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Structure of phytoplankton communities in Kaliakra protected area, summer 2020 – 2021

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Abstract. *Marine protected area (MPA) Kaliakra is an object of interest owning to its geographic location, the peculiarity of the hydrodynamic processes and the influence of the river inflow into the North - West part of the basin. The analysis of phytoplankton in the area of Cape Kaliakra was based on 20 samples from 16 stations in coastal waters in the summer of 2020 and 2021. The aim of this study was to make a recent assessment of the phytoplankton communities in MPA Kaliakra and to analyze the phytoplankton changes compared to previous years. The received results showed high species diversity (88 species of microalgae, 13 taxonomic classes) and development of stable phytoplankton communities. Increased abundance and biomass of phytoplankton and amounts of nutrients in the summer of 2020-2021 in the protected area of Kaliakra demonstrated degraded water quality. In 2020, the small-sized species Merismopedia sp. and small Flagellates were recorded in blooms, while in 2021 phytoplankton blooms were not recorded.*

Keywords: Western Black Sea, Marine Protected Area, Cape Kaliakra, phytoplankton, taxonomic composition, abundance and biomass

Abbreviations: coastal waters - c.w.; Dinophyceae/Bacillariophyceae – Din/Bac; Institute of fish resources – IFR; Marine Protected Area – MPA; nautical miles – n.m.; station – st.; million cells per cubic meter - mln. cells.m^{-3}; milligram per cubic meter - mg.m^{-3}; volume concentration of a solution - v/v

Introduction

Marine Protected Area Kaliakra is part of the Natura 2000, BG0000573 "Kaliakra Complex" and is influenced mainly by eutrophication due to the Danube River outflow. The local anthropogenic activities are insignificant, limited in the mussel aquaculture and the wind farms construction. It has been a nature reserve since 1941 (updated with the Order of the Minister of Environment and Water ND-767/6 Oct 2014). The Kaliakra Reserve is the only Bulgarian reserve covering the sea area – a strip of 500 m wide and 8 km long (LTER).

Marine habitats in the Kaliakra area are characterized by high biological diversity (Trayanov et al., 2007).

The phytoplankton communities, being the first target of nutrient alterations, are perceived to be a decisive factor for the marine water quality and the ecosystem health. They tend to be the most direct visible consequence of natural and man-induced changes (Petrova et al., 2004; Klisarova and Gerdzhikov, 2016).

There are not enough regular surveys for phytoplankton communities in the area of Cape Kaliakra in summer. Nevertheless, the available ones allow us to describe their main characteristics (Petrova, 1963, 1964, 1965; Petrova - Karadjova, 1973; Moncheva and Konsulova, 1983; Moncheva, 1991a,b; Moncheva et al., 1991, 2001; Petrova et al., 2004).

The Danube river outflow nourishes the ecosystem in the northern region of the Bulgarian coastal waters with nutrients and has a significant impact on the sea waters

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(Rozhdestvensky, 1981).

However, in the summer of 2001-2003, low nutrient concentrations were recorded at an average salinity of 16.39‰ caused by remarkably low level of rainfall (Petrova et al., 2004). The period 2001-2003 was characterized most of the time with low concentrations of inorganic nitrogen, commonly related to the low inflow of nutrients from the Danube transformed waters and a remarkably low level of rainfall (Petrova et al., 2004).

Minimum water transparency values were observed in June 2001 and 2002 during phytoplankton blooms and maximum values in August 2003 (between 2 and 8 m), associated with less phytoplankton development and no blooms (Petrova et al., 2004).

High values of chlorophyll-a (up to 2.6 mg.m^{-3}) were observed in June 2002. Chlorophyll-a in August 2003 had relatively low values (0.28-0.36 mg.m^{-3}) (Petrova et al., 2004).

In 2001–2003 the phytoplankton communities were characterized by predominance of heterotrophic *Dinophyceae* species during most of the year (Petrova et al., 2004).

The main part of the phytoplankton abundance in the Kaliakra area was formed by the species: June 2001 - *Pseudo-nitzschia dellicatisima* ((P.T. Cleve, 1897) Heiden, 1928) - 0.18 mln.cells.l^{-1} and *Akashiwo sanguinea* ((K. Hirasaka) G.Hansen & Ø.Moestrup, 2000); June 2002 - *Emiliania huxleyi* ((Lohmann) Hay & Mohler, 1967) - 4.33 mln. cells.l^{-1} and *Heterocapsa triquetra* ((Ehrenberg, 1840) Stein, 1883) - 1.68 mln.cells.l^{-1}; August 2002 – *E.huxleyi* - 3.66 mln.cells.l^{-1}, *Pseudosolenia calcar-avis* ((Schultze, 1858) Sundström, 1986); August 2003 – *E.huxleyi* and *Thalassionema nitzschioides* ((Grunow) Mereschkowsky, 1902) (Petrova et al., 2004).

In the period 2001-2003, no blooms of harmful or potentially toxic algae were observed, respectively, no cases of hypoxia and benthos mortality were detected (Petrova et al., 2004).

In July 2006, the highest phytoplankton biomasses were observed in the northern part of the Bulgarian coast (from Krapets to Varna Bay). The average of biomass for the entire coastal waters was 1186.63 mg.m^{-3} (Petrova and Gerdzhikov, 2008).

Dominant species were the diatoms *Cyclotella caspia* (Grunow, 1878) and *Th. nitzschioides.* The low chlorophyll-a values defined the coastal area in good ecological condition. Small-sized diatoms and flagellates were common in all coastal water areas from Krapets to Veleka (Petrova and Gerdzhikov, 2008).

In June 2007, in front of Cape Kaliakra, small *Flagellates* and *E. huxleyi* (Primnesiophyceae) predominated in terms of numbers. The biomass was dominated by species of Dinophyceae and Bacillariophyceae (authors' unpublished data).

During the investigations of the Kaliakra transect in June (2008 and 2009), lower values of phytoplankton abundance were found (476.40-1216.63 mln.cells.m^{-3}), biomass (490.75 - 727.31 mg.m^{-3}) compared to those established in front of Cape Galata. Shannon-Weaver index was 1.90-1.99. Transparency reached up to 6.20 m (authors' unpublished data).

