Research Article

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Studies on cyanoprokaryotes of the water bodies along the Bulgarian Black Sea Coast (1890-2017): a review, with special reference to new, rare and harmful taxa

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Abstract: The report presents a review of the studies on cyanoprokaryotes from Bulgarian coastal wetlands carried out in the period 1890-2017. The biodiversity of cyanoprokaryotes in coastal water basins (their phytoplankton and phytobenthos) was evaluated and analyzed by wetlands types with emphasis on the new and peculiar taxa described. The conservation status of the recorded species follows the Red List of Bulgarian microalgae. Special attention is paid to the occurrence of cyanoblooms, cyanotoxins and toxic species, as well as to the invasive and alien species.

Key words: biodiversity, harmful blooms, invasive species, new species, threatened species, toxic algae

Introduction

The peculiar prokaryotes named Cyanoprokaryota (Cyanobacteria, Cyanophyta or Blue-green algae) are the only nitrogen-fixing organisms which produce also oxygen through photosynthesis. Highly recognized before for their great potential as providers of ecosystem services, during the last decades they got a lot of negation due to their potential toxicity, keystone role in many harmful blooms and general assuming hazardous for human and ecosystem health (Meriluoto et al. 2017, Stoyneva-Gärtner et al. 2017 and references therein). Therefore, the knowledge on these organisms in coastal wetlands, which are of outsized importance to human welfare due to their high productivity and great potential for commercial activity (MEA 2005), but are also amongst the most threatened of the world's main habitat types (Ramsar Guidelines… 2006), is of primary importance.

This is especially valid of the Bulgarian coastal physico-geographical region for two reasons: 1) it is connected with the very peculiar Black Sea (featured by lack of real tides, low halinity levels of 16-18‰ and significant anoxic layer well below the surface waters); 2) it is a part of Bulgaria – a Balkan country, well-known for its rich biodiversity with many species and habitats of high conservation significance (Peev 2015). Therefore, the aim of the present paper is to evaluate the degree of knowledge on cyanoprokaryote biodiversity, abundance and harmful blooms in the lotic and non-lotic water bodies along the Bulgarian Black Sea coast.

Material and methods

The study covers the Bulgarian Black Sea coastal region, which is 378 km in length (starting from the cape Sivriburun on the Romanian border at the North and finishing on the mouth of Rezovska reka on the border with Republic of Turkey on the South) and is 10 to 40-50 km wide, as it is defined in Stoyneva & Michev (2007) by the border of breeze' influence. The paper aims on outlining the knowledge on cyanoprokaryotes on the background of the general algal biodiversity in Bulgarian coastal water bodies, analysed in Dimitrova et al. (2018). Therefore, it follows the general structural model of the cited paper, as well as all the methods described there in detail with wetlands identification number and conservation status taken from Michev & Stoyneva (2007). The terminology related with alien and invasive species follows Kokocinski et al. (2017). The abbreviations used are: **CP** – cyanoprokaryote, **CPs** – cyanoprokaryotes, **WBs** – water bodies and **RLBMiA** for the Red List of Bulgarian microalgae (Stoyneva-Gärtner et al. 2016), **EX** – extinct, **CR** – critically endangered, **VU** – vulnerable and **EN** – endangered water body.

Results

I. CP data on lotic water bodies

I.1. CP data on coastal rivulets and streams

Petkoff (1919), Valkanov (1935), Mihailova-Neikova (1961), Vodeničarov (1962) and Kirjakov (1985) published ten CPs from Dyavolska reka, Fakiyska reka, Provadiyska reka, Reka Izvorska, Reka Mladezhka and Veleka, and from the "mouths of coastal rivers" as well. They comprise 17% of all 58 algae known from the coastal rivulets. Valkanov (1935) observed "blue coloration" of Provadiyska reka during abundant development of *Chroococcus* sp., which remained for years the only "quantitative" information on the group. The later quantitative data on Ropotamo showed that CPs comprised < 20% of the average phytoplankton numbers and <1% of the biomass (Stoyneva 2003, Pavlova et al. 2007).

