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ARTICLE

Preliminary Findings on Distribution of Bali Sardinella (*Sardinella lemuru*) in Relation to Oceanographic Conditions during Southeast Monsoon in Bali Strait Using Remotely Sensed Data

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ABSTRACT

Bali sardinella (Sardinella lemuru) is the main fishing catches in Bali Strait. The distribution of S. lemuru and its preferred oceanographic condition were investigated from remotely sensed data. The objectives of this study were to elucidate the distribution of S. lemuru and the preferred oceanographic condition of S. lemuru in Bali Strait using remotely sensed data. Sea surface temperature (SST) and sea surface chlorophyll-a (chl-a) were downloaded from ocean colour website meanwhile the fishing location generated from daily Visible Infrared Imaging Radiometer Suite (VIIRS) boat detection (VDB), downloaded from NOAA website. The results showed that at the beginning of southeast monsoon (April), most of the fishing location appeared in the north part of Bali Strait, and moved to south part of Bali Strait at the end of the southeast monsoon (September). The results also revealed that most of fishing location of S. lemuru located in SST value of 26℃ – 30℃ and chl-a value of 0.3 – 0.8 mg/m3. Integration VDB data and oceanographic condition generated from remotely sensed data could form the basis for fisheries management and information system, such as S. lemuru in Bali Strait, in the future.

1. Introduction

Bali sardinella (Sardinella lemuru) is main and an important economic species in the high productive waters between Bali Island and Java Island, Indonesia. It is species catches contribute greatly to the total purse seine catch in the Bali Strait [1,2]. The fish is the leaded species in Bali Strait by ± 90% of total catch landed [3]. However, the S. lemuru has been collaps since 2007 and dramatically vanished in 2010 – 2011. Since the intense period, S. lemuru production has never been the previus production [4].

Environmental condition, fishing effort, and food availability were believed influence the productive of S . lemuru. Production of S. lemuru in Bali Strait might be affected not directly by climate phenomenon such as southern oscillation [5,6]. Some of oceanographic factors that significantly resolve marine pelagic species habitat are chlorophyll-a concentration (chl-a), sea surface temperature (SST), salinity and thermocline depth that will control the swimming area. More specific[7] reported that both chl-a and SST may influence the value of catch per unit effort (CPUE) of pe-

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lagic fish. Therefore, considerate the correlation between oceanographic conditions and the distribution of species is significant for fisheries management.

Most studies of S. lemuru have concentrated on its population dynamics [8], evaluation of production model [9], utilization of S. lemuru [10], biomass stock reduction [11], added value of S. lemuru fisheries products [12], the biology and stock assessment [13], S. lemuru reproduction [14], and the body shapes of S. lemuru [15]. However, integrated high-resolution nighttime satellite images, such as those available in the time-series data from Visible Infrared Imaging Radiometer Suite (VIIRS) boat detection (VDB) and environmental data, have not been used to elucidate the prefer oceanographic condition for S. lemuru.

In Bali Strait, fishing boat for S. lemuru conducted at night and use purse seine, locally known as slerek and which are equipped with light to attract the fishes [16]. These fishing boats for S. lemuru, equipped with lights, can be identified by VIIRS sensor, which is also capable of detecting vastly more lit fishing boat features when compared to Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS). Further explanation about some of the superior of VIIRS sensor compared to OLS has been explained by [17,18]. Liu et al., showed the usage of VIIRS day/band night band for detection of Pacific saury and squid fishing vessel boat around Japan while Starka et al., has used VIIRS day/night band for arctic ship tracking and fisheries management. Therefore, the objectives of this study were to describe the distribution of S. lemuru and the preferred oceanographic conditions of S. lemuru in Bali Strait based on remotely sensed data.

2. Methodology

Bali Strait has been known as a S. lemuru fishing activities areas [21,22]. Therefore, in this study we choosed the Bali Strait as the study area. Bali Strait is placed between Bali Island and Java Island. Bali Strait is indicated by low salinity and cool temperature and is influenced by both mixing in the Pacific Ocean and Indonesian through flow [23].