In the period 2011-2016, during the study of the horizontal distribution of the chlorophyll-a in the Bulgarian coastal waters the maximum (6.56 mg.m^{-3}) for the whole coastal waters was recorded in June 2011 at st. Kaliakra - 1 mile (Klisarova and Gerdzhikov, 2016).

The blooms species were *Ps. delicatissima* and *E. huxleyi*. *Ps. calcar - avis, Ps. delicatissima*, *Pleurosigma elongatum* (W. Smith, 1852), *Chaetoceros scabrosus* (Prosckina-Lavrenko, 1955), *Prorocentrum cordatum* ((Ostenfeld, 1901) Dodge, 1975), *E. huxleyi* were dominant by biomass (authors' unpublished data).

From the literature review it can be concluded that the higher quantitative values in the area of Cape Kaliakra were observed in spring, while in summer they were lower. In summer, the taxonomic structure of phytoplankton in the area was dominated by heterotrophic species of the class Dinophyceae, small-sized diatoms and cryptophytes.

The aim of this study was to make a recent assessment of the phytoplankton communities in MPA Kaliakra and to analyze the phytoplankton changes compared to previous years.

Material and methods

Study area

The present survey was conducted during 11-13 August 2020 and on 16 July 2021 in the marine waters of Kaliakra Protected Area (1 nautical mile from the coast). The scientific expeditions were carried out with fishing vessel (FV) (FV "Lefer") within the frame of the WHITECLAM project (IFR-Varna). Phytoplankton samples (20) were collected from 16 stations located in the nearshore zone to 25 m depth (stations: Balchik-3 m, Balchik-8 m, Balchik-20 m, Bolata-7÷7.4 m, Bolata-15 m, Kaliakra-18 m, Kaliakra-20 m, Kavarna-3.5÷4 m, Kavarna-15 m, Krapets-3 m, Krapets-8 m, Krapets-25 m, Tiulenovo-23 m; Shabla-4 m, Shabla- 8 m and Shabla - 22 m) (Figure 1).

Collecting the samples

A Niskin bottle (5 l) was used to obtain surface water samples (0 - 0.5 m). On the board of the vessel, the samples were fixed with formalin (up to 2% v/v) and then concentrated in the laboratory by the sedimentation method (Morozova-Vodyanitskaya, 1954).

Taxonomic analyses

The qualitative and quantitative analyses of the samples were performed with a light microscope Olympus BX41 (equipped with microphotography camera *uEye*) in counting chambers *Palmer–Maloney* – 0.05 ml and *Sedgwick Rafter* – 1 ml, using standard methods (Moncheva and Parr, 2010). A micrometer eyepiece was used to determine the size of phytoplankton microalgae. The cell volume was calculated by geometric formulas (Edler, 1979; Olenina et al., 2006). We assumed that the density of phytoplankton cells was equal to 1.

Although there are a lot of uncertainties of what constitutes a bloom (Smayda, 1977), in the Black sea concentrations exceeding >1×10^6 cells.l^{-1} for a single species or >5×10^6 cells.l^{-1} for 2-3 species or biomass >10000 mg.m^{-3} are normally considered a bloom (Moncheva and Parr, 2010).

Taxonomic classification of the species was made according to electronic databases "WoRMS" (WoRMS Editorial Board, 2021) and "Algaebase" (Guiry, 2021).

Measurement of physicochemical parameters

Chlorophyll-a measurements were performed with *Turner Designs Fluorometer* and *Cyclops7 Fluorometer* (to multi parameter probe CTD 90M). Transparency was established using a *Secchi* disc. Physicochemical parameters of water were measured with multiparameter devices Eutech - CyberScan PCD650 and CTD90M.

Statistics and graphs

Three software programs, Phytomar 2.0 (Klisarova, 2008), Excel (Microsoft Office) and Ocean Data View 4.7.4 were used for calculations and graphs.

Figure 1. Map with the location of the sampling stations in the Kaliakra protected area, 2020-2021 (*the maximum depth of each station is indicated by meters after its name)

Results and discussion

Taxonomic structure of phytoplankton in the marine coastal waters of MPA Kaliakra

In the surveyed marine areas during July-August, 2020-2021, we recorded the development of a total of 88 phytoplankton species, distributed in 13 taxonomic classes. Representatives of the class Dinophyceae (52.27%; 46 species) dominated, which usually develop with a higher species diversity in summer. They were followed by representatives of the class Bacillariophyceae (25.00%; 22 species). The two classes were recorded with a total of 77.27%. Of the remaining 11 classes, Cryptophyceae, Chlorophyceae, Cyanophyceae - (3-4 species) were found with the highest number of species. The remaining 8 classes (Euglenophyceae, Prymnesiophyceae, Prasinophyceae, Trebouxiophyceae, Chlorophyta i.s., Craspedophyceae, Dinoflagellata i.s., Pyramimonadophyceae) were recorded with 1-2 species (Figure 2).

