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CYANOPROKATYOTE AND ALGAL BIODIVERSITY IN THE TROPICAL LAKE EDWARD (AFRICA) WITH NOTES ON NEW, RARE AND POTENTIALLY HARMFUL SPECIES

MAYA P. STOYNEVA-GÄRTNER[1*] & JEAN-PIERRE DESCY[2]

[1] *Sofia University "St. Kliment Ohridski", Faculty of Biology, Department of Botany, 8 Dragan Tsankov Blvd., BG-1164, Sofia, Bulgaria*
[2] *Université de Liège, Unité d'Océanographie Chimique, Sart Tilman, B-4000, Liège, Belgium*

Abstract. The paper presents data on the biodiversity of prokaryotic and eukaryotic algae in the tropical Lake Edward, compiled from publications of the Damas mission (1935-1936), Hecky & Kling (1987) and our own results from a recent investigation of the lake phytoplankton in a three-year period (2016-2018) in the frame of the HIPE (**H**uman **imp**acts on ecosystem health and resources of Lake **E**dward) project (http://www.co2.ulg.ac.be/hipe). The provided checklist is based on modern algal taxonomy with relevant synonymizing of lists of previous authors. In total, 577 taxa from seven divisions were registered in the lake waters and in the Kazinga Channel. The richest division was Ochrophyta (287 taxa, 274 of which from Bacillariophyceae), followed by Chlorophyta (131 taxa), Cyanoprokaryota (134), Streptophyta (14), Euglenophyta (8), Pyrrhophyta (5) and Cryptophyta (1). 52 species (or only 1% of the taxa found) persisted in the lake since 30s of the 20th century till nowadays. More than half of the cyanoprokaryotes (65) are potentially toxic and harmful species. The checklist contains also data on algal abundance and frequency of occurrence, originally provided by the authors. In the phytoplankton samples, collected during the three cruises of the HIPE project, 248 taxa were found, among which the richest division was Cyanoprokaryota (104). From this total of 248 taxa, only 3 were frequent and 199 were very rare (from 1-3 samples) with 121 taxa found in one sample only. During

**corresponding author*: M. P. Stoyneva-Gärtner – Sofia University "St. Kliment Ohridski", Faculty of Biology, Department of Botany, 8 Dragan Tsankov Blvd., BG-1164, Sofia, Bulgaria; mstoyneva@uni-sofia.bg

2016-2018, the most abundant species in the lake phytoplankton belonged to Cyanoprokaryota, Bacillariophyceae and Chlorophyta. The algae found in the lake have different ecological requirements and besides clear tropical species and some cosmopolites, some "cold water species" from northern and temperate regions were found. For them, as well as for some thermophilic species, considered alien for the lake, transport through different vectors was supposed. In the literature analyzed, 36 new taxa were described. Among them 26 taxa had Lake Edward as a single locality, and 10 were found also in other lakes and adjacent water bodies. Twelve of these new taxa were checked by modern taxonomists, but 24 still need taxonomic reconsideration.

Key words: African great lake, alien species, dominants, phytoplankton, phytobenthos

INTRODUCTION

The knowledge on the algae of the smallest of the Great African lakes – Lake Edward – has to be traced back to the 30s of the twentieth century, when the Belgian scientific mission led by HUBERT DAMAS was conducted. Yet, the publication of this expedition, which studied the lakes Kivu, Edward and Ndalaga (DAMAS 1938), "remains a model of a limnological study, where the results were presented with precision and interpreted in great detail" (DESCY ET AL. 2012). Different types of samples (from the phytoplankton, nanno-plankton, periphyton and qualitative samples from visible algal mats or filaments) were collected from 14 sampling sites of the lake and from the slow-flowing water Kazinga Channel, which connects lakes Edward and George (**Fig. 1**). These samples provided a good opportunity to make an inventory of the algal biodiversity and were given to the leading taxonomists of that time: to PIERRE FRÉMY – for blue-green algae, to FRIEDRICH HUSTEDT for diatoms, to ADOLF PASCHER for golden and synurophycean algae, pyrrophytes, euglenophytes and green flagellates, to WALTER CONRAD – for green coccal and siphonocladal algae, and for yellow-green algae. They all processed the same samples and the phytoplankton of the lake was found to

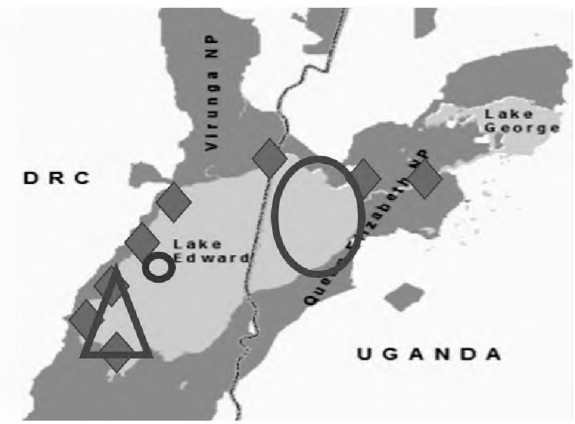

Fig. 1. Map of lakes Edward and George, connected through Kazinga Channel with sampling points:
◆ Main sampling regions of Damas mission (1935-1936)
△ Sampling region of HECKY & KLING (1987)
○ HIPE sampling regions (2016-2018)

be quite abundant and rich in cyanoprokaryotes/cyanobacteria in particular (Conrad & Duvigneaud 1949). In the alkaline (pH about 9) and transparent waters of the lake, phytoplankters developed in a depth range of 0 to 20 m with some algae (*e.g.* *Tetraëdron minimum* (A. Braun) Hansgirg) reaching a depth of 85 m (Conrad & Duvigneaud 1949). The phytoplankton of the lake was studied again much later, in 1972, in a common study of the lakes Albert, Edward, Kivu, Tanganyika and Malawi (Hecky & Kling 1987). The phytoplankton net samples from Lake Edward were collected by them on 16-17 March 1972 as "composites of two or more depths" at three stations in the east-south part of the lake (**Fig. 1**). Although in the text the authors gave some data on cyanoprokaryotes and green algae, with ten dominant or abundant species, they provided a table with camera lucida drawings of 24 taxa. The next study of the phytoplankton of the lake was carried only in the XXI[st] century, in the years 2016-2018 in the frame of the HIPE project (Human impacts on ecosystem health and resources of Lake Edward) project (http://www.co2.ulg.ac.be/hipe). Then, 29 surface samples (at a depth of 1 m) were collected at littoral and pelagic sites during three cruises, mainly in the western part of the lake (**Figs. 1, 2**). Only one sample was taken in the deepest part of the lake, off the Virunga National Park, Democratic Republic of the Congo.

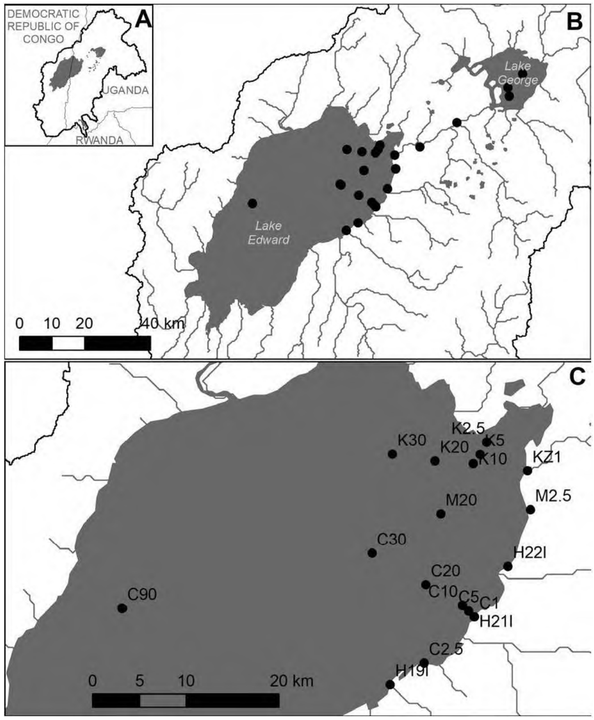

Fig. 2. Map of lakes Edward and George, connected through Kazinga Channel with HIPE sampling points at different scales (A-C): C, H, K, M - operational sampling codes.

The present paper provides summarized data on algal biodiversity of Lake Edward based on modern taxonomical considerations, which allows more reliable comparison in the long-time changes of the species composition. In addition, data on algal abundance or frequency, originally provided by the authors, are included and the most interesting new and rare taxa are outlined. Last but not least, the potentially toxic taxa, which could have adverse effects on ecosystem and human health, are indicated.

MATERIAL AND METHODS

The data concern Lake Edward (also known as Rutanzige or Edward Nyanza), situated in the Western Rift in East Africa on the border between the Democratic Republic of the Congo (DRC) and Uganda. This lake lies at 920 m a. s. l. just a few kilometers below the equator and is the smallest of the Great African lakes. It is a large (2325 km²), deep (max depth = 112 m), weakly stratified tropical lake, draining the Virunga volcanoes and the Ruwenzori Mountains. The lake is fed mainly by the waters of five rivers (Nyamugasani, Ishasha, Rutshuru, Ntungwe and Rwindi) and receives the waters from the above situated Lake George through the Kazinga Channel (https://en.wikipedia.org/wiki/Lake_Edward). In its northern part it outflows into the Lake Albert through the Semliki river. Lake Edward lies within the Virunga National Park (DRC) and the Queen Elizabeth National Park (Uganda) and does not have extensive human habitation on its shores, except at Ishango (DRC) (https://en.wikipedia.org/wiki/Lake_Edward). It is presently mesotrophic but was eutrophic a few decades ago (Lehman et al. 1998).

Cyanoprokaryote and algal biodiversity (*algal biodiversity* from here on) of the lake reported in the XXth century was estimated on the basis of the publications from the Damas's expedition (1938) and Hecky & Kling (1987). The data on the algal biodiversity in years 2016-2018 were originally obtained by the authors after processing of the phytoplankton samples of HIPE project. The main part of the work was done using conventional light microscopy with magnification 100x and immersion on non-permanent slides for non-siliceous algae, and for Bacillariophyceae on permanent slides mounted with Naphrax after peroxide digestion. For Bacillariophyceae, scanning electron microscopy (SEM) was used on some samples and help in identification was provided by Luc Ector and Carlos Wetzel, at the Luxembourg Institute of Science and Technology (LIST).

The work is based on modern algal taxonomy from main standard recent floras (*e.g.* Krammer & Lange-Bertalot 1991, 1997a, b, 2004; Komárek & Fott 1983; Komárek & Anagnostidis 1999, 2005; Komárek 2013, Moestrup & Calado 2018) and relevant current taxonomic papers (*e.g.* Lange-Bertalot 1980; Taylor et al. 2007; Potapova 2009, Sitoki et al. 2013; Trobajo et al. 2013; Wynne & Guiry 2016; Wynne & Hallan 2016; Strunecký et al. 2017; Aguilera et al. 2018) considering data in AlgaeBase (Guiry & Guiry 2018), DiatomBase (Kociolek et al. 2018), CyanoDB (Hauer & Komárek 2018). Taxonomical synonymizing was done after checking of authors taxonomical notes and indicated identification sources, detailed descriptions and drawings. When taxonomical synonymizing was not possible, the original writing of the Latin names and authors was kept and the relevant names were given between quotes. Only synonyms used in the cited literature on Lake Edward are provided in the checklist. The checklist is organized in a table format and the authors' data on algal abundance or frequency of occurrence are provided. We tried to unify the categories, used by different authors, whenever possible without missing or diminishing the nuances of difference. Therefore, all the terms, originally used by authors, are mentioned in the legend of **Table 1** as relevant for the proper abbreviation. For the HIPE samples we indicated in brackets the real number of samples in which a given species was found (numbers from 1 to 29). For easier comparison with data of previous authors, we used the following relative scale: species found in 1-3 samples – very rare; in 4-9 samples - rare, in 10-23 samples – common and in 24-29 samples – pretty common=frequent. The abbreviations for these categories (indicated in the legend of **Table 1**) are written before the real number of samples in which the species was found.

For some groups (*e.g.* Cyanoprokaryota), algal abundance was shown by Frémy (1949) for each sample, for others (*e.g.* Bacillariophyceae) abundance or frequency of occurrence were indicated by Hustedt (1949) for groups of samples. In this way, given species could be *very rare* in one group of samples, but *frequent* or *abundant* in another group. In these cases, we cited in the checklist table all possible variations of abundance and occurrence in different sample groups separated by commas (**Table 1**).

It has to be underlined that despite the general knowledge on groups is given by the relevant authors and parts of the reports of Damas mission, it is possible to find data on some additional species in the reports of other authors on different groups. For example, Pascher (1949) mentions *Rhizoclonium* sp. which was not included in the text of Conrad (1949), or some green algae and diatoms were noted by Frémy (1949). Also, due to differences in the taxonomic positioning of some green and yellow-green algae, their numbers in the publications cited above and our tables appear different. For example, *Tetraëdron mutica* (A. Braun) Hansgirg published by Conrad (1949c) among green coccal algae, recently is considered as the yellow-green alga *Goniochloris mutica* (A. Braun) Fott. *Vice versa*, *Botryococcus braunii* Kützing originally published as a yellow-green alga and therefore included in the Xanthophyceae list (Conrad 1949b), has been transferred to the green coccal algae and we also pointed it among them. Some differences could be found in the writings of taxa names or taxonomic levels in the tables and in the texts by authors (*e.g.* form and variety in the table and text by Hustedt 1949). We tried to eliminate all these differences, but yet recommend to future researchers who need to go deeper in the taxonomy of given species to go through all texts of the Mission Damas publications (1949). Some reference to taxa was done also on the basis of the drawings of H. Kling provided in Hecky & Kling (1987). For example, according to their Appendix 3, Fig. 12, it is possible to state that she found *Cylindrospermopsis helicoides*, which was described much later by Cronberg & Komárek (2004) and then was transferred to *Raphidiopsis helicoidea* by Aguilera et al. (2018). In such cases, relevant notes or figure numbers are given in the checklist text.

The potentially toxic cyanoprokaryotic taxa are indicated after Bernard et al. (2017) with some additions from the papers by Maršálek et al. (2003), Teneva et al. (2013), Stoyneva et al. (2015), Cantoral Uriza et al. (2017) and Stoyneva-Gärtner et al. (2017). In addition, especially for the toxicity of the disputable *Microcystis wesenbergii* (for details see Stoyneva-Gärtner et al. 2017) our current data, which definitely provided evidence on the production of microcystins during the bloom of this species in the reservoir Sinyata Reka (Bulgaria), were taken into account (Stoyneva-Gärtner et al. 2019a, b).

RESULTS

The Checklist containing all taxa reported for Lake Edward in publications from the Damas` Mission (Conrad 1949a-c, Frémy 1949, Hustedt 1949, Pascher 1949a-b) and Hecky & Kling (1987) together with our unpublished data from the HIPE project (2016-2018) is provided below **(Table 1)**.

Table 1. Checklist of algae from Lake Edward. Abbreviations: **TTE-P** – Toxin or toxic effect (potential); **MD** – Mission Damas (1935-1936); **Ph** – phytoplankton samples, **Bn** – benthic/periphytic samples (Aufwuchs); **Ql** - qualitative samples, **Kz** – Kazinga Channel, **KB** – Katakuru-Bach, **HcKL** – Hecky & Kling (1987), **HIPE** – cruises 2016-2018; **ab** – "abondant"=abundant (as "m – massenhaft" in Hustedt 1949); **aab** – "assez abondant"=quite abundant; **c** – common; **dom** – dominant; **ec** –"extrêmement commun partout dans le plancton"=extremely common everywhere in the plankton; **f** – frequent (as "assez commun"=pretty common in Conrad 1949b and "h - häufig" in Hustedt 1949); **pab** – "peu abundant"=scarce; **r** – rare (as "s - selten" in Hustedt 1949); **rp** – "répandu partout"=spread everywhere; **sh** – "sehr häufig"=very frequent; **ss** – "sehr selten"=very rare (also as sv – "sehr vereinzelt"=very isolated in Pascher 1949b); **tab** - "très abondant"=very abundant; **tpa** – "très peu abondant"=very scanty; **trp** – "très répandu partout"=widely spread everywhere; **upp** – "un peu partout"=pretty much everywhere; **x** – occurring ("+ - vorhanden" in Hustedt 1949), without information on abundance or frequency of occurrence. For HIPE samples additionally in brackets the real number of samples in which given species was found is indicated (**numbers from 1 to 29**). For toxins (column TTE-P) the abbreviations are: **Antx-a** – Anataxoxin a, **CYN** – Cylndrospermopsin, **MCs** – Microcystins, **?** – toxins known from other species (or from unidentified species) of the same genus, or species was pointed in field samples, where toxins have been identified.

Taxon/Mission and sample type/Potential toxicity	**1935-1936**					**1972**	**2016-2018**	
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	**HcKl**	**HIPE**	**TTE-P**
CYANOPROKARYOTA								
Anabaena sp.	tab		pab					MCs, Antx-a, ?CYN
Anabaenopsis circularis (G. S. West) Woloszynska & V. Miller in V. Miller 1923	pab						r (4), x, ab	?
Anabaenopsis cunningtonii W. R. Taylor 1932							ss (1)	?
Anabaenopsis doliiformis Noda 1936							ss (1)	?

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Anabaenopsis elenkinii V. V. Miller 1923							ss (1)	?
Anabaenopsis tanganyikae (G. S. West) Woloszynska & V. V. Miller in Miller 1923	pab						ss (2)	?
Anabaenopsis sp.							ss (1)	?
Anagnostidinema amphibium (C. Agardh ex Gomont) Strunecký, Bohunická, J. R. Johansen & J. Komárek 2017 (Syn. *Oscillatoria amphibia* C. Agardh ex Gomont 1892)			aab					SXTs
Anathece bachmannii (Komárek & Cronberg) Komárek, Kastovsky & Jezberová 2011							ss (1)	
Anathece cf. *clathrata* (West & G. S. West) Komárek, Kastovsky & Jezberová 2011							ss (2)	
Anathece minutissima (West) Komárek, Kastovsky & Jezberová 2011 (Syn. *Microcystis minutissima* West 1912)	pab						ss (2)	?
Anathece smithii (Komárková-Legnerová & Cronberg) Komárek, Kastovsky & Jezberová 2011							ss (2)	?
Aphanizomenon/*Anabaena* sp.							ss (1)	
cf. *Aphanizomenon manguinii* Bourrelly in Bourrelly & Manguin 1952							ss (1)	?
Aphanocapsa cf. *delicatissima* West & G. S. West 1912							ss (1)	
Aphanocapsa holsatica (Lemmermann) G. Cronberg & Komárek 1994 (Syn. *Microcystis holsatica* (Lemmermann) Lemmermann 1907)	tpa						ss (2)	?
Aphanocapsa incerta (Lemmermann) G. Cronberg & Komárek 1994 (Syn. *Microcystis incerta* (Lemmermann) Lemmermann 1903)	pab, tpa					dom	ss (1)	?
Aphanocapsa koordersii K. M. Strøm 1923							c (12)	
Aphanocapsa cf. *nubila* Komárek & H. J. Kling 1991							ss (3), x. ab	
Aphanothece elabens (Brébisson ex Meneghini) Elenkin 1938 (Syn. *Microcystis elabens* (Brébisson) Kützing 1846)	pab						ss (1)	?
Aphanothece hegewaldii Kovácik 1988							ss (1)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Aphanothece nidulans P.Richter in Wittrock & Nordstedt 1884							ss (3)	
cf. *Borzia trilocularis* Cohn ex Gomont 1892							ss (1)	
Calothrix castellii Bornet & Flahault 1886			tab					
Calothrix fusca Bornet & Flahault 1886	pab							
Calothrix epiphytica West & G. S. West 1897	aab							
Chamaesiphon incrustans Grunow in Rabenhorst 1865			pab					
Chroococcidiopsis cf. *cubana* Komárek & Hindák 1975							ss (1)	
Chroococcus dispersus (Keissler) Lemmermann 1904							ss (3)	
Chroococcus cf. *distans* (G. M. Smith) Komarkova-Legnerova et Cronberg 1994							ss (1)	
Chroococcus globosus (Elenkin) Hindák 1978 (cf)							ss (1)	
Chroococcus goetzei Schmidle 1902			aab					
Chroococcus cf. *minimus* (Keissler) Lemmermann 1904							ss (1)	
Chroococcus minor (Kützing) Nägeli 1849							ss (1)	
Chroococcus minutus (Kützing) Nägeli 1849			pab					
Chroococcus cf. *planctonicus* Bethge 1935							ss (2)	
Chroococcus spp.						dom	r (4)	
Coelomoron pusillum (Van Goor) Komárek 1988							ss (3)	
Coelomoron sp.							ss (2)	
Coelosphaerium confertum West & G. S. West 1896							ss (2)	
Coelosphaerium kuetzingianum Nägeli 1849							ss (2)	
Cyanocatena imperfecta (Cronberg & Weibull) Joosten 2006							ss (1)	
Cyanodictyon endophyticum Pascher 1914							ss (1)	
Cyanodictyon filiforme J. Komárková-Legnerová & G. Cronberg 1994							ss (1)	
Cyanodictyon reticulatum (Lemmermann) Geitler 1925							ss (2)	

Taxon/Mission and sample type/Potential toxicity	**1935-1936**					**1972**	**2016-2018**	
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	**HcKl**	**HIPE**	**TTE-P**
Cyanotetras crucigenielloides Komárek 1995							ss (1)	
Cyanothece sp. (?*Synechococcus* sp.)							ss (1)	?
Cylindrospermopsis africana J. Komárek & H. Kling 1991 (?*Raphidiopsis africana*)							ss (1)	?
Cylindrospermopsis allantoidispora Komárková in Azevedo 1998, nom. inval. (?*Raphidiopsis allantoidispora*); noted as *Cylindrospermopsis* sp. in Hecky & Kling (1987)						x (?Fig. 10, App. 3)	ss (2)	?
Cylindrospermopsis gangetica (G. U. Nair) Komárek 2012 (?*Raphidiopsis gangetica*)							c (12), x, ab	?
Dolichospermum circinale (Rabenhorst ex Bornet & Flahault) P. Wacklin, L. Hoffmann & J. Komárek 2009 (Syn. *Anabaena circinalis* Rabenhorst ex Bornet & Flahault 1886)	pab, aab							Antx-a, MCs, STXs
Dolichospermum flosaquae (Brébisson ex Bornet & Flahault) P. Wacklin, L. Hoffmann & J. Komárek 2009 (Syn. *Anabaena flos-aquae* Brébisson ex Bornet & Flauhault 1886)	pab, tpa		pab					Antx-a
Dolichospermum spiroides (Klebhan) Wacklin, L. Hoffmann & Komárek 2009 (Syn. *Anabaena spiroides* Klebahn 1895)	pab, aab							Antx-a
Eucapsis aphanocapsoides (Skuja) Komárek & Hindák in Komárek et al. 2016							ss (2)	
Eucapsis cf. *microscopica* (Komárková-Legnerová & G. Cronberg) Komárek & Hindák in Komárek et al. 2016							ss (2)	
Glaucospira laxissima (G. S. West) Simic, Komárek & Dordevic 2014 (Syn. *Spirulina laxissima* G. S. West 1907)	pab						ss (3)	
Gloeothece hindakii Stoyneva, Gärtner & Vyverman 2009							r (4)	
Gloeotrichia longiarticulata G. S. West 1907	pab		pab					?
Gloeotrichia sp. (ad *Gloeotrichia natans* Rabenhorst ex Bornet & Flahault 1886)	pab							?MCs
cf. *Gomphosphaeria natans* Komárek & Hindák 1988							ss (1)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Heteroleibleinia kuetzingii (Schmidle) Compère 1985 (Syn. *Lyngbya kuetzingii* Schmidle 1897)			pab					x
Hormoscilla pringsheimii Anagnostidis & Komárek 1988							ss (1)	
Kamptonema cortianum (Meneghini ex Gomont) Strunecký, Komárek & J. Smarda 2014 (Syn. *Oscillatoria cortiana* Meneghini ex Gomont 1892)			pab					?
Lemmermanniella sp. (ad *Lemmermanniella pallida* (Lemmermann) Geitler 1942)							ss (2)	
Leptolyngbya perelegans (Lemmermann) Anagnostidis & Komárek 1988							ss (1)	?
Leptolyngbya subtilis (West) Anagnostidis 2001							ss (1)	?
Leptolyngbya tenuis (Gomont) Anagnostidis & Komárek 1988 (Syn. *Phormidium tenue* Gomont 1892)			ab					Neuro-toxicity on mouse; ?MCs
Leptolyngbya sp.							ss (1)	?MCs
Limnococcus limneticus (Lemmermann) Komárková, Jezberová, O. Komárek & Zapomelová 2010						x	ss (2)	
Limnolyngbya circumcreta (G. S. West) X. Li & R. Li 2016 (Syn. *Lyngbya circumcreta* G. S. West 1907)	tpa, pab					x	r (5)	
Limnolyngbya spp. (ad *L. circumcreta* (G. S. West) X. Li & R. Li 2016)	tpa						ss (2)	
Leibleinia epiphytica (Hieronymus) Compère 1985 (Syn. *Lyngbya epiphytica* Hieronymus in O. Kirchner 1898)	pab							?MCs
Merismopedia elegans A.Braun ex Kützing 1849	pab							?MCs
Merismopedia glauca (Ehrenberg) Kützing 1845 (Syn. *Merismopedia aeruginea* Brébisson in Kützing 1849)							ss (1)	?MCs
Merismopedia hyalina (Ehrenberg) Kützing 1845							ss (1)	?MCs
Merismopedia tenuissima Lemmermann 1898	pab, tpa						ss (1)	?MCs

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Merismopedia tranquilla (Ehrenberg) Trevisan 1845 (Syn. *Merismopedia punctata* Meyen 1839 nom. illeg.)	tpa, pab						r (6)	?MCs
Merismopedia warmingiana (Lagerheim) Forti 1907							r (7)	?MCs
Merismopedia spp.						dom		?MCs
Microseira wollei (Farlow ex Gomont) G. B. McGregor & Sendall ex Kenins 2017 (Syn. *Plectonema wollei* Farlow ex Gomont 1892)	aab							CYN, dexy-CYN, SXTs
Microcrocis obvoluta (Tiffany) T. H. Frank & A. G. Landman 1988, nom. inval.							ss (1)	
Microcystis aeruginosa (Kützing) Kützing 1846	tab, tpa, pab, aab, ab						r (6)	MCs, Antx-a
Microcystis firma (Kützing) Schmidle 1902	tpa						ss (2)	?MCs
Microcystis flos-aquae (Wittrock) Kirchner 1898	tpa, pab, tab, aab, ab		tpa, pab, ab	pab, ab			ss (1)	MCs
Microcystis ichtyoblabe (G. Kunze) Kützing 1843	aab, pab, tpa		tpa	pab				MCs
Microcystis novacekii (Komárek) Compère 1974							ss (2)	MCs
Microcystis prasina (Wittrock) Lemmermann 1904	pab		pab				ss (1)	?MCs
Microcystis pulverea (H. C. Wood) Forti 1907							ss (1)	?MCs
Microcystis robusta (H. W. Clark) Nygaard in Ostenfeld & Nygaard 1925			pab					?MCs
Microcystis wesenbergii (Komárek) Komárek ex Komárek in Joosen 2006						dom	r(7), x, ab	MCs
Microcystis spp. (separate cells)							ss (3)	?MCs
Myxobaktron sp.							ss (3)	
Oscillatoria planctonica Woloszynska 1912	pab							?
Oscillatoria tenuis C. Agardh ex Gomont 1892			aab					?

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Pannus cf. *planus* Hindák 1993							ss (2)	
Pannus punctiferus (Komárek & Komárková-Legnerová) Joosten 2006							ss (1)	
Phormidium diguetii (Gomont) Anagnostidis & Komárek 1988 (Syn. *Lyngbya diguetii* Gomont in Hariot 1895 as "*Digueti*")	pab		ab					?
Planktolyngbya bipunctata (Lemmermann) Anagnostidis & Komárek 1988 (Syn. *Lyngbya bipunctata* Lemmermann 1899)	aab						r (4)	
Planktolyngbya contorta (Lemmermann) Anagnostidis & Komárek 1988 (Syn. *Lyngbya contorta* Lemmermann 1898)	pab, tpa		pab				r (9), x, ab	
Planktolyngbya sp. (ad *P. contorta* (Lemmermann) Anagnostidis & Komárek 1988)							r (4)	
Planktolyngbya limnetica (Lemmermann) Komárková-Legnerová & Cronberg 1992 (Syn. *Lyngbya limnetica* Lemmermann 1898)	aab, pab						r (7)	
Planktolyngbya microspira Komárek & Cronberg 2001							c (10)	
Planktolyngbya cf. *regularis* J. Komárková-Legnerová & Cronberg 1992							ss (1)	
Planktolyngbya tallingii Komárek & H. Kling 1991							c (13), x, ab	
Planktolyngbya spp.							r (5)	
Potamolinea aerugineo-caerulea (Gomont) M. D. Martins & L. H. Z. Branco 2016 (Syn. *Lyngbya aerugineo-caerulea* Gomont 1892)			aab, tpa					Neuro- and hepatooxicity
Pseudanabaena galeata Böcher 1949							ss (1)	
Pseudanabaena limnetica (Lemmermann) Komárek 1974 (Syn. *Oscillatoria limnetica* Lemmermann 1900)	x						ss (1)	Antx-a, MCs
Pseudanabaena moniliformis Komárek & Kling 1991							ss (1)	
Pseudanabaena mucicola (Naumann & Huber-Pestalozzi) Schwabe 1964 (Syn. *Phormidium mucicola* Nauman & Huber-Pestalozzi in Huber-Pestalozzi & Nauman 1929)	aab						r (6), x, ab	? (associated with toxin-producers)

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Pseudanabaena cf. *recta* Komárek & Cronberg 2000							ss (1)	?
Pseudanabaena sp. (? *Phormidium* sp.)							ss (1)	?
Radiocystis geminata Skuja 1948						x	ss (1)	?
Raphidiopsis catemaco (Komáreková-Legnerová & Tavera) Aguilera, Berrendero Gómez, Kastovsky, Echenique & Salerno 2018							ss (1)	?
Raphidiopsis helicoidea (Cronberg & Komárek) Aguilera, Berrendero Gómez, Kastovsky, Echenique & Salerno 2018 (as *Cylindrospermopsis* sp. in Hecky & Kling 1987)						x (?Fig. 12, App. 3)	ss (3)	?
Raphidiopsis philippinensis (W.R.Taylor) Aguilera, Berrendero Gómez, Kastovsky, Echenique & Salerno 2018							r (5), x, ab	?
Raphidiopsis raciborskii (Woloszynska) Aguilera, Berrendero Gómez, Kastovsky, Echenique & Salerno 2018							ss (2)	CYN, CYN-like, dexy-CYN, Hepatotoxic, SXTs
Raphidiopsis setigera (Aptekar) Eberly 1966							ss (1)	
Rhabdoderma lineare Schmidle & Lauterborn in Schmidle 1900							ss (2)	
Romeria gracilis (Koczwara) Koczwara in Geitler 1932							ss (1)	
Romeria okensis (C. Meyer) Hindák 1975							c (11)	
Romeria simplex (Hindák) Hindák 1988							r (6)	
Snowella atomus Komárek & Hindák 1988							ss (1)	
Snowella littoralis (Häyrén) Komárek & Hindák 1988							ss (1)	
Sphaerocavum microcystiforme (Hindák) Azevedo & Sant' Anna 2003 (Syn. *Pannus microcystiformis* Hindák 1993)							ss (3)	
Synechococcus endogloeicus Hindák 1996							ss (1)	?
Synechococcus nidulans (Pringsheim) Komárek in Bourrelly 1970							ss (3), x, ab	?
Synechocystis aquatilis Sauvageau 1892						x		

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HeKl	HIPE	TTE-P
Synechocystis endobiotica (Elenkin & Hollerbach) Elenkin 1938							r (4)	
Synechocystis salina Wislouch 1924						x		
Woronichinia microcystoides (Komárek) Joosten 2006							ss (1)	?
Woronichinia sp.							ss (1)	?
Xenotholos kerneri (Hansgirg) M. Gold-Morgan, G. Montejano & J. Komárek 1994 (Syn. *Xenococcus kerneri* Hansgirg 1887)			aab					
EUGLENOPHYTA								
Anisonema ovale G. A. Klebs 1892			x					
Euglena pisciformis Klebs 1883			x					
Euglena sp.	x		x				ss (1)	
Petalomonas angusta (Klebs) Lemmermann 1910			x					
Petalomonas angusta var. *pusilla* (Klebs) Lemmermann 1910			x					
Phacus sp. (? nov. sp.)			x					
Trachelomonas impressa Pascher 1949			x					
Trachelomonas volvocina (Ehrenberg) Ehrenberg 1834			x					
PYRRHOPHYTA								
Cystodinium hyalinum Pascher 1944			ss					
Parvodinium africanum (Lemmermann) Carty 2008							ss (1)	
Peridinium sp. (?*Peridiniopsis* sp.)							ss (1)	
Peridiniopsis sp.							ss (1)	
Woloszynskia sp.							ss (1)	
CRYPTOPHYTA								
Cryptomonas sp.						x		
OCHROPHYTA								
Tribophyceae								
Botrydiopsis arhiza Borzi 1895	x							
Botrydiopsis sp.	upp							
Chloridella neglecta (Pascher & Geitler) Pascher 1932			upp					
Gloeobotrys limneticus (G. M. Smith) Pascher 1938			x					

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Goniochloris mutica (A. Braun) Fott 1960 (Syn. *Tetraëdron muticum* (A. Braun) Hansgirg 1888 as "*mutica*")	r, f							
Goniochloris pulchra Pascher 1938							r (4)	
Characiopsis tuba (Hermann) Lemmermann 1914			r					
Monodus chodatii Pascher 1925			x					
Ophiocytium parvulum (Perty) A. Braun 1855	x							
Pleurochloris pyrenoidosa Pascher 1938			x					
Tetraplektron torsum (W. B. Turner) Dedusenko-Shchegoleva in Dedusenko-Shchegoleva & Gollerbach 1962							ss (1)	
Chrysophyceae								
Derepyxis sp.			x					
Lagynion vasicola Pascher 1949			x					
Stokesiella sp.			x					
Synurophyceae								
Mallomonas sp.			x					
Bacillariophyceae								
Achnanthes congolensis Hustedt 1949 (Syn. *Achnanthes atomus* var. *congolensis* Hustedt 1949)		ss						
Achnanthes exigua Grunow 1880 (Syn. *Achnanthes exigua* var. *constricta* (Grunow) Hustedt 1921)		x						
Achnanthes inflata (Kützing) Grunow 1868		x						
Achnanthes simplex Hustedt 1936	ss							
Achnanthidium lineare W. Smith 1855							r (5)	
Achnanthidium minutissimum (Kützing) Czarnecki 1994							ss (1)	
Achnanthidium subhudsonis (Hustedt) H. Kobayasi in Kobayashi et al. 2006 (Syn. *Achnanthes subhudsonis* Hustedt 1921)	x	x						
Afrocymbella beccarii (Grunow) Krammer 2003 (Syn. *Gomphocymbella beccari* (Grunow) Forti 1910)	x, f	x, f		x				
Amphora copulata (Kützing) Schoeman & R. E. M. Archibald 1986							ss (1)	
Amphora ovalis (Kützing) Kützing 1844	x	x		x	x			

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Amphora pediculus (Kützing) Grunow ex A. Schmidt 1875 (Syn. *Amphora ovalis* var. *pediculus* Kützing 1844)	x	x		x	x			
Aneumastus tuscula (Ehrenberg) D. G. Mann & A. J. Stickle in Round, R. M. Crawford & D. G. Mann 1990 (Syn. *Navicula tuscula* Ehrenberg 1840)	ss							
"*Anomoeneis serians* var. *brachysira* (Brébisson) van Heurck"	x							
Anomoeneis sphaerophora Pfitzer 1871	x	x		x				
Anomoeneis sphaerophora var. *guntheri* O. Müller	x							
Asterionella formosa Hassall 1850	x	x						
Aulacoseira agassizii (Ostenfeld) Simonsen 1979 (Syn. *Melosira agassizii* Ostenfeld 1909)					r			
Aulacoseira ambigua (Grunow) Simonsen 1979 (Syn. *Melosira ambigua* (Grunow) O. Müller 1903)	x, f	x						
Aulacoseira granulata (Ehrenberg) Simonsen 1979 (Syn. *Melosira granulata* (Ehrenberg) Ralfs in Pritchard 1861)	x, r				x			
Aulacoseira granulata var. *angustissima* (O.Müller) Simonsen 1979 (Syn. *Melosira granulata* var. *angustissima* O. Müller 1899)	x			x			c (19)	
Aulacoseira italica (Ehrenberg) Simonsen 1979 (Syn. *Melosira italica* (Ehrenberg) Kützing 1844)	x	x		f				
Belonastrum berolinense (Lemmermann) Round & Maidana 2001							ss (2)	
Caloneis amphisbaena (Bory) Cleve 1894	r							
Caloneis bacillum (Grunow) Cleve 1894	x	x			x		r (4)	
Caloneis incognita Hustedt 1911		x						
Caloneis inflata (Hustedt) Metzeltin & Lange-Bertalot 2007 (Syn. *Caloneis bacilum* f. *inflata* Hustedt 1949)	x	x					ss (1)	
Caloneis clevei (Lagerstedt) Cleve 1894	x	x						
Caloneis incognita Hustedt 1911		x						
Caloneis silicula (Ehrenberg) Cleve 1894	x			x				
Caloneis sp.							ss (2)	