I.2. CP data on coastal canals

The new taxon *Oscillatoria geminata* f. *subsalsa,* described by Petkoff (1943) from the canal of Varnensko ezero, was the single CP reported from the total of 16 taxa found in the coastal canals (i.e. only 0.06% of their algal diversity).

I.3. CP data on cold-water springs

Petkoff (1938) published *Phormidium irriguum* (Kütz. ex Gom.) Anagn. et Kom. and *Microcoleus autumnalis* (Gom.) Strun., Kom. et Joh. from the karst spring complex Devnenski izvori, and Lepsi (1926) reported *Oscillatoria* spp. from the springs of Kavarna. These three CPs comprised 10% of all algae known from these coastal WBs.

II. CP studies in lentic and other non-lotic water bodies

II.1. CP studies in coastal lakes and tuzlas

Data on recent CPs of nine coastal lakes, namely Durankulak (IBW0216, CR), Shablensko Ezero (IBW0219, CR), Ezeretsko ezero (IBW0233, CR), Varnensko ezero (IBW0203, CR), Beloslavsko ezero (IBW0227, CR), Pomoriysko ezero (IBW8614, VU), Ezero Vaya (IBW0191, CR), Ezero Uzungeren (IBW0710, VU) and Mandrensko ezero (IBW0810) were given by Petkoff (1919, 1938, 1943), Valkanov (1935, 1936, 1937), Markoff (1935, 1939), Stundl (1937), Paspalew (1943), Cvetkov (1955, 1962), Sashev & Angelov (1959), Mihailova-Neikova (1961), Vodeničarov (1962), Ivanov et al. (1964), Petrova (1961, 1967, 1968a, b), Tsvetkov (1958), Vodenitscharow (1964), Vodenicharov et al. (1971), Petrova-Karadjova (1974, 1975), Valkanov et al. (1978), Naidenov (1981, 1998), Saiz (1981), Moncheva (1991), Chipev & Vassilev (1994), Vassilev et al. (1998), 2015), Beshkova (1998), Kirichova et al. (1998), Stoyneva (1998a, b, 2000a, b, 2002, 2003, 2008, 2010, 2014, 2015), Belkinova et al. (2003, 2014), Mladenov et al. (2003), Pavlova et al. (2006, 2007, 2013a, b, 2014, 2015), Cheshmedjiev et al. (2010), Dimitrova et al. (2014a, b), Stoyanov (2014), Stoyneva et al. (2015), Stoyanov et al. (2013, 2016), Stoyneva-Gärtner et al. (2017). Some "lake" algae have been reported also from stomachs of different fishes (e.g. 4 from 18 taxa in Mihailova-Neikova 1961). In total, more than 115 CPs were found in the lakes, i.e. they represented about 30% of their algal diversity. Varnensko ezero was the second locality of the newly described *Oscillatoria geminata* f. *subsalsa* (Petkoff 1943). Amongst the algae found, two were of conservational importance: *Cyanobacterium diachloros* (Skuja) Kom., Kop. et Cep. and *Oscillatoria annae* Van Goor. They were included in the RLBMiA and comprised 6% of all threatened taxa found in the lakes.

Quantitative data on lake phytoplankton and its structural parameters were scarce (e.g. Saiz 1981, Vassilev 1994, Beshkova 1998, Chipev & Vassilev 1994, Vassilev et al. 1998, Stoyneva 1997, 2002, Dimitrova et al. 2014a). The few comparative data show the multiple increase of phytoplankton numbers and biomass with raised role of CPs (Petrova 1967, 1968b, Petrova-Karadjova 1974, Beshkova 1998, Stoyneva 2000, 2002, Dimitrova et al. 2014a, b, Stoyneva-Gärtner et al. 2017), which indicates the negative trends in the development of the shallow coastal lakes, most of which are threatened (for details see Dimitrova et al., 2018).

