fishes

MDPI

Article

Upwelling Impact on *Sardinella lemuru* during the Indian Ocean Dipole in the Bali Strait, Indonesia

Daduk Setyohadi [1,*], Umi Zakiyah [1], Abu Bakar Sambah [1] and Adi Wijaya [2,3]

[1] Faculty of Fisheries and Marine Science, Brawijaya University, Jalan Veteran No.1 Malang, Jawa Timur 65145, Indonesia; umizakiyah@ub.ac.id (U.Z.); absambah@ub.ac.id (A.B.S.)
[2] Institute for Marine Research and Observation, Ministry of Marine Affairs and Fisheries, Jalan Baru Perancak Negara Jembrana Bali, Jakarta Pusat 10110, Indonesia; adi.wijaya@kkp.go.id
[3] Graduate School of Doctoral Programs, Fisheries Science and Marine, Faculty of Fisheries and Marine Science, Brawijaya University, Jalan Veteran No.1 Malang, Jawa Timur 65145, Indonesia
* Correspondence: daduks@ub.ac.id; Tel.: +62-857-5574-4008

Abstract: Understanding the impact of Indian Ocean Dipole (IOD) on fishery around Indonesia is important as the fishery resources are small compared to the demand. In this study, we analyzed the effect of positive and negative phases of IOD on chlorophyll-a concentration and the catch of *Sardinella lemuru* in the Bali Strait. Data are based on field surveys in the Bali Strait during the positive and negative phase of IOD and Sea Surface Temperature (SST) and Sea Surface Chlorophyll (SSC) obtained from the analysis of satellite images. The results suggest that SSC concentration in the strait significantly correlates with the positive and negative phase of IOD, possibly through a change of upwelling and downwelling there. It is suggested that the change of phytoplankton biomass due to positive IOD would result in an increase of *Sardinella lemuru* in the Bali Strait. This research has direct implications as important information for the government in planning lemuru fisheries management in the Bali Strait based on oceanographic studies and climate phenomena.

Keywords: Bali Strait; Indian Ocean Dipole; sea surfaces temperature; sea surface chlorophyll; *Sardinella lemuru*

Citation: Setyohadi, D.; Zakiyah, U.; Sambah, A.B.; Wijaya, A. Upwelling Impact on *Sardinella lemuru* during the Indian Ocean Dipole in the Bali Strait, Indonesia. *Fishes* **2021**, *6*, 8. https://doi.org/10.3390/fishes6010008

Received: 31 December 2020
Accepted: 13 March 2021
Published: 16 March 2021

1. Introduction

The Indian Ocean is the center of the occurrence of the Indian Ocean Dipole (IOD) phenomenon [1–3]. During the positive IOD period, the incidence of upwelling along the South Coast of Java increased due to the strengthening of the southeasterly winds along the coast, as a result of which there was a significant increase in chlorophyll-a concentration [4,5]. Conversely, during the negative IOD period, the southeasterly wind along the southern coast of Java weakened and caused low chlorophyll-a concentrations [4,6].

The Bali Strait connects water masses from the Indian Ocean to the Bali Sea and vice versa [7,8] with a shallow, narrow and steep bathymetry facing the Indian Ocean, producing high surface inlet and outflow current velocities [8]. Recent velocity results in dynamic exchange of water masses [5,7,9–12]. The waters of the Bali Strait are also indirectly affected by the IOD phenomenon, in which primary productivity fluctuations occur in the surface layer due to the upwelling process that occurs in the Indian Ocean [12–16]. This condition affects the dynamics of *Sardinella lemuru* caught in the Bali Strait. Positive IOD was associated with strong El-Nino Southern Oscillation (ENSO) during 2006 and early 2007, causing fluctuations in *Sardinella lemuru* [7,17].

The IOD period has an impact on the intensity of the upwelling that occurs. This condition affects the variability of chlorophyll-a concentration and sea surface temperature and affects the production of *Sardinella lemuru* in the Bali Strait. This study aims to analyze the upwelling phenomenon when positive IOD occurs in the Bali Strait. The discussion focuses on the spatial and temporal variation of oceanographic parameters on the upwelling phenomenon during the IOD event, and its effect on *Sardinella lemuru* in the Bali Strait.

2. Results

2.1. Variability of Sea Surface Temperature (SST) and Sea Surface Chlorophyll (SSC)

The SST and SSC vertical profiles in the Bali Strait during the IOD (+) years were significantly different (Figure 1). The average of SST was very low (24 °C) at the peak of the IOD (+) phase, whereas at the end of the IOD (+) phase it was very high (29 °C), so there was a very high SST difference between the peak and the end of the IOD (+) phase which was close to 5 °C. At a depth of 20 to 40 m, the temperature difference was higher than the surface temperature, about 4 °C. The thermocline layer rose up to 10 m in the IOD (+) phase. Moreover, the average of SSC during the peak of the IOD (+) phase was 3 mg/m^3, and at the end of the IOD (+) it reached <1 mg/m^3. The SSC difference between the peak and the end of the IOD (+) phase was relatively high (2 mg/m^3). The vertical distribution of SST and SSC showed extreme upwelling during IOD (+) in the year of 2012.

