ISSN 2354-9114 (online), ISSN 0024-9521 (print)
Indonesian Journal of Geography Vol.54 , No. 2, 2022 (254 – 262)
DOI: 10.22146/ijg.66380 website: https://jurnal.ugm.ac.id/ijg

INDONESIAN JOURNAL OF GEOGRAPHY

RESEARCH ARTICLE

Bali Strait's Potential Fishing Zone of Sardinella lemuru

Dinarika Jatisworo, Bambang Sukresno, Denny Wijaya Kusuma and Eko Susilo
Balai Pengelolaan Informasi Sumber Daya Kelautan dan Perikanan- Kementerian Kelautan dan Perikanan, Indonesia

Received: 2022-03-23
Accepted: 2022-06-20

Keywords:
participatory mapping; spatial ability; spatial data quality; Land and Building Tax

Correspondent email:
dinajatisworo@gmail.com

Abstract Catch fluctuation of Sardinella lemuru in the Bali Strait in the period 2007 - 2019 shows a significant decrease. The fishermen of this area demanded information on the Potential Fishing Zone (PFZ) specifically targeted for Sardinella lemuru beyond their traditional. PFZ will be very helpful, especially during the famine years. Identification of a Potential Fishing Zone (PFZ) is highly important for increased fishing yields and also reduced fishing time for fishermen. Bali strait is dominated by Sardinella lemuru and contributes 16,2% of the total small pelagic fishery production in Fisheries Management Area (FMA) 573. Bali Strait also supports the fishing industry in Muncar (Banyuwangi-East Java) and Pengambengan (Jembrana-Bali). This study will produce a special PFZ for Sardinella lemuru that is not yet available in Indonesia by using remotely sensed and observer data. Here, we apply the Empirical Cumulative Distribution Function (ECDF) algorithm approach for Sardinella lemuru detection. ECDF was developed using Sea Surface Temperature (SST) and Chlorophyll-a (Chl-a) data from Aqua MODIS and extracted according to observer data during 2011-2014. PFZ for Sardinella lemuru in Bali strait was affected by 72,8 % Chl-a conditions and 27,2% by SST conditions. The maximum suitable preference for Sardinella lemuru in Bali Strait is Chl-a condition at 0,2 mg/m3 and SST condition at 28,38°C in northwest monsoon, while in southeast monsoon are 0,97 mg/m3 for Chl-a and 25,61°C for SST. ECDF model result has 69,33% accuracy, which shows the result of Sardinella lemuru PFZ has good accuracy.

1.Introduction

Bali Strait is a semi-closed water body, so it has relatively constant oceanographic dynamics. The upwelling process in the southern part of Bali Strait occurred during the east monsoon, which is a part of the broader upwelling process in the Indian Ocean on the south of Java Island. Bali Strait is known to have more upwelled water for longer periods (Ghofar, 2005). The upwelling leads to an increase in Chl-a concentration that attracts the schooling of small pelagic fish groups (Carpenter and Niem, 1999). Changes in SST condition in the Bali Strait also depend on seasonal variation, during the east monsoon the SST is relatively cooler than in the west monsoon (Ridha, Hartoko and Muskanonfola, 2013). The SST of this area was observed to increase in November and reached the highest temperature in March, then decreased in April with the lowest value in September (Susilo, 2015).

The fisheries potential of FMA 573 is dominated by both small and large pelagic fishes, approximately 294,092 thousand tons/year and 505,942 thousand tons/year, subsequently (Republik Indonesia, 2016). The Bali Strait itself contributes 16,2% of the total small pelagic fishery production in FMA 573. The high abundance of fishery resources in the Bali Strait is generally comprised of small pelagic fishes that live in groups. Lemuru (Sardinella lemuru) dominates with a percentage of 90% of the fish caught, followed by a smaller proportion of Tuna (Auxis thazard), Layang (Decapterus sp.), and Tembang (Clupea spp.) (Sartimbul et al., 2016). Bali Strait is very unique, the main catch that fishermen are looking for is Sardinella lemuru (monospecies), fishermen also only use one uniform fishing gear (monogear). Sardinella lemuru is important species in Bali Strait. Sardinella lemuru is important species in Bali Strait. Lemuru is a sardine species found exclusively in Bali Strait, which is why its scientific name is Sardinella lemuru, which perpetuates the local name of this fish. Sardinella lemuru also support fish industry in Muncar (Banyuwangi-East Java) and Pengambengan (Jembrana-Bali).

In recent years, the fishing condition in the Bali Strait is highly volatile for several reasons; the first reason is influenced by climate and annual phenomena such as El Nino or La Nina (Gaol et al, 2004) . The exploitation rate also was greater than the optimum exploitation, indicating overfishing had occurred because of pressure resulting from the high mortality rate and exploitation rate (Wujdi, Suwarso, dan Wudianto, 2012). Catch fluctuation of Sardinella lemuru in the Bali Strait in the period 2007 - 2019 shows a significant decrease. This fluctuation is affected by ENSO and IOD phenomena. Means in 2007 - 2011 La Nina happened concurrently with negative IOD then the catch of lemuru decreased, whereas if there is a positive El Nino and IOD phenomenon the catch will be an increase (Saputra et al., 2017). Catch of small pelagic fish increased sharply in positive IOD years and decreased in negative IOD years and El Nino La Nina years contribute to dramatically Chl-a concentration changes (Gaol, Arhatin and Ling, 2014). Moreover, the fish stock of the Bali Strait is currently overfished. Due to this condition, the fishermen of this area demanded information on whether their area has an oceanographic-based Potential Fishing Zone (PFZ) beyond their traditional PFZ. By using PFZ, fishermen will be very helpful, especially during the famine years. Identification of PFZ is highly important because a previous study indicated that the locations of PFZ were consistently changing, and the prediction has increased the fishing yields in addition to reduced fishing time, thus cut down fishermen's expenses for vessel fuel(Tummala, Masuluri and Nayak, 2008).

