KSÜ Tarım ve Doğa Derg 25 (3): 606-616, 2022
KSU J. Agric Nat 25 (3): 606-616, 2022
https://doi.org/10.18016/ksutarimdoga.vi.904437

Ecological and Phytogeographical Status and Species Composition of the Phytoplankton in the Gulf of Aqaba (Red Sea)

Fatih ŞAHIN[1], Levent BAT[2], Dilek EDIGER[3], Tarıq AL-NAJJAR[4]
[1,2]Sinop University, Faculty of Fisheries, Department of Marine Biology, Sinop, Türkiye, [3]Istanbul University, Institute of Marine Science and Management, Vefa, İstanbul, Türkiye, [4]Faculty of Basic and Marine Sciences, The University of Jordan, Aqaba Branch, Jordan
[1]https://orcid.org/0000-0003-0605-2672, [2]https://orcid.org/0000-0002-2289-6691, [3]https://orcid.org/0000-0003-4417-8815
[4]https://orcid.org/0000-0002-6462-0773
✉: fsahin@sinop.edu.tr

ABSTRACT

One hundred and seven samples were collected from sea surface from 5 stations along the Jordanian coast of the Gulf of Aqaba. Overall,188 species were identified under six phytoplankton classes. Dinoflagellates dominate sixty percent of the total species. Diatoms constituted 38% and other groups represented by 2%. The geographical distribution of the identified species, 37% cosmopolitan, 28% boreal-tropical, 17% tropical, 11% tropical-subtropical, 4% boreal, 2% arcto-boreal and% 1 was determined as subtropical. According to ecological distribution, 88% of the species were marine and 12% marine-brackish origin. Also, 80% of the species were of pelagic origin, and 20% are benthic origin species. The phytoplankton species composition, phytogeographic and ecological distribution and species origins were presented from 2007 through 2008.

Fisheries

Research Article

Article History
Received : 28.03.2021
Accepted : 01.07.2021

Keywords
Gulf of Aqaba
Phytoplankton
Species composition
Bioecology
Biogeography

Akabe Körfezi (Kızıldeniz) Fitoplanktonunun Ekolojik ve Fitocoğrafik Durumu ve Tür Kompozisyonu

ÖZET

Aqaba Körfezi Ürdün kıyılarından 5 istasyondan deniz yüzey suyundan 107 örnek toplanmıştır. Genel olarak, 6 fitoplankton sınıfına ait 188 fitoplankton türü tespit edilmiştir. Toplam tür sayısının %60'ı dinoflagellatlar tarafından domine edilmiştir. Toplam tür sayısının %38'ini diatomlar ve %2'sini diğer gruplar oluşturmuştur. Tespit edilen türlerin coğrafi dağılımı; % 37 kozmopolit, % 28 boreal-tropikal, % 17 tropikal, % 11 tropikal-subtropikal, % 4 boreal, % 2 arkto-boreal ve % 1 subtropikal olarak belirlenmiştir. Ekolojik dağılıma göre türlerin % 88'i deniz, % 12'si deniz-acı su kökenlidir. Ayrıca türlerin % 80'i pelajik kökenlidir ve % 20'si bentik kökenli türlerdir. 2007-2008 döneminde fitoplankton tür kompozisyonu, fitocoğrafik ve ekolojik dağılımı ve türlerin kökenleri sunulmuştur.

Su Ürünleri

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 28.03.2021
Kabul Tarihi : 01.07.2021

Anahtar Kelimeler
Akabe Körfezi
Fitoplankton
Tür kompozisyonu
Biyoekoloji
Biyocoğrafya

To Cite: Şahin F, Bat L, Ediger D, Al-Najjar T 2022. Ecological and Phytogeographical Status and Species Composition of the Phytoplankton in the Gulf of Aqaba (Red Sea). KSU J. Agric Nat 25 (3): 606-616. https://doi.org/10.18016/ksutarimdoga.vi.904437.

Atıf İçin: Şahin F, Bat L, Ediger D, Al-Najjar T 2022. Akabe Körfezi (Kızıldeniz) Fitoplanktonunun Ekolojik ve Fitocoğrafik Durumu ve Tür Kompozisyonu. KSÜ Tarım ve Doğa Derg 25 (3): 606-616. https://doi.org/10.18016/ksutarimdoga.vi.904437.

INTRODUCTION

The Gulf of Aqaba, where the world's amazing tropical coral reefs are located, is a particular marine area of the coastal countries and the world. However, the Gulf is under high pressure from different sources such as urban and industrial pollution, shipping, port activities and tourism (Mergner, 1981; Walker and Ormond, 1982; Abu-Hilal, 1987; Abu-Hilal and Badran, 1990; Abelson et al., 1999). There is a total of 13 km of coral reefs along the 27 km long Jordanian coastline (Lazar et al., 2008). This intermediate and around the reefs is surrounded by seagrass (UNEP/IUCN, 1998). Around 30-40% of untouched natural areas along the coastline have been destroyed and transformed into a port and industrial zone in the last 25 years (Abu-Hilal, 1997). Besides, Aqaba Port was declared as a "Special Economic Zone" in 2001. Industrial and port activities continue to increase since this process (Khalaf and Kochzius, 2002).

Four significant changes highlighting the threat of eutrophication were observed in the region: (1) dissolved inorganic nitrogen in the deep-water pool, (2) deep oxygen depletion, (3) increased growth rate of macroalgae in between coral reefs (4) and increased organic content in the sediment. These findings emphasize the dangers encountered in future eutrophication in the Gulf (Genin, 2005).

Studies on Red Sea phytoplankton composition are very few. The low number of phytoplankton species in the Red Sea and the representation of a large part of the composition (> 95) with ultraplankton (8µm) are characteristic when compared to other seas (Lindell and Post, 1995; Post et al., 2002; Al-Najjar et al., 2007). In previous studies to reveal the composition, a limited number of samples were collected in the short term. The phytoplankton species composition was ignored in most studies (Weikert, 1987; Sommer, 2000; Sommer et al., 2002).

The clear/clean seawater is one of the most critical assets of the Gulf of Aqaba's coastal populations. Because of these waters' high quality, the world-renowned coral reef community has survived for thousands of years. It is a unique hot-spot of biodiversity and a repository and refuge of threatened species.

However, there is overwhelming evidence that the Gulf of Aqaba's reefs have been declining both in live coral cover and in the biodiversity of corals and associated biota in recent years. The concomitant changes in the phytoplankton, whose structure and function are significant to the survival of coral reefs, are also important.

This study provides a taxonomic evaluation of phytoplankton species composition in the Gulf of Aqaba using microscopic analyses. In addition to that, the phytogeography and ecological status were revealed.

MATERIALS and METHOD

Sampling Area

The Gulf of Aqaba lies between the Sinai Peninsula and the Arabian coast and is a part of the great Syrian-East Africa Rift (Gregory, 1921) (Figure 1). There are two major basins in the Gulf: the northern one extending south to Nuweiba with a maximum depth of 1000 m, and the southern one, rising to the Straits of Tiran with a maximum depth of 1800 m. The water mean annual temperature of the is 23.0 °C. Due to the exceptionally intense evaporation (average 200 cm per year) (Godeaux, 1986), the salinity exceeds oceanic salinity and research values of 41.0-42.0 ‰. Surface water salinity increases progressively from south to the north. The Gulf of Aqaba is considered oligotrophic based on chlorophyll-*a* values (0.024-0.522 mg m^{-3}) and primary productivity measurements (36 cg m^{-2} year-1) (Oren, 1970; Azov, 1986; Berman et al., 1986; Kimor, 1990; Sommer et al., 2002; Badran et al., 2005; Al-Najjar et al., 2007). 5 stations were selected to represent Jordan's continental shelf in Aqaba Bay (Figure 1).

