Change in species composition and its implication on climate variation in Bali Strait: Case study in 2006 and 2010

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Abstract: *Sardinella lemuru* is a dominant small pelagic fish (80-90%) caught by purse seiner in Bali Strait, while the remaining 10-20% consist *Decapterus* spp., *Euthynus affinis*, and others. This composition typically varies seasonally, whereas Southeast monsoon season was dominated by *S. lemuru*, while Northwest monsoon season replaced by *Decapterus* spp. and *E. affinis*. Fishing trend in the last 14 years indicated regime shift with the shifting in species composition by a seasonal into the inter-annual due to global climate change, such as El Niño and La Niña 2006 was indicated a cold period of water temperature, which is triggered by the El Nino and positive Indian Ocean Dipole (pIOD). In this cold period, the *S. lemuru* reached peak of fishing, otherwise this fish disappear when warm period (strong La Niña) in 2010. When *S. lemuru* disappeared during warm period, it was substituted by *Decapterus* spp. Furthermore, as predatory fish of both small pelagic fishes, *E. affinis* always appear throughout the year. Understanding the species composition trend from seasonal to longer period is important for better strategy to manage fisheries of Bali Bali Strait in climate change era.

Keywords: Pelagic fish, El Niño, Regime shift, Bali Strait

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Introduction

Sardinella lemuru or commonly known as Bali Sardinella (Fishbase, 2016; FAO, 2016) fishery is part of a long history of fisheries in East Java and Bali. It is a dominant species which is caught in Bali Strait and reached over 90% of the total catch of pelagic fish in Bali Strait (Merta, 1992 a, b; Hendiarti *et al*., 2005). The last four decadal, Bali Strait's fish catch was fluctuated due to some reasons, for example over exploitation (Buchary, 2010) and climate variation, such as El Niño Southern Oscillation (ENSO) (Hendiarti *et al*., 2005; Buchary, 2010; Sartimbul *et al*., 2010). Moreover, *S. lemuru* catch declined dramatically in 2010 to 2012, and caused economic losses as reported in Statistical data report of Fishery Port Muncar (2012).

Even El Nino Southern Oscillation was nothing important to debate in the few decades ago, particularly for fisheries implication, however, in the last two decades it has apparently impacted and responsible to the fisheries dynamics mainly in the tropical Pacific. For example temporary collapse of the Peruvian anchovy population during strong El Niño years (Barber and Chavesz, 1983; Bertrand *et al*., 2004), dramatic changes in the distributions of Pacific tuna, mainly the tropical skipjack (*Katsuwonus pelamis*) species (Kimura *et al*., 1997; Lehodey *et al*., 2006), shifting migration pattern of Pacific bluefin tuna during strong El Niño year in 1997/1998 (Kitagawa *et al*., 2006), increasing S. lemuru catch during weak El Niño and combined by positive Indian Ocean Dipole (IOD+) 2006 in Bali Strait (Sartimbul *et al*., 2010) and Southern East Java (Sambah *et al*., 2012; Sartimbul *et al*., 2010).

Those researches were revealed that climate change was a triggered climatic phenomenon event as ENSO and IOD in 2006/2007 caused increasing upwelling intensity and impact to the *S. lemuru* catch in both regions. Furthermore Hendiarti *et al*. (2004) pointed out that the upwelling caused increasing of primary productivity during Southeast monsoon season. Furthermore, Susanto and Marra (2005) added that the anomalies in the Southeastern Monsoon season caused strong El Niño events in 1997/1998 and was followed by La Nina in relation with Indian Ocean Dipole (IOD), which led to increased productivity of chlorophyll-a in the coast of Java (including Bali) and southern Sumatra.

During 1990s, it is well known that ENSO occurred in 1997/1998 and possibly influence marine organisms all over the world, e.g. the Japan Sea (Chiba and Saino, 2003), while it is also reported that there could be a regime shift around 1998 in the North Pacific (Minobe, 2002; Tian *et al*., 2004). The dynamics of water temperature and fisheries production in Bali Strait may have been connected with such climate events on both decadal and inter-decadal scales. In addition, recent warming may also give a serious effect on the fisheries production in near future (Tian *et al*., 2004; Drinkwater, 2005).