Previous PFZ studies have been extensive, with a variety of methods and tests conducted on specific fish species, each with positive results. The PFZ has mostly explained the relationship between the physical parameters of the oceans and the presence of fish calculated from statistical models. Non-parametric of multiple linear regressions as Generalized Additive Model (GAM), which is can estimate a PFZ by determining the relationship between Catch per Unit Effort (CPUE) and environmental variables (Hastie and Tibshirani, 2017). Example of this approach is a study on *Rastrelliger kanagurta PFZ* in the Exclusive Economic Zone (EEZ) of Malaysia with accuracy 75% (Shaari and Mustapha, 2018). Data mining approach as Boosted Regression Trees, Clustering, or Maximum Entropy can also be used to predict PFZ. Boosted Regression Trees is a forecasting model of the fishing ground by comparing fishing area with fishing effort, which a study performed in the Yellow Sea and the East China Sea to predict the location of mackerel and the results show that the forecasting model of fishing ground has a high prediction performance (Gao et al., 2016). Another study about Boosted regression Trees is PFZ Japanese common squid in the waters of Japan, which show good model performance and the high feasibility of prediction into the actual fishery forecasting (Zhang, Saitoh, dan Hirawake, 2017). Clustering method for PFZ can be done by computing the mean of fish catches for each area, then compare each of that means with the threshold. The maximum entropy model is another option to generate the PFZ prediction of Tuna and has a high value of AUC models Previous studies also using multivariat anaysis for example knowledge-based expert system with some rules or feature exploration used to generate Tuna fishing zone. Both studies show high PFZ accuracy results, which are more than 80%. Last method is Empirical Cumulative Distribution Function (ECDF), this method has been done by for Thunnus detection in the Indian Ocean South of Java using ARGO FLOAT SST data and actual Thunnus catch data. ECDF is spatial modeling that uses polynomial regression equations based on the spatial distribution data of a selected fish species. The results of these studies are Thunnus PFZ maps with more than 80% accuracy. Our research is a part of PFZ method development, means finding a suitable method to improve accuracy on PFZ models. There are many methods to generate PFZ, we choose to adopt the ECDF method to detect Sardinella lemuru. This method is more objective than the parametric statistics, becauses not based on a mathematical function but it is based on data itself. When representing a variable through an empirical distribution, we are not making judgements about the distribution, but it follows the data. This method has also been proven to produce high PFZ and can be applied in Indonesian waters. Further, this study will produce a special PFZ for Sardinella lemuru that is not yet available in Indonesia. The exsistence of this lemuru PFZ will help fishermen in Bali Strait to regarding information where Sardinella lemuru can be captured, especially during famine periods.

2. The Methods

Study Area

Our investigation was directed in the Bali Strait with the coordinate boundary of 8,07° - 8,94° S and 114,16° - 115,27° E (Figure 1), which was focused in the selected red box area . This boundary was assigned based on the catch activity of the Bali Strait fishermen, in which the fishing locations were compiled from several zones, from the north Blimbing sari to the south Jimbaran area. The Bali Strait is a semi-closed strait that separates Java and Bali Islands. This strait is included in the Indonesian Fisheries Management Area (FMA) of 573 so its characteristics are still influenced by oceanographic conditions of the Indian Ocean on the southern part of Java.

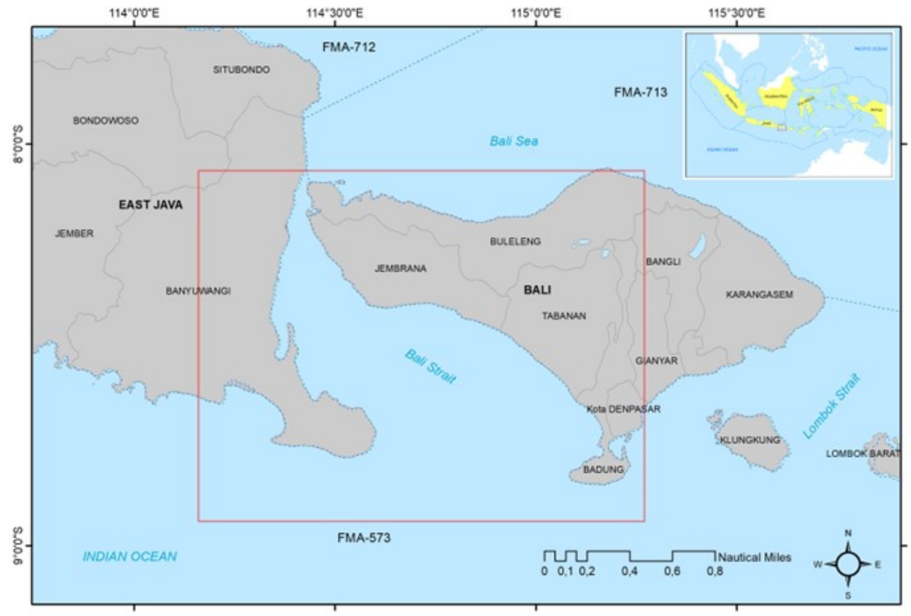

Figure 1. Bali Strait Area

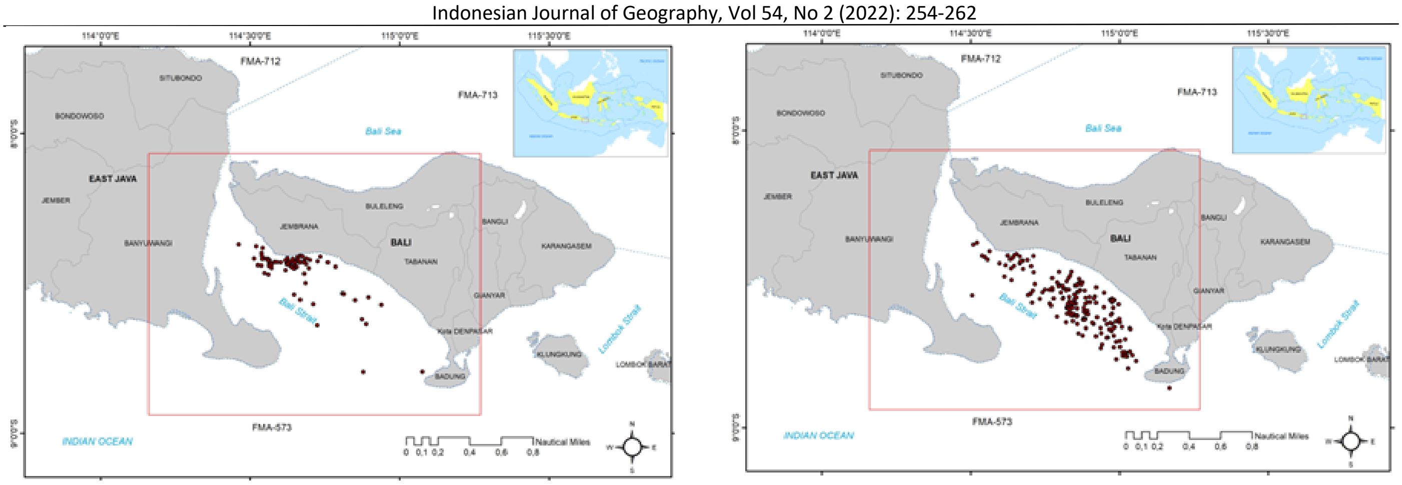

Figure 2. Distribution map of observer data obtained during 2011-2014 in the Strait of Bali in Northwest monsoon (left); Southeast monsoon (right). Observer stations are presented by red dots.

