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ARTICLE

The phytoplankton communities in two eutrophic areas on the Alexandria coast, Egypt

Las comunidades fitoplanctónicas en dos áreas eutroficadas de la costa de Alejandría, Egipto

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Resumen.- Se estudió la comunidad fitoplanctónica en un área históricamente y ecológicamente importante de la costa suroriental Mediterránea de Alejandría, Egipto. Se recolectaron muestras mensuales durante enero a diciembre 2009 de 2 áreas [Bahía Oriental (EH) y Kayet Bey (KB)]. Se identificó un total de 162 especies de fitoplancton en BO y 110 especies en KB, dominada por diatomeas en ambas áreas (100 y 64 especies, respectivamente). El conteo de fitoplancton tuvo un promedio anual de 1,387 x 10^6 células L^{-1} en BO y 0,108 x 10^6 células L^{-1} en KB, y la biomasa (clorofila *a*) de 2,4 y 2,0 µg L^{-1}, respectivamente. Las diatomeas y dinoflagelados mostraron roles claramente diferentes en el ciclo del fitoplancton en las 2 áreas, con la ocurrencia persistente de varias especies tóxicas, algunas veces en alta abundancia, como la diatomea *Pseudo-nitzschia delicatissima* y el dinoflagelado *Scrippsiella trochoidea*, *Pyrophacus horologium*, *Prorocentrum micans*, *Prorocentrum triestinium*, *Prorocentrum cordata*, *Gonyaulax catenata* y *Protoperidinium subinerme*. A pesar de que detuvo gran parte de la descarga de desperdicios al área de estudio, aun hay eutroficación durante todo el año, indicado por las altas concentraciones de nutrientes y el intenso crecimiento del fitoplancton.

Palabras clave: Bahía de Alejandría, nutrientes, diatomeas, algas tóxicas, dinoflagelados

Abstract.- The phytoplankton community was studied in historically and ecologically important area on the southeastern Mediterranean coast at Alexandria, Egypt. Monthly samples were collected during January-December 2009 from 2 areas [Eastern Harbor (EH) and Kayet Bey (KB)]. A total of 162 phytoplankton species were identified in the EH and 110 species in the KB, dominated by diatoms in both areas (100 and 64 species, respectively). The phytoplankton count showed an annual average of 1.387 x 10^6 cells L^{-1} in the EH and 0.108 x 10^6 cells L^{-1} in the KB, and biomass (Chlorophyll *a*) of 2.4 and 2.0 µg L^{-1}, respectively. Diatoms and dinoflagellates demonstrated clearly different roles in the phytoplankton cycle in the 2 areas, with the persistent occurrence of several toxic species, sometimes in high count, like the diatom *Pseudo-nitzschia delicatissima* and the dinoflagellates *Scrippsiella trochoidea*, *Pyrophacus horologium*, *Prorocentrum micans*, *Prorocentrum triestinum*, *Prorocentrum cordata*, *Gonyaulax catenata* and *Protoperidinium subinerme*. Regardless of the stopping of great part of the discharged wastes to the study area, it is still suffering from eutrophication all the year round, as indicated from high nutrient concentrations and intensive phytoplankton growth.

Key words: Alexandria harbour, nutrients, diatoms, toxic algae, dinoflagellates

INTRODUCTION

The Eastern Harbor (EH) and Katey Bey (KB) are among the important marine areas over the world from the historical point of view, as they harbored thousands of ancient Egyptian artifacts. The EH is an area for fishing activities, Yachts sports, boat building and recreation. The KB is directly affected by sewage discharge from a sewer of the adjacent Al Anfoushi area, and both EH and KB indirectly affected by different discharged wastes from El-Umoum Drain to El Mex Bay west of the study area. These wastes include chromium which was recorded in several marine organisms (Aboul Dahab *et al.* 1990), persistent organic pollutants (POPs), organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) (Barakat 2004, El-Naggar *et al.* 2013). In addition, various nutrients (phosphate, nitrogen compounds, sulfate, etc.) along with organic matter from animal farming and domestic wastes were found in the area (EEAA 2008).

