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Phytoplankton quantitative development and species diversity in the Bulgarian Black Sea waters during 2014-2017

Daniela Klisarova[1*], Dimitar Gerdzhikov[1], Gergana Kostadinova[2], Diyana Dermendzhieva[2]

[1]*Institute of Fish Resources, Primorski Blvd. 4, 9000 Varna, Bulgaria*
[2]*Trakia University, Faculty of Agriculture, Department of Applied Ecology and Animal Hygiene, 6000 Stara Zagora, Bulgaria*
[*]*Corresponding author:* danielaklisarova1@abv.bg

Abstract

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The aim of this study is to analyse the characteristics in the development of the phytoplankton communities in the Bulgarian part of Black Sea and in Varna Lake in present days, to trace the occurring changes and to assess their ecological status. During the study period (2014-2017), 196 phytoplankton samples were collected from 52 stations by bathometer type Niskin-5L. The samples were prepared for analysis (fixed and concentrated) and analyzed by routine methods. The analysis of the qualitative and quantitative structure of phytoplankton in the monitored areas revealed the existence of 182 phytoplankton species belonging to 14 taxonomic classes. The share of *Dinophyceae*/*Bacillariophyceae* group in the phytoplankton composition was 72.53%. A total of 8 species in the coastal and shelf zones and 7 species in the water of Varna Lake were found in bloom-causing concentrations. The highest quantities of phytoplankton were produced during the winter-spring period, with a trend toward increasing the numbers and phytoplankton biomass from 2014 to 2017. The ecological assessment based on results for the phytoplankton determined the ecological status of coastal and shelf water as "*moderate*" and the ecological status of Varna Lake water as "*bad*".

Keywords: Black Sea; coast and shelf; Varna Lake; phytoplankton; phytoplankton structure; seasonal dynamics; ecological assessment

Introduction

Phytoplankton plays a key role in biogeochemical processes, the global carbon cycle and the transformation of energy along food chains in marine ecosystems. The status of marine phytoplankton affects the commercial fishing, human health (toxic species), CO_2 uptake, and the reaction of the hydroecosystems to the climate change. To anthropogenic loading or climate change, the phytoplankton community responds by changing of the dominant complexes, species diversity, abundance and biomass quantity (Zaitzev, 1992; Moncheva et al., 2013; Petrova, 2014; Gerdzhikov, 2014; Petrova & Gerdzhikov, 2015). The phytoplankton structure and its biomass are the parameters involved in assessments and ecological categorization of marine waters at EU (Directive 2000/60/EC) and national (Ordinance No. H-4, 2012) levels. The Black Sea, defined as the most isolated sea in the world, is no exception of all these processes.

In the 1970s-1980s, the dramatic changes occurring in the Black Sea ecosystem led to a decrease in biodiversity. A natural response to the intensive eutrophication was the high phytoplankton biomasses and abundance, reaching bloom-causing concentrations and hypoxic situations near the bottom, as well as mass fish deaths (Petrova-Karadzhova, 1984; Nesterova, 1987; Velikova et al., 1999; Mee, 1992; Kamburska et al., 2003).

In the last 25 years, the monitoring analyses in different areas of the Black Sea have outlined a steady tendency towards ecosystem recovery (Bodeanu et al., 1998; Moncheva, et al., 2001; Mee et al., 2005; AAQQWBSB, 2005; Petrova, et al., 2006). This process, albeit slowly, occurs in the conditions of modified taxonomic structure of the phytoplankton and dynamics of the nutrients in the marine environment (Borysova et al., 2005; Moncheva et al., 2013; Klisarova et al., 2015).

The aim of this article is to analyse the characteristics of the development of the phytoplankton communities in the Bulgarian part of the Black Sea and in Varna Lake in present days, to trace the occurring changes and to assess their ecological status.

