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Review of the algological studies of Bulgarian Black Sea coastal water bodies (1890-2017) with special attention to the newly described and threatened species

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Abstract The paper presents a review of the algological studies on Bulgarian surface coastal lotic and non-lotic water bodies carried out during the last ca. 130 years (1890-2017) and reflected in 168 available scientific sources. The algal biodiversity of these different coastal wetlands was evaluated and analyzed with special attention to the new described taxa (two genera and 42 species, varieties and forms) and peculiar taxa noted (17). The conservation status of the studied water bodies followed the Red List of Bulgarian Wetlands, and the threatened status of the species was indicated according to the Red Lists of Bulgarian macro- and microalgae, from which 14 and 64 taxa were found. Quantitative data are mentioned mainly in temporal aspect with reference to the occurrence of algal blooms, toxic species and toxins. The analysis showed the rich algal flora, which comprised of 42 new described taxa and 78 threatened algae, but also lead to the revealing of main gaps in the algological knowledge on our coastal wetlands.

Key words: algae, biodiversity, cyanoprokaryotes, threatened species, Red List, wetlands

Introduction

According to the Millennium Ecosystem Assessment reports (MEA 2005) and Ramsar Guidelines for the rapid ecological assessment of biodiversity in inland water, coastal and marine areas (2006) coastal ecosystems are amongst the most threatened world's main habitat types, which support a very large diversity of life. Therefore, the Bulgarian coastal region of the unique Black Sea (characterized by lack of real tides, low halinity levels of 16-18‰ and significant anoxic layer well below the surface waters) is an important subject for recent biodiversity studies. Moreover, Bulgaria occupies a part of the Balkan Peninsula, recognised as a hot spot of the European biodiversity (Griffiths et al. 2004) and as the richest and the most diverse region of the Western Palearctic in respect to its flora and vegetation (e.g. Blaženčić et al. 2006). The whole country is well-known for its rich biodiversity, among which many species and habitats are of high conservation significance (Peev 2015). The algae are not an exception in this case and therefore the aim of the recent paper is to evaluate the degree of knowledge on their biodiversity in the lotic and non-lotic water bodies along the Bulgarian Black Sea coast. It is estimated on the basis of analysis of all available literature sources, issued in the period 1890-2017. The year 1890 is the starting point for studies of recent Bulgarian algal biodiversity due to the work by Istvánffi (1890), who reported 65 diatoms, yellow-green and green algae collected earlier by Imre Frivaldsky mainly from the Thracian lowland and described the new taxon *Oedogonium cyathigerum* var. *rumelicum* Jstv., without pointing the exact locality.

Petkoff (1911, 1939a, b) depicted the history of botanical (incl. algological) studies in Bulgaria

with annotated bibliography on its flora and mycota. Later on, bibliography on recent Bulgarian algae was published by Draganov (1971), life-time activities of all Bulgarian algologists were summarized by Temniskova & Stoyneva (2011), and the algal biodiversity of the country was evaluated by Vodenicharov et al. (1998), Temniskova et al. (2005) and Stoyneva (2014). According to the last author non-marine algae comprise of ca. 5500 species, varieties and forms of 650 genera and 8 divisions. Data on separate algal groups were reviewed by Petkoff (1936), Vodeničarov et al. (1991), Kiriakov (1994), Temniskova (2001), Kristiansen et al. (2002), Blaženčić et al. (2006), and the first volume of Bulgarian algal flora (Vodenicharov et al. 1971) encompassed blue-green and green algae. Knowledge on toxic algae was summarized by Stoyneva-Gärtner et al. (2016a) and cyanoprokaryote data during the last 15 years were assessed by Stoyneva-Gärtner et al. (2017). A brief summary on the algological studies in coastal wetlands was provided by Petrova-Karadjova (1975). The diversity of algae in lakes and in all non-lotic Bulgarian wetlands was analyzed by Ivanov et al. (1964) and Stoyneva & Temniskova-Topalova (2007), respectively with more detailed data included in the DataBase of Bulgarian wetlands and their biodiversity (Stoyneva & Michev 2007a). Afterwards, diverse data on algae from different Bulgarian coastal wetlands were provided in 18 more works (Cheshmedjiev et al. 2010, Stoyneva 2010a, b, Dimitrova et al. 2014a, b, Pavlova et al. 2013a, b, 2014, 2015, Stoyanov et al. 2013, 2016, Belkinova et al. 2014, Stoyanov 2014, Stoyneva 2014, 2015, Stoyneva et al. 2015, Stoyneva-Gärtner et al. 2016a, 2017). The aim of the present paper is to analyze the algological studies and the knowledge on algal diversity in different types of coastal water bodies since 1890 till nowadays, fulfilling the gaps and correcting some technical mistakes in the former general or more specific overviews.

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 (2007c) by the border of breeze' influence. The analysis of the number of non-lotic water bodies which have been spread or recently exist along the coastal line (305 monostructural and 51 polystructural – Stoyneva & Michev 2007b) shows that they comprise quite low amount (i.e. <0,1%) of the total non-lotic water bodies of the country (ca. 10 000 in Michev & Stoyneva 2007b). However, the surface wetland types in Black Sea coastal region (acc. to the wetland classification system of Stoyneva & Michev 2007c) comprise about 10-14% of all surface wetland types known from the country and are spread in both low mountain and lowland parts of the coastal region with prevalence in the lowlands (Stoyneva & Michev 2007b). This diversity of wetlands, doubtless influences the algal biodiversity, which is presented in this paper in the general hydrobiological wetland categories (Dimitrova et al. 2007). For easier orientation of the readers, in the text below the water bodies are enlisted in alphabetical order with their identification number in the DataBase of Bulgarian non-lotic wetlands and their biodiversity (Stoyneva & Michev 2007a) together with their category of threat.

