THE FLUCTUATION OF CHLOROPHYLL-A CONCENTRATION DERIVED FROM SATELLITE IMAGERY AND CATCH OF OILY SARDINE *(SARDINELLA LEMURU0)*IN BALI STRAIT

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Abstract

The investigation is aimed to know the relationship between chlorophyll-a (chl-a) concentration and the abundance of Oily sardine *(Sardinella lemuru),* in Bali Strait. A time series of monthly mean chl-a data derived from Ocean Color Thermal Scanner (OCTS) sensor and Sea-viewing Wide Field-of View Sensor (SeaWiFS) during 1997-1999 are used in this study. Monthly *Sardinella lemuru* catch during 1997-1999 are obtained from fish landing data. The abundance of *Sardinella lemuru* is determined from acoustic data conducted in Bali Strait in September 1998 and May 1999. The result shows that the fluctuation of chlorophyll-a concentration in Bali Strait is influenced by monsoon and global climate change phenomena such as Dipole Mode (DM) event. During southeast Monsoon the upwelling process occurred around Bali Strait, so that the chl-a concentration is increased and during DM event occurred positive anomaly of chl-a concentration. The catch of *Sardinella lemuru* in Bali Strait is fluctuated during 1997-1999. The correlation between chl-a concentration and lemuru catch is positive and significant with certain time lag.

Key words: Chlorophyll-a, Sardinella lemuru, Bali Strait, Satellite imagery.

I. Introduction

Oily sardine *(Sardinella lemuru),* called "lemuru" in Indonesia plays an important role in economics of fishermen around territorial water of Bali Strait, because 90 % of fishery product in Bali strait is lemuru. This fish is consumed directly beside the used as sardine's raw material for fish canning and bait for Iongline fishing. Fluctuation of lemuru production is very high and until now it is not yet known exactly what the causal is. Some researchers express the possibility of over fishing, but this is weak because production at the certain year increased sharply. The abundance of lemuru can be predicted by oceanographic factors, such as temperature and fertility of waters (Wudianto, 2001; Gaol, *et al.*, 2002).

Lemuru is plankton feeder, but the relationship between phytoplankton and lemuru in Bali Strait is not yet been known exactly, because plankton data obtained from direct measurement is very limited. Therefore, the ocean color images of satellite are expected to give information and contribution on the relationship between chl-a concentration and lemuru abundance. The study is aimed to investigate the fluctuation of chl-a concentration and the relationship with lemuru catch in Bali Strait.

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II. Methods

Monthly composite of mean chl-a concentration during 1997-1999 in Bali Strait are derived from OCTS and SeaWiFS satellite imagery using SeaDAS software. Sea surface temperature (SST) is derived from Pathfinder global data set. Monthly lemuru catch data were obtained from the data of fish landing at Muncar (Figure 1). The oceanographic data and the distribution of fish abundance are determined from acoustic instrument conducted in 1998/1999 by Wudianto (2001). Analysis on the relationship between chl-a concentration and lemuru abundance was done using the following formula (Chatfield, 1975):

$$r = \frac{\left[n\sum_{i=1}^{n} X_i Y_i - \left(\sum_{i=1}^{n} X_i\right)\left(\sum_{i=1}^{n} Y_i\right)\right]}{\sqrt{\left[n\sum_{n=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i\right)^2\right]\left[n\sum_{i=1}^{n} X_i^2 - \left(\sum_{n=1}^{n} \right.\right.}}$$

$$r = \frac{Cov_{XY}}{S_X . S_Y}$$

r = coefficient correlation
X_i = Chl-a concentration
Y_i = Lemuru catch
n = number of data
Cov_{XY} = covariance X and Y
S_X, S_Y = standard deviation

in. Result and Discussion

3.1 Seasonal and Interannual Variabily of Chl-a Concentration

The time series of monthly mean Chl-a concentration derived from SeaWiFS imagery in 1999 show that there are seasonal blooms in Bali Strait (Figure 2a). The Chl-a in 1999 starting to increase in May and reach the highest in September those are coherent with SST fluctuation (Figure 2b). The distribution of temperature in Bali Strait shows that the occurrence of upwelling process during Southeast Monsoon (Figure 3). The average of phytoplankton abundance (35.5 x 10^3 eel/m^3) during Southeast Monsoon is significantly higher than Northwest Monsoon (7.3 x 10^3 cel/m^3) (Wudianto, 2001).

