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Phytoplankton and Macrophytes in Bulgarian Standing Water Bodies

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Abstract. The current status of a lake can be evaluated via monitoring based on biological quality elements. Reference aquatic flora communities reflect pristine situations that exist or would exist with no or very minor disturbances from anthropogenic pressure. Phytoplankton and macrophytes were studied in 10 national lake types (L1, L3, L4, L5, L7, L8, L11, L12, L13, L17). Type-specific taxa and groups character in reference and near reference conditions were described. Abiotic parameters (water chemistry) were also discussed. Descriptor species from 25 FGs were registered in phytoplankton communities in lakes in reference and near reference conditions. Dinoflagellates (L_0) cryptomonads (Y) and various benthic/periphytic taxa (MP) were distributed in almost all lake types. Character descriptor species and FGs were reported for lake types L1 and L5. Motile mixotrophic dinoflagellates (L_0) and cryptomonads (Y) had highest relative biovolume in ultra-oligotrophic alpine lakes (L1) due to their ability to utilize effectively scarce trophic resources. Motile euglenoids (W1, W2), small-celled colonial Cyanobacteria (K), green algae and small cryptomonads (X1, X2), coccal green algae (J) and meroplanctonic diatoms (MP) dominated phytoplankton community in riverine marshes (L5). Recorded FGs from natural lakes were also common in and their analog among heavy modified water bodies: shallow lowland reservoirs L17. Phytoplankton communities of L13 (small and medium-size semi-mountain reservoirs in the Eastern Balkans) were more similar with those of L11 (large deep reservoirs) and mountain L1, L3. Further surveys are needed in order to classify specific features of phytoplankton communities in L3, L4, L7, L11 and L12.

Key words: lakes, reservoirs, phytoplankton, macrophytes, reference conditions.

Introduction

Anthropogenic environmental alterations, such as nutrient pollution, agricultural run off, cage and open water fish farming, as well as changes in the thermal regimes of the water bodies induce modifications in the physical and chemical characteristics of the water, as well as in the biological communities (Yoshev, 1972; Zhivkov & Groupcheva, 1987; Hubenov, 2005; Cheshmedjiev *et al.*, 2010; Stanachkova *et al.*, 2010; Pearl & Huisman, 2008; Elliott *et al.*, 2006; Elliott & May, 2008; Elliott, 2012a; 2012b; Stoychev & Danova, 2012).

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Phytoplankton species are sensitive bioindicators of environmental changes in aquatic ecosystems as the alterations are immediately reflected in composition and biovolume (REYNOLDS, 2006). Reference lakes usually have low phytoplankton biovolume and higher species number. Eutrophication in lentic ecosystems is usually assessed by phytoplankton as oligotrophic taxa, e.g. many chrysophyte species prefer lakes with low level of nutrients. Many colonial and filamentous cyanobacteria are well developed in nutrient rich habitats and are indicators of eutrophication (REYNOLDS *et al.*, 2002; DOKULIL, 2003).

Reference communities of Northern and Central European lowland lakes have different composition (JÄRVINEN *et al.*, 2013). Most distributed indicator species in alkalinity lakes of Northern Europe are chrysophytes, while diatoms were character in Central European high alkalinity lakes. Despite the above differences, species in reference lakes could be recorded in other lakes but with low relative biovolume. The results suggest that a number of true phytoplankton indicators of near-pristine conditions is rather scarce and that the low proportions of the impacted non-reference taxa in reference conditions may be a more reliable indicator.

The major part of the inland waters in Bulgaria are small and shallow artificial lakes (MICHEV & STOYNEVA, 2007), however, the investigations of lentic water bodies is dominated by researches in big, multipurpose reservoirs (NAIDENOW, 1970; NAIDENOV & BAEV, 1987; BESHKOVA, 1996; BESHKOVA & BOTEV, 1994; KALCHEV, 1994; 1999; KALCHEV *et al.*, 1996; 2003; 2004; KALCHEV & BOUMBAROVA, 1996; KOZUHAROV, 1994; 1996; 1999; KOZUHAROV *et al.*, 2007; 2009).

Abundance of submerged macrophytes essentially determines the structure and function of shallow waters. In particular, macrophytes have a pronounced positive effect on water clarity: they take up nutrients and store them long term in their biomass, thus reducing phytoplankton growth and the probability of blooms. Dense submerged vegetation provides refuge for filtering zooplankton, which enhances grazing on algae. In addition, shading effects of submerged macrophytes reduce production of phytoplankton (SCHEFFER, 1999).

One of the main environmental factors affecting the development of aquatic macrophytes in lakes is trophic state (SPENCE, 1967; HUTCHINSON, 1975; BEST *et al.*, 1984). Other factors are general water chemistry (KADONO, 1982; HOYER *et al.*, 1996), substrate characteristics (PEARSHALL, 1920; BARKO *et al.*, 1986), light availability (CANFIELD *et al.*, 1985), prevailing winds (DUARTE & KALFF, 1986) and lake morphology (PEARSHALL, 1917; DUARTE & KALFF, 1986; KALFF, 2002). The effects of these factors can be modified by the water level fluctuation in reservoirs, thus affecting the development of macrophytes. As fluctuations increase in magnitude the macrophyte populations get sparse. This results from the littoral zone of such water bodies being irregularly flooded and dried up, with corresponding changes in basin slope and depth.

When conditions are stable and the above mentioned factors are favorable for aquatic macrophyte growth, significant relations exist between aquatic macrophyte abundance and lake water chemistry (CANFIELD *et al.*, 1983), phytoplankton abundance (LANDERS, 1982) and many other limnological processes (HUTCHINSON, 1975). The highly variable environment in reservoirs affects the biological diversity, biomass, and community structure of the macrophytes, without corresponding changes in the trophic state of the water bodies TRAYKOV & TOSHEVA (2015).

The main studies on the composition of aquatic macrophytes in Bulgaria are the ground works of YORDANOFF (1931) and KOCHEV & YORDANOFF (1981) among others. The assessment of water quality by macrophytes and their relation to the main physicochemical parameters and trophic state in Bulgarian water bodies is given in

Gecheva *et al.* (2010; 2011; 2013a; b), Tosheva & Traykov (2010, 2012, 2013), Savchovska *et al.* (2013), Teneva *et al.* (2014).

