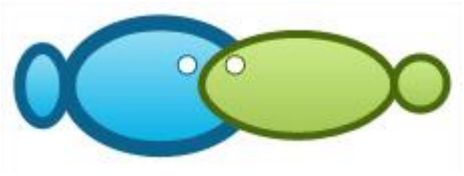

Suitability analysis of pearl oyster farming in Lampung Bay, Pesawaran, Lampung Province, Indonesia

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Abstract. Pearl oyster is fishery product which has a promising prospect. Lampung Province has a potential area of 2260.5 ha. Efforts in pearl oyster farming in the Lampung Bay have been done in Pidada area, and Cape of Putus, however it still failed. Therefore, it is necessary to analyze the level of suitability for pearl oysters farming in the Lampung Bay. Survey method was applied through spatial and temporal approach. The data used in this study were derived from primary and secondary data. Geo-statistical model was used as a form of mapping the earth's surface (biotic and abiotic) through statistical applications. To obtain the suitability class, a suitability matrix of water for physical, chemical and biological parameters was created. Based on the scoring result, it is known that the waters of Lampung Bay is very suitable as pearl oyster cultivation area, especially in the area around the station of 9, 10, 11, 12 (around Puhawang Island), 13, 14, 15 station (around Maitem and Tegal Islands) and station 18 which the farming location belongs to private enterprise (PT. Kyoko Shinju).
Key words: pearl oysters, Lampung Bay, fish farming, suitability analysis.

Introduction. Pearl oyster is fishery product with promising prospect. Until now, the pearl industry still relies on fishing activities from nature. Pearl oyster farming activities have a positive impact, including on reducing fishing oyster from the wild in order to maintain stocks in nature (Haws et al 2010). Pearl oyster farming can also reduce waste/pollutant in coastal water (Gifford et al 2005). Some countries have been developing the pearl oyster farming including, Australia (Wells & Jernakoff 2006), Mexico (Saucedo et al 2007), China (Zhifeng et al 2009), Japan (Fukumori et al 2008; Nagai 2013), and French Polynesia (Andréfouët et al 2012). Most of the farming activities in Indonesia focus on pearl production as compared with oysters for consumption (Rimmer et al 2013). Indonesia has the potential as an industrial area of pearl oysters, not only because it has a stable natural conditions throughout the year, but also because the type of pearl oysters produced in Indonesia is superior to those produced in other countries (Suryanto et al 2005).

Lampung Province is one of area that has the potency of pearl oyster farming. The potency of pearl oyster farming in the Lampung Bay, Indonesia is 3260.5 ha, whereas in 2008 about 2560.50 ha of area has been utilized. Based on data from DKP Pesawaran (2010), the utilization rate of marine culture was approximately ± 73.19% so that the potential of aquaculture can be developed by 26.81%. Pearl oyster cultured in Indonesia is Pinctada maxima (Goldlip Pearl Oyster)(Suryanto et al 2005). Some examples of pearl oyster farming practices developed in Indonesia are located in Papua Barat (Lee et al 2008) and the Province of the South East Sulawesi (Aslan et al 2015).

Pearl farming activities require a location that is free of waste and pollution (Chellam et al 1987). Efforts in pearl oyster culture in the Lampung province had ever been performed in Kyoko, Pidada, and Cape of Putus. However, based on observations, oyster farming was successfully carried out only in the Kyoko area while it failed in Pidada area and cape of putus. Several factors affecting the success or failure of pearl farming activities including physical factors, water quality, biology, and anthropology factor (Suryanto et al 2005). It is also disclosed by (Pouvreau & Prasil 2001) that the environment (the presence of food and temperature) as well as the condition of cultivated land (density, depth, and competitors) are the dominant factors. The purpose of this study is to analyze the degree of suitability of Lampung Bay waters for pearl oyster farming based on ecosystem variables, as well as to determine the appropriate mariculture zoning for pearl oysters. Therefore, this research is expected to minimize the failure of pearl oyster farming in the Lampung Bay.

Material and Method. The study was conducted in April-May 2012 in the waters of Lampung Bay, Pesawaran Regency, Lampung Province, Indonesia. The location was one of Minapolitan development areas. The method used in this study was a survey method through spatial and temporal approach. Spatial approach was carried out to presenting and modeling the spatial aspects of the phenomenon, while the temporal approach was taken to present water conditions at a certain time.

Determining the sampling location. Research was conducted in multiple use zone in Lampung Bay. Determination of the observation point was designed by using purposive sampling method. Sampling point as many as 20 stations were expected to represent all the conditions of the waters by considering the 'ecological preference' of species cultured, that is the pearl oyster (Table 1). Coordinates of sampling were recorded by using the Global Positioning System (GPS) with the format (latitude; longitude). Map of research sites is shown in Figure 1.

