Analysis of oil sardine (*Sardinella lemuru*) fishing grounds in the Bali Strait waters, Indonesia

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Abstract. Oil sardine (*Sardinella lemuru*) has an important economic value for the fishery sector in Indonesia. Until now the understanding of oil sardine fishing grounds is still limited. The present research aims to determine the composition of number and size of oil sardine, to determine the distribution of chlorophyll-*a* and sea surface temperature in the Muncar waters, Banyuwangi, and to evaluate the condition of fishing ground of oil sardine. Data were collected from fishing activities including time and locations of fishing, number and size of fish caught as catch recorded at each fishing location. Fish samples were randomly taken at each fishing location, and then their total body length was measured. Data of chlorophyll-*a* and sea surface temperature (SST) in the study sites obtained by processing images of SST and chlorophyll-*a* were detected by satellite Terra Aqua (MODIS). The study revealed that the catches were dominated by "protolan" group (size of 11–15 cm), only small fraction (21%) of fish with size of larger than 18 cm. In addition, it was found that the concentration of chlorophyll-*a* (0.126-0.259 mg m^{-3}) in the Muncar waters and the Bali Strait affected the composition of oil sardine catches, while the sea surface temperature (SST) (27-30°C) did not have significant effect on the catch. Finally, potential fishing grounds for oil sardine in Muncar waters and the Bali Strait during periods of February-March 2015 were found only in the waters of Sembulungan, Pengambengan, and the Strait of Bali.
Key Words: Bali strait waters, catch composition, chlorophyll-*a*, fishing ground analysis, *Sardinella lemuru*, sea surface temperature.

Introduction. Oil sardine (*Sardinella lemuru*) is one of the superior fishery commodities for fishermen based in Muncar fishing port, Banyuwangi. Muncar is known as the largest producer of oil sardine in Java. Oil sardine is not only strategic as source of income for local fishermen, but also as raw fish material for processing industries. Fishermen collaborate with fish processing factories for processing their catches. DMF (2014) reported that the processed products of oil sardine from Banyuwangi has been distributed to various destinations both local and export scale. The local market of this commodity are Surabaya, Yogyakarta, Malang, Jakarta, Bali and Madura, while the export markets are the US, Europe, and parts of the Middle East.

Fishermen based in Muncar fishing port caught oil sardine not limited to Muncar water, but also in the surrounding water of Bali Strait (Figure 1). Catches of the fishermen were dominated by oil sardine, which was about 81.85% (DMF 2014). Wijaya & Koeshendrajana (2009) stated that oil sardine in the Strait of Bali can be found throughout the year, ranging from small size (juvenile) to adult size.

According to Simbolon & Girsang (2009), juvenile fish are considered as illegal size to be captured (not worth catching). Therefore, the waters dominated by juvenile fish (illegal size) indicates that these waters are categorized as not potential fishing grounds. When the catch is dominated by juvenile fish, it will have a negative impact on the rate of recruitment of fish resources, and will lead to the degradation of fishing areas. This condition may cause a reduction in catches of fishermen because of the depletion of oil sardine stock as reported by Merta (1992). Thus, the size composition of oil sardine caught in the fishing areas needs to be known as early as possible so that the sustainability of fishery can be maintained.

Besides based on the length of fish caught, potential fishing areas are also determined by the abundance of fish. On the other hand, the abundance and presence of fish in water were influenced by oceanographic parameters (Simbolon 2009; Thiaw et al 2017), such as water temperature and water salinity (González Castro et al 2009; Bruno et al 2013). This is because fish (including oil sardine) will select habitat with favorable oceanographic conditions in accordance with the desired biological characteristics. Information on oceanographic profile is relatively easy to obtain these days along with the development of remote sensing technologies.

It has been reported that sea surface temperature (SST) and chlorophyll-*a* concentration played an important role in determining the distribution of oil sardine caught in the Bali Strait (Ridha et al 2013). This indicates that the SST and chlorophyll-*a* can affect the dynamics of fishing areas. The profiles of SST and chlorophyll-*a* which are suitable for the biological characteristics of oil sardine can positively influence the formation process of the fishing grounds. However, Simbolon & Limbong (2012) insist that the SST and chlorophyll-*a* may not directly affect the formation process of fishing grounds at various times and locations. Therefore, an analysis of the SST profile and chlorophyll-*a* in relation to the oil sardine catch needs to be done.

The objectives of this study are: (1) to determine the composition of the number and size of oil sardine, (2) to determine the distribution of chlorophyll-*a* and sea surface temperature in the Muncar waters, Banyuwangi, and (3) to evaluate the condition of fishing ground of oil sardine.

Material and Method

Time and location. The collection of oil sardine catch data was conducted from February to March 2015 in the Muncar water and Bali Strait (Figure 1), where fisherman based in Muncar fishing port catch oil sardine. Data of sea surface temperature (SST) and chlorophyll-*a* were downloaded from the internet (http://oceancolor.gsfc.nasa.gov) in March 2015.