Materials and Methods

Study area

The study was carried out in Bulgarian Black Sea marine area during the period 2014-2017. The monitored water bodies included 52 stations as follows:

- For phytoplankton analyses: Varna lake (A-22; I channel; Rowing base); Varna bay (B-1, B-3, B-5, B-7, B-10, B-6; I-st offshore breakwater and south beach); Cape Galata (G-1, G-3 и G-5 nautical miles); from station Mussel farm in front of Cape Ilandjik.
- In the case of trawling for assessment of turbot (*Scophthalmus maximus*) stocks in the shelf zone from Krapets village to Rezovska River: May 2016 - D12-28.03138/42.73305, D14-28.04179/42.56168, D9-28.07711/42.96836, E13-28.13521/42.64471, E17-28.16282/42.28221, E19-28.10092/42.15599, E8-28.10843/43.07593, F16-28.18097/42.35305, F18-28.178/42.19571, G6-28.27231/43.17465, J5-28.51612/43.27174, J7-28.55314/43.16045, N1-28.85227/43.65155 and May 2017 - C11-27.991158/42.760723, D12-28.026157/42.691906, D14-28.056860/ 42.523510, D16-28.008499/42.411263, D18-28.053497/42.211380, E17-28.151443/42.314110, F7-28.236782/43.099716, J6-28.429201/43.177231, L1-28.713987/43.654457, L3-28.730639/43.449490, M4-28.778536/43.368622 (Fig. 1).

Sampling, sample preparation and analyses

During the monitoring period, 196 phytoplankton samples were collected from all 52 stations. Phytoplankton samples were collected by bathometers type Niskin-5L at surface – bottom horizons in shallow waters; and from 0 m to 10 m in other areas. The samples were fixed onboard in 2% formalin solution and concentrated by the sedimentary method (Morozova-Vodyanitskaya, 1954). The qualitative and quan-

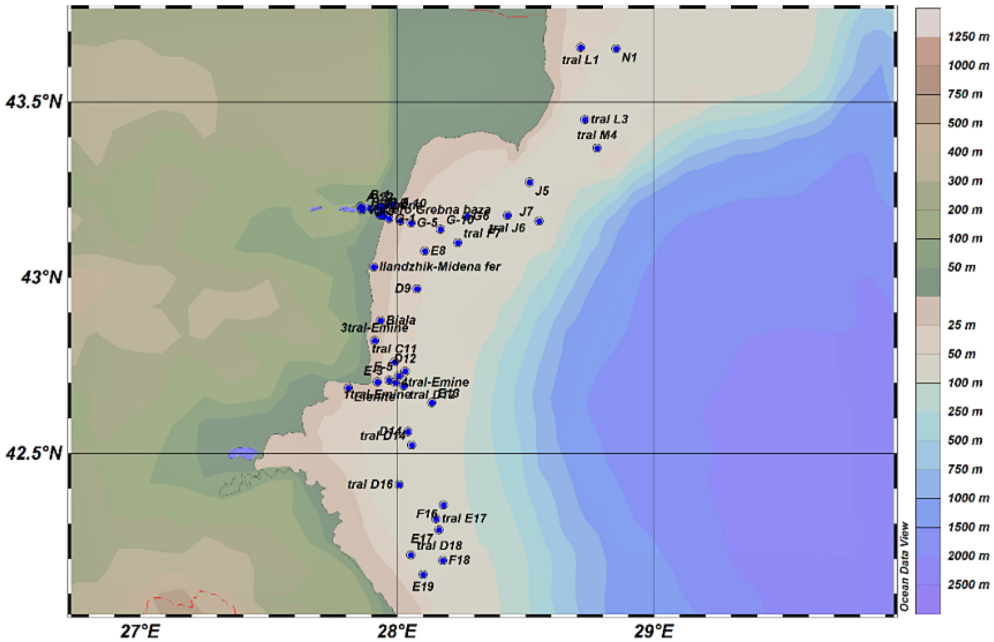

Fig. 1. Map at sampling stations, 2014-2017

titative analyses of the samples were performed with a light microscope OlympusBX41 in counting cells *Sedgewick Rafter* – 1 ml and *Palmer-Maloney* – 0.05 ml, using standard methods (Moncheva & Parr, 2010).

