Spring algal blooms in Alexandria coastal area (Egypt) impacted by anthropogenic forcing: Potential role of habitat alteration

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ABSTRACT

The Alexandria coastal area is presently experiencing two main problems of increasing intensity and concern: eutrophication and exacerbating coastline erosion. Here, we describe the spring discolored massive algal blooms in Alexandria coastal waters during 2021. These blooms were detected at two sites of highly dynamic and rapidly evolving systems with different characteristics on each site regarding abundances of the different causative species, biomass accumulation, and prevailing environmental variables mainly supported by daily discharged water input. The blooms can be considered one facet of the complex hydrographic ecosystem's responses to anthropogenic forcing. The study offers evidence of the potential role of newly created sheltered artificial microhabitats that favor water confinement exacerbated impacts on the water quality, fostering colonization of the bloom causative species, and biomass accumulation. Further ecological studies on the effect of coastal zone modification are required before its deployment, particularly in intensive urbanization areas.

INTRODUCTION

The alarming increase in sea level linked to climate change has strengthened public support for enhancing the deployment of coastal protection structures (**Slott *et al*., 2006)**. Recently, quantifying the potential effects of such urban structures on natural ecosystems (**Williams *et al*., 2018; MacArthur *et al*., 2019; Strain, 2020)** has gained attention as a tool for coastal management. To protect Alexandria's coastline from erosion problems and storms different types of inshore protection structures and methods were used (**Moheb, 2020)**. The successive engineering protection processes carried out have affected the topography of the coastal area, resulting in the formation of shallow semi-closed microhabitats.

The input of discharged wastewater into the coastal area of Alexandria (about $183 \times 10^6 \ \mathrm{m}^3$ monthly) is another challenge to the marine environment, commonly known to constitute a prerequisite factor for the development of massive algal blooms (**Berdalet**

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_et al_**., 2015**). The robust body of information available concerning the algal blooms linked to eutrophication in the coastal area of Alexandria indicates intense recurrent blooms with rising frequency and magnitude, introduction of harmful alien species, changes in biodiversity, occasional limited fish mortality, and an apparent expansion of the geographical distribution (**Mikhail _et al_., 2005; Mikhail, 2008 a, 2008b, 2012; Mikhail and Halim, 2009; Mikhail and Labib, 2014, Mikhail _et al_., 2020**). Indeed, frequent and periodic local bloom events are becoming long-term chronic problems given their regular annual occurrence from late spring to early autumn, although with particularities concerning the duration and proliferating species. Despite the spring blooms having been a recurring feature of an annually regular occurrence in Alexandria waters (**Labib, 2002**), no consensus, in general, has been reached yet on the initial mechanisms and triggers, a matter under debate still for the most part its infancy**.**

The current study is a part of the formal national monitoring program established in 2021 by the National Institute of Oceanography and Fisheries within the framework of the research project entitled "Assessment of red tide phenomena in the Egyptian neritic waters: causes and impacts" funded by the Institute. The program was designed to implement control strategies aimed at impeding/alleviating massive outbreaks and their potential negative impacts.

The study was conducted in the Mex and Qaitbay areas which are vulnerable to annually recurrent algal bloom outbreaks affected by heavy substantial anthropogenic eutrophication and are subjected to rapid coastal foundation processes. The study aims to achieve two goals: 1) to investigate the ambient environmental variables that might force the blooms triggering between late April and late May 2021, abundances of the causative species, and biomass accumulation, and 2) to explore the potential impacts of newly created semi-enclosed microhabitats on the occurrence and biomass accumulation of red tide blooms. To bridge the driving forces, the water quality and other biological elements were investigated inside microhabitats in comparison with the properties of the adjacent outside wave-exposed sites. The gained knowledge assists policymakers and managers in coping properly with environmental problems, favoring coastal conservation, restoring coastal ecosystems, and maintaining the services they provide.

