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Spatial and temporal distribution of phytoplankton with emphasis on the harmful and toxic algae in the Limboto Lake

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ABSTRACT

This study aims to describe Limboto Lake's condition based on the spatial-temporal abundance of phytoplankton and the presence of harmful algae species. Sampling was conducted in February to April 2018 at six stations. The phytoplankton found in Limboto Lake consisted of 7 divisions from 80 species, namely Chlorophyta (35 species), Euglenophyta (17 species), Bacillarophyta (13 species), Cyanophyta (7 species), Cryptophyta (4 species), Dinophyta (3 species) and Chyrosphyta (1 species). The results of phytoplankton distribution in Limboto Lake varied on average among stations as well as observation times. The results show that the average of phytoplankton abundance at station 1, station 2, station 3, and station 4 categorized as medium polluted waters with 4,903 ind. L-1, 5,000 ind. L-1, 9,418 ind. L-1, and 10,049 ind. L-1, respectively. The abundance at station five is included in the lightly polluted category with an average phytoplankton abundance of 1,541 ind/L, while station 6 is in the heavily polluted category with an average value of 20,894 ind. L-1. Species that can be used as indicator species for pollution are those with the highest abundance value, namely Microcystis sp., which indicates that Limboto Lake contains high nitrate and phosphate.

INTRODUCTION

Limboto Lake is the largest lake in Gorontalo Province that has an essential role in supporting people who live around the area. Limboto Lake activities are capture fisheries, aquaculture, agriculture, and tourism (Ladja et al., 2020). Agricultural activities around Lake Limboto can affect the presence of organisms in the lake, including phytoplankton. This lake is used by the community to support activities.

Phytoplankton is part of the plant group of plankton free to float and drift in the water and can photosynthesize also produce oxygen (Apridayanti, 2008). Certain types of phytoplankton can deteriorate water quality if the amount is excessive (blooming) (Anderson et al., 2008). Several types of phytoplankton can produce toxins that have the potential to cause Harmful

Algae Blooms (HABs) when their distribution and abundance are in large quantities in water. The phytoplankton types include *Alexandrium* sp., *Gymnodinium* sp., *Mycrocystis* sp., and *Peridinium* sp. (Mos, 2001).

The distribution of phytoplankton in waters can provide information about water pollution, which can be seen from the composition of a division of plankton organisms in the waters (Sediadi, 2004). The relationship between phytoplankton abundance and water pollution is positive. If the abundance of phytoplankton is high, it also can be said that these waters have high pollution (Sulastri et al., 2008).

Pollution due to the blooming of an organism can occur in Limboto Lake. Observing the organisms that live in these waters is a way to find out this phenomenon. Sahami (2006) reported that Limboto Lake was polluted by organic matter, using gastropods as an indicator. In addition to gastropods, phytoplankton can also be used as an indicator of polluted waters as it is the first organism to take nutrients in the waters. Phytoplankton is very sensitive to environmental changes (Apridayanti, 2008). This study aims to determine Limboto Lake condition based on the spatial-temporal abundance of phytoplankton and the presence of harmful/toxic algae.

MATERIAL AND METHODS

Study site. Sampling was carried out from February to April 2018 in Limboto Lake, Gorontalo Province. The research location is divided into six stations (Figure 1). Sampling was carried out once per month at each station.