The diversity of species and habitats is closely related with the nature conservation and it has to be pointed that 77 of the coastal non-lotic wetlands found their place in the Red List of 346 Bulgarian wetlands (Michev & Stoyneva 2005, 2007a), i.e. coastal wetlands of conservation importance comprise 22% from this category of water bodies in the country. Their distribution in different threatened categories is as follows: Extinct – 16 (from 99 in the country), Critically Endangered – 13 (from 42), Endangered – 14 (from 28), Vulnerable – 26 (from 97) and Data Deficient – 8 (from 74). In addition, more than 55 singular water bodies or wetland complexes are designated by different international and national legislative conservational status, including 7 Ramsar sites (Michev 1993, Michev & Stoyneva 2007a, Vassilev et al. 2013). The species conservation status was evaluated after the Red List of Bulgarian macroalgae – RLBMaA (Temniskova et al. 2008) and Red List of Bulgarian microalgae – RLBMiA (Stoyneva-Gärtner et al. 2016b). For all algae the currently accepted taxonomic names in AlgaeBase (Guiry & Guiry 2017) are used and the general classification system used follows Stoyneva-Gärtner & Uzunov (2017).

The present analysis is based on data provided in 168 sources issued in the period 1890-2017, where many different ways of transliteration and even translation of the geographic names could be found. In this paper, we follow the recent Bulgarian legislative documents (State Gazette 19/13.03.2009, 77/01.10.2010, 77/09.10.2012, 68/02.08.2013 – http://lex. bg/en/laws/

ldoc/2135623667) and, accordingly, the geographic names are transliterated.

Results

Algological studies in lotic water bodies

I.1. Algological studies in coastal rivulets and streams

Data on separate species found in the small coastal rivers (rivulets) Batova, Dyavolska reka, Elenitsa, Fakiyska reka, Irakliysko (=Erekliysko) dere, Kamchiya, Kitenska reka (=Karaagach, Karaagachka reka, Orlyashka reka), Malka Tsarevska reka, Elenitsa, Potamyata, Provadiyska reka, Reka Izvorska, Reka Mladezhka, Ropotamo (=Kargan, Tsarska reka), Sredetska reka (=Kaynardzha, with its tributary Tendzheklidere) and Veleka, as well as from the "mouths of Black Sea coastal rivers", "slow stream below the village Banya", "small streams with slow water from Eminski Balkan", "slow stream nearby Ahtopol", "small river between Tsarevo /=Vasiliko/ and Ahtopol", "small stream in the place Popova kushla between Burgas and Panicharevo", "small stream nearby the saline swamps of Pomorie (=Anhialo)" and from "the river of Anhialo" were published by Petkoff (1906, 1913, 1919, 1932, 1934, 1935, 1938, 1943), Valkanov (1935, 1936), Mihailova-Neikova (1961), Vodeničarov (1962), Vodenicharov et al. (1971, 1986), Temniskova-Topalova (1977), Kiriakov (1978), Vodeničarov et al. (1991), Kirjakov (1985, 1989, 1993, 1998b), Stoyneva (2000b, 2003) and Pavlova et al. (2007). In total, 58 taxa of blue-green, red, golden and green algae, euglenophytes, pyrrhophytes and diatoms were reported and the following new taxa have been described: *Chara foetida* var. *macroptila* f. *thracica* Petk., *Phacus curvicauda* f. *thracica* Kir., *Spirogyra adnata* var. *obscura* Petk. and *S. neglecta* var. *intermedia* Petk. Petkoff (1913, 1934) gave details on a peculiar form of *Chara foetida* var. *macroptila* (*nana, valde incrustata, fragilis*) and peculiar subforms of *C. foetida* var. *subinermis* f. *normalis* Mig., *C. foetida* var. *subinermis* f. *macroptila* subforma 8 (*minor, tenuor* et *minor robustior*) and subforma 11, without noting them as new taxa.

Amongst the recorded taxa was *Thorea hispida* (Th.) Desv. – one of the first algal species proposed for conservation in the country (Draganov & Stoyneva 1994) and later on included in the RLBMaA and in the Red Data Book of Bulgaria (Stoyneva et al. 2015). The other threatened species were: *Paralemanea annulata* (Kütz.) Vis et Sheath (from RLBMaA), *Gongrosira calcifera* Krieg., *Spirogyra adnata* var. *obscura, S. jugalis* (Dillw.) Kütz. and *Uronema intermedium* Bourr. (from RLBMiA).

Quite a few quantitative data are available on Ropotamo phytoplankton (Stoyneva 2000b, 2003, Pavlova et al. 2007). Valkanov (1935, 1936) noted "brownish" colour of the water in the left tributary of Kitenska reka due to a mass autumn development of *Prorocentrum* sp. and a "blue coloration" of Provadiyska reka from abundant development of *Chroococcus* sp. The proposals to use the algal species composition for monitoring (Vodeničarov 1984) in Bulgaria were tested firstly on the coastal river Veleka (Vodeničarov et al. 1984).