Measurements of chlorophyll-*a* (Turner Designs Fluorometer), transparency (Secchi disk) and physicochemical parameters of water (multiparametric device - Eutech - PCD650) were performed.

Statistics

The cell volume was calculated by geometric formulas (Edler, 1979; Olenina et al., 2006). Software Phytomar 2.0 (Institute of Fish Resources – Varna, 2008); Ocean Data View 4.7.4 and Excel 12 (Microsoft Office 2007) were used for calculations and graphs.

Ecological status assessment

The ecological status assessment of the water of the investigated marine areas was made according to a Classification system for ecological status of the specific *types of surface water,* category "Coastal marine waters" published in Ordinance No. H-4 (2012).

Results and Discussion

Qualitative composition of phytoplankton

During the 4 years surveyed, growth of a total of 182 phytoplankton species and forms of 14 taxonomic classes was recorded in the Bulgarian marine aquatory. The highest percentage of the taxonomic composition was occupied by class *Dinophyceae* 43.41%, followed by the classes *Bacillariophyceae* 29.12% and *Chlorophyceae* 8.24%. The remaining microalgae classes did not exceed 3.85% (Fig. 2).

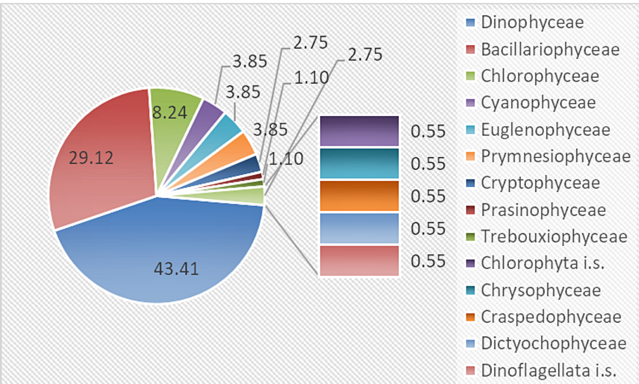

Fig. 2. Taxonomic composition of phytoplankton in the Bulgarian marine areas, 2014-2017

The taxonomic share of the classes of the group "Others" (classes *Chlorophyceae, Cyanophyceae, Euglenophyceae, Prymnesiophyceae, Cryptophyceae, Prasinophyceae, Trebouxiophyceae, Chlorophyta* i.s., *Chrysophyceae, Craspedophyceae, Dictyochophyceae*) decreased from 2014 to 2017, except for the class *Prymnesiophyceae*, whose share increased (Fig. 2 and Fig. 3).

To class *Prymnesiophyceae* were listed the following rare species: *Calciosolenia granii* Schiller, 1925 and *Acanthoica janchenii* Schiller, 1925. The *Dinophyceae/Bacillariophyceae* group increased its share from 2014 to 2017 (from July to December) as the *Dinophyceae* class (Peridinae) prevailed in the total taxonomic composition (Fig. 3). *Dinophyceae* class was established with a high percentage of participation from April to December, and diatoms dominated in February and March. The share of the classes of the group "*Others*" was the highest in the first half of the year (from February to June), then it did not exceed 30% (Fig. 4).

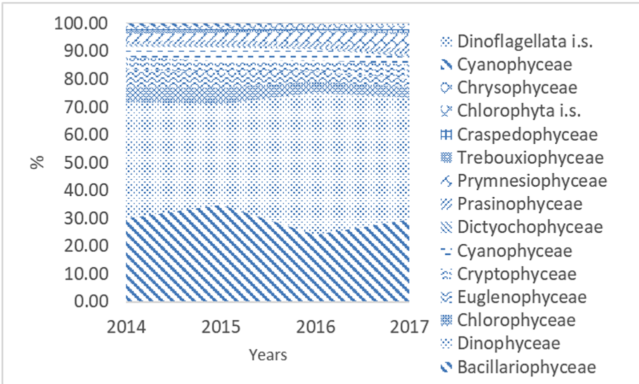

Fig. 3. Annual dynamics in the taxonomic composition of phytoplankton in the Bulgarian marine areas, 2014-2017

