Phytoplankton quality based on species composition in the Kastela waters, Ternate, North Maluku, Indonesia

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Abstract. This study aims to detect the quality of phytoplankton based on species composition in the waters of Kastela Ternate, North Maluku. The research was conducted in July-August 2022 in Kastela waters, Ternate City, North Maluku Province at 5 (five) stations. Sampling was carried out 4 (four) times with a sampling period of 2 (two) weeks. Phytoplankton sampling was carried out by filtering method, then the phytoplankton samples were preserved with 4% Lugol's solution. The quality of the phytoplankton was determined by grouping the species found into harmful algae blooms (HABs) and non-HABs phytoplankton species categories. The results showed that 27 genera of phytoplankton were found from 3 classes, namely Bacillariophyceae (20 genera), Cyanophyceae (4 genera), and Dinophyceae (3 genera). The abundance of phytoplankton found varies between stations with a range of 17,549-71,021 cells L^{-1}. The biological indices of the phytoplankton have a range of values, namely diversity index (H'): 1.3312-2.0763, evenness index (E): 0.6685-0.9017, and dominance index (D): 0.1520-0.3774. Phytoplankton in Kastela waters are still in good quality, so they are not harmful yet to another aquatic biota in these waters.

Key Words: abundance, biological indices, HABs phytoplankton, Kastela waters.

Introduction. Coastal and oceanic areas have ecologically and economically rich resources, in these areas there are various types of aquatic biota that have important or unimportant economic value. One type of biota that is important and has a large role in these waters is phytoplankton (Yuliana et al 2021).

Phytoplankton is a determinant of life in marine waters because it is the beginning of the food chain and becomes important for organisms at a higher level (Vajravelu et al 2018), without the existence of these organisms life in the ocean will not take place properly. Research on the content of phytoplankton in various waters, both between water areas and between certain waters, shows that there is a diversity of numbers and types (Yuliana et al 2021). It is very important to know the species composition or diversity of phytoplankton, especially related to the function and role of this phytoplankton in the waters concerned.

The role of phytoplankton as the beginning of the food chain in the waters has implications for organisms at higher trophic levels. Humans as consumers at the highest trophic level have resulted in people living on sea coast being inseparable from the role of the sea in their daily lives (Tambaru et al 2021). For them, the sea is a source of livelihood to meet economic needs and also the cheapest food source compared to other types of animal protein food sources. However, sometimes the seafood sources are not safe for human consumption.

One of the dangers that threaten the security of marine food sources is the uncontrolled growth of certain types of phytoplankton, especially the dangerous type which was later known as harmful algae blooms (HAB). Harmful algae blooms (HABs) are the growth of phytoplankton in waters (marine or brackish) which can result in the mass death of fish or another marine biota with toxins released by this phytoplankton (Sidabutar et al 2016). Such conditions will have negative impact on the ecosystems and biota populations in the waters concerned, and will even endanger organisms that become comestibles (food) for humans.

Based on the phenomena, it is urgent to conduct this research to detect the quality of phytoplankton based on the species composition in Kastela waters. This study aims to detect the quality of phytoplankton based on species composition in Kastela Ternate waters, North Maluku.

Material and Method

Description of the study sites. This research was conducted in Kastela waters, Ternate City, North Maluku Province, Indonesia from July to August 2022. Sampling was carried out at 5 stations (Figure 1). The number of samples taken from each station was 4 times, with a sampling period (time) of two weeks.

