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Short Communication

Phytoplankton community structure at the eastern entrance of the Gulf of California during El Niño 2023

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ABSTRACT. This work aims to report the phytoplankton species composition and cell density in the Mazatlán coastal region (eastern entrance of the Gulf of California (GC), Mexico) during the strong El Niño event of 2023. Surface water samples (at 2 m depth) for phytoplankton cell determinations were collected in December of 2023, a month in which the numerical value of the Oceanic Niño Index was 2.0. The results showed a total of 197 species, including 113 diatoms (with a total cell density of 51,444 cells L^{-1}), 76 dinoflagellates (with a total cell density of 31,260 cells L^{-1}), four silicoflagellates (with a total cell density of 420 cells L^{-1}), two cyanobacteria (with a total cell density of 2,020 cells L^{-1}), one Euglenophyta (with a total cell density of 900 cells L^{-1}) and one ciliate (with a total cell density of 7,820 cells L^{-1}). The diatom *Dactyliosolen phuketensis* (B.G.Sundström) G.R. Hasle, 1996 and the dinoflagellate *Gyrodinium fusiforme* (Kofoid & Swezy, 1921) presented the highest cell densities with 4,100 and 5,900 cells L^{-1}, respectively, species that have been previously reported in high abundances in Mexican waters in years of warming events, including El Niño. The results presented here contribute to understanding the effects of strong El Niño events on the phytoplankton community structure of the southeastern GC. This topic still needs to be fully addressed. This study also provides an update on the taxonomic lists available for the region of a group of organisms whose nomenclature has been constantly changing in recent years.

Keywords: phytoplankton species richness; phytoplankton abundance; El Niño; Mazatlán coastal region; Gulf of California

The last few years have seen extreme variability in the Earth's climate system. In fact, from the second half of 2020 to the first quarter of 2023, a strong La Niña event was recorded, which, in a quick transition, became an El Niño episode whose intensity can be compared to the strong event of 2015/2016. Data from the Oceanic Niño Index (ONI) showed that the last record of 2023 was 2.0, reflecting that a strong El Niño event was on record during December (NOAA 2024).

El Niño is one of the processes in the Earth's climate system that affect ecosystems and human populations in several aspects, including agriculture, public health, energy generation, and consumption, tourism, the availability of freshwater, fishing, food security, and biodiversity, among others (McPhaden et al. 2021). El Niño has also been related to negative impacts on the phytoplankton community structure in the marine environment as a product of the advection of warm and oligotrophic water masses (Conde et al. 2018).

Phytoplankton is a pivotal group of organisms distributed in the euphotic layer of the oceans. Their photosynthetic processes prompt the release of oxygen

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and the capture of CO_2 (Brierley 2017). Besides being the base of the food chain, phytoplankton is closely interconnected with the production in the higher trophic levels, both oceanic and coastal regions (Robicheau et al. 2022).

Coastal regions are sites recognized for their high diversity and as a place of refuge, growth, and feeding for numerous species (Hunter-Cevera et al. 2016). At the eastern entrance of the Gulf of California (GC), a sea recognized as one of the most biodiverse worldwide stands out in the Mazatlán coastal region (MCR).

As a part of the GC, the MCR is recognized for its high biological productivity levels, high rates of species richness (some of them endangered or threatened), high rates of endemisms, and for being the habitat of many migratory birds, mainly on the three islands that surround the region (Pájaros, Venados, and Chivos) (Hendrickx 1996, Esqueda-González et al. 2018). Hydrodynamically, the presence of tides, the alternation of a cyclonic/anticyclonic circulation pattern, the freshwater contribution of the Presidio River (with a discharge into the Pacific Ocean calculated at 65.8 million cubic meters annually), and an upwelling system make the MCR scientifically relevant. Besides, because of its geographical position, where the Pacific Ocean joins with the GC, the MCR is influenced by the presence of El Niño, a phenomenon that has received increasing attention in the last few years. Indeed, recent research unraveled some aspects related to the annual and interannual variability of sea surface temperature and phytoplankton biomass levels (expressed as chlorophyll-*a*), showing that El Niño has a recurrence interval of between three and four years inducing high sea surface temperature values (>31°C) and low chlorophyll-*a* concentrations (< 0.1 mg m^{-3}) (Durán-Campos et al. 2023).