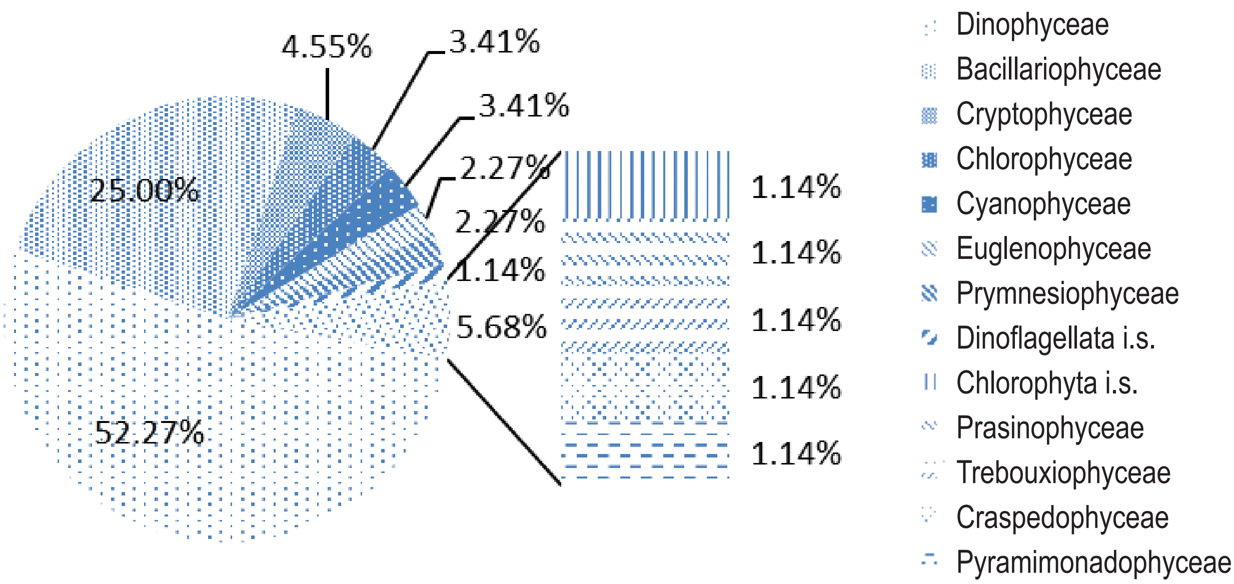


Figure 2. Taxonomic composition of phytoplankton in summer (July, August) in the coastal water zone of Kaliakra protected area, 2020-2021

The data on the qualitative composition of phytoplankton in July and August 2020-2021 were compared with the available data (from our previous studies) for the period 2000-2019 in the region of Cape Kaliakra, and with data for the entire Bulgarian coast up to 3 miles from the shore (surface layer of water 0-1 m).

As a result, we observed that typical for the water area of Kaliakra protected area, in summer was a higher number of species of class Dinophyceae and a lower share of species of class Bacillariophyceae. The share of class Chlorophyceae species was also lower. Typical for the waters around Cape Kaliakra was the ratio of the number of species of Dinophyceae/Bacillariophyceae > 2.07, while the average for the entire Bulgarian coastal waters was 1.29 (Table 1).

This may be due to the higher eutrophication of the area due to the influence of nutrient-rich waters from the Danube river (Petrova et al., 2022). It was found that dinoflagellates are more competitive than diatoms under high nutrients and warming conditions, particularly in highly eutrophic bays and coasts (Bi et al., 2021).

Table 1. Comparison between the taxonomic composition of phytoplankton (%, species) in surface layer marine areas: Kaliakra 2020-2021; Kaliakra 2000-2019; the whole Bulgarian marine coastal area (up to 3 n.m.) 2000-2019, in July and August

№	Taxon/Class	Marine area of Kaliakra 2020-2021	Marine area of Kaliakra 2000-2019	Marine coastal area 2000-2019
1	Dinophyceae	51.81% (43)	49.12% (56)	40.26% (93)
2	Bacillariophyceae	24.10% (20)	23.68% (27)	31.17% (72)
3	Chlorophyceae	3.61% (3)	3.51% (4)	6.49% (15)
4	Cyanophyceae	3.61% (3)	4.39% (5)	4.76% (11)
5	Prymnesiophyceae	2.41% (2)	4.39% (5)	4.33% (10)
6	Cryptophyceae	4.82% (4)	6.14% (7)	3.03% (7)
7	Euglenophyceae	2.41% (2)	2.63% (3)	3.03% (7)
8	Trebouxiophyceae	1.20% (1)	0.88% (1)	2.16% (5)
9	Dictyochophyceae	0.00% (0)	1.75% (2)	0.87% (2)
10	Chlorophyta i.s.	1.20% (1)	0.88% (1)	0.43% (1)
11	Craspedophyceae	1.20% (1)	0.88% (1)	0.43% (1)
12	Dinoflagellata i.s.	1.20% (1)	0.00% (0)	0.43% (1)
13	Prasinophyceae	1.20% (1)	0.88% (1)	0.43% (1)
14	Pyramimonadophyceae	1.20% (1)	0.88% (1)	0.43% (1)
15	Zygnematophyceae	0.00% (0)	0.00% (0)	0.43% (1)
16	Chlorodendrophyceae	0.00% (0)	0.00% (0)	0.43% (1)
17	Chrysophyceae	0.00% (0)	0.00% (0)	0.43% (1)
18	Euglenoidea	0.00% (0)	0.00% (0)	0.43% (1)
	Total number of species	**83 species**	**144 species**	**231 species**
	Ratio Din/Bac	**2.15**	**2.07**	**1.29**

Quantitative analysis of the phytoplankton communities in the Kaliakra marine protected area

Phytoplankton developed at different intensities in the research period. Only in 2020 phytoplankton blooms were recorded (Figure 3).

In 2020, the maximum phytoplankton abundance was found at st. Krapets-25m, 12394.20 mln. cells.m^{-3} and the minimum in the area of Balchik-20m, 795.32 mln. cells.m^{-3}. The maximum of biomass was at Bolata-15m, 4690.25 mg.m^{-3} and the minimum - at Balchik-8m, 904.10 mg.m^{-3} (Figure 3).

The average phytoplankton quantitative values for 2020 in the surface water layer were: abundant - 4464.68 mln. cells.m^{-3}, biomass - 2363.42 mg.m^{-3}; Shannon index - 2.05.