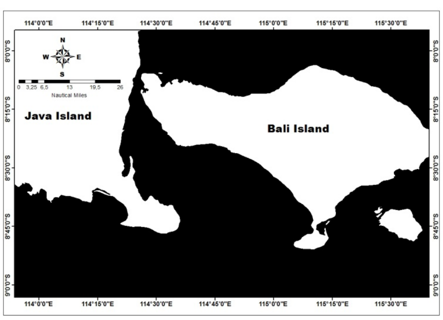

Figure 1. Study area, Bali Strait, located between Bali Island and Java Island

3. Detection of Fishing Boats from VDB

Daily VDB data were downloaded from NOAA website (https://www.ngdc.noaa.gov/eog/viirs/). We collected the data by 5 quality flag (QF 1, QF 2, QF 3, QF 8, and QF 10). The quality flag categorizations: QF1 = highest quality detections, QF2 = weaker detections, and QF3 = blurry detections, QF 8 = recurring light detections and QF 10 = weak and blurry detection [18]. The data was chosen for analysis based on the fishing lights position data during southeast monsoon (April – September) 2013. The period southeast monsoon 2013 was chosen for analysis because it correspond with the available in situ data from local fisherman.

4. Satellite-derived Environment Variable

Sea-surface chlorophyll-a (chl-a) and sea-surface temperature (SST) during southeast monsoon (April – September) 2013 were used to understand the oceanographic condition in Bali Strait. Monthly chl-a and SST data were generated from satellite images from the Moderate Resolution Imaging Spectroradiometer (MODIS)-Aqua mission and were downloaded from ocean color website (http://oceancolor.gsfc.nasa.gov/). These data were processsed with SeaDas package ver. 7. 4 and ArcGIS 10.2

5. Relationship between S. lemuru Distribution and Oceanograpic Conditions

To express the relationship between oceanographic condition of chl-a and SST and distribution of S. lemuru, a simple method is used by overlaid fishing location data on the oceanographic maps. Graphic relationship between oceanography parameters and their frequency was then made to determine the preferered oceanographic conditions of S. lemuru.

6. Results

6.1 Spatio Temporal Distribution of Fishing Locations

Some previous studies pointed out the effectiveness of VDB for detecting lit fishing boats [23,24,18]. The lights on the fishing boat that were used to engage the fish, can be used to determine the fishing zones and count the fishing boat number by using VDB. In this study, we collected 744 VBD data for southeast monsoon (April – September) 2013. All light signals were considered to be emitted by the lemuru fishing boats since there were very few other fishing activities using powerful lights in Bali Strait. In addition, Nugraha et al., reported that during 2013 lem-

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uru fish catches are higher than other fish catches. We assumed that S. lemuru were caught in the same position where fishing boats were identified. Therefore, we were able to evaluate the temporal and spatial distribution of S. lemuru fishing location. In addition, we also collected 66 in situ data from local fisherman as validation data. The number of fishing boats observed by VDB exceeded the number fishing boat reported by local fisherman. This is due to the problem in collecting in situ fishing boat data.

Table 1. Number of fishing boats from Visible Infrared Imaging Radiometer Suite boat detection during southeast monsoon 2013 and in situ data.

	APR	MAY	JUN	JUL	AUG	SEP
VIIRS	158	189	74	87	68	168
In situ	22	12	14	-	-	18

Figure 2 showed the distribution variation of fishing boats from VBD (red dot) and in situ (black dot) data. The figure showed that in the beginning of southeast monsoon (April) most of the fishing boat appeared in the north side of Bali Strait and moved to south part of Bali Strait at the end of the southeast monsoon (September). In general, the distribution of S. lemuru based on the VDB data showed moderate spatial correlation with actual fishing locations.

