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Assessment of Eutrophication Parameters in Lake Balang Tonjong Makassar

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ABSTRACT

The present state of Lake Balang Tonjong Makassar has experienced eutrophication, evident from the murky and foul-smelling water, the abundance of wild plants like lotus and water hyacinth, and the shallowing in various parts of the lake, which has led to flooding in Makassar. Eutrophication occurs due to uncontrolled growth of phytoplankton from the groups Chlorophyta, Basillariophyta, Cyanophyta, and Dinoflagellata. This study aimed to determine the value of physical and chemical environmental parameters in the eutrophication process, find the triggers for eutrophication and determine the level of eutrophication at each station. The research method was carried out using a quantitative descriptive approach, with a purposive sampling technique applied at five station points which were considered to represent the research area. The results of the study on eutrophication in Lake Balang Tonjong Makassar obtained the following: 1) Environmental parameters that affect the eutrophication process show extreme conditions, which in general have exceeded the environmental quality standards set by the government of the Republic of Indonesia. 2) Trophic status at each station is at the eutrophic level (station I, station II and station III; while station IV and station V are at the hypertrophic level; 3) The trigger of eutrophication is very extreme, namely at stations IV and V, around traditional markets and household waste channels.

INTRODUCTION

Lake is a collection of water that is in a certain basin and is one of the freshwater resources on land that has the potential to be developed and utilized according to its designation. Generally, the lake acts as a storage of germplasm; a water source for the community around the lake, supplying surface water; a water source for agriculture and for hydroelectric power generation in addition to serving tourism **(Sidaningrat *et al.*, 2018)**. In addition, lakes are also a form of aquatic ecosystem that has an important role in the hydrological cycle and functions as a water catchment area for the surrounding areas **(Murtiono & Wuryanta, 2016; Yusal, 2019)**. Therefore, the condition of a lake is greatly influenced and determined by the characteristics of its surroundings **(Tulandi,**

2022). The extensive use of the lake land has resulted in environmental degradation, one of which is caused by the eutrophication process **(Sayekti *et al*., 2015)**.

Activities around the lake and those occurring in the lake waters are the main sources of pollutant input that need to receive attention from various parties. The sources of these pollutants include community activities around the river headwaters, from settlements and from activities taking place in the lake waters themselves **(Najib, 2016)**. The main types of pollutants that enter the lake waters consist of organic waste, pesticide residues, inorganic and other materials that quickly or slowly enter the lake waters and will be deposited in the sediment which will certainly pollute the waters and benthic animals of the lake **(West *et al*., 2016)**.

According to Shaw and Leito in **Mardiah *et al*. (2021)**, the trophic status is one of the indicators to determine the level of nutrient contents of a water area. Trophic status can be measured from nutrients, brightness levels and other biological activities that occur in water bodies. High nitrate and phosphate concentrations causing eutrophication in waters also cause pollution to the aquatic environment **(Bahri, 2016)**. Water pollution will cause the water body to be unable to repair itself, but if the input of organic and inorganic materials exceeds its recovery capacity, this condition will result in a reduction or damage to the ecological function of the water body **(Pratiwi *et al*., 2020)**.

According to **Samman *et al*. (2023)**, the trophic status of waters can be indicated by the primary productivity of waters which is closely related to the chlorophyll content of phytoplankton. The high supply of nutrients to the waters can increase the quality of waters. The higher the primary productivity of phytoplankton in waters, the greater the carrying capacity for the life of the community inhabiting it, conversely low primary productivity of phytoplankton indicates low carrying capacity **(Sunaryani, 2023)**.

Lake Balang Tonjong is an area of 48 hectares, initially this area was oriented to be a strategic public space because of its location close to the provincial road **(Indrayuni & Yusuf, 2023)**. It is also a natural lake that has been used as one of the water catchment areas in the city of Makassar **(Jusmiati *et al*., 2021)**. In its development, this lake has undergone changes because many people use this area for various purposes, such as: tourism houses, floating net fisheries, agricultural cultivation, residential waste disposal, and even traditional markets. Land use and increased community activities that do not follow conservation principles in this lake can cause ecological disasters **(Sutrisno & Harnedi, 2018)**.

