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Vertical Distribution of Dissolved OxygenConcentration at The Seashell Pearl Cultivation Development Site, West Lombok, Nusa Tenggara Barat

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Abstract

Iis Triyulianti, Camellia Kusuma Tito and I Gede Adi Suastana. Vertical Distribution of Dissolved OxygenConcentration at The Seashell Pearl Cultivation Development Site, West Lombok, Nusa Tenggara Barat. 2022. Titrimetric method or Winkler Method was applied to determine dissolved oxygen (DO) in seawaters of The Sea Pearl Cultivation Development Site, West Lombok during the South-East monsoon of June 2021. Samples were collected in three (3) locations (Gili Gede, Gili Genting and Autorei) at Sekotong waters, West Lombok, Nusa Tenggara Barat. The salinity was ranging from 31.9 – 32.3 PSU and the temperature ranged from 28.4 – 29.7ºC respectively. The concentration of dissolved oxygen measured with the Winkler method was ranging from 3.4 - 5.2 mg / L. The trend of vertical oxygen concentration in the study area was declining through the depth due to the utilization by marine organisms for the process of respiration and oxidation of organic matter. We found the higher oxygen concentration (5 – 6 mg/L) was measured in the layer of depth at 20 - 25 m where sea shell pearls are developed or cultivated. The results of oxygen concentration measurement indicated that those depths (20 -25 m) are suitable for locations of seashell pearls cultivation. Dissolved oxygen becomes an important abiotic factor for ecosystems that support the sustainability of marine life and marine aquaculture development efforts.

Keywords: *Dissolved Oxygen, Winkler Method, Sea Pearl, Sekotong, West Lombok*

Introduction

The seashell pearl cultivation activities in the coastal waters of Sekotong, West Lombok have been pioneered since 1989 (Asfin, 2000). Pearls of the seashells are one of Indonesia's leading marine culture commodities. Sekotong coastal waters are located in the western part of West Lombok Regency, one of the well-known places for the development of the seashell pearl cultivation with an average production of 600 Kg/year (Aunurohim, 2013). The coastal waters in West Lombok Regency are 1,382.4 Km2, with a coastline length of 1,063.92 Km^2 (Marine and Fisheries Service, 2014). The existence of coastline in Sekotong, West Lombok has potency to be developed for marine culture activities. The marine biodiversity of the coastal waters in Sekotong**,** West Lombok is supported by seagrass ecosystems, coral reefs and mangroves as natural or biological resources**.** Therefore, this coastal water is

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potential for both aquaculture and fishing activities. A research done by Marine Fisheries Service in 2014 showed that the cultivation area for seaweed is 9.944.25 ha, pearl oyster is 2.294 ha, groupers, lobster and other biota is 0.4444ha, respectively. On a certain scale, any use of natural resources in coastal waters can cause changes in the potential wealth of biological resources in the coastal waters of Sekotong, West Lombok. The excess nutrient input from the aquaculture activities impacts the ability of water bodies to water self purity (Schumacher *et al*., 2014; Glibert *et al*., 2011). The activities of fishing and aquaculture could contribute to the increase of degradation of marine water quality.

The development of aquaculture business in sekotong coastal village, West Lombok, West Nusa Tenggara since 1989 is suspected to have an impact on the quality of its waters. The impacts of fish farming activity could be changes in water quality due to increasing nutrients and to decreasing dissolved oxygen. The increasing of nutrients due to the enrichment of water bodies with phosphorus, ammonia, copper, organic matter and other nutrients and decreasing of dissolved oxygen are two of impacts of fish farming activities have been well identified and have received increasing attention in the last two or three decades (Hall et al., 1992, Leung et al., 1999, Holby and Hall, 1991, Wu et al., 1994). Polution has damaged the coastal area which significantly affected the aquaculture processes. Therefore, water quality is need to be monitored and control regularly so the sustainable management of fisheries resuces could be achieved.

Generally, water quality monitoring as one of fisheries and aquatic resources management will generate a large and complex database involving the hydrobiological, physical and chemical oceanography (Tyagi, et al., 2013; Sutadia *et al*., 2015). Those activities will describe the quality of the waters in the coastal waters of Sekotong, West Lombok, Nusa Tenggara Barat. The measurement of Dissolved Oxygen (DO) is important to be done due to its concentration values could determine an ecosystem's ability to support aquatic biota survival. Oxygen is the most important gas in the marine environment because it is essential for breathing or respiration by all bacteria, protists, plants and animals that live in the sea (Mahaffey et al., 2020).

