Phytoplankton Diversity in the Caspian Sea: A Comprehensive Checklist

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Received: 2024-05-29   Accepted: 2024-07-23

Abstract

The Caspian Sea, the world's largest inland body of water, supports a highly diverse community of phytoplankton species that play a crucial role in its ecosystem and overall food web dynamics. This unique, enclosed environment, which spans several countries, is subject to various ecological pressures, including climate change and anthropogenic activities, making it a critical area for biodiversity research. In this study, a comprehensive checklist of these species has been compiled based on an extensive literature review, revealing a total of 970 species and subspecies from 242 genera across 7 phyla. Bacillariophyceae was identified as the dominant class, comprising 347 species (36.37%), followed by Chlorophyta with 289 species (30.29%) and Cyanobacteria with 190 species (19.92%). Other notable groups include Myzozoa with 72 species (7.55%), Ochrophyta with 56 species (5.87%), Cryptophyta with 13 species (1.36%), and Haptophyta with 3 species (0.31%). This detailed inventory provides essential data on the phytoplankton biodiversity in the Caspian Sea, contributing to a deeper understanding of its ecological complexity. The checklist not only highlights the diversity within each phylum but also emphasizes the dominance of diatoms and chlorophytes, which are key to the sea's primary productivity. These findings serve as a critical resource for future ecological and environmental assessments, offering a baseline for monitoring biodiversity changes, potential threats to the ecosystem, and the impacts of climate change and human activities. The rich phytoplankton diversity outlined in this study shows the ecological significance of the Caspian Sea and its importance for regional and global biodiversity conservation efforts.

Keywords: Phytoplankton, Checklist, Biodiversity, Data bank, Caspian Sea

Introduction

The Caspian Sea is the world's largest landlocked water body located deep inside the Eurasian continent (Leroy et al., 2020). Due to its unique physicochemical and biological characteristics, the Caspian Sea is home to a relatively rich diversity of species, including numerous endemic organisms uniquely adapted to its environment, making it a region of significant ecological importance (Clewing et al., 2024). The dynamics of ecosystems mainly depends on the diversity of plankton especially phytoplankton (Otero et al., 2020). Marine phytoplankton are essential for the health of ocean ecosystems and the planet (Sarwat and Singh, 2023).

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DOI: 10.48308/JPR.2024.236835.1087

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As primary producers, they form the base of the marine food web, supporting a wide range of marine life, from small fish to large whales (Ly, 2023). Phytoplankton biomass in the world's oceans amounts to only 1-2% of the total global plant carbon, yet these organisms fix between 30 and 50 billion metric tons of carbon annually (about 40% of the total). Higher nutrient fluxes would lead to both an increase in phytoplankton biomass and higher biomass-specific rates of carbon fixation (Falkowski, 1994). However, ecological pressures in the Caspian Sea, such as pollution from agricultural runoff, climate change, invasive species, and oil extraction have significantly impacted phytoplankton diversity (Tahami et al., 2012; Bagheri and Fallahi, 2014; Nasrollahzadeh Saravi et al., 2014; Jenny et al., 2020). Nutrient pollution from runoff leads to eutrophication (Mozafari et al., 2023), fostering harmful algal blooms that disrupt the natural balance of species. Climate change, by altering water temperature and salinity, has caused shifts in species composition and distribution. Invasive species like *Mnemiopsis leidyi* have indirectly affected phytoplankton by reducing zooplankton populations, while oil extraction introduces hydrocarbons that favor the dominance of more resistant, less diverse phytoplankton species (Tas et al., 2010). These combined pressures reduce overall biodiversity and threaten the stability of the Caspian Sea ecosystem (Nasrollahzadeh, 2010; Mamedov et al., 2016).

Throughout the entire Caspian Sea, 450 species, varieties or forms of phytoplankton exist. Of these, the dominant forms numerically are Cyanophyta, Bacillariophyta, and Chlorophyta. Middle and South Caspian phytoplankton are mixed marine, brackish, fresh-brackish water, and freshwater forms. By contrast, North Caspian phytoplankton are represented by freshwater forms (Mamaev, 2002). The first studies by CEP (1998); Aubrey et al. (1994); Dumont (1998); and Kasymov (1994) identified 450 species and subspecies of phytoplankton in the Caspian Sea. Other studies have reported phytoplankton species in local scales (e.g., Nasrollahzadeh Saravi et al., 2014; Mahmoudi et al., 2016; Rowshan Tabari et al., 2022; Sadat-Tahami and Keyhan Sani, 2022). Therefore, there is a critical need to prepare an updated checklist of phytoplankton in the Caspian Sea.

Such checklist provides a comprehensive baseline for the phytoplankton biodiversity of the region, which is essential for monitoring changes over time due to environmental fluctuations (Batten et al., 2019), pollution (Franc´e et al., 2021), and climate change (Batten et al., 2019). Additionally, understanding the composition and species richness of phytoplankton can offer insights into the ecological dynamics and trophic interactions within the Caspian Sea. Furthermore, this checklist serves as a valuable resource for researchers and policymakers in making informed decisions about conservation strategies, environmental management, and sustainable use of marine resources in the Caspian Sea. Therefore, the aim of the present study was to prepare a comprehensive checklist of these primary producers in the Caspian Sea.

Material and methods

Study area

This study was performed on the collection of papers dealing with phytoplankton species diversity in the Caspian Sea (Fig. 1). The Caspian Sea exhibits high species richness of phytoplankton that is driven by diverse habitat zones, fluctuating salinity levels, and nutrient inputs from rivers creating dynamic conditions that promote the growth of different phytoplankton species adapted to varying environments.

Checklist data

The checklist of phytoplankton species was compiled using a comprehensive review of existing scientific literature and databases from 1994 to 2023. This approach involved analyzing previously published studies, taxonomic keys, reports, and online databases to gather relieable data on species richness. Non peer-reviewed papers and documents were excluded in the study. Validation of identified species was conducted using international standard data repositories such as WORMS and GBIF. Classification of all groups followed standards outlined on the WORMS website.

Results

During the current study, 970 species and subspecies representing 246 genera were recorded. The identified phytoplankton species were classified into 16 classes, 68 orders, 126 families under 7 phyla: Bacillariophyta (diatoms), Chlorophyta (green algae), Cyanobacteria (blue-green algae), Myzozoa (Dinophyceae), Ochrophyta, Cryptophyta, and Haptophyta (Table 1, Figures 2 and 3). Detailed information about the taxonomy of major groups is provided below.

Bacillariophyta (diatoms)

In the present study, Bacillariophyta was the most dominant group, comprising 35.81% of the total phytoplankton. The identified diatoms were classified into one class (Bacillariophyceae), 23 orders, and 36 families. The dominant orders included Naviculales, which comprised 23.05% of the total phytoplankton species with 80 species, followed by Bacillariales at 13.83% with 48 species, Thalassiosirales at 12.10% with 42 species, Cymbellales at 8.07% with 28 species, and Chaetocerotanae *incertae sedis* at 7.49% with 26 species, along with Fragilariales at 6.34% and 22 species.

Among the families, Bacillariaceae was the most prominent, comprising 13.83% of the total phytoplankton species with 48 species, followed closely by Naviculaceae at 13.54% with 47 species, Chaetocerotaceae at 7.49% with 26 species, Stephanodiscaceae at 6.63% with 23 species, and Fragilariaceae at 6.34% with 22 species. A total of 347 species were recorded, representing 58 genera within the Bacillariophyceae (Table 2). The most abundant genus was *Navicula*, comprising 12.97% (45 species), succdeded by *Nitzschia* at 11.53% with 40 species, and *Chaetoceros* at 7.45% with 26 species (Table 2).

Chlorophyta (green algae)

Chlorophyta (green algae) was the second most dominant group, comprising 30.29% of the total phytoplankton. Identified green-algae were classified into five classes: Chlorophyceae, which comprised 57.09% (165 species); Trebouxiophyceae with 22.84% (66 species); Ulvophyceae with

Table 1. Classification of the phytoplankton and their abundance in the Caspian Sea

Phylum	Class	Order	Family	Genus	Species	Reference
Cyanobacteria	Cyanophyceae	10	22	49	190	Nader Jolodar et al. (2016), Afraei Bandpey et al. (2015), Gasanova et al. (2015), Alizadeh Lahijani (2014), Ganjian et al. (2010), Bagheri et al. (2012), Karpinsky et al. (2006)
Bacillariophyta	Bacillariophyceae	23	36	58	347	Vostokov et al. (2023), Vostokov et al. (2022), Sadat Tahami and Keyhan Sani (2022), Rowshan-Tabari et al. (2022), Draredja et al. (2019), Heydari et al. (2018), Nasrollahzadeh (2017), Mahmoudi et al. (2016), Nader Jolodar et al. (2016), Afraei bandpey et al. (2015), Gasanova et al. (2015), Alizadeh Lahijani (2014), Bagheri and Fallah (2014), Bagheri et al. (2014), Bagheri et al. (2012), Nasrollahzadeh (2011), Ganjian et al. (2010), Karpinsky et al. (2006)
Cryptophyta	Cryptophyceae	2	3	3	13	Caspian Sea Biodiversity Project under umbrella of Caspian Sea Environment Programhttps://www.zin.ru/projects/caspdiv/caspian_waterplants.html
Haptophyta	Coccolithophyceae	1	1	1	3	Nasrollahzadeh Saravi et al. (2016),Caspian Sea Biodiversity Project under umbrella of Caspian Sea Environment Programhttps://www.zin.ru/projects/caspdiv/caspian_waterplants.html
Ochrophyta	Chrysophyceae	3	4	7	18	Nasrollahzadeh Saravi et al. (2016), Bagheri and Fallahi (2014), Ganjian (2019), Alizadeh Lahijani (2014), Ganjian et al. (2010), Caspian Sea Biodiversity Project under umbrella of Caspian Sea Environment Programhttps://www.zin.ru/projects/cas.pdiv/caspian_waterplants.html
	Dictyochophyceae	1	1	1	1	
	Eustigmatophyceae	1	1	1	6	
	Phaeophyceae	3	5	12	18	
	Raphidophyceae	1	1	1	3	
	Xanthophyceae	2	3	4	10	
Myzozoa	Dinophyceae	4	11	20	72	Draredja et al. (2019), Nader Jolodar et al. (2016), Gasanova et al. (2015), Pautova et al. (2016) Alizadeh Lahijani (2014), Pourafrasyabi and Ramezanpour (2014), Bagheri et al. (2012), Karpinsky et al. (2006),
Chlorophyta	Chlorodendrophyceae	1	1	1	5	Heydari et al. (2018), Nader Jolodar et al. (2016), Alizadeh Lahijani (2014), Ganjian et al. (2010), Gasanova et al. (2015), Bagheri et al. (2012), Karpinsky et al. (2006)
	Chlorophyceae	6	21	48	165	
	Trebouxiophyceae	4	5	21	66	
	Ulvophyceae	4	9	18	53	
	Nephroselmidophyceae	1	1	1	1	

