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Ecological Effect Analysis in Determining Environmental Suitability for SEAWEED *Kappaphycus alvarezii* Farming in Levun Bay, Southeast Maluku

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Abstract : Farming seaweed *Kappaphycus alvarezii* in Levun bay, Southeast Maluku is important as the source of economic growth for its water areas' potentials which is optimal, productive and sustainable. The research was aimed to analyze the ecological effect in determining environmental suitability for seaweed *K. alvarezii* farming in Levun bay, Southeast Maluku. It used descriptive method with survey technique through field observation and laboratory tests. The analysis of data used GIS approach through measurement and scoring, environmental carrying and supporting capacity analysis. The results showed that Levun bay was potential for *K. alvarezii* farming as it was categorized as very suitable (S1) for 3,511 x 10^3 m^2 or 351.1 ha (89.1 %) while the area categorized as suitable with conditions (S2) was 428 x 10^3 m^2 or 42.8 ha (10,9 %) and not suitable class (N) was undetected or 0%. Environmental supporting capacity for seaweed farming with long line system was about 2,033 units at very suitable area (S1) and suitable with conditions was about 268 units.
Keywords : environmental suitability, supporting capacity, *Kappaphycus alvarezii*, ecological, GIS, water quality, seaweed farming.

Introduction

Seaweed culture is a main commodity for fishery revitalization program expected to have important role as the source of economic growth in accordance with the region's characteristic[1]. The researches related to seaweed culture have been done for quite a while such as Risjani[2,3,4] and Mulyaningrum et al[5] on nitrogen transportation along the thallus, carrageenan content biomass and callus regeneration in managing growth and development in the plant tissue.

Generally *K. alvarezii* grows well along the coastline and reefs and it has various shapes, size, color and compositions[6,7]. The original habitat is the area with constant current of the sea, with small range of temperature and dead coral substrate[8]. The species is commercially potential as it is the source of kappa carrageenan, the phycocolloid often used in thickening and stabilization of food, pharmaceutical and cosmetic products[4,9]. It is used as a derivative product in forms of varied food grade and nonfood grade and the demand of global market for the product is quite high[10],

Seaweed has a very important role in supporting biodiversity and ecological function in marine ecosystems[11]. The growth of seaweed *K.alvarezii* is considered well if the daily growth is not less than 3%[12]. The growth rate is affected by transparency and also by nutrient works as determining factor which improves or hampers the seaweed growth. Therefore to determine seaweed farming location, we need to consider the water quality as technical requirement beside technology and social economic aspect of the society[13]. Ecological factor is the optimal ecosystem capacity or the capacity of a habitat to uphold farming activity without causing any ecological impacts which decrease the ecosystem productivity[14].

Southeast Maluku Regency as one of the autonomous region in Maluku province has developed seaweed farming since 2006 and is one of the seaweed farming center in Maluku. From 2009 to 2010, seaweed production of this region was 4,872.9 tons and the seaweed was *Kappaphycus alvarezii*[15]. Then in 2010 it is established as the region which supports fishery revitalization for development based on fishery production[16]. The government support through Village Fishery Enterprise Development Program (PUMP-PB) has not shown significant result as it only improved production about 1,200 tons or 24.61% from 2011 to 2013 with improvement 8.20% for a year.

Environmental suitability of seaweed farming should be developed based on water quality data[17]. The process of determining location for farming activity can be done through spatial operation with Geographic Information System (GIS)[18]. This operation is a data processing system to process geographical data or data with spatial information related one another in order to get a new information[19].

The management and farming development should be conducted in the range of environmental support capacity and suitability[20]. To support the seaweed production development, some strategies are needed such as optimalization of site productivity, extensification and diversification commodity as well as considering environmental support capacity[21]. Social infrastructure factors such as the port location, boat mooring location, settlement area and anthropogenic effects like agriculture activity, sea traffic, and pearl farming can impose ecological pressure which then causes the environmental degradation as the water quality declines. Therefore, ecological analysis is used to review the environmental suitability through GIS spatial model approach to determine suitable location for seaweed *K. alvarezii* farming in Levun bay.

