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Identifying fishing grounds in the Savu Sea, Indonesia: fishermen's experience compared with the chlorophyll-a forecast maps

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Abstract. The Savu Sea in East Nusa Tenggara Province is the location of fishing activities for most fishermen in East Nusa Tenggara. Despite its potential, the knowledge of the fishing ground is still conventional. Currently, predictive methods for trips planning are available, such as the fishing ground forecast maps based on the chlorophyll-a, sea surface temperature and salinity. The related data are provided by NASA, being processed by the Marine Research and Observation Center to display the potential fishing ground as a box view with an accuracy level of 5 square miles. Eventually, the forecast map of the fishing area will be compared with the fishing locations known by the fishermen, for validation The data collection used a survey method and the data analysis used both a descriptive analysis and the linear regression. The forecast maps matched with the observed fishing locations at only 13.6%. The highest recorded chlorophyll-a concentration was of 1.29 mg m^{-3} (constantly observed in the West Flores) and the lowest was of 0.07 mg m^{-3}. The chlorophyll-a has an effect on 62.2% of the catch and 52% of the catch is composed of *Katsuwonus pelamis*.

Key Words: MODIS, sea surface temperature, catch composition, *Katsuwonus pelamis*.

Introduction. Indonesia is the largest archipelagic country in the world, having a coastline length of 81,000 km^2 and a sea area of about 3,100,000 km^2 (Kusumastanto 1996; Darsono 1999; Latif et al 2019). Managing the fisheries resource requires determining the fish growth patterns and the catch period, in order to avoid over-exploitation (Nugraha et al 2020a). The province of East Nusa Tenggara has a sea area of 200,000 km^2 with a coastline of 5,700 km^2 (MMAF 2016). Savu Sea has a good potential for fisheries and the whole marine sector (Asagabaldan 2017). A fishing area is an area where fish are caught in maximum amount and fishing gear can be operated economically. Assessment and mapping of fishing areas are needed (Nusantara et al 2014). The *Katsuwonus pelamis* is a fast swimming fish and has the greedy character of an opportunistic predator, with food types ranging from small fish (Clupeidae and Engraulidae), squids, crustaceans and zooplankton (Tuli et al 2015). *K. pelamis* is a pelagic fish living in groups, from the coastal areas to the open sea (Nainggolan 2012). Schooling fish should be kept as close to the boat as possible so that they can be easily caught using pole and line fishing rods (Sudirman & Mallawa 2012). The fishing grounds are determined by the waters' condition in the habitat of a species. Water conditions are usually described by oceanographic parameters (Nugraha et al 2020b).

The Sea Surface Temperature (SST) of the *K. pelamis* fishing ground ranges from 29.75 to 30.25°C (Zainuddin et al 2015; Nugraha et al 2020a; Zainuddin 2011). Meanwhile, the potential area has a characteristic chlorophyll-a concentration of around 0.125 mg m^{-3}. This condition is mainly seen in May. Outside of this range, the catch of *K. pelamis* tends to decline, as it happens in April (when the SST values in the Bone-Sea Flores bay are the highest). Likewise, when the chlorophyll-a concentration in the fishing ground significantly increase and the catch tends to decrease. This means that there is a certain range of values for the two oceanographic factors that are very suitable for the presence and abundance of *K. pelamis*. The distribution of chlorophyll-a can be a parameter used for identifying the presence of fish in a water area (Hasyim & Zainuddin 2008; Laurs et al 1984).

The Forecast Maps of Fishing Ground (PPDPI) is the result of a research conducted by the Institute for Marine Research and Observation (IMRO) in order to identify fishing grounds, based on an internet service of information on the fishing areas' characteristics (Sugiari 2015; Panjaitan 2014). PPDPI have been produced for and distributed to the fishing communities of Indonesia, since 2000 (Tambun et al 2018; Farda & Jatisworo 2019). PDPPI was compiled using remote sensing data which is also widely used to detect water conditions such as the thermal front (Cayula & Cornillon 1992; Wibawa 2011; Jatisworo & Murdimanto 2013) and the concentration of chlorophyll-a (Seki et al 2002) which is one of the indicators of water fertility and school of fish. PDPPI preparation was carried out using SST and water fertility data (chlorophyll-a) generated from MODIS Aqua level 3 daily composites, in the Hierarchical Data Format (HDF) (Suniada et al 2015).