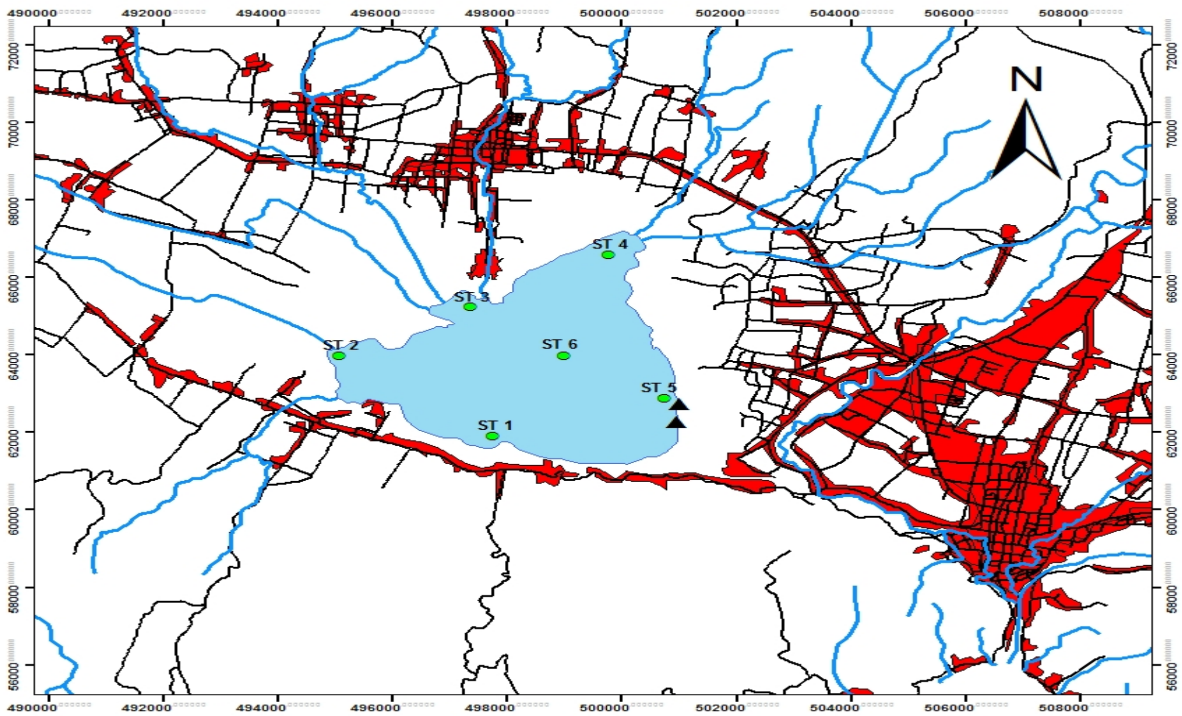

Figure 1. Study area (Limboto Lake). The green dots (•) indicate the coordinate position of the sampling site.

Procedures. The sampling procedure refers to the APHA standard method (Rice et al., 2012). Plankton samples were taken using plankton-net (meshsize 25 μm), then preserved with 1 % Lugol solution. Phytoplankton was identified taxonomically using a light microscope referred to Davis (1955) taxonomical guide. The abundances were measured using SRC, Lackey drop-transect method. Biological diversity index (H') and dominance index (D) were calculated according to the following equation (Shannon & Wiener and Sampson index, 1949 in Odum, 1998). Physical parameters such as temperature, transparency, pH, and dissolved oxygen were conducted in situ in each station. In contrast, nitrate and orthophosphate performed ex-situ and determined using spectrophotometry according to the APHA (Rice et al., 2012) methods.

Data analysis. Water quality parameters and the number of phytoplankton species during sampling were performed descriptively.

RESULTS AND DISCUSSION

Physico-chemical characteristics. The physico-chemical parameter values of Limboto Lake waters during the study can be seen in Table 1.

