Database on Black Sea benthic diatoms (Bacillariophyta): its use for a comparative study of diversity pecularities under technogenic pollution impacts

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Abstract

The taxonomic database of Black Sea benthic diatom algae was created using Microsoft Office Access software and data are based on the review of available literature from 5 coastal zones: the Caucasian, Crimean, Bulgarian and Romanian coasts and the northwestern shelf (NWBS). The results of our own sampling surveys performed along the Crimean and Caucasian coasts in the period 1984-2001 were also used. The total list of Black Sea benthic diatoms holds 553 species (705 species and intraspecific taxa), pooled in 115 genera, 59 families, 31 orders, and 3 classes of Bacillariophyta. The highest species richness of diatoms is registered near Crimea and in the NWBS, representing respectively 64.2% and 69.5% of the total number of benthic diatom species ever registered in the Black Sea.

Comparative multivariate analysis of benthic diatom taxocenes from three near shore water areas of SW Crimea is done by using quantitative data on species diversity and abundance of diatoms. Those biotopes (Laspi bay, a healthy site; the open water area nearby the mouth of Sevastopol bay, a moderately polluted site and the central part of the main Sevastopol bay, a severely polluted area) differ substantially in heavy metal content (Hg, Cu, Pb, Zn, Cr and Mn) and other toxicants (DDT, PCBs, oil hydrocarbons) in the upper sediment layer (1-4 cm). Based on PCA analysis, two principal environmental components (PCs) revealed that in, through technogenically impacted locations, PC1 (55% of the total variance) is associated with the concentration gradient of several heavy metals (Pb, Cu, Mn and Cr), whereas PC2 (24%) can be associated with changes in DDT and PCB content in the upper sediment layer.

In each of the investigated areas, the specific taxocenotic diatom complexes could be statistically separated based on the results from clustering and MDS ordination, using complete linking of the Bray-Curtis similarity. The most important indicator species, which are principally responsible for the similarity within each of assemblages and the most significant discriminating species were also determined. It is proposed to consider *Tabularia tabulata, Amphora proteus* and *Navicula palpebralis* as indicators of conditionally unpolluted biotopes (Laspi bay), whereas *Tryblionella punctata, Nitzschia sigma, Caloneis liber* and *Melosira moniliformis* can be considered as indicators of water areas subject to severe technogenic impact (Sevastopol bay).

Comparative analyses show that the combination of the variables depth, Pb, Mn, Cu and PCBs can have the highest impact (Spearman rank, ρ = 0.73-0.76) on structural and diversity features of a diatom taxocene subject to different extent of toxicants.

Keywords: benthic diatoms; diversity database; taxocene structure; technogenic pollution; Black Sea.

Introduction

Although microphytobenthos is the major primary link in the trophic relationships of sublittoral ecosystems, the study of this taxonomic group is insufficiently developed in biodiversity research in the Black Sea region. Among all other groups of microphytobenthos, the benthic diatom algae (Bacillariophyta) have the highest population densities and species richness. They dwell all sublittoral biotopes, from the surf zone up to depths of about 50-70 m. They play an important role in material and energy transformation, in self-purification processes, in oxygen balance of coastal water areas and they serve as a trophic basis for larval stages of many necto-benthic species and demersal fish. Benthic diatoms are closely associated with a certain biotope and are directly subjected to environmental conditions. All this allows considering them as appropriate indicators of anthropogenic impact in complex monitoring of sublittoral ecosystems.

In contrast with phytoplankton, research on Black Sea benthic diatoms was mostly performed in the western and northwestern areas, whereas the shores of Crimea and Caucasus are less investigated. As a consequence, information on the diatom's flora is almost lacking from the southern and southeastern parts of the Black Sea. Most of the publications are devoted to floristic descriptions of species compositions and seasonal dynamics of diatom algae, whereas a minor amount of references is dedicated to the study of taxocene structures and the measurement of biodiversity based on traditionally used indexes (such as Shannon (H'), Pielou (J), etc.). Nevertheless, the application of these indexes is often inexpedient for comparative analysis of historical data in large-scale spatial and temporal analyses, especially when the frequency of sampling, the number of replicates and the sample size is unknown or when quantitative data are absent and only a species list is available.