The predictive maps of fishing grounds that already exists in Indonesia still have many weaknesses, including the spatial aspect of the points of forecasting located far from the coast and the uncertainty of the predicted type of fish. Thus, if inappropriate gear is selected for the fishing trip, the catch productivity is negatively affected, even in presence of abundant fish populations (Kunarso et al 2019).

Chlorophyll-a is an indicator of the abundance of phytoplankton in waters, playing a role in the photosynthesis process (Huot et al 2007; Zhang & Han 2015). Phytoplankton contributes to a large extent to determine primary productivity in waters. Organic carbon production during photosynthesis is defined as primary productivity or Net Primary Productivity (Lee et al 2016).

Linear regression analysis was carried out on the model of the relationship between chlorophyll-a concentration and primary productivity. The results of this equation can be applied to the satellite imagery so that it can help to monitor the water quality conditions (Nuzapril et al 2017). This abundance of phytoplankton will result in the creation of food chain clusters from phytoplankton to large pelagic fish schools (Sato et al 2015; Behrenfald et al 2005).

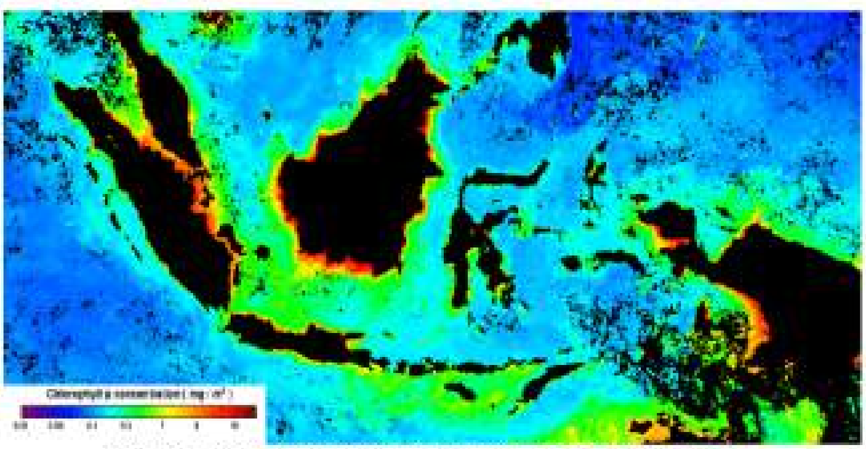


Figure 1. Map of chlorophyll-a concentration (IMRO 2020).

Remote sensing data can show the variables used in determining fish catchment areas. Certain remote sensing images used to extract SST and chlorophyll-a information are provided by the MODIS program (Nurman 2010; Hakim et al 2006).

Satellite imagery is one of the applications of the remote sensing technology. The Moderate-resolution Imaging Spectroradiometer (MODIS) technology uses sensors belonging to the Earth Observing System (EOS), carried by two satellites produced by the

National Aeronautics and Space Administration (NASA), namely Terra and Aqua (http://modis.gsfc.nasa.gov 2007).

The MODIS sensor is a derivative of the Advanced Very High Resolution Radiometer (AVHRR) sensor, Sea-viewing Wide Field-of-View Sensor (SeaWIFS) and High Resolution Imaging Spectrometer (HRS) owned by EOS, which has previously orbited, so it can be used to measure sea and atmosphere-level parameters (such as the sea surface temperature, chlorophyll-a concentration and water vapor content) and marine phenomena (such as the occurrence of upwelling, thermal fronts and others) (http://modis.gsfc.nasa.gov 2007).

Material and Method

Description of the study sites. This research was conducted on a pole and line fishing boat operating in the Flores Sea, East Nusa Tenggara. The satellite image data retrieval was carried out at the Southeast Research and Ocean Observation Center (SeaCORM) Jembrana, Bali. The material used consisted of sea water samples for measuring oceanographic elements. The methods used in data collection are literature study, interview, documentation and observation.

Data analysis method. Regression analysis is a statistical analysis that studies the relationship between two or more variables. In the linear regression analysis it is assumed that this relationship is a linear combination, the simplest case consisting of one independent variable (Pangestu 2016).

