Suitability of Seaweed Culture (*Eucheuma cottonii*) in the Sorkam Barat Sub-District, Tapanuli Tengah Indonesia

D F Manurung¹*, R Rosmasita¹, W Windarti¹, T M Ghazali¹, N U S Sibuea²

¹Lecturer of Matauli College of Fisheries and Marine, 22538, Pandan, Indonesia
²Student of Matauli College of Fisheries and Marine, 22538, Pandan, Indonesia

*dianfitria.manurung@gmail.com

**Abstract.** Coastal and coral reef ecosystem areas in the Sorkam Barat Tapanuli Tengah may be potential sites for seaweed culture. To understand the suitability of that area for planting the seaweed, an initial study was conducted using a Geographic Information System (GIS). The environmental conditions as well as water quality parameters were analysed. The physical and chemical oceanographic factors parameters measured were wave height, temperature, salinity, depth, tide, brightness, pH, current velocity, and dissolved oxygen. While the water quality parameters measured were Total Suspended Solid (TSS), nitrate (NO₃) and phosphate (PO₄). Results shown that the water quality of the Sorkam Barat could be categorized as appropriate and quite suitable for the cultivation of *Eucheuma cottonii*. The suitable area for culture was 3,625.96 ha (92.5%) and the not suitable area was 294.18 ha (7.5%). The recommended planting method is the long-line system path method.

1. **Introduction**

Indonesia is the largest archipelagic country in the world that has the abundant potential for fisheries and marine resources. Seaweed was one of the important fisheries and marine commodities that had enormous potential among several leading commodities owned by Indonesia. There are several types of seaweed that have been cultivated in Indonesia. Types of seaweed that had the potential to be cultivated are from the genera Gracilaria and *Eucheuma*. The attempts to develop seaweed cultivation in Indonesia need to be conducted to increase the quantity and quality of these commodities, most of which were still produced from natural seaweed growth.

*Eucheuma cottonii* is one type of seaweed that was widely cultivated in Indonesia. Indonesia is the largest producer of this type of seaweed [1]. The total production of this seaweed in Indonesia was 10.11 million tons in 2015 [2]. *Eucheuma cottonii* is the most widely used raw material for carrageenan. Carrageenan could be used to increase the stability of foodstuffs in the form of suspension (solid dispersion in liquid), emulsion (gas dispersion in liquid) [3]. In addition, the seaweed species *E. cottonii* is thought to have potential as an anesthetic agent because it was proven to contain compounds with bioactivity as antimicrobial, antifungal, and also anticancer [4].

In Indonesia, one of the regencies in North Sumatra province that has a broad coastline is Tapanuli Tengah. This is because Tapanuli Tengah is located on the west coast of the island of Sumatra with a coastline of approximately 200 km. Several sub-districts in Tapanuli Tengah had conducted field surveys regarding the suitability of the area for seaweed cultivation, such as: Badiri, Tapian Nauli and Andam Dewi sub-districts [5]. Sorkam Barat was also known to be located on the edge of the coast, which was known to have never been tested for the suitability of marine lands so that they are used as seaweed cultivation areas.
Most of the livelihood of Sorkam Barat communities in general were fishermen, fish preservation and marine tourism. Whereas along the coastline it was the prospect that it had the potential to conduct seaweed cultivation activities which could be used as an additional source of income for the communities of Sorkam Barat. The communities of economic income were intended to increase if seaweed cultivation activities could be carried out along the coast in Sorkam Barat. It would also have an impact on increasing seaweed production in Indonesia.

The information that require would be known to be able to organize seaweed cultivation production in Tapanuli Tengah, especially in Sorkam Barat to the maximum so that it could sustain this activities, it is necessary to conduct a study of the suitability of waters for seaweed cultivation locations in terms of physical and chemical parameters of the waters. If there was an error in deciding a location for seaweed cultivation, seaweed production would decrease. Through the development of technology in general, Geographic Information System (GIS) is one of the alternatives in determining the valid location for the development of seaweed cultivation. So that the resulting data produces a new output in the form of a thematic map that has a fairly high level of efficiency and accuracy. The results of this research are expected to provide an overview of the area suitability of the Sorkam Barat.

