CrossMark

ERRATUM

Erratum to: Phytoplankton variability in relation to some environmental factors in the eastern coast of Suez Gulf, Egypt

Mohamed Z. Nassar · Nihal G. Shams El-Din ·
Samiha M. Gharib

The original version of this article contained mistakes.

The corrected abstract paragraph, Table 2 and Table 6 are shown below in bold.

Water samples were seasonally collected from 12 stations of the eastern coast of Suez Gulf during autumn of 2012 and winter, spring, and summer of 2013 in order to investigate phytoplankton community structure in relation to some physicochemical parameters. The study area harbored a diversified phytoplankton community (138 species), belonging to 67 genera. Four algal groups were represented and classified as Bacillariophyceae (90 species), Dinophyceae (28 species), Cyanophyceae (16 species), and Chlorophyceae (4 species). The results indicated a relative high occurrence of some species namely.; *Pleurotaenium trabecula* of green algae; *Chaetoceros lorenzianus*, *Proboscia alata var. gracillima*, *Pseudosolenia calcar avis*, and *Pseudonitzschia pungens* of diatoms; *Trichodesmium erythraeum* and *Pseudoanabaena limnetica* of cyanophytes. Most of other algal species were fairly distributed at the selected stations of the study area. The total abundance of phytoplankton was relatively low (average of 2989 unit/L) in the eastern coast of Suez Gulf, as compared its western coast and the northern part of the Red Sea. The diversity of phytoplankton species was relatively high (2.35–3.82 nats) with an annual average of 3.22 nats in the present study. The results concluded that most of eastern coast of Suez Gulf is still healthy, relatively unpolluted, and **oligotrophic** to **mesotrophic** area, which is **characterized** by the low values of dissolved phosphate (0.025–0.3 μM), nitrate (0.18–1.26 μM), **and relatively high** dissolved ammonium (0.81–5.36 μM). Even if the occurrence of potentially harmful algae species was low, the study area should be monitored continuously. The dissolved oxygen ranged between 1.77 and 8.41 mg/L and pH values between 7.6 and 8.41. The multiple regression analysis showed that the dissolved nitrate and pH values were the most effective factors that controlled the seasonal fluctuations of phytoplankton along the eastern coast of Suez Gulf during 2012–2013.

M. Z. Nassar (✉)
National Institute of Oceanography and Fisheries, B.O.182, Suez, Egypt
e-mail: mnassar65@yahoo.com

N. G. S. El-Din · S. M. Gharib
National Institute of Oceanography and Fisheries, Alexandria, Egypt

Table 2 Relative counts of the recorded phytoplankton species (unit/L) along the eastern coast of Suez Gulf during 2012–2013

