Suitability analysis of aquaculture ponds based on primary productivity parameters in mangrove area of Banda Aceh

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Abstract. Determining the suitability of aquaculture ponds is one of a valuable factor in sustainable aquaculture. One of the factors to consider in establishing a successful aquaculture is aquatic environment, i.e.: the primary productivity of waters and physical-chemical factors. The value of primary productivity describes aquatic trophic and natural food availability. This research was aimed to observe the suitability of aquaculture ponds based on primary productivity, phytoplankton abundance, and water quality (Physical-Chemical factors). The research was conducted on July to August 2018 in mangrove ecosystem at western and eastern coastal area of Banda Aceh with six observation stations, namely Beureunut, Amat Aramanyang, Ruyung, Tibang, Deah Glumpang and Peukan Bada. These stations were determined by stratified random sampling method based on water characteristic. The measurement of primary productivity was conducted by using the dark-light bottle method. The categorizing of suitability of aquaculture ponds was done by using the scoring method. The water quality parameters were given the value and score then following to be divided into four classes of suitability comprise Class S1 (Very suitable), S2 (Suitable), S3 (Conditional Suitable), and TS (Unsuitable). The results showed that the value of primary productivity ranged from 34.72 to 178.82 mgC/m³/hour and the phytoplankton abundance around 1.17 – 3.02 individual/Liter. Land suitability scoring ranged from 70.1 - 75.6%. It was concluded that the station 4th (Tibang) and 5th (Deah Glumpang) were a suitable area for aquaculture ponds with a score of 75.6%.

1. Introduction
Coastal area is an area that is vulnerable to change, both due to natural processes and human intervention. Coastal activities such as capture fisheries, aquaculture (ponds), ports, tourism, settlements and natural reserves can affect the balance of ecosystems and the geomorphology of coastal areas.

Pond is one type of habitat that is used as a place for brackish water activities located on the coast. Moreover, ponds are ecosystem that created by human located near the coast, which is dammed and surrounded by channels that form brackish ponds which are surrounded by mangrove plants. Environmental problems in aquaculture are spatial planning or spatial development of aquaculture that is not concern about the carrying capacity of the environment. The problem occurs because of improper management thus raising the complexity of the environment with all aspects of its complications in a long period of time [1].

Land suitability in aquaculture activities affects the success and sustainability of aquaculture ponds [2]. Aquatic aspects really need to be considered for the success of aquaculture, this is determined by
the good site selection. The study of the suitability of aquaculture ponds through data collection in the area of mangrove ecosystems needs to be done for the development of fish culture so that it supports management of aquatic productivity. The existence of natural food has a major influence on the sustainability of aquatic resources. Nurfadillah et al [3] stated that primary productivity has a relationship with abundance of phytoplankton, nitrate, phosphate, visibility, pH, and temperature. In general, land suitability criteria vary in each location, mainly based on soil factors, water availability and aquatic environment. Therefore, the existence of this research can contribute to the development of aquaculture, namely information related to the selection of suitable cultivation land and meets certain requirements so that life of aquatic biota is not disrupted so gives good results in aquaculture production. The purpose of this study was to analyze land suitability of aquaculture sites based on the primary productivity and water quality (physical-chemical factors). Therefore, it will provide the information to assist the fish farmers and local government to identify the potential of land suitability for fishponds in the western and eastern regions of Banda Aceh, and eventually become reference for the development of aquaculture areas.

