The use of phytoplankton as a fertility indicator of the Sasa waters, Ternate, North Maluku, Indonesia

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Abstract. Sasa waters are one of the important water areas in Ternate City, both from an ecological and economic point of view. These waters are one of the pillars of the economic life, especially for the people who live around them. However, until now, the level of fertility of the Sasa waters is not yet known. This study aimed to determine the fertility conditions of the Sasa Ternate waters, based on the species composition, abundance and biological indices of phytoplankton. The research was conducted in October-November 2020 in the waters of Sasa, Ternate City, North Maluku Province, Indonesia at four stations. The sampling was carried out four times with a sampling period of two weeks. Phytoplankton samples were taken by a filtering method, then the phytoplankton samples were preserved with 4% Lugol solution. The abundance of phytoplankton and the Shannon-Wiener diversity index were calculated. The results showed that 32 phytoplankton genera from 4 classes were identified: Bacillariophyceae (22 genera), Cyanophyceae (2 genera), Chrysophyceae (2 genera) and Dinophyceae (6 genera). The abundance of phytoplankton varied between each station with a range between 45,327 and 178,791 cells L^{-1}. The biological indices of phytoplankton was dertermined as follows: the diversity index (H') ranged between 1.8233 and 2.2089, the evenness index (E) ranged between 0.7108 and 0.8517 and the dominance index (D) ranged between 0.1407 and 0.2480. Sasa waters are in a medium fertility condition, based on the value of the phytoplankton diversity index.

Key Words: species composition, abundance, biological indices, diversity index.

Introduction. Indonesia has large coastal and marine resources which are an alternative for a future development. This region has the potential to be developed both from an ecological and economic perspective. In coastal areas, there are various types of aquatic biota, some of them having an important economic, while others, like the phytoplankton, support these species, having an essential ecological role. Phytoplankton is an organism that can be used as an indicator of the quality and level of fertility of waters, being extremely useful for the management of coastal and marine resources. There is a positive correlation between the abundance of phytoplankton and the level of fertility (productivity) of waters. If the abundance of phytoplankton in certain waters is high, then the productivity in these waters tends to have a high value, as well (Raymont 1980). The content of phytoplankton, based on the research on various aquatic areas, shows a diversity in number and type, even at relatively close locations or originating from the same water mass, due to various environmental factors such as wind, currents, temperature, salinity, nutrients, water depth and to the water mass mixing (Davis 1955). Likewise, in Sasa waters, there are differences in the composition of types and abundance of phytoplankton due to the input load received and to the influence of various environmental parameters on these waters. Sasa waters are one of the waters in Ternate City which has a great potential to be developed as a fishery area, especially for aquaculture (marine culture). However, until now these waters have not been used by the community for aquaculture because there is no information about the fertility level in Sasa waters, despite the importance of the various activities carried out by the people who live in this area. These activities include traditional markets, LIPI research stations and fairly dense residential areas, with the potential to cause ecological pressure on Sasa waters. Thus, in order to support sustainable resource-providing activities of marine biota cultivation and fishery in this area, it is necessary to determine the fertility level of the Sasa waters, which is the aim of this research, based on the species composition, abundance and phytoplankton biological indices.

Material and Method

Description of the study sites. This research was conducted in October-November 2020 in Sasa waters, Ternate City, North Maluku Province, Indonesia at four stations (Figure 1). Sampling was carried out four times, during a sampling period of two weeks.