Algal groups	1	2	3	4	5	6	7	8	9	10	11	12
Diatoms												
Amphiprora alata (Ehrenberg) Kützing (ab)	+		+	+	+		+		+	+		
Amphiprora paludosa W. Smith (ab)	+	+	+	+	+	+	+	+	+	+	+	+
Amphora grevilleana Gregory (WoRMS)	+											
Amphora lineolata Ehrenberg (ab)		+	+		+	+	+	+	+	+	+	
Amphora marina W. Smith (ab)		+	+	+	+	+	+	+	+	+	+	+
Amphora ovalis (Kützing) Kützing (WoRMS)									+			
Asterionella sp.	+		+									
Asterolampra sp.				+								
Aulacoseira granulata var angustissima (O.F. Müller) Simonsen (ab)	+	+	+	+	+	+	+	+	+	+	+	+
Aulacoseira italica (Ehrenberg) Simonsen (ab)	+	+	+							+	+	+
Bacillaria paradoxa J.F. Gmelin (ab)									+			+
Campylodiscus hibernicus Ehrenberg (ab)	++	+	+	+	+	−	+	+	+	+	+	+
Chaetoceros coarctatus* Lauder (ab)		+		+				+		+	+	−
Chaetoceros curvisetus* Cleve (ab)		+										
Chaetoceros densus* (Cleve) Cleve (ab)									+		+	
Chaetoceros lorenzianus* Grunow (ab)	+	+	+	+++	++	++	+	+	++	+	+	+
Chaetoceros peruvianus* Brightwell (ab)				+					+			
Climacodium biconcavum Cleve (WoRMS)				+	+		+		+	++	++	
Climacosphenia moniligera Ehr. (ab)	+	++	+	+	++	++	++	++	++	+	++	++
Cocconeis placentula Ehrenberg (ab)		+			+	+	+	+	+	+	+	−
Coscinodiscus centralis Ehrenberg (WoRMS)		+						+				
Coscinodiscus granii Gough (ab)		+				+	+	+				
Coscinodiscus marginatus Ehrenberg (ab)		+	+									
Coscinodiscus radiatus Ehrenberg (WoRMS)		+++	−	+	+	+	+	+	+	+	−	−
Cyclotella meneghiana* Kützing (ab)				+		+						
Cymbella aspera Ehrenberg Cleve (WoRMS)									+			
Cymbella sp.	+	+	+	+	+				+			+
Cymbella ventricosa (C.Agardh) C.Agardh (ab)			+	+	+	+	+		+			+
Diploneis interrupta (Kützing) Cleve (ab)				+					++			
Diploneis sp.				+	+		+		+			
Fragillaria pectinalis (O.F.Müller), Lyngbye (ab)							+					
Fragillaria construens Ehrenberg Grunow (ab)							+					
Fragillaria sp.	+	+	+	+				+	+			+
Gramatophora marina (Lyngbye) Kützing (ab)		+		+	+	+	+	+	+		+	
Gramatophora oceanica Ehrenberg (WoRMS)				+		+			+			
Guinardia flaccida (Castracane) H.Peragallo (ab)	+	+++	+	+++	++	++	++	++	+++	++	++	+
Gyrosigma acuminatum (Kützing) Rabenhorst (WoRMS)	+	+	+	+	+	+		+	++		+	+
Gyrosigma attenuatum (Kützing) Rabenhorst (ab)	+++	++	++	++	++	++	++	++	+++	+++	++	+++
Gyrosigma balticum (Ehrenberg) Rabenhorst(WoRMS)	+	+	+	+		+			+			+
Hemiaulus membranaceus Cleve				+		+			+			
Hemiaulus sinensis Greville									+			
Lauderia annulata Cleve (WoRMS)											+	
Leptocylindrus danicus (ab)		+		+	+	+	+	+		+++	+	

Table 2 (continued)