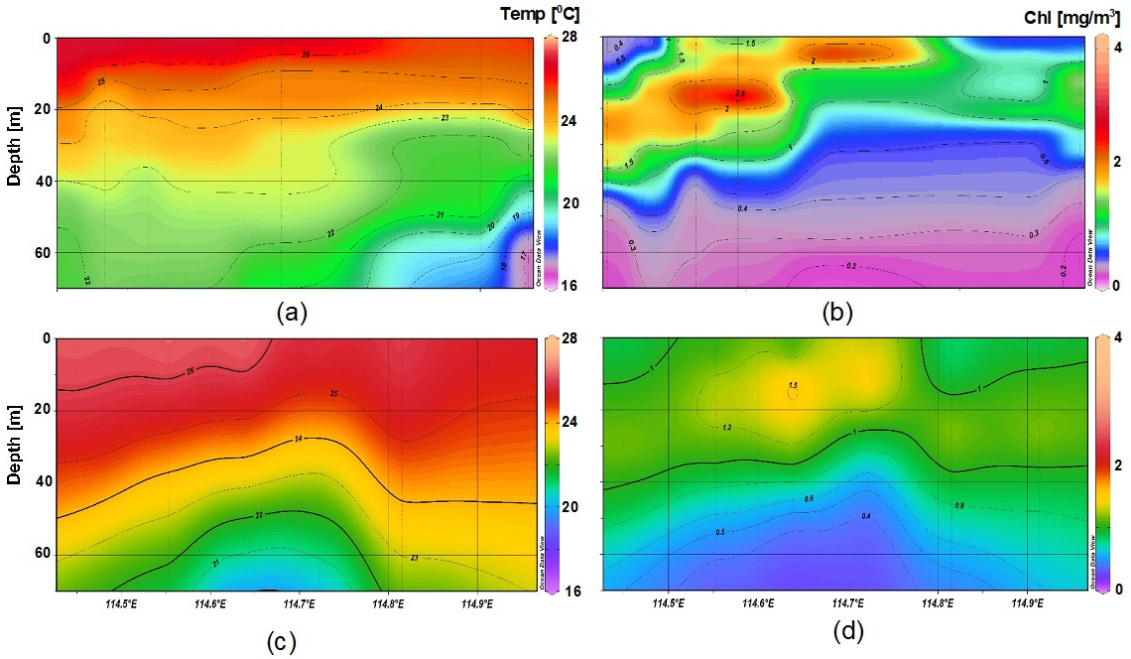

Figure 1. Depth profile observed on July 2012; (**a**) Sea Surface Temperature (SST) (°C) during Indian Ocean Dipole (IOD) (+); (**b**) SSC during IOD (+); and observed on August 2013; (**c**) SST (°C) during IOD (−); (**d**) Sea Surface Chlorophyll (SSC) during IOD (−) in the Bali Strait.

The average SSC at the peak of the IOD (+) phase in the Bali Strait was 1.91 mg/m^3, an increase compared to the end of the IOD (+) phase of 0.92 mg/m^3. The high SSC supports the physical processes that show very strong upwelling in the Bali Strait during the IOD (+) phase. We used the Hovmöller diagram to see the variability of SST and SSC during the IOD (+) and IOD (−) phases from 2000–2019 (Figure 2). This pattern occurs in the eastern monsoon from June to October, and the opposite occurs in the west monsoon period. The effect of the season can be seen from the change in SST at each season shift towards the east season. The transition of seasons was characterized by the changes of warm temperatures described in red to cold temperatures in blue. During the 2000–2019 observation years, there was a similarity in the pattern of warm temperatures (Figure 2) in the west monsoon (DJF) towards transition I (MAM), and cold temperatures in the east monsoon (JJA) to transition II (SON). The upwelling intensity was affected during the IOD phase, where the IOD (+) intensity was higher than the IOD (−) and neutral conditions. It follows a seasonal pattern.