MATERIALS AND METHODS

1. Study area, coastal defense structures, and discharged water

Alexandria is situated on the southwestern part of the Egyptian Mediterranean Sea (29°55′ and 30°04′ E, 31°13′ and 31°19′ N), with narrow beaches of about 15 km long. The coastal area is subjected to continuous intensive protection construction creating several microhabitats (**Fig. 1**). In particular, a concrete breakwater to protect the castle of Qaitbay was designed as a groin curve shape (length 520 m, maximum width of 50m, height of 3.5m above the sea level), located around the castle (29°53′ 07" E, 31°12′ 49" N) and attached to the beach. It extends offshore at about 200 m from the fort and has an

opening of about 120 m for water exchange at 10 m sea depth. At Stanly Beach (31°14′ 04 14″ N, 29°56′ 55.13″ E), 2m water depth, 400 m long, wrapping around a small cove, a marine bridge supported on piles was instructed whose pile foundations and the base layer on the seabed were aimed to dissipate wave energy. At the Glym area, three breakwaters of about 300 m long each were established perpendicular to the coastline, dividing this coastal zone into several small protected semi-enclosed habitats. Two offshore breakwaters (350 m away from shore, at 6-7 m depth, 40 m width at the top) were constructed at the Sidi Beshr area parallel to the coastline to protect the narrow 2 km long sand beach; the eastern and western barriers were, respectively, 500 m and 1.2 km long.

El-Mex Bay (29°47.1′ to 29° 50.4′ E, 31° 7.5′ to 31° 9′ N), west of Alexandria is a shallow sheltered estuary extending for about 15 km (mean depth 10 m, area of about 19.4 km^2, water volume 190.3x10^6 m^3). The bay receives huge amounts (about 2.547x 10^9 m^3 y^{-1}) of agricultural wastewater from a neighboring Lake Mariut, and about 13x10^6 m^3 y^{-1} of untreated industrial wastes dumped directly into the southern part of the bay via pipelines, as well as 1.13x0^6 m^3 y^{-1} from the Western Harbor. The chosen investigated station was located in a shallow basin of the eastern part (El Fanar area).

2. Sampling

Short-term sampling collection was performed with a weekly frequency (weather permitting) between late April and late May 2021 at two fixed sites in the Mex Bay, and Qaitbay area. Other stations east of Qaitbay (31.22-31.26^{o}N - 29.88-29.98$^/$E, **Fig. 1**), where the ongoing shore protection structure project is in progress were sampled during the first week of May. The analyzed physical, chemical, and biological characteristics of the waters at each station included: temperature (°C) and pH measured *in situ* using Hydro lab (HANA, Model HI9828-USA); salinity by using a Bechman salinometer (Model NO. R.S.10) in the laboratory; dissolved oxygen (DO) estimated following modified Winkler's method (**Grasshoff *et al*., 1999**); concentrations of dissolved inorganic nitrite (NO$_2$), nitrate (NO$_3$), silicate (SiO$_4$), phosphate (PO$_4$) and ammonia (NH$_4$) determined on filtered seawater samples (GF/F filters), kept at 4°C and analyzed in the laboratory, following the procedure of **Grasshoff *et al*. (1999)**; oxidizable organic matter (OM) concentrations according to **FAO (1975)** procedure; chlorophyll (Chl. *a*) concentration was determined on the filtered seawater samples, extracted in 90% acetone following the method of **Jeffrey and Humphrey (1975)**. Unfixed net subsamples collected by a plankton net (mesh size 20 μm) were first examined for qualitative phytoplankton estimation using a light inverted microscope (x200 magnification). Quantitative estimation of the phytoplankton cell abundances, hereafter referred to as "microplankton standing crop", was performed on 1 L collected water samples. The samples were preserved by the addition of 4% neutral formalin and counted after sedimentation (**Utermöhl, 1958**). The nomenclatures followed mainly by **Tomas (1997)**.

