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RESEARCH ARTICLE

The microphytobenthos diatoms of the shallow waters of the Black and Azov Sea ecosystems (1987–2017)

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Abstract

The paper summarizes original studies of species composition and quantitative data (abundance and biomass) of microphytobenthos diatoms of the different ecotopes of some protected areas of the Black and Azov ecosystems of the Crimean shallow waters (1987-2017). In total, 251 taxa were detected, which include benthic (194), benthoplanktonic (40) and planktonic (17) ones. 21 harmful species were identified, 18 of them causing the algal bloom. From all benthic and benthoplanktonic species, 75 taxa were in both seas, 221 taxa were found in the Black Sea and 92 ones were identificated in the Sea of Azov. These species belong to the three classes of Coscinodiscophyceae (18), Fragilariophyceae (35) and Bacillariophyceae (181) and represent 24 orders, 42 families and 71 genera. Marine (49.5% and brackish-marine (27.0%) species prevail, 64 taxa are indicators of organic pollution of water. The group of saprobiont species (64.0%), which is a typical for mesotrophic waters, i.e. those with moderate organic pollution, dominated. The phytogeographical elements of the diatom flora are identified as cosmopolitan (25.0%), boreal-tropical (25%), boreal (22%), arctical-boreal-tropical (19%), and arctical-boreal (9%) species. For the first time quantitative data of diatoms are presented. Comparative qualitative and quantitative data of benthic communities are discussed.

Keywords: Diatoms, microphytobenthos, protected areas, Black Sea, Azov Sea

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Introduction

Benthic diatoms of the seas create high primary production and contribute significantly to the enrichment with organic matter in the environment. In addition to photosynthesis, they are capable of organotrophy and bloom of the water especially extensively in the spring during the increase in the concentration of nutrients in the sea (Ryabushko 2003, 2013). By absorbing nutrients, they can purify the environment from organic matter. Diatoms are indicators of organic pollution of water and of the aquatic ecosystems quality. Therefore, these algae are an essential component in the nutrition of many pelagic and bottom organisms, including potentially harmful species that causing algal blooms in the sea and they have a negative impact to biota and humans. In addition to the taxonomic composition, their ecological characteristics are required, for example, their relationship to salinity and saprobity, the type of substrate they inhabit, the seasonal dynamics of species wealth, the abundance and biomass of communities. These data can be especially useful for biomonitoring of the marine protected areas. An additional characteristic of flora is the assessment of its phytogeographical status, which as a whole gives the concept of relationship of diatom flora of the Black and Azov seas with other seas and in waters of conservation in different regions of the world (Ryabushko 2013; Balycheva 2014; Begun *et al*. 2015; Ryabushko and Begun 2015, 2016; Ryabushko and Bondarenko 2016, 2017; Balycheva and Ryabushko 2017; Bondarenko 2017; Ryabushko *et al*. 2017; Niyatbekov and Barinova 2018). In addition, scientific research on quantitative indicators of diatoms abundance and biomass in protected areas is also important for assessing water quality.

Currently, a number of objects of the Crimean coastal waters of the Black and Azov seas have the status of the State Nature Reserves or Sanctuaries with different years of foundation (in parenthesis). There are the Karadagsky Reserve (1979), located in the Eastern Crimea; the Lebyazh'i Islands Reserve (1923), organized in the coastal waters of the Karkinitsky Bay (Western Crimea) and now it is a Branch of the Crimean Nature Reserve; the Kazach'ya Bay Sanctuary (1998), located on the coast of Sevastopol; the Nature Reserve Martyan Cape (1973), situated near the Nikitsky Botanical Garden near Yalta Bay of the Southern coast of the Black Sea; and the Kazantip Nature Reserve (1998), located in the Northwestern part of the Kerch Peninsula on the coast of the Sea of Azov. The function of Nature Reserves and Sanctuaries are to conserve biological diversity of flora and fauna and environmental conditions. For this reason, it is necessary to monitor natural systems and objects and carry out ecological research in the seas. Bottom diatoms of different protected areas of the Crimea are still studied very poorly. There is a lack of comparative data on different types of substrates, seasonal dynamics of the population and biomass, and other aspects.