Current study aimed to describe character composition of autotrophic communities in selected water bodies in near-pristine conditions.

Material and Methods

Selected water bodies represented 10 of the national lake types (Fig. 1, Table 1) and were studied in the period 2009-2018. All studied water bodies (n=15) were assessed in high/good status based on phytoplankton and macrophytes.

Total nitrogen and phosphorus were analyzed following adopted standards (EN ISO 11905-1, EN ISO 6878).

Phytoplankton was sampled once to four times during the vegetation season (April-October) from the deepest location. Phytoplankton sampling and laboratory processing, including chlorophyll-a, followed international standards: ISO 5667-3:2012, EN 15204:2006, ISO 10260:2002. Functional groups (FGs) of the phytoplankton species were determined by their codons following Reynolds *et al.* (2002), and Padisák *et al.* (2006; 2009) and Borics *et al.* (2015). The descriptor species were selected based on their relative biovolume >5% of the total biovolume. Nomenclature of pro- and eukaryotic algae follows Lee (2008). Trophic classification is based on the fixed boundary system (OECD, 1982). According to Regulation H-4 (2013) for ecological status assessment based on phytoplankton were applied Hungarian Lake Phytoplankton Index (HLPI) (Borics *et al*., 2018) and Bulgarian method (Belkinova *et al*., 2013).

The macrophyte surveys were carried out once during the main vegetation period (end of June until September). In each sampling site belt transects of 20–30 m width orthogonal to the shoreline and positioned within an ecologically homogenous section of the littoral were surveyed. The transect numbers were in correlation to the lake size. Species, their abundance and additional relevant parameters were recorded for the defined depth zones (0–1; 1–2; 2–4; and >4 m). The abundance of plant species was estimated on site using a five-scale system (Kohler, 1978). The nomenclature followed Grolle & Long (2000) for liverworts, Hill *et al.* (2006) for mosses, Delipavlov *et al.* (2003) for vascular plants. Ecological status assessment was based on Reference Index (Gecheva *et al*., 2013a).

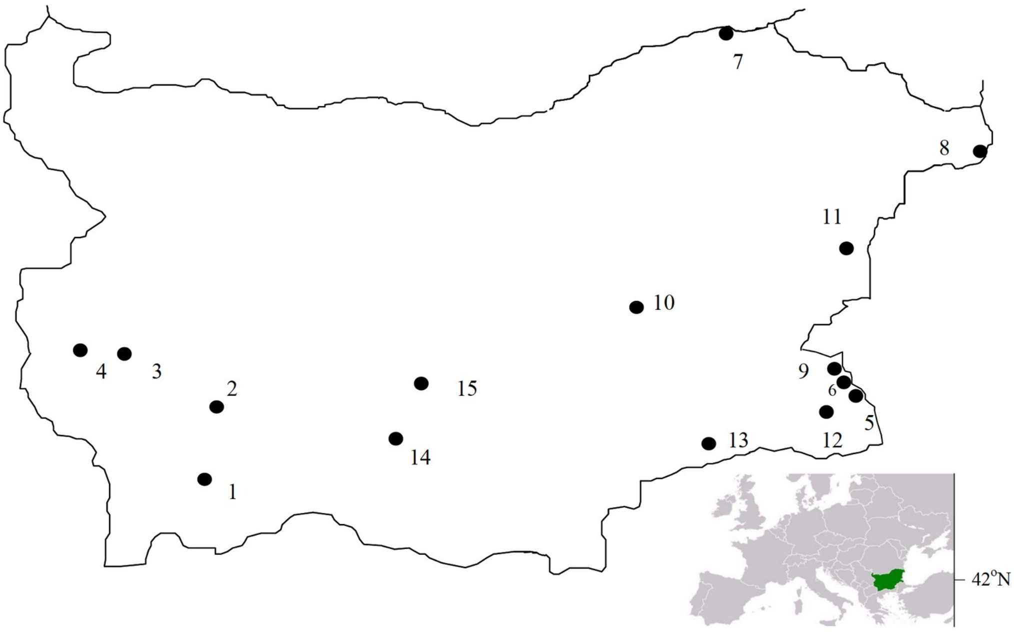

Fig. 1. Map of the studied water bodies. *Legend:* 1-Bezbog ; 2-Chernoto; 3-Studena; 4-Choklyovo; 5-Velyov vir; 6-Arkutino; 7-Srebarna; 8-Shabla; 9-Alepu; 10-Zhrebchevo; 11-Eleshnitsa; 12-Yasna polyana; 13-Malko Sharkovo; 14-Tsankov kamak; 15-Konush.

Table 1. List of surveyed water bodies.

Reservoir	Type	Altitude, m a.s.l.	Area (km^2)	Max depth, m
Bezbog	L1	2240	0.02	7
Chernoto	L1	2302	0.06	15
Studena	L3	846	1.42	16
Choklyovo	L4	940	0.81	3
Velyov vir	L5	8	0.14	1.2
Arkutino	L5	1	0.09	1.1
Srebarna	L5	13.2	10	3.3
Shabla	L7	0	0.64	7.5
Alepu	L8	-0.5	0.14	1.2
Zhrebchevo	L11	273	25.8	52
Eleshnitsa	L12	53	1.18	11.3
Yasna polyana	L12	84	2.32	43
Malko Sharkovo	L13	247	3.9	15
Tsankov kamak	L13	696	200.7	>100
Konush	L17	175	0.38	8

Results

According to the measured physico-chemical parameters (Table 2) studied water bodies were in high and good status (Regulation H-4, 2013), except for Studena (TP), Shabla (TP), Eleshnitsa (Secchi disk transparency), Malko Sharkovo (TN), Tsankov kamak (TP and TN) and Konush (TP and TN). Values of chlorophyll-a corresponded to all trophic categories: from ultra-oligotrophic до hypertrophic.

Phytoplankton communities

In total descriptor species form 25 FGs were registered (Table 3). The number of FGs increased at lower altitude and higher trophic category. Seven FGs were presented in ultra-oligotrophic glacial lakes (L1), while in eu-hypertrophic lowland lakes (L5) FGs were 20. Despite typological specifics (altitude, area, maximum depth) FG $\mathbf{L_0}$ of dinoflagellates was recorded in all lake types. Cryptomonads from FG **Y** and various benthic or periphytic diatom taxa from FG **MP** were wildly represented also**.** The above confirmed results of PADISÁK *et al.* (2009) that codons **L0** (mostly dinoflagellates) and **Y** (large size cryptomonads) occur in broad variety of habitats and are able to survive in all lentic ecosystems conditions. Mobility of dinoflagellates and cryptomonads allow effective nutrient uptake.