I.2. Algological studies of coastal canals

Petkoff (1934, 1943), Valkanov (1935) and Mihailova-Neikova (1961) sampled the coastal lake canals and documented 16 algae, one of which (*Glenodinium* sp.) was outlined to cause a "brownish" bloom in the old canal between the lakes Beloslavsko ezero and Varnensko ezero. Petkoff (1934, 1943) described the new taxon *Oscillatoria geminata* f. *subsalsa* and noted a peculiar subform of *Chara foetida* var. *macroptila* f. *mollis* Mig.

I.3. Algological studies in cold-water springs

Petkoff (1906, 1907b, 1913, 1938, 1942) and Lepsi (1926) published algae from the karst spring complex Devnenski izvori and from springs of Kavarna, some of which were included in the Flora of Bulgarian algae (Vodenicharov et al. 1971). Totally 32 cyanoprokaryotes, diatoms, euglenophytes, red and green algae developed on the stones and walls around the springs. Amongst them were *Thorea hispida* and *Chaetomorpha herbipolensis* Lag. from the RLBMaA, as well as *Cladophora fracta* var. *genuina* (Kütz.) Kirchn. with deviations in dimensions (Petkoff 1907b) and the new taxon described by Petkoff (1938) – *Closterium monilif-erum* f. *devnense* (included in the RLBMiA).

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

II.1. Algological studies in coastal lakes and tuzlas

Data on recent algal flora 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), and of the lakelet Ezertse do Varna (IBW4003) were given by Petkoff (1905, 1907a, b, 1919, 1932,

1934, 1938, 1943), Ivanov (1922), Valkanov (1935, 1936, 1937, 1960, 1964), Markoff (1935, 1939), Stundl (1937), Huber-Pestalozzi (1941), Paspalew (1943), Caspers (1949, 1951), Cvetkov (1955), Zvetkov (1955), Sashev & Angelov (1959), Mihailova-Neikova (1961), Vodeničarov (1962, 1972), Petrova (1957, 1961, 1962, 1966, 1967, 1968a, b), Tsvetkov (1958), Kolarov (1962), Ivanov et al. (1964), Valkanov & Marinov (1964), Vodenitscharow (1964), Vodenicharov et al. (1971), Naidenow (1967), Petrova-Karadjova (1974, 1975), Valkanov et al. (1978), Naidenov (1981, 1998), Saiz (1981), Naidenov & Saiz (1984), Vodenicharov et al. (1986), Moncheva (1991), Vodeničarov et al. (1991), Chipev & Vassilev (1994), Vassilev (1994), Vassilev et al. (1994, 1998), Stoyneva & Michev (1996), Stoyneva (1997), Beshkova (1998), Kalchev (1998), Kirichova et al. (1998), Velikova et al. (1998), Stoyneva (1998a, b, 2000a, b, 2002, 2003, 2008, 2010a, b, 2014, 2015), Belkinova (2001), Belkinova et al. (2003, 2014), Mladenov et al. (2003), Pavlova et al. (2006, 2007, 2013a, 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. (2016a, 2017) and Descy et al. (2018). More than 380 taxa, mainly green algae, cyanoprokaryotes and diatoms, were recorded. One genus ("*Chrysotheca"* Valk.) and other eight taxa were described, or noted for deviations from diagnoses: *Oscillatoria geminata* f. *subsalsa* Petk., *Batrachospermum vagum* f. *densa* Petk., *Botrydium milleri* Vod., "*Chrysotheca minima"* Valk., *Kephyrion valkanovii* Hub.-Pest., *Chara foetida* var. *longibracteata* subforma 2 Petk., *C. foetida* var. *subinermis* f. *macroptila* subforma 6 – *submunda, elongata* Petk. and a subform with short internodes of *C. foetida* f. *gracilis* Mig. Petkoff (1934) found one more peculiar *Chara* (close to *C. gymnophylla* A. Br.) in Varnensko ezero, but because of lack of sexual organs could not describe it as a new taxon. Some "lake" algae have been reported also from stomachs of different fishes (e.g. 18 taxa in Mihailova-Neikova 1961) and Sashev & Angelov (1959) noted „Conjugatae" among the food of industrially important fishes.

Amongst the algae found, 32 were of conservational importance: *Batrachospermum turfosum* Bory, *Laurencia lacustris* Skolka and *Cladophora coelothrix* Kütz. from the RLBMaA, as well as *Arachnochloris maior* Pasch., *Binuclearia tectorum* (Kütz.) Beg., *Botrydium milleri, Botryococcus neglectus* (W. et G.S. West) Kom. et Marv., *Bumilleriopsis peterseniana* Visch. et Pasch., *Closterium setaceum* Ehr. ex Ralfs, *Crucigeniopsis divergens* (Sm.) Hind., *Cyanobacterium diachloros* (Skuja) Kom., Kop. et Cep., *Choricystis hindakii* Tell, *Dichotomococcus bacillaris* Kom., *D. curvatus* Korsh., *Dictyosphaerium granulatum* Hind., *Didymocystis inermis* (Fott) Fott, *Didymogenes anomala* (Sm.) Hind., *Elakatothrix gelatinosa* Wille, *Goniochloris triradiata* Pasch., *Hindakia tetrachotoma* (Pr.) Bock, Prösch. et Krien., *Lagerheimia circumfilata* (Sel.) Hegew. et Schmidt, *Oscillatoria annae* Van Goor, *Phacotus minusculus* Bourr., *Pseudokirchneriella roselata* (Hind.) Hind., *Pteromonas torta* Korsch., *Radiococcus planctonicus* Lund, *Rivularia rufescens* Näg. ex Born. et Flah., *Spermatozopsis exsultans* Korsh., *Lemmermannia triangularis* (Chod.) Bock et Krien. (Syn. *Tetrastrum triangulare* (Chod.) Kom.), *Trachychloron regulare* Pasch., *Uronema elongatum* Hodg. and *Vischeria undulata* Pasch. from the RLBMiA.