Linear regression is a statistical method used to model the relationship between the dependent variable (dependent, response, Y) and one or more independent variables (independent, predictor, X). If there is only one independent variable, it is called simple linear regression, whereas if there is more than one independent variable, it is called multiple linear regression. Regression analysis has at least three use cases, namely for data description, for control and for predictive purposes.

Simple regression is carried out in stages, namely by connecting the independent variable (chlorophyll-a) with the dependent variable (tuna catch, using the data regression analysis function of Microsoft Office Excel (Kurniawan 2008). This simple regression analysis was conducted to determine the relationship between the dependent variable Y (*K. pelamis* catches) and the independent variable X (chlorophyll-a). The regression model used is:

$$Y = a + bX$$

Where:
X - chlorophyll-a;
Y - pole and line catch;
a - the constant (intercept) is the value of Y, when X = 0 which equals the value of a where it intersects the Y axis;
b - regression coefficient.

Chlorophyll-a image analysis. The fishing ground forecast can be predicted from the parameters of sea surface temperature and chlorophyll-a. The analysis of the distribution of sea surface temperature and chlorophyll-a can use level 1b and level 2 Modis images. The Algorithm Theoretical Basic Document Modis (ATBD) 25 is used to determine sea surface temperature and the Morel 4 Algorithm is used to determine the chlorophyll-a. The MODIS image levels 1b and 2 use the RMSE test calculation (Chavula 2012).

From the two Root Mean Squared Error (RMSE) tests carried out between the field data and the Modis image data levels 1b and level 2, more accurate values were obtained from the smallest RMSE sum value, namely the Level 2 Modis image, with an RMSE value of chlorophyll-a of 0.090315. So the best fishing ground forecast can be determined through Level 2 MODIS Images (Febriani & Sukojo 2016).

Results and Discussion

Fishing ground. In this study we used a pole and line fishing boat (Figure 2) that operates in Savu sea, Flores, East Nusa Tenggara.

Figure 2. Pole and line fishing boat (original).

Composition and comparison of catches with the number of settings.

1. In November 2019 the ship made one trip with a catch of *K. pelamis* of 1,020 kg.
2. In December 2019 the ship made 16 trips with a catch of 28,220 kg. The fishing season generally reaches a turning point in the middle of January and in December, according to the graph, the catch will decrease as the wind season arrives.
3. In January 2020 the catch obtained was of 7,990 kg. January is generally the start of the wind season, so ships rarely go to sea.
4. In February 2020 the catches were dominated by *K. pelamis* and *Thunnus albacares*. According to the fishermen, February was generally the peak of the wind season, so that the catch was not good, until the middle or end of March.
5. In March 2020 the catches were dominated by *K. pelamis* and *T. albacares*, but unlike in the previous month, *Coryphaena hippurus* and *Elagatis bipinnulata* were also obtained. In March 2020 the fishermen began to increase the intensity of their trips, but taking into account the strength of the wind and the availability of bait.

The composition of the catch for 5 months can be seen in Table 1.

Table 1

Comparison of catch volumes with the number of settings

Volumes / Period	*November*	*December*	*January*	*February*	*March*
Number of setting (times)	2	43	14	15	13
K. pelamis (kg)	1,020	15,300	2,890	6,290	7,480
T. albacares (kg)	0	9,520	2,040	5,440	4,250
C. hippurus (kg)	0	1,870	1,870	0	1,360
E. bipinnulata (kg)	0	1,530	1,190	0	1,870
Total (kg)	1,020	28,220	7,990	11,730	14,960
Catch rate per setting (kg)	510	656,28	570,71	782	1,150

Catch frequencies can also be visualized in Figure 3.

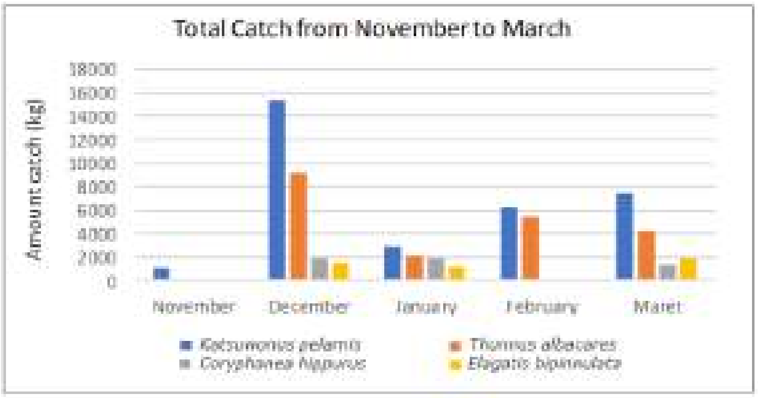


Figure 3. Total catch (November 2019 to March 2020).

