Phytoplankton community structure in Lutan Lake, Palangka Raya, Central Kalimantan, Indonesia

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Abstract. Lake Lutan is one of the hundreds of oxbow lakes in Central Kalimantan, located within the meander belt of the main river, the Kahayan River. The phytoplankton communities in the Lutan Lake can be classified into a variety of functional groups subject to temporal and spatial changes. The phytoplankton diversity index was investigated to test the differences in the phytoplankton composition between different periods. Our results showed that Chlorophyta, Euglenophyta, Chrysophyta, Bacillariophyta dominated the phytoplankton community. High relative abundance percentages were observed in the *Synedra* sp. (9.35%), *Strombomonas* sp. (8.46%), *Euglena* sp. (6.80%) and *Lepocinclis* sp. (4.65%). The abundance of *Euglena* sp. and *Strombomonas* sp. among the species of the Euglenophyceae class commonly occurred in all fishponds during the rainy season. The Shannon index of phytoplankton ranged between 0.56 and 2.33, and the uniformity index between 0 and 1. The increased phytoplankton density during the dry season showed an average of 838.62×10^{5} cell-L^{-1}, suggesting that light and temperature are fundamental factors for the growth of phytoplankton. Light is used by the primary producers to convert energy. *Strombomonas* sp. showed a high abundance during the rainy season, with peaks in November 2017 and March 2018. Those changes were not cyclical, on an annual basis, but seemed to occur more on a long-term basis, as has been recognized earlier in the literature on tropical lakes. The lowest dominance index, of around 0.015, was recorded in the middle of the lake. T-test, ANOVA and Turkey statistics indicated no significant difference between the samples diversity over time and at the collection locations. Phosphate and ammonia analysis had a significantly positive correlation of around 0.78.
Key Words: biodiversity, phytoplankton diversity index, Shannon index, temporal and spatial changes.

Introduction. Long-term climate changes can also induce biotic and abiotic responses of the lake ecosystems, for example changes in the water temperature or in the composition of organisms, such as the phytoplankton (Dokulil et al 2006; Özkan et al 2016). The phytoplankton is one of the main components of a lake ecosystem. It includes a great variety of forms, being the primary producer of the food chain, and has a significant role in the aquatic environment. The presence of phytoplankton plays an essential role in conserving the stability and integrity of the aquatic ecological system (Long et al 2013) and it can be an appropriate indicator of the environmental changes, due to the plankton's sensitivity to the increasing human impact and to the natural disturbances (Pomati et al 2012). Some studies have shown that the phytoplankton community structure depends on the environmental conditions in the lake, which are influenced by different factors, including the seasonal weather variations.

Understanding the phytoplankton biodiversity correlation with the environmental factors is extremely important for monitoring the water quality (Wilken et al 2018; Zhao et al 2019). The plankton community is a biotic community that is very sensitive to the changes and dynamics of the water quality, especially of the nutrients. The hydrodynamic conditions of the Lutan Lake that were formed by the oxbow lake contribute to the phytoplankton composition variations (Yaqoob et al 2021). Identifying the influence of seasonal changes on the phytoplankton can provide a better understanding of the effects of nutrient control and allow adjustments to the mitigation and ecological restoration (Hanson et al 2016; Guo et al 2020).

Lutan Lake is one of the 104 lakes of Palangka Raya City, the capital of Central Borneo Province, with a total area of about 24.36 ha. These lakes are scattered in various areas of the city of Palangka Raya. The lake has a horseshoe shape, originating from a river that formed a cutoff across a meander neck. The research brings a complement of information about the phytoplankton community in tropical oxbow lakes. In this study, we investigated the composition, abundance, and dominant species of phytoplankton communities, during November 2017-December 2018, in the Lutan Lake, one of the main water bodies of Kalimantan.

Material and Method

Description of the study sites. Lutan Lake is one of the four lakes in the Pahandut District, Palangka Raya City. The lake provides multiple services to various users, including fisheries and aquaculture. Lutan Lake is formed on the Kahayan River’s old channel (which changed and shortened its course) and new depositions from the Kahayan river seal off the ends, isolating the Lutan Lake from the river, causing the oxbow formation. In the dry season, the lake partially dries up and in the rainy season, it is flooded again and can even cause the surrounding settlements to overflow. There is an abundant growth of aquatic plants up to half of the length of the lake.