Algal groups	1	2	3	4	5	6	7	8	9	10	11	12
Leptocylindrus minimus Granv (WoRMS)	+++	+++	+	+	++	+	++	++	+	+	+	+
Leptocylindrus sp.	+		+	+					+			+
Licmophora abbreviata C. Agardh (ab)				+					+			
Licmophora flabellata C. Agardh (ab)	+	+	++	++	+	++	+	++	++	++	+	++
Licmophora gracilis (Ehrenberg) Grunow (WoRMS)	+	+	+	+	+	+	+	+	+	+	+	+
Mastogloia sp.		+					+	+			+	
Melosira sp.				+								+
Melosira varians C.Agardh (ab)	+								+		+	+
Navicula dicephala (Ehrenberg) W. Smith (ab)			+	+			+		+			+
Navicula tripunctata (O.F. Müller) Bory de Saint-Vincent (WoRMS)	+	+	+	++	+	+	+	+	+	+	+	+
Navicula placentula (Ehrenberg) Kützing (ab)				+	+	+	+		++	+	+	
Navicula sp			+	+		+	+		+			+
Nitzschia acicularis (Kütz.) W.Sm.	+	+	+	+	+		+		++	+	+	+
Nitzschia closterium* (Ehrenberg) W.Smith (ab)	+		+	+					+			+
Nitzschia longissima* Brébisson) Ralfs in Pritchard (ab)	++	+	+	+	++			++	++	++	+++	+
Nitzschia obtusa W. Smith (ab)	+	+	+	+	+	+	+	+	+	+	+	+
Nitzschia pungens* var. atlantica (Grunow ex Cleve) G.R.Hasle, (ab)	+	+	+	+++	++	++	+	++	+++	+	++	+
Nitzschia sigma (Kützing) W. Smith (ab)	+	+	+	++	+	++	++	+	++	++	+++	++
Nitzschia vermicularis (Kütz.) Hantzsch in Rabenh	+						+					
Odontella aurita (Lyngbye) C.A. Agardh (ab)		+		+	+	+	+	+	+			
Odontella obtusa (Kützing) Ralfs (ab)	+	++	+	+	+	+	+	++	+	+	++	++
Odontella sinensis (Greville) Grunow (WoRMS)									+			
Paralia sulcata (Ehrenberg) Cleve (ab				+								
Plagiotropis lepidoptera (Gregory) Kuntze (ab)		+		+	+	+	+	+	++	+	+	
Pleurosigma angulatum W. Smith (ab)		+			+	+	+	+	+	+	+	
Proboscia alata var.gracillima* (Brightwell) Sündstrom (ab)	++	+++	++	+++	+++	++	+++	+++	+++	++	++	+++
Proboscia alata form indica* Brightwell) Sündstrom (ab)		+	+	++					+			
Pseudosolenia bergoni H. Péragallo (ab)									+			
Pseudosolenia calcar avis (Schultze) Sundström (ab)	++	+++	++	+++	+++	++	++	+++	+++	+++	+++	++
Rhizosolenia fragilissima Bergon		+		+	+	+	+				+	
Rhizosolenia imbricata (Cleve) Schröder WoRMS		++++	+	+	+	+	+	+	+++		++	
Rhizosolenia stoterfothii H. Peragallo (ab)		+		+	+	+				+	+	
Rhizosolenia styliformis Brightwell (ab)	+	+		+	+				+	+	+	+
Skeletonema costatum* (Greville) Cleve (ab)	+	+	+	+		+			+			+
Stephanopyxis turis (Greville & Arnott in Gregory) Ralfs in Pritchard		+						+	–	+	+	
Striatella unipunctata (Lyngbye) C. Agardh (ab)				+					+			
Surirella minuta Brébisson (WoRMS)	++	+	++	+	+	+	+	+	+	+	+	+
Surirella robusta Ehrenberg (ab)	+		+									+
Synedra acus Kütz.	+	+	+	+		+			+			+
Synedra crystalline (C.Agardh) Kützing (WoRMS)		+										
Synedra ulna (Nitzsch) Ehrenberg (ab)	++	++	+	++	++	++	++	++	++	++	+++	++
Synedra undulata (J.W.Bailey) Gregory (ab)	+	+	+		+	+	+	+	+	+	+	+

Table 2 (continued)