Mex Bay (El Fanar station)

Fig 1. Location of the sampling sites and stations (▢)

RESULTS

1. Qaitbay bloom

The measured environmental condition, microplankton standing crop, and Chl. *a* concentration at the Qaitbay inside the site are given in Table 1. The conditions on 21 April, a week earlier than the first peak revealed relatively low water temperature, NO_3, and a very reduced OM concentration, while those of PO_4, NH_4, and SiO_4 were relatively high. The accompanying Chl. *a* reached 4.86 µg L^{-1}. The community was comprised mainly of *Skeletonema costatum* ($0.061x10^6$ cell L^{-1}, 51.2% of the total microplankton standing crop), followed by a relatively much lower contribution of *Prorocentrum triestinum* (16.5%), and *Prorocentrum cordatum* (12.98%).

The physicochemical conditions with the first phytoplankton peak on 28 April showed increased temperature by 4°C, almost unchanged salinity, and NH_4, plenty of NO_3, and marked reduced PO_4 level. *Prorocentrum cordatum* ($0.43x10^6$ cell L^{-1}, 40%) and *P. triestinum* ($0.37x10^6$ cell L^{-1}, 34%) were the main contributors, and the other numerous accompanying species including *S. costatum* (5.81%), *Chaetoceros compressus* and *Euglena acus* (about 4.65% for each).

The second discolored water period (4-6 May) was monitored at 7 stations due to its wide spatial extension, and the bloom dynamics on 5 May were compared inside and outside of the other three established micro habitats east of the Qaitbay site (**Tables 1, 2 & 3, Fig. 2**). The bloom started to be visible at Qaitbay open sea site on 4 May, when Chl. *a* concentration reached 4.88 µg L^{-1}, contributed by *Prorocentrum* population of $0.28x10^6$ cell L^{-1} mainly of *P. cordatum* (92.85%). This light discolored water was seen stretching over a vast coastal area towards the east where the *Prorocentrum* population varied at the other stations between $0.13x10^6$ and $0.21x10^6$ cell L^{-1} (56.76-94.89% of the standing crop). In comparison with the peak on 28 April, the seawater with the massive bloom on 5 May was characterized by a slight temperature, and salinity increase, 64.90% and 78.21% NH_4, and NO_3 lower concentration, respectively, and a marked amount of OM (Table 1). The environmental parameters, microplankton abundance, and biomass measured inside the semi-enclosed shallow protected sites compared with that of the adjacent open sea ones on 5 May (**Tables 2, 3, Fig. 2**) showed higher surface values of water temperature, salinity, NO_2, SiO_4, DO, OM, lower NO_3 and a severe consumption of NH_4, falling by 28.57 to 80.85%. The Chl. *a* values during this unprecedented bloom corresponded well with the abundance, raising pH as high as 9.5, and the DO content to 24.62 mg l^{-1}, with its maximum restricted to the Gylm site, and it was followed by Sidi Beshr. The bloom inside the Stanly site was a unique, exceptional, and unexpected bloom of co-occurring *P. cordatum* and dense swarms of a gelatinous zooplankton species.

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Table 1. Measured environmental variables, microplankton standing crop, and chlorophyll _a_ content at the Qaitbay inside site

Date	21-Apr	28-Apr	5-May	9-May	19-May	20-May
Temperature (^{o}C)	17.5	21.5	22.5	22.5	25	26
Salinity (PSU)	37.5	36.5	38.1	35.5	35	35.5
DO (mg L^{-1})	3.7	6.76	13.28	8.54	6.92	6.92
NH$_4$ (μM)	6.56	5.1	1.79	2.3	5.1	11.9
NO$_3$ (μM)	1.75	13.31	2.9	5.22	0.17	1.23
NO$_2$ (μM)	0.13	0.1	2.7	0.25	0.15	1.35
TN	8.44	18.51	7.39	7.77	5.42	14.48
N/P	8.36	43.04	7.78	20.45	1.23	3.71
N/Si	2.47	4.39	3.66	0.67	31.88	25.4
PO$_4$ (μM)	1.01	0.43	0.95	0.38	4.4	3.9
SiO$_4$ (μM)	3.42	4.22	2.02	11.57	0.17	0.57
OM (mg L^{-1})	0.32	1.28	16	2.88	14.72	14.72
Cell L^{-1} .10^6	0.12	1.08	7.3	0.62	0.53	12.57
Chl _a_ (μ L^{-1})	4.86	20.78	50.44	16.02	12.62	35.44

DO: Dissolved oxygen; TN: Total nitrogen; OM: Oxidizable organic matter

Table 2. Physical, chemical, and chlorophyll _a_ level at the sampled stations on 5 May.