Taxon/Mission and sample type/Potential toxicity	**1935-1936**					**1972**	**2016-2018**	
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	**HcKl**	**HIPE**	**TTE-P**
Cavinula scutelloides (W. Smith) Lange-Bertalot in Lange-Bertalot & Metzeltin 1996 (Syn. *Navicula scutelloides* W. Smith 1856)					x			
Cocconeis pediculus Ehrenberg 1838							ss (2)	
Cocconeis placentula Ehrenberg 1838	x, f	x, f		x	x		ss (2)	
Cocconeis placentula var. *euglypta* (Ehrenberg) Grunow 1884 as *Cocconeis placentula* var. *euglypta* (Ehrenberg) Cleve (1895)	x	x		x				
"*Coscinodiscus rothi* var. *subsalsa* (Juhl.-Dannf.) Hustedt"	ss							
Craticula ambigua (Ehrenberg) D. G. Mann in Round, R. M. Crawford & D. G. Mann 1990 (Syn. *Navicula cuspidata* var. *ambigua* (Ehrenberg) Kirchner 1878)	x	x						
Craticula cuspidata (Kutzing) D. G. Mann in Round, R. M. Crawford & D. G. Mann 1990 (Syn. *Navicula cuspidata* (Kutzing) Kutzing 1844)		x						
Craticula molestiformis (Hustedt) Mayama 1999 (Syn. *Navicula molestiformis* Hustedt 1949)	x							
Cyclostephanos damasii (Hustedt) Stoermer & Håkansson in Theriot, Håkansson, Kociolek, Round & Stoermer 1988 (Syn. *Stephanodiscus damasi* Hustedt 1949)	x, f, sh	x					c (22), x, ab	
Cyclotella atomus Hustedt 1937							ss (1)	
Cyclotella meneghiniana Kützing 1844	x						ss (1)	
Cymbella affinis Kützing 1844					x		ss (1)	
Cymbella lanceolata (C. Agardh) C. Agardh 1830	x							
Cymbopleura inaequalis (Ehrenberg) Krammer 2003 (Syn. *Cymbella cuspidata* Kützing 1844)	ss							
Cymbella parva (W. Smith) Kirchner 1878	ss							
Cymbella tumida (Brébisson) Van Heurck 1880	r	r						
Cymbopleura stauroneiformis (Lagerstedt) Krammer 2003 (Syn. *Cymbella stauroneiformis* Lagerstedt 1873)	ss						ss (1)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Encyonema elginense (Krammer) D. G. Mann in Round, R. M. Crawford & D. G. Mann 1990 (Syn. *Cymbella turgida* (Gregory) Cleve)	x	x			x			
Denticula tenuis Kützing 1844 as "*Denticulus*"	r							
Diadesmis confervacea Kützing 1844 (Syn. *Navicula confervacea* (Kützing) Grunow in Van Heurck 1880)		x		x	x			
Diadesmis contenta var. *biceps* (Grunow) P. B. Hamilton in Hamilton et al. 1992 (Syn. *Navicula contenta* f. *biceps* Arnott ex Hustedt 1930)		x						
Diadesmis contenta var. *parallela* (J.B. Petersen) Spaulding in Spaulding et al. 1997 (Syn. *Navicula contenta* f. *parallela* (J.B.Petersen) Hustedt 1930)	x	x						
Diatoma problematica Lange-Bertalot 1993							ss (1)	
Diatoma tenue var. *elongatum* Lyngbye 1819 (Syn. *Diatoma elongatum* (Lyngbye) C. A. Agardh 1824)		ss						
Diatoma vulgaris Bory 1824 as "*vulgare*"	r	ss			x			
Dickieia danseii Thwaites 1848 (Syn. *Mastogloia elliptica* var. *dansei* (Thwaites) Cleve 1895)	x	x		x				
Didymosphenia geminata (Lyngbye) M. Schmidt in A. Schmidt 1899							ss (1)	
Diploneis elliptica (Kützing) Cleve 1894	x							
Diploneis ovalis (Hilse) Cleve 1891	x							
Diploneis subovalis Cleve 1894	x				x			
Discostella stelligera (Cleve & Grunow) Houk & Klee 2004 (Syn. *Cyclotella stelligera* (Cleve & Grunow) Van Heurck 1882)	x	x						
Dorofeyukea grimmei (Krasske) Kulikovskiy & Kociolek in Kulikovskiy et al. 2019 (Syn. *Navicula grimmei* Krasske in Hustedt 1930)	x	x		x				
Encyonema caespitosum Kützing 1849							ss (2)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Encyonema grossestriatum (O. Müller) D. G. Mann in Round, Crawford & Mann 1990 (Syn. *Cymbella grossestriata* O. Müller 1905)	r							
Encyonema muelleri (Hustedt) D. G. Mann in Round, R. M. Crawford & D. G. Mann 1990 (Syn. *Cymbella mülleri* Hustedt 1937)	x, f	x, ab		x				
Encyonema silesiacum (Bleisch) D. G. Mann in Round, R. M. Crawford & D. G. Mann 1990							ss (2)	
Encyonopsis microcephala (Grunow) Krammer 1997							ss (1)	
Encyonopsis subminuta Krammer & Reichart in Krammer 1997							ss (2)	
Epithemia adnata (Kützing) Brébisson 1838 (Syn. *Epithemia zebra* (Ehrenberg) Kützing 1844)	x	x		x				
Epithemia adnata var. *saxonica* (Kützing) R. M. Patrick in R. M. Patrick & Reimer 1975 (Syn. *Epithemia zebra* var. *saxonica* (Kützing) Grunow 1862)	x							
Epithemia argus (Ehrenberg) Kützing 1844	x							
Epithemia cistula (Ehrenberg) Ralfs in Pritchard 1861	x							
Epithemia gibba (Ehrenberg) Kützing 1844 (Syn. *Rhopalodia gibba* (Ehrenberg) O. Müller 1895)	x, f	x		x				
Epithemia porcellus Kützing 1844 (Syn. *Epithemia zebra* var. *porcellus* (Kützing) Grunow 1862)	x	x			x			
Epithemia operculata (C. Agardh) Ruck & Nakov in Ruck et al. 2016 (Syn. *Cyclotella operculata* (C. Agardh) Brébisson 1838)		ss						
Epithemia sorex Kützing 1844	x, f	x						
Epithemia turgida (Ehrenberg) Kützing 1844	ss							
Epithemia vermicularis (O. Müller) Cocqyut & R. Jahn in Cocquyt et al. 2018 (Syn. *Rhopalodia vermicularis* O. Müller 1895)	x, f	sh						
Eunotia epithemioides Hustedt in A. W. F. Schmidt 1913, nom. inval.		x						

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Eunotia lunaris (Ehrenberg) Grunow 1877	x, f	x						
Eunotia pectinalis (Kützing) Rabenhorst 1864		x						
Eunotia pectinalis var. *ventricosa* (Ehrenberg) Grunow in Van Heurck 1881 (Syn. *Eunotia pectinalis* var. *ventralis* (Ehrenberg) Hustedt 1911)	x			x				
Fragilaria capucina Desmazières 1830							ss (2)	
Fragilaria fragilarioides (Grunow) Cholnoky 1963 (Syn. *Synedra rumpens* var. *fragilarioides* Grunow in Van Heurck 1881)	x	x						
Fragilaria cf. *pectinalis* (O. Müller) Lyngbye 1819							ss (1)	
Frustulia rhomboides (Ehrenberg) De Toni 1891		x						
Frustulia saxonica Rabenhorst 1853 (Syn. *Frustulia rhomboides* var. *saxonica* (Rabenhorst) De Toni 1891)	x							
Frustulia vulgaris (Thwaites) De Toni 1891	x							
Gomphoneis clevei (Fricke) Gil 1989 (Syn. *Gomphonema clevei* Fricke in A. W. F. Schimidt 1902)	x	x		x				
Gomphonema aequatoriale Hustedt 1949	x	x						
Gomphonema africanum G. S. West 1907	x	x						
Gomphonema gracile Ehrenberg 1838	x							
Gomphonema intricatum Kützing 1844					x			
Gomphonema lateripunctatum E. Reichardt & Lange-Bertalot 1991							ss (2)	
Gomphonema grunowii R. M. Patrick & Reimer 1975 (Syn. *Gomphonema lanceolatum* Ehrenberg 1843)	x	x						
Gomphonema insigne W. Gregory 1856 (Syn. *Gomphonema lanceolatum* var. *insigne* (W. Gregory) Cleve 1894 as "*insignis*")	x							
Gomphonema minutum (C. Agardh) C. Agardh 1831							ss (2)	
Gomphonema minusculum Cleve-Euler 1949, nom. illeg.							ss (3)	
Gomphonema olivaceum (Hornemann) Brébisson 1838							ss (1)	

Taxon/Mission and sample type/Potential toxicity	**1935-1936**					**1972**	**2016-2018**	
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	**HcKl**	**HIPE**	**TTE-P**
Gomphonema parvulum (Kützing) Kützing 1849 as "*Gomphonema parvulum* (Kützing) Grunow"	x	x, f						
"*Gomphonema parvulum* var. *lagenula* (Grunow) Hustedt" (? *Gomphonema lagenula* Kützing 1844)		x			x			
Gomphonema pumilum (Grunow) E. Reichardt & Lange-Bertalot 1991 (Syn. *Gomphonema intricatum* var. *pumila* A. Cleve 1932)	x	x					ss (1)	
Gomphonema subclavatum (Grunow) Grunow 1884 (Syn. *Gomphonema longiceps* var. *subclavatum* (Grunow) Hustedt 1930, nom. illeg. as "*subclavata*")		x						
Gomphonitzschia ungeri Grunow 1868	x	x						
Grunowia solgensis (A. Cleve) Aboal in Aboal et al. 2003 (Syn. *Nitzschia interrupta* (Reichelt) Hustedt 1927)	s							
Gyrosigma sciotoense (W. S. Sullivant) Cleve 1895 (Syn. *Gyrosigma spenceri* var. *nodiferum* (Grunow) Cleve 1894 as "*nodifera*")	x	x						
Halamphora montana (Krasske) Levkov 2009 (Syn. *Amphora montana* Krasske 1932)		x						
Halamphora submontana (Hustedt) Levkov 2009 (Syn. *Amphora submontana* Hustedt 1949)		ss						
Halamphora veneta (Kützing) Levkov 2009 (Syn. *Amphora veneta* Kützing 1844)	x							
Hannaea arcus (Ehrenberg) R. M. Patrick in R. M. Patrick & C. W. Reimer 1966 (Syn. *Ceratoneis arcus* (Ehrenberg) Kützing 1844)	ss	ss						
Hantzschia amphioxys (Ehrenberg) Grunow in Cleve & Grunow 1880	x	x		x	x			
Hantzschia distincte-punctata Hustedt in Schmidt et al. 1921	r							
Hippodonta hungarica (Grunow) Lange-Bertalot, Metzeltin & Witkowski 1996 (Syn. *Navicula hungarica* Grunow 1860)	x			x			ss (1)	
Humidophila contenta (Grunow) Lowe, Kociolek, J. R. Johansen, Van de Vijver, Lange-Bertalot & Kopalová							ss (1)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Iconella engleri (O. Müller) C. Cocquyt & R. Jahn in Jahn, Kusber & Cocquyt 2017 (Syn. *Surirella engleri* O. Müller 1904)	x, f, ab, sh	o		sh			r (7)	
Iconella tenera (W. Gregory) Ruck & Nakov in Ruck et al. 2016 (Syn. *Surirella tenera* W. Gregory 1856)	ss	ss						
Lemnicola exigua (Grunow) Kulikovskiy, Witkowski & Plinski in Plinski & Witkowski 2011 (Syn. *Achnanthes exigua* Grunow 1880)	x	x						
Lemnicola hungarica (Grunow) Round & Basson 1997 (Syn. *Achnanthes hungarica* (Grunow) Grunow 1880)	x			x				
Lindavia comta (Kützing) Nakov, Gullory, Julius, Theriot & Alverson 2015 (Syn. *Cyclotella comta* Kützing 1849)	x	x		x	x			
Luticola cohnii (Hilse) D. G. Mann in Round, R. M. Crawford & D. G. Mann 1990 (Syn. *Navicula mutica* f. *cohnii* (Hilse) Cleve 1894)	x							
Luticola lagerheimii (Cleve) D. G. Mann in Round, R. M. Crawford & D. G. Mann 1990 (Syn. *Navicula lagerheimii* Cleve 1894)		x		x				
Luticola mutica (Kützing) D. G. Mann in Round, R. M. Crawford & D. G. Mann 1990 (Syn. *Navicula mutica* Kützing 1844)	x	x		x				
Luticola terminata (Hustedt) J. R. Johansen in J. R. Johansen et al. 2004 (Syn. *Navicula mutica* var. *tropica* Hustedt 1937)		x						
Mastogloia elliptica (C. Agardh) Cleve in A. W. F. Schmidt 1893	r							
Meridion circulare (Greville) C. Agardh 1831	ss							
Navicula bacilliformis Grunow in Cleve & Grunow 1880				x				
Navicula barbarica Hustedt 1949		x, f						
Navicula capitatoradiata H. Germain ex Gasse 1986 *(Syn. Navicula cryptocephala* var. *intermedia* Grunow in Van Heurck 1880)	x	x					r (7)	
Navicula cari Ehrenberg 1836 (Syn. *Navicula graciloides* A.Mayer 1919)					x			

Taxon/Mission and sample type/Potential toxicity	**1935-1936**					**1972**	**2016-2018**	
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	**HcKl**	**HIPE**	**TTE-P**
Navicula cincta (Ehrenberg) Ralfs in Pritchard 1861					x			
Navicula cryptocephala Kützing 1844	x	x		x	x		ss (1)	
Navicula cuspidata var. *ambiqua* f. *subcapitata* O. Müller 1899	x							
"*Navicula exigua* (Greg.) O. Müller"	x							
Navicula exiguiformis f. *elliptica* Hustedt 1949	x	x						
Navicula finitima Hustedt 1949 non *N. finitima* Janisch 1888					x			
Navicula mereschkowskyi O. Müller	r							
Navicula minima Grunow in Van Heurck 1880 (Syn. *Navicula minima* var. *atomoides* (Grunow) Cleve 1894)		x						
Navicula oblonga (Kützing) Kützing 1844	ss							
Navicula radiosa Kützing 1844	x	x						
Navicula rostellata Kützing 1844 (Syn. *Navicula viridula* var. *rostellata* (Kützing) Cleve 1895)		x			x			
Navicula rhynchocephala Kützing 1844	x				x			
Navicula schroeteri F. Meister 1932	x							
Navicula seminuloides var. *sumatrensis* Hustedt 1937	x							
Navicula cf. *simplex* Krasske 1925	x						ss (1)	
Navicula subcontenta var. africana Hustedt 1949				x				
Navicula subrhynchocephala Hustedt 1935	x	x						
Navicula tripunctata (O. F. Müller) Bory in Bory de Saint-Vincent 1822 (Syn. *Navicula gracilis* Ehrenberg 1832)	x				x			
Navicula truncata Kützing 1844 (Syn. *Caloneis silicula* var. *truncata* Grunow as "*truncatula*" - ? Err. typogr.)	x							
Navicula vandamii Schoeman & R. E. M. Archibald 1987							ss (1)	
Navicula viridula (Kützing) Ehrenberg 1836	x	x						
Navicula zanoni Hustedt 1949	x							
Neidium affine (Ehrenberg) Pfitzer 1871		x						
Neidium affine var. *amphirhynchus* (Ehrenberg) Cleve 1894		x						

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HeKl	HIPE	TTE-P
Neidium productum (W. Smith) Cleve 1894		x						
Neidiomorpha binodis (Ehrenberg) M. Cantonati, Lange-Bertalot & N. Angeli 2010 (Syn. *Fragilaria construens* var. *binodis* (Ehrenberg) Grunow 1862)	x							
Nitzschia cf. *accommodata* Hustedt 1949							ss (1)	
Nitzschia acicularis (Kützing) W. Smith 1853	ss							
Nitzschia adapta Hustedt 1949	x, f	x, f						
Nitzschia aequalis Hustedt 1949	x							
Nitzschia amphibia Grunow 1862	x	x, f			x			
Nitzschia amphibia var. *pelagica* Hustedt 1949	x	f						
Nitzschia amphioxoides Hustedt 1949	x	x						
Nitzschia bacata Hustedt 1937	x	f					c (14)	
Nitzschia bacata f. *linearis* Hustedt 1949		x						
Nitzschia capitellata Hustedt in A. W. F. Schimidt 1922, nom. inval.	x						ss (1)	
Nitzschia communis Rabenhorst 1860	x							
Nitzschia congolensis Hustedt 1949	x, f							
Nitzschia consummata Hustedt	x, f	x						
Nitzschia dissipata (Kützing) Rabenhorst 1860	x						ss (1)	
Nitzschia epiphytica O. Müller 1905	x, f	x, ab						
Nitzschia epiphyticoides Hustedt 1949	x, f	x						
Nitzschia inconspicua Grunow 1862							ss (1)	
Nitzschia intermedia Hantzsch in Grunow 1880	x	x					ss (3)	
Nitzschia intermissa Hustedt 1949		x						
Nitzschia jugiformis Hustedt 1922	ss							
Nitzschia cf. *lacuum* Lange-Bertalot 1980 = *Nitzschia fonticola* (Grunow) Grunow in Van Heurck 1881 sensu Hustedt 1949	x, f, ab	x		sh			f (28), x, ab	
Nitzschia lancettula O. Müller 1905	x, f	x		f			c (11)	
Nitzschia linearis W. Smith 1853	x	x						
Nitzschia microcephala Grunow in Cleve & Grunow 1880	ss							
Nitzschia obsidialis Hustedt 1949		x						
Nitzschia obsoleta Hustedt 1949	x	ab						

Taxon/Mission and sample type/Potential toxicity	**1935-1936**					**1972**	**2016-2018**	
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	**HcKl**	**HIPE**	**TTE-P**
Nitzschia palea (Kützing) W. Smith 1856	x	x						
Nitzschia palea var. *tropica* Hustedt 1949	x	x						
Nitzschia perminuta Grunow in Van Heurck 1881	x							
Nitzschia recta Hantzsch ex Rabenhorst 1862	r						ss (1)	
Nitzschia spiculoides Hustedt 1949	x	x						
Nitzschia spiculum Hustedt 1949	x, f	x, f					f (26), x, ab	
Nitzschia stricta Hustedt 1949	x							
Nitzschia subacicularis Hustedt 1922, nom. inval.	x						ss (3)	
Nitzschia tarda Hustedt 1949	x, f							
"*Nitzschia thermalis* Kützing" (? *Nitzschia thermalis* (Ehrenberg) Auerswald in Rabenhorst 1861)	x							
Nitzschia thermalis var. *minor* Hilse 1862	x							
Nitzschia tropica Hustedt 1949				f			f (25), x, ab	
Nitzschia umbonata (Ehrenberg) Lange-Bertalot 1978 (Syn. *Nitzschia stagnorum* Rabenhorst 1860)		x						
Odontidium hyemale (Roth) Kützing 1844 (Syn. *Diatoma hyemalis* (Roth) Heiberg 1863 as "*hiemale*")	r							
Odontidium mesodon (Kützing) Kützing 1849 (Syn. *Diatoma hyemalis* var. *mesodon* (Ehrenberg) Kirchner 1878 as "*hiemale*")	ss							
Orthoseira roeseana (Rabenhorst) Pfitzer 1871 (Syn. *Melosira roeseana* Rabenhorst 1853)				ss				
Pantocsekiella comensis (Grunow) K. T. Kiss & E. Ács in Ács et al. 2016 (Syn. *Cyclotella comensis* Grunow in Van Heurck 1882)		ss			f			
Pantocsekiella ocellata (Pantocsek) K. T. Kiss & Ács in E. Ács et al. 2016 (Syn. *Cyclotella ocellata* Pantocsek 1901)	x							
Pinnularia acoricola Hustedt 1935	ss							
Pinnularia acrosphaeria W. Smith 1853		x		x				
Pinnularia borealis Ehrenberg 1843	x			x				

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Pinnularia brauniana (Grunow) Studnicka 1888 (Syn. *Pinnularia braunii* Cleve 1895)		x						
Pinnularia gibba (Ehrenberg) Ehrenberg 1843		x						
Pinnularia gibba var. *sancta* (Grunow ex Cleve) F. Meister 1932		x		x				
Pinnularia graciloides Hustedt 1937		x						
Pinnularia interrupta W. Smith 1853		x						
Pinnularia mesolepta (Ehrenberg) W. Smith 1853		x						
Pinnularia microstauron (Ehrenberg) Cleve 1891		x						
Pinnularia platycephala (Ehrenberg) Cleve 1891 (Syn. *Navicula platycephala* (Ehrenberg) Cleve & Müller 1882 as "*Navicula platycephala* O. Müller")	ss	ss						
Pinnularia stomatophora (Grunow) Cleve 1895		x						
Pinnularia subcapitata W. Gregory 1856	x	x						
Pinnularia viridis (Nitzsch) Ehrenberg 1843		x						
Placoneis exiguiformis (Hustedt) Lange-Bertalot in Metzeltin, Lange-Bertalot & García-Rodriguez 2005 (Syn. *Navicula exiguiformis* Hustedt 1944)	x, f	x, f					r (4)	
Placoneis gastrum (Ehrenberg) Mereschkowsky 1903 (Syn. *Navicula gastrum* (Ehrenberg) Kützing 1844)	x, f	x, f		x				
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot 1999 (Syn. *Achnanthes lanceolata* (Brébisson ex Kützing) Grunow 1880)	x			x				
Planothidium capitatum (O. Müller) Van de Vijver, Kopalová, C. E. Wetzel & Ector in Wetzel et al. 2014 (Syn. *Achnanthes lanceolata* var. *capitata* O. Müller 1909)	x							
Planothidium rostratoholoarcticum Lange-Bertalot & Bąk in Bąk & Lange-Bertalot 2015 (Syn. *Achnanthes lanceolata* var. *rostrata* Hustedt 1911)	x	x						
Psammothidium cf. *daonense* (Lange-Bertalot) Lange-Bertalot 1999							ss (3)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HeKl	HIPE	TTE-P
Pseudostaurosira brevistriata (Grunow) D. M. Williams & Round 1988 (Syn. *Fragilaria brevistriata* Grunow in Van Heurck 1885)	x	x		f				
Pseudostaurosiropsis geocollegiarum (Witkowski) E. A. Morales 2002							c (12)	
Pseudostaurosiropsis geocollegiarum f. *triradiatum* E. A. Morales 2005							r (7)	
Reimeria sinuata (Gregory) Kociolek & Stoermer 1987							ss (1)	
Rhoicosphenia abbreviata (C. Agardh) Lange-Bertalot 1980 (Syn. *Rhoicosphenia curvata* (Kützing) Grunow 1860)	x	x			x		ss (1)	
Rhopalodia gibba var. *ventricosa* (Kützing) H. Peragallo & M. Peragallo 1900	x, f	x		x				
Rhopalodia gibberula (Ehrenberg) O. Müller 1895	x	x		x	x			
Rhopalodia gracilis O. Müller 1895	x, f	x, sh						
Rhopalodia gracilis f. *linearis* O. Müller	x							
Rhopalodia hirundiniformis O. Müller	x	x			x			
"*Rhopalodia vermicularis* f. *perlonga*" (? *Rhopalodia vermicularis* var. *perlonga* Fricke)	x	x						
Sellaphora damasii (Hustedt) C. E. Wetzel, L. Ector, B. Van de Vijver, Compère & D. G. Mann 2015							ss (2)	
Sellaphora meridionalis Potapova and Ponader 2008							ss (2)	
Sellaphora nyassensis (O. Müller) D. G. Mann 1989 (Syn. *Navicula nyassensis* O. Müller 1910)	x, f	x, f		x				
Sellaphora parapupula Lange-Bertalot in Lange-Bertalot & Metzeltin 1996 (Syn. *Navicula pupula* var. *capitata* Hustedt in Schmidt 1934)	x	x						
Sellaphora perventralis (Hustedt) A. Tuji 2003 (Syn. *Navicula perventralis* Hustedt 1937)	x							
Sellaphora pupula (Kützing) Mereschkovsky 1902 (Syn. *Navicula pupula* Kützing 1844)	x	x		x			ss (1)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Sellaphora rectangularis (W. Gregory) Lange-Bertalot & Metzeltin 1996 (Syn. *Navicula pupula* var. *rectangularis* (W. Gregory) Cleve & Grunow 1880)	x							
Sellaphora rostrata (Hustedt) J. R. Johansen in J. R. Johansen et al. 2004 (Syn. *Navicula pupula* var. *rostrata* Hustedt 1911)	x							
Sellaphora seminulum (Grunow) D. G. Mann 1989 (Syn. *Navicula seminulum* Grunow 1860)		x						
Sellaphora thienemannii (Hustedt) C. E. Wetzel, L. Ector, B. Van de Vijver, Compère & D. G. Mann 2015 (Syn. *Navicula thienemannii* Hustedt 1937)		x						
Sellaphora spp.							ss (1)	
Stauroneis phoenicenteron (Nitzsch) Ehrenberg 1843	x	x						
Staurosira construens Ehrenberg 1843 (Syn. *Fragilaria construens* (Ehrenberg) Grunow 1862)	x	x		f				
Staurosira leptostauron (Ehrenberg) Kulikovskiy & Genkal in Kulikovskiy et al. 2011 (Syn. *Staurosirella leptostauron* (Ehrenberg) D. M. Williams & Round 1988)							r (4)	
Staurosira venter (Ehrenberg) Cleve & J. D. Möller 1879 (Syn. *Fragilaria construens* var. *venter* (Ehrenberg) Grunow in Van Heurck 1881)	x			x			ss (2)	
Staurosirella africana (Hustedt) D. M. Williams & Round 1988 (Syn. *Fragilaria africana* Hustedt 1949)	x	x					ss (2)	
Staurosirella pinnata (Ehrenberg) D. M. Williams & Round 1988 (Syn. *Fragilaria pinnata* Ehrenberg 1843)	x			x			ss (1)	
Stephanodiscus astraea (Kützing) Grunow 1880	x	x			x			
Stephanodiscus hantzschii Grunow in Cleve & Grunow 1880	x							

Taxon/Mission and sample type/Potential toxicity	**1935-1936**					**1972**	**2016-2018**	
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	**HcKl**	**HIPE**	**TTE-P**
Stephanodiscus cf. *minutulus* (Kützing) Cleve & Möller 1882 (Syn. *Stephanodiscus aestraea* f. *minutula* (Kützing) Grunow in Van Heurck 1882 as "*minutula*")	x	x					c (19)	
Surirella engleri f. *constricta* O. Müller 1903	x	x		x				
Surirella fasciculata O. Müller 1903				x				
Surirella füllerborni O. Müller	x, f							
Surirella füllerborni f. *constricta* O. Müller	x, f	x						
Surirella librile (Ehrenberg) Ehrenberg 1845 (Syn. *Cymatopleura solea* (Brébisson) W. Smith 1851)	x	x		x				
Surirella regula Ehrenberg 1843 (Syn. *Cymatopleura solea* var. *regula* (Ehrenberg) Grunow 1862)	x							
Surirella robusta Ehrenberg 1841	x							
Surirella splendida (Ehrenberg) Kützing 1844 (Syn. *Surirella robusta* var. *splendida* (Ehrenberg) Van Heurck 1885)	ss							
Surirella subrugosa C. Cocquyt & R. Jahn in Jahn, Kusber & Cocquyt 2017 (Syn. *Cymatopleura solea* var. *rugosa* O. Müller 1904)					x			
Synedra dorsiventralis O. Müller 1910	x	x						
Tabellaria fenestrata (Lyngbye) Kützing 1844	ss	ss			ss			
Tabellaria flocculosa (Roth) Kützing 1844	ss							
Thalassiosira faurii (Gasse) Hasle 1978							ss (2)	
Thalassiosira rudolfii (Bachmann) Hasle 1978 (Syn. *Coscinodiscus rudolfii* Bachmann 1938)	x, f	x, f		x			ss (1)	
Tryblionella calida (Grunow) Mann in Round, R. M. Crawford & D. G. Mann 1990							ss (1)	
Tryblionella levidensis W. Smith 1856 (Syn. *Nitzschia tryblionella* var. *levidensis* (W. Smith) Grunow in Cleve & Grunow 1880)	x	x						
Ulnaria acus (Kützing) M. Aboal in Aboal et al. 2003							ss (1)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Ulnaria biceps (Kützing) Compère 2001 (Syn. *Synedra ulna* var. *biceps* (Kützing) Schönfeldt 1913)		x						
Ulnaria danica (Kützing) Compère & Bukhtiyarova in Bukhtiyarova & Compère 2006							ss (1)	
Ulnaria delicatissima var. *angustissima* (Grunow) Aboal & P. C. Silva 2004 (Syn. *Synedra acus* var. *angustissima* (Grunow) Van Heurck 1885)	x							
Ulnaria ulna (Nitzsch) Compère 2001 (Syn. *Synedra ulna* (Nitzsch) Ehrenberg 1832)	x	x		x	x		ss (1)	
CHLOROPHYTA								
cf. *Acantosphaera zacchariasii* Lemmermann 1899							ss (2), ab	
Acutodesmus acutiformis (Schröder) Tsarenko & D. M. John 2011 (Syn. *Scenedesmus acutiformis* Schröder 1897)	x							
Ankistrodesmus falcatus (Corda) Ralfs 1848	x							
Binuclearia lauterbornii (Schmidle) Proschkina-Lavrenko 1966 (Syn. *Planctonema lauterbornii* Schmidle 1903)						x	r (8), x, ab	
Botryococcus braunii Kützing 1849	ec		x	aab				
Chlamydomonas komma Pascher 1949			x					
Chlamydomonas lismorensis Playfair 1917			x					
Chlamydomonas pisum Pascher 1949			x					
Chlamydomonas simulans Pascher 1949			x					
"*Chlorella vulgaris*"	x							
Chloromonas modesta (Pascher) Gerloff & Ettl in Ettl 1970 (Syn. *Chlamydomonas modesta* A. Pascher 1949)			x					
Cladophora glomerata var. *crassior* (C. Agardh) C. Hoek 1963 (Syn. *Cladophora crispata* (Roth) Kützing 1843)			ab			x		
Cladophora sp.			x					
Coelastrum microporum Nägeli in A. Braun 1855	c						ss (2)	
Coelastrum pulchrum Schmidle 1892							ss (2)	
Coelastrum reticulatum var. *cubanum* Komárek 1975							ss (3)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Coenochloris fottii (Hindák) Tsarenko 1990 (Syn. *Eutetramorus fottii* (Hindák) Komárek 1979)							ss (1)	
Coenococcus planctonicus Korshikov 1953						x	ss (2)	
Crucigenia tetrapedia (Kirchner) Kuntze 1898								
Crucigenia sp.							ss (1)	
Dictyosphaerium ehrenbergianum Nägeli 1849							ss (2)	
Dictyosphaerium sp.							ss (1)	
Desmodesmus abundans (Kirchner) E. Hegewald 2000							ss (1)	
Desmodesmus armatus (Chodat) E. Hegewald 2000 (Syn. *Scenedesmus armatus* (Chodat) Chodat 1913)	x							
Desmodesmus bicellularis (Chodat) S. S. An, T. Friedl & E. Hegewald 1999 (Syn. *Didymocystis bicellularis* (Chodat) Komárek 1973)							ss (2)	
Desmodesmus brasiliensis (Bohlin) E. Hegewald 2000							ss (1)	
Desmodesmus communis (E. Hegewald) E. Hegewald 2000 (Syn. *Scenedesmus quadricauda* Chodat 1926 p.p.)							ss (3)	
Desmodesmus costato-granulatus (Skuja) E. Hegewald 2000							ss (3)	
Desmodesmus denticulatus (Lagerheim) S. S. An, T. Friedl & E.Hegewald 1999							ss (1)	
Desmodesmus dispar (Brébisson) E. Hegewald 2000 (Syn. *Scenedesmus dispar* Brébisson 1856)	x						r (4)	
Desmodesmus lefevrei (Deflandre) S. S. An, T. Friedl & E. Hegewald 1999 (Syn. *Scenedesmus lefevrei* Deflandre 1924)	x							
Desmodesmus lefevrei var. *muzzanensis* (Huber-Pestalozzi) S. S. An, T. Friedl & E. Hegewald 1999 (Syn. *Scenedesmus lefevrei* var. *muzzanensis* Huber-Pestalozzi 1929)	r							

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Desmodesmus lunatus (West & G. S. West) E. Hegewald 2000 (Syn. *Scenedesmus denticulatus* var. *lunatus* West et G. S. West 1895)	x						ss (1)	
Desmodesmus magnus (Meyen) Tsarenko 2000							r (4), x, ab	
Desmodesmus microspina (Chodat) Tsarenko 2000 (Syn. *Scenedesmus microspina* Chodat 1926)	x							
Desmodesmus opoliensis (P. G. Richter) E. Hegewald 2000 (Syn. *Scenedesmus opoliensis* P. G. Richter 1895)	x						ss (2)	
Desmodesmus opoliensis var. ***carinatus*** (Lemmermann) E. Hegewald 2000 (Syn. *Scenedesmus carinatus* (Lemmermann) Chodat 1913)	x							
Desmodesmus protuberans (F. E. Fritsch & M. F. Rich) E. Hegewald 2000							ss (1)	
Desmodesmus serratus (Corda) S. S. An, T. Friedl & E. Hegewald 1999 (Syn. ***Scenedesmus serratus*** (Corda) Bohlin 1901)	x							
Desmodesmus spinosus (Chodat) E. Hegewald 2000							ss (3)	
Dictyosphaerium ehrenbergianum Nägeli 1849							ss (2)	
Dictyosphaerium sp.							ss (1)	
Euastropsis richteri (Schmidle) Lagerheim 1895	x							
Golenkinia paucispina W. et G. S. West 1902	x							
Gregiochloris lacustris (Chodat) Marvan, Komárek & Comas 1984							ss (1)	
Hariotina reticulata P. A. Dangeard 1889 (Syn. *Coelastrum reticulatum* (P. A. Dangeard) Senn 1899)	c							
Hyaloraphidium contortum Pascher & Korshikov in Korshikov 1931 (considered as belonging to fungi by Ustinova et al. 2000; but accepted as alga again in Tsarenko 2011)						x		
Kirchneriella aperta Teiling 1912							ss (1)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Kirchneriella lunaris (Kirchner) Möbius 1894	x							
Kirchneriella cf. *obesa* (West) West & G. S. West 1894							ss (3)	
Lagerheimia balatonica (Scherffel) Hindák 1978							ss (3)	
Lagerheimia ciliata (Lagerheim) Chodat 1895							r (6)	
Lagerheimia citriformis (J. W. Snow) Collins 1909							ss (1)	
Lagerheimia longiseta (Lemmermann) Printz 1914							ss (3)	
Lagerheimia quadriseta (Lemmermann) G. M. Smith 1926							r (4)	
Lagerheimia subsalsa Lemmermann 1898						x	ss (3)	
Messastrum gracile (Reinsch) T. S. Garcia in T. S. Garcia et al. 2016 (Syn. *Selenastrum gracile* Reinsch 1866)	x							
Microglena braunii (Goroschankin) Demchenko, Mikhailyuk & Proschold in Demchenko et al. 2012 (Syn. *Chlamydomonas braunii* Goroschankin [Gorozhankin] 1890)			x					
Monactinus simplex (Meyen) Corda 1839 (Syn. *Pediastrum simplex* Meyen 1829 as "*Pediastrum simplex* (Meyen) Lemm."; *Pediastrum simplex* var. *radians* Lemmermann; *Pediastrum simplex* var. *granulatum* Lemmermann 1898)	x		x					
Monoraphidium contortum (Thuret) Komárková-Legnerová in Fott 1969							ss (3)	
Monoraphidium griffithii (Berkeley) Komárková-Legnerová 1969 (Syn. *Ankistrodesmus falcatus* var. *acicularis* (A. Braun) G. S. West 1904)	x							
Monoraphidium sp.						x		
Neglectella solitaria (Wittrock) Stenclová & Kastovsky in Stenclová et al. 2017 (Syn. *Oocystis solitaria* Wittrock in Wittrock & Nordstedt 1879)	x							
Nephrochlamys subsolitaria (G. S. West) Korshikov 1953							ss (2)	
Nephrochlamys sp.						x		

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HeKl	HIPE	TTE-P
Octogoniella sphagnicola Pascher 1930							ss (1)	
Oedogonium sp. st.			aab					
Oocystis borgei J. W. Snow 1903							ss (1)	
Oocystis elliptica West 1892	x							
Oocystis lacustris Chodat 1897							ss (2)	
Oocystis marssonii Lemmermann 1898 (Syn. *Oocystis crassa* var. *marssonii* (Lemmermann) Printz 1913)	x					x		
Oocystis naegelii var. *africana* West	x							
Oocystis parva West et G. S. West 1898	x							
Oocystis pusilla Hansgirg 1890	x							
?*Oocystis sphaerica* W. B. Turner 1893	x							
Phacotus lenticularis (Ehrenberg) Diesing 1866 as "*Phacotus lenticularis* (Ehrenberg) Stein"			x					
Pseudocarteria pallida (Korshikov) H. Ettl 1958 (Syn. *Carteria pallida* Korschikov in Pascher 1927)			x					
Pseudopediastrum boryanum (Turpin) E. Hegewald in Buchheim et al. 2005 (Syn. *Pediastrum boryanum* (Turpin) Meneghini 1840)	c		x			x		
Pediastrum asperum Braun (Syn. *Pediastrum boryanum* var. *asperum* A. Braun)				x				
Pediastrum boryanum var. *brevicorne* A. Braun 1855	x							
"*Pediastrum boryanum* var. *divergens* Lemm."	x							
"*Pediastrum boryanum* var. *forcipatum* Racib." (*Pediastrum forcipatum* (Corda) A. Braun 1855 is currently regarded as a synonym of *Pediastrum boryanum* var. *forcipatum* (Corda) Chodat 1902)	x							
"*Pediastrum boryanum* var. *longicorne* Reinsch. f. *glabra* Lemm."	x		x					
Pediastrum cornutum (Raciborski) Troitskaya (Syn. *Pediastrum duplex* var. *cornutum* Raciborski)				x				
Pediastrum duplex Meyen 1829			x	x				
Pediastrum duplex var. *asperum* (A. Braun) Hansgirg 1855 (Syn. *Pediastrum duplex* var. *coronatum* Raciborski 1890)	x							