The study area is characterized by chronic eutrophication which caused drastic changes in the environmental conditions and the dynamics of phytoplankton community (Hussein 1994, Labib 2002, Abdel-Halim & Khairy 2007, Madkour *et al.* 2007). The symptoms of chronic eutrophication in the EH were indicated from the distribution profile of the dinoflagellate *Alexandrium minutum* cysts in the core sediment (Ismael & Khadr 2003) which reflected the repeated bloom of this species on the long-term recorded earlier (Sultan 1975, Zaghloul & Halim 1992, Labib & Halim 1995). *Alexandrium minutum* has disappeared later on and was replaced by several other potentially harmful species (Ismael & Khadr 2003). On the other hand, several changes were recorded in the phytoplankton dynamics in the EH, such as the cyclic abundance of the centric diatom *Skeletonema costatum*, the episodic blooms of less frequent diatoms (*Leptocylindrus minimus* and *Lithodesmium undulatum*), the reappearance of endogenous dinoflagellates (*Gyrodinium sanguineum* and *Gonyaulax spinifera*) and seasonal shift in the dominance of the major dinoflagellate species, *Prorocentrum triestinum*, *Gymnodinium catenatum* and *Scrippsiella trochoidea* (Labib 2002, Ismael 2003). Furthermore, Faragallah *et al.* (2010) recorded high concentration of chlorophyll *a* (up to 78.68 μg L^{-1}) along with high nutrients (up to 10.40 μM for NO_3, 6.19 μM for NH_4, 8.58 μM for PO_4, and 11.9 μM for SiO_4) and organic matter (up to 17.50 mg O_2 L^{-1}) in the EH. On the other hand, the number of phytoplankton species changed drastically with eutrophication conditions in the Western Harbor of Alexandria with approximately complete replacement of the dominant species and more effective role of dinoflagellates than the diatoms (Gharib & Dorgham 2006).

The present study describes the dynamics of phytoplakton community in 2009 in the EH and KB and checks if these dynamics support the long term increase/decrease of eutrophication in the investigated areas after the fundamental changes in the surrounding environmental conditions for more than 50 years.

Materials and methods

Study area

The EH is a shallow semicircular bay, with an area of about 2.8 km^2 and different depths (up to 10 m) located along the central part of the Alexandria City at 29º53´-29º54´E; 31º12´-31º13´N (Fig. 1). The Harbor is isolated from the open sea by an artificial breakwater, except two openings. The KB area lies to the west of the EH as a part of the open seawater surrounding the historical Kayet Bey Castle.

Samples collection

The physico-chemical characteristics of the study area were studied by Khairy *et al.* (2014). The phytoplankton study was based on water samples, whereas 2 L of seawater were collected monthly at each station and preserved in 4% of neutralized formaldehyde solution. The water samples were left 4 days for settling, concentrated and the phytoplankton cells were counted in 3 replicates of 1 mL of the concentrated samples under a research microscope according to Utermohl (1958). Chlorophyll *a* was measured by filtering 1 L of seawater through membrane filter of mesh size 0.45 μm and the filters were kept in 90% acetone in a refrigerator for 24 h. The extraction and measurements of chlorophyll *a* was carried out following APHA (1985). Identification of phytoplankton species followed Meunier (1913, 1919), Hustedt (1930), Cupp (1943), Hendy (1964), Prescott (1975), Dodge (1982), and Opute (1990, 1991 & 2000).

Shannon diversity index (Shannon & Weaver 1963) and Pearson correlations between hydrographic parameters and phytoplankton abundance were calculated using MINITAB© statistical package (Minitab Inc.).

Results

Hydrographic conditions

The values of the hydrographic parameters are illustrated in Table 1. The water temperature varied between a winter minimum of 17.1ºC in February and a summer maximum of 31.5ºC in August, while the difference in temperature between stations was small (0.5ºC).

The surface salinity was relatively low most of the year (35.2-37.9), with a few exceptions (up to 38.9), demonstrating very close annual averages (37.4 and 37.2) in the KB and the EH, respectively. Dissolved oxygen was almost low (3.5-7.7 mg L^{-1}), except high concentrations (8.3-10.1 mg L^{-1}) in December and May. The oxygen saturation in KB fall mostly within the range of 36-64%, increased occasionally to 93-118%, while in the EH, it fluctuated mostly between 72 and 98%, decreased to 39-62% from January to March and in October. The pH demonstrated narrow variations in the whole study area, but it showed slightly wider monthly range (7.6-8.3) in the KB than in the EH (7.8-8.1).