The aim of this work is to summarize and compare long-term data on the species composition and ecology of benthic diatoms of the Crimean shallow waters of the five protected areas of the Black and Azov Seas.

Material and Methods

Sampling of microphytobenthos was performed over the periods of 1987–1996 and 2016–2017 in different ecotopes of the sea (epilithon, epiphyton, sand and silt, epizoon of the shells of the mussels and the skin of dolphins) in different seasons and at depths from 0.5 to 7.0 m in the Crimea of the Black Sea (Figure 1a, b). The temperature of seawater in the study areas ranged from 5.0 to 24.0°C, salinity was from 18.1 to 21.3‰ (Ryabushko 2013; Balycheva and Ryabushko 2017). Samples of benthic diatoms in the Kazantip Cape of the Sea of Azov were collected at 8 stations (Figure 1b) in different seasons in 2005–2014 at depths varying from 0.3 to 1.5 m from different substrates: macrophytes (red, green and brown macroalgae and seagrass), rocks, sand and silt. The temperature of the sea water varied from minus 0.5 to + 27.5°C, and the salinity of water was 10.5–11.5‰ (Ryabushko and Bondarenko 2016). The study of samples was carried out in light microscopes "BIOLAM L-212" with magnifications 10x 40x2.5, 10x90x2.5 and C. Zeiss "Axioskop 40" with the AxioVision Rel. 4.6 software at magnifications of 10x40, 20x40, 10x100 (using immersion oil, refractive index – 1.518), as well as in the scanning electron microscope (SEM) of type "JEOLS" and "PL"(Ryabushko 2013).

Identification of species was carried out on aqueous and permanent preparations prepared according to the described methods (Diatom Analysis 1949; Ryabushko 2013). In determining the species we used the data from (Smith 1853, 1856; Diatom Analysis 1950; Proshkina-Lavrenko 1963a, b; Ryabushko and Begun 2016; Guiry and Guiry 2018). In this paper, the classification system described in (Round *et al.* 1990) is employed. To analyze the relation of species to the organic pollution of the water areas we used the scale (Sládeček 1973). Saprobity of species was determined by the literature data (Barinova *et al*. 2006; Ryabushko 2013; Ryabushko and Begun 2015).

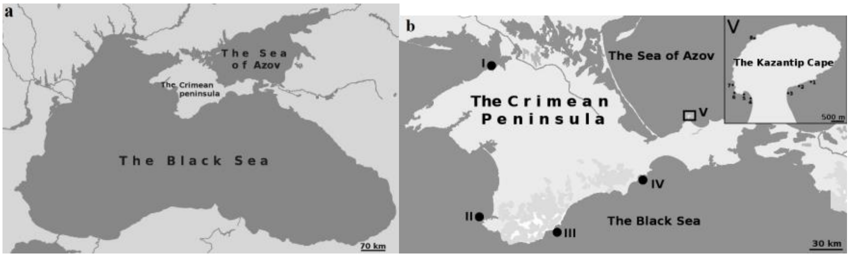

Figure 1a. General view of the Crimean Peninsula location;
b. Map of microphytobenthos sampling of the upper sublittoral of the Black Sea: Lebyazh'i Islands (I); Kazach'ya Bay (II); Martyan Cape (III); Karadag (IV); Kazantip Cape of the Sea of Azov (V, stations 1–8)

Results and Discussion

The check-list of microphytobenthos diatoms of the Nature Reserves and Sanctuary of the Crimean coast of the Black and Azov Seas is represented by

251 taxa. These are 194 benthic and 40 benthoplanktonic species found in two biotopes (benthos and plankton) and 17 planktonic ones deposited on substrates from the water column (Ryabushko 2013; Balycheva 2014; Ryabushko and Bondarenko 2016). The mutual influence of the microalgae of the benthic and pelagic biotopes is particularly noticeable in shallow sea waters, therefore planktonic species are found in the list of diatoms.

