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Article

Current state of periphyton and benthos bacterial communities in natural-anthropogenic biotopes of the Northern Caspian Sea

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Abstract. In the summer and autumn periods of 2023, bacterioperiphyton and bacteriobenthos were studied at the bottom survey stations installed in the northern part of the Caspian Sea in the area of the Yuri Korchagin offshore gas-condensate and oil field. At these stations saprotrophic bacteria were found, their abundance averaged millions of cells: cells/cm^2 in periphyton and cells/g of dry weight in benthos. The number of hydrocarbon-oxidizing bacteria in studied samples reached several thousand cells, while the abundance of sulfate-reducing and thionic bacteria did not exceed hundred cells in both periphyton and grounds. The total bacterial count averaged several million cells per cm^2 in periphyton and several hundred million cells per gram of dry weight in benthos. The total bacterial biomass ranged from tenths of mg C/m^2 to several g C/m^3. The most represented morphological group of bacteria in periphyton at the bottom survey stations were rods (72%), followed by coccoid forms (20%), while curved forms were found in smaller amounts (8%). In benthos, on the contrary, cocci were dominant (69%), rods were subdominant (23%), while vibrios (8%) were also a minor group. The analysis of the summer–autumn dynamics of the studied bacteriocenosis revealed a decrease in the studied parameters in the autumn period by an average factor of 2.0–2.5. The proportion of saprotrophs in the total bacterial count was substantial (it ranged from 4.4 to 5.2% for periphyton and from 3.8 to 5.8% for benthos, on the average, across the seasons of survey) and varied within a wide range (from 0.5 to 20.0%). The proportion of hydrocarbon-oxidizing group in the total bacterial count amounted to hundredths, thousandths, and ten-thousandths of a percent, which is typical for bacteriocenoses of the Northern Caspian Sea. At the same time, the proportion of sulfate-reducing and thionic bacteria amounted to thousandths and ten-thousandths of a percent. Overall, the bacteriocenosis of the studied bottom stations was represented by a stable bacterial community inhabiting the natural-anthropogenic biotopes of the Northern Caspian Sea.

Keywords: Caspian Sea, bottom stations, bacterioperiphyton, bacteriobenthos, saprotrophic bacteria, hydrocarbon-oxidizing bacteria, sulfate-reducing bacteria, thionic bacteria

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Научная статья

Современное состояние бактериальных сообществ перифитона и бентоса в природно-антропогенных биотопах Северного Каспия

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Аннотация. В летний и осенний периоды 2023 г. исследован бактериоперифитон и бактериобентос донных станций, установленных в северной части Каспийского моря в районе морского газоконденсатнонефтяного месторождения им. Ю. Корчагина. На изученных станциях обнаружены: сапротрофные бактерии, численность которых в среднем находилась на уровне млн клеток в перифитоне (кл./см^2) и в бентосе (кл./г сухого веса); количество углеводородокисляющих бактерий достигало нескольких тысяч клеток в исследуемых пробах; численность сульфатредуцирующих и тионовых бактерии не превышала сотен клеток как в перифитоне, так и в грунтах. Общая численность бактерий в среднем равнялась нескольким млн на см^2 в перифитоне и нескольким сотням млн клеток на г сухого веса в бентосе. Общая биомасса бактерий варьировала от десятых долей мгС/м^2 до единиц гС/м^3. Наиболее представленной морфологической группой бактерий в перифитоне донных станций были палочки (72%), далее следовали кокковидные формы (20%), извитые формы встречались в меньшем количестве (8%). В бентосе, наоборот, доминировали кокки (69%), субдоминантами были палочки (23%), вибрионы (8%) также были малочисленной группой. Анализ летне-осенней динамики рассмотренного бактериоценоза выявил снижение изученных показателей в осенний период в среднем в 2.0–2.5 раза. Доля сапротрофов от общей численности бактерий была значительной (по исследуемым сезонам в среднем для перифитона 4.4–5.2% и бентоса 3.8–5.8%) и изменялась в широком диапазоне (от 0.5 до 20.0%). Доля углеводородокисляющей группы от общей численности бактерий составляла сотые, тысячные и десятитысячные доли процента, что характерно для бактериоценозов Северного Каспия. При этом доля сульфатредукторов и тионовых бактерий равнялась тысячным и десятитысячным долям процента. В целом бактериоценоз изученных

донных станций представлен стабильным сообществом бактерий, населяющим природно-антропогенные биотопы Северного Каспия.

Ключевые слова: Каспийское море, донные станции, бактериоперифитон, бактериобентос, сапротрофные бактерии, углеводородокисляющие бактерии, сульфатредуцирующие бактерии, тионовые бактерии

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Introduction

Natural-anthropogenic biotopes can be defined as areas of live nature (in particular, the marine environment) with a potentially high degree of anthropogenic impact. Currently, an ecologically sound way to maintain biodiversity and bioproductivity of such habitats is the introduction of artificial biotechnical structures (Akhmedova et al., 2011a; Isakova, 2009).

Structures installed in the marine environment, consisting of bottom and pelagic parts, generally enhance the productivity of biological communities, increase the biological degradation of pollutants, promote the formation of indicator communities, and enhance the potential of hydrobionts in the self-purification of the water body under study (Akhmedova et al., 2011a, b; Umerbaeva et al., 2019; Ushivtsev et al., 2008, 2017). Bacteria are one of the most important components involved in the active pioneering colonization of bottom stations and the formation of various fouling communities on them, along with phyto- and zooperiphyton.

The species composition of biological communities of the bottom structures can reflect the environmental well-being of their habitat. In this case, most indicative are benthic communities, where the ratio of species that form biodiversity may change depending on the ongoing processes (both natural and anthropogenic) (Vodovsky, 2016; Kurapov et al., 2016; Ushivtsev et al., 2017).

Bottom sediments of the Caspian Sea are abundantly colonized by microorganisms (Baubekova et al., 2022; Idrisova et al., 2016; Kolotova et al., 2017; Menkova et al., 2019; Umerbaeva et al., 2011). Saprotrophic microorganisms are most widespread in grounds; however, their abundance may significantly fluctuate depending on the availability of the nutritious substrate. The presence of other narrow specialized groups of bacteria in bottom sediments is determined mainly by their metabolic characteristics; the abundance of these bacteria can vary within a wide range. At the same time, grounds serve as an accumulator not only for organic matter entering the water area and various allochthonous microorganisms, but also for pollutants. The abundance and the ratio of heterotrophic bacteria groups are among the most important characteristics of benthic biocenoses. Due to their physiological characteristics, heterotrophic bacteria respond much faster to changes in their habitat conditions compared to other members of aquatic biocenoses. Furthermore, they play a crucial role in the mineralization of organic matter and the cycle of nutrients, and, along with other groups of microorganisms, are actively involved in the marine self-purification processes.