* †= Extinct species

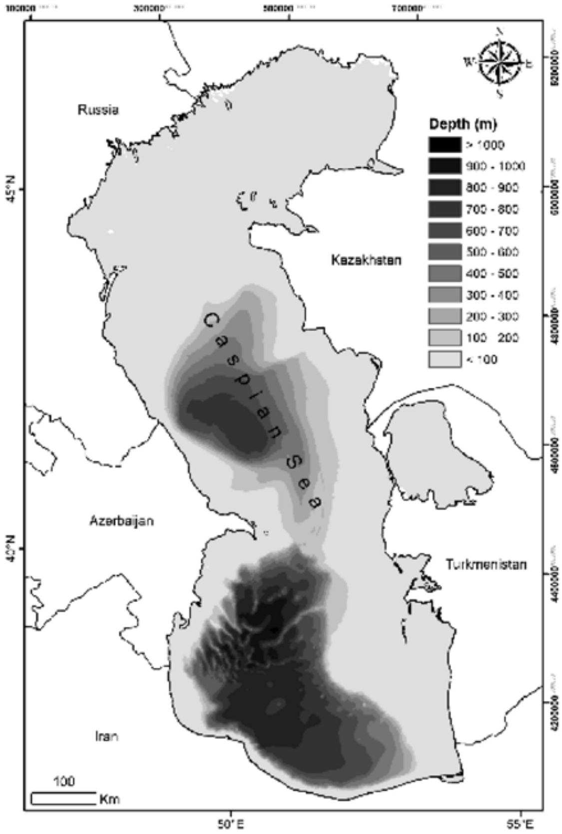

Fig. 1. A map showing the study area (Photo: K. Kabiri)

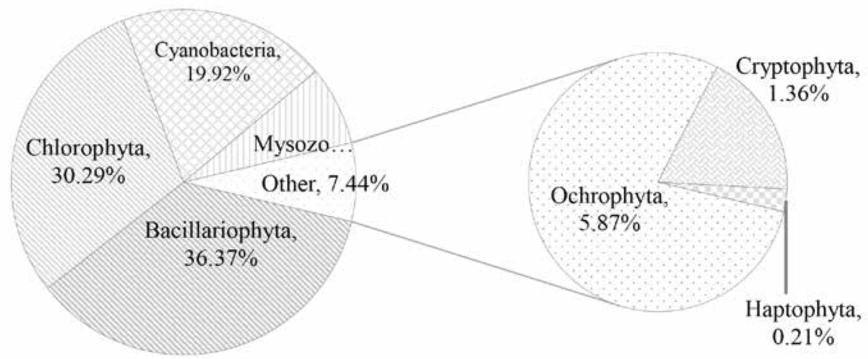

Fig. 2. The relative abundance of different groups of phytoplankton in the Caspian Sea

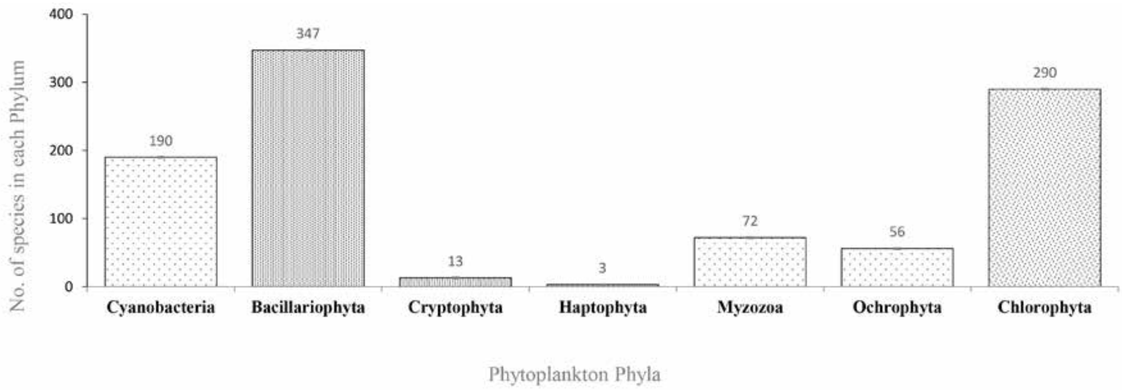

Fig. 3. Number of species of phytoplankton in each phylum in the Caspian Sea

18.34% (53 species); Chlorodendrophyceae with 1.38% (4 species); and Nephroselmidophyceae with 0.35% (1 species). These classes were divided into 16 orders and 37 families. The dominant orders included Sphaeropleales, which comprised 43.25% of the total phytoplankton species with 125 species; Chlorellales with 19.38% and 56 species; Chlamydomonadales with 10.73% and 31 species; and Ulvales with 6.57% and 19 species. The predominant families identified were Scenedesmaceae, which accounted for 17.65% of the total phytoplankton species with 51 species; Oocystaceae, representing 13.15% with38 species; Selenastraceae contributing10.38% with 30 species; and Chlamydomonadaceae, which included 8.65% with 25 species. A total of 289 species were recorded, encompassingto represent 89 genera within Chlorophyta division. The leading genus was *Scenedesmus*, which made up 11.38% (33 species), followed by *Chlamydomonas*, comprising 6.90 % with 20 species (Table 3).

Cyanobacteria (blue-green algae)

The blue-green algae represented the third most dominant group comprising 19.92% of the overal phytoplankton species. Identified blue-green algae were divided into 1 class (Cyanophyceae comprises), 10 orders and 22 families. The dominant orders included Oscillatoriales, which comprised 33.16% of the total phytoplankton species with 63 species; Nostocales with 25.26% and 48 species; Chroococcales with 20.53% and 39 species.

Thepredominantfamilywas Oscillatoriaceae, accounting for17.89% of the total phytoplankton species, which included with 34 species. This was followed by Microcoleaceae and Aphanizomenonaceae, each representing 15.26%with 29 speciesand Microcystaceae, which comprised 10.53% with20 species. The leadinggenus was *Anabaena*, contributing 11.05% with 21 species, followed by *Oscillatoria* at 10% with 19 species), and *Phormidium* at 7.89% with15 species (Table 4).

Myzozoa (dinoflagellates)

In the present study, Myzozoa represented another group that comprises 7.55% (72 species) of the overal phytoplankton composition. The identified dinoflagellate was classified into one class (Dinophyceae), four orders, and eleven families. The predominant orders included Peridiniales, which constituted 62.50% of the total phytoplankton species with 45 species; Prorocentrales, comprising18.06% with 13 species; Gonyaulacales representing 13.89% with 10 species; and Gymnodiniales representing5.56% with four species. The leading family wasPeridiniaceae, accounting for 37.50% of the total phytoplankton species with 27 specie, followed by Prorocentraceae, which comprised 18.06% with13 species.

The most prevalent genus was *Peridinium*, making up 16.67% (12 species) succeded by *Peridiniopsis* at 12.50% with 9 species (Table 5).