Table 1. Mean value of water characteristics of Limboto Lake

No	Parameters	Stations					
		1	2	3	4	5	6
1	Temperature (^{0}C)	31	31.9	30.8	31.1	29.3	32
2	Transparency (cm)	55.2	19.9	25.8	29.5	33.2	34
3	pH	6.5	6.4	6.8	6.6	6.3	7.0
4	DO (mg. L^{-1})	5	5	5.6	5.2	5.6	4.7
5	Nitrate (mg. L^{-1})	1.4	1.4	1.5	1.5	1.3	1.4
6	Phosphate (mg. L^{-1})	3.9	2.8	2.1	3.8	2.3	2.9

The average water surface temperature ranged between 29.3 to 32 ^{0}C. Meanwhile, the highest temperature were found in April (32.6 ^{0}C). The ideal temperature for phytoplankton growth at 27–30 ^{0}C (Boyd et al., 2013). Transparency was ranging from 19.5 to 55.2 cm. During the rainy season in February, the transparency was found in the lowest value (19.4 cm), and the highest was shown in April (dry season), 46.6 cm.

During the sampling period, the mean values of pH were never below 6.3. The pH was recorded between 6.3 and 7. High pH (alkaline) can limit algae growth and photosynthesis performance (Bergstrom et al., 2007). The mean values of dissolved oxygen concentrations ranged between 4.7–5 mg. L^{-1}. The lowest concentration were found in April. Oxygen concentration in waters are strongly influenced by temperature (Koralay et al., 2018). The decrease in DO will affect algae diversity and biomass (Haas et al., 2014).

During the sampling period, nutrient concentration, nitrate, and phosphate were high in all sampling sites. It is indicated that the waters of Limboto Lake were polluted. Mustofa (2015) reported that when the concentration of nitrate was > 0.5 mg. L^{-1} and the phosphate concentration was > 0.03 mg. L^{-1}, that indicated the waters in heavy polluted.

Phytoplankton abundance. Phytoplankton found in Limboto Lake consist of 80 species and 7 divisions (Figure 4), namely Chlorophyta (35 species), Euglenophyta (17 species), Bacillarophyta (13 species), Cyanophyta (7 species), Cryptophyta (4 species), Diniphyta (3 species), and Chyrosphyta (1 species). The number of species found in Limboto Lake is still higher than the research by Lukman et al. (2008), which only found 37 species in Limboto Lake.

Chlorophyta has the highest number of species found in Lake Limboto, followed by Euglenophyta and Bacillarophyta. At the same time, Cyanophyta is the division with the most number of individuals found. According to Adjie et al. (2017), Chlorophyta is mostly found in freshwater, especially stagnant water, qualitatively and quantitatively. Offem et al. (2013) stated that abundance Chlorophyta is due to its being more tolerant of environtmental stresses and has the ability to reproduce and grow faster than other divisions. Garno (2016) stated that Cyanophyta is one of the phytoplankton divisions that is easily found in freshwater plankton communities. Abadi et al. (2014) reported that waters dominated by Cyanophyta is categorized as polluted. It disturbs aquatic life due to the increased toxic content.

Several types of phytoplankton dominate and distribute widely and play an essential role in freshwater, especially lake. The phytoplankton came from the Chlorophyta, Euglenophyta, Bacillarophyta, and Cyanophyta Divisions (Noryadi, 1998 in Sulastri et al., 2008). The average abundance of phytoplankton found during the study varied between 1,541–20,894 ind. L^{-1} (Table 2). The abundance of phytoplankton can be seen in Table 2.

Table 2. The abundance of phytoplankton (ind. L^{-1}) during the study

Stations	Abundance (ind. L^{-1})			Average
	February	March	April	
Station 1	2,280	4,017	5,981	4,093
Station 2	2,720	5,320	6,960	5,000
Station 3	4,680	10,127	13,449	9,418
Station 4	2,920	12,480	14,747	10,049
Station 5	1,280	1,360	1,982	1,541
Station 6	5,280	29,800	27,601	20,894
Avarage	3,193	10,517	11,787	

Spatially, station 6 has the highest average abundance (20,894 ind. L^{-1}), presumably as that location is close to floating net cage activities, which can provide high nutrient input. It is also supported by the highest content of nitrate and phosphate besides station 4. It has the potential to increase the biomass of aquatic plants due to nutrient enrichment. Lehmusluoto (2000) stated that domestic waste pollution is one of the causes of eutrophication in lakes. According to Rahman et al. (2017), one of the eutrophication effects influences phytoplanktons presence in waters. The high concentration of nutrients can be affected by the number of human activities around the waters. Purnamaningtyas & Tjahjo (2017) explained that the activities that have exceeded the environments carrying capacity could increase organic matter due to leftover feed and fish metabolism. Besides, Zhou et al. (2011) reported that an artificial fish feed is rich in nitrogen and phosphorus. If the feed is not entirely consumed, it will increase nutrients, which can increase water fertility.