Dissolved oxygen concentration in the water column is an important chemical element used as a support in the life of organisms, namely for the needs of respiration and plays a role in the biogeochemical cycle of the ocean. Dissolved oxygen in the surface column of waters comes from or results from

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the process of photosynthesis and diffusion between water and air (Millero, 2013). The utilization of dissolved oxygen by aquatic biota through the process of respiration resulted in its concentration can be reduced. The process of biological oxidation through the utilization of dissolved oxygen will break down molecules $((CH_2O)_{106}(NH_3)_{16}(H_3PO_4))$ and produce CO_2, HNO_3, H_3PO_4, and H_2O (Millero, 2013).

Dissolved oxygen concentration in the surface layer of coastal waters is produced by the results of photosynthesis and diffusion from the atmosphere (Millero, 2013). The dynamic of dissolved oxygen concentrations in the ocean is controlled by a combination of physical and biological processes (Millero, 2013 and Mahaffey et al., 2020). The process of oxygen diffusion from the atmosphere to the surface waters or euphotic layer is termed 'air-sea gas exchange. That process is reversible while in the deeper layers, the dissolved oxygen concentration is supplied through the sinking of the water mass which carries high oxygen content from the surface (Millero, 2013). The solubility of oxygen in water declines with increasing temperature and salinity (Millero, 2013), therefore it's needed to measure other hydro oceanography parameters.

The biological production in terms of photosynthesis by phytoplankton is producing of dissolved oxygen in the surface layer or euphotic layer. The concentration of dissolved oxygen will decrease through the depth of water were due to the removal of oxygen by the respiration of sinking organic matter (Millero, 2013). A range of biological processes is controlling the dissolved oxygen in the water column (Mahaffey *et al.*, 2020). Deoxygenation or oxygen-deficient occurs when dissolved oxygen concentrations are less than 6 mg/L (equivalent to ~ 192 µmol/kg) or hypoxic (Mahaffey *et al.*, 2020), the oxygen concentrations are ultimately less than 2 mg/L (equivalent to ~ 64 µmol/kg). The condition of oxygen deficiency, or hypoxia, can have deleterious effects on the marine ecosystem (Vaquer-Sunyer and Duarte, 2008; Freiburg *et al.*, 2018). The decline of dissolved oxygen or deoxygenating is also apparent in the coastal and shelf seas (Diaz and Rosenberg, 2008; Freiburg *et al.*, 2009; Gilbert *et al.*, 2010; Townhill*et al.*, 2017a; Breitburg *et al.*, 2018).

The main objectives of this study are (1) to identify the hydro oceanographic conditions of sea pearl cultivation area in the coastal waters of Sekotong, West Lombok, (2) To identify characteristics of vertical dissolved oxygen in the area of the sea pearl cultivation in Sekotong, West Lombok, Nusa Tenggara Barat.

Materials and Methods

Study Area & Materials

The research was conducted on the coastal waters of Sekotong, West Lombok, Nusa Tenggara Barat and the points stations of the study area were at 115 – 116 East Longitude and 08 South Latitude. The boundaries of the study area in the northern, southern and eastern are the waters of the Sumba Strait (Fig.1). The data collection was conducted in June 2021.

Determination of sampling location or in situ measurement station point and sampling of water sampling is done by purposive sampling method. The distribution of stations point extending from west to east to represent some areas used for the location of seashell pearl cultivation, a typical coastal ecosystem (coral reefs, mangrove dang seagrass), and some locations are close to human living activities (Fig.1).

The measurement of physical, chemical and biological parameters of the waters in the coastal waters of Sekotong includes areas in Gili Genting, Gili Gede, Gili Labuhan Petung, Tanjung Batu Selek, Gili Lontar, Gili Rengit, Gili Nanggu, Gili Sudak, Gili Tangkong, Gili Rengit, Elak-Elak, Tawun, Kares Port, Bangko-Bangko, Gili Asahan, Pandanan, Gili Layar, Tenggolong, GiliKedis, Batu Putih, Autorei, Tanjung Beberak and Tanjung Kablet, West Lombok, Nusa Tenggara Barat. Study areas can be grouped into 3 areas (cluster areas) based on the distribution of point measurement stations and water sampling as seen in Table 1 and Fig.1.

There are 56 stations point of water quality measurements were conducted horizontally and vertically. The selected station points are representatives of various coastal water land use activities as well as coastal ecosystems such as coral reefs, seagrass and mangroves. The selection of study locations is used as a spatial approach to present the characteristics of the coastal waters of Sekotong.

The water quality was measured in each station and the parameters observed in this study were temperature, salinity, surface current velocity, transparency, pH, dissolved oxygen (DO), nitrite (NO_2), nitrate (NO_3), ammonia (NH_3), total phosphorus (TP), and chlorophyll-a. Water samples were taken using a Van Dorn water sampler as two litres. The sample of water was put into the bottle, and transferred to the Testing Laboratory at Balai Budidaya Perikanan Laut Lombok. In situ measurement for hydro oceanographic parameters was using water quality checker at surface layer and we used flow meter for measuring surface current velocity. The water samples were collected from the surface layer (0 – 5 m) and a depth of 25 meters to describe of its vertical dispersion.