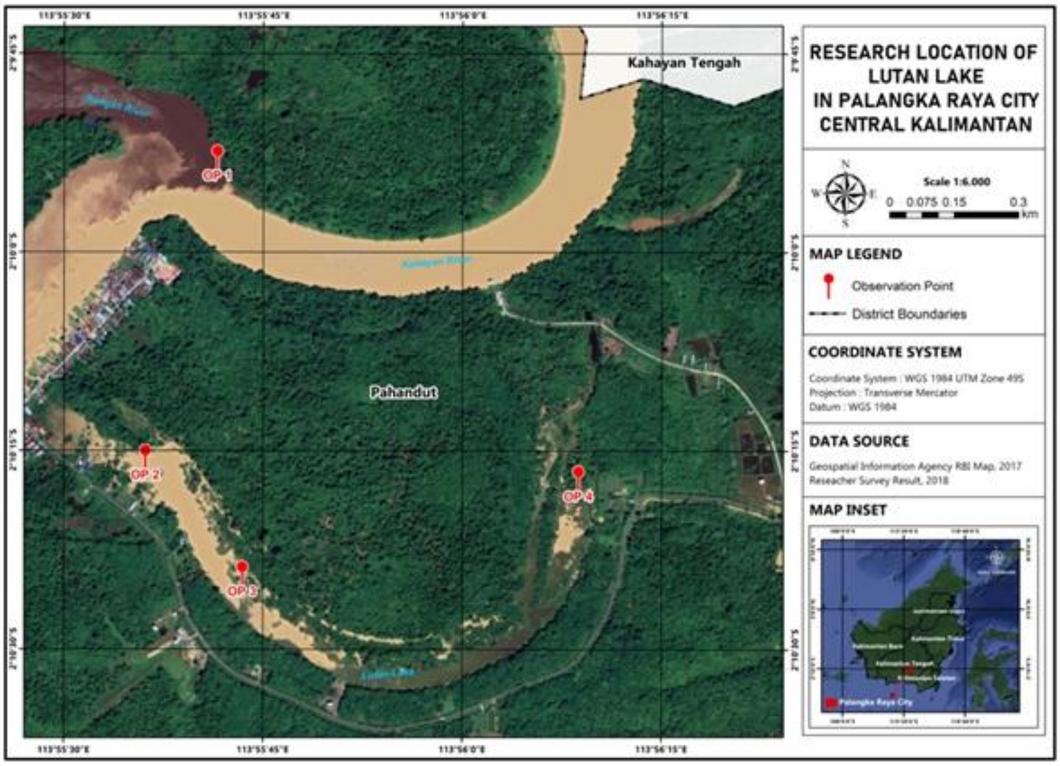

Figure 1. Map of research area of Lutan Lake.

Sampling collection. From November 2017 to December 2018 the samples were collected in Lutan Lake several times each year; different sites were sampled between 4 am and 10 am each time. The samples were taken during the rainy season, from November 2017 until March 2018. The dry season only occurred from July 2018 to October 2018 and another rainy season occurred in November-December 2018. Four sampling sites were chosen: inlet, outlet and middle of the lake, and near the Kahayan River (Figure 1). At the same point, samples of phytoplankton and relevant environmental factors were investigated in early November 2017 (rainy) and in the middle of December (rainy) 2018. Phytoplankton samples were withdrawn from the surface area (0.5 m) using a plankton net with a volume of the water sample of 1,000 mL, from the surface, then fixed with Lugol's solution and preserved in 1% (vol) formalin solution. The treatment, phytoplankton samples analysis and water quality analysis were carried out according to the standards of the Lake Ecosystem Observation Method (Wetzel & Liken 2000). Samples of phytoplankton were later analyzed in the laboratory for enumeration and identification under the light microscope (objective x 40). Samples of lake water were collected simultaneously and analyzed. Environmental parameters, such as temperature, clarity, turbidity, DO and pH were measured. Meanwhile, phytoplankton was collected during the sampling, using a plankton net and the samples were preserved using formaldehyde solution for microscopic enumeration.

