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Site Selection for Lobster Culture in Floating Cage using Multi-criteria Analysis

Muhammad Junaidi[1]*, Nanda Diniarti[1], Nunik Cokrowati[1], Alis Mukhlis[1], Baiq Hilda Astriana[2], Flaxen D. L. Conway[3]

[1]Department of Aquaculture, Faculty of Agriculture, University of Mataram
[2]Department of Marine Sciences, Faculty of Agriculture, University of Mataram
Jl. Pendidikan No. 37, Selaparang, Mataram, Nusa Tenggara Barat, 83115 Indonesia
[3]School of Public Policy, Oregon State University
1600 SW Western Blvd Suite 350 Corvallis OR 97333, USA
Email: m.junaidi@unram.ac.id

Abstract

Spiny lobster is as a very promising culture commodity to be developed due to their high demand in the domestic and global markets. The selection of the suitable location was one of determining factors for the success of lobster cultivation. Various criteria are required for the location of lobster cultivation, both technically and biologically. This research aimed to analyze the suitability sites for lobster culture in floating cages using Multi-criteria Analysis and Geographic Information System (GIS). The research was conducted in May 2018 in North Lombok Regency Water, West Nusa Tenggara. A survey method was applied and used primary and secondary data. Data collected were grouped into 3 categories i.e. oceanographic parameter (water depth, current, wave, and transparency), water quality (temperature, salinity, pH, dissolved oxygen, nitrate, and phosphate), and socio-economic and institutional parameters (legality, easy access, labor availability, and market). Primary data were obtained by measuring oceanography and water quality parameters at 23 observation points on eight transects perpendicular to the coast. Socio-economic and institutional data were obtained from the relevant agencies. Data analysis was done by combining Multi-criteria Analysis and GIS. The result of this research shows that the water condition still supports mariculture activity. The total area covered by this research was 9,087 ha, of which 1,226 ha were found very suitable for lobster culture using floating cage.

Keywords: suitability site, floating net cage culture, multi-criteria analysis, GIS,

Introduction

Spiny lobster (*Panulirus* sp.) was one of the important fishery commodities. Market demand for this commodity steadily increases, particularly in some countries in Southeast Asia, Hong Kong, Taiwan, China, and Japan (Jones, 2015; Witomo and Nurlaili, 2015; Haryono *et al.,* 2016). High international market demand has prompted Indonesia to speed the lobster production through cultivation. Lobster culture using floating cages has established since 2000 in Lombok water, West Nusa Tenggara Province (Hasnawi *et al*., 2011; Erlania *et al*., 2014; Junaidi and Hamzah, 2014; Junaidi *et al*., 2014; Junaidi and Heriati, 2017). Many lobster seeds were found sticking onto the floats and other materials in the seaweed and grouper farming systems (Priyambodo and Sarifin, 2010; Erlania *et al*., 2014). These seeds were then collected and grown in the floating cage (Junaidi and Heriati, 2017). Generally, the seeds used for lobster farming were collected from nature (Setyono, 2006).

North Lombok Regency of West Nusa Tenggara Province has a 125 km of coastline and 505.24 km^2 area which is suitable for marine culture. This area was geographically located in the Flores Sea. There are 3 small islands known as Gili Matra (Meno, Trawangan and Air) in the waters of North Lombok Regency. This cluster islands was a well known marine tourism area for foreign countries with a beautiful and charming tourist destination. In addition of being used as a conservation area and marine tourism, there are 29.54 km^2 potential area for mariculture development and capture fisheries (Pratiwi *et al.,* 2014). However, this area has not been fully utilized, especially for mariculture purposes. Whereas, it is known that mariculture offers several benefits to coastal communities in relation to conservation efforts, including alternative livelihoods, reducing pressure on the coastal environment caused by fishing activities, and increasing public awareness of the importance of natural resources conservation (Albasri and Szuster, 2010).

*) Corresponding author

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Lobster as an aquaculture commodity has a very promising prospect to be developed in North Lombok Regency to support *minawisata* (fisheries and tourism) development. There are many criteria required, both technically and biologically, to develop a potential species through mariculture (Arcenal, 2004). For lobster cultivated in floating cages, it is important to pay attention on water qualities, such as temperature, salinity, pH, dissolved oxygen, and water fertility (Prema, 2013; Sarah *et al.*, 2016; Junaidi *et al*., 2018). In addition, the information on current, water depth, wave and water bottom condition are needed (Setyono, 2006). Other considerations that need to be taken in determining an aquaculture site are non-technical parameters in the form of market share, security, and human resources (Hartoko and Kangkan, 2009). The good data coupled with consideration of the importance of each data, the analysis of the suitability of locations for mariculture becomes more complex and involves a quite long procedure (Giap *et al*., 2005).

Given the development of digital technology, Geographic Information Systems (GIS) provides many facilities to conduct spatial analysis quickly and systematically. GIS has several advantages in its application in the field of aquaculture. GIS not only displays environmental characteristics that include physical, biological and socio-economic conditions, but also conducts analysis that can simplify problems and uses time more effectively (Shih, 2017). The utilization of GIS in the field of aquaculture is undoubted (Hunter, 2009). Currently, there have been a quite number of publications on the use of GIS in mariculture since it was first published in the 1980s by Kapetsky (Kapetsky and Aguilar-Manjarrez, 2015), including the feasibility study of aquaculture sites based on species such as groupers (Szuster and Albasri, 2010; Purnawan *et al*., 2015; Hastari *et al.*, 2017), seaweed (Radiarta *et al*., 2011; Radiarta *et al*., 2012; Yulianto *et al.*, 2017; Teniwut *et al.*, 2019), shrimp (Giap *et al*., 2005; Karthik *et al.*, 2005; Islam *et al.*, 2010), bivalves (Arnold *et al.*, 2000; Salam *et al*., 2003; Buitrago *et al.*, 2005; Silva *et al.*, 2011), and crabs (Salam *et al*., 2003), GIS has also been used for integrated study between different activities in the coastal region. Some examples of such study are those reported by Perez (Perez *et al*., 2003) who analyzed the integration between marine fish farming in floating cages and tourism activities in Tenerife (Canary Islands), and by Goulletquer and Moine (2002) they examined mussels cultivation in line with coastal management in Marennes-Oleron Bay and Charentais, France.