2. Research Methods

2.1. Data collection
This research was conducted in six stations at Mangrove area of Aceh Besar Regency and Banda Aceh. 3 stations were located in the eastern part of Banda Aceh (Beureunut, Amat Aramanyang, Ruyung) and 3 stations were located in the western part of Banda Aceh (Tibang, Deah Glumpang and Peukan Bada). Sampling was carried out from July to August 2018, and samples identification was conducted at marine biology laboratory of the Faculty of Marine and Fisheries, Universitas Syiah Kuala. The stations were determined by using the stratified random sampling method, namely the method of determining the location by selecting several samples from a particular location that was assessed according to the objectives or research problems in a population. Location of the study was presented in Figure 1 that explained the eastern part of Banda Aceh, namely Station 1 (Beurenut); Station 2 (Amat Aramanyang); Station 3 (Ruyung); while the western part of Banda Aceh were Station 4 (Tibang); Station 5 (Deah Glumpang) and Station 6 (Peukan Bada).
Figure 1. Location of the research (Station 1 (Beurenut); Station 2 (Amat Aramanyang); Station 3 (Ruyung); Station 4 (Tibang); Station 5 (Deah Glumpang) and Station 6 (Peukan Bada).

2.2. Measurement of physical-chemical and biological parameters

The measurement of the physical-chemical parameters of the waters was done by in situ (direct) and ex situ. In situ measurement were temperature, salinity, DO, pH, and visibility using by thermometer, Refraktometer, DO meter, pH meter and Seichi disc, respectively. The measurement of nitrate and phosphate was carried out ex situ by taking water samples and then were analyzed in the laboratory. Biological parameters included the measurement of primary productivity and phytoplankton abundance. The method used to measure primary productivity was the dark-light bottle oxygen method. Sampling of phytoplankton sampling was done by using the filtration method.

2.3. Analysis of land suitability

Determination of land suitability based on primary productivity parameters was done by statistical analysis in linear regression and then categorized to determine the level of suitability of pond water quality [4]. The first step was put dependent variable (primary productivity) in regression analysis with independent variables (surface temperature, salinity and dissolved oxygen, pH, visibility, nitrate and phosphate) [4]. It will produce a coefficient of determination or $R^2$. Then the coefficient of determination was then multiplied by 100% and used as a Quantity (B). Each independent variable had a range of values [5; 6; 7; 8] (Table 1). The next step was determining the value (N) of the measurement results of the independent variables of each station. Afterward, the calculation of the score of the independent variable was done by multiplying the value (N) by the quantity (B), and determining the maximum total score by adding up the maximum score for each parameter, then scoring the value of each station to determine the grade of land suitability with the calculation [9].

$$Total \ Score \ (%) = \frac{(B \times N)}{Total \ Score \ Maximum} \times 100$$
Table 1. Assessment of water quality parameters for land suitability analysis.

| Parameter      | Range              | Value (N) | Source |
|----------------|--------------------|-----------|--------|
| Temperature (°C) | 25 – 32            | 3         | [5]    |
|                | 12 – 25            | 2         |        |
|                | <12 or >32         | 1         |        |
| DO (mg/L)      | 4 – 7              | 3         | [6]    |
|                | 2.5 – 4            | 2         |        |
|                | <2.5               | 1         |        |
| pH             | 6 – 8              | 3         | [6]    |
|                | 4 - 6 or 8 – 9     | 2         |        |
|                | <4 or >9.5         | 1         |        |
| Visibility (cm)| 30 – 40            | 3         | [7]    |
|                | 25 - 30 or 40 – 60 | 2         |        |
|                | <25 or >60        | 1         |        |
| Salinity (ppt) | 10 – 20            | 3         | [6]    |
|                | 20 – 35            | 2         |        |
|                | <10 or >35        | 1         |        |
| Nitrate (mg/L) | 0.3 - 0.9          | 3         | [8]    |
|                | 0.9 - 3.5          | 2         |        |
|                | >3.5              | 1         |        |
| Phosphate (mg/L)| >0.21           | 3         | [8]    |
|                | 0.1 - 0.21         | 2         |        |
|                | 0.051 - 0.1        | 1         |        |

Table 2. Land suitability classes.

| Total Score | Level Suitability       | Information                                      |
|-------------|-------------------------|--------------------------------------------------|
| >80         | Very suitable (S1)      | Potential and has no inhibiting factors          |
| 60 – 79     | Suitable (S2)           | fill the minimum requirements                    |
| 40 – 59     | Conditional Suitable (S3)| Has a limiting factor and needs additional input|
| <40         | Unsuitable (TS)         | Has a very severe limiting factor                |

