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Research Article

Algal Blooms and their Importance in Xochimilco and San Gregorio Atlapulco, Mexico

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Abstract

Algal blooms refer to the massive development of photosynthetic microorganisms in aquatic environments. Microalgae are an important source of food for the primary consumers of these ecosystems, purify water, capture atmospheric CO2 and from them a large number of products for industrial use are obtained; however, in Mexico its study is still incipient, especially with regard to blooms of freshwater species. This paper presents the results obtained from the most abundant and important algal blooms of the Ejidos de Xochimilco and San Gregorio Atlapulco Protected Natural Area. 12 samplings were carried out between the years 2012 to 2022. The samples were collected with 54 µm mesh aperture trawl and van Dorn bottle and were fixed with 4% final formalin and 1% lugol, respectively. 17 algal blooms were recorded, among the Cyanoprokaryotes are: *Anabaenopsis circularis, Limnospira maxima, Microcystis aeruginosa, Planktothrix agardhii; among the Chlorophytes Monoraphidium convolutum, Ankistrodesmus falcatus, Closterium acutum, Lemmermannia tetrapedia; among the Euglenophytes Euglena viridis y Phacus pleuronectes and between the Diatoms Cocconeis placentula var. placentula, Stephanocyclus meneghinianus, Epithemia turgida var. turgida, Gomphonema olivaceum, Gomphonema parvulum var. capitata, Hantzschia amphioxys y Craticula cuspidata. Of these species, Limnospira maxima has very high nutritional value, Anabaenopsis circularis, Microcystis aeruginosa y Planktothrix agardhii* are potentially toxic or carcinogenic. It should be noted that all the registered species presented great spatiotemporal variations, for the above and given their great importance, it is necessary to expand their knowledge and carry out constant monitoring, as a tool for their understanding, use and management.

Introduction

Algal blooms consist of the massive development of photosynthetic microorganisms in freshwater, brackish, and marine ecosystems. These organisms are the base of the zooplankton and fish food chains, which in turn are consumed by amphibians, mammals and birds, among others. Microalgae are also important because, by carrying out photosynthesis, they reduce the amount of nitrogenous and phosphate compounds in the water and capture atmospheric carbon to convert it into useful biomass, however, some species produce and accumulate toxins, as is the case of certain dinoflagellates and cyanobacteria, so their excessive increase, especially due to eutrophication processes of anthropic origin, can cause serious health problems both in animals and in humans who consume them or come into contact with the waters that contain them, therefore, to avoid their negative impact, it is necessary to know and monitor them periodically. In Mexico, the study and registration of freshwater microalgae began in 1843 and their knowledge has been growing slowly and isolated [1-6], in addition to this, little attention has been paid to the massive development of these microorganisms in this type of environment. Therefore, the objective of this work was to know the algae blooms of the Ejidos de Xochimilco and San Gregorio Atlapulco Protected Natural Area located in the southern area of the Valley of Mexico, for its proper use and management.

Methods and Materials

10 sampling stations distributed in the Polygon of the Ejidos de Xochimilco and San Gregorio Atlapulco Natural Protected Area (ANP-EXSGA) Mexico City were selected (Table 1), comprising 2 522 hectares, located at the geographic coordinates 19° 15' 11" and 19° 19 15" LN and 99° 00' 58" and 99° 07' 08" LW. The samples collection was carried out in the rainy and dry water season from 2012 to 2022. A van Dorn bottle and a phytoplankton trawl with a mesh opening of 54 µm were used for the collection of the samples. The samples were preserved with lugol 1% and formalin 4% respectively. The review was carried out using optical microscopes on 0.1 mL subsamples, based on the Utermöhl scanning technique [7]. Species were identified using specialized keys and descriptions. The updating of the names was done according to [8]. An inventory of the algae blooms of the Ejidos de Xochimilco and San Gregorio Atlapulco Protected Natural Area was carried out, indicating in some cases, their importance for man.

Table 1: Sampling stations in the Ejidos de Xochimilco and San Gregorio Atlapulco Natural Protected Area.