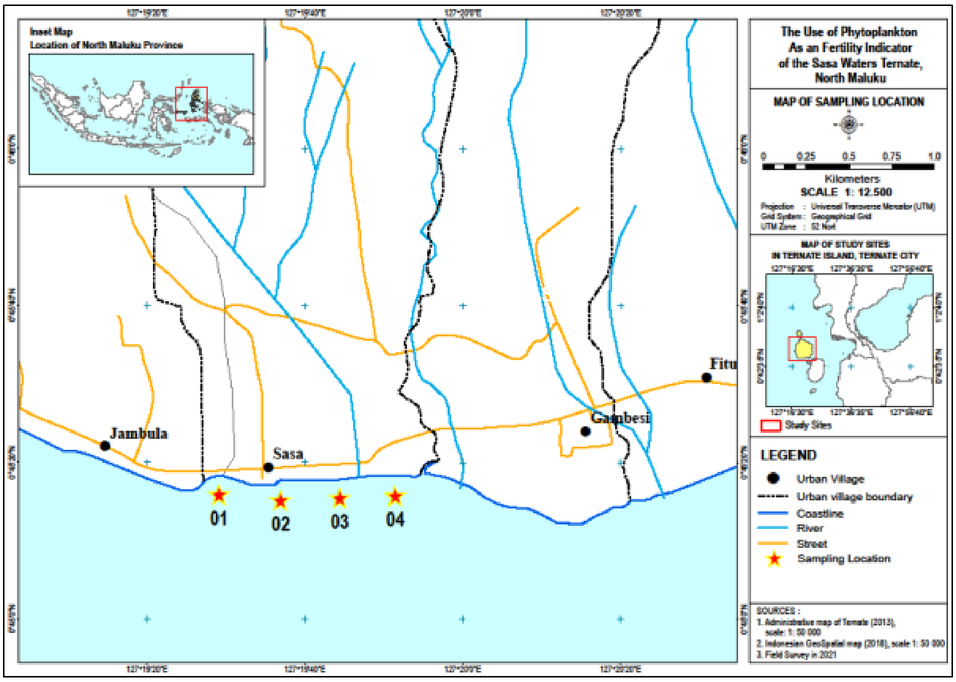


Figure 1. Research location in Sasa waters, Ternate City, North Maluku.

Phytoplankton analysis. 30 L of water sample were filtered using a plankton net with a size of 25 µm for phytoplankton specimens. The filtered water was preserved with a 4% Lugol solution. Furthermore, the sample was identified in the Aquaculture Systems and Technology Laboratory, Faculty of Fisheries and Marine, Khairun University, based on the identification books of Davis (1955), Yamaji (1979) and Tomas (1997).

The abundance of phytoplankton species was calculated based on the equation according to APHA (2005), as follows:

$$N = \frac{O_i}{O_p} \, x \, \frac{V_r}{V_o} \, x \, \frac{1}{V_s} \, x \, \frac{n}{p}$$

Where:
N - number of individuals L^{-1};
Oi - area of the cover glass (mm^2);
Op - area of one field of view (mm^2);
Vr - filtered water volume (mL);
Vo - observed volume of water (mL);
Vs - volume of filtered water (L);
n - the number of plankton in the entire field of view;
p - the number of fields of view observed.

The diversity index was calculated using the Shannon-Wiener index. Meanwhile, the evenness index and dominance index were calculated according to Odum (1998):

1. Diversity index Shannon-Wiener:

$$H' = -\sum_{i=1}^{s}\left(\frac{n_i}{N}\right) ln\left(\frac{n_i}{N}\right)$$

2. Evenness index:

$$E = \frac{H'}{H_{max}}$$

3. Dominance index:

$$D = \sum_{i=1}^{s}\left(\frac{n_i}{N}\right)^2$$

Where:
H' - Shannon-Wiener diversity index;
E - Evenness index;
D - Simpson dominance index;
ni - number of individuals of the genus I;
N - total number of individuals across genera;
H_{max}- maximum diversity index (= ln S, where S = number of species).

As supporting data, measurements were made of several physicochemical water parameters that affect the growth and development of phytoplankton, such as nutrients (N, P and Si), temperature, salinity, brightness and pH.

Determination of the condition of the Sasa waters. The condition (level of fertility) in Sasa waters is determined by calculating the abundance value of phytoplankton and the Shannon-Wiener diversity index. Furthermore, the data from the calculation of the diversity index value was compared with the level of waters fertility, based on the criteria of Wilhelm & Dorris (1968).

Statistical analysis. Data from the research results are displayed in tables and graphs. To make easy calculations in the analysis, the SPSS IBM 23, Minitab 16, SAS 9.1 and Excel Stat Pro 5.0 software tools were used.

