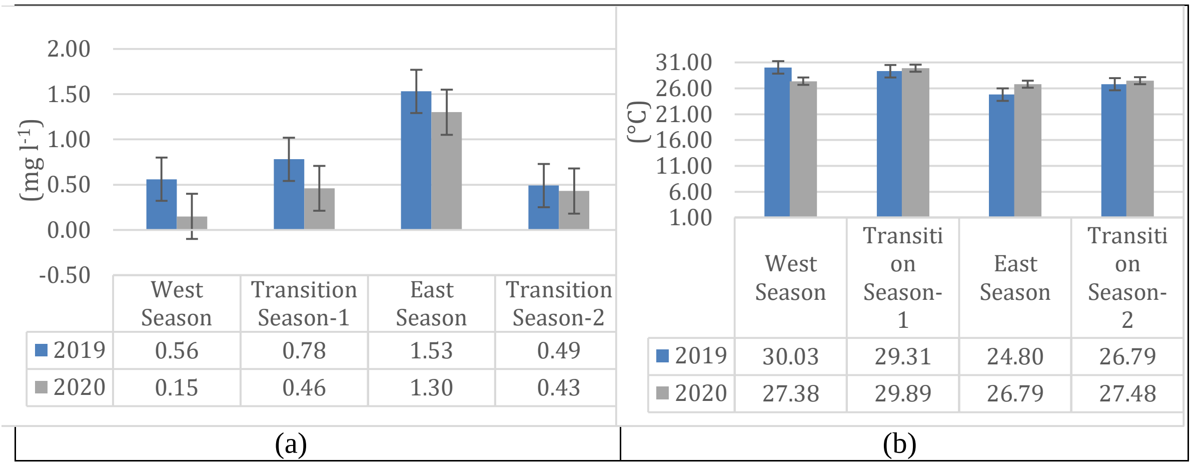


**Figure 2.** Average Distribution of Oceanographic Parameters: (a) Chlorophyll-a (b) SPL

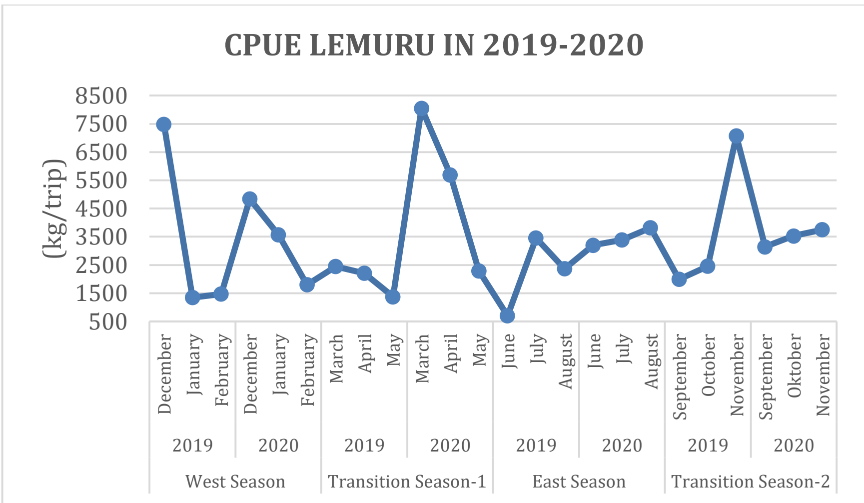


**Figure 3.** CPUE Lemuru fish in 2019-2020

### Catch per Units Effort (CPUE)

The lemuru catch data used in this study was from January 2019 to December 2020. The catch data obtained from PPP Muncar included catch production data, fishing trips, day/date, month and year of catching. This lemuru catch data is grouped into seasonal catches after which CPUE is calculated by dividing the catch by the number of trips each season.

From CPUE calculations, it can be seen that the highest catch of lemuru fish in the Bali Strait in 2019 was in December 2019 of 7,481.60 kg/trip while the lowest catch was in June of 700.53 kg/trip. In 2020, the highest was in March 2020 of 8,053.79 kg/trip, the lowest month was in February, 1,802.63 kg/trip.

**GAM (Generalized Additive Model)**

**1) Prediction of Potential Lemuru Fishing Areas in Bali Strait Waters**

In determining the potential area for Lemuru fish, information on the relationship between oceanography and fish catch is needed so that a GAM statistical model is needed in the R-Studio Application. AIC formula is as follows.

$$AIC(k) = -2) + 2p$$

Description:

$L(\hat{\theta}_k)$ =Maksimum likelihood from multinomial logit model

$p$ = Total of parameter used in the model

**Table 1.** GAM Statistic Model

| No | Model | Parameters | *P-Value* | CDE | AIC |
|---|---|---|---|---|---|
| 1. | Model-1 | Chlorophyll-a | 0.00136** | 1,66 % | 23124.05 |
| 2. | Model-2 | SPL | <2e-16*** | 8.18% | 23044.21 |
| 3. | Model-3 | Chlorophyll-a<br>SPL | 0.000408*** | 5.44% | 23079.48 |

Signif. Codes: 0 '***' 0.001 '**' 0.1 '*' 0.05 '.' 0.1 ' '

After doing statistical processing GAM obtained 3 models, namely Model 1 Chlorophyll-a with an AIC value of 23124.05, a CDE value of 1.66% and a P-Value of 0.00136**. Model-2 is SPL, AIC value is 23044.21, CDE value is 8.18% and P-Value is <2e-16***, Model-3 Chlorophyll-a + SPL AIC value is 23079.48, CDE value is 5.44% and P-Value as big as 0.000408***.