This study aimed to analyze the mariculture sites suitability for lobster cultivation in floating cages using Multi-criteria Analysis and GIS. The result of this study is useful to provide data and information supporting a program for the improvement of aquaculture production as an alternative livelihood for coastal communities in North Lombok Regency.

Materials and Methods

This research was conducted in North Lombok Regency, West Nusa Tenggara Province, Indonesia (Figure 1.). The locations were consisted of four sub-districts, *i.e*. district of Pemenang, Tanjung, Gangga, and Kayangan. The study sites situated at 116^{o}6 '- 116^{o}16' E and 8^{o}14 '- 8^{o}23' S.

The research applied the survey method and analyzed primary and secondary data. Primary data were obtained by measuring oceanography and water quality parameters at 23 observation points on eight transects perpendicular to the coast. Water quality data such as temperature, dissolved oxygen, pH, salinity and brightness were measured in situ, while water samples were taken to laboratory for turbidity, nitrate and phosphate analysis. The socio-economic survey was carried out through visual observations and direct structural interviews to stake holders who carried out the cultivation and tourism activities.

Secondary data in the form of maps were obtained from relevant agencies. These data consisted of basic maps and thematic datasets. The basic maps in the form of coastline map, current, bathymetry and boundaries of the region were obtained from the Indonesian Coastal Environment Map (a scale of 1: 50,000) issued by the Geospatial Information Agency (*Badan Informasi Geospasial* /BIG). The map of thematic datasets in the form of a water current map was obtained from the Physical Oceanographic Map (a scale of 1: 50,000). The flow chart for determining the suitability of lobster culture sites is shown in Figure 2.

The determination of location for lobster culture using floating cages should take into account various factors such as environment (oceanography and water quality), risk, socio-economic, and infrastructure (Setyono, 2006). However, this study only focused on the most influent factors or parameters affecting the development of lobster culture in the North Lombok Regency. These parameters were grouped into three categories according to Yusuf and Soedarto (2013). The first category was oceanographic factor which consisted of water depth, current, wave, and transparency which may influence the design and construction of floating cages. The second was the water quality factors, such as temperature, salinity, pH, dissolved oxygen, nitrate, and phosphate levels which may affect the lobster growth and survival. The third category was socio-economic and institutional factors. These include location legality, ease of access, availability of labor, and proximity to markets.

The level of suitability (score) for analyzing the feasibility of aquaculture sites consists of various scoring systems, for example a score of 1—4 (Salam *et al*., 2003; Giap *et al*., 2005), a score of 1—5 (Buitrago *et al*., 2005); and a score of 1—8 (Perez *et al*., 2003). This study used a score of 1—3 (Hossain and Das, 2010; Karthik *et al*., 2005; Radiarta, Subagja *et al*., 2012) in which "not suitable" = 1, "moderately suitable" = 2, and "the most suitable" = 3. Determination of the score of each parameter was based on the importance this parameter for lobster cultivation. The details of each score are as follows: 1) not suitable, location has a significant limiting factor preventing the possibility of its use; 2) moderately suitable, the location has a rather meaningful limiting factor to maintain the level of management that must be applied. The limiting factor

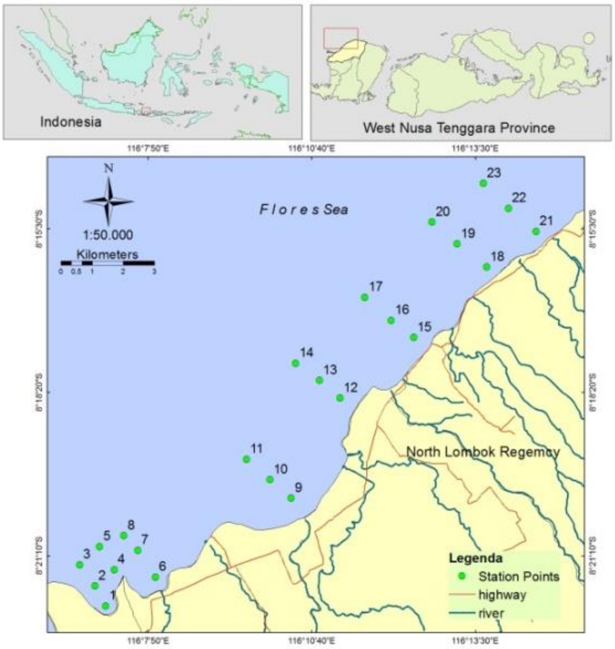

Figure 1. General features of study area at adjacent water of North Lombok Regency and distribution of sampling sites

