Spatial distribution and biophysics chemistry characterization of Pearl Oyster farming in Semau Strait, East Nusa Tenggara

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Abstract. Pearl oyster is one of marine organisms which has high of economic value. One of Indonesia region that potential for pearl oyster farming activity is Semau Strait-East Nusa Tenggara. The purpose of this study is mapping and characterize spatial distribution based on biophysics chemistry condition of pearl oyster farming. Mapping using Geographic Information System (GIS) tools, while grouping and characterize using hierarchical clustering and Mann-Whitney method. Grouping based on character similarity of biophysics chemistry divided the stations distribution into three groups: Group I is excellent group, Group II is good group and Group III is bad group for pearl oyster farming. Group I is excellent area because it has the highest values of dissolved oxygen, chlorophyll-a, and phytoplankton abundance. Group III is bad area because it temperature is high relatively.

1. Introduction

Pearl oyster is one of fisheries resources which has high economic value in Indonesia. The harvest of oyster can be used as jewellery or cosmetic ingredients. Sustainable utilization of pearl oyster resource is very needed, because of pearl market demands are increase. However, the oyster in nature getting limited. Marine culture is one of way to preserve the nature conditions [1]. Technology of pearl oyster farming to produce pearl can take oyster with or within nucleus [2]. An oyster has a double function, they are as the mantle tissue and recipients of mantle donor [3]. A region of Indonesia that potential for pearl oysters farming is Semau Strait, which is that area connecting from Kupang-East Nusa Tenggara to Semau Island.

The condition of biophysics chemistry such as temperature, salinity, pH, dissolved oxygen, ammonia, nitrate, orthophosphate, silica, chlorophyll-a, and phytoplankton abundance are the important parameters to determine of water quality condition. Information about distribution and characterization of biophysics chemistry is needed for pearl oysters farming, thus to know the dynamics of aquatic environments and monitoring in the pearl oyster farming areas.

Distribution of water quality condition can be interpreted by mapping. Mapping is a communicative way to provide information related biophysics chemistry quality in the water. Mapping

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use Geographic Information System. Geographic Information Systems (GIS) is tools used to collect, store, manipulate, analyse, and display of spatial information in map. GIS is a program that converts data become an attractive information to communicate and support to decision-making [4].

GIS can be used to transform the information into maps through analysis tools. GIS can present the maps as like as display pictures [5]. GIS also can inform character of the resource, identify the potential, and analysis of area suitability for its purpose [6]. One of analysis tools in GIS is spatial analysis [7]. Spatial analysis are working through data interpolation principle and linked the score in each station [8], so the score in the field sample which cannot be taken can be predicted by interpolation in GIS. The purpose of this study are mapping and characterize the spatial distribution based on biophysics chemistry condition in the pearl oyster farming, Semau Strait-East Nusa Tenggara.

2. Methods

2.1 Time and Location

The research consist are observations and sampling in 20 points of pearl oyster farming, Semau Strait - East Nusa Tenggara (figure 1). Field research conducted in December 2015.