Ochrophyta

Ochrophyta constituted5.87% of the overallphytoplankton species, totalling56 species. The identified Ochrophyta classified into sixclasses; Chrysophyceae and Phaeophyceae representing 32.14% with

Table 2. Classification of the Bacillariophyta (Diatoma) and their species in the Caspian Sea

Class	Order	Family	Species
Bacillariophyceae	-	-	*Diatoma elongatum* Lamark & Candolle, 1805
			Diatoma hyemalis Bory de Saint-Vincent, 1824
			Diatoma ochki sp.
			Diatoma sp.
			Diatoma tenuis Lamark & Candolle, 1805
			Diatoma vulgare Lamark & Candolle, 1805
	Achnanthales	Achnanthaceae	*Achnanthes brevipes* Bory, 1822
			Achnanthes exilis Bory, 1822
			Achnanthes inflate Bory, 1822
			Achnanthes lanceolata Bory, 1822
			Achnanthes minutissima Kützing, 1833
			Achnanthes sp.
		Cocconeidaceae	*Cocconeis hustedtii* Ehrenberg, 1837
			Coconeis husteli
			Cocconeis pediculus Ehrenberg, 1837
			Cocconeis placentula Ehrenberg, 1838
			Cocconeis scutellum Ehrenberg, 1837
			Cocconeis skvortzowii C.G. Ehrenberg, 1837
			Cocconeis sp. Kützing, 1844
	Bacillariales	Bacillariaceae	*Bacillaria paradoxa* J.F. Gmelin, 1788
			Bacillaria socialis Ralfs, 1861
			Bacillaria sp.
			Cylindrotheca closterium L. Rabenhorst, 1859
			Hantzschia amphioxys Grunow, 1880
			Nitzschia acicularis A.H. Hassall, 1845
			Nitzschia angustata Grunow, 1880
			Nitzschia aquaea A.H. Hassall, 1845
			Nitzschia brevissima A.H. Hassall, 1845
			Nitzschia closterium A.H. Hassall, 1845
			Nitzschia coarctata A.H. Hassall, 1845
			Nitzschia communis A.H. Hassall, 1845

Nitzschia constricta A.H. Hassall, 1845
Nitzschia debilis A.H. Hassall, 1845
Nitzschia dissipata A.H. Hassall, 1845
Nitzschia distans A.H. Hassall, 1845
Nitzschia gracilis A.H. Hassall, 1845
Nitzschia hantzschiana A.H. Hassall, 1845
Nitzschia holsatica A.H. Hassall, 1845
Nitzschia homburgiensis A.H. Hassall, 1845
Nitzschia hungarica A.H. Hassall, 1845
Nitzschia inconspicua A.H. Hassall, 1845
Nitzschia intermedia A.H. Hassall, 1845
Nitzschia lanceolata A.H. Hassall, 1845
Nitzschia linearis A.H. Hassall, 1845
Nitzschia longissima A.H. Hassall, 1845
Nitzschia lorenziana A.H. Hassall, 1845
Nitzschia palea A.H. Hassall, 1845
Nitzschia paleacea A.H. Hassall, 1845
Nitzschia pusilla A.H. Hassall, 1845
Nitzschia recta A.H. Hassall, 1845
Nitzschia reversa A.H. Hassall, 1845
Nitzschia seriata A.H. Hassall, 1845
Nitzschia sigma A.H. Hassall, 1845
Nitzschia sigmoidea A.H. Hassall, 1845
Nitzschia sp. A.H. Hassall, 1845
Nitzschia sublinearis A.H. Hassall, 1845
Nitzschia subtilis A.H. Hassall, 1845
Nitzschia tenuirostris A.H. Hassall, 1845
Nitzschia tenuis A.H. Hassall, 1845
Nitzchia thermalis A.H. Hassall, 1845
Nitzschia tenuirostris A.H. Hassall, 1845
Nitzschia tryblionella A.H. Hassall, 1845
Nitzschia vermicularis A.H. Hassall, 1845
Nitzschia vitrea A.H. Hassall, 1845
Pseudonitzschia seriata H. Peragallo & M. Peragallo, 1900
Pseudonitzschia sp. Ehrenberg, 1831
Tryblionella gracilis W. Smith, 1853

Cymbellales	Cymbellaceae	*Cymbella affinis* C.A. Agardh, 1830
		Cymbella cistula C.A. Agardh, 1830
		Cymbella cymbiformis C.A. Agardh, 1830
		Cymbella elginensis C.A. Agardh, 1830
		Cymbella helvetica C.A. Agardh, 1830
		Cymbella lanceolata C.A. Agardh, 1830
		Cymbella mesiana C.A. Agardh, 1830
		Cymbella parva C.A. Agardh, 1830
		Cymbella prostrata C.A. Agardh, 1830
		Cymbella pusilla C.A. Agardh, 1830
		Cymbella sp. Greville, 1833
		Cymbella tumida C.A. Agardh, 1830
		Cymbella tumidula C.A. Agardh, 1830
		Cymbella ventricosa C.A. Agardh, 1830
	Gomphonemataceae	*Gomphonema acuminatum* Ehrenberg, 1832
		Gomphonema augur C.G. Ehrenberg, 1832
		Gomphonema angustatum C.G. Ehrenberg, 1832
		Gomphonema bohemicum C.G. Ehrenberg, 1832
		Gomphonema clavatum C.G. Ehrenberg, 1832
		Gomphonema lanceolatum C.Agardh, 1831
		Gomphonema olivaceum C.G. Ehrenberg, 1832
		Gomphonema parvulum Kützing, 1849
		Gomphonema salinarum C.G. Ehrenberg, 1832
		Gomphonema sp. Kützing, 1844
		Gomphonema truncatum C.G. Ehrenberg, 1832
		Gomphonema subsalinum C.G. Ehrenberg, 1832
	Rhoicospheniaceae	*Rhoicosphenia curvata* Lange-Bertalot, 1980
		Rhoicosphenia abbreviata A. Grunow, 1860
Mastogloiales	Mastogloiaceae	*Aneumastus tusculus* D.G. Mann & A.J. Stickle in F.E. Round, R.M. Crawford & D.G. Mann, 1990
		Mastogloia baltica G.H.K. Thwaites in W. Smith, 1856
		Mastogloia smithii G.H.K. Thwaites in W. Smith, 1856
Naviculales	Diploneidaceae	*Diploneis bombus* P.T. Cleve, 1894
		Diploneis didyma P.T. Cleve, 1894
		Diploneis interrupta P.T. Cleve, 1894
		Diploneis smithii P.T. Cleve, 1894

	Diploneis stagnarum P.T. Cleve, 1894
	Diploneis subovalis P.T. Cleve, 1894
	Diploneis sp. D. G. Mann, 1990
Naviculaceae	*Caloneis amphisbaena* P.T. Cleve, 1894
	Caloneis sp. Kützing, 1844
	Navicula anglica J.B.M. Bory de Saint-Vincent, 1822
	Navicula bacillum J.B.M. Bory de Saint-Vincent, 1822
	Navicula bombus J.B.M. Bory de Saint-Vincent, 1822
	Navicula capitate J.B.M. Bory de Saint-Vincent, 1822
	Navicula cincta J.B.M. Bory de Saint-Vincent, 1822
	Navicula costulata J.B.M. Bory de Saint-Vincent, 1822
	Navicula crucigera J.B.M. Bory de Saint-Vincent, 1822
	Navicula cryptocephala J.B.M. Bory de Saint-Vincent, 1822
	Navicula cuspidata J.B.M. Bory de Saint-Vincent, 1822
	Navicula decussis J.B.M. Bory de Saint-Vincent, 1822
	Navicula dicephala J.B.M. Bory de Saint-Vincent, 1822
	Navicula elginensis J.B.M. Bory de Saint-Vincent, 1822
	Navicula elliptica J.B.M. Bory de Saint-Vincent, 1822
	Navicula exigua J.B.M. Bory de Saint-Vincent, 1822
	Navicula fluens J.B.M. Bory de Saint-Vincent, 1822
	Navicula forcipata J.B.M. Bory de Saint-Vincent, 1822
	Navicula gastrum J.B.M. Bory de Saint-Vincent, 1822
	Navicula gibbula J.B.M. Bory de Saint-Vincent, 1822
	Navicula gracilis † J.B.M. Bory de Saint-Vincent, 1822
	Navicula gregaria J.B.M. Bory de Saint-Vincent, 1822
	Navicula kotschyi J.B.M. Bory de Saint-Vincent, 1822
	Navicula lanceolata J.B.M. Bory de Saint-Vincent, 1822
	Navicula laterostrata J.B.M. Bory de Saint-Vincent, 1822
	Navicula menisculus † J.B.M. Bory de Saint-Vincent, 1822
	Navicula minima J.B.M. Bory de Saint-Vincent, 1822
	Navicula molestiformis J.B.M. Bory de Saint-Vincent, 1822
	Navicula molestiformis J.B.M. Bory de Saint-Vincent, 1822
	Navicula peregrine J.B.M. Bory de Saint-Vincent, 1822
	Navicula placentula Kützing, 1844
	Navicula platystoma J.B.M. Bory de Saint-Vincent, 1822
	Navicula pseudanglica J.B.M. Bory de Saint-Vincent, 1822

	Navicula pupula J.B.M. Bory de Saint-Vincent, 1822
	Navicula pusilla J.B.M. Bory de Saint-Vincent, 1822
	Navicula radiosa J.B.M. Bory de Saint-Vincent, 1822
	Navicula recens J.B.M. Bory de Saint-Vincent, 1822
	Navicula rhynchocephala Kützing, 1844
	Navicula rostrate J.B.M. Bory de Saint-Vincent, 1822
	Navicula simplex J.B.M. Bory de Saint-Vincent, 1822
	Navicula sp. Kützing, 1844
	Navicula spicula J.B.M. Bory de Saint-Vincent, 1822
	Navicula stroemii J.B.M. Bory de Saint-Vincent, 1822
	Navicula subrhombica J.B.M. Bory de Saint-Vincent, 1822
	Navicula tripunctata J.B.M. Bory de Saint-Vincent, 1822
	Navicula veneta J.B.M. Bory de Saint-Vincent, 1822
	Navicula viridula J.B.M. Bory de Saint-Vincent, 1822
Pinnulariaceae	*Pinnularia gibba* C.G. Ehrenberg, 1843
	Pinnularia interrupta C.G. Ehrenberg, 1843
	Pinnularia microstauron C.G. Ehrenberg, 1843
	Pinnularia nobilis C.G. Ehrenberg, 1843
	Pinnularia sp. D.G. Mann, 1990
Pleurosigmataceae	*Gyrosigma acuminatum* A.H. Hassall, 1845
	Gyrosigma attenuata A.H. Hassall, 1845
	Gyrosigma baicalense A.H. Hassall, 1845
	Gyrosigma balticum A.H. Hassall, 1845
	Gyrosigma fasciola A.H. Hassall, 1845
	Gyrosigma kuetzingii A.H. Hassall, 1845
	Gyrosigma peisonis A.H. Hassall, 1845
	Gyrosigma scalproides A.H. Hassall, 1845
	Gyrosigma sp. Mereschkowsky, 1903
	Gyrosigma spencerii A.H. Hassall, 1845
	Gyrosigma strigilis A.H. Hassall, 1845
	Pleurocapsa rivularis Thuret, 1885
	Pleurosigma angulatum W. Smith, 1852
	Pleurosigma delicatulum W. Smith, 1852
	Pleurosigma elongatum W. Smith, 1852
	Pleurosigma salinarum W. Smith, 1852
	Pleurosigma sp. Mereschkowsky, 1903

