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Phytoplankton characteristics in Lake Matano, Indonesia

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Phytoplankton characteristics in Lake Matano, Indonesia

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Abstract. Lake Matano is one of the oligotrophic lake in Indonesia that has unique phytoplankton characteristic. This study was aimed to find out the composition and abundance of phytoplankton at Lake Matano. Observations were conducted in 2015 (April and August) and 2016 (May and August). A total 10-20 L of water samples were collected from eight locations in the Lake Matano. Temperature, pH, dissolved oxygen, conductivity and turbidity were measured to determine the water quality. Phytoplankton abundance was calculated using the Sedgewick Rafter method. Phytoplankton community structure was analysed by Diversity Index (H'), Evenness Index (E) and Simpson Dominance Index (D). A total five phyla and 80 species of phytoplankton were found in Lake Matano, comprised of Chlorophyta (26 species), Dinophyta (2 species), Bacillariophyta (43 species), Chrysophyta (1 species) and Cyanophyta (8 species). The abundance of phytoplankton ranged between 0.36×10^2– 1.281×10^4 individual/L. *Peridinium inconspicuum* and *P.cinctum* (Dinophyta) was found highest in abundance in April and August 2015 (96.38% of the abundance). Low to moderate community (H'= 0.122 to 3.454) and low uniformity (E = 0.065 to 0.556) among species in phytoplankton community was found in Lake Matano. Dominance species (D = 0.216 to 0.967) occurred in several locations at Lake Matano. CCA ordination shows that the presence of all phytoplankton groups is strongly influenced by turbidity of which the lower turbidity value causes the higher phytoplankton abundance.

1. Introduction

Oligotrophic lake has distinct phytoplankton community characteristics due to their specific environmental conditions such as neutral to slightly alkaline and poor nutrient content. In oligotrophic waters,the value of phytoplankton abundance was usually low. Lander *in*[1]noted that phytoplankton abundance is less than 5000 individuals/L in oligotrophic waters.Dominant groups in the oligotrophic waters include diatoms (i.e. *Cyclotella* and *Tabellaria*) or dinoflagellates (i.e.*Peridinium* and *Ceratium*) [2].

Lake Matano is a tectonic lake located in the Malili lake complex (South Sulawesi, Indonesia), and is categorized as an ancient lake with a depth of up to 590 meters [7]. This lake is categorized as an oligotrophic lake based on the abundance of phytoplankton [3] and the total nitrogen and total phosphorus contents at 100 m below the water surface [4]. The Lake Matano also belongs to an ultraoligotrophic lake based on trophic status of single parameters and composite parameters[5],and based on low carbon fixation rates [6].

Several studies on plankton in Lake Matano were reported, such as the limiting factors of abundance and pelvic phytoplankton composition [8], factors affecting the composition and relative

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abundance of plankton [4], and phytoplankton characteristics in Lake Matano [3]. This study was conducted in order to determine the ecological characteristics and community structure of the phytoplankton in the oligotrophic waters of Lake Matano.

2. Methods

Lake Matano is located in South Sulawesi between 2°28’90” Sand 121°17’90” E. This ancient lake is one of the deepest lakes in the world with a maximum depth of ~ 590 m, and an altitude of 380 m above sea level. The maximum area of the lakes is 16,408 ha [7,9].

Collections were conducted in April and August 2015 (data source from [10]) and May and August 2016 at several littoral zones of Lake Matano and center of Lake Matano (Figure 1). A description of the sampling locations is presented in Table 1. A phytoplankton sample was collected in surface waters by filtering 10 - 20 L through a plankton net no. 25 (53 µm mesh size) and preserved with Lugol 1%. The phytoplankton species was identified according to [11,12,13,14,15,16,17,18] using an inverted microscope with a magnification of 200× and 400×. Abundance was calculated using the Sedgwick Rafter method [19]. A community structure was analysed by Diversity Index (H'), Evenness Index (E) and Simpson Dominance Index (C) [20].

Water temperature, pH, dissolved oxygen (DO), conductivity, and turbidity were determined using a water quality checker YSI, while the water transparency was examined by the measurement of the Secchi depth. Multivariate analysis was used to determine the grouping of phytoplankton at sampling sites based on the condition of the water quality using software Multivariate Statistical Package (MVSP V 3.1).