Table 2. Measured parameters in surveyed water bodies. Legend: * lake-annual values.

Reservoir	Type	TP [mg L^{-1}]	TN [mg L^{-1}]	Secchi [m], mean	Total Biovolume [mg L^{-1}]*	Chl-a [μg L^{-1}] *	Trophic Category [chl]
Bezbog	L1	<0.010	<0.5	>7	0.3	<1	Ultra-oligo
Chernoto	L1	<0.010	<0.5	>15	0.026	<1	Ultra-oligo
Studena	L3	0.06	<0.5	2.00	0.83	1.10	Oligo-
Choklyovo	L4	0.018	<0.5	>2.5	0.6725	<1	Ultra-oligo/Oligo
Velyov vir 2012	L5	0.234	1.97	0.3	6.85	17.34	Eu-
Velyov vir 2014	L5	0.096	0.81	0.3	4.14	19.25	Eu-
Arkutino	L5	0.118	1.51	0.3	8.53	24.73	Eu-
Srebarna	L5	0.159	0.881	0.8	13.54	36.00	Hyper-
Shabla	L7	0.125	0.6	1.95	1.22	2.54	Meso-
Alepu	L8	0.055	0.8	1.20	4.55	6.98	Meso-
Zhrebchevo	L11	<0.010	<0.5	2.20	0.18	3.24	Meso-
Eleshnitsa	L12	0.02	0.378	1.20	0.48	1.0	Oligo-
Yasna polyana	L12	0.025	<0.5	2.18	1.19	1.94	Oligo-

Reservoir	Type	TP [mg L-1]	TN [mg L-1]	Secchi [m], mean	Total Biovolume [mg L-1]*	Chl-a [µg L-1] *	Trophic Category [chl]
Malko Sharkovo	L13	0.051	0.417	3.8	1.1	1.07	Oligo-
Tsankov kamak	L13	0.1	1.694	1.10	3.00	1.48	Oligo-
Konush	L17	0.428	12.14	0.3	25.6	55.0	Hyper-

Table 3. Type-specific taxa and groups – Phytoplankton (FGs) and Macrophytes at least disturbed conditions in studied lake types. Legend: *relative biovolume (%) of phytoplankton species towards total biovolume; / relative biovolume (%) in different samples from one vegetative season.

Lake Type 1 (Chernoto, Bezbog Lakes)			
	Chernoto Lake	**Bezbog Lake**	**Type-specific taxa and groups – Phytoplankton and Macrophytes**
Phytoplankton-Descriptor species	**Chlorophyta** *Elakatothrix gelatinosa*-*7/6 **(F)** *Oocystis apiculata*-7/0 **(F)** *Planktosphaeria gelatinosa*-6.7/0 **(F)** *Radiococcus* sp.- 7/6 **(F)** *Stichococcus lacustris*-7/0 **(X2)** **Chrysophyceae** *Chromulina* sp.- 26.7/0 **(X2)** *Dinobryon crenulatum*-0/6 **(E)** **Cryptophyta** *Cryptomonas ovata* 0/80 **(Y)** *Rhodomonas lacustris*-0/56 **(X2)** **Dinophyta** *Peridinium umbonatum*-40/0 **(L_0)**	**Chlorophyta** *Radiococcus nimbatus*-5/0 **(F)** **Bacillariophyceae** *Aulacoseira italica*-0/35 **(B)** *Diatoma mesodon*-7/0 **(MP)** *Gomphonema parvulum*-0/5 **(MP)** *Pinnularia* sp.-0/11 **(MP)** **Chrysophyceae** *Mallomonas allorgei*-0/6 **(E)** **Dinophyta** *Gymnodinium palustre*-74/0 **(L_0)** *Peridinium inconspicuum*-0/33 **(L_0)**	**Phytoplankton FGs: Species** **B:** *Aulacoseira italica* **MP:** *Gomphonema parvulum, Diatoma mesodon, Pinnularia* sp. **X2:** *Chromulina* sp., *Stichococcus lacustris, Rhodomonas lacustris* **E:** *Dinobryon crenulatum, Mallomonas allorgei* **Y:** *Cryptomonas ovata* **F:** *Elakatothrix gelatinosa, Radiococcus* sp., *R. nimbatus*, *Oocystis apiculata, Planktosphaeria gelatinosa* **L_0:** *Gymnodinium palustre, Peridinium inconspicuum, P. umbonatum*
Macrophytes	*Callitriche palustris* *Juncus filiformis* *Marsupella emarginata* *Spagnum* sp. *Sparganium angustifolium* *Subularia aquatica*	*Dicranum bonjeanii* *Eleocharis palustris* *Isoetes lacustris* *Juncus filiformis* *Polytrichum commune* *Ranunculus aquatilis* *Sparganium angustifolium* *Sphagnum centrale* *Subularia aquatica*	**Macrophytes:** *Spagnum* sp. *Sparganium angustifolium* *Subularia aquatica*
Lake Type 3 (Studena Reservoir)			
Phytoplankton-Descriptor species	**Bacillariophyceae** *Cyclotella comta*-16 **(B)** *Cyclotella ocellata*-76 **(B)** **Cryptophyta** *Chroomonas* sp.-5 **(Y)**		**Phytoplankton FGs: Species** **B:** *Cyclotella comta, C. ocellata* **Y:** *Chroomonas* sp.
Macrophytes	**Macrophytes were not recorded.**		**Macrophytes: n.a.**
Lake Type 4 (Choklyovo marshland)			
Phytoplankton-Descriptor species	**Chlorophyta** *Tetraedron caudatum*-0/13 **(X1)** *Tetraedron minimum*-5/7 **(X1)** **Chrysophyceae** *Chrysococcus rufescens*-5/5 **(X3)**		**Phytoplankton FGs: Species** **C:** *Cyclotella* sp. **D:** *Ulnaria ulna* **X3:** *Chrysococcus rufescens* **X1:** *Tetraedron caudatum,T.*