Studies on the phytoplankton community structure in the MCR have shown a high species richness and abundance. In one of the first taxonomic lists, more than 76 species were documented with marked seasonal variability, with the spring season having the highest number of species; in terms of dominance, diatoms have been reported as the species with the highest abundance relative to other species, constituting approximately 60% of the total abundance (Cortés-Altamirano & Pasten-Miranda 1982a,b, 1984, 1985).

In the MCR, species that generate harmful algal blooms have also been noticed. One of the earliest reports documented algal blooms generated by dinoflagellates (e.g. *Ceratium tripos f. ponticum* (Schiller, 1937) now called *Tripos muelleri f. ponticus*), *Prorocentrum triestinum* (J. Schiller, 1918), and *Gymnodinium catenatum* (Graham, 1943)), by the diatom *Skeletonema costatum* (Cleve, 1873) and the ciliate (*Mesodinium rubrum* (Lohmann, 1908); all of them associated with high mortality of fish, crustaceans, and annelids (Cortés-Altamirano 1987, Cortés-Altamirano et al. 2000, Hernández-Becerril et al. 2000). More recently, a trend toward an increase in toxic algal blooms frequency of the dinoflagellates *G. catenatum* and *Margalefidinium polykrikoides* (Margalef) F. Gómez, Richlen & D.M. Anderson, 2017 was documented with an increase in their duration (Cortés-Altamirano et al. 2019).

Although numerous studies have emerged in the scientific literature evaluating the phytoplankton community structure in the MCR, very few have directed their efforts on documenting the phytoplankton species composition and abundance under El Niño events. Hence, this short communication aims to report the phytoplankton community structure in December of 2023, a month characterized by a strong El Niño event. The above becomes more relevant when prediction models suggest that these events will be increasingly recurrent with larger impacts (Cai et al. 2014, Ying et al. 2022). Therefore, evaluating the impact of these events on phytoplankton community structure in regions recognized by their high biological productivity, such as the MCR, becomes scientifically necessary. For this, fieldwork was carried out on December 5, 2023, to collect water samples for cell determinations at five sampling points in the MCR (Fig. 1). Each collection site was reached with a handheld GPS (Garmin 64sx). Then, surface water (at 2 m depth) was collected with a UWITEC sampler bailer from which subsamples of 1 L were fixed immediately with a Lugol-acetate solution and kept in dark conditions until analyses.

The samples were analyzed immediately after collection using the Utermöhl method with 50 mL sedimentation columns (Edler & Elbrachter 2010). The sedimentation was in dark conditions for 24 h. Afterward, the phytoplankton organisms were identified to species level with a Carl Zeiss inverted microscope (Axiovert A1) using standard keys (e.g. Tomas 1997, Throndsen et al. 2003) and those keys published specifically for the Mexican Pacific Ocean and adjacent regions, such as the GC (e.g. Licea et al. 1995, Moreno et al. 1996, Esqueda-Lara & Hernández-Becerril 2010, Morquecho-Escamilla et al. 2016, Hernández-Becerril et al. 2021). Finally, the number of species was standardized to cell density units following standard protocols (Edler & Elbrachter 2010).

