Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 27(2): 407 - 422 (2023)
www.ejabf.journals.ekb.eg

Phytoplankton and Chlorophyll-a: Distribution, Abundance, and Trophic State Index (TSI) in the Transitional Season in Limboto Lake

Hasim[1], Taufik Rahim[2], Muh. Raziq Faruki H. Sunani[2]

[1]Department of Aquaculture, Faculty Fishery and Marine Sciences, Universitas Negeri Gorontalo, Indonesia
[2]Department of Marine Sciences Magister, Postgraduate Universitas Negeri Gorontalo, Indonesia
[*]Corresponding Author: hasim@ung.ac.id

ARTICLE INFO
Article History:
Received: Nov. 6, 2022
Accepted: Feb. 16, 2023
Online: March 29, 2023

Keywords:
Phytoplankton,
Abundance,
Trophic state index,
Chlorophyll-a

ABSTRACT

Limboto Lake is one of the strategic lakes in Gorontalo Province but has experienced damage to the ecosystem, which has resulted in decreased water productivity. The existence of phytoplankton is fundamental because it is the primary producer in aquatic systems including lakes. In the tropic level system, the presence of phytoplankton is the primary food source for fish larvae and other animal organisms. This study aimed to analyze the distribution of phytoplankton abundance, chlorophyll-a distribution and the relationship between nutrients and phytoplankton abundance. This research was conducted on Limboto Lake, Gorontalo Province, Indonesia. The variables analyzed in this study were the analysis of the abundance of phytoplankton. The results showed that the analysis of the abundance of phytoplankton in water conditions had a phytoplankton diversity index (H') in the waters of imboto Lake, which was in the range of values of 0.515-1.611, indicating that the lake was in the categories of moderately polluted and heavily polluted. Phytoplankton that contributes much chlorophyll-a is class Cyanophyceae, with a total distribution of 238900 Cells/L. The research results showed that Limboto Lake is classified as very productive with a tropical index status; namely, hyper eutropic.

INTRODUCTION

Limboto Lake is one of 15 critical lakes in Indonesia located in Gorontalo Province; it has an area of 2230.6 Ha, and an average depth of ± 2 m. Limboto Lakereceives sediment input from various rivers and tributaries that drain into the lake. Thus, the depth and area of the lake continue to shrink compared to the previous 30 years **(Lihawa & Sutikno, 2009; Julzarika & Carolina, 2015; Hasim *et al*., 2017)**.

Limboto Lake has a strategic role in Gorontalo Province. It serves as a natural reservoir, a source of animal protein, a source of biodiversity, an economical source for freshwater fisheries, and a tourist destination **(Hasim, 2012; Hasim & Mopangga, 2018)**. Therefore, the governmental management for Limboto Lake continues developing via the issuance of PERDA No. 17 of 2017 concerning the Spatial Plan for the Strategic Area of Limboto Lake. However,

Lihawa and Mahmud, (2017) reported that the lake waters have been polluted regarding the quality standard of PP No. 82 of 21. The decline in the quality of lake waters physically and chemically impacts the organisms inhabiting the lake. It was reported that the condition of payangka and manggbai as local fish are experiencing and facing ecological pressure, and thus the population of these two types of fish substantially decreases. These two types of fish are highly demanded and have high economic value.

Krismono *et al*. (2018) stated that, the Limboto Lake is experiencing continuous ecosystem damage. In 2006, the damage occurred due to sedimentation and other anthropogenic activities, resulting in narrowing and silting. Then in 2016, the lake's degradation got worse and had an influential role in decreasing fishery resource production. Remarkably, the coastal lake communities are highly dependent on fisheries commodities as a source of protein and economy **(Hasim & Jasin, 2018)**.

The government has scheduled a revitalization program for the Limboto Lake ecosystem through dredging the shores of the lake, constructing embankments and constructing water exits. In addition, the government has also made a policy to prohibit fishery activities with the floating net cage system (KJA) and develop a reserved area. It is worth noting that, changes in the physical environment and lake water quality degradation would affect the phytoplankton as the primary producer **(Song *et al*., 2010; Simmonds *et al*., 2015; Saab & Hassoun, 2017; Bouraï *et al*., 2020)**. Phytoplankton is essential since it is the primary producer in aquatic systems including lakes. In the tropic level system, the presence of phytoplankton is the primary food source for fish larvae and other animal organisms **(Odum, 1996)**.

