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Caspian cyanobacteria of Azerbaijan: a complete checklist with ecological and geographical characteristics

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ABSTRACT: The article presents the results of a taxonomic revision of the species diversity of cyanobacteria in the Azerbaijani sector of the Caspian Sea according to literature and original data. For the period from 1870 to 2019, 98 species from 44 genera of *Cyanophyceae* were found off the Caspian coast of Azerbaijan. *Phormidium* Kützing ex Gomont, *Chroococcus* Nägeli, *Lyngbya* C. Agardh ex Gomont, *Oscillatoria* Vaucher ex Gomont, *Merismopedia* F.J.F.Meyen and *Spirulina* Turpin ex Gomont lead in species number. 64 species from 32 genera were found in both plankton and benthos. 33 species from 20 genera of cyanobacteria were common for these communities. Off the coast of Azerbaijan, 64.7% of the genera and 48.0% of the species of cyanobacteria known for the Caspian Sea as a whole have been identified, which indicates that the marine cyanoflora of Azerbaijan has been studied quite fully. The analysis of ecological and biogeographic features of the identified species is given. Among the cyanobacteria of the Azerbaijani coast, the inhabitants of fresh waters are the most numerous (39.2%), followed by freshwater/brackish and brackish species (35.1% together), marine species are the third (16.5%). The predominance of freshwater and brackish forms reflects the specificity of the Caspian Sea as a closed water body with a lower salinity in comparison with oceanic waters. By ecotopic confinement, most of the species found are known as benthic (62.9%), the proportion of truly planktonic species is 29.9%. At the same time, film-forming species are widely represented not only in benthic communities (82.8%), but also in the water column, where they account for about half of the identified species (48.5%). This is related to the hydrological features of coastal ecotopes, where the surf-wave impact on the marine littoral contributes to the penetration of bottom filaments into the water column. The geographical spectrum is characterized by the predominance of species with a cosmopolitan (45.4%) and sub-cosmopolitan (30.9%) distribution, which reflects the tense ecological situation in the region.

K e y w o r d s: cyanobacteria, species composition, phytoplankton, phytobenthos, ecology, general distribution, Caspian Sea, Azerbaijan

Introduction

The Caspian Sea, due to its geographic location, exceptional richness of natural resources and historical influence on the economy and life of coastal states, plays a special role in the region. The sustainable state of its ecosystem is not least provided by microalgae, among which the largest share of primary production, along with diatoms, is formed by cyanobacteria. Due to the unique structural and functional organization of cells and the ability to quickly adapt to changes in the environment, these ancient prokaryotic photoautotrophs provide the dynamics of oxygen, carbon, and nitrogen in the aquatic environment, influencing the diversity and abundance of aquatic organisms (Vincent, 2009). They can also have a negative impact on the water quality: under conditions of climatic changes and increased anthropogenic loads on the coastal zones of the Caspian Sea, not least due to the expansion of oil production, more and more cases of cyanobacterial water blooms, including potentially toxic species (Nasrollahzadeh, 2010; Tahami, 2014; Nuriyeva, 2018), are observed. This indicates the importance of studying cyanobacteria at the regional level.

The Caspian is an inland sea located in an extensive continental depression on the border between Europe and Asia. Based on the features of the bottom topography, it is divided into three parts: the North, Middle and South Caspian (Kosarev, 2005). Five countries are located on the shores of the Caspian Sea: Azerbaijan, Iran, Kazakhstan, Russia and Turkmenistan. The Caspian coast of Azerbaijan occupies the southwestern part of the sea within the Middle and South Caspian; the length of the coastline is 955 km. The geomorphological conditions of the littoral zone are quite diverse: from narrow beaches overlooking the sea cliffs to wide sandy areas near river mouths. Bottom sediments are represented by sands, sandy clays, shell rock, silts, as well as coarse and fine-grained sediments. The surface of stones protruding from the water is often covered with sandy soil mixed with shell rock. Water salinity ranges from 7.0‰ in the pre-estuary space of the Kura River up to 13.7‰ near Khara-Zira Island, averaging 12.0–13.0‰. Often, stones and rocks in the splash zone and at shallow depths are covered with algae, including blue-greens. Microscopic cyanobacteria form fouling visible to the naked eye in the form of muddy deposits, films, crusts, mats, etc. In some parts of the coast, in the littoral, there are thickets of algae-macrophytes (Petrov, 1967; Karaeva, Zaberzhinskaya, 2008). Oil production has been the main anthropogenic factor affecting the ecological situation in the Caspian Sea, including off the coast of Azerbaijan, for over 100 years (Éfendieva, 2000). Industrial, agricultural and urban wastewaters are added to the increased oil pollution, which makes the situation in the region quite tense. Therefore, the task of inventorying and monitoring biological diversity remains extremely urgent.

The beginning of the study of the algal flora of the Caspian Sea dates back to the second half of the 19th century (Nuriyeva, 2019a, b); however, over the next century, very little information was accumulated on the algae, including blue-greens, of the Azerbaijani coast of the Caspian. It is interesting that the first finds of cyanobacteria of the sea were made on the Baku coast and concerned