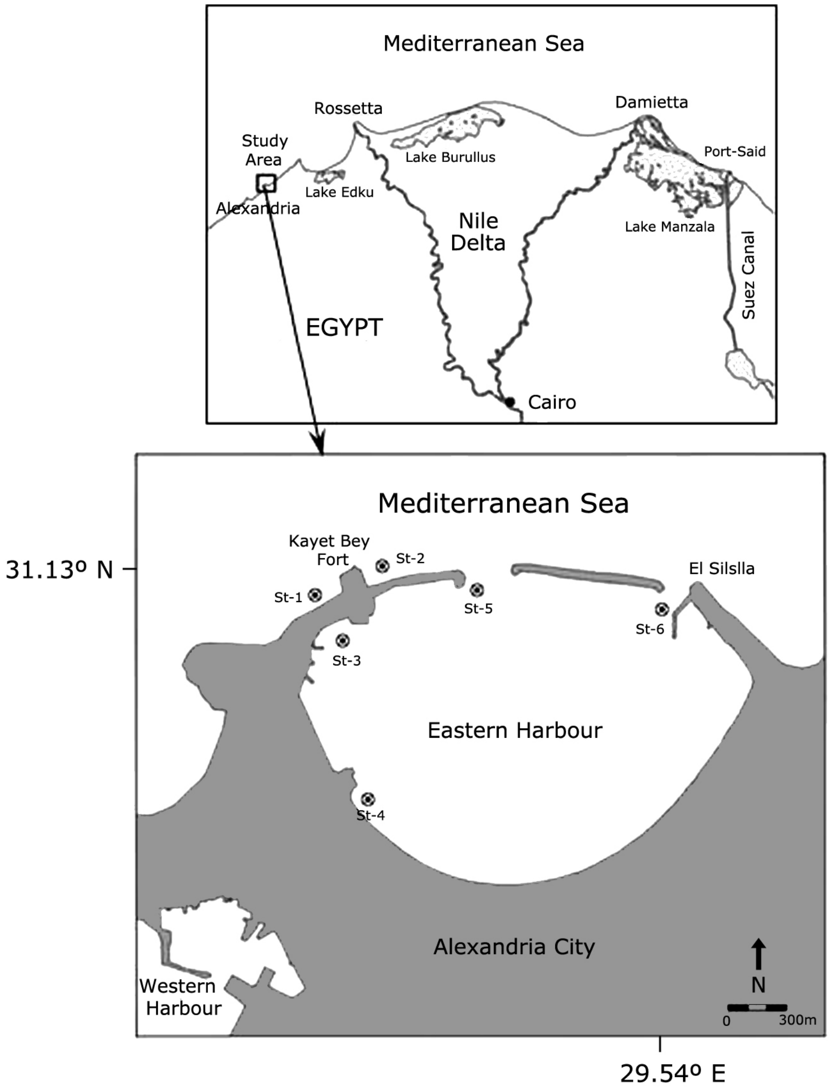

Figure 1. Map showing the position of the study area and sampling stations / Mapa mostrando la posición del área de estudio y estaciones de muestreo

The nutrient levels reflected low as well as high fertility in the study area. Nitrate showed approximately close ranges of monthly variations (1.0-10.83 μM and 0.44-10.46 μM) in the EH and KB, respectively, with relatively higher value (factor of 1.1) in the EH than in the KB. Nitrite fluctuated between 0.02-0.87 μM in the EH and 0.14-1.5 μM in the KB, but the annual average in KB (0.52 μM) was about twice that (0.27 μM) in the EH. Ammonium had the widest range of variation among the inorganic nitrogen forms (0.03-11.84 μM in the EH and 0.45-23.49 μM in the KB). These values resulted in higher annual average (factor of 1.3) in the KB than in the EH. Relatively high concentrations of phosphate were recorded (0.06-1.91 μM) in the whole area, but KB was comparatively richer (annual average: 0.89 μM) than the EH (0.64 μM).

The relation between nitrate and phosphate (N/P) demonstrated wide variations in both the KB (0.3-33.2) and the EH (0.8-27.5) in addition to extremely high values

Table 1. Hydrographic parameters at the sampled stations of the Kayet Bey (Sts. 1-2) and the Eastern Harbor (Sts. 3-6) from January to December 2009 (Average values ± Standard deviation) (After Kairy *et al.* 2014) / Parámetros hidrográficos de las estaciones muestreadas de Kayet Bey (estaciones 1-2) y Bahía Oriental (estaciones 2-6) desde enero a diciembre 2009 (Valores promedio ± desviación estándar) (modificado de Kairy *et al.* 2014)