Data analysis. The plankton community structure can be estimated using the Shannon diversity index (H') of biodiversity, the species equality index (E) and the Simpson dominance index (D). The diversity index was calculated with the Krebs's equation (Krebs 2014).

The index used to determine the level of species diversity in a community is the Shanon Wiener index (Krebs 2014):

$$H = \sum_{i=1}^{n} Pi\ In\ Pi$$

Where:
H - index of species diversity;
Pi - probability function for each part as a whole (ni/N);
ni - number of individuals of type-i;
N - total number of individuals.

The calculation of the uniformity index is based on the equation of Krebs (2014):

$$E = H'/H_{maks}$$

Where:
e - uniformity index;
H' - diversity index;
Hmax - In S;
S - number of types.

The dominance index is used to determine the extent to which a species dominates another group. The dominance index was obtained using the Simpson index (Krebs 2014):

$$D = \sum_{i=1}^{s} \left(\frac{ni}{N}\right)2$$

Where:
D - Simpson dominance index;
ni - number of individuals of type i;
N - total number of individuals;
S - number of types (species).

To detect whether there is any pattern of variation in the composition of the assemblage of phytoplankton and zooplankton, a Detrended Correspondence Analysis (DCA) was employed. In the case of phytoplankton data, it was based on the 17 most abundant taxa and for the zooplankton, all species were included. All the analysis was performed with PAST software (Hammer et al 2001). The differences in the Shannon diversity of the discrete phytoplankton groups were determined by ANOVA. Pairwise comparisons were examined using the Tukey's honestly significant difference (HSD) test. In all the statistical tests, the significance level was considered at $p<0.05$. A Pearson's correlation analysis was conducted to explore the correlations between phytoplankton or zooplankton and environmental factors. All the statistical methods were performed using the PAST statistical package, version 4.

Results. Based on the analysis, a total of 35 species belonging to 4 classes (Chlorophyta, Euglenophyta, Chrysophyta and Bacillariophyta) were recorded during the sampling and 11 species had an abundance of more than 2%. During the whole survey period, the phytoplankton density ranged from 28×10^5 to $4{,}500 \times 10^5$ cell L^{-1}. The phytoplankton abundance was recorded at the river, inlet, middle and outlet lake. The highest relative abundance percentage was recorded for the species: *Synedra* sp. (9.35%), *Strombomonas* sp. (8.46%), *Euglena* sp. (6.80%), *Lepocinclis* sp. (4.65%), *Navicula* sp. (3.40%), *Spirogyra* sp. (3.38%) and *Achnanthes* sp. (2.96%). *Synedra* sp. was the dominant species (9.35%). Meanwhile, *Monoraphidium* sp., *Netrium* sp., *Ulothrix* sp., *Micrasterias* sp., *Sphaerosome* sp., *Diatomella* sp., *Amphora* sp. and *Cymatopleura* sp. recorded the lowest dominance (0.426%). The T-test ($p<0.05$) of the class showed no significant differences in the time of sampling sites.

The density of phytoplankton in Lutan Lake varied greatly between the rainy and dry seasons. In the rainy season, the average density of phytoplankton was 443.67×10^5 cell L^{-1}. The density varied greatly between the different sampling sites. The density of phytoplankton cells around the inlet and in the middle of the lake was higher than at any other site. Meanwhile, in the dry season, the average density of phytoplankton 838.62×10^5 cell L^{-1}, with the highest abundance in the inlet of the lake (St 2, Figure 2).

