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SPECIES COMPOSITION, ABUNDANCE, AND BIOMASS OF PHYTOPLANKTON IN THE KERCH STRAIT IN 2009–2019

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The results of studies of planktonic algae developing in the Kerch Strait in various seasons of 2009–2019 are presented. Phytoplankton included 114 species and several taxa identified down to the genus level covering 11 classes of algae, *inter alia* 64 Dinophyceae species and 32 Bacillariophyceae species. Mean values of abundance and biomass were 140 thousand cells·L^{-1} and 0.386 g·m^{-3}, respectively. Cyanophyceae prevailed accounting for 44% of the total phytoplankton abundance. Bacillariophyceae and Dinophyceae formed a significant part of the total phytoplankton abundance (19 and 18%) and biomass (62 and 35%). Cryptophyceae, Coccolithophyceae, and Chlorophyceae amounted to 18% of the total phytoplankton abundance. In spring, small-cell diatoms *Skeletonema costatum* and *Cyclotella caspia* dominated. In summer, large- and small-cell species of Bacillariophyceae and Dinophyceae prevailed, along with a Coccolithophyceae representative *Emiliania huxleyi*. In autumn, species of Cyanophyceae (*Planktolyngbya limnetica*), Cryptophyceae (*Plagioselmis*), and Chlorophyceae (*Binuclearia* and *Nannochloris*) were the most abundant ones. Bacillariophyceae (*Pseudosolenia calcar-avis*) and Dinophyceae (*Prorocentrum*, *Protoperidinium*, and *Ceratium* species) formed the major part of the phytoplankton biomass.

Keywords: phytoplankton, species composition, abundance, biomass, Kerch Strait

The Kerch Strait connects the Sea of Azov and the Black Sea. Its inhabitants are exposed to effect of both natural and anthropogenic factors: heavy shipping traffic, construction of hydraulic structures, operation of port and roadstead transshipment complexes, exploitation of coastal oil terminals in Taman and the port of Kavkaz, and transshipment of oil and bulk cargo. Also, the problem of the input of biogenic elements with domestic wastewater is becoming more and more urgent [Zhugailo et al., 2011]. Against the backdrop of climate change, increase in the shipping intensity, development of tourism, and industrialization of water recreation, constant monitoring of the environment in the Sea of Azov–Black Sea Basin is required [Matishov, Ivanov, 2012; Matishov et al., 2013]. In this regard, the study of current state of a plankton phytocenosis of the Kerch Strait is of significant interest, for it is one of the most sensitive components of marine ecosystems. Despite the fact that plankton communities of the Kerch Strait are being investigated, data on the seasonal dynamics of phytoplankton composition, abundance, and biomass in this area are insufficient. The aim of our research is to analyze spatial and temporal variability of phytoplankton species richness and abundance under the effect of environmental factors for 2009–2019.

MATERIAL AND METHODS

The provided results were obtained during expeditions covering the Kerch Strait water area (Fig. 1) on the RV "Deneb" of SSC RAS in April 2009, July 2010, June and September 2011, July 2012, and May and July 2013, as well as on the RV "Peleng" of the Sevastopol Branch of the N. N. Zubov's State Oceanographic Institute in August 2016 and 2019, under the projects EMBLAS-II (Improving Environmental Monitoring in the Black Sea – Phase II, ENPI/2013/313-169) and EMBLAS-Plus (Selected Measures, ENI/2017/389-859).

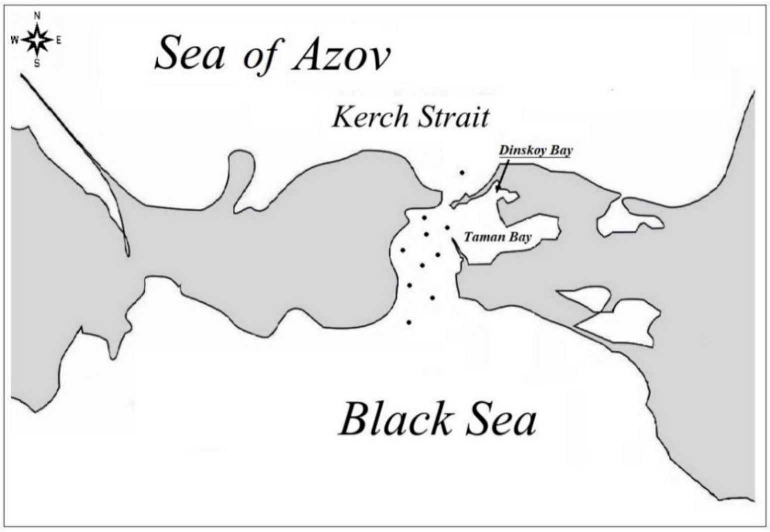

Fig. 1. A scheme of phytoplankton sampling sites in the Kerch Strait waters in 2009–2019

A total of 51 samples were taken and processed. In September 2011, May and July 2013, and August 2016, sampling was carried out in the upper layer of the sea, 0–1 m. In April 2009, June 2011, and July 2010, the vertical structure of phytoplankton was analyzed at two horizons, on the surface and at the bottom. In July 2012 and August 2019, it was studied at horizons of 0–1 m, 5 m, and 10 m, as well as at the bottom. Water was sampled during the daytime from aboard the RV with bathometers, thickened by sedimentation, and fixed with 5% Lugol's solution, neutral formalin, or Watermael acidic solution to a final concentration of 1–2% [Makarevich, Druzhkov, 1989]. Phytoplankton was recorded quantitively under a Mikmed-2 microscope with a magnification of ×100, ×200, and ×400 in a 0.05-mL Nageotte counting chamber. The minimum size of cells to be counted was 3–5 μm. For trichome cyanoprokaryotes, a colony 50–100 μm long was taken as one conventional unit for counting. Species were identified according to guidelines [Dedusenko-Shchegoleva et al., 1959; Dodge, 1982; Gollerbakh et al., 1953; Identifying Marine Phytoplankton, 1997; Kiselev, 1950; Kosinskaya, 1948; Proshkina-Lavrenko, 1955, 1963]. Phytoplankton biomass was determined based on size and shape of cells in accordance with their similarity to the closest stereometric figures, and specific weight of algae was considered equal to one [Bryantseva et al., 2005]. In our work, algal classification ranking follows AlgaeBase [2023]. The Sørensen–Czekanowski coefficient [Clarke et al., 2014] was applied to assess the similarity of taxonomic composition for microalgal communities in the Kerch Strait in different study periods.

RESULTS

1. Taxonomic composition of phytoplankton. In the Kerch Strait, we registered 114 species and several algae not identified down to the species level (Table 1). Those represent 11 classes. Dinophyceae (64 species) and Bacillariophyceae (32 species) were distinguished by high species diversity.

In June 2011 and August 2019, species composition of phytoplankton (Table 1) was the richest (58 and 53 species, respectively). In July 2013, the lowest diversity was observed (16 species). At other times, the total number of algal species varied within 34–45. In June 2011 and August 2019, the maximum diversity of dinoflagellates was noted (37 and 41 species, respectively); in other study periods, the number of species was 6 to 27. Diatoms were most widely represented in April 2009 (19 species); values in other periods were 7 to 14. The number of species from other classes varied depending on season and year in a range from 3 (July 2012 and July 2013) to 10 (April 2009 and July 2010).