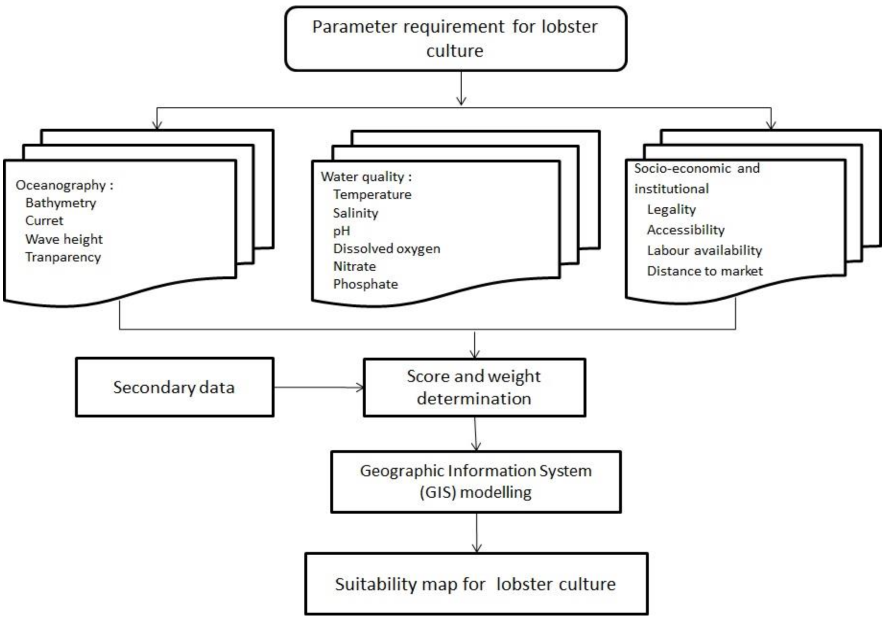

Figure 2. Schematic diagram for determining suitability site for lobster culture

somewhat reduces production, requiring a little cost and time; 3) the most appropriate, the location does not have a meaningful limiting factor to maintain the level of management that must be applied.

The suitability analysis of aquaculture sites in this study was more focused on lobster cultivation in floating cages. The criteria used for preparing the conformity matrix referred to Chou and Lee (1997), Environmental Ministry (2004), Halide *et al*. (2009), and Prema (2013) (Table 1.). The weighting system used in this study was using Analytical Hierarchy Process (AHP) (Saaty, 2008; Bunruamkaew and Murayama, 2011; Shih, 2017; Suwasono and Rosana, 2013). Analytical Hierarchy Process uses a technique known as Pair Wise Comparison which is a technique in Multi-Criteria Analysis in the context of decision making. Each parameter was given a weight based on literature studies and expert opinions. Parameters with dominant and relatively irreversible effect have the greatest weighting factor. In contrast, the less dominant parameters have a smaller weighting factor. The advantage of this technique is that the weight made can be tested by looking at the consistency ratio (CR). A new consistency ratio can be accepted if CR <0.1, and if the value is greater than 1, a weighting must be repeated. The weighting values used in this study are presented in Table 2.

Spatial analysis was done using ArcGIS 10.3 and Surfer 9 software. All data resulting from each parameter were combined in a digital base map by interpolating each observation coordinate into an area (polygon) using the Nearest Neighbor Method (Morain, 1999). Interpolation results for each parameter obtained were grouped according to each factor, namely oceanography, water quality and socio-economic. Water area appropriate for marine aquaculture activities was generated after all parameters were overlaid based on scores and weights using the equation below (Radiarta *et al*., 2007; Radiarta *et al*., 2018):

$$A_i = \frac{\left(\sum_j w_j\, x_{ij}\right)}{n}$$

Note: A_i= suitability index; x_{ij}= the level of suitability (score) of each parameter; w_j= the weighting value; n= the score system. The level of suitability of the location as a whole was obtained from the equation. The value of each suitability level is presented in Table 3.

Result and Discussion

Site capability analysis

Some oceanographic and water quality parameters at the study site were limited for the sustainability of lobster cultivation. Oceanographic parameters limiting factors for lobster cultivation's sustainability are wave height, current velocity, and depth. The water quality parameters which may inhibit lobster growth are nitrate and phosphate levels (Table 4).

Table 1. Suitability of oceanographic parameters, water quality, socio-economic, and institutional conditions for lobster cultivation sites using floating cages

Parameter	Suitability rating and score*		
	Most suitable (3)	Moderately suitable (2)	Not suitable (1)
Oceanography :			
Bathymetry (m)	10 - 20	4 - <10 / 20 - 25	<4 / >25
Current (cm.s^{-1})	20 - 40	5 - <20 / 40 - <50	<5 / >50
Wave height (m)	<1.0	1 - 1.19	>1.20
Transparency (m)	>3	1 - <3	< 1
Water quality :			
Temperature (^{o}C)	27 - 32	24 - <27	< 24 / >32
Salinity (ppt)	30 - 35	20 - <30	< 20 / >35
pH	7.0 - 8.5	6.5 – 6.9	<6.5 / >8.5
Dissolved oxygen (ppm)	6 - 10	3 - <6	< 3
Nitrate (mg.L^{-1})	0 - 0.008	0.009 - 0.016	>0.017
Phosphate (mg.L^{-1})	0 - 0.015	0.016 - 0.030	>0.030
Socio-economic and institutional			
Legality	In accordance with Spatial Plan	Less suitable	Not suitable
Accessibility	Easy	Moderately easy	Difficult
Labour availability	Available	Less available	Not available
Distance to market	Close	Less close	Far

*Chou and Lee, 1997; Environmental Ministry, 2004; Halide *et al*., 2009; Prema, 2013

Table 2. Pairwise comparison matrix for assessing the relative importance of oceanographic parameters, water quality, socio-economic, and institutional for lobster cultivation system using floating cage (numbers indicate the rating of row relative to column factors)