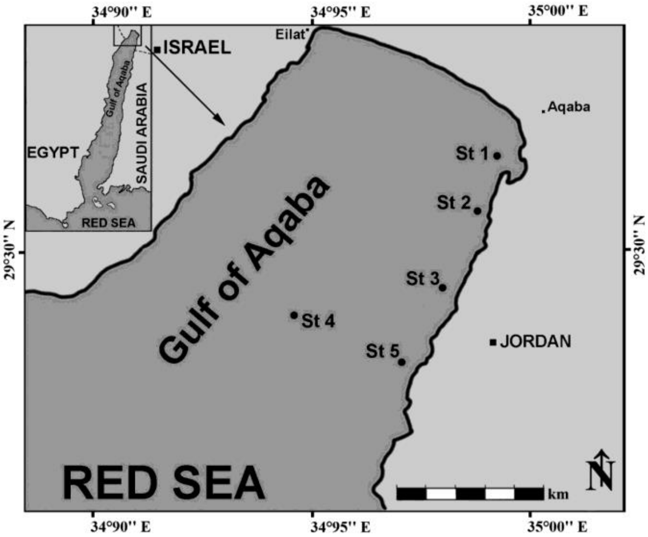

Figure1. Location of the sampling stations in the study area

Şekil 1. İstasyonların çalışma alanındaki konumları

Phytoplankton Sampling and Analyzing

A total of 107 samples were collected from sea surface at five stations along the Gulf of Aqaba's Jordanian coast from January to December 2007 and January to October 2008 (Figure 1). Phytoplankton samples were taken from surface from each station by using Niskin type universal water sampler (5 l). Sea water samples fixed with acidic-lugol iodine solution (2.5-3.0 cc 1^{-1}) and transported to the laboratory (Sukhanova, 1978).

A Sedwick-Rafter counting chamber was used for the micro-phytoplanktonic species with a cell diameter over 15 µm. Cell numbers (l) were counted under Nikon Eclippse E600 at various magnifications. Nano-phytoplanktonic species with a cell diameter <15 µm were mounted on glass slides (0.01 ml) and examined under the same microscope at high magnifications.

The following sources were used for species identification: Cupp,(1943), Kiselev (1950), Proshnika-Lavienko (1955), Rampi and Bernhard (1980), Senichkina (1986), Hillebrand et al. (1999). Taxonomy of species is organized according to AlgaeBASE (Guiry and Guiry, 2021). To establish the ecological and phytogeographical characteristics of the phytoplankton the following sources were used: Heimdal (1989), Medlin and Priddle (1990), Makarevich and Larionov (1992) and Druzhkov and Makarevich (1999).

RESULTS

Species Composition

The phytoplankton species collected at the sampling stations in 2007-2008 is given in Table 1. A total of 188 species was determined in which Bacillariophyceae was represented by 28 genera and 35 species; Coscinodiscophyceae was represented by 11 genera and 20 species; Mediophyceae was represented by 13 genera and 17 species; Dinophycaeae by 21 genera and 112 species; Coccolithophyceae by 1 genus and 1 species and Dictyochophyceae was represented by 2 genera and 3 species. From the species diversity, 60% were represented by dinoflagellates, 38% by diatoms and 2% by the other classes.

When the number of phytoplankton species were examined at the genus level, it was found that dinoflagellates contained the genera with the highest number of species. The highest number of species are from the Dinophyceae class: *Tripos* (29 species), *Protoperidinium* (18 species), *Oxytoxum* (12 species), *Dinophysis* (7 species), *Prorocentrum* (7 species), *Gonyaulax* (5 species) and *Histioneis* (4 species); from the Bacillariophyceae class: *Licmophora* (3 species); from the Coscinodiscophyceae class: *Actinoptychus* (2 species), *Coscinodiscus* (3 species) and *Rhizosolenia* (3 species); from the Mediophyceae class: *Chaetoceros* (4 species) have been identified.

Table 1 Taxonomic composition of the Jordan shores of the Gulf of Aqaba (Red Sea) in 2007-2008 (Phyto-Geographical Group-PG, C: Cosmopolitan species, A-B: Arcto-boreal species, B: Boreal species, B-T: Boreal-tropical species, T: Tropical species, T-ST: Tropical-subtropical species, ST: Subtropical species; Ecological Group-EG, M: Marine species, MB: Marine and Brackishwater species; Geographical Origin-GO, b: benthic-originated species, p: pelagic-originated species; Prevailing field-PF, P: Pelagial, B: Benthal, m: Mobil substratum, h: Hard substratum)

Çizelge 1. Akabe Körfezi (Kızıl Deniz) 2007-2008 dönemi taksonomik kompozisyonu (Fito-Coğrafik Grup-PG, C: Kozmopolit tür, A-B: Arkto-boreal tür, B: Boreal tür, B-T: Boreal-tropikal tür, T: Tropikal tür, T-ST: Tropikal-subtropikal tür, ST: Subtropikal tür; Ekolojik Grup-EG, M: Denizel tür, MB: Denizel ve Acısu tür; Coğrafik Köken-GO, b: bentik orijinli tür, p: pelajik orijinli tür; Bulunuş Alanı-PF, P: Pelajik, B: Bentik, m: Hareketli substratum, h: Sert substratum)