Therefore, collection and comprehensive assessment of taxonomic and biogeographic information makes it possible to expand our current knowledge on benthic diatom structures and their specific ecological characteristics. Besides, comparative analysis using quantitative data allows revealing the changes in species structures that are subject to natural and anthropogenic influences. Finally, to perform good ecological monitoring of the Black Sea, the aim should be to apply this to at least several taxonomical groups of benthos.

The objectives of this study are 1) to integrate existing, but isolated datasets on benthic diatom diversity from several coastal regions of the Black Sea into one consolidated taxon-based database 2) to assess the effect of several heavy metals, chlorine-organic compounds and oil hydrocarbons on the structure and diversity of benthic diatom taxocenes in several near-shore water areas, which substantially differ in the level of chemical pollutants in soft sediment bottoms of the Black Sea.

Material and Methods

The taxonomic database of Black Sea benthic diatoms is based on the review of literature data (Proshkina-Lavrenko, 1963; Bodeanu, 1987-1988; Guslyakov *et al.*, 1992, 1998; Temniskova-Topalova *et al.*, 1998; Guslyakov, 2003) and from our own benthic sampling surveys performed in the period 1984-2001 along the Crimean and Caucasian coasts (Nevrova *et al.*, 2003). The taxonomic database has been created in Microsoft Office Access. According to the system proposed by Round *et al.* (1990), the total updated list of species has been prepared based on available material from 5 coastal regions of the Black Sea: the Caucasian, Crimean, Bulgarian and Romanian coasts and the northwestern shelf (NWBS).

Data on bottom sediment chemistry parameters and benthic diatoms for the assessment of pollution impact upon the taxocene diversity and structure were obtained from the comprehensive ecological surveys carried out between 1994 and 2001 (Petrov and Nevrova, 2004). In this study, three nearshore water areas of SW Crimea were compared. Laspi bay (L) is located close to a marine reserve and is almost unaffected by any technogenic pollution. The water area adjacent to the mouth of Sevastopol bay (M) is characterized by a moderate pollution level. The central part of Sevastopol bay (S) is located in the industrial zone of Sevastopol port, where the average level of toxicants in silty sediments was the highest (Fig. 1).

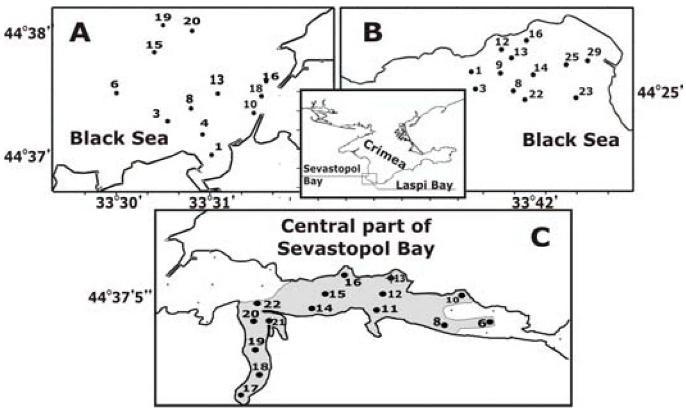

Fig. 1. Schematic map of the sampling locations in the open water area nearby the mouth of Sevastopol bay (A), in Laspy bay (B) and in the central part (grey color area) of Sevastopol bay (C).

Data on several toxicants recorded in the sediments were used to assess the effect of the pollution level on the structure and diversity features of the benthic diatom taxocene in different coastal locations. In the present study, ten toxicants were examined: 6 heavy metals, DDT, PCBs, oil hydrocarbons and bitumens. Comparison of the silty sediments of the three coastal regions showed a pronounced difference in both average values and variation range of the toxicant concentrations (Table I).

Table I. Content (average values) and the variation range (in brackets) of toxic substances recorded in the bottom sediments of the southwestern Crimea area.