Against the intensification of economic activity in the Caspian Sea, the issues of developing and implementing measures aimed at stabilizing and improving the marine environment, increasing its resilience and bioproductivity through the use of various artificial biological systems, are highly relevant. Also, the study of the bacteriocenosis of bottom systems is very promising, including not only surveys of the total abundance and total biomass of bacteria and their saprotrophic group, but also narrow specialized groups of microorganisms, such as hydrocarbon-oxidizing, sulfate-reducing, and thionic bacteria.

The aim of this study was to assess the current state of bacterial communities of periphyton and benthos in natural-anthropogenic biotopes of the Northern Caspian Sea during the summer and autumn periods of 2023.

Materials and methods

During our work held within the environmental monitoring on July 10–20 and September 1–10, 2023 we took 64 samples of bacterioperiphyton (main and pelagic parts) and 32 samples of bacteriobenthos from the bottom stations (BS) installed on the seabed in the northern part of the Caspian Sea in the area of the Yuri Korchagin offshore gas-condensate and oil field (Fig. 1). The stations were located at the depths ranging from 10.1 to 11.3 m.

At the main parts of the bottom stations samples of bacterioperiphyton were taken from the surface using a diver's scraper, and at the pelagic parts samples were taken with scissors. Samples taken were placed into sterile polymeric containers (Fig. 2). Samples of bacteriobenthos were taken using a Van Veen grab sampler with a gripping area of 0.025 and 0.1 m^2 in accordance with GOST 17.1.5.01–80[1] and GOST 17.4.4.02–2017[2].

The total bacterial count (TBC) was determined using the standard method of epifluorescence microscopy (Hoff, 1993; Rukovodstvo po gidrobiologicheskomu monitoringy, 1992; Tepper, 2004). For this purpose, a fixed sample aliquot was stained with acridine orange fluorescent dye and filtered through membrane polycarbonate filters with a pore diameter of 0.2 μm. The stained filters were examined at ×1000 magnification using a Micromed 3-LUM microscope. The size of bacterial cells was determined using a ToupCam imaging system. The cell volume was calculated by the geometric similarity method, using the formula of a sphere for cocci and the formula of a cylinder for vibrios and rod forms. The total bacterial biomass (TBB) was calculated according to the volumes of bacterial cells, followed by recalculation into mg of weight in carbon units per 1 m^3 (Romanova and Sazhin, 2010).

The abundance of ecological-physiological groups of bacteria (saprotrophic, hydrocarbon-oxidizing, sulfate-reducing, thionic) was determined by the method of limiting dilutions on liquid elective media in three replicates (Netrusov, 2005). To determine the abundance of cultivated bacteria on nutrient media,

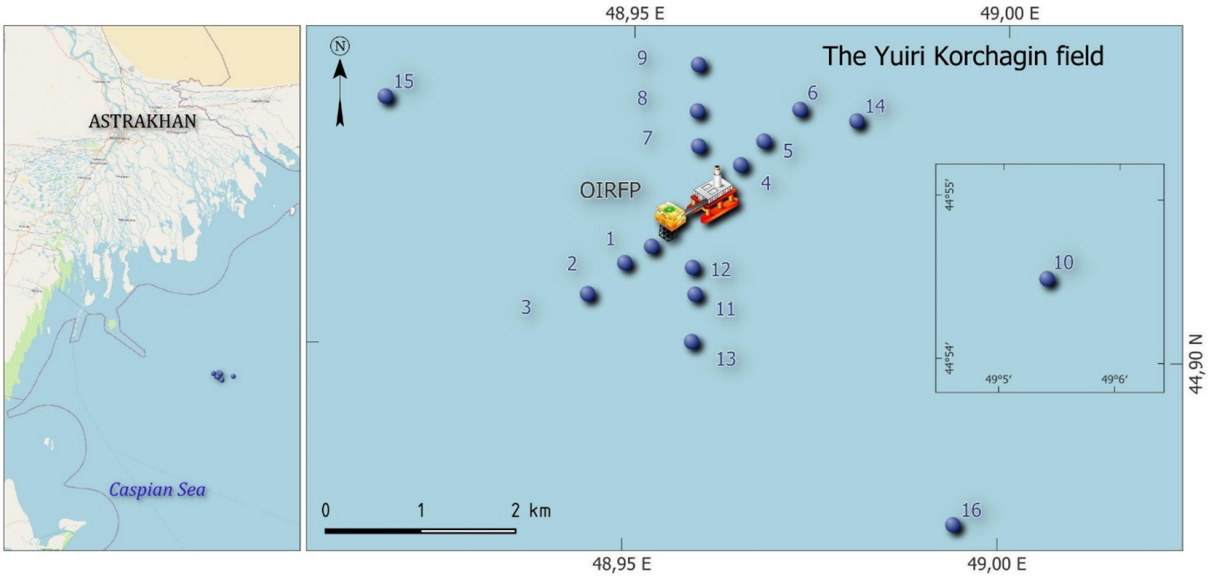


Fig. 1. Layout of the studied bottom stations in the water area of the Northern Caspian Sea in the region of the Yuri Korchagin offshore gas-condensate and oil field.

[1] GOST 17.1.5.01–80. Hydrosphere. General requirements for sampling of bottom sediments of water objects for their pollution analysis.

[2] GOST 17.4.4.02-2017. Environmental Protection. Soils. Methods for sampling and preparation of soil for chemical, bacteriological, helmintological analysis.