Table 1. Species composition of phytoplankton in the Kerch Strait in 2009–2019

Year, month Algal class and species	2009	2010	2011		2012	2013		2016	2019
	IV	VII	VI	IX	VII	V	VII	VIII	VIII
BACILLARIOPHYCEAE									
Chaetoceros affinis Lauder	−	+	++	−	+	−	++	−	+
Chaetoceros curvisetus Cleve	++	−	+	−	−	−	−	−	−
Chaetoceros peruvianus Brightwell	−	−	−	−	−	−	−	+	−
Chaetoceros scabrosus Proshkina-Lavrenko	−	−	−	−	−	−	−	+	−
Chaetoceros simplex Ostenfeld	+	−	−	−	−	−	−	+	−
Chaetoceros subtilis Cleve	+	−	−	−	−	−	−	−	−
Chaetoceros spp.	+	+	−	−	−	−	−	−	−
Cerataulina pelagica (Cleve) Hendey	+	++	+	−	−	−	−	+	−
Climaconeis inflexa (Brébisson ex Kützing) E. J. Cox [= *Amphora inflexa* (Brébisson ex Kützing) Cleve]	+	−	+	−	−	−	−	−	+
Cocconeis scutellum Ehrenberg	+	−	−	−	−	−	−	+	−
Coscinodiscus granii L. F. Gough	++	+	+	++	−	++	−	+	−
Coscinodiscus janischii A. W. F. Schmidt	−	−	+	+	−	++	++	−	−
Coscinodiscus subtilis Ehrenberg	−	−	−	+	−	−	−	−	−
Coscinodiscus sp.	++	+	+	+	−	+	−	+	−
Cyclotella caspia Grunow	+++	+++	−	++	−	−	−	−	−
Cyclotella sp.	−	−	−	+	−	+	−	+	−
Cylindrotheca closterium (Ehrenberg) Reimann & J. C. Lewin	−	−	−	−	−	−	−	+	−
Dactyliosolen fragilissimus (Bergon) Hasle	+	−	+	−	−	−	−	−	++
Ditylum brightwellii (T. West) Grunow	−	+++	−	++	−	−	−	−	−
Gyrosigma sp.	++	−	−	+	−	−	−	+	−
Halamphora hyaline (Kützing) Rimet & R. Jahn (= *Amphora hyaline* Kützing)	+	−	−	−	−	−	−	−	+
Hemiaulus hauckii Grunow ex Van Heurck	−	−	−	+	−	−	−	−	−

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Year, month	2009	2010	2011		2012	2013		2016	2019
Algal class and species	IV	VII	VI	IX	VII	V	VII	VIII	VIII
Leptocylindrus danicus Cleve	–	–	–	–	–	–	–	++	–
Licmophora ehrenbergii (Kützing) Grunow	+	–	–	–	–	–	++	–	–
Licmophora flabellata (Greville) C. Agardh	+	–	–	–	–	+	–	–	–
Melosira moniliformis (Link) C. Agardh	–	–	–	–	–	+	–	–	–
Nitzschia tenuirostris Manguin	++	+++	+	+	+	–	–	++	–
Pleurosigma elongatum W. Smith	+	+	+	–	+	–	+	+	–
Pleurosigma sp.	+	+	–	–	–	–	–	–	+
Proboscia alata (Brightwell) Sundström	–	–	–	–	+	–	–	–	++
Pseudosolenia calcar-avis (Schultze) B. G. Sundström	–	+++	++	++	+++	+++	+++	+++	+++
Pseudo-nitzschia pseudodelicatissima (Hasle) Hasle (complex)	+	++	+	++	++	–	+	+	+++
Pseudo-nitzschia sp.	+	–	+	–	–	–	–	+	–
Skeletonema costatum (Greville) Cleve	+++	++	++	–	–	–	–	+	–
Striatella delicatula (Kützing) Grunow ex Van Heurck	+	–	–	–	–	–	–	–	–
Striatella unipunctata (Lyngbye) C. Agardh	+	–	–	–	–	–	–	–	–
Surirella gemma (Ehrenberg) Kützing	–	–	–	–	–	+	–	–	–
Thalassionema nitzschioides (Grunow) Mereschkowsky	+	+++	+++	++	++	+	+	+	++
Thalassiosira sp.	+	+	–	++	–	–	–	+	–
DINOPHYCEAE									
Akashiwo sanguinea (K. Hirasaka) G. Hansenet Moestrup (= *Gymnodinium sanguineum* K. Hirasaka)	++	–	+	+	+	–	–	+	+
Alexandrium tamarense (Lebour) Balech	–	–	–	–	–	–	–	–	+
Amphidinium sp.	–	–	–	–	–	–	–	+	–
Amphidinium crassum Lohmann	–	+	–	–	–	–	–	–	–
Amphidinium longum Lohmann	–	–	+	–	–	++	–	–	–
Amphidinium flagellans J. Schiller	–	–	–	–	–	–	–	–	+
Amphidinium fusiforme G. W. Martin	–	+	–	–	–	–	–	–	–
Blixaea quinquecornis (T. H. Abé) Gottschling (= *Peridinium quinquecorne* Abé)	–	–	–	–	–	–	–	+	–
Dinophysis acuminata Claparède & Lachmann	+	–	+	–	–	+	–	–	–
Dinophysis acuta Ehrenberg	–	–	+	+	–	–	–	–	+
Dinophysis caudata Kent	–	+	++	–	+	–	–	+	+
Dinophysis fortii Pavillard	–	+	+	–	–	–	–	–	–
Dinophysis sacculus F. Stein	+	–	+	–	+	+	–	–	–
Dinophysis sp.	–	–	+	–	–	–	–	–	–
Diplopsalis lenticula Bergh	+	+	–	+	++	+	–	+	+
Diplopsalis sp.	–	–	–	+	–	–	–	–	–