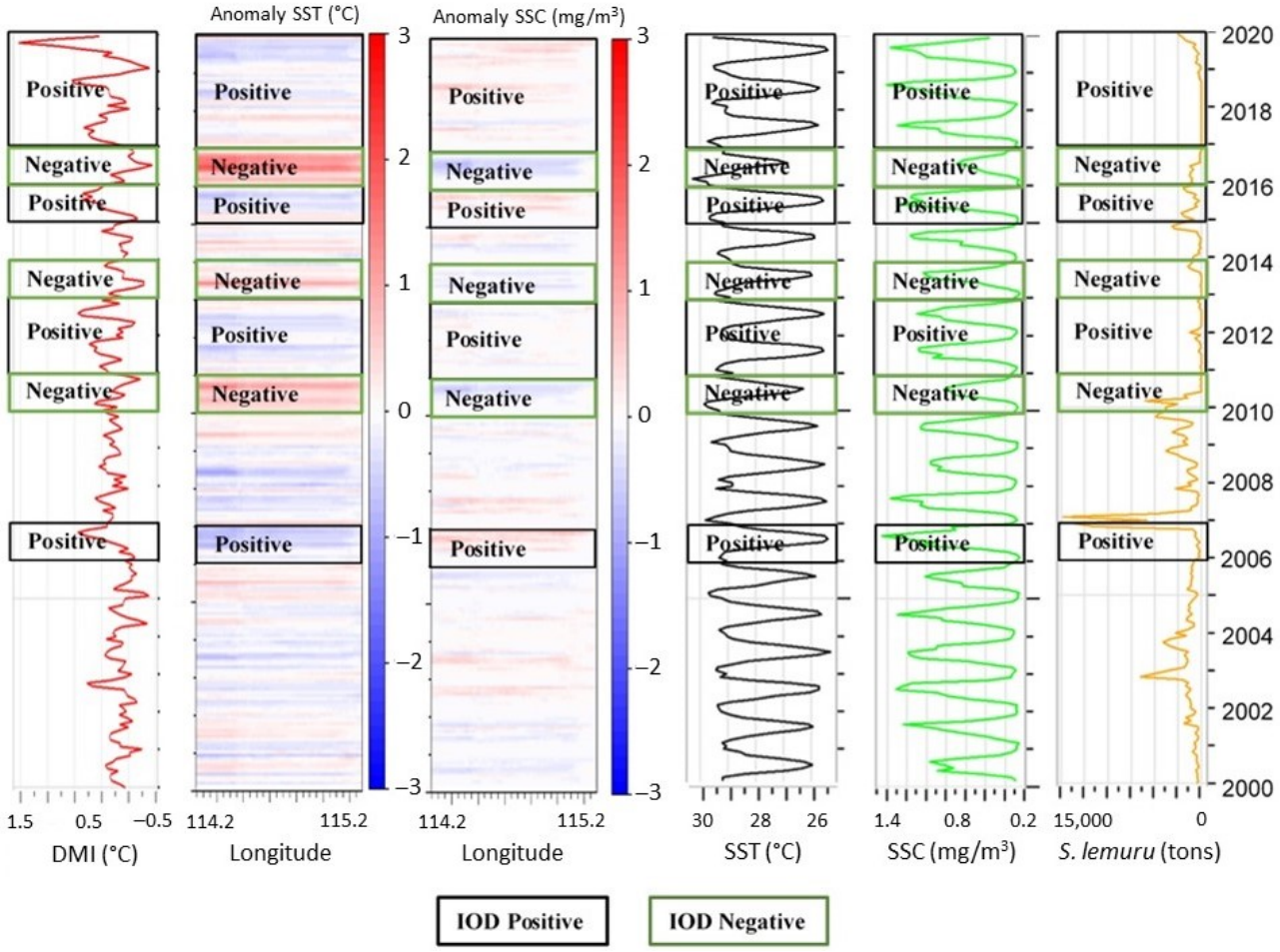

Figure 2. Variability of Dipole Mode Index (DMI) (°C), SST anomaly (°C), SSC anomaly (mg/m^3), SST (°C), SSC (mg/m^3), and *Sardinella lemuru* (tons) in the Bali Strait.

High SSC concentration during IOD (+) explains the extreme upwelling which indicates nutrient-rich waters. The richness of nutrients in these waters causes the surface water level in the Bali Strait to have high primary productivity [8,18]. The IOD period has changed the trophodynamics of the Sardinella lemuru zone in the Bali Strait due to a significant increase in phytoplankton abundance and biomass. The monthly catch of *Sardinella lemuru* over 20 years is shown in Figure 2. During the IOD (+) phase in 2006, 2011, 2012, 2015, 2017, 2018 and 2019, SSC anomalies tended to increase, whereas SST anomalies tended to be low. This phenomenon can be used as an indicator of an increase in phytoplankton biomass which is followed by an increase in the production of Sardinella lemuru. In contrast, during the period of IOD (−) in 2010, 2013 and 2016, the phytoplankton biomass was lower than usual and was followed by a decrease in Sardinella lemuru production (see Figure 2).

2.2. Comparison of Sardinella lemuru Catch with the IOD Phase

The catch of *Sardinella lemuru* in the neutral phase, IOD (+) phase and IOD (−) phase in the Bali Strait fluctuated during 2000-2019 (Figure 3). We found that the total catch of Sardinella lemuru in the IOD (+) phase was higher than that in the IOD (−) phase. Meanwhile, at the neutral phase the catch of *Sardinella lemuru* was more significant than in the IOD phase (+/-), although this was also influenced by the number and intensity of fishing activity in the Bali Strait. The average catch of *Sardinella lemuru* landed at the fishing port around the Bali Strait during the IOD (−) in 2010 was 32,339.96 tons, and during the IOD (+) in 2006 it reached 59,170.51 tons. The correlation analysis described that the critical t-value was 1.25 on the left side and 3.25 on the right side, which indicates that the critical

t-value was calculated with a significant level of 5%. This illustrated the differences in the catch of *Sardinella lemuru* in the IOD (+) and IOD (−) phases, where during the IOD (+) phase it was relatively high, while during IOD (−) phase it was relatively low (see Figure 3).