Taxon/Mission and sample type/Potential toxicity	**1935-1936**					**1972**	**2016-2018**	
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	**HcKl**	**HIPE**	**TTE-P**
"*Pediastrum duplex* var. *genuinum* f. *convergens* Racib."			x	x				
"*Pediastrum duplex* var. *microporum* A. Braun"			x					
"*Pediastrum duplex* var. *recurvatum* A. Braun"			x					
Pediastrum duplex var. *ugandae* Conrad 1949	x							
"*Pediastrum pearsonii* G. S. West var. *orientale* Skuja"	x							
Pediastrum subgranulatum (Raciborski) J. Komárek & V. Jankovsky (Syn. *Pediastrum duplex* var. *subgranulatum* Raciborski)			x, r					
Pediastrum tricuspidatum Conrad 1949	x							
Pseudodidymocystis lineata (Korshikov) Hindák 1990 (Syn. *Didymocystis lineata* Korshikov 1953)							ss (1)	
Pseudodidymocystis planctonica (Korshikov) E. Hegewald & Deason 1989							ss (2)	
Pseudoschroederia robusta (Korshikov) E. Hegewald & E. Schnepf 1986							ss (1)	
Quadricoccus ellipticus Hortobágyi 1973						x		
Rhizoclonium sp.			x					
Saturnella sp.						x	ss (1)	
Scenedesmus cf. *acunae* Comas Gonzáles 1980							ss (1)	
Scenedesmus acutus Meyen 1829 (Syn. *Scenedesmus crassus* Chodat 1926)			x					
Scenedesmus brevispina (G. M. Smith) Chodat 1926							ss (2)	
Scenedesmus carinatus f. *denticulata* Conrad 1949	x							
"*Scenedesmus longispina* Chodat var. *capricornus* Skuja"	x							
Scenedesmus pleiomorphus Hindák 1988							ss (3)	
Scenedesmus producto-capitatus Schmula 1910			x					
Scenedesmus quadricauda Chodat 1926	trp		aab				r (5)	

Taxon/Mission and sample type/Potential toxicity	**1935-1936**					**1972**	**2016-2018**	
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	**HeKl**	**HIPE**	**TTE-P**
Scenedesmus similagineus Hortobágyi 1960							ss (1)	
Scenedesmus sp. 1							ss (1)	
Scenedesmus sp. 2 (single cells)							ss (2)	
Selenastrum bibraianum Reinsch 1866							ss (1)	
Schroederia setigera (Schröder) Lemmermann 1898							ss (1)	
Schroederia spiralis (Printz) Korshikov 1953							ss (1)	
Scotiellopsis sp.							ss (1)	
Stauridium tetras (Ehrenberg) E. Hegewald in Buchheim et al. 2005 (Syn. *Pediastrum tetras* (Ehrenberg) Ralfs 1845)	x						r (4)	
Tetradesmus dimorphus (Turpin) M. J. Wynne 2016							ss (3)	
Tetradesmus lagerheimii M. J. Wynne & Guiry 2016 (Syn. *Scenedesmus acuminatus* (Lagerheim) Chodat 1902; *Scenedesmus falcatus* Chodat 1926)	x						ss (1)	
Tetradesmus lunatus Korshikov 1953							ss (3)	
Tetradesmus obliquus (Turpin) M. J. Wynne 2016 (Syn. *Scenedesmus acutus* Meyen 1829; *Scenedesmus obliquus* (Turpin) Kützing 1833)	trp		x				ss (1)	
Tetradesmus cf. *major* (Fischer) Fott & Komárek 1974							ss (1)	
Tetradesmus wisconsinensis G. M. Smith 1913							ss (2)	
Tetraëdron minimum (A. Braun) Hansgirg 1888 (as "*Tetraedron* ? *minimum* (A. Braun) Hansgirg 1888" in Conrad 1949c; in HIPE samples found in typical form and in the "lemon-like" form described from Lake Kivu by Stoyneva et al. 2012)	x						r (9), x, ab	
"*Tetraedron minimum* var. *scrobiculato-apiculatum* (Reinsch., Lagerh.) Skuja"						x		
Tetraëdron pentaedricum West & G. S. West 1895			x					
Tetraëdron regulare Kützing 1845							r (7), x, ab	
Tetraëdron triangulare Korshikov 1953							ss (3)	

Taxon/Mission and sample type/Potential toxicity	1935-1936					1972	2016-2018	
	MD-Ph	MD-Bn	MD-Ql	MD-Kz	MD-KB	HcKl	HIPE	TTE-P
Tetrastrum staurogeniiforme (Schröder) Lemmermann 1900							ss (1)	
Treubaria triappendiculata C. Bernard 1908						x	ss (2)	
Willea apiculata (Lemmermann) D. M. John, M. J. Wynne & P. M. Tsarenko 2014 (Syn. *Crucigeniella apiculata* (Lemmermann) Komárek 1974)							ss (1)	
STREPTOPHYTA								
Cosmarium bioculatum var. *minutissimum* Krieger 1932	r							
Cosmarium inconspicuum West & G. S. West 1896	x							
Cosmarium laeve Rabenhorst 1868						x		
Cosmarium monochondrum Nordstedt 1873	x							
Cosmarium pachydermum var. *aethiopicum* (West & G. S. West) West & G. S. West 1905	x							
Cosmarium depressum var. *planctonicum* Reverdin 1919							r (5)	
Cosmarium tenue W. Archer 1868	x							
Spirogyra sp. st.			pab					
Staurastrum brevispina Brébisson in Ralfs 1848 as "*brevispinum*"	x							
Staurastrum gracile Ralfs ex Ralfs 1848	x							
Staurastrum muticum Brébisson ex Ralfs 1848						x		
Staurastrum cf. *pingue* Teiling 1942						x		
Staurastrum volans West & G. S. West 1895							ss (1)	
Staurastrum sp.							ss (1)	

The results from counts of algal taxa in different periods and types of samples are summarized in **Table 2**.

DISCUSSION

According to all data analyzed, it is possible to state that totally 577 taxa from seven divisions have been identified in the lake waters (**Table 2**). In the analyzed literature, 36 new taxa were described from Lake Edward, 12 of which have been checked by modern taxonomists and 24 are still awaiting taxonomic reconsideration.

Table 2. Number of algal taxa by taxonomic groups found during different missions and in different types of samples from Lake Edward. Abbreviations: **MD** – Mission Damas (1935-1936); **Ph** – phytoplankton samples, **Bn** – benthic/periphytic samples (from "Aufwuchs"); **Ql** - qualitative samples, **Kz** – Kazinga Channel, **KB** – Katakuru-Bach, **HcKL** – Hecky & Kling (1987), **HIPE** – cruises 2016-2018; **MD-TNT-TG** - total number of taxa in the relevant taxonomic group in the samples of Mission Damas; ***TNT-TG*** – total number of taxa in the relevant taxonomic group; **TNT-RS** – total number of taxa in the relevant samples.

Number of taxa/Missions and sample types	**1935-1936**						**1972**	**2016-18**	***TNT-TG***
	MD-Ph	**MD-Bn**	**MD-Ql**	**MD-Kz**	**MD-KB**	***MD-TNT-TG***	**HcKl-Ph**	**HIPE-Ph**	
CYANOPROKARYOTA	**34**	**0**	**20**	**2**	**0**	**46**	**11**	**104**	***134***
EUGLENOPHYTA	**1**	**0**	**8**	**0**	**0**	**8**	**0**	**1**	***8***
PYRRHOPHYTA	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**4**	***5***
CRYPTOPHYTA	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	***1***
OCHROPHYTA	**184**	**139**	**9**	**49**	**33**	**249**	**0**	**70**	***287***
Tribophyceae	4	0	5	0	0	9	0	2	*11*
Chrysophyceae	0	0	3	0	0	3	0	0	*3*
Synurophyceae	0	0	1	0	0	1	0	0	*1*
Bacillariophyceae	180	139	0	49	33	236	0	68	*274*
CHLOROPHYTA	**44**	**0**	**26**	**5**	**0**	**65**	**13**	**66**	***128***
STREPTOPHYTA	**7**	**0**	**1**	**0**	**0**	**8**	**3**	**3**	***14***
TNT-RS	***270***	***139***	***65***	***56***	***33***	***477***	***28***	***248***	***577***

The following new taxa were described from Lake Edward as a single locality: Chlorophyta - *Chlamydomonas komma* Pascher 1949, nom. illeg. (non *Chlamydomonas komma* Skuja 1934), *Chlamydomonas modesta* A. Pascher 1949 (transferred to *Chloromonas modesta* (Pascher) Gerloff & Ettl in Ettl 1970), *Chlamydomonas pisum* Pascher 1949, *Chlamydomonas simulans* Pascher 1949 (non *Chlamydomonas simulans* (B. Fott) Huber-Pestalozii 1961, nom. illeg.), *Pediastrum duplex* var. *ugandae* Conrad 1949, *Pediastrum tricuspidatum* Conrad 1949, *Scenedesmus carinatus* f. *denticulata* Conrad 1949; Euglenophyta - *Trachelomonas impressa* Pascher 1949; Ochrophyta – Bacillariophyceae: *Achnanthes atomus* var. *congolensis* Hustedt 1949 (currently accepted as *Achnanthes congolensis* Hustedt 1949), *Amphora submontana* Hustedt 1949 (transferred to *Halamphora submontana* (Hustedt) Levkov 2009), *Fragilaria africana* Hustedt 1949 (transferred to *Staurosirella africana* (Hustedt) D. M. Williams & Round 1988), *Gomphonema aequatoriale* Hustedt 1949, *Navicula barbarica* Hustedt 1949, *Navicula exiguiformis* f. *elliptica* Hustedt 1949, *Navicula finitima* Hustedt

1949, *Navicula molestiformis* Hustedt 1949 (transferred to *Craticula molestiformis* (Hustedt) Mayama 1999), *Navicula subcontenta* var. *africana* Hustedt 1949 (from Kazinga), *Nitzschia aequalis* Hustedt 1949, *Nitzschia amphioxoides* Hustedt 1949, *Nitzschia congolensis* Hustedt 1949, *Nitzschia obsidialis* Hustedt 1949, *Nitzschia obsoleta* Hustedt 1949, *Nitzschia spiculoides* Hustedt 1949, *Nitzschia stricta* Hustedt 1949, *Nitzschia tarda* Hustedt 1949 and *Stephanodiscus damasi* Hustedt 1949 (transferred to *Cyclostephanos damasii* (Hustedt) Stoermer & Håkansson in Theriot, Håkansson, Kociolek, Round & Stoermer 1988); Chrysophyceae: *Lagynion vasicola* Pascher 1949.

New taxa found in the samples of Damas mission from Lake Edward and from other water bodies were: *Caloneis bacillum* f. *inflata* Hustedt 1949 (transferred to *Caloneis inflata* (Hustedt) Metzeltin & Lange-Bertalot 2007; also in lakes Kivu and Ndalaga), *Navicula zanoni* Hustedt 1949 (also in Lake Kivu), *Nitzschia adapta* Hustedt 1949 (also in lakes Kibuga and Ndalaga), *Nitzschia amphibia* var. *pelagica* Hustedt 1949 (also in Lake Kibuga and in a swamp near Karisimbi), *Nitzschia bacata* f. *linearis* Hustedt 1949 (also in the lakes Kivu and Kibuga), *Nitzschia epiphyticoides* Hustedt 1949 (also in Lake Kivu), *Nitzschia intermissa* Hustedt 1949 (also in Lake Kivu), *Nitzschia tropica* Hustedt 1949 (also in the lakes Kibuga and Ndalaga), *Nitzschia palea* var. *tropica* Hustedt 1949 (also in Lake Kivu), *Nitzschia spiculum* Hustedt 1949 (also in Lake Kivu and in the Kazinga Channel).

Unclear remains the locality of the new chrysophyceaen genus *Arthrogloea* Pascher 1949 with the new species *Arthrogloea annelidiformis* Pascher 1949 although it is clear that the taxon was found in the samples from the mission of H. Damas in the Albert National Park (Pascher 1949b). However, the genus and the species are currently accepted as taxonomic entities in AlgaeBase (Guiry & Guiry 2018).

In the HIPE phytoplankton samples, 199 very rare, 35 rare, 11 common and 3 frequent taxa were found (**Table 1**). Among the 199 very rare species, 121 (61%) were found in one sample only. Besides the clear tropical species, like *Microcystis novacekii* (Komárek) Compère, we found some thermophilic species (*e.g. Chroococcus globosus* (Elenkin) Hindák), which could originate from the nearby volcano regions. It is possible to suggest the introduction of such algae in the lake by birds or other transport vectors. At the same time, some of the rare species are known as distributed in temperate and/or northern regions of Europe or other continents (*e.g. Chroococcus distans* (G. M. Smith) Komarkova-Legnerova et Cronberg, *Gomphosphaeria natans* Komárek et Hindák 1988, *Microcystis firma* (Kützing) Schmidle). They also could be transported in the lake by different vectors. Similar "cold water" taxa were found by previous lake investigators (*e.g. Microcystis ichtyoblabe* (G. Kunze) Kützing), and in both their and our samples as well (*e.g. Microcystis flos-aquae* (Wittrock) Kirchner). These species, alien for the lake (some of which were included in the checklist with a sign for uncertainty), will be discussed in detail elsewhere.

The most frequent species in the lake phytoplankton were *Nitzschia* cf. *lacuum* Lange-Bertalot (probably corresponding to *Nitzschia fonticola* sensu Hustedt 1949), *Nitzschia spiculum* and *Nitzschia tropica* (**Table 1**). The same species were the most abundant among diatoms. At the same time, quite abundant (sometimes even dominant) in the samples were some coccal (*e.g. Aphanocapsa*, *Microcystis*) and heterocytous cyanoprokaryotes (mainly *Raphidiopsis*), as well as green coccal (*e.g. Tetraëdron*) or filamentous green algae (*Binuclearia lauterbornii* (Schmidle) Proschkina-Lavrenko 1966).

The comparison of data of different authors with our contemporary results (**Tables 1, 2**) can be taken only tentatively due to different approaches, aims of investigations, types of samples, sampling sites and techniques for processing and identification as well. In this way the highest number of taxa published after Damas mission is easily explainable by the presence of benthic and qualitative samples with special investigation of the slow-flowing Kazinga Channel (**Table 2**). Therefore, we shall not underline the floristic similarity/dissimilarity, but shall point only the fact that 52 species (1%) were present in the lake since the mission of H. Damas till nowadays (**Table 1**). Five cyanoporokaryote species were found in all the three studied periods: *Aphanocapsa incerta* (Lemmermann) G. Cronberg et Komárek, *Limnolyngbya circumcreta* (G. S. West) X. Li et R. Li, *Microcystis flos-aquae* (Wittrock) Kirchner, *Microcystis prasina* (Wittrock) Lemmerman and *Planktolyngbya contorta* (Lemmermann) Anagnostidis et Komárek (**Table 1**). The high abundance of cyanoprokaryotes found in the 1930s (Conrad & Duvigneaud 1949) obviously continues to be typical of the lake in the 1970s (Hecky & Kling 1987) and continues nowadays (Stoyneva-Gärtner et al. in prep.). Therefore, it has to be noted, that 65 species of Cyanoprokaryota are potentially toxic and need further attention from the scientific community. This is especially important for Africa, where "freshwater is the resource contributing perhaps more than any other to the nutrition and welfare of the African people" (John 1986, p. 1).

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

AUTHOR CONTRIBUTIONS

Both authors contributed equally to the text preparation. In the processing of the HIPE samples J.-P. Descy worked with diatoms, and M.P. Stoyneva-Gärtner – with the other algal groups.

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CHECKLIST OF ALGAE FROM BULGARIAN THERMAL WATERS

MAYA P. STOYNEVA-GÄRTNER[1*], BLAGOY A. UZUNOV[1] & GEORG GÄRTNER[2]

1 - Sofia University "St. Kliment Ohridski", Faculty of Biology, Department of Botany, 8 Dragan Tsankov Blvd., BG-1164, Sofia, Bulgaria
2 - Universität Innsbruck, Institut für Botanik, Sternwartestraße 15, A-6020 Innsbruck, Austria

Abstract. The paper provides annotated Checklist of Bulgarian thermal algae mentioned in the publications on thermo-mineral springs, baths and their effluents and updated according to the last taxonomic considerations. The list contains data on 35 thermal systems and totally 206 taxa from five algal divisions (phyla): Cyanoprokaryota (82), Rhodophyta (4), Ochrophyta (44: 3 - Tribophyceae, 40 - Bacillariophyceae), Chlorophyta (32) and Streptophyta (44). Among them 21 species are of conservation importance according to the Red Lists of Bulgarian macroalgae and microalgae, and of the Red Data Book of R Bulgaria as well. According to their threatened status they are spread in the following groups: *Critically Endangered* (1), *Endangered* (4), *Vulnerable* (6), *Near Threatened* (5) and *Data Deficient* (5). On the background of the increased pace of habitat losses due to capturing of the springs, construction of new modern SPA centers with permanent cleaning of the algae, or usage of springs for heating purposes or as laundries, this Checklist can serve as a basic archive for future investigations of this important ecological group of extremophilic algae.

Key words: cyanoprokaryotes, extremophiles, threatened species, thermal springs, thermophilic algae, vulnerable habitats

**corresponding author*: M. P. Stoyneva-Gärtner – Sofia University "St. Kliment Ohridski", Faculty of Biology, Department of Botany, 8 Dragan Tsankov Blvd., BG-1164, Sofia, Bulgaria; mstoyneva@uni-sofia.bg

INTRODUCTION

Algae of the thermal springs, their permanent fontal water bodies and effluents form the ecological group commonly named thermophyton. Published data on the species composition of this important group in Bulgaria are quite scattered. The studies started with the papers by Petkoff (1898, 1904, 1907, 1908, 1908-1909, 1913, 1922, 1925, 1929, 1934, 1934-1935, 1942, 1950a, b) and Guérquieff (1906). Later, a few species from thermal waters were mentioned by Georgiev (1948), Valkanov (1955), Vodeničarov (1967) and Semerdzhiev et al. (1980). In the Flora of Bulgarian algae (Vodenicharov et al. 1971) included 36 taxa as found in thermal habitats (mainly springs), almost without indication of the localities. Out of them *Aphanocapsa thermalis* Brügger 1863 and *Trichormus thermalis* (V. Vouk) Komárek & Anagnostidis 1989 (Syn. *Anabaena thermalis* V. Vouk 1916) were indicated as "species which have not been found in Bulgaria". Afterwards the studies on the Bulgarian thermophyton continued with the works by Stoyneva (2003, 2014), Stoyneva & Gärtner (2004) and Lukavsky et al. (2011). Then Gärtner et al. (2015) applied combined light microscopical investigation with transmission electron microscopy and biochemical studies of the cell wall composition for identification of a strain of *Chlorella*, collected from Rupite thermal springs. Currently, Strunecký et al. (2018) published the algal composition from the same region, based on polyphasic approach, which unites conventional light microscopy and modern molecular methods. The first summary on the biodiversity of thermal springs from the region of Pirin Mts and its surrounding valleys and kettles was made by Petkoff (1925). Later on, summaries on the Bulgarian thermophyton were provided in Stoyneva (2003b, 2014), Stoyneva & Michev (2007) and Stoyneva & Temniskova-Topalova (2007). Stoyneva (2003) made a generalization of the knowledge on temperature limits of distribution of green algae with a summarizing table with the temperatures at which green algal species were documented for Bulgarian thermes. Nowadays Strunecký et al. (2018) published data on temperature of findings and cultivation of some species found in Rupite region.

Data published in all works cited above concern mainly effluents of the thermal springs and baths of Slivnitsa and Opitsvet (kettle Sofiyska Kotlovina), Banki (Lyulin Mt), Sofia (incl. Ovcha Kupel, Knyazhevo) and Zheleznitsa (Vitosha Mt), Pancharevo (gorge Iskurski Prolom), Ravno Pole (plain Sofiysko Pole), Sapareva Banya (Rila Mts), Kyustendil (kettle Kyustendilska Kotlovina of Osogovo Mts), Blagoevgrad, Simitli, Rupite, Marikostinovo and Sveti Vrach (valley Strumska Dolina), Dobrinishte, Ognyanovo (incl. Futovishta), Gotse Delchev, Razlog, Banya (Guliyna Banya) and Bansko (Pirin Mts), Vurshetski Bani and Karlovski Bani (Stara Planina Mts), Hisarya spring complex and Strelcha spring (Sredna Gora Mts), Haskovo (valley Trakiyska Nizina), Malo-Belovo, Draginovo (=Korova), Vetren Dol (=Eli-dere), Narechen and Mihalkovo (Rodopi Mts), as well as the thermal springs Novata Voda, Svetata Voda and "thermal spring in Yanensko", for which more geographical data are not provided. The UTM map and main abiotic parameters of most studied springs and limits of main hydrothermal formations were given in STOYNEVA (2003) and STOYNEVA & GÄRTNER (2004).

By time the ecosystems of many Bulgarian thermal springs were completely destructed, lost natural habitats or were severely fragmented because of their transformation into balneotherapy and SPA centers, exploitation of springs for heating purposes or their use as carpet or car washing sites. All these events led to biodiversity losses, noted firstly by PETKOFF (1922, 1929) for the thermal complexes of Ovcha Kupel and Malo Belovo, and afterwards confirmed for them and additionally pointed for the springs in the regions Slivnitsa-Opitsvet-Bezden, Zheleznitsa and Rupite (STOYNEVA 2003, 2014; STOYNEVA & GÄRTNER 2004). Therefore, the thermal springs of Zheleznitsa were included in the first Red List of Bulgarian wetlands with the category *Critically Endangered* (MICHEV & STOYNEVA 2005, 2007). Similar is the example with the only geyser in the last 50 years in our country - the one in Sapareva Banya, which was captured for the needs of the heating of the town and practically remained algologically uninvestigated. This geyser, which arose as a result of the earthquake in 1999, and survived in its natural state for less than a year, was also included in the first Red List of Bulgarian wetlands with the category *Vulnerable* (MICHEV & STOYNEVA 2005, 2007). All thermal habitats of Bulgaria were categorized as *Vulnerable* in the Red Book of Bulgarian habitats (BISERKOV ET AL. 2015) and threatened species were included in the Red Lists of Bulgarian macro- and microalgae (TEMNISKOVA ET AL. 2008; STOYNEVA-GÄRTNER ET AL. 2016) and in the Red Data Book of Bulgarian Plants and Fungi (STOYNEVA ET AL. 2015).

Considering the increase of the modern society in balneotherapy and recreation, and the rising pace of construction of SPA centers combined with the development of tourism, we decided to summarize the knowledge on the algal biodiversity of Bulgarian thermal springs. The Checklist provided below shows the algal distribution by springs and is organized according to the recent state-of-art of modern taxonomy. It is supposed to serve as a biodiversity archive and basis for future investigations and nature conservation measures.

MATERIAL AND METHODS

Data were taken from all published sources on the thermophyton biodiversity, issued in the period 1898-2018: PETKOFF (1898, 1904, 1907, 1908, 1908-1909, 1913, 1922, 1925, 1929, 1934, 1934-1935, 1942, 1950A, B), GUÉRQUIEFF (1906), GEORGIEV (1948), VALKANOV (1955), VODENIČAROV (1967), VODENICHAROV ET AL. (1971), SEMERDZHIEV ET AL. (1980), STOYNEVA (2003), STOYNEVA & GÄRTNER (2004), LUKAVSKY ET AL. (2011), GÄRTNER ET AL. (2015) and STRUNECKÝ ET AL. (2018). Taxonomical updating was done for taxa supplied by descriptions and indications of taxonomical sources used by the authors (in case of different species understanding by later authors and existence of different synonyms) or for taxa with a single, doubtless taxonomical transformation. For all other species the original writing of the Latin and author names is kept and they are represented included in quotes. Species which need further taxonomic assessment due to deviations from the descriptions noted by the authors, are indicated by asterisk (*) after the site, where deviation was observed. We added taxonomic comments in cases when authors provided cytomorphological data which differ from species diagnosis without noting the differences. The Checklist is organized in alphabetical order in each algal division, with the current algal names checked in AlgaeBase (Guiry & Guiry 2019), in CyanoDB 2.0 (Hauer & Komárek 2019) and in DiatomBase (Kociolek et al. 2018) in addition to the standard taxonomic sources (*e.g.* Geitler 1931, 1942; Gollerbakh et al. 1953; Krammer & Lange-Bertalot 1991, 1997a, b, 2004; Krause 1997; Komárek & Fott 1983; Komárek & Anagnostidis 1999, 2005; Eloranta et al. 2011; Komárek 2013). Threatened status of the recorded algae is provided after Temniskova et al. (2008) and Stoyneva et al. (2015) for macrophytes, and after Stoyneva-Gärtner et al. (2016) for the microalgae.

For each species the distribution by thermal systems (altogether 35) is provided. When details on the exact spring or bath basin are not described by the author, we note the whole thermal spring complex, but when the exact name of the spring or bath in a region with more springs is pointed by the author, it is given for the relevant taxon in brackets after the name of the complex. When available, data on algal abundance, are provided in brackets as translation of the original authors texts. The indication "in thermal springs" follows the text in the Flora of Bulgarian algae (Vodenicharov et al. 1971).

RESULTS

The species list provided below contains 205 taxa of algae, found in Bulgarian thermal springs or their effluents during a period of 120 years. They belong to five algal divisions (phyla) and twenty-one of them are of conservation significance according to the Red Lists of Bulgarian macro- and microalgae and Bulgarian Red Data Book.

Division Cyanoprokaryota

***Aphanothece elabens* (Brébisson ex Meneghini) Elenkin 1938** (Syn. *Microcystis elabens* (Brébisson) Kützing 1846) - Bansko

***Aphanothece stagnina* (Sprengel) A. Braun in Rabenhorst 1863** – Bansko

***Aphanothece* sp.** – Rupite

***Beggiatoa alba* Trevisan 1893** – Sapareva Banya (spills of the main spring; abundant)

***Calothrix thermalis* Hasngirg ex Bornet & Flahault 1886** – Pancharevo (dominant together with *Gloeocapsa gelatinosa* in a mat on a concrete wall). In our opinion, this species needs taxonomic reconsideration since the dimensions provided by LUKAVSKY ET AL. (2011, p. 8) are smaller ("Cells width 4 μm, filaments width 5 μm, including yellow coloured mucillage sheath, bearing heterocysts, basal, transparent. The end of filament rounded,width 3 μm, emerging from sheath") than the dimensions in the species description provided by GEITLER (1930-1932: filaments 8-10 μm wide, cells 5-8 μm wide), GOLLERBAKH ET AL. (1953: filaments 9.5-16.5 μm wide at the basis, then 7-11.5 μm wide; trichomes at the basis 5.5-13 μm wide and then 4.5-9.5 μm wide; heterocytes 4.5-11.5 μm …or more or less cylindrical, 5.5-8 μm wide and 9-23 μm long) and KOMÁREK (2013: filaments (8)9-16.5 μm wide at the basis, mostly 7-11.5 μm in the middle, trichome 5.5-13 μm wide at the basis and 4.5-9.5 μm at the middle, heterocytes 4.5-11.5 (23) x (4.5)5.5-8.5 (11.5) μm). More, the species ends with a hair-like protrusion, which is not mentioned by LUKAVSKY ET AL. (2011). *Endangered* in the Red List of Bulgarian microalgae [EN - A4 B3 C4 D3 E1 F4 G4 T23].

***Chlorogloeopsis* sp.** - Rupite

"Chroococcales" - Haskovo

***Chroococcus membraninus* (Meneghini) Nägeli 1849** – Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach (abundant). The text in Bulgarian Flora obviously is a summary of previous findings: "in thermal springs. Valleys of the rivers Mesta and Struma".

***Chroococcus thermalis* (Meneghini) Nägeli 1849** (Syn. *Chroococcus turgidus* var. *thermalis* (Meneghini) Rabenhorst ex Hansgirg 1892) – Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach. The text in Bulgarian Flora obviously is a summary of previous findings: "in effluents of thermal springs in Simitli and Petrich region".

***Chroococcus turgidus* (Kützing) Nägeli 1849** – Bansko

***Cyanobacterium aponinum* I. Moro, N. Rascio, N. LaRocca, M. DiBella & C. Andreoli 2007** - Rupite

***Chroococcus* sp.** – Rupite

***Desertifilum* sp.** - Rupite

***Geitlerinema splendidum* (Greville ex Gomont) Anagnostidis 1989** (Syn. *Oscillatoria splendida* Greville ex Gomont 1892) – Malo Belovo, "…in thermal springs. Belovo, Vitosha Mt, Razlog and Sofia regions", Rupite

***Gloeocapsa gelatinosa* Kützing 1843** (as "*Gloeocapsa gelatinosa* (Meneghini) Kützing 1843") – Pancharevo. *Vulnerable* in the Red List of Bulgarian microalgae [VU - A4 B3 C4 D3 E1 F2 G1 T18].

***Gloeocapsa kuetzingiana* Nägeli ex Kützing 1849** – Hisarya (fountain Tinkova Cheshma)

***Gloeothece fuscolutea* (Nägeli ex Kützing) Nägeli 1849** (Syn. *Gloeocapsa* *fuscolutea* Nägeli ex Kützing 1849 as *Gloeocapsa fusco-lutea*) - Bansko

"Gloetrichia rufescens" (?*Rivularia rufescens* Nägeli ex Bornet & Flahault 1886 as *Rivularia rufescens* (Näg.) Born. et Flah. according to Gollerbakh et al. 1953. *Endangered* in the Red List of Bulgarian microalgae [EN - A4 B4 C4 D3 E1 F4 G4 T24]) – Karlovski Bani

Gomphosphaeria aponina **Kützing 1836** – Bansko

Hapalosiphon pumilus **Kirchner ex Bornet & Flahault 1887** (Syn. *Hapalosiphon fontinalis* Bornet 1889 as "*Hapalosiphon fontinalis* (Ag.) Born.") – "sometimes in thermal springs…Pirin, Rila"

Heteroscytonema crispum **(Bornet ex De Toni) G. B. McGregor & Sendall in G. B. McGregor 2018** (Syn. *Scytonema crispum* Bornet ex De Toni 1907 as "*S. crispum* (Ag.) Born."; *Scytonema cincinnatum* Thuret ex Bornet & Flahault 1886 as "*S. cincinnatum* Thur.") – Malo Belovo (extremely abundant). Petkoff (1929) indicated for Malo Belovo "*Scytonema crispum* f. *pauciramosa*" as "abundant before 1890 and already progressively disappearing in 1929" in addition to the abundant *Scytonema cincinnatum* Thuret (which was included for the same site in this and in his earlier paper – Petkoff (1908-1909). Both species – *S. crispum* and *S. cincinnatum* were given by Komárek (2013, p. 82) as separate taxa, but with unclear relations, considered as synonyms by several authors. The synonymizing of both species under the new generic name *Heteroscytonema* (McGregor 2018; Sendall & McGregor 2018) was accepted in AlgaeBase. Since f. *pauciramosa* is not discussed in the standard taxonomic literature and in AlgaeBase, and Petkoff (1929) did not provide an author name, we believe that with this naming he noted findings of more rarely ramificated thalli in addition to the typical ones. Therefore, in this Checklist we refer both taxa to *H. crispum*. *Endangered* in the Red List of Bulgarian microalgae [EN - A4 B3 C4 D3 E1 F2 G4 T21].

Homoeothrix juliana **(Bornet & Flahault ex Gomont) Kirchner 1898** (as "*Homoeothrix juliana* (Menegh.) Kirchner") – "…also in thermal springs. Vitosha." The combination *Homoeothrix juliana* (Menegh.) Kirchner according to the basionym *Calothrix juliana* Bornet et Flahault was used in Vodenicharov et al. (1971) after Geitler (1930-1932, p. 575).

Jaaginema geminatum **(Meneghini ex Gomont) Anagnostidis & Komárek 1988** (Syn. *Oscillatoria geminata* Menegh). The name and synonym are provided after Komárek & Anagnostidis (2005). Obviously, the writing of the name as *Jaaginema geminatum* (Schwabe ex Gomont) Anagnostidis & Komárek 1988 in AlgaeBase is a technical mistake. - Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach. The text in Bulgarian Flora obviously is a summary of previous findings: "In thermal springs... Valleys of Struma and Mesta…". *Near Threatened* in the Red List of Bulgarian microalgae [NT - A3 B4 C3 D2 E1 F1 G1 T15].

Jaaginema kuetzingianum **(Nägeli in Kützing) Anagnostidis et Komárek 1988**

(Syn. *Oscillatoria kuetzingiana* Nägeli in Kützing as "*Oscillatoria amphibia* Ag. var. *kützingiana* (Näg.) Geitl.") – Haskovo (baths)

***Jaaginema pseudogeminatum* (G.Schmid) Anagnostidis & Komárek 1988** (Syn. *Oscillatoria pseudogeminata* G. Schmid 1914) – Simitli, Marikostinovo, Sveti Vrach, Hisarya

***Kamptonema cortianum* (Meneghini ex Gomont) Strunecký, Komárek & J. Smarda 2014** (Syn. *Oscillatoria cortiana* Meneghini ex Gomont 1892 as "*Oscillatoria cortiana* Menegh. (Syn. *O. formosa* Bory f. *latior* Petkoff)") – "in thermal springs… Rila". The synonymy with *O. formosa* Bory f. *latior* Petkoff needs further checking due to lack of any comments in Vodenicharov et al. (1971).

***Kamptonema okenii* (C. Agardh ex Gomont) Strunecký, Komárek & J. Smarda 2014** (Syn. *Oscillatoria okenii* C. Agardh ex Gomont 1892 as "*Oscillatoria okeni* Ag.") – Pancharevo*, "In thermal springs... Lovech and Sofia regions"

***Leibleinia epiphytica* (Hieronymus) Compère 1985** – Pancharevo (filaments twisted around *Phormidium corium* Gomont ex Gomont 1892). According to Lukavsky et al. (2011) this species has *Schizothrix calcicola* (C. Agardh) Gomont as a synonym requires its further taxonomic reconsideration.

***Leptolyngbya boryana* (Gomont) Anagnostidis & Komárek 1988** – Rupite

***Leptolyngbya compacta* (Hansgirg ex Hansgirg) Komárek in Anagnostidis 2001** - Rupite

***Leptolyngbya fragilis* (Gomont) Anagnostidis & Komárek 1988** (Syn. *Phormidium fragile* Gomont 1893) – Pancharevo* (extremely abundant)

***Leptolyngbya geysericola* (J. J. Copeland) Anagnostidis 2001** - Rupite

***Leptolyngbya tenerrima* (Hansgirg) Komárek in Anagnostidis 2001** (Syn. *Oscillatoria tenerrima* [Kützing 1843, nom. inval.] ex Prain 1905, *Lyngbya tenerrima* [Kützing] Hansgirg ex Hansqirg as "*O. tenerrima* Kütz., *L. tenerrima* (Ktz) Hansq. α var. *genuina* (Ktz) Hnsq.") – Draginovo, Haskovo (in masses, in the springs)

***Leptolyngbya tenuis* (Gomont) Anagnostidis & Komárek 1988** (Syn. *Phormidium tenue* Gomont 1892, also as "*Phormidium tenue* (Menegh.) Gom.") – Ognyanovo, "in… thermal springs…Region of Gotse Delchev and Sofia region"

***Leptolyngbya valderiana* (Gomont) Anagnostidis & Komárek 1988** (Syn. *Phormidium valderianum* Gomont 1892 as "*Phormidium valderiae* (Delp.) Geitler") – Hisarya. In Geitler (1930-1932, p. 1011) *Leptothrix valderiae* Delp. is pointed as synonym of *Phormidium valderianum* (Delp.) Gom. The name *Phormidium valderiae* (Delp.) Geitl. is used in Gollerbakh et al. (1953, p. 486).

***Leptothrix ochracea* Kützing 1843**: 198, nom. inval. – Marikostinovo

***Lyngbya aestuarii* Liebman ex Gomont 1892** (as "*Lyngbya aestuarii* (Martens) Liebmann") – "… more rare in thermal springs. Sozopol and Burgas regions".

***Lyngbya major* Meneghini ex Gomont 1892** – "…in thermal springs. Black Sea coastal region."

***Lyngbya martensiana* Meneghini ex Gomont 1892** - "…and in thermal springs. Plovdiv and Trun regions". According to LUKAVSKY ET AL. (2011) this species pointed for Bulgarian thermal springs in VODENICHAROV ET AL. (1971) coincides with *Lyngbya thermalis*, found by them in Pancharevo. Since *L. thermalis* and *L. martensiana* are listed as separate taxonomic entities in AlgaeBase and standard taxonomic literature on Cyanoprokaryota, and LUKAVSKY ET AL. (2011) have not checked the original material used by VODENICHAROV ET AL. (1971) we do not synonymize both species in this Checklist. More, the description of *L. martensiana* Menegh., provided in Bulgarian Flora is on conformity with its smaller dimensions to the description of *L. martensiana* in GEITLER (1930-1932) and KOMÁREK & ANAGNOSTIDIS (2005) in comparison with *L. thermalis* in the text by GEITLER (1930-1932) and KOMÁREK & ANAGNOSTIDIS (2005).