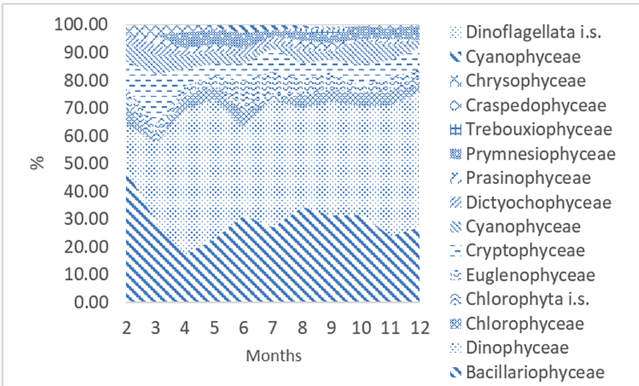

Fig. 4. Monthly dynamics in the taxonomic composition of phytoplankton in the Bulgarian marine areas, 2014-2017

The highest biodiversity of phytoplankton (by number of species) was recorded in spring (May) and late summer (September), (Fig. 5). It correlates with previous studies that established the maximum in biodiversity June - September (Klisarova et al., 2015; Petrova & Gerdzhikov, 2015). The reported slight change might be caused by differences in the intensity and frequency of occurrence of various hydrological impacts on the water column or the periodicity of biogenic supply to the photic water layer (Sommer et al., 1993; Sommer, 1995; Polishchuk, 1999).

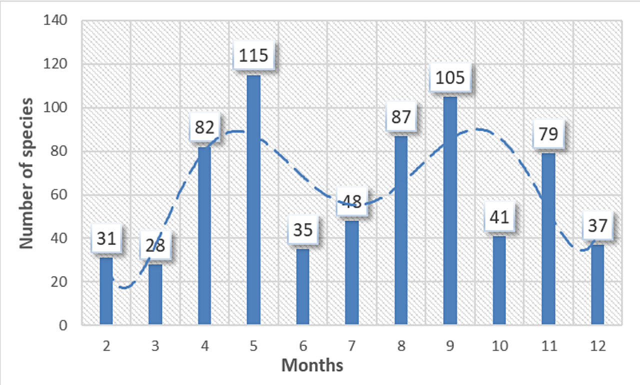

Fig. 5. Monthly dynamics in the number of phytoplankton species in the Bulgarian marine areas, 2014-2017

Quantitative development of phytoplankton

In the quantitative structure of the phytoplanktonic communities, microalgae of the group "Others" dominated in number by an average of 82.02%, class *Bacillariophyceae* and class *Dinophyceae* occupied 9.75% and 8.75%, respectively (Fig. 6a). Phytoplankton biomass was dominated by *Dinophyceae* class (50.30%), and *Bacillariophyceae* and "*Others*" were 23.02% and 27.47%, respectively (Fig. 6b).

Compared with our previous studies (Petrova et al., 2014), we found a significant change in the seasonal quantitative structure of the phytoplankton communities. The share of class *Bacillariophyceae* in biomass decreased significantly during the spring and summer seasons, while the group "*Others*" demonstrated high participation in the phytoplankton biomass in winter and spring (Fig. 6). On average, in the period 2014-2017, the highest phytoplankton numbers and biomass were observed in winter and spring (Fig. 7 and Fig. 8).