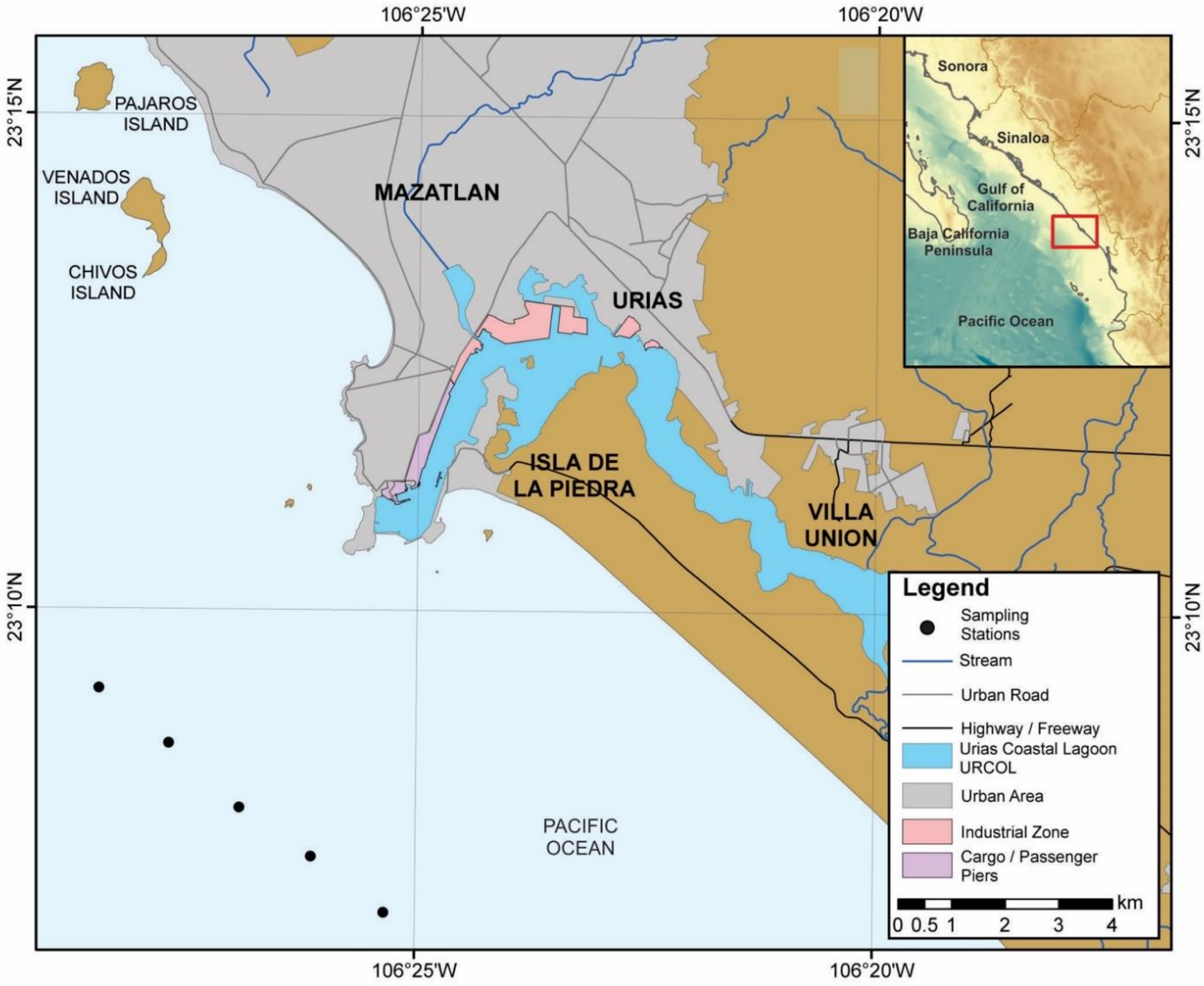

Figure 1. The study area, the Mazatlán coastal region, is at the eastern entrance of the Gulf of California, Mexico. The black dots represent the sampling stations.

The results showed a total of 197 species, including diatoms (113 species), dinoflagellates (76 species), silicoflagellates (4 species), Euglenophythes (1 species), ciliates (1 species), and cyanobacteria (2 species) (Table 1). In terms of cell density, the diatoms summarized 51,444 cells L^{-1}, the dinoflagellates 31,260 cells L^{-1}, the silicoflagellates 420 cells L^{-1}, cyanobacteria 2,020 cells L^{-1}, euglenophytes 900 cells L^{-1} and ciliates 7,820 cells L^{-1}.