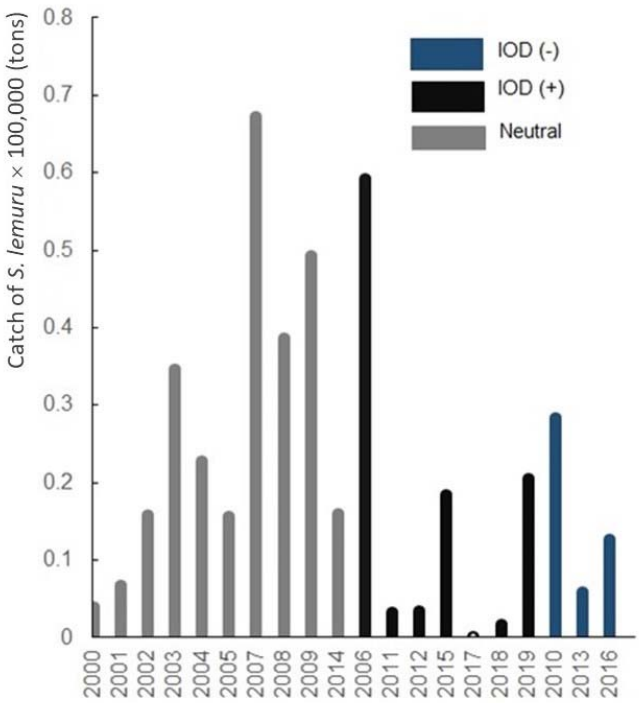

Figure 3. Catches of *Sardinella lemuru* in the Bali Strait during the neutral conditions and IOD (+) and IOD (−) phases.

A cross-correlation analysis was carried out to determine the relationship between Dipole Mode Index (DMI) and catches of *Sardinella lemuru* in the Bali Strait. The analysis was applied to the data during IOD events in 2000–2019, which occurred from June-November. IOD was a predictor of the catch of *Sardinella lemuru* and SSC. The correlation between SSC and DMI showed that the increase in SSC occurred in the first three months, namely June, July and August (Figure 4a). Time lag (month) = 0 indicated June. DMI and SSC were positively correlated. Maximum correlation had zero-time lag. The cross-correlation diagram was asymmetric. Correlation with a positive time lag was more dominant than a negative time lag. The positive correlation between DMI and SSC had a strong relationship with the upwelling events during the IOD phase which occurred in the eastern and transitional monsoons (June–November), resulting in an increase in the growth rate of phytoplankton.

In addition, the correlation between SSC and *Sardinella lemuru* catches at the IOD event was significantly positive, indicating that catches of *Sardinella lemuru* increased at a time lag equal to one, two and three months, or from July, August and September, where the highest catch was in August (Figure 4b). This can be explained as the increase in SSC concentration was not directly followed by a high number of catches, but there was a time lag of about one to three months after that. This correlation also shows that phytoplankton abundance directly affects fish abundance, as *Sardinella lemuru* is a phytoplankton eater. The time lag could be related to fish larvae reaching their first feeding stage at roughly the same time as phytoplankton abundance. Strong downwelling or upwelling events during the IOD (+ or −) phase led to increased/decreased SSC concentrations, which affected the abundance of *Sardinella lemuru* since the key element in larval survival is food availability.