The research was conducted to analyze the ecological effect in determining environmental suitability for seaweed *K. alvarezii* farming in Levun bay, Southeast Maluku through GIS approach.

Methodology

Location and Time of Research

The research was conducted in Levun bay of Sathean Village, Little kei Sub-district, Southeast Maluku Regency, Maluku, Indonesia. It was conducted from March to April 2016.

Data Collection Method

The research used a descriptive method with survey technique. The descriptive method was based on the facts happened during the research[22]. The station determination for observation was done with purposive method which is applied deliberately so it can represent the research location as a whole[23].

The research was conducted in three observation stations in 4,017 x 103 m2 or 401.7 ha wide area. Station A, located in the south of Levun bay, was a secluded area and far from the effect of the strait and the locals' settlement with terrain surrounded by trees, with walls of stony reef and dominated with muddy and soft sand substrate. Station B, located in the middle part of the bay, was closed with the locals' settlement, harbor and strait current in the east of Levun bay with mangroves forest. Station C, located in the north of Levun bay, is the mouth of the bay with a lot of trees, mangroves forest also the location of pearl farming.

The sampling point in all the station was determined with Point-Quarter Method, a method determining sampling points in random from a line transect with the distance between the points is determined in random or systematic[24]. Sampling points in all three stations were linear with the coastal line and marked by GPS (Global Positioning System).

Ecological data collection related to the seaweed growth requirements through the observation and in situ or laboratory measurement consisted of 2 (two) parameters physical and chemical. Physical parameters namely temperature, current velocity, transparency, salinity, depth and substrate were collected in situ. Chemical parameters such as Nitrate, Orthophospate, BOD and COD were analyzed in the laboratory. The data collected from the sites were calculated and analyzed spatially to make the potential map based on the range of environmental suitability through SIG approach.

Data Analysis Method

Environmental suitability analysis for seaweed was started by measuring the parameters and made a matrix of the scores and values. Environmental suitability was divided into 3 (three) classes, S1 (highly suitable), Class S2 (suitable) and Class N (not suitable). The parameters which affect more were valued bigger than the parameters with small effect (See Table 1).

Table 1. Valuation and Score Result of Water Suitability for Each Ecological Parameters

Parameter	Criteria	Measurement Scale (A)	Value (B)	Score (AxB)
Current	0.2 - 0.3 0.1 - 0.19 & 0.31 - 0.4 < 0.1 &> 0.4	5 3 1	3	15 9 3
Nitrate	0.008 - 0.1 < 0.008 > 0.1	5 3 1	3	15 9 3
Orthophosphate	≤ 0.015 0.016 - 0.020 > 0.021	5 3 1	3	15 9 3
Depth	5 - 10 1 - 4 & 11 - 15 < 1 or >15	5 3 1	3	15 9 3
Transparency	> 5 3 - 5 < 3	5 3 1	3	15 9 3
COD	10 - 90 91 - 100 > 100	5 3 1	3	15 9 3
BOD	1 - 2 3 - 5 6 - 9	5 3 1	3	15 9 3
Temperature	27 - 30 24 - 26 & 31 - 33 < 24 or > 33	5 3 1	2	10 6 2
Salinity	30 - 35 28 - 29 & 36 - 37 < 28 or > 37	5 3 1	2	10 6 2
DO	> 5 3 - 5 < 3	5 3 1	1	5 3 1
pH	7 - 8.5 6.5 - 6.9 & 8.6 - 9 < 6.4 or > 9.1	5 3 1	1	5 3 1
Substrate	Reef fragments/rough sand Reef;Rocks Mud;Soft sand	5 3 1	1	5 3 1
Total score				140

Legend :