	Stauroneidaceae	*Stauroneis anceps* C.G. Ehrenberg, 1843
	Neidiaceae	*Neidium affine* E. Pfitzer, 1871
		Neidium ampliatum E. Pfitzer, 1871
		Neidium dubium E. Pfitzer, 1871
Rhopalodiales	Rhopalodiaceae	*Epithemia adnata* F.T. Kützing, 1844
		Epithemia argus F.T. Kützing, 1844
		Epithemia sorex F.T. Kützing, 1844
		Epithemia sp. Topachevs'kyj & Oksiyuk, 1960
		Epithemia turgida F.T. Kützing, 1844
		Rhopalodia gibba O. Müller, 1895
		Rhopalodia musculus O. Müller, 1895
		Rhopalodia sp. Topachevs'kyj & Oksiyuk, 1960
Surirellales	Entomoneidaceae	*Entomoneis paludosa* Ehrenberg, 1845
	Surirellaceae	*Campylodiscus aralensis* C.G. Ehrenberg ex F.T. Kützing, 1844
		Campylodiscus bicostatus C.G. Ehrenberg ex F.T. Kützing, 1844
		Campylodiscus clypeus C.G. Ehrenberg ex F.T. Kützing, 1844
		Campylodiscus echeneis C.G. Ehrenberg ex F.T. Kützing, 1844
		Campylodiscus sp. Surirellaceae Kützing, 1844
		Cymatopleura elliptica W.Smith, 1851
		Cymatopleura solea W. Smith, 1851
		Cymatopleura sp. Kützing, 1844
		Surirella angustata .J.F. Turpin, 1828
		Surirella arcta P.J.F. Turpin, 1829
		Surirella brebissonii Krammer & Lange-Bertalot, 1987
		Surirella elegans P.J.F. Turpin, 1828
		Surirella linearis P.J.F. Turpin, 1828
		Surirella minuta P.J.F. Turpin, 1828
		Surirella ovalis Brébisson, 1838
		Surirella sp. Kützing, 1844
		Surirella splendida P.J.F. Turpin, 1828
Thalassiophysales	Catenulaceae	*Amphora coffeaeformis* C.G. Ehrenberg ex F.T. Kützing, 1844
		Amphora commutata C.G. Ehrenberg ex F.T. Kützing, 1844
		Amphora ovalis C.G. Ehrenberg ex F.T. Kützing, 1844
		Amphora pediculus C.G. Ehrenberg ex F.T. Kützing, 1844
		Amphora sp. Mereschkowsky, 1902
		Amphora veneta C.G. Ehrenberg ex F.T. Kützing, 1844

Eunotiales	Eunotiaceae	*Eunotia bilunaris* C.G. Ehrenberg, 1837
Biddulphiales	Biddulphiaceae	*Biddulphia mobiliensis* S.F. Gray, 1821
Hemiaulales	Hemiaulaceae	*Cerataulina pelagica* H. Peragallo ex F. Schütt in Engler & Prantl, 1896
Chaetocerotanae *incertae sedis*	Chaetocerotaceae	*Chaetoceros abnormis* Proschkina-Lavrenko, 1953
		Chaetoceros affinis Lauder, 1864
		Chaetoceros ceratosporus C.G. Ehrenberg, 1844
		Chaetoceros convolutus C.G. Ehrenberg, 1844
		Chaetoceros delicatulus C.G. Ehrenberg, 1844
		Chaetoceros diversicurvatus C.G. Ehrenberg, 1844
		Chaetoceros gracilis C.G. Ehrenberg, 1844
		Chaetoceros laciniosus C.G. Ehrenberg, 1844
		Chaetoceros minutissimus C.G. Ehrenberg, 1844
		Chaetoceros mirabilis C.G. Ehrenberg, 1844
		Chaetoceros muelleri C.G. Ehrenberg, 1844
		Chaetoceros neogracilis C.G. Ehrenberg, 1844
		Chaetoceros paulsenii C.G. Ehrenberg, 1844
		Chaetoceros pendulus C.G. Ehrenberg, 1844
		Chaetoceros peruvianus C.G. Ehrenberg, 1844
		Chaetoceros rigidus C.G. Ehrenberg, 1844
		Chaetoceros seiracanthus C.G. Ehrenberg, 1844
		Chaetoceros similis C.G. Ehrenberg, 1844
		Chaetoceros simplex C.G. Ehrenberg, 1844
		Chaetoceros socialis C.G. Ehrenberg, 1844
		Chaetoceros sp. Ralfs, 1861
		Chaetoceros subtilis C.G. Ehrenberg, 1844
		Chaetoceros tenuissimus C.G. Ehrenberg, 1844
		Chaetoceros throndsenii C.G. Ehrenberg, 1844
		Chaetoceros turbineus C.G. Ehrenberg, 1844
		Chaetoceros wighamii C.G. Ehrenberg, 1844
Aulacoseirales	Aulacoseiraceae	*Aulacoseira ambigua* G.H.K. Thwaites, 1848
		Aulacoseira distans † G.H.K. Thwaites, 1848
		Aulacoseira granulata G.H.K. Thwaites, 1848
		Aulacoseira islandica .H.K. Thwaites, 1848
		Aulacoseira italica G.H.K. Thwaites, 1848
Coscinodiscales	Coscinodiscaceae	*Coscinodiscus eccentricus* † Ehrenberg, 1840 †

		Coscinodiscus gigas C.G. Ehrenberg, 1839
		Coscinodiscus granii C.G. Ehrenberg, 1839
		Coscinodiscus jonesianus C.G. Ehrenberg, 1839
		Coscinodiscus perforatus C.G. Ehrenberg, 1839
		Coscinodiscus proximus C.G. Ehrenberg, 1839
		Coscinodiscus sp. Kützing, 1844
		Coscinodiscus radiatus C.G. Ehrenberg, 1839
	Hemidiscaceae	*Actinocyclus ehrenbergii* C.G. Ehrenberg, 1837
		Actinocyclus normanii C.G. Ehrenberg, 1837
		Actinocyclus paradoxus C.G. Ehrenberg, 1837
		Actinocyclus tenellus C.G. Ehrenberg, 1837
		Actinocyclus sp. Hendey, 1937 emend Simonsen, 1975
Melosirales	Hyalodiscaceae	*Hyalodiscus sphaerophorus* C.G. Ehrenberg, 1845
		Hyalodiscus parvulus C.G. Ehrenberg, 1845
	Melosiraceae	*Melosira granulata* C.A. Agardh, 1824
		Melosira italica C.A. Agardh, 1824
		Melosira juergensii C.A. Agardh, 1824
		Melosira moniliformis C.A. Agardh, 1824
		Melosira sp. C.A. Agardh, 1824
		Melosira undulata C.A. Agardh, 1824
		Melosira varians C.A. Agardh, 1824
Lithodesmiales	Lithodesmiaceae	*Tropidoneis lepidoptera* P.T. Cleve, 1891
Rhizosoleniales	Rhizosoleniaceae	*Dactyliosolen fragilissimus* Bergon, 1903
		Dactyliosolen sp. De Toni, 1890
		Proboscia alata Bo G. Sundström, 1986
		Rhizosolenia alata T. Brightwell, 1858
		Rhizosolenia calcar-avis T. Brightwell, 1858
		Rhoicosphenia curvata Lange-Bertalot, 1980
		Rhizosolenia eriensis T. Brightwell, 1858
		Rhizosolenia fragilissima T. Brightwell, 1858
		Rhizosolenia setigera T. Brightwell, 1858
		Rhizosolenia sp. De Toni, 1890
		Pseudosolenia calcar-avis B.G. Sundstrom, 1986
Thalassiosirales	Skeletonemaceae	*Skeletonema costata* Cleve, 1873
		Skeletonema costatum R.K. Greville, 1865
		Skeletonema cylindraceum R.K. Greville, 1865

Table 3. Classification of the Chlorophyta (green algae) and their species in the Caspian Sea