Algal groups	1	2	3	4	5	6	7	8	9	10	11	12
*Thalassionema nitzschioides** (Grunow) Mereschkowsky (ab)	+	+	+	+	+			+	+		+	+
Thalassiosira sp.	+				+	++	++					
Thalassiothrix frauenfeldii (Grunow) Grunow (WoRMS)		++		++	+	+		+	++	+	+	
Thalassiothrix longissima Cleve & Grunow (ab)	++	++	++	+++	++	++	++	++	+++	+++	+++	+++
Trachyneis aspera (Ehrenberg; Ehrenberg) Cleve		+		+	++	+	+	+		+	++	
Cyanophytes												
Anabaena sp.		+										
Chroococcus minutus (Kütz.) Nägeli	+		++		++		+	+	+		+	+
Chroococcus turigidus (Kützing) Nägeli (ab)		+	+		+				+			+
Coelosphaerium sp.	+		+	+	+	+			+		+	+
Lyngbya major Pseudoanabaena Meneghini ex Gomont (ab)									+	++	+	
Lyngbya majuscula Harvey ex Gomont (WoRMS)		+			+		+			++	+	
Microcystis sp		+	+	+	+				+		+	+
Trichodesmium erythraeum *(Ehrenberg) Geitler (ab)	+	+	+	+	+++	+	+++	++	++	++++	+++	+++
*Pseudanabaena limnetica** (Lemmermann) Komárek (ab)	++	++	++	+	+++	++	+++	++	++	+++	++	++
*Oscillatoria simplicissima** Gomont (WoRMS)		+	+	+	+	+	+	++	+	+++	+	++
Oscillatoria sp.	+	+++	++	+	++	+	++	+	++	++	++	++
*Oscillatoria tenuis** C. Agardh (WoRMS)		+	+		+		+	+	+	++	+	+
Phormidium sp.	++	++	++	+	++	++	++	++	++	+++	++	++
*Planktothrix formosa**	+	+	+	+	+	+	+	+	+	++	+	++
Spirulina major Kützing ex Gomont (WoRMS)	++											+
Spirulina sp.			+							+		
Dinoflagellates												
Ceratium breve (Ostenfeld & Schmidt) Schroder (ab)	+		+							+	+	+
Ceratium egyptiacum Halim (ab)									+			
Ceratium extensum (Gourret) Cleve-Euler (ab)	+						+					+
*Ceratium furca** (Ehrenberg) Claparède & Lachmann (WoRMS)	+	+	+	+				+	+			+
*Ceratium fusus** (Ehrenberg) Dujardin (ab)	+		+		+				+			+
Ceratium karastenii Pavillard (WoRMS)									+			
Ceratium macroceros (Kofoid) Peters (ab)	+	+	+		+			+	+		+	+
Ceratium massiliense (Gourret) E.G.Jørgensen (ab)	+	+	+	+		+	+	+	++		+	+
Ceratium trichoceros (Ehrenberg) Kofoid (WoRMS)	+	+	+	++	+	+	+	+	++	+++	+++	+
*Ceratium tripos** (O.F.Müller) Nitzsch (WoRMS)	+	+	+	+	+	+	+	+	+	++	++	+
*Dinophysis caudata** Saville-Kent (ab)		+							+	+	+	
Dinophysis sp.				+								
Diplopsalis lenticula						+			+	+		
Exuviaella compressa (Bailey) Knudsen & in Ostenfeld (ab)		+		+	+	++	+	+	+	++	++	
Goniaulax sp.				+			+			+		
Gymnodinium sp.				+					+			
Oxytoxum gracile J.Schiller						+					+	
Phalacroma sp.				+								
Podolampas palmipes Stein		+				+		+				
Prorocentrum compressum (J.W. Bailey) Abé ex Dodge									+			

Table 2 (continued)

Algal groups	1	2	3	4	5	6	7	8	9	10	11	12
*Prorocentrum micans** Ehrenberg (ab)		+		+								
*Prorocentrum minimum** (Pavillard) Schiller		+					+		+	+		
Protoperidinium minutum (Kofoid) Loeblich III		+		+	+	+	+	+	+	+	+	
Protoperidinium cerasus (Paulsen) Balech (ab)	+	+	+	+	+;	+	+	+	+	+	+	+
Protoperidinium depressum (Bailey) Balech (CaRMS)		+				+		+		+		
Protoperidinium divergens (Ehrenberg) Balech (CaRMS)								+				
Protoperidinium ovatum Pouchet (CaRMS)				+		+						
Pyrophacus horologicum Stein (ab)		+							+			
Chlorophytes												
Dictyosphaerium sp.		+									+	
Pediastrum clathratum. (Schröder) Lemmermann (ab)											+	
Pleurotaenium trabecula Nägeli (ab)	+++	+	+++	+++	++++	+++	++++	+++	+++	+++	+++	+++
Treubaria crassipina G. M. Smith (WoRMS)							+	+		++		