benthic filamentous cyanobacteria. Kovalevsky (1870) cited *Oscillatoria leptotricha* Alten (actually accepted name is *Geitlerinema splendidum*[1]) and *O. nigra* Vaucher (=*Phormidium nigrum*). A little later (Grunow, 1878) in the samples collected by Schneider in the port of Baku *Lyngbya crispa* Agardh (=*Heteroscytonema crispum*) was identified. The next publication with data on the species of blue-green algae appeared 40 years later (Kiselev, 1938). The author investigated the phytoplankton of the Middle and South Caspian in February–March 1934. Since the temperature regime at the end of winter does not favor the vegetation of blue-greens, only 17 of the 122 discovered taxa of species and infraspecies rank belonged to *Cyanophyta*. Among them, four species of unicellular cyanobacteria were noted in samples taken off the coast of Azerbaijan. In the same period of time (1934–1938) Kireeva and Schapova studied the phytobenthos of the Caspian Sea, including its western coast and the islands of the Baku archipelago. Based on their own and published data, the authors indicate that by the time of this writing, 33 species of *Cyanophyta* were found in the benthos of the Caspian Sea, of which only 3 species (*Lyngbya estuarii* Liebman ex Gomont, *L. majuscula* Harvey ex Gomont, *Oscillatoria nigra* Vaucher ex Gomont) were found in the western coast and near the islands of the Baku archipelago (Kireeva, Schapova, 1957). A special hydrobotanical study of the Caspian coastal zone near Azerbaijan was carried out in the summer of 1959 and 1962 (Petrov, 1967), which made it possible to obtain a detailed description of phytobenthos communities for 150 stations located along the Azerbaijani coast. These data served as the basis for the classification of underwater phytocenoses and identification of vegetation types, among which a separate type of vegetation was described: communities of blue-green algae, represented by three formations (*Rivularia*, *Symploca laeteviridis*, *Lyngbya*); each of them formed a single-species association of the same name (Petrov, 1967). The text mentions the names of several more genera of blue-green algae (*Anabaena*, *Oscillatoria*); all taxa are listed without authors.

In 1968, a fundamental summary on the phytoplankton of the Caspian Sea was published (Proshkina-Lavrenko, Makarova, 1968), which still remains the reference book of researchers of the Caspian microalgae. The authors carefully summarized and analyzed all the literature available at that time and original long-term observations of planktonic algae throughout the entire sea area. Their phytoplankton list contains valuable information on the occurrence of species in the Caspian Sea, with precise indications of location, ecological conditions and abundance at the time of sampling. The list adds to the previously mentioned records in the Azerbaijani sector of the Caspian Sea six species of planktonic cyanobacteria, which are said to have been found throughout the sea. Although the monograph mentioned the works of Babaev (1963, 1965a, b), devoted to phytoplankton of the western part of the Middle and South Caspian (Proshkina-Lavrenko, Makarova, 1968, p. 21), his data were not included in the list. Totally, Babaev (1968a, b) identified 29 taxa of blue-greens. Thus, by the beginning of the 70s of the 20th century, 33 species (36 forms) of *Cyanophyta* were known

[1] The names of the authors of taxa are in the Table.

for the Azerbaijani coast, of which 31 taxa from phytoplankton and only 4 species were found in phytobenthos.

In the last quarter of the 20th century, special studies of *Cyanophyta* began in the western part of the Caspian Sea, which continue to this day (Nuriyeva, 1980 a, b, 1981, 1983, 1996, 2006, 2007, 2013, 2018, 2019a,b; Nuriyeva, Akhundova, 1992; Akhundova, 1996). A significant part of this data concerns the Azerbaijani sector. For the first time, within the framework of one study, cyanobacteria living in the water column, at the bottom and in fouling of various substrates were studied, which made it possible to significantly expand the list of blue-green algae of the Caspian Sea (Nuriyeva, 1991, 1992, 2010, 2019a).

The active introduction of an integrated approach into the practice of studying cyanoprokaryotes and the adoption of the monophyletic concept of the species (Johansen, Casamatta, 2005) contributed to the description of a large number of new taxa of various ranks and, accordingly, to radical changes in their taxonomy. Therefore, the data accumulated over more than a century needs to be updated through the nomenclature-taxonomic revision of both the systematic structure and the species diversity of the Caspian cyanobacteria of Azerbaijan. The taxonomic structure of *Cyanophyceae* in the Azerbaijani sector of the Caspian Sea in accordance with current changes in the nomenclature is presented in our previous article (Nuriyeva, 2019b).

The purpose of the present work was to analyse the species diversity of marine cyanobacteria of the Azerbaijani coast, taking into account the biotopic confinement, ecological features and data on the distribution of species, as well as to compile their verified list.

Materials and Methods

To compile a verified list of cyanobacteria in the Azerbaijani sector of the Caspian Sea, we analyzed all known literary sources containing the names of taxa, as well as systematic lists from the candidate dissertations of Babaev (1968b) and Nuriyeva (1983). The original materials included over a thousand algological samples taken by the first author of this communication during expedition trips to the western part of the Caspian Sea (including the Azerbaijani sector) and sea excursions along the Azerbaijani coast of the Caspian Sea, starting in 1973. Sampling was carried out in different months from the splash zone to a depth of 50 (less often 100) m by the methods accepted in phycology (Algae…, 1989). The water column, the bottom and surface of various substrates (rocks, stones, hydraulic structures, algae, etc.) were examined. When taking an algological sample, the temperature, transparency, color and active reaction of water were measured, and a sample was also taken to determine the water salinity. Particular attention was paid to the coast of the Absheron Peninsula, where sites for stationary observations were selected.

The identification of species was carried out using a number of keys (Elenkin, 1938-1949; Hollerbakh et al., 1953; Kondratyeva, 1968; Kondratyeva et al., 1984; Komárek, Anagnostidis, 1998, 2005; Komárek, 2013). The dominant species were judged by the results of direct microscopy; the relative abundance of the species was assessed using the Starmach scale (Algae…,

1989). The frequency of occurrence (F) was determined as the ratio of the number of samples in which the species was identified to the total number of samples studied.