2. Methodology

2.1 Study location

The research was conducted in December 2020 - February 2021 in Sorkam Barat. The Sorkam Barat is located in 1°54'06.6"N 98°35'23.9"E. Observation of stations that can represent coastal areas in Sorkam Barat is presented in Figure 1 and Table 1. The total stations in this study were 15 stations.

![Figure 1. Map of research stations in Sorkam Barat Sub-District](image)
Table 1. The geographical position of research stations

| Stations | Direction | South Latitude | East Longitude |
|----------|-----------|----------------|----------------|
| 1.1      | 61,47440000000 | 98,32500000000 | 1,82500000000 |
| 1.2      | 58,74370000000 | 98,37500000000 | 1,82500000000 |
| 1.3      | 54,51100000000 | 98,42500000000 | 1,82500000000 |
| 2.1      | 49,93460000000 | 98,47500000000 | 1,82500000000 |
| 2.2      | 46,14810000000 | 98,52500000000 | 1,82500000000 |
| 2.3      | 44,79100000000 | 98,57500000000 | 1,82500000000 |
| 3.1      | 61,24300000000 | 98,32500000000 | 1,87500000000 |
| 3.2      | 58,57190000000 | 98,37500000000 | 1,87500000000 |
| 3.3      | 53,88000000000 | 98,42500000000 | 1,87500000000 |
| 4.1      | 49,17770000000 | 98,47500000000 | 1,87500000000 |
| 4.2      | 46,93610000000 | 98,52500000000 | 1,87500000000 |
| 4.3      | 60,57970000000 | 98,32500000000 | 1,92500000000 |
| 5.1      | 58,18850000000 | 98,37500000000 | 1,92500000000 |
| 5.2      | 53,45620000000 | 98,42500000000 | 1,92500000000 |
| 5.3      | 50,87970000000 | 98,47500000000 | 1,92500000000 |

Note: The geographical position in this table was modified from researcher

2.3. Data and equipment

The data used in this study were: the 1:75,000 scale Indonesian Coastal Environment Map, the 1:25,000 scale Indonesian Topographical Map, data of the waters from in situ and ex situ. The equipment used for surveying was Global Positioning System (GPS), cameras, and water quality measuring equipment. The ArcGIS 10.2 software was used for the Geographical Information System (GIS).

2.3. Measurement of water quality data

This research was an explorative research. The researchers conducted surveys and direct measurements in the field by using quantitative approach with hypothesis testing. The research variables observed were physical and chemical oceanographic factors parameters of water quality which included wave height, temperature, salinity, depth, tide, brightness, pH, current velocity, and dissolved oxygen. While the water quality parameters measured were Total Suspended Solid (TSS), nitrate (NO$_3$) and phosphate (PO$_4$) with in-situ.

Measurement of wave height obtained by forecasting waves based on existing wind data. Measurement of temperature used Thermometer Hg. Measurement of salinity using Refractometer ATC. Measurement of depth is using a meter that has a distance of 20 meters equipped with a ballast. Measurement of tide used a scale pole for 39 hours with an interval of 1 hour of observation. Observations were made to determine the type of tidal range, as well as to determine the temporary center position of the research location. Measurement of brightness (transparency) is using a secchi disk tool by dipping the tool, when the secchi disk is not visible from the surface then measuring the length of the string used so that the secchi disk is not visible from the surface. Measurement of pH water parameters used the EcoTestrTM pH 2. Water current velocity measurements are used with Flowatch FL-03. Measurement of dissolved oxygen used LUTRON DO meter type AZ-8403.