Toxicant/Region		**Laspi bay**	**Mouth of Sevastopol bay**	**Central part of Sevastopol bay**
Heavy metals, mkg.g^{-1} DW	Hg	0.04 (0.03-0.05)	0.32 (0.15-0.88)	1.11 (0.40-1.88)
	Cu	7.36 (3.40-11.32)	26.17 (20.00-36.55)	8.98 (4.14-19.2)
	Pb	3.69 (3.50-5.00)	25.21 (15.0-37.5)	24.93 (9-39)
	Zn	12.0 (6.0-33.0)	18.17 (3.8-61.2)	32.69 (19.13-48.29)
	Cr	1.91 (1.51-2.62)	10.73 (7.5-20.0)	11.56 (0.53-31.79)
	Mn	6.3 (1.6-7.0)	178.3 (140.0-230.0)	6.11 (2.83-12.68)
COC, ng.g^{-1} WW	DDT	2.8 (1.8-3.0)	64.2 (14-247)	Not measured
	PCBs	5.4 (6.0-8.0)	155.0 (40-604)	1702.1 (711-3770)
CEB and oil H/C, mg.g^{-1}	CEB	0.1 (0.05-0.2)	1.3 (1.2-2.3)	1.8 (0.6-3.2)
	OHC	0.11 (0.09-0.16)	0.38 (0.14-0.90)	7.20 (1.46-15.36)

Note: References on heavy metals and chlorine-organic compounds (COC) were used: Laspi bay (Medinets *et al.*, 1994; Orlova, 1994), mouth of Sevastopol bay (Anon, 1994), Sevastopol bay (Petrov *et al.*, 2005). Data on CEB and oil hydrocarbons (Oil H/C) (Mironov *et al.*, 1992; Polikarpov *et al.*, 1992; Osadchaya *et al.*, 2003). Hg in Sevastopol bay by Kostova S.K. (unpublished data).

The sediment samples (taken from upper layer of 1-4cm) for chemical and biological analysis were collected using a Petersen grab, which was deployed on silty/sandy substrates with a depth range of 8-32m (Nevrova *et al.*, 2003). The quantitative counting of common species was performed and recalculated to 1 cm^2 of seabed. The minimum rated value of diatom abundance was assigned to 250 cells.cm^{-2} (for Sevastopol bay) and 78,600 cells.cm^{-2} (for Laspi bay and the mouth of Sevastopol bay). Species densities found in the samples, but not included in the quantitative calculation was converted to a conventional minimum value of 10 cells•cm^{-2}. A complete taxonomic analysis of diatoms on slides, prepared according to the the standard technique of cold burning in acids (Guslyakov, 2003), was carried out.

Comparative analysis of the diatom taxocene structure and diversity features has been carried out by using multivariate statistical routines included in the PRIMER package (Carr, 1997; Clarke and Warwick, 2001). Multivariate techniques, including clustering, PCA and nMDS ordination, was used to distinguish the station grouping in relation to different levels of anthropogenic pressure (Clarke, 1993; Carr, 1997). Cluster analysis was fulfilled by a hierarchical agglomerative method employing complete-linking of Bray-Curtis similarities, after log-transformation. Ordination of environmental factors, *i.e.* chemistry sediment normalized data on several heavy metals, chlorine-organic compounds (COC), oil hydrocarbons and bitumens (see Table I), was fulfilled by PCA. The significance of the differences between separated groups of stations was tested by using permutation/randomization methods (ANOSIM test).

The SIMPER routine (Clarke and Warwick, 2001) was performed to provide additional information on the species that are principally responsible for the similarity within distinguished benthic assemblages (indicator species) and for the differences between such taxocenotic complexes corresponding to each of the considered geographical locations (discriminating species). The Spearman rank correlation coefficient (ρ) was applied to detect the correlation of the combination of environmental variables, which attain the best match for the high similarities (low rank) in the biotic (abundance data) and abiotic matrices, *i.e.* to recognize a set of abiotic factors "best-explaining" the spatial differences in benthic diatom community patterns across the surveyed bottom area.

Results and discussion

Regional peculiarities in benthic diatom diversity in the Black Sea

The most recent evaluations on total species richness of Black Sea benthic diatoms resulted in 705 species and intraspecific taxa. At the Caucasian coast, 280 species and intraspecies were found, 453 at the Crimean coast, 490 in the NWBS region (without consideration of species from brackish-water estuaries and lagoons), 270 at the Bulgarian coast and 362 at the shelf of Romania. After reviewing all the diatom species dwelling in hyper saline and brackish-water lagoons, the updated list of diatoms from the NWBS includes 576 species and intraspecies (Guslyakov, 2003) and the total number of diatoms registered for the Black Sea is set to 840 species.