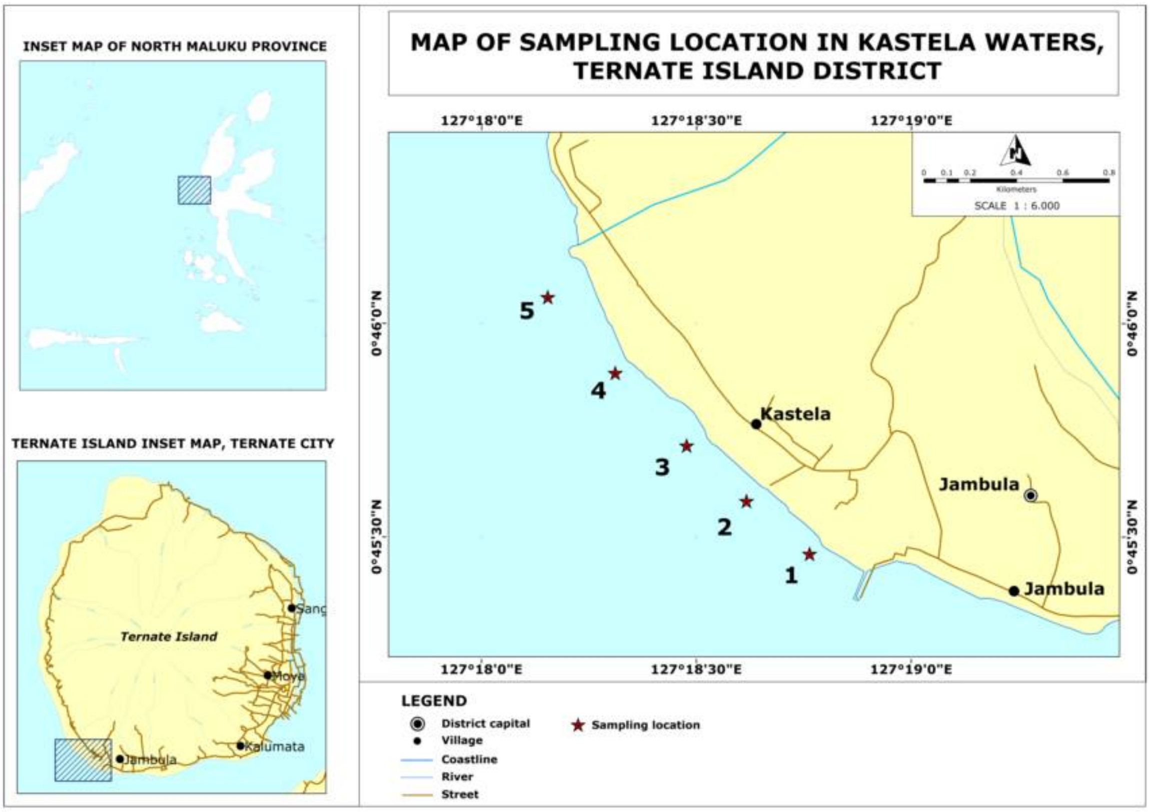

Figure 1. Research location in the Kastela waters Ternate, North Maluku.

Phytoplankton analysis. Phytoplankton specimens were taken by filtering 30 liters of water samples using a 25 µm plankton net. The filtered results were put into sample bottle and preserved with 4% Lugol's solution. These samples were then identified at the Laboratory of Aquaculture Systems and Technology, Faculty of Fisheries and Marine, Khairun University, based on identification books from Davis (1955), Yamaji (1979), Sachlan (1982), and Tomas (1997).

The composition of the types of phytoplankton at each station and the time (period) of observation were calculated by using the formula of Odum (1998):

$$Pi = {}^{ni}/_{N} \; x \; 100 \qquad (1)$$

where: Pi = species composition (%), ni = number of individuals of each i-type (ind), and N = total number of individuals (ind).

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

$$N = {}^{Oi}/_{Op} \times {}^{Vr}/_{Vo} \times {}^{1}/_{Vs} \times {}^{n}/_{p} \quad (2)$$

where: N = number of individuals per liter, Oi = area of the cover glass (mm^2), Op = area of one field of view (mm^2), Vr = volume of filtered water (mL), Vo = observed water volume (mL), Vs = volume of filtered water (L), n = plankton number in the entire field of view, and p = observed number field of view.

The Shannon-Wiener index was used to calculate the species diversity index, the evenness index and dominance index were calculated according to Odum (1998) with the following formulae:

Diversity index of Shannon-Wiener:

$$H' = -\sum_{i=1}^{s} \left({}^{ni}/_{N}\right) \ln\left({}^{ni}/_{N}\right) \quad (3)$$

Evenness index:

$$E = {}^{H'}/_{H_{max}} \quad (4)$$

Dominance index:

$$D = \sum_{i=1}^{s} \left({}^{ni}/_{N}\right)^2 \quad (5)$$

where: H' = diversity index of Shannon-Wiener, E = evenness index, D = Simpson dominance index, ni = number of individuals of the i^{th} genus, N = total number of individuals of all genera, Hmax = maximum diversity index (= ln S, where S = total type).

As supporting data, measurements of several physicochemical parameters of the waters that influence the growth and development of phytoplankton were carried out. Measurements were carried out 4 times at each station with a measurement period of once every two weeks. Water samples for chemical parameters analysis were taken using a Van Dorn volume of 2 liters, sampling was carried out at the surface (0.5 m depth). At each station, 1 liter of water was taken to analyze N, P, and Si nutrients. Nutrient analysis was carried out in the laboratory. Meanwhile, measurements of physicochemical parameters such as temperature, salinity, brightness, and pH were carried out in the field (APHA 2005).

Phytoplankton quality*.* Phytoplankton quality was determined by classifying the species found into HABs and non-HABs phytoplankton species categories.

Statistical analysis. The data from this study were analyzed descriptively and presented in the form of tables and graphs. SPSS IBM 23, Minitab 16, SAS 9.1, and Excel Stat 2017 were used to make calculations easier in the analysis.

Results and Discussion

Species composition and abundance. During the study, 27 genera of phytoplankton were found from 3 (three) classes, namely Bacillariophyceae (20 genera), Cyanophyceae (4 genera), and Dinophyceae (3 genera).