Despite that strong and long-lasting cyanophycean blooms were outlined for some of these lakes in the middle of the last century (e.g. Cvetkov 1955, Tsvetkov 1958) and some of them were related with fish kills (e.g. *Anabaenopsis arnoldii* Apt. bloom in Vaya in 1962 – Petrova 1968a), quantitative data remained scarce, from separate periods, oriented mainly towards phytoplankton abundance (expressed mostly through cell numbers) and, more rarely, towards structural parameters (e.g. Paspalew 1943, Mihailova-Neikova 1961, Saiz 1981, Chipev & Vassilev 1994, Vassilev 1994, Beshkova 1998, Vassilev et al. 1998, Stoyneva 1997, 2002, Dimitrova et al. 2014a). Comparative studies of different lakes of fish productive importance were published by Petrova (1967, 1968b) for the period 1964-1967 and by Petrova-Karadjova (1974) for Vaya in the period 1967-1970, whereas comparisons of the algal composition and abundance for a period of ca. 30 years obtained by different authors have been published only for the lakes Durankulak, Shabla, Ezerets and Vaya (Beshkova 1998, Stoyneva 2000a, 2002, Dimitrova et al. 2014a, b). According to most of these authors data on the multiple increase of phytoplankton numbers clearly show the negative trends in the development of these shallow and therefore quite vulnerable water bodies. The increased abundance of the phytoplankton in combination with the rising significant participation of the cyanoprokaryotes and their blooms (for details see Descy et al., 2018) is related with the cyanotoxins detected in the lakes Durankulak, Shabla and Vaya (Pavlova et al. 2006, 2013a, 2014, 2015, Pavlova 2007, Stoyneva-Gärtner et al.

2016a, 2017). The toxic haptophyte *Prymnesium parvum* Cart. caused fish mortalities in the largest coastal lakes (Varnensko ezero, Beloslavsko ezero and Vaya) in the middle of the last century but during the last four decades, harmful blooms of this alga have not been detected (Valkanov 1960, Kolarov 1962, Petrova 1962, 1966, 1967, Petrova-Karadjova 1975, Stoyneva-Gärtner et al. 2016a). Non-toxic blooms of *Chaetoceros* spp., *Cyclotella choctawhatcheeana* Prasad (Syn. *C. caspia* Grun.), *Prorocentrum cordatum* (Ost.) Dodge and *Prorocentrum micans* Ehr. were registered in Varnensko ezero (Petrova 1961), and of *Euglena haematodes* Lemm. – near the *Phragmites*-belt of Mandrensko ezero (Mihailova-Neikova 1961).

Tuzlas are peculiar natural hyperhaline coastal lowland water bodies situated on the Black Sea shore. After the transformation of Pomoriyska tuzla (IBW8613, EX), nowadays Bulgaria has only three such water bodies: Shablenska tuzla (IBW0218, EN), Nanevska tuzla (IBW0217, EN) and Balchishka tuzla (IBW0213, EN). Despite their regional and even global rarity and peculiarity they have been quite poorly investigated from algological point of view. Only 32 species (mainly diatoms, green and blue-green algae) were reported by Petkoff (1905, 1919, 1943), Ivanov et al. (1964), Valkanov & Marinov (1964), Draganov et al. (1984), Stoyneva (1998b, 2000b, 2003) and Kožuharov et al. (2001).

II.2. Algological studies of the coastal swamps

Petkoff (1913, 1914, 1919) and Kirjakov (1985) sampled coastal plateau and mountain swamps in the most eastern parts of Stara Planina (Blata do Kazul-Kyoy – IBW5367, Blato Kalgamach – IBW0747, DD, Blato Kozichino – IBW0749, DD) and one oxbow – Murtvitsa do Mladezhko (IBW9787) in the most western part of the coastal region of Strandzha Mt. The authors provided data on 30 taxa, amongst which were the newly described *Oedogonium balcanicum* Petk. (recently included in the RLBMiA) and peculiar form of *Chara gymnophylla* f. *submunda* (form 4 – *laxa, valde incrustata, folia atriculorum inferiorum*) Petk.