The highest species richness of diatoms is registered near Crimea and NWBS representing respectively 64.2% and 69.5% of the total number of Black Sea benthic diatom species. In other investigated coastal areas, this relative index was much lower (about 40%) (Fig. 2).

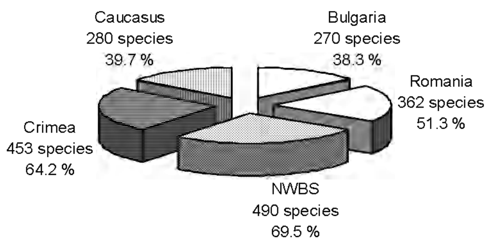

Fig. 2. Percent ratio of benthic diatom species numbers in the investigated regions of the Black Sea.

Comparing the diatom species composition from all investigated coastal regions of the Black Sea, the highest extent of species similarity occurred between the Crimean and the NWBS regions, where the Bray-Curtis similarity coefficient reached up to 77%. The lowest level of species composition similarity was found between the Crimean region of the Black Sea and the Bulgarian coast (53%) (Table II).

Table II. Cross-comparison of the diatom species composition from all investigated areas of the Black Sea, based on the Bray-Curtis similarity coefficient

	Bulgaria	Romania	NWBS	Crimea
Romania	52.5	*	*	*
NWBS	54.2	64.3	*	*
Crimea	53.1	57.2	77.0	*
Caucasus	53.8	56.2	60.5	70.4

The reported species and least inclusive taxa have subsequently been classified into five (I-V) groups, according to their frequency of occurrence (based on the reviewed literature data). In all the investigated regions of the Black Sea, 115 species and intraspecies belonging to group I (occurrence frequency 100%) were common to all regions (Fig. 3). Within this group, there are both common dominant species as well as infrequent and rare species making up the leading complex that never achieve high abundance, but which are permanently present in all the areas. Group II, III and IV (occurrence at 4, 3 and 2 regions, respectively) contain 99, 112 and 167 species and intraspecies, respectively. These are usual and ordinary numbers for benthic diatom assemblages in the Black Sea. Group V is the most numerous and being represented by 212 species, which have cited only once.

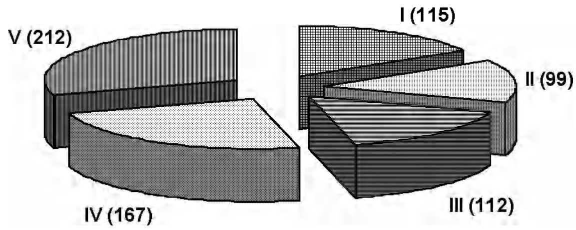

Fig. 3. Occurrence frequency of benthic diatom species of the Black Sea, divided in five groups: I – 100% occurrence; II – 80%, III – 60%, IV – 40 %, V – 20%.

According to recent data on diatom systematics, the most updated and complete list of benthic diatoms of the Black Sea includes 705 species and intraspecific taxa, 115 genera, 59 families, 31 orders, and 3 classes of Bacillariophyta. Of all the benthic diatom species observed, 76.3% are representatives of the class Bacillariophyceae, belonging to 9 orders, 30 families, 60 genera, 538 species and intraspecies. The class Coscinodiscophyceae (12.6%) is represented by 13 orders, 19 families, 28 genera, 89 species and intraspesies, the class Fragilariophyceae (11.1%) by 9 orders, 10 families, 27 genera and 78 species and intraspecies.

The following families are the most represented in the Black Sea: Bacillariaceae (6 genera; 86 species and intraspecific taxa), Catenulaceae (2; 65), Naviculaceae (3; 71), Cocconeidaceae (2; 30), Surirellaceae (4; 32), Diploneidaceae (1; 33), Cymbellaceae (4; 30) and Pleurosigmataceae (4; 28). The highest richness at the genus level was observed for the family Fragilariaceae (16 genera, 37 species and intraspecific taxa).