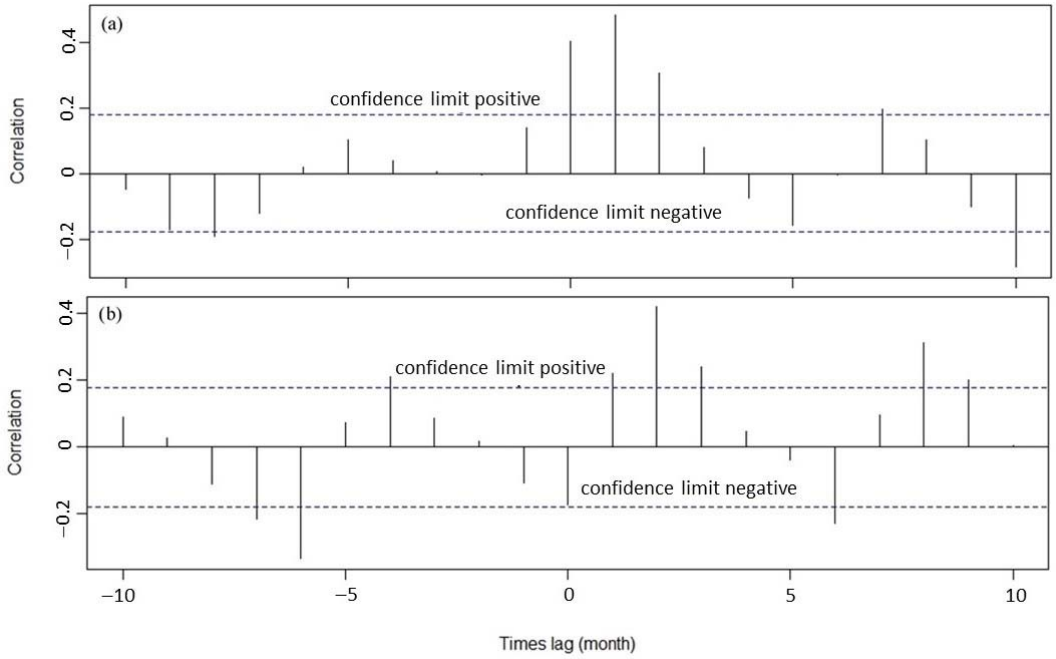

Figure 4. Time-lag cross-correlation coefficient between (**a**) SSC (mg/m^3) and DMI; (**b**) SSC (mg/m^3) and *Sardinella lemuru* catches at the fishing port around the Bali Strait. Blue dashed line is the confidence limits. The analysis focuses on the peak season of IOD (June to November).

3. Discussion

Several previous studies by many oceanographers related to the upwelling phenomenon in the Java Sea have been carried out [18]. The relationship between oceanographic factors, as well as their relationship with fish habitats, has been the focus of several previous studies. In addition to analyzing spatial and temporal variation of oceanographic factors, the current research also analyzes a relationship with short-term climate mode (IOD) and its relation to fish resources (in terms of catches for all season periods). SSC and SST were used for investigations during the IOD (+) and IOD (−) phases. The intense IOD (+) phase was characterized by a strong expansion of SSC and low concentration of SST in the Bali Strait, whereas the reverse event in the IOD (−) phase caused a low concentration of SSC and high SST [4,5,19]. Upwelling in the Bali Strait has a strong seasonal cycle [4,20]. Previous studies have shown that the difference in SST between the southeast (upwelling) and northwest (downwelling) monsoons was only about 2 °C, and the thermocline rose to 40 m in the Bali Strait [21].

The differences in SST avarage, thermocline depth and SSC at the beginning of the IOD (+) phase in 2012 were 23 °C, 40 m and 2 mg/m^3, respectively, indicating very strong coastal upwelling during the IOD (+) phase. Based on the spatial variability of SSC (Figure 1), the anomaly of SSC (Figure 2) and *Sardinella lemuru* catch data, we describe phytoplankton's response to strong upwelling events in the Bali Strait from July to October at the period of IOD. We have confirmed a significant increase in SSC concentration during IOD (+) (Figure 2).

The IOD is strongly phase-locked to a seasonal cycle and peaks around September-October, and this is shown from 2006 and 2019 (Figure 2). The impact of IOD through a change of SSC in the Bali Strait should appear only around June to November, and sometimes until Desember. During the peak season of IOD (one of them occurred in 2006 and 2007), the concentration of SSC increased and reached 0.4 mg/m^3, followed by an increase in the number of *Sardinella lemuru* catches in the Bali Strait. This pattern is almost similar to the other events of IOD (+) phase, where from November–December 2019 the concentration of SSC reached 0.3 mg/m^3. Research by Du et al. [22] reported a new type of the IOD. These are reffered as unseasonable IOD, normal IOD, and prolonged IOD. The

latter two types are termed the canonical IOD. Based on the evolution of the three types of the IOD, in terms of the amplitude the unseasonable IOD is about twothirds of the canonical IOD types. Moreover, based on the temporal evolution, although some unseasonable IOD events may persist into September, they tend to mature in July. In contrast, the normal IOD events tend to form in July, peak in October and end in the beginning of December. Our study found that there was a similar temporal pattern in which the normal IOD events occurred in the period of June to November, where 20 years of data illustrated that there was a positive relationship between the IOD events and an increase in SSC concentration in the study area. In addition, the results showed that an increase in SSC concentration during IOD (+) was also followed by an increase in SST. During the phase of IOD (+), the upwelling event increases, and this could also be caused by very strong southeast winds. This upwelling event could carry water containing high levels of nutrients into the upper layer of the water, resulting in an increase in SSC concentration.

Previous studies have shown a positive anomaly of SSC concentrations in the South Indian Ocean in Java-Bali during the IOD (+) phases of 1997 and 2006 [4,23]. Upwelling during the IOD (+) phase in all areas in the Bali Strait is affected by high SSC concentrations [13]. Based on the research of Susanto and Mara [4,24] and Iskandar [5], we found an increase in SSC concentrations in the Bali Strait during the IOD (+) phase. Conversely, when there was a downwelling event during the IOD (−) phase, the SSC concentration was low (Figure 2). This described the distribution of SSC concentration from July to October in the Bali Strait during IOD (−) phase and IOD (+) phase.

