Checklist of phytoplankton and their abundance in Toba Lake, North Sumatra, Indonesia

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Abstract. The aim of this study is to list and describe phytoplankton communities in freshwater areas highly utilized in Toba Lake and determine the number of phytoplankton species in this location. The sampling was carried out in December 2018, in 4 location (boat docks, control locations, estuary locations near agricultural land, and fisheries locations). 34 phytoplankton species consisting of 12 members of Bacillariophyta, 9 members of Chlorophyta, 7 members of Cyanobacteria, 5 members of Charophyta, and one member of Ochrophyta were identified. Among all species found, three species, namely *Staurastrum* sp., *Sphaerocystis* sp., and *Chroococcus* sp. were the most abundant in the study areas, with an abundance of 14819 ind L^{-1}, 11,877 ind L^{-1}, and 10230 ind L^{-1}, respectively. The most frequent phytoplankton species in all sites were *Chlorococcum* sp., *Chlorogonium* sp., *Chroococcus* sp., *Closteriopsis* sp., *Gloeotila* sp., *Oedogonium* sp., *Pinnularia* sp., *Sphaerocystis* sp., *Staurastrum* sp., *Stigeoclonium* sp., and *Synedra* sp*.* The Chlorophyta phylum was the major structure of phytoplankton community in Toba Lake.
Key Words: Bacillariophyta, Bray-Curtis, communities, freshwater, major groups.

Introduction. An inventory of phytoplankton species as baseline information is important in the studies of phytoplankton communities of freshwater ecosystems. This information can indicate changes in the natural community structure of phytoplankton assemblages, which sometimes might lead to ecological damages caused by the presence of environmental stress from anthropogenic activities, changes in water physicochemical levels, excessive nutrient intakes or eutrophication, excess of pollutants, and the presence of invasive species (Mather et al 2010; Häder & Gao 2015; Lee et al 2015). Fundamental knowledge and information on diversity and richness of native phytoplankton species are important for biomonitoring.

Diatoms (Bacillariophyta) are one of the major groups of phytoplankton community and play important roles in primary production and nutrient cycle of both marine and freshwater ecosystems (Lee et al 2015). The diatoms consist of more than 200 genera with over 8000 known species, but some estimates suggest that there are over 200000 species worldwide; they are vital components, especially in the marine environments (Guiry 2012; Lee et al 2015). A different major component of marine ecosystems is the Cyanobacteria phylum, which consists of over 3000 recorded species out of 8000 estimated species that exist in the world (Nabout et al 2013; https://www.algaebase.org/). Like diatoms and dinoflagellates, cyanobacteria play a great role in the ecosystem, mainly because of its N-fixation ability, phosphorus (P) storage, and iron (Fe) sequestration (Paerl & Otten 2013). However, cyanobacterial blooms are a major environmental problem that threatens both marine and freshwater ecosystems, causing ecological damage and diseases for humans and marine animals (Paerl & Otten 2013).

Lake Toba is the largest lake in Indonesia, located in North Sumatra, about 955 m a.s.l. The lake covers an area of approximately 1129700 ha, with an island in the middle (Tjahjo et al 1998). Lake Toba is currently utilized as an Indonesian tourist spot, cultural-heritage building site, residential area and fishery management site. Water quality has changed gradually in recent years due to anthropogenic activities leading to variability of phytoplankton diversity (Wijopriono et al 2010). Several local studies have reported the gradual changes in water quality of Lake Toba at specific sites. In 2004, a phytoplankton survey has been conducted to assess the water quality in Simanindo, an area of Lake Toba with no evidence of anthropogenic activities. The area was characterized as mildly to lightly contaminated based on the physico-chemical data and its low phytoplankton diversity (Barus 2004). In some cases, human activities tend to increase the number of phytoplankton species. In 2011, a phytoplankton diversity study was conducted at Parapat, a tourism site in Lake Toba, resulting in abundant numbers and species of plankton collected from a residential area (Barus et al 2008). In addition, floating net cages in Lake Toba also contributed to the phytoplankton diversity, due to high organic deposits into freshwater as nutrients (Alvarez-Vázquez et al 2014).