It should be taking into account that the period of occurring is becoming shorter recently; from pentadecadal to bidecadal, from decadal to interdecadal, from interdecadal to annual, and so on. For example Minobe (1999) explained that all three climatic regimes in the 20th century (1920th, 1940th, and 1970th) have involved simultaneous phase reversals between pentadecadal (a period of about 50 years) and bidecadal (a period of about 17 years) oscillation.

In this paper, we discuss the change of species composition of coastal fisheries of Bali Strait due to dynamics of sea surface temperature (SST) and chlorophyll-a (Chl-a) abundance in recent climate change era. Combination of in situ and long period of satellite data of SST, Chl-a, and catch per unit effort (CpUE) of fisheries catch might provide a good tool for understanding the species composition trend from seasonal to longer period for better strategy to manage fisheries of Bali Strait in the uncertainty climate era.

Materials and methods

This research was conducted in Bali Strait at 114°26'00"-115°10'00"E and 08°09'00"-08°50'00"S (Fig. 1) as indicated as fishing ground of the Bali Strait. There are three sampling sites representing the region of fishing ground in the Bali Strait, i.e. 114° 26'11"E and 08°27'14"S (St.1), 114°34'43"E and 08° 37'08"S (St.2), 114°40'11" and 08°42'18"S (St. 3) (Fig. 1). In situ and satellite data were used in the current research. In situ sea surface temperature (SST) and chlorophyll-a (Chl-a) data were collected in February-April 2016. Lack of in situ data were substituted by 15-year (2001-2015) of monthly SST and Chl-a obtained from Satellite Aqua MODIS (www.modis.gsfc.nasa.gov). Furthermore, the fish catch data were obtained from Fishing Port Muncar, Banyuwangi. All data were analyzed their trends and anomalies using MS Excel and SeaSurfer 11.0.

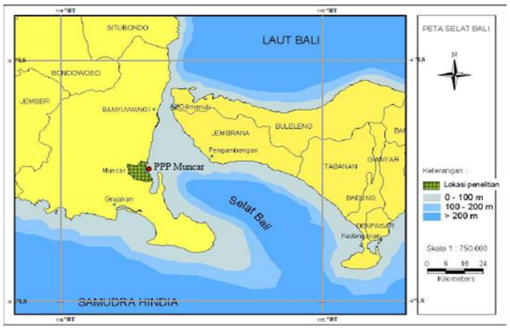


Figure 1: Bali Strait is very unique. Semi eclosesed strait, allowed water mass exchange from Pacific to Indian Ocean. The shallow and deep sea floor of Bali Strait has provided a good fishing and spawning ground of *Sardinella lemuru*. **Nuncar Fishing Port is the main fish landing port of Bali Strait (green).**

In addition to the data of SST and chl-a of Bali, the data catch per unit effort (CpUE) was used in this study. CpUE technique was used to determine the capture rate value of fishing effort based on the division of the total catch (catch) the fishing effort (effort). The common formula used as follows:

$$CpUE_i = \frac{Ci}{fi}$$

Where, C_i: Catch to $_i$ (tonnes), fi: Efforts to $_i$ (trip), and $CpUE_i$: Catch per Unit Effort (kg/trip).

In order to see the deviation trend of data, anomaly technique was used. It is to know how big the data deviated, as following formula:

Anomaly = x-$\bar{x}$

Where:

x: value in day a

$\bar{x}$: Average of value in the same day within whole month or year

Since there were difference ranges in data value, the standardization was used. It is a common method used to standardize whole data to facilitate the making and reading graphs clearly (Sartimbul *et al*., 2010). The equation used is:

$$Z = \frac{xi - \bar{x}}{s}$$

Where:

z : Standardization

xi : value

$\bar{x}$: Average

s : Standard deviation

Result and discussion

Total fish catch

There were three dominant species captured by purse seiner in Bali Strait, i.e. *Sardinella lemuru*, *Decapterus spp*, *E. affinis*, and others. The total catch of 14-year of purse seiner data collected from Muncar fishing port showed that the maximum catch found in 2007, while minimum ones in 2011 (Fig. 2). Based on the inter-annual variation of fish catch (Fig. 3), the trend of fish catch of Bali Strait were mainly developed by S. lemuru, as clearly seen in the percentage of dominant fish caught in Bali Strait (Fig. 3).