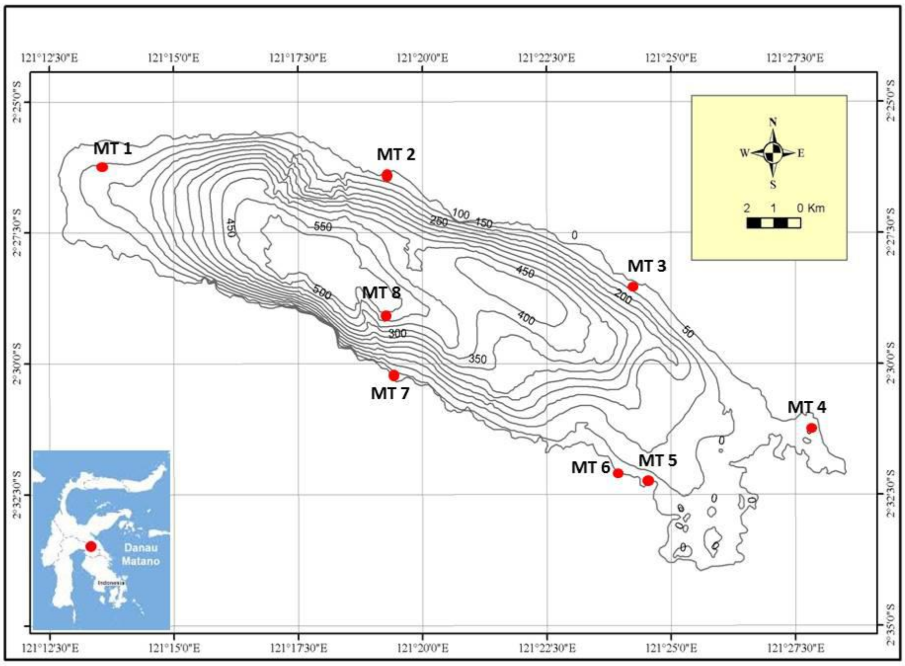


Figure 1. Sampling position at Lake Matano (Map source: modification from Haffner *et al.,*2001 [7]).

Table 1. Description of Sampling Sites at Lake Matano (Source : Husni *et al*, 2017 [10])

Code	Name of Location	Position	Habitat Description
MT. 1	Elawa	121°13'28.7" E 02°25'52.2" S	Lake Matano inlet from Lawa River, sampling site area is still forested, until 2 meters depth the substrate was rocky gravel, at the depth of 5 and 10 meters dominated by sand, disturbance from anthropogenic activities (settlements) are very minimal .
MT. 2	Nuha	121°19'28.06" E 02°26'23.1" S	The location is close to Nuha Village, a fisherman village, boat docks, a boat crossing from the village of Nuha to Sorowako or vice versa. Around the village there are natural vegetation cover (forest) , until 2 meters depth the type of basic substrate was small gravel, a depth of 5 and 10 meters is sand.
MT. 3	Tanah Merah	121°23'58.5" E 02°28'21.2" S	Location named Tanah Merah, around the lake they found the native vegetation (forest), there are several former landslide, anthropogenic activities are still very minimal, from 0 to 1 meter the susbtrates were rocky gravel and hardpan (hard ground), substrate from 2 meters to 10 meters is sand .
MT. 4	Petea	112°27'55.4" E 02°31'16.8" S	Location named Petea, more open area, there is a former forest clearing in order to be converted into plantation areas. Formerly a former area of ??nickel tailings disposal, from a depth of 0 to 2 meters the base substrates were fine mud and sand, depth of 5-10 meters is sand . There are swamps.
MT. 5	Pantai Impian	121°24'46.1" E 02°32'23.9" S	Location named Pantai Impian, the natural vegetation is still there, the location of settlements populatins and settlements workers of PT Vale and close to Sorowako Village, berth of the fishing boats, from 0-2 meters the base substrate were gravel and pebble stone, depth of 5 to 10 meters is sand.
MT. 6	Flats at Soroako Village	121° 23'57,5" E 02°31' 42,3" S	Location is a residential area in the form of flats in Sorowako Village. There is no natural vegetation, is clearing of land for pepper plantations and is the location of pin net cage. The water depth of 0 -2 meters of the base substrate is stone, gravel, and sandstone; the water depth of 5 to 10 meters of the base substrate is sand
MT. 7	Pantai Kupu-Kupu (*Bubble Beach*)	121°19'27.7" E 02°30'11.2" S	Location named Pantai Kupu-Kupu or Bubble Beach, habitat around the site still dominated by native vegetation, on the basis habitat often encountered gas bubbles are suspected of H2S, a depth of 0-2 meters is dominated by gravel, 5 and 10 meter depth of the base substrate is sand
MT.8	Center of Lake	121°28'56.4" E 02°19'57.2" S	Open water