The list was compiled in accordance with the classification of the genera of cyanobacteria (Komárek et al., 2014), taking into account the changes that have appeared since its publication (Guiry, Guiry, 2020). For the convenience of using the list and due to the extreme inconsistency of the systematic position of taxa with a rank higher than the genus at the present stage of intensive development of phylogenetic studies, we do not list families and orders; we arrange the genera (and species within the genus) in alphabetical order. The ecological characteristics and data on the general distribution of species are given according to Kovalenko (2009) and the corresponding issues of *Süsswasserflora von Mitteleuropa* (Komárek, Anagnostidis, 1998, 2005; Komárek, 2013); we also took into account information from *AlgaeBase* (Guiry, Guiry, 2020). We use the terms "plankton" and "benthos" in accordance with the definition of the EU Water Framework Directive (WFD, 2000; https://ec.europa.eu/environment/water/water-framework/index_en.html).

Results and Discussion

According to the generalized literature and original data, 98 species from 44 genera of *Cyanophyceae* were found near the Caspian coast of Azerbaijan (Table). The richest in species genera are *Phormidium* (9 species), *Chroococcus*, *Lyngbya*, *Oscillatoria* (6 species each), *Merismopedia* and *Spirulina* (5 species each). More than half of the genera (59.1%) are represented by one species each (Table). High generic diversity against the background of a low genus/species ratio (1/2.2) is mostly related to active taxonomic rearrangement of the group based on molecular phylogenetic data and the splitting of morphological genera into smaller phylogenetic clusters of the generic level.

The overwhelming number of identified species are characterized by low rates of occurrence and abundance. *Kamptonema laetevirens, Planktolyngbya limnetica*, *Leptolyngbya perelegans*, *Oscillatoria tenuis*, *Coleofasciculus chthonoplastes*, species of genera *Spirulina* (*S. labyrinthiformis*, *S. subtilissima*, *S. tenuissima*) and *Phormidium* (*P. ambiguum*, *P. breve*), *Lyngbya lutea*, *Trichocoleus tenerrimus*, *Calothrix scopulorum*, *Nodularia harveyana*, *Rivularia atra* occurred more often than others. Mass development was noted for a number of filamentous cyanobacteria forming macroscopic accumulations in the water column, on the sea bottom and surface of various substrates. Among them *Limnothrix redekei*, *Lyngbya martensiana*, *L. lutea, Phormidesmis molle*, *Spirulina tenuissima, P. ambiguum*, *P. breve*, *Anabaenopsis tanganyikae*, *Chrysosporum minus*, *Rivularia atra.* Among the species found off the coast of Azerbaijan, 11 are known as toxic: *Aphanizomenon flosaquae*, *Chrysosporum bergii*, *Dolichospermum flosaquae*, *Kamptonema formosum*, *Limnothrix redekei*, *Lyngbya majuscula*, *Microcystis aeruginosa*, *M. flosaquae*, *Nodularia spumigena*, *Planktothrix agardhii*, *Snowella lacustris*.

According to the ecological and geographical analysis, the generalized list of marine cyanobacteria of Azerbaijan reflects the features of the Caspian

region, as well as the specifics of its algofloristic study. In relation to water salinity, among the cyanobacteria of the Azerbaijani coast, the inhabitants of fresh water bodies are most numerous (39.2%), followed by freshwater/brackish and brackish forms (35.1% altogether); marine species rank third (16.5%). Three species each belong to halobionts (*Coleofasciculus chthonoplastes*, *Gloeocapsopsis crepidinum*, *Nodularia harveyana*) and ubiquists (*Dolichospermum flosaquae*, *Spirulina labyrinthiformis*, *S. major*). The predominance of freshwater and brackish taxa is associated with the specificity of the Caspian Sea as a closed water body with a lower salinity in comparison with oceanic waters.

Analysis of the list of cyanobacteria from the point of view of the correspondence of the ecological characteristics of the species with their occurrence in the ecotopes of the Azerbaijani Caspian made it possible to reveal some features of the ecotopic groups of the coast. According to literature data, significant portion of discovered species are known as representatives of phytobenthos (61, including 7 periphytic species) and phytoplankton (29 species); four species live both in the water column and on the surface of various substrates, and three species are characteristic of metaphyton. Interestingly, off the coast of Azerbaijan, film-forming filamentous cyanobacteria were widely represented not only in benthic communities (82.8%), but also in the plankton, where they account for about half of the identified species (48.5%). This is due to the hydrological features of coastal ecotopes, where the surf-wave impact on the sea littoral contributes to the penetration of bottom filaments into the water column. The share of planktonic species in benthic communities was significantly lower: 14.1%. In general, the discovered taxa were distributed as follows: 64 species from 32 genera were found in both plankton and benthos; 33 species from 20 genera of cyanobacteria were common for these ecotopic groups.

The biogeographic spectrum of marine cyanobacteria of Azerbaijan is characterized by the predominance of species with a cosmopolitan (45.4%) and sub-cosmopolitan (30.9%) type of range; nine species are known as inhabitants of temperate latitudes. Four species have the Eurasian range and three each belong to the Eurasian-African and Eurasian-American types of the range. Two species have been described from the Caspian Sea; of these, *Anabaena kisselevii* is also found in the northeastern Black Sea (Nesterova et al., 2006), and *Kamptonema capsicum* is presumably endemic to the Caspian region (Vinogradova, Nuriyeva, 2020). The predominance of cosmopolitan and widespread species in the cyanoflora of the Azerbaijani Caspian reflects the tense ecological situation in the region.