Based on the graph above, there is a decrease in the catch volumes during the 4 months of fishing. The lowest catch was obtained in January with a total of 7,990 kg, consisting of: *K. pelamis* (2,890 kg), *T. albacares* (2,040 kg) and others, such as *E. bipinnulata* and *C. hippurus*. The highest catch was obtained in December is 28,220 kg, dominated by *K. pelamis* with 15,300 kg and *T. albacares* with 9,520 kg. In 2016, Kupang Regency was the largest supplier of *K. pelamis* in East Nusa Tenggara (MMAF 2018).

Catch composition. Table 2 and Figure 4 show that *K. pelamis* is the most dominant catch that lands at Tenau port and at the fishing port around Kupang city, East Nusa Tenggara. This is in accordance with the data from the Fisheries Service of the Province of East Nusa Tenggara, suggesting that *K. pelamis* is one of the main commodities produced in Kupang, with 52%, followed by *T. albacares*, with 33%, *C. hippurus*, with 7% and *E. bipinnulata*, with 8%. The catch compositions (in %) can be seen in Figure 4.

Table 2

Catch rated per setting

Name of fish	*Amount (kg)*	*Catch percentage (%)*
K. pelamis	32,980	52
T. albacares	21,250	33
C. hippurus	4,590	7
E. bipinnulata	5,100	8
Total catch	63,920	100
Catch rate per setting	734.71	1.14

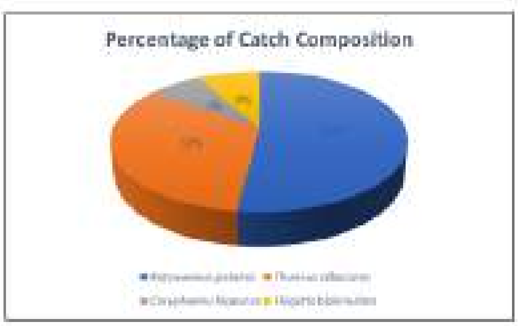


Figure 4. Catch composition diagram.

Conformity between of the fishing ground and PPDPI. Fishing is carried out on FADs that have been installed, with the position of the FADs stored on the GPS of each ship. The following is a map of the fishing grounds with the positions of the FADs. Figure 5 below shows the fishing ground for 5 months of fishing.

Figure 5. Fishing ground.

Forecast map of fishing ground (PPDPI).