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Analysis Method

Water samples for analysis of dissolved oxygen concentratiobn are inserted into a BOD bottle (size 300 ml). Water samples are inserted using rubber hoses up to the surface with the aim of avoiding gas bubbles in BOD bottles. To avoid the bubles, the BOD bottle was filled by the water samples are allowed with the rubber hose until spill about 1/3 the volume of BOD bottles, then the rubber hose is lifted slowly and the bottle is closed until it is ready to be analyzed oxygen content (Hutagalung *et al*., 1997).

The measurement of dissolved oxygen was conducted using the winkler method and to describe oxygen concentration, temperature, salinity and water mass, it was done using the Ocean Data View 4.5.7 program (Schlitzer, 2013).

Data Analysis

The apparent of *Dissolved Oxygen* concentration from samples which is analysed using Titration or Winkler method (Grasshoff, 1976; Parson *et al*., 1984; Hutagalung *et al*., 1997) were calculated by the equation as follows:

Dissoved Oxygen (DO) concentration (mg/L) =

$$\text{DO (mg/L)} = \frac{\text{ml titran x N Thiosulfat x 8x 1000}}{\text{ml sampel }\left(\frac{\text{ml botol BOD} - \text{ml reagen}}{\text{ml botol BOD}}\right)}$$

where ml titran is the volume of sodium thiosulfate ($Na_2S_2O_3$) used for the titration process (ml), N Thiosulfate is Normality of Thiosulfate (0.0225 N), ml sampel is amount of water samples, ml botol BOD is volume of BOD bottle that we used and ml reagen is volume of the reagents used for the titration ($MnSO_4$ and KIO_3).

Result and Discussion

Result

Characteristics of Hydro Oceanography

The hydro oceanography characteristics of the study area are shown by the spatial distribution of measurable values of temperature, salinity and surface current parameters. The results of temperature and salinity measurements are shown in Figure 2. The distribution of surface waters temperatures at all the stations point in June 2021 showed in Figure 2. The average value of surface temperature of the coastal waters in the Sekotong coastal waters was warmer at the cultivation site of seashell pearl cultivation in Gili Genting area.

The average value of sea surface temperature in the study area was 28,2 ± 0,26 ^{o}C. During the study, temperature and salinity levels of the seawater ranged between 28.7 - 29.2 °C, and 31.2 – 31.9 psu in Sekotong coastal waters, respectively (Fig.2). In the study area of the sea pearl cultivation, the highest temperature value (29 °C) was measured at the depth in between 0.5 and 1.0 m at all stations (Fig. 2a). The highest temperature in the study area is characterized by a red spread at the measurement site in the middle area (Fig.2a). The highest salinity value (31.9 psu) was determined at the point station in the west site of the study area where those stations are connecting to the Lombok Strait.

For the results of the surface current velocity in the coastal waters of Sekotong showed the point stations that close in the Gili Genting's Island area (Fig.3) have the values of the sea surface current velocity were more high than the others stations. The results of this study on the sea surface current velocity showed its decrease towards the Gili Genting's area as one of the sea pearl cultivation in Sekotong coastal waters. The lowest values (10 cm/s) was detected at the depth of 0.5 m at some stations in the middle of study area (Fig.3).The highest value of sea surface current velocity was found in the stations located in the west site (Fig.3b). which is directly connected to the mass flow of water from the south to the north or vice versa.

Profile of Dissolved Oxygen and Chlorophyll-a Concentration

The profile of the sea surface Dissolved Oxygen (DO) of the coastal waters of Sekotong, West Lombok ranged from 2.6 to 6.5 mg/L, with a mean value was 4.52 ± 0.7 mg/L (Fig.4). The profile of spatial distribution of DO and chlorophyll-a vertically and horizontally (Fig.4 and Fig.5) provide information related to the characteristic trends of DO content as well as hydro oceanographic parameters measured. There was a significant increasing trend of the sea surface DO concentrations in the study area stations which is located in the west side. Those results showed there is an impact of the connecting of open sea waters from the Lombok Strait into the study area especially some of station were located in the west site on their characteristic of marine biogeochemistry.

All stations at the cultivation site of the sea pearl in Sekotong, West Lombok in the period study have DO concentrations were less than 6 mg/L. Those results showed the condition of water quality status based on DO measurement is oxygen deficient. Physical processes play a key role in the development of oxygen deficient regions (Mahaffey, et al., 2020) Physical processes, such as vertical mixing and horizontal transport, redistribute oxygen vertically and horizontally. We obtained spatial DO changes vertically and horizontally were characterized by an initial increase and the decrease trend that was similar with the chlorophyll-a concentration (Fig. 4 and Fig.5).