Water samples of suspended solids TSS, NO$_3$, and PO$_4$ were taken using the same one bottle of sample provided for each repetition, sampling of suspended solids TSS, NO$_3$, and PO$_4$ by dipping the sample bottle in water and then closing it tightly. After all the sample bottles were filled, the sample
bottles were put in a cool box and then preserved using ice cubes. Each chemical parameter was tested using the Spectrophotometer DREL 2800 in the laboratory.

2.4. Data analysis
Table 2 shows the ranges of water quality parameters that are suitable for seaweed farming.

| Parameters                | Very Suitable       | Suitable         | Not suitable       |
|---------------------------|---------------------|------------------|--------------------|
| Wave height (m)           | 0.2-0.3             | 0.1-0.19 or 0.31-0.40 | < 0.1 or >0.41     |
| Current velocity (m/s)    | 0.2-0.3             | 0.1-0.19 or 0.31-0.40 | < 0.1 or >0.41     |
| TSS (mg/l)                | < 25                | 25-50            | > 50               |
| Salinity (ppt)            | 28-32               | 25-27 or 33-35    | < 25 or >35        |
| Temperature (°C)           | 28-30               | 26-27 or 30-33    | < 26 or >33        |
| Nitrate (mg/l)            | 0.9-3.5             | 0.1-0.8 a or 3.6-4.4 | < 0.1 or >4.5      |
| Phosphate (mg/l)          | 0.51-1              | 0.21-0.5         | < 0.21 or >1       |
| pH                        | 7-8.5               | 6.5 – 6.9 or 8.5-9.5 | < 6.5 or >8.5     |
| Depth (m)                 | 0.6-2.1             | 0.3 - 0.5 or 2.2-10 | < 0.3 or <10       |

Large weights were presented to parameters that had a dominant influence on the determination of the area, on the other hand, parameters that are less dominant or do not have a large effect on Eucheuma cotonii cultivation were presented small weights, the weights could be seen in Table 3.

| Parameters                | Criteria            | Value Limit         | Weight | Score |
|---------------------------|---------------------|---------------------|--------|-------|
| Wave height (m)           | 0.2-0.3             | 3                   | 0.3    | 0.9   |
|                           | 0.1 -0.19 or 0.3-0.4 | 2                   | 0.6    |       |
|                           | < 0.1 or > 0.4      | 1                   | 0.3    |       |
| Current velocity (m/s)    | 0.2-0.3             | 3                   | 0.15   | 0.45  |
|                           | 0.1 -0.19 or 0.3-0.4 | 2                   | 0.3    |       |
|                           | < 0.1 or > 0.4      | 1                   | 0.15   |       |
| TSS (mg/l)                | < 25                | 3                   | 0.15   | 0.45  |
|                           | 25-50               | 2                   | 0.3    |       |
|                           | > 50                | 1                   | 0.15   |       |
| Salinity (ppt)            | 28-32               | 3                   | 0.15   | 0.45  |
|                           | 25 - 27 or 33 – 35  | 2                   | 0.3    |       |
|                           | < 25 or > 35        | 1                   | 0.15   |       |
| Temperature (°C)           | 28-30               | 3                   | 0.15   | 0.45  |
|                           | 26 - 27 or 30 - 33  | 2                   | 0.3    |       |
|                           | < 26 or > 33        | 1                   | 0.15   |       |
| Nitrate (NO₃) (mg/l)      | 0.9-3.5             | 3                   | 0.025  | 0.075 |
|                           | 0.1 -0.8 or 3.6-4.4 | 2                   | 0.05   |       |
|                           | <0.1 or >4.5        | 1                   | 0.025  |       |
| Phosphate (PO₄) (mg/l)    | 0.051 -1            | 3                   | 0.025  | 0.075 |
|                           | 0.021 - 0.05        | 2                   | 0.05   |       |
|                           | < 0.021 or > 1      | 1                   | 0.025  |       |
| pH                        | 7-8.5               | 3                   | 0.025  | 0.075 |
Based on the score of each parameter, an assessment is carried out to determine whether the location is suitable for *Eucheuma cottonii* seaweed cultivation [6] follows:

\[
\text{Evaluation Result Score} = \frac{\text{Total score of each station}}{3} \times 100\%
\]