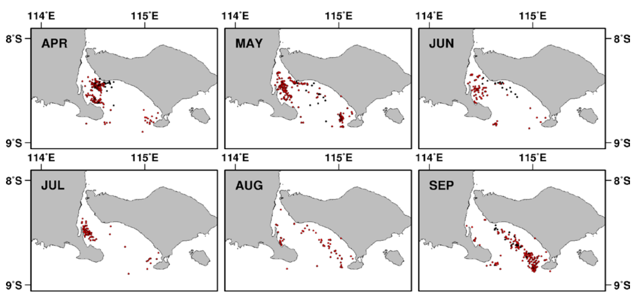


Figure 2. Spatial distribution of fishing location for Sardinella lemuru from VBD (red dot) and in situ (black dot) data during southeast monsoon (April – September) in the Bali Strait.

6.2 Enviromental Variable Conditions.

Figure 3 showed the distribution of S. lemuru overlaid on oceanographic condition of chl-a during southeast monsoon 2013. The variability of chl-a concentration is believed to play significant role in catches and distribution of S. lemuru in Bali Strait. Susilo et al., [2015] reported that fishing activities of S. lemuru occurred in chl-a value of 0.2 – 0.4 mg/m3. However, our results showed that most of S. lemuru appeared in chl-a value of 0.3 – 0.8 mg/m3 (Graph 1).

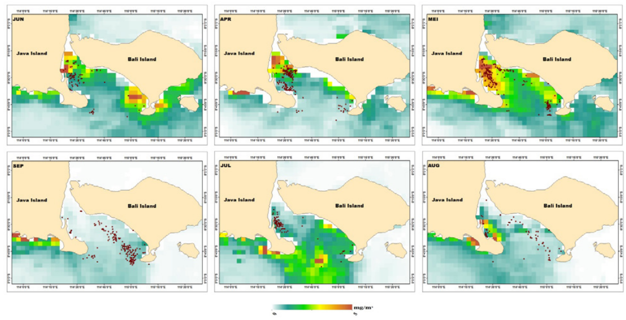
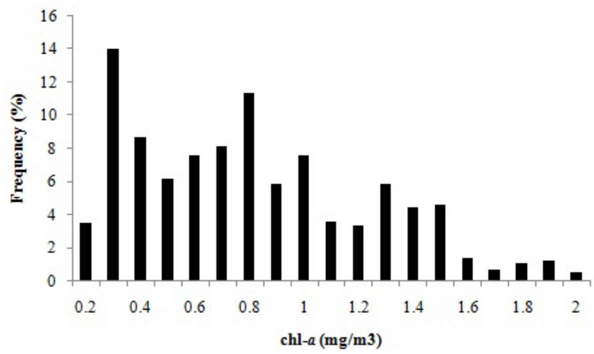


Figure 3. Distribution of fishing location for Sardinella lemuru from VBD (red dot) overlaid on the monthly mean value of sea-surface chlorophyll-a during southeast monsoon (April –September) 2013.



Graph 1. Frequency of sea surface chlorophyll-a (chl-a) during southeast monsoon (April – September) 2013.

The distribution of S. lemuru overlaid on oceanographic condition of SST during southeast monsoon 2013 are shown in figure 4. Temperature is an important abiotic factor as a limiting factor for the distribution of marine organisms, including S. lemuru [26]. Our results showed that most of fishing activities occurred in SST value of 26℃ – 30℃ (Graph 2).

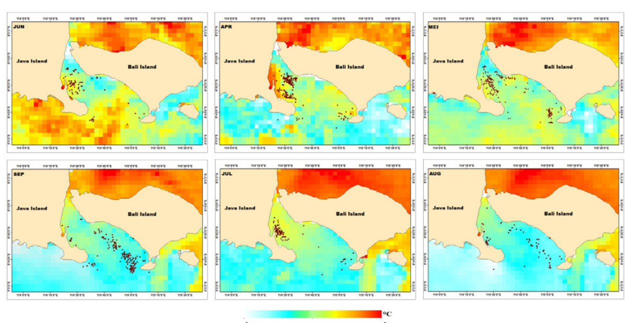


Figure 4. Distribution of fishing location for Sardinella lemuru from VBD (red dot) overlay on the monthly mean value of sea-surface temperature during southeast monsoon (April –September) 2013.