SPECIES LIST	**Sampling Years**		**Phytogeographical-Ecological Status**		
	2007	**2008**	**PG**	**EG-GO**	**PF**
BACILLARIOPHYCEAE	-	+	C	M-b	PBm,h
Achnanthes adnata Bory 1822	-	+	C	M-b	PBm,h
Achnanthes armillaris (O.F.Müller) Guiry 2019	+	+	C	M-b	PBm,h
Amphora lineolata Ehrenberg 1838	+	+	T-ST	MB-b	PBm,h
Campylodiscus neofastuosus Ruck & Nakov 2016	+	+	T-ST	M-b	PBm,h
Campylodiscus sp.	+	-	T-ST	M-b	PB
Coronia decora (Brébisson) Ruck & Guiry 2016	+	+	T-ST	M-b	PB
Cylindrotheca closterium (Ehrenberg) Reimann & J.C.Lewin 1964	+	+	C	M-b	PBm,h
Diploneis interrupta (Kützing) Cleve 1894	+	+	C	MB-b	PBm,h
Diploneis sp.	+	-	C	MB-b	PBm,h
Fragilaria sp.	+	-	C	MB-b	PBm,h
Grammatophora marina (Lyngbye) Kützing 1844	-	+	C	M-b	PBm,h
Halamphora coffeiformis (C.Agardh) Mereschkowsky 1903	-	+	C	MB-b	PBm,h
Licmophora ehrenbergii (Kützing) Grunow 1867	+	+	C	MB-b	PBm,h
Licmophora flabellata (Greville) C.Agardh 1831	+	+	C	M-b	PBm,h
Licmophora gracilis (Ehrenberg) Grunow 1867	+	+	C	M-b	PBm,h
Lyrella lyroides (Hendey) D.G.Mann 1990	+	+	T-ST	MB-b	PBm,h
Mastogloia sp.	+	-	T-ST	MB-b	PBm,h
Meuniera membranacea (Cleve) P.C.Silva 1996	-	+	C	MB-b	PBm,h
Navicula sp.	+	-	C	MB-b	PBm,h
Nitzschia longissima (Brébisson) Ralfs 1861	+	+	B	M-b	Bh
Nitzschia tenuirostris Mer.	+	+	B	M-b	Bh
Petrodictyon gemma (Ehrenberg) D.G.Mann 1990	+	+	T-ST	M-b	PBm,h
Plagiodiscus nervatus Grunow 1867	+	-	C	M-p	PBm
Pleurosigma angulatum (J.T.Quekett) W.Smith 1852	+	+	C	MB-b	PBm
Stenopterobia heribaudii (Playfair) Playfair	+	+	C	M-b	PB
Striatella unipunctata (Lyngbye) C.Agardh 1832	+	+	C	M-b	PB
Surirella hybrida Grunow 1881	+	-	T-ST	M-b	PBm,h
Synedra sp.	+	-	C	M-b	PBm
Tabellaria fenestrata (Lyngbye) Kützing 1844	+	-	C	M-p	PBm
Thalassionema nitzschioides (Grunow) Mereschkowsky 1902	-	+	C	M-p	PBm,h
Thalassiothrix longissima Cleve & Grunow 1880	-	+	A-B	M-p	P
Trachyneis aspera (Ehrenberg) Cleve 1894	+	+	C	M-b	PBm

SPECIES LIST	Sampling Years		Phytogeographical-Ecological Status		
	2007	2008	PG	EG-GO	PF
Tryblionella compressa (Bailey) Poulin 1990	+	+	B-T	M-p	PB,m
Ulnaria ulna (Nitzsch) Compère 2001	-	+	C	M-b	PBm
COSCINODISCOPHYCEAE					
Actinocyclus octonarius Ehrenberg 1837	+	+	B-T	M-p	PBm
Actinoptychus senarius (Ehrenberg) Ehrenberg 1843	+	+	B-T	M-p	PBm
Actinoptychus splendens (Shadbolt) Ralfs 1861	+	+	B-T	M-b	PBm
Asterolampra marylandica Ehrenberg 1844	-	+	C	M-p	P
Asteromphalus flabellatus (Brébisson) Greville 1859	-	+	C	M-p	P
Coscinodiscus centralis Ehrenberg 1839	+	+	B-T	M-p	PBm
Coscinodiscus perforatus Ehrenberg 1844	+	+	B	M-p	PBm
Coscinodiscus radiatus Ehrenberg 1840	+	+	C	M-b	PBm,h
Guinardia delicatula (Cleve) Hasle 1997	+	+	T-ST	M-p	PBm
Guinardia flaccida (Castracane) H.Peragallo 1892	+	+	T-ST	M-b	PBm
Melosira sp.	+	-	B-T	M-b	Bm,h
Neocalyptrella robusta (G.Norman ex Ralfs) Hernández-Becerril & Meave del Castillo 1997	+	-	B-T	M-b	Bm,h
Proboscia alata (Brightwell) Sundström 1986	+	+	C	M-p	P
Proboscia indica (H.Peragallo) Hernández-Becerril 1995	-	+	B-T	M-p	P
Pseudosolenia calcar-avis (Schultze) B.G.Sundström 1986	+	+	B-T	M-p	P
Rhizosolenia imbricata Brightwell 1858	+	+	B	M-p	P
Rhizosolenia setigera Brightwell 1858	+	-	B	M-p	P
Rhizosolenia styliformis T.Brightwell 1858	+	+	B	M-p	P
Triceratium favus Ehrenberg 1839	+	+	B-T	MB-p	P
Triceratium sp.	+	-	B-T	MB-p	P
MEDIOPHYCEAE					
Auliscus sculptus (W.Smith) Brightwell 1860	-	+	C	M-b	PBm
Bacteriastrum delicatulum Cleve 1897	-	+	B-T	M-p	P
Biddulphia alternans (Bailey) Van Heurck 1885	+	-	C	M-p	P
Chaetoceros brevis F.Schütt 1895	-	+	ST	M-p	P
Chaetoceros decipiens Cleve 1873	+	+	A-B	M-p	P
Chaetoceros lauderi Ralfs ex Lauder 1864	-	+	T-ST	M-p	P
Chaetoceros lorenzianus Grunow 1863	-	+	B-T	M-p	PB,m
Climacodium frauenfeldianum Grunow 1868	-	+	B-T	M-b	PB,m
Hemiaulus hauckii Grunow ex Van Heurck 1882	+	-	B-T	M-p	P
Lampriscus shadboltianum (Greville) Peragallo & Peragallo 1902	+	+	B-T	MB-p	P
Leptocylindrus danicus Cleve 1889	+	+	C	M-p	PBm
Odontella aurita (Lyngbye) C.Agardh 1832	-	+	B-T	MB-p	PB,m
Skeletonema costatum (Greville) Cleve 1873	-	+	C	M-p	PB,m
Terpsinoë americana (Bailey) Ralfs 1861	+	-	B-T	MB-p	P
Thalassiosira eccentrica (Ehrenberg) Cleve 1904	+	+	A-B	M-p	PBh
Thalassiosira leptopus (Grunow) Hasle & G.Fryxell 1977	-	+	C	M-b	B,m
Toxarium undulatum Bailey 1854	-	+	C	M-p	P
DINOPHYCEAE					
Acanthogonyaulax spinifera (Murray & Whitting) H.W.Graham 1942	-	+	B-T	M-p	P
Actiniscus pentasterias (Ehrenberg) Ehrenberg 1844	+	+	C	M-p	P
Amphisolenia bidentata B.Schröder 1900	+	+	C	M-p	P
Ceratocorys armata (Schütt) Kofoid 1910	+	+	T	M-p	P
Ceratocorys gourretii Paulsen 1937	+	+	T	M-p	P
Ceratocorys horrida Stein 1883	+	+	T	M-p	P
Corythodinium constrictum (F.Stein) F.J.R.Taylor 1976	+	+	T	M-p	P
Corythodinium milneri (G.Murray & Whitting) F.Gómez 2017	+	-	T	M-p	P
Corythodinium tesselatum (F.Stein) Loeblich Jr. & Loeblich III 1966	+	-	B-T	M-p	P
Dinophysis argus (Stein) Abé 1967	-	+	C	M-p	P