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Year, month	2009	2010	2011		2012	2013		2016	2019
Algal class and species	IV	VII	VI	IX	VII	V	VII	VIII	VIII
Glenodinium pilula (Ostenfeld) J. Schiller	−	−	+	+	−	+	−	−	+
Glenodinium sp.	+	+	+	−	−	+	−	−	−
Gymnodinium agiliforme J. Schiller	−	−	−	−	−	+	−	−	+
Gymnodinium blax T. M. Harris	−	−	+	−	++	−	++	−	++
Gymnodinium elongatum B. Hope	−	−	−	−	−	++	−	−	−
Gymnodinium simplex (Lohmann) Kofoid & Swezy	+	−	+++	−	++	−	−	+	++
Gymnodinium wulffii J. Schiller	+	+	++	−	+	+	+	+	+
Gymnodinium spp.	++	+++	+++	+	++	+++	++	++	+
Gyrodinium lacryma (Meunier) Kofoid & Swezy	−	−	−	−	−	−	−	−	+
Gyrodinium fusiforme Kofoid & Swezy	+	++	+++	++	++	++	−	+	+
Gyrodinium spirale (Bergh) Kofoid & Swezy	−	−	+	+	+	−	−	−	++
Gyrodinium sp.	+	+	+	++	++	++	++	+	++
Gonyaulax digitale (Pouchet) Kofoid	−	+	−	+	+	−	−	−	−
Gonyaulax spinifera (Claparède & Lachmann) Diesing	−	+	−	+	+	−	−	−	−
Gonyaulax polygramma F. Stein	−	−	−	−	−	−	−	−	+
Gonyaulax sp.	−	−	−	−	−	−	−	+	+
Katodinium glaucum (Lebour) A. R. Loeblich III	−	+	++	+	+	−	−	+	++
Lingulodinium polyedra (F. Stein) J. D. Dodge	−	−	+	−	−	−	−	−	−
Margalefidinium citron (Kofoid & Swezy) F. Gómez, Richlen & D. M. Anderson (= *Cochlodinium citron* Kofoid & Swezy)	−	−	+	−	−	−	−	−	+
Mesoporos perforatus (Gran) Lillick	−	−	−	−	−	−	−	−	+
Heterocapsa rotundata (Lohmann) G. Hansen [= *Katodinium rotundatum* (Lohmann) Loeblich III]	−	−	+	−	−	−	−	−	−
Heterocapsa triquetra (Ehrenberg) F. Stein	−	−	+	+	+	−	−	−	−
Heterocapsa sp.	−	−	−	−	−	−	−	+	+
Ensiculifera carinata Matsuoka, Kobayashi & Gains	−	−	+	++	+	−	−	+	−
Oblea baculifera Balech	+	−	−	−	−	−	−	−	−
Oblea rotunda (Lebour) Balech	+	+	−	+	+	−	−	+	++
Oxyrrhis marina Dujardin	−	+++	+	+	−	−	++	−	−
Oxytoxum caudatum J. Schiller	−	+	−	−	−	−	−	−	−
Phalacroma rotundatum (Claparéde & Lachmann) Kofoid & J. R. Michener [= *Dinophysis rotundata* (Claparède & Lachmann) Balech]	−	−	+	+	+	+	−	+	+
Polykrikos kofoidii Chatton	−	+	+	+++	+++	+	−	++	+
Polykrikos schwartzii Bütschli	−	+	+	−	−	−	−	−	−

Continued on the next page…

Year, month Algal class and species	2009	2010	2011		2012	2013		2016	2019
	IV	VII	VI	IX	VII	V	VII	VIII	VIII
Pronoctiluca pelagica Fabre-Domergue	–	–	+	–	–	–	–	–	++
Prorocentrum compressum (Bailey) T. H. Abé ex J. D. Dodge	+	+	++	+	+	+	–	+	+
Prorocentrum cordatum (Ostenfeld) J. D. Dodge [= *P. minimum* (Pavillard) J. Schiller]	+	++	++	+	++	++	+	+	++
Prorocentrum micans Ehrenberg	+	++	++	+++	++	+++	++	+++	++
Prorocentrum sp.	–	–	–	–	–	–	–	+	–
Protoceratium reticulatum (Claparède & Lachmann) Bütschli	–	+	–	–	++	–	–	–	++
Protoperidinium bipes (Paulsen) Balech	+	–	+	–	–	–	–	–	+
Protoperidinium brevipes (Paulsen) Balech	–	–	+	–	–	–	–	+	+
Protoperidinium conicum (Gran) Balech	–	–	–	–	–	+	–	–	+
Protoperidinium crassipes (Kofoid) Balech	–	–	–	–	–	–	–	–	+
Protoperidinium depressum (Bailey) Balech	–	–	–	–	–	+	–	+	++
Protoperidinium divergens (Ehrenberg) Balech	–	+	–	++	++	++	–	–	++
Protoperidinium excentricum (Paulsen) Balech	–	–	–	–	–	–	–	+	–
Protoperidinium globulus (F. Stein) Balech	–	+	–	–	–	–	–	–	–
Protoperidinium granii (Ostenfeld) Balech	+	–	+	–	–	–	–	–	+
Protoperidinium knipowitschii (Usachev) Balech	–	–	–	+	–	–	–	–	–
Protoperidinium pallidum (Ostenfeld) Balech	–	–	+	–	–	–	–	–	+
Protoperidinium pellucidum Bergh	–	–	+	–	–	–	–	–	–
Protoperidinium steinii (Jørgensen) Balech	+	–	–	+	+	+	–	–	+
Protoperidinium spp.	++	+	–	++	+	–	–	+	–
Scrippsiella acuminata (Ehrenberg) Kretschmann, Elbrächter, Zinssmeister, S. Soehner, Kirsch, Kusber & Gottschling [= *Scrippsiella trochoidea* (F. Stein) A. R. Loeblich III]	++	+	–	+	+	+	+	–	++
Speroidium fungiforme (Anisimova) Moestrup & Calado [= *Katodinium fungiforme* (Anisimova) A. R. Loeblich III]	–	–	+	–	–	–	–	–	–
Torodinium robustum Kofoid & Swezy	–	+	+	–	+	–	–	–	++
Tripos furca (Ehrenberg) F. Gómez [= *Ceratium furca* (Ehrenberg) Claparède & Lachmann]	–	–	+	++	++	++	–	+	++
Tripos fusus (Ehrenberg) F. Gómez [= *Ceratium fusus* (Ehrenberg) Dujardin]	–	–	+	+	+	+	–	–	++
Tripos muelleri Bory [= *Ceratium tripos* (O. F. Müller) Nitzsch]	–	–	++	–	–	++	–	–	++
Warnowia aff. *maculate* (Kofoid & Swezy) Lindemann	–	–	–	–	–	–	–	–	+

Continued on the next page…

Year, month	2009	2010	2011		2012	2013		2016	2019
Algal class and species	IV	VII	VI	IX	VII	V	VII	VIII	VIII
COCCOLITHOPHYCEAE									
Emiliania huxleyi (Lohmann) W. W. Hay & H. P. Mohler	+	+	+++	–	+++	+++	–	–	++
CRYPTOPHYCEAE									
Plagioselmis spp.	+	+++	++	++	++	++	+++	++	++
EUGLENOPHYCEAE									
Eutreptia lanowii Steuer	+	+	+	–	+	–	++	+	–
Euglena viridis (O. F. Müller) Ehrenberg	–	–	–	–	–	–	–	–	+
Euglena sp.	–	+	+	++	–	–	–	+	–
ULVOPHYCEAE									
Binuclearia lauterbornii (Schmidle) Proshkina-Lavrenko	+	+++	+	++	–	+	–	+	–
CHLOROPHYCEAE									
Ankistrodesmus convolutus Corda	+	–	+	+	–	–	–	–	–
Golenkinia radiata Chodat	+	–	–	–	–	–	–	–	–
Monoraphidium contortum (Thuret) Komàrková-Legnerová	+	++	+	–	–	++	–	+	–
Scenedesmus bicaudatus Dedusenko	–	+	–	–	–	–	–	–	–
Scenedesmus falcatus Chodat	+	–	–	–	–	–	–	–	–
Scenedesmus obliquus (Turpin) Kützing	–	+	–	–	–	–	–	–	–
Scenedesmus quadricauda Chodat	+	+	+	+	–	–	–	–	–
Tetraselmis sp.	–	–	–	+	–	–	–	–	–
TREBOUXIOPHYCEAE									
Oocystis sp.	+	–	–	–	–	–	–	–	–
aff. *Nannochloris* sp.	–	+	+	++	–	–	–	–	–
PYRAMIMONADOPHYCEAE									
Pterosperma undulatum Ostenfeld	–	+	+	–	+	+	–	–	+
Pterosperma sp.	+	+	–	–	–	–	–	+	–
DICTYOCHOPHYCEAE									
Octactis octonaria (Ehrenberg) Hovasse	–	–	–	–	–	–	–	–	+
CYANOPHYCEAE									
Anabaena flos-aquae Brébisson ex Bornet & Flauhault f. *major* Elenkin	–	–	–	–	–	–	++	+	–
Anabaena spiroides Klebahn	–	–	–	–	–	–	–	++	–
Anabaena sp.	–	+	–	+	–	–	++	++	–
Aphanizomenon sp.	–	+	–	+	–	+	–	–	–
Merismopedia punctata Meyen	+	+	–	–	–	–	–	–	–
Microcystis aeruginosa (Kützing) Kützing	–	–	–	++	–	–	–	–	–
Oscillatoria spp.	+	++	+	–	–	–	–	+	–
Planktolyngbya limnetica (Lemmermann) Komárková-Legnerová & Cronberg	+	+	+	+++	–	+	++	+++	–
Spirulina sp.	+	–	–	–	–	–	–	–	–

Note: +, rare species; ++, common; +++, abundant; and –, absent. Abundant species formed more than 10% of total phytoplankton abundance or biomass; common ones, 1 to 10%; and rare ones, up to 1%.