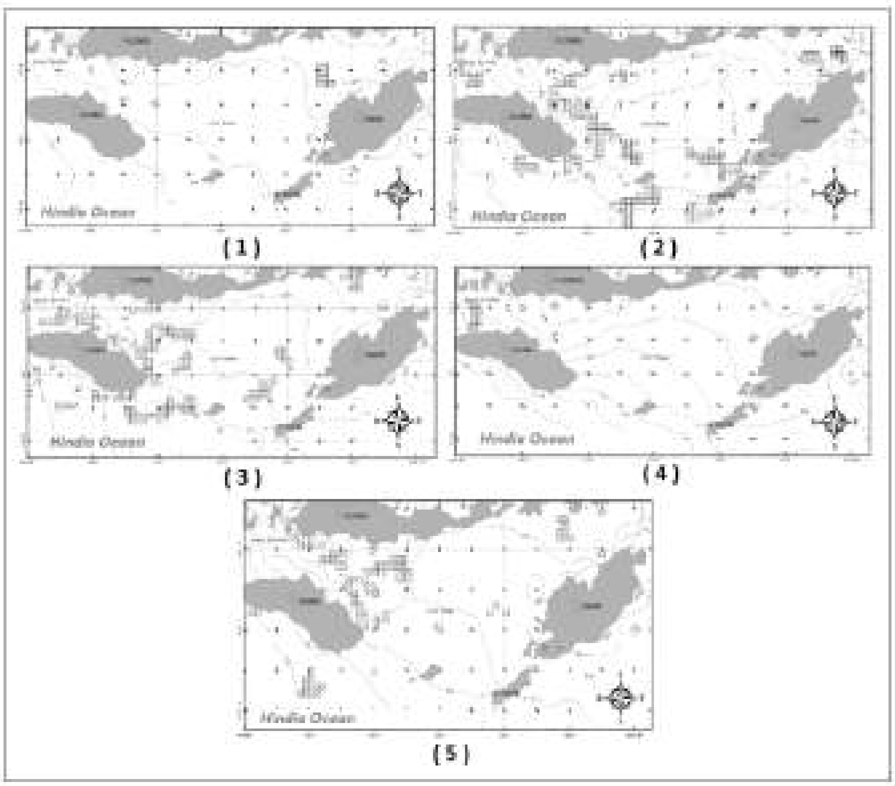


Figure 6. PPDPI period in November (1), December (2) (IMRO 2019); January (3), February (4), March (5) (IMRO 2020).

1. In November the PPDPI that can be used correspond to 29 to 30 November 2019. On this map, the potential fishing grounds are around the northwest of Timor Island with an area of 150 NM.
2. In December, 15 files were issued with an interval of 2 days. In the PDPPI 11 to 12 December 2019, the fishing areas that recommended are in the south of Sawu Island, northeast of Sumba Island and north of Rote Island, as well as many other areas with more than 300 NM (IMRO 2019).
3. In January, only 1 file out of 7 uploaded PPDPI files issued corresponded to the time of the fishing trip. On the 31 December to 01 January map, the potential fishing grounds were located around the southeast of Sumba Island, west of Savu Island, with an area of more than 300 NM (IMRO 2020).
4. In February, as many as 10 PPDPI files were uploaded and 3 files corresponded to the time of the fishing trip. One of the suitable map files was issued on the 26 to 27 February recommending fishing zones located north of Sumba Island with an area of 300 NM. Other areas do not seem to be potential fishing grounds (IMRO 2020).
5. In March there were 4 files matching, at the time of the fishing trip. March should be the turning point of the monsoon season that occurs in East Nusa Tenggara, but each region has a different time. One of the maps is the 16 to 17 March map, the areas that are recommended for fishing activities are in the south of Sumba Island and northeast of Sumba Island, with an area of more than 300 NM. There was also one point with an area of 50 NM located on Semau and Kupang islands (IMRO 2020).

Compatibility between the fishing ground and PDPPI. Of all trips with available PDPPI, there were only 17 files that matched, at the time of the fishing trip. For the 4 months period, 17 maps of fishing ground forecasts were used, with a total of 44 settings (Table 3).

The method used to determine the suitability of fishing grounds with PDPPI, issued by IMRO, uses a comparison method between the position of the actual fishing area and the status of the same location on the forecast map, on that date. From 44 setting positions, 6 positions were in accordance with the PDPPI, which corresponds to a match rate of 13.6%, in terms of chlorophyll-a and sea surface temperature. When the daily PDPPI images from the NASA website are not available, the fishing trips cannot be used as a reference in determining their suitability. With a match rate of 13.6%, it can be said that fishermen using FADs have sufficient accuracy in determining fishing grounds.