Parameter	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6
Temperature °C	24.9±8.3	24.9±8.1	24.9±7.9	25±7.8	24.9±7.4	24.95±7.3
Salinity	37.4±0.8	37.3±0.9	37.2±0.8	37.3±0.8	37.1±0.9	37.3±0.8
pH	7.95±0.2	7.9±0.2	7.94±0.1	7.97±0.2	8.1±0.1	8±0.1
DO mg l^{-1}	5.4±2.1	5.5±2.5	5.3±1.8	6.0±1.9	6.9±2.3	6.6±1.9
Nitrate µM	4.8±2.8	5.18±3.1	6.0±3.3	4.95±2.4	4.7±3.0	5.6±2.8
Nitrite µM	0.57±0.5	0.47±0.3	0.32±0.2	0.27±0.2	0.26±0.2	0.25±0.2
Ammonia µM	5.3±2.8	4.06±3.2	4.5±3.1	3.1±2.4	3.6±2.9	3.2±2.3
Phosphate µM	0.9±0.6	0.85±0.4	0.84±0.5	0.50±0.2	0.70±0.5	0.51±0.3
Silicate µM	7.6±6.7	9.2±7.0	5.6±4.9	5.40±4.3	5.9±4.9	6.5±6.2

(178.6-639.5) occasionally found in the EH. Silicate concentrations were high over the year, sustaining monthly average values from 2.67 µM to 23.79 µM in KB and 0.86-13.73 µM in the EH.

PHYTOPLANKTON COMMUNITY

The phytoplankton community was more diverse in the EH (162 species) as compared to the KB (110 species), while the Shannon index in the EH (annual average: 1.5) was lower than in the KB (2.1). However, the species composition showed pronounced similarity between the sampling stations in the whole area of study (Fig. 2). Diatom species appeared to be the major phytoplankton component (100 and 64 species) in EH and KB, respectively, followed by dinoflagellates (32 and 21 species, respectively). In contrast, freshwater forms were pronouncedly less diverse in both areas and were represented mainly by Cyanophyceae (6 and 10 species, respectively), Chlorophyceae (10 and 11 species) and Euglenophyceae (6 and 4 species). The Shannon diversity index in the dynamic water at KB (0.17-3.2) was wider than in the EH (0.29-2.82), attaining the highest value in February, winter and summer in both areas.

Phytoplankton sustained high count in the whole area, but the EH had pronouncedly higher count (factor of 12.8) than the KB (annual average: 0.108 x 10^6 cells L^{-1}), with the clear dominance of diatoms (86.8 and 74%, respectively) in the 2 areas when compared to the dinoflagellates (12.4 and 23.4%). The freshwater taxa showed almost low count, constituting collectively 0.9% of total phytoplankton in the EH and 2.5% in the KB. On the spatial scale, Station 4 in the EH contained the highest count (factor of 20.2) than the lowest one at station 1in KB (annual average: 0.106 x 10^6 cells L^{-1}).

The abundance cycle of phytoplankton exhibited clearly different patterns in the 2 areas. In the EH, diatoms flourished during spring (March-June) and autumn (October-December), while dinoflagellates showed one peak during summer (July-August) (Fig. 3).

The spring bloom was due to *Chaetoceros affinis* (40.1%), *Ch. curvisetus* (20.8%) and *Ch. decipiens* (9.7%) in March, *Sk. costatum* (77.8%) and *Ch. affinis* (10.1%) in April, *Thalassionema nitzschioides* (41.6%) and *Sk. costatum* (35.4%) in May and *Sk. costatum* (32.3%), *Pseudo-nitzschia delicatissima* (22.3%) and *Ch. affinis* (11.2%) in June. The autumn outgrowth was dominated by *Sk. costatum* (85.7 and 87.6%) in October and November,

