Relationship of primary productivity and phytoplankton abundance in Muara Kuala Raja, Bireuen district, Aceh

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Abstract. Phytoplankton is a major producer in oceans which require the availability of nutrients, pH, temperature and light intensity in order to increase productivity. This study aims to analyse the relationship between the primary productivity and the abundance of phytoplankton in Muara Kuala Raja Bireuen, Aceh. This study was conducted on May 2017. Location sampling have 3 station points. The measure of primary productivity was examined by a light-dark bottle oxygen method. The relationship between the primary productivity and the abundance of phytoplankton was analysed by using Principal Component Analysis (PCA). The results showed that the highest average of gross and net primary productivity were found at station 1 of 209.12 mgC/m³/h and 172.00 mgC/m³/h. The highest abundance of phytoplankton was found at station 1 of 11477.76 ind/l. The result of PCA showed that each of the parameter spread between the two axes indicates the data diversity value. The data diversity value on the 1- axis was 37% and the 2-axis was 59%, so the total of data diversity between 1- and 2-axis was 96%. Based on the PCA analysis, it can be concluded that primary productivity has a strong relationship with the abundance of phytoplankton.

1. Introduction
Kuala Raja is one of the beaches located in Bireuen City. There are many activities in this area such as fishing activities, aquaculture, and marine tourism. Various activities can affect phytoplankton. The aquaculture area contributes nitrate and phosphate contents that can increase the growth of phytoplankton. Phytoplankton is a major producer in the waters, which require the availability of nutrients, pH, temperature and light intensity to increase productivity [1][2]. In otherwise, poor water quality and unbalanced nutrient availability will result in decreased productivity in phytoplankton. Although nutrient plays important role in photosynthesis of phytoplankton, the excess nutrient may not directly indicate high primary productivity [3].

Primary productivity is the total amount of organic matter by the activity of plant photosynthetic. Primary productivity is a food supply for heterotrophic organisms such as bacteria, fungi and animals. The value of primary productivity in waters is more influenced by light intensity compared to the presence of nutrients [4]. Light intensity will affect the presence of phytoplankton. Therefore, it is necessary to study the presence of phytoplankton and its relationship with the primary productivity of Muara Kuala Raja Bireuen, Aceh. The purpose of this study is to describe the value of primary productivity, the value of phytoplankton abundance and analyse the relationship of primary productivity and abundance of phytoplankton in the waters of Muara Kuala Raja Bireuen, Aceh.
2. Research Methods

2.1. Data collection
This research was conducted in Muara Kuala Raja in May 2017. The research area was divided into 3 observation stations, namely station 1 is a domestic and pond area, Station 2 is an estuary area and station 3 is a coastal area. Identification of sample was done at Marine Biology Laboratory of Syiah Kuala University and BARISTAND laboratory Banda Aceh. The location of the research are described in Figure 1.

2.2. Measurement of primary productivity
Measurement of primary productivity using oxygen method by taking water samples at each research location using light bottles, dark bottles and initial bottles as initial oxygen (DOo). Light bottles and dark bottles filled with water samples were incubated for 6 hours starting at 8.30 am - 2.30 pm. Next, measurement of oxygen values for each of the incubated bottles was carried out.

2.3. Sampling of phytoplankton
Phytoplankton sampling was carried out by filtering 100 litres of water samples cumulatively using planktonnet mesh size 40μm. Filtered water samples (30 ml) were included in a collection bottle labeled and then preserved with 2% lugol 8-10 drops. Furthermore, the water samples were observed by a microscope, and identified using the book references [5].

2.4. Measurement of aquatic parameter
Observation of water quality at each station includes current speed, visibility, temperature, pH, DO and salinity. Nitrate and phosphate measurements were carried out in the BARISTAND laboratory using a spectrophotometer method.
2.5. Data analysis

There are some calculations for data analysis in this study. The formula used to calculate primary productivity in waters is as follows [6]:

\[
\text{Gross Primary Productivity (mgC/m}^3/\text{hr)} = \frac{(O_2 \text{LB}) - (O_2 \text{ DB}) \times 1000}{(PQ)(t)} \times 0.375
\]

\[
\text{Net Primary Productivity (mgC/m}^3/\text{hr)} = \frac{(O_2 \text{LB}) - (O_2 \text{ DB}) \times 1000}{(PQ)(t)} \times 0.375
\]

Where \(O_2 \text{LB}\) is concentration of oxygen in the light bottle; \(O_2 \text{ DB}\) is concentration of oxygen in the dark bottle; \(PQ\) is coefficient of photosynthetic=1.2; \(t\) is time of incubation (6 hours); 0.375 is ratio of carbon and oxygen atomic mass.

