DOI: http://dx.doi.org/10.15578/iaj.18.2.2023.133-145 *Indonesian Aquaculture Journal, 18 (2), 2023, 133-145*

Available online at: http://ejournal-balitbang.kkp.go.id/index.php/iaj

THE ENVIRONMENTAL PARAMETERS SUITABILITY FOR MULTISPECIES-BASED MARICULTURE IN PONGOK ISLAND WATERS, BANGKA BELITUNG

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(Received: June14, 2023; Final revision: October 4, 2023; Accepted: October 5, 2023)

ABSTRACT

Pongok Island possesses small islands surrounded by waters with some primary commodities of sea farming. Seeking appropriate locations for marine aquaculture is a careful planning step to acquire optimal results. The sustainability of sea farming areas should be set based on considering species for easy implementation. This research aimed to analyse the area's suitability for aquaculture activities of seaweed cultivation, rearing groupers, and lobsters in floating net cages, and pearl oyster farming. This research occurred from June to November 2022 in Pongok Islands, South Bangka Regency, Indonesia. The method used in this research consisted of parameters weighting and scoring for cultivating seaweeds, groupers, or lobsters utilizing floating net cages and pearl oysters. Sea water samples analysis was processed in the Marine Science Laboratory of Bangka Belitung University and PT Global Quality Analytical, Bogor – West Java. Collected data were then scaled based on expert justification of scaling priority on aquaculture suitability. The mapping area of sea farming locations based on potential resources was then determined using map software. This research indicates that cultivating seaweeds is recommended to be established in two stations, 1 (149.79 ha) and 2 (186.46 ha), that are very suitable (S1) and the suitable (S2) categories, respectively. Station 3 (325.41 ha) and 4 (4.11 ha) are grouped into very suitable (S1) categories for pearl oysters and groupers or lobsters using floating net cages, respectively. The total estimate for sea farming in the waters of Pongok Island is 665.77 ha. Allocating seawater spaces should be assigned for sustainable fishery management. Maps of area suitability for sea farming can obviate conflicts in seawater areas.

KEYWORDS: **Floating net cages; groupers; lobsters; pearl oysters; seaweeds; suitableness**

INTRODUCTION

Coastal areas and small island development can be developed by managing marine biological resources, such as fishery potency, in a sustainable manner. Fishery production substantially contributes to various Sustainable Development Goals (SDGs) targets (Sampantamit *et al*., 2020; Cavalli *et al*., 2021; Elliott *et al*., 2022). Fishery management strategies are potentially carried out in many ways like diversifying the fishery business, developing the processing industry, mitigating climate changes, counseling and empowering coastal communities (Kurohman *et al*., 2020), transforming fishery commodity products and broadening their markets (Rimmer *et al*., 2021; Yanfika *et al*., 2021), refining technology and controlling areas of capture (Yusuf & Muhartono, 2017), lowering environmental impacts and biodiversity loss (Adibrata *et al*., 2013; Sampantamit *et al*., 2020). Climate change is currently having a significant influence on small islands. Temperature and sea surface increase pose dangers to ecosystems, as do sea level rise, land surface subsidence, heavy rainfall, drought on lands, degradation, and land conversion, all of which undermine_food security (Lenderking *et al*., 2020; Filho *et al*., 2021). These previously mentioned examples are also occurring_in the fishing industry, where catches are decreasing. As a result, an alterna-

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tive livelihood of the fishery is required to increase fishermen's incomes through mariculture (Utama & Junianto, 2021).

Indonesia possesses competitiveness in developing mariculture due to its numerous potential locations, stable tropical climate, and lack of cyclones (Rimmer, 2010), particularly seaweeds, which contribute to being a tool for the livelihood strategy of coastal communities in eastern Indonesia (Zamroni, 2021) as well as devoting positively on women's wellbeing and household benefits (Larson *et al*., 2021). Like other sections of Indonesia, the small islands of the Bangka Belitung Province can be optimized for aquaculture. One is in the Pongok Island Sub-district, South Bangka Regency (Perda Number 3 of 2020). On a small scale, mariculture provides an option to improve marine-based productive activities while dealing with declining catch fishery yield (Albers *et al*., 2021). Marine resources are essential in small island management (Bengen *et al*., 2012). Nevertheless, some challenges, such as a proper aquaculture location plan, a better mariculture practice process, and market access, are needed. Additionally, aquaculture development demands improved farming practices (Cavalli *et al*., 2021). Significant challenges remain, including seed stocks, efficient production systems, feed sources, environmental implications, and market opportunities (Rimmer, 2010; Utama & Junianto, 2021). Planning and dealing with these difficulties must minimize environmental damage and conflicts among coastal other users (Adibrata *et al*., 2013; Yucel-Gier *et al*., 2019).