The atmospheric and ocean conditions during the IOD (+) phase modulates upwelling, thereby affecting primary productivity and fish caught in the Bali Strait. The total catch of *Sardinella lemuru* that landed at the *Pangambengan* and *Muncar* Fishery Port during the IOD (+) phase was more significant than during the IOD (−) phase. The catch data from the fishing port reported that *Sardinella lemuru* production increased during the IOD (+) period. Due to the increased coastal transport of water and nutrients during the IOD (+) phase in 2019, it injected plankton-rich waters into major fish spawning areas in southern Java [25]. Along the Bali Strait coast, *Sardinella lemuru* plays an essential role in the fishermen's economy. Fish price fluctuations are quite large due to production uncertainty. When the catch rises during an IOD (+) phase, market demand is stable and prices fall. However, in the IOD (−) phase, the price increases when the fish catch decreases. Uncertainty of fish production affecs the fishing operational costs [26,27]. The variability of *Sardinella lemuru* production affected by the dynamic of SSC concentration is an indicator of primary production in the waters.

4. Materials and Methods

The study area was in the Bali Strait in 114.20–115.20° E and 8.90–8.10° S (Figure 5). This water area has unique oceanographic parameters, with the main pelagic fish resource being Sardinella lemuru, which is a specific species in Indonesia [28]. The Bali Strait waters flow by seasonal cycles, namely the east (southeast) and west (northwest) seasons, and the IOD phenomenon impacts upwelling intensity and fishery potential.

Oceanographic data applied satellite imagery Aqua/Terra MODIS (Sensor Moderate Resolution Imaging Spectroradiometer) for the SSC and SST parameters. The data was downloaded from the NASA website, https://oceancolor.gsfc.nasa.gov/ (accessed on 12 March 2021). The data was level 2 data, with 1 km spatial resolution and daily temporal. Data were analyzed using the SeaWiFS Data Analysis System (SeaDAS) version 7.5.3 LINUX and Algorithm Theoretical Basic Documents MODIS (ATBD-MOD-19 and ATBD-MOD-25) to present sapatial temporal of SSC and SST distribution.

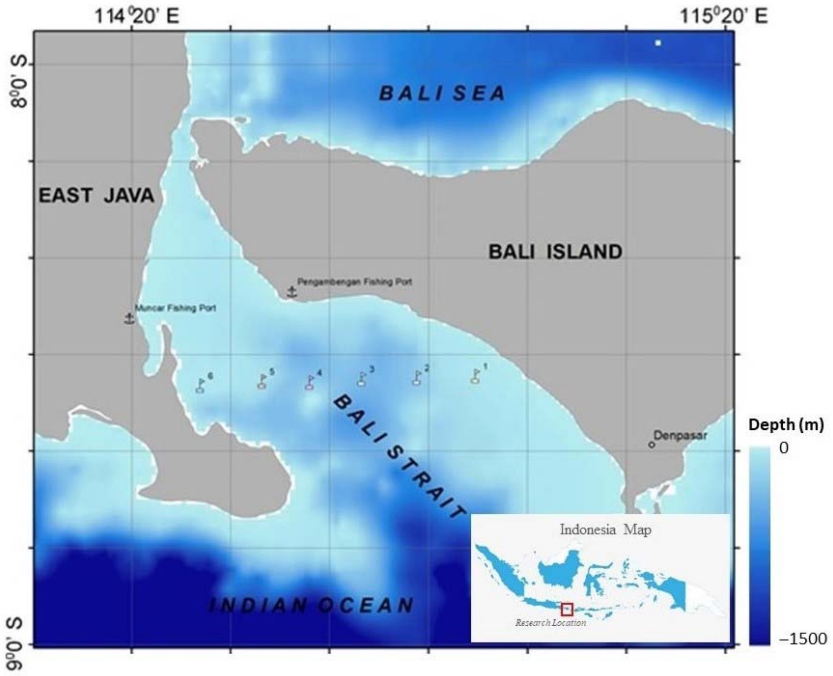

Figure 5. Study area of the Bali Strait, Indonesia.

The daily dataset was composed of monthly data. SSC data errors due to suspended particles, base reflectance and case-2 water conditions ensured the data filter was carried out so that the SSC obtained ranged from 0-5 mg/m^3. The SST data were disturbed by the filtered atmosphere, and the resulting range was 23 < SST < 33 °C. The temperature values were based on previous field measurements, which never exceeded this range. Upwelling intensity was classified into three classes, namely high (SST was 25–26 °C; SSC > 2 mg/m^3), medium (SST 26–27 °C; SSC 1–2 mg/m^3), and low (SST 27-28 °C; SSC 0.7–1 mg/m^3) [29]. Spatial analysis of time series data used hovmoller charts. This diagram was used to illustrate phenomena that changed over time.

The IOD index was obtained from observations of oceanic and atmospheric interactions in the tropical Indian Ocean in the western (50–70° E and 10° S–10° N) and southeastern parts of the Indian Ocean (90–110° E and 10° S–0°/Equatorial) [1]. A positive SST anomaly indicated a favourable IOD period index. Meanwhile, the negative IOD period index was characterized by a negative SST anomaly. The threshold for describing positive and negative IOD was ±0.4 °C. The IOD index refers to The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and Bureau of Meteorology Australia's observations, which were downloaded from the https://stateoftheocean.osmc.noaa.gov/ (accessed on 12 March 2021).