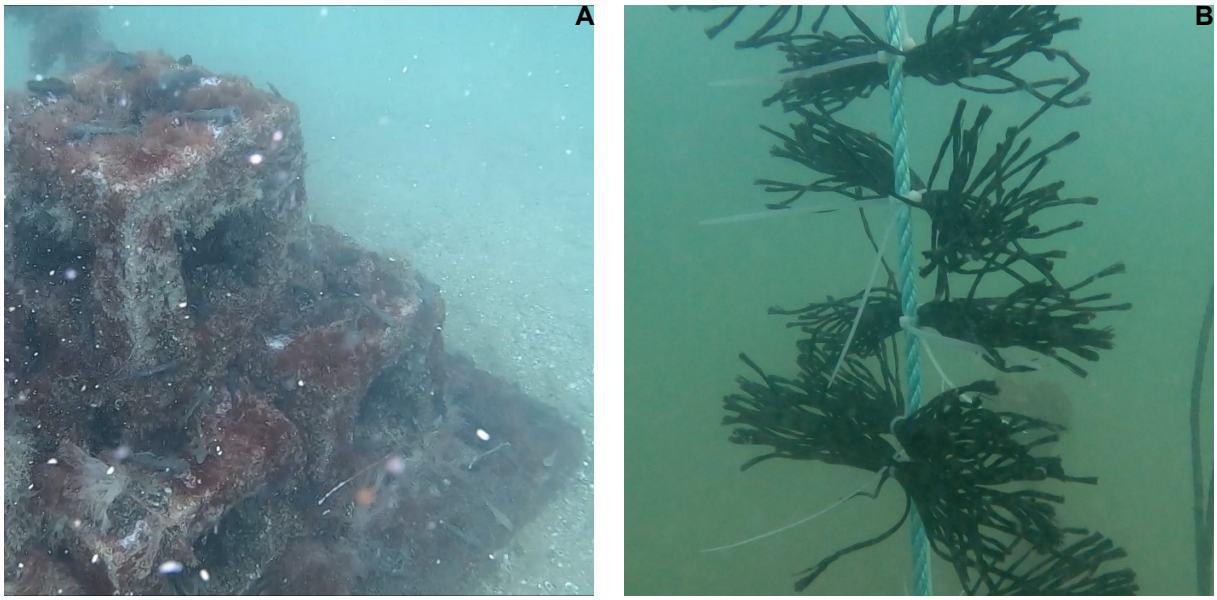


Fig. 2. Bottom stations on the Caspian Sea bed: **A** – bottom concrete blocks, **B** – capron threads of the pelagic part of the station.

a series of successive ten-fold dilutions of the original sample aliquot was prepared. Zobell's medium with a high content of organic matter was used for saprotrophic bacteria (SB); Mills' medium (MMM) with the addition of 0.1% sterile diesel fuel as the sole source of carbon and energy–for hydrocarbon-oxidizing bacteria (HOB); Postgate's B medium containing calcium lactate as an organic substrate–for sulfate-reducing bacteria (SRB); and a nutrient medium with sodium thiosulfate–for thionic bacteria (TB) (Dzerzhinskaya, 2008). The inoculations were incubated in a thermostat for one week to a month at the temperature required for the cultivation of the studied group of microorganisms. The most probable number (MPN) in a sample was determined using McCready's statistical table (Netrusov, 2005).

Samples for determining air-dry weight (d. w.) and moisture content were weighed and dried in a drying oven until complete evaporation of moisture. After that, the weight of the dry sample was determined and a coefficient was calculated for subsequent recalculation of microbiological parameters per air-dry weight (Tepper, 2004).

The assessment of data scatter in the experiments was performed by calculating the mean values and the mean-square deviation to determine the confidence interval at a 95% significance level (Lyalin et al., 2010; Novikov and Novochadov, 2005). The experimental results were processed using standard mathematical statistics methods with the help of the Microsoft Excel 21 software package and Statistica 10.0 program.

Results

The total bacterioperiphyton abundance at the main parts of the bottom stations located in the area of the Yuri Korchagin offshore gas-condensate and oil field in summer 2023 was found to be 94.39 million cells/cm^2 on the average, ranging from 86.98 to 101.04 million cells/cm^2 (Fig. 3**A**). At the pelagic parts, this indicator fluctuated within a smaller range (from 57.02 to 77.97 million cells/cm^2), averaging at 65.93 million cells/cm^2. At the same time, the total abundance of bacteriobenthos at the bottom stations was higher (137.10 million cells per gram of dry weight, ranging from 104.22 to 169.99 million cells per gram of dry weight (Fig. 3**B**). In autumn, TBC within the main area of the bottom stations ranged from 33.15 to 56.49 million cells/cm^2, averaging at 45.35 million cells/cm^2. At the pelagic parts of the BS, the said indicator decreased, averaging at 37.41 million cells/cm^2, varying within a small range (from 34.74 to 41.90 million cells/cm^2). The total benthos abundance was also than that of bacterioperiphyton (52.41 million cells per gram of dry weight), ranging from 34.21 to 68.68 million cells per gram of dry weight.

The analysis of the summer-to-autumn changes in the total bacterioperiphyton abundance showed a decrease of the studied indicator from summer to autumn by almost a factor of 2, both at the bottom and

pelagic parts (Fig. 3). Both in summer and autumn periods TBC values recorded at the main parts of the BS exceeded those recorded at the pelagic parts, which is quite natural due to the greater contact of the former with bottom sediments, as well as the nature of the studied fouling communities (bivalve clusters, algae, etc.). Bacteriobenthos values were found to decline in autumn by a factor of 2.5 compared to summer values. During both study periods, TBC values in grounds were higher than those in periphyton at the main parts of the BS.

