



Co-varying Environmental Conditions Control the Spatiotemporal Dynamics of *Microcystis aeruginosa* and *Botryococcus braunii* in a Freshwater Ecosystem

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NOZHA lake (South of Alexandria City, Egypt), an artificial freshwater basin, receives its water supply from the Nile River and from the surrounded urban area, which affect the ecological balance. Results during a year cycle (December 2017 to November 2018) revealed scums and dispersive blooms of *Microcystis aeruginosa* Kützing (Cyanophyta) and *Botryococcus braunii* Kützing (Chlorophyta), in no particular season, under a wide range of environmental conditions. *Microcystis aeruginosa* was a persistent form during the whole period, culminating in visible blooms in December, June, and September. The distinctive role of temperature was evidenced during the transient periods in spring and summer. The inorganic dissolved nitrate, ammonia, and phosphate might affect the variability in the community structure and abundance. Stoichiometric analyses indicated major potential nitrogen limitation (63.89% of the total observations), whereas 15.28% of the total observations were P limiting, and 20.83% of the total observations were either N or P limiting. Hence, the reduction of only one type of nutrients can lead to an imbalance in the ratio. The major bloom peaks of *M. aeruginosa* and *B. braunii* detected in June and September raised chlorophyll *a* content to its extreme values (16.5 and 21.8 mg L⁻¹, respectively). The blooms of *B. braunii* influenced the accompanied phytoplankton species diversity with different degrees to explain the interaction with eutrophic fast-growing *Chlorella vulgaris* green algae.

Keywords: Algal blooms, Freshwater ecosystem, Nozha lake.

Introduction

Lake eutrophication refers to the enrichment of nutrients that can lead to prominent symptoms as the increase of phytoplankton biomass and the occurrence of algal blooms (Tang et al., 2010) and algal toxins (Shi et al., 2008). In general, harmful algal blooms (HABs) cause undesirable changes in aquatic resources such as reduced water clarity, quality, hypoxia (dissolved oxygen below 2–4 mg L⁻¹), fish kills, loss of biodiversity, and an increase in nuisance species (Wolfe & Patz, 2002). The expected nitrogen (N) and phosphorous (P) concentrations in lakes and reservoirs as annual average in surface water (0.5m) indicate water quality. The annual average of total nitrogen and phosphorus can fluctuate between 0.07 and 1.00 mg L⁻¹ and between 0.005 and 0.1 mg L⁻¹ (website of Ministry of the Environment Government of Japan, <https://www.env.go.jp>).

Cyanobacteria and Chlorophyta blooms have adverse impacts on the environment and human health causing a variety of water quality problems in systems used for human activities, loss of biodiversity, integrity in food webs, and negative health effects on humans and animals (Codd et al., 2005), which commonly lead to a wide range of economic consequences (Berg & Sutula, 2015). Such blooms represent major challenges for the management of aquatic ecosystems. The blooms of *Microcystis* spp. (Chroococcales and Cyanobacteria) are common in freshwater bodies worldwide, and they are of great concern because of the production of microcystin toxins (Khairy & El-Sheekh, 2019). The genus *Botryococcus* (Trebouxiales and Chlorophyta) was cosmopolitan described (Ranga Rao et al., 2007; Demura et al., 2014). It has been widely known for its ability to produce and accumulate long-chain hydrocarbon, lipids, and polysaccharides (Metzger & Largeau, 2005). As a result of the production of lipids, *Botryococcus* may rise to the surface of water where

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they float in a thick layer depending on the growth conditions (Qin, 2005). In addition, the colonial green algae *B. braunii* has been considered as a good source of biofuels, and it converts 3% of solar energy into hydrocarbons and reduces CO₂ emissions up to 1.5×10^5 tons/year (Brennan & Owende, 2010). This species can produce allelopathic substances (a mixture of free fatty acids) that inhibit the growth of other phytoplankton species (Chiang et al., 2004). However, no study has reported that this species is toxic to aquatic organisms, and the occasionally occurred incidents of fish mortality (Papa et al., 2008) might be attributed to a variety of ways as the oxygen stress (Labib et al., 2014).