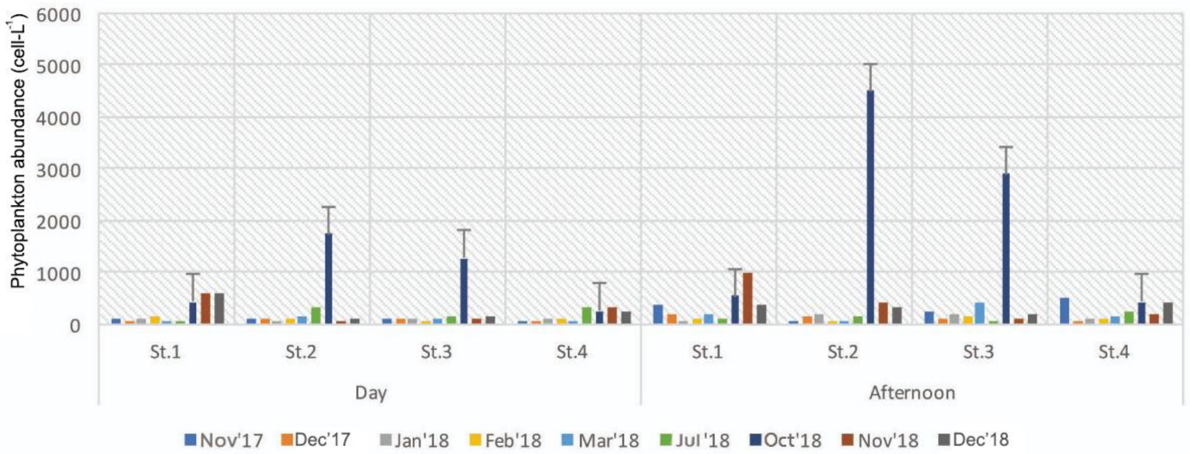

Figure 2. Temporal variation of phytoplankton´s total density in Lutan Lake (November 2017–December 2018).

The fluctuations in the biodiversity index values of the phytoplankton, in the Lutan Lake samples taken during the day (a) and afternoon (b), are shown in Figure 3. The Shannon index of phytoplankton ranged from 0.56 to 2.33 and the uniformity index of phytoplankton ranged from 0 to 1. The Shannon index for the middle of the Lutan Lake was the highest (2.33) at the end of the rainy season (March 2018) and the richness index was 2.15; the Shannon index for the Site 1 was the highest (2.82), and the uniformity index was 0.975. The space distribution tendencies of the Shannon index and of the uniformity index were consistent. In the dry season, especially in July and October 2018, the Shannon index of phytoplankton was ranged from 0 to 1.67. During the dry season, the highest diversity was recorded in the outlet and the lowest in the middle of the lake. The space distribution tendency of the Shannon index and of the species richness index were consistent. The lowest uniformity index of the phytoplankton during the dry season was recorded in the middle of the lake, with a value around 0.283.