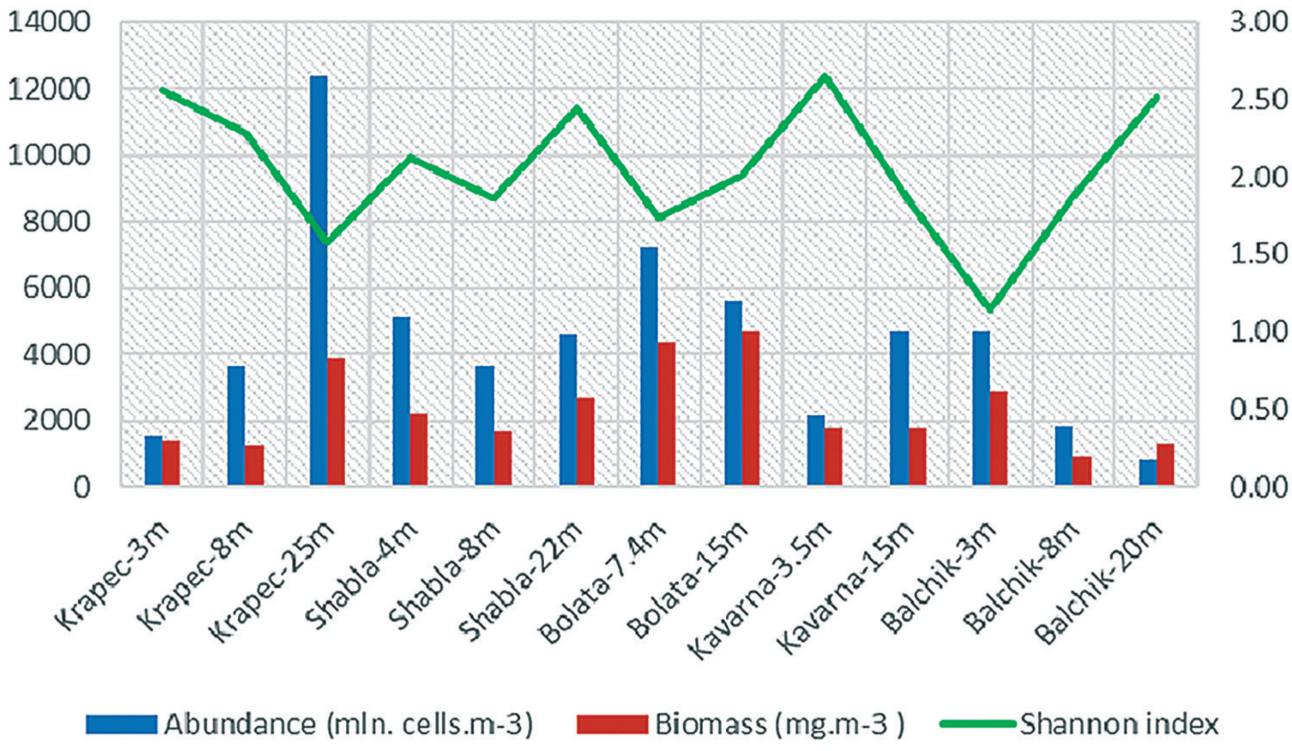


Figure 3. Abundance (mln.cells.m^{-3}), biomass (mg.m^{-3}) and Shannon index of phytoplankton communities in the Kaliakra protected area, August 2020

At the stations located north of Cape Kaliakra, almost twice the abundance and biomass were recorded compared to the stations west of Cape Kaliakra (Figures 1 and 3, Table 2).

With the exception of st. Balchik-3m, at all other stations in 2020 the Shannon index indicated the development of stable phytoplankton communities, according to a report of BDBSR (2004) (Figure 4, Table 1).

Table 2. Average quantitative values of phytoplankton development in the water areas north and west of Cape Kaliakra, 2020

	Average Abundance (mln. cells.m^{-3})	Average Biomass (mg.m^{-3})	Average Shannon index
North of Cape Kaliakra	5478.09	2767.46	2.08
West of Cape Kaliakra	2843.22	1716.97	2.01
Difference	1.93	1.61	1.04

In phytoplankton abundance in 2020 two species with small sizes (~2÷6 µm) were the largest contributors (≥25%); *Merismopedia sp.* (Meyen, 1839), (Cyanophyta) and the cryptophyte small *Flagellates*. *Merismopedia sp.* were recorded in a bloom state at st. Krapets-25m - 9046.67 mln. cells.m^{-3}, and small *Flagellates* at st. Shabla-22m - 1306.92 mln. cells.m^{-3}.

Three diatom species with large individual cell sizes were the largest contributors (≥25%) to phytoplankton biomass in 2020: *Proboscia alata* ((Bright.) Sund., 1986) recorded with 2259.39 mg.m^{-3} at st. Bolata-15m; *Ps. calcar-avis* - 1560.31 mg.m^{-3} at Bolata-7.4m; and *Pseudo-nitzschia seriata* with the maximum 939.79 mg.m^{-3} at st. Shabla-22m.

In recent years, the phytoplankton communities in the Black Sea off the Bulgarian coast have been subjected to changes in the main analyzing parameters (species diversity, taxonomic structure and quantitative development - abundance and biomass). The decrease in the frequency of phytoplankton blooms has been accompanied by an increase in the role of small-sized species in the phytoplankton communities.

In 2021, 6 times lower phytoplankton abundance and 3 times lower biomass were recorded in MPA Kaliakra, compared to the values recorded in 2020, and almost the same average value for the Shannon index.

No significant differences were observed between phytoplankton development north of Cape Kaliakra and west of it. The mean values for 2021 were: abundance - 695.72 mln.cells.m^{-3}, biomass - 824.24 mg.m^{-3} and Shannon index - 2.09 (Figure 4). The most unstable phytoplankton community (according to the Shannon index value) was observed at st. Krapets-4m (Figure 4).