The available information on the phytoplankton dynamics in Nozha lake (Helal et al., 2020), particularly HABs (Labib et al., 2014), was insufficient to fully describe the threats to ecosystem services and function, which was among the decisive targets to conduct the current study. However, previous studies reported signs of eutrophication. The present study, which was operated during a year cycle, aims to reveal the major environmental factors affecting bloom developments of *M. aeruginosa* and *B. braunii* and the impact of these blooms on the co-occurred phytoplankton community.

Materials and Methods

Nozha lake is an artificial freshwater basin located at the south of Alexandria City (31°19'N, 29°57'E), which has an area of 5.5 km² and an average depth of 2.5–3.0m. This lake is used as a fish farm (200–250ton·y⁻¹). The lake receives its water supply from the Nile River via Mahmoudia Canal and through other minor sources from the surrounded urban area. Sampling was operated monthly from December 2017 to November 2018; however, the Nile water input ceased from July to September 2018 because of the ongoing operation of the infrastructure project. This study might

represent a part of the proposed survey to assess the ecosystem management of the lake, within the co-operation strategy between the National Institute of Oceanography and Fisheries and Al-Nozha fish farm (Helal et al., 2020).

Samples were collected before mid-day below the water surface at six sampling stations (Fig. 1). Water parameters *viz.* temperature, salinity, and alkalinity were measured in the sampling sites using the water physical parameter device HANA, Model HI 9828. Water samples were collected in a plastic bottle (1L), cleaned with diluted hydrochloric acid, and washed well with lake waters. Inorganic dissolved nutrient concentrations (NO₃⁻, NO₂⁻, NH₄⁺, and PO₄³⁻) were determined following the procedures of Parsons (1984). Chlorophyll *a* content (Chl. *a*) was measured on the basis of the method of Jeffrey & Humphrey (1975). Nutrient limitation was calculated on the basis of the resultant N:P ratios according to Forsberg & Ryding (1980). A ratio of N:P above 17 indicated P limitation, below 10 indicated N limitation, and between 10 and 17 indicated that either of these nutrients may be limiting. Living phytoplankton samples were first examined to identify species that could be morphologically affected by preservation using a light microscope connected with a digital camera system. Cell and colony sizes were measured using a ruler in one of the eyepieces. The water samples (1L) at each station were fixed by neutral formalin (4%), and a few drops of Lugol's acid solution were used for phytoplankton quantitative estimation by the sedimentation method (Utermöhl, 1958), followed by counting (Hasle, 1978). The average abundance (colony L⁻¹) was based on three replicates (2mL each). Reference consulted for the identification of the main groups included Needham & Needham (1962). Moreover, vertical hauls using a plankton net (20µm) were collected and preserved for further identification of other species that might be escaped from quantitative samples. Furthermore, abundance was expressed as cell L⁻¹.



Fig. 1. Nozha lake map showing sampling stations

Statistical analysis

Pearson correlation was applied to measure the existence (given by a P value) and strength (given by the coefficient *r* between -1 and +1) of a linear relationship between two variables. The results were tested at significance levels of 0.01 and 0.05 using the *P* test (Microsoft Excel, Version 2016).

Results

Physico-chemical characteristics of lake water

Lake water was characterized by distinct physical and chemical properties. Water temperature indicated clear seasonality and varied normally between a minimum in winter (16°C) and a maximum in summer (32°C). No distinct regional difference was observed among the stations during the same month. Early spring warming in March increased water temperature by approximately 3°C compared with late winter. Salinity exhibited no seasonal trends (mean 4.013±1.51 PSU). Values between 3 and 5 PSU represented the major fraction of the total measurements (50.6%). Salinity correlated significantly with temperature ($r=0.71$, $P<0.01$, $n=72$) and negatively with NO_2 ($r=-0.31$, $P>0.05$) and NO_3 ($r=-0.37$, $P>0.05$). The total nitrogen (Sum of NH_4 , NO_2 , and NO_3) exhibited relatively higher levels in winter (0.90±0.11mg L⁻¹), and it was lowest in early autumn (0.02mg L⁻¹), showing no particular seasonal trend. Nitrate represented the main component of N sources (71.8%), followed by almost equal sharing of NH_4 and NO_2 (12.6% and 15.6%, respectively). Spatiotemporal concentrations varied greatly,