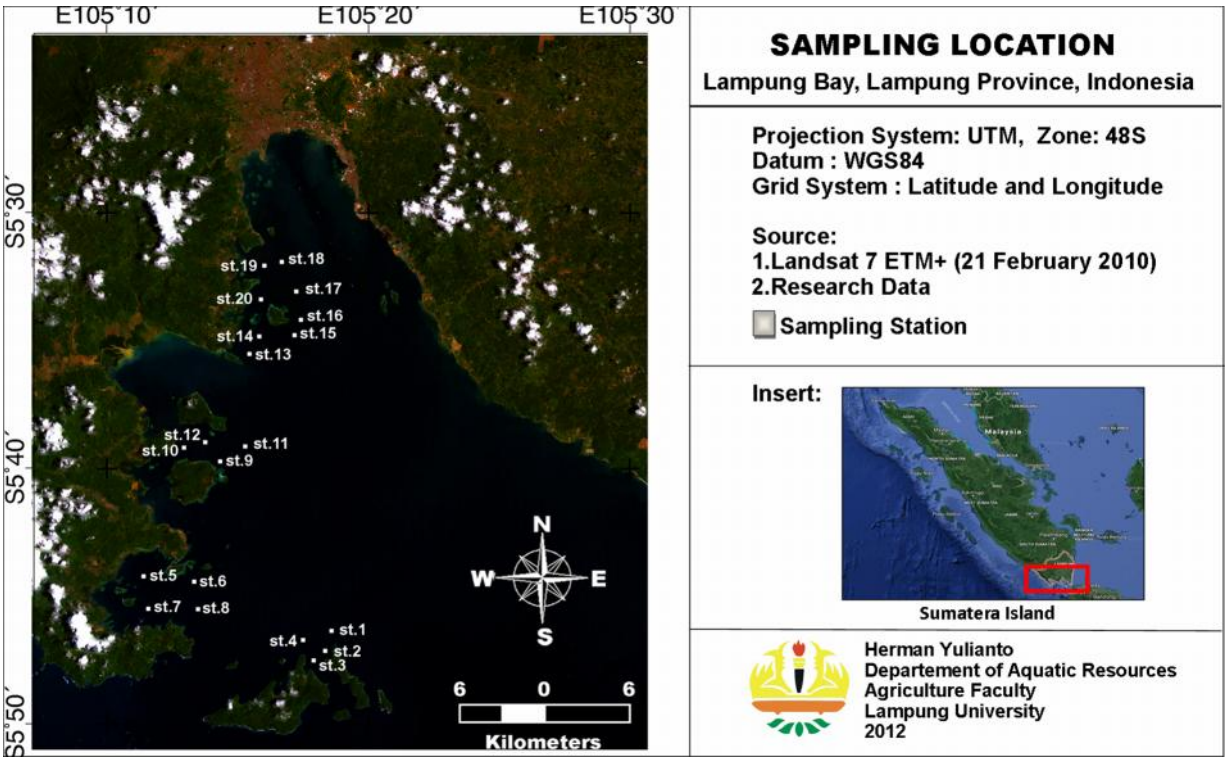

Figure 1. The location of sampling stations.