Source: Pramono et al.[10]

3. Results and Discussion

3.1. Suitability of aquaculture pond

Land suitability can be seen through the percentage level of suitability and the sum of the values of all parameters. At each research station, the observational data of the physical, chemical and biological parameters showed various values. These parameters had criteria in determining land suitability and each category described the level of suitability for cultivation land use. The criteria for the suitability of aquaculture ponds are categorized into four, namely: S1 (very suitable), S2 (suitable), S3 (conditional suitable), and TS (unsuitable) [11].
Table 3. Land suitability scoring for each parameter.

| No | Parameters          | Quantity X Value | Scoring % |
|----|---------------------|------------------|-----------|
|    |                     | 1    2    3    4    5    6 | 1    2    3    4    5    6 |
| 1  | Temperature (°C)    | 1.5  1.5  1.5  1.5  1.5  1.5 | 0.488 0.488 0.488 0.488 0.488 0.488 |
| 2  | DO (mg/l)           | 147  147  147  147  147  147 | 47.805 47.805 47.805 47.805 47.805 47.805 |
| 3  | pH                  | 12   12   12   12   12   12  | 3.902 3.902 3.902 3.902 3.902 3.902 |
| 4  | Visibility (cm)     | 42   21   21   42   42   21  | 13.659 6.829 6.829 13.659 13.659 6.829 |
| 5  | Salinity (ppt)      | 4    8    8    8    12   12  | 1.301 1.301 2.602 2.602 2.602 3.902 |
| 6  | Nitrate (mg/l)      | 22   22   22   22   22   22  | 7.154 10.732 7.154 7.154 7.154 7.154 |
| 7  | Phosphate (mg/l)    | 0.03 0.02 0.01 0.02 0.02 0.03 | 0.010 0.007 0.003 0.010 0.007 0.010 |
|    |                     |      |      |      |      |      | Total |
|    |                     |      |      |      |      |      |        |
|    |                     |      |      |      |      |      |        |

Based on observations of each water quality parameter, it can be seen that stations 4 and 5 were regions that have sufficiently the land suitability class criteria. This can be seen from the value of water quality parameters obtained at this station, which were classified as high. Water quality is an important factor in the life of aquatic biota. Chemical – physical factors that can affect primary productivity are temperature, salinity, pH, visibility, dissolved oxygen (DO), nitrate, and phosphate. Physical– chemical and biological factors of the waters were presented in Table 4.

Table 4. Physical-chemical and biological parameters of water.

| No | Parameter                  | Station |
|----|----------------------------|---------|
|    |                            | 1  2  3  4  5  6 |
| 1  | Temperature (°C)           | 28  32  29  29  31  30 |
| 2  | DO (mg/l)                  | 5    5.7  6.8  5.5  4.9  4.7 |
| 3  | pH                         | 7.1  7.2  7.3  7.1  7.1  7.2 |
| 4  | Visibility (cm)            | 25   61  23   60  53   20 |
| 5  | Salinity (ppt)             | 8    8    23   21  31   13 |
| 6  | Nitrate (mg/l)             | 1.2  0.9  1.5  1.2  1.2  1.3 |
| 7  | Phosphate (mg/l)           | 0.22 0.14 0.04 0.77 0.2  0.26 |
| 8  | Primary Productivity (mgC/m³/hour) | 95.49 34.72 64.24 71.18 133.68 178.82 |
| 9  | Fitoplankton Abundance (ind/l) | 2.51 1.17 2.34 3.02 2.51 1.51 |

Temperature has an important role in the metabolism of aquatic biota. The value of each temperature at the research stations ranged from 28 °C to 32 °C. The temperature was still suitable for the life of aquatic organism. The average water temperature ranged from 29 °C to 32 °C so that in that range plankton can grow and multiply well [12]. The temperature decreases with increasing depth [13]. The temperature range obtained was a good temperature range for aquaculture ponds that included in the very suitable class (S1). This was supported by Pramono et al [10] that stated that good water temperatures for shrimp ponds ranged from 26 °C to 30 °C, because in that range shrimp can do the digestion process properly so that good shrimp growth is followed.