Data on the algal flora of more than 24 coastal lowland swamps (incl. oxbows), namely Alepu (IBW0177, CR), Anhialski Blata (IBW0753), Arkutino (IBW0187, EN), Batovsko Blato (IBW0225, EX), Blata do Topola (IBW0214), Blata do ustieto na Ropotamo (IBW0198), Blata Potamyata (IBW0925, EX), Blata v Longoza na Ropotamo (IBW0899), Blatisti mesta do Burhamskite pyasutsi (IBW9669), Blato Stomoplu (IBW0186, CR), Blato Punchevo (0880), Blato Sinemorets (IBW0902), Blattse do Tzarevo (IBW4540), Chengene-Skele (IBW0715, VU), Dyavolsko Blato (IBW0178, CR), Irakliysko Blato (IBW0205, EN), Karaagachko Blato (IBW0241, EN), Murtvitsa na Reka Kamchiya (IBW0922), Poda (IBW0193), Nesebursko blato (IBW0924, EX) and adjacent small swamps, Novo Panicharevsko Blato (IBW0754), Orlovo Blato (IBW0242, EN), Sindelsko-Sultanlarsko Blato (IBW0195, EX), Uzun-Kum (IBW0220, EX), and Velyov Vir (IBW0711) were provided by Petkoff (1905, 1907a, 1913, 1914, 1919, 1934, 1935, 1938), Valkanov (1935, 1936, 1964), Vodenicharov (1960), Mihailova-Neikova (1961), Vodeničarov (1960, 1962), Vodenitscharow (1964), Ivanov et al. (1964), Temniskova-Topalova (1965), Naidenow (1967), Kiriakov (1974, 1981), Kirjakov (1993), Stoyneva (2000a, b, 2002, 2003, 2014, 2015), Blaženčić et al. (2006), Pavlova et al. (2007), Cheshmedjiev et al. (2010), Belkinova et al. (2014), Stoyanov (2014), Stoyneva et al. (2015), Stoyanov et al. (2016), Stoyneva-Gärtner et al. (2017). These works contain data on about 270 taxa (mainly green and blue-green algae), amongst which the following new taxa have been described or noted: *Lyngbya contorta f. duplo-latior* Petk., *Peridinium marchicum* f. *duplo-major* Petk., *Chara foetida* f. *bulgarica* Petk., *C. foetida* var. *macroptila* f. *euxinopontica* Petk., *C. paragymnophylla* f. *bulgarica* Petk., *Cosmarium galeritum* f. *sultanlarum* Petk., *Zygogonium ericetorum* var. *scrobiculatum* Petk., *Salpingoeca longipes* Valk., *S. maxima* Valk., *Botrydium corniforme* Vod. and *B. milleri*. Petkoff (1913, 1934, 1938) found peculiar subforms of *Cosmarium margaritiferum* f. *regularior* and *Chara foetida* var. *subinermis* f. *normalis* Mig., as well as forms of *Cosmarium bioculatum* Bréb. (ad *hians* West et G. S. West), *C. margaritiferum* Menegh. (ad f. *regularius* (Nordst.) W. et G. S. West), *C. ochtodes* Nordst. and *C. porteanum* Arch. with deviations in dimensions. Valkanov (1964) described the new genus *Koršikovella* with the species *K. vaucheriae* (found in *Vaucheria dichotoma* (L.) C. Mart.), which were renamed by Bourrelly (1965) as *Valkanoviella* and *V. vaucheriae,* respectively. The last species, *Botrydium corniforme, B. milleri*, *Cosmarium galeritum* f. *sultanlarum, Nephroselmis discoidea* Skuja, *Nostoc carneum* (Lyngb.) Ag. ex Born. et Flah., *Oedogonium longatum* Kütz., *Pseudotetrastrum punctatum* (Schm.) Hind., *Selenochloris angusta* Pasch., *Uronema confervicolum* Lag. and *Zygogonium ericetorum* var. *scrobiculatum* were included in the RLBMiA, and *Chara canescens* Desv. et Loisel. with *C. hispida* L. were included in RLBMaA.

II.3. Algological studies of the coastal morasses and soggy meadows

The only sampled coastal morasses and soggy meadows were those situated in close vicinity of the lakes Beloslavsko ezero, Varnensko ezero (IBW9667, etc.), Mandrensko ezero (e.g. IBW0244) and Uzungeren, as well as the morasses surrounding the small haline swamps of Pomorie (IBW4800). Petkoff (1913, 1914, 1934) and Mihailova-Neikova (1961) documented 26 algae amongst which the most peculiar was *Chara foetida* var. *subinermis* f. *macroptila* subforma *6 – submunda, elongata* Petk. For the soggy meadows around Beloslavsko ezero Valkanov (1935: 226) noted the "abundant development of conjugates, which never occur in such amount in the lake".

II.4. Algological studies of the coastal river effluents

Petkoff (1907a, 1919, 1931, 1934), Naidenow (1967), Vodenicharov et al. (1971), Vodeničarov (1972) and Kirjakov (1985, 1989, 1993) studied the effluents of the coastal rivulets Fakiyska reka, Kamchiya, Rezovska reka, Ropotamo, Silistar, Sredetska reka and Veleka (IBW0188, IBW1739, IBW0903, IBW0905, etc.). Amongst the 46 algae found, the newly described were the both discussed above hydro-terrestrial species *Botrydium milleri* and *B. corniforme,* as well as *Aphanocapsa rivularis* f. *major* Petk., *Closterium acutum* f. *latior* Petk., *C. strigosum* f. *brevior* Petk., *Oedogonium cardiacum var. polymorphum* Petk. et f. *pyriforme* Petk., et f. *latior* Petk. et f. *scrobiculatum* Petk., *"Oedogonium* sp." Petk. and *Phacus curvicauda* f. *thracica*. Together with *Aphanocapsa testacea* Näg. and *Ulothrix gigas* (Visch.) Mattox et Bold, they (except *Oedogonium* sp. and forms of *O. cardiacum* var. *polymorphum*) were included in the RLBMiA.

II.5. Algological studies of the coastal lake floods

In the floods of Mandra lake Mihailova-Neikova (1961) found *Amphora ovalis* (Kütz.) Kütz. and *Tabellaria* sp.

II.6. Algological studies of the fontal water bodies and effluents of coastal cold-water springs

Petkoff (1907b, 1913, 1934, 1938) published more than 25 algae from the fontal water bodies and effluents of the karst complex of Devnya springs (IBW0197, IBW0725), from where he described *Chara foetida var. macroptila* f. *devnensis*, *C. foetida* var. *subinermis* f. *macroptila* subforma *6 – submunda, elongata*, *C. foetida* var. *macroptila* subforma ad formam *brevifolia* and *C. foetida* var. *macroptila* f. *robustior valde incrustata fragilis*.