	Bacillariophyceae *Cyclotella* sp.-0/5 **(C)** *Ulnaria ulna*-0/6 **(D)** **Euglenophyta** *Euglena texta*-21/28 **(W1)** **Dinophyta** *Peridinium cinctum*-21/0 **(L_0)** *Peridinium inconspicuum*-11/8 **(L_0)**		*minimum* **L_0:** *Peridinium cinctum, P. inconspicuum* **W1:** *Euglena texta*
Macrophytes	*Ceratophyllum demersum* *Elodea canadensis* *Lemna minor* *Lemna trisulca* *Myriophyllum spicatum* *Myriophyllum verticillatum* *Phragmites australis* *Potamogeton lucens* *Potamogeton natans* *Riccia fluitans* *Scirpus lacustris* *Sparganium erectum* *Typha angustifolia* *Typha latifolia* *Utricularia minor* *Utricularia vulgaris*		**Macrophytes:** *Potamogeton natans* *Riccia fluitans* *Utricularia minor* *Utricularia vulgaris*
Lake Type 5 (Velyov vir, Arkutino, Srebarna Lakes)			
	Velyov vir Lake (2012)	**Velyov vir Lake (2014)**	
Phytoplankton-Descriptor species	**Cyanobacteria** *Aphanocapsa nubilum*-0/7 **(K)** **Chlorophyta** *Micractinium pusillum*-0/5 **(X1)** **Chrysophyceae** *Chrysococcus rufescens*-5/10 **(X3)** **Bacillariophyceae** *Rhopalodia gibba*-20/0 **(MP)** *Stauroneis* sp.-13/0 **(MP)** *Stephanodiscus hantzschii*-0/7 **(D)** *Ulnaria capitata*-5/0 **(MP)** **Cryptophyta** *Cryptomonas erosa*-0/6 **(Y)** **Euglenophyta** *Euglena hemichromata*-30/0 **(W1)** *Trachelomonas armata*-0/24 **(W2)** *Trachelomonas bulla*-0/6 **(W2)**	**Chlorophyta** *Chlamydomonas globosa*-0/0/9 **(X2)** *Closterium gracile*-10/0/0 **(P)** *Sphaerellopsis* sp.-7/0/9 **(X3)** **Chrysophyceae** *Chrysococcus rufescens*-0/5/12 **(X3)** **Bacillariophyceae** *Stephanodiscus hantzschii*-37/0/0 **(D)** *Stephanodiscus minutulus*-0/5/0 **(D)** **Euglenophyta** *Euglena* sp.- 0/11/10 **(W1)** *Lepocinclis ovum*-0/11/0 **(W1)** *Trachelomonas manginii*-0/0/6 **(W2)** *Trachelomonas volvocinopsis*-11/9/0 **(W2)** **Dinophyta** *Peridinium lomnickii*-0/8/0 **(L_0)** **Cryptophyta** *Cryptomonas marssonii*-0/23/11 **(Y)** *Rhodomonas lacustris*-0/0/7 **(X2)**	**Phytoplankton FGs: Species** **A:** *Cyclostephanos* sp. **C:** *Cyclotella meneghiniana* **D:** *Stephanodiscus hantzschii, S. minutulus* **P:** *Aulacoseira granulata, Fragilaria crotonensis, Closterium gracile* **MP:** *Rhopalodia gibba, Ulnaria capitata, Stauroneis* sp., *Pinnularia gibba* **M:** *Microcystis aeruginosa* **H1**: *Anabaena* species **T:** *Mougeotia* sp. **T_c:** *Oscillatoria limosa* **S1:** *Leptolyngbya angustissima* **X3:** *Chrysococcus rufescens, Sphaerellopsis* sp. **X2:** *Chlamydomonas globosa, Rhodomonas lacustris* **X1:** *Micractinium pusillum* **Y:** *Cryptomonas erosa, C. marssonii* **F:** *Dictyosphaerium* sp. **J:** *Pediastrum duplex, P. simplex* **K:** *Aphanocapsa nubilum, A. grevillei* **L_0:** *Peridinium lomnickii* **W1:** *Euglena* sp., *E. hemichromata, E. texta, Lepocinclis ovum* **W2:** *Trachelomonas armata, T. bulla, T. manginii, T. volvocinopsis*
Macrophytes	*Brachythecium rutabulum* *Campyliadelphus chrysophyllus* *Ceratophyllum demersum* *Ceratophyllum submersum* *Ditrichum flexicaule* *Fontinalis antipyretica* *Nuphar lutea* *Nymphaea alba* *Riccia fluitans*	*Ceratophyllum demersum* *Fontinalis antipyretica* *Lemna minor* *Leptodictium riparium* *Lysimachia nummularia* *Nuphar lutea* *Nymphaea alba* *Potamogeton pussilus* *Ranunculus repens*	**Macrophytes:** *Fontinalis antipyretica* *Hydrocharis morsus-ranae* *Riccia fluitans*