The upwelling process occurred around south Java seawaters and reaches the top when the Southeast Monsoon wind is blowing in full, developing in July-September (Wyrtki, 1961, 1962; Purba *etal,* 1997). This process improves and enhances the fertility of waters since nutrient e.g., phosphate increases in Bali Strait, the highest during Southeast Monsoon (Wudianto, 2001).

Besides the change of monsoon, Recently, the Indian DM phenomenon also has an effect on oceanographic condition in Eastern

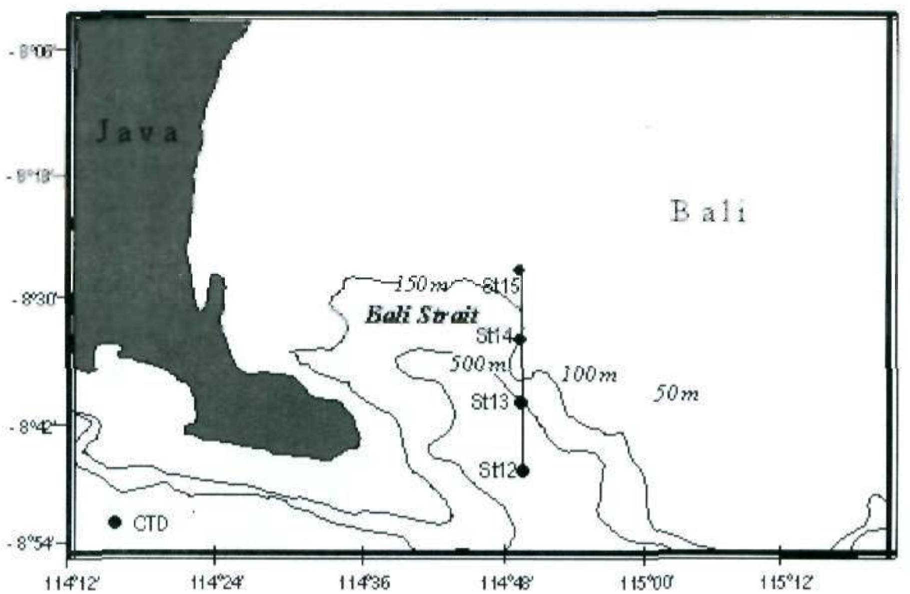

Figure 1. Location of study in Bali Strait

Indian Ocean including Bali Strait (Saji, *et al.*, 1999; Webster, *et al.*, 1999; Martugudde *etal*, 2000). During the DM event, the cool SST anomalies are associated with corresponding opposite anomalies in the zonal winds in the central equatorial Indian Ocean (Yamagata *et al*, 2002). Usually, the chl-a concentration reaches the highest in August-

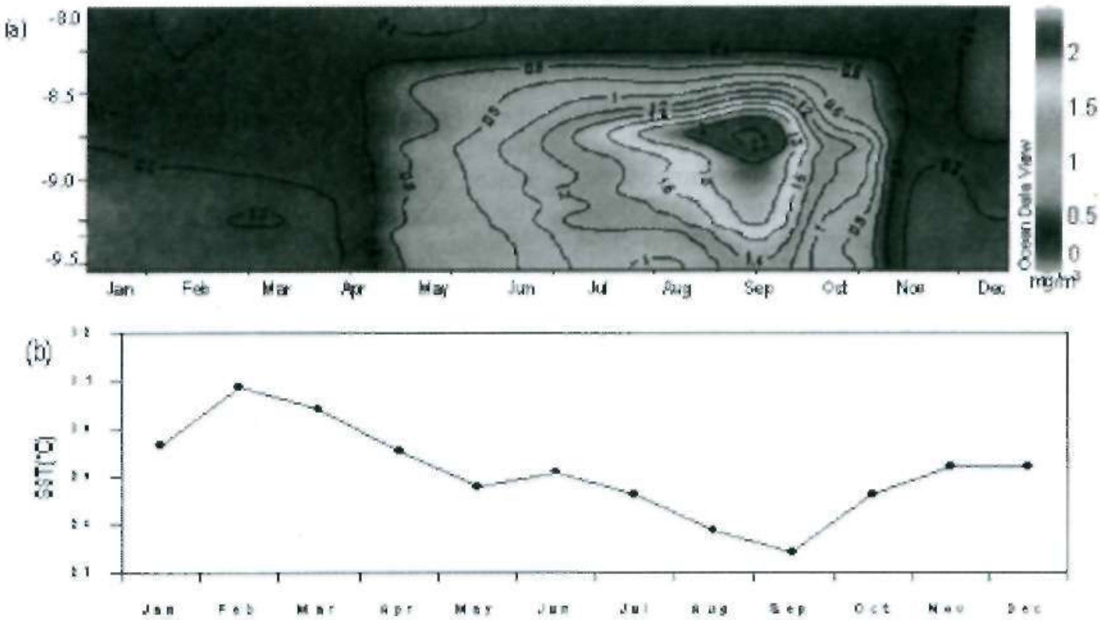

Figure 2. (a) Latitude versus time plot of Chl-a in Bali Strait for period of January – December 1999. (b) monthly mean SST in Bali Strait (1999).