The environmental consequences of mariculture are typically addressed in terms of environmental carrying capacity. In mariculture practices, for instance, lobster in cages, the water quality and sediment quality are impacted 1.4 times higher than in the non-farming areas. Aquaculture's carrying capacity is determined by physical carrying capacity, production, ecological, and social factors (McKindsey *et al*., 2006; Adibrata *et al*., 2013; Phu *et al*., 2022). An example of carrying capacity can be observed in marine finfish and lobster cages from the input of nutrients from leftover feed and fish waste (Utama & Junianto, 2021). It has been explored since the 1960s to estimate a production limit to be profitable economically and sustainably in the local environment (Conides *et al*., 2022). The weakness of the production carrying capacity approach is to deliver an approximation after operating aquaculture activity or ex-post approach.

In contrast, the physical carrying capacity, on the other side, provides information before conducting the aquaculture activities. This approach can outline suitable locations for marine aquaculture (McKindsey *et al*., 2006; Adibrata *et al*., 2013; Yucel-Gier *et al*., 2019). Routine sediment and water quality monitoring in the aquaculture areas to maintain the ecological carrying capacity can promote sustainable development (Mayerle *et al*., 2021). Mapping proper areas for marine aquaculture is perceived as the right first step.

Finding appropriate locations or areas for marine aquaculture is a careful planning step to acquire optimal results. Mapping marine aquaculture areas is essential for economic and food security, species commodities, or specific taxa (Clawson *et al*., 2022). Commodities of sea farming in Indonesia of them are seaweeds (*Kappaphycus alvarezii*), molluscs like pearl oysters (*Pinctada margaritifera*), crustaceans like lobsters (*Panulirus* sp.), marine finfish like groupers (*Epinephelus* sp.) and snapper (*Lutjanus* sp.) using floating net cages (Rimmer, 2010; Adibrata *et al*., 2013; Utama & Junianto, 2021). For easy implementation, the sustainability of mariculture areas should be determined by species. Certain primary commodities of mariculture are also expected to become mainstay commodities to escalate production, strengthen the local economy, and improve coastal community welfare. Research regarding water quality parameters for mariculture have been carried out for different commodities in many areas of Indonesia like green clams in Bali (Wisnawa & Yudi, 2013), seaweeds and floating cage nets in North Sulawesi (Adipu *et al*., 2013), seaweeds in East Java and South Sulawesi (Jailani *et al*., 2015; Yustika *et al*., 2022) and West Nusa Tenggara (Kautsari & Ahdiansyah, 2015), swimming crabs and groupers in Southeast Sulawesi (Sirza *et al*., 2016), groupers in East Java (Hidayah *et al*., 2020) and Aceh (Anhar, 2023), sand sea cucumber in North Maluku (Hamka *et al*., 2021), and pear oysters in Southeast Sulawesi (Iyen *et al*., 2021) and West Nusa Tenggara (Hadinata *et al*., 2019). Information about water quality parameters is essential before conducting mariculture activity in the Pongok Islands to diminish technical and economical failures. This research aimed to assess the area's potential for aquaculture activities such as seaweed cultivation, growing groupers and lobsters in floating net cages, and pearl oyster farming.

MATERIALS AND METHODS

Time and location

Pongok Island is situated in the eastern part of the South Bangka Regency. This island is about 3.5 hours traveling by boat from Sadai Harbour, the main island of Bangka. The seashore of this island is surrounded by mangrove forests consisting of four notable species: *Rhizophora* sp., *Sonneratia* sp., *Avicennia* sp., and *Bruguiera* sp. (Umroh *et al*., 2016). At the same time, in the deeper water, the coral reefs are found in common. In a range of 14.7 to 22.5 m depth, groupers are caught optimally by local fishermen in the coral reef area (Adibrata *et al*., 2018). Pelagic fishing activities are commonly discovered in open water, especially using a lift net at night.

This research was conducted from June to November 2022. The sampling location was on Pongok Island, South Bangka Regency. Water samples analysis was processed in the Marine Science Laboratory of Bangka Belitung University and Global Quality Analytical Inc. at Bogor – West Java.