The highest similarity rates for taxonomic composition of microalgal communities in the Kerch Strait [Sørensen–Czekanowski (Dice) coefficient ≥ 60%] were recorded during the warm season (Table 2), at maximum water temperatures (+21…+28 °C). In this period, high species diversity of microalgae was registered (Table 3).

Table 2. Indicators of similarity [Sørensen–Czekanowski (Dice) coefficient] of taxonomic composition for microalgal communities in the Kerch Strait during different study periods

Year, month		2009	2010	2011		2012	2013		2016
		IV	VII	VI	IX	VII	V	VII	VIII
2010	VII	52							
2011	VI	52	55						
2011	IX	45	55	54					
2012	VII	44	62	59	63				
2013	V	43	44	50	52	51			
2013	VII	33	40	35	33	42	32		
2016	VIII	52	53	54	49	55	44	36	
2019	VIII	37	42	62	46	67	51	26	41

Note: cells highlighted in pale pink depict the coefficient values within 26–37; light pink, 40–49; pink, 50–59; and dark pink, 62–67.

Table 3. The basic hydrological and phytoplankton characteristics for the Kerch Strait in 2009–2019

Month	Year	Water temperature, °C / depth, m	Wind, $m \cdot s^{-1}$ / swell, points	Phytoplankton		
				number of species	abundance, thousand $cells \cdot L^{-1}$	biomass, $mg \cdot m^{-3}$
April	2009	+9.8…+9.9 / 7–11	no data	45	130	57
May	2013	+19…+19.8 / 10–12	E-ES 5–9 / 1–2	34	58	145
June	2011	+22.6…+24 / 6–11	0 / 0	58	62	82
July	2010	+26.8…+27 / 3–15	E-ES 2–3 / 1	44	101	418
	2012	+22…+23 / 4–14	NW 5.3–5.7 / 1–2	37	72	217
	2013	+24…+24.4 / 10	S 2–3 / 0–1	16	19	242
August	2016	+26.2…+28 / 4–16	ES 2–3 / 0–1	39	719	1,922
	2019	+25.8…+26 / 24–28	S 2–2.5 / 0–1	53	22	302
September	2011	+21.3…+21.5 / 3–12	SW 6–8 / 1–2	39	77	93
				114 in total	140 on average	386 on average

In phytoplankton of the Kerch Strait, the most abundant species are those common to the Black Sea and Sea of Azov: diatoms (*Cerataulina pelagica*, *Chaetoceros affinis*, *Chaetoceros curvisetus*, *Chaetoceros subtilis*, *Coscinodiscus granii*, *Cyclotella caspia*, *Ditylum brightwellii*, *Nitzschia tenuirostris*, *Pseudo-nitzschia pseudodelicatissima*, *Pseudosolenia calcar-avis*, *Skeletonema costatum*, and *Thalassionema nitzschioides*), dinoflagellates (*Akashiwo sanguinea*, *Diplopsalis lenticula*, *Gymnodinium simplex*, *Gyrodinium fusiforme*, *Prorocentrum cordatum*, *Prorocentrum micans*, *Protoperidinium granii*, *Protoperidinium divergens*, *Protoperidinium steinii*, and *Scrippsiella acuminata*), and a coccolithophore (*Emiliania huxleyi*) [Studenikina et al., 1999]. Against the backdrop of noticeable abundance of diatoms and dinoflagellates, brackish-water species of the classes Cryptophyceae, Euglenophyceae, Chlorophyceae, and Cyanophyceae developed significantly; these species are widely distributed in the Sea of Azov plankton. Low depths and high hydrodynamic activity of the Kerch Strait contribute to phytoplankton enrichment with periphytic diatoms (*Climaconeis inflexa*, *Cocconeis scutellum*, *Halamphora hyalina*, *Licmophora ehrenbergii*, *Licmophora flabellata*, *Melosira moniliformis*, and *Pleurosigma elongatum*) and representatives of the genera *Gyrosigma* and *Striatella*.

Species richness of phytoplankton we observed in the Kerch Strait in 2009–2019 (114 species) is higher than that described earlier (42–90 species) [Bryantseva et al., 2010; Chernikova, 2004; Zaremba, 2013]. This is probably due to longer period of our research and the coverage of three seasons (spring, summer, and autumn). However, taxonomic composition of planktonic algae was significantly lower than the number of species recorded for a larger area of the Kerch Strait including Dinskoy Bay and Taman Bay in 1997–2000 (154 species) [Kovaleva, 2008].

2. Seasonal dynamics of phytoplankton abundance and biomass. In the Kerch Strait, values of phytoplankton abundance and biomass during the study period (April 2009 to August 2019) varied widely: 19 to 719 thousand cells·L^{-1} and 0.06 to 1.92 g·m^{-3}, respectively. Those averaged (140 ± 220) thousand cells·L^{-1} and (0.386 ± 0.587) g·m^{-3} (Table 3, Fig. 2).