SPECIES LIST	Sampling Years		Phytogeographical-Ecological Status		
	2007	2008	PG	EG-GO	PF
Dinophysis acuminata Claparède & Lachmann 1859	+	-	B	M-p	P
Dinophysis amandula (Balech) Sournia 1973	+	+	C	M-p	P
Dinophysis caudata W.S.Kent 1881	+	-	B-T	M-p	P
Dinophysis doryphorides (P.A.Dangeard) Balech 1967	+	+	B-T	M-p	P
Dinophysis fortii Pavillard 1924	+	+	B-T	M-p	P
Dinophysis sphaerica F.Stein 1883	+	-	C	M-p	P
Diplopsalis lenticula Bergh 1881	-	+	C	MB-p	P
Fragilidium sp.	+	-	B-T	M-p	PB,m
Gonyaulax birostris Stein 1983	+	+	B-T	M-p	P
Gonyaulax monacantha Pavillard 1916	+	+	B-T	M-p	P
Gonyaulax polygramma F.Stein 1883	+	+	B-T	M-p	P
Gonyaulax scrippsae Kofoid 1911	+	+	B-T	M-p	P
Gonyaulax spinifera (Claparède & Lachmann) Diesing 1866	+	+	B-T	M-p	P
Gyrodinium helveticum (Penard) Y.Takano & T.Horiguchi 2004	+	+	C	M-p	P
Gyrodinium britannia Kofoid & Swezy 1921	-	+	C	M-p	P
Gyrodinium fusiforme Kofoid & Swezy 1921	+	+	T, A-B	M-p	P
Gyrodinium spirale (Bergh) Kofoid & Swezy 1921	-	+	B-T	M-p	P
Histioneis elongata Kofoid & J.R.Michener 1911	+	+	T	M-p	P
Histioneis joergensenii J.Schiller 1928	+	-	T	M-p	P
Histioneis longicollis Kofoid 1907	+	-	T	M-p	P
Histioneis sphaeroidea Rampi 1947	-	+	T	M-p	P
Lingulodinium polyedra (F.Stein) J.D.Dodge 1989	+	+	B-T	M-p	PB,m
Ornithocercus magnificus F.Stein 1883	+	-	T	M-p	P
Ornithocercus quadratus Schütt 1900	+	-	T	M-p	P
Oxytoxum caudatum Schiller 1937	+	-	T	M-p	P
Oxytoxum depressum J.Schiller 1937	-	+	C	M-p	P
Oxytoxum globosum Schiller 1937	+	-	B-T	M-p	P
Oxytoxum longiceps Schiller 1937	+	-	T	M-p	P
Oxytoxum longum J.Schiller 1937	+	+	T	M-p	P
Oxytoxum minutum Rampi 1941	+	-	T	M-p	P
Oxytoxum mitra (F.Stein) Schröder 1906	+	-	T	M-p	P
Oxytoxum parvum J.Schiller 1937	+	+	B-T	M-p	P
Oxytoxum rampii Sournia 1973	+	-	T	M-p	P
Oxytoxum sceptrum (F.Stein) Schröder 1906	-	+	B-T	M-p	P
Oxytoxum scolopax F.Stein 1883	+	+	B-T	M-p	P
Oxytoxum tesselatum (F.Stein) Schütt 1895	+	+	T	M-p	P
Parahistioneis acutiformis Rampi 1947	+	-	T	M-p	P
Phalacroma mitra F.Schütt 1895	+	+	C	M-p	P
Phalacroma porodictyum F.Stein 1883	+	-	C	M-p	P
Phalacroma rapa F.Stein 1883	+	-	C	M-p	P
Phalacroma rotundatum (Claparéde & Lachmann) Kofoid & J.R.Michener 1911	+	+	C	M-p	P
Podolampas bipes F.Stein 1883	+	+	T	M-p	P
Podolampas palmipes Stein 1883	+	+	T	M-p	P
Podolampas spinifera Okamura 1912	+	+	T	M-p	P
Prorocentrum cordatum (Ostenfeld) J.D.Dodge 1976	+	+	B-T	M-p	P
Prorocentrum lima (Ehrenberg) F.Stein 1878	+	+	C	M-p	PB,h
Prorocentrum maximum (Gourret) J.Schiller 1931	+	+	B-T	M-p	P
Prorocentrum micans Ehrenberg 1834	+	+	C	M-p	PB,h
Prorocentrum obtusum Ostenfeld 1908	+	+	C	M-p	PB,h
Prorocentrum rotundatum J.Schiller 1918	+	-	B-T	M-p	P
Prorocentrum triestinum J.Schiller 1918	-	+	B-T	M-p	P
Protoperidinium bipes (Paulsen) Balech 1974	-	+	C	M-p	P
Protoperidinium brochii (Kofoid & Swezy) Balech 1974	+	+	C	M-p	P

SPECIES LIST	Sampling Years		Phytogeographical-Ecological Status		
	2007	2008	PG	EG-GO	PF
Protoperidinium cerasus (Paulsen) Balech 1973	+	+	C	MB-p	P
Protoperidinium claudicans (Paulsen) Balech 1974	+	+	C	MB-p	P
Protoperidinium conicum (Gran) Balech 1974	+	-	C	M-p	P
Protoperidinium crassipes (Kofoid) Balech 1974	+	+	B-T	M-p	P
Protoperidinium curvipes (Ostenfeld) Balech 1974	+	+	B-T	M-p	P
Protoperidinium depressum (Bailey) Balech 1974	+	+	C	M-p	P
Protoperidinium diabolus (Cleve) Balech 1974	-	+	T-ST	M-p	P
Protoperidinium divergens (Ehrenberg) Balech 1974	-	+	C	M-p	P
Protoperidinium elegans (Cleve) Balech 1974	-	+	C	M-p	P
Protoperidinium excentricum (Paulsen) Balech 1974	+	+	B-T	M-p	P
Protoperidinium granii (Ostenfeld) Balech 1974	+	+	C	MB-p	P
Protoperidinium pallidum (Ostenfeld) Balech 1973	+	-	C	MB-p	P
Protoperidinium pellucidum Bergh 1881	+	+	C	MB-p	P
Protoperidinium saltans (Meunier) Balech 1973	+	-	B-T	M-p	P
Protoperidinium steinii (E.G.Jørgensen) Balech 1974	+	+	B-T	M-p	PB,m
Protoperidinium thulesense (Balech) Balech 1974	+	-	B-T	M-p	P
Pyrocystis elegans Pavillard 1931	+	-	B-T	M-p	P
Pyrocystis fusiformis C.W.Thomson 1876	+	+	C	M-p	P
Pyrocystis lunula (Schütt) Schütt 1896	+	+	C	M-p	P
Scrippsiella acuminata (Ehrenberg) Kretschmann, Elbrächter, Zinssmeister, S.Soehner, Kirsch, Kusber & Gottschling 2015	+	+	B-T	M-p	PB,m
Tripos arietinus (Cleve) F.Gómez 2013	+	+	T	M-p	P
Tripos belone (Cleve) F.Gómez 2013	+	-	T	M-p	P
Tripos candelabrum (Ehrenberg) F.Gómez 2013	+	+	T-ST	M-p	P
Tripos carriensis (Gourret) Hallegraeff & Huisman 2013	+	-	T-ST	M-p	P
Tripos compressus (Gran) F.Gómez 2013	+	-	T-ST	M-p	P
Tripos contortus (Gourret) F.Gómez 2013	+	-	T-ST	M-p	P
Tripos declinatus (G.Karsten) F.Gómez 2013	+	-	T-ST	M-p	P
Tripos deflexus (Kofoid) Hallegraeff & Huisman 2020	+	-	C	M-p	P
Tripos extensus (Gourret) F.Gómez 2013	+	-	T	M-p	P
Tripos furca (Ehrenberg) F.Gómez 2013	+	+	C	M-p	PB,m
Tripos fusus (Ehrenberg) F.Gómez 2013	+	+	C	M-p	PB,m
Tripos gibberus (Gourret) F.Gómez 2013	+	-	T-ST	M-p	P
Tripos hexacanthus (Gourret) F.Gómez 2013	+	-	T-ST	M-p	P
Tripos horridus (Cleve) F.Gómez 2013	+	+	B-T	M-p	P
Tripos incisus (Karsten) F.Gómez 2013	-	+	B-T	M-p	P
Tripos kofoidii (E.G.Jørgensen) F.Gómez 2013	+	-	ST	M-p	P
Tripos limulus (Pouchet) F.Gómez 2013	-	+	B-T	M-p	P
Tripos lineatus (Ehrenberg) F.Gómez 2013	+	+	B-T	M-p	P
Tripos longissimus (Schröder) F.Gómez 2013	+	+	T	M-p	P
Tripos macroceros (Ehrenberg) Hallegraeff & Huisman 2020	+	+	C	M-p	P
Tripos massiliensis (Gourret) F.Gómez 2013	+	+	B-T	M-p	P
Tripos minutus (E.G.Jørgensen) F.Gómez 2013	+	-	T	M-p	P
Tripos muelleri Bory 1826	+	+	C	M-p	PB,m
Tripos pavillardii (E.G.Jørgensen) F.Gómez 2013	+	-	T	M-p	P
Tripos pentagonus (Gourret) F.Gómez 2013	+	+	T	M-p	P
Tripos platycornis (Daday) F.Gómez 2013	-	+	T	M-p	P
Tripos ranipes (Cleve) F.Gómez 2013	+	+	T	M-p	P
Tripos teres (Kofoid) F.Gómez 2013	+	+	T-ST	M-p	P
Tripos trichoceros (Ehrenberg) Gómez 2013	+	+	T-ST	M-p	P
COCCOLITHOPHYCEAE					
Emiliania huxleyi (Lohmann) W.W.Hay & H.P.Mohler 1967	+	+	C	M-p	PBm,h
DICTYOCHOPHYCEAE					