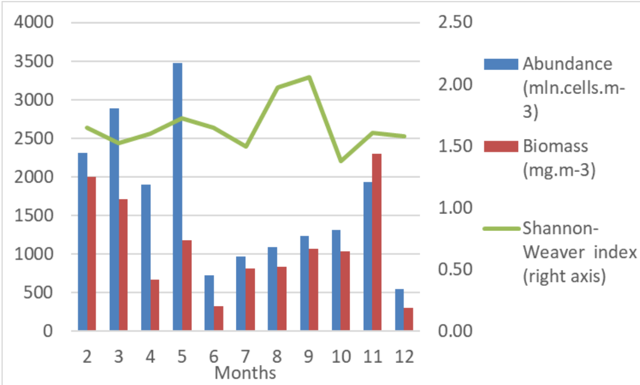

Fig. 7. Average monthly values for abundance (mln. cells.m^{-3}), biomass (mg.m^{-3}) and Shannon-Weaver index, 2014-2017

The highest values of the Shannon-Weaver Index were recorded in August and September with an assessment of the marine water as water in "*very good*" ecological status on this indicator (Fig. 7).

In summer, comparatively low (below 1000 mln.cells.m^{-3} and below 1000 mg.m^{-3}) quantitative values of phytoplankton growth were observed (Fig. 7 and Fig. 8), values describ-

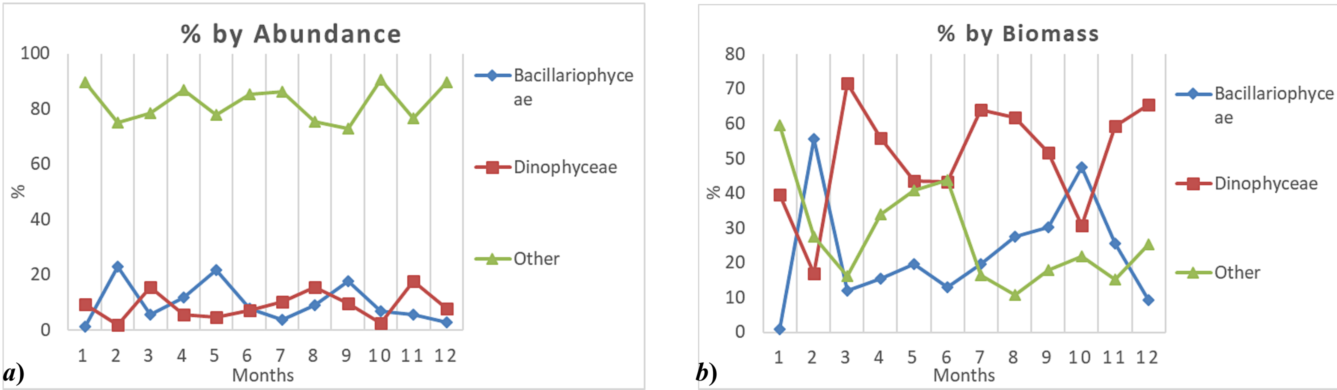

Fig. 6. Phytoplankton quantitative structure, % of the three main taxonomic groups: class *Dinophyceaes*, class *Bacillariophyceae* and the group "*Others*", by months 2014-2017; (*a*) by number, (*b*) by biomass

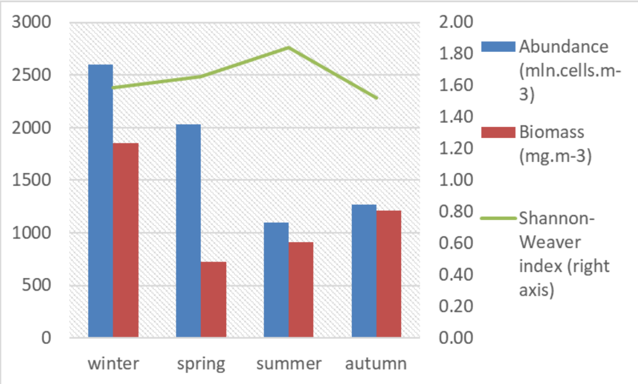

Fig. 8. Seasonal averages values for abundance (mln. cells.m^{-3}), biomass (mg.m^{-3}) and the Shannon-Weaver index, 2014-2017

ing "*good*" ecological status of our marine ecosystem (Klisarova & Gerdzhikov, 2016; 2017) (Fig. 8).