Table 1

Description of sampling stations

Station number	Location	Coordinates (degrees, minutes, seconds)		Station description
		Latitude	Longitude	
1	Siuncal	5°46’21.53"S	105°18’35.95"E	The North of Siuncal Island, about 1.2 km from the coastline.
2	Siuncal	5°47’7.62"S	105°18’21.90"E	Labuhan Sawah area, the north of Siuncal Island, about 0.4 km from coastline.
3	Lesung	5°47’30.68"S	105°17’55.12"E	Located at the mouth of the Siuncal strait (the strait between Siuncal and Legundi Islands).
4	Legundi	5°47’1.20"S	105°17’38.04"E	The north of Legundi Island, about 2 km from coastline.
5	Punduh Pidada	5°44’19.89"S	105°11’33.21"E	Located at Punduh Pidada Bay.
6	Tanjung Putus	5°44’25.93"S	105°13’20.91"E	The south of Lalanggabalak Island is a former pearl oyster farming.
7	Punduh Pidada	5°45’29.82"S	105°11’35.97"E	The area in Punduh Pidada Bay.
8	Punduh Pidada	5°45’30.53"S	105°13’30.01"E	The mouth area of Punduh Pidada Bay.
9	Puhawang	5°42’59.50"S	105°13’40.57"E	The north of Puhawang Island.
10	Puhawang	5°41’38.32"S	105°12’14.48"E	The northwest of Puhawang Island, there are seaweed farming.
11	Puhawang	5°41’36.81"S	105°13’38.43"E	In the middle of Puhawang and Kelagian Islands.
12	Puhawang	5°39’7.89"S	105°15’18.00"E	Approximately 2.5 km to the northeast of the Pahawang Island.
13	Maitem	5°35’30.91"S	105°15’27.94"E	The north of Maitem Island.
14	Maitem	5°34’50.00"S	105°15’49.95"E	In the middle of Maitem and Tegal Islands.
15	Tegal	5°34’46.96"S	105°17’11.23"E	The Southeast of Tegal Island.
16	Tegal	5°34’2.69"S	105°17’23.83"E	The east of Tegal Island.
17	Tegal	5°33’5.12"S	105°17’14.39"E	The north of Tegal Island.
18	Kyoko	5°31’55.78"S	105°16’41.33"E	Pearl oyster farming area owned by PT. Kyoko.
19	Teluk Hurun	5°32’4.11"S	105°16’1.19"E	The area of grouper culture.
20	Ringgung	5°33’23.36"S	105°15’53.39"E	The area of grouper culture.

Data collection. The data used in this study were derived from primary and secondary data. Primary data collected were samples of water quality such as parameters of physical, chemical and biological waters. Secondary data collection includes the earth surface map, image data, and other secondary data. Sampling of water quality was conducted at 8.00 am until 17.00 pm. Especially for the parameters of dissolved oxygen, measurements were taken twice, i.e. when there was sunlight (day-evening) and after sunset (evening-morning). Measurement of depth, brightness, temperature, water flow,

dissolved oxygen, pH, and salinity was measured directly in the field based on APHA method (1992). Samples of phytoplankton, chlorophyll-a and nutrients were analyzed in the laboratory of Balai Besar Pengembangan Budidaya Laut (BBPBL) Lampung with methods that refers to APHA (1976; 1992). List of measured parameters can be seen in Table 2.

Table 2

The list of measured paramters

Measured parameters	Unit	Tools	Location
Physical parameter			
1. Coordinates	-	GPS	In situ
2. Depth	meter	Bathimeter	In situ
3. Brightness	meter	Secchi disk	In situ
4. Temperature	^{o}C	Water quality checker	In situ
5. Water flow	$m\ s^{-1}$	Curent meter	In situ
6. Substrate of bottom waters	-	Ekman Grab Sampler	In situ/Lab
7. MPT	$mg\ L^{-1}$	Milipore filters	Laboratory
Chemical parameter			
1. Dissolved oxygen	$mg\ L^{-1}$	Water quality checker	In situ
2. pH	-	Water quality checker	In situ
3. Salinity	ppt	Water quality checker	In situ
4. Phosphate	$mg\ L^{-1}$	Spectrophotometer	Laboratory
5. Nitrate	$mg\ L^{-1}$	Spectrophotometer	Laboratory
Biological parameter			
1. Phytoplankton	$cell\ L^{-1}$	Microscope, Sedgwick-rafter	Laboratory
2. Chlorophyll-a	$mg\ L^{-1}$	Spectrophotometer	Laboratory

Data analysis

Contour mapping and spatial modeling. Geo-statistical model was used as a form of mapping the earth's surface (biotic and abiotic) through statistical application. The development of this model was based on geodetic data transfer/position (Degree, Minute, Second/DMS) to get a single value, the formula (Hartoko 2000):

The numerical value (Lat; Long) = Degree + {Minute + (Second/60)} / 60

ERMapper 7.0 software was used as a data processing facility to create a layer of parameters of physics, chemistry and biology. ERMapper produces contour by using grid file as the basis for interpolation and extrapolation. This process seems to increase the number of points on the amount of data already existed. In the interpolation procedure was used kriging model (Budiyanto 2005).

Analysis of water suitability for pearl oyster culture. Matrix of water suitability was created to obtain a suitability class for the parameters of physics, chemistry and biology. Preparation of suitability matrix was the basic spatial analysis conducted through scoring and weighting factor. The results of the scoring and weighting were evaluated in order to get a suitability class that described the suitability level of a field for a particular use. Suitability level was divided into four classes according to DKP (2002), namely, Class S1: Highly Suitable; Class S2: Moderately Suitable; Class S3: Marginally Suitable; Class N: Not Suitable where the suitablity value of S1 (> 85-100%), S2 (> 75-85%), S3 (> 65-75%) and N (0-65%).