The previous research on phytoplankton and chlorophyll-a was carried out in 2006 **(Krismono *et al*., 2008)**. However, there is no current information on phytoplankton, chlorophyll-a and their distribution in Limboto Lake. Besides that, phytoplankton can be used as biological indicator of the health status of lake ecosystems **(Maresi *et al*., 2016; Guntur *et al*., 2017; Hemraj *et al*., 2017; Hartanto & Tjahjono, 2020)**. Therefore, this study aimed to analyze the distribution and abundance of phytoplankton, determined Chlorophyll-a and the relationship between nutrients and the abundance of phytoplankton inhabiting the lake. This study would provide comprehensive information serving as a basis for formulating policies for lake fisheries management and sustainable management of Limboto Lake in an integrated manner.

MATERIALS AND METHODS

Research location

This research was conducted on the Limboto Lake, Gorontalo Province, Indonesia. Limboto Lakehas a distance of 20km from the coast, with a height of 25m above the sea level. Geographically, it is located at 1220 42'024" – 1230 03' 1.17"E and 000 30' 2.035" – 000 47' 0 49" North Latitude **(Suryandari & Sugianti, 2017; Sumindar *et al*., 2018)**. Water samples were collected twice in the first and third weeks of September 2019. Water sampling was carried out at eight station points, based on considerations of lake conditions, viz. the inlet part of the lake, areas bordering rice fields, areas bordering settlements, areas where KJA system fish farming exists in addition to the lake outlet section (Fig. 1).

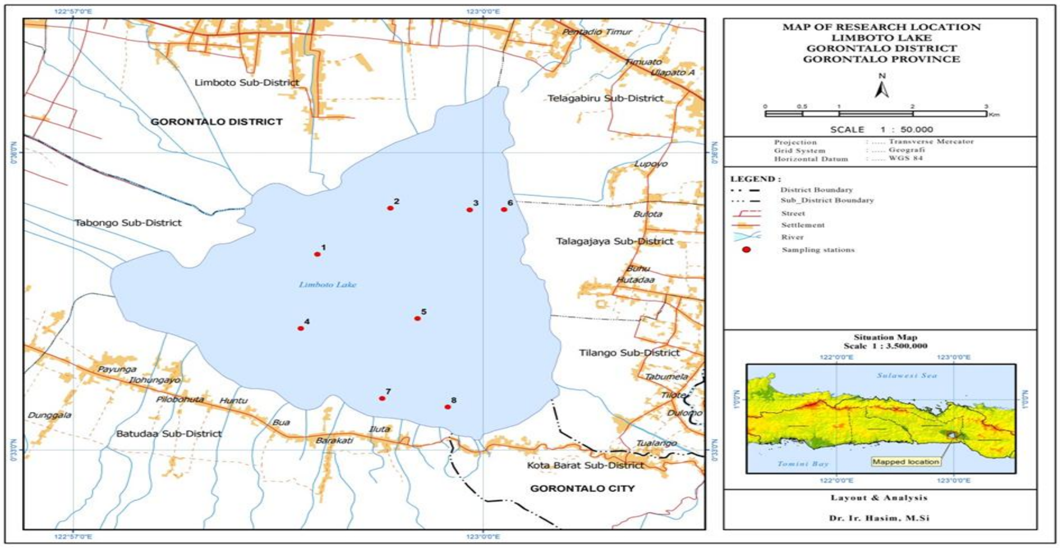

Fig. 1. Map of research location

Methods of collecting data

Physical and chemical parameters of water, including temperature, pH, dissolved oxygen and transparency were measured *in situ* at each sampling station. The tools used for determining the previous parameters were a thermometer, dissolved oxygen meter, pH meter and Sechi disk. A horizontal surface collection of phytoplankton was carried out by a phytoplankton net of 25 micrometer mesh in size with the help of boat from each sampling station. Each sample collected was concentrated in a sample bottle, having 10% Lugol preservative solution **(Kadim *et al.*, 2018)**. Then, the samples were transferred to the Hydrobiota Laboratory of the Faculty of Fisheries and Marine Sciences UNG to be identified based on the guidelines of **Davis (1955)**. Meanwhile, the sampling of nutrient and Chlorophyll-a parameters used a bottle with a volume of 600ml. Furthermore, the samples were analyzed based on the APHA standard guidelines **(APHA, 1989)**.