Oceanography	Bathymetry	Current	Wave high	Transparency	Weight
Bathymetry	1	1/4	1/3	½	0.10
Current	4	1	1	2	0.36
Wave high	3	1	1	3	0.38
Transparency	2	1/2	1/3	1	0.17
Consistency ratio, CR= 0.0165					

Water quality	Temperature	Salinity	pH	Dissolved oxygen	Nitrate	Phosphate	Weight
Temperature	1	½	1	3	2	1	0.17
Salinity	2	1	2	2	2	2	0.27
pH	1	½	1	5	2	1	0.19
Dissolved oxygen	1/3	½	1/5	1	1/5	1/4	0.06
Nitrate	1/2	½	1/2	1/2	1	1	0.14
Phosphate	1	½	1	4	1	1	0.16
Consistency ratio, CR = 0.0542							

Socio-economic and institutional	Legality	Accessibility	Labour availability	Distance to market	Weight
Legality	1	1/3	1/2	1/3	0.11
Accessibility	3	1	1/4	1/3	0.17
Labour availability	2	4	1	1/2	0.30
Distance to market	3	3	2	1	0.42
Consistency ratio, CR= 0.0998					

Criteria for site selection	Oceanography	Water quality	Socio-economic and institutional	Weight
Oceanography	1	2	1	0.41
Water quality	½	1	1	0.26
Socio-economic and institutional	½	1/2	1	0.33
Consistency ratio, CR = 0.0463				

Table 3. Overall suitability rating score for lobster culture site selection

Suitability rating	Range of score*
Most suitable	0.67 - 1.00
Moderately suitable	0.33 - 0.66
Not suitable	0.0 - 0.32

*Radiarta *et al.* (2007; 2018)

From all data collected, it is clear that the nitrate and phosphate levels are quite high compared to the standard values for those parameters. High nitrate and phosphate levels in some waters, especially around estuaries, may be caused by agricultural and household (domestic) waste that flows into the study site.

Oceanographic parameters such as depth, current velocity, wave height, and water transparency may influence the marine fish life (Nath *et al*., 2000). Thematic maps and the results of merging oceanographic parameters (depth, current velocity, wave height, and water transparency) are presented in Figure 3. Table 5 presents the area and percentage of its suitability for lobster cultivation based on each oceanographic parameter. The suitability level of cultivation site based on oceanographic factors showed that the most suitable category was 35.5% (3225.9 ha) while moderately suitable was 64.5%

(5861.1 ha). The most suitable category is found in the area near the coast with the depth of 5-20 m. Whereas inappropriate condition of oceanographic factors is found in the offshore, because the depth were more than 20 m and cover 6315.5 ha waters (69.5%).

Water quality parameters, such as water temperature, salinity, pH, dissolved oxygen, nitrate, and phosphate may influence the growth and survival of fish (Nath *et al*., 2000). Thematic maps and the results of merging water quality parameters including water temperature, salinity, pH, oxygen content, nitrate, and phosphate levels are presented in Figure 4. Table 6 presents the area and percentage of water suitability level for lobster cultivation based on each water quality parameter. The cultivation site suitability level based on water quality parameters was 100% (9087 ha) or the most suitable level (Table 6). Nevertheless there were high level of nitrate and phosphate in some locations, especially in the waters near the coast, with nitrate levels ranging from 0.0016-0.0206 mg.L^{-1} and phosphate level ranging from 0.026-0.042 mg.L^{-1}. Whereas, seawater quality standard for marine biota is a maximum of 0.008 mg.L^{-1} for nitrate and a maximum of 0.015 mg.L^{-1} for phosphate (Environmental Ministry, 2004).

Thematic maps and the results the merging of socio-economic and institutional parameters consist of legality, accessibility, availability of labor, and distance from the market are presented in Figure 5. Table 7 presents the area and percentage of water suitability for lobster cultivation based on socio-economic and institutional parameters. The level of suitability of cultivation sites based on socio-economic and institutional parameters consisted of the most suitable category for an area of 29.6% (2691.7 ha) and moderately suitable for an area of 70.4% (6396.3 ha). The most suitable category was found in the southern waters adjacent to the Gili Matra Aquatic Tourism Area (TWP).