The number of phytoplankton genera found during the study was smaller than research of Yuliana (2015) in Jailolo waters West Halmahera, which founded 30 genera, and research of Rahmadani & Kuntjoro (2021) in the waters of Lusi Island Sidoarjo, which found 42 genera. However, more high compared to research by Haribowo et al (2021) on Kotok Besar Island with a total of 18 genera and research by Wijaya et al (2022) in the Mangrove Waters of Gunung Anyar, Surabaya who found 13 genera.

The number of genera from the Bacillariophyceae class which is more common than the Cyanophyceae and Dinophyceae classes is due to the conditions of the physicochemical parameters of the waters that are suitable for this class, one of which is salinity. Salinity measured during the study has a fairly high value, with a range of 30-31‰. The salinity value is suitable for the growth and development of Bacillariophyceae. As explained by Sachlan (1982) that species from the class Bacillariophyceae include plankton species that live in waters with a salinity level of more than 20‰. In addition to salinity, sunlight which is in the appropriate range is another trigger so that the number of genera from the Bacillariophyceae class was found high. During the research, sampling was carried out when the sun was rising (around 07.30-10.00 Eastern Indonesian Time), this condition resulted in the types of this class being on the surface of the waters because of their nature which is close to the light. During the day the composition of the Bacillariophyceae class tends to be higher because the plankton group of this class is positively phototactic (Madinawati 2010). In addition, the cause of a large number of individuals from the class Bacillariophyceae (diatoms) in the waters is that these organisms can adapt to the environment, are cosmopolitan, resistant to extreme environmental conditions, and have high reproductive power (Barus et al 2008), most easily found in various types of aquatic habitats (Putra et al 2012), and when there is an increase in nutrient concentrations in the waters, Bacillariophyceae can reproduce three times in 24 hours (Damar et al 2013).

The genera found at all stations and observation times were *Biddulphia*, *Rhizosolenia*, and *Surirella*, the three genera came from the class Bacillariophyceae. This means that the physical-chemical parameter conditions in Kastela waters are suitable for these species. While the genera that were only found once during the study were *Hemiaulus* (station 4 period II), *Licmophora* (station 3 period I), *Streptotheca* (station 4 period I), and *Tabellaria* (station 2 period III); these genera came from the class Bacillariophyceae, and *Aphanizomenon* (station 5 period I) from the class Cyanophyceae.

The results of enumeration at each observation station found that all classes were found in all observation periods. However, they have different percentages, with the percentages shown in Figure 2.

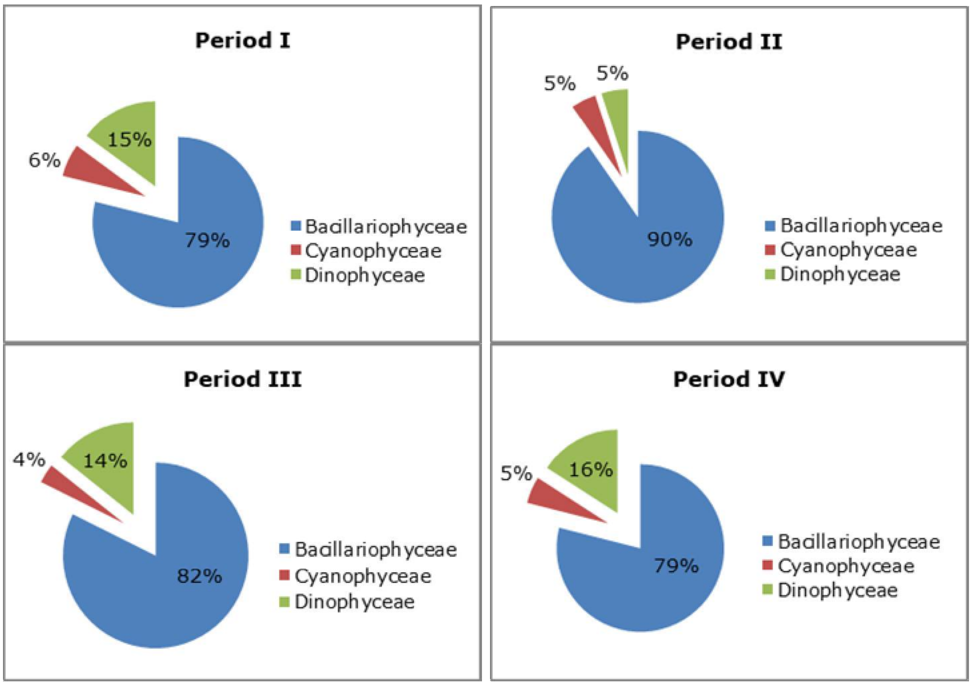

Figure 2. Composition of phytoplankton species found in the Kastela waters Ternate, North Maluku.