3. Results and Discussions

3.1. Composition and abundance of phytoplankton

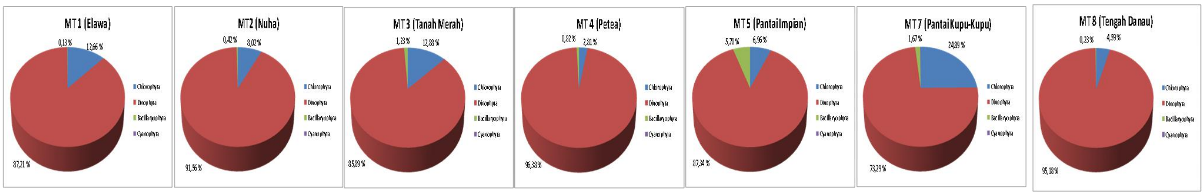
This study found five phytoplankton groups with 80 species, namely Chlorophyta (26 species), Dinophyta (2 species), Bacillaryophyta (43 species), Chrysophyta (1 species) and Cyanophyta (8 species) (Table 1). *Cosmarium contractum*, *Staurastrum prionotum*, *S.limneticum*, *Cymbella gracile*, *Navicula cryptocephala*, *Surirella wolterecki*, *Synedra ulna*, *Peridinium inconspicuum* and *P.cinctum*were found in almost all locations. Among these species, three endemic species in Sulawesi were found, viz, *S.wolterecki*, *S. exellens*and *S. pseudovalis*[15,17].*P. inconspicuum* and *P. cinctum* were found as the highest in the abundance.

During May and August 2016 (Figure 2) the phytoplankton distribution was not evenly distributed, whereas in April and August 2015 the Dinophyta group was abundantly high in all stations (61 05 - 96.38%). In May 2016, the Tanah Merah (MT 3) area of Chlorophyta was high in abundance (98.33%), while the Dinophyta and Chlorophyta percentages in Petea (MT 4), Soroako (MT 6) and Pantai Kupu-Kupu (MT 7) were almost similar. In August 2016, the abunacne of Bacillaryophyta was found high in

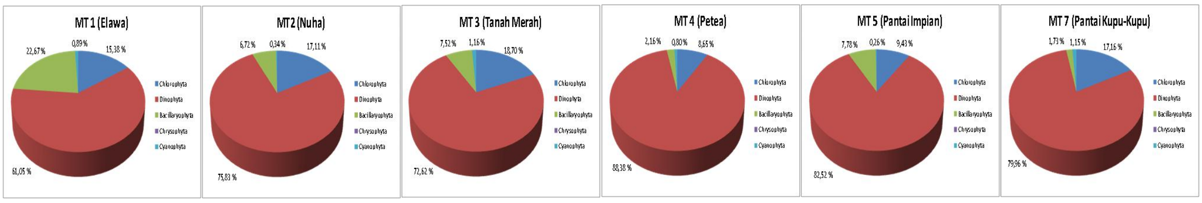
Elawa (MT 1) and Petea (MT 4), while Dinophyta was high in Nuha (MT 2) and Pantai Kupu-Kupu (MT 7).

Abundance ranges from 0.36×10^2– 1.281×10^4ind./L, and the taxa richness ranges from 2 - 27 species (Figure 3). The abundance value and taxa richness of phytoplankton in August 2015 and 2016 were higher than those in April 2015 and May 2016. Highest phytoplankton abundance was found mainly in August 2015 (5.789×10^3– 1.281×10^4 ind./L), while the lowest abundance occurred in May 2016 (0.36×10^2– 1.37×10^2 ind./L). These conditions were almost evenly distributed across all observation stations. In general, water condition in April 2015, and May and August 2016 at Lake Matano were still categorized as oligotrophic waters, according to Lander *in*[1], due to the abundance value of phytoplankton below 5×10^3 ind./L. A high abundance in August 2015 was due to the high Dinophyta group (*P. inconspicuum* and *P. cinctum*).

