Results of Long-Term Bacterioplankton Monitoring in the Northwestern Black Sea

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Introduction

Bacterioplankton is an important component of marine biocenoses responsible for the destruction and mineralization of organic matter (OM) in the ecosystem. At the same time bacterioplankton number is used as a sensitive indicator of changes in the OM concentrations and the trophic state of aquatic systems [SWQ, 1998; Kovaleva et al., 2003; Zaika, 2003]. Studies of bacterioplankton quantitative distribution in the Black Sea have been periodically conducted by researchers since the middle of the last century [Lebedeva, 1958; Tsyban, 1970; Sorokin, 1982; Kovaleva, 2003]; the studies revealed an increased bacteria number in the northwestern Black Sea (NWBS) in comparison with the central marine areas. This fact was explained by the influence of runoff of the Danube, Dniester and Dnieper rivers, whose waters carried a large amount of living and dead organic matter into the sea enriching the marine environment with nutrients. At that, the highest in the NWBS anthropogenic pressure is suffered by the areas influenced by large cities with active shipping, such as the Odesa Bay. Since 2003 the studies of bacterioplankton dynamics in the NWBS have been regularly performed for 18 years as a part of integrated environmental monitoring in the Zmiinyi Island coastal waters at the research station "Zmiinyi Island" of Odesa National I.I. Mechnikov University and in 2016-2017 - in the Odesa Bay [Kovalova et al, 2010; Kovalova and Medinets, 2012; Kovalova et al., 2017, Medinets et al., 2020c, Gazyetov et ak, 2021]. The purpose of these studies has been identification of quantitative changes of the NWBS bacterioplankton over 1978-2020, as well as determination of those changes' dependency on external factors.

Data & Methods.

To analyze the long-term changes in bacterioplankton number we used the data from our own studies performed in the NWBS coastal and open areas in 1978-1997 and in the Zmiinyi Island coastal waters in 2003-2020 (with an interval of 10 days), as well as in the Odesa Bay in 2016-2017 (monthly data). Studied areas are known to be exposed by excessive nutrient loads from both fluvial run-off and atmospheric deposition (Medinets and Medinets, 2010; Medinets, 2014; Medinets et al., 2020a,b). Assessment of total bacteria number was done by direct count under the microscope on Sartorius membrane filters with a pore diameter of 0.2 µm described in (Kovalova et al,2021) using the Olympus BH-2 microscope at the magnification of 1200.

Results.

The results of bacterioplankton study in the NWBS during 42 years (1979-2020) have shown that its number varied within wide range (Fig. 1).

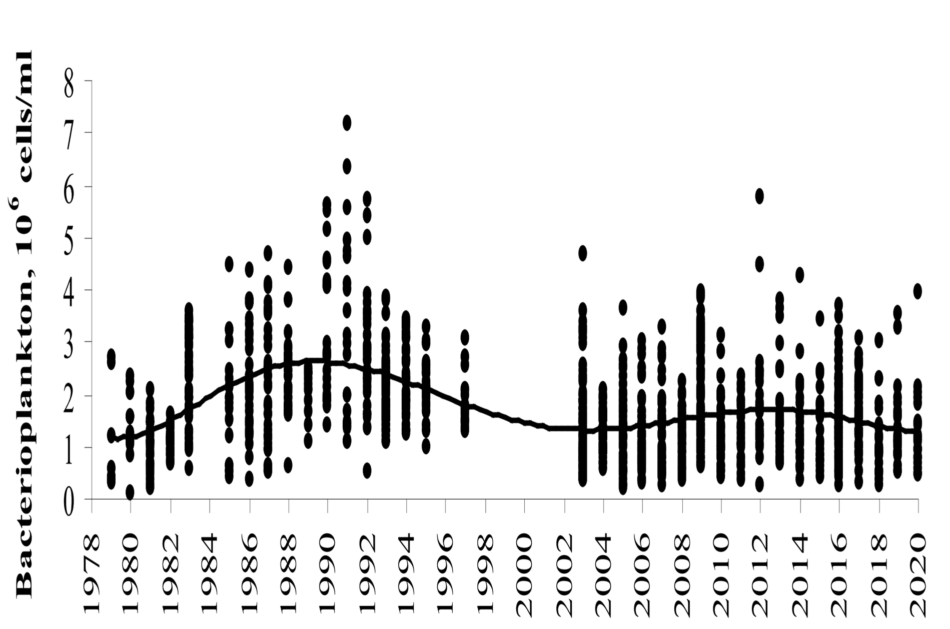

Fig. 1. Long-term bacterioplankton dynamics in the northwestern Black Sea

In 1978-1982 the total bacterioplankton number in the coastal areas of the sea made (0.3-2.6)·106 cells/ml and was significantly higher than in the 60s [Tsyban, 1970], before the intensive eutrophication started in the NWBS. At that, average annual number of bacteria (1.0-1.4)·106 cells/ml in the coastal waters did not exceed the values characteristic of mesotrophic seawater [SWQ, 1998; Zaika, 2003]. However, the number of bacteria was constantly growing in the 80s and reached maximum values (1.0-7.2)·106 cells/ml, which corresponded to eutrophic status of seawater, in early 90s. Since the mid-90s, there has been a downward trend in the quantitative indicators of bacterioplankton and, above all, its maximum values.