Results and Discussion

Composition of phytoplankton. Based on research conducted at four stations with four periods of observation, 32 phytoplankton genera were identified in 4 classes, namely Bacillariophyceae (22 genera), Cyanophyceae (2 genera), Chrysophyceae (2 genera) and Dinophyceae (6 genera). The census results showed that the number of genera between each station and each observation period did not differ much, with a range between 10-18 genera. The highest number of genera was found at station 4, for the period I (18 genera) and the least was at station 1, for the period I (10 genera).

The number of genera obtained in this study is less when compared to the results of the research conducted by Kadim et al (2018) in Gorontalo Bay, which found 39 genera, the research of Takarina et al (2019) in the Batuhideung Fishing Grounds, which obtained 37 genera, and the research of Unbekna et al (2020) on the Lembata Island, which obtained 45 genera. However, more than the results of the research conducted by Kadim & Arsad (2016) in Tomini Bay found 29 genera and the research carried out by Witariningsih et al (2020) in the waters of the Lombok Strait, which obtained 28 genera.

The census results at each observation station revealed that the Bacillariophyceae class was found at all stations, while the Chrysophyceae class was only found at station 4, for the period I and at station 2, for the period IV. This shows that the

Bacillariophyceae class has a wider distribution in these waters, compared to other phytoplankton classes. These results are in line with the research conducted by several previous researches of Yuliana (2006) in Kao Bay, Yuliana (2009) in Guraici waters, Andriani (2009) in Bojo waters, Yuliana et al (2012) in Jakarta Bay, Yuliana (2015) in Jailolo waters, Harianto et al (2017) in the waters of Pulau Saponde Laut, Konawe Regency, and Yuliana (2020) in the waters of Fitu Ternate, concluding that the genera of the Bacillariophyceae class dominate at each observation station, with the highest abundance. Similar abundance conditions have been reported by Nybakken (1992), concerning the Bacillariophyceae class dominating the composition of phytoplankton in marine waters. However, the results of the current research differ from the research conducted by Syahbaniati & Sunardi (2019) on the East Coast of Pananjung Pangandaran, West Java, which found that the Coscinodiscophyceae class dominated the other classes. If analyzed further based on the percentage of classes in each observation period, it was found that the Bacillariophyceae class had the highest contribution in all observation periods, while the Chrisophyceae class had a percentage of 0 in the observation periods II and III, and the Cyanophyceae class also had a percentage 0 in the period IV. The complete percentage of each class is shown in Figure 2.