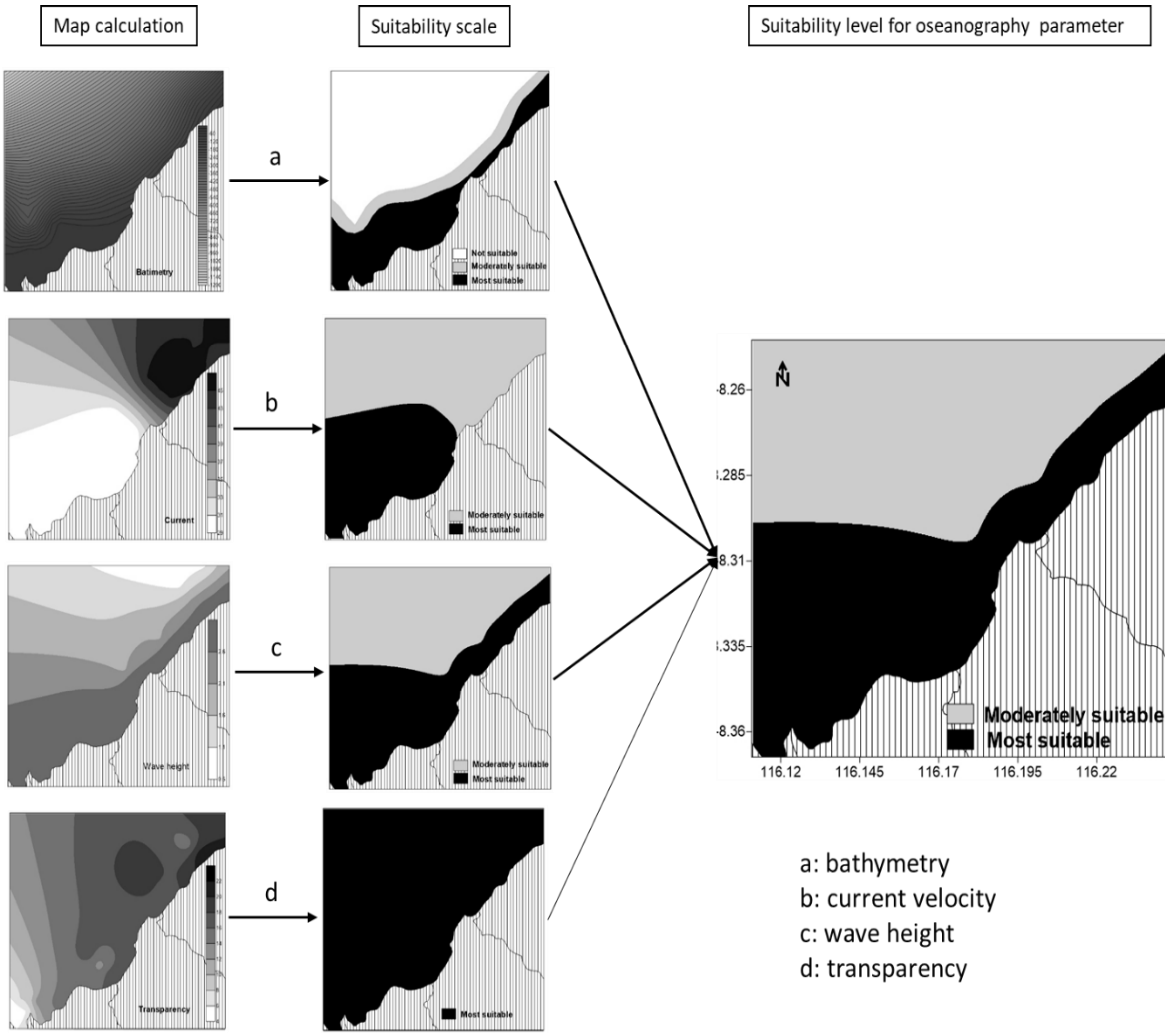

Figure 3. The process of combining oceanographic parameters to suitability level for lobster culture site

Table 4. Value range of oceanographic and water quality parameters at study site

Parameter	Unit	Minimum	Maximum	Mean	Standard value*
Oceanography :					
Bathymetry	m	8	260	67	10-20
Current	cm.s^{-1}	10	30	15	20–40
Wave height	m	0.5	1.5	0.9	<1.0
Transparency	m	4	22	5.3	>3
Water quality :					
Temperature	^{o}C	30.7	31.7	31.06	27-32
Salinity	ppt	29	32	30.5	30-35
pH		8.0	8.2	8.09	7.0–8.5
Dissolved oxygen	ppm	6.8	8.7	7.46	>5
Nitrate	mg.L^{-1}	0.0016	0.0206	0.0105	< 0.008
Phosphate	mg.L^{-1}	0.026	0.042	0.033	< 0.015

* Chou and Lee (1997); Environmental Ministry (2004); Halide *et al.* (2009); Prema (2013)

Table 5. Area and percentage of different suitability level for oceanographic parameters at study area

Parameters	Most suitable		Moderately suitable		Not suitable	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Bathymetry	717.9	7.9	2053.7	22.6	6315.5	69.5
Current velocity	5134.2	56.5	3952.8	43.5	0	0
Wave height	3225.9	35.5	5861.1	64.5	0	0
Water transparency	9087.0	100	0	0	0	0
Sub-overall	3225.9	35.5	5861.1	64.5	0	0

Table 6. Area and percentage of different suitability levels for water quality parameters at study area

Parameters	Most suitable		Moderately suitable		Not suitable	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Temperature	9087.0	100	0	0	0	0
Salinity	9087.0	100	0	0	0	0
pH	9087.0	100	0	0	0	0
Dissolved oxygen	9087.0	100	0	0	0	0
Nitrate	2480.8	27.3	6606.2	72.7	0	0
Phosphate	4043.7	44.5	5043.3	55.5	0	0
Sub-overall	9087.0	100	0	0	0	0

Site suitability analysis

The site suitability for lobster cultivation was produced by combining all thematic maps of oceanographic, water quality, and socio-economic and institutional factors. The result of this analysis showed that out of total study area (9087 ha), 13.5% or 1226.7 ha was most suitable location and 86.5% of total area or 7860.3 ha was a moderately suitable location (Table 8.). Thematic maps of the suitability of water location for lobster cultivation can be seen in Figure 6.

North Lombok Regency is a coastal district, have 503.24 km^2 waters or about 38.33% of the total area of this regency. The coastline is about 125 km and there are 3 small islands known as Gili Matra (Meno, Trawangan and Air) which are preserved as marine protected areas (MPA) (Kurniawan *et al.*, 2016). As a conservation area and marine tourism park, these MPA have beautiful marine ecosystems (coral reefs, seagrasses, and mangroves), diversity of fish species, and beautiful beach which is well-known for foreign tourists and known as beautiful tourist destinations (Pratiwi *et al.*, 2014). Some attractions offered in Gili Matra are diving, snorkeling, sunbathing, canoeing, fishing, and water skiing (Dodds *et al*., 2010; Yulianto *et al.*, 2017). Since it was declared as marine conservation and tourism area in the 1990s (Kurniawan *et al*., 2016), tourism activities in Gili Matra MPA have developed rapidly. Although this condition has caused ecosystem degradation (Suana and Ahyadi, 2012), tourism activities in Gili Matra MPA has brought about economic benefits to the local community, in which 70% local revenue of North Lombok Regency come from the tourism sector (Suana and Ahyadi, 2012). However, these activities also have environmental impact, including threatened coral reef ecosystems. According to Wahyu *et al.* (2018), the damage of coral reef ecosystems due to tourism activities in MPA Gili Matra ranged of 53- 75%. In addition to impacting the aquatic biophysical environment, marine tourism activities affect the social, economic and cultural conditions of the local community (Pratiwi *et al*., 2014).