As the result of gradual decrease in number in the 21st century, the average bacterioplankton values in the 2003-2008 vegetation season were (1.2-1.4)·106 cells/ml and the maximal - (2.2-4.7)·106 cells/ml, which was 1.5-2.5 times less than in early 90s. In the next twelve years (2009-2020) the average annual values of bacteria number varied within wider range (1.2-2.0)·106 cells/ml, however, like in the previous 6 years corresponded to the status of mesotrophic seawater. Average annual maximum out of the last 18 years (2.0·106 cells/ml) was determined in 2012, but that was 1.6 times lower than in 1990-1991 (3.3·106 cells/ml). In general, no pronounced trend of average annual values of the NWBS bacterioplankton number has been revealed according to observations near the Zmiinyi Island for the period of 2003-2020. In turn, large fluctuations in the number of bacterioplankton were associated with seasonal dynamics, which had its own characteristics in different periods of the studies.

Comparison of the bacteria number (BN) seasonal dynamics at the end of the past century and at the beginning of this century (Fig. 2) showed that in 1983-1997 under intensive eutrophication high bacterioplankton number (1.9-2.8)·106 cells/ml), which was characteristic of eutrophic seawater, was recorded for most part of a year (March-October) reaching its a maximum in late summer.

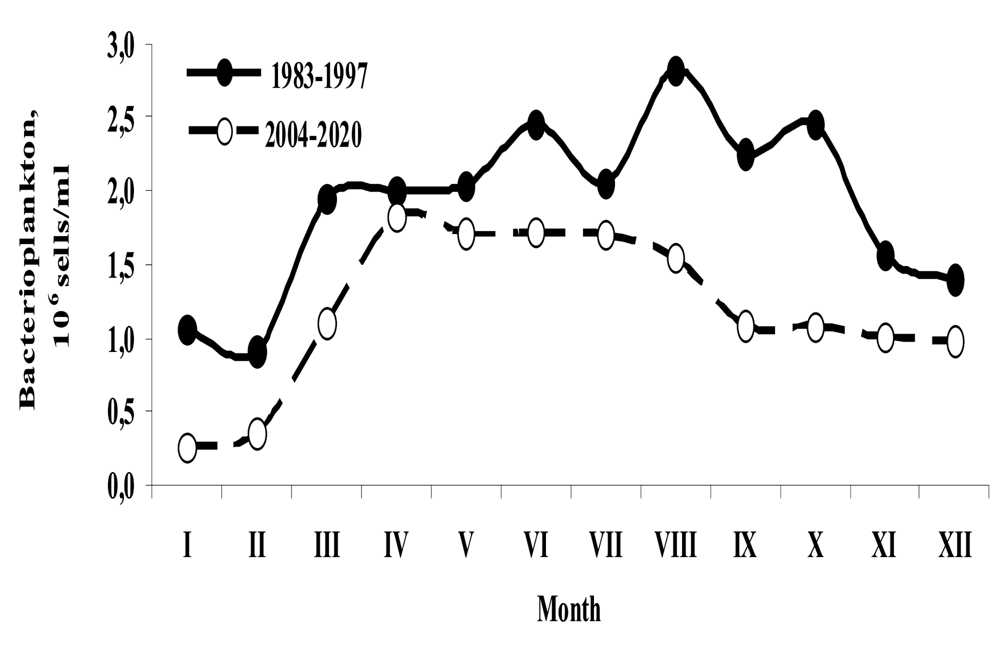

Fig. 2. Seasonal dynamics of BN in the northwestern Black Sea 1983-1997 and 2004-2020

According to the data of 2003-2020, average monthly bacteria number in all seasons of a year corresponded to the mesotrophic status of water (<2.0·106 cells/ml) and the maximal values were observed in April, when the sea received the largest amount of OM brought by floodwaters (Medinets et al., 2020a).

Average annual bacteria number in modern conditions (2004-2020) was 1.6 times lower than in 1983-1997.Quantitative development of bacterioplankton in the sea depends on the presence in the ecosystem of OM of autochthonous origin or the allochthonous OM entering the sea with coastal runoff (Kovaleva et al., 2003).

One of the main sources of the OM easily digestible for bacteria is phytoplankton whose indicator of biomass is chlorophyll a. Close positive correlation between the bacteria number and the chlorophyll a concentration (r2 = 0.10-0.50) in marine surface waters was identified during most (83%) years of observation, which was associated with consumption by bacteria of about one-half of OM produced by algae [Cole et al., 1988].