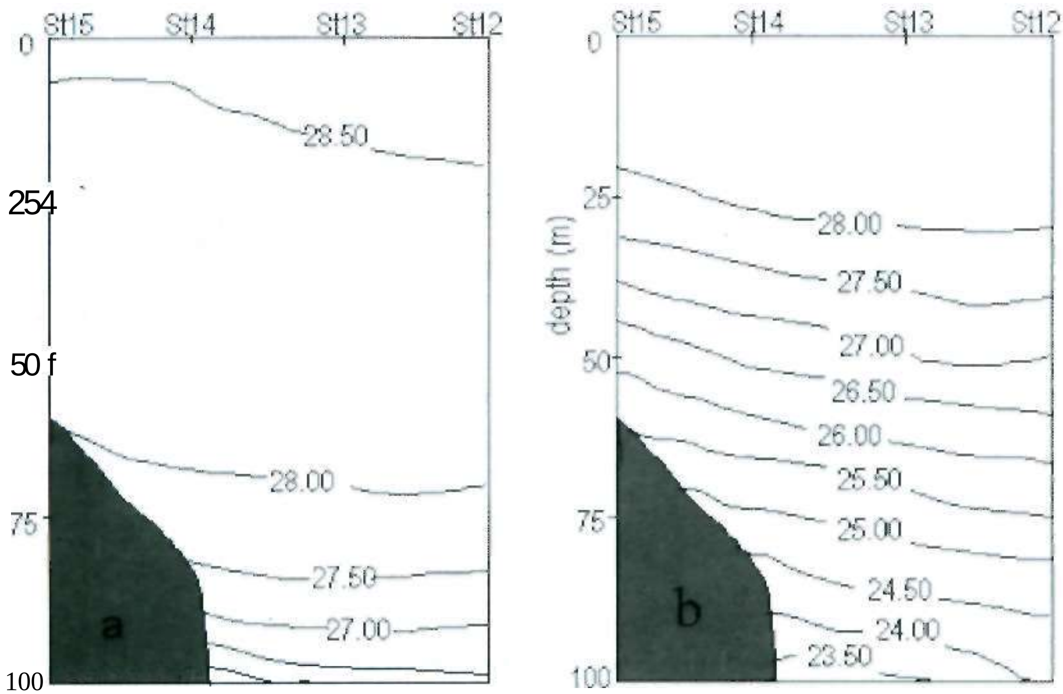

Figure 3 The distribution of temperature (a) during Northwest Monsoon and (b) during Southeast Monsoon in Bali Strait (Wudianto, 2001)

September, but in 1997 the chl-a concentration was the highest until October (Figure 4). The positive anomaly of chl-a in South Java waters was related to upwelling intense during DM event. The relationship between chl-a concentration and DM index around of Bali Strait is significantly positive (r = 0.67; p=0.01), (Gaol, 2003).

3.2. Fluctuation of Lemuru Catch

Lemuru naturally swims in a colony forming a big group (schooling). The spawning season of lemuru in Bali Strait is in around May - July, after reaching adult size (length > 15.5 cm). Fish larva of spawning moves to northern part of Bali Strait living in calm waters habitat until reaching the size of 7.5 - 10.5 cm in August - September. In October - December, the fish size of lemuru is about 11.5-12.5 cm; while in January - February: 13.5 - 14.5, and during March - July will bel5.5-18.5 cm (Wudianto, 2001).

The increase of chl-a is in accordance with lemuru spawning time, resulting in adequate food supply for the larva. The increase of chl-a concentration up to September provides food for the growth of lemuru. The growth of lemuru in Bali Strait has tended to follow the phytoplankton abundance. The coincident of lemuru spawning season and the increase in phytoplankton abundance is predicted as an indirect or direct food for fish juveniles. The phytoplankton abundance increase until the end of Southeast Monsoon is sustains the zooplankton abundance as a food for large fish. The relationship between phytoplankton abundance and fish density show that 52 % of fish density is effected by phytoplankton abundance in Bali Strait (Wudianto, 2001).