A recent investigation of phytoplankton near Toba Lake has revealed 33 phytoplankton species dominated by members of Chlorophyta in Binangalom waterfall, a site without any human interferences (Purba et al 2019). Based on the report, the site has freshwater algae as primary producers, while preserving their niche. However, due to gradual change in water environments of Toba Lake, there is a lack of information of phytoplankton communities from other human-altered sites on the lake. Therefore, this study aimed to describe the species composition of the phytoplankton community in four representative sites of Toba Lake with anthropogenic activities.

Material and Method

Description of the study sites. Field sampling for this study was conducted on December 2018 in the rainy season (Figure 1). Samples were collected from 12 sampling sites consisting of: 3 sites around Parapat City, where ferry ship docking with an intense human transportation from and into Samosir Island takes places (St1, St2, St3); 3 sites around Binangalom waterfall, Situmurun Village, as control sites without any documented human disturbances, but with some parts utilized for recreational purpose (St4, St5, St6); 3 sites around Laguboti District, near the discharge locations of agricultural land waste into freshwater bodies (St7, St8, St9); and 3 sites around Haranggaol District, which are fishery sites utilized for floating net cages and fisheries (St10, St11, St12).

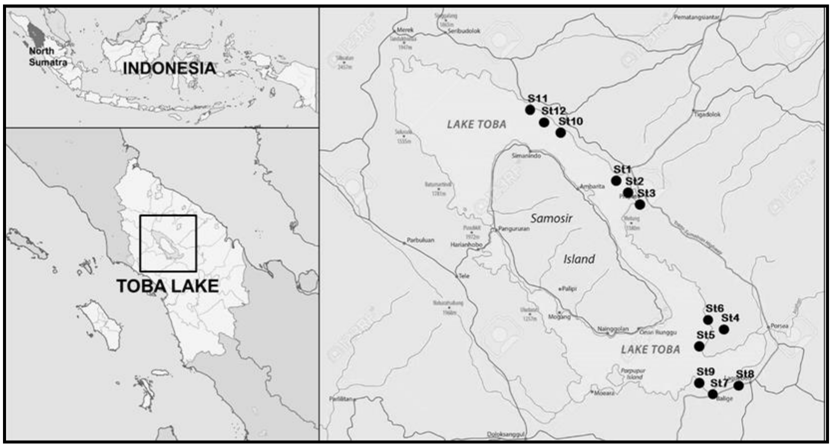

Figure 1. Sampling sites consisted of 12 stations representing four different areas around Toba Lake, North Sumatra, Indonesia.

Phytoplankton sampling and identification. Phytoplankton sampling was conducted manually using a plankton net (Ø 30 cm, mesh 300 μm, length 1.8 m) during the day, at 8:00 AM. 25 L of surface freshwater were sampled and filtered with the plankton net. Five replications of sampling were pooled into a composite of 100 mL freshwater sample. Lugol's iodine (1%, w/v) was added adequately (±3 droplets) into samples, which were stored in cold conditions prior laboratory works. Water samples were transported in 24 h to the Laboratory of Ecology, Faculty of Mathematics and Natural Sciences, Sumatera

Utara University, for species identification. Identification of phytoplankton was based on microscopical examination using a microscope with a low magnification and counted using 5 fields of view (5 columns). The observed images were compared to literature images from available sources (Davis 1955; Mizuno 1966).

Data analysis. The number of species from the phytoplankton community was counted. The individual abundance (*N*), Shannon's diversity index (*H'*), and Evenness index (*E*) were determined. Graphical images were generated using GraphPad Prism ver. 8.0.2. Dendrogram of species composition within each site was generated using Paleontological Statistics (PAST) by calculating the Bray-Curtis similarity index (Hammer et al 2001).

Results and Discussion

Checklist of phytoplankton species. In this study, 34 phytoplankton species were identified, consisting of 12 members of Bacillariophyta, 9 members of Chlorophyta, 7 members of Cyanobacteria, 5 members of Charophyta, and a member of Ochrophyta (Table 1).