1. Measurement scale :

5 : Good
3 : Average
1 : Bad

2. Valuation used rating method.

3. Scores calculated with a formula :Sk = A.i x B

Table 2 shows the class interval and environmental suitability level based on the water ecology with the equation as follows[13]:

$$I_{ks} = \frac{\sum N\, max - \sum N\, min}{\sum k}$$

Legend :

I_{ks} = class interval
k = environemntal suitability class expected
N max = Maximum final value
N min = Minimum final value

Table 2. Environmental Suitability Evaluation Based on Ecological Parameters

No.	Score Range (%)	Suitability Class	Evaluation/Conclusion
1.	103 – 140	S1	Highly suitable
2.	65 – 102	S2	Suitable
3.	28 - 64	N	Not Suitable

The mapping was done through spatial analysis, using of SIG technology. SIG analytic approach was conducted in some steps. First, delineating the limit of the research through digitizing the base map used; second, collecting data on site (point information), third, qualitative spatial analysis through Inverse Distance Weighted (IDW) interpolation method to estimate the score distribution in other areas unmeasure on each parameter[25];fourth, overlay map achieved based on score of each parameter so it became an environmental suitability map of continuous seaweed farming.

Areal support capacity shows maximum capacity of an area to support continuous farming activity without causing environmental quality decline. Water area support capacity for seaweed farming can be calculated with the following[26]:

$$DDL_{RL} = LLS \times KL$$

Legend :

DDLRL = Environmental Support Capacity for seaweed farming (ha)
LLS = Extent of suitable area (ha)
KL = Capacity of the water area (%)

Calculation on the number of long line farming unit can be supported by environment was based on the support capacity achieved from the formula as follows:

$$JUB_{RL} = DDL/LUB$$

Legend:

JUBRL = The number of seaweed farming unit (unit)
DDL = Environmental support capacity (ha)
LUB = extent of farming unit (unit/ha)

Findings and Discussion

Ecological factors are related to the water quality in supporting the environment to affect the growth rate of a mutual relationship such as total organisms, total farming enterprises and total production of an area. Yan and Zhang[27] stated that the comprehension of population calculation mechanism of community and ecological network is an important task in ecological study which can be done through interaction and ecological support capacity, population density of an area can be calculated. The results on water quality observation from the ecological parameter, in a form of physical and chemical data, can be seen in Table 3.

Environmental Ecology

Nitrate value ranged from 0.0032 mg/l – 0.6157 mg/l, high concentration of nitrate was believed to be caused by its closeness with the locals' settlement, boat mooring location and the pearl farming so it was affected by anthropogenic impacts. According to the Minister of Environment Decree Number 15 in 2004[28] and Radiarta[29], the nitrate level suitable for seaweed farming is < 0.008 mg/L and 0.008 – 3.5 mg/L, so generally nitrate level in Levun bay is suitable for seaweed farming.

Phosphate is a limiting factor in oligotrophic environment which enriches composition of bacterioplankton and blooming algae in the water[30,31]. Phosphate level in Levun Bay ranged 0.0006 – 0.0131 mg/L. Compared to the standard quality established by KLH[26] which is ≤ 0,015mg/L, Levun bay is highly suitable for seaweed growth.

Transparency observation showed a range from 2.5 – 10.2 meter, compared to the standard quality according to Aryati et al[32] and KLH[28] which is > 5 meter, then generally it was in the highly suitable category except for C.5 and C.6 observation site which were in suitable category (S2) as the standard quality is 3 – 5 meter and station C.1 showed the lowest transparency level at 2.5 meter and included in nt suitable category. Transparency value according to Effendi[31], is really affected by the weather, the time of observation, turbidity, suspended solidification, and the researchers' level of sight.

Biological Oxygen Demand (BOD) is the amount of oxygen dissolved needed by bio-organisms to decompose the organic matter in the water and is an empirical analysis which had a global role in microbiological process happens in the water, therefore the bigger the BOD, the greater pollution in the water[34]. BOD value range was from 1.2 mg/L – 3.2 mg/L, it showed that the environment has not been polluted even though there was an anthropogenic activity on the coast.