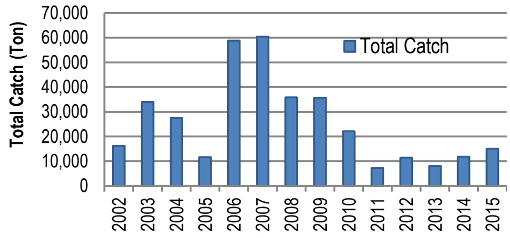


Figure 2: Fourteen-year of total catch of fish landed at Muncar Fishing Port. The maximum catch found in 2007, while minimum catch in 2011.

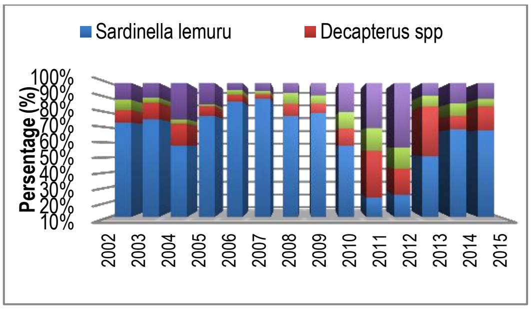


Figure 3: Inter-annual of catch composition and its percentage. *Sardinella lemuru* was dominant for the whole research year except for 2011 and 2012.

S. lemuru dominated in the whole year except for 2011 and 2012. During peak year (2006-2007), there was nearly 80-90% of fish catch was S. lemuru. On the contrary, there was only 10-20% of S. lemuru caught in desert year. The steep declining of *S. lemuru* catch were started in the end of 2010 and continued to the end 2012. Longer period of desert year has apparently giving negative impact on the fishermen in the Bali Strait due to economic loses, because S. lemuru was usually used as raw material of many fisheries industries in Bali Strait as revealed by Pet *et al*. (1996).

Seasonal variation of Sardinella lemuru, sea surface temperature and chlorophyll-a

S. lemuru catch were vary seasonally. Minimum catch occurs in transition-2 (inter-monsoon: Mar, Apr, May) and maximum catch in transition-1 (inter-monsoon: Sep, Oct, Nop) (Fig. 4). This seasonal trend was also revealed by previous researchers, for example Sartimbul *et al*. (2010).

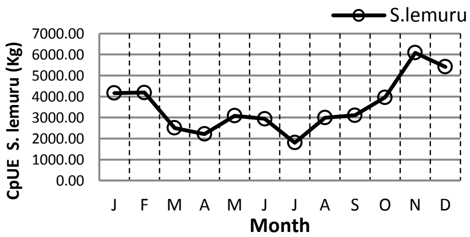
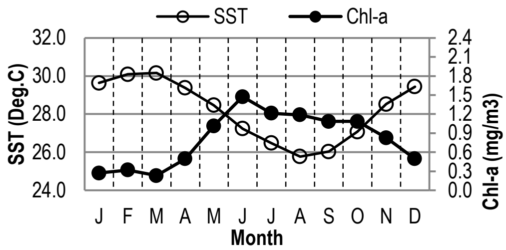


Figure 4: Seasonal trend of Catch per Unit Effort of *Sardinella lemuru* based on 14-year data. Maximum catch of S. lemuru were found in transition-1 (Inter-monsoon: S, O, N)) season.