Of the diatoms identified, *Dactyliosolen phuketensis* (B.G. Sundström) G.R. Hasle, 1996 was the most abundant species, reaching 4,100 cells L^{-1}, followed by *Leptocylindrus danicus* (Cleve, 1889) with 3,960 cells L^{-1}, while *Hemiaulus membranaceus* (Cleve, 1873), *Stigmaphora rostrata* (Wallich, 1860), *Asteromphalus heptactis* (Brébisson) Ralfs, 1861 among others, barely reached 20 cells L^{-1} (Table 1).

The dinoflagellate *Gyrodinium fusiforme* (Kofoid & Swezy, 1921) presented the highest abundance with 5,900 cells L^{-1}, while *Cucumeridinium lira* (Kofoid & Swezy) F. Gómez, P. López-García, H. Takayama & D. Moreira, 2015, *Grammatodinium tongyeonginum* (Z. Li & H.H. Shin, 2017), and *Protoperidinium steinii* (Jørgensen) Balech, 1974 presented the lowest abundance (barely of 20 cells L^{-1}). *Dictyocha californica* (Schrader & Murray 1985) was the most abundant silicoflagellate (300 cells L^{-1}), and *Trichodesmium hildebrandtii* (Gomont, 1892) was the most abundant cyanobacteria. The Euglenophyta, *Euglena acusformis* (Schiller, 1926) reached 900 cells L^{-1}, and the ciliate *Mesodinium rubrum* (Lohmann, 1908) reached 7,820 cells L^{-1} (Table 1).

The fieldwork carried out in December 2023 allowed us to evaluate the phytoplankton community structure of the MCR during a strong El Niño event. To

Table 1. Phytoplankton species composition and their cell density (cells L^{-1}) in the Mazatlán coastal region, eastern entrance of the Gulf of California, Mexico, during the strong El Niño event 2023.

Taxa	Cell density (cells L^{-1})
Diatoms	
Actinocyclus octonarius Ehrenberg, 1837	120
Actinocyclus senarius Ehrenberg, 1838	140
Actinocyclus tenuissimus Cleve, 1878	40
Actinoptychus adriaticus Grunow, 1863	820
Alveus marinus (Grunow) Kaczmarska & Fryxell, 1996	20
Amphora costata W.Smith, 1853	320
Asterionellopsis glacialis (Castracane) Round, 1990	160
Asteromphalus arachne (Brébisson) Ralfs, 1861	500
Asteromphalus elegans Greville, 1859	20
Asteromphalus flabellatus (Brébisson) Greville, 1859	100
Asteromphalus heptactis (Brébisson) Ralfs, 1861	20
Asteromphalus ingens Simonsen, 1974	20
Asteromphalus roperianus (Greville) Ralfs, 1861	20
Azpeitia nodulifera (A.W.F.Schmidt) G.A.Fryxell & P.A.Sims, 1986	160
Bacteriastrum hyalinum Lauder, 1864	100
Bacteriastrum mediterraneum Pavillard, 1916	1840
Bellerochea malleus (Brightwell) Van Heurck, 1885	40
Cerataulina dentata Hasle, 1980	180
Cerataulina pelagica (Cleve) Hendey, 1937	60
Chaetoceros aequatorialis Cleve, 1901	1580
Chaetoceros affinis Lauder, 1864	60
Chaetoceros atlanticus Cleve, 1873	40
Chaetoceros aurivillii Cleve, 1901	40
Chaetoceros brevis (Schütt, 1895)	180
Chaetoceros coarctatus Lauder, 1864	60
Chaetoceros compressus Lauder, 1864	640
Chaetoceros costatus Pavillard, 1911	80
Chaetoceros curvisetus Cleve, 1889	60
Chaetoceros danicus Cleve, 1889	160
Chaetoceros decipiens Cleve, 1873	320
Chaetoceros densus (Cleve) Cleve, 1899	160
Chaetoceros denticulatus H.S.Lauder, 1864	120
Chaetoceros dichaeta Ehrenberg, 1844	20
Chaetoceros didymus Ehrenberg, 1845	40
Chaetoceros diversus Cleve, 1873	220
Chaetoceros laciniosus F.Schütt, 1895	20
Chaetoceros mannaii Li, Boonprakob, Moestrup & Lundholm, 2018	340
Chaetoceros peruvianus Brightwell, 1856	1500
Chaetoceros protuberans Lauder, 1864	40
Chaetoceros rectus Hernández-Becerril, 1992	300
Chaetoceros rostratus Ralfs, 1864	40
Chaetoceros socialis H.S.Lauder, 1864	580
Chaetoceros teres Cleve, 1896	1280
Corethron hystrix Hensen, 1887	140
Corethron pennatum (Grunow) Ostenfeld, 1909	80
Coscinodiscus asteromphalus Ehrenberg, 1844	100
Coscinodiscus centralis Ehrenberg, 1839	100
Coscinodiscus granii L.F.Gough, 1905	160
Coscinodiscus wailesii Gran & Angst, 1931	220
Cyclotella litoralis Lange & Syvertsen, 1989	120