particularly in March (0.16mg L⁻¹, St. VI; 2.3mg L⁻¹, St. III). Phosphate also reached the highest levels in March and April (0.99 and 1.25mg L⁻¹, respectively), followed by a sharp drop in the next 2 months (0.13 and 0.29mg L⁻¹, respectively). Stoichiometric analyses indicated a major potential for N limitation (63.89% of the total observations), whereas 15.28% of the total observations were P limiting, and 20.83% of the total observations were either N or P limiting (Table 1).

Community structure

The phytoplankton community structure comprised five groups, arranged by magnitude as cyanophytes (63.09% of the community), dinoflagellates (12.76%), diatoms (11.36%), chlorophytes (10.63%), and euglenophytes (2.16%). Their relative contribution differed seasonally, but cyanophytes showed predominance all the year round. The community of cyanophytes and chlorophytes included 45 species, mostly from Chlorophyceae spp. The highest species diversity (number) of the two groups was registered in January (10 and 18 spp., respectively) and the lowest in June (3 and 7 spp.). The two groups were significantly correlated with each other ($r=0.69$, $P<0.01$), and temperature and salinity might represent explanatory variables influencing the species diversity of the two groups (Table 2). Meanwhile, the variability of cyanophyta species diversity might be affected by varied NH_4 (-), NO_3 , and PO_4 concentrations, whereas NO_3 and TN were positively correlated with chlorophytes (Table 2).

TABLE 1. Measured physical and chemical properties (mean±S.D)

	Temperature °C	D. Oxygen mg O ₂ L ⁻¹	Salinity PSU	NH ₄	NO ₂	NO ₃	T.N	PO ₄	TN/P ratio
Mean	24.2	6.38	4.13	0.09	0.07	0.39	0.64	0.11	11.73
Standard error	0.61	0.20	0.18	0.01	0.01	0.05	0.06	0.01	2.04
Range	16.0	7.30	5.30	0.37	0.45	2.00	2.28	0.45	117.3
Minimum	16.0	2.40	1.90	0.02	0.01	0.02	0.02	0.01	0.36
Maximum	32.0	9.70	7.20	0.39	0.46	2.02	2.30	0.46	117.6
Confidence level (95.0%)	1.2	0.39	0.36	0.02	0.02	0.09	0.11	0.02	4.1

TABLE 2 Correlation coefficient (r) values of Cyanophyta and Chlorophyta species diversity (number) and the measured physical and chemical variables

Group	Chlorophyta	Temperature	D.Oxygen	Salinity	Alkalinity	NH ₄	NO ₂	NO ₃	Total N	PO ₄	TN/P ratio
Cyanophyta	0.69	-0.68	0.17	-0.51	0.04	-0.23	0.06	0.21	0.12	0.23	-0.02
Chlorophyta	1.00	-0.48	0.00	-0.50	-0.29	0.09	0.28	0.45	0.29	0.02	0.14

Occurrence of M. aeruginosa and B. braunii

Microcystis aeruginosa contributed the major fraction of Cyanophyta annual abundance (75.29%–96.07%), whereas *B. braunii* contributed 11.37%–93.12% of Chlorophyta. The annual distribution, based on the mean values, exhibited remarkable regional fluctuations in all stations. *Microcystis aeruginosa* (3203.72×10^3 colony L⁻¹) achieved its highest abundance at St. II and IV (525.37×10^3 and 946.9×10^3 colony L⁻¹), whereas *B. braunii* (378.51×10^3 Col. L⁻¹) gained its highest abundance at St. III and V (82.5×10^3 and 93.33×10^3 colony L⁻¹). On the contrary, St. I sustained the lowest abundance for both species (321.94×10^3 and 33.36×10^3 colony L⁻¹, respectively). Their occurrences were related to each other ($r=0.30$, $P>0.05$). The major bloom peak of *M. aeruginosa* was recorded in June, whereas that of *B. braunii* in September, with the increase of concomitant Chl. *a* to 16.5 ± 7.11 and 21.8 ± 7.45 mg L⁻¹, respectively. *Microcystis aeruginosa* was a persistent form, which formed visible blooms (Fig. 2) of monospecific and/or multispecific nature in December, June, and September, whereas its lowest densities were restricted from July to August and from October to November (Chl. *a* < 5.4 mg L⁻¹; Fig. 3). The