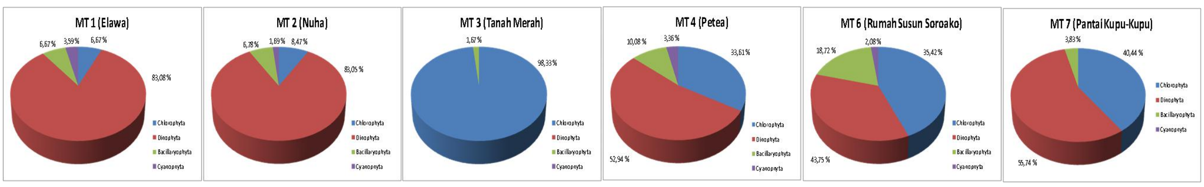
The Dinophyta group (96.38%) has the highest percentage of abundance compared to other groupsin April 2015 (Figure 2). Another study noted that the dinoflagellate is suitable in an oligotrophic environment due to its feeding method and its ability to move, where it can move throughout the water column to obtain nutrients [Pollingher *in*[21]]. Similar results were found in ultraoligotropic lakes (Andean lakes) in Argentina, as the availability of food sources supports highest abundance of cyanobacteria, cilliata and other dinoflagellates [21]. *Peridinium* and *Ceratium* (Dinoflagellates group) were also found dominant in neutral to alkaline lakes with nutrient-poor condition[4,5].



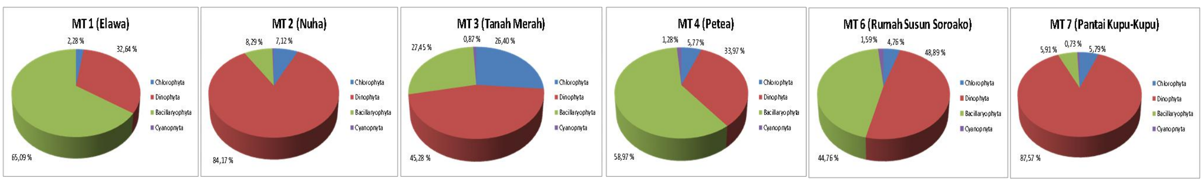
April 2015 (data source from Sulawesty, 2017)



August 2015 (data source from Sulawesty, 2017)



May 2016

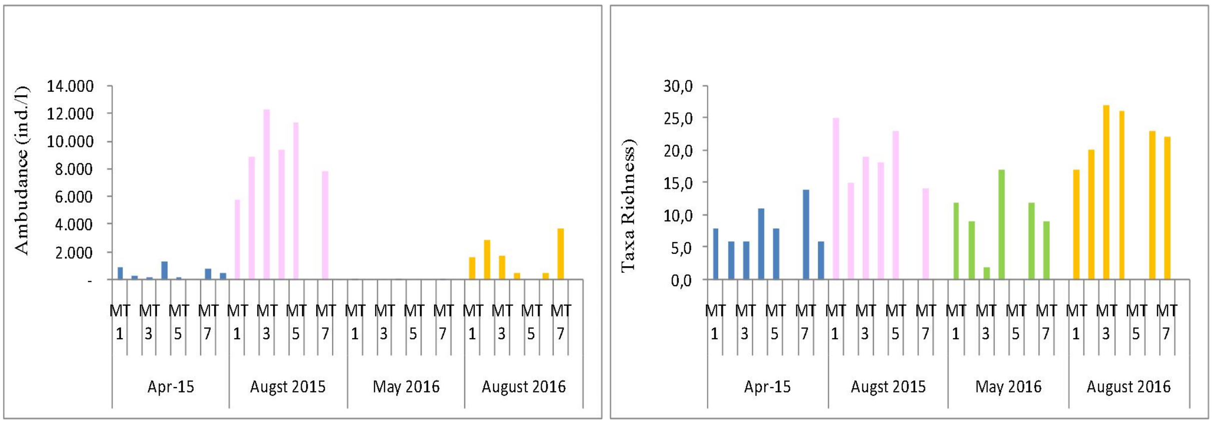


August 2016

Figure 2. Phytoplankton division percentage at surface area of Lake Matano in April &August 2015 and May & August 2016.