Table 3. Ecological Parameters Data and Scores in Levun Bay Water

Station	Coordinates		Nitrate (mg/L)	Phosphate (mg/L)	Transparency (m)	BOD (mg/L)	COD (mg/L)	Current (m/s)	Depth (m)	Temperature (^oC)	Salinity ($^o/_{oo}$)	pH	DO (mg/L)	Substrate	Score (%)
	X	Y													
A1	252430.15	9364471.95	0.0339	0.0113	7.7	2.9	40.2	0.09	19	30.98	31.0	7.96	4.35	2	101
A2	252290.03	9364804.73	0.0233	0.0092	8.2	2.8	40.1	0.08	20	30.99	31.3	7.92	4.40	1	100
A3	252167.43	9365277.63	0.0765	0.0089	9.3	2.4	39.4	0.08	22	30.82	31.3	7.83	4.25	1	106
A4	252146.16	9365785.56	0.0228	0.0074	9.0	1.5	38.5	0.09	24	30.23	31.0	7.78	4.00	2	111
A5	251895.95	9365715.50	0.0812	0.0112	8.5	2.1	39.1	0.10	17	30.03	31.3	7.76	4.01	2	117
A6	251817.13	9366179.65	0.0312	0.0080	8.2	1.2	38.1	0.13	30	30.33	31.7	7.79	3.98	1	116
A7	251817.13	9366696.33	0.0179	0.0045	9.8	1.9	37.7	0.12	29	30.23	31.3	7.73	4.07	2	117
A8	251405.53	9366538.70	0.0051	0.0040	9.2	2.3	39.4	0.11	15	30.16	31.3	7.65	4.33	2	117
B1	251204.11	9366897.76	0.0032	0.0011	9.3	1.6	38.5	0.11	15	30.13	32.0	7.76	4.01	2	117
B2	251659.50	9367107.93	0.0284	0.0073	9.5	1.7	38.6	0.12	14	30.40	31.5	7.74	3.98	2	123
B3	251869.68	9367598.35	0.0129	0.0026	7.0	2.0	38.7	0.11	7	30.27	31.7	7.77	4.09	4	131
B4	251379.26	9367440.72	0.0339	0.0006	10.0	1.8	38.9	0.12	28	30.47	31.0	7.71	3.87	2	117
B5	250932.63	9367291.84	0.0103	0.0023	7.0	2.2	39.4	0.11	7	30.33	31.7	7.70	3.88	5	132
B6	250801.27	9367659.65	0.6157	0.0048	9.7	2.0	38.9	0.12	26	30.57	32.3	7.71	3.76	2	101
B7	251239.14	9367773.50	0.0195	0.0044	9.5	1.9	38.6	0.13	24	30.17	32.0	7.73	3.94	2	117
B8	251641.98	9367878.59	0.0393	0.0074	8.0	2.7	39.7	0.13	8	30.07	32.3	7.69	4.72	5	126
C1	251582.09	9368297.10	0.0324	0.0094	2.5	3.2	40.7	0.09	2.5	30.62	31.7	7.79	4.80	3	96
C2	251186.60	9368158.82	0.0581	0.0117	7.0	2.4	39.4	0.12	7	30.27	32.0	7.74	4.84	5	132
C3	250748.73	9368071.25	0.0108	0.0036	10.2	2.5	39.8	0.11	18	30.13	32.0	7.72	4.81	5	114
C4	250599.85	9368456.58	0.0086	0.0073	8.8	2.8	39.9	0.12	9	30.10	31.7	7.67	4.82	5	120
C5	250993.93	9368526.63	0.0458	0.0061	5.0	2.6	39.8	0.13	5	29.77	31.7	7.73	4.83	5	120
C6	251335.47	9368622.97	0.0787	0.0122	3.0	2.6	39.8	0.12	3	30.23	31.7	7.80	4.76	4	113
C7	251072.75	9368973.26	0.0500	0.0131	6.0	2.7	40.2	0.10	6	30.07	32.0	7.81	4.85	4	125
C8	250582.34	9368929.48	0.0188	0.0059	6.7	2.3	39.3	0.11	7	30.13	32.0	7.83	4.75	4	131