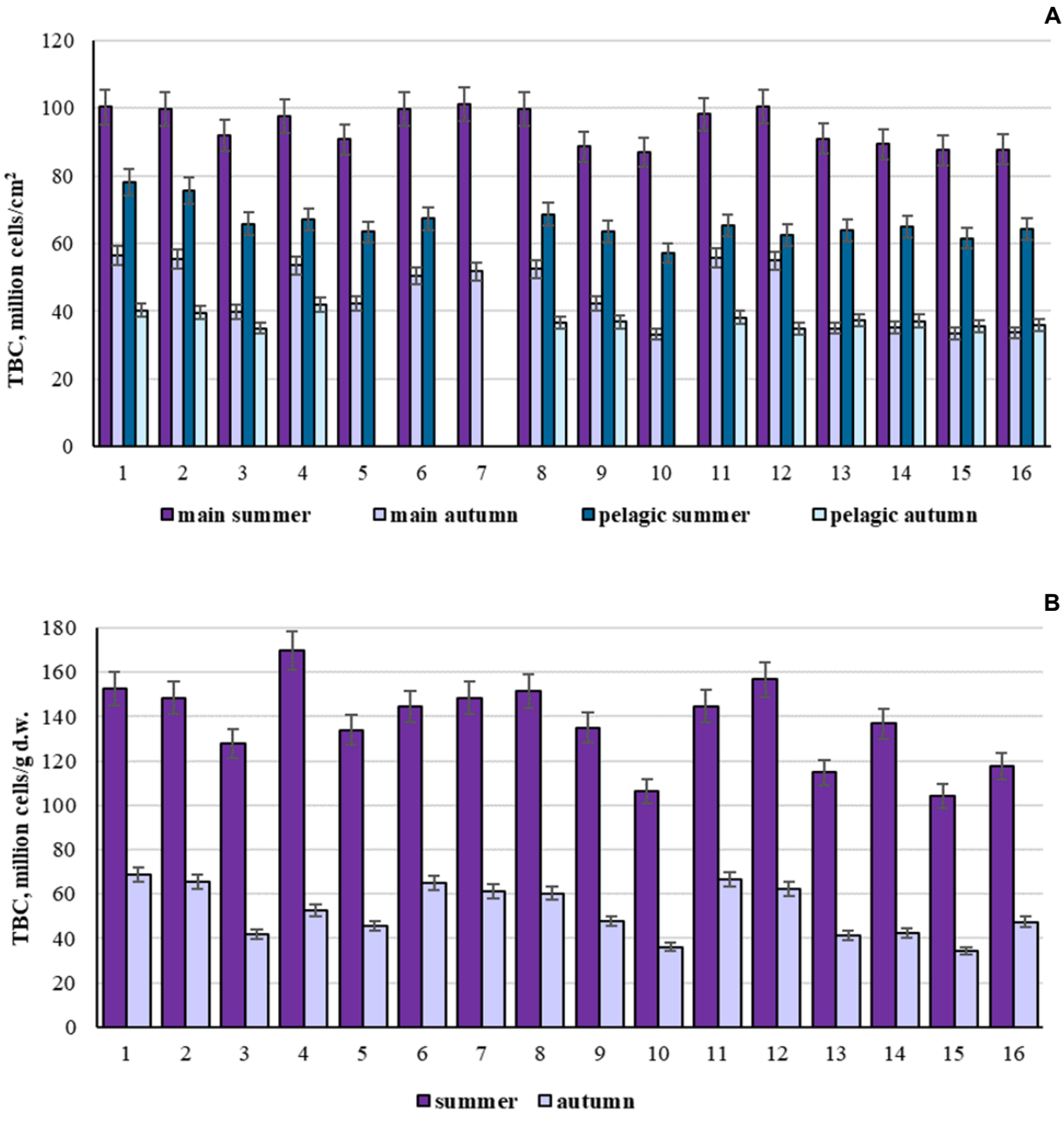


Fig. 3. Dynamics of the total abundance of bacterioperiphyton of the main and pelagic parts (**A**) and bacteriobenthos (**B**) of the bottom stations in the water area of the Northern Caspian Sea in 2023.[3]

[3] Pelagic samples were not taken in summer at station 7, and in autumn at stations 5, 6, 7, and 10, due to the loss of the pelagic parts of these stations for the reasons beyond our control.

The total bacterioperiphyton biomass recorded at the main parts of the BS in summer averaged 59.98 mg C/m^2, fluctuating from 38.68 to 92.73 mg C/m^2 (Fig. 4**A**). At the pelagic parts, this indicator varied within a smaller range (from 37.88 to 60.27 mg C/m^2), averaging at 48.86 mg C/m^2. At the same time, the average value of the total bacteriobenthos biomass on the BS was equal to 6.66 g C/m^3, ranging from 5.09 to 9.53 g C/m^3 (Fig. 4**B**). During the autumn study period, TBB values of periphyton at the main parts of the BS ranged from 16.35 to 44.23 mg C/m^2, averaging at 28.83 mg C/m^2. At the pelagic parts, this indicator was also lower on the average and amounted to 19.84 mg C/m^2, fluctuating within a smaller range–from 16.60 to 22.49 mg C/m^2). The total bacteriobenthos biomass on the BS was found to be 3.22 g C/m^3, varying within a small range (1.94–4.23 g C/m^3).