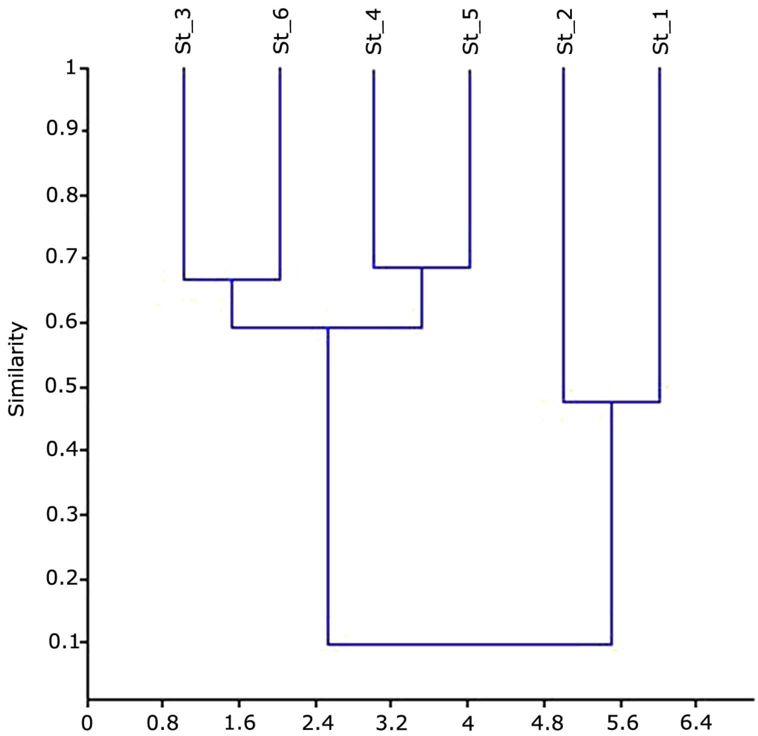

Figure 2. Bray-Curtis similarity of phytoplankton composition between different stations in the whole area / Similitud de Bray-Curtis de la composición del fitoplancton entre diferentes estaciones en toda el área

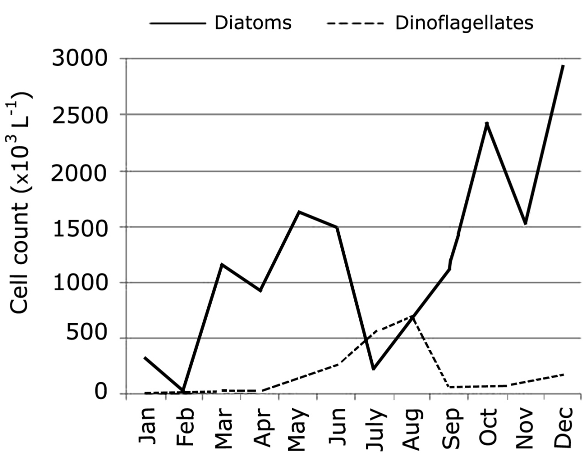

Figure 3. Monthly count of diatoms and dinoflagellates in the Eastern Harbor (January-December 2009) / Conteo mensual de diatomeas y dinoflagelados en Bahía Oriental (enero-diciembre 2009)

respectively, while in December, this species formed 25.6% in association with *Asterionella glacialis* (17.5%), *L. minimus* (16.6%), *Leptocylindrus danicus* (10.6%). The summer was characterized by dinoflagellate peak mainly due to *Prorocentrum minimum* (45.3%), beside *S. trochoidea* (7.7%) and *Protoperidinium minutum* (4.4%) in July, while *S. trochoidea*, *Prorocentrum cordata*, *P. compressa*, *A. minutum*, *P. minimum*, *P. minutum* and *G. catenata* formed together 43.1% of total phytoplankton in August. In addition, the diatom *Cyclotella meneghiniana* showed active contribution (15.9%) in July and *Rhizosolenia fragilissima* (15.9%), *Chaetoceros sociales* (12.1%), *Sk. costatum* (8.2%) and *P. delicatissima* (6.6%) in August.

In the KB, high phytoplankton count was observed from May to July, with a distinctive peak in July, beside a small peak in November (Fig. 4). The diatom *Nitzschia microcephala* was absolutely dominant (93.7%) in May, against *Sk. costatum* (52.7%) accompanied by *N. microcephala*

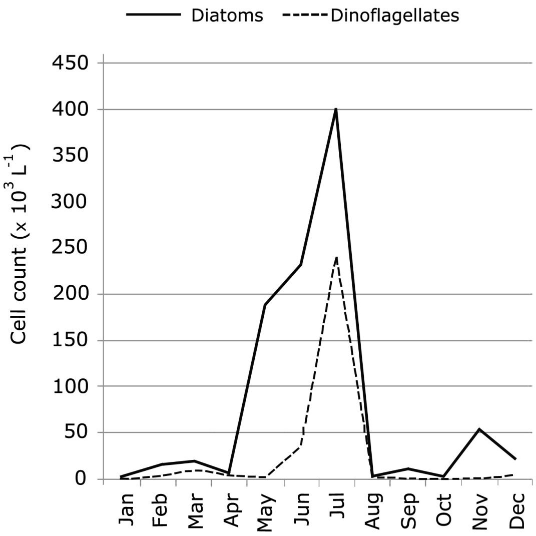

Figure 4. Monthly count of diatoms and dinoflagellates in the Kayet Bey (January-December 2009) / Conteo mensual de diatomeas y dinoflagelados en Kayet Bey (enero-diciembre 2009)