Legend:

Substrate value criteria:

- Mud (1)
- Soft sand (2)
- Reef/rocks (3)
- Rough sand (4)
- Reef fragments (5)

Suitability Class Category:

- S1 (Highly suitable) : 103 – 140
- S2 (Suitable) : 65 – 102
- N (Not suitable) : 28 – 64

COD value in Levun bay ranged from 37.7 – 40.7 mg/l. It was relatively lower than the result of water quality analysis conducted by Sahubawa[35] which was from 22.5 – 150.8 mg/L in polluted Ambon Bay. Permissible COD range for farming activity was 10 – 90 mg/l so Levun bay was suitable for mariculture location. The difference COD values was caused by the abundant organic or inorganic compounds which were difficult to be decomposed biologically.

Current velocity in Levun bay is varied and only affected by the ebb and flow of the tide, furthermore the current pattern affected station B and C with stronger current compared to station A in the inner part of the bay which is more secluded and far from the strait current. The current in Levun bay ranged from 0.08 – 0.13 m/s while the suitable current velocity is from 0.1 – 0.19 m/s and 0.31 – 0.4 m/s.

Generally the depth ranged from 2.5 - 30 m. If the area measured from the lowest depth then the distance to reach the highest depth is 256 m so it is a significant difference. It is connected with the pressure in the water as more depth is followed with more pressure[36].

The temperature measurement ranged from 29.77 – 31.44 oC. It showed a highly suitable temperature and suitable and can be tolerated by the seaweed. Vairappan and Chung[37] stated that the best temperature for K. Alvarezii was from 25 – 30 oC in the water of Malaysia.

Seaweed K. alvarezii is sea algae which cannot stand great range of salinity, best range of salinity for seaweed farming is 30 – 35 ppt[38]. The result of salinity observation in Levun bay was between 31 – 32.3 ppt. It showed that salinity was in a normal range so it supports cell formation, groth and carrageenan of seaweed.

Range of pH level measured on site was 7.65 – 7.96. Based on the national standard SNI[39], pH level which supports seaweed farming was from 7 – 8.5, therefore the pH level in Levun bay is categorized as highly suitable for seaweed farming. Anthropogenic activities on the coast, the port and pearl farming affected the pH level as well as the current of the water.

The result of dissolved oxygen (DO) measured was 3.76 – 4.85 mg/l. It is still a normal range of DO which can be tolerated by seaweed. KLH[28] and Radiarta et al.[40] stated that excellent Do level for seaweed farming is > 5 mg/L. It showed that Levun bay water still contains enough oxygen as the temperature during the day is in normal range and the respiration process of bio-organisms at night does not affect the DO concentration in the water.

The quality standard of substrate was based on Hartoko and Kankan[41], so the kind of substrate in Levun bay was in a highly suitable category (S1) represented by 1,624 x 103 m2 dead reef fragments and rough sand in the depth of 3 – 18 m. In the suitable category (S2) represented by 161 x 103 m2 reefs or rocks in the depth of 2.5 m. And in not suitable category was represented by 2.154x 103 m2 of mud and soft sand at the depth of 14 – 30 m. Area with base of dead reef fragments and rough sand were considered to be excellent for K. alvarezii seaweed farming[41].