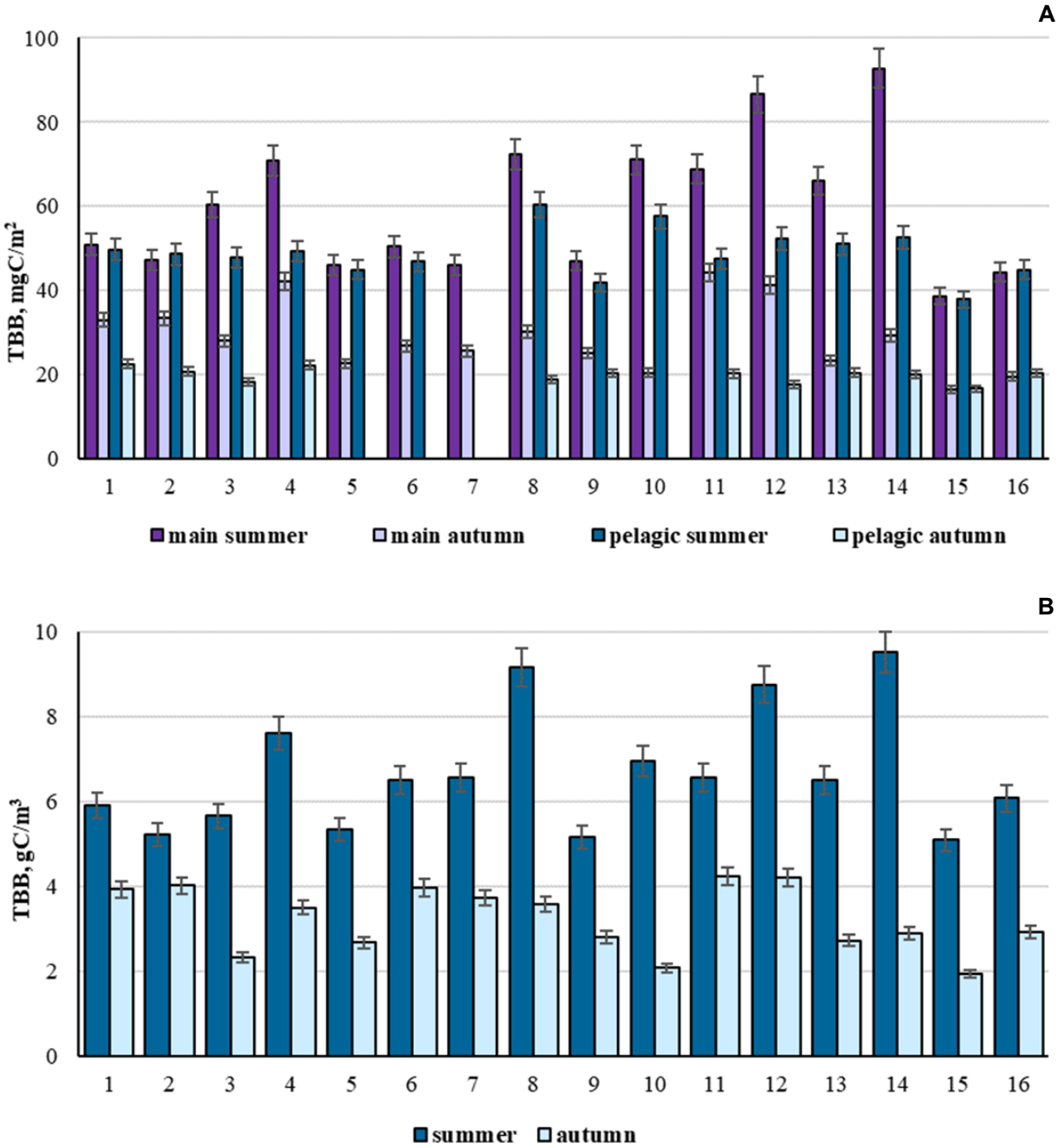


Fig. 4. Dynamics of the total biomass of bacterioperiphyton of the main and pelagic (A) parts and bacteriobenthos (B) of the bottom stations in the water area of the Northern Caspian Sea in 2023.[4]

[3] Pelagic samples were not taken in summer at station 7, and in autumn at stations 5, 6, 7, and 10, due to the loss of the pelagic parts of these stations for the reasons beyond our control.

The total bacterioperiphyton biomass on the bottom stations decreased by a factor of 2–2.5 in autumn compared to summer (Fig. 4). As in the case of TBC, TBB values recorded at the pelagic parts of the BS were lower than those recorded at the main parts during both study periods. The total bacteriobenthos biomass in autumn was also found to decrease compared to summer by a factor of 2. As in the case with TBC, TBB values in bottom sediments exceeded those recorded at the main parts of the BS during both the summer and autumn study periods.

The distribution of bacteria in periphyton and bottom sediments was uneven: quantitative indicators of bacteriobenthos prevailed over those of bacterioperiphyton (Fig. 5).

Spatially, the highest values of the microbiological indicators under consideration during both study periods were recorded mainly in the central part of the studied water area at stations with the minimum sampling depth (10.1–10.4 m), which is explained by more favorable conditions for bacterial development with a decrease in the depth of the studied stations. The lowest values were recorded at the peripheral stations located in deeper waters (10.7–11.3 m).

The most represented morphological group of bacteria in periphyton were rods (72%), followed by coccoid forms (20%), while curved forms were found in smaller amounts (8%) (Fig. 6). In benthos, a different picture was observed: cocci were dominant (69%), followed by rods (23%), while vibrios (8%) were characterized by the lowest values of quantitative indicators. The range of bacterial distribution

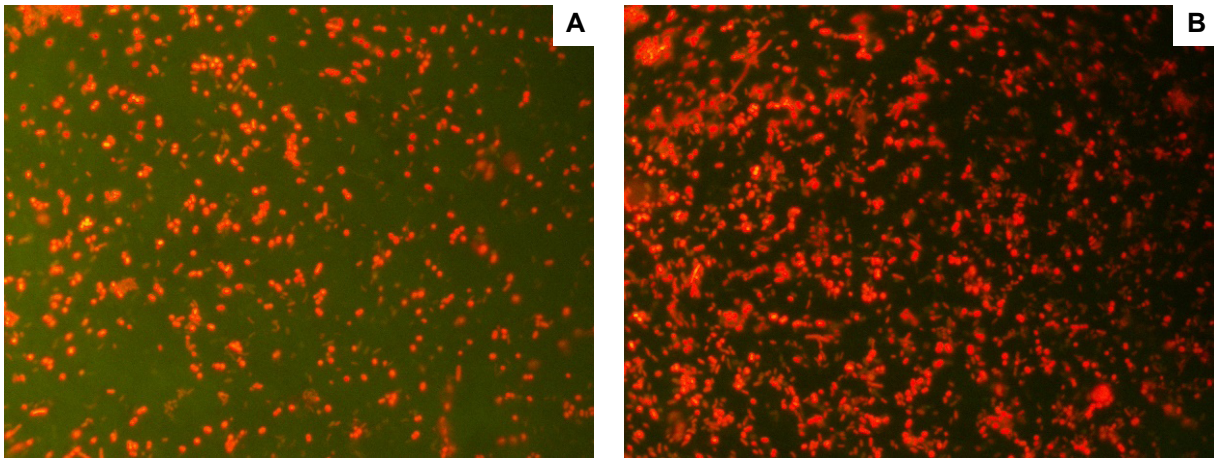


Fig. 5. Bacterioperiphyton (**A**) and bacteriobenthos (**B**) at the bottom stations (epifluorescence microscopy, ×1000).

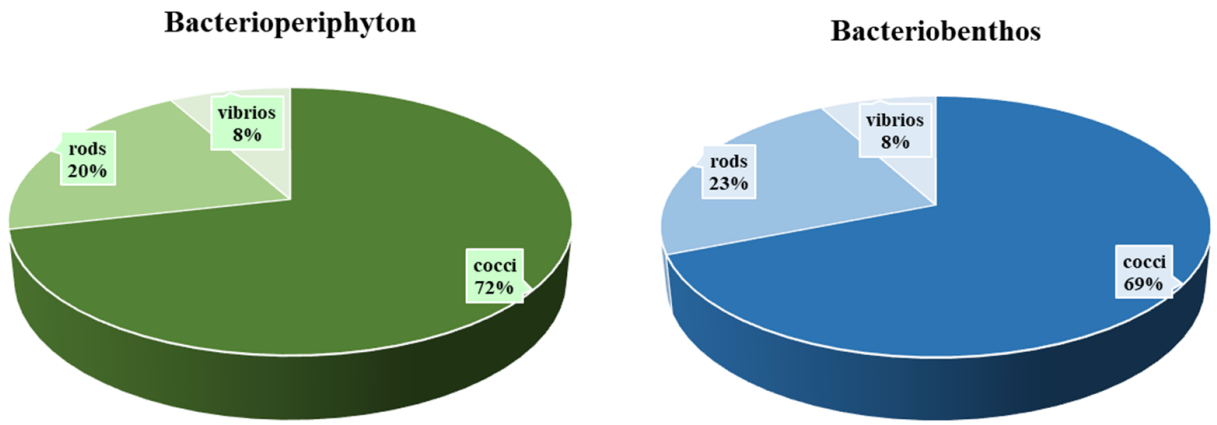


Fig. 6. Ratio of morphological groups of bacterioperiphyton and bacteriobenthos at the bottom stations in the water area of the Northern Caspian Sea in 2023.

by morphological groups at different stations varied slightly, which indicates stability of bacteriocenosis development. The obtained data can possibly be explained by the fact that the formation of coccoid forms can be considered as a way of surviving unfavorable conditions; in particular, this is characteristic of rod-shaped bacteria (Pavlova et al., 2021).