Data analysis

Analysis of the abundance of phytoplankton using the proposed formulation **(Hartanto & Tjahjono, 2020)** is as follows.

$$N = \frac{1}{V} x \frac{Ja}{Jb} x \frac{Vt}{Vs} xn$$

Where, N: Total abundance of phytoplankton (cells/L); V: Volume of filtered water; Ja: the number of squares on the Sedgwick Rafter; Ans: the number of squares on the Sedgwick Rafter observed; Vt sample volume; Vs.: Sample volume in Sedgwick Rafter (1 ml), and n: the number of cells counted. Phytoplankton diversity index analysis was analyzed based on the formulation of the Shanon-Wiener Index **(Odum, 1996)** as follows:

$$H' = -\sum(ni/N)\ln(\frac{ni}{N})$$

Where, H' is Shanon-Wiener diversity index; ni: Number of individuals of species I, and N: The total number of individuals of all species.

Analysis of the Trophic State Index (TSI)

The level of water fertility was analyzed using the trophic status index (TSI) method of **Carlson (1977)** as cited in **Aida and Utomo (2017)** with the following series of formulas:

1. TSI-TP = 14.42 * Ln [TP] + 4.15, where TP = total P in g/L.
2. TSI-SD = 60 –14.41 * Ln [SD], where SD = water transparency in meters.
3. TSI-Chl = 30.6 + 9.81 * Ln [Chl], where Chl = chlorophyll-a in microgram/ L
4. Mean TSI = (TSI-TP + TSI-SD + TSI-Chl)/ 3.

Stock	Trophic status	Description
<30	Ultraoligotrophic	Water fertility is very low. The water is clear, the dissolved oxygen concentration is high all year round and reaches the hypolimnion layer.
30-40	Oligotrophic	Low water fertility, clear water. In summer in shallow lakes, it is possible to periodically limit anoxic to the hypolimnetic layer.
40-50	Mesotrophic	Moderate water fertility. Moderate water brightness, increased change of anoxic properties in hypolimnetic zone during summer.
50-60	Low eutrophic	High water fertility. A decrease in water brightness, the hypo limnetic zone is anoxic, water plant problems begin to occur, only fish are tolerant towards warm water.
60-70	Moderate eutrophic	High water fertility. Dominated by blue-green algae, algae clumping occur, aquatic plant problems are extensive.
70-80	Heavy eutrophic	High water fertility. There is a heavy algal bloom throughout the summer such as in hyper eutrophic conditions.
80>	Hyper eutrophic	Water fertility is very high. There are clumps of algae, fish deaths often occur in the summer.