The most abundant species of benthic diatoms of the Black Sea, which determine the quantitative development of microphytobenthos assemblages, are *Melosira moniliformis* (O. Mull.) Ag., *Striatella delicatula* (Kutz.) Grun., *Rhabdonema adriaticum* Kutz., *Grammatophora marina* (Lyng.) Kutz., *Tabularia tabulata* (Ag.) Snoeijs, *Licmophora ehrenbergii* (Kutz.) Grun., *Achnanthes brevipes* Ag., *Cocconeis scutellum* Ehr., *Navicula pennata* A.S. var. *pontica* Mer., *Navicula ramosissima* Ag., *Berkeleya rutilans* (Trent.) Grun., *Diploneis smithii* (Breb.) Cl., *Caloneis liber* (W.Sm.) Cl., *Trachyneis aspera* (Ehr.) Cleve, *Pleurosigma angulatum* (Queck.) W.Sm., *Amphora proteus* Greg., *Amphora coffeaeformis* (Ag.) Kutz., *Bacillaria paxillifer* (O.Mull.) Hend., *Nitzschia closterium* (Ehr.) W.Sm., *Campylodiscus thuretii* Breb.

In the last 20 years, a number of species were discovered as a new to science: Achnanthes bacescui Bodeanu, Amphora karajevae Gusl., A. macarovae Gusl., Amphora lydiae Gusl., Amphora pogrebnjakovii Gusl., Amphora pontica Gusl., A. proschkiniana Gusl., A. chadjibeiensis Gusl., A. genkalii Gusl., A. topaschevskii Gusl., Cocconeis placentuloides Gusl., Cocconeis kujalnitzkensis Gusl. et Geras., Cymbella odessana Gusl., Cyclotella convexa Bodeanu, C. undulata Bodeanu, Gomphonemopsis domniciae (Gusl.) Gusl., Lyrella phyllophorae Gusl., Navicula gomphonematoides Gusl., Navicula plicata Bodeanu.

There were some new species for the entire Black Sea: *Achnanthes pseudogroenlandica* Hend., *Amphora* sp., *Hantzschia marina* (Donkin) Grunow, *Nitzschia sigmoidea* (Ehr.) W.Sm., *Undatella quadrata* (Breb.) Paddock et Sims. Some species, such as *Cocconeis britannica Naegeli, Pinnularia trevelyana (*Donk.) Rabenh., *Toxonidea insignis* Donk. and *Raphoneis amphiceros* Ehr., have not been found in the Black Sea since XIX century. Twenty-one species are rare and 48 are newly reported species for the Crimean coastal water areas (Nevrova *et al.*, 2003).

The recent increase of diatom species richness, which has been recorded in the last decades, can be a result of intensification of scientific research, but is certainly also due to more active introductions of new species into the Black Sea.

Changes in the diatom taxocene structure under different degrees of technogenic pollution

As shown above, the biodiversity of benthic diatom algae in the coastal waters around Crimea is the most investigated and attains the highest values compared with other coastal regions in the Black Sea. There are now detailed quantitative data available from the Crimean coasts that can be used as a basis for comparative analysis and assessments of changes in benthic diatom diversity patterns in relation to various environmental impacts. Considering this, results of comprehensive floristic and taxonomical surveys in several locations of SW Crimea were used not only for updating the database, but also to perform comparative analysis of diatom diversity changes in accordance with the level of anthropogenic impact.

The contamination gradient across the anthropogenically impacted water areas (M and S) has been observed through the heavy metals and chlorine-organic compounds (COC) concentrations. The possible effect of toxicants on benthic diatom diversity was assessed. Based on the results of PCA analysis, two principal environmental components (PCs) could be distinguished: PC1 (resolving 55% of total variance) is associated with the concentration gradient of several heavy metals (Pb, Cu, Mn and Cr), while PC2 (24% of the total variance) is mainly associated with changes in COC (DDT and PCBs) content in the upper sediment layer (1-4cm).

After clustering, based on the Bray-Curtis similarity index, 39 stations taken from all 3 sites, with a similarity level of about 30%, were subdivided into 3 well-distinguished groups, corresponding to 3 main sampling locations of SW Crimea (Fig. 4).

