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Comparison of temporal and spatial variation of periphytic algal community in two urban lakes in Umuarama-PR (Brazil)

Termoterapia via calor seco para o tratamento de sementes de cártamo

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ABSTRACT

Water resources are very important for all living organisms, and as being of vital importance need to be preserved. Thus, many water bodies are monitored as an essential strategy for identification of possible alterations over space and time. The analyses were performed in two different hydrological conditions, and water sample and rocks were collected in two different points at each lake. The results showed higher values of Ammoniacal Nitrogen in Aratimbó Lake, mainly during dry period (Ammoniacal Nitrogen = 4.2 mgL-1) at P1. However, P2 at Tucuruvi Lake presented higher concentration of Orthophosphate (2.24 mgL-1). Total Periphyton density also demonstrated variation among the different hydrological scenarios and lakes. The Highest density was of 385.30 10^3 ind.cm-2 at Aratimbó Lake and 180.43 10^3 ind.cm-2 at Tucuruvi Lake in rainy condition. Comparing the predominance of species, In Aratimbó Lake, Chlorophyceae class was predominant at P1, while Cyanophyceae class was predominant at P2. In dry period, Bacillarophyceae class was seen as the predominant class for both of lakes and for all sampling points. Differently from Aratimbó Lake, in Tucuruvi Lake Bacillarophyceae class was predominant in both of hydrological scenarios.

Keywords: Periphyton; Ammoniacal Nitrogen; Urbanization

1 INTRODUCTION

The water availability of good quality is a limiting factor for the development of any known life form. Moreover, this important natural resource is a decisive element

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for human economic and social progress (SCHWARZENBACH *et al.*, 2010). Water quantity and quality are the result of a number of natural factors such as runoff, infiltration, precipitation, temperature. And also several anthropogenic factors such as landscape changes, wastewater (domestic and industrial), pesticide application, and others. (AL-SHAMIi *et a*l., 2011). It is reasonable to consider that management strategies need to be employed to improve the way man uses natural resources, as improper use impacts on the quality of available water (PURMALIS *et al*., 2019).

Sustainable use of a resource requires first assessment of the water body, revealing qualitative and quantitative aspects of the system. For this, different techniques used in water quality monitoring programs are employed, the most used taking into consideration physicochemical parameters (MANJARE *et al.*, 2010). However, there is a certain weakness for these measurements, as they do not provide sufficient information about aquatic ecology and its relationship with environmental changes, as they are sensitive parameters to changes in spatiotemporal scales (DEBELS *et al.*, 2005).

An alternative to evaluate and monitor water quality that supplies the scalar limitations of physicochemical parameters is the use of bioindicators. These are living organisms that spend their life, or part of it, in contact with the aquatic environment, or that use the resources present there, directly or indirectly (GORMAN *et al*., 2017). The main groups of organisms used as quality bioindicators of aquatic ecosystems include: plants, plankton, macroinvertebrates and fishes (ILIOPOULOU-GEORGUDAKI *et al.*, 2003; RIZO-PATRÓN V *et al*., 2013). Thus, the use of these organisms has been linked to physical and chemical parameters to detect changes in ecosystem quality in an integrated manner.

An organism complex has been widely used to evaluate water quality, the so-called periphyton. This is a biofilm composed of a diversity of living organisms of different classes such as: algae, cyanobacteria, heterotrophic microbes, small crustaceans, rotifers, protozoa; as well as inorganic material such as suspended colloids, which aid fixation on submerged surfaces in most aquatic ecosystems.

Periphyton has an important ecological function occupying a relevant portion of the trophic web base in aquatic environments (DENICOLA & KELLY, 2014; KLUIJVER *et al.*, 2015). Another important factor is that the biofilm formed by the peritonitis acts as a retainer of contaminants, removing them from water and restricting their free movement through the environment, especially phosphorus, nitrogen and potassium (DODDS, 2003). Even the control of cyanobacteria's blooms has been found, by the allelopathic processes (WU *et al*., 2011).