***Lyngbya thermalis* Kützing ex Gomont 1892**: 152, nom. inval. – Pancharevo. See the notes on *L. martensiana.*

***Mastigocladus laminosus* Cohn ex Kirchner 1898** (Syn. *Hapalosiphon laminosus* Hansgirg ex Bornet & Flahault 1886) – Guliyna Banya (abundant), Pancharevo, Sofia, Kazichane, Zhelznitsa, Ravno Pole, Strelcha, Gradeshnitsa, Rupite and Sandanski, and without locality included in the Algal flora of Bulgaria (VODENICHAROV ET AL. 1971). According to LUKAVSKY ET AL. (2011, p. 10) "VODENICHAROV ET AL. (1971) did not list *Mastigocladus laminosus*, but they mentioned *Hapalosiphon fontinalis* in the thermal waters of the Pirin and the Rila ranges. Maybe *Mastigocladus* was not recognised, since there are no drawings of the species". In fact, *Mastigocladus laminosus* as *Hapalosiphon laminosus* was first reported for Guliyana Banya by PETKOFF at temperature of 56°C (1925, p. 37, p. 103) and then was included in Bulgarian Algal Flora (VODENICHAROV ET AL. 1971, p. 96-97) as "representative found in Bulgaria" without pointing the exact location), while in the same flora *H. fontinalis* (Ag.) Born. was included as "sometimes found in thermal waters" (op. cit., p. 95-96). *M. laminosus* was presented with a *Vulnerable* status in the Red List of Bulgarian microalgae [VU - A2 B3 C4 D3 E1 F2 G4 T19].

***Microcoleus autumnalis* (Gomont) Strunecky, Komárek & J. R. Johansen in Strunecky et al. 2013** (Syn. *Phormidium autumnale* Gomont 1892) – Vurshets, Rupite (rarely found; mentioned also as *Microcoleus* sp.)

***Merismopedia glauca* (Ehrenberg) Kützing 1845** - Malo Belovo (abundant)

***Merismopedia tranquilla* (Ehrenberg) Trevisan 1845** (Syn. *Merismopedia punctata* Meyen 1839) – "….in thermal springs. Pirin Mt, Plovdiv region, Rila Mt, Black Sea coastal region."

***Microcoleus amoenus* (Gomont) Strunecky, Komárek & J. R. Johansen in Strunecky et al. 2013** (Syn. *Oscillatoria amoena* Gomont 1892) – "in thermal springs. Lovech region"

***Microcystis pulverea* (H. C. Wood) Forti 1907** (Syn. *Polycystis pulverea* (Wood) Wolle) - Malo Belovo (in great amounts)

***Microcystis* sp.** - Rupite

***Nostoc linckia* Bornet ex Bornet & Flahault 1886** – Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach

***Nostoc muscorum* C. Agardh ex Bornet & Flahault 1888** – "… and in thermal springs. regions of Plovdiv, Sozopol, Sofia."

***Nostoc paludosum* Kützing ex Bornet & Flahault 1886** - Bansko

***Nostoc verrucosum* Vaucher ex Bornet & Flahault 1886** - Narechen

"Nostocales" – Haskovo

***Oculatella* sp.** - Rupite

"**Oscillatoria antiliaria Juerg."**, Cooke Freshw. algae p. 250, pl. 97, fig. 2; (*Oscillatoria antiliiaria* (Jurg.) Hansg. var. *genuinea* Krch. (Hansq. I, c. II, p. 114)" – Sapareva Banya (abundant)

***Oscillatoria arachnoidea* C. Agardh ex Gomont 1892** (Syn. *Beggiatoa arachnoidea* (C. Agardh) Rabenhorst 1865) – Draginovo (quite spread), Haskovo (abundant)

***Oscillatoria curviceps* C. Agardh ex Gomont 1892** - Haskovo

***Oscillatoria princeps* Vaucher ex Gomont 1892** – Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Rupite, Marikostinovo, Sveti Vrach, Bansko, Haskovo, "… and in thermal springs. Widely distributed species in Bulgaria".

***Oscillatoria proboscidea* Gomont 1892** – Hisarya

***Oscillatoria spiralis* Carmichael ex Gomont 1892** (Syn. *Oscillatoria spiralis* Carmichael 1833) – Sapareva Banya (abundant in the middle basin named Srednoto Topilo)

***Oscillatoria tenerrima* var. *nigricans* Hansgirg ex Drouet 1957** (as "*Oscillaria tenerrima* var. *nigricans* Hansgirg") – Haskovo (abundant in Kutela and other sites)

***Oscillatoria tenuis* C.Agardh ex Gomont 1892** (as "*Oscillatoria tenuis* (Ag.) Hansg." and as "*Oscillatoria tenuis* Ag.") – Kyustendil (lower baths), Svetata Voda (abundant), Sapareva Banya

***Oxynema acuminatum* (Gomont) Chatchawan, Komárek, Strunecky, Smarda & Peerapornpisal 2012** (Syn. *Oscillatoria acuminata* Gomont 1892) – "….in thermal springs"

***Phormidesmis molle* (Gomont) Turicchia, Ventura, Komárková & Komárek 2009** - Pancharevo

***Phormidium ambiguum* Gomont 1892** – "in… thermal springs….Rila, Sofia region, Black Sea coastal region"

***Phormidium breve* (Kützing ex Gomont) Anagnostidis & Komárek 1988** (Syn. *Oscillatoria brevis* Kützing ex Gomont 1892, *Oscillatoria neapolitana* Kützing ex Gomont 1892) – Ovcha Kupel ("separate filaments between *Symploca*")

***Phormidium carboniciphilum* (Prát) Anagnostidis & Komárek 1988** (Syn. *Oscillatoria carboniciphila* Prát 1929) – Marikostinovo, Mihalkovo

***Phormidium chalybeum* (Mertens ex Gomont) Anagnostidis & Komárek 1988** (Syn. *Oscillatoria chalybea* Mertens ex Gomont 1892) - "in… thermal springs. Black Sea coast"

***Phormidium corium* Gomont ex Gomont 1892** - Pancharevo

***Phormidium favosum* Gomont 1892** (as "*Phormidium favosum* (Bory) Gom.") – ".. and in thermal springs…Lovech, Samokov region"

***Phormidium fragile* Gomont 1893** (as "*Phormidium fragile* (Menegh.) Gom.") – "in…. thermal springs. Sofia region."

***Phormidium papyraceum* Gomont ex Gomont 1892** (as "*Ph. papyraceum* (Ag.) Gom.") – Sapareva Banya

***Phormidium terebriforme* C. Agardh ex Gomont) Anagnostidis & Komárek 1988** (Syn. *Oscillatoria terebriformis* C. Agardh ex Gomont 1892) – Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo (Futovishta), Banya (Guliyna Banya), Marikostinovo, Sveti Vrach. The text in Bulgarian Flora obviously is a summary of previous findings: "in thermal springs. Valleys of the rivers Struma and Mesta, Sofia region"

***Phormidium uncinatum* Gomont ex Gomont 1892** – Opitsvet, Vurshets, Malo Belovo, "… and in thermal springs. Widely distributed species in Bulgaria".

"*Scytonema mirabile* var. *leprieurii* (Mont.) Born. et Flah." – Bansko (rare, in the spring effluents). This variety is not included in ALGAEBASE and in KOMÁREK (2013), and in the opinion of GEITLER (1930-1932) had not to be separated from the main species *Scytonema mirabile*. GOLLERBAKH ET AL. (1953) included *Scytonema mirabile* f. *leprieurii* (Mont.) Kossinsk. as a form typical for thermal springs. In his notes, PETKOFF (1925) provided description of the form compared to the main species. He noted also that this form was found in thermal springs in Italy with outermost thin and colorless layer of the mucilage sheath as a main difference with the typical species.

***Spirulina subsalsa* Oersted ex Gomont 1892** – "in thermal springs"

***Spirulina subtilissima* Kützing ex Gomont 1892** – Haskovo, Malo Belovo (extremely abundant), "in sulphur springs. Village Belovo, Razlog region, … Rodopi Mts, Stara Planina Mts"

***Spirulina thermalis* Meneghini ex Kützing 1847** (as "*Spirulina subtilissima* Kuetz. var. *thermalis* (Menegh.) Kabh.") – Haskovo (rare). According to GEITLER (1930-1932) the variety *thermalis* with the author Rabenhorst had to be included in the main species *Spirulina subtilissima*. KOMÁREK & ANAGNOSTIDIS (2005) had included *Spirulina thermalis* Meneghini ex Kützing 1847 among the unrevised species. Currently, in ALGAEBASE (2019) this species without any synonym was included as an entity that is currently accepted taxonomically but with a lower "Taxonomic note": "Unrevised species." (KOMÁREK &

Anagnostidis 2005: 154). - (25 Feb 2014) - M. D. Guiry". There is also a "Nomenclature note: Often attributed to "Meneghini ex Gomont" even though it was merely listed as a Species inquirendate by Gomont (1892: 255). - (25 Feb 2014) - M. D. Guiry". These all, in our opinion, explains the obvious typographic error in the author name "Kabh." provided by Petkoff (1908) after the name of Meneghini in brackets.

***Symploca meneghiniana* Kützing ex Gomont 1892** – Ovcha Kupel (extremely abundant). The text in Bulgarian Flora obviously is a summary of previous findings: "In thermal springs, on wet walls. Sofia region".

***Symploca thermalis* Gomont 1892** – Pancharevo (dominated in some samples). Endangered in the Red List of Bulgarian microalgae [EN - A4 B3 C4 D3 E1 F4 G4 T23]

***Synechococcus bigranulatus* Skuja 1933** – Rupite (rarely observed)

***Synechocystis aquatilis* Sauvageau 1892** – Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach. The text in Bulgarian Flora obviously is a summary of previous findings: "….in thermal waters. Along the valleys of the rivers Mesta and Struma".

***Thermoleptolyngbya albertanoae* Sciuto & Moro 2016** - Rupite

Division Ochrophyta

Class Tribophyceae

***Tribonema bombycinum* (C. Agardh) Derbès & Solier in Castagne 1851** (Syn. *Conferva bombycina* C. Agardh 1817) – Knyazhevo (as "*Conferva bombycina* var. *genuina*"), Bansko (abundant). Most probably, here is to be referred also "*Conferva bombycina* (Ag.) Lagerh. var. *pallida* Kuetz." found in Malo Belovo.

***Vaucheria geminata* (Vaucher) De Candolle in Lamarck & De Candolle 1805** – Opitsvet (extremely abundant), Vurshets, Malo Belovo

***Vaucheria sessilis* (Vaucher) De Candolle in Lamarck & De Candolle 1805** – Opitsvet (extremely abundant)

Class Bacillariophyceae

***Amphora affinis* Kützing 1844** (Syn. *Amphora ovalis* var. *affinis* (Kützing) Van Heurck 1885 as "*Amphora ovalis* var. *affinis* Kütz.") – Blagoevgrad (Shafa Banya - rare), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach

***Amphora ovalis* (Kützing) Kützing 1844** - Razlog

"*Amphora ovalis* var. *tenuis* Kützing" – Malo Belovo

***Brachysira exilis* (Kützing) Round & D. G. Mann 1981** (Syn. *Navicula exilis* Kützing 1844) – Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach, Bansko

***Caloneis amphisbaena* (Bory) Cleve 1894** (Syn. *Navicula amphisbaena* Bory in J. V. Lamouroux et al. 1827) – Blagoevgrad (Shafa Banya - abundant)

***Cocconeis thwaitesii* W. Smith 1853** – Bansko (abundant)

***Craticula cuspidata* (Kutzing) D. G. Mann in Round, R. M.Crawford & D. G. Mann 1990** (Syn. *Navicula cuspidata* (Kutzing) Kutzing 1844) - Marikostinovo

***Ctenophora pulchella* var. *lanceolata* (O'Meara) Bukhtiyarova 1995** (Syn. *Synedra pulchella* var. *lanceolata* O'Meara 1875) – Dobrinishte. *Data Deficient* in the Red List of Bulgarian microalgae.

***Cymatopleura elliptica* (Brébisson) W. Smith 1851** – Bansko, Malo Belovo (not evenly distributed but abundant in some sites)

***Cymbella aspera* (Ehrenberg) Cleve 1894** (Syn. *Cymbella gastroides* (Kützing) Kützing 1844) - Razlog

"*Cymbella* sp." – Haskovo

***Diatoma vulgaris* Bory 1824** (as "*Diatoma vulgare* Bory") – Malo Belovo

"Diatomaceae" – Opitsvet

***Diploneis elliptica* (Kützing) Cleve 1894** (Syn. *Navicula elliptica* Kützing 1844) - Blagoevgrad (Shafa Banya - rare), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach, Bansko

***Epithemia adnata* (Kützing) Brébisson 1838** (Syn. *Cystopleura zebra* (Ehrenberg) Kuntze 1891) – Blagoevgrad (Shafa Banya - rare), Dobrinishte, Guliyna Banya, Bansko (rare)

***Epithemia turgida* (Ehrenberg) Kützing 1844** (Syn. *Cystopleura turgida* (Ehrenberg) Kuntze 1891) – Dobrinishte

***Epithemia turgida* var. *westermannii* (Ehrenberg) Grunow 1862** (Syn. *Cystopleura turgida* var. *westermannii* (Ehrenberg) De Toni 1892) – Dobrinishte ("abundant on *Oedogonium* together with E. adnate")

***Gomphonema acuminatum* Ehrenberg 1832** (Syn. *G. acuminatum* var. *laticeps* (Ehrenberg) Grunow in van Heurck 1880 as "*G. acuminatum* var. *laticeps* (Ehr.) V.H") – Malo Belovo

***Gomphonema constrictum* Ehrenberg in Kützing 1844** – Malo Belovo

***Gomphonema ventricosum* W. Gregory 1856** – Malo Belovo

***Iconella hibernica* (Ehrenberg) Ruck & Nakov in Ruck et al. 2016** (Syn. *Campylodiscus hibernicus* Ehrenberg 1845). According to the "Status of name" in the species page in Algaebase (http://www.algaebase.org/search/species/detail/?species_id=r89bfc8cbc8b4d99a) "This name is of an entity that is currently accepted taxonomically". However, in the "Taxonomic notes" to the same species on the same page of Algaebase it is written: "Combination also proposed by E. C. Ruck, T. Nakov, A. J. Alverson & E. C. Theriot, 2016: 155, appendix A, but it is invalid: format of online material not qualifying as effective publication. [INA] - (9 Oct 2016) - Salvador Valenzuela Miranda" – Bansko, Malo Belovo

"*Navicula appendiculata* var. *budense* Grun." (In Zabelina et al. (1951; p. 345) *Navicula appendiculata* is synonym of *Pinnularia appendiculata* (Ag.) Cl. and additionally is included *P. appendiculata* var. *budense* Grun.) - Ognyanovski

Bani (Futovishta)

***Navicula amphigomphus* var. *amphigomphus* Ehrenberg 1843** (Syn. *Navicula iridis* var. *amphigomphus* (Ehrenberg) van Heurck 1880) - Bansko

"*Navicula nobilis* (Ehr.) Kütz." (most probably *Pinnularia nobilis* (Ehrenberg) Ehrenberg 1843, Syn. *Navicula nobilis* Ehrenberg 1841; *Data Deficient* in the Red List of Bulgarian microalgae) – Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach

***Neidium affine* (Ehrenberg) Pfitzer 1871** (Syn. *Navicula affinis* Ehrenberg 1843) – Marikostinovo. *Vulnerable* in the Red List of Bulgarian microalgae [VU - A3 B3 C4 D3 E1 F1 G2 T17]

***Nitzschia sinuata* (Thwaites) Grunow 1880** – Bansko (rare)

***Pinnularia appendiculata* (C. Agardh) Schaarschmidt 1881** (Syn. *Navicula appendiculata* (C. Agardh) Kützing 1844) – Ovcha Kupel

***Pinnularia major* (Kützing) Rabenhorst 1853** (Syn. *Navicula major* (Kützing) Ehrenberg 1838) – Malo Belovo

***Pinnularia viridis* (Nitzsch) Ehrenberg 1843** (Syn. *Navicula viridis* (Nitzsch) Ehrenberg 1832) – Blagoevgrad (Shafa Banya), Simitli, Dobrinishte, Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach, Bansko, Haskovo

***Pinnularia* sp.** – Marikostinovo

***Pleurosigma spenceri* (Bailey ex Quekett) W. Smith 1856** - Ovcha Kupel

***Rhoicosphenia abbreviata* (C. Agardh) Lange-Bertalot 1980** (Syn. *Rhoicosphenia curvata* (Kützing) Grunow 1860) - Malo Belovo

***Stauroneis phoenicenteron* (Nitzsch) Ehrenberg 1843** – Bansko. *Vulnerable* in the Red List of Bulgarian microalgae [VU - A3 B3 C4 D3 E1 F1 G2 T18]

***Staurosirella mutabilis* (W. Smith) E. Morales & Van de Vijver in Morales et al. 2015** (Syn. *Odontidium mutabile* W. Smith 1856) – Bansko (abundant)

"*Suriraya ovalis* var. *ovata* Kütz." – Blagoevgrad (Shafa Banya - rare), Simitli, Dobrinishte (rare), Ognyanovo, Guliyna Banya

"*Suriraya spiralis* Ktz" (most probably *Surirella spiralis* Kützing 1844, which is currently regarded as a synonym of *Iconella spiralis* (Kützing) E. C. Ruck & T. Nakov in Ruck et al. 2016. According to the "Status of name" in the species page in Algaebase (http://www.algaebase.org/search/species/detail/?species_id=161230) "This name is of an entity that is currently accepted taxonomically". However, in the "Taxonomic notes" to the same species on the same page of Algaebase it is written: "Combination also proposed by E. C. Ruck, T. Nakov, A. J. Alverson & E. C. Theriot, 2016: 155, appendix A, but it is invalid: format of online material not qualifying as effective publication. [INA] - (9 Oct 2016) - Salvador Valenzuela Miranda"; *Vulnerable* in the Red List of Bulgarian microalgae [VU - A3 B3 C4 D4 E1 F1 G3 T20]) – Bansko (rare)

"***Surirella biseriata* (Ehr.) Bréb. f. *minor obtusa* V. Heurck**" and "***Suriraya biseriata* Breb. f. *minor obtusa* V. Heurck**" (According to Algaebase (http://www.

algaebase.org/search/species/detail/?species_id=32189) *Surirella biseriata* Brébisson in Brébisson & Godey 1835: 53, pl. VII [7] (as '*Surirella* (*Suriraya*) *biseriata*') has the homotypic synonyms *Surirella biseriata* Brébisson 1835 and *Suriraya biseriata* (Brébisson) Pfitzer 1871, and is currently regarded as a synonym of *Iconella biseriata* (Brébisson) Ruck & Nakov in Ruck et al. 2016. According to the "Status of name" in the page of the last species in Algaebase (http://www.algaebase.org/search/species/detail/?species_id=161635). "This name is of an entity that is currently accepted taxonomically". However, in the "Taxonomic notes" to the same species on the same page of Algaebase it is written: "Combination also proposed by E. C. Ruck, T. Nakov, A. J. Alverson & E. C. Theriot, 2016: 155, appendix A, but it is invalid: format of online material not qualifying as effective publication. [INA] - (9 Oct 2016) - Salvador Valenzuela Miranda") - Malo Belovo

***Surirella minuta* Brébisson ex Kützing 1849** (Syn. *Surirella ovalis* var. *ovata* (Kützing) Van Heurck 1885 and *Suriraya ovalis* var. *ovata* (Kützing) Gutwinski 1899 as "*Suriraya ovalis* var. *ovata* Kütz.") – Blagoevgrad (Shafa Banya - rare), Simitli, Dobrinishte (rare), Ognyanovo, Banya (Guliyna Banya), Marikostinovo, Sveti Vrach, Haskovo

***Surirella ovalis* Brébisson 1838** (Syn. *Suriraya ovalis* (Brébisson) Pfitzer 1871 as "*Suriraya ovalis* Bréb." – Blagoevgrad (Shafa Banya - rare)

***Ulnaria ulna* (Nitzsch) Compère 2001** (Syn. *Synedra ulna* (Nitzsch) Ehrenberg 1832) – Marikostinovo, Malo Belovo ("some forms")

Division Chlorophyta

***Bulbochaete* sp. st.** - Bansko

***Chaetomorpha herbipolensis* Lagerheim 1887**: commented in Stoyneva & Gärtner (2004) – Opitsvet (abundant; not found in 2002). *Data Deficient* in the Red List of Bulgarian macroalgae

***Chaetophora elegans* (Roth) C. Agardh 1812** (as "*Chaetophora elegans* (Roth) Ag. f. *genuina* (Roth) Hansg.") – Malo Belovo

***Chlorella vulgaris* Beyerinck [Beijerinck] 1890** - Rupite

"Chlorococales": commented in Stoyneva & Gärtner (2004) – Haskovo (Haskovski Mineralni Bani)

***Cladophora glomerata* (Linnaeus) Kützing 1843**: the material from Hisarya commented in Stoyneva & Gärtner (2004) – Vurshets, Hisarya (Tinkova Cheshma, Havuz Dere)

***Cladophora fracta* (O. F. Müller ex Vahl) Kützing 1843** – "..thermal springs… Balchik region, Varna region… Vitosha Mt"

***Cladophora* sp. I**: commented in Stoyneva & Gärtner (2004) – Hisarya (Chair Banya)

***Cladophora* spp.** – Opitsvet, Ovcha Kupel

***Coelastrum proboscideum* Bohlin in Wittrock, Nordstedt & Lagerheim 1896** –

Bansko (rare)

Draparnaldia acuta **(C. Agardh) Kützing 1845** (Syn. *Draparnaldia glomerata* var. *acuta* C. Agardh 1824) – Malo Belovo

Gloeocystis vesiculosa **Nägeli 1849** - Bansko

Hydrodictyon reticulatum **(Linnaeus) Bory 1824** – Sapareva Banya, Ognyanovski Bani (Futovishta), Karlovski Bani

Neglectella solitaria **(Wittrock) Stenclová & Kastovsky in Stenclová et al. 2017** (Syn. *Oocystis solitaria* Wittrock in Wittrock & Nordstedt 1879; *Oocystella solitaria* (Wittrock in Wittrock et Nordstedt) Hindák 1988) – Bansko (rare)

Oedogonium capillare **Kützing ex Hirn 1900** – Malo Belovo

"*Oedogonium cardiacum* (Hass.) Wittr. f. *thermalis* Petkoff" (*Oedogonium cardiacum* Wittrock ex Hirn 1900 is an entity that is currently accepted taxonomically, but f. *thermalis* is not included in AlgaeBase) – Ovcha Kupel. The text in Bulgarian Flora obviously is a summary of previous findings: "Sofia region".

Oedogonium concatenatum **Wittrock ex Hirn 1900** – "in ... thermal springs. Vitosha Mt, Sofia region"

Oedogonium intermedium **Wittrock ex Hirn 1900**: commented in Stoyneva & Gärtner (2004) – Hisarya (spring Samodivsko Kladenche)

Oedogonium **spp. st.**: commented in Stoyneva & Gärtner (2004) – Dobrinishte, Malo Belovo, Opitsvet, Zheleznitsa

Palmella mucosa **Kützing 1843**: commented in Stoyneva & Gärtner (2004) – Bansko

Pediastrum boryanum **var.** ***vagum*** **(A. Braun) Chodat** (Syn. *P. vagum* A. Braun): not included in AlgaeBase, commented in Stoyneva & Gärtner (2004) - Bansko

Pithophora roettleri **(Roth) Wittrock 1877** (Syn. *Pithophora kewensis* Wittrock 1877; *Pithophora oedogonia* (Montagne) Wittrock 1877): commented in Stoyneva & Gärtner (2004) – Hisarya (spring Samodivsko Kladenche; "uncaptured spring of Hisarya with temperature about 30°C")

Pithophora **sp.**: commented in Stoyneva & Gärtner (2004) – Hisarya

Pseudopediastrum boryanum **(Turpin) E. Hegewald in Buchheim et al. 2005** (Syn. *Pediastrum boryanum* (Turpin) Meneghini 1840) – Malo Belovo (abundant)

Rhizoclonium hieroglyphicum **(C. Agardh) Kützing 1845**: commented in Stoyneva & Gärtner (2004) - Zheleznitsa, Opitsvet

Scenedesmus bijugatus **var.** ***seriatus*** **Chodat 1902** – Bansko (quite often)

Scenedesmus quadricauda **(Turpin) Brébisson in Brébisson & Godey 1835** – Draginovo, Haskovo (abundant)

Sphaerellocystis ampla **(Kützing) Nováková 1964** (Syn. *Gloeocystis ampla* (Kützing) Rabenhorst 1863) – Bansko (abundant)

Stauridium tetras **(Ehrenberg) E. Hegewald in Buchheim et al. 2005** (Syn.

Pediastrum tetras (Ehrenberg) Ralfs 1845) – Bansko (quite often)

***Stigeoclonium thermale* A. Braun in Kützing 1849**: commented in Stoyneva & Gärtner (2004) – Hisarya, Zheleznitsa, Opitsvet, "mainly, preliminary in thermal springs"

***Ulothrix zonata* (F. Weber & Mohr) Kützing 1833**: commented in Stoyneva & Gärtner (2004) – Ovcha kupel (on the thalli of *Chara foetida* f. *thermalis* Petkoff, extremely abundant in the spring before its capture), Opitsvet

***Ulothrix zonata* var. *rigidula* (Kützing) Hansgirg 1886** - Simitli

Division Streptophyta

***Chara braunii* C. C. Gmelin 1826** (Syn. *Chara coronata* J. B. Ziz ex G. W. Bischoff 1828): commented in Stoyneva & Gärtner (2004) – Hisarya (Samodivski Izvor and nameless spring in front of the fountain Tinkova Cheshma), Karlovski Bani

"*Chara coronata* Ziz. f. *intermedia* Petkoff (inter f. *humilior* A. Br. et f. *tenuior* A. Br."). (*Chara coronata* J. B. Ziz ex G. W. Bischoff 1828 is currently regarded as a synonym of *Chara braunii* C. C. Gmelin 1826): commented in Stoyneva & Gärtner (2004) – Karlovski Bani

"*Chara foetida* A. Br. α) *subinermis* ß) *longibracteata* A. Br." (? *Chara foetida* var. *subinermis* f. *longibracteata*; *Chara foetida* A. Braun 1834 is currently regarded as a synonym of *Chara vulgaris* Linnaeus 1753): commented in Stoyneva & Gärtner (2004) – Malo Belovo

"*Chara foetida* f. *macrostephana* Wahldst" (*Chara foetida* A. Braun 1834 is currently regarded as a synonym of *Chara vulgaris* Linnaeus 1753): commented in Stoyneva & Gärtner (2004) – Malo Belovo

"*Chara foetida* f. *macroptila*. 2. *Minor, humilior, pauciramosa brevipapillosa*" (*Chara foetida* A. Braun 1834 is currently regarded as a synonym of *Chara vulgaris* Linnaeus 1753): commented in Stoyneva & Gärtner (2004) – Malo Belovo

"*Chara foetida* f. *microptilla* Mig." (*C. foetida* A. Braun 1834 is currently regarded as a synonym of *Chara vulgaris* Linnaeus 1753): commented in Stoyneva & Gärtner (2004) – Malo Belovo

"*Chara foetida* f. *minor*, *humilior*, *pauciramosa brevipapillosa*" (*C. foetida* A. Braun 1834 is currently regarded as a synonym of *Chara vulgaris* Linnaeus 1753) – Malo Belovo

"*Chara foetida* f. *thermalis* Petkoff" (*C. foetida* A. Braun 1834 is currently regarded as a synonym of *Chara vulgaris* Linnaeus 1753): commented in Stoyneva & Gärtner (2004) - Ovcha Kupel (abundant before capture; not found in 2002)

"*Chara fragilis* Dezv. f. *normalis* Mig." (*Chara fragilis* Desvaux in Loiseleur Deslongschamps 1810 is currently regarded as a synonym of *Chara globularis* Thuiller 1799): commented in Stoyneva & Gärtner (2004) – Vetren Dol

“***Chara gymnophylla* f. *thermalis* Petkoff 1934”** (*Chara gymnophylla* A. Braun 1835 is currently regarded as a synonym of *Chara vulgaris* var. *gymnophylla* (A. Braun) C. F. Nyman 1884): commented in Stoyneva & Gärtner (2004) including its mentioning as *Chara gymnophylla* f. *pulchella* Mig. – Malo Belovo (extremely abundant in 1913, 1934)

***Closterium acerosum* Ehrenberg ex Ralfs 1848**: commented in Stoyneva & Gärtner (2004) - Dobrinishte (rare)

***Closterium closterioides* (Ralfs) A. Louis & Peeters 1967**: commented in Stoyneva & Gärtner (2004) - Zheleznitsa

***Closterium decorum* f. *minor* Petkoff** – see *Closterium delpontei* (Klebs) Wolle 1885

***Closterium delpontei* (Klebs) Wolle 1885**: commented in Stoyneva & Gärtner (2004) with the proposal that *Closterium decorum* f. *minor* Petkoff 1925 belongs to this species - Bansko (rare). *Near Threatened* in the Red List of Bulgarian microalgae [NT - A4 B3 C4 D1 E1 F1 G1 T15]

“***Closterium digitus*”**: commented in Stoyneva & Gärtner (2004) as most probably belonging to *Netrium digitus* (Brébisson ex Ralfs) Itzigsohn & Rothe in Rabenhorst 1856; according to AlgaeBase (2019) *Closterium digitus* Ehrenberg 1832: 68, nom. inval. should be regarded as synonym of *Netrium digitus* (Brébisson ex Ralfs) Itzigsohn & Rothe in Rabenhorst 1856) – Marikostinovo

***Closterium ehrenbergii* Meneghini ex Ralfs 1848** – Malo Belovo

***Closterium lanceolatum* Kützing ex Ralfs 1848** – Vurshets, Malo Belovo

***Closterium pritchardianum* W. Archer 1862**: commented in Stoyneva & Gärtner (2004) – Ovcha Kupel. *Near Threatened* in the Red List of Bulgarian microalgae [NT - A3 B4 C3 D2 E1 F2 G1 T16]

“***Closterium*”** - Opitsvet

***Cosmarium botrytis* Meneghini ex Ralfs 1848**: commented in Stoyneva & Gärtner (2004) – Bansko (often, even abundant), Malo Belovo (“between the filaments of *Scytonema cincinatum* and *O. splendida*”)

“***Cosmarium botrytis* ad var. *paxilosporum* West et West”**: commented in in Stoyneva & Gärtner (2004) – Bansko* (often, even abundant)

***Cosmarium laeve* Rabenhorst 1868**: commented in in Stoyneva & Gärtner (2004) – Bansko

***Cosmarium meneghinii* Brébisson ex Ralfs 1848** - Bansko

***Cosmarium sexnotatum* Gutw. ad var. *tristriatum* (Luetkemüller) Schmidle**: the species is currently accepted taxonomically, but the variety is not discussed in Algae Base; Petkoff 1925 identified it after “West et G. G, West, p. 228, pl. LXXXVI, fig. 8-9” and provided a description; comments on the description are given in Stoyneva & Gärtner (2004) – Simitli*

***Cosmarium subtumidum* Nordstedt in Wittrock, Nordstedt & Lagerheim 1878**: commented in in Stoyneva & Gärtner (2004) with pointing the similarity in dimensions with *C. subtumidum* var. *klebsii* (Gutwinski) W. et G. S. West (which is not discussed in AlgaeBase)- Bansko

Cosmarium tinctum **Ralfs** 1848 – Bansko

Cosmarium turpinii **Brébisson 1856** – Vurshets

Cosmarium venustum **(Brébisson) W. Archer in Pritchard 1861** – Bansko (rare)

"*Cosmarium*" – Opitsvet

"*Euastrum binale* f. *secta* Turn." (*Euastrum binale* Ehrenberg ex Ralfs 1848 is currently accepted taxonomically, but f. *secta* Turn. is not included in AlgaeBase) – Bansko (often)

Euastrum insulare **(Wittrock) J. Roy 1877** - Bansko

Mesotaenium endlicherianum **var. *grande* f. *brevior* Petkoff 1925**: commented in Stoyneva & Gärtner (2004) – Bansko (rare). *Data Deficient* in the Red List of Bulgarian microalgae.

Mougeotia angusta **(Hassall) Czurda 1932** (Syn. *Mougeotia parvula* var. *angusta* (Hassall) Kirchner): commented in Stoyneva & Gärtner (2004) – Bansko. *Near Threatened* in the Red List of Bulgarian microalgae [NT - A4 B3 C4 D1 E1 F2 G1 T16]

Mougeotia **spp. st.**: commented in Stoyneva & Gärtner (2004) – Zheleznitsa, Opitsvet, Narechenski Bani

Netrium digitus **(Brébisson ex Ralfs) Itzigsohn & Rothe in Rabenhorst 1856**: commented in Stoyneva & Gärtner (2004); see also "*Closterium digitus*" - Bansko

Pleurotaenium trabecula **Nägeli 1849**: commented in Stoyneva & Gärtner(2004) – Bansko* (rare)

Spirogyra columbiana **Czurda 1932**: commented in Stoyneva & Gärtner (2004) – Ovcha Kupel. *Vulnerable* in the Red List of Bulgarian microalgae [VU - A3 B2 C4 D2 E1 F4 G3 T19]

Spirogyra crassa **(Kützing) Kützing 1843** (as "*Spirogyra crassa* (Kuetz.) Petit.") – Malo Belovo, Ovcha Kupel

Spirogyra jugalis **(Dillwyn) Kützing 1845**: commented in Stoyneva & Gärtner (2004) – Marikostinovo; *Data Deficient* in the Red List of Bulgarian microalgae

Spirogyra neglecta **(Hassall) Kützing 1849** – Malo Belovo

Spirogyra reticulata **Nordst. *forma* Petkoff 1934/35**: commented in Stoyneva & Gärtner (2004) – Vurshets

Spirogyra varians (Hassall) Kützing 1849: commented in Stoyneva & Gärtner (2004) - Bansko

Spirogyra **spp. st.**: commented in Stoyneva & Gärtner (2004) – Dobrinishte, Svetata Voda, Novata Voda, spring in Yanensko, Hisarya, Narechen, Zheleznitsa, Opitsvet

Zygnema **spp. st.** – Dobrinishte

Zygnema **sp. st.** (? *Zygogonium* sp. ster. ad *Zygogonium ericetorum* Kützing 1843): commented in Stoyneva & Gärtner (2004) - Opitsvet

Division Rhodophyta

***Audouinella chalybea* (Roth) Bory 1823** (Syn. *Chantransia chalybea* (Roth) Fries 1825) – Malo Belovo

"*Batrachospermum moniliforme* Roth var. *helminthoides* Sirod" (most probably *Batrachospermum helminthosum* Sirodot 1884, nom. illeg. which is accepted by Eloranta et al. (2011) as a synonym of *Batrachospermum confusum* (Bory 1808) Hassal 1845 emend. Vis et al. 1995; the variety is not included in AlgaeBase) – Malo Belovo (well developed before 1908, completely disappeared before 1929)

***Hildenbrandia rivularis* (Liebmann) J. Agardh 1851** – Malo Belovo (well developed before 1908, progressively disappearing in 1929). *Near Threatened* in the Red List of Bulgarian macroalgae

***Thorea hispida* (Thore) Desvaux 1818** (Syn. *Thorea ramosissima* Bory 1808) – Gotse Declhev (Toplitsi, karst), Malo Belovo (abundant in 1908 but in 1929 mentioned as "completely disappeared since the last 10 years"). *Critically Endangered* in the Red List of Bulgarian macroalgae [CR B1ab(i,ii,iii); C1] and in the Red Data Book of R Bulgaria.

In addition to all taxa enlisted above, Stoyneva (2003) considered species from the unpublished diploma paper of Lukov (1964) and summarized data on 14 taxa from the papers by Petkoff (1900, 1904, 1907, 1908, 1913, 1922, 1934) reported for villages with thermal springs without indication of the exact localities. In the opinion of Stoyneva (2003) it is difficult to refer the last taxa to thermal habitats but they have to be considered in further studies.

Considering the results from the checklist provided above, the order of thermal complexes according to their algal biodiversity is as follows: Bansko – 45, Malo Belovo – 40, Dobrinishte – 22, Marikostinovo – 21, Simitli – 18, Ognyanovo – 15, Rupite – 17, Blagoevgrad (Shafa Banya) – 17, Banya (Guliyna Banya) – 16, Haskovo – 15, Opitsvet -15, Hisarya -14, Sveti Vrach – 14, Pancharevo – 11, Ovcha Kupel – 10, Vurshets – 7, Sapareva Banya – 6, Zheleznitsa – 6, Karlovski Bani – 4, Razlog – 4, Draginovo – 3, Narechen – 3, Gotse Delchev – 2. From each of the other thermal springs only one species was published.

DISCUSSION

Although records on biodiversity of Bulgarian thermophyton are scarce, the results from literature search proved its general richness – 206 taxa from five divisions (phyla): Cyanoprokaryota (82), Rhodophyta (4), Ochrophyta (44: 3 - Tribophyceae, 40 - Bacillariophyceae), Chlorophyta (32) and Streptophyta (44) – **Fig. 1**. This total number of taxa, obtained after the recent taxonomic updates, is on conformity with the total number of "more than 200 species, varieties and forms" pointed by Stoyneva (2003, p. 566). The highest number of cyanoprokaryotes and important role of green algae, followed by diatoms was already indicated by Stoyneva (2003) and illustrated by her Figures 1 and 2. Some differences in species distribution and total composition (with presence of glaucophytes in particular) between this paper and the paper by Stoyneva (2003) come from her considering of some hardly available unpublished data, which were not taken into account in this paper.