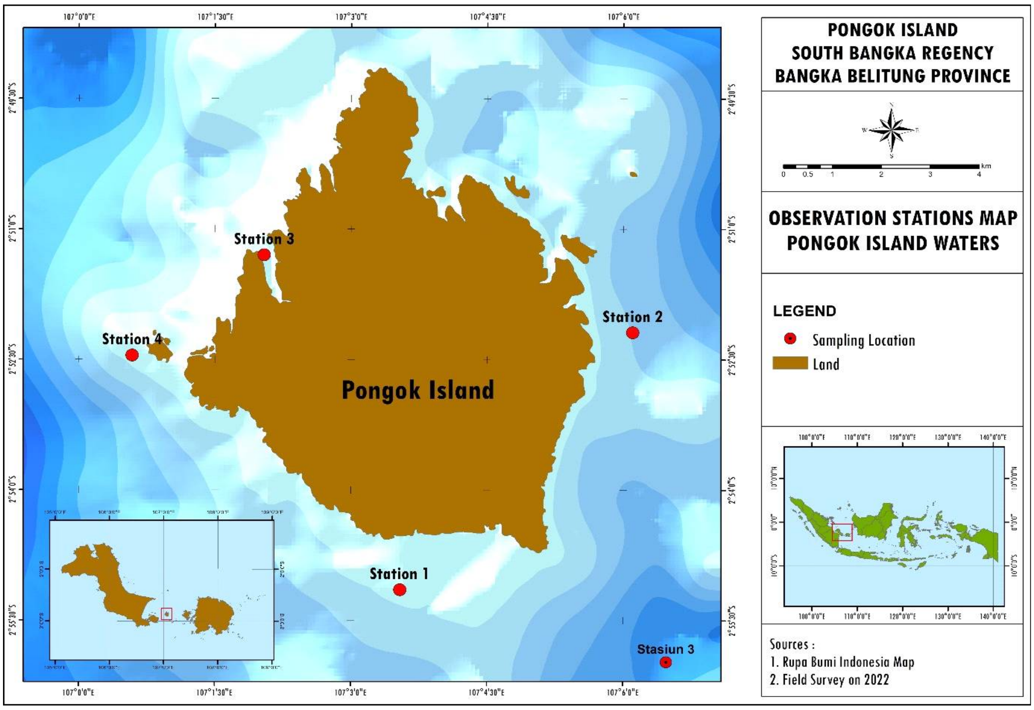

Figure 1. Field survey stations map.

Method

Determining specific locations as stations for this research was done by considering four main wind directions and coastal topography. Four stations were decided to observe the hydro-oceanographic condition and water quality parameters using a purposive sampling technique. These stations represented the south and east parts of the island in station 1 and 2, the estuary area, and the nearest villages in station 3 and 4, respectively. These stations in the current research were intended to avoid spotting; however, they referred to coverage areas. Dots in the research map (Figure 1) were set for location marking only.

The water quality parameters affecting aquaculture production consist of physical and chemical parameters. Some physical parameters, for instance, are water temperature, light attenuation, current, and bathymetry. Coastal tides are also a concerned parameter in this research. Furthermore, some chemical parameters are total suspended solids (TSS), pH, salinity, dissolved oxygen (DO), ammonia (NH_3), ammonium ion (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), orthophosphate (PO_4^-), and biological oxygen demand (BOD) (Adibrata *et al*., 2013; Hastari *et al*., 2017; Yulianto *et al*., 2017; Helal & Mustafa, 2019; Saenuddin *et al*., 2021; Sarjito *et al*., 2022). Data were collected during this research consisting of research coordinate locations, protection, current velocity, bathymetry, substrate, transparency, temperature, DO, salinity, water pH, tides, nitrate, and phosphate.

After gathering those water quality parameters above, three matrixes of parameters were set for the assessed commodities (seaweeds, groupers or lobsters, and pearl oysters). Each parameter contained weight, category, class, and score. The order of parameters begins from the most or highest (number 1) affecting parameters to the lowest affecting parameters (number 12). Weighting these parameters was determined by expert's justification. In this research, eight experts have been involved in scaling those parameters. The average of this weighting was set to determine the order of parameters. Categories in the matrix consisted of very suitable (S1), suitable (S2), and not suitable (N) (Adibrata *et al*., 2013). Further, values of the class in matrixes were set by researchers (Afandi & Musadat, 2018). S1, S2, and N scores are 5, 3, and 1, respectively. The total score of each category was acquired by multiplying the weight of each parameter with the score of the class in each category. Each commodity has a different total score for every class. Interval class is variedly referring to aquaculture commodities and environmental conditions (Hasnawi *et al*., 2013; Radiarta & Erlania, 2015; Sirza *et al*., 2016; Afandi & Musadat, 2018; Ermawati, 2020; Kendarto & Nuryadin, 2021). Thus, different total scores make the range of suitability conditions different for any commodities. In the last step, the suitability category was gathered on each research station and mapped using ArcGIS 10.8. Expanding areas figured in the map to draw a covering area of suitable locations for each commodity was bolstered by field observation (Afandi & Musadat, 2018; Ernawati, 2020). Matrixes of weight and score for those three commodities are listed in the following tables.

1. Area suitability for seaweed cultivation

The method used to analyze area suitability for seaweeds was carried out by scoring some criteria referring to the matrix below (Table 1).