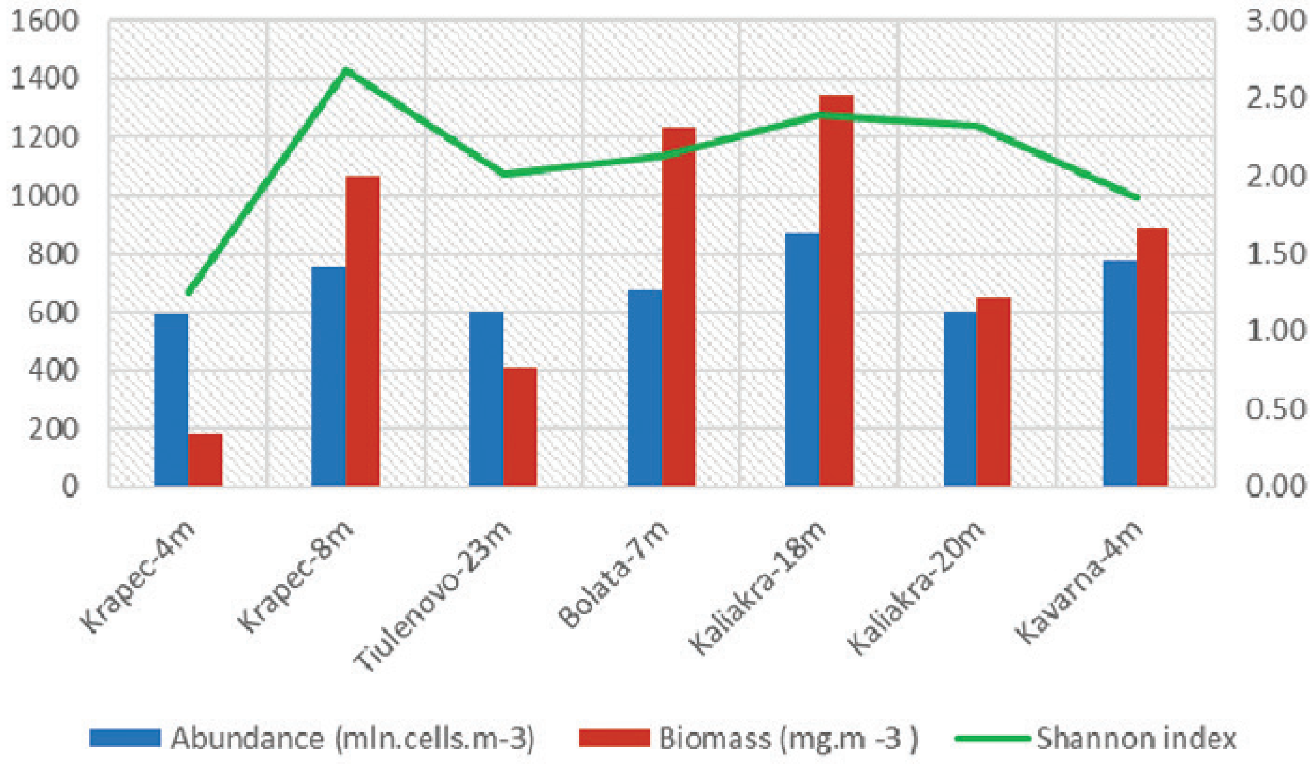


Figure 4. Abundance (mln.cells.m^{-3}), biomass (mg.m^{-3}) and Shannon index of phytoplankton in the Kaliakra marine protected area, July, 2021

No phytoplankton blooms were recorded in 2021. Phytoplankton abundance was dominated by two species: small *Flagellates* (Cryptophyceae) with a maximum of 552.67 mln.cells.m^{-3} at st. Kavarna-4m and *E. huxleyi* (Prymnesiophyceae) - 239.50 mln. cells.m^{-3} at st. Kaliakra-20m.

Dominance of *E. huxleyi* was also recorded in the summer of 2002, but then it developed in bloom abundances (Petrova et al., 2004).

According to Moncheva et al. (2013), during the current stage of the Black Sea ecosystem development (post-eutrophication) *E.huxleyi* was often recorded as the dominant species in phytoplankton abundance.

The phytoplankton biomass in 2021 was dominated (≥25%) by 6 species Dinophyceae (*Akashiwo sanguinea* – biomass 830.41 mg.m^{-3} at st. Kaliakra-18m; *Gymnodinium sp.* - 388.70 mg.m^{-3}, st. Bolata-7m; *Gymnodinium najadeum* (Schiller, 1928) - 291.09 mg.m^{-3}, st. Krapets-8m; *Peridinium breve* (O.W.Paulsen, 1907) - 267.94 mg.m^{-3}, st. Kavarna-4m; *Gonyaulax spinifera* (Diesing, 1866) - 167.20 mg.m^{-3}, Kaliakra-20m) and small *Flagellates* (Cryptophyceae) at st. Krapec-4m. Class Bacillariophyceae were dominant during the 2020.

The mean values of chlorophyll-a were similar in both years of study, the maximum value was recorded in 2020 at st. Krapets-25m - 0.61 mg.m^{-3} (Figure 5).

Chlorophyll-a values (a proxy variable for phytoplankton biomass assessment (Moncheva et al., 2013) are dependent on the physiological state of phytoplankton cells, kind of phytoplankton species and other factors.

In August 2020, the average chlorophyll-a value in MPA Kaliakra was 0.27 mg.m^{-3} (max-0.61, min-0.12), about 2 times higher values were recorded north of Cape Kaliakra (average 0.32 mg.m^{-3}) compared to stations located to the west (0.17 mg.m^{-3}) (Figure 5).

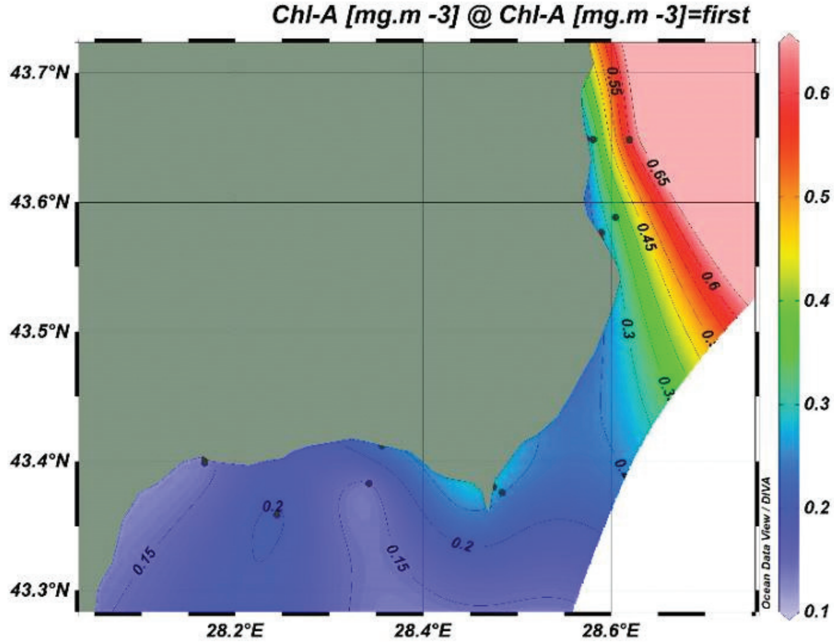


Figure 5. Horizontal distribution of chlorophyll-a values (mg.m^{-3}) in the Kaliakra protected area, 2020