Site		Tem.	Salinity	pH	DO	NH$_4$	NO$_3$	NO$_2$	TN	PO$_4$	SiO$_4$	N/P	N/Si	OM
		^{o}C	PSU		mg L^{-1}	μg L^{-1}	Ratio	mg L^{-1}						
Qaitbay	Outside	22.3	36	NM	3.02	9.35	5.45	0.53	15.33	0.34	1.71	45.09	8.96	0.64
	Inside	22.5	38.15	8.7	13.28	1.79	2.9	2.7	7.39	0.95	2.02	7.78	3.66	16
Stanly	Inside	23.8	37.1	8.65	12.31	3.9	9	0.8	13.7	0.6	6.5	22.83	2.1	9.6
Glym	Outside	26	36	NM	2.38	3.08	6.6	0.35	10.03	1.39	4.79	7.22	2.09	6.08
	Inside	32.4	36.1	9.5	24.62	2.2	0.3	0.5	3	1.6	7.3	1.88	0.41	38.4
Sidi Beshr	Outside	26	36	9	3.35	5.03	11	0.25	16.28	0.58	0.11	28.06	148	1.28
	Inside	31.5	37.9	9.4	20.41	3.3	10.78	0. 50	14.58	0.7	7.4	20.19	1.9	19.2

NM: Not measured

The environmental parameters, microplankton abundance, and biomass measured inside the semi-enclosed shallow protected sites compared with that of the adjacent open sea ones on 5 May **(Tables 2, 3; Fig. 2)** showed higher surface values of water temperature, salinity, NO$_2$, SiO$_4$, DO, OM, lower NO$_3$ and a severe consumption of NH$_4$, falling by 28.57 to 80.85%.   The Chl. values during this unprecedented bloom corresponded well with the abundance, raising pH as high as 9.5, and the DO content to 24.62 mg l^{-1}. The maximum Chl. _a_ was restricted to the Gylm site, followed by Sidi Beshr. The bloom inside the Stanly site was a unique, exceptional, and unexpected bloom of co-occurring _P_. _cordatum_ and dense swarms of a gelatinous zooplankton species.

Table 3. The abundance of *Prorocentrum* species at the different stations on 5 May. % refers to the abundance of *P. cordatum* and the *P. triestinum* cells in the whole microplankton standing crop

Site		*P. cordatum* Cell L^{-1}.10^6	%	*P. triestinum* Cell L^{-1}.10^6	%	Chl- *a* μg L^{-1}
Qaitbay	Outside	0.88	46.05	0.79	42.4	4.81
	Inside	3.4	85	0.6	15	50.44
Stanly	Inside	2.2	98.21	0.4	1.8	19.17
Glym	Outside	2.2	98.21	0.04	1.79	40.65
	Inside	9.6	77.42	2.8	22.58	388.3
Sidi Beshr	Outside	1.48	97.72	0.035	2.31	15.32
	Inside	4.8	77.42	1.4	22.58	177.33