Table 2. Species composition of phytoplankton at Lake Matano in April &August 2015 [7] and May & August 2016.

SPECIES COMPOSITION OF PHYTOPLANKTON				
CHLOROPHYTA	DINOPHYTA	BACILLARYOPHYTA	CHRYSOPHYTA	CYANOPHYTA
Ankistrodesmus braunii	*Peridinium inconspicuum*	*Achnanthes* sp.	*Chrysosphaerella* sp.	*Anabaena* sp.
Asterococcus	*Peridinium cinctum*	*Achnanthes longipes*		*Anabaena spiroides*
Closteriopsis longissima		*Amphiprora* sp.		*Aphanocapsa* sp.
Closterium gracile		*Amphora ovalis*		*Chroococcus* sp.
Coelastrum microporum		*Asterionella* sp.		*Chroococcus turgidus*
Cosmarium contractum		*Cocconeis* sp.		*Microcystis* sp.
Crucigenia apiculata		*Cymbella aspera*		*Oscillatoria* sp.
Golenkinia sp.		*Cymbella lauceolata*		*Spirulina* sp.
Kirchneriella lunaris		*Cymbella graciles*		
Mougeotia sp.		*Cymbella tumida*		
Oocystis sp.		*Diatoma vulgaris*		
Pediastrum duplex		*Epithemia* sp.		
Pediastrum simplex		*Fragilaria* sp.		
Scenedesmus sp.		*Frustulia* sp.		
Spirogyra sp.		*Frustulia rhomboides*		
Spondylosium nitens		*Gomphonema* truncatum		
Staurastrum arachne		*Gyrosigma* sp.		
Staurastrum prionotum		*Gyrosigma attenuatum*		
Staurastrum gracile		*Melosira granulata*		
Staurastrum limneticum		*Melosira varians*		
Staurastrum sebaldi		*Nitzschia* sp.		
Staurastrum woltereckii		*Navicula* sp.		
Staurastrum xanthium		*Navicula bacillum*		
Tetraedron trigonum		*Navicula cryptocephala*		
Ulothrix sp.		*Navicula elegans*		
Westella sp.		*Navicula gracillis*		
		Navicula pupula		
		Navicula radiosa		
		Navicula rhyncocephala		
		Navicula viridis		
		Pinnularia viridis		
		Pleurosigma sp.		
		Pleurosigma fasciola		
		Rhapolodia sp.		
		Rhapolodia gibba		
		Surirella sp.		
		Surirella elegans		
		Surirella excellens		
		Surirella pseudovalis		
		Surirella robusta		
		Surirella wolterecki		
		Synedra ulna		
		Tabellaria sp.		



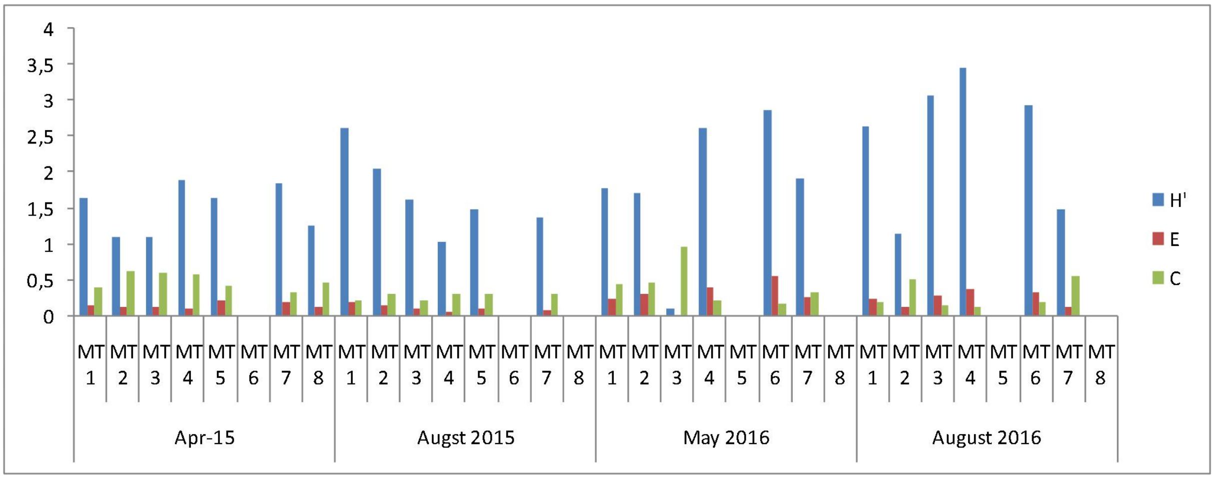
Notes :