RESULTS

Chorophylla-a Distributian

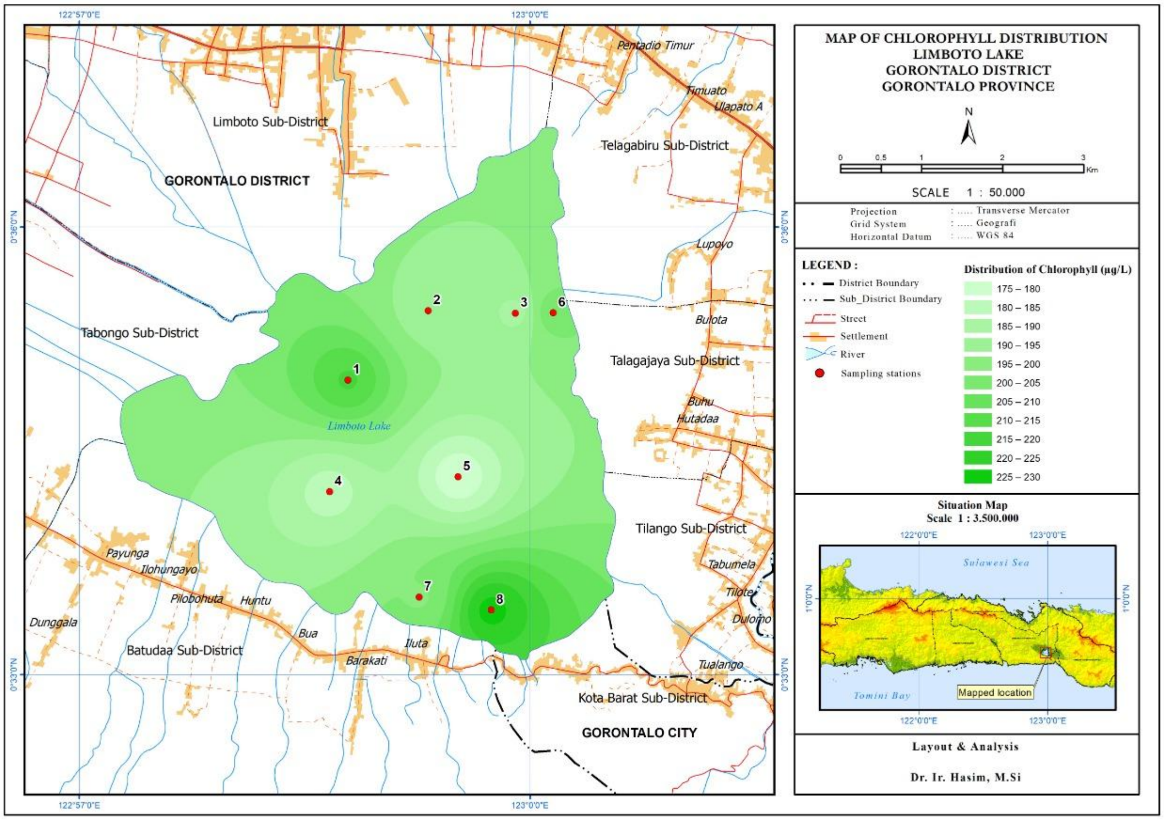

Fig. 2. Distribution of phytoplankton abundance

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Phytoplankton abundance, Cholorophyll-a and Physico-chemical parameters

Table 2. Phytoplankton abundance, chlorophyll-a concentration, transparencies and physico- chemical parameters of water of Limboto Lake within the two measurements of collection I and II

	Phytoplankton (Sel/L)		Chlorophyll-a (μg/L)		Transparence (M)		Temperature (^oC)		pH		Dissolved oxygen (mg/L)		Nitrate (mg/L)		Phosphate (mg/L)	
	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II
1	16300	39400	214	193	21	10	27	30	6.6	7.5	5.5	6.2	14.1	17.2	0.27	0.74
2	28800	40600	224	217	23	10	28	30	5.3	7.2	5.3	6.4	16.2	15.9	0.82	0.8
3	20000	13600	196	168	15	13	28	30	6.7	7.8	6	5.6	14.9	13.3	0.33	0.3
4	21000	28200	213	170	18	13	27	29	6.8	7	5.5	6	11.2	12.9	0.37	0.55
5	20500	23400	208	157	20	12	27	20	8	7.1	5.8	5.5	13.4	13.7	0.42	0.4
6	30500	22706	236	160	27	14	29	32	7.1	7.5	6.2	5.4	10.3	12.9	0.52	0.43
7	39900	30300	275	186	30	11	25	28	6.6	7.3	6.5	6	11.2	9.6	0.82	0.5
8	13500	28100	195	156	10	15	25	27	6.8	7.8	5.3	5.3	15	15	0.18	0.27
Mean	23812.5	28288	220	176	20.5	12.25	27	28.25	6.738	7.4	5.7625	5.8	13.29	13.81	0.466	0.499
SD	8097.91	8291	240	20	5.979	1.7139	1.323	3.419	0.693	0.283	0.412121	0.37749	2.01	2.149	0.225	0.18