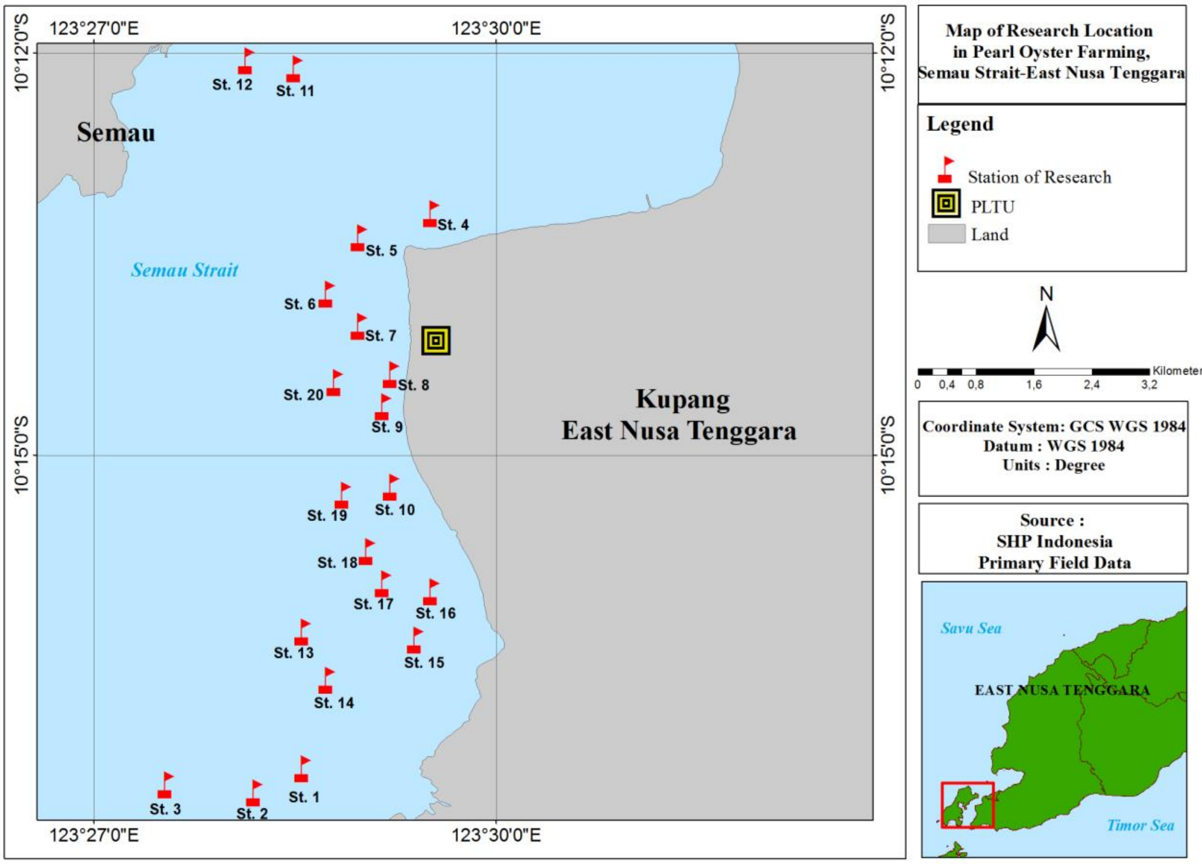

Figure 1. Research Location

Parameter analysis and data processing in Aquatic Productivity and Environment Laboratory, Micro Biology Laboratory and Mapping and Geospatial Modelling Laboratory, FPIK-IPB. The activity was conducted in January-March 2016.

2.2 Data Collecting
Total research points are 20, horizontally on the surface of the sea. The primary data consists are physics, chemistry, and biology parameters. Physic parameter is temperature. Chemistry parameters are salinity, pH, dissolved oxygen, nitrate, orthophosphate, ammonia and silica. Biology parameters are chlorophyll-a and phytoplankton. Research are in situ observed at the field and analysis laboratory. Biophysics chemistry parameters analysis refer to standard method of [9] that shown below on table 1.

Table 1. Collecting biophysics chemistry parameters data

Parameters	Units	Tools	More information
Physic			
Temperature	°C	Thermometer	*in situ*
Chemistry			
Salinity	‰	Refractometer	*in situ*
pH		pH paper	*in situ*
Dissolved oxygen	mg/L	DO meter	*in situ*
Nitrate	mg/L	Spectrophotometer	Laboratory
Silica	mg/L	Spectrophotometer	Laboratory
Orthophosphate	mg/L	Spectrophotometer	Laboratory
Ammonia	mg/L	Spectrophotometer	Laboratory
Biology			
Chlorophyll-a	mg/m^3	Spectrophotometer	Laboratory
Phytoplankton	$cell/m^3$	SRC (*Sedgwick Rafter Chamber*)	Laboratory

2.3 Data Analysis
Data were collected analysed by spatial and statistical analysis. Spatial analysis using Geographic Information Systems (GIS) which spline with barrier interpolation method. Meanwhile, statistical analysis use hierarchical clustering and Mann-Whitney as the methods. Spatial analysis have function to determine the distribution of parameters in study area, spatially. Statistical analysis used to determine the similarity based on the score range of biophysics chemistry parameters and significant differences in each groups. Group of station generated from spatial analysis based on distribution, hierarchical clustering, and further correction through Mann-Whitney. Then, characterized based on significant differences in each groups.