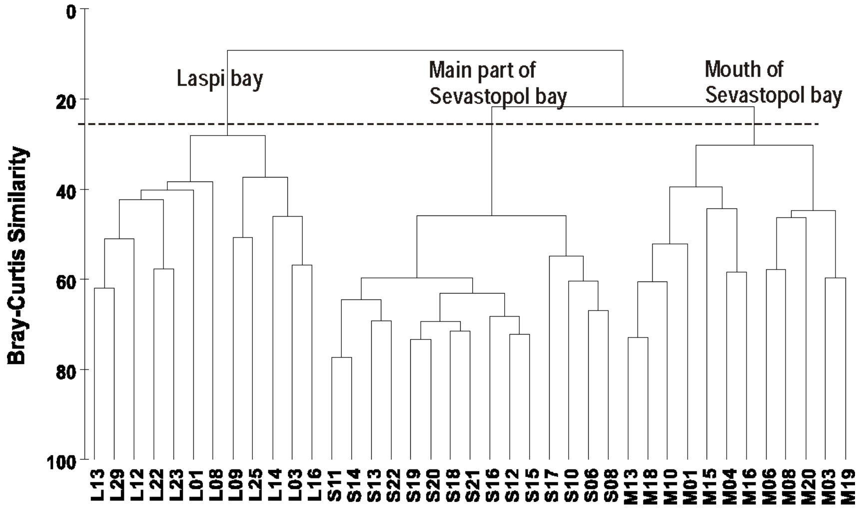

Fig. 4. Dendrogram representing the relative similarity of stations (based on Bray-Curtis similarity of log-transformed diatom abundance). The dotted line indicates the integration level (about 30%) of clusters into taxocene complexes for three coastal locations.

Results of an MDS ordination performed with the samples taken at Laspi bay (L), Sevastopol bay (S) and the open water area near the mouth of Sevastopol bay (M), show three non-overlapping areas (fig. 5).

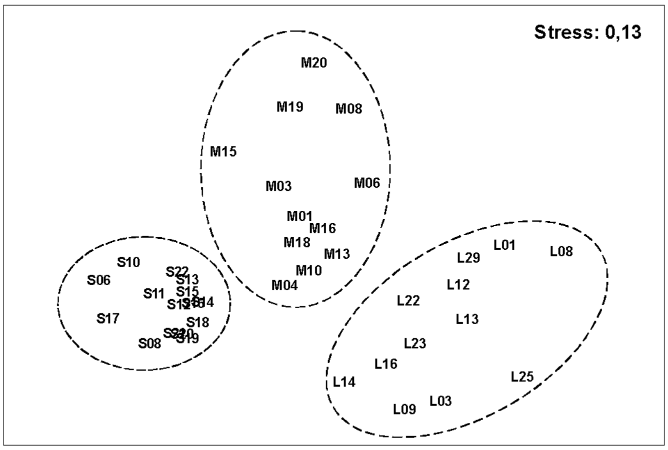

Fig. 5. The results of ordination (MDS) analysis: grouping of stations into complexes from Bray-Curtis similarity of diatom algae abundance (log-transformed). Samples are from Laspi bay (L), Sevastopol bay (S) and the mouth of Sevastopol bay (M).

Low stress function values (0.13) from the MDS analysis indicate a reliable allocation of the sample projection on 2-D plot. Differences between groups were statistically significant: the value of global R-statistics was high (0.84) at a significance level of 0.1%; pair wise testing resulted in R_p values from 0.73 to 0.94 (0.1%). These results also verify that each of the compared coastal locations is characterized by a certain taxocene complex of diatom algae. The average values of the taxocene diversity parameters for the three groups of stations are presented in Table III.

Table III. Average abundance and other species diversity parameters for 3 taxocene complexes of benthic diatoms in different coastal locations in southwestern Crimea.

Region	**Average abundance (106 cells • cm-2)**	**Total number of species**	**Number of common species**	**Number of rare species**
Laspi bay	3.020±0.562	176	53	123
Mouth of Sevastopol bay	2.572±0.413	128	38	90
Central part of Sevastopol bay	0.068±0.018	146	86	60

Differences in structure and diversity patterns between groups of stations can be explained by the influence of environmental factors (mostly technogenic impact) on the structure and quantitative development of diatom complexes. Results of SIMPER data analysis provided additional information concerning the species (indicator and discriminating ones) which are mainly responsible for the similarity within each of the distinguished taxocene complexes and for differences between such complexes (Table IV).