Table 3. Abundance of phytoplankton along different stations

	Class/Species	Abundance (cell/l)									
		1	2	3	4	5	6	7	8	Total	Total of Class
	Chlorophyceae										
1	*Schroederia setigera* (Schrorder) Lemmermann	300	200	300	1200	200	100	200	200	2700	3700
2	*Tetrastrum heteracanthum* (Nordstedt) Chodat	0	0	0	0	0	0	0	0	0	
3	*Secenedemus acuminatus* (Lagerheim) Chodat	0	0	0	0	100	0	200	0	300	
4	*Pediastrum simplex* Parra Barrientos	0	0	300	0	0	0	100	0	400	
5	*Scenedesmus* sp. Chodat	0	0	0	0	0	0	0	0	0	
6	*Ankistrodesmus falcatus* (Corda) Ralfs	0	0	0	0	0	0	300	0	300	
	Conjugatophyceae										
1	*Penium minutum* West	500	500	0	100	0	0	400	200	1700	2100
2	*Closterium intermedium* Ralfs	100	100	0	0	0	0	0	0	200	
3	*Pleurotaenium nodosum* (Bailey ex Ralfs) P.Lundell	0	0	200	0	0	0	0	0	200	
4	*Penium spirostriolatum* J.Barker	0	0	0	0	0	0	0	0	0	
5	*Closterium acerosum* (Schrank) Ehrenb. ex Ralfs	0	0	0	0	0	0	0	0	0	
	Trebouxiophyceae										
1	*Kirchneriella contorta* (Schmidle) Bohlin	200	200	0	0	0	0	0	0	400	1100
2	*Geminella mutabilis* (Brébisson) Wille	0	200	500	0	0	0	0	0	700	
	Zygnematophyceae										
1	*Cosmarium reniforme* (Ralfs) W.Archer	100	0	0	0	300	100	1400	100	2000	2000
	Bacillariophyceae										
1	*Pinnularia interrupta* W.Smith	0	0	0	0	0	0	0	0	0	16700
2	*Gomphonema gracile* Ehrenberg	0	0	0	0	0	0	0	0	0	
3	*Amphora ovalis* (Kützing) Kützing	0	0	0	100	0	0	0	0	100	
4	*Nitzschia tryblionella* Hantzsch	0	0	0	0	0	0	0	0	0	
5	*Synedra utermoehlii* Hustedt	0	200	0	0	0	0	0	0	200	
6	*Thalassiothrix nitzschioides* Grunow	0	100	200	0	0	0	0	0	300	
7	*Achnanthes lanceolate* (Brébisson ex Kützing) Grunow	0	100	200	0	0	0	0	0	300	
8	*Nitzschia longissima* (Brébisson) Ralfs	0	600	0	300	0	200	0	0	1100	
9	*Coscinosira oestrupii* Ostenfeld	300	0	0	0	100	0	100	300	800	
10	*Cylindrotheca sp.* Rabenhorst	200	1000	1900	400	300	700	3000	600	8100	
11	*Navicula sp*. Bory	300	800	1900	600	700	400	700	400	5800	

	Mediophyceae										
1	*Lauderia borealis* Grand	0	0	0	0	0	300	0	0	300	1100
2	*Cerataulina bergonii* (H.Peragallo) F.Schütt	0	0	0	400	100	100	0	200	800	
3	Coscinodiscophyceae										
4	*Coscinodiscus ocolus-iridis* (Ehrenberg) Ehrenberg	0	0	0	100	500	300	400	700	2000	2000
	Cyanophyceae										
1	*Microystis aeruginosa* (Kützing) Kützing	12600	20200	12500	14400	91000	1740 0	25500	7400	20100 0	238900
2	*Oscillatoria tenuis* C.Agardh ex Gomont	1100	1900	1100	2600	7200	8900	5900	2600	31300	
3	*Albrightia tortuosa* J.Copeland	0	0	0	100	0	100	200	100	500	
4	*Oscillatoria chalybea* Mertens ex Gomont	0	900	500	300	200	500	0	100	2500	
5	*Merismopedia sp.* Meyen	0	0	300	0	0	0	0	0	300	
6	*Dermocarpa rostrate* Copeland	0	0	0	0	100	500	1300	200	2100	
7	*Rivularia sp*. C.Agardh ex Bornet & Flahault	0	0	0	0	200	800	0	200	1200	
	Dinophyceae										
1	*Prorocentrum sp*. Gourret	0	1300	100	400	1200	0	0	200	3200	4800
2	*Peridinium sp*. Ehrenberg	0	500	0	0	100	0	0	0	600	
3	*Gymnodinium palustre* A.J.Schilling	600	0	0	0	100	100	200	0	1000	
	Total	16300	28800	20000	21000	102400	30500	39900	13500	272400	272400

Table 4. Biodiversity index of phytoplankton along different stations

Stasion	Biodiversity index
1	1.000
2	1.311
3	1.439
4	1.208
5	0.515
6	1.271
7	1.329
8	1.611