2. Mex Bloom (El Fanar station)

Inspection of the environmental conditions during the spring bloom revealed a complex scenario **(Table 4)**, this bloom is characterized by a general increase in temperature, a clear influence of freshwater input detected by the marked reduced salinity (average 31.92±2.8), being < 30 during late April-early May, and wide variation ranges of nutrient concentrations and ratios. The different blooms were dominated by nine species with different degrees of predominance and belonging to different taxonomic classes. The peaks observed on 21 April, 5**,** and 9 May occurred with significantly high NH$_4$, raising DO up to 8.76 mg L^{-1} on 5 May, while the peak on 19 May triggered at high NO$_3$ and OM. Meanwhile, the high SiO$_4$ seems to help the bloom on 5 and 9 May. The standing crop varied between 0.92x10^6 to 5.01x10^6 cell L^{-1}, corresponding to Chl. *a* at 20.09 and 82.49 μg L^{-1}. The major causative species and their relative contribution to the total standing crop are given in Table 5. Generally, the temporal succession **(Table 5)** revealed the dominance of the centric diatom, *Cyclotella meneghiniana* on 21 April, and it was replaced by the raphidophycean *Heterosigma akashiwo* during late April-early May, culminating in its major peak on 5 May. This peak was signicficantly shared by the chlorophyte *Eutreptiella gymnastica* and the pennate diatom *Pseudonitzschia longissima*. The centric diatom *Thalassiosira pseudonana* was the most common contributor (12.44-50.24%), achieving its major peak on 9 May. The bloom of centric diatom *S. costatum* on 19 May caused a severe reduction in PO$_4$ concentration. Its predominance was followed at the end of May by the chlorophyte *Micromonas* sp. under low NH$_4$, PO$_4$, and SiO$_4$, but at relatively higher NO$_3$.

Table 4. Measured environmental condition, microplankton standing crop, and chlorophyll *a* content at Mex station.

Date	21-Apr	28-Apr	5-May	9-May	19-May	30-May
Temperature (^{o}C)	20.5	23.4	26	22.5	25	27
Salinity (PSU)	33	29	29	35	35	30.5
DO (mg L^{-1})	6.38	5.19	8.76	5.38	7.03	5.27
NH$_4$ (μM)	22.98	6.25	29.5	17.8	5.55	4.26
NO$_3$ (μM)	5.07	7.52	6.3	4.68	9.4	8.46
NO$_2$ (μM)	1.23	1.68	2.1	3.88	1.78	1.08
TN	29.28	15.45	37.9	26.36	16.73	13.8
N/P	3.19	32.18	61.13	7.22	26.98	12.55
N/Si	57.41	7.32	2.82	1.9	2.97	4.74
PO$_4$ (μM)	9.17	0.48	0.62	3.65	0.62	1.1
SiO$_4$ (μM)	0.51	2.11	13.42	13.86	5.64	2.91
OM (mg L^{-1})	3.52	1.28	12.88	3.2	17.28	5.12
Cell L^{-1} .10^6	0.92	2.52	5.01	4.72	4.28	1.98
Chl a (μ L^{-1})	20.09	44.5	82.49	35	27.03	26.25

Table 5. Abundance of the major causative species and their relative contribution at Mex station.

Date	Causative species	Cell L^{-1} .10^6	%
21 Ap.	*Cyclotella meneghiniana*	0.25	27.15
	Thalassiosira pseudonana	0.22	23.58
	Micromonas sp.	0.13	13.61
28 Ap.	*Heterosigma akashiwo*	0.65	28.65
	Eutreptiella gymnastica	0.47	20.67
	Thalassiosira pseudonana	0.37	16.27
5-May	*Eutreptiella gymnastica*	1.3	18.38
	Heterosigma akashiwo	1.28	18.09
	Pseudo-Nitzschia longissima	1.04	14.7
	Thalassiosira pseudonana	0.88	12.44
9-May	*Thalassiosira pseudonana*	2.1	50.24
	Cyclotella meneghiniana	0.81	19.38
	Prorocentrum cordatum	0.75	17.94
	Prorocentrum triestinum	0.56	13.4
	Eutreptiella gymnastica	0.43	10.29
19-May	*Skeletonema costatum*	2	43.48
	Euglene granulata	1.1	23.91
	Prorocentrum triestinum	0.98	21.3
30-May	*Micromonas* sp.	1.02	48.38
	Thalassiosira pseudonana	0.51	24.39

Qaitbay   Stanly

Glym   Sidi Beshr

Mex Bay (El Fanar station)

Fig 2. Water discoloration inside the different stations on 5 May

DISCUSSION

The results indicated the Mex Bay and Qaitbay areas are particularly complex hydrographic ecosystems suffering from the interaction of multiple environmental factors, especially supporting discharged water. These areas host the most well-known bloom-forming marine, estuarine, and freshwater microalgae that were previously recorded along the Alexandria coastal zone (**Labib, 2010**). The causative species contributing to the Chl. peaks found in the two sites during the same sampling days were markedly different and were restricted to each site. In addition, the ongoing coastal defense structures affecting the water condition can modulate the spatial distribution of a massive algal bloom, resulting in high biomass accumulation.