Data

Satellite-derived environment variable

Environmental variables used in this study were SST and Chl-a concentration. These variables were derived from Aqua MODIS daily and monthly satellite data with a spatial resolution of 4 km from 2011 to 2014. Aqua MODIS data obtained from Ocean Ecology Laboratory, Ocean Biology Processing Group for providing Moderate-resolution Imaging Spectroradiometer (MODIS) Aqua 11µm Day/Night Sea Surface Temperature Data; 2018 Reprocessing. NASA OB.DAAC, Greenbelt, MD, USA on https://oceancolor.gsfc.nasa.gov/data/10.5067/AQUA/MODIS/L3M/SST/2014 for SST and Imaging Spectroradiometer (MODIS) Aqua Chlorophyll Data; 2018 Reprocessing. NASA OB.DAAC, Greenbelt, MD, USA on https://oceancolor.gsfc.nasa.gov/data/10.5067/AQUA/MODIS/L3M/CHL/2018 for Chl-a datasets. The satellite data were then matched with the location and date of observer data. Both data are used to develop the ECDF algorithm of Sardinella lemuru PFZ in the northwest monsoon and southeast monsoon.

Observer Data

The observer is a specific fishing vessel personnel who monitors fishing activity onboard and also records all details regarding catch information i.e. fishing ground coordinates, fish biology data, oceanographic data, total catch, length-weight of fish, and type of fish. All data recorded by the observers are called observer data. The observer data of Bali Strait were recorded continuously from 2011 to 2014 from observers of purse seine fishing vessels. Daily recorded data were based on the dates of boarded vessels. In this study, the main information taken from observer data was fishing ground coordinates and the total of catches. Each fishing ground coordinate is used for the extraction of SST and Chl-a from satellite images. In total, there were 247 observer stations during 2011-2014, of which we used 70 % of the data for model development and 30 % of the data for model validation. Figure 2 showed the distribution of all observer data recorded in 2011-2014 in northwest and southeast monsoons.

Methods

This study will calculate the contribution value of SST and chlorophyll-a data to the catch of lemuru. The result of the contribution value will determine the peak of the probability value of each parameter in the ECDF polynomial graph. The ECDF algorithm will produce the values of f(t), g (t), and d(t). f(t) represents the frequency of fish occurrence, g(t) represents the frequency of fish abundance, and d(t) represents the suitable area preference of fish. The PFZ generated from this research also needs to be seen for its accuracy. Therefore, it is necessary to test the performance of the model. Model performance test is carried out using the confusion matrix, which is the expected accuracy value is more than 50%.

The Main data used is MODIS, so the SST and Chl-a data obtained are surface information. The data are then juxtaposed with the occurrence of the fish. There is thus a difference in information between the presence of fish and the physical parameter. This difference is not significant due to the lemuru found in the homogeneous layers of water. Sardinella lemuru is a small pelagic fish that lives grouping at depths and found at depths of less then 60 meters (Susilo, 2015). In the waters, there are usually homogeneous layers, as well as in the Bali Strait. Mixed layer depth forms a homogeneous layer to a certain depth (Ryandhini et al., 2015) In the west monsoon the homogeneous layer has a thickness of approximately 100 meters, while during upwelling in the east monsoon the homogeneous layer becomes thinner, which is less than 30 meters (Ilahude, 1978; Ryandhini et al., 2015). Therefore, with information on the water surface, conditions in vertical waters tend to be the same as on the surface.

Conditional Permutation Importance

The permutation Importance function was selected to calculate the feature importance of an estimator for a given dataset. This step was used to calculate the percentage contribution from environmental variables to the amount of catch in observer data. Following the statement of(Strobl et al., 2009), a variable that is correlated with a relevant predictor variable can receive a high importance score. Percent Contribution (PC) in this step is fully carried out using R package version 3.4 (R Core Team, 2018). To develop a PFZ algorithm based on ECDF analysis, it is necessary to calculate the percentage contribution of SST and Chl-a, to find out which variables that have higher contribution values than other variables.

Empirical Cumulative Distribution Function

ECDF analysis was applied to the data of SST and Chl-a. SST and Chl-a data were extracted according to observer date and location. The presence of fish in the observer data was represented by the frequency (modus) of t. The t value is obtained from the extracted environmental variables from satellite images at each observer location. The frequency of fish occurrence was then analyzed based on the distribution curve of the function f (t) as follows:

l(xi) = 1, if xi ≤ t
= 0, otherwise (1)

where f(t): empirical cumulative frequency distribution function, t: observed oceanographic variable from lowest to highest value, n is the number of observer data, l (xi): function indication, xi: the value of oceanographic variable extracted from each observer data. The frequency of fish abundance that represents a suitable preference of SST and Chl-a of each fishing ground was analyzed using the distribution curve of function g(t) :

$$f(t) = \frac{1}{n}\sum_{i=1}^{n} l(xi) \quad (2)$$

where g(t): catch-weighted cumulative distribution function, yi: volume of fish catchment at each observer data, and ȳ: average of the fish catchment. The suitable preference of PFZ was developed based on the function of d(t) as follows:

$$g(t) = \frac{1}{n}\sum_{i=1}^{n} \left(\frac{yi}{\bar{y}}\right) \times l(xi) \quad (3)$$

Where d(t): the absolute value of the difference between the curve f(t) and g(t) at any point of t.

PFZ performance test

One method of measuring model performance is the confusion matrix or usually called the error matrix. A confusion matrix summarizes the classification performance of a classifier concerning some test data and contains a two -dimensional matrix, indexed in one dimension by the true class of an object and in the other by the class that the classifier assigns (Ting, 2017) . This method was chosen because observer data in northwest monsoon are very few and the total observer data used for validation in this study is measly, it is not quite right to use regression to calculate the accuracy. PFZ results are classified into the value of probability from 0-1 (low-high) and will be compared with fish catch volume in kilograms. Classification of PFZ probability differentiated P > 0,5 (high) and P < 0,5 (low) as predictive values. On other hand, actual values were presented by catch volume in the same location of PFZ. Catch volume was also classified into two class V > 1000 kg (high) and V < 1000 kg (low). Representation of the confusion matrix results is True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN). The performance metrics that we will get from the confusion matrix are sensitivity (recall), specificity (precision), and accuracy(Kohavi and Provost, 1998). The equation for each performance metric is as follows:

$$d(t) = max\ |f(t) - g(t)| \quad (4)$$

$$Sensitivity = \frac{TP}{TP + FN}\ x\ 100\% \quad (5)$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}\ x\ 100\% \quad (6)$$

3. Result and Discussion

Spatio-temporal variation of SST and Chlorophyll-a

Monthly average conditions of SST and chlorophyll-a in the Bali Strait during the period of 2011-2014 showed fluctuating patterns with temperatures ranging from 24 ° C to 30 ° C (Figure 3). The pattern observed from these data showed that the increase of SST was followed by Chl-a decrease and vice versa. During the selected period, the highest average temperature occurred in February 2011 and the lowest in September 2011, while Chl-a was the highest in August 2012 and the lowest in December 2014.