The Bacillariophyceae class had the highest contribution in Kastela waters during the study, with a percentage of 79-90% (Figure 2). While the lowest was the Cyanophyceae class, with a percentage of only 4-6%. Similar conditions have been found by Aisoi (2019) in the coastal waters of Holtekamp City of Jayapura with a percentage of 94% Bacillariophyceae and 1% Cyanophyceae, research by Haribowo et al (2021) in the waters of Kotok Besar Island with a Bacillariophyceae percentage of 89%, as well as research by Dewanti et al (2018) in Serangan Island waters, Bali with a composition of 96.93% Bacillariophyceae. However, this is different from what was found by Kadim et al (2018) in Gorontalo Bay that the Chrysophyceae class dominated the phytoplankton with a contribution of 63.3%. The high contribution of the Bacillariophyceae class found indicates that the types from the Bacillariophyceae class have a larger distribution compared to other classes, the Kastela water conditions are suitable so that they allow the types from this class to grow and develop properly, and the Bacillariophyceae class has good adaptations towards the environmental conditions of Kastela waters which have a low supply of nutrients from the mainland. In addition, the class Bacillariophyceae (Diatom) is cosmopolitan, resistant to extreme conditions, has a high reproductive capacity (Odum 1998), is the most common class and plays an important role in estuarine and marine waters (Tungka et al 2016), it can adapt to little light, can tolerate changes in environmental conditions around it (Munthe et al 2012), and has a very fast response to the addition of nutrients compared to genera from other classes (Nybakken 1993; Lagus et al 2004).

Meanwhile, the class of phytoplankton that contributed the second most after Bacillariophyceae was the Dinophyceae class, with a percentage of 5-16% (Figure 2). These phenomena are common in marine waters, as explained by Cokrowati et al (2014) that the second largest group of phytoplankton after Bacillariophyceae which is often found in marine waters is the Dinophyceae class. This indicates that the species from the Dinophyceae class have a good ability to adapt and grow in the waters of Kastela.

The abundance of phytoplankton which found has varying values between each station and time (period) of observation, with a range of 17,549-71,021 cells L^{-1} (Figure 3). The highest abundance was found at station 3 period IV with a value of 71,021 cells L^{-1} and the lowest at station 2 period III with a value of 17,549 cells L^{-1}.

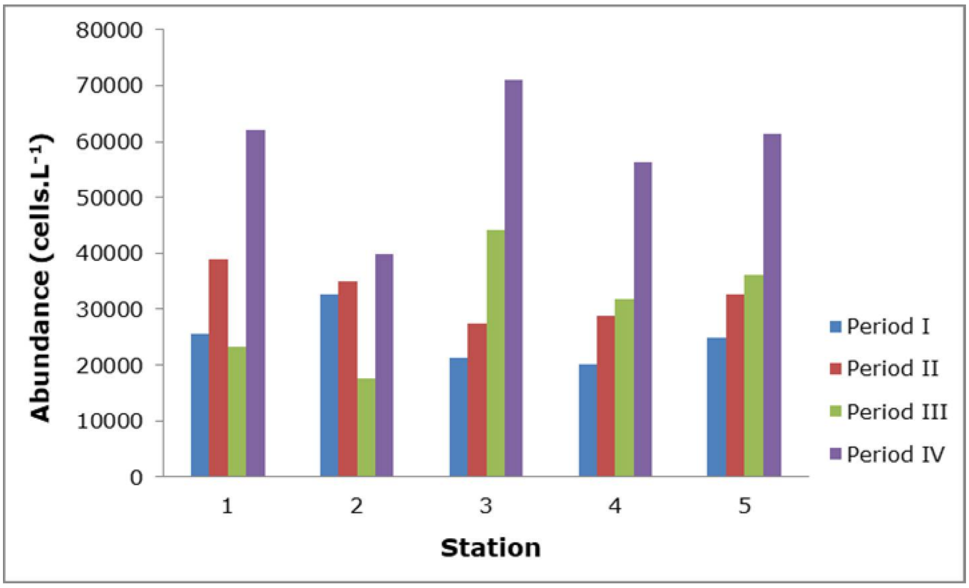

Figure 3. The abundance of phytoplankton found in the Kastela waters Ternate, North Maluku.

The abundance values found during the study were included in the low category when compared to the study by Yuliana et al (2021) in the waters of Sasa Ternate with an abundance of 45,327-178,791 cells L^{-1}. However, it is higher than the study by Fitrianti et al (2022) in the coastal waters of the Batang PLTU Megaproject Central Java with an abundance of 2,581-10,137 cells L^{-1} and the research of Ramadhanty et al (2020) on the Maron beach, Semarang, with an abundance of 7,109-11,550 cells L^{-1}.