Table IV. Contribution from the most significant species (indicator species) into average similarity within taxocene complexes of benthic diatoms in comparing locations of southwestern Crimea

Species in comparing locations	*N*, **cells•cm^{-2}**	S_i	*S*	S_i *(%)*
L - average similarity 41.6%				
Tabularia tabulata (Ag.) Snoeijs	1139775	4.0	1.6	9.6
Amphora proteus Greg.	150667	3.5	1.9	8.5
Navicula pennata A.S. var. *pontica* Mer.	216392	2.4	1.1	5.8
Navicula palpebralis Breb. var. *semiplena* (Greg.) Cl.	98350	2.1	1.0	5.0
Grammatophora marina (Lyngb.) Kutz.	72158	1.4	1.0	3.5
Diploneis smithii (Breb.) Cl.	45867	1.2	1.1	2.8
Pleurosigma angulatum (Queck.) W.Sm.	59033	1.1	1.0	2.8
Fallacia forcipata (Grev.) Stick et Mann	32800	1.1	1.6	2.7
Cocconeis scutellum Ehr. var. *parva* Grun.	45908	1.0	0.7	2.5
Amphora coffeaeformis (Ag.) Kutz.	58975	1.0	0.9	2.4
Bacillaria paxillifera (O. Mull.) Hend.	52392	1.0	0.8	2.4
Other species				51.9
M – average similarity 43.1%				
Navicula pennata A.S. var. *pontica* Mer.	349108	4.8	1.2	11.2
Diploneis smithii (Breb.) Cl.	209275	4.1	1.3	9.5
Tryblionella punctata W. Sm.	104625	2.6	1.1	6.0
Cocconeis scutellum Ehr.	122050	2.0	1.0	4.7
Caloneis liber (W. Sm.) Cl.	226975	1.8	1.0	4.3
Nitzschia sigma (Kutz.) W. Sm.	104542	1.8	0.9	4.2
Fallacia forcipata (Grev.) Stick et Mann	157133	1.7	0.7	3.9
Ardissonea crystallina (Ag.) Grun.	104625	1.6	0.7	3.7
Other species				52.4
S – average similarity 61.2%				
Tryblionella punctata W. Sm.	8583	3.1	2.6	5.1
Diploneis smithii (Breb.) Cl.	6909	2.9	5.9	4.8
Nitzschia sigma (Kutz.) W. Sm.	3248	2.7	5.9	4.5
Caloneis liber (W. Sm.) Cl.	3719	2.7	5.4	4.4
Melosira moniliformis (O. Mull.) Ag.	2970	2.4	3.0	4.0
Tabularia gaillonii (Bory) Bukht.	1166	2.1	4.3	3.5
Navicula cancellata Donk.	2870	2.0	1.9	3.3
Grammatophora marina *(Lyngb.) Kutz.*	2235	1.9	2.6	3.1
Lyrella abrupta (Donk.) Gusl. et Kar.	1932	1.8	2.6	3.0
Cocconeis scutellum Ehr.	801	1.7	2.7	2.9
Other species				61.4%

Note: *N,* cells•см$^{-2}$- average abundance of ***i-th*** species in taxocene complex, ***S*** – similarity function, S_i – absolute and $S_i(\%)$ – the relative contribution of ***i-th*** species in average Bray-Curtis similarity within the benthic taxocene complexes.

The average similarity of stations within each of the pollution-related taxocene complexes, evaluated by the Bray-Curtis similarity coefficient, appeared to be rather low for complex L (41.6%) and M (43.1%), whereas in complex S - where environmental conditions (pollution level) are remarkably different from the two other biotopes - average similarity value was highest (61.2%).