The northwest monsoon was represented by the average data of December, January, and February, while the southeast monsoon was represented by the average data of June, July, and August. The SST of the southeast monsoon was relatively colder than during the northwest monsoon, with the average SST in the southeast monsoon being 26,4° C, while the northwest monsoon is 29.5°C. The SST was

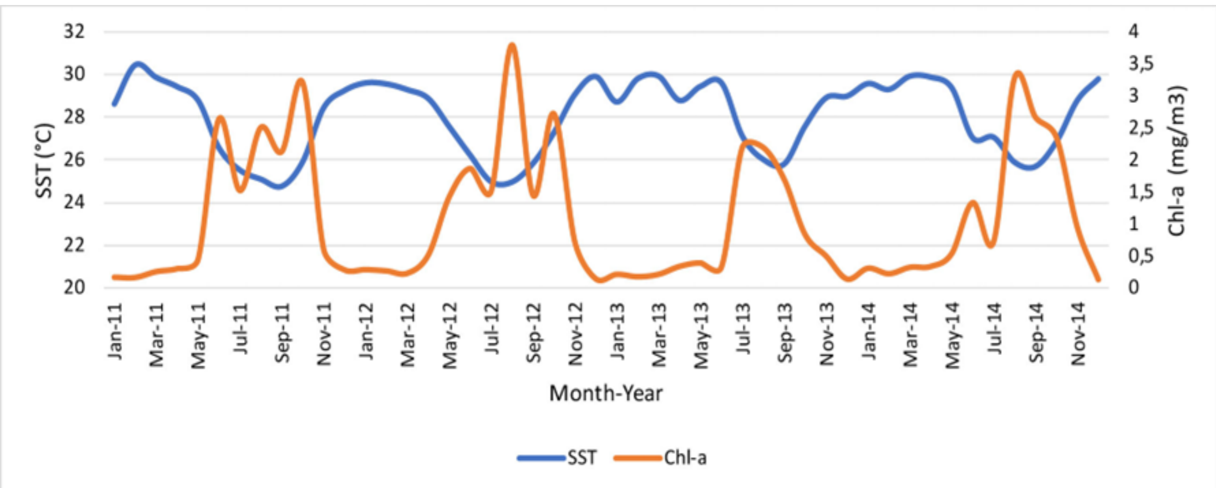

Figure 3. Monthly variability of SST and Chl-a derived from Aqua MODIS in the Bali Strait during 2011-2014

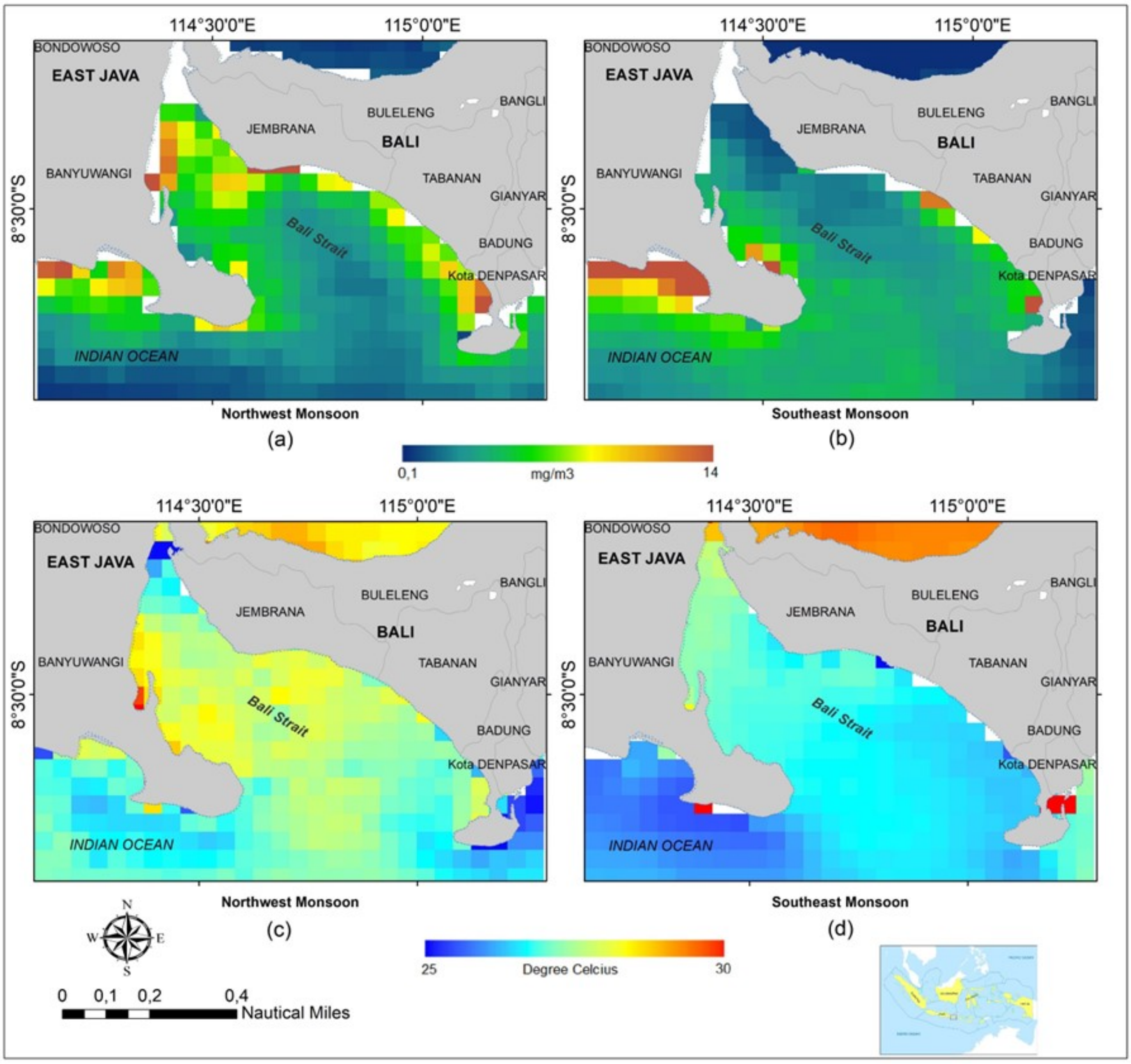

Figure 4. Spatial distribution of (a-b) Chl-a and (c-d) SST in the Northwest and Southeast Monsoons