Tuzlas are peculiar natural hyperhaline coastal lowland WBs situated on the Black Sea shore. After the transformation of Pomoriyska tuzla (IBW8613, EX), Bulgaria has only three such WBs: Shablenska tuzla (IBW0218, EN), Nanevska tuzla (IBW0217, EN) and Balchishka tuzla (IBW0213, EN). Petkoff (1919, 1943), Ivanov et al. (1964), Draganov et al. (1984), Stoyneva (2003) and Kožuharov et al. (2001) reported 21 CPs, which represented 66% of the algal biodiversity in these WBs.

II.2. CP studies of the coastal swamps

Only *Anabaena oscillarioides* Bory ex Born. et Flah. was recorded by Petkoff (1919) in the swamp complex Blata do Kazul-Kyoy (IBW5367). This single CP represented 3% of the total algal diversity of coastal plateau and mountain swamps.

Data on the CPs of 11 coastal lowland swamps and swamp complexes, namely Alepu (IBW0177, CR), Arkutino (IBW0187, EN), Blata do Topola (IBW0214), Blato Punchevo (IBW0880), Blato Stomoplu (IBW0186, CR), Blattse do Tzarevo (IBW4540), Chengene-Skele (IBW0715, VU), Poda (IBW0193), Orlovo Blato (IBW0242, EN), Sindelsko-Sultanlarsko Blato (IBW0195, EX) and Velyov Vir (IBW0711) were provided by Petkoff (1907, 1919, 1938), Vodeničarov (1962), Vodenitscharow (1964), Naidenow (1967), Kiriakov (1974, 1981), Stoyneva (2000, 2002, 2003, 2014, 2015), Pavlova et al. (2007), Stoyanov (2014), Stoyneva et al. (2015), Stoyanov et al. (2016), Stoyneva-Gärtner et al. (2017). These works contain data on about 90 CPs (i.e. 33% of their algal diversity), with one new taxon described by Petkoff (1938) - *Lyngbya contorta f. duplo-latior*.

II.3. CP studies of the coastal river effluents

Data on CPs from the effluents of the small coastal rivers Ropotamo and Veleka have been published by Petkoff (1907, 1931) and Vodenicharov et al. (1971). Amongst the 45 algae found, five were CPs. *Aphanocapsa rivularis* f. *major* described by Petkoff (1931) and *Aphanocapsa testacea* (A.Br. ex Kütz.) Näg. were included in the RLBMiA.

II.4. CP studies of coastal fountains and watermills and their outfalls

Two CPs (*Phormidium subfuscum* var. *joaninum* Gom., *Microcoleus autumnalis*) were found by Petkoff (1919) in a fountain and a watermill with their outfalls in the region of Kavarna. The new taxon *Phormidium favosum* f. *tenuior* was described by Petkoff (1943) on the basis of material brought by A. Valkanov from a coastal fountain, for which no additional description was provided. CPs comprised 25% of the total algal diversity in these WBs.