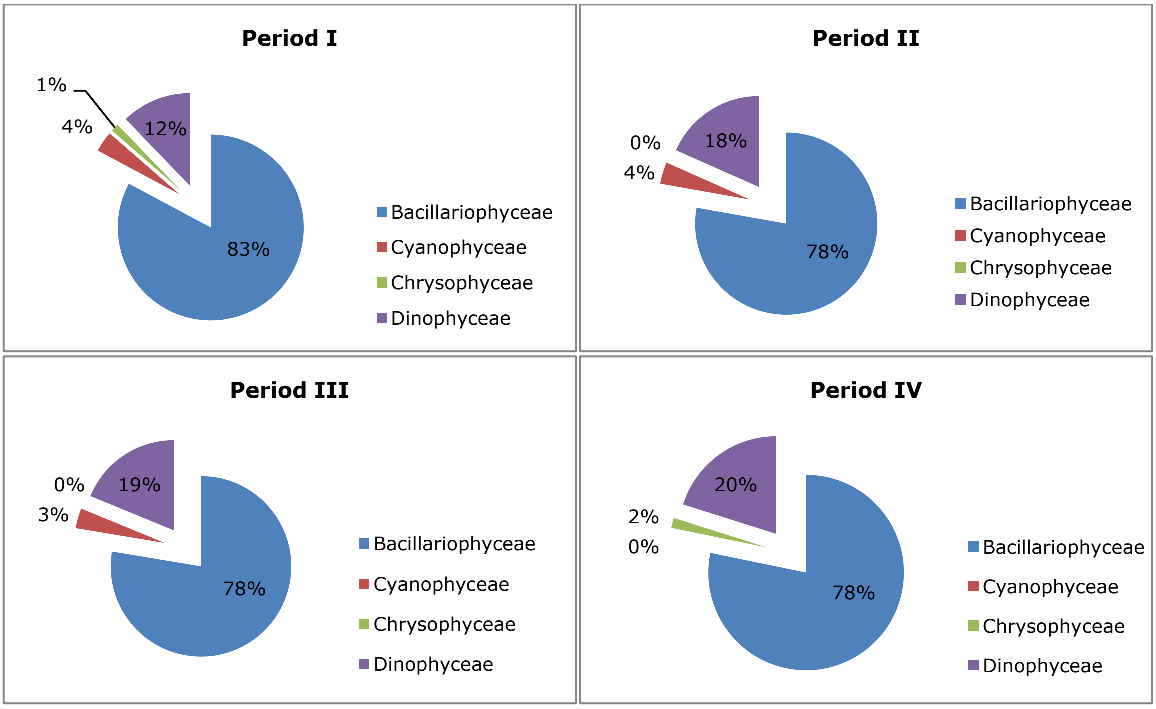


Figure 2. Composition of phytoplankton species in Sasa waters, Ternate City, North Maluku.

The distribution of genera between each class, based on stations and observation periods, showed that there were several genera found at all stations and observation times. These genera are *Biddulphia, Cossinodiscus, Diatoma, Gyrosigma, Nitzschia*, *Rhizosolenia* and *Triceratium* (Bacillariophyceae class), as well as *Gymnodinium* (Dinophyceae class). This is in line with the research of Wiyarsih et al (2019) in Segara Anakan Cilacap, who found that the genus *Coscinodiscus* was the genus most frequently found. The genera that were only found at one station and time of observation were the genus *Amphiprora, Amphora, Campylosira, Ditylum, Plagiogramma*, and *Stigmophora* (Bacillariophyceae class), *Pelagothrix* (Cyanophyceae class), *Dictyocha* and *Distephanus* (Chrysophyceae class) and *Ceratium, Cochlodinium*, and *Cochlodinium*, *Leptotintinnus* (Dinophyceae class). This fact proves that the Bacillariophyceae class dominates in all locations and periods (time) of research.

The abundance of phytoplankton. The abundance of phytoplankton varied between each station and time of observation, with a range between 45,327 and 178,791 cells L^{-1} (Figure 3). The highest abundance was found at station 4, period I, with a value of 178,791 cells L^{-1} and the lowest was at station 1, period II, with a value of 45,327 cells L^{-1}. The value of the abundance of phytoplankton obtained during the research in Sasa waters is higher compared to the results of the researchof: Syahbaniati & Sunardi (2019) on the East Coast of Pananjung Pangandaran, West Java, who obtained an abundance range of 5,080-26,900 cells L^{-1}, Yuliana (2020) in Fitu waters, with an abundance range of 7,928-39,268 cells L^{-1} and Ramadhanty et al (2020) at Maron Beach Semarang, with an abundance of 7,109-11,550 cells L^{-1}.

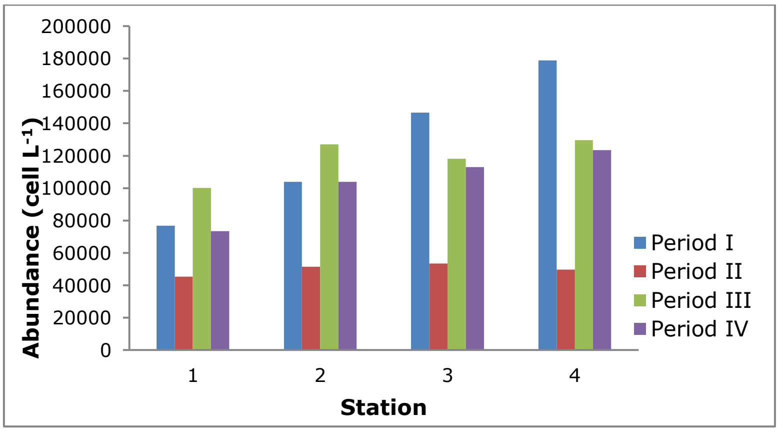
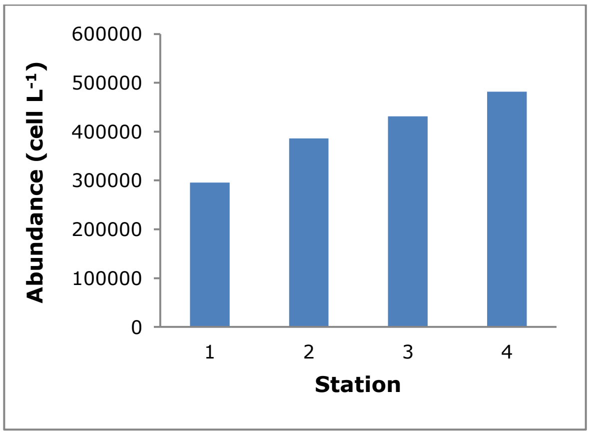