**Table 4.** Determination of Eligibility Category Based on Class Interval

| Score Range (%) | Assessment Results Evaluation |
|-----------------|------------------------------|
| 85 – 100        | Very Suitable: Stations do not have significant boundaries |
| 60 – 84         | Suitable: Stations have tolerable barriers |
| < 60            | Not suitable: Stations have heavy barriers |

### 3. Results and Discussion

#### 3.1. General Location Condition
Sorkam Barat is one of the sub-districts in Tapanuli Tengah with an area of 44.58 square kilometres. This district is a coastal area that has coral reef areas, one of which was located in the coastal area of Pasar Sorkam, Binasi Beach and Maduma Beach (Madani). This location was chosen because this location is an area that was directly adjacent to Sorkam Island and Pane Island. Where some people use the waters in Sorkam Barat as one of the locations for community livelihoods in fishermen, fish preservation and marine tourism.

#### 3.2. Water Quality Data
Water quality data profile on *Eucheuma cottonii* seaweed cultivation in Sorkam Barat can be seen in the Table 5 about water quality cultivation parameters. Based on the data in Table 5 Water quality data from oceanographic physics-chemical parameters in the waters of Sorkam Barat are waves height located between 0.1 m – 0.3 m, current velocity in the range 0.1 m/s – 0.3 m/s, TSS at range of 70 mg/l – 114 mg/l, salinity in the range of 30 ppt – 33 ppt, temperature is around 30 °C – 33 °C, Nitrate content is about 0.9 mg/l – 1 mg/l, phosphate is about 0.71 mg/l – 0.96 mg/l, pH in the range 7 – 7.7, DO in the range 7.32 mg/l – 8.74 mg/l, depth in the range 3.3, m – 6.16 m, and the brightness in the range of 73.7% - 100%.

**Table 5.** Water Quality Profile In *Eucheuma cottonii* Seaweed Cultivation Periods

| Stations | Wave height (m) | Current velocity (m/s) | TSS (mg/l) | Salinity (ppt) | Temperature (°C) | Nitrate (mg/l) | Phosphate (mg/l) | pH | Depth (m) |
|----------|-----------------|------------------------|------------|----------------|------------------|----------------|-----------------|----|----------|
| 1.1      | 0.3             | 0.1                    | 70         | 23             | 30               | 0.98           | 0.83            | 7.7 | 3.8      |
| 1.2      | 0.3             | 0.2                    | 82         | 21             | 30               | 1.03           | 0.89            | 7.3 | 4.56     |
| 1.3      | 0.2             | 0.1                    | 74         | 30             | 30               | 0.95           | 0.85            | 7.4 | 6.16     |
| 2.1      | 0.2             | 0.2                    | 94         | 29             | 31               | 0.98           | 0.84            | 7.4 | 3.1      |
| 2.2      | 0.2             | 0.2                    | 88         | 30             | 31               | 0.93           | 0.76            | 7.4 | 4.1      |
| 2.3      | 0.1             | 0.1                    | 92         | 22             | 31               | 0.95           | 0.84            | 7.7 | 5.9      |
| 3.1      | 0.3             | 0.1                    | 112        | 31             | 31               | 0.98           | 0.88            | 7.6 | 4.1      |
| 3.2      | 0.3             | 0.3                    | 118        | 32             | 31               | 0.98           | 0.96            | 7   | 3.12     |
The average wave height at Sorkam Barat is between 0.1 m – 0.3 m (Figure 2). Waves are very influential in *Eucheuma cotonii* seaweed cultivation activities. For seaweed cultivation activities, the wave height is not more than 40 cm [7]. Waves that are too large can cause turbidity of the waters so that it can inhibit photosynthesis, besides that large waves can make it difficult for plants to absorb nutrients so that it can inhibit growth.