SPECIES LIST	Sampling Years		Phytogeographical-Ecological Status		
	2007	2008	PG	EG-GO	PF
Dictyocha fibula Ehrenberg 1839	+	+	C	M-p	PBm,h
Octactis speculum (Ehrenberg) F.H.Chang, J.M.Grieve & J.E.Sutherland 2017	+	+	C	M-p	PBm,h
Octactis octonaria (Ehrenberg) Hovasse 1946	+	+	B-T	M-p	PBm,h

Phytogeographical and Ecological Compositions

65% of the species belonging to the Bacillariophyceae class have been determined as cosmopolitan species, 23% tropical-subtropical species, 6% boreal species, 3% boreal-tropical species and 3% arcto-boreal species.

50% of the species belonging to the Coscinodiscophyceae class have been determined as boreal-tropical species, 20% cosmopolitan species, 20% tropical species and 10% tropical-subtropical species.

41% of the species belonging to the Mediophyceae class have been determined as boreal-tropical species, 35% cosmopolitan species, 12% arcto-boreal species, 6% tropical-subtropical species and 6% subtropical species.

30% of the species belonging to the Dinophyceae have been determined as cosmopolitan species, 30% boreal-tropical species, 29% tropical species, 9% tropical-subtropical species, 1% boreal species and 1% subtropical species.

The only sampled species belonging to the Coccolithophceae class, *Emiliania huxleyi* is a cosmopolitan species.

67% of the species belonging to the Dictyochophyceae have been determined as cosmopolitan species and 33% boreal-tropical species.

Different types of phytoplankton classes are examined and have been identified as marine species according to ecological groups. 69% of the species belonging to the Bacillariophyceae class are marine species and 31% are marine-brackish species, 90% of the species belonging to the Coscinodiscophyceae class are marine species and 10% are marine-brackish species, 82% of the species belonging to the Mediophyceae class are marine species and 18% are marine-brackish species, 95% of the species belonging to the Dinophyceae class are marine species and 5% are marine-brackish species and the species belonging to the Coccolithophceae and Dictyochophyceae classes have been identified as marine species (Table 1).

When phytoplankton classes are evaluated according to their geographical origins, it has been determined that 86% of Bacillariophyceae species are benthic originated species and 10% are pelagic originated species, 75% of Coscinodiscophyceae species are pelagic originated species and 25% are benthic originated species and 82% of Mediophyceae species are pelagic originated species and 25% are benthic originated species. All species belonging to dinoflagellates, coccoliths and silicoflagellates have been identified as pelagic originated species.

The phytogeographic status of the phytoplankton groups was examined, it was found that 47% of diatoms, 30% of dinoflagellates and 75% of the other groups were represented by cosmopolitan species. Marine species dominate 78% of diatoms, 95% of dinoflagellates and all other groups. It was determined that 53% of the species belonging to the diatom group as benthic originated species, and the species belonging to dinoflagellates and other groups were determined as pelagic originated species (Table2).

Table 2 The phytogeographical and ecological characteristics of the phytoplankton groups (C: Cosmopolitan species, A-B: Arcto-boreal species, B: Boreal species, B-T: Boreal-tropical species, T: Tropical species, T-ST: Tropical-subtropical species, ST: Subtropical species; M: Marine species, MB: Marine and Brackishwater species; p: pelagic-originated species, b: benthic-originated species)

Çizelge 2. Fitoplankton gruplarının fitocoğrafik ve ekolojik özellikleri (C: Kozmopolit tür, A-B: Arkto-boreal tür, B: Boreal tür, B-T: Boreal-tropikal tür, T: Tropikal tür, T-ST: Tropikal-subtropikal tür, ST: Subtropikal tür; M: Denizel tür, MB: Denizel ve Acısu tür; p: pelajik-orijinli tür, b: benthic-orijinli tür)

Phytoplankton Groups	% Phyto-Geographical Group							T
	C	A-B	B	B-T	T	T-ST	ST	%
Diatom	47	4	8	25	-	15	1	100
Dinoflagellate	30	-	1	30	29	9	1	100
Other	75	-	-	25	-	-	-	100

Phytoplankton Groups	% Ecological Group		T	% Geographical Origin		T
	M	MB	%	p	b	%
Diatom	78	22	100	47	53	100
Dinoflagellate	95	5	100	100	-	100
Other	100	-	100	100	-	100

DISCUSSION and CONCLUSION

The limited number of phytoplankton species composition studies conducted in Gulf of Aqaba and the Red Sea are given in Figure 2. Halim (1969) identified 209 phytoplankton species (125 dinoflagellates, 84 diatoms) covering the entire Red Sea. Dowidar et al. (1978) detected 224 species (111 dinoflagellates, 112 diatoms) in their studies off the coast of Saudi Arabia. In another study conducted off the coast of Saudi Arabia (Shaikh et al., 1986), 283 species (110 dinoflagellates, 137 diatoms) were reported. Madkour et al. (2007) detected 181 phytoplankton species (117 dinoflagellates, 60 diatoms) in their study in the northern Red Sea, which includes the Gulf of Aden and the Gulf of Aqaba. In the study, 184 phytoplankton species (113 dinoflagellates, 71 diatoms) were identified, including 148 (97 dinoflagellates, 51 diatoms) in 2007 and 131 (76 dinoflagellates, 55 diatoms) in 2008. In 2007-2008, 4 species were identified from other groups.