Station 5, the Limboto Lake outlet area, has the lowest average abundance (1,541 ind. L^{-1}). The low abundance value is presumably due to the lower nutrient content in this station than other stations even though the DO value at this station is high. The low phytoplankton population in the outlet area was also shown by the research of Soeprobowati & Suedy (2010) in Lake Rawa Pening even though it had high productivity. In addition, phytoplankton is thought to have been carried away by the current as of the characteristics of its life, which are strongly influenced by the movement of the current. Apridayanti (2008) states that phytoplankton is part of plankton from plant groups free to float and drift in the water.

The average abundance of phytoplankton in February was the lowest and then continued to increase in March and April. During the research, February was the end of the rainy season and still rained frequently. In contrast, March and April are the beginning of dry season and have a long exposure, allowing phytoplankton to rise to the surface due to phytoplankton positive phototaxis. Thoha (2010) stated that phytoplankton will perform photosynthesis and reproduce well if they are in water conditions exposed to sunlight as they are positive phototaxis.

Phytoplankton distribution. Based on the value of the Evenness Index, it ranges from 0.49 to 0.93. This value indicates that the distribution of the species in Limboto Lake varies. The results of the evenness index calculation are presented in Table 3.

Table 3. Evenness Index in Limboto Lake

Stations	Evenness Index (E)		
	February	March	April
Station 1	0.92	0.85	0.83
Station 2	0.91	0.59	0.69
Station 3	0.73	0.72	0.72
Station 4	0.89	0.39	0.63
Station 5	0.93	0.92	0.95
Station 6	0.42	0.55	0.49

Table 3 shows that spatially stations 1 and 5 have a very even distribution (> 0.75). station 2, station 3, and station 4 are categorized as unstable distribution (0.50–0.75). Station 6 has an uneven distribution (< 0.50) as it is located in the middle of the lake, where floating cage net activity is irregular. Temporally, observations in February showed a very even distribution of phytoplankton (> 0.75), while in March and April, the distribution was unstable (0.50–0.75). Haumahu (2005) states that environmental conditions and nutrient distribution influence phytoplankton distribution in rough waters. Zhou et al. (2011) stated that intensive floating cage net activities can accumulate nitrogen and phosphate in the bottom waters due to the remaining feed, which can increase water nutrients.

The Dominance Index shows the species richness in a community and the balance of the number of individuals of each species. The results of the calculation of the Dominance Index are presented in Table 4.

Table 4. Phytoplankton Dominance Index in Limboto Lake

Stations	Dominance Index (D)		
	February	March	April
Station 1	0.059	0.091	0.089
Station 2	0.064	0.366	0.206
Station 3	0.232	0.150	0.130
Station 4	0.084	0.571	0.212
Station 5	0.111	0.09	0.065
Station 6	0.555	0.403	0.337

Table 4 shows the Dominance Index (D) value at the observation station ranging from 0.09 to 0.571. This range indicates that, spatially and temporally, no phytoplankton species dominate the waters of Lake Limboto. The D value of station 6 is relatively high compared to other stations. Although *Mycrocystis* sp. found in relatively high numbers at this station, the index value, which is not close to 1, indicates that there are no dominating species.