3. Result and Discussion
Human factor only affect about 10% influence the growth rate, such as determining the hue and size of pearls oyster that produced [10]. In the other hand, the most important factor for pearl oyster growth is environment factors. Thus, biophysics chemistry parameters is needed to observe. Table 2 shown on the result of biophysics parameters.

Observation of chlorophyll-a, phytoplankton abundance and temperature as biophysics parameters at 20 stations provide different results on each station observation. Based on the table known that the highest value of chlorophyll-a, phytoplankton and temperature are is 2.198 mg/m3, 14900 sel/m3 and 34oC. Moreover, the lowest are 0.308 mg/m3, 3898 sel/m3 and 28oC.

Chlorophyll-a is a pigment in phytoplankton to photosynthesis reactions and produce of organic compounds. Chlorophyll-a pigment is the most dominant and the largest in comparison with chlorophyll-b and chlorophyll-c [11]. However, phytoplankton are plankton species that have function to photosynthesis and primary productivity in the aquatic. Phytoplankton also have the important function in pearl oyster farming. Phytoplankton is the main food of pearl oysters, because they are filter feeders organism. Hence it, they need phytoplankton as their feeds. Phytoplankton and organic matter in the aquatic is obtained through gills absorption or membrane coat of pearl oyster [12].

Table 2. The observation result of pearl oyster farming biophysics parameters

Parameters Stations	Biology		Physic
	Chlorophyll-a (mg/m^3)	Phytoplankton (sel/m^3)	Temperature (°C)
1	0.663	14900	28
2	0.339	14277	29
3	0.576	12663	28
4	1.599	4687	31
5	0.866	5200	32
6	0.543	4398	33
7	0.308	3898	34
8	0.732	9429	34
9	0.663	5269	34
10	0.766	6199	32
11	0.486	5834	30
12	1.687	5805	32
13	2.198	8693	31
14	1.123	6604	31
15	0.952	4930	31
16	0.935	10840	30
17	1.258	5563	30
18	0.646	8700	30
19	0.647	10862	30
20	0.953	8439	30

Based on spatial analysis result known that the chlorophyll-a in the pearl oyster farming ranges from 0308-2198 mg / m3. The highest of chlorophyll-a found at Station 13 and the lowest of chlorophyll-a at Station 7. Chlorophyll-a in some stations have not linier relation with phytoplankton abundance. It can be caused by phytoplankton distribution and it batimetry. Phytoplankton abundance in pearl oyster farming ranges from 3898-14900 cells / m3. The highest of phytoplankton abundance found at Station 1 and the lowest of phytoplankton abundance at Station 7. Phytoplankton which have the highest abundance are *Chaetoceros* sp. *Chaetoceros* sp. dominan in the aquatic due to this genus have growth rates higher than dinoflagellates group. *Chaetoceros* sp belong to the Bacillariophyta genus is dominant in the aquatic because has the ability to synthesize of nutrients, highly. *Chaetoceros* sp. also can save the nitrate and phosphate compounds as feed reserves in their cells [13]. Research of pearl oyster feed habits conducted by [14] stated that the main feed of pearl oyster is *Chaetoceros* sp. which belong to the Bacillariophyta.

Sea surface temperature is one of essential factor for living organisms in the sea. Temperature can affect the metabolic activity and proliferation of aquatic organisms [15]. Temperature also can describing that aquatic still be inhabited by aquatic organisms [16]. Sea surface temperatures in the upper layer is relatively homogeneous. In tropic, the homogeneous layer (mixed layer) in the depth of 50 m to 100 m [17].

Based on the results of spatial analysis known that the temperature in the pearl oyster farming have ranges between 28-34oC. The highest temperature are located at Station 7, 8 and 9 while the lowest temperature are located at Station 1 and 3. Some station point in the pearl oyster farming have the temperature higher than other, because the stations close with power plant activity. The disposal of hot waste water discarded into aquatic system, while around the aquatic there are some pearl oyster farming activities. The aquatic temperature increased by 10°C causes increase 2-3 times in oxygen consumption by aquatic organisms. Increasing temperatures can also cause increasing in the organic matter decomposition by phytoplankton [18]. Extreme increased of temperature can cause disruption for aquatic organisms metabolism and physiology. Near of mainland has lower salinity than the salinity where near of open sea. The condition occurs because near of mainland, the water quality are still influenced by river runoff. Therefore, salinity distribution was influenced by rainfall seasons, topography, tidal and evaporation [19].