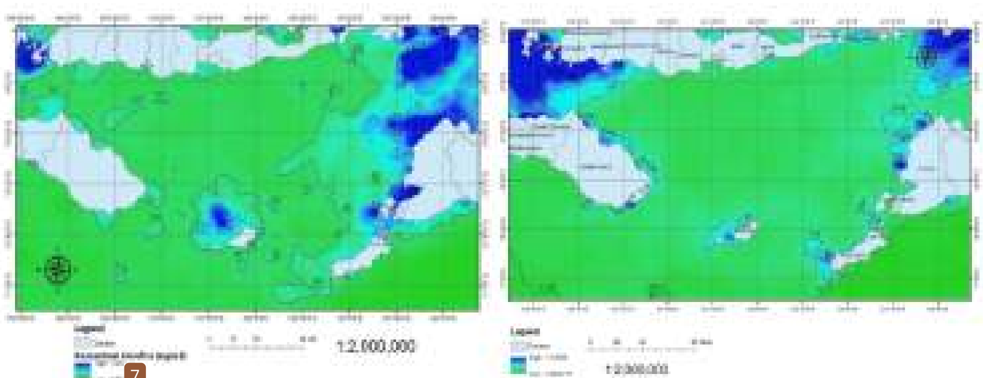
Table 3

Compatibility of the fishing ground with the PPDPI

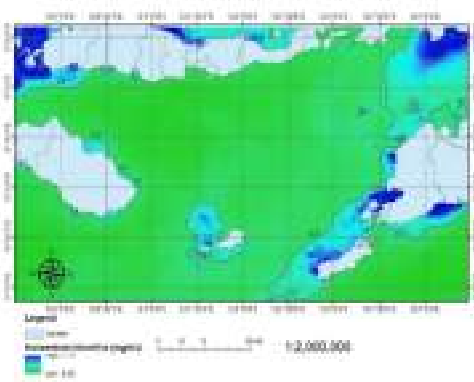
No	*Setting*	*Position*		*Chlorophyll-a* ($mg\ m^{-3}$)	*Information*
		Latitude	*Longitude*		
1	1	10^0 12' 27" S	121^0 40' 16" E	0.41	Inappropriate
	2	10^0 09' 43" S	121^0 37' 40" E	0.31	Inappropriate
2	1	09^0 56' 38" S	122^0 25' 03" E	0.3	Appropriate
	2	10^0 42' 09" S	121^0 50' 28" E	0.27	Inappropriate
	3	10^0 26' 28" S	122^0 47' 58" E	0.27	Appropriate
3	1	09^0 32' 11" S	123^0 20' 42" E	0.24	Inappropriate
	2	09^0 45' 37" S	123^0 13' 20" E	0.22	Inappropriate
4	1	10^0 04' 18" S	122^0 32' 21" E	0.27	Appropriate
	2	10^0 28' 31" S	122^0 41' 16" E	0.31	Inappropriate
	3	10^0 12' 31" S	122^0 05 10" E	0.33	Appropriate
5	1	10^0 40' 10" S	122^0 15' 30" E	0.29	Inappropriate
	2	09^0 40' 33" S	122^0 55' 15" E	0.39	Inappropriate
6	1	09^0 31' 40" S	123^0 05' 09" E	0.21	Inappropriate
	2	09^0 05' 45" S	123^0 00' 41" E	0.28	Inappropriate
	3	09^0 47' 16" S	122^0 58' 34" E	0.13	Inappropriate
7	1	09^0 40' 08" S	123^0 22' 31" E	0.29	Inappropriate
	2	09^0 50' 28" S	122^0 53' 17" E	0.30	Inappropriate

No	Setting	Position		Chlorophyll-a ($mg\ m^{-3}$)	Information
		Latitude	Longitude		
8	1	10^0 38' 15" S	121^0 40' 30" E	0.41	Inappropriate
	2	10^0 42' 09" S	121^0 50' 28" E	0.38	Inappropriate
	3	10^0 49' 25" S	121^0 01' 51" E	-	Inappropriate
9	1	09^0 32' 11" S	123^0 20' 42" E	0.28	Inappropriate
	2	09^0 45' 37" S	123^0 13' 20" E	0.24	Inappropriate
	3	09^0 54' 26" S	123^0 01' 51" E	-	Inappropriate
10	1	10^0 21' 15" S	122^0 35' 07" E	0.45	Inappropriate
	2	10^0 10' 35" S	122^0 05' 37" E	-	Inappropriate
	3	10^0 03' 47" S	122^0 45'10 " E	0.54	Appropriate
11	1	09^0 40' 36" S	122^0 05' 15" E	0.8	Inappropriate
	2	09^0 50' 17" S	121^0 35' 20" E	1.1	Inappropriate
12	1	09^0 30' 14" S	122^0 50' 33" E	-	Inappropriate
	2	09^0 21' 52" S	123^0 00' 16" E	-	Inappropriate
13	1	10^0 40' 16" S	123^0 41' 40" E	-	Inappropriate
	2	10^0 39' 13" S	123^0 45' 36" E	-	Inappropriate
	3	10^0 40' 41" S	123^0 40' 22" E	-	Inappropriate
14	1	09^0 50' 20" S	122^0 10' 31" E	-	Inappropriate
	2	09^0 18' 50" S	122^0 46' 15" E	-	Inappropriate
	3	09^0 30' 16" S	123^0 01' 51" E	-	Inappropriate
15	1	10^0 03' 15" S	122^0 45' 17" E	0.31	Inappropriate
	2	10^0 03' 40" S	121^0 48' 29" E	-	Inappropriate
16	1	10^0 08' 36" S	123^0 07' 12" E	-	Inappropriate
	2	10^0 15' 53" S	122^0 46' 41" E	-	Inappropriate
	3	10^0 03' 09" S	122^0 53' 08" E	-	Inappropriate
17	1	09^0 29' 21" S	122^0 30' 14" E	0.6	Inappropriate
	2	09^0 50' 15" S	122^0 30' 35" E	0.54	Inappropriate
	3	09^0 55' 23" S	121^0 20' 54" E	0.49	Appropriate