blooms during December and June appeared as scattered dispersed visible patches primarily concentrated toward the North-eastern area of the lake, whereas in September, the accumulative colonies turned the surface water into a foam-like dense green layer that occupied the whole water body. The blooms with different frequencies maintained a wide range of temperature (17.5°C–31°C), salinity (2.4–6 PSU), elevated pH values reaching the highest of 8.9 in June, well-oxygenated water, changeable nutrient concentrations, and relatively high NO₃ values with dispersive bloom in December (Table 3 A). Defining the principal factor/s influencing the annual occurrence of *M. aeruginosa* is difficult; however, the negative relation among NH₄, TN, and PO₄ is effective. Meanwhile, the change in nutrient ratios had no significant contribution to its seasonal abundance variation (Table 4). Some other species progressed actively within the bloom periods in June, including the diatom *Cyclotella meneghiniana*; the chlorophyceans *Chlorella vulgaris* and *Scenedesmus bijuga*; and the dinoflagellates *Gymnodinium* and *Scrippsiella trochoidea*. Moreover, *Scenedesmus quadricauda*, the cyanophycean *Merismopedia glauca*, and *Gymnodinium* were recorded in September.

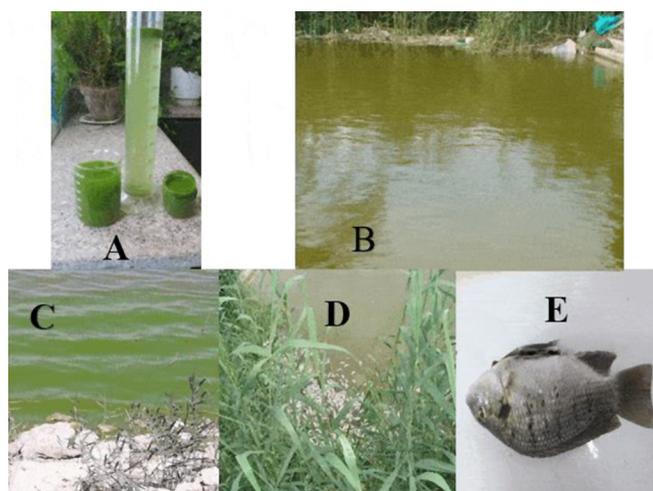


Fig. 2. September bloom photos: (A) Laboratory image, (B–C) Field images, (D) Fish mortality, and (E) Dead *Tilapia* sp.