The current condition of Lake Balang Tonjong Makassar has certainly experienced a eutrophication process, this can be seen from the quality of the water which is cloudy and smelly, the many wild plants such as lotus, water hyacinth, and the occurrence of shallowing in several lake bodies. With these concerning conditions, it is very important to determine the level of eutrophication that has occurred or the trophic status of the lake **(Zulfia & Aisyah, 2013)** so that it can be a reference to revitalize the function of Lake Balang Tonjong as a normal water catchment area to prevent flooding that always occurs every year in the city of Makassar and will also be a natural habitat for various biota in the lake ecosystem. Based on this background, the purpose of this study was to examine the trophic status and environmental parameters that influence and cause eutrophication in Lake Balang Tonjong Makassar.

MATERIALS AND METHODS

The research was conducted using a quantitative descriptive approach, with purposive sampling techniques applied at five station points that were considered to represent the research area. In this case, direct observation was carried out by taking samples of each parameter to be studied. The research area at research station, which was considered as a source of eutrophication triggers, was subjected to special observations as preparation for the study of eutrophication levels in Lake Balang Tonjong.

Several station points were considered sources of eutrophication, namely fisheries cultivation, agricultural cultivation, traditional markets, household waste channels, and tourist houses. The level of eutrophication in Lake Balang Tonjong was described through several anthropogenic activities around the lake environment. The source of eutrophication was studied descriptively by looking at the results of direct observations at the research points/stations, where the research area borders on fisheries cultivation, agricultural cultivation, traditional markets, household waste channels and tourist houses.

Research location and research time

The research was conducted at Lake Balang Tonjong, Antang sub-district, Manggala district, Makassar City, with an area of approximately 48Ha. The study was conducted during June-October 2024.

Fig. 1. Research location

Several research station points that are the focus of the research are as follows:
Station 1 is located around agricultural cultivation.
Station 2 is located in the floating net fisheries cultivation area.
Station 3 is located near the tourist house.
Research station 4 is located in the domestic wastewater channel.
Research station 5 is located around the traditional market.

Measurement of physical-chemical parameters of water

Several physicochemical parameters of the aquatic environment measured during the research can be seen in Table (1).

Table 1. Water quality parameters observed during the study

Parameter	Unit	Tools/Methods
Water temperature	℃	Water Quality Checker, *in situ*
Turbidity	NTU	Turbidity Meter, *in situ*
pH of water	mS/cm	Water Quality Checker, *in situ*
BOD	mg/L	Water Quality Checker, *in situ*
COD	mg/L	Water Quality Checker, *in situ*
Oxygen saturation	mg/L	Water Quality Checker, *in situ*
Nitrate (N-NO3)	mg/L	Spectrophotometry (Naphthylamine), *ex situ*
Orthophosphate (P-PO4)	mg/L	Spectrophotometry (Brucine sulphate), *ex situ*
Chlorophyll-a	mg/L	Spectrophotometry (Nessler), *ex situ*

Measurement of environmental physical-chemical parameters was carried out *in situ* and in the laboratory. Measurements were carried out at the Makassar Health Laboratory Center and the Animal Husbandry Laboratory of Hasanuddin University, Makassar.

Fertility level measurement

Measurement of the fertility level of waters using the TRIX method or trophic index was conducted according to the method of **Vollenweider *et al*. (1998)**. This method can describe the fertility level of waters using four variables, namely chlorophyll a, saturated dissolved oxygen (DO saturation), mineral nitrogen (nitrate) and phosphorus (orthophosphate). Analysis of nitrate, chlorophyll a and phosphate was carried out in the laboratory. For DO measurements, it was carried out directly in the field using a multitester.

The trophic index (TRIX) was calculated using the following formula:

$$\text{TRIX} = \frac{[\log 10\ (\text{PO4 x Tn x Chl} - ?\ \text{x DO Saturasi})}{\text{b}}$$

Chl a : Chlorophyll a concentration in µg/l
TP : Total phosphorus concentration inmg/l
DIN : Inorganic Nitrogen Concentrationmg/l
K : Customizable constants

Scaling factor (Constant) is a measure of fertility (trophic) on a scale from 0 to 10, where a greater value index indicates a higher the level of eutrophication in the waters. After all parameter values were obtained, they were entered into the TRIX calculation formula, and adjusted to the fertility index classification (Table 2).