The profiles for DO and Chl a (spasial dan vertical) in Fig. 4 and 5, are well representative of area observations in the west, middle and east regions of Sekotong coastal

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waters, West Lombok. The oxygen and Chl a profiles were vertically almost homogeneous, except in the west and middle stations, where oxygen was typically higher in the water column at 5 into 25 metres compared to the upper.

During most of the sampling period, the spatial distribution DO and chlorophyll-*a* values (Fig.4a, and Fig.4b) were higher in the layer below upper layer (0-5 m) or in the euphotic zone. The range values of chlorophyll-a were between 0.06 to 0.22 mg/L measured in the waters layer of 0 – 5 m and 5 – 25 m. Spatial distribution is created to give an idea of the results of measuring parameters vertically and horizontally (Fig.4 and Fig.5). The highest chlorophyll-a concentration was determined at surface layer found in middle are of study area or the stations were close to Gili Gede (Fig.4).

The vertical profile of DO concentration and chlorophyll-a in the coastal waters of Sekotong are shown in Fig.5a and Fig.5b. Sekotong coastal waters in West Lombok have the characteristic of the vertical stratification of DO and chlorophyll-a where the highest concentration of DO ultimately was recorded not in the surface water (0-5 m) at all stations in June 2021. The increasing of DO and chlorophyll-a concentrations were detected at the depth of 5 into 25 m at all stations. Trend of the highest values of DO and Chlorophyll concentrations vertically were different (Fig.5).

The depth of the water column observation (0 – 25 m) of dissolved oxygen content and chlorophyll-a is a euphotic zone that generally has uniform (homogenous) temperature and salinity characteristics. The euphotic zone is an area at a certain depth of water whose intensity of light is sufficient to perform photosynthesis and in those zones is inhabited by phytoplankton with an abundance that varies by area. Euphotic zones generally also have high brightness values. The condition of the results of the measurement of the water's brightness in the study area using secchi disc with its dissolved oxygen concentration displayed in Figure 6. The depth of secchi with the spread of dissolved oxygen content concentration shows the highest dissolved oxygen concentration found at the study site with water brightness levels of 1 and 1.5 meters.

Dissolved Oxygen results show that 80% of the measurement had probability of being below 6.0 mg/L vertically and horizontally. Another trend of the vertical distribution of Dissolved Oxygen (DO) and Chlorophyll-a is the location or station which have value higher below the layer of 0 – 5 meters. The concentration of oxygen at a depth of 5 to 25 meters at the west side research site tends to be higher than the eastern station point. The opposite condition for vertical distribution patterns of chlorophyll at depths of 5 to 25 meters, the highest concentration values are found at research sites around Gili Gede or in the middle area of the study site (Fig 5.). The results showed the depth of water brightness of 1 -1.5 meters found the highest concentration of dissolved oxygen (Fig.6).

Discussion

The result of surface waters temperature has average value indicates that the coastal waters in the Sekotong coastal waters was warmer at the cultivation site of seashell pearl cultivation in Gili Genting area or in the middle area (in Fig.2a). The higher temperature at those stations (in the middle area) was suggested due to physical process such as evaporation (Tchernia, 1980). In tropical waters such as Indonesia sea waters, the variations of sea water temperature throughout the year are not large, sea surface temperatures range from 27^{o}C-35^{o}C, where the temperature is the ideal temperature for life in the sea (Moniharapon *et al*., 2014). Based on the Quality Standards, the temperature of the Sekotong waters is still in the category of both marine life and marine tourism which is ranged between 20 ^{o}C – 30 ^{o}C (Wibisono, 2005 and Setyobudiandi, 1995)

The highest salinity value (31.9 psu) was determined at the point stations in the west site of the study area (Figure 2b) where those stations are connecting to the Lombok Strait. Based on quality standards decree LH No 51 of 2004 the designation of marine lifes, the range of salinity that suitable for the growth of seashell pearl cultivation is 15 – 35 psu.

The result of numeric calculation on the sea surface current velocity in West Lombok (Hendrianti et al., 2018) showed the sea level elevation of the coastal waters of Sekotong in tides reach in to 0.915 m upper the average value of the sea level and the direction of sea surface current moves from the north east to the west and the southwest with the velocity of current is in ranged from 15 to 21 cm/s (Hendrianti, *et al*., 2018).