The highest abundance found at station 3 period IV was caused by the condition of the physicochemical parameters of the waters which were suitable for phytoplankton to grow and develop. The main factors affecting the growth of phytoplankton are the availability of light and nutrients, both of which determine the abundance of phytoplankton in water. If the intensity of sunlight is appropriate, the abundance of phytoplankton will be high. Likewise, when the availability of organic matter is high, the abundance of phytoplankton in water will also be high (Sachlan 1982). The main types of nutrients needed by phytoplankton are nitrogen and phosphorus, these two types of nutrients become a limiting factor in the growth of phytoplankton. If nitrogen and phosphorus are at optimum conditions, the phytoplankton will grow optimally. However, if one of them is at an inappropriate concentration, these organisms will not grow optimally. At station 3 period IV we found nitrate content of 0.286 mg L^{-1} and phosphate with a value of 0.222 mg L^{-1}. The content of these two types of nutrients is in the appropriate range for phytoplankton to grow and develop. As explained by Paiki & Kalor (2017) that the nitrate content which is good for the growth of phytoplankton is in the range between 0.09 and 3.5 mg L^{-1} and phosphate in the range of 0.08-1.80 mg L^{-1}. Hidayat (2017) further explained that the minimum requirement for nitrate that can be absorbed by phytoplankton, especially diatoms, is in the range of 0.001-0.007 mg L^{-1}.

In addition, silica also takes an important role in the growth of phytoplankton, this element is mainly used by diatoms. Different concentrations of silica in water will cause differences in the abundance of diatoms. Silica concentration at station 3 period IV was 1.296 mg L^{-1}. This silica content is in the range suitable for the growth of phytoplankton. As stated by Turner (1980) in Widjaja et al (1994) that if the silica content is less than 0.5 mg L^{-1}, phytoplankton, especially diatoms, cannot develop properly.

Meanwhile, the values of the other water physicochemical parameters at station 3 period IV were temperature: 26.54°C, salinity: 30‰, and pH: 7.59. These values are in the optimal range for the growth of phytoplankton, as stated by Anisah (2017) that the temperature range between 25 and 32ºC is the optimum temperature for the growth of phytoplankton in tropical waters. Berge et al (2010) stated that the pH range of 7-8.5 resulted in an optimum growth rate of phytoplankton. Sachlan (1982) further explained that a salinity value greater than 20‰ is suitable for phytoplankton and allows these organisms to survive, multiply and actively carry out photosynthesis. Furthermore, Raymont (1980) emphasized that the range between 10 and 40 ppt is the optimum salinity in supporting the growth of phytoplankton.

The lowest abundance obtained at station 2 period III was more due to the low nitrate content. The nitrate concentration found was 0.045 mg L^{-1}. Meanwhile, the content of phosphate and silica was still in the range suitable for phytoplankton. The range of the two types of nutrients respectively was phosphate: 0.202 mg L^{-1} and silica: 2.584 mg L^{-1}. Likewise, other water physicochemical parameters such as temperature (26.71°C), salinity (30‰), and pH (7.58) all were still in the appropriate range for the growth of phytoplankton. In addition, the low abundance can be caused by grazing by zooplankton. In addition, the low abundance of phytoplankton can be caused by grazing by zooplankton and planktivore fish (Lau & Lane 2002; Jiang et al 2014).

If traced further, it was found that the genus that had the highest abundance during the study was *Biddulphia* (class Bacillariophyceae) with an abundance of 326,821 cells L^{-1} and the lowest abundance was for the genera *Amphora* (class Bacillariophyceae) and *Aphanizomenon* (class Cyanophyceae) with an abundance of 206 cells L^{-1} each. The results obtained are different from the research by Kadim et al (2018) in Gorontalo Bay, Indonesia, who found that the type of phytoplankton that had the highest abundance was *Chaetoceros affinis* with an average abundance of 25,441 cells L^{-1}.

Biological indices. The biological indices observed were the diversity index (H'), the evenness index (E), and the dominance index (D). These indices show the species richness in a community and the balance of the number of individuals of each species. The complete results of the calculation of the phytoplankton biological indices are presented in Table 1.

The diversity index values obtained during the study ranged from 1.3312 to 2.0763 (Table 1). Referring to Krebs (1998) who classifies the value of diversity as $H' < 1$: small diversity, $1 \leq H' \leq 3$: moderate diversity, and $H' > 3$: high diversity, then the diversity index value obtained during the study is included in the category moderate. This index value indicates that the phytoplankton community is in a stable condition. It means that the types of phytoplankton present in Kastela waters during the study can adapt to the conditions of the physicochemical parameters of the waters concerned. The diversity index value of a community depends on the number of genera and the uniformity index of the number of individuals of each genus. The higher the number of genera and the uniformity of the genus, the higher the value of the diversity index (Pielou (1966) in Risanty (2001)).