The number of phytoplankton species identified in this study has more than the number of species (Total: 137, 49 diatoms, 88 dinoflagellates) detected in Gulf of Aqaba in Madkour et al.'s (2007) study. Also, compared to other studies, the number of species in this study is less than the previous studies. The number of dinoflagellate species found in this study is in parallel with previous studies. The decrease in the total number of species is due to the number of diatom species identified in this study. The low number of diatom species compared to other reviews can be explained by the method of this study. In previous studies, samples were taken with plankton net and at the same time, sampling was made from the whole water column. The samples were taken from the surface water in this study using Niskin bottle. Studies carried out in the Red Sea have shown that species diversity decreases towards the north (Halim, 1969; Weikert, 1987).

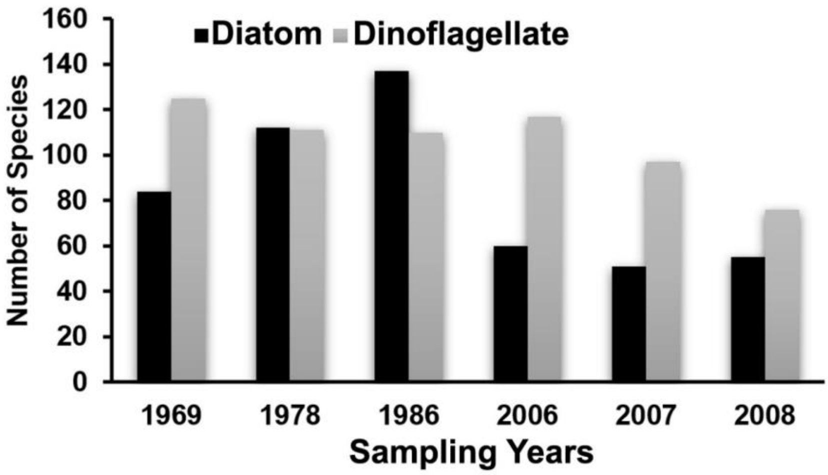

Figure 2. Diatom-dinoflagellate species numbers determined in studies conducted in the Red Sea (1969: Halim, 1969; 1978: Dowidar et al., 1978; 1986: Shaikh et al., 1986; 2006: Madkour et al., 2007; 2007-2008: This study)

Şekil 2. Kızıldeniz'de yapılan çalışmalarda belirlenen diatom-dinoflagellat tür sayıları (1969: Halim, 1969; 1978: Dowidar ve ark., 1978; 1986: Shaikh ve ark., 1986; 2006: Madkour ve ark., 2007; 2007-2008: Bu çalışma)

In studies conducted in the Red Sea, the low number of diatom species has been characterized as typical. Halim (1969) reported that the number of diatom species decreased dramatically, especially in warm periods (June-October period), and even was not encountered from time to time. Madkour et al. (2007) also reported that the number of diatom species decreased especially in the late spring-early autumn periods. This study is also in parallel with other studies. It is striking that the number of diatom species is scarce, especially during the 2008 hot period. Studies have reported that the qualitative and quantitative scarcity of diatom and dinoflagellate species is due to limited nutrient input and grazing, especially on diatoms (Sommer, 2000; Sommer et al., 2002; Al-Najjar et al., 2007). Especially in experimental studies, the scarcity of diatom and dinoflagellate species was attributed to the movements of the nutrient cycle in the gulf from the bottom to the surface and from the surface to the bottom (Sommer, 2000).

A genus with the highest number of species were determined as *Tripos*, *Protoperidinium*, *Oxytoxum*, *Dinophysis*, *Prorocentrum*, *Gonyaulax*, *Licmophora*, *Actinocyclus*, *Coscinodiscus*, *Rhizosolenia* and *Chaetoceros* have been identified in this study. Diatoms tend to collapse into deep water when turbulence in the body of water decreases and nutrients are depleted. Dinoflagellates can stay in the euphotic zone because of their movements, and so, explaining its high diversity in surface waters (Spector, 1984). Dinoflagellates have adapted very well to the high temperature values of the Red Sea (especially in the summer period) (Halim, 1969). Nutrient increase and vertical stratifications triggered by winter monsoons do not affect dinoflagellates because of their high adaptability to the region's environmental conditions (Halim, 1969; Sommer, 2000; Al-Najjar, 2007). *Neoceratium* (*Tripos*) genus is the most crucial dinoflagellate genus in tropical waters (Dowidar, 1983). It has been determined that the *Neoceratium* genus has the highest number of species in all studies conducted in the region (Halim, 1969; Dowidar, 1983; Madkour et al., 2007). Madkour et al. (2007) stated that the genera *Neoceratium*, *Protoperidinium*, *Chaetoceros*, *Rhizosolenia* and *Nitzschia* are dominant in terms of number of species. Subra Rao and Al-Yamani (1998) reported that the most critical genera they identified in their study in the Persian Gulf were *Chaetoceros*, *Coscinodiscus*, *Rhizosolenia*, *Neoceratium*, *Protoperidinium* and *Prorocentrum*.

When the prevalence of species in the community was examined spatially and temporally, it was found that the following were observed as constant species, including *Coscinodiscus perforatus*, *Thalassiosira eccentrica*, *Dictyocha fibula*, *Ceratocorys armata*, *Gymnodinium helveticum*, *Gyrodinium fusiforme*, *Tripos arietinus*, *Tripos furca*, *Tripos lineatus*, *Tripos macroceros*, *Tripos teres*, *Phalacroma rotundatum*, *Prorocentrum micans*, *Protoperidinium steinii*, *Pyrocystis fusiformis*, *Scrippsiella acuminata*, *Triceratium favus* and *Emiliania huxleyi*. This result shows remarkable similarities with the constant species that Madkour et al. (2007) obtained from samples taken from many stations in the Red Sea, including the Gulf of Aqaba, between 2005-2006. Halim (1960) reported the *Nitszchia delicatissima*, *Leptocylindrus danicus, Hermesinum adiraticum, Chaetoceros affinis, Cerataulina bergoni, Chaetoceros decipiens, Biddulphia rhombus*, *Exuviaella cordata, Skeletonema costatum, Chaetoceros curvisetus, Hemiaulus sinensis, Chaetoceros costatus, Rhizsolenia hebetata semispina* and *Chaetoceros socialis* species detected in study on the coasts of Egypt in 1956 as the constant species of the region. Kimor et al. (1987) reported that the species belonging to the *Rhizosolenia-Chaetoceros* genus, *Thalassiothrix frauenfeldii* and *Gymnodinium* sp. species are constant species that show distribution in layers close to surface water.

The results of this study were similar to the phytogeographic composition obtained in previous studies in the region. In our research, most of the phytoplankton species were found to be cosmopolitan species (> 50%), besides boreal-tropical species and subtropical species were also determined. Most of the identified species are marine species. In previous studies, more than 60% of the species composition consists of cosmopolitan, tropical, and subtropical species characteristic of the Indo-Pacific Region (Halim, 1960; 1969, Dowidar et al., 1978; Shaikh et al., 1986; Madkour et al., 2007).