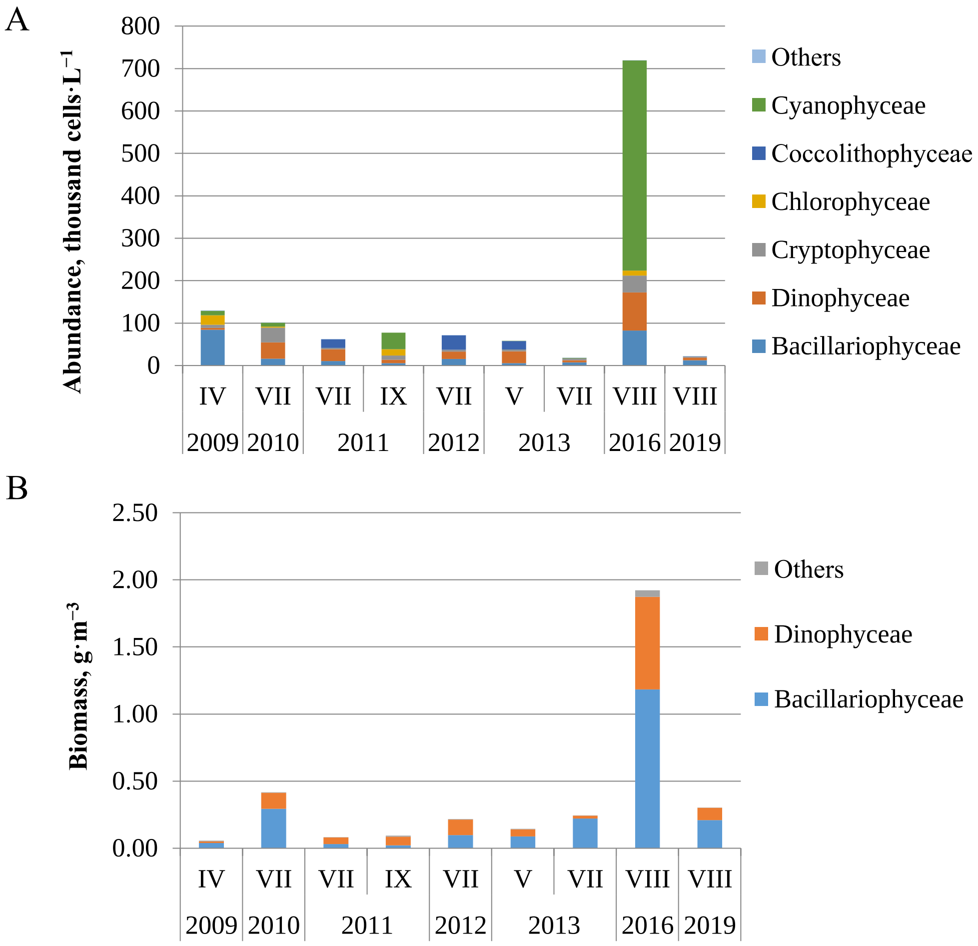

Fig. 2. Abundance (A) and biomass (B) of planktonic algae in the Kerch Strait area in 2009–2019

Cyanoprokaryotes dominated by abundance (44% on average over the study period). Diatoms and dinoflagellates constituted a noticeable part of the total abundance (19 and 18% on average, respectively) and biomass (62 and 35%). Cryptophyceae, Coccolithophyceae, and Chlorophyceae formed 18% of abundance and 3% of biomass of the plankton phytocenosis. Representatives of other classes accounted for < 1% of abundance and biomass in total. The maximum development of planktonic algae was noted in August 2016: 719 thousand cells$\cdot$L^{-1} and 1.922 g$\cdot$m^{-3}. Accordingly, mean values of phytoplankton abundance and biomass in summer (166 thousand cells$\cdot$L^{-1} and 0.531 g$\cdot$m^{-3}, respectively) were 2–5 times higher than values registered in spring and autumn (94 and 77 thousand cells$\cdot$L^{-1} and 0.101 and 0.093 g$\cdot$m^{-3}).

In spring and summer 2009–2019, vertical distribution of phytoplankton abundance and biomass was uneven and depended on the hydrodynamic activity of waters contributing to a more uniform distribution of planktonic algae in a water column. Specifically, in July 2012, because of intensive wind activity, uniform distribution of coccolithophores was noted (those made up 43–50% of the total abundance) in the water column (0–14 m). In June 2011, in calm weather, coccolithophores were concentrated (42% of the abundance) in the upper layer of the sea (0–1 m) and were absent at the bottom (6–11 m). Due to mass development of large species (up to 200 µm) of benthic–planktonic diatoms in the bottom layer of the pelagic zone, their biomass at the bottom was 1.4–2 times higher than in the upper layers of the strait (0–5 m) in April 2009, June 2011, and August 2019.

Spring. In April 2009, due to intensive development of mostly medium- and large-sized dinoflagellate *A. sanguinea* (40–200 µm) and periphytic diatoms of the genera *Gyrosigma* and *Striatella*, phytoplankton abundance in bottom layers of the strait was 1.3 times higher than on the surface, and biomass was 1.9 times higher. Diatoms averaged 65% of abundance and 69% of biomass of pelagic phytoplankton; those formed 61% of abundance and 49% of biomass on the surface of the strait and 68 and 79%, respectively, at the bottom. Out of them, *S. costatum* and *C. caspia* developed most intensively, while *N. tenuirostris* and *C. curvisetus* were subdominant species. *Coscinodiscus*, *Thalassiosira*, and *Gyrosigma* representatives formed the basis of biomass of diatoms, along with *S. costatum*, *C. caspia*, and *C. curvisetus* prevailing by abundance. A key role in formation of the total biomass of communities (21% on average) was played by dinoflagellates: 33% on the surface of the strait and 14% at the bottom. Interestingly, their share in the total abundance did not exceed 2%. Out of them, the main ones were *Oblea baculifera*, *S. acuminata*, *A. sanguinea*, and *P. micans*, as well as *Gymnodinium* and *Protoperidinium* representatives. Also, high values of abundance were registered for several species of green algae (*Binuclearia lauterbornii* and *Monoraphidium contortum*), cyanoprokaryotes (*Oscillatoria* and *Planktolyngbya* representatives), and cryptophytes (*Plagioselmis* spp.). Representatives of these classes formed 17, 8, and 6% of phytoplankton abundance, respectively, and about 9% of its biomass in total. Small flagellate algae with a mean abundance of 2 thousand cells$\cdot$L^{-1} were occasionally encountered in the studied water area.

In May 2013, diatoms accounted for 9% of phytoplankton abundance and 60% of its biomass. Out of them, a large-cell species *P. calcar-avis* developed most intensively (89% of abundance and 88% of biomass of diatoms). *T. nitzschioides* and *Coscinodiscus* representatives were registered as subdominants. The main species of coccolithophores, *E. huxleyi*, accounted for 35% of the total abundance and, due to small size of its cells, only 2% of biomass. Dinoflagellates formed the basis of phytoplankton abundance (48%) and a noticeable part of its biomass (37%). Out of them, the most abundant species were *Gymnodinium* and *Prorocentrum* representatives. The core of biomass of dinoflagellates included *P. micans* and large species of the genera *Protoperidinium* and *Tripos*. Representatives of other classes of algae accounted for no more than 6% of abundance and 1% of biomass.

Summer. In June 2011, on the surface, *E. huxleyi* contribution was noticeable: this coccolithophore formed 42% of phytoplankton abundance. At the bottom, it did not develop which seems to result from darkening of the photic layer because of churning. In the upper layer, abundance of algae (98 thousand cells·L^{-1}) was almost 4 times higher, while their biomass (0.067 g·m^{-3}) was 1.4 times lower than at the bottom (26 thousand cells·L^{-1} and 0.096 g·m^{-3}, respectively). Dinoflagellates prevailed accounting for 44 and 54% of abundance and 67 and 56% of biomass on the surface and at the bottom, respectively. Out of them, the main species in terms of abundance were *Gymnodinium* representatives and *G. fusiforme*. *P. minimum* and *Gyrodinium spirale* were found in smaller abundance. Biomass of dinoflagellates chiefly included *Tripos furca*, *Tripos muelleri*, and *Gyrodinium* representatives. Diatoms formed 17% of phytoplankton abundance on average (46% at the bottom and 8% on the surface) and 37% of its biomass (27 and 44%, respectively). *T. nitzschioides* was the most abundant species; *P. pseudodelicatissima*, *C. affinis*, and *C. granii* were less abundant ones. Biomass was mainly formed by large cells of *P. calcar-avis*, *C. granii*, and an abundant species *T. nitzschioides*. Cryptophytes and green algae accounted for about 5% of the total phytoplankton abundance.

