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LONG-TERM CHANGES OF BACTERIOPLANKTON AND CHLOROPHYLL *a* AS INDICATORS OF CHANGES OF NORTH-WESTERN PART OF THE BLACK SEA ECOSYSTEM DURING THE LAST 30 YEARS

N. KOVALOVA, S. MEDINETS, O. KONAREVA, V. MEDINETS*

Odessa National I.I. Mechnikov University, 7 Mayakovskogo Lane, 65 082 Odessa, Ukraine
E-mail: medinets@te.net.ua

Abstract. The data on many-years dynamics of bacterioplankton number and chlorophyll *a* concentration as indicators of the state of pelagic ecosystem of the north-western Black sea shelf (NWBS) are presented and analysed. It has been shown that in the end of the last century the quantitative characteristics of these factors grew steadily and reached the maximum values characteristic of highly eutrophic sea water in the early 90's. From mid-90's the trend of decrease in bacterioplankton number and chlorophyll *a* concentration began to slow down. At the beginning of this century their concentration was twice as low as in the years of maximum values. These changes indicate the decrease in the NWBS waters trophic level and improvement of the state of environment in the region. As a result of analysis a conclusion was made that in 1980–1990 maximum of chlorophyll *a* concentrations and maximum of eutrophication processes in the NWBS have been registered. It was suggested to use bacterioplankton and chlorophyll *a* together with nutrients furtheron as the simple indicators of marine water quality and of long-term changes in eutrophication processes in the Black sea.

Keywords: bacterioplankton, chlorophyll *a*, long-term changes, the Black sea.

AIMS AND BACKGROUND

The main aim of our research was to study the long-period changes in bacterioplankton number and chlorophyll *a* concentration in the NWBS coastal areas and in the marine water around the Zmeiny island. The task of the studies also included determination of seasonal changes in quantitative characteristics of the parameters studied under current conditions.

It is known[1,2] that bacterioplankton number and chlorophyll *a* concentration are the most important indicators of aquatic ecosystems state. Regularities of quantitative distribution of bacteria in the north-western part of the Black sea (NWBS) have been studied since mid-60's of the last century[3] and the information collected at that time is considered as the background for the period of the north-western shelf[4–10]

* For correspondence.

progressing eutrophication that followed in the 70's. Time series of chlorophyll *a* observation in the NWBS coastal areas and near the Zmeiny island is somewhat shorter than for bacterioplankton and it begins with the 80's (Refs 11–14).

EXPERIMENTAL

The authors have used and generalised the results of many years observations done in the coastal waters and in the open areas of the NWBS (1978–1997) and near the shores of the Zmeiny island (2003–2008). Material was collected during the research cruises on board of the research vessels 'Miklukho-Maklay', 'Priboy', 'Vladimir Parshin', 'Argon', and 'Tsyklon'. For the last four years the measurements were done regularly every 5 days on the basis of the research station 'Ostrov Zmeiny' (the Zmeiny island). To analyse the long-period changes 770 determinations of total bacterioplankton number and 350 measurements of chlorophyll *a* concentration in the surface waters of the studied area were used. Total bacterial number was determined using the method of direct count[15] under microscope on membrane filter with pore size 0.2 μm. The content of chlorophyll *a* was measured by means of standard spectrophotometry[16] using a JENWEY spectrophotometer. Trophic status of waters was determined according to the classification suggested in Refs 1 and 2.

RESULTS AND DICSUSSION

The results of bacterioplankton studies carried out by us for 30 years (1979–2008) have shown that during the period its number varied in wide range (Fig. 1). At the end of the 70's and the beginning of the 80's, after the process of the NWBS eutrophication began, total number of bacterioplankton in the coastal and estuarine areas made 0.3–2.6 mln cells/ml and was an order of magnitude higher than in the 60's (Refs 3 and 4), before intensive eutrophication started. At that, the average density of bacterioplankton (1.0–1.4 mln cells/ml) did not exceed the values that were characteristic of mesotrophic waters.

In 1980 the number of bacteria continued to grow and reached maximum values (1.0–7.2 mln cells/ml) in the early 90's (Refs 5–9). The average bacterioplankton number during vegetation period in these years corresponded to eutrophic marine waters (2.0–3.3 mln cells/ml) and exceeded the values in the late 70's (Ref. 4) 2–3 times.