The dynamics of phytoplankton compositions are significantly influenced by the physical and chemical properties of the water column (Lindell and Post 1995; Labiosa et al., 2003; Laiolo et al., 2014). The effect of the Gulf trophic level, including the mesotrophic conditions in winter and oligotrophic conditions in summer and autumn, is crucial to phytoplankton groups relative changes.

The thermal stratification and low nutrient level suppress the small-scale organisms such as *Emiliania huxleyi* throughout the year and revealing that these organisms are more advantageous in low nutrient concentration in surface waters. This condition may be due to high nutrient uptake efficiency, large surface: small volume structures, or low nutrient requirements (Genin et al., 1995; Al-Qutob et al., 2002; Mackey et al., 2007).

Studies on large groups of phytoplankton should be included in the scope of long-term monitoring programs to control the increasing eutrophication pressure in the Gulf of Aqaba and on the coral reefs, which are very important for the region. In addition to this, it is necessary to regularly monitor not only along the Jordanian part of the Gulf but also in all Gulf of Aqaba's territorial waters.

ACKNOWLEDGEMENT

This work was supported by NATO for "The Protection of the Gulf of Aqaba from Anthropogenic and Natural Stress in the Face of Global Climate Change Project (SfP 981883)". A part of the data used in the present study has formerly been the subject of the Ph. D thesis (Sahin, 2010) for Fatih Şahin prepared in Ondokuz Mayıs University, Department of Biology, Graduate School of Natural and Applied Sciences (Supervisor: Prof. Dr. Levent Bat).

Author's Contributions

Fatih Şahin: Conception and design of study, Acquisition of data, Analysis and interpretation of data, Writing-original draft. Levent Bat: Conception and design of study, Writing-review & editing. Dilek Ediger: Conception and design of study, Writing-review & editing. Tarıq Al-Najjar: Conception and design of study, Acquisition of data, Writing-review & editing.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

REFERENCES

Abelson A, Shteinman B, Fine M, Kaganovsky S 1999. Mass Transport from Pollution Sources to Remote Coral Reefs in Eilat (Gulf of Aqaba, Red Sea). Mar. Poll. Bull. 38(1): 25-29. https://doi.org/10.1016/S0025-326X(99)80008-3.

Abu-Hilal AH 1987. Distribution of Trace Elements in Nearshore Surface Sediments from The Jordan Gulf of Aqaba (Red Sea). Mar. Poll. Bull. 18(4) : 190-193. https://doi.org/10.1016/0025-326X(87)90245-1.

Abu-Hilal AH 1997. Effects of Coastal Zone Development and Management on the Coral Reefs of The Jordan Gulf of Aqaba (Red Sea). NOAA (ed) Report of the Middle East Seas Regional Strategy Workshop for the International Coral Reef Initiative. Aqaba, Jordan, 21-25 September 1997, pp. 245-260, National Oceanic and Atmospheric Administration, Silver Springs, MD.

Abu-Hilal AH, Badran MM 1990. Effect of Pollution Source on Metal Concentration in Sediment Cores from The Gulf of Aqaba (Red Sea). Mar. Poll. Bull. 21(4) : 190-197. https://doi.org/10.1016/0025-326X (90)90501-X.

Al-Najjar T, Badran MI, Richter C, Meyerhoefer M, Sommer U 2007. Seasonal Dynamics of Phytoplankton in The Gulf of Aqaba, Red Sea. Hydrobiologia 579: 69-83. http://dx.doi.org/10.1007/s10750-006-0365-z.

Al-Qutob M, Häse C, Tilzer MM, Lazar B 2002. Phytoplankton Drives Nitrite Dynamics in The Gulf of Aqaba, Red Sea. Mar. Ecol. Prog. Ser. 239: 233-239. https://doi.org/10.3354/meps239233.

Azov Y 1986. Seasonal Patterns of Phytoplankton Productivity and Abundance in Near Shore Oligotrophic Waters of The Levant Basin (Mediterranean). J. Plankton Res. 8(1): 41-53. https://doi.org/10.1093/plankt/8.1.41.

Badran M, Rasheed M, Manasrah R, Al-Najjar T 2005. Nutrient Flux Fuels The Summer Primary Productivity in the Oligotrophic Waters of The Gulf of Aqaba, Red Sea. Oceanologia 47(1): 47–60.

Berman T, Azov Y, Schneller A, Walline P, Townsend DW 1986. Extent, Transparency, and Phytoplankton Distribution of the Neritic Waters Overlying The Israeli Coastal Shelf. Oceanol. Acta 9(4): 439-447.

Cupp EE 1943. Marine Plankton Diatoms of The West Coast of North America. UC San Diego: Library-Scripps Digital Collection. Retrieved from https://escholarship.org/uc/item/922945w8.

Dowidar NM 1983. The Genus *Ceratium* from the Red Sea. J. Fac. Mar. Sci. 3: 5-37.

Dowidar N, Raheem El-Din S, Aleem A 1978. Pytoplankton Populations in the Region of Obhor, Jeddah, Saudi Arabia. Bull. Fac. Sci. King Abdull Aziz Univ., Jeddah, 2: 271-292.

Druzhkov NV, Makarevich PR 1999. Comparison of the Phytoplankton Assemblages of the South-Eastern Barents Sea and South-Western Kara Sea: Phytogeographical Status of the Regions. Botanica Marina 42:103-115.

Genin A 2005. The Israel National Monitoring Program in the Northern Gulf of Aqaba. Israel Ministry of the Environment, Science Report for Year 2004, p.129.

Genin A, Lazar B, Brenner S 1995. Vertical Mixing and Coral Death in the Red Sea Following the eruption of Mount Pinatubo. Nature 377: 507-510. http://dx.doi.org/10.1038/377507a0.

Godeaux J 1986. The Gulf of Aqaba, A Zone of Great Biological Interest. UNESCO Tech. Pap. Mar. Sci. 49: 104-106.

Gregory JW 1921. The Rift Valleys and Geology of East Africa. Seely, Service and Co., London, p. 479.

Guiry MD, Guiry, GM 2021. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. https://www.algaebase.org; searched on 09 March 2021.

Halim Y 1960. Observations on the Nile Bloom of Phytoplankton in the Mediterranean. Extrait Du Journal Conseil International Pour L' exploration De La Mer, 26(1) : 5-67.

Halim Y 1969. Plankton of the Red Sea. Oceanography and Marine Biology, A. Rew, 7: 231-275.

Heimdal, BR 1989. Arctic ocean phytoplankton. In: (Y. Herman, ed.) The Arctic Seas: Climatology, Oceanography,Geology, and Biology. Van Nostrans Reinhold Company, New York. pp. 193-222.

Hillebrand H, Dürselen CD, Kirschtel D, Pollingher U, Zohary T 1999. Biovolume Calculation for Pelagic and Benthic Microalgae. Journal of Phycology 35: 403-424. http://doi.wiley.com/10.1046/j.1529-8817.1999.3520403.x.

Khalaf MA, Kochzius M 2002. Changes in the Trophic Community Structure of Shore Fishes at an Industrial Site in The Gulf of Aqaba, Red Sea. Mar. Ecol. Prog. Ser. 239: 287-299. https://www.jstor.org/stable/24866067.