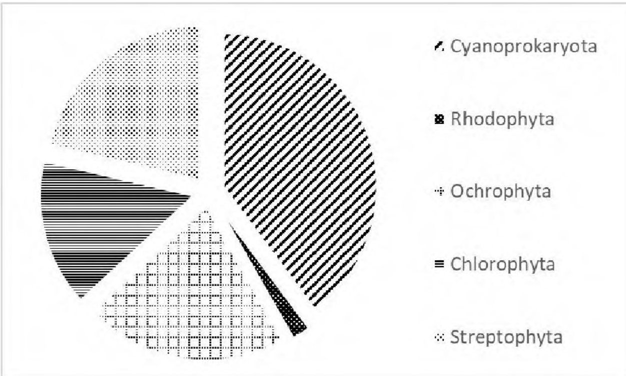

Fig. 1. Taxonomic structure of the algal flora of Bulgarian thermal springs, baths and their effluents. The position of taxonomic groups followes clockwise direction.

Doubtless, the rich algal biodiversity reflects the diversity of thermal spring and system types, which exist in Bulgaria (for details, see Stoyneva 2003 and Stoyneva & Gärtner 2004). Among all taxa found, there are 21 species of conservation importance: *Critically Endangered* (1), *Endangered* (4), *Vulnerable* (6), *Near Threatened* (5) and *Data Deficient* (5). It is possible to suppose that further more detailed studies with modern polyphasic approach will reveal more rare and threatened species.

The distribution of species by thermal systems outlines the thermal springs of Bansko and Malo Belovo as the richest in algal biodiversity (45 and 40 algae, respectively). Considering the thermal types of Vouk (1923, 1948) it is easily explainable by the cool (chliarithermal) type of these two springs and their effluents – 21°C and 22-23.5°C of the main springs, respectively. Logically, they are followed by the group of springs of eu- and akrothermal waters (30-50 °C and 50-70 °C, respectively) with lowest number of species found in hyperthermal waters (>70 °C). However, this conclusion is quite tentative since for most of the species the exact temperature of finding was not indicated while in most publications the temperature of the main source is given. The same problem was outlined by Stoyneva (2003) in discussion of the real temperatures of occurrence and limits of distribution of green algae. Additionally, we have to note that most data were based on single samplings at a spot and this is strongly reflected in the results on site biodiversity evaluations. More, 151 taxa (or, 74%) are published as found in one site only and for other 15 taxa (7%) only general distribution in thermal springs was noted without indication of the location. Our results are in accordance with the data of Stoyneva (2003) that 68% of green algae were documented for one site only.

Many of the species from the Checklist were noted as found in the effluents of the thermal springs without pointing the exact distance from the source, or temperature difference. Therefore, it is difficult to state that all species listed above are strictly thermal and more detailed investigations in this aspect are needed. More, all algae have been found in a period of 120 years and it is not possible to state that they all occurred at the same time and could be find recently in the thermal spring systems of Bulgaria. However, in the increased pace of habitat losses due to capturing of the springs, construction of new modern spa centers with permanent cleaning of the algae, or usage of springs for heating purposes or as laundries, this Checklist can serve as a basic archive for future investigations of this important ecological group of extremophilic algae.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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NEW DATA OF *GENTIANA LUTEA* SSP. *SYMPHYANDRA* (GENTIANACEA) IN BULGARIA

DIMITAR R. PEEV, ANTONINA A. VITKOVA*, LYUBA N. EVSTATIEVA & NATALIA V. VALYOVSKA

Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Str., 1113 Sofia, Bulgaria

Abstract. *Gentiana lutea* ssp. *symphyandra* is a target species in the National System for monitoring of biodiversity in Bulgaria, where it is included in category 1 – *Priority species*. The control populations are located in the Central Balkan National Park (above the hut *Tuzha*), Vitosha Nature Park (below the locality *Reznyovete*), Rila National Park (localities *Tiha Rila* and *Urdina reka*) and in the Pirin National Park (locality *Kazanite*). The paper presents new data on the population structure (in terms of space and age) of *Gentiana lutea* subsp. *symphyandra*, its vegetation dynamics, reproductive capacity and participation in different phytocenoses and habitats. Eleven natural populations of the subspecies in five mountains located in four floristic regions and one subregion of Bulgaria were examined. Evidence for *under the snow development* of plants is reported for the first time. Prognosis and proposals for better protection of the species are given.

Key words: habitats, medicinal plant, protection, reproductive capacity, threats

INTRODUCTION

Gentiana lutea ssp. *symphyandra* (Murb.) Hayek is a target taxon in the National System for monitoring of biodiversity of Bulgaria (NBMS), where it is included in category 1 – *Priority species*. At the same time, there are some taxonomical

**corresponding author*: A. A. Vitkova – Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Acad. G. Bonchev Str., 1113 Sofia, Bulgara; avitkova@bio.bas.bg

uncertainties and gaps in the knowledge on its distribution and reproduction in Bulgaria. According to Tutin (1972) *G. lutea* ssp. *lutea* is widespread throughout the range of the species, except the Balkan Peninsula, while *G. lutea* ssp. *symphyandra* occurs on the Balkan Peninsula and in South-Eastern Alpes.

The first data on the occurrence of *Gentiana lutea* in Bulgaria (localities around *Suhoto Ezero* and *Kobilino Branishte* in the Rila Mt) were reported by Velenovsky (1898). During the next period of about hundred years, there was less progress in the studies of this species, but in the last three decades Kozhuharov & Petrova (1982), Kozhuharova et al. (1994), Kozhuharova (1997, 1999), Vitkova & Evstatieva (1999), Evstatieva & Vitkova (1999), Kozhuharova & Bozilova (2001), Kozhuharova & Hadzieva (2004), Georgieva (2007) and Assyov & Petrova (2012) have contributed to its chorology in Bulgaria. The interspecific variability and taxonomic status of *G. lutea* in Bulgarian populations have been interpreted in different ways. For example, Velenovsky (1898) noted the species without any variability, while later (Hayek 1928) included in his *Prodromus G. lutea* ssp. *symphyandra* (Murb.) Hayek. Stoyanov & Stefanov (1925) accepted this distinction, but pointed out the taxon with a different taxonomic level: *G. lutea* var. *symphyandra* Murb. Later on, Kozhuharov & Petrova (1982) rejected the possibility of occurring of *G. lutea* ssp. *lutea* in Bulgaria, while Assyov & Petrova (2012) accepted the species *G. lutea* s.l. as spread in the country. Most information about *G. lutea* s.l. in Bulgaria can be found in Georgieva & Evstatieva (2000) and Georgieva & Russakova (2000). Currently, the species is spread in five floristic regions of Bulgaria – the mountains Stara Planina, Vitosha, Rila, Pirin and the Rodopi (Georgieva 2007). The author reported 37 localities according to herbarium materials, her own research and literature data, where the species populations covered area between 50 and 10 000 m^2 on silicate or limestone rock bases at different soil horizons and different humidification.

The information on the vegetation dynamics of *Gentiana lutea* s.l. reported by different authors is quite similar. Certain data about the height distribution of the species can be found for the Stara Planina Mt, Rila Mt, Pirin Mt. and Rodopi Mts, where the altitude range is between 1200 m a.s.l. (Kozhuharov & Petrova 1982) and 2900 m a.s.l. (Assyov & Petrova 2012). Evstatieva (2015) reports that *G. lutea* grows on rocky slopes or forest meadows, located near the upper border of the forest. The slopes of the terrain occupied by the species vary from almost equal to 45°.

The species is pollinated by insects, less often by wind, and is propagated generatively by seeds and vegetatively by growing from the rhizome. Comparative testing of fresh harvested seeds showed very low germination (4%) (Georgieva 2007). A low reproductive capacity /<1/ was reported from three localites of *G. lutea* ssp. *symphyandra* in the Rila Monastery Reserve (Sidjimova et al. 2014).

The value of *G. lutea* as a medicinal plant is well known. The activity of its root compounds in the treatment of dyspepsia, anemia, and fatigue after severe illness was shown by KITANOV (1987), PETKOV (1982) and NIKOLOV (2006). The phenolic content and antioxidant activity in roots and leaves collected from Bulgarian populations of *G. lutea* ssp. *symphyandra* were investigated (NIKOLOVA ET AL. 2012). According to the official data, during the last 75 years more than 5000 kg roots of the population of the locality *Yurushka Gramada* in the Stara Planina Mts have been excavated. This activity has led to a significant reduction of the population area and in abundance of plants, which have not recovered yet. A similar case was observed in the locality Skakavitsa of the Rila National Park. Some years ago the population was destroyed by illegal collection of roots and now it exists through some individuals only (GEORGIEVA 2007). Because of such threats, *G. lutea* s.l. was recently included in the MEDICINAL PLANT ACT (2000), BIOLOGICAL DIVERSITY ACT (2002), SUPPLEMENT 3 OF THE ACT ON AMENDING AND SUPLEMENTING THE BIOLOGICAL DIVERSITY ACT (2007), in the Red List of Bulgarian vascular plants (PETROVA & VLADIMIROV 2009) and in the Bulgarian Red Data Book (PEEV 2015) with the IUCN category *Endangered*. As it was outlined above, *Gentiana lutea* ssp. *symphyandra* in particular, is a target priority taxon in the National System for monitoring of biodiversity of Bulgaria.

Considering the conservational importance of this subspecies and the background of unresolved problems of its taxonomy and distribution, the main aims of the present study were: 1) To investigate the spread of *G. lutea* ssp. *symphyandra* and to map its populations in Bulgaria; 2) To reveal the occurrence of the species in plant communities and habitats; 3) To determine its breeding capacity, as well as the spatial and age structure of the populations; 4) To outline the main threats an d propose relevant conservation measures.

MATERIAL AND METHODS

The present study was carried out in the periods July-September 2010 and April – October 2011. A chorological review of the herbarium collections of SOM, SO, SOA was done. Populations of the species were investigated in four floristic regions of Bulgaria - Rila Mt (Rila National Park), Pirin Mt (Pirin National Park), Vitosha Mt (Vitosha Nature Park), Rodopi Mts (Shabanitsa Natural Reserve) and floristic subregion Stara Planina (central) (National Park Central Balkan) - **Fig. 1.** The control populations (according to NSMB) are located in the Central Balkan National Park (above the hut *Tuzha*), Vitosha Nature Park (below the locality *Reznyovete*), Rila National Park (localities *Tiha Rila* and *Urdina reka*) and in the Pirin National Park (locality *Kazanite*).

During the field research, GPS coordinates were taken, and some biotic and abiotic parameters were measured. The area, altitude, exposure and slope inclination are provided in **Table 1**. The age structure of the populations of *G. lutea* ssp. *symphyandra* was evaluated by transects. The number of plants was examined on two sites with an area of 1-10% of the total population area.

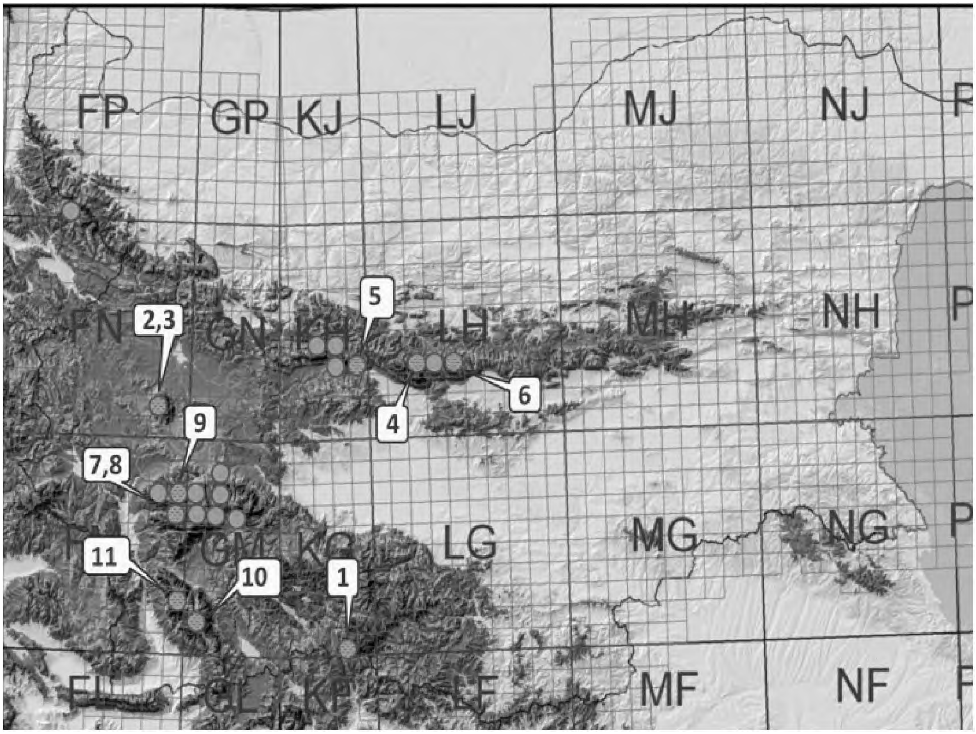


Fig. 1. Map of Bulgaria with indication of the studied populations of *Gentiana lutea* ssp. *symphyandra* (map modified after PEEV 2015).

The age scale used in the study was as follows:

- Juvenile individuals – only rosettes from 5 to 10 cm in diameter (no stems)
- Vegetative individuals – only rosettes from 11 to 25 (30) cm in diameter (no stems)
- Flowering /generative/ individuals – a rosette with a diameter of over 25 cm and flowering stems

Juvenile, vegetative and generative individuals per m^2 were counted (**Table 1**). Based on these data, the number of individuals in the area of each population was calculated. The number of seeds per individual was estimated/ and the seed production of the populations was calculated (**Table 2**). The seed reproductive capacity (RC) was calculated as a ratio between the number of all individuals in the population and the number of seeds obtained from all identified generative individuals, using the standard formula: RC% = (number of all individuals in the population/the number of seeds in all generative individuals) x 100.

The habitats in which *G. lutea* ssp. *symphyandra* was distributed were determined according to KAVRUKOVA ET AL. (2009) and (BISERKOV 2015).

Table 1. Localities of the studied populations of *Gentiana lutea* ssp. *symphyandra* and their age structure.

	Population /site, geographic coordinates, altitude, area, exposure, slope/	**Juvenile plants per m²**	**Vegetative plants per m²**	**Generative plants per m²**	**Total number of plants per m²**
1.	The Rodopi Mts., Shabanitsa Nature Reserve, 41°32'31.4" N 24°27'29.3" E, 1806 m a.s.l.; 5 ha; Southeast; 1-5°	0.07	0.25	0.09	0.41
2.	Vitosha Nature Park, below peaks *Maluk Rezen* and *Golyam Rezen* 42°34'31.9" N 23°17'96.2" E 1891 m a.s.l.; 0.02 ha; East; 10-15°	0.01	0.04	0.08	0.13
3.	Vitosha Nature Park, along a path from *Aleko* hut to *Fiskulturnik* hut 42°34'09.1" N 23°17'85.1" E 1925 m a.s.l.; 0.2 ha; Southeast; 15-20°	0.002	0.20	0.01	0.21
4.	Central Balkan National Park, loc. *Kupena*, 42°42'58.6" N 23°49'29.5" E 1678 m a.l.s.; 4 ha; East; 10-15°	-	0.002	0.003	0.005
5.	Central Balkan National Park, loc. *Kozya stena*, 42°47'26.7"N 24°32'23.6"E 1589 m a.l.s.; 0.01 ha; West; 10-15°	-	0.007	0.005	0.01
6.	Central Balkan National Park, loc. above hut *Tuzha*, 42°44'43.9"N 24°58'25.6"E 1753 m a.l.s.; 10 ha; Southeast; 5-10°	0.10	0.31	0.02	0.43
7.	Reserve Rilski Manastir (Rila Monastery Reserve), loc. *Tiha Rila - Energoto* 42°08'07.8" N 23°28'44.5" E 1780 m a.s.l.; 1.2 ha; West; 5-10°	0.003	0.03	0.01	0.04
8.	Reserve Rilski Manastir (Rila Monastery Reserve), loc. *Tiha Rila* – south from the bridge, 42°07'54.6" N 23°28'54.3" E 1801 m a.s.l.; 1.5 ha; West; 1-5°	0.0001	0.0003	0.006	0.01
9.	Rila National Park, loc. *Urdina Reka – Golemoto pole*. 42°13'23.5"N 23°48'09.0"E 1807 m a.s.l.; 1.2 ha; Northeast;1-5°	0.001	0.050	0.005	0.06
10.	Pirin National Park, loc. *Yavorova Polyana*, 41°49'35.6"N 23°23'38.1"E 1698 a.s.l.; 1 ha; East; 1-5°	0.005	0.070	0.030	0.11
11.	Pirin National Park near Vihren peak – loc. *Kazanite* 41°46'.19.5" N 23°24'53.7" E 2220 m a.s.l; 10 ha; East; 20-25°	0.007	0.030	0.02	0.06

The data from the control populations were included in a special "Terrain form" for plants accepted by the Bulgarian National Biomonitoring System (Gussev et al. 2008). The data will be used as a basis for the official National Data Base for *Gentiana lutea* ssp. *symphyandra*. The fulfilled forms were deposited in the National Environmental Executive Agency, in the directorates of National Parks as well as in the Regional Inspectorate of Environment and Waters.

RESULTS AND DISCUSSION

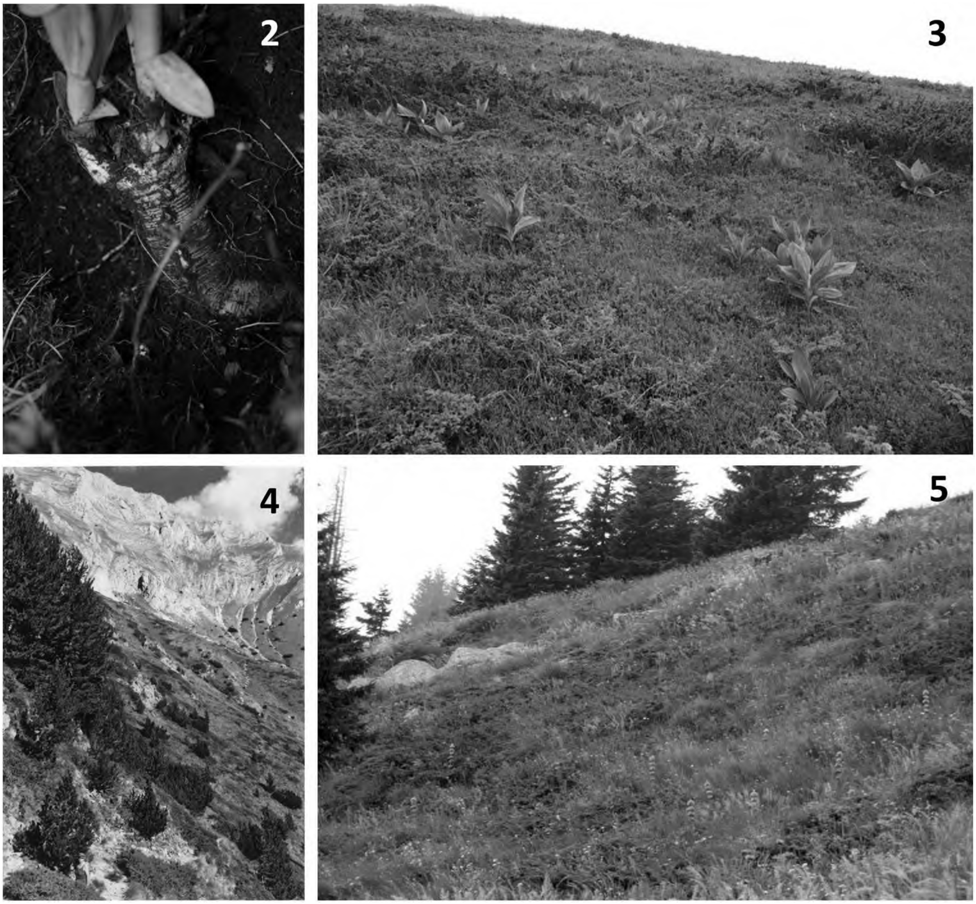
1. *Gentiana lutea* ssp. *symphyandra* and its presence in phytocenoses and habitats

1.1. Phytocenoses

In the course of the present study it was found that most of the localities of *G. lutea* ssp. *symphyandra* were found at the altitudes between 1589 and 2200 m a.s.l. According to the vertical zonation of the Bulgarian forest complex, the populations of the subspecies were found mostly in the coniferous belt and in the alpine belt (Radkov 1963). The populations were distributed in the open places in the *Pinus peuce* forests (Rila National Park, around the chalet *Skakavitsa*) in grass-lands of *Picea abies* forests (Rila National Park, localities *Kirilova polyana* and *Beliya Uley*). In addition, we observed a very interesting coenotic combination of *G. lutea* ssp. *symphyandra* with *Pinus heldreichii* Christ. in the localities *Yavorova Polyana* and *Pogledets* of the Pirin National Park.

The disposition of significant populations in different coenotic structures corresponded with relatively high ecological plasticity of the subspecies and its compatibility with the function of mountain plant communities. The distribution of the populations allowed finding the ecological optimum for the development of the investigated plant in the Bulgarian mountains. In the altitude range of 1800–2220 m a.s.l., the populations of *G. lutea* ssp. *symphyandra* were observed within communities of *Juniperus sibirica* Burgsd. and/or *Pinus mugo* Turra (Rila Monastery Reserve/Rila National Park – locality *Tiha Rila*, Pirin National Park - locality *Kazanite*, Central Balkan National Park and Vitosha Nature Park). In this zone, the species grew on rich, highly humid, brown forest soil, with occasional small rocky fragments. The populations were distributed in open spaces in coniferous forests. The well-developed root system of the plants makes them a stable element in the communities occupying steep terrains. The bottom part of the root is oriented perpendicularly to the slope **(Fig. 2)** and this prevents the plants from eradicating in case of accelerated melting of the snow. The highest studied population was at 2200 m a.s.l. in the locality *Kazanite* in the Pirin National Park. There the species grows in the extreme conditions of the steep terrain and soil mixed with rock fragments. Similar are the environmental conditions, in which grow the populations of Vitosha Natural Park, located along the paths between the huts *Aleko* and *Fizkulturnik*. The populations of *Kozya Stena* in the Central Stara

Planina and *Yavorova Polyana* in Pirin National Park are located at lower altitudes and terrain with a smaller slope (**Table 1**).



Figs. 2-5: 2 - *Gentiana lutea* ssp. *symphyandra* - position of the root of the plant in relation to the slope of terrain; **3** - Central Balkan National Park, near the hut *Tuzha,* habitat 4060*;* **4** - Pirin National Park, locality *Kazanite*, habitat 4070; **5** - Vitosha Nature Park, along the path between the huts *Aleko* and *Fizkulturnik*, habitat 9410.

We found some contradiction with Scharfetter (1953 - cit. acc. to Kozuharova 2005) who reported that "*G. lutea* doesn't react to the temperature and light gradient and this reaction is interpreted as a primitive feature". If this is true for *G. lutea* ssp. *lutea*, it is not valid for *G. lutea* ssp. *symphyandra*, since its populations grow in places with maximum light and high soil temperature because of higher albedo of the brown mountain soils. Our results also show that the population areas recorded in 2010-2011 were larger than the areas reported by Georgieva (2007).

1.2. Habitats

The populations of *G. lutea* ssp. *symphyandra* are distributed in the following significant habitats of European importance by Directive 92/438EEC:

4060. Alpine and boreal heaths; EUNIS: F2.2A2 Balkano-Hellenic dwarf bilberry heaths; (Central Balkan National Park, near the hut *Tuzha* **(Fig. 3)** and at *Kozya Stena*).

4070 *Bushes with Pinus mugo and *Rhododendron hirsutum*; EUNIS: F2.48 Balkano-Rhodopide (Pirin National Park, locality *Kazanite* **(Fig. 4)**.

91BA Moesian silver fir forests; EUNIS: G.3.16 Moesian [*Abies alba*] forests (Rila Monastery Reserve, locality *Tiha Rila - Energoto*).

Figs. 6-7, 9-10: 6 - National Park Rila, population above *Sedemte Rilski Ezera*, habitat 4070; **7** - The Rodopi Mts, Shabanitsa Nature Reserve, habitat 91CA; **9** - *Gentiana lutea* ssp. *symphyandra* - plant with vegetative buds at the end of the growing season; **10** - Cultivarion of *Gentiana lutea* ssp. *symphyandra* in the experimental field *Beglika* /Western Rodopi Mts./

9410. Acidophillous *Picea* forests of the montane to alpine levels (Vaccinio-Piceetea); EUNIS: G3.1E Southern European [*Picea abies*] forests; (Vitosha Nature Park, along the path between the huts *Aleko* and *Fizkulturnik* **(Fig. 5)** and between the peaks *Maluk Rezen* and *Golyam Rezen* **(Fig. 6)**.

95A0. High oro-Mediterranean pine forests; EUNIS: G3.623 Rila and Pirin Macedonian pine forests, (Pirin National Park, locality *Yavorova Polyana*)

91CA. Rhodopi and Balkan Range Scots pine forests; EUNIS: G3.4C Southeastern European [*Pinus sylvestris*] forests (Rodopi Mts, Shabanitsa Nature Reserve **(Fig. 7)**.

According to the distribution of the studied populations in the habitats mentioned above, it is possible to accept them as elements of shrub and forest communities in open places under mountain conditions in Europe. However, there was one exception – the combination of *Gentiana lutea* ssp. *symphyandra* with *Pinus heldreichii* in the habitat 95A0 with typical sub-Mediterranean origin in the region of Pirin National Park).

2. Vegetation dynamics

During our field studies, we found that the first flowering individuals were observed in late May and early June at the altitude of 1600-1900 m a.s.l. **(Fig. 8)**. In the middle of August till the end of September, the seeds in these populations became ripe and were scattered. At altitudes between 1900 and 2100 m a.s.l this process was delayed by 10-15 days and ripe seeds could be found around the middle of October. The late flowering period in the populations above 2100-2200 m a.s.l. resulted in maturing of the seeds after mid-October.

Fig. 8. *Gentiana lutea* ssp. *symphyandra* in a phase of mass flowering.

The ripe capsules were dehiscent and the seeds were easy dispersed over long distances by the wind. Typical examples were found around the chalet *Tiha Rila* (Rila Monastery Reserve) and at the peak *Kozya Stena* (Central Balkan National Park) where single young individuals could be seen 1 km away from the "mother" population. Our observations fully correspond to the data by Georgieva (2007) and Evstatieva (2015) on the flowering time and on the formation of ripe seeds in the populations of *G. lutea* ssp. *symphyandra*). At our late autumn visits in the mountains, we observed under-snow development of plants. The same process was also found in other high-mountain plants, such as *Primula deorum* Velen. (Peev, unpubl.). The plants form vegetative buds on the rhizome at the end of the growing season **(Fig. 9)**. Thus, alpine plants are preparing for the coming vegetation season, which is relatively short at the altitude of 1700-2200 m a.s.l.

3. Spatial structure

According to the mode of propagation and microtopographic conditions of the populations, their spatial structures were identified as follows:

- Single individuals: at 300–400 m distance from the main group (in the locality *Tiha Rila* of the Rila Monastery Reserve and in the Pirin National Park – on the eastern slope in the locality *Kazanite*)
- Small-numbered group (40-50 individuals): at a distance of 4-15 m from each other (Rila National Park - locality *Golyamo Pole* - cirque of the rivulet *Urdina Reka*; Vitosha Nature Park - along the path between the huts *Aleko* and *Fizkulturnik*);
- Middle-numbered group (up to 1000 individuals): in a relatively small area, at a distance of 0.8–1.5 m from each other in Rila Mt. (locality *Tiha Rila*);
- Numerous group (more than 1000 individuals): at a distance of 1–14 m from each other, covering a comparatively large area (1.5–10 ha). Such examples were observed in the Central Balkan National Park, above the chalet *Tuzha*; in the Pirin National Park, locality *Kazanite*; and in the Rodopi Mts, locality *Shabanitsa*.

The highest abundance of the species was recorded in the localities near huts *Tuzha* and *Shabanitsa*, with 0.43 plants m^2 and 0.41 plants m^2, respectively **(Table 1)**.

4. Age structure

During the survey in 2011, the vegetative individuals dominated in the all observed populations **(Table 1)**. The number of generative /flowering/ plants was about three times less compared to the number of vegetative plants. This ratio can be interpreted as a big biotic reserve of the species for future vegetation seasons. The highest number of flowering individuals per m^2 was found in the localities *Shabanitsa* (The Rodopi Mts), between the peaks *Maluk Rezen* and *Golyam Rezen* (Vitosha Mt), and *Yavorova Polyana* (Pirin Mt). Most vegetative individuals were found in the localities above *Tuzha* hut, *Shabanitsa* and along the path between the huts *Aleko* and *Fizkulturnik*. The highest number of juvenile plants was found in the localities near the hut *Tuzha* and *Shabanitsa* (The Rodopi Mts). The highest total number of juvenile, vegetative and generative plants was found in the localites *Tiha Rila* (Rila National Park) and *Shabanitsa* Natural Reserve (Rodopi Mts). This high biological potential is most likely due to the favorable environmental conditions in these areas combined with the conservation regime in Rila National Park and *Shabanitsa* Natural Reserve. The latter reserve is situated at the southern state border of Bulgaria, where the former border regime restricted the number of tourists and gatherers.

5. Reproductive capacity

It is widely known that the reproductive capacity is strongly related to the pollen productivity, pollination effectiveness and seeds production. The populations of *G. lutea* ssp. *symphyandra* could be accepted as clear panmictic populations since only groups of cross-pollinated individuals were observed. This was experimentally proved by covering the flowers by bags, thus protecting them from visits of eventual pollinators, as a result of which they did not form seeds. Therefore, it is possible to state that there is a difference from the opinion of Kozuharova et al. (1994), Kozuharova & Bozilova (2001) and Kozuharova (2004) that this subspecies forms partially self-pollinated groups of individuals and is characterized by geitonogamy.

The metapopulations observed in one season (2011) had a total of about 8092 flowering plants. Each of these plants had 1 to 3 flowering stems on average. The average number of flowers per stem was 25, therefore it could be accepted that each flowering plant had 112.5 flowers on average. According to Georgieva & Evstatieva (2000), each fruit capsule contains about 70-100 seeds. In our study, we found 68.2 seeds per capsule on average. The general seed production of all studied populations in one season (2011) could be estimated? maximum 8092 flowering plants with average of 7677 seeds per individual, which makes a total of 62 125 757 seeds (**Table 2**). Since the number of vital seeds is about 50% of their total number (Georgieva & Evstatieva 2000), *i.e.* maximum number of seeds that could be produced in real conditions is 31 062 878. However, despite the great seed productivity of the species in the natural populations, very few seeds actually germinate. This is due to both the physiological features of the subspecies and the specific ecological conditions in the habitats in which it occurs. Georgieva (2007) followed seed germination of *Gentiana lutea* s.l. under controlled conditions and found that it was very low (4%). According to her observations, plants enter a generative period at the age of ten years, when they begin to bloom and form seeds. During our study, the generative individuals were found to bloom over a 2-3 (4) year period in most localities of *G. lutea* ssp. *symphyandra*. Similar results were reported by Brouz (1992) and Sidjimova et al. (2014).

6. The populations of *G. lutea* ssp. *symphyandra* and their threats

The studied populations of *G. lutea* ssp. *symphyandra* in Bulgaria are distributed over different types of protected Bulgarian areas and on some sites from of the European ecological network NATURA 2000. However, inhibited/restricted/arrested? development of the species was observed on some localities caused by the negative anthropogenic impact such as the destruction of the vegetation by the passage of large groups of tourists (in the locality *Rilski Ezera*),

Table 2. Reproductive capacity of *Gentiana lutea* ssp. *symphyandra* at the studied localites.

	Locality	**Total number of plants**	**Number of flowering plants**	**Number of seeds from 1 plant**	**Number of seeds from all flowering plants**	**Repro-ductive capacity, %**
1.	The Rodopi Mts. Shabanitsa Nature Reserve	20 500	4 500	7 900	35 550 000	0.06
2.	Vitosha Nature Park, below the peaks *Maluk Rezen* and *Golyam Rezen*	26	16	8 066	129 056	0.02
3.	Vitosha Nature Park, along a path from *Aleko* hut to *Fizkulturnik* hut	466	22	7 236	159 192	0.29
4.	Central Balkan National Park, *Kupena*	200	120	4550	546 000	0.04
5.	Central Balkan National Park, *Kozya Stena*	12	5	5100	25 500	0.05
6.	Central Balkan National Park, above *Tuzha* hut	21 500	1000	8457	8 457 000	0.25
7.	Rila Monastery Reserve, loc. *Tiha Rila - Energoto*	516	120	6400	768 000	0.07
8.	Rila Monastery Reserve loc. *Tiha Rila* - south of the bridge	87	5	5891	29 455	0.30
9.	Pirin National Park, loc. *Urdina Reka – Golemoto Pole*	53	4	5588	22 352	0.24
10.	Pirin National Park loc. *Yavoro-va Polyana*	1 050	300	6964	2 089 200	0.05
11.	Pirin National Park, loc. *Kazanite*	3000	2000	7175	14 350 000	0.01
	Total for the meta-population	47 410	8092	average: 7677	62 125 755	average: 0.11

illegal root extraction, terrain erosion (nearby hut *Skakavitsa*) and strong grazing pressure (in the locality *Tiha Rila*). Excessive presence in the communites of *G. lutea* ssp. *symphyandra* of dominant species such as *Juniperus sibirica* Burgsd. or *Chamaecithysus absinthioides* (Janka) Kuzm., as well as the climate warming, led to a reduction of the frequency of occurrence and of the territories covered by its populations. A similar trend was observed in the Rila National Park in the vicinity of the locality *Tiha Rila* and in the Central Balkan National Park near hut *Tuzha*. Some negative effects were caused by the wild boars (which eat the roots of *Gentiana*) and by the rolling stones on the steep slopes in the Pirin National Park (locality *Kazanite*) and Rila National Park (locality *Beliya Uley*). Regarding the conservation and sustainable use of this valuable medicinal plant, its cultivation is necessary. Successful trials were already conducted in the Rodopi Mts., on the *Beglika Experimental Field* (Georgieva 2007; Vitkova et al. 2012) - **Fig. 10**.

CONCLUSION

The results of the present study provide valuable information on the current state of the populations of the protected plant *Gentiana lutea* ssp. *symphyandra* in Bulgaria. Its populations were found to be in good condition, but climate change, natural phytocenotic processes and anthropogenic pressures have negative impact on some of them. Although this plant has a very high seed production, its reproductive capacity is comparatively low in nature, with approximately 0.1% of the seeds germinating and forming plants in the natural populations. This is due to the following reasons: 1) The thick grass cover often prevents seeds to fall under conditions favorable to their germination; 2) In some cases, due to the steep slope, strong erosion involves the soil together with the germinating seeds and young plants.

The warming of the climate in recent years has probably changed the optimal conditions necessary for the development of this high-mountain plant in the natural populations. The elaboration of Action plans, microtopographic mapping of the populations and serious control in situ by the Park's directorates make it possible to give a positive prognosis for further protection. In relation to the conservation of *G. lutea* ssp. *symphyandra* in nature, as well as its sustainable use in medicine, the species needs to be cultivated in conditions close to those in the natural habitats.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

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FLORA AND VEGETATION IN FOREST NATURAL HABITATS OF NATURA 2000 PROTECTED AREA *KAMCHIA* (BG0000116) AND *BEACH SHKORPILOVTSI* (BG0000100)

ALEXANDER N. TASHEV[1*], ANTONINA A. VITKOVA[2] & ALEXANDRA V. ALEXANDROVA[1]

[1] *Faculty of Forestry, University of Forestry, 10 Kliment Ohridski Blvd., 1797 Sofia, Bulgaria*
[2] *Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences, 2 Gagarin Str., 1113 Sofia, Bulgaria*

Abstract. The flora and vegetation in the protected area *Kamchia* were studied, as part of the European ecological network Natura 2000 within the implementation of the project *Mapping and determination of the environmental status of natural habitats and species – phase I.* Contract Nr. 04-014/05.04.2011. The paper presents data on the flora and vegetation in five types of forest natural habitats with codes 91E0, 91F0, 91G0, 91M0 and 92A0. Totally 222 high plant species were recorded in the studied habitats and seven of them were with conservation status. All obtained data confirmed the high conservation value of the flora and vegetation of the protected area and need for strict measures for its protection.

Key words: forest habitats, EUNIS, Directive 92/43/EC, protected species

INTRODUCTION

The present study aimed to assess the current status of the flora and vegetation of the forest natural habitats in the protected area (PA) *Kamchia* (BG0000116),

**corresponding author*: A. N. Tashev – Faculty of Forestry, University of Forestry, 10 Kliment Ohridski Blvd., 1797 Sofia, Bulgaria; altashev@abv.bg

which is a part of the European ecological network NATURA 2000. The literature review shows that there is one preceding publication on the flora of the studied area and more data on its vegetation with a stress on riparian forests (Penev 1984; Ivanov et al. 2002; Peev et al. 2003; Georgiev 2004, 2008; Rusev 2004; Zhelev & Yurukov 2004). Current status of its five forest and non-forest natural habitats was discussed by Tashev et al. (2018a,b) with special attention on the flora and vegetation of the non-forest habitats (Tashev et al. 2017).