Figure 3. Abundance of phytoplankton found in Sasa waters Ternate, North Maluku.

Several factors affect the high abundance of the phytoplankton at station 4, period I, including the environmental parameters that support the growth and development of phytoplankton at this station, in suitable conditions. The main factors that influence the growth and development of this phytoplankton are nutrients and light. The main inorganic nutrients needed by phytoplankton are nitrogen and phosphorus. The content of the two nutrients, observed at station 4, period I, is: nitrate <0.001 mg L^{-1}, and phosphate: 0.749 mg L^{-1}, respectively. The concentration of nitrate at the time of research, at this location, was low and had become a limiting factor for the optimal phytoplankton needs, however, the phytoplankton could still grow and develop well. This is in line with Mackentum (1969), who states that phytoplankton requires a nitrate content in the range of 0.9-3.5 mg L^{-1} for an optimal growth. The high abundance of phytoplankton at this station, even though it has a low nitrate content, is thought to be due to the already used nitrates by the phytoplankton's metabolism. Meanwhile, the phosphate content has a value suitable for an optimal growth and development of phytoplankton. This is supported by Mackentum (1969), who stated that phytoplankton requires an orthophosphate content of 0.09-1.80 mg L^{-1} for its optimal growth, and by Bruno et al (1979), who found that the optimal orthophosphate content for the phytoplankton growth was of 0.27-5.51 mg L^{-1}. With this phosphate content, the phytoplankton can optimally grow and develop at this station, compared to the other combinations of stations and observation times. Likewise, the silica concentration, at this station, has a content of 2.841 mg L^{-1}. The silica value is at a concentration suitable for the phytoplankton growth and development. This is supported by Turner et al (1998), who stated that phytoplankton, especially diatoms, cannot develop properly if the silica content is less than 0.5 mg L^{-1}. In addition to the nutrient parameters, other water physical and chemical parameters are suitable, such as a light intensity, a temperature of 26.98°C, a pH of 7.10 and a salinity of 34.16 ppt, and there are no heavy metals interfering with the phytoplankton growth and development.

Although, the physicochemical parameters of the waters that affect the growth of phytoplankton are almost the same as the other stations, at station 1, period II, a lower abundance of phytoplankton than at other stations and observation times was recorded. This is more due to the predation factor (grazing) by zooplankton at this station, during the observation period. Phytoplankton is the main food for zooplankton, so there is a negative correlation between phytoplankton and zooplankton.

If the abundance value of phytoplankton in Sasa waters is analyzed by station, an increasing trend can be identified in the abundance of phytoplankton from stations 1 to 4 (Figure 4). The highest abundance was found at station 4 with a value of 481,569 cells L^{-1} and the lowest at station 1 with a value of 295,758 cells L^{-1}. Meanwhile, based on the time (period) of observation, it was found that the abundance of phytoplankton fluctuated with the observation period (Figure 4). The highest abundance was observed in the period I, with an abundance value of 506,025 cells L^{-1} and the lowest in the period II, with an abundance value of 199,962 cells L^{-1}.