The study also got information on chemistry parameters such as salinity, pH, dissolved oxygen, nitrate, silica, orthophosphate and ammonia. The result of chemistry parameter shown on table 3.

Table 3. The observation result of pearl oyster farming chemistry parameters

Parameters Stations	Salinity (‰)	pH	Dissolved Oxygen (mg/L)	Nitrate (mg/L)	Silica (mg/L)	Orthophosphate (mg/L)	Ammonia (mg/L)
1	35	7	10.3	0.066	0.291	0.025	0.08
2	36	7	10.2	0.059	0.194	0.023	0.063
3	37	7	8	0.034	0.172	0.023	0.082
4	35	6.5	9.5	0.009	0.104	0.031	0.072
5	35	6	10.9	0.004	1.592	0.026	0.08
6	34	7	8.1	0.001	0.179	0.03	0.094
7	33	6.5	8.4	0.016	0.196	0.035	0.067
8	33	6.5	8.5	0.014	0.316	0.035	0.109
9	33	6.5	8.8	0.015	0.316	0.031	0.135
10	35	7	11.1	0.025	0.264	0.036	0.098
11	36	7.5	9.2	0.053	0.111	0.033	0.166
12	35	7.5	8.5	0.009	0.206	0.049	0.099
13	37	7.5	6.3	0.028	0.386	0.051	0.161
14	37	7.5	7.9	0.037	0.615	0.034	0.166
15	36	6.5	3.9	0.026	0.311	0.067	0.234
16	35	6	4	0.019	0.564	0.063	0.177
17	34	7	5.6	0.025	0.554	0.034	0.162
18	35	7	5.5	0.016	0.773	0.042	0.189
19	35	6.5	3.3	0.018	0.211	0.02	0.206
20	36	6.5	3.7	0.031	0.537	0.033	0.308

Observation of salinity, pH, dissolved oxygen, nitrate, silica, orthophosphate, ammonia as chemistry parameters at 20 stations gave different results on each station observation. Based on the table known that the highest value of salinity, pH, dissolved oxygen, nitrate, silica, orthophosphate, ammonia are 37‰, 7.5, 11.1 mg/L, 0.308 mg/L, 0.066 mg/L, 0.67 mg/L, 1.592 mg/L. Besides, the lowest are 33‰, 6, 3.3, 0.063 mg/L, 0.001 mg/L, 0.020 mg/L, 0.104 mg/L.

Toxicity of chemical compounds are affected by pH. Alkaline conditions (high pH) are commonly form non-ionized ammonia and toxic. Some stations have a low pH value ranged of 6-6.5. That assessment because the station near the coast allow for anthropogenic pollution and an acidic waters in the rainy season. Rainwater contains carbonic acid that may affect the acidity in the waters [20].

Based on results of spatial analysis known that salinity in the pearl oyster farming ranges 33-37 ‰. The highest salinity located at station 13 and 14, while the lowest salinity at Station 7. 8 and 9. Salinity differences affect to aquatic organisms especially in osmotic pressure. The balance of osmotic pressure in the aquatic organisms need stabilized to make balance between internal and external fluid. Large fluctuations can affect the performance of internal and external fluids of organisms and in the pearl oyster [11]. Besides, pH in pearl oysters farming ranges from 6 to 7.5. The pH value of this research still within the range allowed for marine culture [21]. The pH value still to be volatile until reaches ≥ 4 concentration in the maximum salinity up to 35 ppm [22]. The pH value still in the normal range if they have value ranges of 6-8 [16]. Otherwise, if pH value is less than 6 will affect the diversity and abundance of phytoplankton [18].

Dissolved oxygen are used by marine organisms for respiration. Sources of dissolved oxygen comes from atmosphere and photosynthesis activity by aquatic plants and phytoplankton [18]. Marine organisms need oxygen in sufficient concentration. The concentration of dissolved oxygen in the water less than 5.0 mg/L induce to decrease of marine organisms types even will die [18]. However, dissolved oxygen used by phytoplankton for photosynthesis.