MATERIAL AND METHODS

The studied protected area (PA) *Kamchia* is a part of the European ecological network NATURA 2000, declared as such with a decree of the Council of Ministers of the Republic of Bulgaria Nr. 802/04.12.2007 (State Gazette Nr.107/2007). The territory of PA *Kamchia* is 129 199.37 dka and includes a nature reserve with the same name. PA *Kamchia* covers the easternmost parts of the Kamchia river valley and the foothills of Stara Planina (Balkan Range) going to the Black Sea. The zone covers the territories on the banks of Kamchia from Grozdyovo village from the West to the mouth of the Kamchia river in the Black Sea at the East. It is announced protected area according to Directive 92/43/EEC/ and Directive 2009/147/EC with the name Complex Kamchia (BG0002045). The orography of PA *Kamchia* is variable – it is plain along Kamchia river and becomes hilly in the north and south direction. On the entire territory of the area, longer or shorter ravines are deeply jutted into the rock fundament, thus forming steep and very steep slopes. The studied area belongs to the Continental-Mediterranean climatic area, Black Sea climatic sub-area and Northern Black Sea climatic region (Velev 2002, 2010). The climate is characterized by warm summer and mild winter, relatively small annual temperature amplitude, and autumn-winter precipitation maximum and the absence of annual sustainable snow cover in regions out of the mountains. Annual precipitation amounts are between 500 and 1000 mm and the higher values are related to the ways of the Mediterranean cyclones. The soils are classified as belonging to Carpatho-Danubian soil region, and the East Balkan province (Malinova 2010). The predominant soil types are Luvisols, Chromic Luvisols, which form complexes with Rankers and Lithosols in some places. There are also Fluvisols and Alluvial Fluvisols. Soils are mainly IV productivity class, characterized with acid reaction, poor, seasonal surface over-moisturising, erosion processes and shallow.

The field work was conducted during the period July-September 2011. The identification of habitats was done according to Kavrukova et al. (2008) and to the Red Data Book of the Republic of Bulgaria (Biserkov 2015). Each natural habitat was checked also using EUNIS classification. The choice of the places for description was done after visual evaluation of typical sectors within a plant community. The area of description was 256 m^2 (16x16 m experimental plots – EP). Full floristic inventory was done for each plot and the cover of each taxon was evaluated according to Braun-

Blanquet (1964). In the presence of vertical fragmentation, the description of the floristic composition is done by vertical levels from top to bottom. GPS coordinates, including altitude, were taken for each description plot (**Tables 1, 3, 5, 7, 9**).

Table 1. Geographical coordinates of phytocoenological descriptions of natural habitat 91E0.

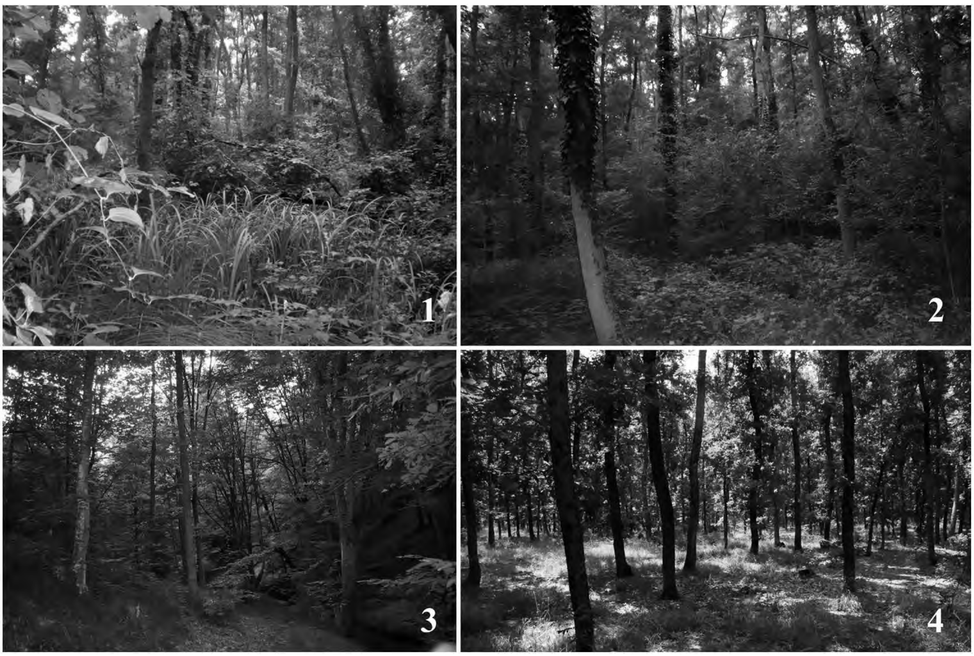
Experimental Plot	Geographical coordinates		Altitude [m]	Date
	N	E		
EP 1	43.02129	27.84326	13	3.08.2011
EP 2	43.01991	27.72668	21	5.08.2011
EP 3	42.99890	27.88502	2	6.08.2011
EP 4	43.00119	27.87231	9	7.08.2011
EP 5	43.05241	27.54002	30	8.08.2011
EP 6	43.03054	27.70299	22	10.08.2011
EP 7	43.01904	27.71494	21	10.08.2011

The plant taxa were identified according to Jordanov et al. (1963-1989), Velchev (1982, 1989), Kozuharov (1995), Delipavlov & Cheshmedzhiev (2011) and Kozuharov & Anchev (2012). The data were analyzed according to the habitat type. Species of conservation status were identified following Petrova & Vladimirov (2009), Peev (2015), the Biological Diversity Act (2007) with Appendices № 3 and 4 (amended in State Gazette 101/22.12.2015), and according to Directive 92/43/EC/21.05.1992 for conservation of natural habitats of the wild flora and fauna. Also, the Convention on the Conservation of European Wildlife and Natural Habitats Appendix I. (Bern Convention, 1979), European Red List of Vascular Plants (Bils et al. 2011) and 1997 IUCN Red List of Threatened Plants (Gillet & Walters 1998) were considered.

Because of difficulties to determine some plant species during the field work, for them herbarium material was taken for identification in the laboratory. Cameral work included processing of data obtained from field work into tables according to types of natural habitats (**Table 2, 4, 6, 8, 10**). Plant species there are divided according to biological type and for each species the experimental plot in which it was found is shown together with its relative abundance. Species with conservation status were also identified according to national and international reference documents (**Table 12**) – Red List of Bulgarian vascular plants (Petrova & Vladimirov 2009) and Red Data Book of the Republic of Bulgaria (Peev 2015), Biological Diversity Act (Act on Amending and Supplementing 2007, Appendices Nr.3 and 4, amended State Gazette 101/22.12.2015) and Directive 92/43/EEC/21.05.1992 for conservation of natural habitats and of wild flora and fauna. Among the international documents Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1973), Convention on the Conservation of European Wildlife and Natural Habitats Appendix I. (Bern Convention 1979), European Red List of Vascular Plants (Bils et al. 2011) and 1997 IUCN Red List of Threatened Plants (Gillet &Walters 1998) were taken into account.

RESULTS AND DISCUSSION

A total of 37 phytosociological descriptions were performed for the typical plant communities on the territory of PA *Kamchia*. Below are presented data on the floristic composition and phytocoenological peculiarities of the five forest natural habitats identified in the area (Tashev et al. 2018a): **1) Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*,** *Alnion incanae*, *Salicion albae*) **(91E0). EUNIS: G1.413 Southern Helleno-Balkanic swamp alder woods (Fig. 1)**. During the current study in this habitat, 7 phytocoenological descriptions were done and totally 76 species were found **(Tables 1-2)**. According to the limited occurrence and plants biodiversity, the habitat is of a high nature conservation value.



Figs. 1-4: 1 - Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*) (91E0) in PA *Kamchia*; **2 -** Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*) (91F0) in PA *Kamchia*; **3 -** Pannonic woods with *Quercus petraea* and *Carpinus betulus* (91G0) in PA *Kamchia*; **4 -** Pannonian-Balkanic turkey oak-sessile oak forests (91M0) in PA *Kamchia*.

However, during the last decades, as a result from the changed water regime of the River Kamchia because of the building of the reservoirs Kamchia and Tsonevo, the territories of this habitat rapidly decreased. This demands immediate measures for conservation and rehabilitation of the habitat; **2) Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*) (91F0). EUNIS: G1.2232 Helleno-Balkanic ash-oak-alder forests (Fig. 2)**. The forests in this habitat are riparian mixed deciduous forests, which are periodically flooded and are known with the term *longoz* (DIMITROVA ET AL. 2007). It has to be boldly underlined that the proclamation of the reserve had the aim to preserve exactly this habitat type. During the study, seven phytocoenological investigations were done and 123 higher plants were recorded **(Tables 3-4)**. The conservation priority of longozes is due both to their rare type and taxonomic richness. However, due to the anthropogenic impact on the habitat in the region of investigation, the occurrence of numerous dangerous and strongly competitive invasive species was observed (TASHEV ET AL. 2018A). The rapid decrease of the area of this habitat noted during the last years (BISERKOV 2015) could be explained with the influence of the reservoirs Kamchia and Tsonevo, which were built in the watershed of the Kamchia River and changed its water regime (TASHEV ET AL. 2018A). Undesirable succession, expressed by replacement of hygrophytes in phytocoenoses by more drought-resistant plant species, was observed in the communities and showed the need of urgent measures for the conservation and restoration of this natural habitat; **3) Pannonic woods with *Quercus petraea* and *Carpinus betulus* (91G0). EUNIS: G1.A1C31 Moesian mesophile oak-hornbeam forests (Fig. 3)**. In the investigated area for this habitat, two phytocoenological descriptions were made and 52 species were determined **(Tables 5-6)**. Due to the difficultly accessible terrains there was no negative anthropogenic impact on this habitat; **4) Pannonian-Balkanic turkey oak-sessile oak forests (91M0). EUNIS: G1.768 Moesio-Danubian thermophilous oak forests (Fig. 4)**. In this habitat four phytocoenological descriptions were done and 79 species were recorded **(Tables 7-8)**. The habitat is anthropogenically impacted and invasion of *Robinia pseudoacacia* has been observed; **5) *Salix alba* and *Populus alba* galleries (92A0). EUNIS: G1.3155 Rhodopine Mediterranean poplar galleries (Fig. 5)**. This type of habitat was

Fig. 5. *Salix alba* and *Populus alba* galleries (92A0) in PA *Kamchia*.

reported for the first time in the PA *Kamchia* (Tashev et al. 2018a). Six phytocoenological descriptions were made and 84 species were recorded (**Tables 9-10**). A degradation was established in this habitat as a result from the anthropogenic activity due to the recreation to large groups of people and fishing (Tashev et al. 2018a).

The conservation value of the investigated types of natural habitats and plant species on the territory of PA *Kamchia* is presented on **Tables 11-12**.

Table 2. Floristic and phytocoenological characterization of natural habitat 91E0 Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*) in PA *Kamchia*.

№	**Species**	**Abundance (after Braun-Blanquet 1964)**						
		EP1	**EP2**	**EP3**	**EP4**	**EP5**	**EP6**	**EP7**
	Trees							
1.	*Acer campestre* L.	-	+	-	1 - 2	-	-	+
2.	*Alnus glutinosa* (L.) Gaertn.	2 - 3	4	4	2	-	-	2
3.	*Carpinus betulus* L.	-	1	-	-	-	1 - 2	1 - 2
4.	*Fraxinus excelsior* L.	3 - 4	-	-	-	-	-	-
5.	*Fraxinus oxycarpa* M. Bieb. ex Willd.	-	3	2	4	2	2	2
6.	*Populus alba* L.	-	-	3	-	2 - 3	-	3
7.	*Pyrus pyraster* Burgsd.	-	-	+	-	-	-	-
8.	*Quecus robur* L.	-	-	+ - 1	-	-	1 - 2	-
9.	*Salix alba* L.	-	1	-	-	2	2	3
10.	*Salix fragilis* L.	-	-	-	-	2	2	-
11.	*Salix triandra* L.	-	-	-	-	-	1 - 2	-
12.	*Tilia platyphyllos* Scop.	-	+	-	-	-	-	-
13.	*Ulmus leavis* Pall.	-	-	-	2	2	1 - 2	1
14.	*Ulmus minor* Mill.	+	1	1	2	2	1 - 2	1
	Shrubs and lianas							
15.	*Cornus sanguinea* L.	+	1	-	-	-	1 - 2	+
16.	*Corylus avellana* L.	-	+	-	-	-	-	-
17.	*Crataegus monogyna* Jacq.	+	+	+	1 - 2	-	1	-
18.	*Evonymus europaeus* L.	-	1	-	1	-	-	+
19.	*Hedera helix* L.	-	1	r	1 - 2	-	-	1 - 2
20.	*Periploca graeca* L.	+	+ - 1	2	+	-	-	+
21.	*Rosa canina* L.	-	-	-	-	-	-	+

№	Species	Abundance (after Braun-Blanquet 1964)						
		EP1	EP2	EP3	EP4	EP5	EP6	EP7
22.	*Rubus caesius* L.	-	-	-	3	5	-	+
23.	*Rubus hirtus* Waldst. & Kit.	1	-	+	-	-	-	-
24.	*Salix purpurea* L.	-	-	-	-	+ - 1	-	-
25.	*Sambucus nigra* L.	-	+	-	-	-	-	-
26.	*Vitis sylvestris* C. C. Gmel.	-	-	+	-	-	-	-
	Herbaceous plants							
27.	*Aegopodium podagraria* L.	-	1 - 2	-	-	-	+	-
28.	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	-	-	-	-	-	+ - 1	-
29.	*Angelica sylvestris* L.	-	1	-	-	-	2	-
30.	*Arctium tomentosum* Mill.	-	-	-	-	+	-	-
31.	*Asparagus tenuifolius* Lam.	-	-	r	-	-	-	-
32.	*Brachypodium sylvaticum* (Huds.) P. Beauv.	-	-	+	-	+	-	-
33.	*Calamagrostis pseudo-phragmites* (Haller f.) Koeler	+	-	-	-	-	-	-
34.	*Calystegia sepium* (L.) R. Br.	-	+	+	-	-	+	+ - 1
35.	*Carex remota* L.	-	-	+	2 - 3	-	+	+
36.	*Carex* sp.	+	-	-	-	-	-	-
37.	*Chaerophyllum* sp.	-	-	-	-	+	-	-
38.	*Circaea luteciana* L.	+	-	-	-	-	-	-
39.	*Cucubalus baccifer* L.	-	-	-	-	+	-	-
40.	*Dactylis glomerata* L.	-	-	-	-	-	-	+
41.	*Equisetum arvense* L.	+	-	-	-	-	-	-
42.	*Equisetum telmateia* Ehrh.	-	2 - 3	-	-	-	1	1
43.	*Euphorbia palustris* L.	-	-	-	-	r	-	-
44.	*Galium aparine* L.	-	-	-	1	1 - 2	+ - 1	-
45.	*Galium palustre* L.	1 - 2	-	-	1	+	+	-
46.	*Geum urbanum* L.	-	-	-	-	-	+	+
47.	*Humulus lupulus* L.	-	-	-	-	2 - 3	-	1 - 2
48.	*Iris pseudacorus* L.	+	+	-	1	-	-	-
49.	*Lapsana communis* L.	-	-	-	-	+	-	-
50.	*Leucojum aestivum* L.	+	+	-	3	-	+ - 1	1
51.	*Lycopus europaeus* L.	+	+	+	+	+	+	+

№	Species	Abundance (after BRAUN-BLANQUET 1964)						
		EP1	EP2	EP3	EP4	EP5	EP6	EP7
52.	*Lysimachia nummularia* L.	+	+	-	+	-	-	-
53.	*Lysimachia punctata* L.	+	-	-	-	-	-	-
54.	*Lythrum salicaria* L.	-	-	+	-	-	+	1
55.	*Lythrum* sp.	-	-	-	-	-	-	2
56.	*Mentha aquatica* L.	-	-	-	-	-	+	-
57.	*Oenanthe aquatica* (L.) Poir.	-	1	-	-	-	+	-
58.	*Persicaria hydropiper* (L.) Opiz (Syn. *Polygonum hydropiper* (L.) Delabre)	-	+	-	-	-	-	-
59.	*Phytolacca americana* L. (Syn. *Phytolacca decandra* L.)	-	-	-	-	+	-	-
60.	*Phragmites australis* (Cav.) Trin. ex Steud.	-	-	-	-	-	-	+ - 1
61.	*Potentilla reptans* L.	-	-	+	-	-	-	-
62.	*Ranunculus lanuginosus* L. var. *constantinopolitanus* DC. (Syn. *Ranunculus constantinopolitanus* (DC.) D'Urv.)	+	-	-	-	-	-	-
63.	*Ranunculus repens* L.	+	-	-	-	-	-	-
64.	*Rumex sanguineus* L.	+	-	-	-	-	-	-
65.	*Ruscus aculeatus* L.	-	-	r	-	-	-	-
66.	*Scirpus lacustris* L. (Syn. *Schoenoplectus lacustris* (L.) Palla)	-	4	-	-	-	1 - 2	1 - 2
67.	*Scirpus sylvaticus* L.	4	-	-	+	-	-	-
68.	*Scirpus triqueter* L. (Syn. *Schoenoplectus triqueter* (L.) Palla)	-	-	-	-	-	-	1 - 2
69.	*Smilax excelsa* L.	+	3	+	+	-	2	+
70.	*Solanum dulcamara* L.	1 - 2	+	+	-	-	+	+
71.	*Stachys palustris* L.	+	-	-	-	-	-	-
72.	*Stellaria nemorum* L.	-	-	-	-	-	+	-
73.	*Symphytum officinale* L.	1	-	-	-	-	-	-
74.	*Tamus communis* L.	-	-	+	-	-	-	-
75.	*Urtica dioica* L.	+	-	-	-	1	1	-
76.	*Viola odorata* L.	-	-	+	-	-	-	-
77.	Bryophyta	-	-	-	1 - 2	-	-	-

Table 3. Floristic and phytocenological characterization of natural habitat 91F0 Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)) in PA *Kamchia.*

№	Species	Abundance (after Braun-Blanquet)																	
		EP 1	EP 2	EP 3	EP 4	EP 5	EP 6	EP 7	EP 8	EP 9	EP 10	EP 11	EP 12	EP 13	EP 14	EP 15	EP 16	EP 17	EP 18
Trees																			
1.	*Acer campestre* L.	2	+	-	+	+	1	2 - 3	2	+	-	-	-	1 - 2	2	2 - 3	2 - 3	-	3
2.	*Acer negundo* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
3.	*Alnus glutinosa* (L.) Gaertn.	-	-	-	-	-	1 - 2	-	-	-	-	-	-	-	-	-	-	3	-
4.	*Carpinus betulus* L.	1 - 2	-	-	2	2	-	-	3	-	-	-	-	+	-	-	-	-	2
5.	*Carpinus orientalis* Mill.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
6.	*Fraxinus oxycarpa* M. Bieb. ex Willd.	2 - 3	3	4	2	3	3	4	2 - 3	3 - 4	3	3	4	4	3	3 - 4	3	4	3 - 4
7.	*Gleditsia triacanthos* L.	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
8.	*Juglans nigra* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
9.	*Morus alba* L.	-	-	-	-	-	-	-	-	-	+	1	-	+	-	-	-	-	-
10.	*Morus nigra* L.	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11.	*Populus alba* L.	+	-	-	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-
12.	*Prunus cerasifera* Ehrh.	+	-	-	-	+	+	+	-	+	+	+	+	+	+ - 1	-	+	-	+
13.	*Prunus domestica* L. subsp. *insititia* Schneider (Syn. *Prunus insititia* L.)	-	-	-	-	-	-	-	-	-	-	-	-	+ - 1	-	-	-	-	-
14.	*Prunus padus* L.	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

№	Species	Abundance (after Braun-Blanquet)																	
		EP 1	**EP 2**	**EP 3**	**EP 4**	**EP 5**	**EP 6**	**EP 7**	**EP 8**	**EP 9**	**EP 10**	**EP 11**	**EP 12**	**EP 13**	**EP 14**	**EP 15**	**EP 16**	**EP 17**	**EP 18**
15.	*Pyrus pyraster* Burgsd.	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-
16.	*Quercus cerris* L.	-	-	+	-	2	-	-	-	-	-	-	-	+	-	-	-	-	-
17.	*Quercus frainetto* Ten.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
18.	*Quercus petraea* (Mattuschka) Liebl.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
19.	*Quecus robur* L.	2 - 3	2	+	2	-	3	3	2 - 3	3	-	-	-	2	+	-	-	-	+
20.	*Sorbus torminalis* (L.) Crantz	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
21.	*Tilia platyphyllos* Scop.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
22.	*Ulmus leavis* Pall.	2	1	+	+	-	-	2	1 - 2	2	2	2	+ - 1	1	1	1 - 2	2	2	-
23.	*Ulmus minor* Mill.	1	2	+	+	-	-	2	1 - 2	2	2	-	+	1	1	1 - 2	2	-	2
	Shrubs and lianas																		
24.	*Amorpha fruticosa* L.	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
25.	*Clematis vitalba* L.	+	-	-	1	-	-	-	-	+	+	+	-	-	+	-	1 - 2	-	-
26.	*Cornus mas* L.	-	-	-	-	-	-	-	1 - 2	-	-	-	-	-	-	-	-	-	+
27.	*Cornus sanguinea* L.	+ - 1	+	-	-	-	+	-	-	-	-	-	+	1	1	+	+ - 1	-	+ - 1
28.	*Crataegus monogyna* Jacq.	+	+ - 1	2	+	+	+	3	1	3	1	+	+	1 - 2	2	+	+ - 1	-	+ - 1

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		EP 1	EP 2	EP 3	EP 4	EP 5	EP 6	EP 7	EP 8	EP 9	EP 10	EP 11	EP 12	EP 13	EP 14	EP 15	EP 16	EP 17	EP 18
29.	*Evonymus europaeus* L.	+	+	-	-	-	+	+	1	-	-	-	-	+	-	-	1 - 2	+ - 1	+
30.	*Hedera helix* L.	2 - 3	3	-	4	5	3	1 - 2	5	-	-	-	-	+	-	3	-	1 - 2	4
31.	*Ligustrum vulgare* L.	+	-	-	-	-	+	-	1 - 2	-	-	-	-	-	-	-	-	-	-
32.	*Periploca graeca* L.	+	-	-	-	-	+ - 1	-	+	-	-	-	-	-	-	-	-	+	-
33.	*Robinia pseudoacacia* L.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34.	*Rosa canina* L.	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	-	-	+
35.	*Rubus caesius* L.	-	-	-	-	-	-	-	-	-	+ - 1	-	-	-	-	-	-	-	-
36.	*Rubus hirtus* Waldst. & Kit.	2	3	2	-	-	2	3	1	2 - 3	-	-	+ - 1	+ - 1	2	-	+	2	1
37.	*Sambucus nigra* L.	-	-	-	-	1	-	-	-	3	2	1 - 2	+ - 1	+	-	1	+	-	-
38.	*Staphylea pinnata* L.	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
39.	*Vitis sylvestris* C. C. Gmel.	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Herbaceous plants																			
40.	*Aegopodium podagraria* L.	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41.	*Agrimonia eupatoria* L.	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-
42.	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	+	-	-	+	1	+	+ - 1	+ - 1	1	-	-	-	-	-	1	-	-	-

№	Species	Abundance (after Braun-Blanquet)																	
		EP 1	EP 2	EP 3	EP 4	EP 5	EP 6	EP 7	EP 8	EP 9	EP 10	EP 11	EP 12	EP 13	EP 14	EP 15	EP 16	EP 17	EP 18
43.	*Angelica sylvestris* L.	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+ - 1	-
44.	*Anthriscus sylvestris* (L.) Hoffm.	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-
45.	*Arctium lappa* L.	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+ - 1	-	-
46	*Arctium tomentosum* Mill.	+	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-
47.	*Aristolochia clematitis* L.	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
48.	*Artemisia absinthium* L.	-	-	-	-	-	-	-	-	-	1 - 2	-	-	-	-	-	-	-	-
49.	*Artemisia annua* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
50.	*Artemisia vulgaris* L.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-
51.	*Arum orientale* M. Bieb.	-	-	-	-	-	-	-	+	r	-	-	-	r	-	-	-	-	-
52.	*Ballota nigra* L.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
53.	*Brachypodium sylvaticum* (Huds.) P. Beauv.	+	1	3	+	+	+	1	1	+ - 1	3	+	1 - 2	3	1	+	4	-	+ - 1
54.	*Bromus* sp.	-	-	+	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-
55.	*Bromus sterilis* L.	-	-	-	-	-	-	-	-	-	3	-	3	-	-	-	-	-	-
56.	*Calamintha sylvatica* Bromf.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
57.	*Calystegia sepium* (L.) R. Br.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+
58.	*Campanula trachelium* L.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
59.	*Cardamine pratensis* L.	-	-	+ - 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60.	*Carex divulsa* Stokes	-	1	+	-	-	+	-	-	-	-	1	-	+	-	-	+	-	+

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		EP 1	EP 2	EP 3	EP 4	EP 5	EP 6	EP 7	EP 8	EP 9	EP 10	EP 11	EP 12	EP 13	EP 14	EP 15	EP 16	EP 17	EP 18
61.	*Carex remota* L.	+	+ - 1	-	+	-	-	-	-	+	-	-	-	-	2	-	+	-	-
62.	*Carex* sp.	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
63.	*Carex sylvatica* Huds.	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-
64.	*Chaerophyllum byzantinum* Boiss.	-	+	+ - 1	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
65.	*Chaerophyllum* sp.	-	-	-	-	-	-	-	-	-	1	2	+	+ - 1	+	1 - 2	1	-	+
66.	*Chelidonium majus* L.	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
67.	*Chenopodium* sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
68.	*Cichorium inthybus* L.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
69.	*Circaea luteciana* L.	-	+	-	-	-	+	+	-	-	-	-	+	+	-	-	-	-	-
70.	*Cirsium alatum* (S. G. Gmel.) Bobr.	+	-	+	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
71.	*Cirsium* sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-
72.	*Conium maculatum* L.	-	-	-	-	-	-	-	-	-	-	1	2 - 3	-	-	-	-	-	-
73.	*Conyza canadensis* (L.) Cronquist	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
74.	*Dactylis glomerata* L.	-	+ - 1	-	+	+	-	-	+ - 1	-	+	-	-	1 - 2	-	-	-	-	+ - 1
75.	*Daucus carota* L.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
76.	*Dipsacus* sp.	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
77.	*Erigeron annuus* (L.) Pers.	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-
78.	*Euphorbia amygdaloides* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+

№	Species	Abundance (after Braun-Blanquet)																	
		EP 1	EP 2	EP 3	EP 4	EP 5	EP 6	EP 7	EP 8	EP 9	EP 10	EP 11	EP 12	EP 13	EP 14	EP 15	EP 16	EP 17	EP 18
79.	*Festuca gigantea* (L.) Vill.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
80.	*Galium aparine* L.	+	+	1	-	1	-	1 - 2	1	1 - 2	2 - 3	2	2 - 3	+ - 1	1 - 2	-	+	+	-
81.	*Galium rotundifolium* L.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
82.	*Geum urbanum* L.	+	+	+	+	+	+	+	+	1	-	+	+	+ - 1	1	2	1	+	+
83.	*Glechoma hederacea* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
84.	*Heracleum sibiricum* L.	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-
85.	*Hordeum* sp.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
86.	*Humulus lupulus* L.	-	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1	-
87.	*Iris pseudacorus* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3 - 4	-
88.	*Lamiastrum galeobdolon* (L.) L. (Syn. *Lamium galeobdolon*)	-	-	-	-	+ - 1	-	-	-	-	-	-	-	-	-	-	-	-	-
89.	*Lapsana communis* L.	-	-	+ - 1	-	-	-	-	-	-	+	+	-	-	-	-	-	-	+
90.	*Lathyrus laxiflorus* (Desf.) Kuntze	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
91.	*Leucojum aestivum* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	2 - 3	-	-	2 - 3	-
92.	*Lycopus europaeus* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
93.	*Lysimachia nummularia* L.	+ - 1	-	+	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-
94.	*Lysimachia punctata* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-

№	Species	Abundance (after Braun-Blanquet)																	
		EP 1	EP 2	EP 3	EP 4	EP 5	EP 6	EP 7	EP 8	EP 9	EP 10	EP 11	EP 12	EP 13	EP 14	EP 15	EP 16	EP 17	EP 18
95.	*Lythrum salicaria* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
96.	*Melissa officinalis* L.	-	-	+	+	-	-	-	-	-	1 - 2	-	+	+	-	-	+	-	+
97.	*Mercurialis annua* L.	-	-	-	-	+ - 1	-	-	-	-	-	-	-	-	-	-	-	-	-
98.	*Myrrhoides nodosa* (L.) Cannon	+	-	2	+	1 - 2	-	-	-	+	-	+	-	+	2 - 3	3	-	-	-
99.	*Oenanthe aquatica* (L.) Poir.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
100.	*Parietaria officinalis* L. (Syn. *Parietaria erecta* Mert. & Koch)	+	+	-	-	-	-	-	-	+	+	1 - 2	1	+	+	-	+	1	-
101.	*Phragmites australis* (Cav.) Trin. ex Steud.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+ - 1	-
102.	*Plantago major* L.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
103.	*Poa sylvicola* Guss.	-	-	+	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-
104.	*Polygonatum latifolium* (Jacq.) Desf.	-	-	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-
105.	*Potentilla reptans* L.	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
106.	*Primula acaulis* (L.) L. (Syn. *Primula vulgaris* Hudson)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
107.	*Prunella vulgaris* L.	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-
108.	*Ranunculus lanuginosus* L. var. *constantinopolitanus* DC. (Syn. *Ranunculus constantinopolitanus* (DC.) D'Urv.)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

№	Species	Abundance (after Braun-Blanquet)																	
		EP 1	EP 2	EP 3	EP 4	EP 5	EP 6	EP 7	EP 8	EP 9	EP 10	EP 11	EP 12	EP 13	EP 14	EP 15	EP 16	EP 17	EP 18
109.	*Rumex sanguineus* L.	-	+	+	-	+	-	+	+	+	+	-	+	+	+	-	+	+	+
110.	*Ruscus aculeatus* L.	-	-	-	-	+	2	-	2	-	-	-	-	-	-	-	-	-	+ - 1
111.	*Sambucus ebulus* L.	-	-	-	-	-	-	-	-	-	-	1 - 2	2 - 3	-	-	-	-	-	-
112.	*Scirpus lacustris* L.(Syn. *Schoeno-plectus lacustris* (L.) Palia)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
113.	*Scirpus sylvaticus* L.	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
114.	*Smilax excelsa* L.	-	-	-	+	-	2	-	+	-	-	-	-	-	+	-	-	-	-
115.	*Solanum dulcamara* L.	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
116.	*Sonchus palustris* L.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	r	+	-
117.	*Stachys sylvatica* L.	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-
118.	*Stellaria nemorum* L.	+ - 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
119.	*Symphytum tauricum* Willd.	-	-	-	-	+	-	-	-	-	-	-	-	r	-	-	-	-	-
120.	*Tamus communis* L.	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+
121.	*Urtica dioica* L.	+	+	2	1	+	-	-	-	+	+ - 1	2	-	+	+	-	1	+	+
122.	*Viola hirta* L.	-	-	-	-	-	-	-	-	-	+	-	+	1 - 2	-	3	-	-	+
123.	*Viola odorata* L.	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+

Table 4. Geographical coordinates of phytocoenological descriptions of natural habitat 91F0.

Test areas	Geographical coordinates		Altitude [m]	Date
	N	E		
EP 1	43.02267	27.82036	14	2.08.2011
EP 2	43.01213	27.84977	21	3.08.2011
EP 3	43.01335	27.81955	5	4.08.2011
EP 4	43.01575	27.80878	20	4.08.2011
EP 5	43.01950	27.72357	24	5.08.2011
EP 6	42.99141	27.88591	6	6.08.2011
EP 7	43.01695	27.86377	12	7.08.2011
EP 8	43.00076	27.87090	5	7.08.2011
EP 9	43.04485	27.54675	31	8.08.2011
EP 10	43.03987	27.56107	28	8.08.2011
EP 11	43.04646	27.60319	20	9.08.2011
EP 12	43.04103	27.62228	18	9.08.2011
EP 13	43.04356	27.64681	23	10.08.2011
EP 14	43.02443	27.69195	17	11.08.2011
EP 15	43.03098	27.66532	23	11.08.2011
EP 16	43.00809	27.72123	5	12.08.2011
EP 17	43.02178	27.88754	1	12.08.2011
EP 18	42.98320	27.88395	5	12.08.2011

Table 5. Geographical coordinates of phytocoenological descriptions of natural habitat 91G0.

Experimental Plot	Geographical coordinates		Altitude [m]	Data
	N	E		
EP 1	43.03707	27.72630	85	5.08.2011
EP 2	43.04326	27.64681	25	10.08.2011

Table 6. Floristic and phytocoenological characterization of natural habitat 91G0 Pannonic woods with *Quercus petraea* and *Carpinus betulus* in PA *Kamchia*.

№	Species	Abundance (after Braun-Blanquet 1964)	
		EP1K	EP2K
Trees			
1.	*Acer campestre* L.	1	2
2.	*Acer tataricum* L.	-	+

№	Species	Abundance (after BRAUN-BLANQUET 1964)	
		EP1K	**EP2K**
3.	*Carpinus betulus* L.	3	3
4.	*Carpinus orientalis* Mill.	+	-
5.	*Fraxinus oxycarpa* M. Bieb. ex Willd.	2	+
6.	*Prunus cerasifera* Ehrh.	-	+
7.	*Quercus cerris* L.	2	2 - 3
8.	*Quercus frainetto* Ten.	2	-
9.	*Quecus robur* L.	-	4
10.	*Tilia platyphyllos* Scop.	2	-
11.	*Ulmus leavis* Pall.	-	+
12.	*Ulmus minor* Mill.	-	+
Shrubs and lianas			
13.	*Clematis vitalba L.*	-	1 - 2
14.	*Cornus mas L.*	-	+
15.	*Cornus sanguinea L.*	+	-
16.	*Crataegus monogyna Jacq.*	+	1
17.	*Evonymus europaeus L.*	-	+
18.	*Hedera helix L.*	4	+ - 1
19.	*Ligustrum vulgare L.*	-	+
20.	*Rubus hirtus Waldst. & Kit.*	+	-
21.	*Sambucus nigra L.*	-	+
Herbaceous plants			
22.	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	+	-
23.	*Bilderdykia convolvulus* (L.) Dumort. (Syn. *Fallopia convolvulus* (L.) A. Love)	+	-
24.	*Brachypodium sylvaticum* (Huds.) P. Beauv.	-	2
25.	*Buglossoides purpurocaerulea* (L.) I. M. Johnst.	1	-
26.	*Calamintha sylvatica* Bromf.	+	-
27.	*Campanula rapunculoides* L.	+	-
28.	*Campanula* sp.	+	-
29.	*Campanula trachelium* L.	+	-
30.	*Carex divulsa* Stokes	-	+ - 1

№	Species	Abundance (after BRAUN-BLANQUET 1964)	
		EP1K	EP2K
31.	*Carex* sp.	1	-
32.	*Chaerophyllum* sp.	-	+
33.	*Circaea luteciana* L.	+	+ - 1
34.	*Clinopodium vulgare* L.	+	-
35.	*Dactylis glomerata* L.	1	-
36.	*Doronicum orientale* Hoffm.	+	-
37.	*Festuca drymeja* Mert & Koch	1 - 2	-
38.	*Galium aparine* L.	-	+ - 1
39.	*Galium pseudoaristatum* Schur	+	-
40.	*Geum urbanum* L.	+	1
41.	*Lapsana communis* L.	+	-
42.	*Lathyrus niger* (L.) Bernh.	+	-
43.	*Leonurus cardiaca* L.	-	+
44.	*Mycelis muralis* (L.) Dumort.	1 - 2	-
45.	*Parietaria lusitanica* L.	+	-
46.	*Poa nemoralis* L.	+	-
47.	*Polygonatum latifolium* (Jacq.) Desf.	+	+
48.*	*Symphytum tauricum* Willd.	-	+
49.	*Tamus communis* L.	+	+
50.	*Urtica dioica* L.	+	1 - 2
51.	*Viola alba* Besser	+	-
52.	*Viola hirta* L.	+	1 - 2
53.	Bryophyta	+ - 1	-

Table 7. Geographical coordinates of phytocoenological descriptions of natural habitat 91M0.