II.5. CP studies in the salines

Data on CPs from five costal salt-productive complexes - Burgaski solnitsi (IBW8804), Solnitsi nad Gelareto (IBW0551, EX), Starite solnitsi nad Balchik (IBW0213, EX), Pomoriyski solnitsi (IBW8805) and Sozopolski solnitsi (IBW8145, EX) and on the effluents below the stone-salt productive factory of Provadia were given by Petkoff (1919, 1943), Caspers (1952), Komárek (1956), Ivanov et al. (1964), Vodenitscharow (1964), Vodenicharov et al. (1971), Temniskova-Topalova (1977), Vassilev (1994), Stoyneva (1997, 2003, 2010, 2014, 2015), Chipev & Vassilev (1994), Pavlova et al. (1998), Vassilev et al. (1998), Pavlova et al. (2007), Stoyanov (2014), Stoyneva et al. (2015), Stoyanov et al. (2016), Stoyneva-Gärtner et al. (2017). Data on four CP species from the extinct Sozopolski solnitsi, Balchishki solnitsi and Solnitsi nad Gelareto were provided by Petkoff (1919, 1943): *Lyngbya confervoides* Ag. ex Gom., *Coleofasciculus chthonoplastes* (Thur. ex Gom.) Sieg., Johans. et Friedl, *Phormidium thwaitesii* Umez. et Watan. and *Spirulina subsalsa* Oerst. ex Gom. *L. confervoides* developed in masses on the bottom of Pomoriyski solnitsi and in combination with *C. chtonoplastes* in Sozopolski solnitsi (Petkoff 1919). More recently about 20 CPs were documented for the saltworks of Burgaski solnitsi and Pomoriyski solnitsi with quantitative data and structural parameters of their phytoplankton communities (Vassilev 1994, Chipev & Vassilev 1994, Stoyneva 1997, 2010, Pavlova et al. 1998, Vassilev et al. 1998). *Phormidium bulgaricum* (Kom.) Anagn. et Kom. was described by Komárek (1956) from the canals of the complex wetland Atanasovsko ezero. Afterwards it was reported from more sites of Bulgarian Black Sea coast (Chipev & Vassilev 1994, Vassilev et al. 1998, Dimitrova et al. 2014b, Stoyanov 2014, Stoyneva 2014, Stoyanov et al. 2016) and included in the RLBMiA..

In the effluents of stone-salt factory of Provadiya Petkoff (1938) found abundant development of *Kamptonema laetivirens* (H. Crouan et P. Crouan ex Gom.) Strun., Kom. et Smarda and discovered a special form of *Oscillatoria tenuis* f. *tergestina* (Rabenh. ex Gom.) Elenk. without outlining it as a new taxon.

II.6. CP studies in the coastal lowland reservoirs and microreservoirs

Data on CPs from the coastal lowland reservoirs and microreservoirs Aheloy (IBW3032), Mandra (IBW1720, EN), Poroy (IBW3038), Studena voda (IBW2883) and Yasna polyana (IBW2887) were given by Petrova (1967, 1968a, b), Petrova-Karadjova

(1974), Ivanov et al. (1980), Kirjakov (1985), Moneva & Vodenicharov (1988), Pavlova et al. (2006, 2007, 2013), Cheshmedjiev et al. (2010), Stoyanov et al. (2013, 2016), Belkinova et al. (2014), Stoyanov (2014), Stoyneva et al. (2015), Stoyneva-Gärtner et al. (2017). There ca. 50 CPs were found, which comprised 25% of the algal diversity of the reservoirs.

Petrova (1968b), Petrova-Karadjova (1974) and Ivanov et al. (1980) evaluated the seasonal phytoplankton dynamics (expressed in cell numbers) in the reservoir Mandra in the periods 1964-1966, 1967-1970 and 1964-1967.

II.7. CP studies in coastal park lakes

Vodeničarov (1962) found *Microcystis pulverea* f. *irregularis* (Peters.) Elenk. and *Aphanothece stagnina* (Spreng.) A. Br. in the small garden lakes of the Balchik Palace. These two CPs comprised 70% of the algal flora of coastal park lakes.

II.8. CP studies in industrial water bodies

In the water collectors and in the plankton of purification WBs of the refinery Neftochim-Burgas of the Poda region Simeonov (1980, 1985) and Kirjakov (1998) recorded 71 algae, 11 of which (i.e. 15%) were CPs, mostly non-heterocytous filamentous species.

II.9. CP studies in coastal temporary pools and puddles

Petkoff (1919, 1938), Temniskova-Topalova (1977), Starmach (1969) and Kiriakov (1974) reported 13 CP taxa from small coastal temporary pools with fresh, brackish or even "salty" water. This comprises 12% of the algal flora of these WBs. Starmach (1969) denoted the community of CPs in the sea-side pools in Bulgaria as *Lyngbyetum aestuarii diatomosum*. The similar co-existence of CPs and diatoms was noted by Petkoff (1919) for the sand pools below Primorsko with mass development of *Merismopedia* species.