The abundance of the saprotrophic group of heterotrophs in bacterioperiphyton at the bottom stations was on the level of several million cells per cm^2 and mainly showed a decrease in values from summer to autumn, prevailing in quantitative terms at the main parts of the BS (Fig. 7**A**). It should be noted that the range of variation of this indicator was wider in summer compared to autumn at both the main and pelagic parts of the BS. During both study periods, the proportion of the saprotrophic group in the total bacterioperiphyton abundance within the two studied parts of the BS averaged at 4.4–5.2% and varied within a rather wide range (from 0.5 to 20.0%), which is explained primarily by the significant natural presence of cultured saprotrophic groups in the overall composition of the periphyton bacteriocenosis within the studied water area of the field during both study periods. At the same time, in autumn, the range of these fluctuations in percentage content was smaller.

The concentration of saprotrophs in bacteriobenthos was about several million cells per gram of dry weight and also decreased in the autumn period (Fig. 7**B**). The proportion of the saprotrophic group in the total bacteriobenthos abundance in both study periods averaged 3.8–5.8% and varied within a wide range (0.7–17.3%), continuing to be the dominant group among the studied bacterial groups. In autumn, the range of variation in bacteriobenthos abundance compared to that of bacterioperiphyton was wider, which is most likely associated with the ongoing processes of organic matter mineralization in the water body under study. It should also be noted that saprotrophs generally have a relatively high abundance compared to other groups of bacteria (Kolotova et al., 2017; Umerbaeva et al., 2011), and bottom sediments themselves are capable of accumulating organic and mineral substances, creating favorable conditions for bacterial development.

We observed a spatial heterogeneity in the distribution of abundance of saprotrophic heterotrophs within the studied BS. However, the highest values were mainly recorded in the central part of the studied water area, where stations with the minimum sampling depth were located. The lowest values of saprotroph abundance were observed at the deeper stations.

The content of the sulfate-reducing group of bacteria within the main and pelagic parts of the BS tended to decrease towards autumn, ranging from several hundred to several thousand cells/cm^2 in

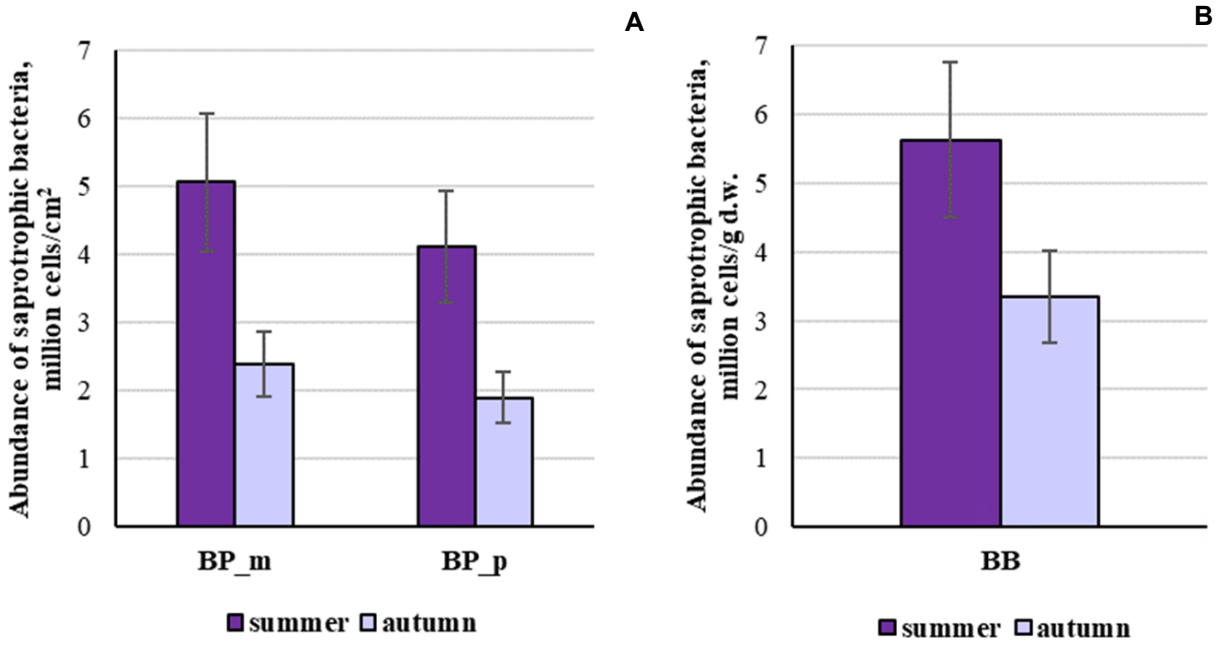


Fig. 7. Dynamics of the abundance of saprotrophic bacteria of the main (BP_m) and pelagic (BP_p) parts (**A**) and bacteriobenthos (BB) (**B**) of the bottom stations in the water area of the Northern Caspian Sea in 2023.

summer and from several dozen to several hundred cells/cm^2 in autumn (Fig. 8**A**). Sulfate-reducing bacteria were characterized by relatively high quantitative values in summer compared to autumn; this group of bacteria was absent in most periphyton samples taken in autumn. While in summer no growth of sulfate-reducing bacteria was recorded at 3 main parts and 5 pelagic parts of the BS; in autumn, the corresponding figures were 10 and 12, respectively. The absence of sulfate-reducing bacteria at some stations is most likely due to the lack of possibility of creating anaerobic environmental conditions at the main and pelagic parts of the BS (Burdiyan, 2022; Burdiyan and Alemov, 2020).

In summer, the abundance of sulfate-reducing bacteria in bottom sediments was found to be around one million cells per gram of dry weight and ranged from several hundred to one million cells per gram of dry weight. In autumn, it decreased to several hundred cells per gram of dry weight, fluctuating within a smaller range (Fig. 8**B**). Most likely, more favorable conditions for the development of this group of bacteria were created in the grounds. In summer, no growth of sulfate-reducing bacteria was recorded in benthos at just one station, in autumn, they were no longer found at 8 stations within the field. During the periods of survey, the proportion of sulfate-reducing bacteria in TBC amounted to thousandths and ten-thousandths of a percent in all studied samples.