In the taxocene complex of the unpolluted Laspi bay, the 11 most significant indicator species (of the total list of 176) determining structural features of the taxocene, bring about 48% of total input into the average similarity within this complex. *Tabularia tabulata* and *Amphora proteus* are the top ranged species of this list (combined relative contribution is 18.1%). In the severe polluted Sevastopol bay, about 39% of the total contribution to the average similarity within the complex is determined by a group of ten top ranged indicator species (of the total list 146). *Tryblionella punctata* var. *punctata, Nitzschia sigma, Caloneis liber* and *Melosira moniliformis* are the leading taxa, displaying the highest values (5.1 – 4.0%) of their relative contribution. These parameters define the indicator role of these species in a given taxocene complex, which is formed under strong technogenic impact on the biotope. In the complex corresponding to the moderately contaminated open water area (M), a list of 8 top-ranged indicator forms (of the total list of 128) was represented by species which can be found in both polluted and healthy environments, such as: *Navicula pennata, Diploneis smithii, Cocconeis scutellum, Fallacia forcipata* and a few others.

While comparing the lists of top ranged indicator species of the two most polluted complexes (L and S), from 18 species and intraspecies, only three appeared to be common. Such a low affinity level (1/6) indicates a pronounced eco-floristic difference between these complexes, probably caused by a different tolerance of most indicator species to pollution. Besides, a high dissimilarity level (average dissimilarity amounted 72.2%) was also revealed when comparing taxocene complexes in the surveyed bays. This testifies to the significant differences between the compared water areas in species structure of a taxocene and the quantitative development of key species.

The most significant indicator species proposed by their relative contribution into average similarity within each of the complexes can also be considered as a discriminating species, hereby contributing extensively to species structure dissimilarity between taxocene complexes in the 3 compared biotopes differentiated by the degree of anthropogenic load. It is proposed to consider *Tabularia tabulata, Amphora proteus* and *Navicula palpebralis* as indicators of conditionally unpolluted biotopes (Laspi bay), whereas *Tryblionella punctata* var. *punctata, Nitzschia sigma* var. *sigma, Caloneis liber* and *Melosira moniliformis* can be considered as indicators of biotopes subject to technogenic impact.

Through a comparative evaluation, the Spearman rank correlation coefficient (ρ) showed that the combination of the variables: depth, Pb, Mn, Cu and PCBs, are best correlated (ρ = 0.73-0.76) with the alteration in structure and diversity patterns of diatom taxocene at a different extent of toxicants.

Conclusion

The database allowed revealing a contemporary state of the art on benthic diatom diversity in the coastal zone of the entire Black Sea. The total list of Black Sea benthic diatoms includes 705 species and intraspecific taxa, pooled in 115 genera, 59 families, 31 orders, 7 subclasses and 3 classes of Bacillariophyta. The highest diatom species richness is registered near Crimea and in the northwestern shelf (NWBS) representing 64.2% and 69.5% respectively of the total number of benthic diatom species in the Black Sea. The comparison of the diatom species composition from the five investigated coastal areas of the Black Sea showed that the highest level of species similarity was revealed between the Crimean and the NWBS area, where the Bray-Curtis similarity index reached up to 77%.

A comparative multivariate analysis of the benthic diatom taxocenes from the three near shore water areas of southwest Crimea showed that these biotopes differ substantially in heavy metal and other pollutant concentrations in the upper sediment layer.

The certain taxocenotic complexes were distinguished in each of the investigated water areas based on cluster analysis and MDS ordination, and significant differences in species structure between the taxocenotic complexes were also revealed. The most important indicator species, which are principally responsible for the similarity within each of the complexes, were determined as well as the most significant discriminating species. Such species can be considered as indicators of the diatom taxocene' state in a comparative assessment of biotopes in different environmental conditions. *Tabularia tabulata, Amphora proteus* and *Navicula palpebralis* are proposed as indicators of conditionally unpolluted biotopes (Laspi bay), whereas *Tryblionella punctata* var. *punctata, Nitzschia sigma* var. *sigma, Caloneis liber* and *Melosira moniliformis* can be seen as indicators of water areas subject to severe technogenic impact (Sevastopol bay).

As the result of a comparative evaluation, the Spearman rank correlation coefficient (ρ) showed that the changes in the structure and diversity features of a diatom taxocene are best associated with a combination of depth, Pb, Mn, Cu and PCBs (ρ = 0.73-0.76).

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