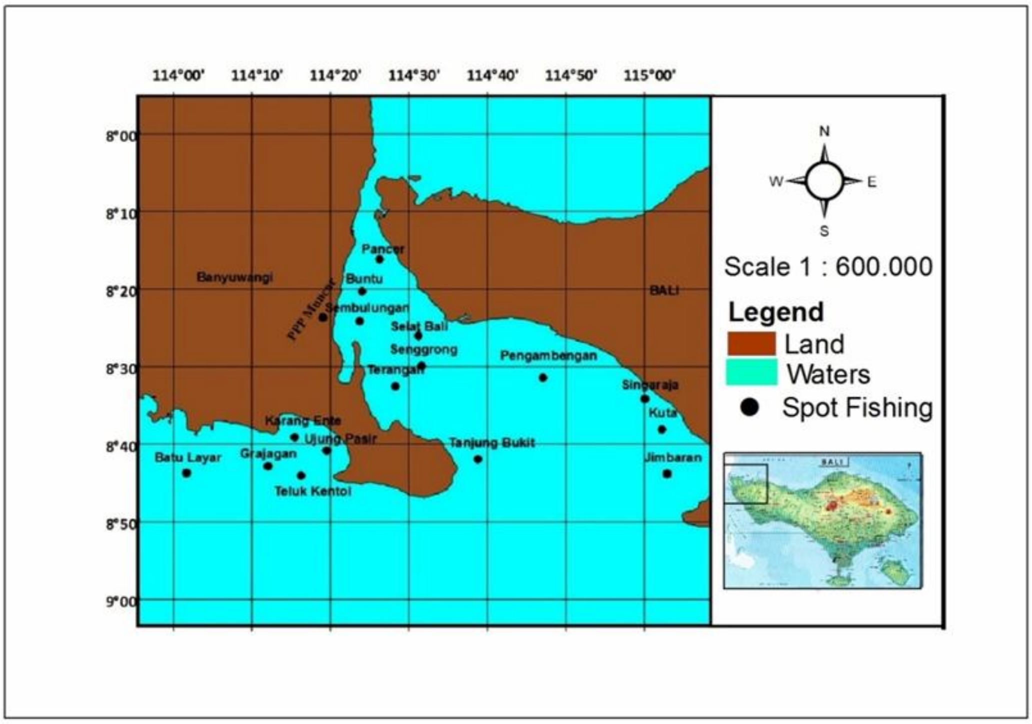

Figure 1. Distribution of oil sardine fishing ground in Muncar water and the Bali Strait.

Data collection. The present study applied a survey method, by observing 120 units of purse seiners catching oil sardine as samples. Data collected from fishing activities included the time and location or position of fishing, the number and size of fish caught.

Oil sardine catches were recorded at each fishing location. Fish samples were randomly taken at each fishing position, and then their total body length was measured.

Data of chlorophyll-*a* and SST in the study sites were obtained by processing images of SST and chlorophyll-*a* detected by satellite Terra/Aqua (MODIS). These images were available on the Internet (http://oceancolor.gsfc.nasa.gov). The selected images consisted of daily SST data and level 3 chlorophyll-*a* at the same time and location, in accordance with the fishing operations, namely at position 08,1667º-09,00º S and 114,00º-115,1667º E.

Data analysis

Catch composition. The catch was analyzed to determine the temporal and spatial fishing productivity represented by catch per fishing effort (CPFE). CPFE was calculated by the following formula:

$$\mathrm{CPFE} = \frac{\mathrm{C}}{\mathrm{f}}$$

where: C: catch (kg);
f: fishing day (trip).

Fish size data were categorized into four groups according to category suggested by Wijaya & Koeshendrajana (2009), namely: 1) "Sempenit" with length less than 11 cm; 2) "Protolan" with length of 11-15 cm; 3) "Lemuru" with length of 15-18 cm; and 4) "Lemuru kucing" with length larger than 18 cm. The percentage of each size group was calculated by formula:

$$Pi = \frac{ni}{N} x100\%$$

where: P: the percentage of size group i (%);
ni: number of fish of size group i (i = 1, ..., 4);
N: total number of fish sampled.

All data were presented as the average ± standard deviation of replicate measurements (n = 3). Significance of results was tested by an analysis of variance (ANOVA) and Duncan's Multiple-Range Test. Significance of differences was defined at $p < 0.05$.

Sea surface temperatute and chlorophyll-a distribution. Distribution of SST and chlorophyll-*a* gained from TerraAqua MODIS satellite were processed by software seaDAS 6.4 level 3 to obtain data in the form ascii. Ascii data were then processed by using Excel and are presented in graphical form. The use of level 3 was because the image data at that level has been processed and corrected radiometrically and geometrically.

Sea surface temperatures data were obtained by using algorithm of Miami Pathfinder SST (MPFSST) (Minnett et al 2002) with the formula as follows:

$$modis_{sst} = c_1 + c_2 * T_{31} + c_3 * T_{3132} + c_4 * (\sec(\theta) - 1) * T_{3132})$$

where: T31: is the brightness temperature (BT) at 31 band (the AVHRR channel 4);
T3132: is the difference between BT at 31 band and 32 band (in AVVHRR channel 4 and 5);
c1, c2, c3, c4: is the coefficient of 31 band and 32 band;
θ is the zenith angle of the satellite.

The distribution of chlorophyll-*a* was obtained by using algorithms formulation OC3M (ocean chlorophyll three-band algorithms for MODIS):

$$Chlor\_a = 10^{(a_0 + a_1 xR + a_2 xR2 + a_3 xR3 + a_4 xR4)}$$

where: a_0 = 0.2830, a_1 = -2.753, a_2 = 1.457, a_3 = 0.659 and a_4 = -1.403.

$$R = \log 10\left(\frac{R_{rs}403\rangle R_{rs}488}{R_{rs}551}\right)$$

where: R_{rs} is a remote sensing reflectance.

Variability or diversity of data is one of the techniques that are used to describe the data homogeneity of SST and chlorophyll-*a*. Variability or diversity of data can be calculated using the following formula (Sugiyono 2007):

$$s^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}$$

$$s = \sqrt{s^2}$$

$$Kv = \frac{s}{x}.100\%$$

where: s^2: variance of sample;
s: standard deviation;
xi: data *i*;
x: average;
Kv: coefficient of variation.

Relationship between catches and SST, and chlorophyll-a. A descriptive analysis by overlaying the SST data with CPFE and the chlorophyll-*a* data with CPFE was performed in order to determine the relationship between chlorophyll-*a* with catch, and between sea surface temperature with the catch. The overlay results were then presented in the form of thematic maps.

Evaluation of the fishing grounds. The indicators used in evaluating the fishing grounds include the CPFE, the average body length of fish caught, the concentration of chlorophyll-*a*, and SST. These indicators were weighted or scored.