The evenness index obtained during the study has values ranging from 0.6685 to 0.9017 (Table 1). These values indicate that the uniformity between each genus is high and evenly distributed at each station and time (period) of observation. This is in accordance with what was stated by Brower et al (1998) that an evenness index value that is more than or equal to 0.6 indicates high uniformity. Thus, it can be explained that the phytoplankton community in Kastela waters during the study was in more even to very even conditions or in the good to very good category. If the evenness index value is related to the statement of Daget (1976), then it can be explained that the phytoplankton community is in an unstable to stable condition. The phytoplankton community in Kastela waters can adapt and live well with the physical and chemical parameters of the waters concerned.

Dominance index values found during the study at all stations and observation times had values close to zero or < 0.5, with values ranging from 0.1520 to 0.3774 (Table 1). A value close to zero indicates that the community structure of the phytoplankton in Kastela waters is in a stable condition, there are no extreme species of phytoplankton that dominate the other species. The physicochemical parameters of the waters that affect the growth of these organisms are in suitable conditions, each species can adapt to aquatic environmental conditions, and there is no competition between each species so that all species have equal opportunities to grow and develop well in Kastela waters.

Table 1

Phytoplankton biological indices found in the Kastela waters Ternate, North Maluku

Period	*Station*	*Biological indices*		
		H'	*E*	*D*
I	1	1.7786	0.7724	0.2508
	2	1.6866	0.7676	0.2378
	3	1.8065	0.7846	0.2129
	4	1.7226	0.7840	0.2397
	5	1.5699	0.7145	0.2733
II	1	1.4595	0.7500	0.2999
	2	1.5014	0.7220	0.2865
	3	1.3312	0.7429	0.3369
	4	1.6309	0.7423	0.2647
	5	1.6803	0.7647	0.2496
III	1	2.0763	0.9017	0.1520
	2	1.8671	0.7514	0.2161
	3	1.6852	0.7670	0.2571
	4	1.6753	0.6986	0.2725
	5	1.3901	0.6685	0.3774
IV	1	1.6121	0.6723	0.2989
	2	1.7314	0.7519	0.2602
	3	1.7960	0.7002	0.2548
	4	1.7168	0.6909	0.2633
	5	1.6942	0.7358	0.2838

Description: H '= diversity index; E = evenness index; and D = dominance index.

Phytoplankton quality. Determination of the quality of phytoplankton in Kastela Ternate waters was carried out by analyzing the proportion of abundance between species belonging to the HABs group of phytoplankton and non-HABs phytoplankton at each station and time of observation. The results of the complete analysis are showed in Figure 4.

The results of the enumeration showed that 22 types of phytoplankton were found from the non-HABs group and 5 types from the HABs group. The types of potentially dangerous phytoplankton (HABs) detected were *Chaetoceros* and *Nitzschia* from the Bacillariophyceae class, as well as *Cochlodinium*, *Gymnodinium*, and *Peridinium* from the Dinophyceae class. This is accordance with what was stated by Wiadnyana (1996) that these genera are types that belong to the classes of phytoplankton that cause HABs. These species are categorized as dangerous phytoplankton because they are species that can have negative impact to the other aquatic biota, which in turn can disrupt ecosystems and human health.

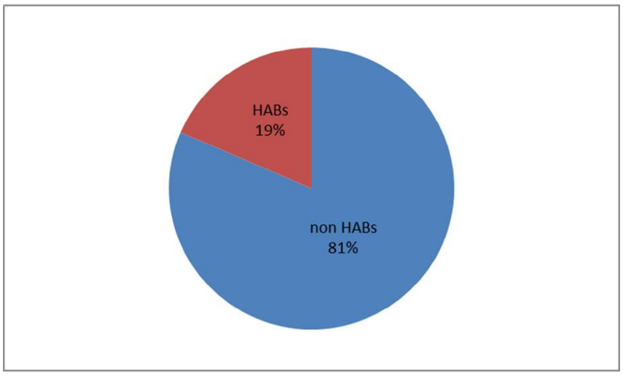

Figure 4. Percentage of HABs and non-HABs phytoplankton found in the Kastela waters Ternate, North Maluku.

The abundance of phytoplankton species that cause HABs is further detected using a proportion analysis, by comparing the abundance of phytoplankton that causes HABs with non-HABs phytoplankton. The results of the analysis during the study showed that the group of phytoplankton from the type of HABs was lower (lower) compared to the non-HABs group, with a percentage of 19% HABs and 81% non-HABs (Figure 4). This indicates that the growth and development of phytoplankton in Kastela waters can be categorized as good, even though HABs have started to appear. Based on these facts, it can be explained that the phytoplankton in Kastela waters is still in good quality, so they are not harmful yet to other aquatic biota in the waters concerned.