Table 1. Matrix of weight and scores for cultivating seaweeds

No.	Parameters	Weight	S1 (Very Suitable)		S2 (Very Suitable)		S3 (Less Suitable)	
			Class	Score	Class	Score	Class	Score
1	Protection	20	Very protected	5	Protected	3	Open	1
2	Seawater current velocity (m/s)	20	0.25 – 0.35	5	0.1 – <0.25 or >0.35 – 0.45	3	<0.1 or >0.45	1
3	Bathymetry (m)	15	3 – 5	5	1 – <3 or >5 – 10	3	<1 or >10	1
4	Substrate	15	Rocky sand	5	Muddy sand	3	Mud	1
5	Transparency (%)	15	85 – 100	5	70 – <85	3	<70	1
6	Temperature (°C)	15	27 – 30	5	24 – <27 or >30 – 34	3	<24 or >34	1
7	DO (mg/L)	15	7 – 8	5	5 – <7 or >8 – 10	3	<5 or >10	1
8	Salinity (ppt)	15	30 – 33	5	25 – <30 or >33 – 35	3	<25 or >35	1
9	Water pH	10	7.5 – 8.5	5	7 – <7.5 or >8.5 – 9	3	<7 or >9	1
10	Tides (m)	5	1 – 2	5	0.5 – <1 or >2 – 2.5	3	<0.5 or >2.5	1
11	Nitrate (mg/L)	5	0.05 – 0.1	5	0.01 – <0.05 or >0.1 – 0.5	3	<0.01 or >0.5	1
12	Phosphate (mg/L)	5	0.05 – 0.1	5	0.005 – <0.05 or >0.1 – 0.5	3	<0.005 or >0.5	1
	Total weight x score			775		465		155

Note: weighting scores was based on a priority scale of expert justification. S1, S2, and S3 are environmental categories for very suitable, suitable, and less suitable, respectively. The higher total score of class indicate the the water quality parameters are very suitable for the intended fishery commodity.

Source: modification from Adibrata *et al*. (2013); Tiensongrusmee *et al*. (1986) in Sunyoto (1997)

The range starts from 155-775 = 620 (divided into three classes to be 207). Then, classifying the condition of water quality parameters and properties mentioned in Table 1 above is referred to into three categories.

Very suitable (S1) = <568 – 775

Suitable (S2) = 362 – 568

Not suitable (N) = 155 – < 362

2. Area suitability for rearing groupers or lobsters using floating net cages

The method utilized in analyzing the area suitability for rearing groupers or lobsters using floating net cages refers to the criteria in the matrix (Table 2).

The range starts from 145-725 = 580 (divided into three classes to be 193). Then, classifying the condition of water quality parameters and properties mentioned in Table 2 above is referred to into three categories.

Very suitable (S1) = <531 – 725

Suitable (S2) = 338 – 531

Not suitable (N) = 145 – < 338

Table 2. Matrix of weight and scores for rearing groupers or lobsters using floating net cages

No.	Parameters	Weight	S1 (Very Suitable)		S2 (Suitable)		N (Not Suitable)	
			Class	Score	Class	Score	Class	Score
1	Seawater current velocity (m/s)	20	0.25 – 0.35	5	0.1 – <0.25 or >0.35 – 0.45	3	<0.1 or >0.45	1
2	Bathymetry (m)	20	15 – 25	5	7 – <15 or >25 – 40	3	<7 or >40	1
3	Substrate	20	Rocky sand	5	Muddy sand	3	Mud	1
4	Protection	15	Very protected	5	protected	3	Open	1
5	Transparency (%)	10	85 – 100	5	70 – <85	3	<70	1
6	Temperature (ºC)	10	27 – 30	5	24 – <27 or >30 – 34	3	<24 or >34	1
7	DO (mg/L)	15	7 – 8	5	5 – <7 or >8 – 10	3	<5 or >10	1
8	Salinity (ppt)	10	30 – 33	5	27 – <30 or >33 – 35	3	<27 or >35	1
9	Tides (m)	10	1 – 2	5	0.5 – <1 or >2 – 2.5	3	<0.5 or >2.5	1
10	Water pH	5	7.5 – 8.5	5	7 – <7.5 or >8.5 – 9	3	<7 or >9	1
11	Nitrate (mg/L)	5	0.05 – 0.1	5	0.01 – <0.05 or >0.1 – 0.5	3	<0.01 or >0.5	1
12	Phosphate (mg/L)	5	0.05 – 0.1	5	0.005 – <0.05 or >0.1 – 0.5	3	<0.005 or >0.5	1
	Total weight x score			725		435		145

Note: weighting scores was based on a priority scale of expert justification. S1, S2, and S3 are environmental categories for very suitable, suitable, and less suitable, respectively. The higher total score of class indicate the the water quality parameters are very suitable for the intended fishery commodity.

Source: modification from Adibrata *et al*. (2013); Tiensongrusmee *et al*. (1986) in Sunyoto (1997)

3. Area suitability for developing pearl oysters

The method utilized in analyzing the area suitability for developing pearl oysters refers to the criteria in the matrix (Table 3).

The range starts from 150-750 = 600 (divided into three classes to be 200). Then, classifying the condition of water quality parameters and properties mentioned in Table 3 above is referred to into three categories.