Catch data of *Sardinella lemuru* was collected from the Muncar and Pengambengan Fishing Port from March 2000 until December 2019. Monthly data on the catch of Sardinella lemuru were compared with oceanographic and atmospheric phenomena to see the effect of upwelling and IOD phenomena on fish catches. At this stage, we performed paired t-tests and cross-correlation to evaluate the strength of the relationship between IOD and upwelling and between upwelling and Sardinella lemuru production.

5. Conclusions

During the interannual cycle of IOD (+) phases, a very strong coastal upwelling phenomenon occurs. This can be seen from the difference in SST and SSC concentration during the eastern monsoon in the Bali Strait. Conversely, during the IOD (−) phase, strong downwelling occurs. During the IOD (+) phases, SSC concentrations become very high over the Bali Strait, where there is an increase in upwelling intensity, and vice versa. The abundance of SSC has influenced lemuru catch dynamics in the Bali Strait. The variation

in SSC concentration due to IOD events has a significant effect on the *Sardinella lemuru* resources. The increase in SSC concentration was not directly followed by a high number of *Sardinella lemuru* catches, but there was a time lag of about one to three months. The information or predictions of the IOD phase can be used as a basis of information for sustainable fishery management in the Bali Strait.

Author Contributions: Conceptualization, D.S., A.B.S. and A.W.; methodology, D.S., A.B.S. and U.Z.; validation, D.S. and A.W.; formal analysis, D.S., A.B.S., U.Z. and A.W.; data curation, A.W. and D.S.; writing—original draft preparation, A.W.; writing—review and editing, D.S., U.Z., A.B.S. and A.W.; visualization, A.W.; project administration, A.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Directorate General of Higher Education, Ministry of Education and Culture, Indonesia, grant number 037/SP2H/LT/DRMP/2020.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: Thank you to the Institute for Marine Research and Observation (IMRO) for providing modelling and in situ data for this study. The author thanks Frida Sidik, (Associate Expert Researcher from the IMRO), for her discussion, suggestions and written articles.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Saji, N.H.; Goswami, B.N.; Vinayachandran, P.N.; Yamagata, T. A dipole mode in the tropical Indian Ocean. *Nature* **1999**, *401*, 360–363. [CrossRef]
2. Webster, P.J.; Moore, A.M.; Loschnigg, J.P.; Leben, R.R. Coupled ocean-temperature dynamics in the Indian Ocean during 1997-98. *Nature* **1999**, *401*, 356–360. [CrossRef]
3. Murtugudde, R.; McCreary, J.P.; Busalacchi, A.J. Oceanic processes associated with anomalous events in the Indian Ocean with relevance to 1997-98. *J. Geophys. Res.* **2000**, *105*, 3295–3306. [CrossRef]
4. Susanto, R.D.; Marra, J. Chlorophyll-a Variability Along the Southern Coasts of Java and Sumatra. *Oceanography* **2005**, *18*, 663–671. [CrossRef]
5. Iskandar, I.; Rao, S.A.; Tozuka, T. Chlorophyll- a bloom along the Southern Coasts of Java and Sumatra during 2006. *Int. J. Remote Sens.* **2009**, *30*, 663–671. [CrossRef]
6. Horii, T.; Ueki, I.; Ando, K.; Mizuno, K. Eastern Indian Ocean warming associated with the negative Indian Ocean dipole: A case study of the 2010 event. *J. Geophys. Res. Oceans* **2013**, *118*, 536–549. [CrossRef]
7. Sartimbul, A.; Nakata, H.; Rohadi, E.; Yusuf, B.; Kadarisman, H.P. Variations in chlorophyll-a concentration and the impact on *Sardinella lemuru* catches in Bali Strait, Indonesia. *Prog. Oceanogr.* **2010**, *87*, 168–174. [CrossRef]
8. Berlianty, D.; Yanagi, T. Tide and Tidal Current in the Bali Strait, Indonesia. *Mar. Res. Indones.* **2011**, *36*, 25–36. [CrossRef]
9. Wijaya, A.; Zakiyah, U.; Sambah, A.B.; Setyohadi, D. Spatio-temporal variability of temperature and chlorophyll-a concentration of sea surface in Bali Strait, Indonesia. *Biodiversitas* **2020**, *21*, 5283–5290. [CrossRef]
10. Sukresno, B.; Jatisworo, D.; Kusuma, D.W. Multilayer Analysis of Upwelling Variability in Southern Java Waters. *J. Kelaut. Nas.* **2018**, *13*, 15–25. [CrossRef]
11. Lumban-Gaol, J.; Wudianto, B.P.; Pasaribu, D.; Manurung, E.R. The Fluctuation of Chlorophyll-a Concentration Derived from Satellite Imagery and Catch of Oily Sardine (*Sardinella lemuru*) in Bali Strait. *Remote Sens. Earth Sci.* **2014**, *1*, 24–30. [CrossRef]
12. Ningsih, N.S.; Rakhmaputeri, N.; Harto, A.B. Upwelling Variability along the Southern Coast of Bali and in Nusa Tenggara Waters. *Ocean Sci. J.* **2013**, *48*, 49–57. [CrossRef]
13. Susanto, R.D.; Gordon, A.L.; Zheng, Q. Upwelling along the coasts of Java and Sumatra and its relation to ENSO. *Geophys. Res. Lett.* **2001**, *28*, 1559–1602. [CrossRef]
14. Susanto, R.D.; Moore, T.S.I.I.; Marra, J. Ocean Color Variability in the Indonesian Seas during the SeaWiFS Era. *Geochem. Geophys. Geosyst.* **2006**, *7*, 1–16. [CrossRef]
15. Hendiarti, N.; Siegel, H.; Ohde, T. Investigation of Different Coastal Processes in Indonesian Waters Using SeaWiFS Data. *Deep-Sea Res. Part II Top. Stud. Oceanogr.* **2004**, *51*, 85–97. [CrossRef]
16. Qu, T.; Du, Y.; Strachan, J.; Meyers, G.; Slingo, J. Sea Surface Temperature and its Variability in the Indonesian Region. *Oceanography* **2005**, *18*, 50–61. [CrossRef]
17. Sambah, A.B.; Miura, F.; Kadarisman, H.P.; Sartimbul, A. Remote Sensing Application for *Sardinella lemuru* Assessment: A Case Study of the South Waters of Malang Regency, East Java, Indonesia. *Remote Sens. Mar. Environ.* **2012**, *85250*. [CrossRef]