As a bioindicator of water quality, periphyton also stands out because the responses of the organisms to pollutants can be measured at a variety of scales, representing changes from physiological to functional at the community level. The detection of anthropogenic changes (ZEBEK, 2013), such as simple turbidity increase, can affect the composition of the periphyton community, causing detachment of substrates in which it lives. According to the United States Environmental Protection Agency (U.S. EPA) (1999) periphyton serves as an indicator of water quality as it has certain characteristics for bioindication, such as: (1) Possessing a naturally high number of species; (2) Has a quick response to changes; (3) Easy sampling; and (4) Present tolerance levels and sensitivity to changes.

Considering the importance of water quality and the maintenance of aquatic ecosystems, as well as the importance of applying methods of assessment and monitoring of water bodies by different sampling methods. This research aimed to evaluate the water quality of two urban lakes located in Umuarama-PR, through physicochemical analysis as well as to verify the spatial and temporal variation of periphytic community in different climatic and hydrological condition. In addition, the study also aimed to answer the following questions: Is there difference among periphytic algal community class predominance in different hydrological conditions from Aratimbó Lake to Tucuruvi Lake? Is there difference of water quality among the Lakes?

2 MATERIAL AND METHODS

2.1 STUDY AREA

This research was conduct in two lakes located in the city of Umuarama, Paraná (Brazil). The municipality of Umuarama locates at northwest region of Paraná state, with a territorial area of 1.227,425 km² (BOTARI et al., 2016). According to IBGE (2019) the population of Umuarama is of 111.557 habitants. The Urban area of Umuarama is among the following coordinates: 23°47’55” S de latitude e 53°18’48” W de longitude. Altitude range from 340 to 500 meters (FRANÇA JUNIOR; VILLA, 2013).

According to classification of Koeppen (1948), region of Umuarama presents mesothermic humid subtropical climate (Cfa). Summer months are warm with precipitation and without definite dry season. The annual mean precipitation is about 1.500 mm. Rainy season is among October and January while dry season is among July and August (CUNHA et al., 1999).

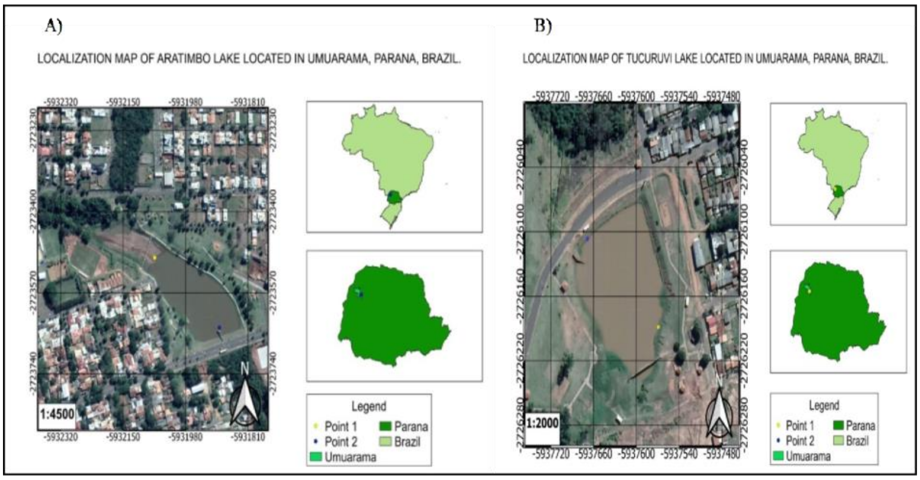
Aratimbó Lake is an important recreational and touristic point in Umuarama. Firstly, this artificial water body was created to recover degraded areas due to the erosive process and to be a great landscaping and leisure area (CAETANO et al., 2011; TAKEDA et al., 2011). Total area of Lake Aratimbó is approximately of 30.000m² (CAETANO et al., 2011). In addition, this water body has also been area of study for water quality (CAETANO et al., 2011; TAKEDA et al., 2011) and verification of presence of metal contamination in the water (CONSALTER et al., 2019),

Figure 1A shows the location map of Aratimbó Lake in Umuarama with the sample points. Point 1 (P1) is located in the initial part of lake, where receive input of a stream. In addition, this point looks like to be most influenced on land use by residences. Point 2 is located close to the street, and it is far away from the input of the stream.