Continuation

Taxa **Diatoms**	Cell density (cells L^{-1})
Cylindrotheca closterium (Ehrenberg) Reimann & Lewin, 1964	360
Dactyliosolen fragilissimus (Bergon) Hasle, 1996	140
Dactyliosolen mediterraneus (H.Peragallo) H.Peragallo, 1892	1960
Dactyliosolen phuketensis (B.G.Sundström) G.R.Hasle, 1996	4100
Detonula pumila (Castracane) Gran, 1900	460
Ditylum brightwellii (T.West) Grunow, 1885	420
Eucampia cornuta (Cleve) Grunow, 1883	580
Eupyxidicula palmeriana (Greville) S.Blanco & C.E.Wetzel, 2016	20
Eupyxidicula turris (Greville) S.Blanco & C.E.Wetzel, 2016	180
Guinardia flaccida (Castracane) H.Peragallo, 1892	80
Guinardia striata (Stolterfoth) Hasle, 1996	480
Gyrosigma spenceri (Bailey ex Quekett) Griffith & Henfrey, 1856	20
Haslea trompii (Cleve) Simonsen, 1974	2240
Haslea wawrikae (Husedt) Simonsen, 1974	300
Helicotheca tamesis (Shrubsole) M.Ricard, 1987	80
Hemiaulus hauckii Grunow ex Van Heurck, 1882	200
Hemiaulus membranaceus (Cleve, 1873)	20
Hemiaulus sinensis Greville, 1865	80
Hemidiscus cuneiformis Wallich, 1860	20
Lauderia annulata Cleve, 1873	20
Leptocylindrus convexus D.Nanjappa & A.Zingone, 2013	440
Leptocylindrus danicus Cleve, 1889	3960
Lioloma pacificum (Cupp) Hasle, 1996	100
Lithodesmium undulatum Ehrenberg, 1839	80
Lithodesmium variabile H.Tanako, 1979	40
Meuniera membranacea (Cleve) P.C.Silva, 1996	20
Neodelphineis indica (F.J.R.Taylor) Y.Tanimura, 1992	200
Nitzschia bicapitata Cleve, 1901	300
Nitzschia ikeanae Fryxell & H.Y.Lee, 1996	20
Nitzschia longissima (Brébisson ex Kützing) Grunow, 1862	2200
Nitzschia sigma (Kützing) W.Smith, 1853	20
Odontella aurita (Lyngbye) C.Agardh, 1832	40
Planktoniella sol (G.C.Wallich) Schütt, 1892	1420
Pleurosigma acutum (Norman ex Ralfs, 1861)	60
Pleurosigma latum Cleve, 1880	20
Pleurosigma normanii (Ralfs, 1861)	100
Pleurosigma salinarum (Grunow) Grunow, 1880	80
Pseudo-nitzschia multistriata (H.Takano) H.Takano, 1995	1500
Pseudo-nitzschia pseudodelicatissima (Hasle) Hasle, 1993	2100
Pseudo-nitzschia pungens (Grunow ex Cleve) Hasle, 1993	2340
Pseudo-nitzschia roundii Hernández-Becerril, 2006	3220
Pseudo-nitzschia subfraudulenta (Hasle) Hasle, 1993	140
Pseudoguinardia recta Stosch, 1986	200
Ralfsiella smithii (Ralfs) P.A.Sims, D.M.Williams & Ashworth, 2018	200
Rhizosolenia bergonii H.Peragallo, 1892	60
Rhizosolenia pungens Cleve-Euler, 1937	40
Shionodiscus oestrupii (Castracane) H.H.Gran, 1900	2920
Skeletonema pseudocostatum Medlin, 1991	1100
Skeletonema tropicum Cleve, 1900	740
Stigmaphora rostrata (Wallich, 1860)	20
Tetramphora decussata (Grunow) Stepanek & Kociolek, 2016	300
Thalassionema bacillare (Heiden) Kolbe, 1955	60