Table 2. TRIX value range classification

TRIX scale	Water quality status	Eutrophication level
0.0-4.0	Oligotrophic	Low
4.1-5.0	Mesotrophic	Currently
5.1-6.0	Eutrophic	Tall
6.1-10.0	Hypertrophic	Very higt

Source: **Alves *et al*. (2013)**

RESULTS

Data analysis of stations and environmental variables

Analysis of environmental variables on water quality at five stations in Lake Balang Tonjong Makassar, provides an overview of the concentration of phosphate, nitrate, chlorophyll, and dissolved oxygen (DO) at each location. Variations in the concentration of these environmental parameters provide an indication of ecosystem conditions and potential water quality problems (Table 3).

Table 3. Mean and standard deviation values of all stations

Station	Phosphate	Nitrate	Chlorophyll	DO	Turbidity	pH	BOD	COD	Temperature
Station I	0.04±8.4	1.214±0.08	21.7±10.61	5.18±0.03	136.3±43.87	6.63±0.02	6.46±0.60	16.49±2.12	29±0
Station II	0.04±8.49	2.67±0.07	21.43±29.9	2.36±0.07	256.5±163.2	6.62±0.65	27.53±6.40	69.10±16.10	28.66±0.57
Station III	0.04±8.49	2.86±0.23	25.5±12.50	1.92±1.14	96.36±58.52	6.49±0.05	31.23±2.15	77.13±5.84	28.33±0.47
Station IV	0.34±0.43	2.39±0.05	9±12.51	1.31±0.85	177±119.05	6.53±0.04	24.99±13.7	63.62±33.65	27.66±0.,57
Station V	0.21±1.23	5.25±2.03	26.62±18.31	0.36±0.172	179±119.05	6.53±0.04	24.99±13.7	53.62±33.65	27.66±0.57

In these data, the phosphate concentration at Stations I-III was low (0.04mg/ L), which generally indicates minimal phosphate content. However, the very large standard deviation (8.4 to 8.49) indicates extreme variations in the measurements. This may be due to fluctuations in phosphate concentrations at various time points or sampling locations within the station. Station IV has a phosphate concentration of 0.34mg/ L, while Station V has a much higher concentration of 0.21mg/ L, indicating the presence of significant sources of phosphate pollution, such as waste from traditional markets and drift waste from various household sources. Fig. (2) shows the range of environmental parameter data in the research location.

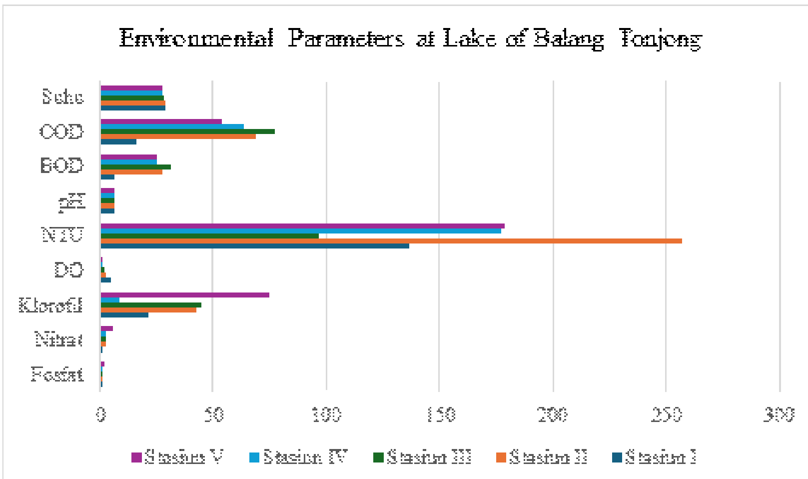

Fig. 2. Environmental parameters at each station

Trophic status and anthropogenic factors triggering eutrophication

Determination of trophic status and eutrophication trigger factors was carried out by analyzing data using the trix index, which can be seen in Table (4).