increased in the northwest monsoon starting in September and then decreased in April. The Chl-a variability was opposite to SST variability, as Chl-a was high in the southeast monsoon with an average reached 1,99 mg/m3 and was decreased in the northwest monsoon with an average of 0,21 mg/m3. Chl-a was increased in the southeast monsoon starting in April and decreased in the northwest monsoon of November. A spatial comparison of Chl-a and SST conditions in both monsoons can be observed in Figure 4. The condition of Chl-a as presented in Figure 4 showed that the water of Bali Strait was always fertile despite different seasons. The chlorophyll-a values in both seasons were ranging from 0.1 to 2.0 mg/m3. Referring to the average environmental condition of Indonesian seas, these values of chlorophyll-a were suitable for fisheries. From the data above, it can be inferred that during the selected period, the Bali Strait is an area that has a high potential to catch fish throughout the year. The difference in Chl-a values between the northwest and southeast monsoons was ranging from 0.2-2.0 mg / ml3, with homogeneously lower distribution in the middle of Bali Strait. High Chl-a in the coastal area is predicted due to the inflow of recently upwelled water from the Indian Ocean. To avoid errors due to high Chl-a in the coastal area or near shore, the Chl-a range 0.1 to 2.0 mg/m3 is used as the upper and lower threshold for the selection of Chl-a values, so it will not be in the miss interpreted area.

Percentage contribution of SST and Chlorophyll-a and ECDF analysis

The result of Conditional Permutation Importance is shown in Table 1. Indicated that Chl-a percent contribution was greater than the SST variable. Chlorophyll-a was the main driver of Sardinella lemuru's environmental preferences, which has a 72.8% effect on lemuru. While SST is the second parameter because only 27.2% of the contribution has affected the occurrence of Sardinella lemuru. These values were used to determine the proportion of influence of each variable on the ECDF algorithm.

Table 1. Value of Percent Contribution

Variable	Percent Contribution (%)
Chl-a	72,8
SST	27,2

Source : Data Processing

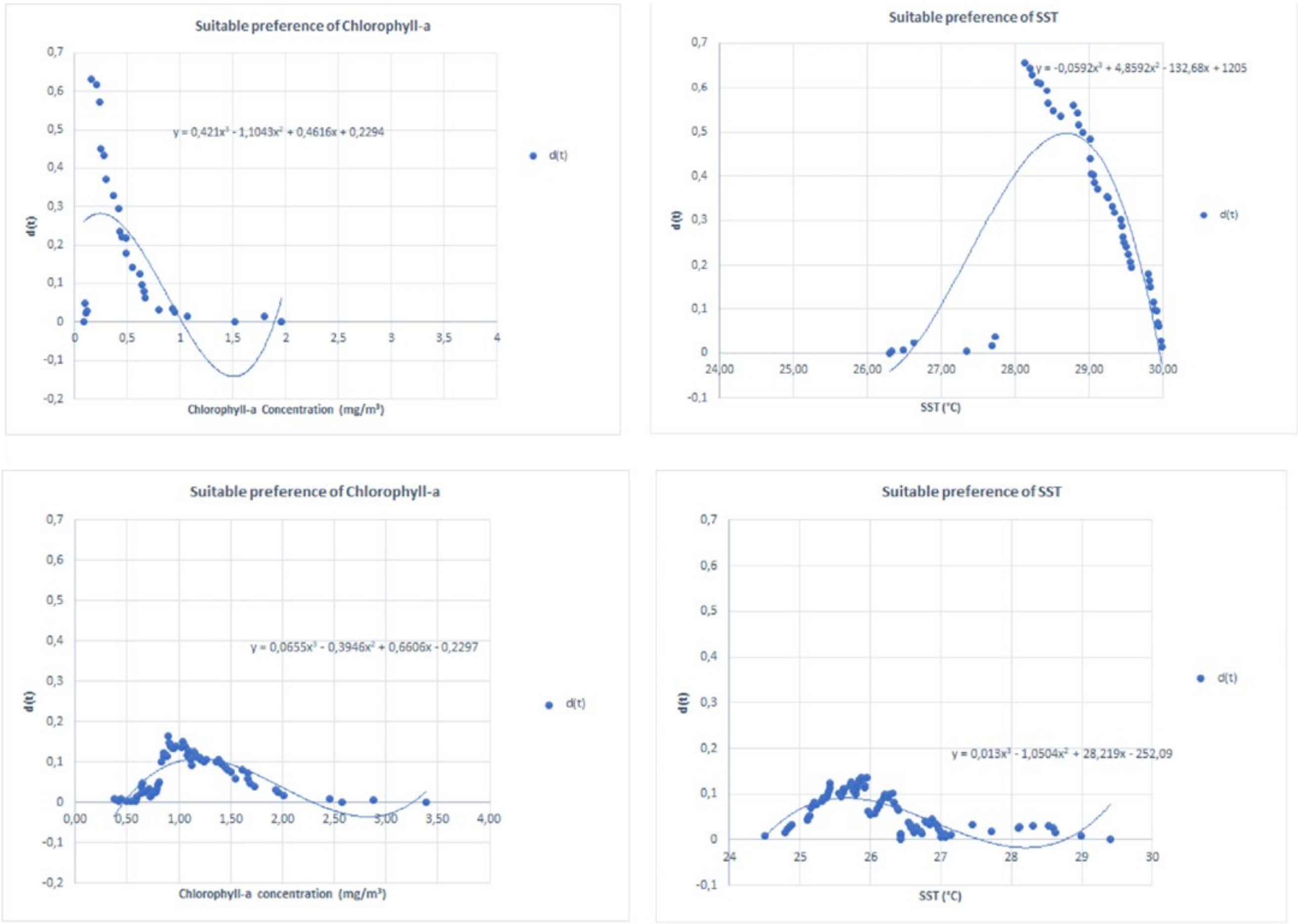

Figure 5. Suitable preference Chl-a and SST in Northwest Monsoons (upper) and Southeast Monsoons (lower). d(t) is presented by blue dots, blue solid line is the trendline of polynomial regression orde 3.

Primary production (PP) can be estimated from marine planktonic, while in remote sensing total Chl-a concentration is used to proxy phytoplankton biomass because it is colored, specific to, and shared amongst all primary producers (Huot et al., 2007). The fact of Chl-a as the main variable for PFZ is highly influencing the presence of pelagic fishes in the Bali Strait. The reason why the percent contribution of Chl-a was the dominating variable is closely related to the food chain process. The Chl-a condition was suitable for planktivorous fish as the consumers, whose position in the food chain process is not too far from the primary producer (phytoplankton). The growth of lemuru in Bali Strait has tended to follow the phytoplankton abundance, this condition following an increase in Chl-a up to September and followed by an increase in zooplankton abundance as food for large fish (Gaol et al., 2004). These small and planktivorous fishes thus play a crucial role in the trophic dynamics of marine ecosystems, either by top-down controlling planktonic organisms or bottom-up controlling predators. The concentration of Chl-a reaches a peak in the southeast monsoon (June to August) because along the southern coasts of Java southeasterly wind generates upwelling, bringing cooler waters and nutrients to the surface, whereas conditions are reversed during the northwest monsoon (December to February)(Ningsih dkk., 2013).