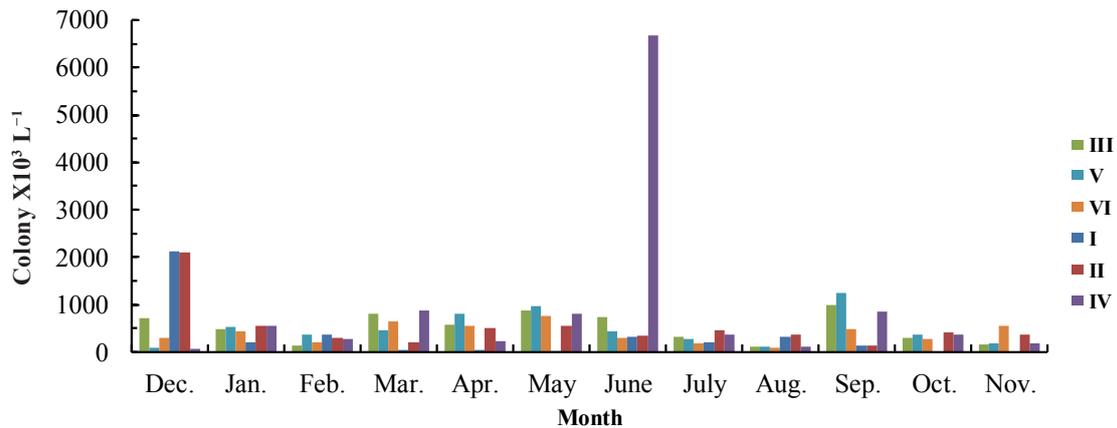


Fig. 3. Spatiotemporal distribution of *Microcystis aeruginosa*

TABLE 3. Accompanied physical and chemical parameters with regional *Microcystis aeruginosa* (A) and *Botryococcus braunii* (B) bloom peaks

Parameter	A			Parameter	B	
	Month				Month	
	Dec. 2017	June	Sep.		April	Sep.
	Station				Station	
Temperature	17.5	31	22	Temperature	22	22
Salinity	2.4-2.6	5.3	5.8-6	Salinity	4.3	5.8
pH	7.9-8.3	8.9	8.5	pH	8.5	8.5
D.Oxygen	5.4-7.6	8.4	6.6-7.4	D. Oxygen	6.3	6.6
NH ₄	0.3-0.5	0.04	0.03-0.1	NH ₄	0.017	0.06
NO ₂	0.1-0.3	0.03	0.03-0.2	NO ₂	0.044	0.03
NO ₃	0.15-1.18	0.251	0.06-0.16	NO ₃	0.4	0.12
Total N	0.33-1.26	0.32	0.3-0.75	Total N	0.46	0.48
PO ₄	0.28-0.32	0.04	0.05-0.24	PO ₄	0.22	0.05
TN/P ratio	6.22-45.0	8	1.67-8.89	TN/P	2.09	8.89
Colony. l ⁻¹ x10 ³	726-2133	6666.6	850-1250	Colony. l ⁻¹ x10 ³	300	380
Bloom type	Dispersive	Dispersive	Scums	Bloom type	Dispersive	Scums
	I, II, III	V	IV, V, VI		IV	VI

TABLE 4. Pearson's correlation coefficient (r) values between environmental factors and *Microcystis aeruginosa* and *Botryococcus braunii* annual abundance

Species	Temperature	D.Oxygen	Salinity	Alkalinity	NH ₄	NO ₂	NO ₃	T.N	PO ₄	TN/P
<i>M. aeruginosa</i>	0.06	0.11	0.01	-0.12	-0.19	-0.13	-0.06	-0.15	-0.14	-0.04
<i>B. braunii</i>	0.23	-0.07	0.20	-0.04	-0.23	-0.12	-0.10	-0.17	0.10	-0.06

The microscopic examination of *B. braunii* revealed irregularly, indefinitely shaped aggregated colonies of various sizes (70µm to 300µm in diameter), attached by thread-like mucilaginous connections. The limited number of individual cells appeared ovoid to pyriform in shape, with

size length between 6–11 µm and width 5–8 µm. 72% of the measured cell length ranged from 6 to 9 µm. This species was first seen in February (20×10^3 – 66.7×10^3 Colony L⁻¹) with increased water temperature by approximately 4 °C and relatively higher NH₄ concentrations (1.77mg L⁻¹)

compared with that observed in January (0.6mg L^{-1}). The species culminated two major peaks in April (St. IV) and September (St. VI; Fig. 4, Table 3 B); the April bloom was monospecific. The highly buoyant-dwelling aggregates found in September accumulated as visible thick scums or scattered spots (Fig. 2). Furthermore, several minor peaks ($>100\times 10^3$ – 270×10^3 colony L^{-1}) were observed between March and July. The density declined between late summer and mid-winter. Temperature, salinity, and NH_4 in reverse correlation with the annual abundance of *B. braunii* were important regulators of its monthly occurrence, and the effect of TN/P changes was comparably weaker than that of absolute nutrient element concentrations (Table 4). The accompanied community composition showed no significant changes at all stations irrespective of varied *B. braunii* density. The co-existing species, which peaked in April, were composed primarily of a well-diversified Cyanophyta (16 spp.) and a few growing diatoms, including *Nitzschia longissima* (357×10^3 cell L^{-1}), *Cyclotella meneghiniana* (40×10^3 cell L^{-1}), and dinoflagellate *Gymnodinium* sp. (163×10^3 cell L^{-1}). The blooms of *B. braunii* with different frequencies could affect the relatively reduced densities of other species, particularly chlorophycean *Chlorella vulgaris*, decreasing from 440×10^3 cell L^{-1} at St. I to 3.3×10^3 cell L^{-1} at St. IV.