The results might confirm the importance of the increased temperature and reduced salinity, mainly influenced by the daily discharged water input, on the development of the spring blooms, their timing, and magnitude (**Mikhail, 2001; Lu *et al*., 2022**). These two physical variables affecting the water characteristics might favor the proliferation of

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certain species and consequently, determine the bloom dynamics. The water thermohaline stratification certainly developed by the early spring warming might represent an important factor for the present bloom-forming dinoflagellate species (**Labib, 2000a; Heil *et al*., 2005; Wells *et al*., 2015**). However, the limited data and unknown biological response hamper drawing a picture of the modulation of the spring blooms by these factors. For instance, little is known about the effects of salinity on *P*. *cordatum* (**Antonina *et al*., 2019**). The newly created sheltered, shallow microhabitats with their water stagnation also provide additional proper conditions.

While the pH variation remained within a narrow alkaline range, such a high pH level of up to 9.5 measured with the biomass peaks of *P. cordatum was* frequently reported to accompany other dinoflagellate blooms in eutrophic waters (**Hinga, 2002; Mikhail and Labib, 2014**). Generally, pH has not been regarded as a crucial determinant of *P. cordatum* blooms (**Hansen *et al*., 2007**), yet, high pH concomitantly with high OM and N availability contributes to the *Prorocentrum* bloom duration (**Zhao and Zhuo, 2011**), because *P. cordatum* can utilize organic nutrients supplied regardless of its nutrient status (**Granéli *et al.*, 1985**).

The present data suggest a continuous changeable supply of different nutrients contributing to eutrophication that might accelerate the bloom developments. The high N/P ratio observed in combination with the elevated NH_4 concentrations indicated the investigated areas were subjected to nitrogen pollution (**Xiao *et al*., 2018**). Yet, nutrients are not the unique solo factor explaining high biomass of extended duration since areas with high nutrient levels do not always coincide with high chlorophyll concentration (**Heisler *et al*., 2008; Kudela *et al*., 2010; Berdalet *et al*., 2014**).

The bloom of *S. costatum* on 19 May occurred under almost similar conditions previously mentioned in Alexandria waters (**Labib, 2000a**), and elsewhere (**Li *et al*., 2009**). This species is a major component of the recurrent blooms in Alexandria waters, able to accumulate at the surface with a density of up to 225.5×10^6 cells l^{-1} (**Mikhail, 2008b**). It can adapt to a wide range of environmental variations, which gives it the capacity to survive and achieve high biomass blooms, outcompeting many other diatoms under eutrophication (**Yamamoto *et al*., 2004**). The current *Prorocentrum* bloom after that of *S. costatum* was a well-known species succession pattern in Alexandria waters and elsewhere (**Mikhail *et al*., 2007; Mikhail, 2008a; Taş and Yilmaz, 2015**).

The present study showed in part a unique bloom inside the shallow Stanly basin of the dinoflagellate *P. cordatum* and co-occurred massive swarms of a gelatinous zooplankton species (**Mikhail *et al*., 2021**).

The composition of the different species of restricted occurrence at each site might confirm the originality of each bloom. In particular, the *Prorocentrum* bloom in the Qaitbay might be attributed to the vegetation of germinated cysts of previously recorded blooms (**Mikhail, 2008a**), under improved conditions, and/or the presence of a suitable initial cell number. Cysts produced from the asexual division of *P*. *triestinum* have been

described by **Bursa (1959)**, and that of *P. cordatum* recently by **Skarlato *et al*. (2018b)**. There has been no consensus on whether *P. cordatum* is toxic **(Wikfors, 2005)**, but **Glibert and Burkholder (2018)** reported it as a toxigenic species. Thus, the monitoring of the frequencies and causes of *P. cordatum* recurrent blooms is necessary to reduce/eliminate its negative impact on public health.