Assessment of catch productivity (CPFE) was based on comparison of average CPFE to the CPFE during the study. If the value of CPFE at a fishing ground was larger than the average CPFE, then it was categorized as potential fishing ground and given a weighting or scoring of 1. Conversely, if CPFE was less than or equal to average CPFE, then these waters were not categorized as potential fishing ground and given a weighting of 0 (Table 1).

Table 1

Assessment of fishing ground through CPFE indicators

CPFE category	*Criteria*	*Fishing ground category*
High	CPFE > Average CPFE	Potential
Low	CPFE ≤ Average CPFE	Not potential

Source: Ismajaya (2007).

Assessment of oil sardine length sizes refers to the size of the adult oil sardine category. Wujdi et al (2013) stated that oil sardine is categorized as adult when they are mature gonads, with the length size of 17.8 cm. Furthermore, Simbolon & Limbong (2013) stated that the waters which were dominated by adult fish (worth catching) were categorized as a potential fishing ground, and conversely, waters in which were dominated by not adult fish were categorized as not potential fishing grounds. Therefore, if the size of oil sardine caught in a fishing ground ≥ 17.8 cm, then the fish are categorized worth catching and waters are categorized as potential fishing grounds, so given a weighting of 1. On the contrary, if the size of oil sardine < 17.8 cm then the fish enter the category is not worth catching and the waters are classified as not potential fishing grounds, so given a weighting of 0 (Table 2).

Table 2

Assessment of fishing ground through indicators of fish size

Length category	*Criteria*	*Fishing ground category*
Large	length ≥ length at first maturity (LM)	Potential
Small	length < LM	Not potential

Source: Simbolon & Girsang (2009).

Assessment of chlorophyll-*a* concentration indicator referred to Widodo (1999), which stated that the waters having the chlorophyll-*a* concentration of 0.2 mg m^{-3} are classified as high category. Waters with the chlorophyll-*a* concentration greater than 0.2 mg^{-3}, are categorized as a potential fishing areas and given weighting of 1. Conversely, waters with the chlorophyll-*a* of less than or equal to 0.2 mg m^{-3}, then the areas are not considered as potential fishing ground and given weighting of 0 (Table 3).

Table 3

Assessment of fishing ground through indicators of chlorophyll-*a*

Chlorophyll-a category	*Criteria*	*Fishing ground category*
Many	chlorophyll-*a* > 0.2 mg m^{-3}	Potential
Few	chlorophyll-*a* ≤ 0.2 mg m^{-3}	Not potential

Source: Widodo (1999).

Assessment of indicators of SST referred to Setyohadi (2011) which stated that optimal SST for oil sardine was 27-30°C. If the SST of fishing grounds is optimum, then the fishing ground is classified as a potential category (Basuma 2009), and given weighting of 1. On the contrary, if the SST of fishing ground is not optimum for oil sardine fishing, then the fishing ground is categorized as not potential (Basuma 2009), and given weighting of 0.

The values of the four indicators for oil sardine fishing grounds were then accumulated. Fishing ground said to be potential if all four criteria are met or score equals to 4. Fishing areas are categorized as just potential if three of the four criteria are met, or a score of 3. The fishing area is said to be not potential if less than 3 criteria are met.

Results and Discussion

Oil sardine production landed in PPP Muncar. The total of oil sardine catches landed in Muncar fishing port at the time of the study was 558.5 tonnes. The catch was taken from Muncar water and Bali Strait (Figure 1). Distribution of the production and productivity (CPFE) of oil sardine in various regions of fishing grounds is shown in Figure 2. The highest production was landed in Sembulungan (39.60 tons) with a productivity of 7.92 tonnes $trip^{-1}$. The lowest production was landed in Kuta (4.44 tonnes) with a productivity of 0.89 tonnes $trip^{-1}$. It shows a pattern that oil sardine high production in a fishing ground was followed by a high productivity. Conversely, a low production of oil sardine was followed by a low productivity.

Oil sardine fishing operations in the Bali Strait were not only done by fishermen from Muncar, Banyuwangi but also carried out by fishermen from Bali. Utilization of oil sardine in Bali Strait sometimes led to conflict between the two groups of fishermen because each claimed that the waters were their fishing area. Therefore, all relevant stakeholders needed to develop clearer fishing zones as a reference in sharing the use of fishing grounds in the Strait.

Average productivity or CPFE during the study was 4.43 tons per trip. Based on the fishing productivity, fishing areas in Pengambengan, Bali Strait, Sembulungan, Senggrong, Singaraja, Teluk Kentol, Terangan, and Ujung Pasir could be categorized as potential fishing grounds. On the other hand, unproductive (less potential) fishing grounds were found in Batu Layar, Buntu, Grajagan, Jimbaran, Karang Ente, Kuta, Pancer, and Teluk Bukit.

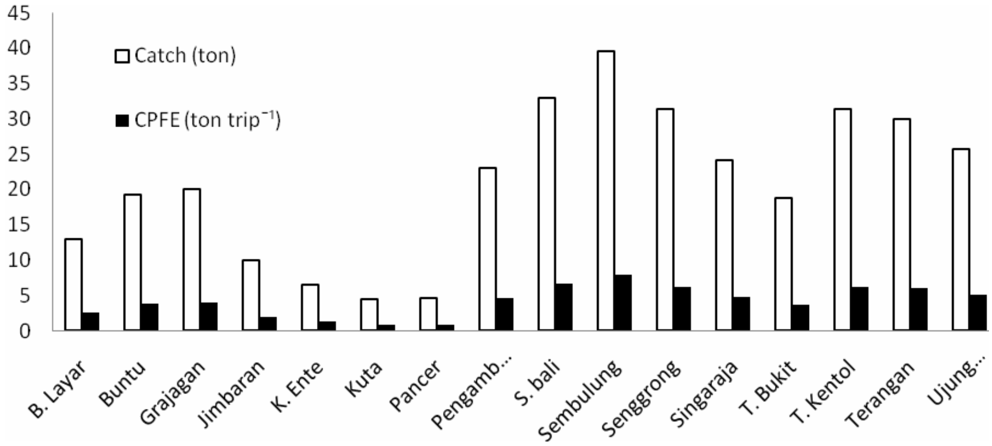

Figure 2. Distribution of production and productivity (CPFE) of oil sardine in various regions of fishing grounds in the study area, February-March 2015.