18. Wyrtki, K. The upwelling in the region between Java and Australia during the southeast monsoon. *Mar. Freshw. Res.* **1962**, *13*, 217–225. [CrossRef]
19. Iskandar, I.; Lestari, D.O.; Utari, P.A.; Khakim, M.Y.N.; Poerwono, P.; Setiabudidaya, D. Evolution and impact of the 2016 negative Indian Ocean Dipole. *J. Phys. Conf. Ser.* **2018**, *985*, 012017. [CrossRef]
20. Siswanto, E.; Horii, T.; Iskandar, I.; Gaol, J.L.; Setiawan, R.Y.; Susanto, R.D. Impacts of climate changes on the phytoplankton biomass of the Indonesian Maritime Continent. *J. Mar. Syst.* **2020**, *212*, 103451. [CrossRef]
21. Matsuyama, M.; Senjyu, T.; Natih, N.M.N. Oceanographic conditions in Pelabuhanratu Bay, West Java. *Lamer* **1996**, *34*, 283–291.
22. Du, Y.; Cai, W.; Wu, Y. A new type of the Indian Ocean Dipole since the mid-1970s. *J. Clim.* **2013**, *28*, 959–972. [CrossRef]
23. Sari, Q.W.; Utari, P.A.; Setiabudidaya, D.; Yustian, I.; Siswanto, E.; Iskandar, I. Surface chlorophyll-a variations in the Southeastern Tropical Indian Ocean during various types of the positive Indian Ocean Dipole events. *Int. J. Remote Sens.* **2019**. [CrossRef]
24. Lumban-Gaol, J.; Leben, R.R.; Vignudelli, S.; Mahapatra, K.; Okada, Y.; Nababan, B.; Mei-Ling, M.; Amri, K.; Arhatin, R.E.; Syahdan, M. Variability of satellite-derived sea surface height anomaly, and its relationship with Bigeye tuna (*Thunnus obesus*) catch in the Eastern Indian Ocean. *Eur. J. Remote Sens.* **2015**, *48*, 465–477. [CrossRef]
25. Matsuura, H.; Sugimoto, T.; Nakai, M.; Tsuji, S. Oceanographic conditions near the spawning ground of southern bluefin tuna; northeastern Indian Ocean. *J. Oceanogr.* **1997**, *53*, 421–434.
26. Dahl, R.E.; Oglend, A. Fish price volatility. *Mar. Resour. Econ.* **2014**, *29*, 305–322. [CrossRef]
27. Sathiadhas, R.; Narayanakumar, R. Price policy and fish marketing system in India. *J. Biol. Educ.* **1994**, *11*, 225–241.
28. Pet, J.S.; Van Densen, W.L.T.; Machiels, M.A.M.; Sukkel, M.; Setyohadi, D.; Tumuljadi, A. Length-based analysis of population dynamics and stock identification in the sardine fisheries around East Java, Indonesia. *Fish. Res.* **1997**, *31*, 107–120. [CrossRef]
29. Kunarso; Ningsih, N.S.; Supangat, A. Characteristics of Upwelling along the Waters of Southern NTT to West Sumatra. *J. Ilmu Kelaut.* **2005**, *10*, 17–28. [CrossRef]