Tucuruvi Lake is another lentic water body located in the city of Umuarama. This lake is smaller compared to Aratimbó Lake and also present problem with erosion and siltation. Due to its geographic position Tucuruvi Lake receives rainwater of several neighborhoods located above the water body.

Figure 1B also shows the location map of Tucuruvi lake in Umuarama with the sample points. P1 is located in a region with presence of macrophytes and closer to residences area. Point 2 is located close to the street and on the side of this point there is a small spillway to control water level in this lake during high amount of precipitation.

Figure 1 – Location of Aratimbó Lake and Tucuruvi Lake



On left is the map from Aratimbó Lake. On right is the map from Tucuruvi Lake
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2.2 Sampling and variables analyzed

The research was performed collecting water sample and substrate in the littoral zone of two points (P1 and P2) for Aratimbó Lake and Tucuruvi Lake in June/2019 (1, Figure 3A) and August/2019 (2, Figure 3A). Water was collected in the surface using polyethylene flasks with capacity of approximately 300 mL. Substrate (rocks) was also preserved in polyethylene flasks (Figure 4A), however, with capacity of 1000mL. The samples were preserved in thermal box. The water quality parameters were analyzed at the same day of collect, while periphyton analyzes after collect day.

Rainfall data (Figure 2) were obtained from the Paraná Water Institute (AP, 2020). Collect in June (1) was done with a total precipitation of 34. 7 mm before the campaign, while August (2) there was no precipitation. Figure 3B shows the variation of precipitation amount in Umuarama along 2019.

Figure 2 – Precipitation (mm) in Umuarama in 2019

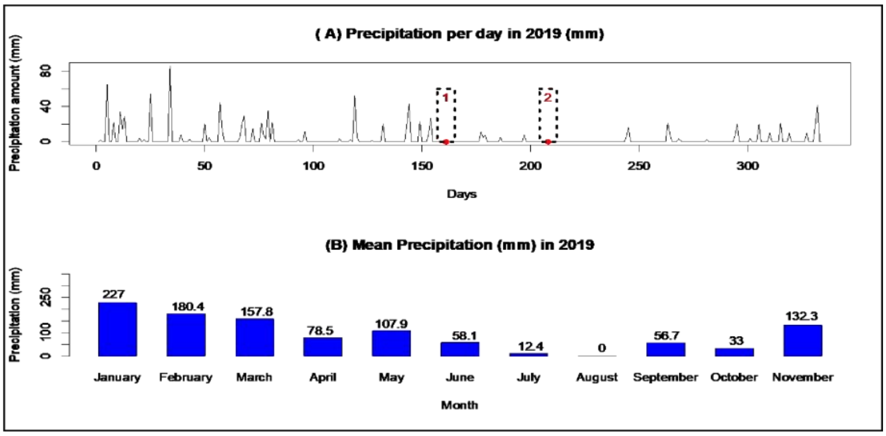

Figure 2A shows the daily precipitation along the year of 2019. Figure 2B shows the mean precipitation in Umuarama in 2019
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Measurements of water temperature (°C) and electrical conductivity (µS /cm) was obtained with a conductivity meter (Tecnopon). pH was obtained using a pH meter (LUCA-210P, Lucadema). Turbidity was quantified using a turbidimeter (DLT-WV, Del lab). All equipment were previewed calibrated. Soluble Orthophosphate (P-PO_4^{3-}) was measured according to molybdovanadophosphoric acid method (APHA, 2005). It used a photocolorimeter (ALFAKIT/AT 10P) in the wavelength of 470nm. Ammoniacal Nitrogen (N-NH_4^+) was quantified according to indophenol-blue method (APHA, 2005). It used a photocolorimeter (ALFAKIT/AT 10P) in the wavelength of 640nm.