Seasonal pattern of *S. lemuru* has relation to dynamics of SST and chl-a pattern in different time lag. Seasonal variation of SST showed that maximum temperature occurs on Feb-Mar, while minimum temperature found on Aug-Sep (Fig. 5). During Southeast monsoon (Jun, Jul, Aug), wind prevails from Australia to south Indonesia then generates increasing upwelling intensity in South Indonesia (including Bali Strait). During this season, primarily production of South Java increases. Indeed Bali Strait reaches the blooming season of plankton, that represented by increasing chl-a concentration. During Southeast monsoon season, chl-a concentration was the highest and continued to transition-2 season. However, lowest chl-a concentration occur in northwest monsoon season. During this season, there is no intensity of upwelling at Bali Strait. It is common that there is negative correlation between Sea surface temperature and chl-a as, and has a month lagged shown in Fig. 5.



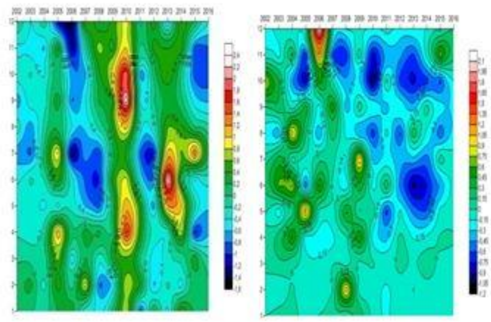
Figrue 5: Seasonal variation of sea surface temperature and chlorophyll-a in Bali Strait. Highest temperature occurs in Feb-Mar, while minimum temperature in Aug-Sep vice versa for chlorophyll-a.

Sea surface temperature gives impact on chl-a about 1 month lagged (Merta, 1992a) while 3-month lagged on S. lemuru caused of grazing process (Sartimbul *et al*., 2010).

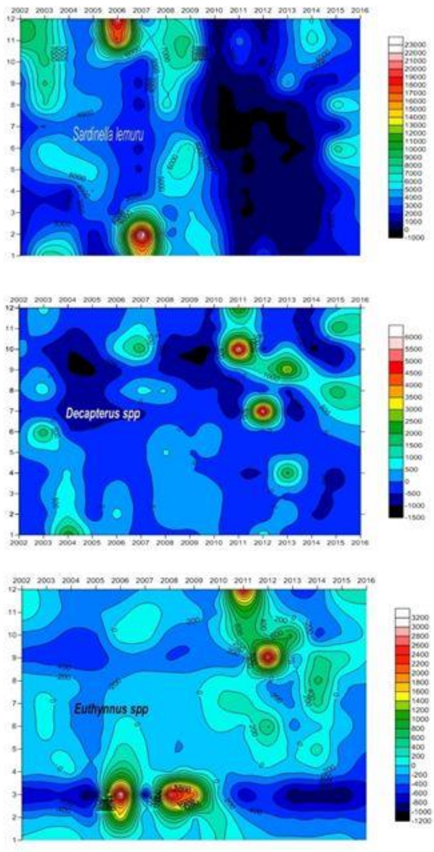
Inter-annual variation of fish catch, sea surface temperature, and chlorophyll-a

Temperature is the first physical parameter of sea water. Fig. 6 showed the seasonal and annual variation of sea surface temperature.

However, current trend showed that *S. lemuru* did not only vary seasonally but also inter-annually (Fig. 7). SST declines in 2006 from June December. Decreasing temperature in 2006 coincided with El Nino and modified by positive Indian Ocean Dipole (Sartimbul *et al*., 2010).



Figrue 6: Seasonal and annual sea surface temperature (left panel) and chlorophyll-a (right panel).