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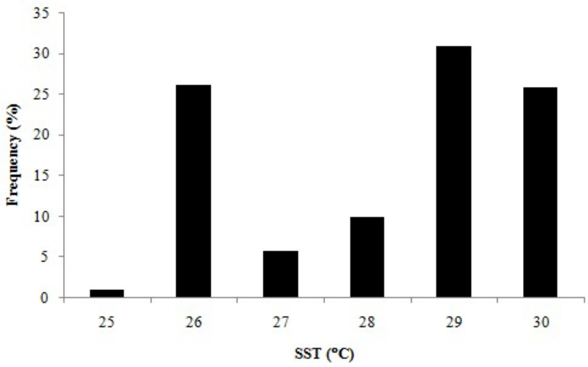
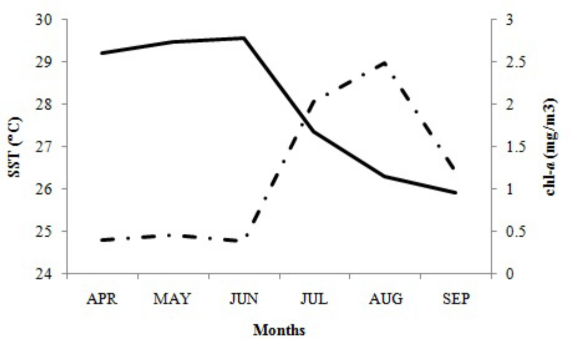


Graph 2. Frequency of sea surface temperature (SST) during southeast monsoon (April – September) 2013.

Graph 3 showed the variation and relation between chl-a and SST in Bali Strait. The figure pointed out that the decrease in SST was pursued by increases of chl-a. This condition demonstrates that the increase in chl-a is strongly influenced by upwelling processes such as during ENSO and IOD events [27,28].



Graph 3. Sea surface temperature (solid line) and chl-a (the line with dashes and 1 dot) variation in Bali Strait during southeast monsoon (April – September) 2013.

7. Discussions

Fishing location and environmental factors were used to understand the preferred oceanographic condtions for S. lemuru in Bali Strait. To our knowledge, this study was the first attempt to use VDB to determine the fishing location for S. lemuru in Bali Strait. Analyses of VDB allowed us to understand the distribution of fishing boats and we assumed that S. lemuru were caught in areas where fishing boats were classified. Based on the derived fishing boats position, the spatial and temporal distribution for S. lemuru can be evaluated. Wudianto & Wujdi, [2001] reported that the population of S. lemuru divided into two larger age-structured, juvenile concentrated in the northern part (coastal waters) and adult that concentrated in the southern part of Bali Strait, respectively.

More specific, Merta [2003] reported that S. lemuru spread along the west coast of Bali Island and the east coast of Banyuwangi in shallow sea water with depth of less than 60 m and often move to lagoons, bays and river mouths.

Hendiarti et al., [2005] reproted that S. lemuru is the main species catch in the pelagic fishery of Bali Strait. Beside as a coastal schooling species, S. lemuru is also recognized as a strong migratory species. Eastern Indian Ocean (Thailand, Western Australia, south coast of East Java and Bali), and the western Pacific (Taiwan, Hong Kong, southern Japan, and Java Sea north to the Philippines) are the distribution areas of S. lemuru [31]. Furthermore, S. lemuru is filter-feeder fish with phytoplankton and zooplankton as the main prey [31]. Pradini, [2001] reported that Coscinodiscus sp. is the main prey of S. lemuru, while Pleurosigma sp. and Nitzschia sp. play as the secondary prey for phytoplankton. In addition, [33] and [34] reported that 90% of S. lemuru`s food composition from zooplankton is copepode (calanoid).

Productivity, migration pattern and fish distribution are influenced by changes in the environment evident from the variations in temperature, chlorophyll-a concentration, currents, salinity, and wind fields [35,36,37]. This study showed that most of S. lemuru appeared in chl-a value of 0.3 – 0.8 mg/m3. Sartimbul et al., [2010] pointed out that increased catches of S. lemuru were most highly correlated with increased chl-a in the prior three months. They also reported that chl-a concentration and CPUE of S. lemuru had matched condition with positive correlation r = 0.71. The seasonal upwelling and strong tidal mixing are believed influences chl-a concentration in the Bali Strait [21].