It is known, that detection of potentially harmful and toxic species that affect the biota and individuals eating the products of mollusk cultivation is especially important for protected areas in both seas (Ryabushko 2003, 2013). In the bottom communities of the Black and Azov Seas of Crimea 21 species of harmful diatoms we found, 18 of them cause the algal bloom in the sea: *Skeletonema costatum* (Greville) P.T. Cleve 1878, *Sk. subsalsum* (A. Cleve) Bethge 1928, *Cyclotella choctawhatcheeana* Prasad 1990, *Coscinodiscus jonesianus* (Greville) Ostenfeld 1915, *Cerataulina pelagica* (Cleve) Hendey 1937, *Cylindrotheca closterium* (Ehrenberg) Reimann et Lewin 1964, *Thalassionema nitzschioides* (Grunow) Mereschkowsky 1902 and benthic species: *Tabularia fasciculata* (C.A. Agardh) D. M. Williams et Round 1986, *T. tabulata* (C.A. Agardh) Snoeijs 1992, *Licmophora abbreviata* C.A. Agardh 1831, *L. flabellata* (Greville) C.A. Agardh 1830, *Striatella unipunctata* (Lyngbye) C.A. Agardh 1832, *Grammatophora marina* (Lyngbye) Kützing 1844, *Parlibellus delognei* (Van Heurck) E.J. Cox 1988, *Berkeleya micans* (Lyngbye) Grunow1868, *B. rutilans* (Trentepohl) Grunow 1880. Five other species are potentially toxic: *Pseudo-nitzschia calliantha* Lundholm, Moestrup et Hasle 2003, *P. delicatissima* (Cleve) Heiden 1928, *P. prolongatoides* Hasle (Hasle) 1993, *P. seriata* (Cleve) H. Peragallo 1908 and *Halamphora coffeiformis* (C.A. Agardh) Levkov 2009.

In total, we found 234 taxa of benthic and benthoplanktonic diatoms in the protected areas of two seas. They belong to three Classes: Coscinodiscophyceae (18), Fragilariophyceae (35) and Bacillariophyceae (181), 24 Orders, 42 Families and 71 Genera, 75 of which are found both in the Black and Azov Seas (Table 1).

It is known that salinity of water affects the development of biota and its species composition. Diatoms are indicators of salinity of sea water (Proshkina-Lavrenko 1953).The salinity of the Black Sea (16–21‰) and the Sea of Azov (9–12‰) are described as brackish or slightly salty. Below are the data of the ecological and phytogeographic characteristics of benthic and benthoplanktonic diatom communities of the two seas (Table 1). The diatoms are marine (49.5%), brackish-marine (27.0%), brackish (11.5%), freshwater-brackish (8.0%), and freshwater (4.0%) ones (Figure 2).

In addition, an important characteristic of the flora in protected areas is in assessment of organic pollution of their waters by means of the diatomic analysis (Proshkina-Lavrenko and Alfimov 1954; Barinova *et al*. 2006; Ryabushko 2013; Ryabushko and Begun 2015, 2016). Our original and other published data on the saprobity indices of diatoms of two seas are shown for 64 species (Table 1).