MT 1 : Elawa
MT 2 : Nuha
MT 3 : Tanah Merah
MT 4 : Petea
MT 5 : Pantai Impian
MT 6 : Flats of Soroako Village
MT 7 : Pantai Kupu-Kupu
MT 8: Center of Lake

Figure 3. Phytoplankton abundance (left) and taxa richness (right) at Lake Matano in April & August 2015 (data source from Sulawesty, 2017[7]) and May & August 2016.

3.2. Phytoplankton diversity

Diversity Index, Evenness Index and the Dominance Index in Lake Matano during this study ranged from 0.122 - 3.454, 0.022 - 0.556 and 0.134 - 0.635, respectively(Figure 5). This showed the stability of the phytoplankton community [20], low uniformity between species in the community, and several species dominance.*Peridinium cinctum*was dominant in Nuha, Tanah Merah and Petea (April 2016), *Cosmarium contractum* was dominant in Elawa, Nuha and Tanah Merah (May 2016) and *P. incospicuum*was dominant in Tanah Merah; and at Nuha and Pantai Kupu-Kupu (August 2016)(Figure 5).



Notes :

MT 1 : Elawa
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MT 4 : Petea
MT 5 : Pantai Impian
MT 6 : Flats of Soroako Village
MT 7 : Pantai Kupu-Kupu
MT 8: Center of Lake

Figure 4. Diversity Index (H), Evenness Index (E) and Dominance Index (C) at Lake Matanoin April &August 2015 (data source from Sulawesty, 2017[7]) and May & August 2016.

3.3. Water quality

Water quality at Lake Matano during April and August 2015 as well as May and August 2016 was showed in Figure 5. Temperature ranged between 26.34°C – 30.5°C, this value is similar with previous studies [5,8,9] which ranged from 27.3°Cto 29.62ºC. Water temperature in August 2015 was lower than April 2015, May 2016 and August 2016. Phytoplankton abundance in August 2015 was found highest (Figure 3). Temperature is one of the important factors that determine the phytoplankton growth, nutrient stoichiometry, and spatial and temporal distribution in freshwater systems[22], The phytoplankton response to temperature also depends on the type of phytoplankton. For example, green algae and diatoms tended to decrease with increasing temperature while the cyanobacteria tended to increase with increasing temperature [22]. Study at Kinneret Lake found that *Peridinium* blooms in the winter - spring when the water temperature is 20°C - 24°C, where the level of solar radiation was moderate, and respiratory losses were relatively small [23].