Sea surface temperature had the most contribution in the distribution of S lemuru in Bali Strait [26]. Ridha et al., [2013] pointed out that correlation coefficient between SST and S. lemuru catches during southeast monsoon was higher than during northeast monsoon. They also reported that most of S. lemuru mostly appeared in SST value of 22 ̊C – 28 ̊C . In general, the variability of SST in the Bali Strait is small in comparison with that in the tropical eastern Pacific due to a lack of strong equatorial upwelling. However, higher variability (>4.0 C) exist along and offshore of the Java (including Bali Strait) and Sumatra Coasts, reflected of a robust remote impact of the equatorial Indian Ocean combined with local upwelling [38].

The monsoonal wind system and interannual forcing correlated with El Niño–Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD), particularly in the upwelling region along the coast of Java (including Bali) was made ocean-colour fluctuation in Indonesian waters [28,29]. During southeast monsoon (April–October), southeasterly winds from Australia create upwelling, bringing cooler waters and

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elevated nutrients to the surface along the south coast of Java (including Bali) and Sumatra [27]. Contrast conditions are occur during the northwest monsoon (October–April). Southeast monsoon is indicated by high chl-a concentration and low SST, while northwest monsoon is indicated by low chl-a and high SST. Monsoon cycles are believed affected the variability of chl-a and SST and as consequences affect the distribution and CPUE of S. lemuru. in the Bali Strait. In addition, [6] and [39] pointed out that the population dynamics of S. lemuru mainly affected by the environmental condition, such as Southern Oscillation Index (SOI) and Dipole Mode Index (DMI).

Finally, VDB data were found to be helpful to explore the distribution of the light of fishing boat for S. lemuru in Bali Strait. VDB data pointed out a high potential for improving the management and sustainable use of fisheries where lighting is used to attract catch. Combining VDB data with vessel monitoring system (VMS) data it would be possible to determine boats that lack VMS signal. In addition, integration VDB and oceanographic data with statistical and habitat modeling in the future could be useful to understand the potential fishing zones for S. lemuru in Bali Strait.

8. Conclusion

Visible Infrared Imaging Radiometer Suite (VIIRS) boat detection (VDB) was useful to identify the distribution of fishing boats for S. lemuru in Bali Strait.

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References

[1] Merta, I.G.S, Widana, K., Yunizal., & Basuki, R. Status of the lemuru fishery in Bali Strait; its development and progress. Papers Presented at the Workshop on the Fishery and the Management of Bali Sardinella (Sardinella Lemuru) in Bali Strait, Denpasar 6 – 8,1999. FAO : 76.

[2] Wudianto, W., & Wujdi, A. Temporal and spatial variation in size of Bali Sardinella (Sardinella lemuru Bleeker) in Bali Strait waters. Jurnal Penelitian Perikanan Indonesia, 2001, 20(1): 9-17. In Indonesia with English Abstract.

[3] Buchary, E. A. In search of viable policy options for responsible use of sardine resources in the Bali Strait, Indonesia. Doctor of philosophy - PhD, University of British Columbia, 2010.

[4] Puspasari, R., Rahmadi, P., Rahmawati, P. F., & Samu-Samu, A. S. Climate variability interaction with coral reef ecosystem and reef fish resources. Jurnal Penelitian Perikanan Indonesia, 2015, 4: 211-220. In Indonesia with English Abstract.

[5] Purwanto. Bio - Economic optimal levels of the Bali Strait sardine fishery operating in a fluctuating environment. Indonesia Fisheries Research Journal, 2011, 17(1): 1 – 12 .

[6] Prasetyo, A.P. & Natsir, M. The impact of extreme climate to lemuru fisheries in Bali Strait. Proceeding seminar on the best research result 2010 the agency of marine and fisheries research and development, 2010, 21-38. ISBN : 978-979-3692-33-3.