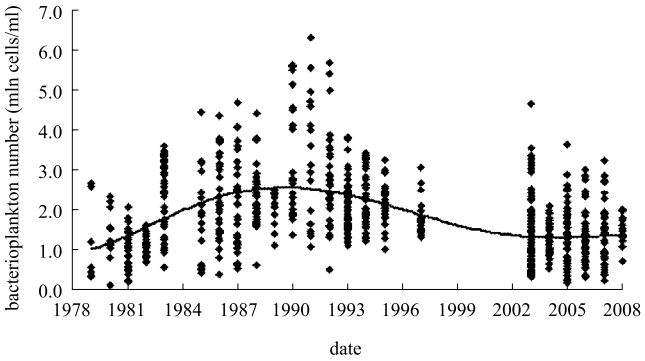

Fig. 1. Many-years dynamics of bacterioplankton in the surface layer of coastal waters in the north-western part of the Black sea

Since mid 90's the tendency of decrease in bacterioplankton[10] total number and, first of all, in its maximum values, began to decrease. According to the data collected during last six years (2003–2008) the average bacterioplankton number during vegetation period made 1.2–1.3 mln cells/ml which was characteristic of mesotrophic marine waters, and it was 1.5–2 lower than the values revealed at the beginning of 1990 (Ref. 8).

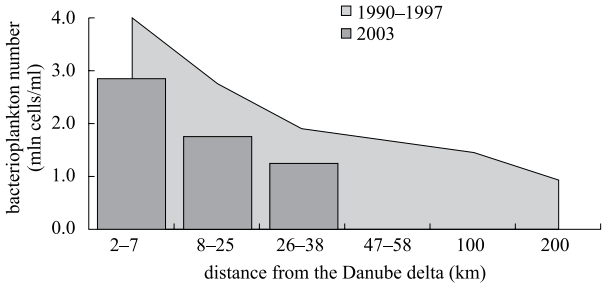

Fig. 2. Changes of bacterioplankton number in the Black sea surface waters at different distance from the Danube delta

Changes of bacterioplankton number in the lower Danube area of the Black sea depending on the distance from the Danube delta in 1990–1997 and 2003 are presented in Fig. 2. Analysis of the data presented show that in 1990–1997 specific number of bacteria in the surface water layer near the Danube delta was 3–4 times higher than further eastwards in the open parts of the sea. The observed decrease in bacterioplankton number further from the Danube delta, in our opinion, was caused by decrease with the distance from the Danube of the Danube discharge influence carrying allochthonous organic matter and nutrients. The same regularity was observed in 2003, the only difference was 1.4–1.6 times lower absolute values of bacterioplankton number. At that, in the region of the Zmeiny island

(37 km far from the Danube delta) the number of bacteria was 2 times lower than in the estuarine zone.

At present, as it was 20 years ago, minimum values of bacterioplankton number are observed in January-February and maximum – in late summer when organic matter gets accumulated by the ecosystem. At the end of last century[8] high average monthly values of bacterioplankton (1.56–2.86 mln cells/ml) characteristic of eutrophic marine waters were observed most part of a year from March till November. According to our data, at the beginning of this century the average values of bacterial number, which are characteristic of eutrophic waters were registered only in July-August and were 1.5 times lower than at the previous decades[8]. At present average annual bacterioplankton number is 2 times lower than at the end of the last century.

Analyses of seasonal dynamics of total bacterial number and comparison with the data collected during the last century[8] have shown (Fig. 3) that there were both general regularities and significant differences in quantitative characteristics.

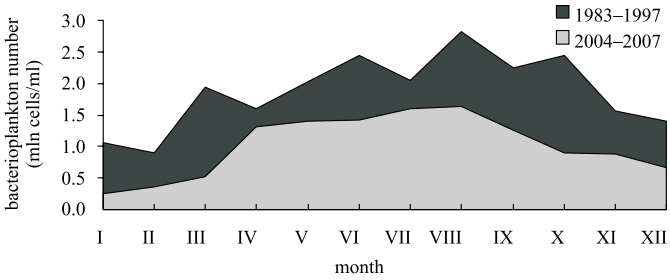

Fig. 3. Comparative characteristics of bacterioplankton number seasonal dynamics in the north-western Black sea surface waters at the end of last century and at the beginning of this century

We think that the decrease in bacterioplankton number is connected with decrease of total concentration of autochthonous and allochthonous organic matter easily assimilated by bacteria. Among the positive changes in the state of the north-western shelf contributing to it are: decrease in algal blooms[17] intensity and decrease of scale of the phenomena of bottom fauna mass mortality[18] observed in 2003.

The results of analyses of the data about chlorophyll *a* content in sea water show the tendency of its concentration decrease for the last 20 years (Fig. 4). It could be seen more vividly from the changes of maximum values of chlorophyll *a* content with time: 1989 – 46–55 μg/l, 1995 – 26–32 μg/l, 2005 – 22–28 μg/l. The results of observations in the region of the Zmeiny during the 5 last years (2003–2007) have shown that the changes of chlorophyll *a* concentrations in the surface water layer varied from 0.13 to 28.04 μg/l.