II.7. Algological studies of coastal fountains and watermills and their outfalls

Some coastal fountains and their outfalls have been studied by Petkoff (1907b, 1919, 1938, 1943) and Kiriakow (1970). The finding of the abundant development of *Bangia atropurpurea* (Mert. ex Roth) Ag. on the wall of a fountain situated nearby the village Topola served to publish the first data on red algae in Bulgaria (Petkoff 1907в). There and in some other coastal fountains and watermills with their outfalls ten more blue-green, diatom, yellow-green and green algae were found and the new taxon *Phormidium favosum* f. *tenuior* Petk. was described. By contrast with the inland fountain near the village Varvara from which a species of the aero-terrestrial genus *Coelastrella* was isolated (Dimitrova et al. 2016), this alga had never been reported from coastal fontains.

II.8. Algological studies in the salines

Data on five costal salt-productive complexes – Burgaski solnitsi (=Solnitsi na Atanasovskoto ezero – IBW8804), Solnitsi nad Gelareto (IBW0551, EX), Starite solnitsi nad Balchik (IBW0213, EX), Pomoriyski solnitsi (=Anhialski solnitsi – IBW8805) and Sozopolski solnitsi (IBW8145, EX) and on the effluents below the stone-salt productive factory of Provadia were given by Petkoff (1905, 1919, 1938, 1943), Ivanov (1922), Caspers (1952), Komárek (1956), Ivanov et al. (1964), Vodenitscharow (1964), Valkanov (1970), Vodenicharov et al. (1971), Temniskova-Topalova (1977), Vassilev (1994), Stoyneva & Michev (1996), Stoyneva (1997, 2000b, 2003, 2008, 2010a, b, 2014, 2015), Chipev & Vassilev (1994), Pavlova et al. (1998), Vassilev et al. (1998), Blaženičić et al. (2006), Pavlova et al. (2007), Cheshmedjiev et al. (2010), Belkinova et al. (2014), Stoyanov (2014), Stoyneva et al. (2015), Stoyanov et al. (2016), Stoyneva-Gärtner et al. (2017). Few algological data on separate species from the extinct Sozopolski solnitsi, Balchishki solnitsi and Solnitsi nad Gelareto (situated above the Black Sea cape Kaliakra) were provided by Petkoff (1905, 1919, 1943). About 250 taxa, mainly cyanoprokaryotes, diatoms and green algae, but also some euglenophytes, pyrrhophytes and golden algae (s.l.) were documented for the saltworks from the complex wetlands Atanasovsko ezero and Pomoriysko ezero situated near the towns Burgas and Pomorie (i.e. Burgaski solnitsi and Pomoriyski solnitsi). Quantitative data and structural parameters of their phytoplankton

communities are available in the works by Chipev & Vassilev (1994), Vassilev (1994), Stoyneva (1997, 2010a), Pavlova et al. (1998) and Vassilev et al. (1998). The most quantitatively important macrophytes in the salines were the genera *Ulva* L. (e.g. Petkoff 1905, Vassilev 1994, Stoyneva 2010b) or *Cladophora* (Ivanov 1922), while amongst the phytoplankters seasonal and spatial variations in the composition and abundance were more pronounced, depending on the halinity of the water.

The cyanoprokaryote *Phormidium bulgaricum* (Kom.) Anagn. et Kom. (Syn. *Oscillatoria bulgarica* Kom.) was discovered by Komárek (1956) from the canals of the complex wetland Atanasovsko ezero. The following two new green algae were described from the salines of Atanasovsko ezero, where they were found as dominants: *Nephrochloris nudum* Valk. and *Lobocystis michevii* Stoyneva. *P. bulgaricum* and *L. michevii* were included in the RLBMiA together with *Dunaliella lateralis* Pasch. et Jah., *Thorakomonas korschikoffii* Conr. and *Spermatozopsis exsultans*. Petkoff (1913) provided details on the deviations from the description of *Chara aspera* f. *marina* Mig., which developed abundantly "in the temporariry haline pools between Atanasovsko ezero and Black Sea", but did not note it as a new taxon. It was included in the RLBMaA as synonym of *Chara aspera* Willd.

In the effluents of stone-salt factory of Provadiya Petkoff (1938) found *Kamptonema laetivirens* (H. Crouan et P. Crouan ex Gom.) Strun., Kom. et Smarda (Syn. *Oscillatoria laetivirens* H. Crouan et P. Crouan ex Gom.) as an abundant species, *Gyrosigma acuminatum* (Kütz.) Rabenh. as a rare species, and discovered a special form of *Phormidium tergestinum* (Rabenh. ex Gom.) Anagn. et Kom. (Syn. *Oscillatoria tenuis* var. *tergestina* (Kütz.) Rabenh.) without outlining it as a new taxon.