Continuation

Taxa	Cell density (cells L^{-1})
Diatoms	
Thalassionema frauenfeldii (Grunow) Tempère & Peragallo, 1910	680
Thalassionema nitzschioides (Grunow) Mereschkowsky, 1902	800
Thalassiosira allenii H. Takano, 1965	120
Thalassiosira angustelineata (A.W.F.Schmidt) G.Fryxell & Hasle, 1977	80
Thalassiosira concaviuscula Makarova, 1978	20
Thalassiosira eccentrica (Ehrenberg) Cleve, 1904	140
Thalassiosira leptopus (Grunow) Hasle & Fryxell, 1977	20
Thalassiosira punctifera (Grunow) Fryxell, Simonsen & Hasle, 1974	20
Thalassiosira tenera Proshkina-Lavrenko, 1961	180
Triceratium formosum Brightwell, 1856	80
Trieres mobiliensis (Bailey) Ashworth & E.C.Theriot, 2013	20
Dinoflagellates	
Achradina pulchra Lohmann, 1903	200
Akashiwo sanguinea (K.Hirasaka) Gert Hansen & Moestrup, 2000	860
Alexandrium minutum Halim, 1960	200
Alexandrium monilatum (J.F.Howell) Balech, 1995	840
Alexandrium tamarense (Lebour) Balech, 1995	80
Azadinium caudatum (Halldal) Nézan & Chomérat, 2012	280
Azadinium poporum Tillmann & Elbrächter, 2011	800
Azadinium spinosum Elbrächter & Tillmann, 2009	1100
Blepharocysta denticulata D.-S.Nie, 1939	1620
Blepharocysta paulsenii Schiller, 1937	40
Boreadinium breve (T.H.Abé) Sournia, 1984	20
Centrodinium pulchrum Bohm, 1933	20
Ceratocorys armata (Schütt) Kofoid, 1910	20
Corythodinium biconicum (Kofoid) F.J.R.Taylor, 1976	20
Corythodinium mucronatum (B.Hope) F.Gómez, 2017	20
Cucumeridinium coeruleum (Dogiel) F.Gomez, P.López-García, H.Takayama & D.Moreira, 2015	80
Cucumeridinium lira (Kofoid & Swezy) F.Gómez, P.López-García, H.Takayama & D.Moreira, 2015	20
Diplopelta asymmetrica (Mangin) M.Lebour ex Balech, 1988	1920
Diplopsalopsis orbicularis (Paulsen) Meunier, 1910	80
Fragilidium mexicanum Balech, 1988	20
Gonyaulax fusiformis H.W.Graham, 1942	20
Grammatodinium tongyeonginum Z.Li & H.H.Shin, 2017	20
Gymnodinium catenatum H.W.Graham, 1943	60
Gymnodinium impudicum (S.Fraga & I.Bravo) Gert Hansen & Moestrup, 2000	600
Gyrodinium fusiforme Kofoid & Swezy, 1921	5900
Heterocapsa orientalis Iwataki, Botes & Fukuyo, 2003	80
Kapelodinium vestifici (Schütt) Boutrup, Moestrup & Daugbjerg, 2016	40
Karenia bicuneiformis Botes, Sym & Pitcher, 2003	560
Karenia brevisulcata (F.H. Chang) Gert Hansen & Moestrup, 2000	1100
Lingulodinium polyedrum (F.Stein) J.D. Dodge, 1989	1980
Nematodinium armatum (Dogiel) Kofoid & Swezy, 1921	20
Noctiluca scintillans (Macartney) Kofoid & Swezy, 1921	20
Ornithocercus heteroporus Kofoid, 1907	40
Oxytoxum sceptrum (F.Stein) Schröder, 1900	700
Oxytoxum variabile J.Schiller, 1937	160
Phalacroma argus F.Stein, 1883	20
Prorocentrum gracile F.Schütt, 1895	800
Prorocentrum koreanum M.-S.Han, S.Y.Cho & P.Wang, 2016	560
Prorocentrum lenticulatum (Matzenauer) F.J.R.Taylor, 1976	120
Prorocentrum mexicanum Osorio-Tafall, 1942	140