Table 1

Phytoplankton community in Toba Lake, North Sumatra, Indonesia

No	*Phytoplankton*	*Dock*			*Waterfall*			*Farm*			*Fishery*		
		St1	*St2*	*St3*	*St4*	*St5*	*St6*	*St7*	*St8*	*St9*	*St10*	*St11*	*St12*
I	Bacillariophyta												
1	*Bacillaria* sp.	+	+	+	-	+	-	+	+	+	+	+	-
2	*Coscinodiscus* sp.	+	+	+	+	+	-	+	+	+	+	+	+
3	*Cymbella* sp.	+	+	+	+	+	+	-	-	-	+	-	+
4	*Denticula* sp.	-	+	-	+	+	+	+	-	+	+	+	-
5	*Diatoma* sp.	+	+	+	+	+	-	+	+	+	+	+	+
6	*Fragilaria* sp.	+	+	+	+	+	+	+	+	-	+	+	+
7	*Melosira* sp.	+	+	-	+	+	+	+	+	+	-	+	-
8	*Navicula* sp	+	+	+	+	+	-	+	+	+	+	+	+
9	*Nitzschia* sp.	+	+	+	+	+	+	+	+	-	+	+	+
10	*Pinnularia* sp.	+	+	+	+	+	+	+	+	+	+	+	+
11	*Synedra* sp.	+	+	+	+	+	+	+	+	+	+	+	+
12	*Tabellaria* sp.	+	+	-	+	+	+	+	+	+	+	+	-
II	Charophyta												
13	*Closterium* sp.	+	+	+	+	+	-	+	+	-	-	+	-
14	*Gonatozygon* sp.	+	+	-	+	+	+	+	+	+	+	+	+
15	*Spirogyra* sp.	+	-	+	+	+	+	+	+	+	-	-	-
16	*Staurastrum* sp.	+	+	+	+	+	+	+	+	+	+	+	+
17	*Zygnema* sp.	+	+	-	+	+	+	+	+	+	+	+	+
III	Chlorophyta												
18	*Chlorogonium* sp.	+	+	+	+	+	+	+	+	+	+	+	+
19	*Chlorococcum* sp.	+	+	+	+	+	+	+	+	+	+	+	+
20	*Closteriopsis* sp.	+	+	+	+	+	+	+	+	+	+	+	+
21	*Gloeotila* sp.	+	+	+	+	+	+	+	+	+	+	+	+
22	*Oedogonium* sp.	+	+	+	+	+	+	+	+	+	+	+	+
23	*Sphaerocystis* sp.	+	+	+	+	+	+	+	+	+	+	+	+
24	*Stigeoclonium* sp.	+	+	+	+	+	+	+	+	+	+	+	+
25	*Ulothrix* sp.	+	+	+	+	+	+	-	-	-	-	-	-
26	*Volvox* sp.	+	+	-	-	+	-	+	+	-	-	-	-
IV	Cyanobacteria												
27	*Anabaena* sp.	+	+	-	+	+	+	-	+	-	-	-	-
28	*Aphanizomenon* sp.	-	-	-	+	+	+	+	+	+	-	-	-
29	*Chroococcus* sp.	+	+	+	+	+	+	+	+	+	+	+	+
30	*Microcystis* sp.	+	+	+	+	+	+	-	-	-	-	-	-
31	*Oscillatoria* sp.	+	+	+	+	+	+	+	+	+	+	+	+
32	*Plectonema* sp.	-	+	-	+	+	-	-	-	-	+	+	-
33	*Spirulina* sp.	-	-	-	+	-	+	-	-	-	-	-	-
V	Ochrophyta												
34	*Tribonema* sp.	-	-	-	-	+	-	+	+	+	+	+	+

Note: St - station.