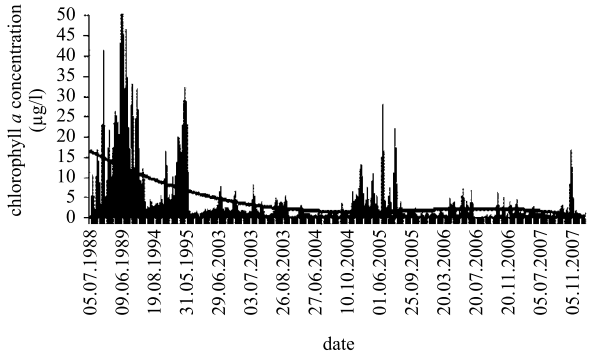

Fig. 4. Many-years dynamics of chlorophyll *a* in the north-western Black sea coastal Waters surface layer

Big range of changes is reflecting the complicated hydrological structure of this Black sea region which is influenced, on the one hand, by the Danube discharge bringing lots of nutrients to the sea and, on the other, by the waters of the open sea which are poor of nutrients. The peculiarities of hydrological and climatic conditions in the recent years seem to have influenced the average values of the chlorophyll *a* concentrations which differed twice (Table 1).

Table 1. Limits of changes and average values of chlorophyll *a* concentrations (µg/l) in plankton of the north-western Black sea near the Zmeiny island in vegetative periods of 2003–2007

Month and year	Surface layer		Bottom layer	
	limits of changes	average	limits of changes	average
V-IX 2003	0.28–7.75	1.25	0.25–1.26	0.76
VI-XI 2004	0.22–12.02	2.41	0.26–5.72	1.48
IV-XI 2005	0.19–28.03	2.90	0.18–2.93	1.03
IV-XI 2006	0.13–7.29	1.53	0.13–5.55	0.75
IV-XI 2007	0.13–16.80	1.33	0.15–1.44	0.78

At that, seasonal changes in chlorophyll concentration during these 5 years have been similar. Figure 5 presenting seasonal changes in the chlorophyll *a* concentration was made using the averaged data for five years.

Maximum values were observed in April-June and in October-November, minimum – during winter period and in August. The bimodal seasonal dynamics of chlorophyll *a* received is characteristic of the phytoplankton development cycles and had been described for the eastern and western Black sea in the 80' of the last century[11].

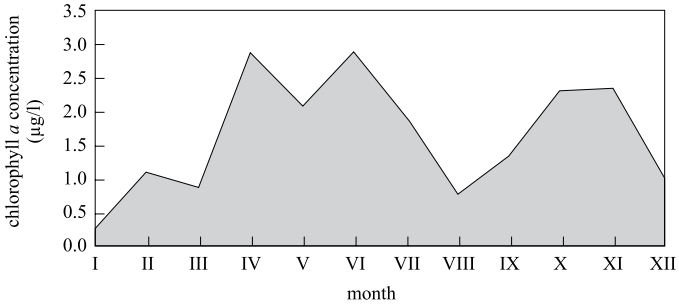

Fig. 5. Seasonal dynamics of chlorophyll *a* in the surface Black sea waters at the coast of the Zmeiny island in 2004–2007

At present seasonal changes of chlorophyll *a* concentration near the Zmeiny island have the features that are characteristic of sea water. During most of the year the average monthly values of chlorophyll *a* content were 1.32–2.88 μg/l, which were characteristic of eutrophic marine waters, however, in winter and during summer the minimum of the concentration of chlorophyll *a* decreased to 0.26–0.84 μg/l, which corresponded to mesotrophic level.

Analyses of the data obtained show that the average values of chlorophyll *a* concentrations in the surface water near the Zmeiny island during vegetation periods of 2003–2007 appeared to be 1.6–3.6 times less than the average many years value (4.52 μg/l) calculated for the region of the Zmeiny island for 1980–1995 (Ref. 12). This fact is an indirect evidence of decrease in the NWBS pelagic ecosystem trophic level, but at the same time it stays rather high and corresponds to the status of eutrophic sea waters.

CONCLUSIONS

It has been determined that the range of bacterioplankton number changes in the surface waters of the sea near the Zmeiny island at present (2003–2008) makes 0.16–3.65 mln cells/ml reaching maximum values in summer. The average values of bacterial numbers for the last 6 years of observations were 1.5–2 times lower than in the end of the 80's of the last century, which is an evidence of decrease in the level of organic pollution in the north-western Black sea.

It is shown that under current conditions (2003–2007) the concentration of chlorophyll *a* in the surface waters near the Zmeiny island has been changing within the limits of 0.13–28.04 μg/l. As a result of seasonal dynamics of pigments analyses it is determined that maximum concentrations have been registered in spring-summer period and in autumn, and minimum – in winter and during the period of summer minimum in August. Average concentration of chlorophyll *a* in the last years was 1.6–3.6 times lower than in 1980–1995.

Changes in bacterioplankton number and chlorophyll *a* concentration in the NWBS coastal waters for the last 30 years show that the highest level of eutrophication of the water area was observed in the late 80's and early 90's of the last century.

Many years integrated monitoring of the north-western Black sea shelf shows that bacterioplankton and chlorophyll *a* reflect well the changes of biological processes intensity in the NWBS and could be used as simple and reliable indicators of marine water quality and the long-period changes in eutrophication processes in the Black sea.

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