![Figure 2. The water quality spatial distribution pattern for waves height](image)

The current velocity in the range 0.1 m/s – 0.3 m/s (Figure 3). Current is the movement of sea water that results in horizontal mass transfer of water [8]. In general, the current speed is quite good for the benefit of *Eucheuma cotonii* seaweed cultivation, ranging from 0.1-0.4 m/s [9,10,11]. Circulation of sea water currents can help the process of providing nutrients and help clean the dust attached to the seaweed thallus so that the photosynthesis process runs perfectly [12].
Figure 3. The water quality spatial distribution pattern for current velocity

TSS at range of 70 mg/l – 114 mg/l [Figure 4]. TTS for marine aquaculture is 5-25 mg/l [13]. The TSS content in this study is classified as very high. This is possible because of the community activities of the Sorkam Barat which carry out salting fish and beach tourism activities. The concentration and composition of TSS varies temporally and spatially depending on the physical factors that affect the distribution of TSS, especially the pattern of water circulation, deposition, and suspended sediment. But the most dominant factor is water circulation [14].

Figure 4. The water quality spatial distribution pattern for TSS

The salinity in the range of 30 ppt – 33 ppt (Figure 5). This condition is not much different from the statement that the salinity level is very suitable for the location of Eucheuma cottonii seaweed cultivation, which is between 28-34 ppt [15]. One of the advantages of the Sorkam Barat waters for seaweed cultivation business activities is that these waters do not have the potential to experience rapid salinity fluctuations because they are far from the influence of river water flow.
The temperature is around 30 °C – 33 °C (Figure 6). The average temperature of these waters is not in the very suitable category for seaweed cultivation. Because the suitable water temperature in seaweed cultivation is 27 °C – 30 °C [16]. The water temperature is measured when the time span is 1 pm to 2 pm, so it can be seen that the water temperature in the Sorkam Barat waters can reach 32 °C.

The nitrate content is about 0.9 mg/l – 1 mg/l (Figure 6). The phosphate is about 0, 71 mg/l – 0.96 mg/l (Figure 7). Based on the location suitability matrix, the nitrate concentration very suitable for seaweed cultivation is 0.6 mg/l - 3.5 mg/l, while the water phosphate concentration is very suitable for *Eucheuma cotonii* seaweed cultivation is > 0.20 mg/l. Sufficient nitrogen and phosphate content in the waters will help the metabolism and reproduction of seaweed [17].
Figure 7. The water quality spatial distribution pattern for nitrate

Figure 8. The water quality spatial distribution pattern for phosphate

The DO in the range 7.32 mg/l – 8.74 mg/l (Figure 8). Factors that reduce oxygen levels in seawater are the increase in water temperature, respiration (especially at night), the presence of an oil layer above the sea surface and the entry of easily biodegradable organic waste into the marine environment. For the growth of *Eucheuma cottonii* seaweed, 2-4 ppm dissolved oxygen is needed in the waters, but growth is better if dissolved oxygen is above 4 ppm [18].

Water depth is one of the limiting factors in choosing a location for seaweed cultivation. Waters that are too deep will make it difficult to handle seaweed and are easily blown away by waves. On the other hand, waters that are too shallow have the potential to be exposed to direct sunlight on the seaweed thallus and the dust covered the seaweed thallus so that it inhibits the photosynthesis process.
This research of depth in the range 3.3 m – 6.16 m (Figure 9). In general, the water depths that are appropriate and quite suitable for *Eucheuma cotonii* seaweed cultivation are in coastal areas with a maximum distance of about 10 km [19].