II.10. CP studies in coastal lithotelms

Draganov et al. (1984) and Georgiev et al. (1985) published 28 CPs found in the coastal lithotelms, most of which with mixohaline waters. This comprised 77% of all 36 taxa reported for these small WBs. Amongst them was *Gloeocapsopsis crepidinum* (Thur.) Geitl. ex Kom. from the RLBMiA.

III. Comparative CP studies in different types of coastal water bodies

Petrova (1968a, b) and Petrova-Karadjova (1974) made comparisons between the phytoplankton composition and dynamics of different coastal bodies of fish importance with noting the role of CPs. Stoyneva (2000, 2003) and Pavlova et al. (2007) provided data on purposive comparative studies of the role of different algal groups in diverse coastal WBs with outlining the significance of CPs and documentation of rare steady-state assemblages with participation of CPs as keystone species in the shallow coastal lake Vaya. More recently, Stoyneva-Gärtner et al. (2017) showed the problems related with increased CP amounts on the background of the total algal abundance and cyanotoxins as serious risk factors for human and ecosystem health. Stoyneva (2015) proved the taxonomic richness of the algae (incl. CPs) along the Bulgarian Black Sea coast in relation with the important bird migration route *Via Pontica* (Michev et al. 2012). She described different vectors for algal distribution (incl. water birds as notable transporting agents for CPs and other algae with mucilage sheaths) with a special attention to the spread of both invasive and alien CPs in the coastal wetlands. The exotic CPs like *Anabaena attenuata* Kiss., *Anabaenopsis knipowitschii* (Usach.) Kom., *A. nadsonii* Woron., *A. cunningtonii* Tayl., *Nodularia spumigena* f. *littorea* (Kütz.) Elenk., *Planktolyngbya circumcreta* (G. S. West) Anagn. et Kom., *P. undulata* Kom. et Kling, *Pseudanabaena papillaterminata* (Kiss.) Kukk, *Raphidiopsis curvata* Fr. et Rich, *Woronichinia fremyi* (Kom.) Kom. et Hind., etc. occurred in single specimens or in very low amounts and never caused water blooms, most probably due to the significant differences in the morphometry and chemical features of the Bulgarian coastal WBs with the African and Asian lakes, from which most of them originated (op. cit.). By contrast, the invaders like *Cylindrospermopsis raciborskii* (Wol.) Seen. et Subba Raju, the debatable *Raphidiopsis mediterranea* Skuja and *Microcystis wesenbergii* (Kom.) Kom. developed and produced blooms in stressed and frequently disturbed WBs (op. cit.). The analysis of CP studies, published during the last 15 years even revealed *C. raciborskii* as the second species with widest distribution in the country (Stoyneva-Gärtner et al. 2017).

IV. Newly described taxa, general data and checklists of CPs from different coastal water bodies without their exact indication

Petkoff (1906, 1919) mentioned *Anabaena oscillarioides* Bory ex Born. et Flah. and *Oscillatoria princeps* Vauch. ex Gom. from the Black Sea coastal region without detailed description of the localities. Vodeničarov (1962) noted the frequent summer development of *Nodularia harveyana* Thur. ex

Born. et Flah. and *N. spumigena* Mert. ex Born. et Flah. in "coastal swamps, lakes, river mouths with brackish or freshwater". The Flora of Bulgarian algae (Vodenicharov et al. 1971) also contains general broad information on 58 CPs amongst 132 algae widely, or frequently distributed along the coastal line, for most of which the occurrence in standing (fresh or brackish) waters is pointed. Only *Merismopedia affixa* Richt. and *M. mediterranea* Näg. were included in the RLBMiA.