As the result above, i t is quite possible to produce PFZ using Chl-a as the main variable for the prediction of small pelagic fishes. There is a positive correlation between small pelagic production and chlorophyll-a concentration(Gaol et al., 2004). Small pelagic species like Sardinella lemuru, lived above the thermocline, it would distribute shallower, and possible to detect their habitat from satellite data.

The condition of SST between the two seasons showed a non-significant change. The difference between both times was homogeneous in all parts of Bali Strait, which was around 2.0 - 2.5 ° C. The smaller percentage of SST to influence the PFZ has changed our previous assumption of PFZ production in this area. SST was generally the least important variable because the relationship between SST and fish presences varied considerably, especially for fish that had the largest range and variation in SST (Lanz et al., 2009).

The suitable preference of SST and Chl-a based on a calculation of fish occurrence and fish abundance in both monsoons using ECDF analysis was presented in Figure 5.

The maximum of suitable preference of Chl-a at 0,2 mg/m3 and SST at 28,38°C in northwest monsoon, while in southeast monsoon is 0,97 mg/m3 for Chl-a and 25,61°C for SST. This value following higher Chl-a concentration and colder SST results in southeast monsoon.

PFZ of Sardinella lemuru

The spatial distribution of PFZ in the Bali Strait has changed in both seasons, were provide in Figure 6. Areas with medium-high potency in northwest monsoon concentrated in the southern part of Bali Strait. This condition change in southeast monsoons, medium-high

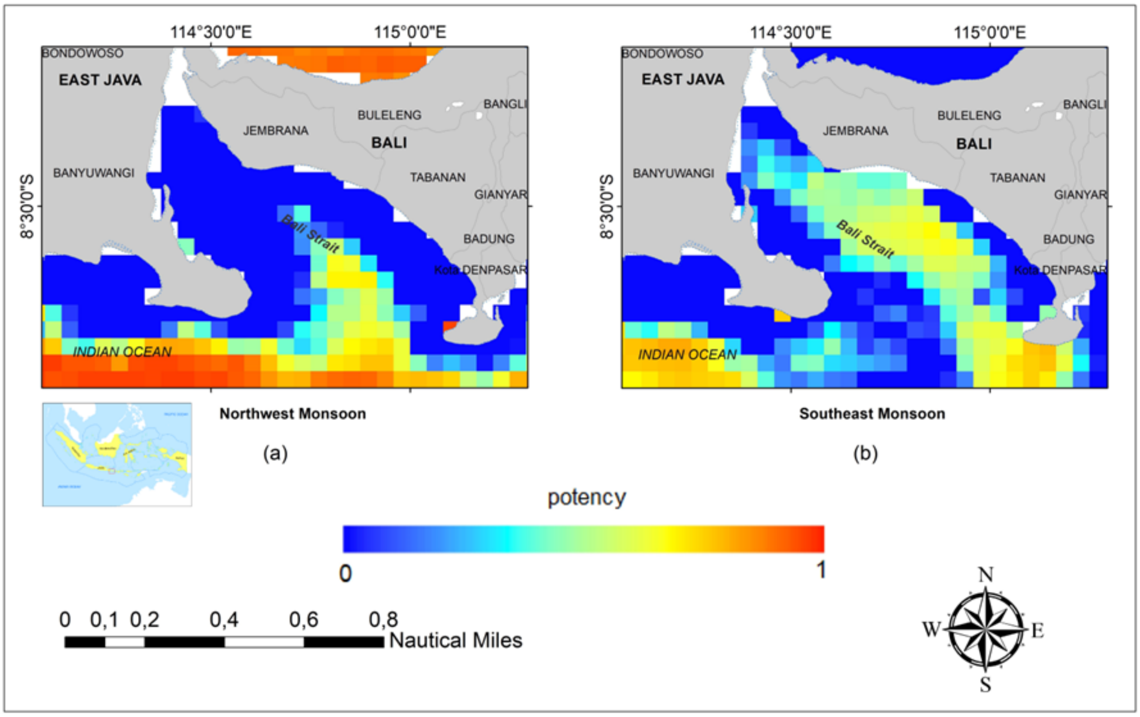

Figure 6. PFZ in the Northwest and Southeast Monsoons. PFZ value from 0-1 which means low to high potency and presented by blue-red color according to potency value as shown in the color bar.

Table 2. PFZ Algorithm in the northwest and southeast monsoon, $x_{chl\text{-}a}$ = Chl-a, x_{sst} = SST

Monsoons	Algorithm
Northwest	$(-60{,}331\ x_{chl\text{-}a}^{2} + 24{,}132\ x_{chl\text{-}a} - 1{,}6832)+(-0{,}0618\ x_{sst}^{2} + 3{,}5084\ x_{sst} - 49{,}515)$
Southeast	$(-1{,}9618\ x_{chl\text{-}a}^{2} + 3{,}806\ x_{chl\text{-}a} - 1{,}1159)+(-0{,}2153\ x_{sst}^{2} + 11{,}021\ x_{sst} - 140{,}8)$

Source : Data Processing

Table 3. Confusion Matrix of PFZ Model, actual values are catch volume (kg), predicted value are PFZ potency

		Actual Values		
		High (> 1000 kg)	Low (< 1000 kg)	
Pre-dicted Values	High (> 0,5)	26	7	Sensitivity = $\frac{26}{26+16}\ x\ 100\%$
	Low (< 0,5)	16	26	Specificity = $\frac{26}{7+26}\ x\ 100\%$ = 78,79 %
Total (∑) population = 75		42	33	Accuracy = $\frac{26+26}{26+26+7+16}\ x\ 100\%$ = 69,33 %

Source : Data Processing

potency wider and spread along in Bali Strait from north to south. Ignore high potency in other areas of Bali Strait, like the Bali Sea (north of Bali Island) and also seas in southern of East Java (Indian Ocean). ECDF analysis taken from observer data only at Bali Strait (Figure 2), it is possible PFZ in the outside area of Bali Strait have false value with high error.

PFZ in Bali Strait above is generated using ECDF analysis, an algorithm in both monsoons provided in Table 2, where SST and Chl-a are data from the satellite.