Distribution of oil sardine fishing productivity tended to fluctuate during the study (Figure 3). The productivity has declined below average CPFE in March 8, 9, 14, 15, 16, 17, 18, 19, 20, and 23. The fluctuation of CPFE may be due to technical factors such as lack of fishermen knowledge and experience in determining potential fishing grounds. Fishermen did not have the same information related to the existence oil sardine in particular fishing areas. In addition, severe weather also affected the productivity because it will affect fishing operations. Furthermore, according to Merta (1992), oil sardine catches in the Strait of Bali were affected by oceanographic conditions such as water temperature.

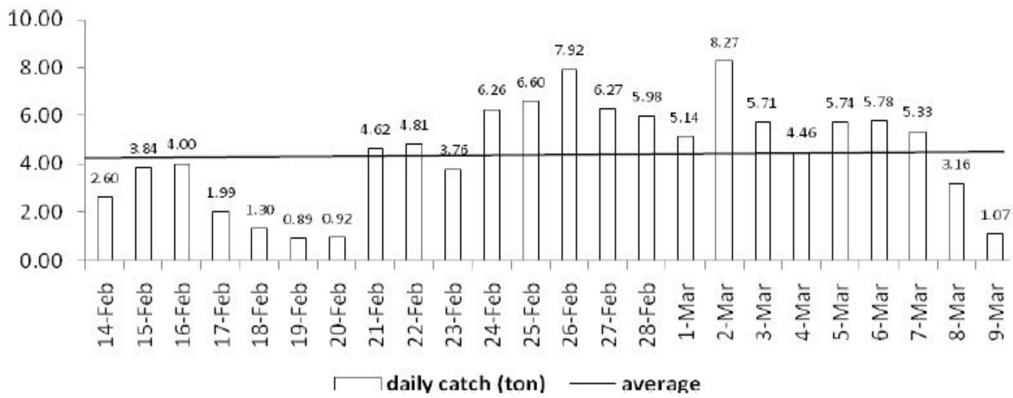

Figure 3. Temporal distribution of oil sardine production taken from the Bali Satrait in February-March 2015.

Body length of oil sardine. The size of the oil sardine caught during the study very diverse ranging from small to large sizes (Figure 4). Based on the length, Wijaya & Koeshendrajana (2009) classifies oil sardine into four, namely "sempenit" (< 11 cm), "protolan" (11-15 cm), "lemuru" (15-18 cm), and "lemuru kucing" (> 18 cm). The dominant group caught in this study (February-March 2015) was "protolan", i.e 46% of the total 1400 individuals. The second dominant group was "sempenit" (24%), followed by "lemuru" (21%) and "lemuru kucing" (9%). If individuals of "lemuru kucing" group (size larger than 18 cm) were assumed as a legal-size and the other three groups regarded as illegal size, then only 9% of oil sardine caught were decent to be caught. It meant that lemuru fishery in Muncar water and Bali Strait caught mostly not feasible size of oil sardine (91%).

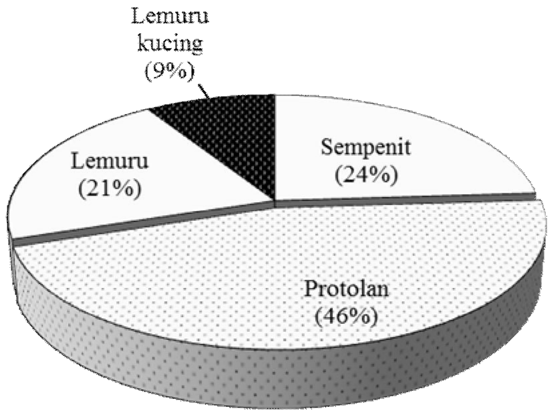

Figure 4. The composition of the total catch by group size oil sardine landed in Muncar fishing port, periods of February-March 2015.

The dominance of "protolan" group in this study, according to the findings of Wijaya & Koeshendrajana (2009) was due to "protolan" season in the Strait of Bali found throughout the year (Table 4). In Table 4 shows that the fishing season of "sempenit", "lemuru", and "lemuru kucing" did not occur in February-March but the three groups of fish were still caught even only in small proportions. This indicates that the group of "sempenit", "lemuru", and "lemuru kucing" remained found even though not during the fishing season.

Table 4

The peak season of oil sardine based on body length category in the Bali Strait and surrounding waters

Category (length of oil sardine)	*The peak season on month*											
	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Sempenit (< 11 cm)								✓	✓	✓	✓	✓
Protolan (11-15 cm)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lemuru (15-18 cm)					✓	✓	✓	✓	✓	✓	✓	✓
Lemuru kucing (>18 cm)										✓	✓	✓

Source: Wijaya & Koeshendrajana (2009).

The catch dominated by "protolan" group during February-March 2015 showed that Muncar waters and the Strait of Bali were not the potential fishing grounds of oil sardine during those periods. Catches dominated "protolan" were strongly associated with the season of the group. In addition, the fishing gears (i.e. purse seines) used were less selective to the fish size. Simbolon (2008) stated that rate of recruitment will be disrupted if the fish catches are dominated by juvenile fish (in this case, protolan), since it will reduce number of spawners. Furthermore, according to Simbolon & Girsang (2009), low recruitment rate will degrade fishing grounds due to the reduction in fish stocks, and in the long term it can even threaten the sustainability of fishery.