Table 4. Results of Tropical Index Analysis Based on Station

Station	Test	Phosphate (mg/L)	TN (mg/L)	Chlorophyll (mg/L)	DO Saturation	a	b	Tropical Status
	1	0.04	1.214	32.201	5.16	1.5	1.2	
I	2	0.04	1.08	21,941	5.22	1.5	1.2	eutrophic
	3	0.04	1,089	10,986	5.16	1.5	1.2	
	average	0.04	1.127	21,709	5.18	1.5	1.2	
	1	0.04	2,583	30,004	2.43	1.5	1.2	
Ii	2	0.04	2,697	21,623	2.28	1.5	1.2	eutrophic
	3	0.04	2,733	12,686	2.37	1.5	1.2	
	average	0.04	2,671	21.43	2.36	1.5	1.2	
	1	0.04	3.119	23,388	2.43	1.5	1.2	
III	2	0.04	2,818	28,062	0.61	1.5	1.2	eutrophic
	3	0.04	2,663	25,057	2.73	1.5	1.2	
	average	0.04	2,866	25,502	1.92	1.5	1.2	
	1	0.84	2.333	23,454	1.88	1.5	1.2	
IV	2	0.05	2.424	2,052	0.33	1.5	1.2	hypertrophic
	3	0.13	2.433	1,505	1.72	1.5	1.2	
	average	0.34	2.396	9.003	1.31	1.5	1.2	
	1	0.13	4.635	23,665	0.42	1.5	1.2	
V	2	0.36	7.53	26,946	0.5	1.5	1.2	hypertopic
	3	0.16	3.608	29.255	0.7	1.5	1.2	
	average	0.21	5.257	26.62	0.36	1.5	1.2	

DISCUSSION

The high phosphate concentration at stations IV and V indicates that the nutrient content is above the permitted lake water quality standards outlined in the Government Regulation No. 22 of 2021. This condition poses a eutrophic risk that threatens the water quality of Lake Balang Tonjong. Organic phosphate pollutants that enter the lake body come from anthropogenic activity waste from traditional markets and household waste that goes to the research station. This is in accordance with **Sulasri (2021)** who states that high phosphate levels come from human activities such as domestic waste or other activities that enter the water and affect the water quality.

The highest nitrate concentration (5.25mg/ L) with a large standard deviation (2.03) was found at station V, the high nitrate at this station indicated a high nitrogen input, possibly from the runoff of organic materials from various waste products. Station I had the lowest nitrate concentration (1.131mg/ L), indicating a relatively low nitrogen input but could support the risk of eutrophication. Stations II-IV had moderate nitrate concentrations (2.39-2.86mg/ L), which still indicated a potential risk of increased algae, although not as severe as Station V.

In general, the distribution of nitrate concentrations at each research station has exceeded the lake water quality standards set by the Government of the Republic of Indonesia. The range of nitrate concentrations is between 1.131-5.25mg/ L, while the quality standards permitted by the government are around 0.75mg/ L. The high nitrate content spread across each research station has also increased the risk of increasing trophic status in Lake Balang Tonjong. Increased organic nutrients such as nitrate will stimulate uncontrolled phytoplankton growth or what is called algal blooming or dinoflagellates. Phytoplankton which resulted in the occurrence of algal bloom in lakes including *Cholorococcus* sp., *Haemarococcus pluvialis* (Cholorophyta); *Navicula* sp., *Synedra ulna* (Basillariophyta), *Nostoc* sp., *Oscillatoria* sp. (Cyanophyta), and *Peridinium* sp. (Dinoflagellata). Algal bloom followed by uncontrolled development in aquatic plants such as *Eucornia crassipes*, *Hydrilla verticillate*, and *Salvina cucculata*.

Blooming events will deplete the dissolved oxygen content in the waters, resulting in mass death of aquatic fauna, such as fish species due to lack of oxygen. In addition, the decomposition process in blooming will produce toxic gases NH3 and H2S which are very dangerous for organisms living in aquatic environments. This is in congruent with the study of **Garnet (2020)**, who states that blooming events in reservoir environments will threaten the lives of fauna living in the surrounding environment because they are dominated by toxic phytoplankton, decomposing toxic substances, and suppressing dissolved oxygen content until it runs out or is called anoxia.