Trophic state index

Table 5. Status Trophic state index along different stations in Limboto Lake

Station	Chlorophyll-a (µg/L)	Transparence (M)	Phosphate (µg/L)	TSI Chlorophyll-a	TSI Transparence	TSI Phosphate	TSI
1	203.5	0.155	505	93.91	86.86	82.75	87.84
2	220.5	0.165	810	100.72	85.96	83.53	90.07
3	182	0.14	315	87.10	88.33	81.65	85.70
4	191.5	0.155	460	92.56	86.86	82.15	87.19
5	182.5	0.16	410	90.90	86.41	81.68	86.33
6	198	0.205	475	93.02	82.84	82.48	86.11
7	230.5	0.205	660	97.77	82.84	83.97	88.19
8	175.5	0.125	225	82.25	89.96	81.29	84.50

Physical and chemical parameters

Based on two measurements in the field and the results of laboratory analysis, the parameters of physics, chemistry, nutrients, chlorophyll-a and abundance of phytoplankton at each station showed varied data (Table 1). Physical parameters such as transparency showed an average value of 20.25cm in the initial measurement, while in the 2^{nd} measurement, the average was 12.25cm. The difference in data shows that the dynamics of Lake Limboto's waters are very high, impacting its transparency. The temperature parameter shows an average degree of 27^0C in the first measurement (I), and the second measurement shows an average of 28.25^0C. The SD value in measurement II is higher than that recorded in measurement I.

This explains that temperature dynamics have a higher variation in measurement I compared to measurement II. The temperature parameter data highlights its association with the transparency parameter. Dissolved oxygen measurement in measurement I showed an average value of 5.76mg/ L, and measurement II showed an average value of 5.8mg/ L. The SD value in measurement I and measurement II recorded a small value. This explains that the variation of dissolved oxygen at each station in the two measurements is relatively stable. The phosphate parameter showed the same trend, with a relatively small SD value in measurement I and measurement II and an average value of 0.466mg/ L in measurement I and 0.499mg/ L in measurement II.

On the other hand, the nitrate parameter in measurements I and II recorded the same average. However, the SD value is relatively large, with an average value of 13.29mg/ L in the first and 13.81mg/ L in the second measurements. This indicates that the nitrate parameter has a high variation at each station. The pH value showed an average value of 6.73 in observation I, and observation II, showing an average value of 7.4 with a low SD value. This indicates that the pH value does not vary much at each station and each observation.

Based on data collected twice (Table 2), biological parameters were determined for nine classes of phytoplankton; namely, Chlorophyceae, Conjugatophyceae, Trebouxiophyceae, Zygnematophyceae, Bacillariophyceae, Mediophyceae, Coscinodiscophyceae, Cyanophyceae and Dinophyceae. The average number of phytoplankton in observation I amounted to 23812.5 individuals; in observation II, it amounted to 28288 individuals, with a high SD value in observation II. This explains the variation detected in the number of phytoplankton individuals during each observation time. In contrast to Chlorophyll-a, the SD value recorded a small number in observations I and II, with an average value of 220µg/ L and 176µg/ L, respectively. This means that there is a low variation in the weight of chlorophyll-a in each observation at each station. The most abundant type of phytoplankton found was Cyanophyceae at each station, with a total distribution of 238900 cells/ L.

Based on Fig. (2), the distribution of chlorophyll was at its the highest at station 8 and station 1, while the lowest was detected at stations 5 and 4. Chlorophyll distribution in the waters of Limboto Lake looks quite evenly distributed at each station. The amount of chlorophyll is closely related to the presence of phytoplankton in the waters in addition to the number of nutrients and phosphate. The results of the diversity index test showed that the phytoplankton at each observation station in Limboto Lake had a diversity index value (H') ranging from 0.515-1.611. The level of phytoplankton diversity at each station is in the medium category. Except for station 5, diversity is in a low category, with an H value of 0.515.