Kimor B 1990. Microplankton of the Red Sea, the Gulf of Suez and the Levantine Basin of the Mediterranean. Bull. Istit. Oceanographique, Monaco 7: 29–38, no. special.

Kimor B, Berman T, Schneller A 1987. Phytoplankton Assemblages in the Deep Chlorophyll Maximum Layers off the Mediterranean Coast of Israel. J. Plankton Res. 9(3): 433-443. https://doi.org/10.1093/plankt/9.3.433.

Kiselev IA 1950. Dinoflagellate of the Seas and Fresh Waters of the USSR. Leningrad /Moscow. p. 279 (in Russian).

Labiosa RG, Arrigo KR, Genin A, Monismith SG, Dijken G 2003. The Interplay Between Upwelling and Deep Convective Mixing in Determining the Seasonal Phytoplankton Dynamics in the Gulf of Aqaba: Evidence from SeaWiFS and MODIS. Limnol. Oceanogr. 48(6): 2355–2368.

http://doi.wiley.com/10.4319/lo.2003.48.6.2355.

Laiolo L, Barausse A, Dubinsky Z, Palmeri L, Goffredo S, Kamenir Y, Al-Najjar T, Iluz D 2014. Phytoplankton Dynamics in the Gulf of Aqaba (Eilat, Red Sea): A Simulation Study of Mariculture effects. Mar. Pollut. Bull. 86(1-2): 481-493. https://doi.org/10.1016/j.marpolbul.2014.06.026.

Lazar B, Erez J, Silverman J, Rivlin T, Rivlin A, Dray M, Meeder M, Iluz D 2008. Recent Environmental Changes in the Chemical-Biological Oceanography of the Gulf of Aqaba (Eilat). In: Por, F.D. (Ed.), Aqaba-Eilat, the Improbable Gulf. Environment, Biodiversity and Preservation. Magnes Press, Jerusalem. pp. 49-62.

Lindell D, Post AF 1995. Ultraphytoplankton Succession is Triggered by Deep Winter Mixing in the Gulf of Aqaba (Eilat), Red Sea. Limnol. Oceanogr. 40(6): 1130-1141. http://doi.wiley.com/10.4319/lo.1995.40.6.1130.

Mackey KRM, Labiosa RG, Calhoun M, Sreet JH, Post A, Paytan A 2007. Phosphorus Availability, Phytoplankton Community Dynamics, and Taxon-Specific Phosphorus Status in the Gulf of Aqaba, Red Sea. Limnol. Oceanogr. 52(2): 873-885. http://doi.wiley.com/10.4319/lo.2007.52.2.0873.

Madkour FF, El-Sherbiny MM, Aamer MA 2007. Phytoplankton Population Along the Egyptian Coastal Water of the Northern Red Sea. Int. Conf. on Rapid Urbanization and Land Use Conflicts in Coastal Cities, 30 October- 01 November 2007, Aqaba-Jordan, pp. 93-102.

Makarevich PR, Larionov VV 1992. Taxonomic composition of phytoplankton and history of the phytoplankton studies in the Barents Sea. In: (L. L. Kuznetsov, ed.) Phytoplankton of the Barents Sea. Kola Science Centre of the Russian Academy of Sciences, Apatity. pp. 17-51.

Medlin, LK, Priddle J 1990. Polar Marine Diatoms. Antarctic British Survey, Cambridge. 214 pp.

Mergner H 1981. Man-Made Influences on and Natural Changes in the Settlement of the Aqaba Reefs (Red Sea). In: Proceedings of the Fourth International Coral Reef Symposium 1. pp. 193-207.

Oren OH 1970. Seasonal Changes in the Physical and Chemical Characteristics and the Production in the Low Trophic Level of the Mediterranean Waters off Israel. Special Publication. Sea Fisheries Research Station, Haifa. p. 238.

Post AF, Dedej Z, Gottlieb R, Li H, Thomas DN, El-Absawi M, El-Naggar A, El-Gharabawi M, Sommer U 2002. Spatial and Temporal Distribution of *Trichodesmium* spp. in the Stratified Gulf of Aqaba, Red Sea. Mar. Ecol. Prog. Ser. 239: 241-250. https://doi.org/10.3354/meps239241.

Proshkina-Lavienko AI 1955. Diatoms of the Plankton of the Black Sea. Leningrad/Moscow. p. 220 (in Russian).

Rampi L, Bernhard R 1980. Chiave per la Determinazione delle Peridinee Pelagiche Mediterranee. Comi. Naz. Energia Nucleare, CNENRT/B10, 80, 8, Rome.

Sahin F 2010. Gulf of Aqaba, Red Sea Phytoplankton Composition and Marker Pigments. PhD Thesis, Ondokuz Mayıs University, Institute of Natural and Applied Sciences, Department of Biology, Samsun-Turkey. p. 476 (in Turkish).

Senichkina L 1986. The Calculation of Cell Volumes on Diatoms Using the Coefficients at Volumetric Capacity. Hydrobiological Journal 22 (1): 56-59 (in Russian).

Shaikh EA, Roff JC, Dowidar NM 1986. Phytoplankton Ecology and Production in the Red Sea off Jiddah, Saudi Arabia. Marine Biology: International Journal on Life in Oceans and Coastal Waters 92(3), 405-416. https://doi.org/ 10.1007/BF00392681.

Sommer U 2000. Scarcity of Medium-Sized Phytoplankton in the Red Sea Explained by Strong Bottom-up and Weak Top-down Control. Mar. Ecol. Prog. Ser. 197: 19-25. http://www.jstor.org/stable/24855741.

Sommer U, Berninger UG, Böttger-Schnack R, Cornils A, Hagen W, Hansen T, Al-Najjar T, Post AF, Schnack-Schiel SB, Stibor H, Stübing D, Wickham S 2002. Grazing During Early Spring in the Gulf of Aqaba and the Northern Red Sea. Mar. Ecol. Prog. Ser. 239: 251-261. https://doi.org/10.3354/meps239251.

Spektor DL 1984. Dinoflagellates, Academic Press, Florida, p. 543.

Subra Rao DV, Al-Yamani F 1998. Phytoplankton Ecology in the Waters Between Shatt Al-Arab and Straits of Hormuz, Arabian Gulf: A Review. Plankton Biol. Ecol. 45(2): 101-116.

Sukhanova ZN 1978. Settling Without the Inverted Microscope. In: Sournia A. (Ed.) Phytoplankton Manual. UNESCO, page Brothers (Nourisch) Ltd., pp. 97-98.

UNEP/IUCN 1998. United Nations Environment Programme/International Union for Conservation of Nature and Natural Resources. Coral Reefs of The World. UNEP Regional Seas Directories and Bibliographies. IUCN, Gland, Switzerland, and Cambridge, UK, and UNEP, Nairobi, pp. 145-151.

Walker DI, Ormond RFG 1982. Coral Death from Sewage and Phosphate Pollution at Aqaba, Red Sea. Mar. Pollut. Bull. 13(1): 21-25. https://doi.org/10.1016/0025-326X(82)90492-1.

Weikert H 1987. Plankton and the Pelagic Environment. In: Edwards, A.J., Head, S.M. (Ed.), Key Environments: Red Sea. Pergamon Press, Oxford, pp. 90-111.