The stations point on the east side is directly related to Lombok Strait which have influence of Indonesia Througflow (ITF). The influence of Indonesian Throughflow (ITF) passing through the western area of the Lombok Strait is suspected to be the cause of the high value of DO in the western region of the Lombok Strait.The mass of water from the Pacific crosses the western part of the Lombok Strait which has a depth of more than 1,000 m (Hamzah & Trenggono, 2013).

The research results of Susanto *et al*., (2005), stated that north of the Lombok Strait are deeper than the central and southern stations.This is thought to affect the concentration of dissolved oxygen where the flow of water mass moving from the Pacific to the Indies through the Lombok Strait, has its own mechanism to carry oxygen to the inner layer (Ramesh *et al*., 2013).

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The solubility of oxygen in seawater is affected by temperature, with oxygen being more soluble in colder water and less soluble in warmer water. The concentration of oxygen in the atmosphere readily exchanges with the surface ocean, termed 'air–sea gas exchange (Mahaffey et al., 2020). This may explain the condition of the dissolved oxygen concentration in the sea level layer (0-5 meters) at the study site is lower than the oxygen concentration in the lower layer.

Conclusion

The results of measurements of dissolved oxygen content and hydro oceanographic parameters in the coastal waters of Sekotong, West Lombok, West Nusa Tenggara can be concluded that coastal waters that have been utilized for pearl shell cultivation activities, especially in three areas namely Gili Genting, Gili Gede and Autorei have different characteristics of temperature distribution, salinity and current speed.

High oxygen content is found in the water column with a depth of 25 m or below the upper layer (5 m) of the sea pearls are developed or cultivated. This condition indicates that the presence of cultivated sea pearls has utilized dissolved oxygen in the process of respiration and oxidation of organic matter. Dissolved oxygen becomes an important abiotic factor for ecosystems that support the sustainability of marine life and marine aquaculture development efforts.

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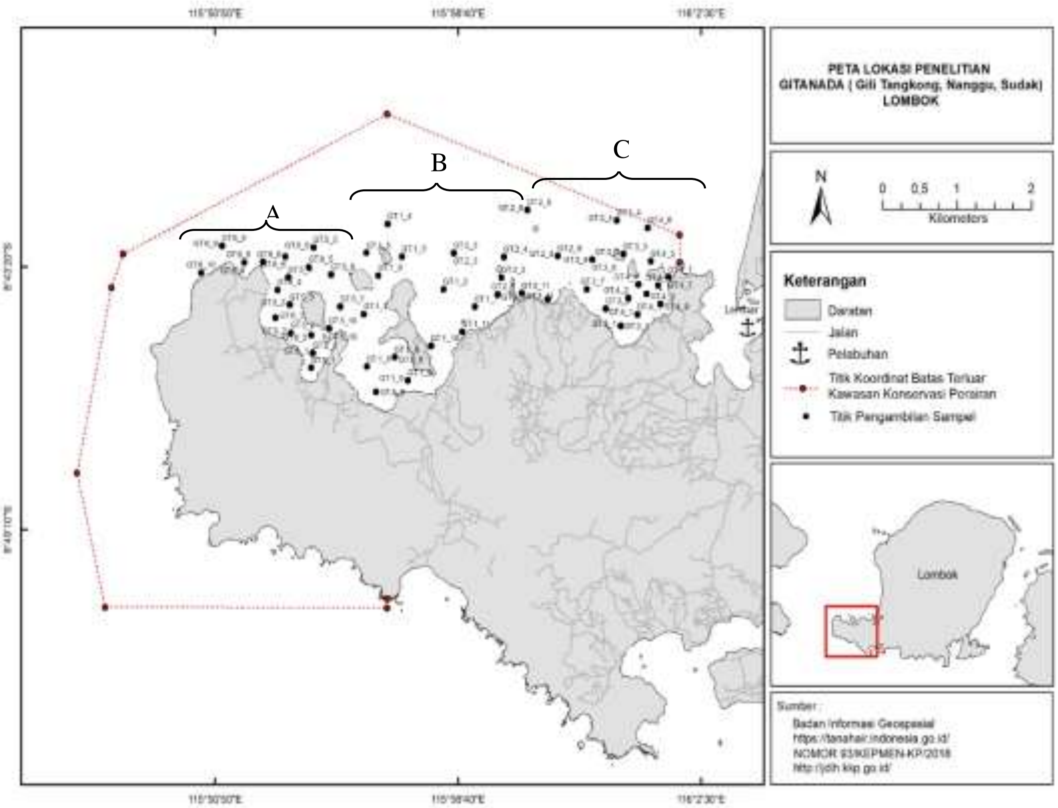

Figure 1. The Coastal Waters of Sekotong, West Lombok, Nusa Tenggara Barat Location Stations of ○ The Sea Pearl Cultivation Development Site, A : West area, B : Middle area, C : East area

Table 1.