2.3 Periphytic Algal Community

Figure 3A shows the field and laboratory procedure performed at this study. For the analyses of species composition and periphyton density, it was collected one rock (epilithon) (Figure 3B) per point from each aquatic ecosystem in each month. After taken from lake bottom (depth = 15-30 centimeters), the substrate was put in polyethylene flasks until the scraping in the laboratory. After quantification analysis the results were processed and were plotted barplot using Software R (Figure 3C).

Periphytic microalgal material was removed from substrate (scraping area = 9cm²) with brush and jets of distilled water until complete a volume of 80mL in a glass beaker. The samples were not fixed. After the procedures of scraping the sample was stored in the darkness (fridge) before the quantitative and qualitative analyses. The analyzes were performed in three blades (triplicate, n=3).

Algal quantifications were performed by the adapted method of Lobo et al. (2016) using an optical microscope. The classification system adopted for level class followed by Van de Hoek et al. (1995), Bicudo and Menezes (2006), Cordeiro et al. (2017) for genus . For identification of periphytic community was used specialized literature for each class of microalgae (BICUDO; MENEZES, 2006).

Figure 3 – Analysis of periphytic community

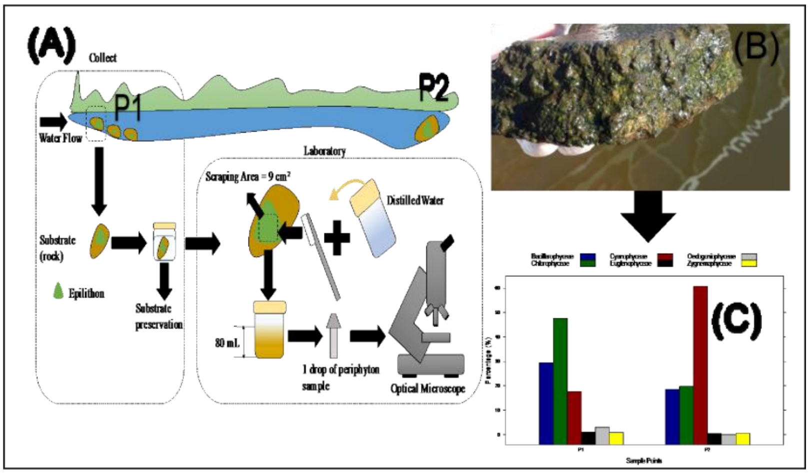

Fig.3A Laboratory and field procedures. Fig. 3B Substrate collected in the Lake Aratimbó. Fig. 3C Bar Graph to study the classes of microalgae in the periphytic community
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Periphyton density was calculated using the formula adapted from Gogoi et al. (2018). The number of individuals cells per cm² (N) is the result of division of the total number of periphyton units counted in a cover slip (P) multiplied by volume of final concentrate of the sample (C) by area of scraped surface (S) (N = (P*C) /S).

3 RESULTS AND DISCUSSION

3.1 Water Quality Parameters

Table 1 shows the water quality parameters for each campaign performed at Aratimbó Lake and Tucuruvi Lake. pH varied from slightly acid to alkaline. In general, Tucuruvi Lake presented higher pH values than Aratimbó Lake. The exception was at P2 in August (dry campaign). For both of lakes, pH was higher at P2. In addition, pH was lower during the collect with precipitation. Cordeiro et al. (2017) also found highest pH values in the dry period for three lentic environments. However, França et al. (2011) found mean pH values almost the same in dry (6.9) and rainy (7.1) season for an urban lake located in Rio Branco-AC.

Water Temperature varied from 19.25 to 24.5 °C, both of these results were seen at P1 in Aratimbó Lake. In Tucuruvi Lake the water temperature variation was from 20.56 to 22.5 °C. Temperature and light are factors that can control periphyton (CETTO et al., 2004). This physical parameter controls the chemical reactions, affects the fish growth, influence on dissolved oxygen concentration in the water, influence the process of photosynthesis by photosynthetic organisms in aquatic ecosystems (BHATERIA; JAIN, 2016). According to Bhateria and Jain (2016), exists an optimal temperature range for aquatic organisms. In addition, factors such as weather, alteration of stream bank vegetation, discharging of cooling waters, urban storm water might alter this parameter.