![Figure 9](image)

**Figure 9.** The water quality spatial distribution pattern for DO

![Figure 10](image)

**Figure 10.** The water quality spatial distribution pattern for depth

The brightness (transparency) is in the range of 73.7% - 100% or 14.58 m - 4.6 m (Figure 10). The water brightness factor is also one of the important factors for the growth of *Eucheuma cotonii* seaweed so that it needs to be considered in the selection of cultivation sites. The brightness of the waters is related to the ability of sunlight to penetrate into the waters for the benefit of the photosynthesis process of seaweed for its growth. A high level of brightness is an absolute requirement in selecting a location for seaweed cultivation because the seaweed thallus will optimally utilize sunlight for the benefit of photosynthesis [20].
3.3. The water suitability for seaweed cultivated

The results of the scoring analysis to see the suitability level of the waters as an area of Eucheuma cottonii seaweed cultivated development is generated in the distribution of water quality parameters. The level suitability scoring has 3 categories, which are “suitable” is given a score of 3, the “suitable enough” class is given a score of 2, and the class “not suitable” is given a score of 1. The result of scoring from physical parameters (waves height, current velocity, temperature, and depth) and chemical parameters (salinity, pH, TSS, phosphate, and nitrate) can be seen in the distribution map (Table 6).

| Stations | Wave height | Current velocity | TSS | Salinity | Temperature | Nitrate | Phosphate | pH | Depth | Evaluation Result Score |
|----------|-------------|------------------|-----|----------|-------------|---------|-----------|----|-------|--------------------------|
| 1.1      | 0.9         | 0.3              | 0.15| 0.15     | 0.45        | 0.075   | 0.075     | 0.05|       | 74.2 %                   |
| 1.2      | 0.9         | 0.45             | 0.15| 0.15     | 0.45        | 0.075   | 0.075     | 0.05|       | 79.2 %                   |
| 1.3      | 0.9         | 0.3              | 0.15| 0.45     | 0.45        | 0.075   | 0.075     | 0.05|       | 84.2 %                   |
| 2.1      | 0.9         | 0.45             | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 84.2 %                   |
| 2.2      | 0.9         | 0.45             | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 84.2 %                   |
| 2.3      | 0.9         | 0.3              | 0.15| 0.15     | 0.45        | 0.075   | 0.075     | 0.05|       | 84.2 %                   |
| 3.1      | 0.9         | 0.3              | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 79.2 %                   |
| 3.2      | 0.9         | 0.45             | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 79.2 %                   |
| 3.3      | 0.9         | 0.45             | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 84.2 %                   |
| 4.1      | 0.9         | 0.3              | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 79.2 %                   |
| 4.2      | 0.9         | 0.3              | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 79.2 %                   |
| 4.3      | 0.9         | 0.3              | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 79.2 %                   |
| 5.1      | 0.9         | 0.3              | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 79.2 %                   |
| 5.2      | 0.9         | 0.45             | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 79.2 %                   |
| 5.3      | 0.9         | 0.45             | 0.15| 0.45     | 0.3         | 0.075   | 0.075     | 0.05|       | 84.2 %                   |

From the evaluation score data, it is known that almost every research station that has a fairly Suitable enough value, but there is one research station that is declared not suitable which is located at station 2.3 with an evaluation score of 59.2%. In fact, if it is observed from the class interval for the quite Suitable enough category, station 2.3 is not so far from that assessment.

The sea waters in the Sorkam Barat include waters that can be said to be high seas. because the protection of these waters if close only there are Sorkam islands and Pane islands. The condition of the Sorkam Barat waters receives more waves and ocean currents.In addition, from the research data, it is also known that the TSS content is very high, presumably due to high community activities along the
Several community activities from fishing, salting fish and marine tourism. The most striking thing is the salting of fish, indirectly the waste from the disposal of fish to the waste from the stew will be disposed of into sea waters. Related to the salted fish waste, also has an impact on the salinity of the waters. Water depth data is also classified as a weighted value of 2 for each station, resulting in a low value of weighting for cultivation land. The water temperature is also not so significant, from several research stations giving a rating of 2 and 3. But it is still dominated by a rating of 2. The temperature distribution in the waters of the Sorkam Barat is not very good. For the weight of the assessment of the parameters of pH, nitrate and phosphate are classified as very well. Because the overall rating weight of each station has a value of 3.