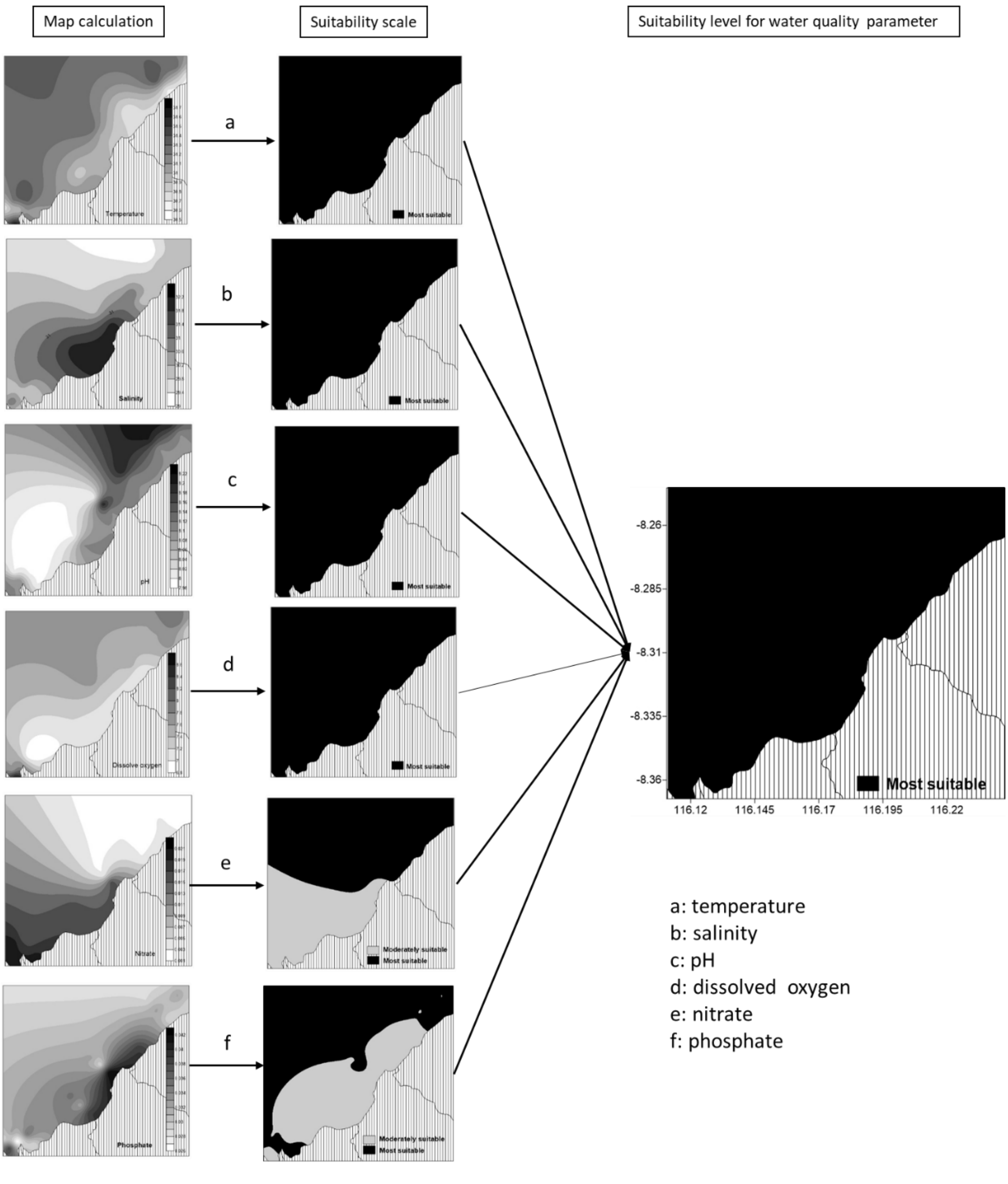

Figure 4. The process of combining water quality parameters to suitability level for lobster culture