V. Studies of CP blooms, toxic CPs and cyanotoxins in different coastal water bodies

The occurrence of toxic blooms in Bulgarian coastal lakes was firstly linked with the haptophyte *Prymnesium parvum* Cart. (for details see Dimitrova et al., 2018). Concerning CPs, much earlier Petkoff (1919) outlined the abundance of *Dolichospermum flos-aquae* (Bréb. ex Born. et Flah.) Wackl., Hoffm. et Kom. in Beloslavsko ezero vs. its rarity in Durankulak. Valkanov (1936) described the yellow colour of the Vaya waters in summer during six consecutive years (1930-1936), caused by mass development of *Nodularia spumigena.* However, the regular occurrence of summer strong and long-lasting cyanophycean blooms was outlined as a typical event for some of coastal lakes only in the middle of the last century (e.g. Cvetkov 1955, Tsvetkov 1958). Summarising the studies on Mandrensko ezero, Mihailova-Neikova (1961: 122) wrote that despite that phytoplankton "is not very rich", "as far as quantity is concerned, blue-green algae prevailed" with *Anabaenopsis arnoldii* Apt. amongst the mass forms (dominants). Petrova (1961) paid special attention to the first recorded bloom of this species in Varnensko ezero in September 1952 (12,97‰ halinity) but noted that the alga occurred earlier (August 1946) in the lake in smaller amounts and then appeared again in August 1954. Petrova (1967) was the first who discussed toxic phytoplankton with a special attention to cyanoprokaryotes blooms and their potential harmful effect on fish production in our coastal lakes. Petrova (1968a) and Petrova-Karadjova (1975) described the strong bloom of *A. arnoldii* in Vaya with a mortality of *Cyprinus carpio, Mugil cephalus* and *Sander lucioperca* in 1962. At that time, cyanotoxin investigations were not carried out, but according to the authors the strongest fish-kills coincided with the spots of the highest algal concentrations. Petrova (1968a) predicted the future permanent mass development of this species in Vaya and its eventual role as a causative agent of fish losses. However, it was not detected in the "toxic" samples from Bulgarian WBs collected in the period 2000-2015 (Stoyneva-Gärtner et al. 2017) and recent summaries on cyanotoxins also do not include it as a toxin-producing alga (Meriluoto et al. 2017). According to Sashev & Angelov (1959), the summer fish kills in extremely shallow (50-60 cm) Vaya waters with temperatures of 25-30 °C, were due to lack of oxygen. In 1966, *A. arnoldii* was found as strongly blooming in Vaya, while in the other coastal lakes (Beloslavsko ezero, Shablensko ezero and Durankulak) its development was not abundant (Petrova 1967). From Vaya Petrova-Karadjova (1974) reported also on *Aphanizomenon flos-aquae* Ralfs ex Born. et Flah. bloom in 1967, *Microcystis aeruginosa* (Kütz.) Kütz. bloom in 1968 and a mass development of both species in 1969. In the eu-hypertrophic lake Vaya Stoyneva (2003) registered CP blooms with a two weeks period of dominance without biomass change of *Microcystis wesenbergii*, *Aphanizomenon gracile* Lemm. and *Dolichospermum spiroides* (Kleb.) Wackl., Hoffm. et Kom. in August–September 2001, three weeks dominance of *M. wesenbergii, Aph. flos-aquae* and *D. spiroides* in August–September 2001 and a four weeks dominance of *M. wesenbergii* and *A. gracile* in August–September 2002. In the same lake Pavlova (2007) and Pavlova et al. (2006, 2007) detected microcystins, which were on conformity with finding of representatives of toxic genera *Microcystis, Aphanizomenon*, etc., confirmed later by Dimitrova et al. (2014a). Dimitrova et al. (2014b) noted the main role of CPs in forming of total phytoplankton biomass of Vaya with strong peaks in summer periods of 2004-2006, with *Planktothrix agardhii* (Gom.) Anagn. et Kom. as most frequently occurring species. Petrova-Karadjova (1975) indicated blooms of *Microcystis aeruginosa* and *Aphanizomenon flos-aquae* as a common feature of the lakes Vaya, Mandra and Durankulak. Dimitrova et al. (2014a) noted *Dolichospermum affine* (Lemm.) Wackl., Hoffm. et Kom., *Anabaenopsis elenkini* Mill., *Microcystis aeruginosa, M. flos-aquae* (Wittr.) Kirchn., *M. viridis* (A. Br.) Lemm. and *M. wesenbergii* amongst the 30 common species in the algal flora of Vaya, Shabla, Ezerets, and Durankulak. The significance of CPs in both phytoplankton abundance and composition in these WBs with high trophicity in 90s of 20th century was described in detail by Stoyneva (2000, 2002). Before these works, the eutrophic character of Durankulak with long-lasting CP blooms (incl. *M. aeruginosa*, *Pseudanabaena mucicola* (Naum. et Hub.-Pest.) Schw., *Aph. flos-aquae, D. spiroides* and *Anabaena contorta* Bachm.) was outlined by Naidenov (1981) and Saiz (1981). The last author reported on a single bloom of *Dolichospermum scheremetieviae* (Elenk.) Wackl., Hoffm. et Kom. in the summer of 1978 vs. *Aph. flos-aquae*, which bloomed "every year". Cheshmedjiev et al. (2010) and Belkinova et al. (2014) reported "second degree" bloom of *M. aeruginosa* (2.65 mg l^{-1}) in 2009. Beshkova (1998) and Naidenow (1998) noted summer-autumn abundance (1992-1994) of *M. aeruginosa* in the lake Shabla. Shabla and Durankulak were the two other coastal lakes (in addition to Vaya) in which the presence of microcystins LR, LA, RR, YR and similar to YR-type was proved by High Performance Liguid Chromatography – HPLC (HPLC-DAD and/or HPLC-MS) and enzyme-linked immunosorbent assay - ELISA (for details see Stoyneva-Gartner et al. 2017). In all these lakes toxic CPs were detected, incl. the invasive CPs discussed above (for details see Stoyneva 2015, Kokocinski et al. 2017, Stoyneva-Gartner et al. 2017).