The acoustic survey at the end of Southeast Monsoon in September 1998, shows that the abundance of pelagic fish was higher than that of during May 1999 (Figure 5). The lemuru catch in September 1998 was also higher than that of in May 1999 (Figure 7).

The cross correlation analysis shows the positive correlation between lemuru catch and chl-a concentration, meaning that increase of chl-a caused the abundance increase of lemuru. The cross correlation between chl-a concentration and lemuru catch is significant on 4lh month (Figure 6), since there is a lag time for lemuru to grow.

Besides the change of monsoon season, the global climate change also has an effect on chl-a and lemuru abundance in Bali Strait. Usually, the abundance of lemuru increases from October until January, then in February gradually decrease, but in 1997-1998, from October 1997 until July 1998 the catch of lemuru was increasing (Figure 7). The increase of lemuru catch until 1998 was due to phytoplankton blooming in 1997 (Gaol *etai*, 2002). The positive anomaly of chl-a in 1997 related to upwelling intenses during Indian Ocean DM in 1997 (Saji *etai.*, 1999; Webster *et al.*, 1999), so that the abundance of chl-a until the end of 1997 sustained the stock of lemuru.

IV. Conclusion

The fluctuation of chl-a concentration in Bali Strait is the effect of monsoon and Indian Ocean DM. The chl-a correlates a significantly with the abundance of lemuru with

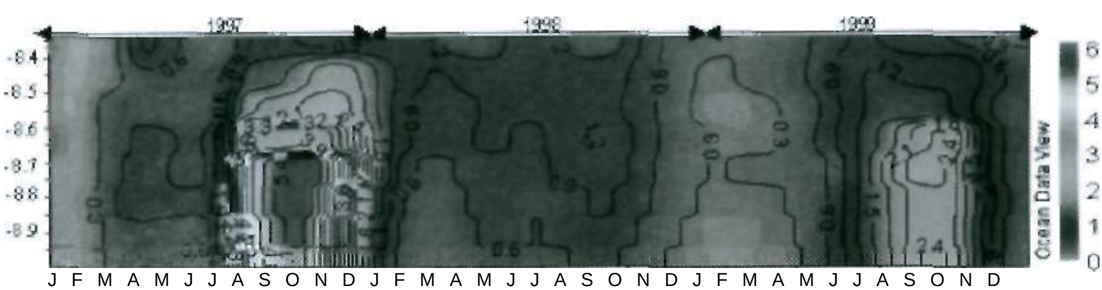

Figure 4. Latitude versus time plot of monthly mean of Chl-a in Bali Strait for period of January 1997 - December 1999.

the 4 month time lag. Therefore, the procurement of satellite image time series is very good to present information on when to fish lemuru and to conduct reliable fishery management in Bali Strait. Considering the difficulties to obtain marine environmental data in Indonesian waters (e.g., chl-a content, temperature) by using conventional method which is expensive and time consuming the usage of satellite image is a good choice for the optimal utilization fish resources and to guarantee the sustainable fishery conduct.

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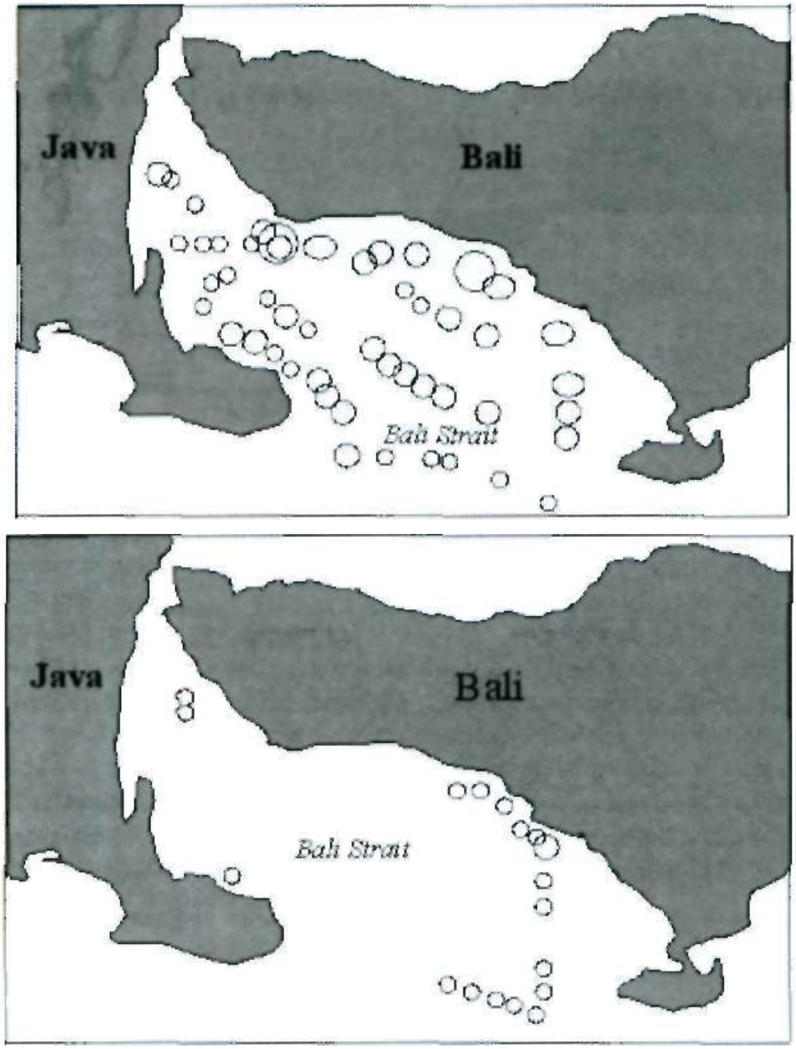
(a)