Stations	Coordinates
Treated wastewater dump, in San Gregorio Atlapulco	19° 15' 77" LN; 99° LW
Cuacontle Pier	19° 15' 65" LN; 99° 02' 54" LW
Puente de Urrutia	19° 15' 65" LN; 99° 04' 53" LW
South shore of Lake San Gregorio Atlapulco	19° 16' 07" LN; 99° 03' 48" LW
Lake San Gregorio Atlapulco Center	19° 16' 17" LN; 99° 03' 46" LW
Southeast shore of Lake San Gregorio Atlapulco	19° 16' 02" LN; 99° 03' 34" LW
East shore of Lake San Gregorio Atlapulco	19° 16' 25" LN; 99° 02' 80" LW
Canal de Apatlaco	19° 15' 77" LN; 99° 02' 28" LW
Canal de Japón	19° 16' 73" LN; 99° 04' 33" LW
Canal de Cuemanco	19° 16' 31" LN; 99° 06' 13" LW

Results and Discussion

390 species were recorded, of which 36 % belong to the Division Chlorophyta; 23 % to Euglenophyta; 23% to Chrysophyta (Class Bacillariophyceae); 14% to Cyanoprokaryote, 3% to Pyrrophyta and 1% to Chromophyta. 17 algal blooms were recognized for the study area (Table 2, Plate 1), in addition to indicating their maximum abundances, the seasons of the year in which they were observed and the years.

Table 2: Maximum abundances of the species registered in the Ejidos de Xochimilco and San Gregorio Atlapulco Natural Protected Area (ANP-EXSGA), Mexico City, as well as times and years in which they were observed.

Species	Abundance x 1000 Cél / mL	Season	Year
Gomphonema olivaceum var. capitata Jurilj 1954	310	Dry	2012
Microcystis aeruginosa (Kützing) Kützing 1846	9896	Dry	2012
Hantzschia amphioxys (Ehrenberg) Grunow 1880	290	Rain	2012
Planktothrix agardhii (Gomont) Anagnostidis & Komárek 1988	2450	Rain	2012
Gomphonema parvulum (Kützing) Kützing 1849	295	Rain	2012
Closterium acutum Brébisson 1848	520	Dry	2013
Craticula cuspidata (Kutzing) D.G. Mann 1990	540	Rain	2013
Monoraphidium convolutum (Corda) Komárková-Legnerová 1969	2544	Rain	2015
Euglena viridis (O. F. Müller) Ehrenberg 1830.	1425	Rain	2016
Cocconeis placentula var. placentula Ehrenberg 1838	700	Dry	2017
Stephanocyclus meneghinianus (Kützing) Kulikovskiy, Genkal & Kociolek 2022	1264	Dry	2017
Ankistrodesmus falcatus (Corda) Ralfs 1848	5490	Rain	2017
Anabaenopsis circularis (G.S.West) V. V. Miller 1923	4750	Rain	2018
Lemmermannia tetrapedia (Kirchner) Lemmermann 1904	340	Dry	2020
Epithemia turgida var. turgida (Ehrenberg) Kützing 1844	900	Rain	2021
Phacus pleuronectes (O. F. Müller) Nitzsch ex Dujardin 1841	1850	Rain	2021
Limnospira maxima (Setchell & N.L.Gardner) Nowicka-Krawczyk, Mühlsteinová & Hauer 2019	6666	Rain	2022