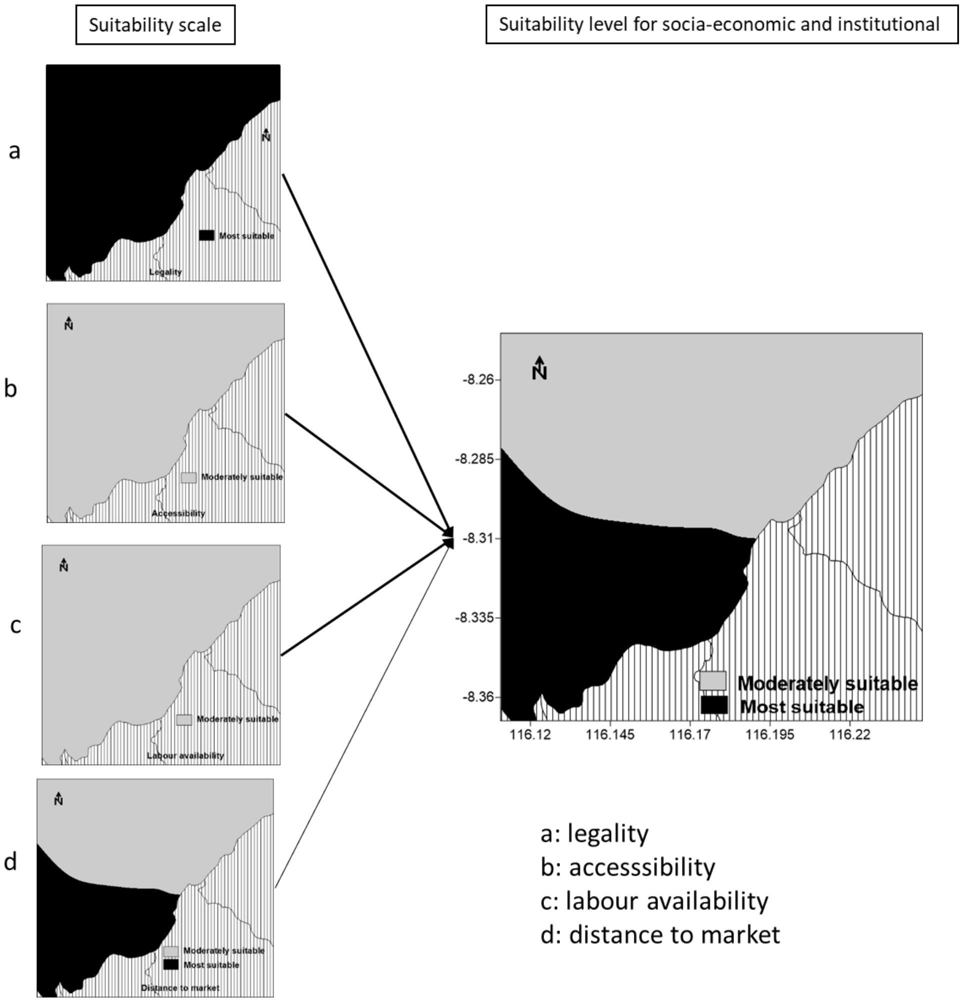

Figure 5. The process of combining socio-economic and institutional parameters to suitability lever for lobster culture

Table 7. Area and percentage of different suitability level for socio-economic and institutional parameters at study area

Parameters	Most suitable		Moderately suitable		Not suitable	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Legality	9087.0	100	0	0	0	0
Accessibility	0	0	9087.0	100	0	
Labour availability	0	0	9087.0	100	0	0
Distance to market	2691.7	29.6	6396.3	70.4	0	0
Sub-overall	2691.7	29.6	6396.3	70.4	0	0

Table 8. Area and percentage of different suitability level for lobster culture at study area

Criteria	Most suitable		Moderately suitable		Not suitable	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Oceanography	5134.2	56.5	3952.8	43.5	0	0
Water quality	9087.0	100	0	0	0	0
Socio-economic and institutional	2691.7	29.6	2691.7	29.6	0	0
Overall suitability of site	1226.7	13.5	7860.3	86.5	0	0

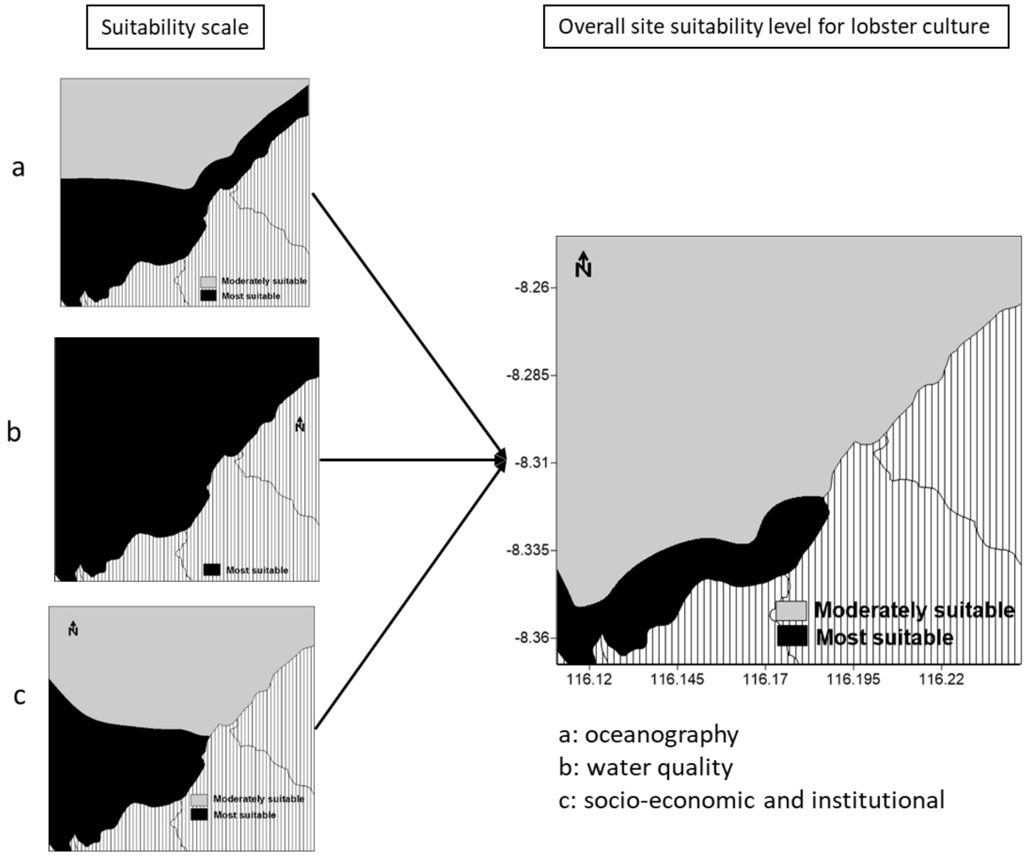

Figure 6. Suitability map for lobster culture at adjacent water of North Lombok District