Note: 0–50 rare +, > 50–100 frequent ++, > 100–200 common +++, > 200 abundant ++++

The species marked with astrics are potential harmful

Table 6 The correlations between total phytoplankton counts, phytoplankton classes, dominant species and the physico-chemical parameters during 2012–2013

	Temp	pH	DO	PO_4	NO_3	NH_4
	°C	–	mgO_2/l	μM		
Total phytoplankton	−0.20	**−0.63**	**0.51**	0.44	**0.66**	**−0.47**
Diatoms	**−0.51**	**−0.69**	**0.48**	**0.69**	**0.63**	**−0.46**
Dinoflagellates	0.01	−0.22	**0.52**	0.33	0.34	−0.09
Cyanophytes	0.27	−0.18	0.19	0.14	0.27	−0.18
Chlorophytes	0.38	−0.08	−0.02	0.02	0.17	−0.22
Chaetoceros lorenzianus	−0.08	−0.35	0.07	**0.42**	**0.50**	**−0.51**
Gyrosigma attenuatum	0.09	−0.20	0.14	0.39	**0.49**	−0.27
Pseudosolenia calcar-avis	0.10	−0.24	−0.03	0.28	**0.40**	**−0.49**
Pleurotaenium trabecula	0.38	−0.02	−0.05	−0.03	0.11	−0.16
Proboscia alata var.gracillima	0.33	0.27	0.07	−0.10	−0.15	0.23
Pseudo-Nitzschia pungens	**−0.45**	**−0.43**	0.31	**0.63**	**0.52**	−0.32
Trichodesmium erythraeum	0.29	−0.15	0.17	0.14	0.25	−0.17
Pseudanabaena limnetica	**0.50**	0.10	−0.01	−0.04	0.10	−0.03

Note: Bold correlations are significant at $p < 0.05$ and $n = 47$)

In the Correlation matrices and multiple regressions under Statistical Analysis section the corrected paragraph is shown below.

The statistical analysis of the data indicated that the phytoplankton abundance was positively correlated with nitrate (r=0.66) and dissolved oxygen (r=0.51) but inversely correlated with pH values (r=−0.63) **and with ammonia (r=−0.47)**, whereas the groups and dominant species showed varied correlations with physicochemical characteristics as shown in Table 6. The multiple regression analysis indicated that the dissolved nitrate and pH values were the most effective factors that controlled the seasonal fluctuations of phytoplankton in the eastern coast of Suez Gulf during 2012–2013. The regression model was phytoplankton counts = 1379.2341 + 0.662 NO$_3$ − 0.33 pH (MR = 0.662, N = 47, $p < 0.1278$). The similarity index revealed four clusters (Fig. 3).

In the Discussion section the corrected paragraphs are shown below.

In general, the high nitrate concentrations enhance the phytoplankton growth during the study period. This was confirmed by the positive correlation between NO3 and the total counts of phytoplankton (r=0.66) and the regression analysis (phytoplankton counts = 1379.2341 + 0.662 NO$_3$ − 0.33 pH). However, natural phytoplankton communities typically prefer to take up nitrogen in the reduced form of ammonium rather than the oxidized forms nitrite and nitrate. **In the present study there was a negative correlation between total phytoplankton abundance and ammonium (r=−0.47) and there was a negative correlation between diatoms and ammonium (r=−0.46).** This may be due to that various phytoplankton groups and taxa exhibit differential abilities to take up and assimilate dissolved organic nitrogen vs. dissolved inorganic nitrogen (Twomey et al. 2005). **Due to the low values of dissolved phosphate (0.025–0.3 μM), nitrate (0.18–1.26 μM), and relatively high concentration of ammonium (0.81–5.36 μM) during 2012–2013, the eastern coast of Suez Gulf is still healthy, relatively unpolluted, and oligotrophic to mesotrophic area.** This is established with the data reported by Fahmy (2003) who concluded that nitrogen, phosphorus, and reactive silicate concentrations were generally low and allowed classifying the Egyptian Red Sea coastal water as oligotrophic to mesotrophic. This is in