It is important to point out that most of the species are essential to maintain the balance and health of ecosystems, as part of the different trophic levels, and participate in the purification of contaminants of natural and anthropogenic origin, however the blooms of the cyanobacteria *Anabaenopsis circularis*, *Microcystis aeruginosa* and *Planktothrix agardhii* are potentially toxic or carcinogenic and tend to increase significantly with the constant processes of eutrophication of water bodies, as is the case of the Natural Protected Area Ejidos de Xochimilco and San Gregorio Atlapulco. On the other hand, the presence of the cyanobacterium *Limnospira maxima* was observed, which has a high nutritional and cultural value since it has been consumed by the human communities of Mesoamerica from pre-Hispanic times to the present day, this species only develops in the conservation lake of San Gregorio Atlapulco. The San Gregorio lagoon and the Cuemanco channel were the sites with the highest number of species, standing out the algal blooms of *Limnospira maxima* and *Microcystis aeruginosa* with 6666 x 10^3 and 9896 x10^3 cel/L respectively. Most algal blooms occurred in the rainy season (11 of 17), probably due to the resuspension and transport of nutrients due to rainfall. In 2012, the largest number of algae blooms (five) occurred, which may be due to the fact that there was a lot of contaminating pressure on the ecosystem due to poor water management (clandestine dumps, deficient water treatment in water treatment plants and overload of tourist activities), later improvements were observed in water treatment and probably due to the COVID 19 pandemic that reduced tourism in the area and allowed the partial recovery of the ecosystem [9].

The abundance of the species presented notable changes from one season to another and over the years, due to the large number of microenvironments in the ANP-EXSGA as well as natural seasonal and climatic changes and anthropic pressures. In this sense, the massive development of cyanobacteria is observed, which are indicators of eutrophication caused by the use of agrochemicals and sewage discharge. On the other hand, it should be noted that several of the registered species could not be identified at the species level because no records were found in the literature consulted, and they may be new species, but further studies are required. In other cases it was observed that some species have changed their name and taxonomic location due to the new contributions of molecular biology as a working tool. As an example of the above, it is observed that some species are still in the process of revision, such is the case of *Limnospira maxima* that some authors consider it as a synonym of Arthrospira maxima, formerly Spirulina maxima.

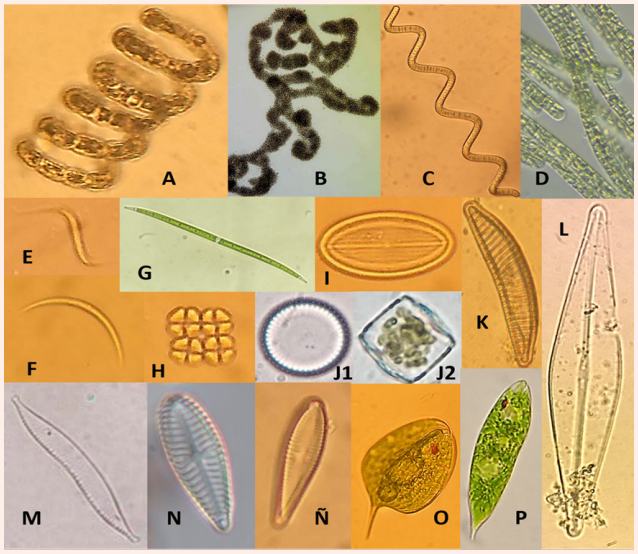

Figure: 1A) *Anabaenopsis circularis*, 1B) *Microcystis aeruginosa*, 1C) *Limnospira maxima*, 1D) *Planktothrix agardhii*, 1E) *Monoraphidium convolutum*, 1F) *Ankistrodesmus falcatus*, 1G) *Closterium acutum*, 1H) *Lemmermannia tetrapedia*, 1I) *Cocconeis placentula var. placentula*, 1J 1-2) *Stephanocyclus meneghinianus*, 1K) *Epithemia turgida* var. turgida, 1L) *Craticula cuspidata*, 1M) *Hantzschia amphioxys*, 1N) *Gomphonema parvulum*; 1Ñ) *Gomphonema olivaceum* var. *capitata*, 1O) *Phacus pleuronectes*, 1P) *Euglena viridis*.

Conclusions

17 algal blooms were recorded for the ANP-EXSGA, it is observed that the composition and abundance of microalgae is complex and diverse since the ecosystem presents great changes in space and time, which are reflected in the diversity of organisms and in the notable increase of extremophile species of beneficial cyanobacteria such as *Limnospira maxima* as well as harmful species such as *Anabaenopsis circularis*, *Microcystis aeruginosa* and Planktothrix agardhii. Due to the speed with which ecosystems are being modified, it is necessary to monitor them periodically to find patterns in the formation of algal blooms, for their proper use and management.

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