In July 2021, the average concentration of chlorophyll-a in the area of Cape Kaliakra was 0.35 mg.m^{-3} (max-0.5, min-0.23). There was no difference in this parameter between the area north of Cape Kaliakra and that located to the west (Figure 6). The maximum value was recorded at the station Bolata-7m, 0.5 mg.m^{-3}.

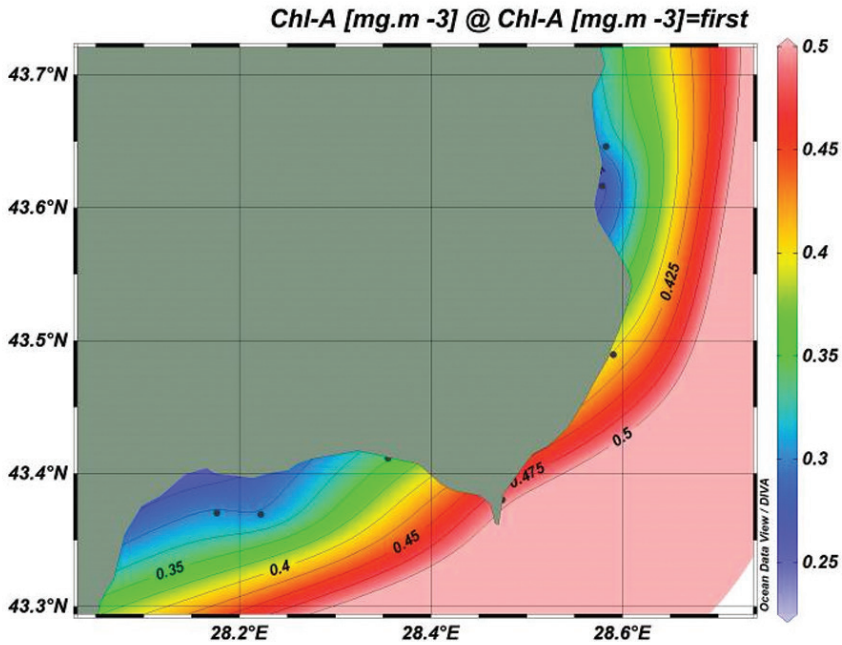


Figure 6. Horizontal distribution of chlorophyll-a values (mg.m^{-3}) in the Kaliakra protected area, 2021

The recorded values of chlorophyll-a in the area of Cape Kaliakra during the present study were comparable to the results of the studies in August 2003 (0.1-1.0 mg.m^{-3}) (Petrova et al., 2004), but also they were lower than those established in June 2011 (6.56 mg.m^{-3}) (Klisarova and Gerdzhikov, 2016)

We compared the mean abundances and biomasses of the phytoplankton communities in the Kaliakra area found in the current study with the long term (2000-2019) mean values in the surface water and the mean values for the whole Bulgarian coastal area (up to 3 n.m.) for the years 2000-2019 (Figure 7).

We found that in the Kaliakra area in summer a long-term persistent trend for higher phytoplankton abundances and lower biomasses were formed, compared to other coastal water areas. The observed (2020-2021) higher abundances and biomasses can be explained by increasing eutrophication pressure and deterioration of the ecological status in the zone (Figure 7).

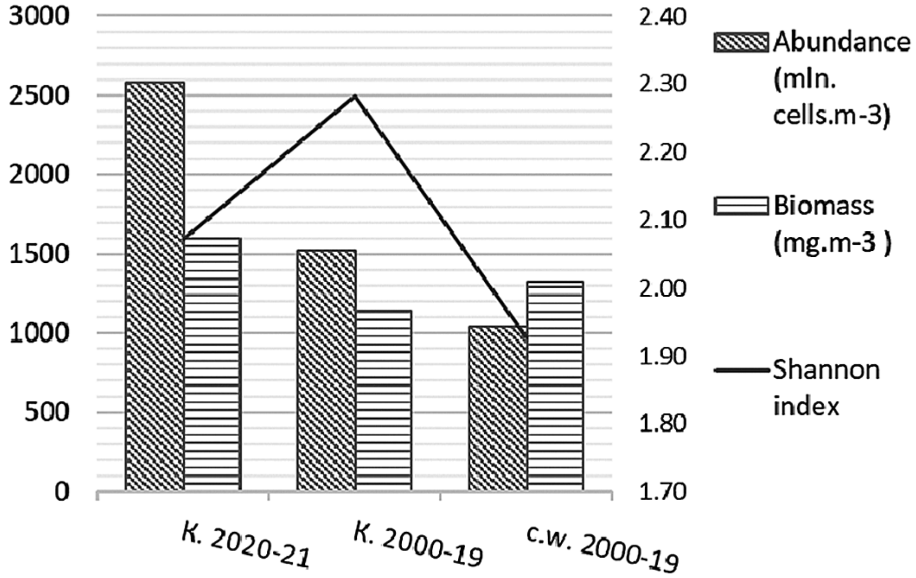
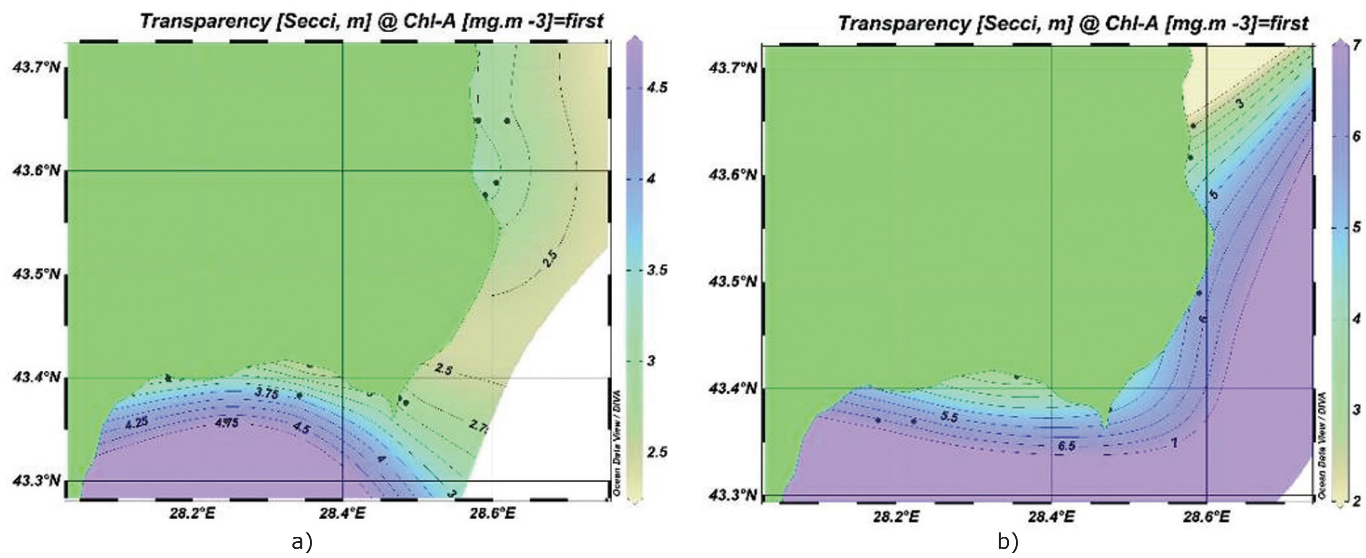