Among the species found, 3 species, namely *Staurastrum* sp., *Sphaerocystis* sp., and *Chroococcus* sp. were the most abundant in the study areas with an abundance of 14819 ind L^{-1}, 11877 ind L^{-1}, and 10230 ind L^{-1}, respectively. The most frequent phytoplankton species in all sites were *Chlorococcum* sp., *Chlorogonium* sp., *Chroococcus* sp., *Closteriopsis* sp., *Gloeotila* sp., *Oedogonium* sp., *Pinnularia* sp., *Sphaerocystis* sp., *Staurastrum* sp., *Stigeoclonium* sp., and *Synedra* sp*.* Hence, the most frequent group was Chlorophyta with 7 species. On the contrary, the least frequent species was *Spirulina* sp., which was only found in St4 and St6.

Phytoplankton abundance. In this study, the number of phytoplankton species found at each site varied between 21 to 32 species (Figure 2).

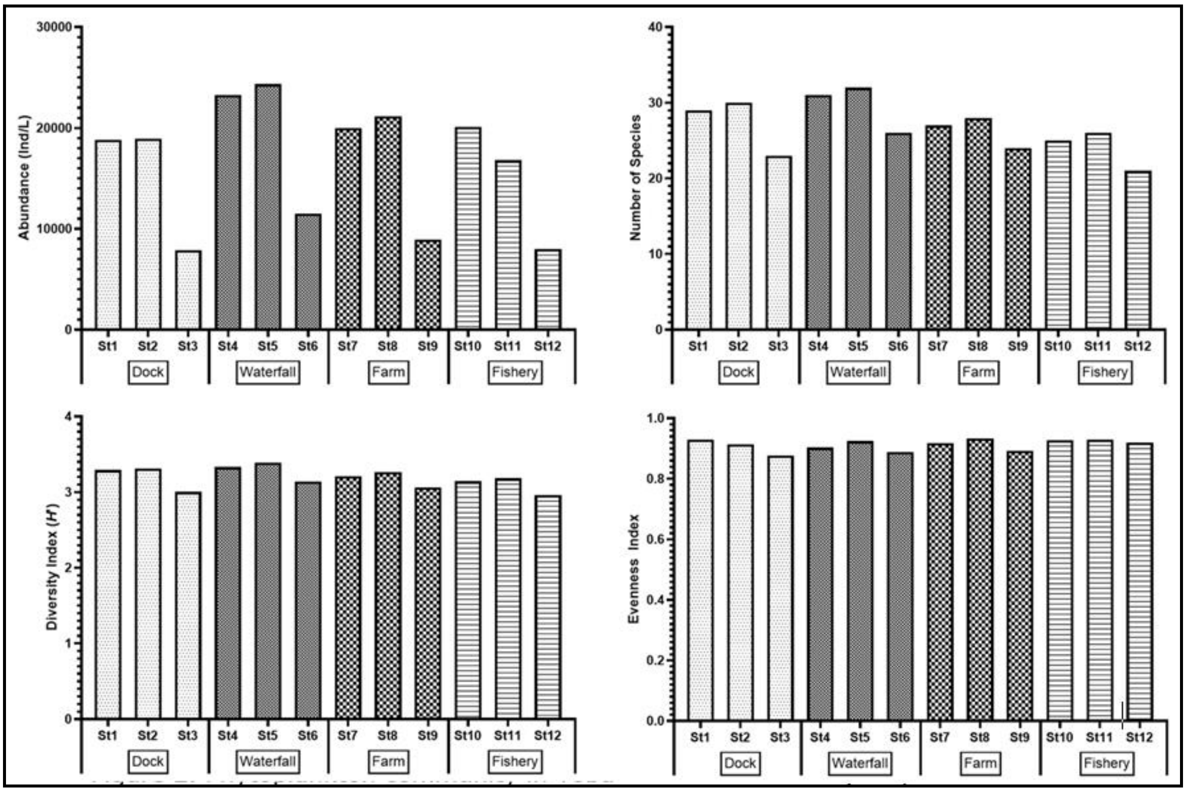

Figure 2. Phytoplankton in Toba Lake and ecological parameters.