Chlorophyll-a in the Bali Strait and its relationship with oil sardine catch. Concentration of chlorophyll-*a* in the Bali Strait fluctuated every day (Figure 5). The concentration of chlorophyll-*a* was found ranging from 0.126 to 0.259 mg m^{-3}, with average chlorophyll-*a* concentration of 0.188 mg m^{-3}. Content of chlorophyll-*a* varied daily, which tended to be high at the end of February and on March 2 and 9, 2015. The chlorophyll-*a* images were not continuous available because at particular day, satellite imagery Aqua/Modis was blocked by clouds so it was not detected any chlorophyll-*a* in the Bali Strait. The content of chlorophyll-*a* on February 26, 2015 had the greatest concentration (0.259 mg m^{-3}) and the lowest concentration of 0.126 mg m^{-3} was occurred on February 15 and March 1, 2015.

Variance obtained for the distribution data of chlorophyll-*a* in February 2015 was 0.002, with the coefficient of variation of chlorophyll-*a* was 25.189. The coefficient of variation (Kv) represents ratio of standard deviation to the mean. The smaller the value of Kv then the data is more homogeneous, and Kv = 0 indicates each data element exactly the same (Siregar 2004). Hence, the daily distribution of chlorophyll-*a* in the study areas was relatively heterogeneous or dispersed.

Wudianto's study in 2001 showed that the abundance of plankton, evaluated based on content of chlorophyll-*a*, in the waters around the Strait of Bali fluctuated depending on the change of seasons. Variations in the concentration of chlorophyll-*a* had direct or indirect influence on the production of oil sardine in the Bali Strait. However, as been reported for other species such as *E. fimbriate*, the effect of chlorophyll-a is less than that of SST (Diankha et al 2013).

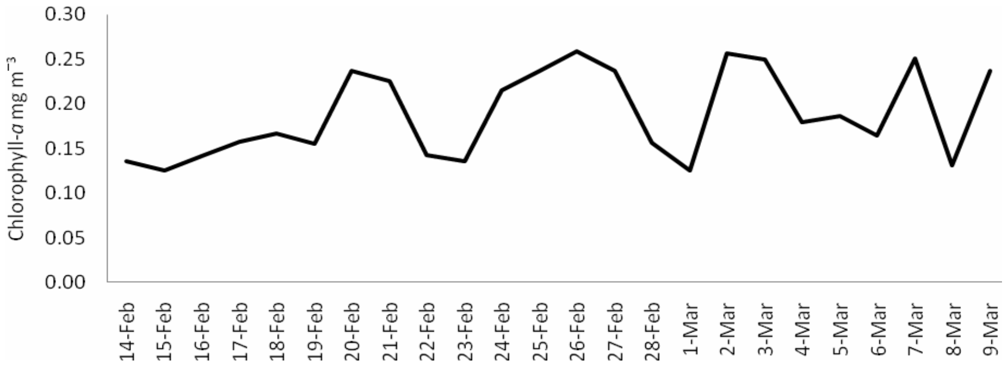

Figure 5. Average daily chlorophyll-*a* concentration in the Strait of Bali.

The relationship between chlorophyll-*a* and production of oil sardine landed in TPI Muncar for one month (February-March 2015) is presented in Figure 6. Overall trends showed that chlorophyll-*a* concentration fluctuated in the same rhythm with production of oil sardine. However, their peaks did not occur simultaneously.

The presence of chlorophyll-*a* influences the amount of the catch of fishermen in Muncar (Figure 6). As the concentration of chlorophyll-*a* decreased on February 14, 2015 until February 24, 2015, the landed catch of oil sardine in Muncar fishing port also showed a decrease. On February 25, 2015 until March 9, 2015 the concentration of chlorophyll-*a* increased, and the volume of oil sardine catches also increased. However, an increase in chlorophyll-*a* on March 8, 2015 was not followed by an increase in the number of catches. This suggests that an increase in the amount of plankton in the waters does not always have a direct impact on oil sardine catches. This was due to the time lag in the food chain. In addition, environmental factors also greatly influenced the spread of the fish. Oil sardine generally prefers waters with weak currents (Simbolon & Girsang 2009).

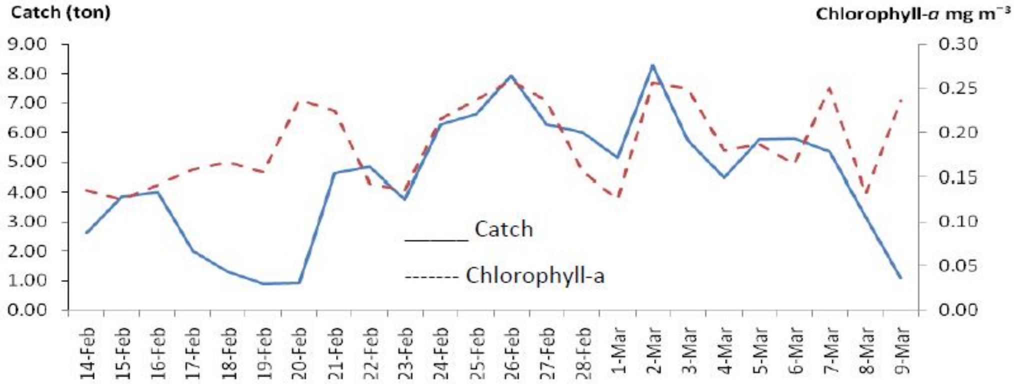

Figure 6. Relationship between temporal chlorophyll-*a* concentration with oil sardine production in Muncar fishing port.

The relationship between the increase in concentrations of chlorophyll-*a* and oil sardine production in the waters of the Strait of Bali and Muncar was also related to the abundance of plankton as a food source of oil sardine. During the west season, the strait of Bali experienced upwelling (Syihab et al 2014), as consequence, there was nutrients transported to the sea surface. These nutrients supported the growth of plankton. Since oil sardine is a plankton feeder, abundant plankton would lead to increase in oil sardine abundance in the waters.