**2) Relationship of Catches with Oceanographic Parameters**

After obtaining information on the three models from the two oceanographic parameters, namely (chlorophyll-a and Sea Surface Temperature) which were associated with the catch of Lemuru Fish (S. lemuru) for two years, starting from January 2019 to December 2020 in the Bali Strait, apart from the results obtained AIC, CDE, and P-value values are also obtained by GAM plots which show the influence between oceanographic parameters and catches with several symbols such as the X axis explaining the value of each variable used and the Y axis showing a smoother contribution to the tested value. In the GAM plot, the sign ("ǀ") on the X axis describes the value of each parameter at the fishing point for lemuru fish (S. lemuru). On the Y axis = 0 or zero line, if the tested oceanographic parameter value is above the zero line, then the frequency value is high and if it is below the zero line the value is low. The dotted line itself shows the 95% confidence interval for each estimator variable.

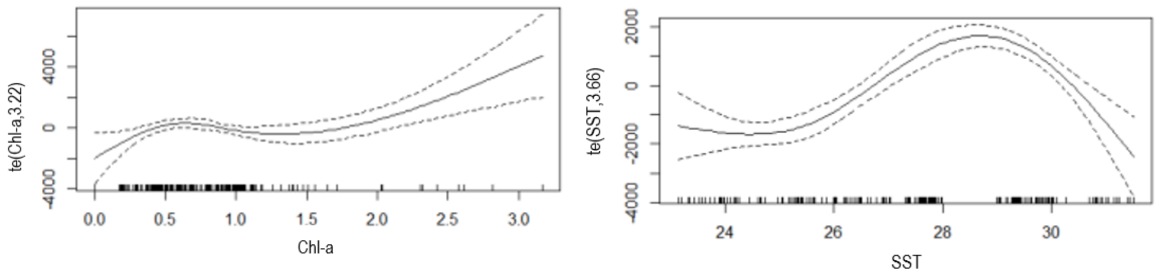


**Figure 4.** Smoothing Curve GAM (Generalized Additive Model)

### 3) Fishing Potential Zone Map

The potential zone for catching Lemuru Fish (S. lemuru) based on the results of GAM analysis with model 3, namely the incorporation of all oceanographic parameters (Chlorophyll-a and Sea Surface Temperature) has been spatially overlaid on the Arcgis application, the overlay method used is the weighted overlay method. with the scoring system used based on the frequency of values in the total data of fishing operations, the weight order of each parameter has been calculated in the estimation of GAM analysis. The results of the analysis of potential zones for catching Lemuru Fish (S. lemuru) in the waters of the Bali Strait for each season in 2019-2020 were obtained. The lemuru fishing index is divided into from the lowest 0 to the highest 1, and to determine the potential zone point based on the number of fishing locations in the Bali Strait.

Map of potential fishing zones for Lemuru Fish (S. lemuru) in 2019-2020 can be seen in Figure 5. with details based on seasons, namely picture (a) is the West Season, picture (b) is in Transitional Season 1, picture (c) in the East Season, and figure (d) in the Transitional Season 2.

Based on the potential fishing potential zone for Lemuru (S. lemuru) in the Bali strait, it was found that the lemuru fish are in different areas each season according to the optimum temperature and also the optimum chlorophyll in that season. The entire waters of Bali itself is a potential area for the existence of lemuru with one of the factors being the waters in the form of a strait, the fishermen themselves catch lemuru fish every day in groups, only the departure and return times are different, but fishermen only use the chasing method so it is less efficient in using it. fuel and time

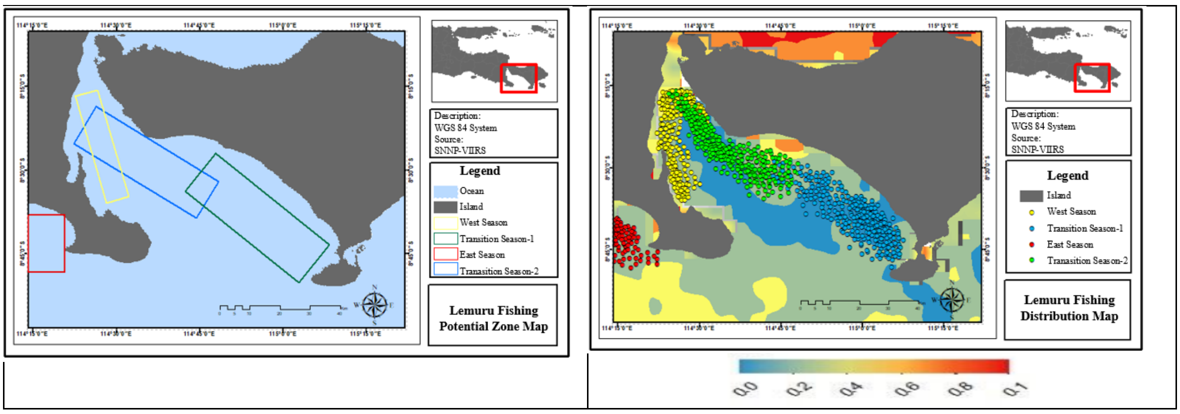


**Figure 5.** Lemuru Fishing Distribution Map

## CONCLUSION

According to GAM statistical modelling, the most appropriate fishing area was data combination among data fishing, sea surface temperature of AIC and CDE AIC around 23044.21, and CDE 8.18%. The whole area of Bali strait is Lemuru fish distribution yet located in different areas each season such as west season at latitude (-8.26°)-(-8.59°)

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**GRATITUDE**

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