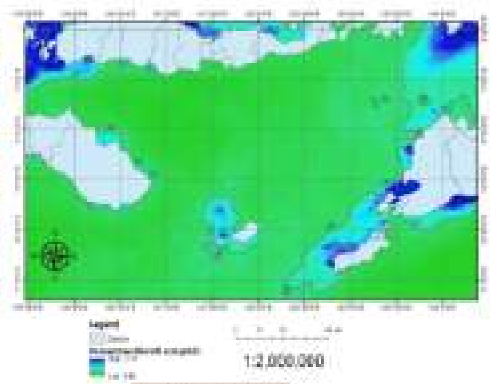
Concentration and distribution of chlorophyll-a. Chlorophyll-a concentrations can be obtained by downloading data levels 1, 2 and 3 on the NASA website. Data needs a longer time span such as months and years can use level 3 image data with better quality than others, but level 3 images only contain one specific information depending on what is needed. In this study, the basis used is a level 3 image which only requires chlorophyll-a information with a time span of months. Figure 7 images and Table 4 data correspond to level 3 chlorophyll-a concentration.



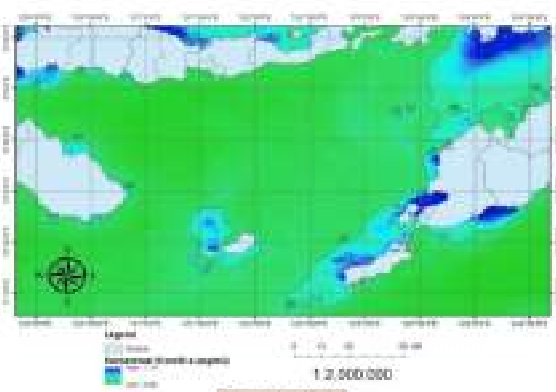
November 2019 December 2019



January 2020



February 2020



March 2020

Figure 7. Concentration of chlorophyll-a map (www.oceancolour.gsfc.nasa.gov).

The distribution map of chlorophyll-a concentrations (Table 4) from November to March shows elevated values around the west of Flores Island, Sumba Island and also Larantuka, suggesting that food chain occur in the area.

Table 4

Concentration and distribution of chlorophyll-a

Period	*November*	*December*	*January*	*February*	*March*
Concentration of chlorophyll-a (mg m^{-3})					
a. Lowest	0.07	0.08	0.08	0.08	0.08
b. Highest	1.29	1.14	1.15	1.19	1.17
Average value (mg m^{-3})	0.2	0.3	0.2	0.2	0.2
Distribution center	North of Kupang city, Sabu Island, and west of Flores	West of Flores	Kupang city, Sabu Island, Rote Island, and west of Flores	Kupang city, Rote Island, and west of Flores	Kupang city, west of Flores
Compatibility level	Appropriate	Inappropriate	Appropriate	Appropriate	Inappropriate

Conclusions. Based on the results of the study it can be concluded: simultaneously, chlorophyll-a had an effect of [illegible]2.2% on the catch. The highest concentration of chlorophyll-a recorded was 1.29 mg m^{-3} and the lowest was 0.07 mg m^{-3}; the fishing area used by fishermen has a level of conformity with the forecast map for fishing areas of 13.6%. Not all fishing trips can be used as a reference in determining the suitability of fishing grounds with PDPPI, because not every day PPDPI can be uploaded because it is limited by the availability of images obtained from the NASA website.

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Conflict of interest. The authors declare no conflict of interest.

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