In July 2010, a decrease in abundance was recorded with a change in depth: from 116 thousand cells·L^{-1} on the surface to 86 thousand cells·L^{-1} at the bottom. Biomass was almost equal at all horizons: 0.41–0.43 g·m^{-3}. On the surface, dinoflagellates formed 40% of phytoplankton abundance and 31% of its biomass; at the bottom, 36 and 27%, respectively. Out of them, *Oxyrrhis marina*, *P. micans*, and representatives of *Amphidinium* and *Gymnodinium* were highly abundant on the surface, while *P. cordatum*, *G. fusiforme*, and *Katodinium glaucum* were abundant at the bottom. The biomass was mainly formed by large *Dinophysis fortii*, *P. divergens*, *D. lenticula*, and *Polykrikos kofoidii*, as well as by abundant *P. micans*, *O. marina*, and *K. glaucum*. Diatoms constituted 15–16% of abundance and 67–71% of biomass on the surface and at the bottom; *C. caspia*, *D. brightwellii*, *N. tenuirostris*, *T. nitzschioides*, and *P. calcar-avis* prevailed in abundance. The basis of biomass was formed by *C. granii*, *P. calcar-avis*, *D. brightwellii*, and *Coscinodiscus* sp. At the bottom, the role of *P. calcar-avis* rose (26% of the total biomass), and on the surface, the role of *D. brightwellii* increased (46% of biomass). High abundance of cryptophytes *Plagioselmis* spp. and cyanoprokaryotes of the genera *Oscillatoria*, *Planktolyngbya*, and *Aphanizomenon* was revealed: 30–38 and 9–10% of the total abundance, respectively. A brackish-water species *B. lauterbornii* and a marine one *Pterosperma undulatum* developed predominantly at the upper horizon forming 4% of the total abundance.

In July 2012, a relatively uniform vertical distribution of phytoplankton abundance and biomass was established (67–80 thousand cells·L^{-1} and 0.203–0.228 g·m^{-3}, respectively). The same as during the summer 2011, a coccolithophore *E. huxleyi* prevailed in abundance (47%). Its maximum (34–38 thousand cells·L^{-1}) was observed in the upper layer of the strait (0–5 m); the value decreased with depth (29 thousand cells·L^{-1}). Due to small size of its cells, *E. huxleyi* formed < 2% of the total biomass. Diatoms constituted 22% of abundance on average (from 15% at the bottom to 21–28% in the layer of 0–5 m) and 45% of biomass (from 33% on the surface and at the bottom to 67% at the horizon of 5 m). In terms of abundance, *P. pseudodelicatissima*, *T. nitzschioides*, and *P. calcar-avis* dominated, with the latter one forming about 42% of the total biomass. Intensive development of this thermophilic species is associated with high temperature on the surface of the strait (+23 °C).

C. affinis, *Proboscia alata*, *N. tenuirostris*, and *P. elongatum* were subdominants. Maximum values for the latter two species were recorded at the bottom. Dinoflagellates formed 24% of phytoplankton abundance and 53% of its biomass. *Gymnodinium* and *Gyrodinium* species developed in abundance; out of them, *Gymnodinium blax*, *G. simplex*, and *G. fusiforme* predominated. *P. cordatum*, *P. micans*, and *P. kofoidii* were abundant as well. Biomass of dinoflagellates was chiefly formed by large species *T. furca*, *P. kofoidii*, and *P. divergens*. Interestingly, the role of the first one increased at the bottom, while the second and third ones prevailed in the upper layer of the strait (0–5 m). *Dinophysis caudata*, *Phalacroma rotundatum*, *D. lenticula*, *P. micans*, and *Protoceratium reticulatum* contributed to formation of biomass as well. In the water layer from 5 m down to the bottom, cryptophytes predominated (5% of the total abundance); on the surface, a mesosaprobic species *Eutreptia lanowii*, a euglenid, vegetated, with abundance up to 2 thousand cells·L^{-1}. Out of green algae, a marine species *P. undulatum* was found.

In July 2013, diatoms *C. affinis* and *P. pseudodelicatissima* dominated (39% of abundance and 91% of the total biomass of phytoplankton). The species *C. affinis*, *P. pseudodelicatissima*, and *P. calcar-avis* formed 58% of the abundance and 96% of the biomass of diatoms. Against the backdrop of their intensive development, dinoflagellates formed no more than 27% of phytoplankton abundance and 8% of its biomass. Out of them, the key ones were small- and medium-sized species: *Gymnodinium nana*, *Gymnodinium* sp., *O. marina*, and *P. micans*. Biomass was chiefly formed by *O. marina*, *P. micans*, *S. acuminata*, and *Gyrodinium* sp. (96% of biomass of dinoflagellates). The share of cryptophytes and cyanoprokaryotes of the genera *Planktolyngbya* and *Anabaena* accounted for 30% of the total abundance of phytoplankton. Euglenids were characterized by low abundance (3%).

In August 2016, the highest values of abundance and biomass of planktonic algae (3,046 thousand cells·L^{-1} and 4.589 g·m^{-3}, respectively, *i. e.*, at the level characteristic of water bloom) were observed at individual stations in areas further from the coast; there, we recorded high values for a mesosaprobic dinoflagellate *P. micans* (272 thousand cells·L^{-1} and 2.960 g·m^{-3}) and for cyanoprokaryotes (2,411 thousand cells·L^{-1} and 0.197 g·m^{-3}). The lowest values (34–44 thousand cells·L^{-1} and 0.109–0.664 g·m^{-3}) were revealed at coastal stations. In general, cyanoprokaryotes, *Planktolyngbya limnetica* and *Anabaena* species, dominated in the studied area of the strait: 49 and 20% of the total abundance, respectively. Diatoms and dinoflagellates formed a significant part of the total abundance of phytoplankton (11 and 12%, respectively) and were the main component of its biomass (62 and 36%). Out of diatoms, *P. calcar-avis* developed in mass (5% of the total abundance of communities and 60% of their biomass). Also, we registered vegetation of *Leptocylindrus danicus*, *N. tenuirostris*, *T. nitzschioides*, and species of the genus *Pseudo-nitzschia* which formed 56% of the total abundance of diatoms. Out of dinoflagellates, *Gymnodinium* and *Heterocapsa* representatives prevailed in abundance, along with *P. micans* and *P. cordatum* (80% of dinoflagellates). A significant part of phytoplankton biomass was formed by *P. micans* cells (34%).

In August 2019, diatoms and dinoflagellates dominated accounting for an average of 57 and 28% of the total abundance of phytoplankton and 69 and 30% of its biomass. A coccolithophore *E. huxleyi* and cryptophytes formed no more than 13% of the total abundance. Other classes of planktonic algae provided less than 2% of abundance and 1% of biomass. The highest values (24 thousand cells·L^{-1} and 0.361 g·m^{-3}) were revealed in the water layer of 12–30 m; the indicators were 1.3–2 times lower on the surface (18 thousand cells·L^{-1} and 0.185 g·m^{-3}). At lower horizons (30 m), the maximum shares of abundance (71%) and biomass (92%) were formed by diatoms; at the horizons of 0–25 m, values decreased (52–56% of abundance and 64–78% of biomass). In the middle water layer (12–25 m), shares of dinoflagellates in abundance and biomass were of 32 and 35%, respectively. In the lower layer (30 m), these algae formed 17% of abundance and 8% of biomass; on the surface, 26 and 21%. Values for cryptophytes in the entire studied water column were of 9–12% of the total abundance. On the sea surface, coccolithophores constituted more than 8% of the total phytoplankton abundance. Out of diatoms, *P. pseudodelicatissima* and *P. calcar-avis* were the most abundant species in the studied area. Subdominants *P. alata* and *T. nitzschioides* formed 6% of abundance of communities. Out of dinoflagellates, the key species were *P. micans*, *P. cordatum*, *S. acuminata*, *Pronoctiluca pelagica*, *K. glaucum*, and *Torodinium robustum*, as well as *Tripos*, *Gymnodinium*, and *Gyrodinium* representatives. The basis of phytoplankton biomass was formed by a large-cell diatom *P. calcar-avis* and dinoflagellates: *P. kofoidii*, *P. divergens*, *P. reticulatum*, *Tripos* species, and representatives of the genera *Prorocentrum*, *Gymnodinium*, and *Gyrodinium* prevailing in terms of abundance.