Comparison of the analyzed list of cyanobacteria with data for the entire Caspian Sea allows us to conclude that the marine cyanoflora of Azerbaijan has been studied quite fully: it comprises 64.7% of genera and 48.0% of species known for the sea as a whole. The list includes 15 species that were found in the Caspian Sea only off the coast of Azerbaijan. Among them are the previously mentioned historical finds: *Geitlerinema splendidum* (Kovalevsky, 1870) and *Heteroscytonema crispum* (Grunow, 1878) found in the Baku region. These are widespread inhabitants of the benthos of continental waters; further for the

Caspian Sea were not given. Also, only in the Azerbaijani sector were recorded such representatives of marine phytobenthos as the cosmopolitan *Oscillatoria corallinae* and two rather rare species of the genus *Symploca*, which should be mentioned separately. *Symploca laeteviridis* was cited as the edifier of the both association and formation described by Petrov on the basis of the samples collected at one station located on the small rocky island in the water area of the Absheron Peninsula. Cyanobacteria formed "filmy sinusia on rocky surfaces open by the surf in the splash zone from 0.75 m to 1 m above sea level." (Petrov, 1967, p. 131). Revealing of thin-filamentous tropical cyanobacteria in hydrobotanical survey based on the dominant approach seems to us extremely doubtful. *S.laeteviridis* was described from the coast of Key West Isl. in the Gulf of Mexico. The range of this species covers the oceanic coasts of Southeast Asia, Australia, New Zealand and South America (Komárek, Anagnostidis, 2005; Guiry, Guiry, 2020). Morphologically, this species is indistinguishable from many representatives of oscillatorian algae with trichomes 1.5–3.5 μm wide. Considering the morphology and geographical distribution of *S. laeteviridis*, as well as the fact that identification was carried out without the use of immersion optics, we consider this identification doubtful. Another representative of the genus *Symploca*, *S. funicularis*, was found in a number of sites along the coast of the Middle and South Caspian, both in epilithic on stones in the splash zone and on silty bottom at a depth of 10–12 m (Nuriyeva, 1983). These findings do not contradict the ecological and geographical characteristics of this species: it was described from the Pacific coast of the United States, but also found in Europe (Scandinavian countries, Spain, including the Canary Islands). The rest of the species, found so far only off the coast of Azerbaijan, are widespread taxa with a wide ecological amplitude; therefore, their absence in other regions of the sea may be due to the fact that the benthic communities of the Caspian coast as a whole are much less studied than plankton ones.

Conclusions

As a result of a taxonomic revision of the literature and original data, a checklist of cyanobacterial genera and species of the Azerbaijani sector of the Caspian Sea was compiled. For the period from 1870 to 2019, 98 species from 44 genera of *Cyanophyceae* were recorded. The most diverse genera are *Phormidium*, *Chroococcus*, *Lyngbya*, *Oscillatoria*, *Merismopedia* and *Spirulina*; they account for 39.2% of all revealed species. Almost half of the genera (44.4%) are represented by one species each.

Sixty four species from 32 genera were found in both plankton and benthos; 33 species from 20 genera of cyanobacteria were common for these ecotopic groups. According to the ecotopic preference of the revealed species, most of them are known as benthic (62.9%), the proportion of truly planktonic species is 29.9%. At the same time, due to the surf-wave impact on the sea littoral, mat-forming filamentous cyanobacteria were widely represented not only in benthic communities (82.8%), but also in the samples of phytoplankton, where they account for about half of the identified taxa (48.5%).

In relation to water salinity, among the cyanobacteria of the Azerbaijani coast, the inhabitants of fresh waters are most numerous (39.2%), followed by freshwater/brackish and brackish forms (35.1% altogether); marine species rank third (16.5%). The predominance of freshwater and brackish species reflects the specificity of the Caspian Sea as a closed water body with a lower salinity in comparison with oceanic waters.

The biogeographical spectrum is characterized by the predominance of species with a cosmopolitan (45.4%) and sub-cosmopolitan (30.9%) ranges, which reflects the tense ecological situation in the region.

The list includes 64.7% of genera and 48.0% of species known for the Caspian Sea as a whole. 15 species were found only off the Azerbaijani coast. This is partly due to the fact that the benthic cyanobacteria of the northern and southern Caspian have hardly been studied.

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Нурієва М.А[1]., Виноградова О.М[2]. 2020. **Ціанобактерії азербайджанського сектора Каспійського моря: перевірений список та еколого-географічні особливості.** *Альгологія.* 30(4): 325–340.

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У статті представлені результати таксономічної ревізії видового різноманіття ціанобактерій азербайджанського сектора Каспійського моря за літературними та оригінальним даними. За період 1870–2019 рр. біля каспійського узбережжя Азербайджану виявлено 98 видів з 44 родів *Cyanophyceae*. Найбільш різноманітно представлені роди *Phormidium* Kützing ex Gomont, *Chroococcus* Nägeli, *Lyngbya* C. Agardh ex Gomont, *Oscillatoria* Vaucher ex Gomont, *Merismopedia* F.J.F. Meyen и *Spirulina* Turpin ex Gomont. У планктоні і бентосі виявлено по 64 види з 32 родів ціанобактерій; спільними виявилися 33 види з 20 родів. Подано аналіз біотопічної приналежності, экологічних та біогеографічних особливостей знайдених видів. Серед ціанобактерій азербайджанського узбережжя найчисленнішими були мешканці прісних вод (39,2%), за ними йдуть прісноводно/солонуватоводні та солонуватоводні форми (разом 35, 1%), на третьому місці морські види (16,5%). Переважання прісноводних і солонуватоводних форм відбиває специфіку Каспійського моря як безстічної водойми зі зниженою, в порівнянні з океанічними водами, солоністю води. За екотопічною приуроченністю більшість виявлених видів відомі як представники фітобентосу (62,9%), частка істинно планктонних видів становить 29,9%. При цьому види-плівкоутворювачі широко представлені не тільки в бентосних угрупованнях (82.8%), а й в товщі води, де на їхню частку припадає близько половини виявлених видів (48,5%). Це пов'язано з гідрологічними особливостями прибережних екотопів, де прибійно-хвильовий вплив на морську літораль сприяє потраплянню донних нитчаток у товщу води. Географічний спектр характеризується переважанням видів з космополітним (45,4%) і субкосмополітним (30,9%) типами ареалу, що відображає напружену екологічну ситуацію в регіоні.