II.9. Algological studies in the coastal lowland reservoirs and microreservoirs

Data on the algae from the coastal lowland reservoirs and microreservoirs Aheloy (IBW3032), Izvor (IBW2875), Mandra (IBW1720, EN), Marinka (IBW2877), Poroy (IBW3038), Studena voda (IBW2883) and Yasna polyana (IBW2887) have been provided by Vodenitscharow (1964), Petrova (1967, 1968a, b), Petrova-Karadjova (1974), Ivanov et al. (1980), Kirjakov (1985, 1989), Moneva & Vodenicharov (1988), Mladenov (1997), Belkinova (2001), Pavlova et al. (2006, 2007, 2013a), Cheshmedjiev et al. (2010), Belkinova et al. (2014), Stoyanov (2014), Stoyneva et al. (2015), Stoyanov et al. (2013, 2016), Stoyneva-Gärtner et al. (2017) and Descy et al. (2018). Totally 200 algae were reported, most of which green and blue-green. Long-term data on the phytoplankton abundance (expressed as numbers) are available only for the reservoir Mandra for the period 1964-1978 (Ivanov et al. 1980). The same authors reported general increase of algal abundance after 1972 with blooms of diatoms (*Cyclotella* sp. and *Aulacoseira distans* (Ehr.) Sim.) and cyanoporokaryotes (*Aphanizomenon flos-aquae* Ralfs ex Born.et Flah. and *Microcystis aeruginosa* (Kütz) Kütz.) and their alteration in reservoir waters. Toxic species and blooms were detected in the reservoirs Aheloy, Mandra and Poroy, microcystins were proved in Mandra, while their purposive sampling in Yasna polyana showed negative results (Petrova 1967, 1968a, Petrova-Karadjova 1974, Moneva & Vodenicharov 1988, Belkinova et al. 2003, 2014, Mladenov et al. 2003, Cheshmedjiev et al. 2010, Stoyneva-Gärtner et al. 2017, Descy et al. 2018). The lack of strong cyanoblooms in Yasna polyana was predicted by Angelov (1968).

II.10. Algological studies in coastal park lakes

Vodeničarov (1962) and Wodeničarov & Kabassanova (1970) found three algae, namely *Aphanocapsa elachista* var. *irregularis* Peters., *Aphanothece stagnina* (Spreng.) A. Br. and *Cosmarium laeve* Rabenh. in the small garden lakes of the Balchik Palace.

II.11. Algological studies in industrial water bodies

Simeonov (1980, 1985) investigated the water collectors of the Poda region and documented 25 taxa. Kirjakov (1998a) noted the finding of the golden alga *Ollicola pascheri* (Goor) Vørs in the plankton of purification water bodies of the refinery Neftochim-Burgas amongst other 60 taxa of blue-green, green, euglenophyte and diatom algae. Altogether 71 taxa (mainly chlorophytes) were included in these three works.

II.12. Algological studies in coastal temporary pools and puddles

Petkoff (1905, 1907b, 1913, 1919, 1938), Vodeničarov (1963), Vodenitscharow (1964), Temniskova-Topalova (1965, 1975, 1977), Naidenow (1967), Starmach (1969), Vodenicharov et al. (1971), Kiriakov (1974) and Kirjakov (1993) reported 107 algal taxa (cyanoprokaryotes, diatoms, euglenophytes and green algae) from small coastal temporary pools with fresh, brackish or even "salty"

water. Among them is the new species *Micractinium valkanovii* Vod., which is included in the RLBMiA and the peculiar form of *Chara aspera* (close to its form *marina* Mig.), outlined by Petkoff (1913). As it was mentioned above, this form was included in the RLBMaA as *Chara aspera.* The community of the blue-green algae in the sea-side pools in Bulgaria was denoted as *Lyngbyetum aestuarii diatomosum* to emphasize the large number of diatoms (>82) living there together (Starmach 1969).

II.13. Algological studies in coastal lithotelms (small temporary rock pools)

The first studies of the freshwater lithotelms along the Black Sea coast were carried out by Petkoff (1943). Later on, Czapik (1952), Vodenicharov et al. (1971), Draganov et al. (1984) and Georgiev et al. (1985) published some algae found in the coastal lithotelms, most of which with mixohaline waters. Altogether 36 taxa of blue-green, green and pyrrhophyte algae have been reported, among which was *Gloeocapsopsis crepidinum* (Thur.) Geitl. ex Kom. from the RLBMiA.

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

Comparisons between the phytoplankton composition and dynamics of different coastal bodies of fish importance are available from Petrova (1968a, b) and Petrova-Karadjova (1974). Data on purposive comparative studies of the role of different algal groups in diverse coastal water bodies could be found only in Stoyneva (2000a, 2003) and Pavlova et al. (2007), where the significant role of cyanoprokaryotes and green algae was outlined, and rare steady-state assemblages have been documented from the shallow coastal lake Vaya. More recently, a comparison of planktonic data from different water bodies in the country, including 12 different coastal wetlands, showed the problems related with increased cyanoprokaryote amounts on the background of the total algal abundance and cyanotoxins as serious risk factors for human and ecosystem health (Stoyneva-Gärtner et al. 2017, Descy et al. 2018). A special type of comparative studies on algal distribution proved the taxonomic richness of the algae along the Bulgarian Black Sea coast covered by important bird migration route *Via Pontica* (Michev et al. 2012) and pointed different vectors for algal distribution, among which the water birds were mentioned as notable transporting agents and the spread of invasive algal species with a special attention to the coastal wetlands was discussed (Stoyneva 2015).