In general, the spatial distribution of chlorophyll-*a* spatially was followed by high fishing productivity of oil sardine (Figure 7). Nevertheless, from the overall of 15 oil sardine fishing grounds, only six fishing grounds show high fishing productivity which was related to chlorophyll-*a* concentrations, namely Sembulungan, Bali Strait, Senggrong, Pengambengan, Singaraja, and Ujung Pasir.

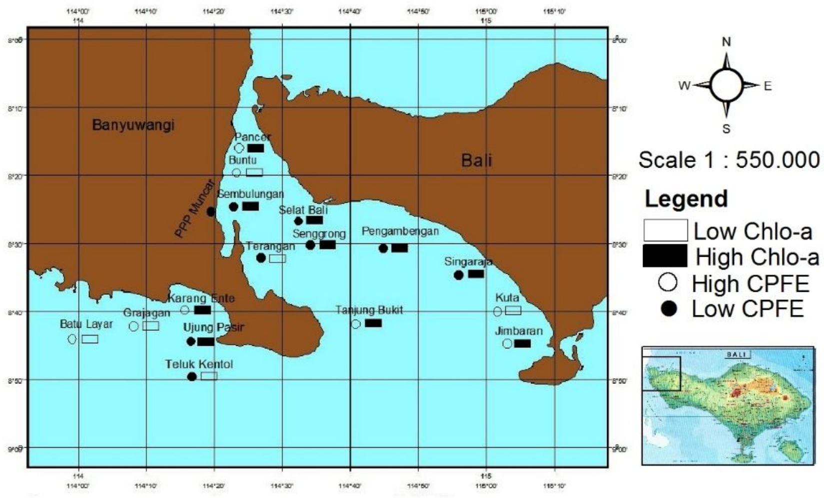

Figure 7. Spatial distribution of chlorophyll-*a* and oil sardine catches in PPP Muncar.

Relationship between sea surface temperature distribution and oil sardine catch in the Bali Strait. Most of oil sardine landed (98%) in Muncar fishing port were caught by purse seine operating at night. SST at night in the waters of the Strait of Bali periods of February-March 2015 ranged between 27 and 30°C, with average of 29.16°C (Figure 8). This was consistent with Ridha et al (2013) which reported the temperature of the waters of the Strait of Bali in the west season ranged between 27-30°C. Results of this study are also in line with the opinion of Nontji (2005) that the sea water temperature in Indonesia generally ranged between 28-31°C.

The lowest temperature occurred on February 14 and 15, namely 27.72°C. Very drastic increased in temperature occurred on February 16, and reached the highest temperature on 18 February, i.e. 29.57°C. This might be due to the high rainfall and thick cloud cover on February 14 to 15. Because low intensity of sun radiation reached sea surface, the SST during the periods was also very low (Simbolon 2009).

Variance for daily data of temperature distribution in February 2015 was 0.028, with coefficient of variation (Kv) of 0.018. The coefficient of variation represents ratio of standard deviation to mean. Therefore, the smaller value of Kv, the data is more homogeneous. Very small Kv value of temperature obtained from the present study indicated that the data were relatively homogeneous.

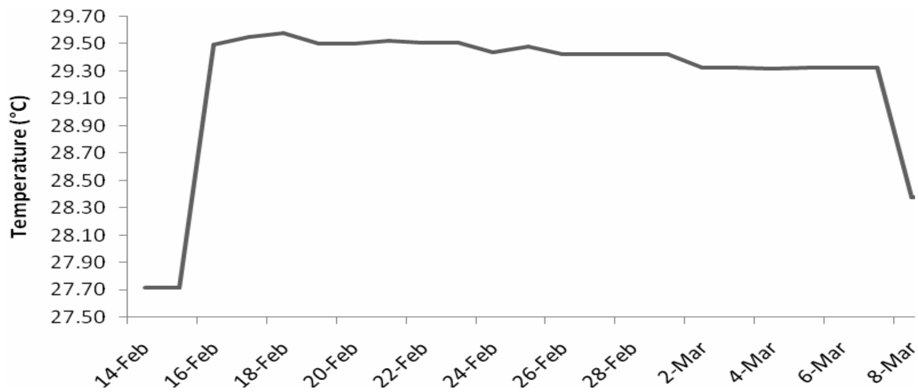

Figure 8. Distribution of sea surface temperature (SST) in the waters of the Strait of Bali in February-March 2015.

SST distribution and oil sardine production landed in Muncar fishing port during February 2015 is presented in Figure 9. From February 17 to 20, daily catches declined due to periods of the full moon. During the periods of full moon only very few fishermen went fishing. Oil sardine were caught when the sea temperature ranged from 27.57 to 29.57ºC, with average temperature of 29.04ºC. The highest catches occurred on March 2, 2015 (41.35 tons), which was coincided with SST of 29.33ºC. This finding were consistent with Setyohadi (2011) in which oil sardine were most abundant in waters that had temperature ranging from 27.96 to 30.58ºC. Also, Wudianto (2001) found that oil sardine tended to be abundant at the optimum temperature between 28.20-28.40ºC. On the contrary, Indrawati (2000) stated that oil sardine preferred waters with low temperature (23-26ºC). This is because water temperature influences the metabolism of fish (Lacoursière-Roussel et al 2016) and abruptly changes in water temperature may result in fish death (Blaber 2000). The lowest catch, on February 20, 2015, was concurrent with the SST of 29.5ºC. This might be due to the influence of moon phase which was close to full moon period.

Simbolon (2008) stated that the effect of water temperature on fish distribution was highly dependent on temperature variability itself. If the distribution of the water temperature is in the value range that can be tolerated by fish, then it will have no effect on fish. This condition was probably to occur in this study, where the SST did not significantly affect oil sardine catches.