Matrix of water suitability was developed through literature review and consideration of technical culture, so variables to be referenced in assigning weights were known (Table 3). Important and dominant variables considered to be the basic weight determinant for dominant and less dominant variables. To see the existence of the

variables above, relationships among several dominant variables toward variables as supporting data were needed. The relationship was analyzed using a mathematical model of multiple regression. Software Statistical Product and Service Solutions (SPSS) was used as an analysis tool.

Table 3

Assessment system of water suitability for the aquaculture area of pearl oyster

Parameters	Ranges	Ratings (A)	Percentage (B)	Score (AxB)
1	2	3	4	5
Plankton abundance (cell L^{-1})	> 15.000 & < 5 x 10^5 2000-15000 and 5 x 10^5-10^6 < 2000 & > 10^6	5 3 1	40	200 120 40
Water flow (cm s^{-1})	15< – <25 10–15 and 25-30 < 10 and >30	5 3 1	20	100 60 20
Dissolved oxygen (mg L^{-1})	5< – <8 4–5.5 and 8–9 < 4 and > 9	5 3 1	10	50 30 10
Water brightness (m)	4.5–6,5 3.5-<4.5 and 6.5< -7.7 < 3.5 and > 7.7	5 3 1	10	50 30 10
Water salinity (ppt)	30-35 20–30 < 20 and > 35	5 3 1	10	50 30 10
Chlorophyll-a (mg L^{-1})	> 10 4–10 < 4	5 3 1	10	50 30 10
Total score			(100 %)	

Information:

1. Criteria used in the preparation of suitability and weighting matrix for determining the feasibility of pearl oyster farming are modified by some authors with reference to the criteria developed by mariculture researchers (oyster pearl) by Winanto (2000; 2004), DKP (2002), Radiarta et al (2003; 2004), Suryanto et al (2005), Kangkan et al (2007) and Hartoko et al (2010), as well as Indonesian Decree of the Ministry of Environment Number 51 2004 on Sea Water Quality Standard.
2. Score Rating is based on DKP instructions (2002), namely
   5: Good
   3: Medium
   1: Less.
3. Weight based library/consideration of the influence of the dominant variables.
4. Score is $\sum_{i=1}^{n} = A \times B$

The total score obtained was analyzed for its level of suitability by using Table 4.

Table 4

Evaluation of suitablity assessment on zoning of pearl oyster farming

Total scoring (%)	Evaluation/Conclusion
>85 – 100	Highly suitable
>75 – 85	Moderately suitable
>65 – 75	Marginally suitable
0 – 65	Not suitable

Information :

- Total scoring recommendations of DKP (2002);
- Total scoring obtained by the following formula;
- Total scoring = (total score/maximum total score) x 100%.

Results and Discussion

Environmental conditions of Lampung Bay. In general, coastline conditions (west) were twisty with some small Bays included Hurun Bay, Ratai Bay and Pidada Bay. Cluster of small islands were found along the beach. Besides, beach topography was with slightly slope. The existence of Siuncal and Legundi Islands located at the mouth of the Lampung Bay (south) increased the level of water protection from the threats of the waves, both from the Indian Ocean and from the Java Sea.

Generally, the characteristic of Lampung Bay waters in coastal area of Pesawaran district was relatively stable and supported the application of mariculture activities (Table 5). The results show that the water quality value was still within the range required for marine biota (Decree of Ministry of Environment Number 51 Year 2004 on Sea Water Quality Standard). Saucedo et al (2001) stated that the suitable temperature for pearl oyster is at 24^{o}C, while the temperature of 28^{o}C still can be tolerated by pearl oysters. The adverse effect on the growth of pearl oysters is at temperature of >30^{o}C (Pouvreau & Prasil 2001). However, the survival and growth of larvae can be increased through constant temperature and low stocking density (Saucedo et al 2007). In addition, salinity also influences the growth of pearl oyster. Based on the data obtained, Lampung Bay had a suitable salinity for pearl oysters, which was in the range of 32-35 ppt (O'Connor & Lawler 2004).