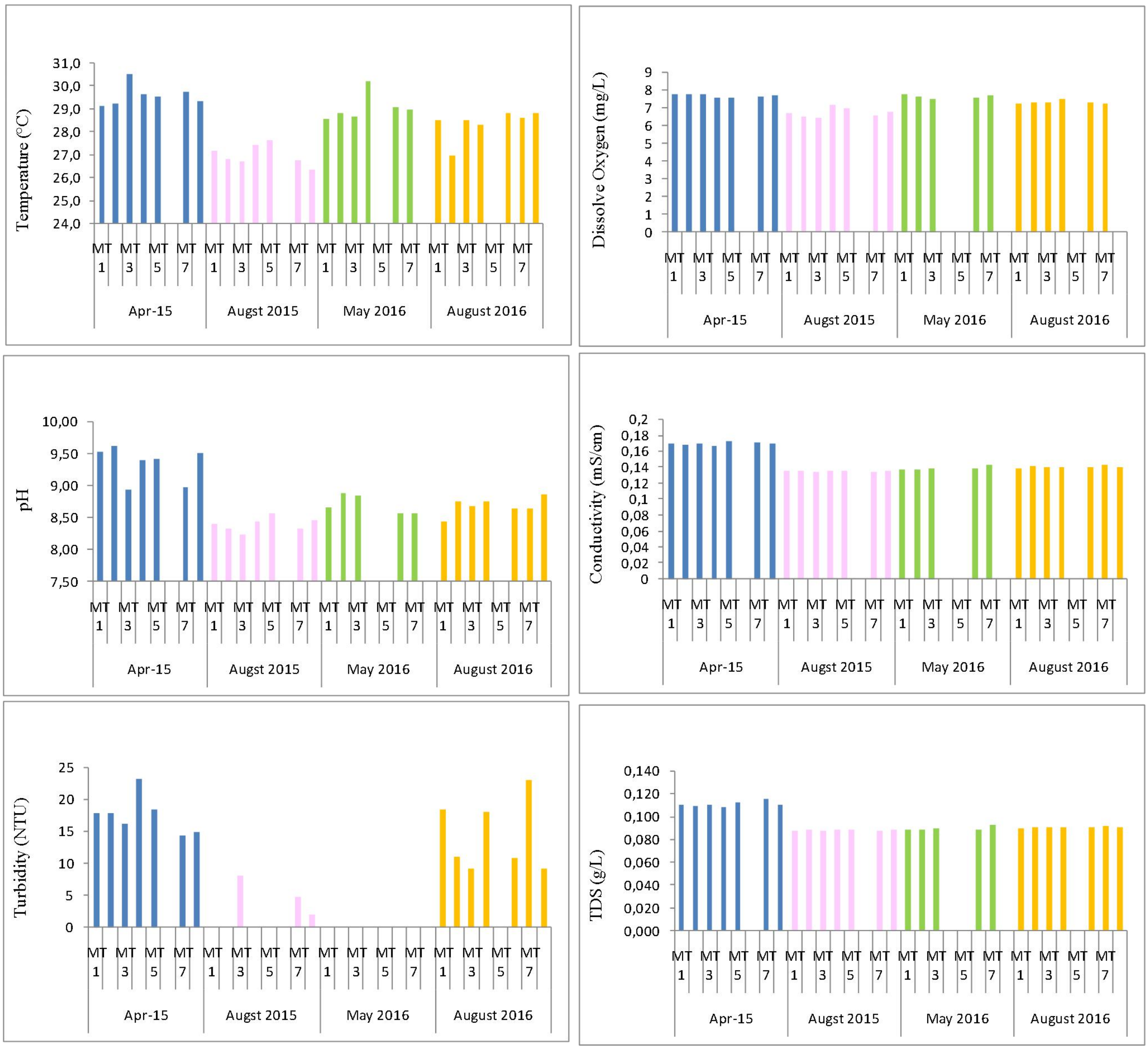

Figure 5. Water quality condition at Matano Lake in April &August 2015 (data source from Sulawesty, 2017[7]) and May & August 2016.

A condition of dissolved oxygen (6.43 – 7.73 mg/L) in the lake was found supporting the phytoplankton life. An aerobic condition at Lake Matano was found to a depth of 95 m, while anaerobic condition occurs from a depth of 100 m to the bottom [5]. The pH values ranged from 8.23 to 9.61 indicating that Lake Matano is alkaline[5, 8]. Turbidity ranged between 0 – 23.2 NTU and total dissolve solids (TDS) ranged between 0.087 – 0.115 g/L. Turbidity in April 2015 and August 2016 was higher than August 2015, meanwhile the phytoplankton abundance in April 2015 and August 2016 werelower compared to August 2015. Low phytoplankton productivity was caused by the limited light due to high turbidity and not due to low productivity capacity [24].Conductivity value of Lake Matano was high (0.134 – 0.177 mS/cm), and the conductivity was also high reflecting high ground water input [8].Water depth ranged between 12.6 – 300 m and Secchi depth ranged between 7.4 – 23.4 m (Figure 6).