Conductivity ranged from 72.97 to 163.1 μScm^{-1}. The highest value was found at Lake Aratimbó (August-dry period) and the lowest value was found at Lake Tucuruvi (June-rainy period). Cordeiro et al. (2017) also found the highest conductivity values in dry period. Values of electrical conductivity in aquatic ecosystems could increase due to input of wastewater with concentrations of chloride, phosphate and nitrate (BHATHERIA; JAIN, 2016).

Highest values of N-NH_4^+concentration were seen at P1 in the Lake Aratimbó. At dry period the value of ammonium was more than double found in June for P1. However, at P2 in Lake Tucuruvi the highest value of ammonium was 0.41 mgL^{-1}. This nitrogen form could represent the indication of biochemical breakdown of organic nitrogen compounds (KANOWNIK et al., 2019). High concentrations of ammonium could indicate recent pollution. At the same region of P1, Caetano et al. (2006) found Biochemical Oxygen Demand Concentration (BOD) of 15.10 mgO_2L^{-1}. Takeda et al. (2011) also analyzed BOD in Lake Aratimbó and the maximum value was of 5.56 mgO_2L^{-1}.

Orthophosphate concentration was higher in dry period. This trend was also seen by França et. al (2011) when they found highest mean total phosphate concentration in dry season when compared to rainy season. Nitrogen and phosphorous are limiting nutrients for periphyton (CETTO et al.; 2004). High concentrations of phosphorous in water bodies can accelerate the plant growth, microalgae blooms, decrease in the concentration of dissolved oxygen (BHATHERIA; JAIN, 2016). In June at Tucuruvi Lake the concentrations were very low. The highest concentration of orthophosphate was 4.7 mgL^{-1} at P1 in August.

Table 1 – Nutrients and Water quality parameters results

Parameter	**Aratimbó Lake**				**Tucuruvi Lake**			
	P1		P2		P1		P2	
	June (J)	August (A)	June	August (A)	June	August (A)	June	August (A)
pH	6.50	7.40	7.17	8.35	7.25	7.76	7.50	7.74

Turbidity (NTU)	12.63	20.5	8.53	10	15.63	23.2	32.70	22.6
Conductivity (µS /cm)	121.86	163.1	111.50	153.1	75.38	88.67	72.97	88.01
Temperature (°C)	19.25	24.5	19.68	24.2	20.56	22.5	21.06	21.8
Ammoniacal Nitrogen (mg/L)	2.23	4.7	1.25	1.19	1.06	0.20	0.18	0.41
Orthophosphate (mg/L)	1.22	1.42	1.43	1.74	< DL*	1.22	< DL	2.24

* Detection Limit (DL)
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3.2 Microalgae Composition

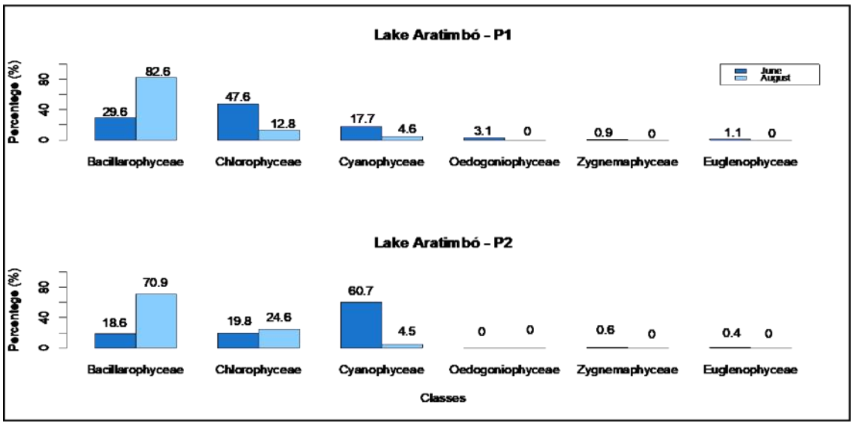
Figure 4 shows the percentage for each class of microalgae seen in the two different campaigns performed at Aratimbó Lake. The mean result of Bacillariophyceae class was higher compared to other classes. It could be explained due to their specific characteristics, in which influence on their fixation and developing on substrates. According to Cetto et al. (2004), diatoms are considered as efficient and fast colonizers due to some species possess specialized structures to fixate on substrates, production of gelatinous matrices and colony formation. The results of Adame, Dunck and Rodrigues (2018) showed predominance of diatoms (Bacillarophyceae class) in all environment over time, proving that diatoms presents high tolerance to seasonal changes as well as hydrological regime.