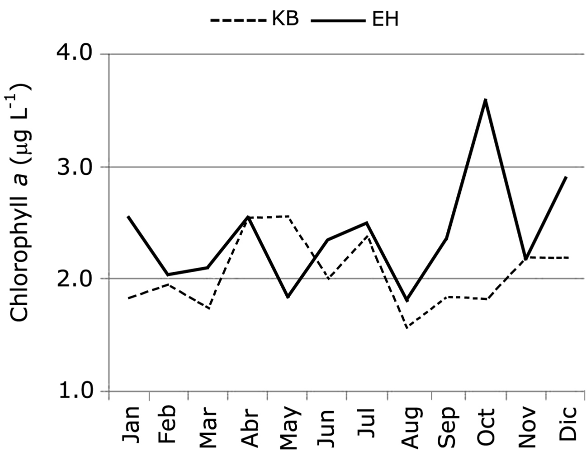

Figure 5. Monthly variations of phytoplankton biomass in the Eastern Harbor (EH) and the Kayet Bey (KB) (January-December 2009) / Variaciones mensuales de la biomasa de fitoplancton en Bahía Oriental (EH) y Kayet Bey (KB) (enero-diciembre 2009)

(7.4%), *C. closterium* (5.3%), *P. delicatissima* (5.0%) and *C. meneghiniana* (4.9%) in June. The July peak was caused by two dinoflagellates (*P. minimum,* 21.7% and *P. compressa,* 13.7%) and approximately equal share of the diatoms *Thalassiosira subtilis* (13.7%), *C. meneghiniana* (12.6%), *Cyclotella* sp. (10.6%), *Melosira varians* (10.5%) and *Synedra ulna* (9.9%).

Twenty eight species were persistent in the EH and 8 species in the KB, among them, the diatoms *Navicula cryptocephala*, *P. delicatissima*, *Sk. costatum* and the dinoflagellate *P. micans* were common in both areas. On the other hand, several toxic dinoflagellates were found all the year round, sometimes with high count (Table 2).

The phytoplankton biomass represented by chlorophyll *a* exhibited wide range of variation (0.87-6.97 µg L^{-1}) in the EH and narrow range (1.44-2.88 µg L^{-1}) in KB. On the monthly scale, five chlorophyll peaks were observed in the EH and one only in KB (Fig. 5), but the annual average value in the EH was about 1.2 fold that in the KB.

Discussion

The chronic eutrophication in the study area was caused mainly by the long-term sewage discharge for about 50 years. Although the sewage discharge to the EH has stopped since about 2 decades, the present study indicated the continuity of eutrophication conditions. In the KB, eutrophication continuity is attributed to the direct effect of sewage discharge which currently is still acting, as indicated from the abnormally high ammonia particularly in October and high nitrate in January which pronouncedly greater (factor of 11.7 and 2.6) than the criteria of eutrophication (4 µM for nitrate and 2 µM for ammonium) proposed by Vucak & Stirn (1982), Franco (1983), Marchetti (1984) and Oczkowski & Nixon (2008). In the EH the remobilization of nutrients from sediments (Awad 2004) may play a crucial role in eutrophication, whereas ammonia and nitrate attained values (factor of 5.9 and 2.7) greater than those of eutrophication criteria, especially during the strong winter mixing.

The great similarity in phytoplankton composition between the EH and KB is explained by the active water exchange between the harbor and the open sea (Abdalla 1979) through seasonal water currents (El-Geziry & Maiyza 2006). However, the higher number of species (factor of 1.5) in the EH could be related to the relatively stable conditions in the EH as a semi-closed basin compared to the dynamic water at KB (110 species). Therefore, the Shannon diversity index in KB (0.17-3.2) was wider than in the EH (0.29-2.82). However, close values (0.19-2.42) were observed earlier in the latter area (Madkour *et al.* 2007), while similar to those in KB (0.0-3.12) were also recorded in the open sea of Abu Qir Bay (Shams El-Din & Dorgham 2007).