In the northwest monsoon, PFZ is formed in the southern part of Bali Strait, far from Muncar (Banyuwangi) and Pengambengan (Bali). Fishermen will be closer if departing from Kedongan (Bali). This condition is related to the pattern of water mass circulation in Bali Strait, that the surface water mass enters the Bali Strait from the Indian Ocean (South-Southeast) towards the Bali Sea (North-Northwest) (Pranowo and Realino, 2006). The southern part of the Bali Strait is the inflow and outflow of water from the Indian Ocean. It affects primary productivity. In the Norwest

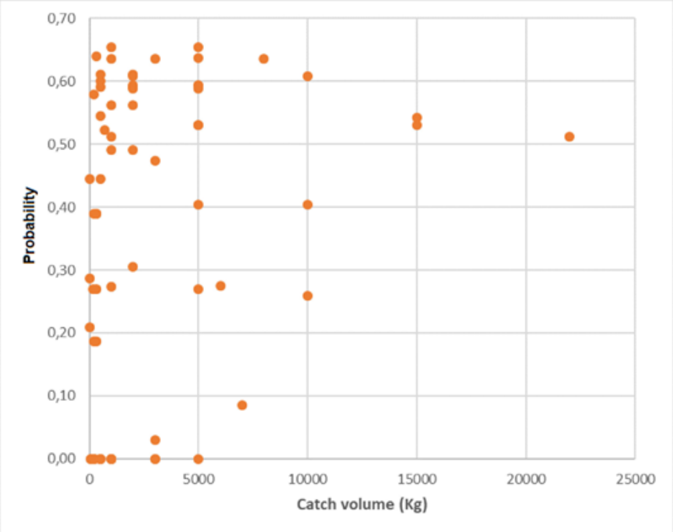

Figure 8. The plot of actual values versus predicted values of PFZ, total data sample are 75 points presented by orange dots.

monsoon, the highest chlorophyll-a distribution occurs in the open sea, that is in southern part of the Bali Strait. So in the Northwest monsoon the PFZ is formed in the Southern part of the Bali Strait. This condition changes with the change of monsoons, upwelling in Indian Ocean occurs more intensely during the Southeast monsoon, which causes indirect upwelling in the middle part of Bali Strait. Therefore, in the Southeast monsoon, PFZ will form and spreading in the middle part of the Bali Strait. That is the reason when Southeast monsoon, PFZ is formed mostly close to Pengambengan rather than Muncar. This condition is very profitable for Pengambengan fishermen because a closer catch route will consume less fuel. The PFZ locations of both seasons showed that Sardinella lemuru fishes were always present and scattered around of Bali Strait.

PFZ model performance

Combination prediction values and actual values using confusion matrix provided in Table 3, model performance is determined by overall accuracy in percent. From Table 3 we have 4 combinations, there are High actual values - High predicted value (True Positive), High actual values – Low predicted values (False Negative), Low actual values - High predicted value (False Positive), and Low actual values – Low predicted values (True Negative). Total True Positive and True Negative is 52 samples from 75 validation sample, so we have at least 23 samples that do not fit with the model. All plot distribution of validation data in a cartesian diagram is also presented in Figure 8. Performance metrics that we get from the calculation of the confusion matrix are sensitivity 61,90%, specificity 78,79 %, and overall accuracy 69,33%.

False Positive (FP) and False Negatif (FN) are the number of interpreting errors in the model. Means, prediction results do not match with actual conditions(Sokolova and Lapalme, 2009). The result of performance metrics shows False Positive value is 7 and FN value is 16. Thus, the error in model prediction is relatively small.

Using sentitivity, we can assess how well our model is able to identify the actual true result. The resulting PFZ model is also a fairly good one because it has a sensitivity value over 50%. Overall accuracy in this PFZ model is 69,33%, the value is above the minimum threshold accuracy value. Minimum threshold accuracy value is on 0.5 or 50% and perfect in 1.0 or 100% (Phillips and Dudík, 2008). Lastly, the performance test for the produced PFZ model was still using the old and measly observer data, thus it would be better if there is a more recent Bali Strait observer data to validate the PFZ model. This ECDF method can be applied in other areas based on actual data on fishing in that area, so that the PFZ algorithm for each waters is actually built based on the condition of the fish in these waters, not just taking the existing algorithms for granted. The weakness of this research is the lack of real fisheries data that contain coordinated information. If supported by large and comprehensive coordinated fishing data, then this method is very good and will have a better accuracy.

4. Conclusion

ECDF model had a great performance for detection of Sardinella lemuru in Bali Strait. ECDF method also give fairly good accuracy result for Sardinella lemuru detection, which is above 50%. Area with medium-high potency in Bali Strait wider and spread along Bali Strait at southeast monsoon, it means southeast monsoon is the best time for capture Sardinella lemuru. Furthermore, according to percent contribution values, Chl-a is the most important variable to generate PFZ with influence until 72,8%, but this percentage may change if applied to other small pelagic fish and located in other regions. The maximum of suitable preference of Chl -a at 0,2 mg/m3 and SST at 28,38°C in northwest monsoon, while in southeast monsoon is 0,97 mg/m3 for Chl-a and 25,61°C for SST.

5. Acknowledgment

We acknowledge NASA Goddard Space Flight Center for providing MODIS Aqua satellite data.

5. Author's Note

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the data and the paper are free of plagiarism. All authors are main contributors that are equally responsible for the manuscript.

References

Carpenter, K. ., & Niem, V. . (1999). *The Living Marine Resources of the Western Central Pacific. Batoid Fishes, Chimaeras and Bony Fishes Part 1 (Elopidae to Linophrynidae). In FAO Species Identification Guide for Fishery Purposes* (Volume 3). Rome: FAO.

Gao, F., Chen, X., Guan, W., & Li, G. (2016). A New Model to Forecast Fishing Ground of Scomber Japonicus in The Yellow Sea and East China Sea. *Acta Oceanologica Sinica*, *35*(4), 74–81. https://doi.org/10.1007/s13131-015-0767-8

Gaol, J. Lumban, Wudianto, Pasaribu, B. ., Manurung, D., & Endriani. (2004). The Fluctuation of Chlorophyll-a Concentration Derived from Satelite Imagery and Catch of Oily Sardine (Sardinella Lemuru0) in Bali Strait. *International Journal of Remote Sensing and Earth Sciences (IJReSES)*, *1*(1). https://doi.org/10.30536/j.ijreses.2004.v1.a1325

Gaol, Jonson Lumban, Arhatin, R. E., & Ling, M. M. (2014). Pemetaan Suhu Permukaan Laut Dari Satelit Di Perairan Indonesia Untuk Mendukung " One Map Policy ." *Seminar*

Nasional Penginderaan Jauh 2014: Deteksi Parameter Geofisik Dan Diseminasi Penginderaan Jauh, 433–442. Bogor, Indonesia: LAPAN.

Ghofar. (2005). Co-existence in Small-pelagic Fish Resources of The South Coast of East Java, Straits of Bali, Alas and Sape - Indonesia. *Imu Kelautan-Indonesian Journal of Marine Sciences*, *10*(3), 149–157.