This group of bacteria developed mostly at bottom stations with a greater depth of location, where more favorable conditions are created for their development. The lowest values were recorded at the stations with a lower sampling depth.

At most bottom stations thionic bacteria were found in small numbers, ranging from several dozen to several hundred cells/cm^2. Their number decreased in autumn compared to summer, and the decrease was more pronounced at pelagic parts (Fig. 9**A**). A summer to autumn decrease in the count of this group of bacteria was also observed in bacteriobenthos and was almost three-fold. The range of variation of this indicator was wider in summer compared to autumn (Fig. 9**B**). In both study periods, the proportion of thionic bacteria in TBC in all samples amounted to thousandths and ten-thousandths of a percent. As in the case of sulfate-reducing bacteria, thionic bacteria were recorded not at all stations within the field: in summer, bacteria of this group were recorded at the main parts of 5 stations, pelagic parts of 4 stations and at 3 stations in benthos; in autumn, they were observed only at 4 stations. The obtained microbiological pattern is most likely explained by the metabolic characteristics of this group of bacteria–the presence of substances that serve as sources of carbon and energy for the bacteria under consideration (Burdiyan, 2022; Burdiyan and Alemov, 2020). Spatially, the distribution of thionic bacteria was mosaic in both study periods.

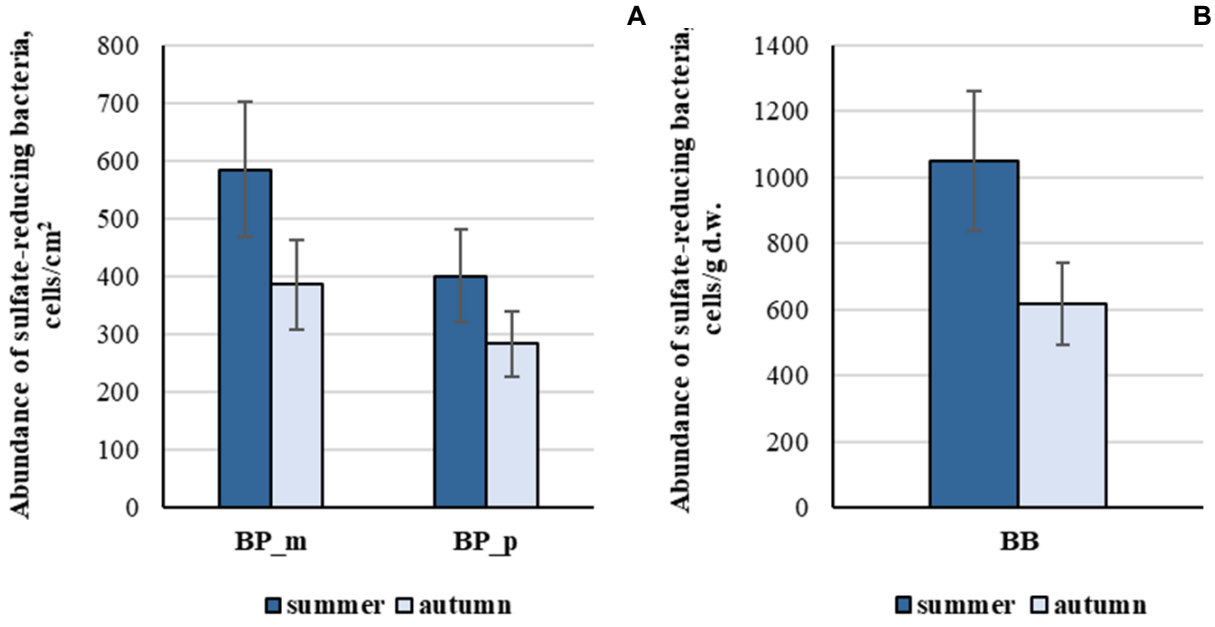


Fig. 8. Dynamics of the abundance of sulfate-reducing bacteria of the main (BP_m) and pelagic (BP_p) parts (**A**) and bacteriobenthos (BB) (**B**) of the bottom stations in the water area of the Northern Caspian Sea in 2023.

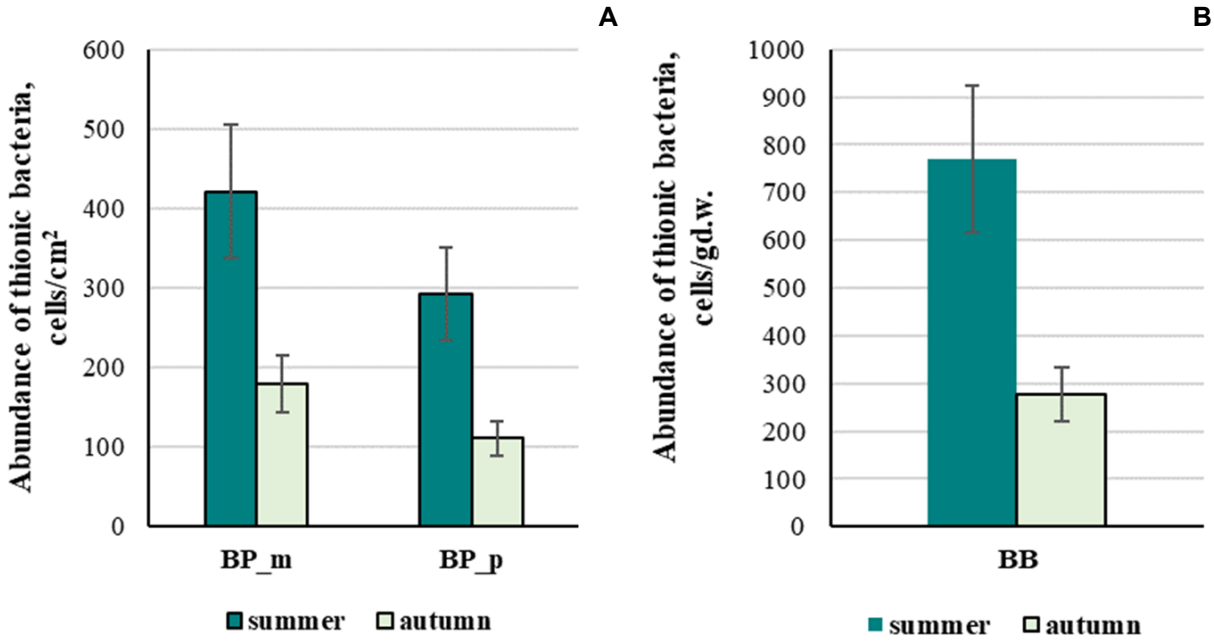


Fig. 9. Dynamics of the abundance of thionic bacteria of the main (BP_m) and pelagic (BP_p) parts (**A**) and bacteriobenthos (BB) (**B**) of the bottom stations in the water area of the Northern Caspian Sea in 2023.