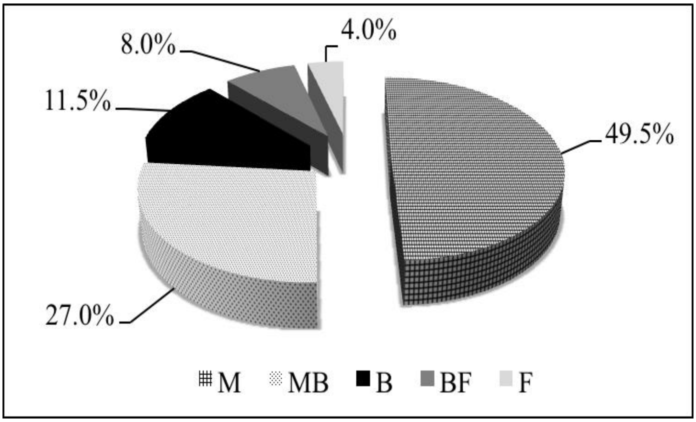

Figure 2. The ecological groups (% of total number of species) of diatoms typical for waters with different salinity in the Crimean coast of the Black and Azov Seas. M: marine, MB: marine-brackish, B: brackish, BF: brackish-freshwater, F: freshwater

Table 1. The List of microphytobenthos diatoms from five protected regions of the Crimean shallow waters, ecological (H, S, RS) and phytogeographical (PG) characteristics of species of the both the Black and Azov Seas

Taxa	Characteristics of diatoms			
	H	*S*	RS	PG
Achnanthes brevipes C.A. Agardh 1824	B	*β*	MB	C
A. longipes C.A. Agardh 1824	B	*β*	M	C
Amphora delicatissima Krasske 1930	B	–	F	B
A. ovalis (Kützing) Kützing 1844	B	*o-β*	BF	C
A. parvula Proschkina-Lavrenko 1963	B	–	MB	B
Ardissonea crystallina (C.A. Agardh) Grunow 1880	B	*β*	MB	BT
Bacillaria paxillifera (O.F. Müller) T. Marsson 1901	BP	*β*	MB	C
Berkeleya micans (Lyngbye) Grunow 1868	B	–	MB	B not.
B. rutilans (Trentepohl ex Roth) Grunow 1880	B	–	M	C
Cerataulina pelagica (Cleve) Hendey 1937	BP	–	M	BT not.
Cocconeis costata Gregory 1855	B	*β*	M	C
C. neodiminuta Krammer 1990	B	*o-χ*	BF	C
C. placentula var. *intermedia* (Héribaud et M. Peragallo) P.T. Cleve 1895	B	*o-β*	M	AB
C. scutellum Ehrenberg 1838	B	*β*	MB	C
Coscinodiscus oculus-iridis (Ehrenberg) Ehrenberg 1854	BP	–	M	C
C. radiatus Ehrenberg 1841	BP	–	M	C
Cylindrotheca closterium (Ehrenberg) Reimann et Lewin 1964	BP	*β*	MB	C