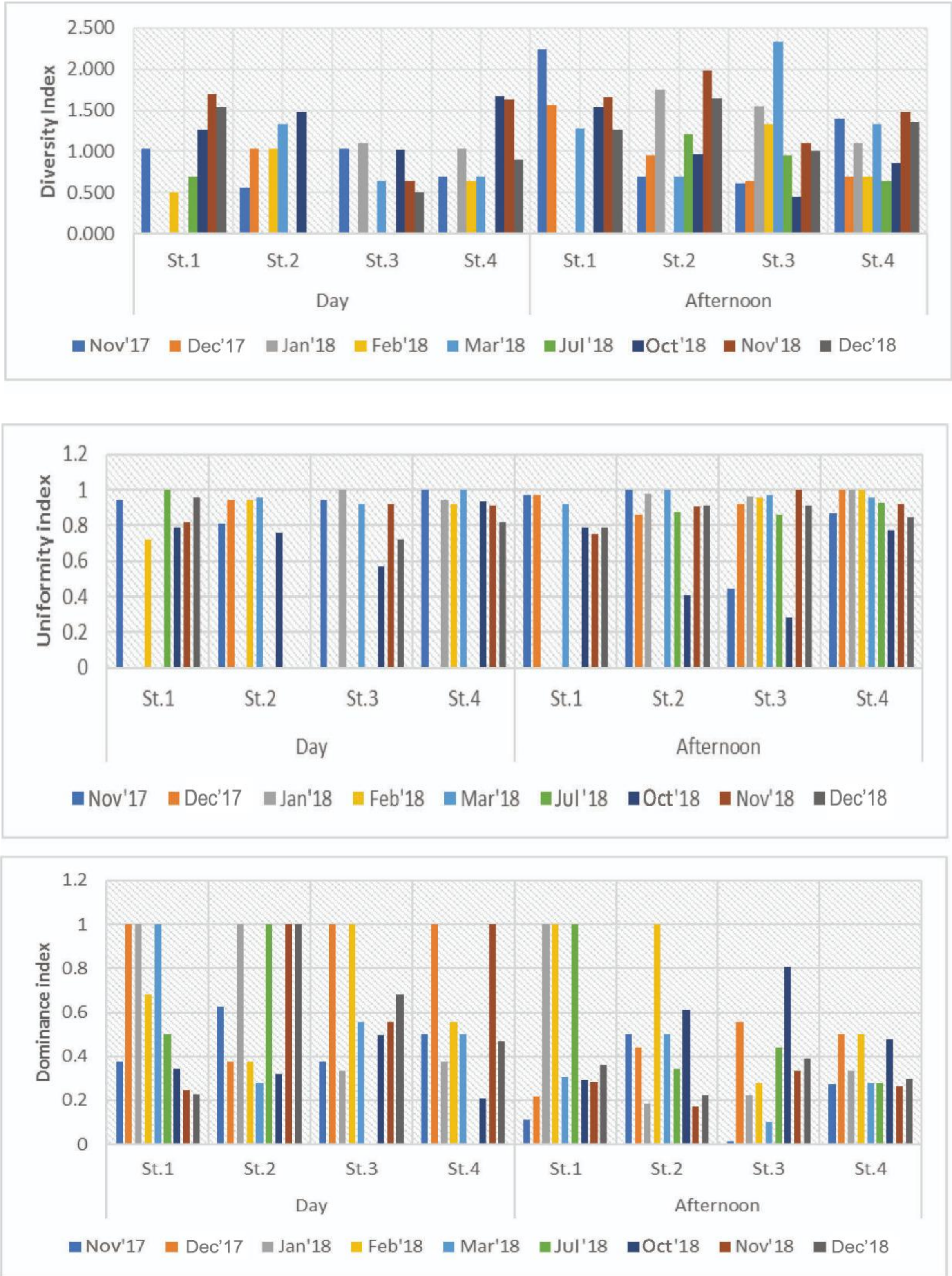

Figure 3. Biodiversity index of the phytoplankton in different sampling sites in Lutan Lake in the morning and in the afternoon.

According to the results, in the Lutan Lake, there were more species of phytoplankton in the rainy season than in the dry season. And there were dominant species in a few site locations, indicating that the ecosystem wasn’t stable. The lowest dominance index around 0.015 represented the Middle of the lake around November 2017. Chlorophyta and Cyanophyta dominated the community in both seasons. Based on ANOVA and Tukey statistical tests, there were no significant differences ($p<0.05$) between diversities in the samples.

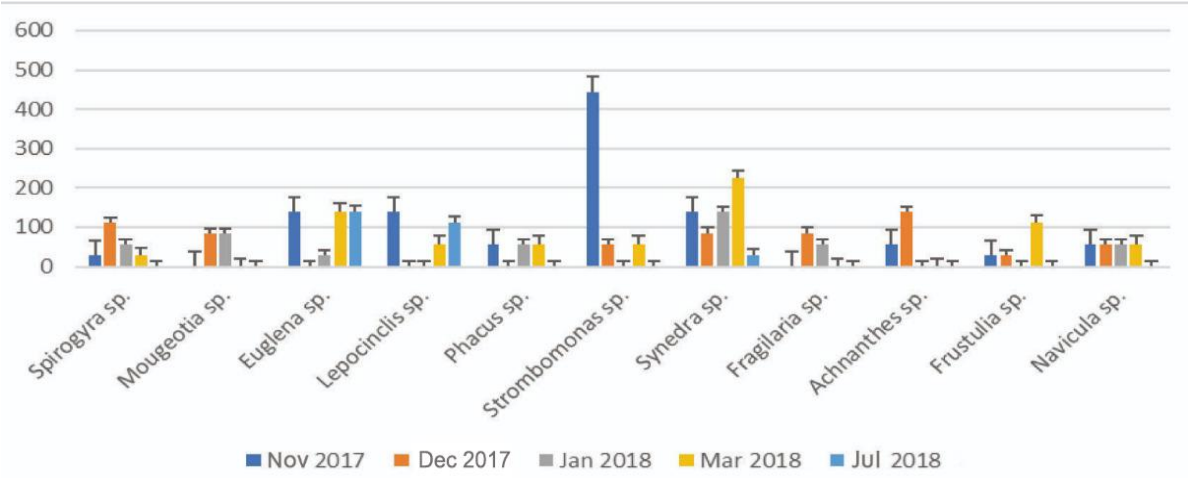

Figure 4. Temporal variations of the abundance and species frequency of phytoplankton at Lutan Lake (November 2017–July 2018).