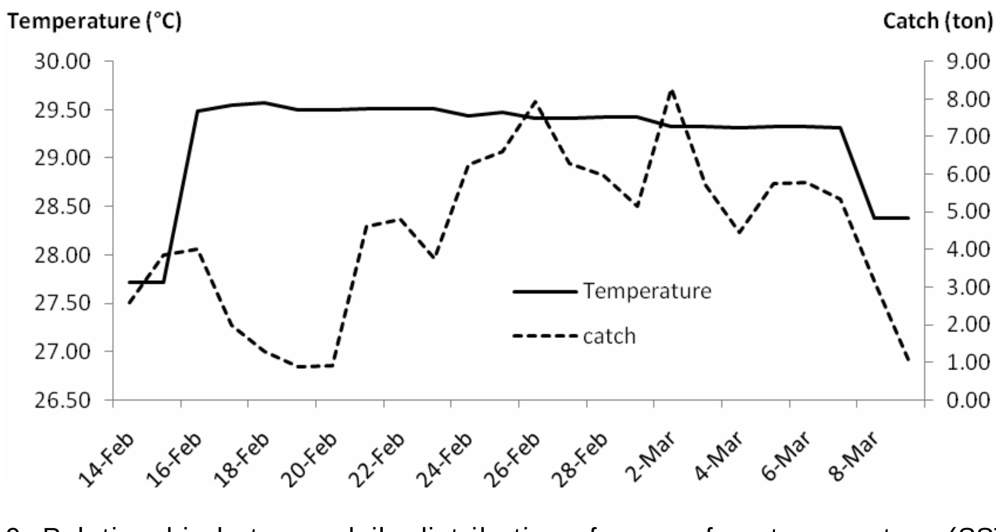

Figure 9. Relationship between daily distribution of sea surface temperature (SST) and oil sardine catches in February-March 2015.

Distribution of oil sardine fishing grounds based on the SST profile and CPFE in Muncar waters and the Bali Strait during the study are presented in Figure 10. All the fishing grounds of oil sardine had optimum SST for oil sardine. Statistical test showed that the SST did not affect the spatial distribution of catches since the SST at all fishing grounds was optimum for fishing of oil sardine.

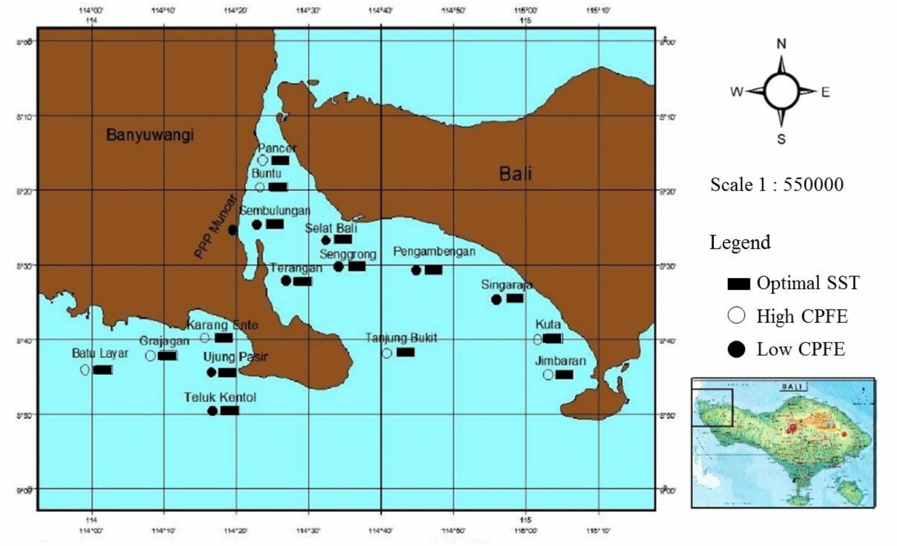

Figure 10. Spatial distribution of sea surface temperature and oil sardine catches in Muncar.

Forecasting of oil sardine fishing grounds. Fishing grounds of oil sardine in Muncar water during periods of February-March 2015 were evaluated based on four indicators: CPFE, the body length of the fish caught, chlorophyll-*a*, and sea surface temperature. Most oil sardine fishing grounds in Muncar water were categorized as not potential (Table 5). Fishing ground said to be potential if all four indicators are met or score 4. Fishing ground is being categorized as moderate potential if three out of four indicators are met or a score of 3. The fishing area is said to be less potential if the indicator is met only two indicators, or less than 2 indicators.

Based on CPFE indicator, fishing areas included in the category of high CPFE is Pengambengan, Bali Strait, Sembulungan, Senggrong, Singaraja, Gulf Kentol, Ujung Pasir. Fishing areas where the body lengths of oil sardine caught were large, were Pengambengan, Bali Strait, Sembulungan, and Terangan. Fishing areas including in category with high concentration of chlorophyll-*a* were Jimbaran, Karang Ente, Pancer, Pengambengan, Bali Strait, Sembulungan, Senggrong, Singaraja, Tanjung Bukit, and Ujung Pasir. Lastly, fishing grounds having optimum temperature for oil sardine were found in all fishing areas of the Strait of Bali.

Fishing grounds categorized as potential were found in three locations, namely Pengambengan, Bali Strait, and Sembulungan. Fishing grounds categorized as moderate were found in four locations, i.e. Senggrong, Singaraja, Blatant, and Ujung Pasir. The remaining nine fishing grounds were classified as not potential, namely Batu Layar, Buntu, Grajagan, Jimbaran, Karang Ente, Kuta, Pancer, Tanjung Bukit, and Teluk Kentol (Figure 11).

Fishing operations conducted by Muncar fishermen were most in the eastern region of Muncar (around the Strait of Bali). Only few of the fishermen fished in the southern and northern waters Muncar. However, it cannot be used as indicators level of fishing intensity among these regions. More data is needed to confirm that fishing activities were more intense in the eastern region than in the southern and northern regions.