Setyobudiandi et al. (2009) explained that the dominance index value < 0.50 means low and no organisms dominate. If the dominance value ranges from 0.75 to 1.00, it means that it is high or there is a dominating organism. Also, Nugroho et al. (2012) stated that the greater the dominance index (D), the greater the tendency for certain species to dominate the waters. Conversely, the smaller the dominance index (D), the smaller the species that dominate.

Harmful and toxic algae. The results of the Dominance Index value (Table 4) indicate that there are no dominant phytoplankton species in Limboto Lake. *Mycrocystis* sp. has a relatively high abundance value among other species, with the highest value of 17,720 ind. L^{-1} in March. This species was only found in March and April at all stations (Table 5), with the highest abundance in March at station 5. *Mycrocystis* sp. is one of the harmful and toxic algal (Moreira et al., 2014; Mos, 2001).

Blooming *Mycrocystis* sp. causes a drastic decrease in dissolved oxygen due to excessive utilization of oxygen to decompose dead organisms (Panjaitan, 2009). Suryanto & Umi (2019) stated that *Mycrocystis* sp. able to adapt to polluted environmental conditions. Garno (2016) stated that eutrophication waters would eventually be dominated by particular phytoplankton types, which are generally inedible by aquatic fauna, especially zooplankton and fish, including as they are poisonous. The presence of the *Mycrocystis* sp. in waters indicates eutrophication. Samudra et al. (2013) stated that *Mycrocystis* sp. is phytoplankton, which can be used as an indicator of polluted waters as it is toxic. Other harmful and toxic algal species in Limboto Lake, even though in small numbers, are *Peridinium* sp. (Mos, 2001), *Anabaena* sp., and *Pseudo-anabaena* sp. (Moreira et al., 2014).

Table 5. Spatial-temporal distribution of harmful and toxic algae in Limboto Lake during research

No	Species	February						March						April					
		1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1	*Mycrocystis* sp.	x	x	x	x	x	x	√	√	√	√	√	√	√	√	√	√	√	√
2	*Anabaena* sp.	√	√	x	√	√	x	√	√	√	√	x	√	x	√	√	√	x	√
3	Pseudo-*anabaena* sp.	√	x	x	√	√	x	√	√	√	x	√	x	√	√	√	x	√	x
4	*Peridinium* sp.	x	√	x	x	√	x	√	√	√	√	x	√	√	√	√	√	x	√

Note : x : absent √ : present

In many cases, the responding dominant species of phytoplankton are not toxic and beneficial until they exceed the assimilative capacity of the system, after which hypoxia and other adverse effects occur (suffocation of fish, direct toxic effects on fish and shellfish, the suffocation of fish from stimulation of gill mucus production, mechanical interference with filter-feeding by fish and bivalve mollusks, and deleterious effects on submerged grasses and benthic habitat organisms). When that threshold is reached, seemingly harmless species can have negative impacts (Ferreira et al., 2011).

Harmful algal blooms cause significant ecological and economic damage, such as impacts on wildlife, aquaculture, human health, and tourism (GEOHAB, 2006). Organic nutrients are essential in developing blooms of various harmful algal species, particularly cyanobacteria and dinoflagellates (Glibert et al., 2001). The high content of organic nitrogen relative to phosphorus suggests an excess of nitrogen during bloom conditions (Loza et al., 2013). The way to mitigate harmful algal bloom since phytoplanktons growth is limited primarily by nitrogen (Moreira et al., 2014).

CONCLUSION

There are 80 species from 7 divisions found in Limboto Lake during the observation. The thirty-five species belong to the Chlorophyta and Cyanophyta groups, the divisions with the largest number of individuals. Spatially, station 6 has the highest phytoplankton abundance (20,894 ind. L^{-1}), and station 5 is the lowest (1,541 ind. L^{-1}). Temporally, the lowest abundance occurred in February and increased in March and April. The harmful and toxic algal species found in Limboto Lake are *Mycrocystis* sp., *Peridinium* sp., *Anabaena* sp., and *Pseudanabaena* sp.

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