К л ю ч о в і с л о в а : ціанобактерії, видовий склад, фітопланктон, фітобентос, екологія, загальне поширення, Каспийське море, Азербайджан

Table. **Verified list of cyanobacteria of the Azerbaijani coast of the Caspian Sea**
(1 – ecotopic grouping, 2 – relation to the salinity of the environment, 3 – general distribution)

Taxon	Azerbaijani coast		Ecological and geographical characteristics of the species		
	1	Reference*	1	2	3
Anabaena Bory ex Bornet et Flahault, 1886					
Anabaena kisselevii Proshkina-Lavrenko	pl	20, 22, 23	pl	br	BS, CS
Anabaenopsis V.V.Miller, 1923					
Anabaenopsis cunningtonii W.R.Taylor	pl	20, 22, 23, 25	pl	fw	E, A, Af, S Am
A. elenkinii V.V.Miller	pl	5, 14	pl	br	wd
A. raciborskii Woloszynska	pl	5	pl	br	wd
A. tanganyikae (G.S.West) Woloszynska et V.V.Miller	pl	4, 5, 20, 22, 23, 25	pl	fw	wd
Anagnostidinema Strunecký, Bohunická, J.R.Johansen et J.Komárek, 2017					
Anagnostidinema acutissimum (Kufferath) Strunecký, Bohunická, J.R.Johansen et J.Komárek [*Oscillatoria acutissima* Kufferath]	pl, bn	12, 14, 15, 17, 18, 22	bn	fw	temp
Anathece (Komárek et Anagnostidis) Komárek, Kastovsky et Jezberová, 2011					
Anathece clathrata (W. et G.S.West) Komárek, Kastovsky et Jezberová [*Aphanothece clathrata* W. et G.S.West]	pl, bn	14, 17, 22	pl	fw/br	cosmo
Aphanizomenon Morren ex Bornet et Flahault, 1886					
Aphanizomenon flosaquae Ralfs ex Bornet et Flahault	pl	4, 5, 13, 14, 20, 21, 22, 23, 25	pl	fw	temp
Aphanocapsa Nägeli, 1849					
Aphanocapsa grevillei (Berkeley) Rhabenhorst [*Microcystis grevillei* (Hassall) Elenkin]	pl, bn	5, 13, 14, 22, 23	tr	fw	temp
A. holsatica (Lemmermann) G.Cronberg et Komárek [*M. pulverea* f. *holsatica* (Lemmermann) Elenkin]	pl	22	pl	mar/ fw	cosmo
Aphanothece Nägeli, 1849					
Aphanothece elabens (Brébisson ex Meneghini) Elenkin [*Aphanothece elabens* (Brébisson) Elenkin f.minor]	pl	14, 17, 22	pl/bn	fw	E, A, S Am
Arthrospira Sitzenberger ex Gomont, 1892					
Arthrospira platensis Gomont [*Spirulina platensis* (Gomont) Geitler]	pl	14, 15, 21, 22, 23	pl/bn	mar/ fw	wd
Calothrix C.Agardh ex Bornet et Flahault, 1886					
Calothrix scopulorum C.Agardh ex Bornet et Flahault	bn	12, 13, 14, 19, 20, 22, 23	bn	mar	cosmo
Chroococcus Nägeli, 1849					
Chroococcus cohaerens (Brébisson) Nägeli [*Gloeocapsa cohaerens* (Brébisson) Hollerbach]	bn, pl	13, 14, 17, 22	bn	aer	E, A, N Am
C. dispersus (Keissler) Lemmermann [*Gloeocapsa minor* (Kützing) Hollerbach f. *dispersa* (Keissler) Hollerbach	pl	14, 22, 25	pl	fw/br	temp
C. minimus (Keissler) Lemmermann [*Gloeocapsa minima* (Keissler) Hollerbach; *Gloeocapsa minima* f. *smithii* Hollerbach]	pl, bn	13, 14, 17, 22	pl	fw	temp
C. minor (Kützing) Nägeli [*Gloeocapsa minor* (Kützing) Hollerbach]	pl, bn	10, 14, 17, 22	bn	fw/br	temp
C. minutus (Kützing) Nägeli [*Gloeocapsa minuta* (Kützing) Hollerbach]	pl	6, 14, 17, 22	pl	fw/br	cosmo
C. turgidus (Kützing) Nägeli [*Gloeocapsa turgida* (Kützing) Hollerbach]	pl, bn	6, 12, 14, 17, 19, 22	bn	fw	cosmo