The dissolved oxygen content in water is the most important water quality modifying parameter for aquaculture ponds. Dissolved oxygen values in Western and Eastern beach of Banda Aceh ranged from 4.7 to 6.8 mg/l. According to Effendi [14], waters designed for fishery purposes should have
oxygen levels of not less than 5 mg/l. Dissolved oxygen levels of less than 4 mg/l cause the adverse effects for almost all aquatic organisms, dissolved oxygen levels of less than 2 mg/l can result in death. According to Mukherjee [15] that oxygen is very necessary for the production of all fish and crustacean species.

The degree of acidity (pH) is very influential in the adaptation of the organism. The pH value at the study site ranged from 7.1 – 7.3. According to Nybakken [16], waters with varying pH values between 6.8 – 8 can still be tolerated by most aquatic biota. Optimal water pH on shrimp life on intermediate farms 7.5 - 8.5 [17]. Water conditions that are very acidic or very alkaline will endanger the survival of the organism because it will cause metabolic and respiratory disorders.

Based on the salinity of each station, the highest value obtained at station 5 (31 ppt) (included in the suitable class (S3)), while the lowest was at stations 1 and 2 with 8 ppt salinity (included in the unsuitable class (TS)). The difference in salinity at each station can be influenced by the presence of an estuary that provided the supply of sea water and freshwater from the land. Salinity is important to maintain osmotic pressure between the organism's body and the waters. Variation in salinity can determine the abundance and distribution of phytoplankton. Salinity is one of the parameters that determine the types of phytoplankton contained in waters. The salinity value obtained at each observation station ranged from 8 ppt to 31 ppt. The salinity obtained was different for each station. Hanafi and Badayos [18] explained that good salinity for shrimp farming is 12-20 ppt, while shrimp will die at salinity greater than 50 ppt. Shrimp pigment metabolism is imperfect and susceptible to disease if the pond water salinity is less than 12 ppt.

The highest nitrate content was found at station 3 (1.5 ppm) (included in the very suitable (S1)), and the lowest was at station 2 (0.9 ppm) (included in the suitable class (S2)). Nitrate was generally found to be in high concentration at the study site. Nitrate levels are very closely related to the content of organic waste which generally contains protein such as the accumulated food waste. Furthermore, ponds that carry out nitrate fertilization will increase the levels of nitrates in the water [19].

High trophic status is a major factor in high primary productivity. Net primary productivity values ranged from 34.72 - 178.82 mgC/m3/hour. The primary productivity was higher around waters close to the land, and lower towards the open sea. Asriyana and Yuliana [20] stated that the open sea waters receive less supply of nutrients needed by marine plants to produce primary productivity.

Pond fertility is also determined by clay content at 50 percent levels [18]. The results of measurements of soil texture showed different types of soil at the six research stations. Station 1 had a texture of clay sandy soil, station 2 had a texture of dusty soil, station 3 had a texture of sandy clay, station 4 had a texture of clay and dusty clay, station 5 had a texture of clay, and station 6 had a texture of sandy clay. Based on observations of physical-chemical and biological parameters, the results showed that Tibang and Deah Glumpang areas were suitable (S2) for aquaculture ponds.

4. Conclusion

The suitability of aquaculture pond was influenced by physical-chemical and biological parameters. Based on the scoring analysis it was found that all stations included in the suitable category with the scores ranged from 68.8 - 75.6%. DO levels was the most important parameter in determining land suitability. At all stations, the DO value was suitable for aquaculture. Nitrate, phosphate and temperature levels at station 4 and 5 belong to the very suitable (S1), nevertheless the salinity was limiting factor in this research area. The salinity at station 4 (Tibang) and 5 (Deah Glumpang) were also Suitable (S2). The highest scoring was obtained in Tibang and Deah Glumpang, which are included in the suitable category for aquaculture pond.

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