Figure 7. Comparison between mean abundance (mln.cells.m^{-3}), biomass (mg.m^{-3}) and Shannon index (in the surface water layer) of phytoplankton in MPA Kaliakra (K.) 2020-2021 and Kaliakra (K.) 2000-2019, and coastal regions along the Bulgarian Black Sea coast (c.w.) (up to 3 n.m.) 2000-2019, in July and August

In 2020, in the Kaliakra area, seawater transparency was recorded, in Secchi (m), ranging between 2.40 and 4.70 m, averaging 3.15 m (Figure 8a). In 2021 it was between 2.20 and 6.60 m, averaging 4.69 m, about 1 m higher than the previous year (Figure 8b). This fact correlates with lower phytoplankton abundances in 2021. The zone of lower transparency in 2020 extended southwards to Cape Kaliakra (Figure 8a), whereas in 2021 it was shifted northwards, in the area above st. Krapets (Figure 8b), perhaps demonstrating the weaker influence of the Danube transformed waters in the second year (Figure 8).



a) b)

Figure 8. Transparency of marine waters in Kaliakra protected area, a) 2020, b) 2021

Conclusion

The phytoplankton in MPA Kaliakra during the summer of 2020-2021 was distinguished by a relatively high species diversity. A total of 88 species of microalgae in 13 taxonomic classes were observed. The classes Dinophyceae (52.27%; 46 species) and Bacillariophyceae (25.00%; 22 species) were dominating. In August 2020 and July 2021 in the waters around Cape Kaliakra a ratio between the number of species of Dinophyceae/Bacillariophyceae > 2.07 was found. During the period 2000-2019 the ratio of the number of species of Dinophyceae/Bacillariophyceae for the entire Bulgarian coastal waters was equal to 1.29. In 2020, the highest quantitative values for the study period were recorded in the Kaliakra MPA - abundance 4464.68 mln.cells.m^{-3}, biomass - 2363.42 mg.m^{-3}. In 2021, the average abundance in the area was 6 times lower and the biomass 3 times - 695.72 mln.cells.m^{-3} and 824.24 mg.m^{-3}. In a retrospective analysis of the available data in the Kaliakra MPA in the summer season of 2000-2019, higher abundances and lower biomasses of phytoplankton were found compared to the average phytoplankton values in Bulgarian coastal waters for the same period. In the study period (2020-2021) we recorded an increase in both phytoplankton abundance and biomass (compared to 2000-2019). This is due to the measured higher concentrations of nutrients in the waters off Cape Kaliakra compared to previous years. In 2020, the dominant species by abundance were *Merismopedia sp.* and small *Flagellates* (blooms), and by biomass – *Pr. alata*, *Ps. calcar-avis* and *Ps.seriata*. No phytoplankton blooms were recorded in 2021. High abundance occurred in: small *Flagellates* and *E.huxleyi*. The phytoplankton biomass was dominated by 6 species of dinoflagellates: *Ak. sanguinea*, *Gym. sp.*, *Gym. najadeum*, *Per. breve* and *Gon. spinifera*; and small *Flagellates* (Cryptophyceae). Shannon index showed the development of stable phytoplankton communities in the Kaliakra area: 2020 - 2021. Chlorophyll-a was observed with low values between 0.12 - 0.61 mg.m^{-3}. The average transparency of marine waters was between 3.15 - 4.69 m. The results obtained in this study can be taken as an indication of increasing eutrophication, deterioration of ecological water quality and described the bad state of the waters according to the "Classification system for the ecological state of certain types of surface waters from the category "Coastal marine waters", (SG №79, 2014) in the Kaliakra MPA.

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References

Bi R, Cao Zh, Ismar-Rebitz S, Sommer U, Zhang H, Ding Y and Zhao M, 2021. Responses of Marine Diatom-Dinoflagellate competition to multiple environmental drivers: Abundance, elemental, and biochemical aspects. Frontiers in Microbiology, 12, 1-15. https://doi.org/10.3389/fmicb.2021.731786

Edler L, 1979. Recommendations for marine biological studies in the Baltic Sea phytoplankton and chlorophyll. Baltic Marine Biologists, 5, 1-38.