During the study (2014-2017), average values for abundance - 1794 mln.cells.m^{-3}, biomass - 1117.76 mg.m^{-3} and Shannon-Weaver Index - 1.76, determinates marine water in the ranges of "*good*" ecological status (Fig. 9). A trend of increasing the average annual quantities of phytoplankton was registered, as in 2017 they were the highest for the past ten years (Fig. 9).

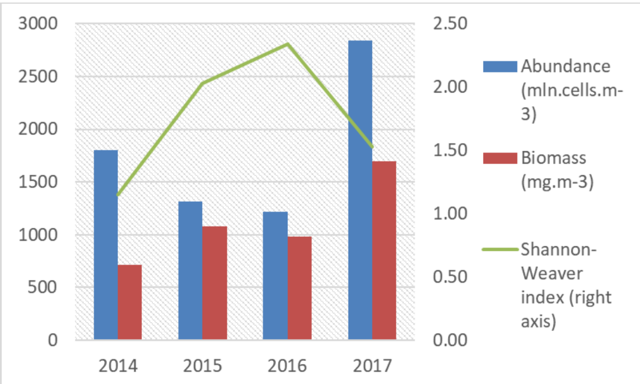

Fig. 9. Annual average numbers (mln.cells.m^{-3}), biomass (mg.m^{-3}) and Shannon-Weaver index, 2014-2017

The autumn peak in the seasonal dynamics was recorded in November 2015 when an intense bloom of the peridinae *Prorocentrum cordatum* (biomass 25 g.m^{-3}) (Petrova & Gerdzhikov, 2013) and the small Flagellates was observed in the southern part of Varna Bay (Fig. 10). When compared to the so-called "clean period" of the 20th century (50-60s), the established summer and autumn values were higher, but significantly lower than those recorded during the eutrophication period (70-80-90s of the 20th century) (Klisarova & Gerdzhikov, 2017).

Eight phytoplankton species developed with blooming concentrations >1 mln. cells.m^{-3}: *Cyclotella caspia* Grunow, 1878; *Emiliania huxleyi* (Lohmann) Hay & Mohler, 1967; *Merismopedia sp.* Meyen, 1839; *small Flagellates*; *Oscillatoria sp.* Vaucher ex Gomont, 1892; *Prorocentrum cordatum* (Ostenfeld, 1901) Dodge, 1975; *Pseudo-nitzschia delicatissima* (P.T. Cleve, 1897) Heiden, 1928; *Skeletonema costatum* (Greville) Cleve, 1873 (Fig. 10).

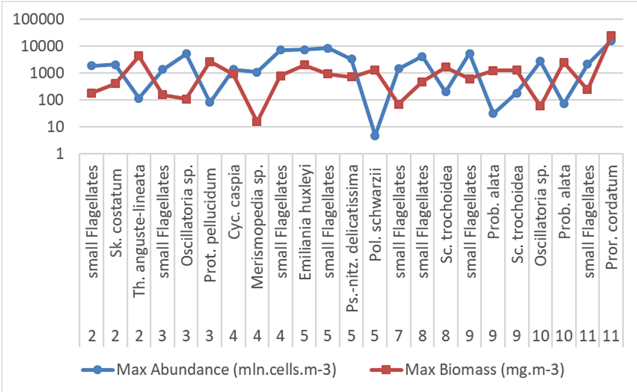

Fig. 10. Maximum abundances (mln.cells.m^{-3}) and biomass (mg.m^{-3}) of blooming and dominant phytoplankton species in Bulgarian coastal waters (excluding Varna Lake), by months, 2014-2017

Six phytoplankton species were developing with high biomass (> 1 g.m^{-3}) in the coastal aquatory: *Thalassiosira anguste-lineata* (Schm.) G.Fryxell & Hasle, 1977; *Protoperidinium pellucidum* Bergh, 1882; *Emiliania huxleyi*; *Polykrikos schwarzii* Bütschli, 1873; *Scrippsiella trochoidea* (Stein, 1883) Balech ex Loeblich III, 1965; *Proboscia alata* (Bright.) Sundström, 1986; *Prorocentrum cordatum*. Increased phytoplankton biomass in February and March was caused by the intense development of the diatom *Th. anguste-lineata* and the peridine *Prot. pellucidum* (Fig.10).