Based on spatial analysis known that the dissolved oxygen in pearl oysters farming ranges from 3.3 to 11.1 mg/L. The highest of dissolved oxygen at station 10 and the lowest at station 19. The values of dissolved oxygen in the research has the lowest value in the coastal which near mainland. It related to the turbidity of seawater and caused by increasing microorganisms activity to break down organic matter into inorganic substances that use dissolved oxygen in these waters [23]. Horizontally, dissolved oxygen concentration will decrease if go to the onshore [24]. Some stations such as stations 19 and 20 have low dissolved oxygen. It caused that the station uses a raft system that has lack of covering the pearl oyster farming area to photosynthesis, consequently the photosynthesis process is inhibited. That is giving impact are declining the dissolved oxygen caused by respiration and decomposition (decomposition) process of organic matter and evaporation processes [25]. Declining of dissolved oxygen is inverse to the increasing levels of ammonia. It was shown at station 20. Station has low pH values induce the low of dissolved oxygen while increasing carbon dioxide concentrations [18]. Carbon dioxide is a form of gases from respiration result [16].

Some of ammonia source in the water are from breakdown of organic nitrogen (protein and urea) and contained both inorganic nitrogen in the soil and water from organic materials decomposition such as aquatic organisms had death [18]. The excessed of ammonia value will interfere the growth of marine culture organisms [26]. The un-ionised ammonia is more easily absorbed into the aquatic organisms as compared to ammonium [18]. Based on the results of spatial analysis are known that the ammonia in the pearl oyster farming ranges from 0.063 to 0.308 mg / L. The highest ammonia at station 20 and the lowest at station 2. According to data, ammonia value was high and exceeds the threshold, it can be an indicator of organic matter contamination derived from domestic sewage, industrial and river runoff. Some points of the research station has high ammonia value compared with other stations point. It was induced that some stations close to the mainland which there are settlements and rivers in the region. However, some of the station point applied raft system in the pearl oyster farming to give higher ammonia input compared with the floating system. This was caused, raft systems contain higher organic matter from wood or bamboo and there was activity and preparation work hut X-ray pearl oysters in the area around the station.

Nitrate (NO3) is the main form of nitrogen and a major nutrient for the growth of aquatic plants and phytoplankton. Nitrate is soluble in the water and stable [18]. Nitrates are not toxic for aquatic organisms and relatively stable to aquatic plants and phytoplankton in the quality standards of set limits. The high nitrate value in the waters near the river run of, that is suspected because of the organic material input from any settlement or other anthropogenic activities. Based on the results of spatial analysis known that nitrate in the pearl oysters farming ranges from 0.001 to 0.066 mg/L. The highest nitrate contained in Station 1 and the lowest nitrate contained in Station 6.

Orthophosphate is a form of soluble phosphate. Source orthophosphate is derived from the decomposition of organic materials. Industrial waste, domestic waste, and other anthropogenic activities, such as waste of detergent [18]. Orthophosphate acts as a nutrient in the water. The nutrients can be used to help the photosynthesis performed by aquatic plants and phytoplankton. Orthophosphate value is relatively high in the waters where near river. It is suspected because of the input of organic material from any settlement or other anthropogenic activities. Based on the results of spatial analysis known that orthophosphate in the pearl oyster farming ranges from 0.02 to 0.067 mg/L. The highest of orthophosphate at stations 7 and 8, and the lowest at station 19.

Generally, silica in the aquatic are soluble or bonded to the element oxide (SiO4). The existence of silica does not generated toxic. Silica is an essential element for living beings. Some algae, especially diatoms (Bacillariophyta) requires frustule or silica to form the cell wall [18]. Based on the results of spatial analysis known that the silica in the pearl oysters farming ranges from 0.104 to 1.592 mg/L. Source of silica in the coastal commonly from the weathering of soil minerals containing silica, then dissolved in streams [27]. The silica value at stations where close to the coast is relatively high compared with other station area. Station 5 has the highest concentration, because rocks from the beach morphology entered into the sea. Additionally, high silica can be caused by high mineral content in the aquatic. That is related to the condition of water bottom substrate and water depth

Grouping station by similarity of biophysics chemistry character in the pearl oyster farming Semau Strait-East Nusa Tenggara in December 2015 shown in figure 2.