Stations Code	Locations	Area
GT.1_1	Gili Genting	Middle
GT.1_2	Gili Genting	Middle
GT.1_3	Labuhan Petung	Middle
GT.1_4	Gili Layar	Middle
GT.1_5	Gili Layar	Middle
GT.1_6	Gili Layar	Middle
GT.1_7	Gili Gede	Middle
GT.1_8	Gili Gede (The Sea Pearl Cultivation)	Middle
GT.1_9 (5 m)	Gili Gede	Middle

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Stations Code	Locations	Area
GT.1_10 (25 m)	Gili Gede (Seagrass & Mangrove)	Middle
GT.1_11 (5 m)	Tanjung Batu Selek (Coral Reef)	Middle
GT.2_1 (5 m)	Gili Genting (The sea pearl cultivation)	Middle
GT.2_2	Gili Lontar	Middle
GT.2_3 (5 m)	Gili Rengit	Middle
GT.2_4	Gili Lontar	Middle
GT.2_6 (5 m)	Gili Rengit	Middle
GT.2_8 (5 m)	Gili Rengit	Middle
GT.3_1 (5 m)	Tawun	East
GT.3_3 (5 m)	Gili Nanggu (sea dolphin)	East
GT.3_4 (5 m)	Gili Nanggu (sea dolphin)	East
GT.3_6 (5 m)	Gili Nanggu	East
GT.3_7	Pandanan	East
GT.3_10	Pandanan	East
GT.3_11 (5 m)	Elak-elak	East
GT.3_8	Tawun	East
GT.4_1	Bukit Tuak	East
GT.4_2	Gili Tangkong (sea turtle)	East
GT.4_3	Gili Sudak	East
GT.4_4	Gili Tangkong (ecotourism)	East
GT.4_5	Gili Sudak	East
GT.4_6	Gili Sudak	East
GT.4_7	Gili Kedis	East
GT.4_8	Gili Sudak (sea turtle)	East
GT.4_8	Gili Sudak	East
GT.5_1	Batu Putih	west
GT.5_2	Gili Asahan	west
GT.5_3	Autorei (The sea pearl cultivation)	west

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Stations Code	Locations	Area
GT.5_4	Autorei (The sea pearl cultivation)	west
GT.5_5	Bangko-bangko	west
GT.5_6	Gili Layar	west
GT.5_7	Gili Layar	west
GT.5_8	Gili Gede	west
GT.5_9	Pewaringan	west
GT.5_10	Tenggolong	west
GT.6_1	Pelabuhan Kores	west
GT.6_2	Gili Asahan	west
GT.6_3	Gelundung	west
GT.6_4	Autorei	west
GT.6_5	Gili Asahan	west
GT.6_6	Tanjung Beberak	west
GT.6_7	Bangko-bangko	west
GT.6_8	Bangko-bangko lokasi kampung nelayan	west
GT.6_9	Pandanan	west
GT.6_10	Tanjung Kablet	west

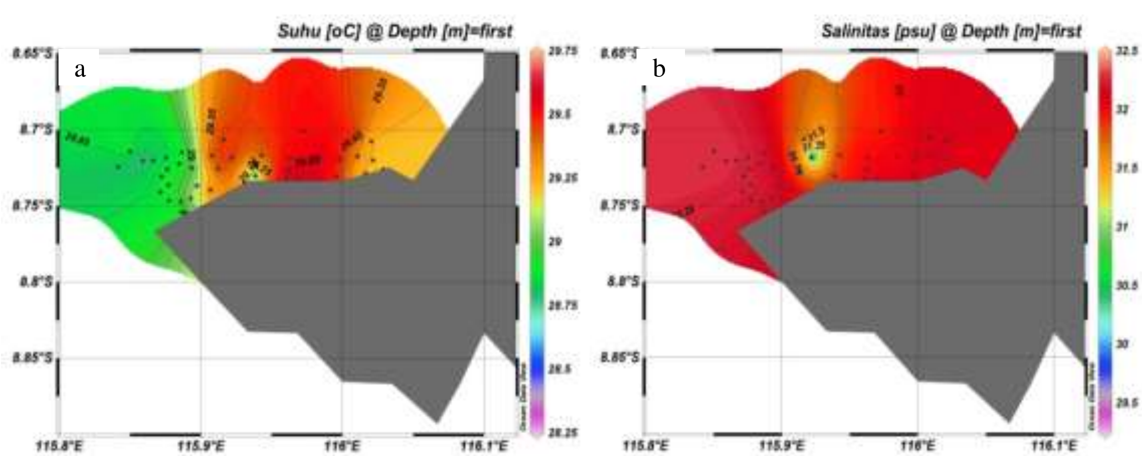

Figure 2. Spatial Distribution of Sea Surface Temperature (a) and Sea Surface Salinity (b)