(b)



0< 10 ton/nmi^2 O 50- 110 ton/nmi^2

O 10-50 ton/nmi^2 (~) > 100 ton/nmi^2

Figure 5. Horizontal distribution of fish densities (ton/nmi^2) in 4-29 meter depth derived from acoustic survey (a) September 1998 and (b) May 1999 (Wudianto, 2001).

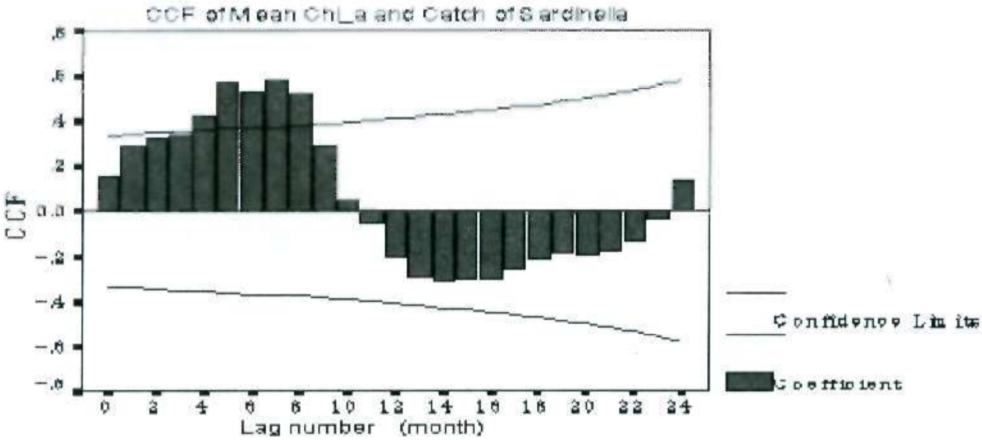


Figure 6. Cross correlation coefficient between monthly mean chlorophyll-a concentration and monthly total catch of lemuru.

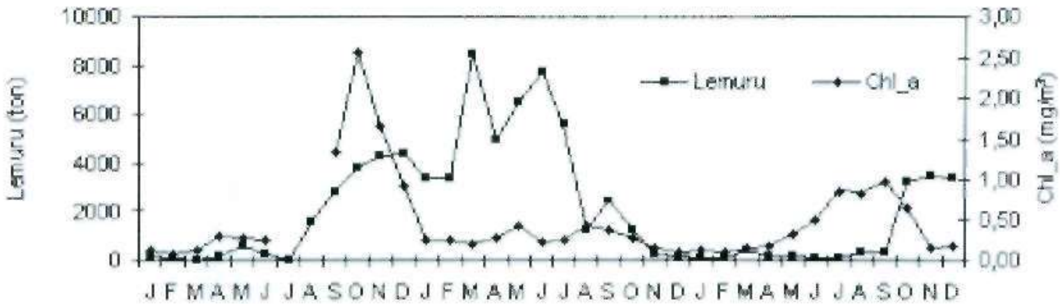


Figure 7. Fluctuation of monthly mean of chlorophyll-a concentration and monthly total catch of lemuru (1997-1999).