addition to the relatively low total abundance of phytoplankton (average of 2989 unit/L), compared with the data reported in its western coast in 1995 (average of 5862 unit/L) by Nassar (2000) and in 2006 (average 15,591 unit/L) by Nassar (2007a), as well as the data reported in 2002 by Shams El-Din et al.(2005) along the both sides of Suez Gulf (average of 6284 unit/L). However, Ghobrani et al. (2014) mentioned that oligotrophic waters are characterized by high clarity and little counts of algae.

However, the relative high abundance of phytoplankton in this study was found at St. 9 followed by St. 10 with total counts of 4169 and 3840 unit/L, respectively. This may be due to their subject to fractions of petroleum hydrocarbons and sewage discharge, which could promote the phytoplankton growth as reported by Nayar et al. 2005 and Nassar et al. 2014. On the other hand, the lowest occurrence of phytoplankton was recorded at St. 1 and St. 3, with similar total counts of 2218 and 2251 unit/L, respectively. This may be due to the effect of thermal waters discharged from the cooling systems of the Electrical Power Station of Ayon Mousa near St. 1, as well as the high tourist and human activities at the beach of Ras **Sedr** near St. 3.

As all marine coastal areas, diatoms were the dominant group forming high percentage (67.48 %) and prevailed during the four seasons (53.03–82 %) and at all stations (57–80 %). Whereas, the cyanophytes were the second dominant group, indicating the presence of freshwater discharge in the study area. On the other hand, the contribution of three groups Cyanophyceae, Dinogflagellates, and Chlorophyceae increased during summer at high temperature (28.1–31.5 °C). Eker and Kideyş (2000) suggest that there is a positive relationship between dinoflagellates and water temperature; thus, dinoflagellates may be better adapted to the high temperatures. Most dinoflagellates are found in temperate waters, are most prevalent in summer months (Taylor 1987), and dominate the phytoplankton in warm seasons (Tait 1981). In this connection, Schabhüttl et al. (2012) reported that green algae and diatoms showed a trend to perform better at lower temperatures, while Cyanobacteria showed stronger responses with increasing temperatures in mixed communities. **In the present study, temperature was negatively correlated with diatoms (r=−0.51), whereas it was not a**

limiting factor for dinoflagellates, cyanophytes and chlorophytes.

The similarity index based on spatial and temporal fluctuations of phytoplankton counts revealed **four** clusters: cluster 1 (St. 1, 3, and 12), cluster 2 (St. 10), cluster 3 (St. 4, 6, and 9), cluster 4 (St. 2, 8, 5, 7, and 11). The lowest similarity level was 41.11 % between St. 1 and St. 10, whereas the highest level was 76.91 % between St. 3 and St. 12. However, cluster 2, which includes only one station, reflects the unique ecological conditions at this station (oil effluents from Petropil Company). In contrast, the other clusters indicated that the included stations in each cluster have more or less similar ecological conditions, depending on the degree of similarity.

In the Conclusion section the corrected paragraph is shown below**.**

The study area is considered as **oligotrophic** to **mesotrophic** and healthy, despite land-base, human, and tourism activities, since the total counts of phytoplankton was low accompanied with **generally** low nutrient concentrations and high values of diversity. But due to the appearance of potentially harmful algae species even in low counts, make the region of the eastern coast susceptible to drastic effects at flourishing of these species during favorable conditions. Thus, monitoring continuously of this area is imperative, to follow probable bloom of these species, to predict negative effects resulting from increasing landbased activities in order to protect the eastern coast of Suez Gulf from any undesirable change there.