Continuation

Taxa	Cell density (cells L^{-1})
Dinoflagellates	
Prorocentrum obtusidens J.Schiller, 1928	400
Prorocentrum robustum Osorio-Tafall, 1942	60
Prorocentrum sigmoides Böhm, 1933	40
Protoceratium reticulatum (Claparède & Lachmann) Bütschli, 1885	40
Protoperidinium acutum (G.Karsten) Balech, 1974	40
Protoperidinium bispinum (J.Schiller) Balech, 1974	80
Protoperidinium brochii (Kofoid & Swezy) Balech, 1974	20
Protoperidinium claudicans (Paulsen) Balech, 1974	40
Protoperidinium conicum (Gran) Balech, 1974	40
Protoperidinium consimile (T.H.Abé) Balech, 1994	60
Protoperidinium corniculum (Kofoid & J.R.Michener) F.J.R.Taylor & Balech, 1988	160
Protoperidinium depressum (Bailey) Balech, 1974	20
Protoperidinium divergens (Ehrenberg) Balech, 1974	20
Protoperidinium obtusum (Karsten) Parke & J.D.Dodge, 1976	2380
Protoperidinium pentagonum (Gran) Balech, 1974	40
Protoperidinium perplexum (Balech) Balech, 1974	20
Protoperidinium punctulatum (Paulsen) Balech, 1974	2200
Protoperidinium pyrum (Balech) Balech, 1974	40
Protoperidinium robustum (Meunier) Hernández-Becerril, 1991	1260
Protoperidinium saltans (Meunier) Balech, 1973	20
Protoperidinium simulum (Paulsen) Balech, 1974	40
Protoperidinium steinii (Jørgensen) Balech, 1974	20
Protoperidinium subinerme (Paulsen) A.R.Loeblich III, 1969	40
Protoperidinium tuba (J.Schiller) Balech, 1974	1160
Ptychodiscus noctiluca Stein, 1883	20
Pyrocystis pseudonoctiluca Wyville-Thompson, 1876	200
Scrippsiella acuminata (Ehrenberg) Kretschmann, Elbrächter, Zinssmeister, S. Soehner, Kirsch, Kusber & Gottschling, 2015	20
Scrippsiella spinifera G.Honsell & M.Cabrini, 1991	280
Torquentidium convolutum (Kofoid & Swezy) H.H.Shin, Z.Li, K.W.Lee & K.Matsuoka, 2019	40
Torquentidium helix (Lemmermann) H.H.Shin, Z.Li, K.W.Lee & K.Matsuoka, 2019	160
Triadinium polyedricum (Pouchet) J.D.Dodge, 1981	20
Tripos balechii (Meave, Okolodkov & M.E.Zamudio) F.Gómez, 2013	80
Tripos falcatus (Kofoid) F.Gómez, 2013	120
Tripos furca (Ehrenberg) F.Gómez, 2013	840
Tripos gravidus (Gourret) F.Gómez, 2013	40
Tripos trichoceros (Ehrenberg) F.Gómez, 2013	20
Silicoflagellates	
Dictyocha calida Poelchau, 1976	20
Dictyocha californica Schrader & Murray, 1985	300
Dictyocha fibula Ehrenberg, 1839	60
Octactis octonaria (Ehrenberg) Hovasse, 1946	40
Euglenophyta	
Euglena acusformis J.Schiller, 1926	900
Ciliates	
Mesodinium rubrum Lohmann, 1908	7820
Cyanobacteria	
Trichodesmium hildebrandtii Gomont, 1892	1360
Trichodesmium thiebautii Gomont, 1890	660

the best of our knowledge, in the MCR, there are very few reports on the phytoplankton species richness and their abundance during El Niño events. Therefore, it becomes complicated to establish robust comparisons. However, some studies focused mainly on evaluating the generation of harmful algal blooms in the region suggest that El Niño may have a direct effect on the presence and intensity of the blooms due to the advection of warm water masses that, in turn, weakens the upwelling processes that occur there (Cortes-Altamirano 1987).