Station V showed the highest chlorophyll value (26.62mg/ L), which is most likely due to the high availability of nutrients, creating favorable conditions for algal blooms. Stations II and III also showed high chlorophyll concentrations (21.43 and 25.5mg/ L), indicating ongoing eutrophication. In contrast, Station IV had the lowest chlorophyll (9m/ L), indicating lower algal activity and possibly better water conditions in this context.

The distribution of chlorophyll concentration at each station is quite high but has not passed the lake water quality standards set by the Government of the Republic of Indonesia. This shows that the fairly high chlorophyll content is triggered by an increase in nutrient content or hydrological factors of the aquatic environment, such as phosphate, nitrate, and temperature. **Sayekti *et al*. (2015)** consider this as very appropriate, since they reported that the distribution of chlorophyll concentration in waters is greatly influenced by hydrological factors such as phosphorus, nitrate, temperature, and salinity. In addition, chlorophyll content can be used as a standing stock of phytoplankton or an indicator of water fertility. Chlorophyll-a is the main product to increase primary productivity in the ecological cycle of the food chain produced through the process of photosynthesis with the help of sunlight, which is able to change nutrients in the water into products that are ready to be used by microscopic organisms floating passively in water.

Station I had the highest DO level (5.18mg/ L), indicating healthier conditions that are suitable for supporting aquatic life. In contrast, Station V had very low DO levels (0.36 mg/L), indicating hypoxia (lack of oxygen), a condition that can cause mass mortality of fish and other aquatic organisms. Stations II-IV also showed relatively low DO (1.31-2.36mg/ L), which may indicate conditions that are not ideal for many aquatic species, especially if these conditions persist for a long time.

In general, the dissolved oxygen (DO) content at several stations in Lake Balang Tonjong (II, III, IV, and V) is classified as very low and at the same time indicates high contaminants from organic waste entering the water body which triggers the blooming of certain organisms which are very dangerous to the surrounding environment. The DO content at several research stations has been below the lake water quality standards set by the Government of the Republic of Indonesia, hence there is a decrease in water quality and this leads to water pollution due to the input of organic waste. High contaminants from organic waste also increase the trophic status of the aquatic environment. This condition has increased primary productivity which is characterized by uncontrolled growth in primary producers such as algae or phytoplankton (blooming). This is very dangerous because it can trigger mass death of aquatic biota living in the surrounding environment. The same thing was stated by **Yusal and Hasyim (2022)**, who showed that low DO content is a serious threat to the water. Low DO content values are triggered by an increase in the rate of anthropogenic activities that produce polluting and hazardous waste, such as organic or inorganic waste.

Station II has the highest turbidity level (256.5 NTU), indicating very turbid water and may be affected by sediment or solid material runoff from land. Station III has lower turbidity (96.36 NTU), indicating relatively clearer water. High turbidity can affect the health of organisms in the water, because light needed for photosynthesis cannot penetrate the water properly.

In general, the turbidity level at several research stations is relatively high and is in the range of 96.36-256.5 NTU; in this case it has exceeded the lake water quality standards set by the Government of the Republic of Indonesia. The distribution of high turbidity is a bad thing for organisms that live in aquatic environments since it will hinder the lighting process that enters the water body. Similar finding was recorded in the study of **Sulasri (2021)** who elucidated that turbidity in the aquatic environment can reduce the intensity of sunlight entering the water. Turbidity has reflected the optical properties of water which are determined based on the intensity of light absorbed and emitted by materials in the water. Turbidity is also triggered by the presence of organic and inorganic materials that are suspended and dissolved (mud and fine sand), or inorganic and organic compounds in the form of plankton and other microorganisms.

All stations have almost the same pH (around 6.49-6.63), indicating that the water at all five stations is in the neutral to slightly acidic range. This range is generally good for aquatic life, although a slight decrease in pH (more acidic) can have a negative impact on some sensitive species.