Table 2. Abundance (x 10^3 cells L^{-1}) and frequency of occurrence of toxic phytoplankton species in the Eastern Harbor (EH) and the Kayet Bey (KB) / Abundancia (x 10^3 células L^{-1}) y frecuencia de ocurrencia de especies tóxicas del fitoplancton en Bahía Oriental (EH) y Kayet Bey (KB)

Toxic species	KB		EH	
	Count	Frequency (Months)	Count	Frequency (Months)
Pseudo-nitzschia delicatissima	0.3-13.6	8	1.95-394.2	12
Alexandrium minutum	0.1-6.4	5	0.05-110.8	7
Dinophysis acuta	0.0	0.0	0.0-0.07	1
Dinophysis caudata	0.0	0.0	0.0-0.08	1
Gonyaulax catenata	0.9-7.7	5	0.1-68.2	8
Protoperidinium granii	0.0	0.0	0.08-4.7	4
Protoperidinium subinerme	0.3-1.3	5	0.04-18.8	8
Protoperidinium conicum	0.0-0.2	1	0.02-0.3	4
Protoperidinium steinii	0.0-0.4	1	0.3-11.2	7
Prorocentrum cordata	0.5-1.4	4	0.9-133.7	8
Prorocentrum micans	0.1-2.0	8	0.1-58.4	10
Prorocentrum minimum	0.4-139.9	3	0.3-368.0	5
Prorocentrum triestinum	0.2-2.1	4	0.1-18.4	8
Scrippsiella trochoidea	0.05-2.4	5	0.4-139.8	12
Pyrophacus horologium	0.04-0.2	2	0.05-1.0	10

The environmental conditions in the study area play fundamental role in the dynamics of the phytoplankton community. The December peak at 22.6ºC was dominated by diatoms, while dinoflagellates showed their peak at high temperature in summer, demonstrating a positive significant correlation with temperature (Table 3). These findings are in agreement with Ismael (2003) who observed heavy blooms of dinoflagellates in summer and the dominance of diatoms in winter and with Labib (2002) who recorded intermittent predominance of dinoflagellates in summer. It seems that salinity is important factor affecting the species composition in the study area, whereas it showed positive significant correlation with the dinoflagellates, euglenophyceae and some abundant diatom species (Table 3). Similarly, Labib (2002) stated that salinity fluctuation was a crucial factor limiting the phytoplankton variability in the EH.

Regarding the nutrient effect, the high phytoplankton count in the EH in May-June coincided with the lowest nitrite and nitrate, but in autumn it was associated with high concentration of both salts. On the other hand, the phytoplankton count displayed reversed monthly relationship with the ammonium concentration most of the year. This may be explained by the inhibiting effect of ammonia on the living biota as indicator of organic pollution. It seems that nitrite has a pronounced role in the growth of phytoplankton in the study area, whereas it showed significant correlation with several dominant species (Table 3). This may be attributed to easy uptake of nitrite by phytoplankton as an intermediate compound between ammonia and nitrate. The abnormal variations of N/P ratio in the study area (0.3-33.2) is also one of the factors causing irregular phytoplankton growth in the study area. Welch (1980) stated that N/P varies with

Table 3. Significant correlations between environmental parameters and phytoplankton groups and dominant species / Correlaciones significativas entre parámetros ambientales y los grupos de fitoplancton y especies dominantes

	Temperature	Salinity	pH	Chl.	Nitrite	Ammonia	Silicate
Dinoflagellates	0.72	0.56			0.57		
Euglenophyceae	0.57	0.55					
Cyclotella meneghiniana	0.65	0.56			0.67		
Lpetocylindrus danicus						0.72	
Lpetocylindrus minimus						0.6	
Ceratoneis closterium		0.57					
Pseudo-nitzschia delicatissima	0.58	0.59					
Rhizosolenia fragilissima		0.56					
Skeletonema costatum							0.56
Gonyaulax catenata	0.59						
Protoperidinium minutum	0.66				0.53		
Prorocentrum compressa		0.57					
Prorocentrum cordata	0.53	0.68					
Scrippsiella faeroense	0.60						
Scrippsiella trochoidea	0.59						
Pyrophacus horologium	0.60	0.62					
Euglena acus	0.59	0.71	0.57				
Total phytoplankton				0.522			

trophic state and decreases with increased eutrophication. However, phosphate concentration may play a role in phytoplankton growth, as phosphorous is the key nutrient controlling eutrophication (Schindler & Fee 1974, Schindler 1975, 1977).