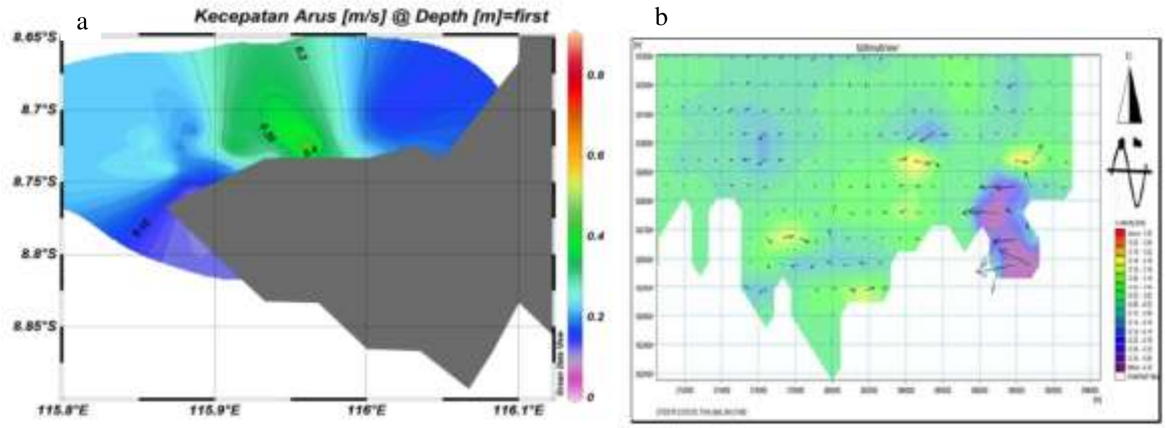

Figure 3. Spatial Distribution of Sea Surface Current Velocity from in situ Meeasurement (a) and from Modelling(Hendrianti et al., 2018) (b)

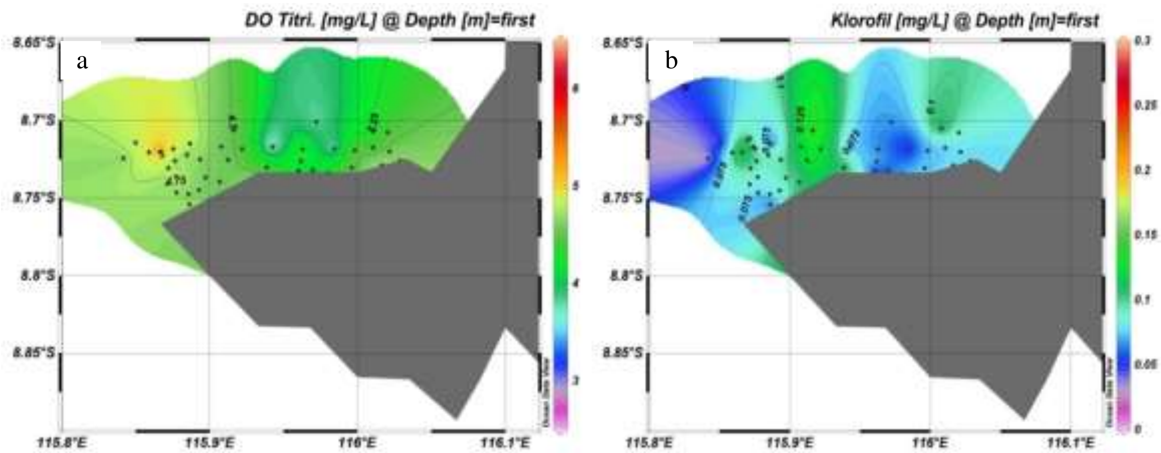

Figure 4. Spatial Distribution of Dissolved Oxygen (a) and Chlorophyll-a (b)