Hastie, T. J., & Tibshirani, R. J. (2017). *Generalized Additive Models* (1st Editio). New York: Routledge. https://doi.org/10.1201/9780203753781

Huot, Y., Babin, M., Bruyant, F., Grob, C., Twardowski, M. ., & Claustre, H. (2007). Does chlorophyll \textlessi\textgreatera\textless/i\textgreater Provide the Best Index of Phytoplankton Biomass for Primary Productivity Studies? *Biogeosciences Discussions*, *4*, 707–745.

Ilahude, A. G. (1978). On The Factors Affecting The productivity of The Southern Makassar Strait. *Marine Research in Indonesia*, *21*, 81–107. https://doi.org/10.14203/mri.v21i0.391

Kohavi, R., & Provost, F. (1998). Glossary of Terms: Special Issue on Applictions of Macine Learning and the Knowledge Discovery Process. *Machine Learning*, *30*(2).

Lanz, E., López-Martínez, J., Nevárez-Martínez, M., & Dworak, J. . (2009). Small Pelagic Fish Catches in the Gulf of California Associated with Sea Surface Temperature and Chlorophyll. *California Cooperative Oceanic Fisheries Investigations Reports*, *50*, 134–146.

Ningsih, N. S., Rakhmaputeri, N., & Harto, A. B. (2013). Upwelling Variability along The Southern Coast of Bali and in Nusa Tenggara Waters. *Ocean Science Journal*, *48*(1), 49–57. https://doi.org/10.1007/s12601-013-0004-3

Phillips, S. J., & Dudík, M. (2008). Modeling of Species Distributions with Maxent: New Extensions and A Comprehensive Evaluation. *Ecography*, *31*(2), 161–175. https://doi.org/10.1111/j.0906-7590.2008.5203.x

Pranowo, W., & Realino, B. (2006). Sirkulasi Arus Vertikal Di Selat Bali Pada Monsun Tenggara. *Prosiding Forum Perairan Umum Indonesia*. Jembrana: Balai Penelitian dan Observasi Laut Jembrana.

R Core Team. (2018). *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.

Republik Indonesia. *KEPMEN-KP Nomor 77.* , Pub. L. No. 93 (2016).

Ridha, U., Hartoko, A., & Muskanonfola, M. R. (2013). Analisa Sebaran Tangkapan Ikan Lemuru (Sardinella lemuru) Berdasarkan Data Satelit Suhu Permukaan Laut Dan Klorofil-A Di Perairan Selat Bali. *Management of Aquatic Resources Journal (MAQUARES)*, *2*(4), 53–60. https://doi.org/10.14710/marj.v2i4.4268

Ryandhini, N. A., Zainuri, M., & D. K., A. R. T. (2015a). Characteristics of Mixed Layer Depth and Its Effect on Concentration of Chlorophyll-a (Karakteristik Mixed Layer Depth dan Pengaruhnya Terhadap Konsentrasi Klorofil-a). *Ilmu Kelautan: Indonesian Journal of Marine Sciences*, *19*(4), 219. https://doi.org/10.14710/ik.ijms.19.4.219-225

Ryandhini, N. A., Zainuri, M., & D. K., A. R. T. (2015b). Karakteristik Mixed Layer Depth dan Pengaruhnya Terhadap Konsentrasi Klorofil-a. *ILMU KELAUTAN: Indonesian Journal of Marine Sciences*, *19*(4), 219. https://doi.org/10.14710/ik.ijms.19.4.219-225

Saputra, C., Arthana, I. W., & Hendrawan, I. G. (2017). The Vulnerability Study Of Lemuru (Sardinella lemuru) Fish Resources Sustainability In Bali Strait In Corellation With ENSO and IOD. *ECOTROPHIC : Jurnal Ilmu Lingkungan (Journal of Environmental Science)*, *11*(2), 140. https://doi.org/10.24843/EJES.2017.v11.i02.p02

Sartimbul, A., Rohadi, E., Yona, D., Yuli H., E., Bakar Sambah, A., & Arleston, J. (2016). Change In Species Composition and Its Implication On Climate Variation In Bali Strait: Case Study In 2006 and 2010. *The 3rd International Conference on Fisheries and Aquaculture*, 1–7. Ngombo, Sri Lanka. https://doi.org/10.17501/icfa.2016.3101

Shaari, N. ., & Mustapha, M. . (2018). Predicting Potential Rastrelliger kanagurta Fish Habitat using MODIS Satellite Data and GIS Modeling: A Case Study of Exclusive Economic Zone, Malaysia. *Sains Malaysiana*, *47*(07), 1369–1378. https://doi.org/10.17576/jsm-2018-4707-03

Sokolova, M., & Lapalme, G. (2009). A Systematic Analysis of Performance Measures for Classification Tasks. *Information Processing & Management*, *45*(4), 427–437. https://doi.org/10.1016/j.ipm.2009.03.002

Strobl, C., Hothorn, T., & Zeileis, A. (2009). Party on! A New,Conditional Variable Importance Measure for Random Forests Available in the party Package. *The R Journal*, 1–2. Retrieved from http://www.stat.uni-muenchen.de

Susilo, E. (2015). Variabilitas Faktor Lingkungan Pada Habitat Ikan Lemuru Di Selat Bali Menggunakan Data Satelit Oseanografi Dan Pengukuran Insitu. *Omni-Akuatika*, *14*(20), 13–22.

Ting, K. M. (2017). Confusion Matrix. In *Encyclopedia of Machine Learning and Data Mining* (pp. 260–260). Boston, MA: Springer US. https://doi.org/10.1007/978-1-4899-7687-1_50

Tummala, S. K., Masuluri, N. K., & Nayak, S. (2008). Benefits Derived by The Fisherman Using Potential Fishing Zone (PFZ) Advisories. In R. J. Frouin, S. Andrefouet, H. Kawamura, M. J. Lynch, D. Pan, & T. Platt (Eds.), *Remote Sensing of Inland, Coastal and Oceanic Waters* (p. 71500N). https://doi.org/10.1117/12.804766

Wujdi, A., Suwarso, & Wudianto. (2012). No Title. *BAWAL*, *4*(3), 177–184. Retrieved from http://ejournal-balitbang.kkp.go.id/index.php/bawal/article/view/687/693http://ejournal-balitbang.kkp.go.id/index.php/bawal/article/view/687/693

Zhang, X., Saitoh, S.-I., & Hirawake, T. (2017). Predicting Potential Fishing Zones of Japanese Common Squid (Todarodes pacificus) Using Remotely Sensed Images in Coastal Waters of South-Western Hokkaido, Japan. *International Journal of Remote Sensing*, *38*(21), 6129–6146. https://doi.org/10.1080/01431161.2016.1266114