Table 5

The ranges of water quality parameters in the waters of Lampung Bay

Parameters		Average	Standard deviation
Temperature (°C)		29.99	0.50
Dissolved oxygen (mg L^{-1})	[A]	5.22	0.29
	[B]	5.63	0.42
Salinity (ppt)		33.07	0.13
pH		8.16	0.12
Depth (m)		26.99	6.53
Brightness (m)		11.32	2.92
Water flow (cm s^{-1})		20.00	6.89
MPT (mg L^{-1})		47.05	18.02
Nitrate (NO_3) (mg L^{-1})		0.06	0.07
Phosphate (PO_4) (mg L^{-1})		0.08	0.09
Chlorophyll-a (mg L^{-1})		4.37	1.26
Plankton abundance (cell L^{-1})		89800.17	12447.56
The substrate of bottom waters		Sandy rocks	

Source: Yulianto (2013)
Information:
[A]: measurement at 12.00 am until 06.00 am
[B]: measurement at 09.00 am until 04.00 pm.

The suitability of pearl oyster farming. The scoring results indicate that all locations were feasible to be pearl oyster farming location (Table 6). Eight stations which resulted in scores between 85-100%, namely 88% and 92%, shows that they reached the suitability level of Highly Suitable (S1). While 12 locations which showed the final score between 75-84% with value of 76%, 80% and 84%, indicated the suitability level achieved was the Moderately Suitable (S2). The range of the final score obtained was 76-88 on the highest score value of 100.

Furthermore, judging from the results of this scoring, any treatments/feedback on ecosystem variables to the implementation of the pearl oyster farming in these waters were not needed. The abundance level of plankton, according to researchers, is the most influential variable on the determination of the suitability of pearl oyster farming. All stations were found to have the proper range to perform pearl oyster farming. Score obtained by each station was 5, which was the highest value. The success of pearl oyster culture is strongly influenced by the food presence (Pouvreau & Prasil 2001). Phytoplankton is the main food for Pinctada sp. (Fukumori et al 2008). Research conducted by Fournier et al (2012) showed that the concentration of plankton has a close correlation to the development of pearl oyster gametes. In addition to the presence of food, water flow is also an important factor. Water flow is needed to bring food to the pearl oyster, if the water flow is high then the food supply is also abundant (Lacoste et al 2014). The results of measurements of water flow showed that score of 3 was only obtained at station 1, 3, 5, 6, 16 and 17 which means that those stations had appropriate marginal score while the other stations achieved value of 5 or very good.

Considering the scoring result, it can be interpreted that the waters of the Lampung Bay is very feasible for pearl oyster farming. The best locations to be utilized for oyster culture were around the station 9, 10, 11, 12 (around Pulau Puhawang), 13, 14, 15 station (around Maitem and Tegal Islands) and station 18 which was the culture location of a privately owned company (PT. Kyoko Shinju).

Pearl oyster farming zones. Water suitability zoning of pearl oyster farming (Figure 2) shows that the area around Puhawang Island (station 9, 10, 11, 12) to Tegal Island (station 13, 14, 15) achieved the highest score as well as the area around Tegal Island to the Hurun Bay (station 17 and 18). Thus, these areas became the most suitable places to be used as a pearl oyster farming zones in the Lampung Bay. Surely, considerations used in zoning were not only based on the ecosystem variable, they were related to other interests that view the use of water from Lampung Bay.

Other considerations that support these waters to be pearl oyster farming are the protection level of Lampung Bay waters which were relatively good, and also the stability of the water flow. Pearl oyster requires stable environmental conditions to grow. Fluctuating water conditions can trigger the disease in pearl oysters (Kuchel et al 2011). High light intensity in these waters also supports pearl oyster culture as oysters relying on phytoplankton as a food (Tomaru et al 2002). Phytoplankton has a role in enhancing the growth of pearl oysters (Lodeiros et al 2002). Research published by Deng et al (2013) have shown that oysters consuming various types of microalgae have a better shell growth than those which only eat one type of microalgae.

Furthermore, the existence of PT. Kyoko Shinju, which has been conducting pearl oysters culture in the Lampung Bay until today, can be used as a benchmark of water suitability in Lampung Bay for cultivation of pearl oysters. From a spatial model obtained, water area that can be used for the cultivation of pearl oysters in suitability level of highly suitable (S1) of 18917 ha, moderately suitable (S2) of 14151.58 ha and marginally suitable (S3) of 778.54 ha of the total study area of 33847.12 ha.