The highest number of species was found at St5 around the waterfall (control site), while the lowest was found at St12, representing the fishery site (floating net cages). In a similar trend, the highest abundance was also found in St5, while the lowest was found at St3 (the ferry ship dock). The Shannon's diversity index for each site ranged between 2.961 (St12) to 3.388 (St5), which indicated a medium to high level of biodiversity. Based on the evenness index, there was an absence of a dominating species, despite the high occurrence of Chlorophyta species in waters around Toba Lake. When comparing each representative site, the highest abundance was documented in the control site (Binangalom waterfall region), as expected, for being the most suitable habitat for phytoplankton in the natural environment (Figure 3).

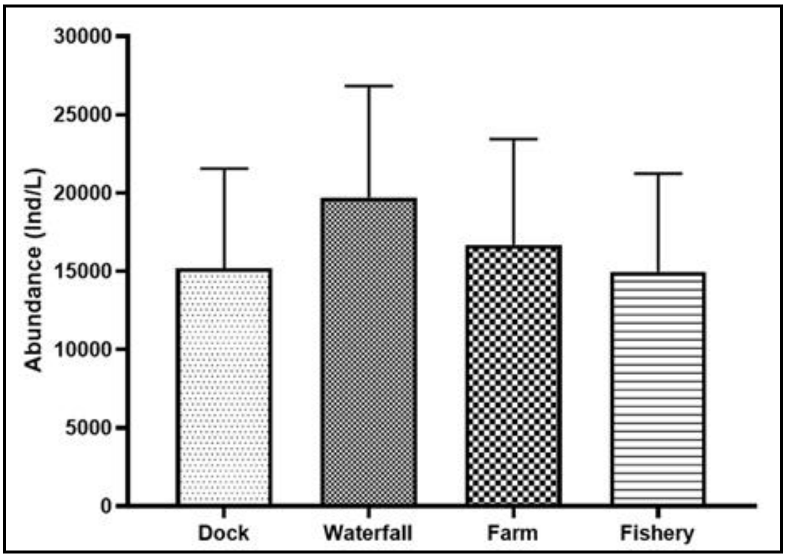

Figure 3. Mean phytoplankton abundance in the study areas.

Phytoplankton community assemblage*.* The phytoplankton composition based on its abundance varied inconsistently. Three sites representing the same environmental condition had been selected as sources of phytoplankton samples; however, based on the dendrogram construction, at least 1 site of each region was grouped indiscriminately. Four sites, namely St3, St6, St9, and St12 were clustered together above a similarity of 0.6, albeit representing different regions in study area (Figure 4). Following these findings, we argue that there could be other spatial factors which contributed to the results. In addition, the remaining results were considered consistent, and showed the grouping of phytoplankton based on anthropogenic activities or natural assemblages in the control site.