The abundance decrease is mainly the result of the decline of the most abundant species. The abundance of the *Strombomonas* sp*.* population had large peaks in November 2017 and March 2018 (the beginning and the end of the rainy season) and then it presented small peaks in Jan and July 2018. *Fragilaria* sp. was abundant only in December 2018 (Figure 4). *Synedra* sp. and *Euglena* sp. were frequently abundant every month, but the largest peaks were observed in March 2018 and November 2017. Other species with low abundances remained constant or showed an increase in recent years. *Spirogyra* sp*.*, *Achnanthes* sp*.*, *Frustulia* sp. showed this behavior: these species were abundant from December 2017 to March 2018, with several abundance peaks. Meanwhile, *Navicula* sp. remained constant. Diatoms were present throughout the year, with a great abundance during the rainy season. A decrease was observed in the class during the dry periods. Bacillariophyta had its highest mean monthly distribution in November 2017 and the lowest in July 2018.

Generally, the DCA performed for the Lutan Lake distinguished the period of November 2017 to July 2018 (Figure 5). After the seasonal change, there was a shift in the phytoplankton composition, mainly an increase in the frequency of Chlorophyceae and diatoms, such as Euglena, Strombomonas and Chodatella, during November (beginning of the rainy season). In a previous study, *Euglena* sp. and *Strombomonas* sp*.* occurred in all fishponds, during the rainy season (Tavares et al 2010).

Meanwhile, *Eunotia* sp. and *Strombomonas* sp. can be found during the dry and rainy seasons (Trang et al 2019). The presence of Euglenophyceae indicates the period of input of organic material from the surrounding vegetation near the lakes into the aquatic environment, during the rainy periods (Bortolini & Bueno 2013). Chlorophyta exhibits a surprising level of nutritional variation. Results showed that the phytoplankton (e.g. the Euglenoidae species) density was at its maximum during the dry season, which was March-July 2018. *Tracelomonas* sp. indicated freshwater and was often found in peaty pools and other habitats, being a a cosmopolitan species. Light and temperature are the fundamental conditions for the phytoplankton growth, because they need light to convert energy, as primary producers of the aquatic environment (Mercurio et al 2016). During December 2017, *Spirogyra* sp., *Fragilaria* sp. and *Mougeotia* sp. gradually increased in the diatom biomass under rising water levels. It likely indicated a better adaptation to a heterogeneous and structured environment and more nutrient inputs due to higher freshwater levels during rainfalls (Whitmore et al 2018; Dai et al 2018).