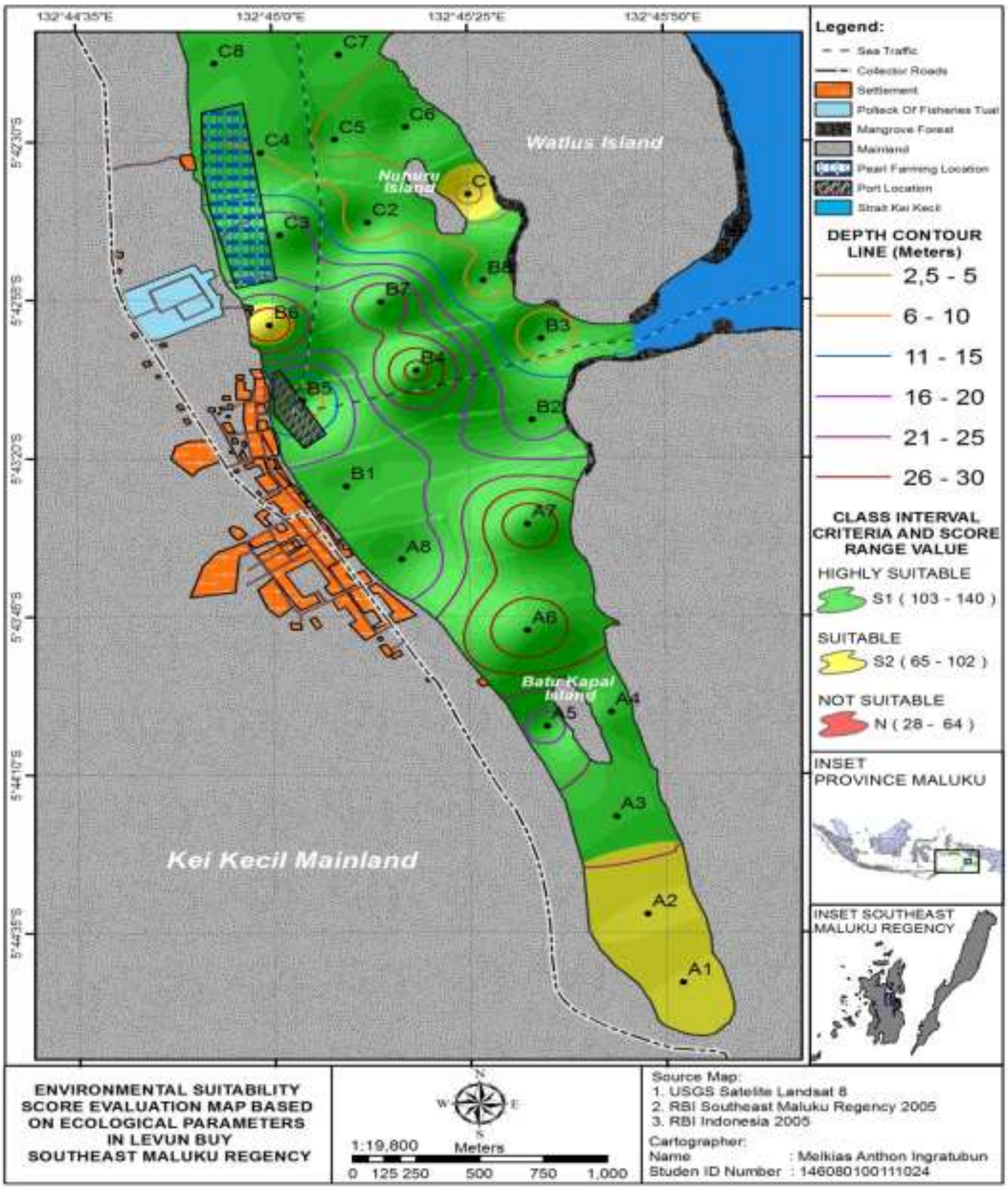

Figure 1. Environmental Suitability Score Evaluation Map Based on Ecological Parameters in Levun Bay in Southeast Maluku Regency.

Environmental suitability score evaluation based on ecological parameters

Environmental suitability measurement is an evaluation effort made on spatial analysis of physical and chemical parameters so quantitative measurement which support the continuity of seaweed farming either for long line units or volume of the water area which can be used maximally by the main farmers.