Chrysosporum E.Zapomelová, O.Skácelová, P.Pumann, R.Kopp et E.Janecek, 2012					
Chrysosporum bergii (Ostenfeld) E.Zapomelová, O.Skácelová, P.Pumann, R.Kopp et E.Janecek [*Anabaena bergii* Ostenfeld]	pl	5, 20, 22, 23, 25	pl/bn	br	wd
Chrysosporum minus (Kiselev) Komárek [*Anabaena bergii* Ostenfeld f. *minor* Kiselev]	pl	4, 5, 14, 20, 22, 23, 25	pl	fw	E, A
Coleofasciculus M.Siegesmund, J.R.Johansen et T.Friedl, 2008					
Coleofasciculus chthonoplastes (Thuret ex Gomont) M.Siegesmund, J.R.Johansen et T.Friedl [*Microcoleus chthonoplastes* Thuret ex Gomont]	bn	12, 13, 14, 17, 22, 23	bn	hb	cos mo
Cuspidothrix P. Rajaniemi, J. Komárek, R.Willame, P.Hrouzek, K.Kastovská, L.Hoffmann et K.Sivonen, 2005					
Cuspidothrix issatschenkoi (Usachev) P.Rajaniemi, J. Komárek, R.Willame, P.Hrouzek, K.Kastovská, L.Hoffmann et K.Sivonen [*Aphanizomenon issatschenkoi* (Usachev) Proshkina-Lavrenko]	pl	5	pl	fw/br	wd
Cuspidothrix ussaczevii (Proshkina-Lavrenko) P. Rajaniemi, J. Komárek, R.Willame, P. Hrouzek, K. Kastovská, L.Hoffmann et K. Sivonen [*Aphanizomenon ovalisporum* Forti f. *caspica* Usachev]	pl	5	pl	fw	CS
Dolichospermum (Ralfs ex Bornet et Flahault) P. Wacklin, L.Hoffmann et J. Komárek, 2009					
Dolichospermum flosaquae (Brébisson ex Bornet et Flahault) P.Wacklin, L.Hoffmann et J.Komárek [*Anabaena flos-aquae* Brébisson in Brébisson et Godey]	pl	5, 13, 14, 20, 22, 23	pl	fw	cos mo
Geitlerinema (Anagnostidis et Komárek) Anagnostidis					
Geitlerinema splendidum (Greville ex Gomont) Anagnostidis [*Oscillatoria leptothricha* Alten]	bn	11	bn	fw/br	cos mo
Gloeocapsopsis Geitler ex Komárek, 1993					
Gloeocapsopsis crepidinum (Thuret) Geitler ex Komárek [*Gloeocapsa crepidinum* (Thuret) Thuret]	bn	14, 17, 19, 22	bn	hb	cos mo
Gomphosphaeria Kützing, 1836					
Gomphosphaeria aponina Kützing	pl	14, 22, 23, 25	pl	fw	cosmo
G. cordiformis (Wille) Hansgirg [*Gomphosphaeria aponina* Kützing var. *cordiformis* Wolle]	pl	10, 22	pl	fw	wd
G. multiplex Komárek [*Gomphosphaeria aponina* Kützing var. *multiplex* Nygaard]	pl	22, 25	pl	fw	wd
Heteroleibleinia (Geitler) Hoffmann, 1985					
Heteroleibleinia kossinskajae (Elenkin) Anagnostidis et Komárek [*Lyngbya kossinskajae* Elenkin]	bn	22, 23	ep	fw	E, A
H. kuetzingii (Schmidle) Compère [*Lyngbya kuetzingii* Schmidle]	bn	14, 17, 18, 22, 23	ep	fw	cos mo
H. ucrainica (Shirshov in Elenkin) Anagnostidis et Komárek [*Lyngbya kuetzingii* f. *ucrainica* Shirshov]	bn	2, 18, 22, 23	ep	fw	E, CS
Heteroscytonema McGregor et Sendall, 2018					
Heteroscytonema crispum (Bornet ex De Tony) G.B.McGregor et Sendall [*Lyngbya crispa* C. Agardh]	bn	7	bn	fw	wd
Jaaginema Anagnostidis et Komárek, 1988					
Jaaginema geminatum (Schwabe ex Gomont) Anagnostidis et Komárek [*Oscillatoria geminata* Schwabe ex Gomont]	pl, bn	6, 14, 18	ep	fw/br	cos mo
J. pseudogeminaum (G.Schmid) Anagnostidis et Komárek [*Oscillatoria pseudogeminata* G.Schmid]	pl, bn	14, 17, 18, 22	pl/bn	fw	E, A, S Am
Kamptonema Strunecký, Komárek et J.Smarda, 2014					
Kamptonema capsicum (Usachev) O.Vinogradova et M. Nuriyeva [*Oscillatoria tanganyikae* f. *caspica* Usachev]	pl	5	pl	fw/br	CS
K. formosum (Bory ex Gomont) Strunecký, Komárek et J.Smarda [*Oscillatoria formosa* Bory ex Gomont]	bn	14, 17, 18, 22	bn	fw/br	cos mo
K. laetevirens (H.M.Crouan et P.L.Crouan ex Gomont) Strunecký, Komárek et J.Smarda [*Oscillatoria laetevirens* (H.M.Crouan et P.L.Crouan ex Gomont]	pl, bn	14, 17, 18, 19, 22, 23	bn	mar/hb	E, N Am