The abundance of the hydrocarbon-oxidizing group of heterotrophs at bottom stations also decreased by almost twice in the autumn period of studies and averaged at several thousand cells/cm^2 in both study periods, varying within a smaller range in autumn. Like saprotrophs, these degrading bacteria quantitatively prevailed on the main parts of the BS, being found in smaller numbers on the pelagic parts of the BS. During the study periods, the proportion of hydrocarbon-oxidizing bacteria in TBC amounted to hundredths, thousandths, and ten-thousandths of a percent in all studied bacterioperiphyton samples, which indicates a shift towards the predominance of the saprotrophic group of heterotrophs and is typical for bacteriocenoses of the Northern Caspian Sea (Baubekova et al., 2022; Kolotova et al., 2017; Menkova et al., 2019). A similar pattern of autumn decline in abundance was observed for bacteriobenthos. As in the case of bacterioperiphyton, saprotrophic bacteriobenthos dominated over hydrocarbon-oxidizing bacteria. The proportion of the latter in TBC averaged at 0.72%, varying within a smaller range.

Spatial distribution of hydrocarbon-oxidizing bacteria was uneven. However, as in the case with saprotrophs, the degrading bacteria were mainly concentrated in the northern part of the studied water area. The lowest abundance areas were recorded on the periphery with a greater depth of location.

Discussion

The total bacterial count in bottom sediments of the studied stations, acting as a kind of natural-anthropogenic biotopes in the reviewed part of the Caspian Sea, averaged several hundred million cells/g, which corresponds to the range of total bacteriobenthos abundance reported in the literature: from 10 to 10^6 million cells/g depending on the seasonal conditions (Baubekova et al., 2022; Idrisova et al., 2016; Kolotova et al., 2017; Menkova et al., 2019; Umerbaeva et al., 2011). At the same time, saprotrophic bacteria on the average amounted to 4.4–5.2% of the total bacteriobenthos in grounds, which is also consistent with the literature data (0.02–5.00% of the total benthos bacterial count). Abundance of other narrow specialized groups of bacteria in bottom sediments is determined mainly by their metabolic characteristics, and can vary widely: from a few to thousands of cells per 1 g of ground. During the study period, the abundance of these groups of bacteria averaged at hundreds of cells per gram.

Bacteria of all studied ecological-physiological groups (saprotrophic, hydrocarbon-oxidizing, sulfate-reducing, and thionic) inhabiting the natural-anthropogenic biotopes of the considered part of the Caspian Sea were found in the composition of bacterioperiphyton and bacteriobenthos at the studied bottom

stations. The presence of saprotrophs at all studied stations and their predominance in abundance and biomass is explained by the fact that the saprotrophic group has high growth rates and use labile organic matter in their metabolism, which is present in high concentrations in the studied water area. At the same time, narrow specialized groups of bacteria were not found at some stations, which can be explained by the absence of nutrients serving as sources of carbon and energy for these groups. It should be noted that the hydrocarbon-oxidizing group of heterotrophs is a natural component of bacteriocenosis of marine water bodies and is capable of utilizing a wide range of organic substrates in addition to hydrocarbons. According to the chemical studies conducted within the environmental monitoring in the considered water area, the content of petroleum products in bottom sediments is below the detection limit of the measurement method used[5], which is indicative of the natural presence of this bacterial group at the studied bottom stations. The presence of such narrow specialized groups of bacteria as sulfate-reducing and thionic bacteria in the studied bacteriocenosis indicates the naturally occurring processes of anaerobic degradation.

Analysis of summer-autumn successions of studied bacteriocenosis revealed a decrease in the indicators under consideration in autumn, which may be associated with the completion of organic matter mineralization processes in the grounds, as well as with the gradual depletion of nutrients dissolved in water involved in the biochemical activity of the studied groups of bacteria.

The observed higher values of bacteriocenosis indicators at the main parts of the bottom stations over the values observed at the pelagic parts, as well as the greater abundance and biomass of bacteriobenthos compared to bacterioperiphyton, is explained, first, by the maximum contact of the main parts of the bottom stations with the ground, and, second, by the nature of the studied fouling communities and the greater accumulative capacity of the bottom sediments compared to that of fouling communities.

In the spatial distribution of total abundance, total biomass of bacterioperiphyton, bacteriobenthos and the saprotrophic group of heterotrophs, it was noted that the highest values are characteristic of the central part of the studied water area, mainly the shallowest areas (10.1–10.4 m). The lowest values of these indicators were recorded at the deeper areas along the periphery of the studied water area (10.7–11.3 m). This microbiological pattern is quite natural and is explained by the formation of more favorable conditions for bacterial development with decrease in the depth of the studied stations. The lowest and the highest values of the total abundance and total biomass of bacteria in grounds and the main parts of the bottom stations generally had a similar spatial arrangement, indicating a close relationship between the two studied research horizons. Spatially, the distribution of narrow specialized groups of bacteria was mosaic in nature. However, for sulfate-reducing bacteria, on average, maximum development was recorded at BS with greater depth, where more favorable conditions are created for this group. Spatial distribution of hydrocarbon-oxidizing and thionic bacteria was more uneven.

Bacteriocenosis of the studied bottom stations is represented by a bacterial community actively colonizing the natural-anthropogenic biotopes of the Caspian Sea. Among the studied ecological-physiological groups, the saprotrophic group prevailed, the share of which from the total bacterial count was significant (up to 20%). Hydrocarbon-oxidizing, sulfate-reducing, and thionic bacteria were inoculated from the studied periphyton parts and bottom sediments in smaller quantities. The total abundance and biomass of bacteria at the considered bottom stations corresponded to the quantitative characteristics of bacteriocenoses of the considered area of the Caspian Sea. Therefore, the installation of bottom stations in the water area of the Northern Caspian Sea, which is subject to various anthropogenic impacts, can contribute to maintaining the bioproductivity of the studied marine water area through the pioneer colonization of natural-anthropogenic biotopes by the bacterial group, which acts as the primary link in the trophic structure of the forming biocenoses.

[5] PND F 14.1:2:4.168. Quantitative chemical analysis of water. Methodology (method) for measuring the mass concentration of petroleum products in samples of drinking, natural, and treated wastewater by IR spectrophotometry using KN series concentrators.

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