In turn, much OM is brought to the NWBS by rivers (Medinets et al., 2020a) and the indicator of river water distribution in the sea is salinity. It was established that negative correlation between bacterioplankton and salinity was even closer than between bacterioplankton and chlorophyll a (r2 = 0.20-0.82), which indicated an increase in the number of bacteria with the decrease of salinity. According to the obtained empirical regression equation, with growth of salinity from 7.70‰ to 19.70‰ the number of bacterioplankton decreases more than 5 times (from 4.19·106 cells/ml, which is typical of eutrophic waters, to 0.78·106 cells/ml, which is characteristic of mesotrophic sea water). The value of salinity, which distinguishes between eutrophic and mesotrophic waters in determining of trophic status according to bacterioplankton number is 14 ‰.

The relative number of marine surface water samples having mesotrophic and eutrophic status according to the estimated number of bacterioplankton samples varied in 2,3 (from 39 to 89%) and in 5,1 (from 11 to 56%) times during different periods of studies (Table 1). However, most of observations (34%) on average over 18 years of studies indicated mesotrophic status, while 28% of the NWBS waters were eutrophicated.

Table 1. Relative quantity (%) of surface water samples from the NWBS with mesotrophic (<2.0·106 cells/ml) and eutrophic (>2.0·106 cells/ml) status according to bacterioplankton number assessment.

Years of Studies	Samples	Mesotrophic	Eutrophic
1979-1984	122	70	30
1985-1989	135	44	56
1990-1995	206	39	61
2003-2008	319	89	11
2009-2014	225	68	32
2015-2020	205	77	23

Large fluctuations in bacterioplankton number are associated with seasonal changes in the ecosystem (Kovalova et al., 2010). A characteristic feature of bacterioplankton seasonal dynamics in the Zmiinyi Island water area was spring maximum in April-May (1.8·106 cells/ml) when flood water was carrying the largest amount of OM into the sea. A 2-fold decrease in bacteria number compared to the spring maximum is observed in September-October and the minimal values (0.25-0.36)·106 cells/ml were determined in January-February. It should be noted that bacterioplankton seasonal dynamics can have certain differences in different areas of the NWBS (Fig.3).

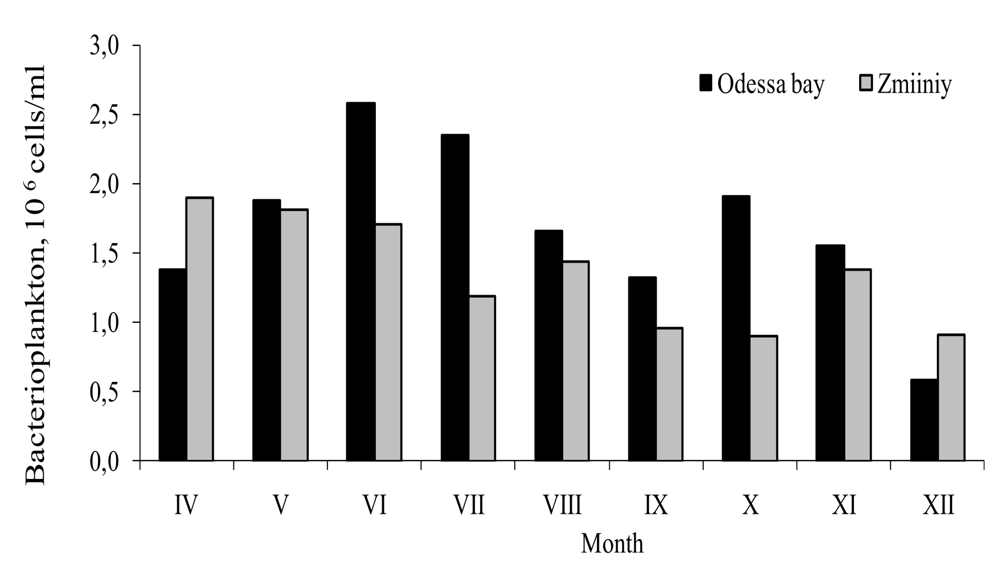

Fig. 3 Seasonal changes of BN in the Odesa Bay water area and near the Zmiinyi Island in 2016-2017.

Simultaneous studies of bacterioplankton at two sites of the NWBS in 2016-2017 showed that in the Odesa Bay its number averaged to 1.69·106 cells/ml and was 1.2 times higher than near the Zmiinyi Island coast (1.35·106 cells/ml). At the same time, maximum values (2.35-2.58)·106 cells/ml were recorded in bacterioplankton seasonal dynamics of the Odesa Bay in summer months (June-July), which corresponded to eutrophic status of water, while near the Zmiinyi Island the highest number of bacteria (1.89·106 cells/ml) was registered in April and corresponded to mesotrophic status of water. Increased bacterioplankton number in the waters of the Odesa Bay in comparison with that near the Zmiinyi Island may be due to the anthropogenic impact – the influence of the port and the city with million inhabitants on the marine ecosystem.

Conclusions

The tendency of decrease by 40% of relative number of surface water samples, which corresponded to eutrophic waters according to bacteria number in modern conditions (2003-2020) compared to 1990-1995. Dominant majority (80%) of observations performed in the past 18 years gives evidence of mesotrophic status of the NWBS water.

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