Silicate is considered as a essential nutrient for the growth of diatoms. This was clear from the association of high phytoplankton count with low silicate during October-December due to the intensive consumption of silicate by diatoms, as indicated from their significant correlation with the dominant diatom species *Sk. costatum* (Table 3). Meanwhile, high silicate along with low phytoplankton count in January and February was attributed to little silicate uptake during winter, but high silicate in August was due to the dominance of dinoflagellates (48.7%) which do not need silicate in their growth.

It seems that the long term changes in the environmental conditions, particularly the nutrient concentrations and clear variability in N/P ratio (Table 4) were reflected on the phytoplankton count in the EH. During the present study the count (1.4 x 10^6 cells L^{-1}) was markedly lower (factor of 2.9 and 3.1 respectively) than those of Hussein (1994) and Abdel-Halim & Khairy (2007), and the phytoplankton biomass (chlorophyll *a*) dropped clearly during the present study 2.4 µg L^{-1} as compared to the earlier records (4.9 µg L^{-1} and 3.08 µg L^{-1}) of Hussein (1994) and Madkour *et al.* (2007), respectively. The environmental changes in the EH resulted also in distinctive variability in the dynamics of the phytoplankton community, whereas one abundance peak was observed in January (Ismael 1993), March (Abdel-Halim & Khairy 2007) and April (Madkour *et al.* 2007) and 3 peaks in February, June and October (Tawfik 2001) against 4 peaks during the present study. On the other hand, our study recorded more diverse community (162 species) than that (131 species) of Hussein (1994), 76 species of Tawfik (2001) and 96 species of Abdel-Halim and Khairy (2007).

The occurrence of several toxic species during the present study sometimes in high count could be considered as symptoms of eutrophication as documented by previous studies (Hussein 1994, Abdel-Halim & Khairy 2007, Madkour *et al.* 2007).

Table 4. N/P ratio in the Eastern Harbor during the last two decades / Razón N/F en Bahía Oriental durante las dos últimas décadas

Date	N/P	Reference
1989	3.8	Ibrahim 1999
1990-91	6.5	Hussein 1994
1996	7.3	El-Rayis & Hinckly1999
2000	28	EEAA 2000
2001	11.4	EEAA 2001
2002	6.1	EEAA 2002
2003	18	EEAA 2003
2004-2005	7.8	Abdel-Halim & Khairy 2007
2009	8.3	Present study

It is worth to mention that, the permanent occurrence of the diatom *Sk. costatum* over long time in the EH (El-Maghraby & Halim 1965, Halim *et. al.* 1980a,b; Hussein 1994, Abdallah *et. al.* 1995, Abdel-Halim & Khairy 2007) is indicative of chronic eutrophication as it was found among dominant species in other eutrophic areas (Mihnea 1985, El-Sherif 1994, El-Sherif & Gharib 1994, Gharib & Dorgham 2006).

Regardless of the great similarity in the phytoplankton community between the EH and KB, the dominance pattern was different. *Skeletonema costatum* was the dominant in the EH, while *N. microcephala, P. minimum, C. meneghiniana, Prorocentrum compressa* and *Th. subitilis* shared the dominance with *Sk. costatum* in the KB.

On the long term scale, the phytoplankton count in the KB area amounted to 15.9 x 10^3 cells L^{-1} (Dorgham *et al.* 1987), 236.4 x 10^3 cells L^{-1} (Nessim & Zaghloul 1991) and 108 x 10^3 cells L^{-1} during the present study. Also chlorophyll *a* showed pronounced changes from 4.72 $\mu g\ L^{-1}$ (Dorgham *et al.* 1987), 1.4 $\mu g\ L^{-1}$ (Nessim & Zaghloul 1991), 2.71 $\mu g\ L^{-1}$ (Metcalf & Eddy International 1997) and 2.05 $\mu g\ L^{-1}$ during the present study. Such changes are in accordance with changes in nutrient salts (Dorgham *et al.* 1987, Nessim & Zaghloul 1991 and present study).

The present study indicated that the EH and KB are still suffering from eutrophication although great part of discharged wastes have been stopped, particularly to the Eastern Harbor, since two decades. This phenomenon was indicated from high nutrient concentrations and intensive phytoplankton growth. In the meantime, the phytoplankton community experienced drastic changes in the species composition, abundance, dominance and biomass on the long term scale, beside the permanent existence of several toxic species.

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