The distribution of pH values at several research stations shows that the research location is slightly acidic because it is in the range of 6.49-6.63. A pH value = 7 indicates neutral waters, while a pH value <7 is categorized as acidic waters. A pH value > 7 is categorized as acidic. pH fluctuations are greatly influenced by the respiration process of the carbon dioxide gas produced. The higher the carbon dioxide produced from respiration, the lower the pH will be. Conversely, if photosynthesis activity is higher, it will cause the pH to be higher. Changes in pH values and oxygen concentrations that act as indicators of water quality can occur as a result of the abundance of chemical compounds, both pollutants and non-pollutants. Low pH values (high acidity) will reduce dissolved oxygen content, as a result of which oxygen consumption decreases, respiratory activity increases and appetite decreases. The opposite happens in alkaline conditions **(Noviasari, 2018)**.

High BOD values usually indicate a lot of organic matter in the water, which can result in a decrease in dissolved oxygen levels due to the decomposition process. Station III had the highest BOD (31.23mg/ L), indicating a significant amount of organic matter, most likely from domestic waste. Station I had a lower BOD (6.46mg/ L), indicating relatively cleaner water with less organic matter.

COD is a measure of the total oxidants needed to break down organic and inorganic chemicals in water. Station V had the highest COD (53.62mg/ L), indicating significant levels of chemical pollution. Station I had the lowest COD (16.49mg/ L), indicating lower levels of pollution compared to the other stations. High COD can indicate the presence of pollution or toxic chemicals that require oxidation.

In general, the distribution of BOD and COD content values in Lake Balang Tonjong is very high and has exceeded the lake water quality standards set by the Government of the Republic of Indonesia. High BOD and COD content will affect the DO content in the waters, in this case causing DO to decrease further, making it very dangerous for organisms living in the waters. This is emphasized by **Device (2019)**, who states that waters that contain a lot of organic waste, then the amount of oxygen needed by microorganisms to break down the waste will be large and this means that the BOD and COD numbers are high. High BOD and COD numbers mean low DO numbers, because a lot of oxygen is used to break down the waste. Waters that have high BOD or COD and low DO, will generally cause an unpleasant odor because the breakdown of organic waste takes place anaerobically (without oxygen). The anaerobic process is a breakdown of waste (oxidation) that does not use oxygen so that it will produce compounds - NH_3, H_2S, CH_4 which smell bad. High BOD and COD and low DO cease the ability of aquatic animals and plants to grow properly and can even cause the death of these organisms.

Water temperature affects the metabolic rate of aquatic organisms and the solubility of oxygen. At all stations, the temperature was relatively uniform, ranging from 27.66 to 29°C. This temperature is considered warm and can affect the solubility of oxygen since warm water usually holds less oxygen than cold water. The increase in water temperature can be caused by high exposure to sunlight and lack of water exchange.

In general, the temperature at several research stations is considered capable of supporting the rate of life of organisms in Lake Balang Tonjong. The existing temperature range is in accordance with the temperature conditions that generally occur in tropical areas. Temperature fluctuations are caused by hydrological parameter factors such as depth, current speed, and weather when sampling. This is in accordance with **Sulasri (2021)**, who reported that the temperature with different ranges is suspected due to time difference factors at the time of observation and is influenced by air circulation, cloud cover and flow and depth of water bodies. The process of temperature change in the aquatic environment will cause changes to all-natural processes in the water. An increase in water temperature will trigger an increase in chemical reactions, evaporation, viscosity, vitalization, and a decrease in dissolved gases in water such as O_2, CO_2, N_2, CH_4 and so on.

Overall, Station V appears to be the station with the worst water quality, with high phosphate, nitrate, chlorophyll, BOD, COD values, and very low dissolved oxygen levels. This indicates serious pollution problems that may be caused by anthropogenic activities such as waste disposal around the traditional market and accumulation of water flow nearby.

Station I showed better quality than the other stations with high DO levels, low BOD and COD, and stable temperatures, indicating that this is an area with minimal anthropogenic disturbance. Stations II-IV showed some problems with low turbidity, BOD, and DO, although not as severe as the conditions at Station V. This area may be moderately polluted but still needs attention.

According to the results of the TRIX index analysis (Table 4), station I has a TRIX value of 5.4 which means that station I has a high TRIX value category. This indicates that these waters are in a nutrient-rich condition. High primary productivity here indicates poor water quality, with the risk of eutrophication. This impact could mean that this habitat is less supportive of higher biodiversity due to the large amount of disturbance by excessive algae growth.