Very suitable (S1) = >550 – 750

Suitable (S2) = 350 – 550

Not suitable (N) = 150 – < 350

RESULTS AND DISCUSSION

The recommendation of research frequently is faced on data and analysis power problems like massive data with minimum analysis and data need to optimize analysis. This research represents the east monsoon season due to the observing period was only conducted during this season. Changing over seasons from east to west monsoons will affect water quality parameters due to weather conditions and wind-blowing direction. However, an absence of the west monsoon season data would make this research less accurate in figuring out a whole-year situation. Therefore, the data provided in this research is only expected to be implemented from May to October. Lack of data is commonly caused by limiting factors such as cost, time, and human resources. Even though there any limited data, the results of this research can be followed up through an in-situ trial implemented by local people. Mariculture activities in the coastal area are essential for small-scale fishermen. The role of small-scale fishermen needs to be empowered with alternative businesses like good practice aquaculture planning. It promotes sustainable fishery resource management, food security, and poverty alleviation. Aquaculture ought to be practiced in certain locations with reasoning on a unique set of natural resources, social, and economy (Yucel-Gier *et al*., 2019). The current research builds upon a biotechnical consideration that requires management and economic aspects to realize aquaculture.

Table 3. Matrix of weight and scores for developing pearl oysters

No.	Parameters	Weight	S1 (Very Suitable)		S2 (Suitable)		N	
			Class	Score	Class	Score	Class	Score
1	Seawater current velocity (m/s)	20	0.25 – 0.5	5	0.1 – <0.25 or >0.5 – 0.75	3	<0.1 or >0.75	1
2	Bathymetry (m)	20	15 – 35	5	7 – <15 or >35 – 50	3	<7 or >50	1
3	Protection	15	Very protected	5	Protected	3	Open	1
4	Substrate	15	Rocky sand	5	Muddy sand	3	Mud	1
5	Transparency (%)	15	85 – 100	5	70 – <85	3	<70	1
6	Temperature (ºC)	15	27 – 30	5	24 – <27 or >30 – 34	3	<24 or >34	1
7	DO (mg/L)	15	7 – 8	5	5 – <7 or >8 – 10	3	<5 or >10	1
8	Salinity (ppt)	10	30 – 33	5	27 – <30 or >33 – 35	3	<27 or >35	1
9	Tides (m)	10	1 – 2	5	0.5 – <1 or >2 – 2.5	3	<0.5 or >2.5	1
10	Water pH	5	7.5 – 8.5	5	7 – <7.5 or >8.5 – 9	3	<7 or >9	1
11	Nitrate (mg/L)	5	0.05 – 0.1	5	0.01 – <0.05 or >0.1 – 0.5	3	<0.01 or >0.5	1
12	Phosphate (mg/L)	5	0.05 – 0.1	5	0.005 – <0.05 or >0.1 – 0.5	3	<0.005 or >0.5	1
	Total weight x score			750		450		150

Note: weighting scores was based on a priority scale of expert justification. S1, S2, and S3 are environmental categories for very suitable, suitable, and less suitable, respectively. The higher total score of class indicate the the water quality parameters are very suitable for the intended fishery commodity.

Source: modification from Adibrata *et al*. (2013); Tiensongrusmee *et al*. (1986) in Sunyoto (1997)

Optimizing sea farming relies on cultured species, methods, spread density, feed, hydro-oceanographical conditions, and aquaculture management practices. Waters with limited carrying capacity should be paid attention to a precautionary aspect, mainly regarding the physical condition of the area and environmental polluting load. Evaluating seawater carrying capacity is an effective way to utilize and evolve marine resources rationally and to provide an early warning of marine ecological problems (Huang *et al*., 2022). The environmental capability and carrying capacity are well-kept when ecosystem degradation is also prevented (Yusuf, 2013). The area suitability of marine aquaculture dealing with proposed commodities should calculate environmental conditions and tolerable life parameters. The current research focuses only on four primary commodities: seaweeds, groupers or lobsters, and pearl oysters. Each species has specific tolerance limits on parameters affecting its life, particularly hydro-oceanic conditions. Tolerable water quality parameters are important for those commodities in resulting a maximum production. Mariculture practices especially on a specific species will lead to economic generating in coastal areas. Therefore, the mentioned commodities above are believed to be a mainstay in bolstering production, local economy, and coastal community well-being. The analysis of area suitability is beneficial in the zone planning of mariculture. The planning begins with either a strategic environmental study or after being a document followed by an environmental audit review.

The local regulation (Perda Number 3 of 2020) about zone planning of Bangka Belitung Provinces instructs the Pongok Island Sub-district waters to become one marine aquaculture center. Relating to the mandate, a further step is to map the area suitability of cultivating proper species commodities. The resulting map delivers alternative locations to conduct mariculture activities with three categories, namely very suitable (S1), suitable (S2), and not suitable (N) (Yusuf, 2013). The mariculture map uplifts an understanding of fishery aquaculture location, production intensity and efficiency, and possible impacts on the social, economic, and environmental of aquaculture (Clawson *et al*., 2022).

Results of this research obtained for 12 water quality parameters depict stations of research locations (stations). Each parameter is classified into suitability score and multiplied by its weight (described in the method). Characteristics of stations are different from each other based on their parameter. The conditions and value ranges of hydro-oceanographical parameters obtained in each station during this research are listed in Table 4.