Table 1. Continued

Diatoma tenuis C.A. Agardh 1812	BP	*o*	BF	C
D. vulgaris Bory 1824	BP	*β*	BF	B not.
Diploneis didyma (Ehrenberg) Ehrenberg 1854	B	*β*	M	ABT not.
Entomoneis paludosa (W. Smith) Reimer 1975	BP	*β-α*	MB	AB not.
Fragilaria crotonensis Kitton 1869	BP	*o-β*	BF	ABT
Fr. pediculata Proschkina-Lavrenko 1962	BP	–	B	B
Grammatophora marina (Lyngbye) Kützing 1844	B	*β*	M	C
Gyrosigma scalproides (Rabenhorst) P.T. Cleve 1894	B	*β*	BF	C
G. spencerii (W. Smith) Griffith et Henfrey 1856	B	–	B	C
Halamphora coffeiformis (C.A. Agardh) Levkov 2009	B	*α*	MB	ABT
Licmophora abbreviata C.A. Agardh 1831	B	*β*	M	C
L. dalmatica (Kützing) Grunow 1867	B	–	M	B
L. gracilis (Ehrenberg) Grunow 1867	B	–	M	ABT
L. oedipus (Kützing) Grunow 1881	B	–	M	AB
L. paradoxa (Lyngbye) C.A. Agardh 1828	B	–	M	C
Mastogloia kariana Grunow 1880	B	–	M	B
M. smithii Thwaites 1856	B	*o*	B	BT not.
M. pusilla Grunow 1878	B	–	MB	BT not.
Melosira moniliformis (O.F. Müller) C.A. Agardh 1824	BP	*β*	MB	ABT not.
Navicula ammophila var. *intermedia* Grunow 1862	B	–	MB	AB
N. cancellata Donkin 1872	B	–	M	C
N. digitoradiata (Gregory) Ralfs 1861	B	*β*	MB	ABT
N. directa (W. Smith) Ralfs 1861	B	–	M	ABT
N. lanceolata (C.A. Agardh) Ehrenberg 1838 var. *lanceolata*	B	–	F	AB not.
N. lanceolata var. *tenuirostris* Skvortzov 1937	B	–	F	B
N. palpebralis Brébisson ex W. Smith 1853	B	–	M	ABT
N. ramosissima (C.A. Agardh) P.T. Cleve 1895	B	–	MB	ABT
N. salinarum Grunow 1880	B	*β*	B	AB not.
N. schoenfeldii var. *diversipunctata* Proschkina-Lavrenko 1962	B	–	MB	B
N. veneta Kützing 1844	B	*α-o*	B	C
Nitzschia dissipata (Kützing) Grunow 1862	B	*β-o*	F	C
N. hybrida f. *hyalina* Proschkina-Lavrenko 1963	B	–	MB	C
N. lanceolata W. Smith 1853	B	*β*	B	BT not.
N. obtusa W. Smith 1853	B	*β-α*	B	C
N. scalpelliformis Grunow 1880	B	*β*	B	BT not.
N. sigma (Kützing) W. Smith 1853	B	*α*	B	ABT not.
N. spathulata Brébisson 1853	B	–	M	BT
N. tenuirostris Mereschkowsky 1902	BP	–	B	B
Parlibellus delognei (Van Heurck) E.J. Cox 1988	B	–	M	ABT
P. delognei var. *remotiva* (Proshckina-Lavrenko) L.I. Ryabushko 2006	B	–	B	B
Planothidium hauckiana (Grunow) Round et Bukhtiyarova 1996	B	*o*	F	BT not.
Pleurosigma aestuarii (Brébisson et Kützing) W. Smith 1853	B	–	M	AB
Pl. angulatum (Queckett) W. Smith 1852	B	*β*	M	C
Pl. cuspidatum (Cleve) H. Peragallo1891	B	–	M	B
Pl. elongatum W. Smith 1852	B	*β*	MB	C
Pl. normanii Ralfs 1861	B	–	M	C

Table 1. Continued

Rhoicosphenia abbreviata (C.A. Agardh) Lange-Bertalot 1980	B	*o-α*	BF	AB not.
Rh. marina (W. Smith) M. Schmidt 1889	B	*β*	M	AB
Skeletonema costatum (Greville) P.T. Cleve 1878	BP	*α*	M	C
Staurophora salina (W. Smith) Mereschkowsky 1903	B	–	MB	AB
Striatella delicatula (Kützing) Grunow ex Van Heurck 1885	BP	–	MB	ABT
Synedra curvata Proschkina-Lavrenko 1951	B	–	B	B
Tabularia fasciculata (C.A. Agardh) Williams et Round 1986	B	β-α	MB	C
T. parva (Kützing) Williams et Round 1990	B	*α*	MB	ABT
T. tabulata (C.A. Agardh) Snoeijs 1992	B	*β-α*	MB	C
Thalassionema nitzschioides (Grunow) Mereschkowsky 1902	BP	–	M	C
Tryblionella hungarica (Grunow) J. Frenuelly 1942	B	*α-o*	B	C
Undatella lineolata (Ehrenberg) L.I. Ryabushko 2006	B	*β*	MB	ABT