Class	Order	Family	Species
Chlorodendrophyceae	Chlorodendrales	Chlorodendraceae	*Tetraselmis arnoldii* .Stein, 1878
			Tetraselmis contracta .Stein, 1878
			Tetraselmis cordiformis F.Stein, 1878
			Tetraselmis sp. Oltmanns, 194
Chlorophyceae	Chaetophorales	Chaetophoraceae	*Ectochaete leptochaete* J.Agardh, 1841
			Stigeoclonium sp. Greville, 1824
		Schizomeridaceae	*Schizomeris* sp. G.M.Smith, 1933
	Chlamydomonadales	Chlamydomonadaceae	*Carteria globosa* Diesing, 1866
			Chlamydomonas angulosa Ehrenberg, 1833
			Chlamydomonas asymmetrica Ehrenberg, 1833
			Chlamydomonas debaryana Goroschankin 1891
			Chlamydomonas elliptica Ehrenberg, 1833
			Chlamydomonas floscularіae Ehrenberg, 1833
			Chlamydomonas globosa Ehrenberg, 1833
			Chlamydomonas incerta Ehrenberg, 1833
			Chlamydomonas media Ehrenberg, 1833
			Chlamydomonas monadina Ehrenberg, 1833
			Chlamydomonas noctigama Ehrenberg, 1833
			Chlamydomonas olifaniae Ehrenberg, 1833
			Chlamydomonas ovalis Ehrenberg, 1833
			Chlamydomonas pertyi Ehrenberg, 1833
			Chlamydomonas proboscigera Korshikov, 1927
			Chlamydomonas pseudopertusa Ehrenberg, 1833
			Chlamydomonas reinhardtii Ehrenberg, 1833
			Chlamydomonas similis Ehrenberg, 1833
			Chlamydomonas simplex Ehrenberg, 1833
			Chlamydomonas snowiae Ehrenberg, 1833
			Chlamydomonas sp. F.Stein, 1878
			Chloromonas vulgaris Gobi, 1899
			Emergosphaera superficialis W.W.Miller, 1921
			Gloeomonas mucosa Klebs, 1886
			Lobomonas stellata P.-A.Dangeard, 1899
		Chlamydomonadales *incertae sedis*	*Desmatractum indutum* West & G.S. West, 1902

		Echinosphaerella sp.
	Goniaceae	*Gonium pectorale* O.F.Müller, 1773
		Gonium sociale O.F.Müller, 1773
	Haematococcaceae	*Chlorogonium acutiforme* Ehrenberg, 1836
		Chlorogonium minimum Ehrenberg, 1836
Oedogoniales	Oedogoniaceae	*Oedogonium* sp. Bary ex Hirn, 1900
Sphaeropleales	Characiaceae	*Korshikoviella limnetica* P.C.Silva, 1959
	Hydrodictyaceae	*Pediastrum angulosum* Meyen, 1829
		Pediastrum boryanum Meyen, 1829
		Pediastrum duplex Meyen, 1829
		Pediastrum integrum Meyen, 1829
		Pediastrum simplex Meyen, 1829
		Pediastrum sp. Meyen, 1829
		Pediastrum tetras Meyen, 1829
		Sorastrum spinulosum Kützing, 1845
		Tetraëdron caudatum Kützing, 1845
		Tetraëdron incus Kützing, 1845
		Tetraëdron minimum Kützing, 1845
		Tetraëdron pentaedricum Kützing, 1845
		Tetraëdron sp. Dumortier, 1829
		Tetraëdron triangulare Kützing, 1845
		Tetrapedia sp. Dumortier, 1829
	Neochloridaceae	*Golenkinia paucispina* Chodat, 1894
		Golenkinia radiata Chodat, 1894
		Golenkinia sp. Ettl & Komárek, 1982
	Phacotaceae	*Pteromonas aculeata* Seligo, 1887
		Pteromonas angulosa Seligo, 1887
		Pteromonas robusta Seligo, 1887
		Pteromonas torta Seligo, 1887
	Radiococcaceae	*Coenochloris pyrenoidosa* Korshikov, 1953
		Coenococcus planctonicus Korshikov, 1953
		Coenococcus polycoccus Korshikov, 1953
		Coenocystis obtusa Korshikov, 1953
	Scenedesmaceae	*Coelastrum astroideum* Nägeli, 1849
		Coelastrum indicum Nägeli, 1849
		Coelastrum microporum Nägeli, 1849

Coelastrum pulchrum Nägeli, 1849
Coelastrum sp.
Coelastrum sphaericum Nägeli, 1849
Coelastrum sphaericum Nägeli, 1849
Komarekia appendiculata Fott, 1981
Pseudotetrastrum punctatum Hindák, 1977
Tetrastrum elegans Chodat, 1895
Tetrastrum heteracanthum Chodat, 1895
Tetrastrum sp. Oltmanns, 1904
Tetrastrum staurogeniaeforme Chodat, 1895
Tetrastrum triacanthum Chodat, 1895
Tetrastrum staurogeniaeforme Chodat, 1895
Scenedesmus abundans Meyen, 1829
Scenedesmus acuminatus Meyen, 1829
Scenedesmus acutiformis Meyen, 1829
Scenedesmus acutus Meyen, 1829
Scenedesmus apiculatus Meyen, 1829
Scenedesmus arcuatus Meyen, 1829
Scenedesmus armatus Meyen, 1829
Scenedesmus bernarlii Meyen, 1829
Scenedesmus bicaudatus Meyen, 1829
Scenedesmus bijuga Meyen, 1829
Scenedesmus bijugatus Meyen, 1829
Scenedesmus brasiliensis Meyen, 1829
Scenedesmus caudato-aculeolatus Meyen, 1829
Scenedesmus communis Meyen, 1829
Scenedesmus costato-granulatus Meyen, 1829
Scenedesmus curvatus Meyen, 1829
Scenedesmus denticulatus Meyen, 1829
Scenedesmus falcatus Meyen, 1829
Scenedesmus gutwinskii Meyen, 1829
Scenedesmus incrassatulus Meyen, 1829
Scenedesmus insignis Meyen, 1829
Scenedesmus intermedius Meyen, 1829
Scenedesmus obliquus Meyen, 1829
Scenedesmus obtusus Meyen, 1829

	Scenedesmus opoliensis Meyen, 1829
	Scenedesmus papillosum Meyen, 1829
	Scenedesmus protuberans Meyen, 1829
	Scenedesmus quadricauda Meyen, 1829
	Scenedesmus sp.
	Scenedesmus sempervirens Meyen, 1829
	Scenedesmus spinosus Meyen, 1829
	Scenedesmus triangulare Meyen, 1829
	Scenedesmus verrucosus Meyen, 1829
	Tetradesmus wisconsinensis G.M.Smith, 1913
	Westella botryoides De Wildeman, 1897
	Westella sp.
Schroederiaceae	*Schroederia robusta* Lemmermann, 1898
	Schroederia setigera Lemmermann, 1898
	Schroederia sp. Lemmermann, 1898
	Schroederia spiralis Lemmermann, 1898
Selenastraceae	*Ankistrodesmus acicularis* Corda, 1838
	Ankistrodesmus angustus Corda, 1838
	Ankistrodesmus arcuatus Corda, 1838
	Ankistrodesmus convolutus Corda, 1838
	Ankistrodesmus densus Corda, 1838
	Ankistrodesmus falcatus Corda, 1838
	Ankistrodesmus fusiformis Corda, 1838
	Ankistrodesmus sp. Blackman & Tansley, 1903
	Ankistrodesmus spiralis Corda, 1838
	Chlorolobion braunii Korshikov, 1953
	Kirchneriella aperta Schmidle, 1893
	Kirchneriella irregularis Schmidle, 1893
	Kirchneriella lunaris Schmidle, 1893
	Kirchneriella obesa Schmidle, 1893
	Kirchneriella sp. Blackman & Tansley, 1903
	Monoraphidium arcuatum Komárková-Legnerová, 1969
	Monoraphidium circinale Komárková-Legnerová, 1969
	Monoraphidium contortum Komárková-Legnerová, 1969
	Monoraphidium griffithii Komárková-Legnerová, 1969
	Monoraphidium irregulare Komárková-Legnerová, 1969

			Monoraphidium komarkovae Komárková-Legnerová, 1969
			Monoraphidium minutum Komárková-Legnerová, 1969
			Monoraphidium komarkovae Komárková-Legnerová, 1969
			Quadrigula pfitzeri Printz, 1916
			Raphidocelis contorta Hindák, 1977
			Raphidocelis sigmoidea Hindák, 1977
			Selenastrum bibraianum Reinsch, 1867
			Selenastrum gracilis Reinsch, 1867
			Selenastrum obtusum Reinsch, 1867
			Selenastrum sp. Blackman & Tansley, 1903
		Sphaeropleaceae	*Ankyra ancora* Fott, 1957
			Ankyra judayi Fott, 1957
			Ankyra viridis Fott, 1957
		Sphaeropleales *incertae sedis*	*Polyedriopsis spinulosa* Schmidle, 1899
		Treubariaceae	*Treubaria euryacantha* C.Bernard, 1908
			Treubaria planctonica C.Bernard, 1908
			Treubaria schmidlei C.Bernard, 1908
			Treubaria triappendiculata C.Bernard, 1908
		Volvocaceae	*Eudorina elegans* Ehrenberg, 1832
			Eudorina sp. Ehrenberg, 1834
			Pandorina charkowiensis Bory de Saint-Vincent, 1824
			Pandorina morum Bory de Saint-Vincent, 1824
			Pandorina sp. Ehrenberg, 1834
	Tetrasporales	Sphaerocystidaceae	*Dictyochlorella reniformis* P.C.Silva, 1959
			Dictyochlorella globosa P.C.Silva, 1959
			Planctococcus sphaerocystiformis Korshikov, 1953
			Sphaerocystis planctonica R.Chodat, 1897
	Volvocales	Dunaliellaceae	*Spermatozopsis exsultans* Korshikov, 1913
Trebouxiophyceae	Chlorellales	Chlorellaceae	*Actinastrum fluviatile* Lagerheim 1882
			Actinastrum hantzschii Lagerheim 1882
			Actinastrum raphidoides Lagerheim 1882
			Actinastrum sp. Brunnthaler, 1913
			Chlorella sp. Brunnthaler, 1913
			Closteriopsis acicularis Lemmermann, 1899
			Dicellula planctonica Svirenko, 1926