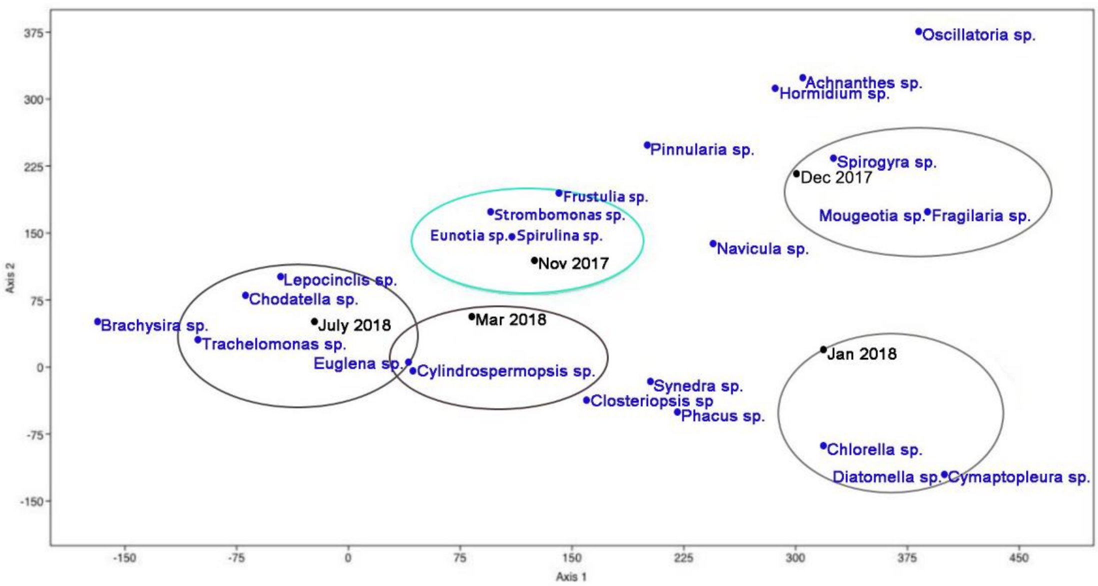

Figure 5. Detrended corespondence analysis phytoplankton in Lutan Lake.

Table 1

Pearson correlation of physical and chemical parameters

Parameters	*Temp*	*Clarity*	*Depth*	*Turbidity*	*DO*	*pH*	*Nitrate*	*Ammonia*	*Phosphate*
Temp		-0.41	0.30	0.22	-0.034	0.26	0.10	-0.29	-0.03
Clarity	-0.41		-0.06	-0.43	-0.02	-0.25	-0.16	0.17	-0.12
Depth	0.30	-0.06		-0.19	-0.36	-0.18	-0.10	-0.26	0.087
Turbidity	0.22	-0.43	-0.19		-0.01	0.50	0.34	-0.09	-0.13
DO	-0.03	-0.02	-0.36	-0.01		-0.014	0.14	0.48	0.46
pH	0.26	-0.25	-0.18	0.50	-0.01		-0.14	-0.32	-0.28
Nitrate	0.10	-0.16	-0.10	0.34	0.14	-0.14		0.58	0.40
Ammonia	-0.29	0.17	-0.26	-0.09	0.48	-0.32	0.58		0.78
Phosphate	-0.03	-0.12	0.08	-0.13	0.46	-0.28	0.40	0.78	

Pearson's correlation analysis was conducted to reveal the relationships between the environmental parameters in Lutan Lake. Based on the Pearson analysis, phosphate and ammonia have a significantly positive correlation (0.78), nitrate and ammonia (0.58), nitrate and phosphate (0.4). DO has a relative strong correlation with ammonia (0.48), with phosphate (0.46). pH has correlated with turbidity (0.5). High negative correlations occur between temperature and clarity (-0.41), turbidity and clarity (-0.43). An increase in ammonia influenced by increases in DO (Erisman 2021).

Based on the result, the difference of phytoplankton composition is obtained from a combination of physical conditions and water chemistry, affecting the floating mechanism, because plankton can migrate vertically, causing distribution fluctuations. High nutrient concentration increase phytoplankton population and some condition when the organic content too hight able to reduced DO (Bosman et al 2021).

The density of phytoplankton and the dominant species can indicate the eutrophication degree of certain water. According to this research, Cyanophyta and Chlorophyta became dominant in the phytoplankton community, which may be caused by the increased organic matter originating from industrial wastewater and domestic sewage effluents discharging into Lutan Lake. Phytoplankton has an important role inaquatic ecosysytem due to their fast responds to changes (Soeprobowati et al 2021). Phytoplanktons require nutrients such as nitrate, phosphate, some phytoplanktons can fix nitrogen and can grow in areas where nitrate concentrations are low (Kumar et al 2020).

Conclusions. In general, the phytoplankton composition in the rainy season was higher than in the dry season. In contrast, a one-way ANOVA test showed that the phytoplankton compositions were not significantly different ($p>0.05$). Furthermore, phytoplankton densities were not significantly different each month, but only between the rainy and dry seasons. The current study confirmed that plankton had different responses to variations in the water quality, based on the biodiversity index. Changes in the phytoplankton community in Lutan Lake are mainly associated with specific lake conditions, such as ammonia and phosphate concentrations. In order to analyze phytoplankton variations in tropical lakes, it is necessary to have data from several years, since changes in the conditions of each lake are generally subtle and occur slowly.

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Conflict of interest. The authors declare no conflict of interest.

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