Although Bacillariophyceae was also seen in rainy period, this class was not the main class during collect with precipitation. Thus, in June with high precipitation amount there was a decrease in the percentage of Bacillariophyceae. According to Cetto et al. (2004), rainy and warmer period (as seen in August) can affect the velocity of sucessional process of periphyton. It could probably influence on quantity and qualitative aspects of periphytic community as seen in the current results. Cordeiro et al. (2017) found highest densities of Bacillarophyceae in the dry period.

Chlorophyceae was seen in higher quantity at P1 at rainy period. Their decrease in composition percentage could be explained due the high percentage of Cyanophyceae at P2 in the same period. Cyanophyceae are extremely competitive in relation to other groups of algae (CORDEIRO, et al., 2017), where environmental factors could favor the appearance and predominance of Cyanobacteria such as certain conditions of luminosity, temperature and pH (FERNANDES et al., 2009). According to Fernandes et al. (2009), the factors that favor the developing of a specie could not be the same for other species. Moreover, Cordeiro et al. (2017) found Chlorophyceae and Cyanophyceae in higher density during rainy period.

Oedogoniophyceae, Zygnemaphyceae and Euglenophyceae were just seen during rainy collect, where Oedogoniophyceae was seen only at P1. According to Silva et al. (2018) Zygnemaphyceae algae are aquatic organisms typical from freshwater with low orthophosphate concentration such oligo-mesotrophic environment. These environment presents orthophosphate concentration to up 5 (µg L^{-1}) (BELLINGER; SIGEE, 2010). In eutrophic systems, the literature has shown relative low contribution of Zygnemaphyceae to total biomass of algae (SILVA et al., 2018).

Figure 4 – Percentage distribution of different classes of periphytic community at two points at Lake Aratimbó under two different hydrological scenarios



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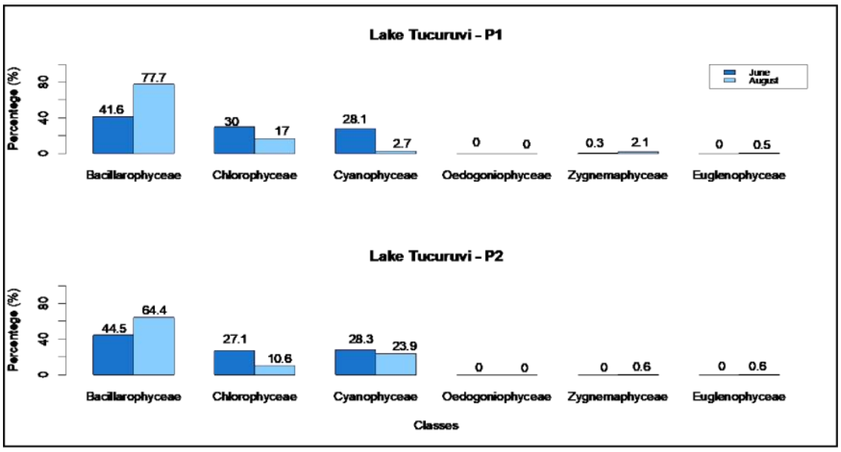
As well as in Aratimbó Lake, the Baccilarophyceae class was dominant in the periphyton composition for the both of sample points at Tucuruvi Lake (Figure 5). In addition, It is also seen the same behavior for Cyanophyceae, where in the collect with precipitation there was a higher percentage compared to dry period. However, different from Aratimbó Lake at this lentic environment there was predominance of Bacillarophyceae in the rainy period.