	Dictyosphaerium anomalum Nägeli, 1849
	Dictyosphaerium ehrenbergianum Nägeli, 1849
	Dictyosphaerium pulchellum Nägeli, 1849
	Dictyosphaerium tetrachotomum Nägeli, 1849
	Golenkiniopsis longispina Korshikov, 1953
	Golenkiniopsis parvula Korshikov, 1953
	Golenkiniopsis solitaria Korshikov, 1953
	Micractinium pusillum Fresenius, 1858
	Micractinium quadrisetum Fresenius, 1858
	*Siderocelis ornata*Fott, 1934
	*Siderocelis sphaerica*Fott, 1934
Oocystaceae	*Chodatella breviseta* West & G.S.West, 1902
	Chodatella chodati
	Chodatella ciliate Lemmermann, 1898
	Chodatella sp. *Bohlin, 1901*
	Coenolamellus botryoideus A.I.Proshkina-Lavrenko, 1966
	Crucigeniella apiculata Morren, 1830
	Crucigeniella rectangularis Morren, 1830
	Didymocystis bicellularis Korshikov, 1953
	Didymocystis inermis Korshikov, 1953
	Didymocystis lineata Korshikov, 1953
	Didymocystis planctonica Korshikov, 1953
	Franceia ovalis Lemmermann, 1898
	Lagerheimia ciliata R.Chodat, 1895
	Lagerheimia citriformis R.Chodat, 1895
	Lagerheimia genevensis R.Chodat, 1895
	Lagerheimia longiseta R.Chodat, 1895
	Lagerheimia quadriseta R.Chodat, 1895
	Lagerheimia subsalsa R.Chodat, 1895
	Nephrochlamys allanthoidea Korshikov, 1953
	Nephrochlamys subsolitaria Korshikov, 1953
	Oocystis apiculata Nägeli ex A.Braun, 1855
	Oocystis borgei Nägeli ex A.Braun, 1855
	Oocystis composita Nägeli ex A.Braun, 1855
	Oocystis echinulata Nägeli ex A.Braun, 1855
	Oocystis eremosphaeria Nägeli ex A.Braun, 1855

			Oocystis gigas Nägeli ex A.Braun, 1855
			Oocystis lacustris Nägeli ex A.Braun, 1855
			Oocystis marssonii Nägeli ex A.Braun, 1855
			Oocystis nodulosa Nägeli ex A.Braun, 1855
			Oocystis pandriformis Nägeli ex A.Braun, 1855
			Oocystis parva Nägeli ex A.Braun, 1855
			Oocystis rupestris Nägeli ex A.Braun, 1855
			Oocystis socialis Nägeli ex A.Braun, 1855
			Oocystis solitaria Nägeli ex A.Braun, 1855
			Oocystis sp. Bohlin, 191
			Oocystis submarina Nägeli ex A.Braun, 1855
			Siderocystopsis fusca Swale, 1964
			Trochiscia aciculifera Kützing, 1834
	Prasiolales	Koliellaceae	*Koliella longiseta* Hindák, 1963
	Trebouxiales	Botryococcaceae	*Botryococcus braunii* Kützing, 1849
	Trebouxiophyceae ordo *incertae sedis*	Trebouxiophyceae *incertae sedis*	*Crucigenia crucifera* Morren, 183
			Crucigenia fenestrata Morren, 183
			Crucigenia lauterbornei Morren, 183
			Crucigenia leautebornii Morren, 183
			Crucigenia quadrata Morren, 183
			Crucigenia rectangularis Morren, 183
			Crucigenia sp.
			*Crucigenia tetrapedia*Morren, 183
Ulvophyceae	Cladophorales	Cladophoraceae	*Chaetomorpha aerea* Kützing, 1845
			Chaetomorpha linum Kützing, 1845
			Cladophora aegagropila Kützing, 1843
			Cladophora bakuana Kützing, 1845
			Cladophora fracta Kützing, 1843
			Cladophora glomerata Kützing, 1843
			Cladophora gracilis Kützing, 1843
			Cladophora laetevirens Kützing, 1843
			Cladophora microcladia Kützing, 1843
			Cladophora nitida Kützing, 1843
			Cladophora rupestris Kützing, 1843
			Cladophora sericea Kützing, 1843

			Cladophora sp. Wille, 1884
			Cladophora vagabunda Kützing, 1843
			Rhizoclonium fontanum Kützing, 1843
			Rhizoclonium hieroglyphicum Kützing, 1843
			Rhizoclonium Kochianum Kützing, 1843
			Rhizoclonium riparium Kützing, 1843
	Bryopsidales	Ostreobiaceae	*Ostreobium queckettii* Bornet & Flahault, 1889
	Ulotrichales	Binucleariaceae	*Binuclearia lauterbornii*Wittrock, 1886
			Binuclearia sp. Škaloud & Leliaert, 218
		Gomontiaceae	*Gomontia polyrhiza* Bornet & Flahault, 1888
		Monostromataceae	*Monostroma latissimum* Thuret, 1854
			Monostroma wittrockii Thuret, 1854
		Ulotrichaceae	*Geminellopsis fragilis* A.A.Korschikov, 1939
			Ulothrix albicans Kützing, 1833
			Ulothrix flacca Kützing, 1833
			Ulothrix implexa Kützing, 1833
			Ulothrix pseudoflacca Kützing, 1833
			Ulothrix sp. Kützing, 1843
			Ulothrix subtilissima Kützing, 1833
			Ulothrix tenerrima Kützing, 1833
			Ulothrix zonata Kützing, 1833
			Urospora penicilliformis Areschoug, 1866
	Ulvales	Kornmanniaceae	*Blidingia marginata* Kylin, 1947
		Ulvaceae	*Enteromorpha ahlneriana* Linnaeus, 1753
			Enteromorpha clathrata Linnaeus, 1753
			Enteromorpha complanata Linnaeus, 1753
			Enteromorpha compressa Linnaeus, 1753
			Enteromorpha crinita Linnaeus, 1753
			Enteromorpha erecta Linnaeus, 1753
			Enteromorpha flexuosa Linnaeus, 1753
			Enteromorpha linza Linnaeus, 1753
			Enteromorpha prolifera Linnaeus, 1753
			Enteromorpha ramulosa Linnaeus, 1753
			Enteromorpha salina Linnaeus, 1753
			Enteromorpha torta Linnaeus, 1753
			Ulva lactuca Linnaeus, 1753
		Ulvellaceae	*Acrochaete parasitica* P.L.Crouan & H.M.Crouan, 1859
			Entocladia viridis Reinke, 1879
			Epicladia flustrae Reinke, 1889
			Pringsheimiella scutata P.L.Crouan & H.M.Crouan, 1859
			Ulvella lens P.L.Crouan & H.M.Crouan, 1859
Nephroselmidophyceae	Nephroselmidales	Nephroselmidaceae	*Nephroselmis minuta* F.Stein, 1878

Table 4. Classification of the cyanpbacteria (blue-green algae) and their species in the Caspian Sea

Class	Order	Family	Species
Cyanophyceae	Geitlerinematales	Geitlerinemataceae	*Geitlerinema amphibium*Anagnostidis, 1989
	Gomontiellales	Cyanothecaceae	*Cyanothece aeruginosa* Komárek, 1976
	Leptolyngbyales	Leptolyngbyaceae	*Heteroleibleinia kuetzingii* L.Hoffmann, 1905
			Leptolyngbya angustissima Anagnostidis & Komárek, 1988
			Leptolyngbya fragilis Anagnostidis & Komárek, 1988
			Leptolyngbya lagerheimii Anagnostidis & Komárek, 1988
			Leptolyngbya perelegans Anagnostidis & Komárek, 1988
			Leptolyngbya valderiana Anagnostidis & Komárek, 1988
			Planktolyngbya contorta Anagnostidis & Komárek, 1988
			Planktolyngbya limnetica Anagnostidis & Komárek, 1988
		Trichocoleusaceae	*Schizothrix lenormandiana* Kützing ex Gomont, 1892
			Trichocoleus tenerrimus Anagnostidis, 2001
	Pseudanabaenales	Pseudanabaenaceae	*Limnothrix planctonica* Meffert, 1987
			Limnothrix redekei Meffert, 1987
			Pseudanabaena limnetica Lauterborn, 1915
			Pseudanabaena mucicola Lauterborn, 1915
	Nostocales	Aphanizomenonaceae	*Anabaena abnormis* Bory de Saint-Vincent ex Bornet & Flahault, 1886
			Anabaena affinis Bory de Saint-Vincent ex Bornet & Flahault, 1886
			Anabaena aphanizomenoides Bory de Saint-Vincent ex Bornet & Flahault, 1886
			Anabaena attenuata Bory de Saint-Vincent ex Bornet & Flahault, 1886
			Anabaena bergii Bory de Saint-Vincent ex Bornet & Flahault, 1886
			Anabaena circinalis Bory de Saint-Vincent ex Bornet & Flahault, 1886
			Anabaena constricta Bory de Saint-Vincent ex Bornet & Flahault, 1886
			Anabaena contorta Bory de Saint-Vincent ex Bornet & Flahault, 1886