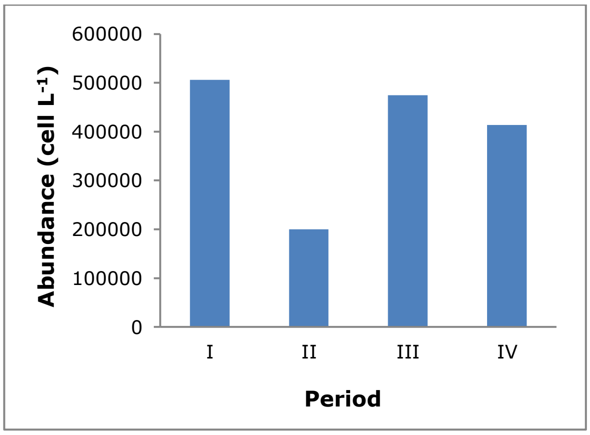


Figure 4. The abundance of phytoplankton by station (left) and by period of observation (right) in the Sasa waters, Ternate, North Maluku.

Biological indices. The diversity index (H'), evenness index (E) and dominance index (D) were calculated, showing the diversity of species in the community, as well as the balance of the number of individuals of each species, as presented in Table 1.

Table 1

Biological indices of phytoplankton found in Sasa waters, Ternate City, North Maluku

Time	*Station*	*Biological indices*		
		H'	*E*	*D*
Period I	1	1.9126	0.8306	0.2063
	2	2.0593	0.8029	0.1884
	3	2.2089	0.8157	0.1530
	4	2.1235	0.7347	0.1896
Period II	1	1.9214	0.7281	0.2269
	2	2.1698	0.8460	0.1509
	3	1.9733	0.8229	0.1908
	4	2.1170	0.8254	0.1655
Period III	1	1.8233	0.7108	0.2480
	2	2.0909	0.8152	0.1749
	3	1.9968	0.8036	0.1936
	4	2.1078	0.7784	0.1793
Period IV	1	2.1201	0.8266	0.1643
	2	2.1339	0.7880	0.1628
	3	2.1003	0.7958	0.1610
	4	2.1845	0.8517	0.1407

H'-Diversity index; E-Evenness index; D-Dominance index.

The diversity of phytoplankton in Sasa waters has a value that is not too different between each location and time of observation, with a range between 1.8233 and 2.2089 (Table 1). The highest value was obtained at station 3, period I, namely 2.2089. The high value of diversity at this station, when compared to other stations, is partly due to a better environmental quality. Meanwhile, the lowest diversity value was found at station 1, period III, namely 1.8233, because the phytoplankton community at this station is experiencing a disruption of the environmental parameters that affect the growth and development of phytoplankton. The results of the analysis show that all observation locations in these waters have an evenness index value greater than 0.50 or in the range of 0.7108-0.8517 (Table 1). This means that the existing phytoplankton community is in an unstable to a stable condition, based on Daget's (1976) criteria. The highest E value was found at station 4, period IV, with an E value of 0.8517 and the lowest at station 1, period III, with E=0.7108.

The dominance index obtained at all locations and observation times has a value close to 0, in the range of 0.1407-0.2480 (Table 1). The highest value was observed at station 1, period III, namely 0.2480, and the lowest at station 4, period IV, namely 0.1407. This indicates that in the phytoplankton community structure being observed there are no species that dominate other species, the physicochemical parameters of the water are in the appropriate range so there is no competition, all species have the same opportunity to grow and develop well. This shows that the condition of the community structure is stable, the environmental conditions are suitable and there is no ecological pressure (stress) on the biota (phytoplankton), in the habitat concerned.

Sasa waters conditions. Determining the condition (fertility level) of the water can be done by examining several physicochemical parameters of the waters, including nitrogen and phosphorus content, chlorophyll-a concentration and the presence of phytoplankton. However, in this study, the level of fertility in the waters at the study site was determined by approaching the species composition and biological indices of the phytoplankton. Based on the species composition, only 32 genera from 4 phytoplankton classes were found. Likewise, considering the biological indices, in particular the diversity index, it can be inferred that Sasa waters are included in the category of waters that have a moderate fertility, with a diversity index value (H') range of 1.8233-2.2089.

Conclusions. Based on the current research that has been conducted in the Sasa waters, it can be concluded that Sasa waters are included in the category of waters with moderate fertility levels based on the diversity index value, species composition, and abundance of phytoplankton.

Conflict of interest. The authors declare no conflict of interest.

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