Table 4. Field data collected for farming four species

No.	Parameters	Numbers of Data	**Station 1** 02° 53' 30.95" S 107° 1' 50.15" E	**Station 2** 02° 54' 5.72" S 107° 05' 18.41" E	**Station 3** 02° 50' 4.17" S 107° 02' 2.13" E	**Station 4** 02° 52' 15.7" S 107° 01' 10.7" E
1	Protection*		Very protected (East Monsoon) Open (West Moonsoon)	Open (East Moonsoon) Protected (West Moonsoon)	Protected (East Monsoon) Open (West Moonsoon)	Very protected (East Monsoon) Protected (West Moonsoon)
2	Seawater current velocity (m/s)*	22	0.10 – 0.44	0.12 – 0.42	0.10 – 0.46	0.10 – 0.22
3	Bathymetry (m)*	22	8 – 15	16 - 25	8 - 15	10 - 11
4	Substrate	22	Dead coral, algae, sand	Dead coral, algae, sand	Dead coral, algae, sand	Dead coral, algae, sand
5	Transparency (%)*	22	8 – 13	6.5 – 20	7 – 15	7 – 11
6	Temperature (°C)*	22	28 – 31	29.0 – 30.3	27 – 32	29.6 – 32.0
7	DO (mg/L)*	22	6.5 – 8.1	6.2 – 7.9	5.7 – 8.0	5.7 – 8.2
8	Salinity (ppt)*	22	29 – 34	28 – 33	27 – 33	28 – 33
9	Water pH*	22	7.6 – 8.0	7.4 – 8.0	7.3 – 8.0	7.8 – 8.0
10	Tides (m)	22	0.65 – 1.50	0.65 – 1.50	0.65 – 1.50	0.65 – 1.50
11	Nitrate (mg/L)*	22	0.064 – 0.066	0.050 – 0.063	0.013 – 0.10	0.012 – 0.13
12	Phosphate (mg/L)*	22	0.003 – 0.005	0.004 – 0.009	0.004 – 0.016	0.005 – 0.010

Note: data gathered on east monsoon (8 primary data analyzed by the team, The grouping; 14 secondary data acquired from Adibrata (2012). * indicates primary data.

Data gathered in Table 4 above is then compared with the suitable matrixes in Tables 1, 2, and 3 to determine the life suitability of determined commodities. Each parameter is classified into suitability score and multiplied by its weight (described in the method). The grouping of 12 parameters is summed to be the only one value. This result value compared with the category of suitability as S1 (very suitable), S2 (suitable), and N (not suitable) based on range values of suitability area of rearing intended commodities. The results of this categorizing are listed in Table 5.

Table 5. Sea farming area suitability of four survey stations on east monsoon

No.	Species Commodities	**Station 1** 02° 53' 30.95" S 107° 1' 50.15" E	**Station 2** 02° 54' 5.72" S 107° 05' 18.41" E	**Station 3** 02° 50' 4.17" S 107° 02' 2.13" E	**Station 4** 02° 52' 15.7" S 107° 01' 10.7" E
1	Seaweeds	705 (S1)	525 (S2)	525 (S2)	575 (S1)
2	Grouper or lobster using floating net cages	505 (S2)	535 (S2)	535 (S2)	595 (S1)
3	Pearl oysters	390 (S2)	420 (S2)	640 (S1)	580 (S1)

S1, S2, and N are environmental categories for very suitable, suitable, and less suitable, respectively. The higher total score of class indicate the the water quality parameters are very suitable for the intended fishery commodity.

Based on Table 5 above, as analysis results, all four study areas were found to be suitable to some degree for cultivating seaweeds utilizing the horizontal long-line technique. Stations 1 (149.79 ha) and 2 (186.46 ha) were found to be category S1 (very suitable), with category S2 (suitable) found in stations 3 (325.41 ha) and 4 (4.11 ha).