Discussion

In general, the temporal and regional physico-chemical variations were parallel with previously reported results in the lake (Labib et al., 2014; Helal et al., 2020) and elsewhere (Campbell et al., 1996). Relatively higher salinity values and reduced accompanied phytoplankton abundance in July–August might be attributed to the cease of Nile freshwater input into the lake. Data showed the effects of NO_3 , NH_4 , and PO_4 on the

community structure and abundance, commonly known in lakes and water reservoirs (Maberly et al., 2020), stressing the importance of nutrient concentration reduction to avoid the severity of noxious algal blooms. Meanwhile, the nutrient ratios showed relatively less effect. The distinctive role of temperature in conjunction with algal occurrence was clear during the transient period in spring and summer, thereby showing the highest production; the role of temperature as an effective factor was previously documented (Paerl et al. 2014). The water turbidity during the winter mixed period (Secchi values at $<30\text{cm}$) and subsequent relatively high nutrient concentrations might be used as agents to alter the growth and community structure. These conditions favored Cyanophyta, rather than Chlorophyta, species diversity at 22°C . Considering that the impact is species-specific, previously reported data regarding the role of winter conditions in a harsh eutrophic environment are inconsistent (Malazarte et al., 2017). The current study indicated the great ability of Chlorophyta and Cyanophyta to tolerate a wide temperature range, forming monospecific and/or multispecific dense blooms in no particular season. However, notably, the maintenance of cyanobacteria as perennial and predominant forms and the overall occupation of the lake during the bloom periods might be due to its dynamic nature caused by the presence of gas vesicles, which keep these mobile organisms in the water column, assisting them in getting light and nutrients (Scheffer et al., 1997). The contribution of combined *M. aeruginosa* and *B. braunii* to September heavy bloom might be attributed to the similarity in the mean optimum growth temperatures of approximately 29°C . According to Demura et al. (2014), *B. braunii* tolerates desiccation and extreme temperatures, which allows its global dispersion in different environments.