Experimental Plot	Geographical coordinates		Altitude [m]	Date
	N	E		
EP 1	43.02726	27.82842	30	3.08.2011
EP 2	43.04940	27.81825	72	4.08.2011
EP 3	43.03731	27.72665	122	5.08.2011
EP 4	43.05579	27.64328	72	10.08.2011

Table 8. Floristic and phytocoenological characterization of natural habitat 91M0 Pannonian-Balkanic turkey oak-sessile oak forests (91M0) in PA *Kamchia.*

№	Species	Abundance (after Braun-Blanquet 1964)			
		EP1	EP2	EP3	EP4
	Trees				
1.	*Acer campestre* L.	+	-	+	+ - 1
2.	*Carpinus orientalis* Mill.	-	-	3	+
3.	*Fraxinus ornus* L.	+	-	2	-
4.	*Prunus cerasifera* Ehrh.	+ - 1	-	+	+
5.	*Pyrus pyraster* Burgsd.	+	-	-	-
6.	*Quercus cerris* L.	4	2	2	3
7.	*Quercus frainetto* Ten.	3	4	3	2
8.	*Quercus petraea* (Mattuschka) Liebl.	-	1	-	-
9.	*Sorbus domestica* L.	-	-	+	-
10.	*Sorbus torminalis* (L.) Crantz	-	2	+	-
11.	*Ulmus minor* Mill.	+ - 1	-	-	-
	Shrubs and lianas				
12.	*Clematis vitalba* L.	-	-	+	-
13.	*Cornus mas* L.	1	+	-	2
14.	*Crataegus monogyna* Jacq.	1	+	+	1
15.	*Evonymus europaeus* L.	+	-	-	+
16.	*Genista tinctoria* L.	-	-	+	-
17.	*Hedera helix* L.	-	-	+ - 1	-
18.	*Ligustrum vulgare* L.	-	-	-	+ - 1
19.	*Prunus spinosa* L.	+ - 1	-	-	+
20.	*Rosa canina* L.	+	+	-	+ - 1
	Herbaceous plants				
21.	*Agrimonia eupatoria* L.	-	+	-	-
22.	*Allium flavum* L.	-	+	-	-
23.	*Arabis glabra* (L.) Bernh.(Syn. *Turritis glabra* L.)	-	-	-	+
24.	*Arctium tomentosum* Mill.	-	+	-	-
25.	*Aremonia agrimonoides* (L.) DC.	-	+	-	-
26.*	*Asparagus tenuifolius* Lam.	+	-	r	-
27.	*Brachypodium sylvaticum* (Huds.) P. Beauv.	2 - 3	-	+	2 - 3

№	Species	Abundance (after Braun-Blanquet 1964)			
		EP1	EP2	EP3	EP4
28.	*Bromus squarrosus* L.	-	+	-	-
29.	*Calamintha sylvatica* Bromf.	-	-	+	-
30.	*Campanula bononiensis* L.	-	-	-	+
31.	*Campanula persicifolia* L.	-	-	+	-
32.	*Carex* sp.	-	-	+	1
33.	*Chaerophyllum byzantinum* Boiss.	-	+	-	-
34.	*Cirsium arvense* (L.) Scop.	+	-	-	-
35.	*Cirsium* sp.	-	+	-	-
36.	*Clinopodium vulgare* L.	-	-	+	-
37.	*Cynanchum acutum* L.	+	-	-	-
38.	*Dactylis glomerata* L.	+	2	2	+
39.	*Daucus carota* L.	-	+	-	-
40.	*Deschampsia caespitosa* (L.) P. Beauv.	-	-	+	-
41.	*Dorycnium herbaceum* Vill.	-	+	-	-
42.	*Eryngium campestre* L.	-	+	-	-
43.	*Euphorbia amygdaloides* L.	-	-	+	-
44.	*Festuca heterophylla* Lam.	1 - 2	1	2	+
45.	*Festuca pratensis* L.	-	-	-	+
46.	Festuca *valesiaca* Schleich. ex Gaudin	+	+	-	+
47.	*Filipendula vulgaris* Moench	+	-	-	-
48.	*Fragaria vesca* L.	+	-	-	+
49.	*Galium pseudoaristatum* Schur	-	-	1	-
50.	*Geum urbanum* L.	+	+	-	-
51.	*Hypericum perforatum* L.	-	+	+	-
52.	*Lapsana communis* L.	+ - 1	+	+	+ - 1
53.	*Lathyrus laxiflorus* (Desf.) Kuntze	+	+	-	+
54.	*Lathyrus niger* (L.) Bernh.	1	1 - 2	1 - 2	-
55.	*Lithospermum officinale* L.	+	-	-	-
56.	*Luzula forsteri* (Sm.) DC.	-	-	-	+
57.	*Lychnis coronaria* (L.) Desr.	-	+	+	-
58.	*Lysimachia vulgaris* L.	+	-	-	-
59.	*Muscari comosum* (L.) Mill.	+	+	-	+

№	Species	Abundance (after Braun-Blanquet 1964)			
		EP1	EP2	EP3	EP4
60.	*Myosotis sylvatica* Ehrh. ex Hoffm.	-	-	-	+
61.	*Poa nemoralis* L.	+	+	+ - 1	+
62.	*Poa pratensis* L.	+ - 1	+ - 1	-	+ - 1
63.	*Polygonatum latifolium* (Jacq.) Desf.	-	-	+	+
64.	*Prunella vulgaris* L.	+	-	-	+
65.	*Rumex sanguineus* L.	-	+	-	-
66.	*Silene viridiflora* L.	-	+	+	+
67.	*Tanacetum corymbosum* (L.) Sch. Bip.	-	-	r	+
68.	*Teucrium chamaedrys* L.	-	-	-	+
69.	*Trifolium alpestre* L.	-	+	-	+
70.	*Trifolium montanum* L.	-	-	-	+
71.	*Trifolium pannonicum* Jacq.	-	-	-	+
72.	*Trifolium* sp.	-	+	-	-
73.	*Verbascum phoeniceum* L.	-	-	-	+
74.	*Veronica chamaedrys* L.	+	-	+	-
75.	*Veronica officinalis* L.	-	-	+	-
76.	*Veronica orchidea* Crantz (Syn. *Pseudolysimachium orchideum* (L.) Rauschert)	+	+	-	-
77.	*Viola odorata* L.	-	-	+	-
78.	*Viola reichenbachiana* Jord. ex Boreau	+	-	-	-
79.	*Xeranthemum annuum* L.	-	+	-	-
80.	Bryophyta	-	-	+ - 1	-

Table 9. Geographical coordinates of phytocoenological descriptions of natural habitat 92A0.

Experimental Plot	Geographical coordinates		Altitude [m]	Date
	N	E		
EP 1	43.01232	27.85741	12	7.08.2011
EP 2	43.04052	27.55403	27	8.08.2011
EP 3	43.04996	27.59413	22	9.08.2011
EP 4	43.04149	27.63415	21	9.08.2011
EP 5	43.02883	27.67261	5	11.08.2011
EP 6	43.01656	27.72096	18	12.08.2011

Table 10. Floristic and phytocoenological characterization of natural habitat 92A0 *Salix alba* and *Populus alba* galleries in PA *Kamchia*.

№	Species	Abundance (after Braun-Blanquet 1964)					
		EP1	EP2	EP3	EP4	EP5	EP6
Trees							
1.	*Acer campestre L.*	+	-	-	-	-	+
2.	*Acer negundo* L.	-	1	-	1	-	+
3.	*Fraxinus oxycarpa* M. Bieb. ex Willd.	3	-	+ - 1	+	-	+
4.	*Juglans regia* L.	-	-	-	+ - 1	-	-
5.	*Morus alba* L.	-	+	1	+	-	+
6.	*Populus alba* L.	2 - 3	2 - 3	4	3	2 - 3	3
7.	*Prunus cerasifera* Ehrh.	+	+	+	-	-	+
8.	*Quecus robur* L.	+	-	+	-	-	-
9.	*Salix alba* L.	4	3	2	2 - 3	3	3 - 4
10.	*Salix fragilis* L.	-	-	2	-	3	2
11.	*Ulmus leavis* Pall.	-	1	1	+ - 1	+	+
12.	*Ulmus minor* Mill.	1 - 2	1 - 2	-	+ - 1	-	+
Shrubs and lianas							
13.	*Amorpha fruticosa* L.	+ - 1	+	1 - 2	+	+ - 1	2
14.	*Clematis vitalba* L.	+	+	-	-	-	1
15.	*Crataegus monogyna* Jacq.	-	1	-	-	-	-
16.	*Hedera helix* L.	+ - 1	-	-	-	-	-
17.	*Ligustrum vulgare* L.	-	+	-	-	-	-
18.	*Periploca graeca* L.	2	-	-	+	-	-
19.	*Prunus spinosa* L.	-	+	-	-	-	-
20.	*Rubus hirtus* Waldst. & Kit.	2	2	3 - 4	2	2	2 - 3

№	Species	Abundance (after Braun-Blanquet 1964)					
		EP1K	EP2K	EP3K	EP4S	EP5S	EP6
21.	*Sambucus nigra* L.	-	-	-	-	-	+
Herbaceous plants							
22.	*Agrostis capillaris* L.	-	-	1	1 - 2	-	-
23.	*Agrostis stolonifera* L.	-	-	-	-	+	-
24.	*Agrostis verticillata* Vill. (Syn. *Polypogon viridis* (Gouan) Breistr.)	-	3	-	-	-	-
25.	*Angelica sylvestris* L.	-	-	+	+	-	-
26.	*Anthriscus sylvestris* (L.) Hoffm.	+	-	-	-	-	-
27.	*Arctium lappa* L.	-	+	-	-	-	-
28.	*Arctium tomentosum* Mill.	+	-	-	-	+	-
29.	*Aristolochia clematitis* L.	+	-	-	-	-	-
30.	*Artemisia absinthium* L.	-	+	-	-	-	-
31.	*Artemisia annua* L.	-	+	-	-	-	-
32.	*Artemisia vulgaris* L.	+	+	+	+	1	-
33.	*Aster amellus* L.	+	-	-	-	-	-
34.	*Ballota nigra* L.	-	+	-	-	-	-
35.	*Bidens tripartita* L.	-	-	-	-	+	-
36.	*Brachypodium sylvaticum* (Huds.) P. Beauv.	2	+	+	+	+	-
37.	*Bromus* sp.	-	1 - 2	-	-	-	-
38.	*Bromus sterilis* L.	2 - 3	-	-	1 - 2	-	-
39.	*Calamagrostis pseudophragmites* (Haller f.) Koeler	-	+	-	-	-	-
40.	*Calystegia sepium* (L.) R. Br.	-	-	+	-	+	-
41.	*Campanula trachelium* L.	+	-	-	-	-	-
42.	*Carex* sp.	+	-	-	-	-	-
43.	*Chaerophyllum* sp.	-	-	-	+	+	+
44.	*Chelidonium majus* L.	-	-	-	+	-	+
45.	*Chenopodium album* L.	-	-	-	-	+	-
46.	*Cichorium inthybus* L.	+	-	-	-	+	+
47.	*Cirsium alatum* (S. G. Gmel.) Bobr.	-	-	+	1	+	-
48.	*Cirsium arvense* (L.) Scop.	-	+	-	-	-	-
49.	*Conium maculatum* L.	-	-	-	-	+ - 1	-
50.	*Conyza canadensis* (L.) Cronquist	-	1	+	-	+	-
51.	*Cucubalus baccifer* L.	+	-	+	+	-	+
52.	*Epilobium hirsutum* L.	-	-	-	+	-	-
53.	*Equisetum arvense* L.	-	+	-	-	+	-
54.	*Erigeron annuus* (L.) Pers.	-	1	+	+	+	-

№	Species	Abundance (after Braun-Blanquet 1964)					
		EP1K	EP2K	EP3K	EP4S	EP5S	EP6
55.	*Eupatorium cannabinum* L.	-	+	+	-	-	-
56.	*Galium aparine* L.	1 - 2	1	2	1	-	2 - 3
57.	*Geum urbanum* L.	+	-	+	-	-	-
58.	*Heracleum ternatum* Velen.	1 - 2	-	-	+	+	-
59.	*Humulus lupulus* L.	+	-	+ - 1	-	+ - 1	2
60.	*Inula* sp.	-	+	-	-	-	-
61.	*Linaria vulgaris* Mill.	-	-	-	-	+	-
62.	*Lycopus europaeus* L.	-	+	+	-	+	-
63.	*Lythrum salicaria* L.	-	+	+	+	+	+
64.	*Mentha aquatica* L.	-	+	-	-	-	-
65.	*Panicum* sp.	-	-	-	-	-	+
66.	*Parietaria officinalis* L. (Syn. *Parietaria erecta* Mert. & Koch)	-	+	+	+ - 1	-	+
67.	*Persicaria hydropiper* (L.) Opiz (Syn. *Polygonum hydropiper*)	-	+	-	-	1 - 2	-
68.	*Phalaris arundinacea* L.	-	-	-	+	-	-
69.	*Phragmites australis* (Cav.) Trin. ex Steud.	+	-	+	+	+ - 1	+
70.	*Phytolacca americana* L.	-	-	+	-	-	-
71.	*Plantago media* L.	-	-	-	-	-	+
72.	*Rumex sanguineus* L.	-	-	+	-	+	-
73.	*Sambucus ebulus* L.	-	1	-	1	+	-
74.	*Saponaria officinalis* L.	+ - 1	+	-	-	-	-
75.	*Solanum dulcamara* L.	-	+	+	-	-	+
76.	*Stellaria media* (L.) Vill.	-	1	+	+	+	-
77.	*Stellaria palustris* Retz.	-	-	-	-	2	-
78.	*Tanacetum corymbosum* (L.) Sch. Bip.	-	-	-	+	-	-
79.	*Taraxacum officinale* L.	+	-	-	-	-	-
80.	*Taraxacum* sp.	-	+	-	-	-	+
81.	*Urtica dioica* L.	1	+	1 - 2	2	+ - 1	1 - 2
82.	*Urtica urens* L.	-	-	-	-	+	-
83.	*Verbascum* sp.	-	+	-	-	-	-
84.	*Xanthium italicum* Moretti	-	-	-	-	-	+

Table 11. Conservation significance of natural habitats in the protected area *Kamchia*; code NATURA 2000 is the four-figure code pointed out in the standard form of NATURA 2000; the sign „+" means that the relevant type of natural habitat is included in appendix 1 of the Law for amendment of the Law for Biological Diversity (2007), appendix 1 of the Bern Convention (1979) and Directive 92/43/EEC (1992); the sign „-" means that the relevant type of natural habitat is presented in the relevant list; categories after The Red Book of the Republic of Bulgaria on Natural habitats (Biserkov 2015): EN – Endangered, CR – Critically Endangered, VU – Vulnerable, NT – Nearly Threatened.

№	Natural habitats	Code Natura 2000	Bdv. Act (2007)	BernConv. (1979)	Direct. 92/43/ EEC	BG Red Book (2015)
1	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion*, *Alnion incanae*, *Salicion albae*)	91E0	+	+	+	EN
2	Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)	91F0	+	+	+	CR
3	Pannonic woods with *Quercus petraea* and *Carpinus betulus*	91G0	+	+	+	NT
4	Pannonian-Balkanic turkey oak-sessile oak forests	91M0	+	+	+	EN
5	*Salix alba* and *Populus alba* galleries	92A0	+	-	+	VU
	Total		**5**	**4**	**5**	**5**

CONCLUSION

During the field work in the PA *Kamchia*, rich plant species composition (222 vascular plants in total) was recorded in the registered five types of forest natural habitats. However, we registered changes in the flora and vegetation which could be linked with their xerophytisation and were expressed also in the occurrence of invasive and ruderal species. Despite of this, seven of the species found are of high conservation significance and together with the high conservational value of all five habitat types proves the need to keep favourable nature-conservation level there as proposed in Tashev et al. (2018a).

Table 12. Conservation status of the species of higher plants established on the territory of the protected area *Kamchia*. Legent: Bulgarian Red Data Book of Plants and Fungi (Peev 2015) with the following category: EN – *Endangered*; the sign „+" means that the relevant taxon is included un appendix 2 of the Biodiversity Law (2002) or appendix 3 and 4 of the Law for amendment of the Law for Biological Diversity (2007), and those ones with the sign „*" are included in appendix 4; the sign „-" means that the relevant taxon does not appear in the relevant list.

№	Species	Conservation significance	Conservation measures taken	
		Red Data Book of the Republic of Bulgaria (2015)	Biodiversity Act (2002)	Biodiversity Act (2007)
1.	*Asparagus* sp. div.*	-	-	+
2.	*Cardamine penzesii* Ancev & Marhold (Syn. *Cardamine pratensis* L.)	-	+	+
3.	*Primula acaulis* (L.) L. (Syn. *Primula vulgaris* Hudson)*	-	-	+
4.	*Leucojum aestivum* L.*	-	-	+
5.	*Ruscus aculeatus* L.*	-	-	+
6.	*Sonchus palustris L.*	EN	-	+
7.	*Symphytum tauricum* Willd.	EN	-	-
	Total	**2**	**1**	**6**

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

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BIODIVERSITY OF MEDICINAL PLANTS FROM THE NORTHERN BLACK SEA COASTAL WETLANDS. PART 1. BIODIVERSITY OF MEDICINAL PLANTS FROM SHABLA-EZERETZ LAKE COMPLEX PROTECTED AREA

DOBRI L. IVANOV & DJENI P. CHERNEVA*

Faculty of Pharmacy, Department of Biology, Medical University „Prof. D-r Paraskev Stoyanov"- Varna, 55 Marin Drinov Str., 9000 Varna, Bulgaria

Abstract. This study aims to supplement the available research data on medicinal plants for the territory of Shabla-Ezeretz Lake Complex Protected Area by carrying out a taxonomic and analysis of the floristic elements and creating a database of their therapeutic action, usable parts and the groups of diseases they are applicable for.

The medicinal plants identified as such in our surveys constitute 113 species of higher plants referring to 46 families and 91 genera. The predominant biological types are herbaceous perennial plants - 69 species or 61 percent. With respect to moisture and humidity as a factor dominant position hold the mesophytes - 49 species (43%). Eurasian geo-elements are prevalent (26 species or 23%), followed by Euro-Mediterranean, cosmopolitans and sub-Mediterranean (14 species or 12%). Among the medicinal plants in the studied wetlands there are 33 species (29%) of conservation significance. The established medicinal plants have a wide variety of more than 38 types of healing action. Half of them are used mainly for the treatment of gastrointestinal diseases, kidney and urinary tract diseases, respiratory diseases, and those with haemostatic action. The species in which the above ground part (herba) is collected dominate over the rest and represent half of the established for the area medicinal plants.

Keywords: etnobotany, thretened species, wetlands

**corresponding author*: D. P. Cherneva - Faculty of Pharmacy, Department of Biology, Medical University „Prof. D-r Paraskev Stoyanov" - Varna, 55 Marin Drinov Str., 9000 Varna, Bulgaria; djeni_cherneva@abv.bg

INTRODUCTION

The wetlands are among the most productive ecosystems on Earth providing unique living conditions for numerous plants and animal species, many of which are protected or found only within that area. The latter is setting their conservation as a priority in human activities since the deterioration and annihilation of species would lead to their extinction. In this respect, the Northern Black Sea Coastal Wetlands of Bulgaria among which is the Shabla-Ezeretz Lake Complex included in the Ramsar List of Wetlands of International Importance (Ramsar Convention Secretariat 2010), and in the Red List *Critically Endangered* category wetlands in Bulgaria (Michev & Stoyneva 2007), represent a definite research interest.

In-depth floristic studies of the Shabla-Ezeretz Lake Complex Protected Area were carried out within the 1992-1994 period as part of the North Wetlands Coastal Area project of the Bulgarian – Swiss Biodiversity Conservation Programme (BSBCP) (Philipova et al. 2002). However, there is limited evidence on the medicinal plants in the area. Information is found in a few publications referring to the biological diversity of medical plants along the Northern Black Sea coast (Dimitrov et al. 2000; Filipova et al. 2002; Ivanov et al. 2002; Zahariev et al. 2016). This has driven us to supplement the available data on medicinal plants on the Shabla-Ezeretz Lake Complex area by producing a taxonomic analysis, analysis of the floristic elements and creating a database of their healing action, usable parts and the groups of diseases they exert influence on.

MATERIALS AND METHODS

The Shabla-Ezeretz Lake Complex is located in the most North-eastern part of Bulgaria, 24 km from the Bulgarian-Romanian border and 3-5 km northeast of Shabla, district of Dobrich. The wetlands area includes two coastal lakes - Shabla Lake and Ezerets Lake connected by a canal, adjacent sand dunes, grassland, forest-tree and shrub communities and arable agricultural land (Georgiev et al. 2003).

Field surveys were conducted by way of the inventory route technique during the 2013-2015 vegetation seasons.

The floristic analysis was based on the method of Tolmachev (1974).

Species were identified after the *Flora of the Republic of Bulgaria* (Yordanov 1963-1979; Velchev 1982-1989; Kozhuharov 1995; Peev 2013) and *Identification. Guide to Higher Plants in Bulgaria* (Kozhuharov 1992).

The analysis of the floristic elements is according Asyov & Petrova (2006).

The status of medicinal plants is based on the Medicinal Plants Act (2000, 2014) and the *National Strategy for Biodiversity Conservation* (Hardalova et al. 1994).

The conservation status of the species has been determined nationwide accordant with the *Red Data Book of the Republic of Bulgaria* (Peev 2013), the Biological

Diversity Act (2002, 2007), Order RD-83 of 03.02.2014, Lucas (1983), the IUCN Red List (2014), Appendix 1 to the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention 1979) and the Appendices to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1975) were used as determinants and basis at an international level. Endemism is demonstrated at the level of Balkan and Bulgarian endemics, according to the *Balkan Endemics in the Bulgarian Flora* (Petrova & Vladimirov 2010) and the *List of Bulgarian Endemic Plants* (Petrova & Velchev 2006).

The phytotherapeutic characteristics of the plants are reported after Petkov (1982), Asenov (1988) and Nikolov (2006), and their uses and utilization in traditional medicine are according to Petkov (1982).

RESULTS AND DISCUSSIONS

From 278 species of higher plants of the flora in the area we determined 113 species as medicinal plants. Of these, 105 (92%) are medicinal plants as per the Medicinal Plants Act (2000, 2014) and 47 (41%) are classified as medicinal plants according to the National Strategy for Biodiversity (Hardalova et al. 1994). In total, they account for 41% of the area's higher plants and for 15% of the medicinal wild plants in Bulgaria.

The medicinal plants established for the Shabla-Ezeretz Lake Complex belong taxonomically to 46 families and 91 genera. Families with the greatest number of species are: Lamiaceae - 21 species or 19%, Asteraceae - 16 species or 14%, Fabaceae - 7 species or 6%, and Apiaceae - 5 species or 4%, which club together for 43% of the established types of medicinal plants. These families, with the exception of Poaceae, Cyperaceae, Brassicaceae and Chenopodiaceae, are among the most species-rich families among the flora of the research area (Filipova et al. 2002). The least presented are 9 families with 2 species each and 25 families with 1 species each. Families with the largest genera variety of medicinal plants are: Asteraceae (13), Lamiaceae (12), Fabaceae (5), Apiaceae (4) and Brassicaceae (4), the same being the most well represented in the flora of the area. Genera with the most species are *Arthemisia* (4), *Mentha* (4), *Salvia* (3) and *Teucrium* (3). At the same time the genera *Arthemisia* and *Salvia* are among the richest in species and in the flora of the area (Filipova et al. 2002).

Herbaceous perennial type plants are the predominant biological type - 69 (61%), followed by the annual ones - 21 (18%), and the shrubs - 9 (8%). The biennials are represented by 7 species (6%), annuals to biennials - with 3 species (3%), annuals to perennials are presented by 2 species (2%), while biennials to perennial and perennial to shrubs have only 1 species (1 %) each to account for. Analysis display that the distribution of the biological types identified in the area follows that of all plants species of the same area (Filipova et al. 2002).

Moisture and humidity as factors differentiate the medicinal species as follows: mesophytes occupy the dominant position of 49 species (43%), followed by the xerophytes - 39 species (35%); hygrophytes - 21 species (19%) and hydrophytes presented with only 4 species (3%). A similar ecological structure for the flora of Shabla-Ezeretz Lake Complex is established by FILIPOVA ET AL. (2002).

Primary analysis of the floristic elements of the established medicinal plants indicates predominance of the Eurasian geo-elements (26 species or 23%). Second in numbers come the Euro-Mediterranean, cosmopolitan and Sub-Mediterranean (14 or 12%), followed by Boreal (13 species or 11%), European (8 species or 7%) and Euro-Siberian (7 or 6%). In total, there are 35 species with different types of Mediterranean distribution, representing 31% of the overall number of species. The count of species with different types of European distribution is 57 representing 50% of the total number of species. Analysis of the floristic elements of the flora of Shabla-Ezeretz Lake Complex Protected Area shows similar distribution (FILIPOVA ET AL. 2002). The presence of a large number of cosmopolites among the medicinal species (12%), as well as within the area's flora (14%) is due mainly to the fact that the subject of our survey is a wetlands area dominated by marsh plants the majority of which are cosmopolitans.

There are 33 species (29%) of medicinal plants with conservation significance in the studied wetland area. Depending on the degree of threat to the biological diversity they refer to different conservation categories and status.

The *Near Threatened* category (NT) of the European Red List for endangered species includes 22 species: *Alisma plantago-aquatica* L., *Apium graveolens* L., *Bidens tripartita* L., *Butomus umbellatum* L., *Ephedra distachya* L., *Equisetum palustre* L., *Myriophyllum spicatum* L., *Iris pseudacorus* L., *Lycopus europaeus* L., *Mentha aquatica* L., *Mentha pulegium* L., *Mentha spicata* L., S*alvia officinali*s L., *Lemna minor* L., *Lythrum salicaria* L., *Najas marina* L., *Nymphaea alba* L. , *Galium palustr*e L., *Salix alba* L., *Veronica beccabun*ga L., *Sparganium erectum* L. and *Typha angustifolia* L. The Bulgarian Red Data Book for endangered species includes 3 species: *Eryngium maritimum* L., *Nuphar lutea* (L.) S. et S. and *Nymphaea alba* L.

Protected plants according to BULGARIAN BIOLOGICAL DIVERSITY ACT, Appendix 3, Article 37, are 6 species: *Eryngium maritimum* L., *Artemisia lerchiana* Web., *Ephedra distachya* L., *Euphorbia pepli*s L., *Nuphar lutea* (L.) S. et S. and *Nymphaea alba* L. There are 2 species fully prohibited for collection from their natural habitats according to Order № RD-83 of 03.02.2014 of the Minister for the Environment and Water issued on the basis of the MEDICINAL PLANTS ACT, Article 10: *Althaea officinalis* L. and *Artemisia santonicum* L. subsp. *patens* (Neibr.) K. Pers.

On account of research data for the healing activity and plant substances, we grouped the medicinal plants of the studied Shabla-Ezeretz Lake Complex according to the diseases they are relevant or appropriate (**Table 1**).

Table 1. Groups of diseases, healing action and plant substance

Species	Healing action	Plant substance
Plants used for treatment of cardiovascular diseases		
Adonis aestivalis L.	cardiovascular, diuretic, sedative	Herba Adonidis
Lycopus europaeus L.	coronary dilated	Herba Lycopi
Nymphaea alba L.	cardioactive agent	Rhizoma Nymphaeae albae
Vincetoxicum hirundinaria Medic.	cardiovascular, laxative, anti-ulcer	Rhizoma et radix Vincetoxici
Plants used for treatment of gastrointestinal diseases		
Artemisia vulgaris L.	appetite exciting, sedative, haemo-static action	Herba et radix Artemisiae
Artemisia absinthium L.	appetite exciting	Herba Absinthii
Ballota nigra L.	spasmolytic, anti-inflammatory, pain reliever	Herba Ballotae
Cichorium inthybus L.	appetite exciting, diuretic, stimu-lating bile release	Flores Cetaureae
Convolvulus arvensis L.	laxative, diuretic, epithelium tonic	Herba Convolvuli
Cuscuta europaea L.	purgative, diuretic, analgesic	Herba Cuscutae
Datura stramonium L.	spasmolytic	Folium Stramonii
Lythrum salicaria L.	constipative, haemostatic action, antiseptic	Herba Litri salicarii
Malva sylvestris L.	spasmolytic, expectorant, sedative	Flos et folium Malvae syl-vestris
Matricaria chamomilla L.	anti-inflammatory, antiseptic, spasmolytic	Flores Chamomillae
Mentha arvensis L.	carminative, antiseptic	Folium et oleum Menthae arvensis
Mentha pulegium L.	spasmolytic, carminative, anti-septic	Folium et oleum Menthae pulegiumae
Mentha spicata L.	spasmolytic, carminative, anti-septic	Folium et oleum Menthae spicatae
Mentha aquatica L.	spasmolytic, carminative, anti-septic	Folium et oleum Menthae aquaticae
Nuphar lutea (L.) S. et S.	anti-inflammatory	Rhizoma Nupharis Jutei
Potentila reptans L.	constipative, haemostatic action, anti-inflammatory, spasmolytic	Herba Potentillae reptani
Prunus spinosa L.	astringent, anti-inflammatory	Flos et fructus Pruni spinosae

Species	Healing action	Plant substance
Rhamnus catharticus L.	laxative, anti-inflammatory	Cortex, folium et fructus Rhamni cathartici
Solanum nigrum L.	spasmolytic, sedative, analgesic	Herba Solani nigri
Teucrium scordium L.	anti-inflammatory, analgesic, astringent, constipative	Herba Teucrii
Teucrium chamaedrys L.	anti-inflammatory, analgesic, astringent, constipative	Herba Teucrii
Teucrium polium L.	disinfecting, constipative, analgesic	Herba Teucrii
Plants used for treatment of liver and biliary tract		
Marrubium vulgare L.	stimulating bile release, spasmolytic	Herba Marrubii
Marrubium peregrinum L.	stimulating bile release, spasmolytic	Herba Marrubii
Taraxacum officinalis Veb.	stimulating bile release, diuretic	Herba et radix Taraxaci
Plants used for treatment of respiratory diseases		
Althaea officinalis L.	expectorant, anti-inflammatory	Radix Althaeae
Anchusa officinalis L.	expectorant, constipative	Herba Anchusi
Glechoma hederacea L.	anti-inflammatory	Herba Glechomae
Iris pseudacorus L.	expectorant, anti-inflammatory, analgesic	Radix Iridis
Iris pumila L.	anti-inflammatory	Radix Iridis
Papaver rhoeas L.	expectorant	Flos Rhoeados
Salvia aethiopis L.	expectorant, anti-inflammatory	Folium Salviae
Sideritis montana L.	expectorant	Herba Sideritis montanae
Verbascum tapsiforme Schrad.	expectorant, anti-inflammatory	Flos Verbasci
Veronica beccabunga L.	expectorant, expectorant, anti-inflammatory	Herba Veronicae
Plants used for treatment of kidney and urinary tract diseases		
Agropyron repens L.	diuretic, laxative	Rhizoma Graminis
Alisma plantago-aquatica L.	diuretic	Rhizoma Plantaginis aquaticae
Apium graveolens L.	diuretic, appetite exciting, anti-rheumatic	Radix, folium et fructus Apii
Arctium lappa L.	diuretic, anti-ulcer	Radix Bardanae
Asparagus officinalis L.	diuretic	Radix et rhizoma Asparagi
Carduus acanthoides L.	diuretic, strengthens the secretion of the digestive tract	Herba Carduus acanthii

Species	Healing action	Plant substance
Cynodon dactylon L.	diuretic, expectorant, laxative	Rhizoma Graminis italici
Eryngium campestre L.	diuretic, spasmolytic	Radix Eringii
Eryngium maritimum L.	diuretic, spasmolytic	Radix Eringii
Galium palustre L.	astringent, anti-inflammatory, antimicrobial, laxative	Herba Galii palustri
Galium aparine L.	diuretic, laxative, analgesic	Herba Galii aparinis
Herniaria hirsuta L.	diuretic, spasmolytic	Herba Herniariae
Ononis arvensis L	diuretic, anti-inflammatory	Radix Ononidis
Ononis spinosa L.	diuretic, anti-inflammatory	Radix Ononidis
Polygonum aviculare L.	diuretic, astringent, haemostatic action	Herba Polygoni avicularis
Reseda lutea L.	diuretic, capillary reinforcing	Herba Resedae luteae
Sambucus ebulus L.	diuretic, antiseptic, expectorant	Radix, fructus et flos Ebuli
Plants used for treatment of rheumatic and colds diseases		
Salix alba L.	antipyretic, anti-rheumatic	Cortex Salicis
Salvia verticillata L.	anti-inflammatory, disinfecting, expectorant	Folium Salviae
Salvia officinalis L.	anti-inflammatory, disinfecting, expectorant	Folium et oleum Salviae
Solanum dulcamara L.	stimulation of sweat, anti-inflam-matory	Herba Dulcamarae
Verbena officinalis L.	stimulation of sweat, antipyretic, sedative	Herba Verbenae
Xanthium spinosum L.	anti-rheumatic, anti-inflammatory	Herba et fructus Xanthii spinosi
Xanthium strumarium L.	anti-rheumatic, anti-inflammatory	Herba et fructus Xantii strumarii
Plants used for treatment of metabolic and endocrine diseases		
Galega officinalis L.	hypoglycaemic, diuretic	Herba Galegae
Lepidium ruderale L.	antidiabetic, stimulation of sweat, diuretic, sedative	Herba Lepidii
Plants used for treatment of parasitic diseases		
Artemisia santonicum L. subsp. *patens* (Neibr.) K. Pers.	anthelmintic	Flos Artemisiae
Artemisia lerchiana Web.	anthelmintic	Flos Artemisiae
Nepeta cataria L.	antimicrobial, anthelmintic	Herba Nepetae catariae
Ranunculus ficaria L.	antibacterial	Herba et rhizome Ficarii

Species	Healing action	Plant substance
Plants that affect central nervous system		
Conium maculatum L.	analgesic	Fructus et herba Conii
Consolida regalis S. F. Gray	anthelmintic, laxative	Herba et semen Consolidae
Ephedra distachya L.	anti-asthmatic, hypertonic	Herba Ephedrae
Melilotus alba Med.	sedative	Herba Meliloti
Melilotus officinalis (L.) Pall.	sedative	Herba Meliloti
Ranunculus repens L.	analgesic	Rhizoma Ranunculi repensis
Scutellaria altissima L.	spasmolytic, astringent, diuretic, sedative	Herba Scutelarii
Plants with predominantly haemostatic action		
Achillea millefolium L.	haemostatic action, anti-inflam-matory	Herba Millefolii
Bidens tripartita L.	astringent, diuretic, stimulation of sweat	Herba Bidentis
Capsella bursa-pastoris (L.) Medic.	haemostatic action	Herba Bursae - pastoris
Echium italicum L.	haemostatic action, expectorant, antiepileptic	Radix et folium Ehii italici
Erodium cicutarium (L.) L`Her.	haemostatic action	Herba Erodii cicutarii
Plumbago europaea L.	anti-inflammatory, astringent	Radix et herba Plumbaginis
Sangusorba minor Scop.	haemostatic action, astringent, anti-inflammatory	Rhizona et radix Sanguisorbe
Urtica dioica L.	haemostatic action, diuretic	Folium Urticae
Plants used primarily for wound healing		
Hypericum perforatum L.	regenerative, anti-inflammatory, astringent, anti-ulcer, haemostatic action, sedative	Herba Hyperici
Plantago lanceolata L.	anti-inflammatory,laxative, anti-ul-cer, diuretic	Folium Plantaginis lanceo-latae
Plantago major L.	anti-inflammatory, laxative, an-ti-ulcer, diuretic	Folium Plantaginis majoris
Stachys annua L.	regenerative, spasmolytic	Herba Stachi annuae
Stachys recta L.	regenerative, spasmolytic	Herba Stachi rectae
Plants used in skin diseases		
Euphorbia amygdaloides L.	keratolytic	Succus Euphorbiae

Species	Healing action	Plant substance
Euphorbia peplis L.	keratolytic	Succus Euphorbiae
Plants with other types of actions		
Anthemis tinctoria L.	hair bleaching	Fructus, folium et cortex
Butomus umbellatum L.	nutrient	Rizoma Butomi
Chenopodium album L.	nutrient	Folium et semen Chenopodii
Chenopodium hybridum L.	nutrient	Herba Chenopodii hybridi
Lamium purpureum L.	nutrient	Herba Lamii
Lotus corniculatus L.	fodder	Herba Corniculati
Salicornia europaea L.	nutrient	Herba Salicornii
Sisymbrium loeselii L.	rich in vitamins	Herba Sysimbrii
Trifolium repens L.	fodder	Herba Trifolii repensis

Analysis display that half of the studied medicinal plants are used primarily for treatment of gastrointestinal diseases, kidney and urinary tract diseases, respiratory diseases, along with those with haemostatic action. The remaining types of diseases are associated with 1 to 5 medicinal plant species.

Medicinal plants established for the area have a wide variety of healing action - more than 38 types. Most of the medicinal plants of the studied area have diuretic (15 species), anti-inflammatory (11 species) and spasmolytic action (8 species). The rest of the plants` healing activities relate to less than 5 medicinal plants.

Different vegetative and generative parts are used as a plant substance from the established medicinal plants. The above ground part (herba) of the plant is collected from half of the species. Different plant parts can be harvested and used in a quarter of all analyzed species.

CONCLUSION

There is a considerable taxonomic variety of medicinal plants on the territory of Shabla-Ezeretz Lake Complex. The results obtained could be grounds for comparative floristic studies of the medicinal plants in Bulgaria`s wetlands. They could be used to promote wetlands` role in the life-system of the population and to outline conservation perspectives and requisites for rational use of the medicinal plant resources.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

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ANTIOXIDANT POTENTIAL OF BULGARIAN YARROW AND THYME

NELLY G. GEORGIEVA, GANKA T. CHANEVA & MIROSLAVA K. ZHIPONOVA*

Department of Plant Physiology, Faculty of Biology, Sofia University "St. Kliment Ohridski", 8 Dragan Tsankov Blvd., 1164 Sofia, Bulgaria

Abstract. Phenols (sometimes called phenolics) are synthesized by plants for their general defense and particularly in response to antioxidative stress. These biologically active compounds are well known to have beneficial effects on human health. The aim of the present study was to apply a fast in vitro approach to compare the antioxidant potential of yarrow (*Achillea millefolium* L.) and thyme (*Thymus vulgaris* L.) that were freshly collected from their natural habitat in the Rodopi Mts with some randomly selected herbs for infusion from traders in Sofia region. Ethanol extracts from yarrow and thyme plants were compared with an extract from the Chinese white tea (*Camellia sinensis* (L.) Kuntze) used for infusion and known for its high phenolic content with antioxidant effect. The total quantity of phenols in both studied herbs varied in a close range but was 5-8 times lower than this in the white tea. The average antioxidant activity in thyme was slightly higher than in yarrow but was nearly four times lower in comparison to their activity in the white tea. Slight variations between the herbs from the Rodopi Mts and Sofia were found in the phenolic content of yarrow and thyme, and in the antioxidant activity of thyme. Significant positive correlation between the content of phenolic and antioxidant activity was observed in white tea and thyme, but not in yarrow but our in vitro approach would need to be confirmed by further in vivo analyses. Our results show that the genotype, habitat and storage conditions could influence the plant antioxidant potential and that it is likely that the Bulgarian herbs contain additional classes of metabolites which determine distinct biological activities.