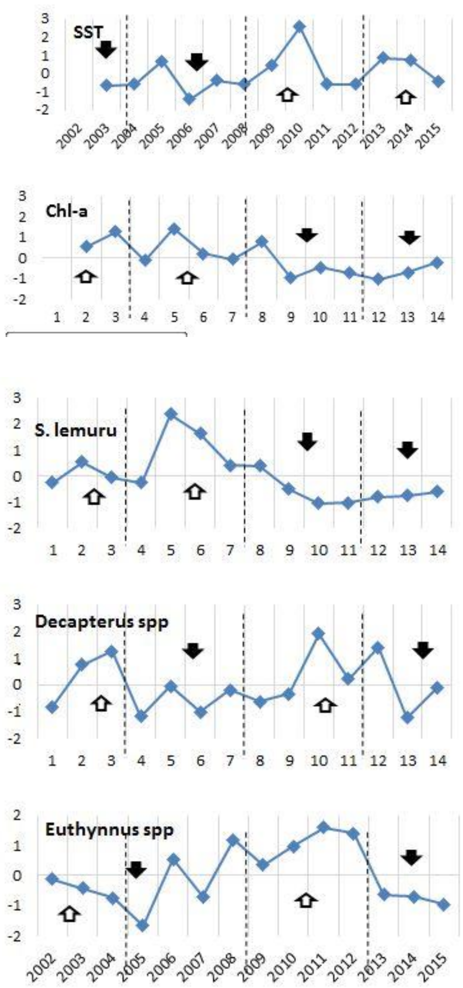


Figrue 7: Time series CpUE anomaly for three dominant species which landed at Muncer Fishing Port. *Sardinella lemura* catch reached peak year in the end of 2006 and continued in early 2007.

During El Nino event, trade wind weakening and let eastern Pacific sea surface temperature kept stagnant. It has implication to the declining of water temperature about 1.5°C below normal year due to upwelling intensity at western Pacific including Bali Strait. On the contrary, in 2010 was indicated as La Nina (**Merta, 1992a**). Water temperature increased about 2.4°C above normal year.Increasing water temperature has begin on May to December and continued on June 2013. Standardization method in Fig. 8 were used to obtain the difference value be standard and provided easy reading of graph. In Fig. 8, sea surface temperature dropped in 2006 lead to strong upwelling in Bali Strait. Strong upwelling produced high productivity that represented by high concentration of Chl-a. As the result, after 3 month lagged, catch of S. lemuru dramatically increased as shown by Fig. 8. The higher intensity of upwelling activity in the 2006 well known due to El Nino and positive IOD phenomenon (Sartimbul *et al*., 2010).

On the contrary, during La Nina even (2010), SST increased in Bali Strait. There were no upwelling throughout the year and prolong to 2011. As the result chl-a concentration dropped moreover for catch of S. lemuru in Bali Strait. There was reported that S. lemuru was disappeared from 2010 to 2011, and causes economic loses for Bali Strait.

As a function of resilience of environment, disappearance of one species usually will be substituted by other species (Bakun, 1996; Mann and lazier, 2006).



Figrue 8: Standardization of SST, chl-a, and *Sardinella lemura*, *Decapterus* spp., and *Euthynus affinis*.

Similarly, loses of *S. lemuru* therefore it has been substituted by Decapterus spp to handle his function in the food web of marine ecosystem of Bali Strait. Furthermore, as higher tropic level than *S. lemuru*, *Decapterus spp.* and *E. affinis* always appeared in every season or annually due to food availability for this species.

Conclusion

Sardinella lemuru is important species for coastal economic development in Bali Strait. Repeatedly losses of *S. lemuru* fishery of Bali Strait are important as reminder tool for government to manage *S. lemuru* fishery in Bali Strait wisely and properly for the future sustainable fishery. Sea surface temperature, chlorophyll-a and climate index have provided good tool for fish abundance prediction in Bali Strait. Understanding the change in species composition due to climate variability in Bali Strait has provided information for fisheries manager to manage fisheries sustainable.

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References

Barber, R.T. and Chavez, F.P., 1983. Biological consequences of el nino. *Science*, 222(**4629**),1203-10.

Bertrand, T.F., Fredric, T. and Robert, N., 2004. Production and partial characterization of a thermostable amylase from Ascomycetes yeast strain isolated from starchy soil. McGraw-Hill Inc., New York, pp. 53-55.

Bakun, A., 1996. Patterns in the ocean: ocean processes and marine population dynamics. California Sea Grant, in cooperation with Centro de Investigaciones Biologicas del Noroeste, La Paz, Mexico. 323P.

Chiba, S. and Saino,T., 2003. Variation in mesozooplankton community structure in the Japan/East Sea (1991–1999) with possible influence of the ENSO scale climatic variability, Progress in Oceanography, 57, 317-339.