During the last century CP blooms were not registered in Varnensko ezero (Petrova 1961, Moncheva 1991), only Paspalew (1943) noted the most abundant development of the group with prevalence over diatoms and other algal groups in spring (April). There is no recent evidence for occurrence of harmful cyanoblooms in this large coastal lake with a strong connection with the Black Sea (Stoyneva-Gärtner et al. 2017).

The only data on a positive effect of mass *Microcystis* development in coastal lakes were given by Cvetkov (1962): the colonies which sank to the muddy bottom, served as a good nutritional basis for the larvae of *Pelopia,* in which they comprised >50% of the ingested food.

First data on CP blooms in the reservoirs could be found in Petrova (1968b), Petrova-Karadjova (1974) and Ivanov et al. (1980). The last two works outlined the summer CP blooms of *Aphanizomenon flos-aquae* and *Microcystis aeruginosa* in the reservoir Mandra (which was built on the basis of the former coastal lake Mandrensko ezero). The summer CP bloom in 1967 was interrupted through opening of the reservoir gateways to the Black Sea, preventing the potential harm on fishes (Petrova-Karadjova 1974). Petrova (1968b) mentioned a problem in the heating power station of the Chemical factory of Burgas caused by the strong summer cyanobloom in the reservoir Mandra. Later Ivanov et al. (1980) pointed on the general increase of algal abundance after 1972 with blooms of *A. flos-aquae* and *M. aeruginosa* and Moneva & Vodenicharov (1988) noted the blooms of *Anabaenopsis arnoldii* and *Arthrospira* af. *platensis* in the summer period of 1988. The assessment of Stoyneva-Gärtner et al. (2017) showed that toxic species and blooms were detected in the reservoirs Aheloy, Mandra and Poroy, microcystins were found in Mandra, while their purposive sampling in Yasna polyana showed negative results in accordance with the earlier predicted lack of strong cyanoprokaryote blooms in Yasna polyana (Angelov 1968).