Conclusions. Based on the results of the research that has been done, it can be concluded as follows: in Kastela waters there are 27 genera of phytoplankton from 3 classes namely Bacillariophyceae, Cyanophyceae, and Dinophyceae; phytoplankton in Kastela waters are still of good quality, so they are not harmful yet to other aquatic biota in these waters.

Conflict of interest. The authors declare that there is no conflict of interest.

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References

Aisoi L. E., 2019 [The abundance and diversity of phytoplankton in the coastal waters of Holtekamp, Jayapura City]. Jurnal Biosilampari 2(1):6-15. [in Indonesian]

Anisah S., 2017 [The relationship between nitrate and phosphate concentrations and chlorophyll-a from phytoplankton in different aquatic environment conditions in Pundatan Baji, Pangkep Regency]. Skripsi. Departemen Ilmu Kelautan, Fakultas Ilmu Kelautan dan Perikanan, Universitas Hasanuddin, Makasar, 56 pp. [in Indonesian]

APHA, 2005 Standard methods for the examination of water and wastewater. 21th edition. APHA, AWWA (American Waters Works Association) and WPCF (Water Pollution Cobtrol Federation), Washington, pp. 3-42.

Barus T. A., Sinaga S. S., Tarigan R., 2008 [Primary productivity of phytoplankton and its relationship with physical-chemical factors of water in Parapat waters, Lake Toba]. Jurnal Biologi Sumatera 3(1):11-16. [in Indonesian]

Berge T., Daugbjerg N., Andersen B. B., Hansen P. J., 2010 Effect of lowered pH on marine phytoplankton growth rates. Marine Ecology Progress Series 416:79-91.
Brower J. E., Zar J. H., Von Ende C. N., 1998 Field and laboratory methods for general ecology. 4th edition. McGraw-Hill, Boston, 273 pp.
Cokrowati N., Amir S., Abidin Z., Setyono B. D. H., Damayanti A. A., 2014 [Abundance and composition of phytoplankton in Kodek Bay Pemenang Lombok Utara]. Depik 3(1):21-26. [in Indonesian]
Daget J., 1976 [Mathematical models in ecology]. Masson, Paris, 172 pp. [in French]
Damar A., Vitner Y., Palmirmo P., Kadir M. S., 2013 [Detection of environmental factors triggering the emergence of a phytoplankton population explosion (red tide) in the Jakarta Bay Waters and their relation to the eutrophication of coastal and marine waters]. Laporan Penelitian. Lembaga Penelitian dan Pangabdian Kepada Masyarakat-Institut Pertanian Bogor, Bogor, Indonesia. [in Indonesian]
Davis G. C., 1955 The marine and freshwater plankton. Michigan State University Press, USA, 562 pp.
Dewanti L. P. P., Putra I. D. N. N., Faiqoh E., 2018 [Relationship between phytoplankton abundance and diversity with zooplankton abundance and diversity in Serangan Island Waters, Bali]. Journal of Marine and Aquatic Sciences 4(2):324-335. [in Indonesian]
Fitrianti F. B., Ario R., Widianingsih, 2022 [Phytoplankton community structure in coastal waters of the Batang PLTU Megaproject, Central Java]. Journal of Marine Research 11(3):437-445. [in Indonesian]
Haribowo D. R., Wicaksono A. Z., Muhammad A. A., Ramadhan F., Rijaluddin A. F., Assuyuti Y. M., 2021 [Seasonal variation of phytoplankton and waters quality of Kotok Besar Island]. Berita Biologi: Jurnal Ilmu-ilmu Hayati 20(3):235-246. [in Indonesian]
Hidayat T., 2017 [Abundance and community structure of phytoplankton in the reclamation area of Seruni Beach, Bantaeng Regency]. Skripsi. Program Studi Ilmu Kelautan. Departemen Ilmu Kelautan, Fakultas Ilmu Kelautan dan Perikanan, Universitas Hasanuddin, Makasar, 62 pp. [in Indonesian]
Jiang Y. J., He W., Liu W. X., Qin N., Ouyang H. L., Wang Q. M., Kong X. Z., He Q. S., Yang C., Yang B., Xu F. L., 2014 The seasonal and spatial variations of phytoplankton community and their correlation with environmental factors in a large eutrophic Chinese lake (Lake Chaohu). Ecological Indicators 40:58-67.
Kadim M. K., Pasisingi N., Kasim F., 2018 Spatial and temporal distribution of phytoplankton in the Gorontalo Bay, Indonesia. AACL Bioflux 11(3):833-845.
Krebs C. J., 1978 A review of the Chitty Hypothesis of population regulation. Canadian Journal of Zoology 56(12):2463-2480.
Lagus A., Suomela J., Wethoff G., Heikkila K., Helminen H., Sipura J., 2004 Species-specific differences in phytoplankton responses to N and P enrichment and the N:P ratio in the Archipelago Sea, northern Baltic Sea. Journal of Plankton Research 26(7):779-798.
Lau S. S. S., Lane S. N., 2002 Biological and chemical factors influencing shallow lake eutrophication: a long-term study. The Science of the Total Environment 288(3): 167-181.
Madinawati, 2010 [The abundance and diversity of plankton in the Laguna waters of Tolongano Village, South Banawa District]. Media Litbang Sulten 3(2):119-123. [in Indonesian]
Munthe V., Aryawati R., Isnaini, 2012 [Community structure and distribution of phytoplankton in Sungsang waters, South Sumatra]. Maspari Journal 4(1):122-130. [in Indonesian]
Nybakken J., 1993 Marine biology: an ecological approach. 3rd edition. Harper Collins Publishers, 462 pp.
Odum E. P., 1998 [Fundamentals of ecology]. 3rd edition. Samingan T. (ed), Universitas Gadjah Mada Press, Yogyakarta, 697 pp. [in Indonesian]
Paiki K., Kalor J. D., 2017 [Distribution of nitrate and phosphate on phytoplankton abundance in East Yapen coastal waters]. Journal of Fisheries and Marine Science 1(2):65-71. [in Indonesian]