Guiry MD, 2021. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. from http://www.algaebase.org; accessed on 12 November 2021.

Klisarova D, 2008. System for calculation of quantitative indicators of phytoplankton in the Black Sea. PhytoMar, Version 2.0, Institute of Fish Resources – Varna (Bg).

Klisarova D and Gerdzhikov D, 2016. Dynamics of chlorophyll-a concentrations off the Bulgarian coast 2011 - 2016. Proceedings of the Union of Scientists - Varna, Marine Sciences Series, 37-42 (Bg).

LTER. from http://www.lter-bulgaria.net/wordpress/en/black-sea/, accessed on 24 June 2022.

Moncheva SP, 1991a. On the thermohaline development of some mass phytoplankton species from the northern part of the Bulgarian coast. Oceanology, BAS, Sofia, 21, 14-20 (Bg).

Moncheva SP, 1991b. Quantitative development of phytoplankton species as an indicator of eutrophication of the Bulgarian Black Sea coast. Oceanology, BAS, Sofia, 21, 21-30 (Bg).

Moncheva S and Konsulova Ts, 1983. Phytoplankton in the diet of cultivated mussels *Mytilus galloprovincialis* Lam. in the area of Cape Kaliakra. Proceedings of IFR - Varna, 20, 145-152 (Bg).

Moncheva S and Parr B, 2010. Manual for phytoplankton sampling and analysis in the Black Sea, 68 p. http://documents.blacksea- commission.org/Downloads/Phytoplankton_%20Mannual-Final-1.pdf, accessed on 01 June 2010.

Moncheva SP, Rusev CR and Sofronov I, 1991. On the biological cyclicity of some bloom-forming phytoplankton species from the Bulgarian coast. Oceanology, BAS, Sofia, 21, 31-38 (Bg).

Moncheva S, Slabakova V and Doncheva V, 2013. Dominant habitat types in the water column - Phytoplankton. In: Initial assessment of the state of the marine environment, according to Article 8 of the WFD and the NOEMS, Basin Directorate for the Black Sea Region centered in Varna, 168-180 (Bg).

Moncheva S, Gotsis-Skretas O, Pagou K and Krastev A, 2001. Phytoplankton blooms in Black Sea and Mediterranean coastal ecosystems subjected to anthropogenic eutrophication: Similarities and differences. Estuarine, Coastal and Shelf Science, 53, 281-295. doi:10.1006/ecss.2001.0767

Morozova-Vodyanitskaya NV, 1954. Phytoplankton of the Black Sea, Part II. Proceedings of the Sevastopol Biological Station, 8, 11-99 (Ru).

Olenina I, Hajdu S, Edler L, Andersson A, Wasmund N, Busch S, Göbel J, Gromisz S, Huseby S, Huttunen M, Jaanus A, Kokkonen P, Ledaine I and Niemkiewicz E, 2006. Biovolumes and size-classes of phytoplankton in the Baltic Sea. HELCOM Baltic Sea Environmental Proceedings, 106, 144.

Petrova - Karadjova VY, 1973. Dynamics of phytoplankton biomass in the Black Sea off the Bulgarian coast during the period 1964 - 1970. Proceedings of IOF - Varna, XII, 41 – 66. (Bg)

Petrova E, Mihneva V, Stoykov S, Dineva S, Gerdzhikov D, Petrova D, Uzunova S and Penchev F, 2022. Supplementing the information on descriptors D1 and D3 to the MSFD. Final report of the project “Research on white mussel species and proposal for new management measures (WHITECLAM)”, funded by the Marine and Fisheries Programme 2014-2020, №MDP - IP - 01 - 34/ 25.03.2019, 101 pp. (Bg).

Petrova D and Gerdzhikov D, 2008. The phytoplankton community – an indicator of the ecological state along the Bulgarian Black sea coast. In: Cercetari marine, INCDM, 38, 53-72.

Petrova D, Shtereva G and Velikova V, 2004. Nutrients, chlorophyll-a and phytoplankton in Bulgarian Black Sea (Cape Kaliakra) – In: Proceeding of BALWOIS Conference, 24-29 May 2004, Ohrid, Macedonia.

Petrova VY, 1963. Phytoplankton along the Bulgarian coast of the Black Sea during the period 1954 - 1957. Proceedings of CRIFFF - Varna, 3, 31-60 (Bg).

Petrova VY, 1964. Phytoplankton along the Bulgarian coast of the Black Sea during the period 1958 – 1960. Proceedings of IFR-Varna, 5, 5-32 (Bg).

Petrova VY, 1965. Peculiarities in the development of phytoplankton in the Black Sea off the Bulgarian coast in 1961-1963. Proceedings of NIFO - Varna, 6, 63 -74 (Bg).

Report of BDBSR, 2004. Assessment of the current water quantity and quality in the Black Sea basin district for 2005”, MoEW, BDBSR - Varna. Uzunov J. et al., 2004. “Determination of reference points and intercalibration sites according to the requirements of WFD” 508/2004, funded by the Ministry of Environmental Protection (Bg).

Rozhdestvensky AV, 1981. Causes and hydrochemical effect of seawater blooms on the Bulgarian coast in 1979. Oceanology, BAS, 8, 29-39 (Bg).

SG №79, 2014. State Gazette, No. 79 of 23 September 2014, Official Gazette of the Republic of Bulgaria (Bg).

Smayda T, 1997. What is a bloom? A commentary. Limnology and Oceanography, 42, 1132-1136.

Trayanov T, Raykov V, Marinova V, Michneva V, Zaharia T, Maximov V, Yankova M and Golumbeanu M, 2007. Marine protected areas in the northern part of the Bulgarian Black sea shelf. Journal of Environmental Protection and Ecology, 8, 574-590.

WoRMS Editorial Board, 2021. World Register of Marine Species. from https://www.marinespecies.org at VLIZ, accessed on 18-November-2021.

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