Autumn. In September 2011, cyanoprokaryotes, cryptophytes, and green algae dominated by abundance (50, 13, and 19% of the total abundance, respectively). However, those accounted for < 7% of phytoplankton biomass. In the Sea of Azov, the most abundant cyanoprokaryote was *P. limnetica*; less abundant ones were *Microcystis aeruginosa*, *Merismopedia punctata*, and representatives of *Aphanizomenon* and *Anabaena*. Out of green algae, *B. lauterbornii* and *Nannochloris* species prevailed; *Scenedesmus quadricauda*, *M. contortum*, and *Ankistrodesmus convolutus* developed at the level of subdominants. Diatoms and dinoflagellates formed no more than 7 and 10% of phytoplankton abundance, respectively, and the core of its biomass: 22 and 69%. Out of dinoflagellates, the prevailing species were *P. micans*, *P. cordatum*, *G. fusiforme*, *Ensiculifera carinata*, *K. glaucum*, *A. sanguinea*, *P. kofoidii*, *S. acuminata*, and *Gymnodinium* representatives. The basis of biomass was formed by *P. micans*, *E. carinata*, rare large-cell species of the genus *Protoperidinium*, and *P. kofoidii*. Out of diatoms, the main species were *C. caspia*, *P. pseudodelicatissima*, and *T. nitzschioides*, while subdominants included *P. calcar-avis* and *Thalassiosira* sp. In terms of biomass, a diatom *P. calcar-avis* and abundant *Thalassiosira* sp. were of greatest importance (58%). About 40% of biomass was formed by *C. caspia*, *D. brightwellii*, *T. nitzschioides*, and representatives of *Gyrosigma* and *Coscinodiscus*.

DISCUSSION

The hydrological regime of the Kerch Strait is governed by its shallowness, active water exchange between the Black Sea and Sea of Azov, and meteorological conditions [Sytnik et al., 2017]. Water masses heat up and cool down quickly throughout the water column. The annual course of water temperature is characterized by significant amplitude with a pronounced minimum in February–March (down to −1 °C) and a maximum in July–August (up to +30 °C); mean long-term values are +2.0 and +24.2 °C, respectively. The mean annual water temperature in the strait is about +13 °C. In the deeper central area of the strait, the wave height can be of 2–3 m, while off the coast, especially with the wind blowing from the shore, the wave height does not exceed 1.5 m. Water salinity usually fluctuates 12.0 to 18.0‰ and depends on the prevailing type of currents. Wind conditions in the strait area are varied which is determined by the diversity of synoptic situations and the nature of the relief. The frequency of calms is 1 to 2%. The mean annual wind speed is 5.3–6.9 $m \cdot s^{-1}$, and the maximum one can be of 40 $m \cdot s^{-1}$. Water masses in the strait are easily identified by salinity and content of biogenic elements and also visually: by water color and transparency. The total frequency of currents for the year, with direction of mixed flows taken into account, averages 62% for the Sea of Azov flow and 38% for the Black Sea one. With southern winds, the Black Sea current becomes dominant.

A total of 154 algal species were registered in phytoplankton of the Kerch Strait, Dinskoy Bay, and Taman Bay (Table 4). Those are diatoms, dinoflagellates, green algae, ochrophytes, cryptophytes, cyanoprokaryotes, prasinophytes, haptophytes, and euglenophytes. Phytoplankton is represented by marine, freshwater, and brackish-water species. Such diversity was facilitated by wide ranges of water salinity and temperature. High values of phytoplankton biomass were confined to the warm season: October–December 2007, August 2008 and 2009, and July 2010. Medium ones were noted in May 2003, October 2005, June and September 2008, August 2011, and March 2020. Low values were observed at other times. In August 2009, abundant development of planktonic algae (at the level characteristic of water bloom) was recorded. At other times, abundance of phytoplankton cells was noticeably lower. The results of studies carried out in the western and central Kerch Strait in August 2009 showed as follows: within this relatively small water area, values of phytoplankton abundance and biomass can vary by several orders of magnitude [Bryantseva et al., 2010].

In the Kerch Strait area, significant seasonal and interannual fluctuations in species richness, abundance, and biomass of planktonic algae were noted. In spring, small diatoms *S. costatum* and *C. caspia* dominated which is typical for this time of year [Makarevich, 2022]. In summer, both small diatoms (*P. pseudodelicatissima*, *C. caspia*, and *T. nitzschioides*) and large ones (*P. calcar-avis* and *D. brightwellii*) prevailed, as well as relatively small dinoflagellates of the genera *Gymnodinium*, *Gyrodinium*, *Oxyrrhis*, and *Prorocentrum* and large ones representing *Dinophysis*, *Tripos*, *Polykrikos*, and *Protoperidinium*. The role of large species of diatoms and dinoflagellates usually increases in the Black Sea and Sea of Azov during late summer and autumn [Makarevich, 2022; Yasakova, Makarevich, 2017]. In autumn 2011, the most abundant algae were a cyanoprokaryote (*P. limnetica*), cryptophytes of the genus *Plagioselmis*, and green algae representing *Binuclearia* and *Nannochloris*. The probable reason for the dominance of brackish-water forms of planktonic flora was a drop in salinity values in September 2011 due to a strong northeastern wind preceding the investigations: it formed the Sea-of-Azov type of waters in the Kerch Strait [Ivanov et al., 2014]. Throughout the study period, the basis of phytoplankton biomass were large species of diatoms (*P. calcar-avis*) and dinoflagellates (*Protoperidinium* and *Tripos* representatives). Interestingly, *P. micans* often causes red tides in the shallow northwestern Black Sea, and the bloom of cyanoprokaryotes during formation of a blocking layer can result in hypoxia in the coastal zone of the Sea of Azov [Matishov, Fushtei, 2003; Nesterova, 2001].

The development of a coccolithophore *E. huxleyi* in the Kerch Strait area was observed in June 2011, July 2012, and May 2013, and this species accounted for 34–47% of phytoplankton abundance. In the Black Sea, abundance of this alga tends now to reach the level characteristic of water bloom annually; moreover, there is a trend towards its intensifying development which is confirmed by satellite observations [Mikaelyan et al., 2006, 2011; Silkin et al., 2009]. An abnormally intensive and long-lasting (May to July) *E. huxleyi* bloom in the Black Sea was registered in 2012 after a cold winter and active wind mixing [Yasakova, Stanichny, 2012]. Due to the ability of this species to regulate CO_2 level in the atmosphere and, accordingly, to affect the temperature regime and climatic conditions of our planet, investigations on the dynamics of *E. huxleyi* development in the modern period are of particular importance [Yasakova et al., 2017].