[7] Suniada., K.I. & Susilo, E. Linkages of oceanographic conditions to pelagic fisheries in the Bali Strait. Jurnal Penelitian Perikanan Indonesia, 2017, 23(4): 275 – 286. In Indonesia with English Abstract.

[8] Merta, I.G.S. Population dynamic of Bali Sardine, Sardinella lemuru Bleeker (Pisces: Clupeidae) in Bali Strait and its alternative management. Dissertation, Bogor Agricultural University. Bogor.

[9] Tinungki, G. M. Evaluation of surplus production model in estimating maximum sustainable catches to support the policy of lemuru fisheries management in the Bali Strait. Dissertation, Bogor Agricultural University. Bogor, 2005: 154.

[10] Djamali, R. A. Evaluation of sustainability and optimization of utilization of lemuru fish resources (Sardinella Lemuru Bleeker) in Bali Strait waters. Dissertation, Bogor Agricultural University. Bogor, 2007: 154.

[11] Purwaningsih, R., Widjaja, S., & Partiwi, S. G. The effect of marine fish biomass stock reduction to fishers revenue (a case study of sardinella lemuru fisheries on Bali Strait) IPTEK. The Journal for Technology and Science, 2011, 22(3): 166 – 176.

[12] Purwaningsih, R. Analysis added value of lemuru fisheries products in Muncar Port, Banyuwangi. Journal of Industrial Engineering Scientific, 2015, 14(1): 13 – 23.

[13] Gaughan, D. J., & Mitchell, R. W. D. The biology and stock assessment of the tropical sardine, sardinella lemuru of the midwest coast of Western Australia. Fisheries Research Report 119, Fisheries Department. Western Australia, 2000: 136.

[14] Mahrus. Study of lemuru fish reproduction (S. Lemuru Bleeker) in the Alas Strait waters, West Nusa Tenggara. Thesis (unpublished), Bogor Agricultural University. Bogor : 84.

[15] Luceño, A. J. M., Torres, M. A. J., Tabugo, S. R. M., & Demayo, C. G. Describing the body shapes of three populations of Sardinella lemuru (Bleeker, 1853) from

Mindanao Island, Philippines using relative warp analysis. International Research Journal of Biological Sciences, 2014, 3(6): 6 –17.

[16] Himelda, Wiyono, E. S., Purbayanto, A., & Mustaruddin. Selection of the fishing gear type and technology in the utilization of lemuru resources in the Bali Strait. Buletin PSP, 2012, 20(1): 89 – 102.

[17] Elvidge, C. D., Baugh, K. E., Zhizhin, M.., & Hsu, F. C. Why VIIRS data are superior to DMSP for mapping nighttime lights. Proc. Asia – Pac. Adv. Netw, 2013, 35(62 – 69).

[18] Elvidge, C. D., Zhizhin, M, Baugh, K., & Hsu, F.C. Automatic boat identification system for VIIRS low light imaging data. Remote sensing, 2015, 7, 3020-3036.

[19] Liu, Y., Saitoh, S-I., Hirawake, T., Igarashi, H., & Ishikawa, Y. Detection of Squid and Pacific Saury fishing vessels around Japan using VIIRS Day/Night Band data. Proc. of the Asia–P cific Advanced Network, 2015, 39, 28-39.

[20] Starka, W. C., Seaman, C. J., Baugh, K., Cole, K, Stevens, E., & Miller, S. D. Utilization of the Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) day/night band for arctic ship tracking and fisheries management. Remote sensing, 2015, 7: 971-989.

[21] Hendiarti, N., Suwarso, E., Aldrian, Amri, K., Andiastuti, R., Sachoemar, S., & Wahyono, I. B. Seasonal variation of pelagis fish catch around java. Oceanography, 2005, 18(4), 112 –123.

[22] Ridha, U., Muskananfola, M. R., & Hartoko, A. Analysis of lemuru (Sardinella lemuru) catches based on sea surface temperature and chlorophyll-a satellite data in Bali Strait waters. Diponegoro Journal of Maquares, 2013, 2(4) : 53-60.