Station II with TRIX value of 5.7 shows a slightly higher TRIX value, including the eutrophic category. This indicates that there is a slight increase in primary productivity in these waters. Nutrients are also more available and are at an alarming level. The impact allows for an increase in algae populations that can cause significant water quality problems.

The increase in primary productivity also indicates the fertility of the waters, which is characterized by the presence of phytoplankton which act as primary producers. The same thing was reported by **Tambaru and Hasanuddin (2022)**, who stated that phytoplankton are primary producers that play an important role in the food chain in waters. In addition, nutrients greatly affect the abundance of phytoplankton populations. The composition and abundance of phytoplankton in waters are highly dependent on the availability of nutrients and are closely correlated with temperature, brightness, salinity, nitrate and phosphate in waters.

Station III with TRIX value of 5.9 shows TRIX value in eutrophic range. This indicates significant increase in nutrient level and primary productivity. Eutrophication has also occurred, where algae are likely to grow faster, reaching severe level. This results in the decrease of water transparency and the increase in the growth of aquatic vegetation.

Station IV with TRIX value of 9.2 shows quite large fluctuations in TRIX value, indicating hypertrophic conditions, this indicates a period of very high nutrient increase, which causes algal blooms. The impacts include the potential for decreased water quality and the possibility of hypoxia (lack of oxygen) in these waters.

Meanwhile, Station V with a TRIX value of 10.0 shows a very high TRIX value, in the hypertrophic category. This high value indicates excessive nutrient content, which has the potential to cause a massive algae bloom. The impact can be very bad, such as decreased dissolved oxygen, mass death of aquatic organisms (especially fish), and disruption of the overall ecosystem. These waters require management actions to reduce nutrient loads and restore water quality.

Station V is a station that has the highest TRIX value among other research stations, in this case the station is located in the center of community activity (traditional market in Manggala sub-district). This condition increases the possibility of releasing a variety of organic waste to enter the water body. This is in accordance with the findings of **Fahruddin *et al.* (2021)**, who postulated that the increase in human activity in various sectors of life often produces pollutants that can disrupt and damage the environment. Population growth and development have consequences for increasing industrial growth and are followed by an increase in the amount of waste dumped into the environment.

In conclusion, Station I is in eutrophic condition, while Station II and Station III experiencing increased nutrients that are recommended to address. Station IV and Station V show hypertrophic conditions that require an immediate intervention. Management at each station must be adjusted to the conditions of each to maintain water quality and ecosystem balance.

CONCLUSION

Based on the results of research on eutrophication in Lake Balang Tonjong Makassar, the following conclusions can be drawn: 1) Environmental parameters that affect the eutrophication process show extreme conditions, which in general have exceeded the environmental quality standards set by the government of the Republic of Indonesia. 2) Trophic status at each station is at the eutrophic level (station I, station II and station III; while station IV and station V are at the hypertrophic level; 3) The trigger of eutrophication is highly extreme, namely at stations IV and V, around traditional markets and household waste channels.

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REFERENCES

Agatha Sih Piranti. (2021). Controlling Eutrophication of Lake Rawapening (April Issue).

Bahri, S. (2016). Identification of sources of Nitrogen (n) and Phosphorus (p) pollution in the abundant growth of aquatic plants in Lake Tempe, South Sulawesi. Journal of Water Resources, 12(2), 159–174.

Barat, S.; Syawal, M.S.; Wardiatno, Y. and Hariyadi, S. (2016). The Effect of Anthropogenic Activities on Water Quality, Sediment and Molluscs in Lake. 16(1), 1–14.

Fahruddin; Samawi, M.F.; Tuwo M. and Tanjung, R.E. (2021). The Effect of Heavy Metal Lead (Pb) on the Growth of AmmoniaDegrading Bacteria and Physical Changes of Eichhornia crassipes in Groundwater Phytoremediation. International Journal on Advanced Science, Engineering and Information Technology 11(3), 994-1000.

Garno, Y.S. (2020). Coastal Water Quality Status of Bukit Ameh in the Mandeh Special Economic Zone in Pesisir Selatan Regency. Journal of Environmental Technology, 21(2), 190–197.