Note. H: the species on these habitat (B: benthos, BP: benthoplankton); *S*: relation of species to saprobity of water (*o:* oligosaprobiont, *o-χ:* oligo-xenosaprobiont, *o-β*: oligo-betamesosaprobiont, *o-α*: oligo-alphamesosaprobiont, *β-o*: beta-oligosaprobiont, *β*: betamesosaprobiont, *β-α:* beta-alphamesosaprobiont, *α:* alphamesosaprobiont, *α-o:* alpha-oligosaprobiont); RS: relation of species to salinity of water (M: marine, MB: marine-brackish, B: brackish, BF: brackish-freshwater, F: freshwater); PG: phytogeographical elements of diatom flora (C: cosmopolitan, ABT: arctical-boreal-tropical, BT: boreal-tropical, B: boreal, AB: arctical-boreal, not.: notal species)

According to Barinova *et al*. (2006), it is established that saprobiontic species are typical for mesotrophic waters (*β*-mesosaprobic level, or Class III water quality), i.e. for waters with moderate organic pollution. They dominate and account for 64.0% of the total number of species. The fraction of eutrophic water indicator species (*α*-mesosaprobic level, or Class IV water quality) is 19.0%. The indicators of oligo- and xenotrophic (or naturally clean) waters (*o*-saprobic level, or Class II, and *χ*-saprobic, or Class I) make 8.0 % and 9.0%, respectively (Figure 3).

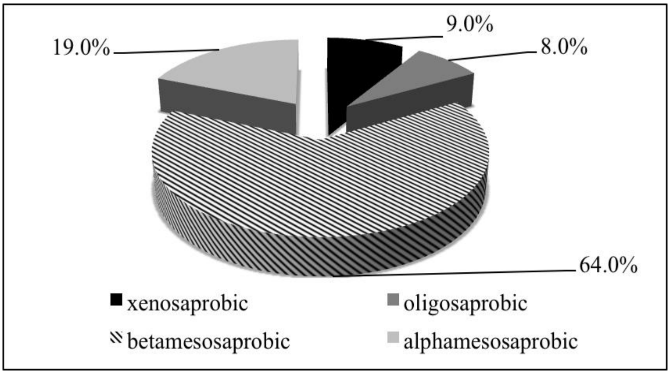

Figure 3. The ecological groups (% of total number of species) of diatoms typical for waters of different saprobity near the Crimean coast of the Black and Azov Seas

The phytogeographic elements of diatom flora were also revealed. Cosmopolitan and boreal-tropical species prevail (25.0% species in each) over boreal (22.0%), arctic-boreal-tropical (19.0%) and arctic-boreal (9.0%) ones (Figure 4). Furthermore, 20.0% of the total number of species are notal (Table 1). They are found in the southern hemisphere as well.

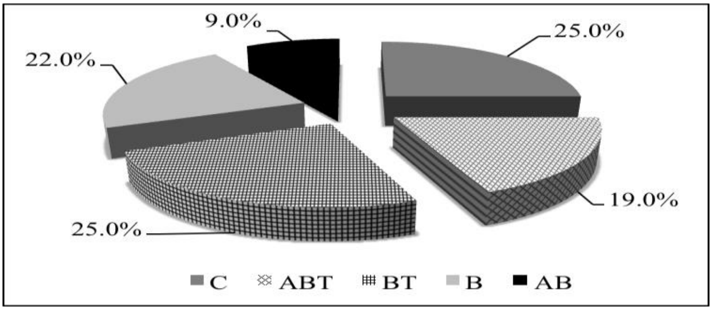

Figure 4. Phytogeographical elements (% of total number of species) of diatom flora in the Crimean coastal waters of the Black and Azov Seas: C (species-cosmopolites), ABT (arctical-boreal-tropical species), BT (boreal-tropical species), B (boreal species) and AB (arctical-boreal species)

Below we present similar characteristics for the coastal waters of the protected areas of the Black and Azov Seas separately.