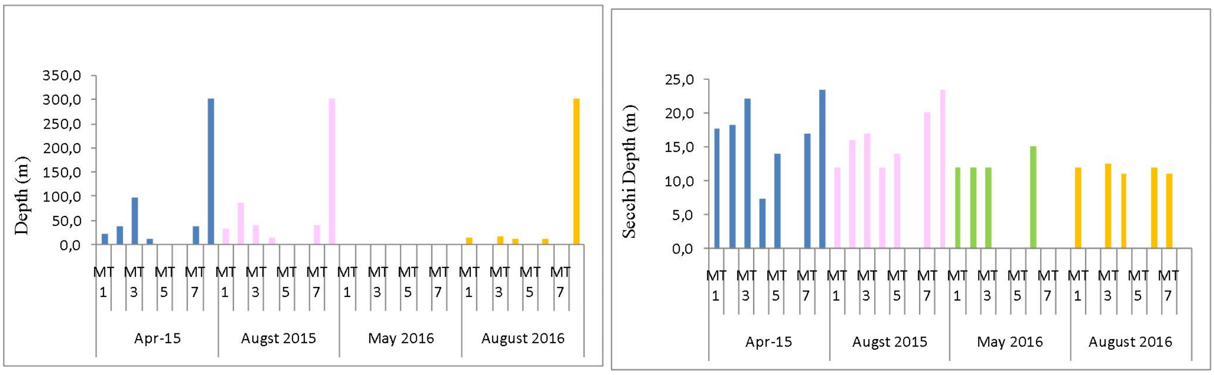

Figure 6. Water depth and Secchi depth at Matano Lake in April &August 2015 (data source from Sulawesty, 2017[7]) and May & August 2016.

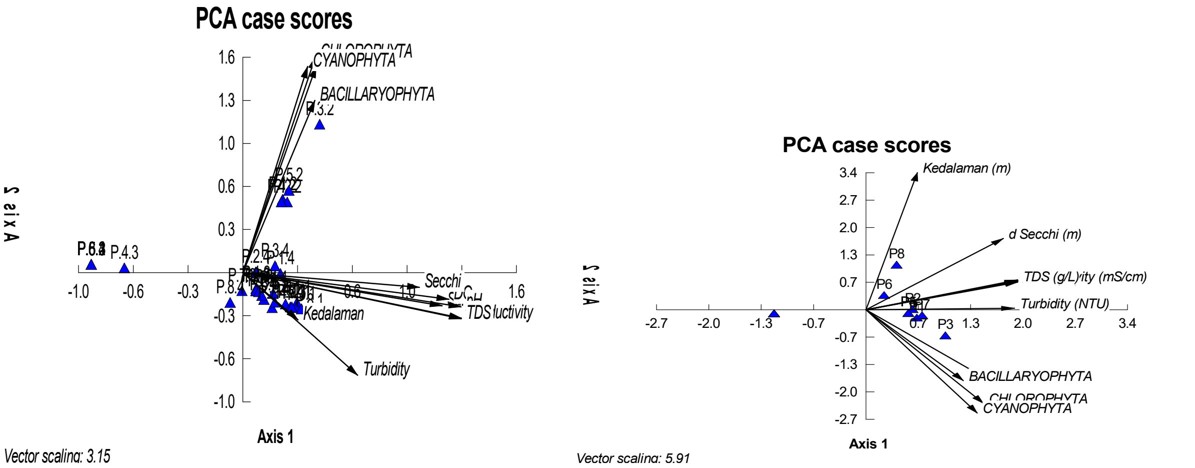

Figure 7. CCA ordination at Lake Matano in April & August 2015 (data source from Sulawesty, 2017[7]) and May & August 2016.

The main component analysis / PCA (Figure 5) showed the relative importance of each factor in calculating the variance of all analysed variables. The first, second and third componentsdescribed 47.9%, 27.1% and 8.7%of the total variables, respectively. The first component was probably dominated by physical chemical variables such as temperature, pH, DO, conductivity, TDS and Secchi depth. The second component consists of all types of phytoplankton and turbidity physics variables. While the third component was only occupied by the depth variable. This showed that the presence of all phytoplankton groups was strongly influenced by the turbidity, as the lower turbidity value caused the higher abundance.

4. Conclusions

Five groups of phytoplankton with 80 species were found in Lake Matano, namely Chlorophyta (26 species), Dinophyta (2 species), Bacillaryophyta (43 species), Chrysophyta (1 species) and Cyanophyta (8 species). *Peridinium inconspicuum* and *P.cinctum* abundance were higher than other species. The PCA analysis showed that the presence of all phytoplankton groups was strongly influenced by the water turbidity.

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