DISCUSSION

The chlorophyll content in waters is closely related to the presence of phytoplankton abundance in the waters **(Rufus & Karina, 2017)**. Results of observations and lab analysis showed that the range of chlorophyll-a was from 156µg/ L – 270µg/ L, with the highest distribution at station 8. The distribution of chlorophyll-a was closely related to the existence of phytoplankton, which was widely distributed in the coastal areas of the lake with high amounts of nutrients. In this context, **Marian *et al.* (2015)** stated that, the distribution of chlorophyll-a is an indicator of fertility level resulting from the presence of phytoplanctons. With the distribution pattern of chlorophyll-a, it seems that phytoplanktons are more dominant in waters close to the coast, where water cycles are found such as rivers, river mouths and lake shores. This pattern decreases gradually with increasing the distance from the mainland. Changes in the amount of chlorophyll-a are closely related to nutrients due to various human activities and subsequent environmental changes; fertility status based on the content of chlorophyll-a is classified as the trophic level of water.

The status of water pollution with a low level is based on the Decree of the Minister of the Environment No. 28/2009, regarding the carrying capacity of lake and reservoir water pollution loads; namely, in oligotrophic status ranging from < 2µg/ L, followed by mesotrophic with a value of < 5µg/ L, eutrophic with a value of < 15µg/ L, and hyper-eutrophic status with a value of 200µg/ L **(Pertiwi *et al*., 2017)**. Based on chlorophyll-a values in Limboto Lake, the status of the waters at the tropic level is already in the hypereutrophic category, or in other words, the waters are heavily polluted.

Based on the diversity index (H') of phytoplankton in Limboto Lake, it is in the ranging values of 0.515-1.611. **Wilhelm and Dorris (1968)** stated that, the value of H' < 1 reflects the condition of low diversity; value 1 < H' < 3 conditions is that of a moderate diversity and H' value > 3 refers to high diversity. These results indicate that the condition of phytoplankton diversity is low - moderate. Based on the H' value obtained, the waters of Limboto Lake are in the lightly - heavily polluted category. **Lee *et al*. (1978)** as cited in **Sagala (2013)** commented that, the diversity index value > 2.0 and > 6.5 means that the water environment is not polluted, the diversity index 1.6-2.0 and DO 4.5-6.5 indicates that the water environment is lightly polluted, the index value 1.0-1.5 and DO 2.0-4.4 means a moderately polluted water environment, while diversity index value <1.0 and DO < 2.0 points to a heavily polluted water environment.

The distribution of phytoplankton in waters is strongly influenced by water quality and climate, air temperature, rainfall and temperature **(Zhang *et al*., 2021)**. Temperature, underwater light conditions, and nutrients determine phytoplankton density in lake waters **(Xiong *et al*.,**

2021). The biological characteristics of microorganisms in utilizing nutrient waters are more dominant in influencing the density and distribution of phytoplankton **(Khazmi, 2014)**.

Temperatures in the waters of Limboto Lake range from 25-30 ^{o}C. Based on field observations, the waters of Limboto Lake have different levels of brightness. There may be no close relationship between the brightness and primary productivity of the waters at each station; however, the brightness level of the waters of each station can explain the relationship with primary productivity of 0.1652. In contrast, the rest is explained by other factors as a limiter. The transparency of Limboto Lake ranges from 10- 30cm. **Nuzapril *et al*. (2017)** stated that, good brightness for the photosynthesis process is waters that have a water brightness level that reaches 9.52 m. Phytoplankton production will take place if there is light penetration into the waters. The value of transparency can describe the photosynthesis process in water bodies. **Rahayu & Muntalim (2017)** added that the brightness level, which shows a low value and has a dark watercolor, has the potential to reduce the abundance of phytoplankton and the structure of the phytoplankton community in the waters.

The pH of the waters of Limboto Lake ranges from 5.3-8. **Nuzapril *et al.* (2017)** stated that biochemical processes, namely pH, can influence the productivity of phytoplankton, and the average value of a suitable pH in the waters is 6.0-7.8. The decomposition of aquatic plants influences the cause of high and low pH. **Sihombing *et al.* (2013)** that the high and low productivity of water is categorized as a general indicator of pH, high pH values are the result of biological processes by anaerobic organisms, the degree of acidity of the waters also has an essential role because it affects the toxicity of a chemical compound in the aquatic environment. Dissolved Oxygen in Limboto Lake ranges from 5.3-6.5 ppm. Based on observations in the field, Limboto Lake has different DOs, marked by a close relationship between DO and the primary productivity of waters at each station. DO waters of each station can explain the relationship with a primary productivity value of 0.5165. In contrast, other factors explain the rest as limiting factors. **Salmon (2005)** stated that dissolved oxygen levels between 2.33-2.84 mg/L are the tolerable limit for phytoplankton, and oxygen is a vital water indicator because it plays a role in determining the biological activity of aerobic organisms in the form of photosynthetic activity. Hence, it affects the level of water productivity. Dissolved oxygen plays an essential role in reducing the pollution load in water naturally and through aerobic processes. Dissolved oxygen as an abiotic factor dramatically affects the survival of microalgae in the waters, especially in the respiration process by phytoplankton so that it supports the absorption of energy from the photosynthesis process, an indicator of the food chain in the waters **(Harmoko & Krisnawati, 2018).**