Although, Oedogoniophyceae are typically periphytic and are also efficient competitors for environment resources such as light and space, it was not seen at this lake. Still, this algae are related to high concentrations of nutrients and electrical conductivity (BICHOFF, et al., 2016). Oedogoniophyceae was only seen at P1 in Aratimbó lake. At this collect, electrical conductivity was 121.86 μS cm^{-1} and concentration of ammoniacal nitrogen and orthophosphate were 2.23 and 1.22 mgL^{-1} respectively. All this results were not the highest value found for this parameters. Differently from Aratimbó Lake it was seen Zygnemaphyceae in dry period (2.1%). Euglenophyceae appeared just in dry period with maximum percentage of 0.6%.

Figure 5 – Figure 6. Percentage distribution of different classes of periphytic community at two points at Lake Tucuruvi under two different hydrological scenarios



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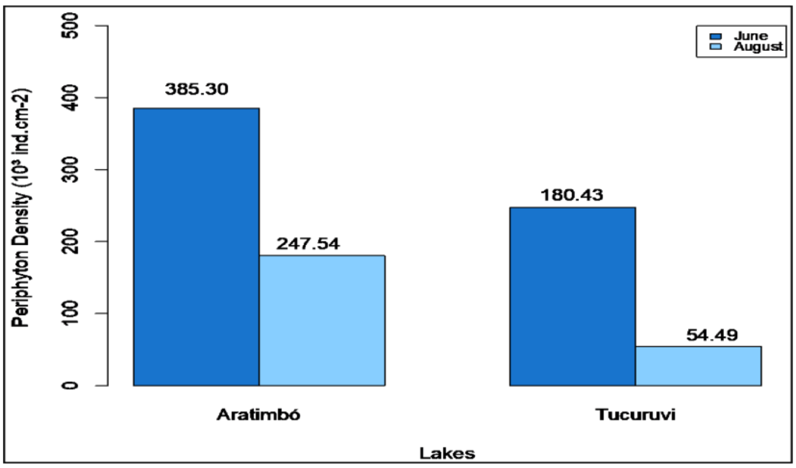
In addition, species richness could also be affected most probably for difference of morphometric characteristics of each lake. According to Rodrigues and Bicudo (2001), morphometric characteristics also influence on development of aquatic macrophytes and also allows the development of both firmly or loosely attached forms.

3.3 Periphyton density

Figure 6 shows the mean periphyton density for each lakes. For both of lakes, the total density of periphytic algae increased in the rainy month. Cordeiro et al. (2017), also found total density higher in rainy period compared to dry period. Comparing to water quality values, the density was higher with higher ammoniacal nitrogen (exception was for P1 in august at Aratimbó and P2 at Tucuruvi Lake) concentration and lower orthophosphate concentration. According to Cetto et al. (2004), nitrogen and phosphorous are the main limiting nutrients for periphyton and there is an ideal proportion of nitrogen per phosphorous, in which could influence on periphyton density. In addition, the high periphyton density with low orthophosphate concentration could indicate the consumption by these organisms. According to results of Rooney et al. (2020), periphyton could play another important service in aquatic ecosystems, they purify water taking up chemical substances present in water such as pesticides. Thus, there was a decrease of 35% of Periphyton Density in relation to rainy month for Aratimbó Lake and approximately 70% for Tucuruvi Lake.

Figure 6 – Mean Periphyton Density for Aratimbó Lake and Tucuruvi Lake in June and August



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Periphyton density was calculated (Table 2 - Aratimbó Lake, Table 3 - Tucuruvi Lake) to identify variation in the community of algae in different hydrological conditions. In Aratimbó Lake, the different scenarios showed variation of predominant class for each point. At P1 in the period with precipitation, Chlorophyceae class was found in higher density, while in the dry period Bacillariophyceae was the main class in the periphytic community. These results were similar with results found by Cordeiro et al. (2017). The authors also found highest densities of Bacillariophyceae in dry period and increase of cyanobacteria and chlorophytes in the rainy period. In addition, in dry period at P1 was not found members of Oedogoniophyceae, Zygnemaphyceae and Euglenophyceae classes.