	Anabaena flos-aquae Bory de Saint-Vincent ex Bornet & Flahault, 1887
	Anabaena hassallii Bory de Saint-Vincent ex Bornet & Flahault, 1886
	Anabaena kisseleaii Bory de Saint-Vincent ex Bornet & Flahault, 1886
	Anabaena oscillarioides Bory de Saint-Vincent ex Bornet & Flahault, 1887
	Anabaena planctonica Bory de Saint-Vincent ex Bornet & Flahault, 1886
	Anabaena reniformis Bory de Saint-Vincent ex Bornet & Flahault, 1886
	Anabaena scheremetievi Bory de Saint-Vincent ex Bornet & Flahault, 1887
	Anabaena sigmoidea Bory de Saint-Vincent ex Bornet & Flahault, 1886
	Anabaena sp. Elenkin, 1938
	Anabaena sphaerica Bory de Saint-Vincent ex Bornet & Flahault, 1886
	Anabaena spiroides Klebahn, 1895
	Anabaena subcylindrica Bory de Saint-Vincent ex Bornet & Flahault, 1886
	Anabaena viguieri Bory de Saint-Vincent ex Bornet & Flahault, 1886
	Aphanizomenon aphanizomenoides A.Morren ex Bornet & Flahault, 1888
	Aphanizomenon flosaquae A.Morren ex Bornet & Flahault, 1888
	Aphanizomenon issatschenkoi A.Morren ex Bornet & Flahault, 1888
	Aphanizomenon sp. Elenkin, 1938
	*Aphanizomenon ussaczevii*P.Rajaniemi, J.Komárek, R.Willame, P.Hrouzek, K.Kastovská, L.Hoffmann & K.Sivonen, 2005
	Cylindrospermum sp.
	Cylindrospermopsis sp. Elenkin, 1938
	Gloeotrichia echinulata J.Agardh ex Bornet & Flahault, 1886
Nodulariaceae	*Anabaenopsis arnoldii* V.V.Miller, 1923
	*Anabaenopsis circularis*Wołoszyńska & V.V.Miller, 1923
	Anabaenopsis cunningtonii V.V.Miller, 1923
	Anabaenopsis elenkinii V.V.Miller, 1923
	Anabaenopsis nadsonii V.V.Miller, 1923

		Anabeanopsis raciborskii V.V.Miller, 1923
		Anabeanopsis sp. Elenkin, 1916
		Anabaenopsis tanganyikae V.V.Miller, 1923
		Nodularia harveyana Mertens ex Bornet & Flahault, 1886
		Nodularia sp. Elenkin, 1916
		Nodularia spumigena Mertens ex Bornet & Flahault, 1886
	Nostocaceae	*Nostoc linckia* Bornet & Flahault, 1886
		Nostoc sp. Eichler, 1886
	Rivulariaceae	*Calothrix scopulorum* C.Agardh ex Bornet & Flahault, 1886
		Rivularia atra C.Agardh ex Bornet & Flahault, 1886
		Rivularia planctonica C.Agardh ex Bornet & Flahault, 1886
	Scytonemataceae	*Scytonema crispum* C.Agardh ex Bornet & Flahault, 1886
		Scytonema hofmanii C.Agardh ex Bornet & Flahault, 1886
	Tolypothrichaceae	*Tolypothrix distorta* Kützing ex Bornet & Flahault, 1886
Chroococcales	Chroococcaceae	*Chroococcus limneticus* Nägeli, 1849
		Chroococcus minimus Nägeli, 1849
		Chroococcus minutus Nägeli, 1849
		Chroococcus pallidus Nägeli, 1849
		Chroococcus sp. Rabenhorst, 1863
		Chroococcus turgidae Nägeli, 1849
		Dactylococcopsis acicularis Lemmermann, 1900
		Dactylococcopsis echini Rosenvinge, 1934
		Dactylococcopsis fascicularis Lemmermann, 1898
		Dactylococcopsis raphidioides Hansgirg, 1888
		Dactylococcopsis sp. Rabenhorst, 1863
	Cyanothrichaceae	*Johannesbaptistia pellucida* G.De Toni, 1934
	Geminocystaceae	*Microcrocis irregularis* Richter, 1892
		Snowella lacustris Elenkin, 1938
		Snowella rosea Elenkin, 1938
	Gomphosphaeriaceae	*Gomphosphaeria aponina* Kützing, 1836
		Gomphosphaeria lacustres Kützing, 1836
		Gomphosphaeria sp. Elenkin, 1933

		Gomphosphaeria virieuxii Kützing, 1836
	Microcystaceae	*Aphanocapsa crassa* C.Nägeli, 1849
		Aphanocapsa delicatissima C.Nägeli, 1849
		Aphanocapsa grevillei C.Nägeli, 1849
		Aphanocapsa holsatica C.Nägeli, 1849
		Aphanocapsa incerta C.Nägeli, 1849
		Aphanocapsa parasitica C.Nägeli, 1849
		Aphanothece clathrata C.Nägeli, 1849
		Aphanothece elabens C.Nägeli, 1849
		Aphanothece microscopica C.Nägeli, 1849
		Aphanothece sp. Elenkin, 1933
		Aphanothece stagnina C.Nägeli, 1849
		Gloeothece palea Nägeli, 1849
		Microcystis aeruginosa Lemmermann, 1907
		Microcystis flos-aquae Lemmermann, 1907
		Microcystis ichthyoblabe Lemmermann, 1907
		Microcystis novacekii Lemmermann, 1907
		Microcystis pulverea Lemmermann, 1907
		Microcystis sp. Elenkin, 1933
		Microcystis wesenbergii Lemmermann, 1907
		Synechocystis salina Sauvageau, 1892
Chroococcidiopsidales	Aliterellaceae	*Gloeocapsa alpina* Kützing, 1843
		Gloeocapsa cohaerens Kützing, 1843
		Gloeocapsa compacta Kützing, 1843
		Gloeocapsa limnetica Kützing, 1843
		Gloeocapsa minor Kützing, 1843
		Gloeocapsa punctata Kützing, 1843
		Gloeocapsa sp. J.Rigonato & al., 2016
		Gloeocapsa turqida Nägeli, 1849
		Gloeocapsopsis crepidinum Geitler ex Komárek, 1993
		Gloeocapsopsis magma Geitler ex Komárek, 1993
Oscillatoriales	Microcoleaceae	*Arthrospira platensis* Sitzenberger ex Gomont, 1892
		Coelomoron pusillum Buell, 1938
		Coelosphaerium kuetzingianum Nägeli, 1849

	Lyngbya aestuarii C.Agardh ex Gomont, 1892
	Lyngbya birgei C.Agardh ex Gomont, 1892
	*Lyngbya circumcreta*C.Agardh ex Gomont, 1892
	Lyngbya confervoides C.Agardh ex Gomont, 1892
	Lyngbya limnetica C.Agardh ex Gomont, 1892
	Lyngbya majuscula C.Agardh ex Gomont, 1892
	Lyngbya martensiana C.Agardh ex Gomont, 1892
	Lyngbya semiplena C.Agardh ex Gomont, 1892
	Lyngbya sp. O.Strunecky, J.R.Johansen & J.Komárek, 2013
	Lyngbya spiralis C.Agardh ex Gomont, 1892
	Microcoleus chthonoplastes Desmazières ex Gomont, 1892
	Microcoleus subtorulosus Desmazières ex Gomont, 1892
	Microcystis aeruginosa Lemmermann, 1907
	Microcystis pulverea Lemmermann, 1907
	Merismopedia convoluta Meyen, 1839
	Merismopedia elegans A.Braun ex Kützing, 1849
	Merismopedia glauca Meyen, 1839
	Merismopedia insignis Meyen, 1839
	Merismopedia minima Meyen, 1839
	Merismopedia punctata Meyen, 1839
	Merismopedia sp. Elenkin, 1933
	Merismopedia tenuissima Meyen, 1839
	Merismopedia warmingiana Meyen, 1839
	Planktothrix agardhii Anagnostidis & Komárek, 1988
	Porphyrosiphon luteus Kützing ex Gomont, 1892
	Trichodesmium lacustre Ehrenberg ex Gomont, 1892
Oscillatoriaceae	*Oscillatoria agardhii* Vaucher ex Gomont, 1892
	Oscillatoria anguina Vaucher ex Gomont, 1892

Oscillatoria chalybea Vaucher ex Gomont, 1892
Oscillatoria caerulescens Vaucher ex Gomont, 1892
Oscillatoria corallinae Vaucher ex Gomont, 1892
Oscillatoria curviceps Vaucher ex Gomont, 1892
Oscillatoria geminata Vaucher ex Gomont, 1892
Oscillatoria limosa Vaucher ex Gomont, 1892
Oscillatoria lloydiana Vaucher ex Gomont, 1892
Oscillatoria margaritifera Vaucher ex Gomont, 1892
Oscillatoria princeps Vaucher ex Gomont, 1892
Oscillatoria putrida Vaucher ex Gomont, 1892
Oscillatoria rupicola Vaucher ex Gomont, 1892
Oscillatoria sancta Vaucher ex Gomont, 1892
Oscillatoria setigera Vaucher ex Gomont, 1892
Oscillatoria simplicissima Vaucher ex Gomont, 1892
Oscillatoria sp. Engler, 1898
Oscillatoria tangayikae Vaucher ex Gomont, 1892
Oscillatoria tenuis Vaucher ex Gomont, 1892
Phormidium ambiguum Kützing ex Gomont, 1892
Phormidium amoenum Kützing ex Gomont, 1892
Phormidium beggiatoiforme Kützing ex Gomont, 1892
Phormidium boryanum Kützing ex Gomont, 1892
Phormidium breve Kützing ex Gomont, 1892
Phormidium chalybeum Kützing ex Gomont, 1892
Phormidium formosum Kützing ex Gomont, 1892
Phormidium irriguum Kützing ex Gomont, 1892