	Salvinia natans *Sparganium erectum* *Spirodella polyrhiza* *Typha latifolia*	*Sparganium erectum* *Spirodela polyrhiza*	*Stratiotes aloides* *Utricularia vulgaris*
Phytoplankton-Descriptor species	**Arkutino Lake** **Cyanobacteria** *Anabaena kisseleviana*-7/0/0 **(H1)** *Oscillatoria limosa*-0/17/69 **(T_c)** **Chlorophyta** *Dictyosphaerium* sp.-0/7/0 **(F)** **Bacillariophyceae** *Rhopalodia gibba*-0/0/5 **(MP)** *Pinnularia gibba*-0/20/0 **(MP)** *Stephanodiscus* sp.- 0/28/0 **(D)** **Euglenophyta** *Euglena texta*-56/0/0 **(W1)** *Trachelomonas volvocinopsis*-8/0/0 **(W2)** **Cryptophyta** *Cryptomonas erosa*-0/0/13 **(Y)**	**Srebarna Lake** **Cyanobacteria** *Anabaena scheremetievii*-7/0/0/0 **(H1)** *Anabaena spiroides*-8/0/0/0 **(H1)** *Aphanocapsa grevillei*-0/8/0/0 **(K)** *Leptolyngbya angustissima*-0/0/8/7 **(S1)** *Microcystis aeruginosa*-0/0/0/7 **(M)** **Chlorophyta** *Mougeotia* sp.-0/9/0/0 **(T)** *Pediastrum duplex*-0/0/0/17 **(J)** *Pediastrum simplex*-0/0/0/17 **(J)** **Chrysophyceae** *Chrysococcus rufescens*-0/7/0/0 **(X3)** **Bacillariophyceae** *Aulacoseira granulata*-0/71/30/8 **(P)** *Fragilaria crotonensis*--0/19/0/6 **(P)** *Cyclotella meneghiniana*-0/16/22/5 **(C)** *Cyclostephanos* sp.-0/12/0/0 **(A)**	
Macrophytes	*Bidens cernua* *Carex riparia* *Ceratophyllum demersum* *Cyperus fuscus* *Galium palustre* *Hydrocharis morsus-ranae* *Lemna minor* *Lycopus europaeus* *Lythrum salicaria* *Nuphar lutea* *Nymphaea alba* *Oenanthe aquatica* *Polygonum mite* *Solanum dulcamara* *Sparganium erectum* *Spirodela polyrhiza* *Typha angustifolia*	*Alisma plantago-aquatica* *Butomus umbellatus* *Carex riparia* *Ceratophyllum demersum* *Cyperus lacustris* *Eleocharis palustris* *Epilobium hirsutum* *Hydrocharis morsus-ranae* *Hydrocharis morsus-ranae* *Salvinia natans* *Lemna minor* *Lemna trisulca* *Lemna trisulca* *Lycopus europaeu* *Lythrum salicaria* *Najas marina* *Phragmites australis* *Salvinia natans* *Scirpus cf. sylvaticus* *Spirodela polyrhiza* *Stratiotes aloides* *Thelipteris pallustris* *Typha angustifolia* *Typha angustifolia* *Utricularia vulgaris*	
Lake Type 7 (Shabla Lake)			
Phytoplankton-Descriptor species	**Chlorophyta** *Oocystis elliptica*-6 **(F)** **Bacillariophyceae** *Aulacoseira granulata*-44 **(P)** *Rhoicosphenia abbreviata*-5 **(MP)** **Dinophyta** *Peridinium* sp.-27 **(L_0)**		**Phytoplankton FGs: Species** **P:** *Aulacoseira granulata* **MP**: *Rhoicosphenia abbreviata* **F:** *Oocystis elliptica* **L_0:** *Peridinium* sp.

Macrophytes	*Bolboschoenus maritimus* *Butomus umbellatus* *Calystegia sepium* *Cyperus longus* *Echinochloa crus-galli* *Hydrocharis morsus-ranae* *Lycopus europeus* *Lythrum salicaria* *Myriophyllum spicatum* *Najas marina* *Nuphar lutea* *Nymphaea alba* *Phragmites australis* *Polygonum lapathifolium* *Potamogeton pectinatus* *Potamogeton perfoliatus* *Scirpus lacustris* *Scyrpus triqueter* *Sparganium erectum* *Typha latifolia* *Utricularia minor* *Vallisneria spiralis* *Veronica beccabunga*	**Macrophytes:** *Hydrocharis morsus-ranae* *Potamogeton pectinatus* *Potamogeton perfoliatus* *Utricularia minor* *Vallisneria spiralis*
	Lake Type 8 (Alepu Lake)	
Phytoplankton-Descriptor species	**Chlorophyta** *Closterium ehrenbergii*-0/45/0/0 **(P)** *Coelastrum microporum*-8/0/0/0 **(J)** *Eudorina elegans*-0/13/5/0 **(G)** *Mougeotia* sp.-0/0/7/0 **(T)** *Planktosphaeria gelatinosa*-63/0/0/0 **(F)** *Staurastrum gracile*-0/0/32/0 **(N)** **Chrysophyceae** *Chrysococcus rufescens*-0/15/0/0 **(X3)** **Bacillariophyceae** *Gyrosigma attenuatum*-0/0/0/10 **(MP)** *Navicula* sp.-6/0/0/0 **(MP)** **Euglenophyta** *Euglena acus*-5/0/0/0 **(W1)** *Euglena korshikovii*-0/0/0/12 **(W1)** *Lepocinclis caudata* -5/0/0/16 **(W1)** *Lepocinclis* sp.-5/0/0/0 **(W1)** **Dinophyta** *Gymnodinium* sp.-0/0/20/9 **(L_0)** *Peridinium inconspicuum*-0/0/11/7 **(L_0)** **Cryptophyta** *Cryptomonas marssonii*-0/13/13/8 **(Y)**	**Phytoplankton FGs: Species** **N:** *Staurastrum gracile* **P:** *Closterium ehrenbergii* **MP:** *Gyrosigma attenuatum, Navicula sp.* **T:** *Mougeotia* sp. **X3:** *Chrysococcus rufescens* **Y:** *Cryptomonas marssonii* **F:** *Planktosphaeria gelatinosa* **G:** *Eudorina elegans* **J:** *Coelastrum microporum* **L_0:** *Gymnodinium* sp., *Peridinium inconspicuum* **W1:** *Euglena* acus, *E. korshikovii, Lepocinclis caudata, Lepocinclis* sp.
Macrophytes	*Cyperus longus* *Juncus effusus* *Lycopus europeus* *Lythrum salicaria* *Mentha aquatica* *Phragmites australis* *Salvinia natans* *Typha angustifolia*	**Macrophytes: n.a.**
	Lake Type 11 (Zhrebchevo Reservoir)	
Phytoplankton-Descriptor species	**Chlorophyta** *Pandorina morum*-6 **(G)** *Staurastrum gracile*-5 **(N)**	**Phytoplankton FGs: Species** **B:** *Cyclotella ocellata* **N:** *Staurastrum gracile*