[23] Gordon A. The Oceanography of the Indonesian Seas and their throughflow. Oceanography, 2005, 18(4) : 14-27.

[24] Miller, S.D., Straka III, W. Mills, S.P., Elvidge, C.D., Lee, T.F., Solbrig, J., Walther, A., Heidinger, A.K., & Weiss, S.C. 2013. Illuminating the capabilities of the Suomi National Polar-Orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) day/night band. Remote Sens, 5: 6717–6766.

[25] Nugraha, S.W., Ghofar, A., & Wijaya, S. Monitoring lemuru fisheries in Bali Strait waters. Management of Aquatic Resources, 2018, 7. 1: 130 - 140.

[26] Susilo, E., Wibawa, T. A., & Wijaya, A. Estimation of lemuru fishing area in the Bali Strait based on food chain using oceanographic satellite data. Proceedings of the National Seminar Geografi, UMS, Surakarta, 2015.

[27] Sartimbul, Nakata, A. H, Rohadi, E., Yusuf, B., & Kadarisman, H.P. Variations in chlorophyll-a concentration and the impact on Sardinella lemuru catches in Bali Strait, Indonesia. Progress in Oceanography, 2010, 87. 1-4 : 168-174.

[28] Susanto, R.D. & Marra, J. 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, 2005, 18. 4 : 124-127.

[29] Susanto, R. D., Moore II, T. S. & Marra. J. Ocean color variability in the Indonesian seas during the SeaWiFS era. Geochem. Geophys. Geosyst., 2006, 7. 5: Q05021. DOI:10.1029/20055GC001009.

[30] Merta, G.S. Review of the lemuru fishery in the Bali Straits. in Potier, M and S. Nurhakim. BIODYNEX: biology, dynamics, exploitation of the small pelagic fish in the java Sea, 2003: 97- 106 Jakarta: MMAF.

[31] Carpenter, K.E., & Niem, V.H. FAO species identification guide for fishery purposes. the living marine resources of the western Central Pacific. Volume 3. Batoid Fishes, Chimaeras and Bony Fishes Part.1 (Elopidae to Linophrynidae). Roma, 1999: FAO.

[32] Pradini, S. M. R. Food habits of lemuru fish (Sardinella Lemuru) in Muncar waters, Banyuwangi. Jurnal Iktiologi Indonesia, 2001, 1(1): 41-45.

[33] Burhanuddin, M., Hutomo, S., Martosewojo, & Moeljanto, R. Lemuru fish resources. Jakarta, 1984: LIPI.

[34] Susilo, E. Variability of environmental factors on lemuru fish habitats in the Bali Strait using oceanographic satellite data and in situ measurement. Omni Akuatika, 2015, 14(20) : 13-22.

[35] Alheit, J., & Hagen, E. Long-term climate forcing of European herring and sardine populations. Fish. Oceanogr, 6, 1997: 130-139.

[36] Tian, Y., Akamine, T., & Suda, M. Variations in the abundance of Pacific saury (Cololabis Saira) from the Northwestern Pacific in relation to oceanic-climate changes. Fisheries Research, 2003, 60 : 439–454.

[37] Yasuda, I., & Watanabe, T. On the relationship between the oyashio front and saury fishing grounds in the northwestern pacific: a forecasting method for fishing ground locations. Fisheries Oceanography, 2007, 3: 172–181.

[38] Qu, B., Gabric, A. J, & Matrai, P. A. The satellite-derived distribution of chlorophyll-a and its relation to ice cover, radiation and sea surface temperature in the Barents Sea. Polar Biology, 2005, 29: 196–210.

[39] Puspasari, R., Rahmawati, P. F., Susilo, E, Wijopriono, & Wiadnyana. The impact of environmental changing, food availability and atropogenic pressure on sardine (Sardinella lemuru) CPUE in Bali Strait waters. Jurnal Segara, 2018, 14(2): 107 – 116.

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