In our study, diatoms presented the highest number of species, agreeing with previous reports that pointed to this group as dominant in the phytoplankton community structure in the MCR. Indeed, some studies have reported that diatoms usually dominate around 60% of the total (e.g. Cortes-Altamirano & Pasten-Miranda 1985), as was our case.

In our study, the diatom *Dactyliosolen phuketensis* presented the highest abundance. This species has been reported in Mexican waters in years with warming events, such as the case of El Blob 2013/2015 (a sudden overheating of surface waters in the Pacific Ocean that occurred in that period whose causes are not yet fully understood) and El Niño 2015/2016 (Jiménez-Quiroz et al. 2019) and in the Acapulco Bay (Mexican Pacific) in March of 2010. This month presented El Niño conditions (Meave-del-Castillo et al. 2012). Concordantly, studies carried out in the southern GC (González-López & Siqueiros-Beltrones 1990), in the western coast of South America (Conde et al. 2018), and in the southwestern Atlantic Ocean (Barrera-Alba et al. 2019) have documented that species of the genus *Dactyliosolen* tend to be indicators of warming events associated with the presence of El Niño events; even, blooms of species of this genus have been related to El Niño conditions (González-Narváez et al. 2021), which could explain the high cell density observed in our study.

Gyrodinium fusiforme was the most abundant dinoflagellate in our study (with 5,900 cells L^{-1}). This species has been reported in high cell densities in Mexican waters during El Niño events, particularly in Acapulco Bay (Mexican Pacific) (Meave-del-Castillo et al. 2012) and in Concepción Bay (GC) (Verdugo-Díaz et al. 2010). Species of the genus *Gyrodinium* have also been reported with high cell densities related to El Niño events in different environments around the world. Indeed, in northern Chile, increases in species of this genus were reported during El Niño 1982/1983 (Avaria & Muñoz 1987). In Hong Kong, an atypical bloom of *Gyrodinium aureolum* was reported during El Niño 1997/1998 (Yin et al. 1999), while high cell densities of *Gyrodinium acutum* have been reported in Ecuador (Eastern Pacific Coast) during El Niño events (Torres et al. 2019).

Another species observed with relatively high cell density was the ciliate *Mesodinium rubrum*, previously reported in the MCR as bloom-forming algae (Cortes-Altamirano 1987). Numerous reports in the scientific literature on the presence of this species in El Niño events, including the Peruvian coast (Sánchez et al. 2021), the Ecuadorian coast (Conde et al. 2018), and the Galápagos Islands (Carnicer et al. 2019), agree with our observations.

In summary, the results presented here contribute to understanding the effects of strong El Niño events on the phytoplankton community structure in the MCR. This study also provides an update of the taxonomic lists available for the region of a group of organisms whose nomenclature has been constantly changing in recent years. Besides, the taxonomic list presented here represents a reference to the phytoplankton community structure under strong El Niño events; the last could act as a baseline for future studies in the region under different events, whether El Niño or La Niña.

Credit author contribution

E. Durán-Campos: conceptualization, validation, sampling, species identification, formal analysis, writing-original draft; C.M. Torres-Martínez: validation, sampling, species identification, formal analysis, writing-original draft; E. Coria-Monter: conceptualization, validation, sampling, species identification, formal analysis, writing-original draft; D.A. Salas de León: conceptualization, validation, formal analysis, funding acquisition, writing-original draft; M.A. Monreal-Gómez: conceptualization, validation, formal analysis, funding acquisition, writing-original draft. All authors have read and accepted the published version of the manuscript.

Conflict of interest

The authors declare no potential conflict of interest in this manuscript.

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