Benthic species, including benthoplanktonic ones, dominate in the benthic communities of the Black Sea. They are represented by 221 species, which belong to three classes: Coscinodiscophyceae (19), Fragilariophyceae (34) and Bacillariophyceae (168). Among them, the diatoms detected were in the Kazach'ya Bay Sanctuary (157 species) and Nature Reserves: Karadagsky (157 species), the Lebyazh'i Islands (68 species) and Martyan Cape (63 species) (Guslyakov and Maslov 1987; Chepurnov 1988; Ryabushko 2002, 2013; Balycheva and Ryabushko 2017). There are 113 marine, 58 marine-brackish, 26 brackish, 17 brackish-freshwater and 7 freshwater species. Among them, 15 species are harmful algae and 54 species are indicators of organic water pollution, with β-mesosaprobionts (30) predominating.

Ninty-two benthic and bentoplanktonic species were found in the Kazantip Nature Reserve of the Sea of Azov (Bondarenko 2017).

Another characteristic of diatoms is their quantitative characteristics in respect of different ecotopes of the sea. For example, 110 taxa were found in epiphyton of the bottom vegetation of Kazach'ya Bay, including 97 taxa on the thalli of red algae of the genus *Gracilaria* Greville 1830 (Ryabushko 2013), which often dominated benthic communities of the Black Sea shelf and are important and promising industrial cultivation objects for agar production (Sud'ina *et al*. 1994).

In Kazach'ya Bay, 74 species of diatoms were found in the mud substrate under the thalli of *Gracilaria*. In the epiphyton of brown algae of the genus *Cystoseira* C.A. Agardh 1820, 22 species were registered. In the epiphyton of green algae of the genera *Ulva* A.C. Agardh 1823, *Chaetomorpha* Kützing 1845, and *Cladophora* Kützing 1843, 30 species were found. Diatom species were also identified in the epizoon of the skin of dolphins as well as in water containing mammals of the oceanarium (23) and in the epizoon of shells of mussel *Mytilus galloprovincialis* Lamarck 1819 (101 species) (Ryabushko 2013).

The quantitative data of benthic diatom communities significantly supplement algalogical and ecological characteristics. We have established that the quantitative data of the species distribution depending on season, substrate type and water temperature (Ryabushko 2013). The largest values of abundance (*N*) and biomass (*B*) of diatoms on mussel shells in Kazach'ya Bay were registered at the depth of 2.5 m at the end of March at water temperature 7.7°C. The average N=488.3·10^3 cells·cm^{-2} at B=1.64 mg·cm^{-2} with maximum values N=830·10^3 cells·cm^{-2} and B=3.69 mg·cm^{-2} were obtained due to the development of year-round solitary species *Nitzschia hybrida* f. *hyalina*, *Gyrosigma tenuissimum*, *Trachyneis aspera*, *Pleurosigma elongatum*. These species were found together with the colonial diatoms *Ardissonea baculus*, *Toxarium undulatum*, *Striatella unipunctata*, and they dominated in terms of either abundance or biomass over some months. The colonial fouling species of *Licmophora* spp., *Tabularia* spp. and others dominated on all substrates in winter and spring. The abundance and biomass of diatoms in the epiphyton of the *Gracilaria* in Kazach'ya Bay were twice as low as those on the surface of the live mussel (Ryabushko 2013).

Sixty-eight taxa of diatoms were found in the Lebyazh'i Islands including 41 species in the epilithon of stones and 27 species on sand and silt (Balycheva and Ryabushko 2017). The abundance of diatoms varied within (48–75)·10^3 cells·cm^{-2} with the maximum biomass 0.011 mg·cm^{-2}, and the richness of species varied from 11 to 13 with the predominance of the marine benthic species *Seminavis ventricosa* (Gregory) M. Garcia-Baptista 1993, a *β*-mesosaprobiont and cosmopolitan which was found in the Kazach'ya Bay and Karadagsky Reserves.