	Bacillariophyceae *Cyclotella ocellata*-51 **(B)** *Fragilaria crotonensis*-17 **(P)** **Euglenophyta** *Euglena sp.*-6 **(W1)**		**P:** *Fragilaria crotonensis* **G:** *Pandorina morum* **W1:** *Euglena* sp.
Macrophytes	*Bidens tripartita* *Ceratophyllum demersum* *Myriophyllum spicatum* *Najas marina*		**Macrophytes: n.a.**
Lake Type 12 (Eleshnitsa, Yasna polyana Reservoirs)			
	Eleshnitsa	**Yasna polyana**	
Phytoplankton-Descriptor species	**Chlorophyta** *Cosmarium* sp.-6 **(N)** *Hariotina polychorda*-13 **(J)** *Phacotus coccifer*-13 **(X_{Ph})** *Staurastrum* sp.-10 **(N)** *Stichococcus minutissimus*-13 **(X2)** **Dinophyta** *Ceratium hirundinella*-6 **(L_0)**	**Cyanobacteria** *Limnothrix redekei*-35 **(S1)** **Chrysophyceae** *Dinobryon divergens*-8 **(E)** **Euglenophyta** *Euglena* sp.-30 **(W1)**	**Phytoplankton FGs: Species** **N:** *Cosmarium* sp., *Staurastrum* sp. **S1:** *Limnothrix redekei* **X2:** *Stichococcus minutissimus* **X_{Ph}:** *Phacotus coccifer* **E:** *Dinobryon divergens* **J:** *Hariotina polychorda* **L_0:** *Ceratium hirundinella* **W1:** *Euglena* sp.
Macrophytes	Macrophytes were not recorded.	*Ranunculus trichophyllus*	**Macrophytes: n.a.**
Lake Type 13 (Malko Sharkovo and Tsankov kamak reservoirs)			
Phytoplankton-Descriptor species	**Malko Sharkovo** **Cyanobacteria** *Microcystis flos-aquae* 0/13 **(M)** **Chlorophyta** *Mougeotia* sp.-0/7 **(T)** **Bacillariophyceae** *Cyclotella ocellata*-8/8 **(B)** *Cyclotella comta*-83/55 **(B)** **Dinophyta** *Ceratium furcoides*-0/9 **(L_0)**	**Tsankov kamak** **Cyanobacteria** *Snowella fennica*-0/7/0 **(L_0)** **Chlorophyta** *Eutetramorus planctonicus*-0/9/0 **(F)** *Pandorina morum*-26/0/0 **(G)** **Bacillariophyceae** *Fragilaria crotonensis*-0/0/31 **(P)** *Navicula tripunctata*-0/0/13 **(MP)** *Tabellaria fenestrata*-0/0/35 **(N)** *Ulnaria ulna*-12/0/0 **(D)** **Dinophyta** *Ceratium furcoides*-12/8/10 **(L_0)** *Gymnodinium* sp.-7/0/0 **(L_0)** *Peridinium cinctum*-8/0/0 **(L_0)** *Peridinium* sp.-0/50/0 **(L_0)** **Cryptophyta** *Cryptomonas marssonii*-25/15/0 **(Y)**	**Phytoplankton FGs: Species** **B:** *Cyclotella ocellata, C. comta* **D:** *Ulnaria ulna* **N:** *Tabellaria fenestrata* **P:** *Fragilaria crotonensis* **MP:** *Navicula tripunctata* **M:** *Microcystis flos-aquae* **T:** *Mougeotia* sp. **Y:** *Cryptomonas marssonii* **F:** *Eutetramorus planctonicus* **G:** *Pandorina morum* **L_0:** *Ceratium furcoides, Snowella fennica, Gymnodinium* sp., *Peridinium cinctum, Peridinium* sp.
Macrophytes	*Myriophyllum spicatum* *Polygonum hydropiper*	Macrophytes were not recorded.	**Macrophytes: n.a.**
Lake Type 17 (Konush Reservoir)			
Phytoplankton-Descriptor species	**Cyanobacteria** *Anabaenopsis milleri*-0/6/0 **(H1)** *Pseudanabaena limnetica*-5/0/0 **(S1)** **Chlorophyta** *Chlamydomonas* sp.-0/0/18 **(X2)** *Pediastrum simplex*-0/21/0 **(J)** **Bacillariophyceae** *Aulacoseira granulata*-0/9/0 **(P)** *Cyclotella meneghiniana*-4/3/43 **(C)** *Stephanodiscus hantzschii*-7/1/0 **(D)** *Stephanodiscus minutulus*-0/0/10 **(D)** **Euglenophyta**		**Phytoplankton FGs: Species** **C:** *Cyclotella meneghiniana* **D:** *Stephanodiscus hantzschii, S. minutulus* **P:** *Aulacoseira granulate* **X2:** *Chlamydomonas* sp. **S1:** *Pseudanabaena limnetica* **H1:** *Anabaenopsis milleri* **J:** *Pediastrum simplex* **L_0:** *Ceratium furcoides*, *Peridinium* sp. **W1:** *Euglena eherenbergii, E. texta,*

	Euglena eherenbergii-0/0/7 **(W1)** *Euglena texta*-0/6/5 **(W1)** *Lepocinclis ovum*-0/8/0 **(W1)** *Lepocinclis* sp.-0/8/0 **(W1)** **Dinophyta** *Ceratium furcoides*-26/30/0 **(L_0)** *Peridinium aciculiferum*-1/6/0 **(L_0)**	*Lepocinclis ovom, Lepocinclis* sp.
Macrophytes	*Juncus effusus* *Lycopus europeus* *Lythrum salicaria* *Scyrpus maritimus* *Typha angustifolia* *Typha latifolia*	**Macrophytes: n.a.**

From lake type L1 (glacial lakes in high mountains) Chernoto and Bezbog lakes were studied**.** They are small lakes (<0.06 km^2) at altitude above 2240 м (Table 1), characterized with high transparency (up to the bottom) and ultra-oligotrophic conditions (Table 2). Descriptor species represented 7 FGs: **B**, **MP**, **X2**, **E**, **Y**, **F** и **L_0** (Table 3). Charater dominant species were colonial chlorococcocaleans *Radiococcus* species, *Planktosphaeria gelatinosa, Oocystis apiculata* (**F**). Specific conection with ultra-oligotrophic conditions had also centric diatom *Aulacoseira italica* (**B**), motile chrysophyceans *Dinobryon*, *Mallomonas* (**E**) and meroplanktonic diatom *Diatoma mesodon* (**MP**). Motile mixotrophic dinoflagellates *Peridinium*, *Gynodinium* (**L_0**), Cryptomonas species (**Y**) were with higher biovolume, which confirmed results of BESHKOVA (2000). In a similar study of phytoplankton assemblages of high mountain lakes and reservoirs in the Rila Mountains, BESHKOVA *et al.* (2016) also emphasized the importance of motile mixotrophic organisms (Chryso- and Dinophyceae) for more complete utilization of trophic resources. In oligotrophic high altitude lakes diatoms of the genus *Cyclotella* and flagellates (chrysophytes, dinoflagellates and cryptophytes) are frequently dominant (JÄRVINEN *et al*., 2013).