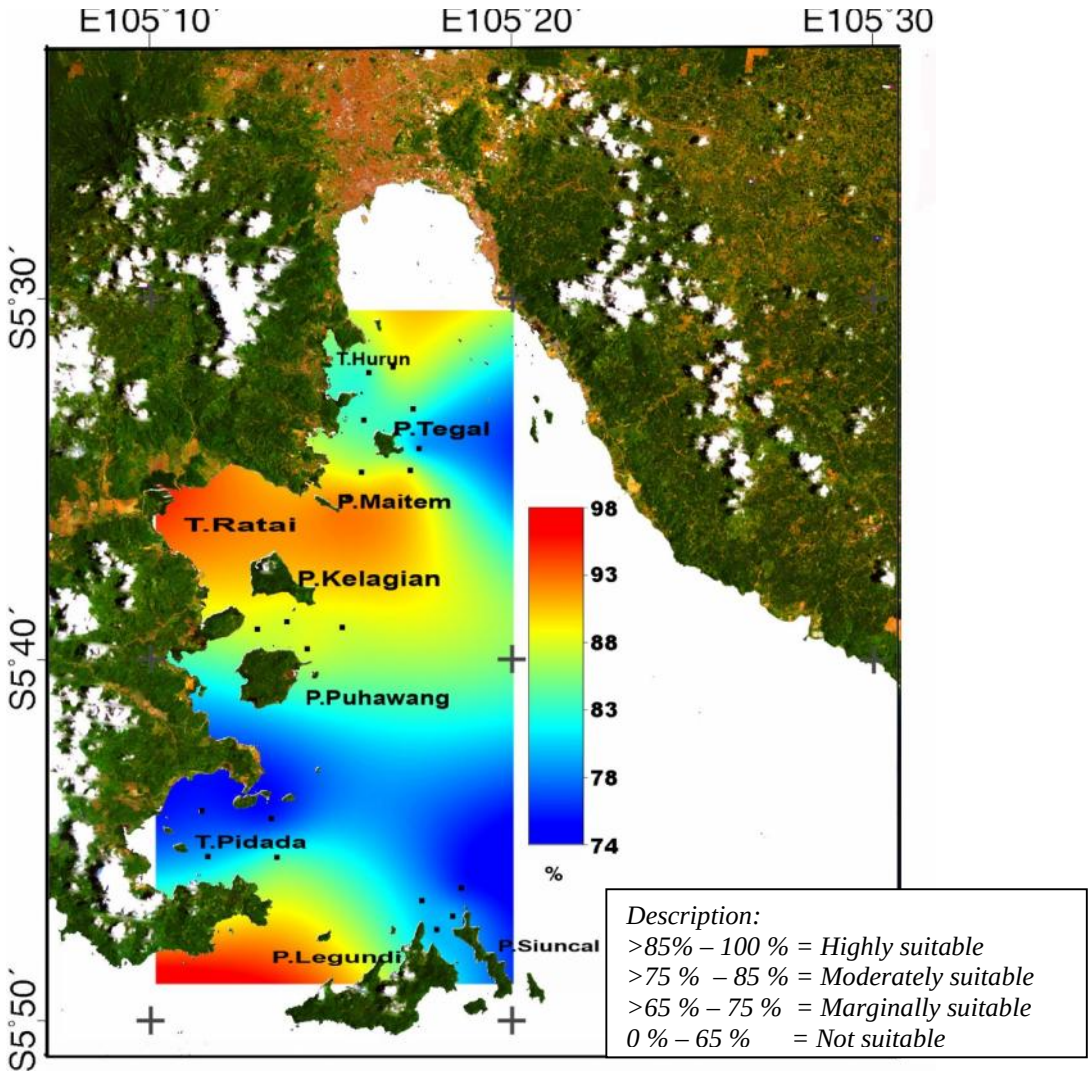

Figure 2. Zoning of water suitablity for pearl oyster farming.

Conclusions. The suitable area for cultivation of pearl oysters is 33847.12 ha. The composition levels of suitablity are: Highly Suitable (S1) 18917 ha, Moderately Suitable (S2) 14151.58 ha and Marginally Suitable (S3) 778.54 ha. Oyster cultivation zone is located in the area around the station 9, 10, 11, 12, 13, 14, 15, 16 and 18, which is the area between Puhawang Island and Maitem Island, as well as the areas in the north of Tegal Island which is the cultivation area of pearl oysters belonging to private enterprise (PT. Kyoko Shinju). By looking at the potential of the waters of the Lampung Bay, planning for appropriate areas as a cultivation zone is needed.

Conflict of Interest. Authors are not currently affiliated to and the research is not sponsored by any organization with a direct economic interest in subject of the article.