At P2, the highest density was of Cyanophyceae class during the collect with precipitation, and Bacillariophyceae class in the dry period. Silva et al. (2018) found higher density contribution due to Cyanobacteria class using Epilithon as substrate in urban eutrophic ponds. Oedogoniophyceae Class was just seen at P1 in the period with precipitation. Results from Cordeito et al. (2017) also showed low representability and higher density of Oedogoniophyceae class in rainy period.

In Aratimbó Lake, Zygnemaphyceae class was found just in the collect with precipitation, with density of 2.66 10^3 ind.cm^{-2}. This result is similar among the results seen by Silva et. al (2018), where the authors studied nine eutrophic urban ponds located in Goiania and they found a range mean from 0.412 to 18.12 10^3 ind.cm^{-2} of Zygnemaphyceae class.

Table 2 – Periphyton density at Aratimbó Lake

Classes	**Density (10^3 ind.cm^{-2}) - Aratimbó Lake**			
	P1		P2	
	June	August	June	August
Bacillariophyceae	92.44	149.03	85.33	128.00
Chlorophyceae	148.44	22.81	90.66	44.74

Cyanophyceae	55.11	8.29	278.22	7.70
Oedogoniophyceae	9.77	-	-	-
Zygnemaphyceae	2.66	-	2.66	-
Euglenophyceae	3.55	-	1.77	0.29

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In Tucuruvi Lake, there was smaller periphyton density than Aratimbó Lake, in which could be due to difference of morphometric characteristics of each lake, characteristics of each substrate collected and nutrients availability in each water body. In addition, Tucuruvi Lake presented in all campaigns, for the both of points the predominance of Bacillariophyceae class. In addition, the density of Chlorophyceae class was seen higher in June (collect with precipitation) as seen in Aratimbó Lake. However, it was not seen any individual from Oedogoniophyceae class (Table 3).

Table 3 – Periphyton density at Tucuruvi Lake

Classes	**Density (10^3 ind.cm^{-2}) - Tucuruvi Lake**			
	P1		P2	
	June	August	June	August
Bacillariophyceae	114.67	43.25	97.77	34.37
Chlorophyceae	82.66	9.48	59.55	5.62
Cyanophyceae	77.33	1.48	62.22	12.74
Oedogoniophyceae	-	-	-	-
Zygnemaphyceae	0.88	1.18	-	0.29
Euglenophyceae	-	0.29	-	0.29

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4 CONCLUSIONS

Concerning about water quality parameters the water bodies presented high values of nutrients such as Ammoniacal Nitrogen and Orthophosphate, mainly during in the dry period, where there was the highest value of Ammoniacal Nitrogen in Aratimbó Lake, in which is a larger lake compared to Tucuruvi lake and it is very sensible of urbanization influence. In addition, the water quality parameters were influenced by climatic and hydrological condition, for instance, pH was higher during the warmer campaign with no precipitation. Conductivity also increased with increase of temperature during the dry period. Complementarily, the periphytic algal community also varied along the water bodies for each collect. Total periphyton density showed higher values during the rainy campaign where there was predominance of different classes for each point and each lake. In Aratimbó Lake, Chlorophyceae class was predominant at P1, while Cyanophyceae class was predominant at P2. In dry period, Bacillarophyceae class was seen as the predominant class for both of lakes and for all sampling points. Differently from Aratimbó Lake, in Tucuruvi Lake Bacillarophyceae class was predominant in both of hydrological scenarios. Therefore, these two urban lakes, although located in the same city, presented different values of water quality parameters as well as periphyton composition and quantity, in which demonstrates that there are a lot of variables that play important roles in the quality of an aquatic ecosystem as well in the composition and quantity of periphytic algal individuals.

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