Reservoir Studena is from lake type L3 (mountain lakes in the Eastern Balkans). It is a deep mountain oligotrophic reservoir with high transparency (Table 1, 2). Phytoplankton community was dominated totally by centric diatoms *Cyclotella comta* and *C. ocellata* from **B** (Table 3). The low number of descriptor species and FGs is probably due to the insufficient data. Further researches of the type should supply opportunity for more complete description of L3 phytoplankton assemblages in undisturbed conditions.

Choklyovo marschland represents lake type L4 (lowland or semi-mountain natural lakes and swamps). It is shallow, with high transparency and oligotrophic conditions (Tables 1, 2). Detailed previous phytoplankton studies reveled high species richness (STOYNEVA & VALCHANOVA, 1997). Phytoplankton descriptor species belong to FGs connected with shallow environments **D** (*Ulnaria ulna*), **X1** (*Tetraedron caudatum*, *T. minimum*) and **W1** (*Euglena* spp.) – Table 3. Oligotrophic conditions are reflected by codon **X3** (*Chrysococcus rufescens*), which inhabited shallow, well mixed oligotrophic environments (REYNOLDS *et al.*, 2002, PADISÁK *et al*., 2009).

Velyov vir, Arkutino and Srebarna (L5, riverine marshes in the Pontic Province) were with highest number of FGs с descriptor species (Table 3). Riverine marshes Velyov vir and Arkutino are extremely shallow (Table 1), macrophyte-dominated lakes with deep layer of silt. Both lakes are not under anthropogenic pressure and phytoplankton dynamic is a result of natural processes (macrophyte decomposition, deposition of phyto- and zooplankton, strong seasonal water level fluctuations). They are naturally eutrophic lakes, characterized by high richness and dynamics of phytoplankton community (GECHEVA *et al.*, 2013b). FGs of the descriptor species were typical for shallow, nutrient-rich habitats (PADISÁK *et al.*, 2009): euglenoids from **W1** (*Euglena* spp., *Lepocinclis* spp.) and **W2** (*Trachelomonas* spp.), small-celled colonial Cyanobacteria from **K** (*Aphanocapsa* spp.), green algae and small cryptomonads from **X1** (*Micractinium*) and **X2** (*Chlamydomonas* spp., *Rhodomonas*), coccal green algae from **J** (*Pediastrum* spp). The small depth supported the abundance of meroplanktonic diatoms from **MP** (*Rhopalodia*, *Stauroneis*, *Pinnularia*). For eutrophic standing waters, or slowflowing rivers with emergent macrophytes is caharcter FG $\mathbf{T_c}$ (*Oscillatoria limosa*).

Srebarna Lake is eutrophic lake formed on a previous Danube River meander (UZUNOV *et al.*, 2012). It has larger surface area and is deeper in comparison with Velyov vir and Arkutino (Table 2). Multi annual studies of BESHKOVA *et al.* (2012) revealed that phytoplankton structure in Srebarna is connected with water level fluctuations and connectivity with Danube River. Descriptor species of bloom-forming cyanobacteria **H1** (*Anabaena* spp.), **M** (*Microcystis aeruginosa*) and high TP (Tables 2, 3) showed that the lake has becomed eutrophic. This is also confirmed by the presence of planctic diatoms from **P** (*Aulacoseira granulata*, *Cyclotella meneghiniana*) (REYNOLDS *et al.*, 2002, PADISÁK *et al.*, 2009).

Shabla Lake belongs to lake type L7 (Black Sea freshwater coastal lakes) and is relatively shallow, meso-eutrophic, with salinity <0.5‰ (Table 1). Phytoplankton was with underlined freshwater character (Table 3). Descriptor species from **P** (*Aulacoseira granulata*) and dinoflagellates from $\mathbf{L_0}$ (*Peridinium* spp.) were with highest biovolume.

Alepu Lake is from type L8 (Black Sea oligohaline coastal lakes) and is shallow, oligotrophic lake with salinity 0.5-5‰; typical representative of transitional waters (Table 1). Mid-seasonal values of chlorophyll-a were in the range of mesotrophic conditions, while TP in eutrophic category (Table 2). Polymictic character of the lakes supported descriptor species with high sinking rate, e.g. chlorococcaleans from **J** (*Coelastrum* spp.) and **F** (*Planktosphaeria*), planktonic desmids from **N** (*Staurastrum*) and **P** (*Closterium*) and planktonic **T** (*Mougeotia*). Similar with shallow lakes from L5 and L8 typical descriptor species were euglenoids from **W1** (*Euglena* spp., *Lepocinclis* spp.).

Zhrebchevo Reservoir (L11, large deep reservoirs) is representative of the largest and deepest Bulgarian reservoirs. Mid-seasonal chlorophyll-a levels reflected mesotrophic category (Table 3). With highest relative biovolume were planctic descriptor species from **B** (*Cyclotella ocellata*), **P** (*Fragilaria crotonensis*) and **N** (*Staurastrum* spp.), character for the epilimnia of stratified lakes (PADISÁK et al., 2009). Dominance of *Cyclotella ocellata* and *Fragilaria crotonensis* in Zhrebchevo Reservoir is confirmed by BESHKOVA *et al.* (2014) and DOCHIN (2019). Motile volvocaleans oт **G** (*Pandorina morum*) are developed in stable phases in larger storage reservoirs (PADISÁK *et al.*, 2009).