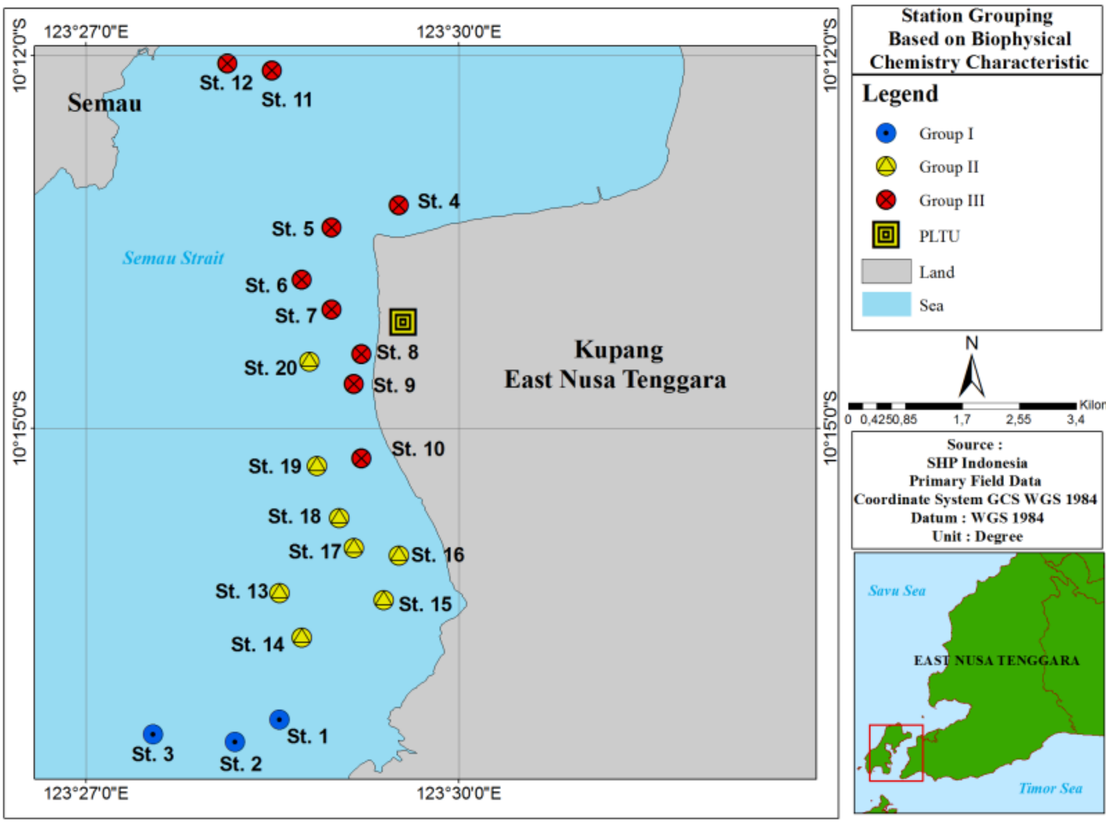

Figure 2. Station grouping by aquatic biophysics chemistry character similarity in pearl oyster farming

Based on the data, whole stations are dividing into four groups: Group I consists of Stations 1, 2 and 3; Group II consists of stations 13, 14, 15, 16, 17, 18, 19 and 20; Group III consists of Station 4, 6, 7, 8, 9, 10, 11 and 12; and Group IV is Station 5. Then the correction of the Mann-Whitney known there are no significant differences between group IV with three other groups. Furthermore. The identified within the nearest known that Group IV. Group IV has a closeness with Group III. Based on the analysis. grouping stations are divided into three groups: Group I consists of Stations 1, 2. and 3; Group II consists of stations 13, 14, 15, 16, 17, 18, 19 and 20; and group III consists of stations 4, 5, 6, 7, 8, 9, 10, 11 and 12.