In August 2019, phytoplankton abundance and biomass in the Kerch Strait were noticeably lower than in 2016: by 32 and 6 times, respectively. The likely reason for such a drop in abundance could have been the construction of hydraulic structures of the Crimean Bridge in 2017–2019. A significant content of heavy metals (1–2.5 MPC) and petroleum products in bottom sediments could negatively affect phytoplankton abundance and photosynthetic activity of algae sensitive to the darkening of the photic layer and to occurrence of various pollutants in water (Table 5).

Table 4. Main hydrological characteristics, number of taxa, and mean abundance and biomass of phytoplankton in the Kerch Strait and adjacent waters in 1989–2020

Study period	The Kerch Strait area	Number of species	Water temperature, °C / salinity, ‰	Abundance, thousand cells·L^{-1}	Biomass, mg·m^{-3}	Reference
May–September 1989	The northern area	90 taxa	+17…+25 / 11–16	–	–	Chernikova, 2004
June 1997 and 2000; December 1998 and 1999	The Kerch Strait, Dinskoy Bay, and Taman Bay	154	0…+26 / 5–27	–	–	Kovaleva, 2008
November 2003	The southern area	44	–	43.5	81.9	Zaremba, 2011
October 2005	–″–	48	–	69.1	355.1	–″–
October 2007	–″–	46	–	275.6	1,514.7	–″–
September 2008	–″–	46	–	79.5	378.6	–″–
June 2009	The southern area	47	–	27.8	111.3	Zaremba, 2013
June 2010	–″–	46	–	26,9	263,3	–″–
June 2011	–″–	42	–	90,0	202,3	–″–
June 2012	–″–	54	–	65.9	209.2	–″–
October 2007	The central area	–	–	220	4,500	Matishov et al., 2013
November 2007	–″–	42	+7.2…+11 / –	365	5,800	–″–
December 2007	–″–	–	–	250	1,500	–″–
April 2008	–″–	–	–	405	200	–″–
June 2008	–″–	–	–	145	400	–″–
August 2008	–″–	–	–	205	1,200	–″–
August 2009	The central and western areas	27	– / 11–14	2,298 ± 1,945 (96.12–9,754.4)	4,128 ± 2,023 (162.2–9,887.55)	Bryantseva et al., 2010
August 2011	The central area	72	+27.6 / 12.22–16.59	45.6	412.95	Trotsenko et al., 2012
May–December 2000–2011	The southern area	–	+5…+27 / 15.11–17.78	–	436 (80–1,400)	Zhugailo et al., 2011
September 2018	The southern area	84	+20…+21 / –	105.7 ± 22	227 ± 32	Remizova, Teyubova, 2021
March 2020	The central area	33	–	389.2 (356.8–421.6)	426.4 (346.0–506.7)	Zagorskaya et al., 2021
June 2020	–″–		–	582.9 (553.3–612.4)	66.1 (53.1–79.0)	–″–
August 2020	–″–		–	37.9 (35.1–40.6)	28.4 (26.2–30,6)	–″–
November 2020	–″–		–	24.6 (20.6–28.5)	35.8 (34.1–37.4)	–″–

Note: a dash (–) denotes no data; in parentheses, the range of values are given.

Table 5. The content of pollutants in bottom sediments (from the surface layer of the bottom, 0.0–0.2 m) of the Crimean Bridge construction area [Sytnik et al., 2017]

Chemical element / pollutant	MPC, mg·kg^{-1}	Content in sediment samples, mg·kg^{-1}
Mercury	2.1	3.6–5.5
Petroleum products	no data	725.9–1,147.4
Lead	32	14.3–27.4
Arsenic	2	0.9–1.8
Cadmium	0.5	0.6–1.32
Nickel	20	1.1–3.2
3.4-benz(a)pyrene	0.01	≤ 0.01

Conclusions:

1. Taxonomic composition of phytoplankton in the Kerch Strait in 2009–2019 included 114 species of microalgae. The highest species diversity of diatoms was recorded in spring (April 2009), and that of dinoflagellates, in summer (June 2011 and August 2019). Species richness of representatives of other phytoplankton classes varied slightly depending on the season. Waters of the strait were mainly characterized by occurrence of diatoms, dinoflagellates, and coccolithophores common to the Black Sea and Sea of Azov, as well as brackish-water species and periphytic diatoms.
2. The highest similarity rates for taxonomic composition of microalgal communities of the Kerch Strait [Sørensen–Czekanowski (Dice) coefficient ≥ 60%] were registered during the warm season (June to September).
3. In spring, small-cell diatoms dominated; in summer, coccolithophores prevailed, as well as small and large diatoms and dinoflagellates; and in late summer and autumn, the role of cyanoprokaryotes and large diatoms and dinoflagellates increased.
4. Phytoplankton abundance in the Kerch Strait area in 2009–2019 varied from 19 to 719 thousand cells·L^{-1}, and its biomass, from 0.057 to 1.92 g·m^{-3}. The highest values were observed in August 2016 when cyanoprokaryotes and dinoflagellates were the most abundant. At this time, biomass was chiefly formed by a large diatom *Pseudosolenia calcar-avis* and abundant dinoflagellate *Prorocentrum micans*. High biomass values for the summer of 2010, 2012, and 2013 were determined by the occurrence of a large-cell species *P. calcar-avis* in plankton. This alga developed intensively due to the onset of warm weather.
5. Vertical distribution of phytoplankton abundance and biomass was uneven and depended on the hydrodynamic activity of waters.
6. The construction of hydraulic structures of the Crimean Bridge in 2017–2019 seemed to cause a noticeable decrease in phytoplankton abundance and biomass in the Kerch Strait during the late summer 2019: the values dropped by 32 and 6 times, respectively, compared to those for 2016.

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ВИДОВОЙ СОСТАВ, ЧИСЛЕННОСТЬ И БИОМАССА ФИТОПЛАНКТОНА В КЕРЧЕНСКОМ ПРОЛИВЕ В 2009–2019 ГГ.

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В работе представлены результаты исследований планктонных водорослей Керченского пролива в весенне-осенний период 2009–2019 гг. В составе фитопланктона обнаружено 114 видов и несколько таксонов, определённых до рода, из 11 классов водорослей, в том числе 64 вида динофитовых и 32 вида диатомовых. Средние значения численности и биомассы — 140 тыс. кл.·л$^{-1}$ и 0,386 г·м$^{-3}$ соответственно. Цианопрокариоты доминировали по численности (44 % общего числа клеток). Диатомовые и динофитовые составили основу (62 и 35 %) биомассы и значительную часть численности фитопланктона (19 и 18 %). Представители криптофитовых, кокколитофорид и зелёных водорослей в сумме формировали 18 % общего обилия фитопланктона. Весной доминировали мелкие диатомовые *Skeletonema costatum* и *Cyclotella* *caspia*. В летний период преобладали мелкие и крупные виды диатомовых и динофитовых, а также кокколитофорида *Emiliania huxleyi*. Осенью наиболее многочисленными были цианопрокариоты (*Planktolyngbya limnetica*), криптофитовые (из рода *Plagioselmis*) и зелёные водоросли (из родов *Binuclearia* и *Nannochloris*). Диатомовые (*Pseudosolenia calcar-avis*) и динофитовые из родов *Prorocentrum*, *Protoperidinium* и *Ceratium* формировали основу биомассы фитопланктона.

Ключевые слова: фитопланктон, таксономический состав, численность, биомасса, Керченский пролив