Table 6

Data of scoring result on each station

PARAMETERS	MAX SCORE	STATION																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Dissolved oxygen (mg L^{-1})	50	50	50	10	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Salinitity (ppt)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Brightness (m)	50	30	10	50	10	10	10	10	10	10	10	10	10	30	10	10	10	10	10	10	10
Chlorophyll-a	50	10	10	10	10	30	30	10	30	30	30	30	30	30	30	30	30	30	30	10	10
Water flow (cm s^{-1})	100	60	100	60	100	60	60	100	100	100	100	100	100	100	100	100	60	60	100	100	100
Plankton abundance (cell L^{-1})	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Total	500	400	420	380	420	400	400	420	440	440	440	440	440	460	440	440	400	400	440	420	420
Final score		80	84	76	84	80	80	84	88	88	88	88	88	92	88	88	80	80	88	84	84

Information: S1 (Highly Suitable); S2 (Moderately Suitable); S3 (Marginally Suitable); N (Not Suitable)

References

American Public Health Association (APHA), 1976 Standard methods for the examination of water and waste water. 14th edition, Washington D.C.

American Public Health Association (APHA), 1992 Standard methods for the examination of water and wastewater, 16th Edition. Washington DC. 76 p.

Andréfouët S., Charpy L., Lo-Yat A., Lo C., 2012 Recent research for pearl oyster aquaculture management in French Polynesia. Marine Pollution Bulletin 65:407–414.

Aslan L. O. M., Iba W., Bolu L. O. R., Ingram B. A., Gooley G. J., Silva S. S., 2015 Mariculture in SE Sulawesi, Indonesia: Culture practices and the socio economic aspects of the major commodities. Ocean & Coastal Management 116:44-57.

Budiyanto E., 2005 [Contour mapping and 3D spatial modeling using surfer]. Andi Publisher, Yogyakarta. [In Indonesian]

Chellam A., Velayudhan S., Victor C. C., 1987 Pearl oyster farming. CMFRI Buletin 39:72-77.

Decree of Ministry of Environment Indonesia Number 51 Year 2004 about Sea Water Quality Standard. P.1489-1498.

Deng Y., Fu S., Liang F., Du X., Xie S., 2013 Growth and survival of pearl oyster Pinctada maxima spat reared under different environmental conditions. Journal of Shellfish Research 32(3):675–679.

Departement of Marine and Fisheries (DKP) Pesawaran, 2010 http://dkp.pesawarankab.go.id/ index.php

Departement of Marine and Fisheries (DKP), 2002 [Socialization and orientation of spatial planning module for marine, coastal, and small island]. Directorate General of Coastal and Small Islands. Marine Spatial Planning Directorate, Coastal and Small Islands, Jakarta. [In Indonesian]

Fournier J., Levesque E., Pouvreau S., Le Pennec M., Le Moullac G., 2012 Influence of plankton concentration on gametogenesis and spawning of the black lip pearl oyster Pinctada margaritifera in Ahe atoll lagoon (Tuamotu Archipelago, French Polynesia). Marine Pollution Bulletin 65:463–470.

Fukumori K., Oi M., Doi H., Okuda N., Yamaguchi H., Kuwae M., Miyasaka H., Yoshino K., Koizumi Y., Omori K., Takeoka H., 2008 Food sources of the pearl oyster in coastal ecosystems of Japan: Evidence from diet and stable isotope analysis. Estuarine, Coastal and Shelf Science 76:704-709.

Gifford S., Dunstan H., O'Connor W., Macfarlane G. R., 2005 Quantification of in situ nutrient and heavy metal remediation by a small pearl oyster (Pinctada imbricata) farm at Port Stephens, Australia. Marine Pollution Bulletin 50:417–422.

Hartoko A., 2000 [Dynamic mapping technology pelagic resources through integrated character analysis of oceanography and NOAA satellite data, Landsat_TM and SeaWIFS_GSFC in Indonesian sea waters]. Office of the State Minister for Research and Technology, National Research Council, Jakarta. [In Indonesian]

Hartoko, Kangkan A. L., 2010 Spatial modeling for marine culture site selection based on ecosystem parameters at Kupang Bay, East Nusa Tenggara – Indonesia. International Journal of Remote Sensing and Earth Science 6:57-64.

Haws M., Crawford B., Portella M. C., Ellis S., Jiddawi N., Mmochi A., Gaxiola-Camacho E., Rodriguez-Dominguez G., Rodriguez G., Francis J., Leclair C. R., Coze A. S., Hernandez N., Sandoval E., Jaroszewska M., Dabrowski K., 2010 Aquaculture research and development as an entry-point and contributor to natural resources and coastal management. Coastal Management 38:238–261.

Kangkan A. L., Hartoko A., Suminto, 2007 [Location's determining study for the development of marine aquaculture based on the parameters of physics, chemistry and biology in the Gulf of Kupang, East Nusa Tenggara]. Jurnal Pasir Laut 3(1):76-93. [In Indonesian]

Kuchel R. P., O'Connor W. A., Raftos D. A., 2011 Environmental stress and disease in pearl oysters, focusing on the Akoya pearl oyster (Pinctada fucata Gould 1850). Reviews in Aquaculture 3:138–154.