Nitrate in the waters of Limboto Lake ranged from 9.6-17.2 ppm. **Tunguska *et al.* (2017)** stated that nitrate content exceeding 0.010 mg/l in water affects water quality because it can cause eutrophication and trigger phytoplankton blooms. This condition can be exacerbated because phytoplankton species contain toxins in the body (Harmful Alga Blooms), which cause disruption of the food chain in the waters.

Phosphate in the waters of Limboto Lake ranges from 0.18 to 0.82 ppm. **Nugroho *et al.* (2014)** stated that it was concluded that the value of phosphate could be an indicator of the tropic level of waters, based on the phosphate content of the waters from 0.717 mg/l-1.350 mg/l has been classified in hypertrophic waters because it becomes a pollutant that causes the imbalance of life. Organisms in the water body cause a decrease in water quality. **Lestari *et al*. (2015)** stated that aquaculture activities and the disposal of accumulated metabolites could cause an increase in phosphate, which results in lower water quality so; that it reduces dissolved oxygen levels in the waters, and encourages anaerobic organisms to grow.

The phytoplankton types found in Limboto Lake consist of 9 classes: Chlorophyceae, Conjugatophyceae, Trebouxiophyceae, Zygnematophyceae, Bacillariophyceae, Mediophyceae, Coscinodiscophyceae, Cyanophyceae, and Dinophyceae. Several classes of phytoplankton can be found in freshwater, namely the Bacillariophyceae, Dinophyceae, and Coscinophyceae classes **(Rufus & Karina, 2017)**. The Cyanophyceae class nominated the type of phytoplankton in Limboto Lake with a total distribution of 238900 Cells/L. The Species *Microystis aeruginosa*, Class Cyanophyceae, has the highest contribution of chlorophyll-a. **Fachrul *et al*. (2008)** stated that if the type of phytoplankton is abundant and dominant and is present in each sampling area, the ecological effect caused is the ecosystem imbalance in the waters. The existence of phytoplankton is closely related to the nutrients in the waters. The higher the nutrient value in the waters, the more phytoplankton there are.

The abundance of phytoplankton class Cyanophyceae indicates that water has a very high level of fertility through its role in the waters as a biofertilizer **(Sari, 2011)**. Phytoplankton class Cyanophyceae has toxic potential, requiring particular observation and vigilance, especially in waters intended for aquaculture activities **(Prihantini *et al.*, 2008)**.

The value of the trophic status index of Limboto Lake using the 1977 Carlson method using the results of the measurement of the quality of the waters of brightness, total phosphorus content, and chlorophyll-a content can be seen in table 5. Each station's trophic status index (TSI) value is between 84.50-90.07. The waters of Limboto Lake are included in the category of hyper-eutrophic (very high water fertility). Water fertility is very high, so clumps of algae and fish deaths often occur in the summer. The cause of high fertility of the waters is caused by organic matter from the fishery, agricultural, household waste, and aquatic plants that cover the waters. The very high level of water fertility in Limboto Lake causes water hyacinth to proliferate so that it covers most of the water. Water hyacinth can cause siltation, decrease in volume, and decrease in the water area, causing the carrying capacity of the waters to decrease.

CONCLUSION

The results showed that the results of the analysis of the abundance of phytoplankton in water conditions had a phytoplankton diversity index (H') in the waters of Limboto Lake, which was in the range of values of 0.515-1.611, which meant that the lake was in the lightly polluted-heavy polluted category. Most of the phytoplankton that donated chlorophyll-a are class

Cyanophyceae with a total distribution of 238900 cells/L. The results of the TSI analysis showed a value between 84.50-90.07 or included in the category of very high fertility.

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