The overlay based on the scoring of each parameter of water quality in Figure 1 showed the result of ecological spatial mapping in Levun bay. Generally there are two suitability class categories suitable, highly suitable class (S1) with potential extent of 3,511 x 103 m2 or 351.1 ha (89.1 %) and suitable category (S2) about 428 x 103 m2 or 42.8 ha (10.9 %).

Ecological factors have important roles and impacts for suitability of the area in Levun bay. General condition visualized potential suitability for seaweed farming. Excellent development can be done by minizing negative impacts caused by the physical and chemical characteristics as the limiting factors of the environment.

According to Radiarta, et al.[29] seasonal change affects the climate and the physical and chemical characteristics and causes ice-ice disease. Productivity of seaweed farming is affected by the location and the seasons. Seasonal change affects the condition of the area which indirectly also affects the seaweed K. alvarezii farming.

Environmental support capacity

Environmental capacity is based on the difference of the water area extent suitable for farming divided with suitable water area and multiplied by 100 %. The extent of farming unit (p1ℓ1) is acquired from the average farming unit extent in Levun bay, 24 x 50 meters. The extent of area suitable for farming (p2ℓ2) was acquired from the environmental suitability analysis. The areal distance between the farming unit was 5 meters for boat activity and ownership of areal faming unit of the farmers.

The ecological parameters used as indicators of environmental suitability in Levun bay were expected to answer the challenges and expectation of the farmers in maximizing the production as the result of the spatial analysis, on farming suitable areal extent (highly suitable and suitable categories), areal capacity for long line farming unit and the number of seaweed farming unit according to the environmental support and carrying capacity of Levun bay (can be seen in Table 4).

Based on the analysis of the water suitability and the support capacity, the suitable areal capacity highly suitable (S1) for farming was 243.9 ha and in suitable category (S2) was 32.2 ha while the number of seaweed farming unit which can be supported in highly suitable area were 2,033 units and in suitable category were 268 units. If the number of seaweed farming units were summed then the total farming units which can be used in Levun bay were about 2,301 units with support capacity or water areal capacity about 276.1 ha.

Table 4. Ecological Suitability and Support Capacity for Seaweed Farming in Levun Bay.

No.	Station	Areal extent (ha)	Water Areal extent (ha)	Suitable water areal extent (ha)	Suitable water areal extent (ha)		Support capacity / DDL (ha)		Carrying capacity (Seaweed farming unit number / JUB)	
					Highly suitable	Suitable	Highly suitable	Suitable	Highly suitable	Suitable
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*
1	A	141.6	137.1	137.1	101.7	35.4	76.5	26.6	638	222
2	B	140	140	131.9	129	2.9	97.1	2.2	809	18
3	C	120.1	116.8	97.9	93.4	4.5	70.3	3.4	586	28
	Total	**401.7**	**393.9**	**366.9**	**324.1**	**42.8**	**243.9**	**32.2**	**2.033**	**268**

Legend :
- 1*d* = 1*c* – Batu Kapal Island (4.5 ha)
- 3*d* = 3*c* – Nuhuru Island (3.3 ha)
- 2e = 2d – Port / boat mooring location and ST (8.1 ha)
- 3e = 3d – Pearl farming location and ST (18.9 ha)
- ST (Sea Traffic) = 6.5 ha
- Port = 4 ha
- Pearl farming = 16.5 ha
- Water areal capacity (KL) = 75.24 %
- Seaweed farming unit extent (LUB) with long line system = 1,200 m or 0.12 ha.
- Support capacity (DDL) = suitable water areal extent x KL
- The number of farming unit (JUB) = DDL / LUB

Conclusion

Levun bay environmental suitability analysis results based on ecological analysis showed highly suitable class category (S1) and and suitable class category (S2) while Not suitable class (N) was not detected. Environmental support capacity for highly suitable class (S1) was 243.9 ha with 2,033 farming units while suitable class (S2) was 32.2 ha with 268 farming units.

Suitable class category (S2) has a limit for optimal seaweed farming, so it can affect the productivity and farming continuity. Therefore, it is suggested to use the area for suitable fish farming.

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