In relation to blooms and toxic species distribution, a multivariate analysis on a dataset from 61 chosen WBs (incl. 10 coastal WBs) was run to outline the role of environmental gradients on the spread of CPs. The redundancy analysis outlined clearly the speciality of the group of coastal lakes with a core of CP genera well known for their ability to form water blooms due to presence of gas vesicles, like *Microcystis*, *Anabaena* s.l. (mainly *Dolichospermum*), *Aphanizomenon* s.l., *Cylindrospermopsis* and *Planktothrix,* and of the group of high-coductivity saltworks with the core of smallest coccal non-blooming and non-toxic CPs (Stoyneva-Gärtner et al. 2017). Total phytoplankton biomass, total CP biomass, as well as CP assemblages showed a strong response to the environmental variables, with an expected major influence of total phosphorus (op. cit.). Earlier, the PCA analyses conducted on a group of 19 chosen WBs from the country (incl. 6 coastal WBs) showed clear separation of WBs according to environmental variables (with grouping of shallow eutropic WBs, incl. all coastal WBs) with responses of phytoplankton groups according to their general ecological preferences, where a conspicuous relation of CP biomass with the increase of the total phosphorus concentration, pH and chlorophyll a was detected (Stoyneva et al. 2015). The last work provided conclusions from careful checking of the indices and parameters with their weighted values, used in the Bulgarian legislation documents with special attention to the "percentage representation of CPs". It was underlined that, when estimated according to the Water Framework Directive (Annex V), this index influences and often distorts the final result due to the fact that it is generally lower in comparison with the realistic situation and does not take into account many exotic and invasive species (e.g. *C. raciborskii, R. mediterranea*), which were detected as forming 'blooms' in some of our WBs (op. cit.).

Data on CP blooms in coastal fish ponds are extremely scarce. Petrova-Karadjova (1974) and Ivanov et al. (1980) mentioned briefly a harmful *Microcystis*-bloom with a strong fish kill of *Cyprinus carpio* with significant economic damages, which happened in the summer of 1978 in the State fishery near Dolno Ezerovo (IBW0868). According to these authors the bloom appeared after a technical accident, which led to the "invading" of blooming water from the reservoir Mandra. This information needs an additional checking since these fishponds are situated on the western coast of the lake Vaya.

Discussion

In total, 80 works issued in the period 1890-2017 contain information on CPs from more than 90 different lotic and non-lotic WBs situated along the Bulgarian Black Sea Coast, which comprises 48% of the 168 algological works aimed on the coastal region (Dimitrova et al., 2018). In agreement with the conclusions on the general algal biodiversity in Bulgarian coastal WBs (op.cit.), it has to be outlined that because all the studies analyzed were quite different in aims, details and sampling design and because during the last century most of the coastal WBs underwent serious changes of their hydrological regime, the credible comparisons of the species composition and abundance are extremely difficult, if possible at all. But, despite of the unsufficient character of many data, it is possible generally to conclude that coastal Bulgarian WBs contain rich CP flora (ca. 330 taxa), from which with 3 forms were described as new for science, one form was noted as having significant peculiarities and eight threatened CPs were included in the RLBMiA.

However, most of the works issued during the period 1890-2017 were in Bulgarian language (47) and were published in local journals or conference proceedings, which make them quite invisible for the world scientific community. Therefore, this review can serve as a good starting point for designing future studies, in which all the accumulated data could be used as a comparative basis and as a useful tool for biomonitoring and restoration of our coastal wetlands. This is of outsized importance taking into account both their threatened status of generally extremely vulnerable shallow WBs and detected negative trends of the increasing role of CPs in algal communities with development of toxic and invasive species, which are serious risk factors for the human and ecosystem health in Bulgaria.

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