As such, all locations are likely suitable for cultivating seaweeds with relatively few limiting factors like seawater current velocity and bathymetry. Some limiting factors of growing seaweeds are temperature (ideally in a range of 20-32ºC), salinity (in a range of 23-38 ppt) (San, 2012), seawater current velocity (in a range of 20-40 cm/s) (Rahadiati *et al*., 2017), light intensity (Herliany *et al*., 2017), and other factors such as suspended solids, waves, DO, pH, CO_2, nitrate, and phosphate (Ya'la, 2022). Seaweed is a potential commodity to be cultivated in Pongok Island waters. Table 5 indicates two locations (stations 1 and 4) that are very suitable (S1) for this commodity while two other areas are grouped into a suitable category (S2). However, due to cultivating seaweed needs large areas, station 4 is limited. Hence, by considering coastal topography and seawater condition that was taken descriptively through visual and manual sketches during field surveys, the authors prefer to recommend cultivating seaweeds can be conducted in station 1 and 2 (Figure 2). Cultivating seaweed can be carried out using a long line technique because these locations are protected and not significantly disturbed by wave threats during east monsoon. Cultivating seaweeds is new and attractive for people in the Pongok Islands sub-district. This marine resource commodity is widely cultured in many areas of Indonesia, like *Eucheuma cottonii* or *Kappaphycyus alvarezii* in South Sulawesi (Jailani *et al*., 2015; Sarjito *et al*., 2022), North Sulawesi (Adipu *et al*., 2013) and Bali (Nashrullah *et al*., 2021) with different techniques of cultivation. The current research indicates very suitable in two locations with total scores of 705 (Station 1) and 575 (Station 2), respectively. While two other stations are classified into suitable category with total scores of 525. These suitability in terms of total scores are different with research conducted by Iyen *et al*. (2021), Nashrullah *et al*. (2021) and Susanto *et al*. (2021) due to different numbers of scores, input variables, and locations. Furthermore, according to interviewing local fishermen, the nearest location of cultivating seaweeds (*Eucheuma cottonii jumbo*) in other parts of South Bangka is in Tukak Sadai subdistrict that is about four hours by boats in distance. This condition enables local fishermen of the Pongok Islands to get the seaweeds seedlings. Moreover, coastal people widely accept seaweeds due to low capital and operational costs, relatively easy cultivating technique, requiring relatively low human resource skills, short reproduction cycle of about 30-40 days, and providing constant income (Rimmer *et al*., 2021). To make this commodity believed living well in the research area, a pilot project of cultivating needs to be implemented as the recommended areas. It will inform the local people that the seaweed is a prospect to be developed in the coastal areas.

Classifying the potential area for rearing groupers or lobsters using a floating net cages system in the Pongok Island waters indicates different suitability levels. A suitability class denotes Station 4 is categorized into S1 (very suitable), and three other areas are S2 (suitable). Groupers (*Epinephelus* sp.) is one of the existing fishery commodities in Pongok Island. Local fishermen capture it in the wild using wired traps for many years (Adibrata *et al*., 2013). The captured groupers are then reared using floating net cages until specific sizes or prices. While lobster is still a new potential commodity to be raised due to an absence of lobster seeds in the local area. By examining water quality parameters and the physical condition of Pongok Island waters, the authors advise raising both fishery commodities in station 4. The area suitability for the mentioned commodities is based on the physical analysis without any consideration of economic and management aspects (Adibrata *et al*., 2013). Looking at all parameters, some limiting factors affecting these commodities (grouper and lobster) are dominantly slow water current velocity and the water depth of about a minimum of 10 m in station 4. The sheltering parameter is highly affected and becomes a supporting factor in this location. It is why local fishermen are still interested and have survived using floating net cages at the location for rearing groupers for years. The floating net cages must also bear in mind business management aspects like easy control of the location, safety, and adjacent to the settlement (Adibrata *et al*., 2013). Regarding trash fish feed supply, the location evidences no trouble dealing with feed transportation making fish raisers' mobility fast and easy. Feeds are obtained from the lift net fishermen and gill net fishermen. During the east monsoon or transition period, the water current in the location will be calm with a velocity of lower than 0.2 m/s. This condition can potentially threaten the reared groupers, primarily from diseases and parasites. Feed residue buried on the sea floor in huge numbers can poison the upper water column and be a hideout of parasitic organisms and a food source for parasites like sea fleas (*Neobendenia* sp., and *Bendenia* sp.) attacking the reared fish.

Farming pearl oysters has the potential to be undertaken in the water of Pongok Island utilizing the vertical long-line method. Furthermore, according to the suitability class, stations 3 and 4 are classified as S1 (very suitable), whereas stations 1 and 2 are classified as S2 (suitable). The last commodity, pearl oysters (*Pinctada* sp.), is essential for generating economic activities in coastal areas because almost all parts of their body are valuable (Dody, 2017). This commodity is found wildly in Pongok Island waters, with a small amount nearest to local settlements. Because of the fewest restricting variables, the authors recommend station 3 for pearl oyster mariculture (Figure 2). The field survey estimated the area descriptively using visual and manual sketching. By considering water quality parameters and aquaculture technique of raising this commodity using the vertical long line method, this station is an excellent choice for the commodity during the east monsoon or transition season, while other places are advised for other commodities. Some essential water quality parameters that should be paid attention on culturing this commodity are current, sea surface temperature, and salinity (Habib *et al*., 2018). Field observation also indicates that this location is adjacent to mangrove areas around a small estuary. A very suitable area is nearest to the mainland due to being more protected and close to the river which contributes to organic materials loading from the mainland (Hadinata *et al*., 2019).

The increased skill of coastal communities in assessing environmental and economic implications aids adaptive response to natural and human system stressors like climate change and Covid-19. The allocation of sea space use has to be determined for sustainable fishery management. The effective potential management of small-scale aquaculture can escalate economic development and household incomes (Albers *et al*., 2021). The map of area suitability for sea farming (Figure 2) can help to avoid conflicts over sea space. It would promote sustainable fishery resource management, food security, and poverty reduction.