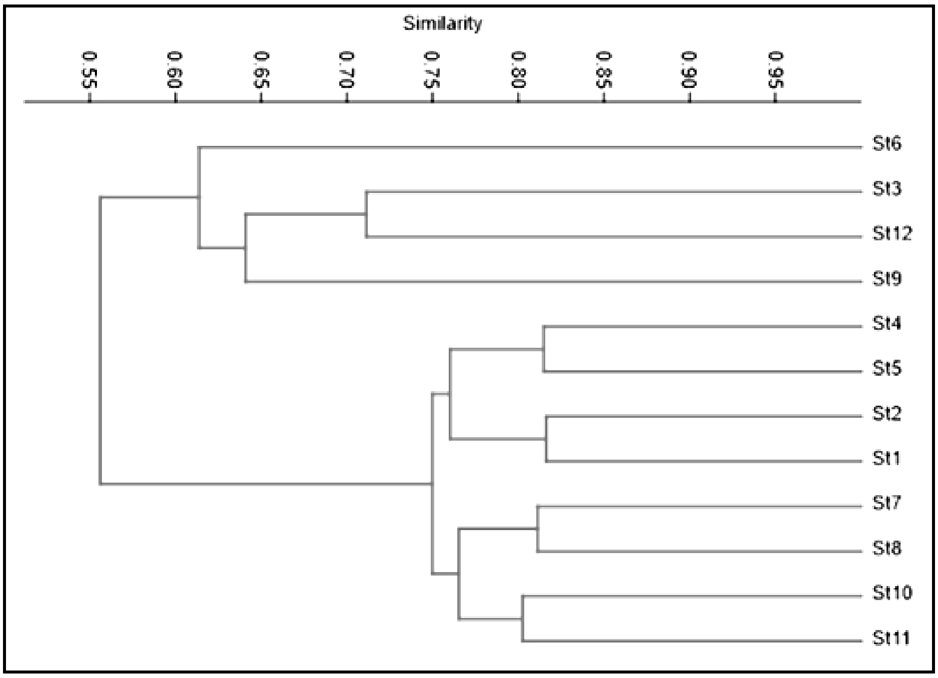

Figure 4. Bray-Curtis similarity of phytoplankton composition between different sites in Toba Lake, North Sumatra, Indonesia.

The dominance of diatoms (Bacillariophyta) among the phytoplankton community in all studied sites was expected mainly because it is typical for most aquatic ecosystems, even under anthropogenic disturbances and industrial waste discharges (Oseji et al 2018). High density and diversity of diatoms are considered a normal condition in most aquatic ecosystems. However, some anthropogenic activities in the estuary may alter the temperature and nutrient ration in the water column, which can later delay the growth of diatoms. The current sampling effort was sufficient to capture a general view of the phytoplankton community structure in Toba Lake. However, based on the similarity index between sites, it was not sufficiently discriminative to cluster the phytoplankton composition based on habitat. Therefore, it is suggested for any future study dealing with phytoplankton community structure to conduct a spatio-temporal study among sites within the region of Toba Lake.

The most abundant species in this study was *Staurastrum* sp., which is a desmid. Desmids have cosmopolitan distribution and high environmental plasticity (Brook 1981). Due to its unique genetic feature, the species is characterized by high polymorphism in dealing with changes in the environment. The morphological and physiological modifications of planktonic algae are environmental adaptations (Morales et al 2002). Under harmful condition, *Staurastrum* sp. can develop a mucilaginous layer to adjust tp microclimate conditions and it is a possible cationic protection against pollutants, especially acidic substances in the water (Coesel 1994).

As mentioned earlier, a regular checklist of phytoplankton species is crucial to quickly determine the presence of new, and possibly, invasive species in the freshwater ecosystems (Mather et al 2010; Lee et al 2015). The species checklist was especially important in coastal areas, which receive an increasing anthropogenic pressure, such as Toba Laek and adjacent regions. Unfortunately, due to the lack of an in-depth study of phytoplankton diversity in the study area, it was not possible to determine which species in this study were new and non-native to the freshwaters of the lake. Thus, a regular checklist of species like in this study is vital in monitoring the existence of non-native and potentially invasive species. Information on the phytoplankton species could also help the management process to mitigate anthropogenic impacts on the diversity of marine planktonic organisms in the ecosystem of Toba Lake.

Conclusions. A survey of phytoplankton community in Toba Lake has documented a total of 34 phytoplankton genera inhabiting the freshwater region of four representative areas. The genera consisted of 12 members of Bacillariophyta, 9 members of Chlorophyta, 7 members of Cyanobacteria, 5 members of Charophyta, and a member of Ochrophyta. A high occurrence of Chlorophyta was noted as an important structure of phytoplankton community in Toba Lake.

Acknowledgements. We would like to express the highest gratitude to Doni Hutahaean and Edwarman Zalukhu for their field assistances during the survey in Lake Toba. Special thanks to Shafera Enviro Laboratory for providing the technical equipment for phytoplankton sampling and preservatives.

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

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Received: 23 April 2021. Accepted: 08 June 2021. Published online: 30 October 2021.
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How to cite this article:
Purba I. R., Barus T. A., Mulya M. B., Ilyas S., 2021 Checklist of phytoplankton and their abundance in Toba Lake, North Sumatra, Indonesia. AACL Bioflux 14(5):3104-3110.