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

Vilhelm (1912: 29-30) described a new form of *Chara* "from the vicinity of the town of Varna, which is situated on the Black Sea coast of Bulgaria" on the basis of material, collected by A. Yavashev – *Chara gymnophylla* f. *velenovskyi* Vilh. Data on separate algal species from different sites (mainly with standing waters) along the Black Sea coast, without more detailed descriptions, were provided by Petkoff (1905, 1906, 1907b, 1913, 1919, 1934, 1936, 1943), Vodeničarov (1958, 1962), Wodenitscharov (1960**),** Temniskova-Topalova (1963) and Wodenitscharow (1963). The last author reported 8 charophytes for "the Black Sea coastal phyto-climatic region of Bulgaria" and outlined this region as the richest in charophyte taxa (together with the West-Bulgarian mountain region). Petkoff (1932) provided a checklist of 288 algae ("Schizophyceae – 24, Bacillariales – 134, Conjugatae – 8, Rhodophyceae – 39, Phaeophyceae – 15, Chlorophyceae – 57, Charales – 13") found as "marine, brackish or freshwater" along the Black Sea coast as an addition to his former (i.e. Petkoff 1931) data. The Flora of Bulgarian algae (Vodenicharov et al. 1971) also contains general broad information on 132 algae (widely or frequently) distributed along the coastal line (58 cyanoprokaryotes and 74 green algae), for most of which the occurrence in standing (fresh or brackish) waters is pointed. Among the algae noted by Petkoff (1913, 1934) the most peculiar were "*Chara foetida* var. *macroptila* f. *robustior valde incrustata fragilis"* and a form of *Lamprothamnus alopecuroides* (Del.) A. Br. The last was included as *Lamprothamnus papulosus* (Wallr.) Bég. et Formigg. in the RLBMaA together with *Chara kokeilii* A. Br., *Chara connivens* Salzm. ex A.Br. (Syn. *C. globularis* f. *connivens* (Salzm. ex A. Br.). Wood), *C. tomentosa* L. and *Nitella flexilis* (L.) C. Ag.

Valkanov (1962) conducted studies on the development of *Hymenomonas coccolithophora* Conr., which was found frequently in brackish ditches and also as a blooming species in eutrophic coastal lakes. Nowadays it is included in the RLBMiA together with *Dangeardinella saltathrix* Pasch., *Lauterborniella elegantissima* Schm., *Merismopedia affixa* Richt., *M. mediterranea* Näg., *Micractinium crassisetum* Hortob., *Oedogonium longatum* and *Thorakomonas korschikoffii* (all found in different coastal standing waters).

Discussion

In total, 168 works issued in the period 1890-2017 contain information on algae from more than 150 different lotic and non-lotic water bodies situated along the Bulgarian Black Sea Coast. Nevertheless of the high total number of publications and of sites sampled, the knowledge on algae from the coastal water bodies is far away from being sufficient: 1) there is no purposively and thoroughly investigated algal group in any type of lotic or non-lotic coastal water body; 2) not all algal taxonomic and ecological groups have been equally investigated, depending on the knowledge of the relevant researcher, aims and design of the studies and benthic algae and communities are more often omitted when compared with planktonic ones; 3) there is an obvious lack of long-term qualitative and quantitative data in the vast majority of coastal wetlands; 4) there are still unstudied or very poorly studied types of coastal water bodies; 5) molecular studies of the newly described species and especially of the endemics are necessary in combination with recent re-checking of their morphological and ecological descriptions. Most of these conclusions, logically correspond with the statements made earlier by Stoyneva & Temniskova-Topalova (2007) on the basis of data on non-lotic Bulgarian wetlands. We can also fully agree with these authors that "the 'white spots' depicted above were not mistakes of the researchers cited but could be rather explained with the diversity of Bulgarian coastal wetlands combined with high algal diversity on all taxonomic levels, on the background of the low number of investigators and total lack of network of real monitoring hydrobiological teams and stations in the country. All the works devoted to wetland studies were based on the authors enthusiasm more than on a real financial support and this is the explanation of the high number of publications based on results of one-day sampling without complete set of environmental data" (op. cit.: 167).

All the studies analyzed are quite diverse, different in aims, details and sampling design (sometimes even without clear indication of the sampling sites). Moreover, during the last century most of the coastal water bodies passed serious transformation and changing of their hydrological regime (for details see Michev & Stoyneva 2007b). Therefore, credible comparisons of the species composition for long periods and outlining trends in the development of biodiversity are extremely difficult, if possible at all. But, despite of the unsufficient character of many data, it is possible to conclude that generally coastal Bulgarian water bodies contain rich algal flora (>850 taxa), and 2 genera and 42 species, varieties and forms were described as new for science and 17 were noted as having significant peculiarities. This comprises 24% of all new algal taxa described or noted from the non-lotic water bodies in the country (Stoyneva & Temniskova-Topalova 2007) and 20% of all new taxa found there (Stoyneva & Michev 2007b). Amongst the threatened species 14 were macroalage and 64 – microalgae, i.e. 9% of the taxa in the Red Lists of Bulgarian algae (82 in Temniskova et al. 2008, 757 in Stoyneva-Gärtner et al. 2016b), or 17% from the RLBMaA and 8% from the RLBMiA. The present analysis revealed that some newly described or noted as peculiar taxa have not been included in the lists of threatened algae, mainly because of their Data Deficient character. However, in our opinion, they are worth of being re-analysed from conservational point of view and this is especially valid for the diatom and charophyte taxa, published in older studies. Such re-evaluation is important since all the accumulated data could serve as a good starting point and comparative basis in future studies, as well as a useful tool for biomonitoring and restoration of our coastal wetlands.

The analysis of all available sources showed also that many studies were published in local journals and conference proceedings (some of which old and unavailable in electronic versions) or in Bulgarian language, which, despite being accepted as European language, remains *exotic* for most of the scientists. Therefore, one of the tasks of recent Bulgarian algologists is to make the knowledge on rich Bulgarian coastal algal diversity more visible and more easily available for the world scientific community.

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