For comparison with other regions of specially protected natural areas, a list of benthic diatoms of the Martyan Cape was used. Guslyakov and Maslov (1987) indicated 63 taxa. In connection with the revision of the nomenclatural names of Bacillariophyta, this list was critically revised by us and included in the general summary of the species of the Black Sea Nature Reserves.

In the microphytobenthos of Kazantip Cape of the Sea of Azov, 92 taxa of benthic and benthoplanktonic forms were found. They belong to classes Coscinodiscophyceae (6), Fragilariophyceae (18) and Bacillariophyceae (68).

Among them, 12 taxa are harmful, capable of causing the algal bloom of the water. Marine and marine-brackish species prevail, but unlike the Black Sea microalgae, the diatoms in waters of these two salinity categories are represented by the similar number of species (32 and 30 ones, respectively). There are 15 brackish, 8 brackish-freshwater and 7 freshwater species of diatoms of Kazantip (Bondarenko 2017). Saprobity indices were established for 46 species. It was found that 63.0%, 22.0%, and 15.0% of these values are typical for mesotrophic, eutrophic, and oligotrophic waters, respectively. As in the protected regions of the Black Sea, cosmopolitan species (30) dominate, with 19 arctic-boreal-tropical, 12 boreal-tropical, 21 boreal and 10 arctic-boreal ones also being present in this region.

In the shallow waters of the Kazantip Reserve of the Sea of Azov, 74 taxa were found in the epiphyton of macrophytes, 42 taxa were in the epilithon, and 36 ones were registered in the communities on sand and silts. The largest quantity indices of diatoms in 2006 were obtained for the epiphyton of macrophytes at the maximum richness of species (18) and abundance (N) of the dominant species *Thalassionema nitzschioides* and *Berkeleya rutilans* (N=277.1·10^3 cells·cm^{-2} and 226.9·10^3 cells·cm^{-2}, respectively) in April at water temperature t=10.0°C; *Tabularia tabulata* (N=154.8·10^3 cells·cm^{-2}) in August at t=26.0°C and *Rhoicosphenia abbreviata* (N=240.9·10^3 cells·cm^{-2}) in September at 19.3°C. The abundance of the dominant species in the epilithon of stones was N=16.8·10^3 cells·cm^{-2} and 13.4·10^3 cells·cm^{-2} (for *Rh. abbreviata*) in August and September, respectively, and N=3.8·10^3 cells·cm^{-2} (for *T. tabulata*) in September The abundance of *Rh. abbreviata* was 16.8·10^3 cells·cm^{-2} in epilithon, in August (Bondarenko 2017).

Conclusions

Results of research of microphytobenthos diatoms at five protected areas of the Crimean coastal waters of the Black and Azov Seas have been summarized and analyzed, which is novel as applied to seas of Russia. The list of benthic and benthoplanktonic species of Bacillariophyta is represented by 234 taxa. They belong to three classes, 24 orders, 42 families and 71 genera. Among them, 221 species are found in the Black Sea and 92 species are in the Sea of Azov and 75 species that were found in both seas.

The common features in the diatom flora have been revealed: the prevalence of benthic and cosmopolitan taxa as well as marine and marine-brackish forms, and the equal number of freshwater species for all the areas under study. The dominant group of β-mesosaprobic species characterizes the studied protected waters as mesotrophic. Quantitative data on the abundance and biomass of populations dominant in different ecotopes of the seas have also been given. The highest values of species number and abundance of diatoms have been observed in the epiphyton of bottom vegetation in comparison with other ecotopes. The distinctive feature of the microphytobenthos diatoms is the nearly equal proportion of marine and brackish-marine microalgae in the Sea of Azov, whereas the number of marine species in the Black Sea is twice as large as that of brackish-marine ones. Thus, for the regular biomonitoring of protected areas of the seas, the obtained data on the species composition, ecology and phytogeography and the quantitative characteristics of the structure of communities of the bottom diatoms are necessary to assess the habitat of microalgae in different ecotopes and seasons, as well as to identify similarities and differences of qualitative and quantitative characteristics of species.

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