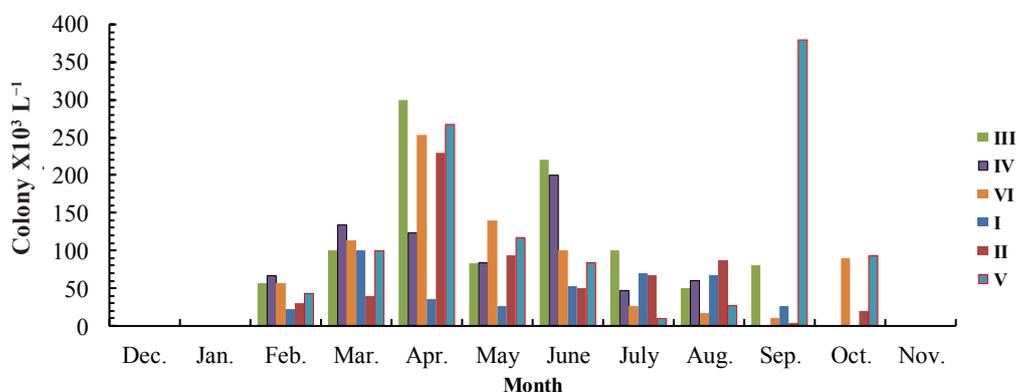


Fig. 4. Spatiotemporal distribution of *Botryococcus braunii*

Nutrient concentrations were always above limiting thresholds of chlorophytes and cyanophytes for optimum growth, and the excess inputs of nutrients can cause harmful blooms (Paerl et al., 2018). The N/P ratio changed sufficiently with Chlorophyta bloom in September and with Cyanophyta in May and June, elucidating symptoms of heavy eutrophication in the lake. Although N limitation was dominant, the present data indicated the importance of P for the development of over algal growth, which was consistent with other work (Figueiredo et al., 2004). Therefore, the data provide evidence that the continuous supply of nutrients with different quantity and specific composition might hinder the study of nutrients as decisive limiting growth factors; consequently, the interaction between seasonality in nutrient supply and algal nutrient limitation remains poorly understood (Andersen et al., 2020). However, this finding does not mean that a massive bloom can persist without an ample supply of nutrients. In general, Cyanophyta blooms maintained relatively higher N/P ratios than Chlorophyta blooms, which was inconsistent with the results of Mischke (2003), who reported low ratio levels along with other factors (thermal stratification, reduced transparency, and an increase in water temperature and pH), and frequently enhanced the occurrence of Cyanobacteria blooms. In addition, the pioneering study by Jensen et al. (1994) indicated that Cyanobacteria lost its high degree of dominance at low TN:TP ratio or low inorganic N concentrations. Andersen et al. (2020) found that cyanobacteria represented a proportionally larger fraction of the phytoplankton assemblage under N-limiting conditions. Although reducing external nutrients loading has been widely recommended as the first step to control such blooms in eutrophic ecosystems (Conley et al., 2009; Lewis et al., 2011), the present data indicate that the reduction of only one type of nutrients can lead to an imbalance in the N:P ratio of the water column, thereby leading to the worsening of Cyanophyta and/or Chlorophyta problems, particularly at high concentrations of nutrients. Thus, dual nutrient management strategies must incorporate N and P. The scientific consensus is limited on the importance of N:P ratios as a driver for freshwater algal blooms and the mitigation of eutrophication by controlling limiting nutrients (Schindler & Hecky, 2009). Present statistical analyses revealed a close relation between absolute concentrations and production rather than

with N:P ratios. However, considering that the environmental parameters work simultaneously in concert, separating the impact of nutrient concentrations and ratios from other co-occurring environmental variables to quantify the specific effect on the development of Cyanobacteria and Chlorophyta blooms in the lake is difficult. Considering the increasing populations and human activity in Alexandria City, the increase in N and P will exceed the assimilative capacity of the resident phytoplankton. Therefore, the changes in the N: P ratio have a little effect on the growth of a particular taxon, and the more enriched the system in N and P, the greater the total Cyanobacteria biomass (Davidson et al., 2012).

The lack of information on *M. aeruginosa* in the lake causes difficulty in conducting a detailed comparative study for its occurrence. On the contrary, *B. braunii* received a limited attention as its major peaks have been previously reported during January and February 2012 (maximum at 55.3×10^3 colony L^{-1}), causing brown water discoloration and fish mortality (Labib et al., 2014). The current data showed higher densities; however, *B. braunii* can reach 7.4×10^6 colony L^{-1} (Teng et al., 2021). The measured dimensions of *B. braunii* cells might nominate the present strain as L race. Based on the hydrocarbons present in this alga, Metzger & Largeau (2005) identified three different races with different sizes, where the cells of race L were smaller (8 to $9 \mu m \times 5 \mu m$) compared with $13 \mu m \times 8$ to $9 \mu m$ of race A and race B (Metzger et al., 1988; Dayananda et al., 2007). However, cell shape and size vary on different environmental or growth conditions (Tran et al., 2010). The present study demonstrated different recurrent blooms of *B. braunii* of diverse growth frequencies irrespective of varying seasonal temperatures. This result might deny the assumption stated by Labib et al. (2014), that is, this strain was only cold adapted in the lake water. Several studies have proven that this species can tolerate temperature between $20^\circ C$ and up to $33^\circ C$ (Qin, 2005) and salinity (Ranga Rao et al., 2007) and may require low levels of NO_3 and PO_4 to produce the highest hydrocarbon content (Raj et al., 2016). Blooms of *B. braunii* can release free fatty acids to the ambient environment (Qin, 2005) depending on its magnitude and ability. This finding can affect the phytoplankton diversity to different degrees, which in turn disturb the ecological stability in