Drinkwater, K.F., 2005. The response of Atlantic cod (*Gadus morhua*) to future climate change. *ICES Journal of Marine Science*, 62, 1327–1337

FAO, 2016. *Sardinella lemuru* Bleeker 1853, Fisheries and Aquaculture Department, Accessed on 17/08/2016. http://www.fao.org/fishery/species/2892/en

Fishbase, 2016. *Sardinella lemuru* Bleeker 1853, accessed at 17/08/2016. http://www.fishbase.org/summary/1510

Hendiarti, N., Suwarso, Aldrian, E., Amri, K., Andiastuti, R., Sachoemar, I. and Wahyono, I.B., 2005. Seasonal variation of pelagic fish catch around Java. In: The Indonesian Sea. *Oceanography I,* 18(**4**), 113-123.

Hendiarti, N., Siegel, H. and Ohde, T., 2004. Investigation of different processes in Indonesian waters using SeaWiFS data. *Deep Sea Res*, 51, 85-97.

Kimura, K.D., Tissenbaum, H.A., Liu, Y. and Ruvkun, G., 1997. *Science*, 277, 942–946.

Kitagawa, T., Sartimbul, A., Nakata, H. Kimura, S., Yamada, H. and Nitta, A., 2006. The effect of water temperature on habitat use of young Pacific bluefin tuna Thunnus orientalis in the East China Sea. *Fisheries Science*, 72, 1166-1176.

Lehodey P., Alheit, J., Barange, M., Baumgartner, T., Beaugrand, G., Drinkwater, K., Fromentin, J.M., Hare, S.R., Ottersen, G., Perry, R. Roy, I.C., van der Lingen, C.D. and Werner, F., 2006. Climate variability, Fish and Fisheries. *Journal of Climate*, 19, 5009-5030.

Mann, K.H. and Lazier, J.R.N., 2006. Dynamics of marine ecosystems: biological-physical interactions in the Oceans (Third Edition), by, Black-well Publishing, , 496P.

Merta, I.G.S., 1992a. Result and biomass analyses per recruit and the "lemuru", *Sardinella lemuru* Bleeker 1853, fishery management in Bali Strait. *Journal of Marine Fisheries Research Institute*, 67, 73-84 (In Indonesian)

Merta, I.G.S., 1992b. The "Lemuru" fish stock assessment in the Bali Strait with the cohort analyses. *Journal of Marine Fisheries Research Institute*, 69, 9-18 (In Indonesian)

Minobe, S., 1999. Resonance in bidecadal and pentadecadal climate oscillations over the North Pacific: Role in climatic regime shifts, Geophys. *Research Letters*, 26, 855-858.

Minobe, S., 2002. Interannual to interdecadal changes in the Bering Sea and concurrent 1998/99 changes over the North Pacific. *Progress in Oceanography,* 55, 45-64.

Sambah A.B., Miura, F., Kadarisman, H.P. and Sartimbul, A., 2012. Remote sensing application for Sardinella lemuru assessment: A case study of the south waters of Malang Regency, East Java, Indonesia. *SPIE*, Vol. 8525.

Sartimbul, A., Nakata, H., Rohadi, E., Yusuf, B. and Kadarisman, H.P., 2010. Variations in chlorophyll-a concentration and the impact on Sardinella lemuru catches in Bali Strait, Indonesia. Progress in Oceanography, 87(**1**), 168-174.

Susanto, R.D. and Marra, J., 2005. Effect of the 1997/1998 El Nino on chlorophyll a variability along the southern coasts of Java and Sumatra. In: The Indonesian Seas. *Oceanography I*, 18, 4, 124-127

Tian, Y., Ueno, Y., Suda, M. and Akamine, T., 2004. Decadal variability in the abundance of Pacific saury and its response to climatic/oceanic regime shifts in the northwestern subtropical Pacific during the last half century, *J. Mar. Syst*, 52(**1–4**), 235–257. Doi:10.1016/j.jmarsys.2004.04.004.