Indrayuni, A. and Yusuf, M.A (2023). Potential for Ecotourism Development Based on Floating Architecture in Lake Balang Tonjong Makassar. Journal of Technoscience, 17 (1), 36–46.

Jusmiati, J.; Burhanuddin, B. and A.S.Z. (2021). Lake Balang Tonjong Tourism Design Based on Local Wisdom. Timpalaja: Architecture Student Journals, 3(2), 153–160.

Mardiah, A.A.; Sofarini, D. and Dharmaji, D. (2021). Status of the Trophic and the Level of Pollution of the Waters of the Swamp "Lake Bangkau" 4(3), 129–141.

Murtiono, U.H. and Wuryanta, A. (2016). Study of Eutrophication in Rawapening Natural Reservoir. Proceedings of the 2016 UMS National Geography Seminar, 170–181.

Nadjib, M. (2016). The Problems of Collaborative Management in Rawapening Lake. Journal of Society and Culture, 18(3), 487–502.

Government Regulation No. 22 of 2021. (2021). Appendix VI concerning National Water Quality Standards - PP Number 22 of 2021 concerning the Implementation of Environmental Protection and Management. State Secretariat of the Republic of Indonesia,

Piranti, A.S. (2019). Control of Eutrophication of Rawa Pening Lake (February Issue).

Sayekti, R.W.; Yuliani, E.; Bisri, M.; Juwono, P.T.; Prasetyorini, L.; Sonia, F. and Putri, A.P. (2015). Evaluation study of the quality and trophic status of Selorejo Reservoir water due to the eruption of Mount Kelud for fisheries cultivation. Journal of Irrigation Engineering, 6(1), 133–145.

Sidaningrat, I.; Arthana, I.W. and Suryaningtyas, E.W. (2018). Water Fertility Level Based on Phytoplankton Abundance in Lake Batur, Kintamani, Bali. Metamorphosis: Journal of Biological Sciences, 5(1), 79.

Sulasri, S. (2021). Water Fertility Based on the Trophic Index in the Waters of Ranooha Raya Village, Moramo District, South Konawe Regency [Water Fertility Based on the Trophic Index in the Waters of Ranooha Raya Village , Moramo District , South Konawe Regency] Des. 6(1), 71–82.

Sunaryani, A. (2023). Determination of Water Quality Status and Trophic Status in Lake Maninjau Waters. Journal of Environmental Technology, 24(1),

Sutrisno, S. and Harnedi, J. (2018). Building a Tourism-Aware and Disaster-Aware Community in the Lake Lut Tawar Takengon Area. As-Salam Journal, 2(3), 93–102.

Tambaru, R. and Hasanuddin, U. (2022). Determination of the Most Dominant Parameters Affecting Phytoplankton Growth in the Dry Season in the Coastal Waters of Maros, Prosiding Simposium Nasional Pengelolaan Pesisir, Laut, dan Pulau-pulau Kecil ISBN : 978-979-19034-4-8

Pratiwi, T.M., N.; Hariyadi, S.; Bagoes Soegesty, N. and Yuni Wulandari, D. (2020). Determination of Trophic Status Through Several Approaches (Case Study: Cirata Reservoir). Indonesian Journal of Biology, 16(1), 89–98.

Tulandi, S.S. (2022). Analysis of Lake Sineleyan Tomohon Water Quality Based on Macrozoobenthos Diversity Structure Study. Info Science Magazine, 3(1), 27–37.

Yusal, M.S. (2019). Study of Eutrophication Potential on the Losari Coast, Makassar. Enggano, 2(2), 348–357.

Yusal, M.S. and Hasyim, A. (2022). Water Quality Study Based on Meiofauna Diversity and Physico-Chemical Parameters on the Losari Coast, Makassar. Journal of Environmental Science, 20(1), 45–57. https://doi.org/10.14710/jil.20.1.45-57

Zulfia, N. and Aisyah. (2013). Trophic Status Of Rawa Pening Waters Evaluated From The Nutrients (NO3 and PO4) and chlorophyll-a. Bawal, 5(3), 189–199.