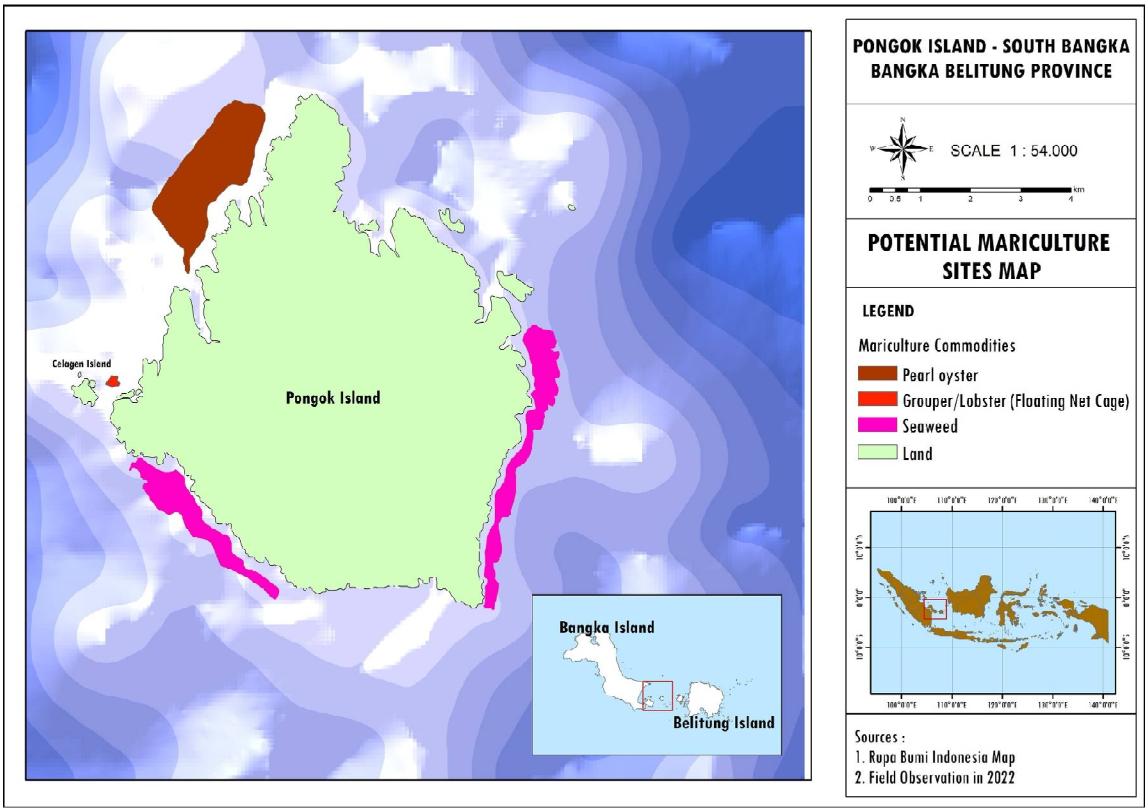

Figure 2. A map of selecting mariculture suitability.

CONCLUSION

Based on the area suitability analysis, considering hydro-oceanography and water quality parameters can recommend the proper locations for sea farming. This research's hydro-oceanography and seawater quality parameters are bathymetry, substrate, temperature, water current velocity, tide, pH, salinity, DO, protection, nitrate, and phosphate. There are three potential main categories of sea farming with different suitability levels in the waters of Pongok Island. Station 1 is categorized as S1 or very suitable (149.79 ha) for cultivating seaweeds on the east monsoon, and Station 2 is grouped as S2 or suitable (186.46 ha) on the west monsoon blowing period for growing the same commodity. Furthermore, stations 3 and 4 are grouped into category S1 or very suitable (325.41 ha in station 3) and (4.11 ha in station 4) for farming pearl oysters and groupers or lobsters, respectively. Station 3 is only protected during east monsoon blowing. Station 4 is a closed area for east and west monsoon blowings. The total estimate for sea farming in the waters of Pongok Island is 665.77 ha. Results discussed through this research consider only an east monsoon season because of limited data on the west monsoon season. The presence of west monsoon data will complete a whole year's analysis. The allocation use of sea space should be established for sustainable fishery management. The map of area suitability for mariculture can obviate conflicts of sea space use. After all those considerations above, the authors suggest conducting an in-situ trial for cultivating or raising up mentioned commodities.

ACKNOWLEDGEMENTS

The authors would like to thank Thomas Gammage for his comments and the two anonymous reviewers for their insightful suggestions and careful reading of the manuscript. Thanks to LPPM Bangka Belitung University, experts for justification in the analysis of this research, and students who participated in the research. The authors thank The Higher Education Directorate General of Kemendikbudristek that, have financing this research. This research was funded through a schema of Skema Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) or Decentralised research of 2022 with contract number: 455.A/UN50/L/PP/2022. This research becomes a reference for implementing mariculture, especially in Bangka Belitung Province.

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