Spatially, grouping station by similarity of aquatic biophysics chemistry character divided into three groups: Group I, II and III. Similarities of biophysics chemistry influenced by morphology area and the distance between stations. Morphology of area has same character and location of each station could be expected to provide the effect between the stations. Group I is the excellent group for pearl oyster farming, the located quiet far to the coastal area that has a lot of anthropogenic activities and power plant. The second group is the group that located in the centre of all area in pearl oyster farming and away from the power plant activities. That area is close to the coast and estuaries. Group II is good group. Group III is the closest group to power plant activities. Group III is bad group for pearl oyster farming. Group I is the excellent group for pearl oyster farming activities because it has the highest value of dissolved oxygen, chlorophyll-a and phytoplankton abundance compared to other groups. Group II is good group for pearl oyster farming activities, but need monitoring of increasing in nutrients and eutrophication in the area. Group III is bad group for pearl oyster farming activities because it has high temperature

Significant differences of parameters between Group I and Group II contained in ammonia, temperature, dissolved oxygen, nitrate, silica, chlorophyll-a and phytoplankton abundance parameters. Chlorophyll-a, dissolved oxygen and phytoplankton abundance in Group I are higher than Group II. Significant differences of parameters between Group I and III contained in temperature. Salinity, nitrate, orthophosphate and phytoplankton abundance. Temperature in Group III is higher than Group I. The significant difference of parameters between Group II and III contained in temperature, salinity, silica, dissolved oxygen, nitrate, ammonia and phytoplankton abundance. Temperatures in Group III is higher than Group II.

Further research is needed to determine the suitability, carrying capacity of area, monitoring of biophysics and chemistry parameters in pearl oysters farming-Semau Strait, temporally. The influence of marine environment and the study of pearl oysters on integrated coastal management of each stakeholder in the coastal area, Semau Strait-East Nusa Tenggara.

4. Conclusion

Spatial mapping by biophysics chemistry similarity dividing the stations into three groups. Group I consists are Stations 1, 2 and 3; Group II consists are stations 13, 14, 15, 16, 17, 18, 19 and 20; and group III consists are stations 4, 5, 6, 7, 8, 9, 10, 11, and 12. All groups have different characteristics and categories for pearl oyster farming activity. Group I is excellent group, because it group has the highest values of dissolved oxygen, chlorophyll-a, and phytoplankton abundance. Group II is good group, because it group has moderate biophysics chemistry quality in each parameters and Group III is bad groups, because it group has high temperature.

Acknowledgement

Authors wishing acknowledge, especially for financial support from Collaborate Research Project between IPB and Ehime University. Therefore, special for our research location in PT Timor Otsuki Mutiara Kupang, East Nusa Tenggara and those technical staff who help us. Besides, acknowledge to Laboratory of Aquatic Productivity and Environmental, Bogor Agricultural University, Laboratory of Micro Biology, Bogor Agricultural University and Laboratory of Mapping and Geospatial Modelling, Bogor Agricultural University