Kamptonema okenii (C.Agardh ex Gomont) Strunecký, Komárek et J.Smarda [*Oscillatoria okenii* C.Agardh ex Gomont]	pl, bn	12, 13, 14, 17, 18, 22	bn	fw/br	cos mo
Leptolyngbya Anagnostidis et Komárek, 1988					
Leptolyngbya fragilis (Gomont) Anagnostidis et Komárek [*Phormidium fragile* Gomont]	bn	14, 18, 22	bn	mar	cos mo
Leptolyngbya perelegans (Lemmermann) Anagnostidis et Komárek [*Lyngbya perelegans* Lemmermann]	bn	12, 14, 15, 17, 18, 22	bn	fw	cos mo
L. tenuis (Gomont) Anagnostidis et Komárek [*Phormidium tenue* Gomont]	bn	14, 18, 22	bn/tr	fw	wd
L. valderiana (Gomont) Anagnostidis et Komárek [*Phormidium valderiae* f. *majus* Hollerbach]	bn	14, 15, 17, 22	bn	fw	cos mo
Limnococcus (Komárek et Anagnostidis) Komárková, Jezberová, O.Komárek et Zapomelová, 2010					
Limnococcus limneticus (Lemmermann) Komárková, Jezberová, O.Komárek et Zapomelová *[Gloeocapsa limnetica* (Lemmermann) Hollerbach]	pl, bn	5, 6, 10, 14, 17, 19, 22, 23, 25	pl	fw/br	cos mo
Limnothrix M.-E.Meffert, 1988					
Limnothrix redekei (Goor) Meffert [*Oscillatoria redekei* Goor]	pl, bn	12, 13, 14, 16, 17, 18, 21, 22, 23	pl	fw	temp
Lyngbya C.Agardh ex Gomont, 1892					
Lyngbya aestuarii Liebman ex Gomont	bn	9, 12, 13, 14, 16, 22, 23	bn	mar	cos mo
L. confervoides C.Agardh ex Gomont	bn	14, 17, 18, 22	bn	mar	cos mo
L. lutea Gomont ex Gomont	bn	12–15, 17–19, 21–23	bn	fw/br	cos mo
L. majuscula Harvey ex Gomont	bn pl	3, 5, 9, 14, 17, 18, 21, 22	bn	mar	cos mo
L. martemsiana Meneghini ex Gomont	pl, bn	1, 4, 12, 14, 17, 18, 21, 22	mph	fw/br	cos mo
L. semiplena J.Agardh ex Gomont	bn	12, 14, 15, 17, 18, 19, 21, 22, 23	ep, el	mar	cos mo
Merismopedia Meyen, 1839					
Merismopedia glauca (Ehrenberg) Kützing	pl, bn	5, 10, 12, 14, 17, 22, 23, 25	bn/pl	fw	cos mo
M. mediterranea Nägeli [*Merismopedia glauca* f. *mediterranea* (Nägeli) Collins]	pl	3, 4, 5, 14, 17, 22	bn	mar	wd
M. minima G.Beck	pl, bn	5, 13, 14, 22	bn/tr	fw	temp
M. punctata Meyen	pl, bn	5, 6, 10, 12, 13, 14, 17, 22, 23, 25	pl	fw	cos mo
M. tenuissima Lemmermann	pl, bn	5, 6, 10, 12, 14, 17, 22, 25	bn	fw/br	cos mo
Microcoleus Desmazieres ex Gomont, 1892					
Microcoleus amoenus (Gomont) Strunecký, Komárek et R.J.Johansen [*Oscillatoria amoena* Gomont]	pl, bn	13–15, 17, 18, 22, 23	bn/tr	fw	wd
M. beggiatoiformis (Gomont) Strunecký, Komárek et R.J.Johansen [*Oscillatoria beggiatoiformis* (Gomont) f. *maxima* (Copeland) Kondratyeva]	pl	14, 15, 17, 22	bn	fw	E, A
Microcoleus subtorulosus Gomont ex Gomont	bn	14, 17	bn	fw	wd

Microcystis Kützing ex Lemmermann, 1907					
Microcystis aeruginosa (Kützing) Kützing	pl	5, 8,13, 14, 21, 22, 23	pl	fw/br	cos mo
M. flosaquae (Wittrock) Kirchner [*Microcystis aeruginosa* (Kützing) Kützing f. *flos-aquae*]	pl	22	pl	fw	temp
M. pulverea (H.C.Wood) Forti	pl, bn	3, 4, 5, 14, 17, 22, 23, 25	bn	fw	cos mo
Nodularia Mertens in Jürgens ex Bornet et Flahault, 1888					
Nodularia harveyana Thuret ex Bornet et Flahault	pl	4, 5, 12,14, 17, 20, 22, 23, 25	pl/ bn	mar/ fw	cos mo
N. spumigena Mertens ex Bornet et Flahault	pl	4, 5, 20, 21, 22, 23, 25	aq/tr	mar	cos mo
Oscillatoria Vaucher ex Gomont, 1892					
Oscillatoria corallinae Gomont ex Gomont	bn	12, 14, 17, 18, 22	bn	mar	cos mo
O. levis (N.L.Gardner) Anagnostidis [*Oscillatoria tenuis* f. *levis* (N.L.Gardner) Kondratyeva]	pl	13, 14, 17, 18	bn	fw	E, A, S Am
O. limosa C.Agardh ex Gomont	pl, bn	6, 14, 17, 22	bn	fw	wd
O. margaritifera Kützing ex Gomont	bn	5, 14, 17, 18	bn	mar	wd
O. sancta Kützing ex Gomont	bn	12, 14, 17–19, 21–23	bn	fw	cosmo
O. tenuis C.Agardh ex Gomont	pl, bn	12, 14, 17, 18, 22	bn	fw	cos mo
Oxynema Chatchawan, Strunecký, Komárek, Smarda et Peerapornpisal, 2012					
Oxynema lloydianum (Gomont) Chatchawan, Strunecký, Komárek, Smarda et Peerapornpisal [*Oscillatoria lloydiana* Gomont]	bn	14, 17, 22	bn	mar	E
Phormidesmis Turicchia, Ventura, Komárková et Komárek, 2009					
Phormidesmis molle (Gomont) Turicchia, Ventura, Komárková et Komárek [*Phormidium molle* Gomont]	pl, bn	14, 15, 17, 22	bn	fw/br	cos mo
Phormidium Kützing ex Gomont, 1892					
P. ambiguum Gomont	bn	12–14, 16–19, 21–23	bn	mar/ fw	cos mo
P. boryanum (Bory ex Gomont) Anagnostidis et Komárek [*Oscillatoria boryana* Bory ex Gomont]	pl, bn	14, 15, 17, 22	bn	fw	wd
P. breve (Kützing ex Gomont) Anagnostidis et Komárek [*Oscillatoria brevis* Kützing ex Gomont]	bn, pl	5, 12, 13, 14, 17–19, 22, 23	bn	fw/br	cos mo
P. chalybeum (Mertens ex Gomont) Anagnostidis et Komárek [*Oscillatoria chalybea* Mertens ex Gomont]	pl, bn	14, 17, 18, 22	bn	mar/ fw	cos mo
P. irriguum (Kützing ex Gomont) Anagnostidis et Komárek [*Oscillatoria irrigua* Kützing ex Gomont]	pl, bn	12, 14, 17, 18, 22	bn/tr	fw	cos mo
P. nigrum (Vaucher ex Gomont) Anagnostidis et Komárek [*Oscillatoria nigra* Vaucher ex Gomont]	bn	9, 11	bn	fw	wd
P. papyraceum Gomont ex Gomont	bn	14, 16, 17, 18, 22	bn	fw/mar	cos mo
P. tergestinum (Rabenhorst ex Gomont) Anagnostidis et Komárek [*Oscillatoria tenuis* f. *tergestina* (Kützing) Elenkin; *Oscillatoria tenuis* f. *uralensis* (Woronichin) Elenkin]	pl, bn	14, 15, 17, 18, 22, 23	bn	fw	wd
P. variabile (Wille) Anagnostidis et Komárek [*Oscillatoria variabilis* (Wille) Kondratyeva]	bn	22	bn	hb	E, A