Lacoste E., Moullac G. L., Levy P., Gueguen Y., Gaertner-Mazouni N., 2014 Biofouling development and its effect on growth and reproduction of the farmed pearl oyster Pinctada margaritifera. Aquaculture 434:18–26.
Lee A. M., Williams A. J., Southgate P. C., 2008 Modelling and comparison of growth of the silver-lip pearl oyster Pinctada maxima (Jameson) (Mollusca: Pteriidae) cultured in West Papua, Indonesia. Marine and Freshwater Research 59:22–31.
Lodeiros C., Pico D., Prieto A., Narváez N., Guerra A., 2002 Growth and survival of the pearl oyster Pinctada imbricata (Röding 1758) in supended and bottom culture in the Golfo de Cariaco, Venezuela. Aquaculture International 10:327–338.
Nagai K., 2013 A history of the cultured pearl industry. Zoological Science 30:783–793.
O'Connor W. A., Lawler N. F., 2004 Salinity and temperature tolerance of embryos and juveniles of the pearl oyster, Pinctada imbricata Roding. Aquaculture 229:493–506.
Pouvreau S., Prasil V., 2001 Growth of the black-lip pearl oyster, Pinctada margaritifera, at nine culture sites of French Polynesia: synthesis of several sampling designs conducted between 1994 and 1999. Aquat Living Resour 14:155−163.
Radiarta I. N., Saputra A., Priono B., 2004 [Feasibility mapping of land for development of marine aquaculture in the Gulf Saleh, West Nusa Tenggara]. Jurnal Penelitian Perikanan Indonesia 10(5):19-32. [In Indonesian]
Radiarta I. N., Wardoyo S. E., Priono B., Praseno O., 2003 [Application of geographic information system for determination of marine aquaculture development area in the Gulf Ekas, West Nusa Tenggara]. Jurnal Penelitian Perikanan Indonesia 9(1):67-79. [In Indonesian]
Rimmer M. A., Sugama K., Rakhmawati D., Rofiq R., Habgood R. H., 2013 A review and SWOT analysis of aquaculture development in Indonesia. Reviews in Aquaculture 5:255–279.
Saucedo P. E., Ormart-Castro P., Osuna-García M., 2007 Towards development of large-scale hatchery cultivation of larvae and spat of the pearl oyster Pinctada mazatlanica in Mexico. Aquaculture 273:478–486.
Saucedo P., Rodriguez-Jaramillo C., Aldana-Aviles C., Monsalvo-Spencer P., Reynoso-Granados T., Villarreal H., Monteforte M., 2001 Gonadic conditioning of the calafia mother-of-pearl oyster, Pinctada mazatlanica (Hanley, 1856) under two temperature regimes. Aquaculture 195:103–119.
Suryanto H., Ari A., Dartoyo, Gatot H. P., 2005 [Norma, procedures, guidelines, specifications and standards (N P P S S)]. Procedures and Technical Specifications Conformity Analysis pearl oyster cultivation. Marine Natural Resource Survey Center. Bakosurtanal. [In Indonesian]
Tomaru Y., Udaka N., Kawabata Z., Nakano S., 2002 Seasonal change of seston size distribution and phytoplankton composition in bivalve pearl oyster Pinctada fucata martensii culture farm. Hydrobiologia 481:181–185.
Wells F. E., Jernakoff P., 2006 An assessment of the environmental impact of wild harvest pearl aquaculture (Pinctada maxima) in Western Australia. Journal of Shellfish Research 25(1):141–150.
Winanto Tj., 2000 [Preference of spat pearl oyster Pinctada maxima (Jameson) (Bivalvia: Pteriidae) toward diameter and roughness level material collectors]. Thesis. Bogor Agricultural University Graduate Program. [In Indonesian]
Winanto Tj., 2004 [Pearl oyster spat production]. Penebar Swadaya, Jakarta [In Indonesian]
Yulianto H., 2013 [Spatial distribution mapping of water quality nutrients in Gulf Lampung]. Aquasains (2)1:113-118. [In Indonesian]
Zhifeng G., Qingyin W., Jianguang F., Naihao Y., Yuze M., Yaohua S., Yan W., Aimin W., 2009 Growth of cultured pearl oyster (Pinctada martensii) in Li'an Lagoon, Hainan Island, China. Journal of Shellfish Research 28(3):465–470.

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