Declining quality of resources and environment in several tourist destinations has also occurred in the Buleleng Regency, Bali (Yudasmara, 2016a,b). To get optimal benefit from fisheries and tourism resource in North Lombok District, fisheries and marine tourism development need to be translated into a more integrated concept based on environmentally friendly principles. The intended concept is called *Minawisata (fishery tourism)*. In the fisheries business system, *mina* (fish) is often used to replace the word of "fishery" which basically means the same as the word "fish" itself, while *wisata* (tourism) is a form of exploitation of natural resources that relies on natural services for human satisfaction (Amri and Arifin, 2017). Thus, *Minawisata* is an economic activity of the community and region based on the utilization of the potential of marine, fisheries and tourism resources in an integrated manner in a certain area (Dermawan and Aziz, 2012; Yudasmara, 2016a,b; Amri and Arifin, 2017). This could be an alternative tourist attraction in coastal and marine areas and can improve economic benefits on a local scale (Moksness *et al*., 2011).

The development of *Minawisata* in Indonesia already exists in several regions such as in the island of Nanggu, West Lombok Regency, and West Nusa Tenggara Province Barat (Mukhti, 2016). The income of community groups who manage the grouper farming using floating cages comes from marketing the fish to restaurants and hotels around the aquaculture location. Furthermore, floating cages used for the farming activity can be used as a tourist attraction, where many tourists visit the cages to enjoy underwater scenery or fishing. The result of tourism development in these locations has significantly increased the income of the community. Thus, *Minawisata* has a promising prospect to be developed in North Lombok Regency. Considering that according to the result of this study in the area 9087 ha, there are 1226.7 ha as the most suitable area for floating cages mariculture. This area is located in the southern part of North Lombok Regency waters, adjacent to Gili Matra MPA.

To develop lobster cultivation using floating cages which support environmentally friendly *Minawisata*, the potential area should not be fully utilized. There should be also proposed as buffer zones and spaces that enable cultivation operations to run effectively and efficiently, such as internal shipping lines between cultivation units. From the total potential area, there is about 122.67 ha which could be effectively utilized for lobster cultivation using floating cages. This means that the area that can be used is only 10% (Radiarta *et al*., 2005; Hasnawi *et al*., 2011; Affan, 2012). One hectare of lobster cultivation can be placed effectively of 8 units floating cage (10% of ideal area), where 1 unit of floating cage consists of 9 cages with a size of 3x3x3 m^3 per cage (Junaidi and Heriati, 2017). According to Radiarta *et al*. (2005), if 1 floating net cage unit consists of 4 cages with a size of 1.5x1.5x2.5 m^3, then 1 ha of cultivation area can be utilized effectively for 100 floating cage units.

Lobster as an aquaculture commodity has a very promising prospect to be developed in North Lombok Regency to support *Minawisata*. In addition to oceanographic conditions, socio-economic, and institutional factors that are very suitable, water quality parameters are also important. The result of water quality measurements, such as water temperature, salinity, pH, and solubility of oxygen, compared with suitability criteria for lobster cultivation using floating cages showed that the condition of waters in study area strongly supports the development of lobster cultivation (Junaidi *et al*., 2018). This activity is also supported by a high abundance of phytoplankton and zooplankton (Junaidi *et al*., 2018a,b). However, in the context of lobster cultivation management that guarantees a sustainable fisheries business and selecting suitable aquaculture sites, using the environmentally friendly cultivation technology is the first step (Costa-pierce, 2008). The application of integrated multi-trophic aquaculture (IMTA) system could be another step (Chopin *et al*., 2012). This aquaculture system combines several different trophic levels species (such as fish and shrimp) with one species absorbing inorganic wastes (e.g. seaweed), and another species absorbing the organic wastes (suspension and deposit feeders, such as bivalves (Troell *et al*., 2009; Chopin *et al*., 2012).

IMTA is an option for developing aquaculture in the future (Chopin *et al*., 2012; Radiarta *et al*., 2014). This is because, in addition to increasing production from several commodities simultaneously, it can also minimize negative impacts of aquaculture in the environment. IMTA implementation is very flexible and can be applied in open water or land cultivation units, both fresh and marine waters, even the development of IMTA has also spread to the open ocean (Troell *et al*., 2009). The most important thing in implementing IMTA is the selection of commodities in accordance with their functions in an ecosystem and paying attention to the economic value of these commodities. IMTA-based aquaculture development model is very relevant to support tourism in North Lombok Regency. IMTA can increase production maximally without damaging the environment (zero waste) so that it can lead to sustainable aquaculture development.

Conclusion

The study of the suitability of lobster cultivation site using Multi-criteria Analysis and GIS provided more accurate and maximum results and showed that there were 1226.7 ha waters as the most suitable location, but out of those area, only 122.67 ha as potential area that can be effectively used for lobster cultivation in floating cages. This shows North Lombok Regency water is very prospective and could be developed for lobster cultivation area using floating cages to support tourism. As an anticipatory step, development of mariculture in the North Lombok Regency should take into account carrying capacity of the aquatic environment, and its relation to assimilation capacity of the environment. Thus, it is necessary to estimate the cultivation area that can be developed without damaging or disturbing the balance of the aquatic environment receiving the waste produced from mariculture activities.

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