Calculation of phytoplankton abundance in this study uses field view method by using the formula [7]:

\[
N \text{ (ind/l)} = \frac{Vt \text{ (ml)} \times Acg \text{ (mm)}^2}{Vcg \text{ (ml)} \times Aa \text{ (mm)}^2 \times Vd \text{ (l)}}
\]

Data analysis about the relationship between phytoplankton abundance and primary productivity and several other variables using the Principal Component Analysis (PCA) method.

3. Results and Discussion

3.1. Primary productivity

The value of primary productivity at each research station shows differences, this is caused by the differences in the activity of aquatic organisms in using oxygen both for respiration and decomposition of bacterial activity. Gross primary productivity is total photosynthesis which includes organic material used for respiration during measurement. While the net primary productivity is the storage of organic materials during measurement. The results of gross and net primary productivity can be seen in Table 1.

| No | Primary Productivity (mgC/m^3/hour) | Station 1 mgC/m^3/hour | Station 2 mgC/m^3/hour | Station 3 mgC/m^3/hour |
|----|-------------------------------------|------------------------|------------------------|------------------------|
| 1  | Gross Primary Productivity          | 209.12                 | 57.29                  | 61.65                  |
| 2  | Net Primary Productivity            | 172.00                 | 46.87                  | 47.04                  |

In table 1, the highest average gross and net productivity values are found at station 1, that is 209.12 mgC/m^3/hour and 172.00 mgC/m^3/hour. The high value of primary productivity at station 1 is thought to be due to the influence of high brightness values on the station so that it affects the intensity of light entering the waters. Increased light intensity will always be followed by increasing the value of primary productivity to the optimum point [4]. The intensity of exceeding the optimum light is the inhibiting light and under optimum light is also a limiting light [8]. Increased light intensity is followed by an increase in temperature so that it affects the presence of phytoplankton and the value of primary productivity [9]. In addition to light intensity, the high value of primary productivity at station 1 is due to the high nitrate content (1.6 mg/l) and phosphate (0.11 mg/l) derived from household activities and aquaculture areas. The presence of nutrients in the waters affects the presence of phytoplankton. Phytoplankton utilize nutrients for their growth and breeding rate. Changes in environmental parameters including light intensity, DO, salinity, temperature, nitrate, silica and
phosphate affect variations in the distribution and abundance of phytoplankton in the waters [10]. The high nutrient values and primary productivity of phytoplankton in the waters showed the natural ability of the aquatic environment to absorb the effects of enrichment of nutrients from land such as nitrate, silica and phosphate [11].

The lowest primary productivity is found in station 2. The low primary productivity in this region is thought to be due to the low contribution of nutrients from the land and the low water temperature compared to other stations (26.3°C). Temperature plays an important role in controlling the condition of aquatic ecosystems. Aquatic organisms have a certain temperature range in their lives. The difference in the intensity of light entering the water column gives a difference in temperature distribution at each depth. Temperature effects on primary productivity depended on light intensity, under light limited conditions, temperature had a negative effect on primary productivity, because warming strongly increases grazing activity of phytoplankton consumers and community respiration, whereas the carbon incorporation process is limited by light [9].

3.2. Phytoplankton Abundance

In this study, the composition of phytoplankton was obtained in 2 classes, namely Bacillariophyceae and Dinophyceae. Table 2 shows that the percentage level of Bacillariophyceae class is 81% higher than the Dynophyceae class at 19%. This is consistent with research conducted by Aryawati and Thoha in the Berau waters of East Kalimantan that found as many as 28 genera of phytoplankton which were divided into 2 classes namely Bacillariophyceae as many as 24 genera and Dynophyceae as many as 4 genera [12]. This is suspected of Bacillariophyceae or diatoms have high productivity compared to Dynophyceae. Bacillariophyceae is commonly found because it is easy to adapt to the environment, and a wide distribution of sea water, fresh water [13][14]. The existence of phytoplankton is very dependent on the condition of the waters that can affect and produce different species communities in each water column. According Onyewa [15] that phytoplankton composition is not always evenly distributed in a waters.