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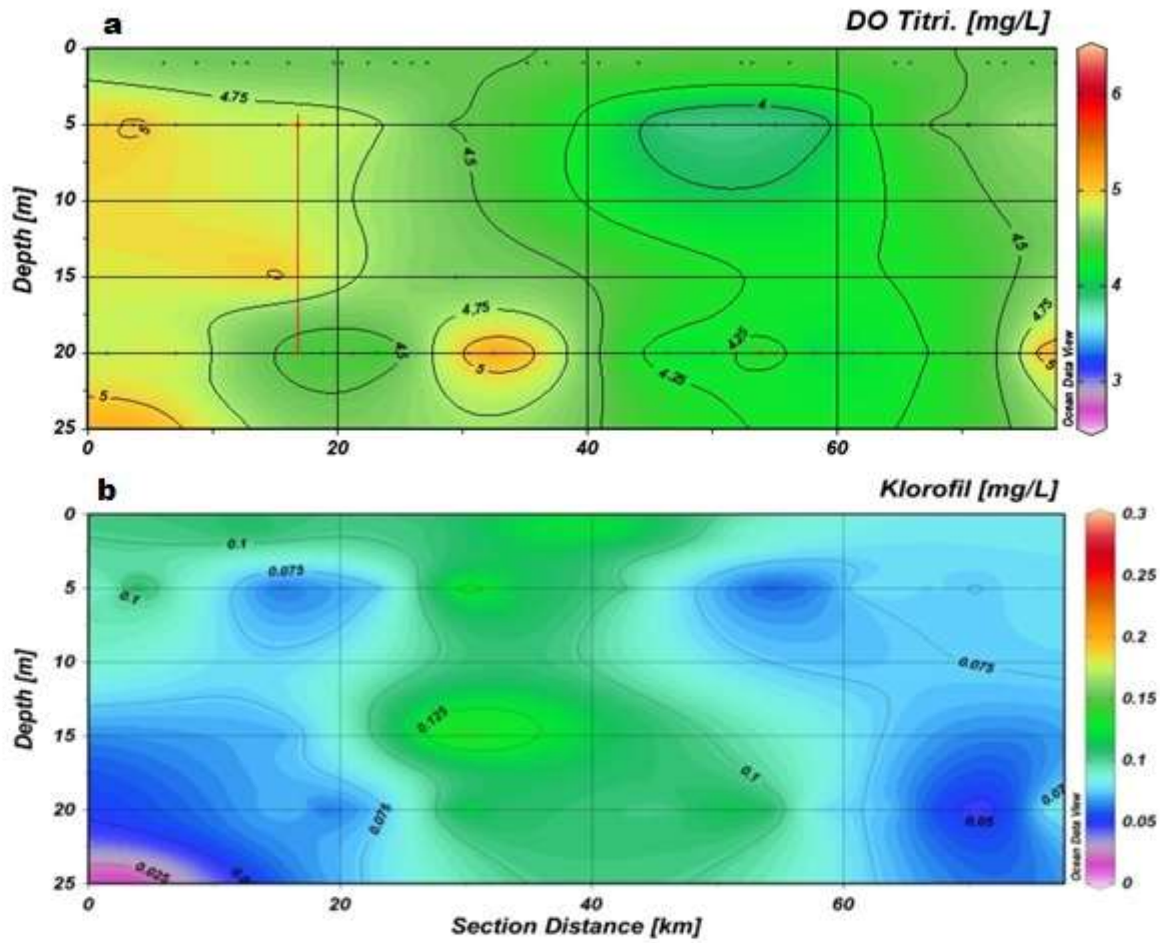

Figure 5. The vertical profiles of Dissolved Oxygen (a) and Chlorophyll a (b)

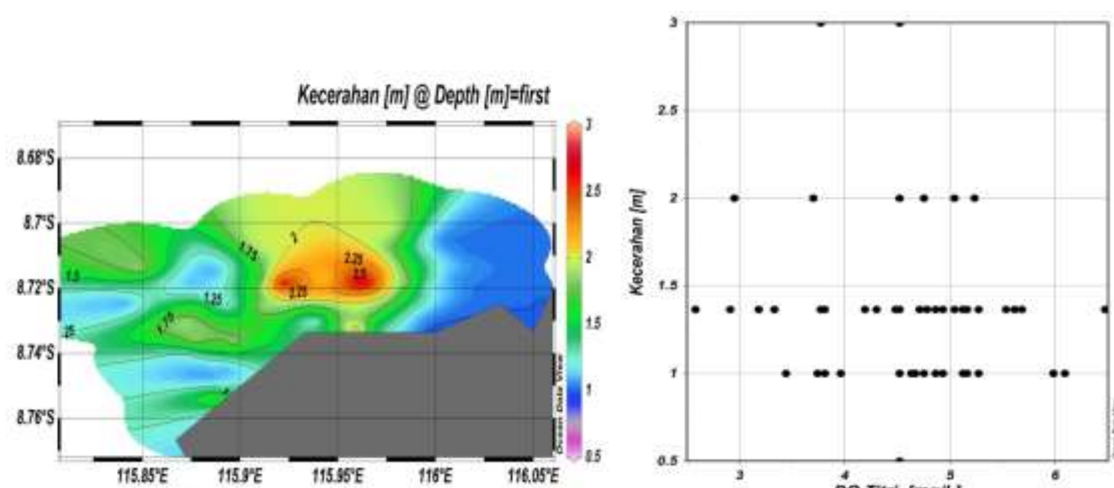

Figure 6. Spatial distribution of brightness in meter (a) and section of brightness and oxygen (b)