		Phormidium laetevirens Kützing ex Gomont, 1892
		Phormidium molle Kützing ex Gomont, 1892
		Phormidium okenii Kützing ex Gomont, 1892
		Phormidium papyraceum Kützing ex Gomont, 1892
		Phormidium pavlovskoense Kützing ex Gomont, 1892
		Phormidium sp. Engler, 1898
		Phormidium tenue Kützing ex Gomont, 1892
Spirulinales	Spirulinaceae	*Spirulina meneghiniana* Turpin ex Gomont, 1892
		Spirulina labyrinthiformis Turpin ex Gomont, 1892
		Spirulina laxissima Turpin ex Gomont, 1892
		Spirulina major Turpin ex Gomont, 1892
		Spirulina sp. L.Hoffmann, J.Komárek & J.Ka in J.Komárek et al., 2014
		Spirulina subsalsa Turpin ex Gomont, 1892
		Spirulina subtilissima Turpin ex Gomont, 1892
		Spirulina tenuis Turpin ex Gomont, 1892
Synechococcales	Synechococcaceae	*Rhabdogloea planctonica* Schröder, 1917
		Rhabdogloea smithii Schröder, 1917
		Synechococcus sp.
	Synechococcales *incertae sedis*	*Jaaginema geminatum* Anagnostidis & Komárek, 1988
		Jaaginema kisselevii Anagnostidis & Komárek, 1988
		Jaaginema pseudogeminatum Anagnostidis & Komárek, 1988

18 species; Xanthophyceae accounting for 17.86% with10 species; Eustigmatophyceae comprising 10.71% with6 species; Raphidophyceae making up 5.36% with3 species); and Dictyochophyceae which included 1.79% with1 species). This group encompassed 11 orders and 15 families. The predominant orders wereEctocarpales, which represented 28.57% of the total phytoplankton species with 16 species، and Chromulinales accounting for 21.43% and 12 species.

The dominant family included Dinobryaceae and Chordariaceae which made up 16.07% of the total phytoplankton species with nine species; Goniochloridaceae comprising 10.71% with six species; and Ectocarpaceae, which accounted for 10.71% with six species. The most prevalent genus were *Dinobryon,* representing 14.29% with 8 species, followed by *Goniochloris* at 10.71% with 6 species, and *Ectocarpus* at 8.93% with 5 species (Table 6).

Cryptophyta

Cryptophyta comprised 1.34% of the total phytoplankton species, comprising 13 distinct species. The identified Ochrophyta species were categorized into one class (Cryptophyceae), 2 orders and 3 families. The orders included Cryptomonadales, which accounted for 84.62% with 11 species, and Pyrenomonadales accounted for 15.38% with 2 species. The families were classified as Cryptomonadaceae with 76.92% and 10 species, Pyrenomonadaceae with 15.38%; and 2 species, and Hemiselmidaceae with 7.69% and 1 species. A total of 13 species were documented, representing three genera within the Ochrophyta group (Table 7). The dominant genus was *Cryptomonas,* which comprised76.92% of the total with 10 species (Table 7).

Haptophyta

Haptophyta as the least dominant group comprised 0.31% with three species of the total phytoplankton. Ochrophyta was classified into one class (Coccolithophyceae), 1 order (Prymnesiales), one family (Chrysochromulinaceae), one genus (Chrysochromulina), and three species (Table 8).

Discussion and conclusion

The findings of this study are consistent with and build upon previous research on phytoplankton diversity in the Caspian Sea, reinforcing the critical role of Bacillariophyceae (diatoms) and Chlorophyta in this unique ecosystem. The identification of 970 species and subspecies across seven phyla highlights the Caspian Sea's status as a biodiversity hotspot and provides a more comprehensive overview compared to earlier studies.

Numerous studies have documented the dominance of diatoms in the Caspian Sea. For instance, Ganjian et al. (2010) reported that diatoms made up 43% of the total phytoplankton taxa, a finding that aligns closely with the 36.37% representation of Bacillariophyceae observed in this study. Similarly, Nasrollahzadeh Saravi et al. (2017, 2016, 2014) identified 81 species of Bacillariophyta out of a total of 195 species, further underscoring the importance of diatoms in this ecosystem.

Bagheri et al. (2012) and Bagheri and Fallah

Table 7. Classification of the Cryptophyta and its species in the Caspian Sea

Class	Order	Family	Species
Cryptophyceae	Cryptomonadales	Cryptomonadaceae	*Cryptomonas caudata* Ehrenberg, 1831
			Cryptomonas caudata Ehrenberg, 1831
			Cryptomonas curvata Ehrenberg, 1831
			Cryptomonas erosa Ehrenberg, 1831
			Cryptomonas gracilis Ehrenberg, 1831
			Cryptomonas marssonii Ehrenberg, 1831
			Cryptomonas obovata Ehrenberg, 1831
			Cryptomonas ovata Ehrenberg, 1831
			Cryptomonas reflexa Ehrenberg, 1831
			Cryptomonas salina Ehrenberg, 1831
		Hemiselmidaceae	*Chroomonas acuta* Hansgirg, 1885
	Pyrenomonadales	Pyrenomonadaceae	*Rhodomonas lacustris*
			Rhodomonas lens Pascher & Ruttner, 1913
			Rhodomonas G. Karsten, 1898

Table 8. Classification of the Haptophyta and its species in the Caspian Sea

Class	Order	Family	Species
Coccolithophyceae	Prymnesiales	Chrysochromulinaceae	*Chromulina freiburgensis* L.Cienkowsky, 1870 *Chrysochromulina* sp. Edvardsen, Eikrem & Medlin, 2011 *Chrysochromulina vagans*

abundant group, with 25 and 70 species identified, respectively. These studies, along with those by Afraei Bandpey et al. (2015) and Mahmoudi et al. (2016), which also noted the dominance of diatoms, contribute to a growing body of evidence that these organisms are crucial to the Caspian Sea's primary production and ecological stability.

The significant presence of Chlorophyta, comprising 30.29% of the species in this study, is also in line with earlier research. For example, Ganjian et al. (2010) identified Chlorophytes as the second most abundant group, and similar findings were reported by Nasrollahzadeh Saravi et al. (2017, 2016, 2014) and Heydari et al. (2018). The consistent identification of Chlorophyta as a major component of the phytoplankton community across multiple studies underscores its ecological significance in the Caspian Sea.

Cyanobacteria, accounting for 19.92% of the species in this study, have also been consistently reported as a key group in the Caspian Sea's phytoplankton community. Studies by Gasanova et al. (2015) and Pourgholam et al. (2013) noted the prevalence of Cyanobacteria alongside diatoms, further supporting their role in the region's nutrient cycling and primary production.

The shifts in phytoplankton community structure over time, particularly the increase of ctenophore, *Mnemiopsis leidyi*, as reported by Ganjian et al. (2010), highlight the dynamic nature of the Caspian Sea ecosystem. The observation that dinoflagellates temporarily became more prevalent than diatoms emphasizes the importance of ongoing monitoring to track changes in species composition and to understand the potential impacts of environmental stressors, such as invasive species and climate change. While a comparative analysis with previous studies to identify significant changes or trends in phytoplankton diversity would be valuable, this approach is constrained by inconsistencies in species reporting across different studies. The comprehensive checklist compiled here includes all species mentioned in prior research, making it difficult to discern consistent patterns or temporal shifts.

This study enhances the existing body of knowledge by providing a more detailed and updated inventory of phytoplankton species, offering crucial insights into the biodiversity and ecological functioning of the Caspian Sea. The consistency of findings across multiple studies highlights the need for continued research and conservation efforts to preserve the ecological health of this unique inland sea. Future research should focus on understanding the functional roles of these diverse phytoplankton species within the Caspian Sea's ecosystem, particularly in relation to nutrient cycling, food web dynamics, and the response to environmental stressors. Additionally, long-term monitoring programs are essential to detect shifts in species composition and abundance, which could indicate broader ecological changes within the Caspian Sea. This study sets a strong foundation for such efforts, emphasizing the importance of phytoplankton diversity as a key indicator of the health and sustainability of aquatic ecosystems.

In this study, we have compiled a comprehensive checklist of phytoplankton species in the Caspian Sea, documenting a total of 970 species and subspecies across 242 genera and seven phyla. Bacillariophyta emerged as the most dominant group, followed by Chlorophyta, reflecting similar patterns observed in previous studies. Our findings highlight the significant diversity and complexity of the phytoplankton community in this unique marine environment. This updated checklist provides an essential baseline for future ecological and environmental monitoring, contributing to our understanding of the Caspian Sea's biodiversity. It highlights the importance of ongoing research and conservation efforts to protect and sustain the health of this vital ecosystem. In addition, this checklist serves as a valuable resource for researchers and policymakers in making informed decisions about conservation strategies, environmental management and sustainable use of marine resources in the Caspian Sea. Future research should focus on assessing the impacts of climate change and human activities on phytoplankton diversity in the Caspian Sea. Emphasis should be placed on changes in species composition, the likelihood of invasive species emergence, and the enduring ecological ramification for marine ecosystems.

Acknowledgments:

We gratefully acknowledge financial support from the Department of Environment of the Islamic Republic of Iran (grant number 1402/S/261) for this research.

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