Planktolyngbya Anagnostidis et Komárek, 1988					
Planktolyngbya limnetica (Lemmermann) Komárková-Legnerová et Cronberg [*Lyngbya limnetica* Lemmermann]	pl, bn	5, 6, 8, 12, 13, 14, 17, 18, 22	pl	fw	cos mo
Planktothrix Anagnostidis et Komárek, 1988					
Planktothrix agardhii (Gomont) Anagnostidis et Komárek [*Oscillatoria agardhii* Gomont]	pl	5, 12, 14, 17, 18, 22	pl	fw	cos mo
Pseudanabaena Lauterborn, 1915					
Pseudanabaena limnetica (Lemmermann) Komárek [*Oscillatoria limnetica* (Kützing) Gomont]	pl	12, 13, 14, 17, 18, 22	bn, pl	fw	cos mo
Rivularia C.Agardh ex Bornet et Flahault, 1886					
Rivularia atra Roth ex Bornet et Flahault	bn	12, 14, 17, 19, 20, 22,23	bn	mar	wd
Schizothrix Kützing ex Gomont, 1892					
Schizothrix lenormandiana Gomont	bn	14, 17, 22	bn/tr	fw	E
Snowella Elenkin, 1938					
Snowella lacustris (Chodat) Komárek et Hindák [*Gomphosphaeria lacustris* Chodat]	pl, bn	4, 5, 14, 22, 25	pl	fw	cos mo
Spirulina Turpin ex Gomont, 1892					
Spirulina labyrinthiformis Gomont	bn	12, 13, 17–19, 21–23	pl	uq	wd
S. major Kützing ex Gomont	bn	14, 17, 18, 22	pl	mar/fw	cosmo
S. subsalsa Oersted ex Gomont	pl	22, 23	el, ep	mar/fw	cosmo
S. subtilissima Kützing ex Gomont	pl, bn	12–14, 17, 18, 22, 24	el, ep	mar/fw	cosmo
S. tenuissima Kützing	pl, bn	12, 13, 14, 17, 18	bn	mar	E, A, Af
Symploca Kützing ex Gomont, 1892					
Symploca funicularis Setchell et N.L.Gardner	bn	14, 15, 17, 18	bn	mar	E, A, N, Am
S. laeteviridis Gomont	bn	22, 24	bn	mar	S As, S Am, A et NZ
Tolypothrix Kützing ex Bornet et Flahault, 1886					
Tolypothrix distorta Kützing ex Bornet et Flahault	pl	3, 4, 5, 20, 22	bn	fw	wd
Trichocoleus Anagnostidis, 2001					
Trichocoleus tenerrimus (Gomont) Anagnostidis [*Microcoleus tenerrimus* Gomont]	bn	12, 13, 14, 17, 22	bn	br	cos mo
Woronichinia Elenkin, 1933					
Woronichinia compacta (Lemmermann) Komárek et Hindák [*Gomphosphaeria lacustris* Chodat f. *compacta* (Lemmermann) Elenkin]	pl	5, 10, 22, 25	pl	fw/br	temp

* Literary sources are numbered as indicated in the list of references (numbers in bold in square brackets).

Abbreviations: AC – Azerbaijani coast of the Caspian Sea, pl – plankton, mph – metaphyton, bn – benthos, el – epilithon, ep – epiphyton; fw – freshwater, br – brackish, mar – marine, hb – halobiont, tr – terrestrial, aq –aquatic, aer – aerophytic; uq – ubiquist; cosmo – cosmopolitan, wd – widespread (subcosmopolitan), temp – common in temperate latitudes; E – Europe, As – Asia, Af – Africa, N Am – North America, S Am – South America, A et NZ – Australia and New Zealand; BS – Black Sea, CS – Caspian Sea.