Putra A. W., Zahidah, Lili W., 2012 [Plankton community structure in the upper Citarum River, West Java]. Jurnal Perikanan dan Kelautan 3(4):313-325. [in Indonesian]
Rahmadani D., Kuntjoro S., 2020 [The diversity of tolerant plankton in the coastal waters of Lusi Island Sidoarjo Regency]. LenteraBio: Berkala Ilmiah Biologi 9(3):258-266. [in Indonesian]
Ramadhanty M. U., Suryono S., Santosa G. W., 2020 [Composition of phytoplankton at Maron Beach, Semarang]. Journal of Marine Research 9(3):296-302. [in Indonesian]
Raymont J. E. G., 1980 Plankton and productivity in the ocean. 2nd edition. Pergamon Press Inc., New York, USA, 489 pp.
Risanty D., 2001 [Vertical distribution of ephyllitic diatoms in the Kelekar river, Inderalaya]. Thesis, FMIPA, Universitas Sriwijaya, 43 pp. [in Indonesian]
Sachlan M., 1982 [Planktonology]. Direktorat Jenderal Perikanan, Departemen Pertanian, Jakarta, 178 pp. [in Indonesian]
Sidabutar T., Bengen D. G., Wouthuyzen S., Prartono T., 2016 The abundance of phytoplankton and its relationship to the N/P ratio in Jakarta Bay, Indonesia. Biodiversitas 17(2):673-678.
Tambaru R., Burhanuddin A. I., Massinai A., Amran M. A., 2021 Detection of marine microalgae (phytoplankton) quality to support seafood health: a case study on the west coast of South Sulawesi, Indonesia. Biodiversitas 22(11):5179-5186.
Tomas C. R., 1997 Identifying marine phytoplankton. Academic Press, 858 pp.
Tungka A. W., Haeruddin, Ain C., 2016 [Concentration of nitrate and orthophosphate at Banjir Kanal Barat and their relationship with the abundance of harmful algae blooms]. Indonesian Journal of Fisheries Sciences and Technology 12(1):40-46.
Vajravelu M., Martin Y., Ayyappan S., Mayakrishnan M., 2018 Seasonal influence of physic-chemicalcal parameters on phytoplankton diversity, community structure and abundance at Parangipettai coastal waters, Bay of Bengal, South East Coast of India. Oceanologia 60(2):114-127.
Wiadnyana N. N., 1996 [Dangerous microalgae in Indonesian waters]. Oseanologi dan Limnologi di Indonesia 29:15-28. [in Indonesian]
Widjaja F., Suwignyo S., Yulianda F., Effendi H., 1994 [Species composition, abundance, and distribution of marine plankton in Pelabuhan Ratu Bay, West Java]. Research report, Faculty of Fisheries and Marine Sciences, IPB Bogor, 10 pp. [in Indonesian]
Wijaya N. I., Sari A. K. A., Mahmiah, 2022 [Effect of phosphate and nitrate concentrations on phytoplankton abundance in mangrove waters of Gunung Anyar, Surabaya]. Jurnal Pertanian Terpadu 10(1):64-77. [in Indonesian]
Yamaji I., 1979 [Illustration of the marine plankton of Japan]. Hoikusha Publishing Co., Japan, 537 pp. [in Japanese]
Yuliana, 2015 [Distribution and composition of phytoplankton types in Jailolo waters, West Halmahera]. Akuatika 6(1):41-48. [in Indonesian]
Yuliana, Mutmainnah, Irfan M., 2021 The use of phytoplankton as a fertility indicator of the Sasa waters, Ternate, North Maluku, Indonesia. AACL Bioflux 14(6):3741-3749.

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