Eleshnitsa and Yasna polyana reservoirs represented L12 (small and medium-size semi-mountain reservoirs in the Pontic Province). These reservoirs are up to 10 km^2, usually with mid-depth of up to 15 m, but with maximum depth that can reach 40 m (Table 1). Eleshnitsa and Yasna polyana reservoirs are lowland and levels of chlorophyll-a and TP corresponed to oligo-mesotrophic conditions (Table 2). In comparison with L11, descriptor species were form higher number of FGs: **N**, **S1**, **X2**, $\mathbf{X_{Ph}}$, **E**, **J**, $\mathbf{L_0}$, **W1**. Indicators of oligo-mesotrophic environments are desmids from **N** (*Cosmarium* spp., *Staurastrum* spp.), chrysophyceans from **E** (*Dinobryon* spp.) and small green algae from **X2** (*Stichococcus*). Presence of motile flagellats *Phacotus coccifer* ($\mathbf{X_{Ph}}$) in Eleshnitsa Reservoir probably represented specific physico-chemical characteristics because $\mathbf{X_{Ph}}$ inhabits calcium rich, well illuminated, alkaline environments (PADISÁK *et al*., 2009).

Malko Sharkovo and Tsankov kamak Reservoirs from L13 lake type were studied (small and medium-size semi-mountain reservoirs in the Eastern Balkans). Descriptor species of L13 represented 10 FGs: **B**, **D**, **N**, **P**, **MP**, **T**, **Y**, **F**, **G**, $\mathbf{L_0}$ (Table 3). Despite L12 and L13 are analogical types in the two ecoregions, they had only two common FGs: **N** и $\mathbf{L_0}$. Lake type 13 was characterized by high relative biovolume of oligomesotrophic descriptor species: centric diatoms from **B** (*Cyclotella ocellata*, *C. comta*), pennate diatoms from **N** (*Tabellaria fenestrata*) and **P** (*Fragilaria crotonensis*), gelatinous chlorococcaleans from **F** (*Eutetramorus planctonicus*), large dinoflagellates from $\mathbf{L_0}$ (*Peridinium* spp.). With respect to the above, phytoplankton community of L13 reveled more similarity with L11 and mountain L1, L3.

Konush Reservoir belongs to lake type L17 (small and medium-size lowland reservoirs in the Eastern Balkans). High phytoplankton diversity was recorded. Descriptor species belonged to 9 FGs, character for eutrophic habitats (Table 3). Comparison with reservoirs from L17 and its analog L5 as shallow natural lakes showed that FGs were comon. With highest relative biovolume were FGs **C** (*Cyclotella meneghiniana*), **J** (*Pediastrum*), **X2** (*Chlamydomonas* spp.) and $\mathbf{L_0}$ (*Peridinium*, *Ceratium*).

Community structure of macrophytes

Seventy-three species were registered, among them nine taxa belonged to bryophytes (Table 3). Bezbog and Chernoto lake (L1) supported well developed macrophyte communities, dominated by *Isoetes lacustris* at up to 4 m colonization depth at Bezbog and *Sparganium angustifolium* at Chernoto Lake.

No macrophytes were registered at Studena Resevoir, which as a water body for drinking water supply probably do not present conditions for macrophyte development. Studied water bodies from types L4, L5 and L7 had species rich macrophyte communities and high abundance of the taxa. *Potamogeton natans* dominated Choklyovo swamp at up to 4 1.5 m depth. *Nymphaea alba, Nyphar lutea* and *Ceratophyllum demersum* were the most abundant species in Velyov vir during 2012, while in 2014 *Potamogeton pussilus* and aquatic moss *Fontinalis antipyretica* replaced water lilies as dominants. Water lilies dominated Arkutino Lake as well; in Srebarna dominants were *C. demersum, Salvinia natans* and *Uricularia vulgaris*. *Najas marina* and *Nuphar lutea* were the most abundant macrophytes in Shabla.

Alepu supported abundant bank vegetation, but except *Salvinia natans* no aquatic macrophytes were recorded. The same was registered at Konush Reservoir (*Typha, Juncus, Lythrum, Lycopus, Scirpus*) and could be linked to the fishfarming and low transparency.

Macrophytes were recorded in a single transect in Zhrebchevo Reservoir, as well as in Yasna polyana Reservoir. Tsankov kamak Reservoir did not support macrophytes due to water-level fluctuations, slope and substrate, which affect the distribution of macrophytes communities. Malko Sharkovo had a monodominant macrophyte community. Despite it is from one lake type with Tsankov kamak, the sloping banks and substrate (sand and silt) created suitable conditions – demonstrated by the positive response of submerged macrophytes.

Conclusions

Descriptor species from 25 FGs were registered in phytoplankton communities at undisturbed water bodies from 10 national lake types (L1, L3, L4, L5, L7, L8, L11, L12, L13, L17). The number of FGs increased at lower altitude and higher trophic category: 7 FGs were recorded in ultraoligotrophic glacial lakes L1, while 20 FGs in eutrophic riverine marshes L5. Common for almost all lake types were dinoflagellates ($\mathbf{L_0}$), cryptomonads (**Y**) and various benthic/periphytic taxa (**MP**).

The most separable were character descriptor species and FGs in lake types L1 and L5. Additional studies are needed for defining specific characteristics of phytoplankton communities in L3, L4, L7, L11 и L12.

Motile mixotrophic dinoflagellates (**L_0**) and cryptomonads (**Y**) had highest relative biovolume in ultra-oligotrophic alpine lakes (L1) due to their ability to utilize effectively scarce trophic resources. Character descriptor species were also gelatinous chlorococcocaleans (**F**), centric diatom (**B**) and motile chrysophyceans (**E**).

Motile euglenoids (**W1, W2)**, small-celled colonial Cyanobacteria (**K**), green algae and small cryptomonads (**X1, X2**), coccal green algae (**J**) and meroplanctonic diatoms (**MP**) dominated in riverine marshes L5. The presence of bloom-forming cyanobacteria (**M, H1**) as descriptor species is a sign of anthropogenic eutrophication (Srebarna Lake). Another general finding was that natural lakes (L5) and their analog in the group of shallow lowland reservoirs (L17) have common FGs. Although semi-mountain reservoirs L12 and L13 are analog in the two ecoregions, they differed in descriptor species and FGs. The phytoplankton communities of L13 were more similar with those of L11 (Large deep reservoirs) and mountain L1, L3.

Rising of the water level in deep regulated lakes (Studena, Zhrebchevo, Yasna polyana, Tsankov kamak) may result in a macrophyte depopulation, due to a compressed vertical niche for macrophytes. Moreover, in such lakes macrophytes in the littoral zones may also suffer from declining water levels. This knowledge could be applied as a management tool to mitigate effects from anthropogenic pressure.

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