References

[1] Kordi K M G H 2011 Marikultur: Prinsip dan Praktik Budidaya Laut (Yogyakarta: Lily Publisher)
[2] Cartier L E and Krzemnicki M S 2013 New Developments in farming pearl production: Use of organic and Baroque Shell Nuclei *Journal of The Australian Gemmologist* **25** 6-13
[3] Hanni H A 2007 A Description of pearl farming with Pinctada Maxima in South Asia *Journal Gemmoligist* **30** 357-365
[4] Bunch M J 2012 Using geographic information systems (GIS) for spatial planning and environment management in India: Critical considerations *International Journal of Applied Science and Technology* **2** 1-15
[5] Wedding L M, Gibson B A, Walsh W J and Battista 2011 Integrating remote sensing products and GIS tools to support marine spatial management in West Hawai *Journal of Conservation Planning* **7** 60-73
[6] Yunandar 2007 *Analisis pemanfaatan ruang di kawasan pembangunan perikanan pesisir muara kintap Kabupaten Tanah Laut Propinsi Kalimantan Selatan* thesis (Semarang: Dipenogoro University)
[7] Daly C 2006 Guidelines for Assessing the Suitability of Spatial Climate Data Sets *International Journal of Climatology* **26** 707-721
[8] Chiu C A, Lin P H and Lu K C 2009 GIS-based tests for quality control of meteorological data and spatial interpolation of climate data *Journal of Mountain Research and Development* **29** 339-349
[9] APHA, AWWA, WEF 2005 *Standard Methods for examination of water and wastewater 22nd ed*. (Washington: American Public Health Association) pp 1360
[10] Harramain E H M 2008 *Kajian Faktor Lingkungan Habitat Kerang Mutiara (Stadia Spat) di Pulau Lombok, Nusa Tenggara Barat* undergraduate thesis (Bogor: Bogor Agricultural University)
[11] Kangkan A L 2006 *Studi Penentuan Lokasi untuk Pengembangan Budidaya Laut berdasarkan Parameter Fisika. Kimia dan Biologi di Teluk Kupang. Nusa Tenggara Timur* undergraduate thesis (Semarang: Dipenogoro University)
[12] Lucas J S dan Southgate P C 2003 *Aquafarming: Farming Aquatic Animals and Plants* (Australia: Blackwell Publishing)
[13] Sahubawa L 2001 Dampak pembuangan limbah terhadap perubahan kualitas oseanografi biofisik kimia dan produksi ikan teri (*Stolephorus spp.*) di Perairan Laut Teluk Ambon *Jurnal Manusia dan Lingkungan* **8** 15-29
[14] Anwar K, Toelihere M, Affandi R, Azwar N R dan Etty R 2004 Kebiasaan makan tiram Mutiara Pinctada maxima di Perairan Teluk Sekotong, Lombok *Jurnal Ilmu-Ilmu Perairan dan Perikanan Indonesia* **11** 73-79
[15] Limbong M 2008 *Pengaruh Suhu Permukaan Laut terhadap Jumlah dan Ukuran Hasil Tangkapan Ikan Cakalang di Perairan Teluk Palabuhanratu, Jawa Barat* undergraduate thesis (Bogor: Bogor Agricultural University)
[16] Purba N P and Khan A M A 2010 Karakteristik fisika-kimia perairan Pantai Dumai pada musim peralihan *Jurnal Akuatika* **1** 69-83
[17] Sediadi A 2004 Efek upwelling terhadap kelimpahan dan distribusi fitoplankton di perairan Laut Banda dan sekitarnya *Jurnal Makaira Sains* **8** 43-51
[18] Effendi H 2003 *Telaah Kualitas Air* (Yogyakarta: Kanisius)
[19] Nybakken J W 2000 *Biologi Laut: Suatu Pendekatan Ekologis* (Jakarta: Gramedia)
[20] Wardhani N K Ihwan A and Nurhasanah 2015 Studi tingkat keasaman air hujan berdasarkan kandungan gas CO_2, SO_2 dan NO_2 di Udara *Jurnal Prisma Fisika* **3** 9-14
[21] Keputusan Menteri Kependudukan dan Lingkungan Hidup No 2 Tahun 1988 tentang Pedoman Penetapan Baku Mutu Lingkungan diperuntukkan budidaya perikanan biota laut

[22] Lucas J S and Southgate P C 2003 *Aquaculture: Farming Aquatic Animals and Plants*. (Australia: Blackwell Publishing)
[23] Patty S I, Hairati A and Malik S 2013 Zat Hara (Fosfat, Nitrat), Oksigen Terlarut, dan pH Kaitannya dengan Kesuburan di Perairan Jikumerasa, Pulau Buru *Jurnal Pesisir dan Laut Tropis* **1** 43-50
[24] Nybakken J W 1988 *Biologi Laut: Suatu Pendekatan Ekologis* (Jakarta: Gramedia)
[25] Armita D 2011 *Analisis Perbandingan Kualitas Air di Daerah Budidaya Rumput Laut dengan Daerah Tidak Ada Budidaya Rumput Laut. di Dusun Malelaya. Desa Punaga, Kecamatan Mangarabombang, Kabupaten Takalar* undergraduate thesis (Makassar: Universitas Hasanuddin)
[26] Kordi K M G H and Tancung A B 2007 *Pengelolaan Kualitas Air dalam Budidaya Perairan* (Jakarta: PT Rineka Cipta)
[27] Lukman M, Nasir A, Amri K, Tambaru R, Hatta M, Nurfadilah and Rahmat J N 2014 Silikat Terlarut di Perairan Pesisir Sulawesi Selatan *Jurnal Ilmu dan Teknologi Kelautan Tropis* **6** 461-478