the lake. The observed population interactions between *B. braunii* and the small, fast-growing green algae, *Chlorella vulgaris*, indicated that the regional distribution of the bloom causative species deeply affected *C. vulgaris* abundance. Song et al. (2012) found that the high density of *B. braunii* reduced algal competition. The observed multispecific bloom in September caused the mortality of hundreds of fish, primarily *Tilapia* sp. However, the fish-killing mechanism was not identified, and several factors might be involved such as gill clogging and oxygen stress. However, the gut content of dead *Tilapia* fish, characterized by its yellow body color, indicated the remains of Cyanobacteria and Chlorophyta species in the gut components (about 70%), whereas Euglenophyta, Bacillariophyta, and Dinophyta species showed less abundance by an order of magnitude.

Conclusion

Nozha Lake is a harsh eutrophic environment with clear symptoms indicated by monospecific and/or multispecific dense harmful blooms of a few Chlorophyta and Cyanophyta species in no particular season.

Dual N and P input reductions are required to combat the potential noxious blooms in the future. Future studies must include other biological factors, grazing, species interaction, metrological data, and the presence of toxins assessed through allelopathic tests to obtain a comprehensive understanding of the system function. Therefore, developing a risk plan to support policymaking is necessary.

Conflicts of interest: No conflicts of interest have been declared.

Authors' contribution: Shimaa Hosny: Field work, Collect samples, taxonomic identification of phytoplankton samples, draft the manuscript and editing of it. Wagdy Labib: Participated in the design of the study and approved the final version of manuscript.

Ethical approval: Not applicable

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تحكم الظروف البيئية المختلفة في ديناميكية التواجد الزماني والمكاني لـ *Microcystis aeruginosa* في بيئة المياه العذبة

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تعتبر بحيرة النزهة (جنوب مدينة الإسكندرية، مصر) حوض مياه عذبة اصطناعي، تتلقى إمداداتها المائية من نهر النيل ومن المنطقة الحضرية المحيطة مما يعرضها لارتفاع نسب المغذيات ولذلك تعتبر البحيرة بيئة قاسية، مما يؤدي إلى ازدهار الطحالب بصورة متكررة على مدار العام ومن هنا يؤثر على التوازن البيئي للبحيرة. وكشفت النتائج من خلال التقييم البيئي للبحيرة من ديسمبر 2017 إلى نوفمبر 2018 عن ازدهارات مشتتة لكلا من *Microcystis aeruginosa* وهو نوع من الطحالب الخضراء المزرقه و *Botryococcus braunii* وهو من الطحالب الخضراء، وذلك تحت ظروف بيئية ومواسم مختلفة. وكان لـ *Microcystis aeruginosa* تواجد ثابتاً خلال الفترة بأكملها، وبلغ ذروته في الإزهار المرئي في ديسمبر ويونيو وسبتمبر. تم إثبات الدور المميز لدرجة الحرارة خلال فترة الربيع والصيف. وقد ظهر أيضاً تأثير النترات المذابة غير العضوية، والأمونيا والفوسفات على التباين في بنية المجتمع ووفرتة. كما تم رصد قمم التكاثر الرئيسية لـ *M. aeruginosa* و *B. braunii* في يونيو وسبتمبر مما رفع محتوى الكلوروفيل a إلى درجته القصوى. أيضاً أثر ازدهار *B. braunii* على تنوع أنواع العوالق النباتية المصاحبة بدرجات مختلفة كما في الطحالب الخضراء *Chlorella vulgaris* سريعة النمو. ومن هنا يتطلب الأمر إلى العمل على انخفاض نسبة النيتروجين والفوسفات الداخلة للبحيرة لمحاربة تكرار الازدهار وكثرتة بالإضافة إلى زيادة نسبة الدراسات البيولوجية وتفاعل الأنواع مع بعضها ودراسة السموم الناتجة من التفاعل الأليوباثي لبعض الأنواع مما يدعم ويطور من سياسة خطة تجنب المخاطر والمشاكل قبل حدوثها.