The highest abundance of phytoplankton is found at station 1 at 11477.76 ind / L and the lowest abundance value is at station 3 of 3487.68 ind / L. Ditylum sol is an abundant species, it is suspected that nitrate phosphate levels in the sampling area are in accordance with the environment of phytoplankton and suitable for the habitat of this species. Tomas [16] states that Ditylum sol live in warm waters. The temperature at station 1 is 31°C which is classified as warm water. While the value of the lowest abundance of phytoplankton species is the type of Nitzschia sp and Synedra sp. It is suspected that this species is at a temperature not available with the habitat of his life. Synedra sp lives in cold waters [16]. The types of Nitzschia sp and Synedra sp abundant in Lake Laut Tawar with low temperature criteria (24°C) [2]. Temperature increases have been reported to have a positive effect on the abundance of species in the sea and in some terrestrial ecosystems [17][18][19].
### Tabel 2. Abundance of Phytoplankton

| NO | Genus                      | Location |
|----|----------------------------|----------|
|    |                            | Site 1   | Site 2 | Site 3 |
| 1  | *Asterionella* sp.         | 639.36   | 0      | 0      |
| 2  | *Biddulphia* sp.          | 351.36   | 0      | 31.68  |
| 3  | *Chaetoceros affinis*     | 799.68   | 0      | 0      |
| 4  | *Chaetoceros antlanticus* | 0        | 0      | 384    |
| 5  | *Chaetoceros sp.*         | 543.36   | 0      | 0      |
| 6  | *Coscinodiscus nitidus*   | 543.36   | 0      | 0      |
| 7  | *Ditylum sol*             | 3360     | 864    | 1152   |
| 8  | *Hyalodiscus sp.*         | 31.68    | 447.36 | 0      |
| 9  | *Navicula sp.*            | 63.36    | 511.68 | 0      |
| 10 | *Nitzschia longissima*    | 96       | 0      | 0      |
| 11 | *Coscinodiscus sp.*       | 607.68   | 0      | 0      |
| 12 | *Pleurosigma sp.*         | 543.36   | 351.36 | 0      |
| 13 | *Rhizosolenia hebetata*   | 799.68   | 415.68 | 864    |
| 14 | *Rhizosolenia cal-caravis*| 511.68   | 31.68  | 384    |
| 15 | *Rhizosolenia sp.*        | 543.36   | 63.36  | 0      |
| 16 | *Synedra sp.*             | 0        | 384    | 0      |
| 17 | *Thalasiothrix sp.*       | 31.68    | 0      | 0      |
| 18 | *Triceratium favus*       | 511.68   | 0      | 0      |
|    | **Dynophyceae**           |          |        |        |
| 19 | *Ceratium furca*          | 988.8    | 480    | 672    |
| 20 | *Ceratium cariense*       | 0        | 351.36 | 0      |
| 21 | *Dynophysis homunculus*   | 511.68   | 31.68  | 0      |
| 22 | *Streptotheca indica*     | 0        | 384    | 0      |
|    | **Total**                 | 11477.76 | 4316.16 | 3487.68 |

### 3.3. Relationship of primary productivity to phytoplankton abundance

The relationship of primary productivity with several parameters is done by the Principal Component Analysis (PCA) method. Based on PCA analysis shows a very close relationship with factor analysis value of 96%. Analysis can be seen in Figure 2.

Based on Figure 2 showed that some parameters have a positive correlation to primary productivity including abundance of phytoplankton, nitrate, phosphate, visibility, pH, temperature. On the negative axis are salinity and current. Parameters that are close to the positive axis have an influence on primary productivity and are different from salinity and currents that are in the negative axis, which means that they do not have a major influence on primary productivity. Parameters included in the positive correlation (phytoplankton abundance, nitrate, phosphate, visibility, pH, temperature) appear to have a significant effect on primary productivity. This is consistent with the research of Yulianto et
al., in Pulau Panjang Jepara waters that the value of primary productivity at 181.25 mgC/m^3/hour, and obtaining abundance of phytoplankton at the same station was 56.559 ind/l which means in this study primary productivity is affected by phytoplankton abundance [20].

![Figure 2. PCA Analysis](image)

Temperature did not affect phytoplankton diversity, but species richness directly increased primary productivity, probably as result of the strong selection effect [9]. But, The influence of abiotic factors, such as light, temperature, and hydrology is more evident on the temporal fluctuations of productivity rates, when compared to that of biotic factors [1]. However, primary productivity and producer biomass are separate ecosystem functions, with productivity measuring carbon flux and biomass measuring carbon accumulation [21].

4. Conclusion
The highest value of gross and net primary productivity at station 1 is 209.12 mgC/m^3/hour and 172.00 mgC/m^3/hour while the highest phytoplankton abundance value at station 1 is 11477.76 ind/l and the lowest in Station 3 is 3487.68 ind/l. Based on PCA analysis shows a close relationship between primary productivity and phytoplankton abundance of 96%. Phytoplankton abundance, nitrate, phosphate, visibility, pH, temperature to have a significant effect on primary productivity.

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