Based on the spatial (overlay) analysis results of water suitability for *Eucheuma cottonii* seaweed farming in Sorkam Barat, Tapanuli Tengah with the seaweed growth determinants such as wave height, temperature, salinity, depth, tide, brightness, pH, current velocity, and dissolved oxygen. Total Suspended Solid (TSS), nitrate (NO$_3$) and phosphate (PO$_4$). It was found that the total water area with a suitable enough rate was 3,625.96 ha (92.5%) and the site with not suitable rate was 294.18 ha (7.5%) (Figure 10).

**Figure 12.** Site suitable enough and not suitable location for *Eucheuma cottonii* in Sorkam Barat

4. **Conclusion**

Suitable enough and not suitable areas for the development of seaweed culture on the coast of Sorkam Barat. The coverage area included in the suitable enough area category is 3,625.96 ha (92.5%) and the not enough area category is 294.18 ha (7.5%). Some water quality parameters that are not suitable for *Eucheuma cottonii* seaweed cultivation activities are TSS, temperature and salinity parameters. While the other parameters are still categorized into high weighting intervals. Each station has a fairly appropriate assessment evaluation result, so that *Eucheuma cottonii* seaweed cultivation activities can be carried out using the long-line system path method.

**Acknowledgements**

This research was fully funded by Maju Tapian Nauli (MATAULI) foundation.

**References**

[1] Kambey C S B, I Campbell, C F A Sondak, A R M Nor, P E Lim and E J Cottier-Cook 2020 *Journal of Applied Phycology*

[2] Food Agriculture Organization Fisheries and Aquaculture Information and Statistics Branch FAO-FIGIS 2019 [*FIGIS-Time series query on Aquaculture*]
[3] Endang S, Gunawan W S and Agus D 2017 *Buletin Oceanografi Marina* **6(2)**: 88–93
[4] Ninik P, Endang W, Khaswar S and Joko S 2021 *Aquaculture and Fisheries* 2468-550X
[5] LIPI 2009 Retrieved from http://coremap.oceanografi.lipi.go.id/berita/958
[6] Utojo M A T and Hasnawi 2007 *Jurnal Ilmu Kelautan dan Perikanan Torani*
[7] Aslan LM 1991 Seaweed cultivation *Kanisius Publishers Yogyakarta*
[8] Nybakken J W 1992 Marine Biology *Gramedia Pustaka Utama Publishers Jakarta*
[9] Neksidin, Pangerang U K and Emiyarti 2013 *Jurnal Mina Laut Indonesia* **3**: 147–149
[10] Alamisyah R 2016 *Jurnal Agrominansia* **1**: 64–65
[11] Rahmayanti F, Diana F and Kusumawati I 2018 *Jurnal Akuakultura* **2**: 27–28
[12] Tell Y 2018 *Jurnal Ilmiah Tribuana* **1**: 165 – 166
[13] KLH 1988 *Minister for Population and Environment, Jakarta*
[14] Wardjan Y 2005 *Thesis* Bogor: IPB University p 66
[15] Adipu Y, Lumenta C, Kaligis E and Sinjal H J 2013 *Jurnal Perikanan dan Kelautan Tropis* **9** (1): 25–26
[16] Rahmayanti F, Diana F and Kusumawati I 2018 *Jurnal Akuakultura* **2**: 27–28
[17] Afandi A and Musadat F 2018 *Jurnal Akuakultura* **2**: 74
[18] Indriani H and E. Sumiarsih 1991 *Penebar Swadaya Publishers Jakarta*
[19] Logo M F, Perbani C and Priyono B 2018 *Artikel Seminar Nasional Geomatika 2018*
[20] Rahmayanti F, Diana F and Kusumawati I 2018 *Jurnal Akuakultura* **2**: 27 – 28