The newly created shallow microhabitats in comparison with the adjacent wave-exposed sites were expected to be subjected to different hydrodynamic regimes (water-reduced renovation, expected reduced wave regime, higher stability and residence time, modification of the water flow **(Martin *et al*., 2005)**. These semi-closed small habitats influenced by intensive urbanization and recreational use of coastal watersheds were characterized by conspicuous differences in the measured environmental conditions, relatively increased nutrient loading of some nutrient elements, and OM as well. The high SiO_4 measured inside was mainly attributed to the limited need for dinoflagellates to consume it, able to favor the subsequent proliferation of diatoms. The results indicated that these small habitats with effects of several proposed factors such as meteorological conditions, topography, habitat change, and eutrophication can accumulate high biomass, and govern temporal expansion and duration period of a phytoplankton bloom. Upon the confining of the coastal marine waters, and present optimal conditions the areas are susceptible to maintaining repeated blooms of huge biomass, particularly of the dinoflagellates as *Prorocentrum* species which thrive preferentially under abiotic stability **(Telesh *et al*., 2021)**. It cannot be discarded that these calm and shallow small areas of low advection and notable nutrient-rich waters might represent proper areas for the settlement of alien, non-native dinoflagellate species, which might be toxic to serious negative impacts on public health **(Berdalet *et al*., 2015)**. On the one hand, the increasing number of small created protected areas and the continuous coastal modification works in different very close adjacent areas give the opportunistic species a great possibility to be easily translocated. This fact, coupled with the ability of harmful species to develop resistant stages (i.e., resting cysts) viable in the sediments for a long time, might act as "seed reservoirs" of harmful species **(Garcés *et al.,* 2010)** that can promote new bloom outbreaks in the following favorable period **(Bravo and Figueroa, 2014)**. However, understanding the degree to which these structures impact phytoplankton blooms requires a longer time frame of several years. Intensive monitoring is necessary, especially with the progressive continuation of increased nutrient load input of varying chemical composition with the expected increase in human population, associated necessities, and economic development. Coastal protection structures by humans and climate change have been postulated as the main explanation for the increasing frequency and magnitudes of blooms in the Mediterranean Sea **(Garcés *et al.,* 2000)**, particularly those of the dinoflagellates **(Vila *et al*., 2021)**.

The blooms at Mex comprised a few species of different groups that have been previously reported as major bloom-forming species linked to progressive eutrophication

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in Alexandria waters, indicating a persistent seed bank of the local pool or might be transferred from Lake Mariout. The community structure was characterized by rapid changes in the replacement of the dominant species. Generally, the centric diatom, *T. pseudonana* (Hustedt) Hasle et Heimdal, registered cosmopolitan, freshwater and marine diatom was the pioneer; this species occasionally reaches 10.8×10^6 cells l^{-1} in Alexandria waters **(Labib, 2002)**. The raphidophyte, *H. akashiwo* recently introduced as an alien species in Alexandria waters **(Mikhail, 2001)**, succeeded in forming recurrent harmful blooms during summer and fall, with limited fish mortality **(Mikhail *et al*., 2020)**. *Micromonas* sp. is a cosmopolitan species **(Not *et al*., 2004)** and was found to form several harmful blooms during spring with peaks of up to 28.3×10^6 cell L^{-1} **(Labib, 2002)**. The euglenoid *E. gymnastica* represented a common constituent of the present harmful blooms, it was considered a euryhaline form with remarkable growth in a broad range of salinity **(Lee and Lim, 2006)**.

CONCLUSION

By studying the high biomass spring bloom in the harsh Mex and Qaitbay ecosystems, and the potential effect of the artificially newly created semi-enclosed areas with coastal protection engineering, we provide some pieces of evidence of anthropogenic impacts on the environment. So far, the impacts of such infrastructures have not been considered in policy decisions regarding coastal protection, which is becoming increasingly urgent in the Alexandria coastal area. Similar studies combined with hydrographic data and models are required for efficient science-based coastal management and protection of the environment. In final consideration, to keep our coastline in good condition, we must rethink the world we want to live in and act accordingly.

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