The use of fishing gear with small mesh sizes resulted in substantial proportion of immature fish gonads caught. This could threaten the sustainability of the oil sardine stock. According to Wujdi et al (2013), prediction of oil sardine spawning season starts to occur in September to October or November, and located in the southern part of Bali Strait. We recommend that local authorities and relevant stakeholders are fully aware of the high fishing intensity and develop policy to reduce fishing efforts and to avoid catching illegal size of oil sardine in the areas. This will warrant the oil sardine sustainability in Muncar water and the Bali Strait.

Table 5

Assessment indicators of fishing grounds

Name of fishing ground	*Indicator of fishing ground*								*Category of FG*	
	CPFE		*Length of Bali sardinella*		*Chlorophyll-a*		*SST*			
	N	*B*	*L*	*B*	*K*	*B*	*T*	*B*	*Total*	*Category*
Batu Layar	2596	0	17.2	0	0.139	0	27.96	1	1	TP
Buntu	3838	0	16.6	0	0.174	0	27.96	1	1	TP
Grajagan	4004	0	17.1	0	0.163	0	29.49	1	1	TP
Jimbaran	1992	0	12.8	0	0.239	1	29.55	1	2	TP
Karang Ente	1300	0	15.6	0	0.212	1	29.58	1	2	TP
Kuta	888	0	17.0	0	0.147	0	29.50	1	1	TP
Pancer	920	0	13.3	0	0.247	1	29.50	1	2	TP
Pengambengan	4620	1	18.3	1	0.210	1	29.52	1	4	P
Selat bali	6600	1	17.2	1	0.348	1	29.51	1	4	P
Sembulungan	7920	1	17.1	1	0.328	1	29.51	1	4	P
Senggrong	6262	1	13.6	0	0.259	1	29.44	1	3	PS
Singaraja	4814	1	14.1	0	0.299	1	29.48	1	3	PS
Tanjung Bukit	3760	0	11.0	0	0.205	1	29.42	1	2	TP
Teluk Kentol	6268	1	12.0	0	0.155	0	29.42	1	2	TP
Terangan	5980	1	18.4	1	0.116	0	29.42	1	3	PS
Ujung Pasir	5140	1	14.7	0	0.231	1	29.42	1	3	PS

Description: N - value of CPFE; B - weight; L - body length of oil sardine; K - the concentration of chlorophyll-*a*; T - sea surface temperature; P - potential fishing ground; PS - moderate potential fishing ground; TP - less potential fishing ground.

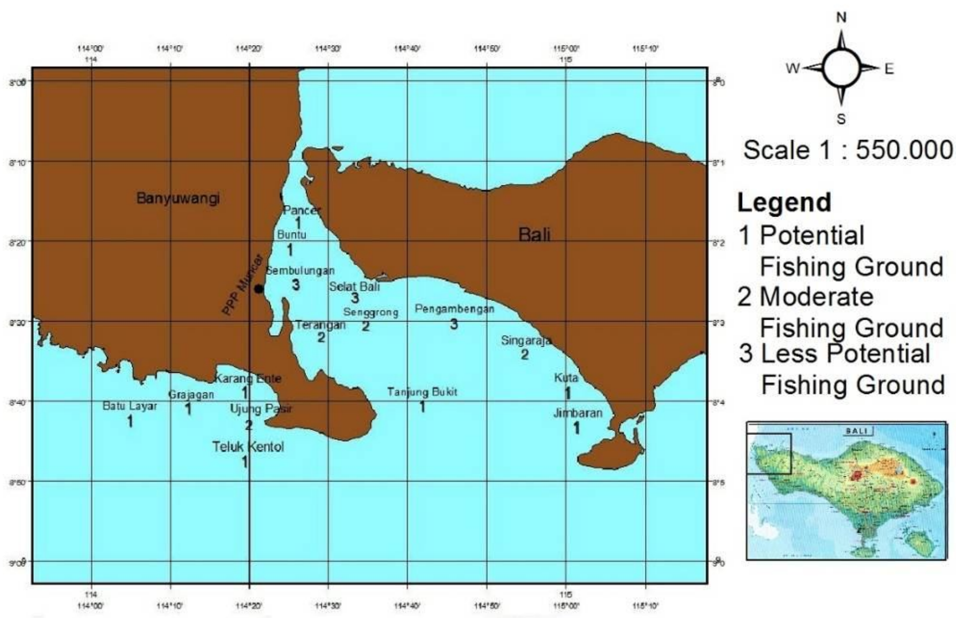

Figure 11. Map of the distribution of oil sardine fishing grounds in the Bali Strait.

Conclusions. Number of oil sardine production caught in Muncar water and the Strait of Bali was 558.5 tons, with the CPFE of 4180 kgs per trip. The catches were dominated by "protolan" group (646 individuals or 46.14%), followed by lemuru group (289 individuals or 20.64%), “sempenit” group (343 individuals or 24.50%), and lemuru "kucing" group (122 or 8.71%). The percentage of legal sizes of lemuru caught was only 9%.

The concentration of chlorophyll-*a* in the Muncar waters and the Bali Strait in February 2015 affected the composition of oil sardine catches landed in Muncar fishing port, while the SST did not have influence on the number of oil sardine caught.

Potential fishing grounds for oil sardine in Muncar waters and the Bali Strait during periods of February-March 2015 were found only in the waters of Sembulungan, Pengambengan, and the Strait of Bali.

Further research related to the oil sardine catches in entire fishing season needs to be done so that the dynamics of the oil sardine fishing grounds in different seasons can be understood.

The number of fishing gears and the purse seine mesh sizes operating in the Muncar water and the Strait of Bali need to be properly regulated in order to achieve environmentally friendly and sustainable fisheries.

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