In the Lake of Varna, a total of 7 phytoplankton species in bloom-causing concentrations were recorded: *Apedinella radians* (Lohmann) Campbell, 1973 (Syn. *Ap.spinifera*); *Cyclotella caspia*; *Heterocapsa triquetra* (Ehrenberg, 1840) Stein, 1883; *small Flagellates*; *Oscillatoria sp.*; *Prorocentrum cordatum*; *Skeletonema subsalsum* (Cleve-Euler) Bethge, 1928, (Fig. 11).

Five species developed with high biomass in the lake: *Cyclotella caspia*, *Heterocapsa triquetra*, *Skeletonema subsalsum*, *Scrippsiella trochoidea*, *Prorocentrum cordatum* (Fig. 11).

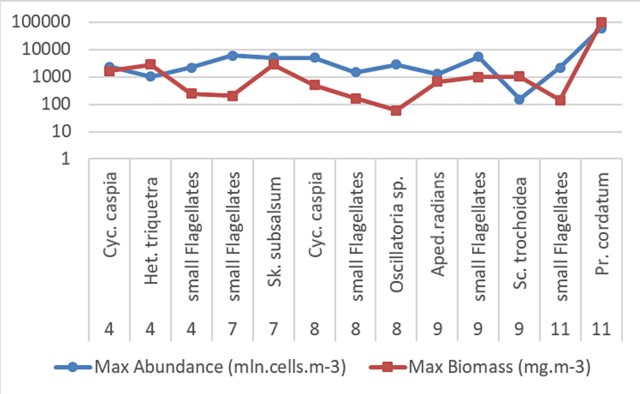

Fig. 11. Maximum abundances (mln.cells.m^{-3}) and biomass (mg.m^{-3}) of blooming and dominant phytoplankton species in Varna Lake, by months, 2014-2017

The average values of chlorophyll-*a* within the study period were relatively high: on the coast, an average monthly value of 0.98 mg.m^{-3} was measured, and in Varna Lake -19.40 mg.m^{-3}. According to the classification system of Wasmund et al. (2001), on this indicator our coastal waters were defined as mesotrophic, and the Lake waters - as hypereutrophic.

The average transparency of the seawater was 4.79 m, which determinates the ecological status of water as "*very good*". For Varna Lake the average water transparency was 1.45 m, which characterized the ecological status of water as "*very bad*" (Ordinance No. H-4, 2012).

Conclusions

A total of 182 phytoplankton species belonging to 14 taxonomic classes were recorded in Bulgarian Black Sea coastal marine water and in Varna Lake water during the period 2014-2017. The *Dinophyceae*/*Bacillariophyceae* group occupied 72.53% of the total taxonomic composition with an increase from 2014 to 2017. The highest biodiversity of phytoplankton was recorded in May and September of the studied period. Eight species in the coastal aquatory and seven species in Varna Lake were recorded in bloom-causing concentrations. Microalgae from the group "Others" (82.02%) dominated in the number of phytoplankton and the *Dinophyceae* class dominated in the biomass (50.30%). From 2014 to 2017, there was a trend to increase the numbers and biomass of phytoplankton, especially in 2017, when the measured values were the highest for the last decade. The highest quantitative values of the phytoplankton were produced during the winter-spring period of the year, demonstrating a return to the normal annual growth cycle for the temperate latitudes. The ecological assessment of the water in the study areas based on the results obtained for phytoplankton determines the ecological status of coastal water as "*moderate*" and the Varna Lake water as "*bad*".

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