Key words: antioxidant activity, herbs, phenolics, tea, white tea

**corresponding author*: M. K. Zhiponova, Sofia University "St. Kliment Ohridski", Faculty of Biology, Department of Plant Physiology, 8 Dragan Tsankov Blvd., BG-1164, Sofia, Bulgaria; zhiponova@uni-sofia.bg

INTRODUCTION

The secondary plant metabolites serve as reducing agents that result in decrease of the amount of active oxygen species inside the cell, which prevents further damages and cell malfunction (Gupta & Sharma 2006; Pereira et al. 2013). The phenols (sometimes called phenolics) are secondary metabolites, widespread in herbal plants, and often studied for their antioxidant potential. The variable biological properties of the phenolics are due to their molecular structure including at least one phenol ring in which the hydrogen is usually replaced by a more active residue, such as hydroxyl, methyl or acetyl. These compounds often contain more phenolic rings, therefore they are called polyphenols (Dzialo et al. 2016). Plants synthesize phenolic compounds mainly to protect themselves against unfavourable environmental conditions such as ultraviolet light, herbivores and pathogens, as well as to attract pollinators and animals dispersing the seeds (Boudet 2007). The defence costs are paid mainly in the form of energy, carbon, and nitrogen, while phenolics are suggested to be cheaper than alkaloids because of the additional effort that is required to make inorganic nitrogen bioavailable (Mithöfer & Boland 2012).

Polyphenols are the subject of increasing scientific interest as they have various functions in the human body - antioxidant protection, anti-viral, antibacterial, anti-tumor and anti-inflammatory activity (Pandey et al. 2009). Epidemiological studies and associated meta-analyses strongly suggested that long term consumption of diets rich in plant polyphenols offered some protection against development of cancers, cardiovascular diseases, diabetes, osteoporosis, and neurodegenerative diseases (Pandey et al. 2009). The teas made from *Camellia sinensis* (L.) Kuntze contain polyphenols and flavonoids (mainly catechins), which are considered as their most important phytochemicals in terms of health benefits due to their ability to act as antioxidants by donating electrons or hydrogen protons to reactive oxygen or nitrogen species (Shannon et al. 2018). White teas have been reported to possess higher antielastase, anticollagenase, and antioxidative activity than green tea, which has led to an increased interest in this tea type (Thring et al. 2009). In comparison, tisanes derived from herbs or fruit infusions, as chamomile and berry/hibiscus, also contain polyphenols but at significantly lower levels than *C. sinensis* derived teas.

Ethnobotanical studies highlighted the members of the Asteraceae and Lamiaceae families among the most popular medicinal plants in Bulgaria and other countries on the Balkan Peninsula, with different species of yarrow (*Achillea* L.) and thyme (*Thymus* L.) as commonly used herbs (*e.g.* Evstatieva et al. 2007; Jarić et al. 2015). The application of these medicinal plants in food industry, cosmetology and pharmacology has been increasingly studied (Mekinić et al. 2014; Boutaoui et al. 2018). Previous research work on these plants has been mainly confined to their essential oil, however, much attention has recently been directed to the water-soluble components (Benetis et al. 2008; Kratchanova et al. 2010; Mekinić et al. 2014; Rogova et al. 2015; Boutaoui et al. 2018). In yarrow, phenolic compounds such as flavonoids (*e.g.* vicenin-2, luteolin-3',7-di-O-glucoside, luteolin-7-O-glucoside, rutin, apigenin-7-O-glucoside, luteolin, apigenin) and phenolic acids (*e.g.* rosmarinic acid, m-hydroxybenzoic acid, o-coumaric acid, caffeic, ferulic acid) constitute one of the most important groups of pharmacologically active substances (Benetis et al. 2008; Mekinić et al. 2014). Recent investigation on bioactive substances in thyme species also revealed high content of phenolic compounds (benzoic acid, epicatechin, chlorogenic acid, syringic acid, naringin, catechin, o-coumaric acid) - Boutaoui et al. (2018).

Plant extracts made with water are nutritionally more relevant since herbs are traditionally ingested as hot-water infusions. However, stronger polar solvents (methanol, acetone, ethanol) are preferred for more exhaustive extraction of polyphenol compounds due to their polar groups (Benetis et al. 2008; Kratchanova et al. 2010). Kratchanova et al. (2010) investigated the influence of the extraction agent on the extractability of polyphenol components and the antioxidant activity of 25 Bulgarian medicinal plants, among which *A. millefolium* and *T. vulgaris*. It was found that the antioxidant potential was higher for 80% acetone extraction than for water extraction.

The phytochemical composition of medicinal plants is influenced by variables such as cultivar, ontogenetic factors, growth conditions, processing conditions, storage (Fiehn 2002; Kapchina et al. 2014; Boutaoui et al. 2018; Shannon et al. 2018). In the present study, we applied a simple preliminary, but fast *in vitro* approach to examine the total quantity of phenolic compounds and antioxidant activities of yarrow and thyme herbs from two different regions in Bulgaria, and compared them to the antioxidant potential of Chinese white tea, when using ethanol as a solvent.

MATERIALS AND METHODS

Plant material

The plant material was collected on 24th June 2017, from a natural habitat in Bulgaria, the Rodopi Mts (Plovdiv Province, village Dryanovo, latitude 41.7946091; longitude: 24.7867012; altitude 1000 m a.s.l.). The voucher specimens were deposited in the Herbarium of Sofia University „St. Kliment Ohridski", as follows: SO107842 for *Achillea millefolium* L. (yarrow) and SO107844 for *Thymus vulgaris* L. (thyme). Flowers were air dried at room temperature in darkness until no significant change of the dry weight was detected. The samples were analyzed four weeks after the collection. The commercially purchased yarrow and thyme herbs were randomly selected from Bulgarian producers in Sofia region (at average altitude of 500 m a.s.l.). The white tea (*Camellia sinensis*) consisted of unopened buds and it was purchased from a herbal pharmacy in Sofia in 2017.

Preparation of extracts

For extract preparation 50 mg of air-dried plant material was homogenized with 5 ml 100% ethanol and disintegrated in ultrasonic bath for 2 min. After centrifugation (at 9000 rpm for 20 min) the supernatant was subjected to further analyses.

Total phenolic content analysis

The total phenolic content was determined according to SINGLETON ET AL. (1999). Test samples contained 0.1 ml plant extract, 1.5 ml Folin-Ciocalteau reagent (previously dissolved in distilled water 1:10), 1.4 ml 7.5% Na_2CO_3. The samples were incubated in darkness, at room temperature for 30 min. The absorbance was measured at λ = 765 nm by spectrophotometer Shimadzu UV 1800. Standard curve based on known concentrations of gallic acid (GA) was used to calculate the amount of phenolic compounds as GA equivalents per dry weight (mg $GA.g^{-1}$ DW).

Total antioxidant activity analysis

The total antioxidant activity of each extract was measured according to PRIETO ET AL. (1999). Each sample contained 0.25 ml extract and 2.5 ml reagent solution (0.6 M H_2SO_4, 28 mM CH_3COOK and 4 mM $(NH_4)_6Mo_7O_{24}$). The samples were incubated in a water bath for 90 min at 95°C. The reaction was stopped by placing the samples on ice. The absorbance was measured at λ = 695 nm by spectrophotometer Shimadzu UV 1800. The total antioxidant activity is calculated according to PRIETO ET AL. (1999) by multiplication with a coefficient from a standard curve with known concentrations of α-tocopherol and expressed as mM α-tocopherol per DW ($mM.g^{-1}$ DW).

Statistical analysis

The shown values are mean values of six to nine measurements (three extractions with two-three technical repetitions) and the related standard deviation. The *t*-test was applied for statistical evaluation with a threshold $P < 0.05$. For the correlation analysis, first, linear regression analysis was applied after checking the assumptions for normality and equality of the variances. Next, Pearson Product Moment Correlation coefficient (*r*) was calculated with $P = 0.05$ accepted as a level of significance. Data analysis was made by SigmaPlot software.

RESULTS

The maximal phenolics content of yarrow and thyme ranged in close limits (28.0 -47.0 $mgGA.gDW^{-1}$). However, there were statistically significant differences between the material from the Rodopi Mts and Sofia regions. In yarrow, the phenolic content was higher in the plants from the Rodopi Mts in comparison to the plants from Sofia region (35.8 and 28.0 $mgGA.gDW^{-1}$, respectively). By contrast, in

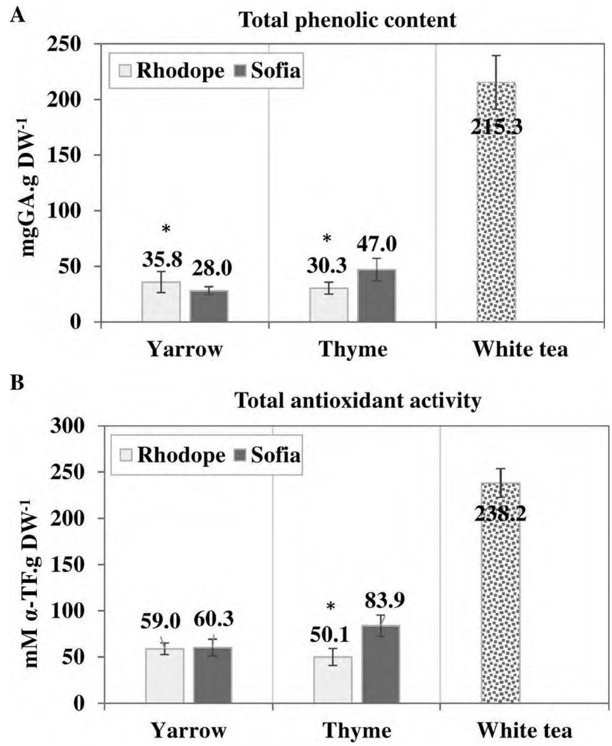

Fig. 1. Antioxidant potential of medicinal plants. Total content of phenolic compounds (A) and total antioxidant activity (B). Each variant from Rodopi Mts is compared to the one from Sofia region, and the presence of statistical difference is indicated with asterisks (* $P<0.05$; n>6).

thyme, the phenolic content was higher in the plants obtained from Sofia region (30.3 and 47.0 mgGA.gDW^{-1}, respectively; **Fig. 1A**).

The maximal antioxidant activity in thyme was slightly higher than this in yarrow (83.9 and 60.3 mM α-TF.gDW^{-1}, respectively; **Fig. 1 B**). There was no difference between the antioxidant activity of the yarrow samples from the Rodopi Mts and Sofia, while in thyme a higher antioxidant potential was found in the material from Sofia **(Fig. 1A, B)**.

The total phenolics content in the Chinese white tea was five to eight times higher in comparison to the studied yarrow and thyme material. Similarly, its antioxidant activity was four times higher **(Fig. 1, 2)**.

Statistically significant Pearson correlation was established between the amount of phenolics and the antioxidant activity in thyme plants, from both studied regions (r=0.908; $P < 0.001$) and in the white tea (r=0.999; $P < 0.03$), as well. By contrast, in the case of yarrow such correlation was not established.

RESULTS

The maximal phenolics content of yarrow and thyme ranged in close limits (28.0 -47.0 mgGA.gDW^{-1}). However, there were statistically significant differences between the material from the Rodopi Mts and Sofia regions. In yarrow, the phenolic content was higher in the plants from the Rodopi Mts in comparison to the plants from Sofia region (35.8 and 28.0 mgGA.gDW^{-1}, respectively). By contrast, in thyme, the phenolic content was higher in the plants obtained from Sofia region (30.3 and

47.0 mgGA.gDW^{-1}, respectively; **Fig. 1A**).

0%	50%	100%

		Total content of phenols relative to white tea	Total antioxidant activity relative to white tea
Yarrow	Rhodope	17%	25%
	Sofia	13%	25%
Thyme	Rhodope	14%	21%
	Sofia	22%	35%
White tea		100%	100%

Fig. 2. Heat map data representation of the antioxidant potential of Bulgarian yarrow and thyme relative to the white tea.

The maximal antioxidant activity in thyme was slightly higher than this in yarrow (83.9 and 60.3 mM α-TF.gDW^{-1}, respectively; **Fig. 1B**). There was no difference between the antioxidant activity of the yarrow samples from the Rodopi Mts and Sofia, while in thyme a higher antioxidant potential was found in the material from Sofia (**Fig. 1 A, B**).

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DISCUSSION

There is a belief in Bulgaria that medicinal plants collected at sunrise after Saint John's Eve celebration (24th June) have great potential to cure and improve health. Our study did not reveal striking differences in the phenolic content and antioxidant activity of yarrow and thyme herbs collected in the natural habitats in the Rodopi Mts on 24th June and the same herbs obtained from random Bulgarian producers. Although the yarrow plants from both studied regions showed almost identical total antioxidant activities, their phenolic content differed. Since antioxidant capacity is not coming solely from the phenolics but could be due to the presence of some other phytochemicals (*e.g.* ascorbic acid, tocopherol, pigments, essential oils) or to the synergistic effects among them (SENGUL ET AL. 2009; KRAUJALIS ET AL. 2011), it could be suggested that some other compounds in the plants from Sofia region are capable of antioxidant activity, thus compensating the lower content of phenolics. This means that in yarrow, besides polyphenolics, there are additional metabolites to be explored that might have special beneficial effects on human health.

Our results are in accordance with some previous studies, which demonstrated the effect of the habitat on the antioxidant potential of yarrow. For example, considerable variation in accumulation of phenolic compounds among the flowers of *A. millefolium* L. from different localities was observed (BENETIS ET AL. 2008).

In this study, the total amount of the identified phenolics in yarrow flowers from different populations varied from 13.290 to 27.947 mg.g^{-1}. Since the examined populations of *A. millefolium* were located in different regions of Lithuania within habitats with different environmental conditions (*e.g.* in microclimate, soil, ultraviolet radiation), it was concluded that the observed diversity could have a genetic basis, but it may be attributed also to the environmental differences. In Bulgaria, ROGOVA ET AL. (2015) performed similar screening of the antioxidant potential of the endemic species *A. thracica* Vel., grown *in vivo*, *in vitro* and *ex vitro* conditions, and reported lack of correlation between the phenolics content and the total antioxidant activity. Most of the studies on different *Achillea* species (including the endemic *A. thracica*) in Bulgaria were focused on their essential oil composition with revealing a dependence of the sesquiterpene lactone profile from the habitat or cultivation conditions (TODOROVA ET AL. 2000, 2004, 2007; YORDANOVA ET AL. 2017).

The comparison of the phenolics and antioxidant activity of all studied yarrow and thyme plants showed that they were several folds lower than in the Chinese white tea. As in other screens for the antioxidant potential of herbs, our work is an *in vitro* approach and the determined values could differ from those *in vivo* since polyphenols undergo extensive modification during digestion via conjugation in the intestinal cells and liver by sulphation, methylation, and glucuronidation (SETCHELL ET AL. 2003). Therefore, for revealing the real antioxidant potential of the investigated herbs, it would be more useful to use more antioxidant methods and to investigate the biological activities of the extracts from medicinal plants which can provide more detailed information about the specific roles of the metabolites (BADARINATH ET AL. 2010; MEKINIĆ ET AL. 2014). However, our results show the potential of the applied screening of total phenolics content and antioxidant activity as a fast approach to overview the general trend in the antioxidant potential and factors (such as genotype, habitat and storing conditions) that influence it in medicinal plant species used for infusions in the households.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

AUTHOR CONTRIBUTIONS

N.G.G. performed experimental work; G.T.C. and M.K.Z. designed the experiments and interpreted the results; M.K.Z. wrote the manuscript.

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REPORT ON THE INTERNATIONAL MEETING *PAYMENT FOR ECOSYSTEM SERVICES - FOREST FOR WATER* (COST ACTION 15206 PESFOR-W), ALBENA, BULGARIA

MARIYANA LYUBENOVA[1*] & GREGORY VALATIN[2]

[1] *Department of Ecology and environmental protection, Faculty of Biology, Sofia University “St. Kliment Ohridski”, 8 Dragan Tsankov Blvd., 1164 Sofia, Bulgaria*
[2] *Forest Research, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, GU10 4LH, UK*

Abstract. The paper reports on the meeting of the Payment for Ecosystem Services Cost Action/18.10.2016-17.10.2020 (CA 15206 PESFOR-Water), which took place from 25th to 27th September, 2018 in the Congress Center of the Flamingo Grand Hotel, Albena, Bulgaria. The meeting was related to the European scientific program COST (European Co-operation in Science & Technology). COST Action PESFOR-W includes representatives of 39 countries.

A meeting related to the European scientific program COST (European Co-operation in Science & Technology) and in particular to the Payment for Ecosystem Services Cost Action/18.10.2016-17.10.2020 (CA 15206 PESFOR-Water) took place from 25th to 27th September, 2018 in the Congress Center of the Flamingo Grand Hotel, Albena, Bulgaria **(Figs. 1-4)**.

COST Action PESFOR-W includes representatives of 39 countries, out of which the following 32 are COST countries: Austria, Belgium, Bosnia and Her-

**corresponding author*: M. Lyubenova – Department of Ecology and environmental protection, Faculty of Biology, Sofia University “St. Kliment Ohridski”, 8 Dragan Tsankov Blvd., 1164 Sofia, Bulgaria; ryana_l@yahoo.com

Figs. 1-4: Meeting of the Cost Action/18.10.2016-17.10.2020 (CA 15206 PESFOR-Water) in the Congress Center of the Flamingo Grand Hotel, Albena, Bulgaria.

zegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, FYROM, Germany, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Montenegro, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom. Representatives of institutions from Ukraine, Jordan, Morocco, Tunisia, China, Japan, New Zealand, as well as of international organizations, including the European Forest Institute and the United Nations Economic Commission for Europe/FAO, also participate in the Action. The Chair of the Action is Dr Gregory Valatin (United Kingdom), and the Vice Chair is Prof. Gebhard Shueler (Germany) (http://www.cost.eu/COST_Actions/ca/CA15206)

The scientific activities in Action CA15206 are divided into four working groups: 1) Design and Governance (leaders Prof. Paola Gatto and Dr Alessandro Leonardi); 2) Environmental Effectiveness (leaders Dr Tom Nisbet and Dr Yiying Cao); 3) Cost-Effectiveness (leaders Dr Alexander Shikalanov and Paola Ovando), and 4) Communication, Dissemination & Marketing (leaders Prof. Dr Lars Högbom and Dr Rik De Vreese; http://www.forestresearch.gov.uk/research/pesforw).

The main objective of this international scientific cooperation is to synthesize knowledge and promote research in order to improve Europe's capacity to use Payments for Ecosystem Services (PES) to achieve the Water Frame Directive (WFD) objectives and other policy goals through initiatives for planting forests to reduce diffuse pollution from agriculture. Gathering and synthesizing information on existing developing woodlands for water PES schemes will help the design of a user manual to aid the development of future schemes. Look-up tables on the effectiveness of planting trees at reducing agricultural diffuse pollution to watercourses are under development, and a common approach to calculating the cost-effectiveness of woodlands for water PES schemes is also currently under discussion.

The meeting in Albena reported on the Action progress. A focus of the field visit organised as part of the meeting was on the forest belts created in the agricultural areas to reduce nitrate, phosphate, pesticide and sediment pollution as the main pollutants causing water eutrophication, as well as for demonstration of the irrigation role of the forest belts on the adjacent territories and agricultural lands. Further studies on the effects of planting different tree species, as well as on the effects of species mix, woodland structure, age, area, management, etc. are needed to identify the most efficient and cost-effective ways to increase surface water quality. Demonstrations on exploring the potential of trees in helping to preserve the water quality of regionally important wetlands for biodiversity protection was a further focus of the visit.

The hosts of the meeting were Prof. Dr Mariana Lyubenova from the Faculty of Biology, Sofia University and Assoc. Prof. Alexander Shikalanov from the Faculty of Information Sciences, University of Library Studies and Information Technologies, who are members of the Management Committee of the Action.

The meeting was held with the assistance of: Director of the Basin Directorate *Black Sea Region* Eng. D. Konsulova, Director of the Regional Inspectorate of Environment and Water - Varna Eng. H. Genova, Executive Forestry Agency in the person of Assoc. Prof. D. Pandeva (Director of Science and International Activities Directorate), Director of the Northeastern State Enterprise Eng. V. Ninov, Director of the Forest Protection Station, Varna Eng. M. Kirilova, Director of the Forestry Institute (BAS) Assoc. Prof. M. Zhianski, Director of State Hunting Farm, Balchik Eng. K. Todorova and Eng. R. Radev, Director of State Forestry Farm, General Toshevo Eng. Y. Stoyanova and Eng. Dr. J. Petrov, Institute for Economic Research (BAS) Dr Y. Kirilova and Dr D. Velkova, WWF in Bulgaria V. Kavrakova (Director) and G. Stefanov, National Archaeological Institute with Museum (BAS) with Dr. I. Weissov as Head of Archeological Studies of the Eneolithic Settlement Mound - The Big Island (Durankulak Lake Protected Area), Director of the Vitosha Nature Park Directorate Landsc. arch. S. Petrova and Senior Specialist and Coordinator Visitor Center and Museum A. Staneva, Director of the Green Educational Center at Shabla Municipality Dr. D. Todorova, and experts from Shabla Municipality - Chief Expert Ecology G. Camberova and Senior Expert Cultural

Figs. 5-10: Presentation of Meeting Reports: **1** - *Control and management of surface water. Assessment indicators. Management and Payment Schemes* (K. Kusheva & S. Ivanova); **6** - *The Costs Directive and the Floods Directive - the Bulgarian example* (Y. Kirilova & D. Velkova); **7, 8** - *Forest and water resources in Bulgaria. Estimation of Ecosystem Services from Forests* (D. Pandeva); **9** - *Soil related ecosystem services provided by natural, urban and suburban forest ecosystems - assessment and mapping* (M. Zhianski); **10** - *Cost-efficiency assessment of forest ecosystem services for water protection and research in Bulgaria* (A. Shikalanov & M. Lyubenova).

and historical heritage I. Hristakiev.

The representatives of Bulgarian institutions introduced their achievements related to the management of water resources, development of payment schemes, management of forest resources in Bulgaria, mapping and assessment of forest ecosystem services, and legislative developments (*e.g.* the Article in the Forests Act concerning the forest ecosystem services and an Ordinance providing for their valuation). These included the following reports: *Control and management of surface water. Assessment indicators. Management and Payment Schemes* (K. Kusheva & S. Ivanova) – **Fig. 5**; *The Costs Directive and the Floods Directive - the Bulgarian example* (Y. Kirilova & D. Velkova) – **Fig. 6**; *Forest and water resources in Bulgaria. Estimation of Ecosystem Services from Forests* (D. Pandeva) – **Figs. 7, 8** and *Soil related ecosystem services provided by natural, urban and suburban forest ecosystems - assessment and mapping* (M. Zhianski) – **Fig. 9**.

The first results from the Bulgarian project *Development of an ecosystem services assessment scheme, their effectiveness for purification and protection of water and other natural components in the regions* (Contract DCOST 1/30/20.12.2017 of the National Scientific Fund, Ministry of Education and Sciences as addition to the COST Action Payment for Ecosystem services (Forest for Water)/ CA 15206 PESFOR; http://www.e-ecology.org were presented under the title *Cost-efficiency assessment of forest ecosystem services for water protection and research in Bulgaria* (A. Shikalanov & M. Lyubenova) – **Fig. 10**. This project includes some of the implementations of the first dendrometers in natural forests, which will scan 24-hour radial growth of *Quercus frainetto* Ten. and *Quercus cerris* L. to help monitor the state of oak forests and the sustainability of ecosystem service provision, and develop more robust growth forecasts (**Figs. 11, 12**). Long-term observations will help create a useful database to underpin future participation in international projects.

Achievements related to the development of PES schemes as part of different projects carried out by WWF, Bulgaria (http://www.wwf.bg) were presented by G. Stefanov (*Development of PES schemes for wetlands and forests for water*).

Professor Margaret Shannon of Baldy SUNY Buffalo Law School gave an insightful presentation on *Critical transformational deliberative science: A critical element for PESFOR - W*.

The Bulgarian experience of the construction, maintenance and management of field forest protection belts in the Bulgarian part of Dobrudzha was reported. The large-scale network of belts is considered a unique phenomenon in forest/agricultural practice as reported in the following presentations: *The system of protection forest belts in Dobrudzha. Meaning, status, perspectives and management issues. Possible ways of financing the activities* (R. Radev) – **Fig. 13** and *Coastal forest belts in Dobrudzha. Design, construction, schemes for creation, growth, condition and efficiency* (Y. Petrov) – **Fig. 14**. Some background on the development of forest protection belts in Bulgaria is provided below.

Figs. 11-16: **11, 12** - The implementations of dendrometers in natural forests for scaning of 24-hour radial growth of *Quercus frainetto* Ten. and *Quercus cerris* L.; **Meeting Reports: 13** - *The system of protection forest belts in Dobrudzha. Meaning, status, perspectives and management issues. Possible ways of financing the activities* (R. RADEV); **14** - *Coastal forest belts in Dobrudzha. Design, construction, schemes for creation, growth, condition and efficiency* (Y. PETROV); **15, 16** - visit of the system of forest belts in Balchik municipality.

The first field protective forest belts (shelter belts) in Bulgaria were created in 1925. Their wider application in agroforestry dates back to the beginning of the 1950s. According to the Northeastern State Enterprise - Shumen, a system of forest belts covering area of 14 631 ha exists within the territory of Dobrich Region, 8 110 ha of which are state protective belts (with a length of about 1000 km in total) and 6 522 ha are non-state protective belts (with a length of over 4000 km). The area of existing forest belts today is only half of the planned area and 2/3 of the area that existed in the 1960s, and only 53% of the belts are currently in good condition, with 22% satisfactory and 25% in poor condition (Petrov et al. 2002). In addition to water quality benefits, the system of forest shelterbelts provides a set of ecosystem services, including wildlife habitats and biodiversity, soil protection from the strong winds, microclimate improvements, protection of water supplies in the soil, and humidity of the air. In drought conditions, relative humidity in protected areas is 5-7% higher, absolute humidity is 12-15% higher, and soil temperature at 20 cm depth in protected areas is 2-3 to 7-8% lower. Improving the conditions for growth of agricultural crops has been found to increase crop yields. For example, at an altitude of 8 to 17 m, the average increase in yields for the period 1956-1995 was as follows: 9.8%, 15.5%, 10.6% and 8% respectively for wheat, maize, sunflower and common beans (*e.g.* Ivanov et al. 1995; Tonev et al. 1996, 2002; Tonev & Iliev 2005).

The participants in the meeting visited the system of forest belts in Balchik municipality. Eng. R. Radev and Eng. Dr J. Petrov showed belts formed from different main species with different structures and in different phases of development and management. They highlighted existing problems with the financing, creation, exploitation and management of the belts and answered a number of questions of great interest to the participants, as many of them had not seen such an agro-forestry system previously (**Figs. 15, 16**). The forest belt system in Dobrudzha can be considered a national asset, because of its uniqueness and the complex of benefits (services) it offers. In order to preserve, maintain and develop the network of forest belts, it is useful to consider how PES schemes can provide funding for their sustainable management, as well as for the reconstruction and creation of new belts. The experience of creating forest belts in Bulgaria is worthy of wider consideration as creating forest belts may potentially play an important role in other European countries, where similar to those in Bulgaria financing issues may arise.

Furthermore, the participants in the meeting visited the Green Educational Center at Shabla Municipality (http://www.shabla-greencenter.info), where Dr. D. Todorova presented the purpose and activities of the Center for the environmental education in relation to the sustainable development of local wetlands, as well as potential to develop PES schemes; the project activities of the center and the opportunities for cooperation – **Figs. 17, 18**.

The biodiversity of wetlands in the Shabla Municipality and the ecosystem services that the wetlands provide were presented by G. Camberova (*Ecosystem*

Figs. 17-22: **17, 18** - Visit of the Green Educational Center at Shabla Minicipality; **19, 20** - visit of the protected area of the lake Durankulak; **21, 22** - visit of the *Baltata* Managed Reserve, located in close proximity to the *Albena* resort, which hosts the northernmost longoz forests at the lower part of Batova river.

Services of Wetlands in Shabla Municipality).

The meeting participants visited also the protected area of the lake Durankulak **(Fig. 19, 20)**, which is one of the most significant coastal wetlands in Bulgaria, registered under the Ramsar Convention (Michev & Stoyneva 2007) and included in the Natura 2000 network. During the field trip, the meeting participants also visited the Big Island in Durankulak Lake and the Museum Collection in the Green Educational Center. Mr. I. Illiev talked about the rich cultural and historical heritage of Dobrudzha, which is an attractive center for cultural and archaeological tourism.

In addition, the participants in the meeting visited the *Baltata* managed reserve, located in close proximity to the *Albena* resort, which hosts the northernmost longoz forests at the lower part of Batova river (**Figs. 21, 22**). These forests are unique communities in the vegetation of Bulgaria with significant biodiversity and species of importance for conservation (Anonymous 2004; Michev & Stoyneva 2007).

The reserve *Baltata* contributes significantly to the unique conditions that *Albena* offers to its guests - a combination of preserved nature and a modern tourist resort providing various forms of recreation and ecotourism (**Figs. 20, 21**). The reserve provides a natural example of the role of forests in surface water purification. The river Batova flows through five villages and resorts: Dolishte (Ahtopol municipality), Batovo (Municipality of Dobrich), Tsurkva, Obrochishte, Kranevo, Balchik and Albena (Balchik region). During the summer the large part of the area is a massively used recreational destination, while its other part is occupied by agricultural lands. Two roads of the national road network pass through the river valley: between Obrochishte and Kranevo - a section of 5.1 km of road I-9 (Durankulak - Varna - Burgas - Malko Turnovo), and, between the villages of Batovo and Obrochishte, a section of 9.5 km from the road II-71 (Silistra - Dobrich - Obrochishte). Although very high pollution of the surface water flowing into the river Batova could be expected, the national monitoring data indicate that it is characterized by medium to low water pollution, with very pure water flowing into the Black Sea. The regulating and supporting ecosystem services that the longoz forests provide are of great importance to maintain the good ecological status of the surface waters in the Batova basin and the coastal seawater.

As it could be seen from the report above, the field trip elaborated on the Bulgarian experience in creation of forest protecting belts as providers of important ecosystem services, and on the good practices in nature conservation with focus on the significant role of the wetlands and their ecosystem services. Together with the successful theoretical sessions, they contributed to the meeting work in developing ideas for further proceeding of the COST Action.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this article.

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Book review: Grigorov B. G. 2018. Critically Endangered Plants of the Planet. Alians Print, Sofia, 376 pp. (In Bulgarian)

This brief review presents the new book, authored by BORISLAV GRIGOROV, PhD who is a Main Assistant and teaches in the Department of Lanscape ecology and environmental protection in the Faculty of Geology and Geography at Sofia University "St Kliment Ohridski".

The problem of biodiversity conservation is increasingly central to today's society, and the main reason for its loss is the disturbance of habitats caused by human activities. We must be concerned about the conservation of biodiversity, even from the point of view of its benefits - biological resources and ecosystem services. Plant conservation is a central element of biodiversity conservation efforts, and without them there is no life, and as a whole, the functioning of the planet and our survival depend on them.

The book under consideration, titled *Critically Endangered Plants* of the Planet, presents accessible information on globally critically endangered plant species included in the IUCN Red List, which is currently lacking in the Bulgarian botanical and nature conservation literature. It fills a gap in this direction, and not only for the purposes of university education, but can be enjoyed by anyone concerned with the conservation of plant life. The book's introduction includes information on the importance of plants as a source of ecosystem services, as well as a review of the activities of the International Union for Conservation of the Nature (IUCN). Subsequently, the categories of threats on the Red List have been commented, with particular attention being paid to critically endangered taxa that have been interpreted as critically endangered natural capital. The information on the individual critically endangered plant species is grouped on continents, according to the accepted natural geographic regionalization, following the principles of systematics. The Red List category and criteria version of the Red List and the author / team making the evaluation are included in the information after the name of each species. Information is given on the geographical distribution and main threats for each species. For some species it is noted whether they are covered by the Convention on International Trade in Endangered Species of Wild Fauna and

Flora (CITES), and for others the information on their including into the Bern Convention is provided. For third, it is commented on whether they fall under the Habitats Directive and whether they are included in Natura 2000 sites.

The need for the book is highlighted by several of its peculiarities. Due to the specifics of the Red List terminology and the foreign language character of the presentation of the information, the author believes that for its easier use for educational purposes and reaching a wider audience in Bulgarian, there is a need for a Bulgarian edition. Moreover, following the principles of systematics is more appropriate for presenting information than the alphabetical order used in the electronic version of the Red List. This version provides a way to differentiate geographic information, but terrestrial territories are not divided by continents according to the nature-geographic understanding, which is necessary for more synthesized data acquisition and avoid confusion. It has to be noted that this problem is solved in the book. In addition, it solves another problem related to the listing of all critically endangered species in a given geographical region, regardless of which kingdom they belong to. In the present edition, critically endangered plant species are separated from critically endangered species from other kingdoms and then attached to their adjacent geographic space. It also provides a summary of the number of critical species of plants in each continent, as well as in some of its natural geographic and political-geographic units. The synthesized information about families and species that fall on the territory of more than one continent is also presented. In this book there is a representation of several types on one and the same map, which is different from the global Red List where each type is presented separately. This option allows for a wider view of the geographical distribution of individual species, which would facilitate the analysis of the information.

The literature review at the end of the book is comprehensive and includes a number of publications that can be used to expand the reader's horizons. In addition, there is a list of sources of information related to the lists of protected species in many countries and regions of the world. The Alphabetical index allows the reader to quickly search for a specific look and one of the merits of the book. At the very end, an application with photos of a number of commented critically endangered plant species is provided, which provides a good illustration of the published taxa.

Assoc. Prof. Asen I. Asenov, PhD
Head of the Department of Landscape ecology and environmental protection
Faculty of Geology and Geography, Sofia University "St. Kliment Ohridski"

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The scientific names of the taxa (genera, species and lower ones) must be quoted completely, denominating the name of the genus, species epitheton (if necessary subspecies, cultivar etc.) and the author, when mentioned for the first time in the text. Full scientific names, as a rule, should be mentioned in the summary also. The author names in the scientific names should not be formatted. The classification system used is up to the authors, but in case of different from commonly approached, should be properly indicated.

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Journals:

IVANOV I. P. 2013. Photosynthetic CO2-fixation pathways. – Ann. Rev. Plant Physiol. 21 (2): 141–263.

IVANOV I. P. & PETROV P. I. 2013. Photosynthetic CO2-fixation pathways. – Ann. Rev. Plant Physiol. 21 (2): 141–263.

IVANOV I. P., PETROV P. I. & DIMITROV V. N. 2013. Photosynthetic CO2-fixation pathways. – Ann. Rev. Plant Physiol. 21 (2): 141–263.

Alternatively, we accept full text citations of journal titles. However, the reference list must be consistent in this regard.

Books:

DIMITROV D. G. & IVANOV A. N. 2017. Biodiveristy of the seashores of Bulgaria. Springer, Heidelberg, 405 pp.

IVANOV W. H., STOYANOV H. M. & PETROV F. B. (Eds) 2000. Water ecosystems. Elsevier, New York, 265 pp.

Book chapters:

PETROV F. K. 2000. Grazing in water ecosystems. – In: IVANOV W. J., STOYANOV H. P. & PETROV F. B. (Eds), Water ecosystems, Elsevier, New York, 59–105.

When the cited paper/chapter occupies only one page, it should be written as follows:

PETROV F. K. 2000. *Padina pavonica*. – In: IVANOV W. J., STOYANOV H. P. & PETROV F. B. (Eds), Water ecosystems, Elsevier, New York, p. 49.

Conference papers (or abstracts if they provide essential information):

BOGDANOV D. M. 2017. Danube Delta. - In: SOMOV N. P. & KARAKUDIS F. E. (Eds), Proceedings of the First European Symposium *Conservation and management of biodiversity in the European seashores*, Melnik, Bulgaria, 8-12 May 2017, 36-46.

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BOGDAN D. M. 2017. Biosphere reserves and special legislation for environmental protection. - In: VENEV N. (Ed-in-Chief), Book of Abstracts First European

Symposium *Conservation and management of biodiversity in the European seashores*, 8-12 May 2017, Primorsko, Bulgaria, p. 36.

Electronic publications should be cited with their author or title in the references with indication of the date of retrievement or of the last access of their full web address:

Geneva M. M. 2011. *Cortinarius caperatus*. – In: Penev D. (Ed.), Red Data Book of the Republic of Bulgaria. Vol. 1. Fungi. Retrieved from http://eclab. bas.bg/rdb/en/vol1/ on 14.11.2014.

Index Fungorum. Retrieved from http://www.indexfungorum.org/Names/Names.asp on 19.11.2017.

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Index Fungorum. http://www.indexfungorum.org/Names/Names.asp (Last accessed on 19.11.2017).

In special cases, as an exception, the websites of electronic publications could be placed in the text.

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Journal:

Petkov N. H. 1915. La flore algologique du mont Pirin-planina.- Sbornik na Bulgarskata Akademiya na Naukite 20: 1–128 (In Bulgarian).

Petkov N. H. 1915. La flore algologique du mont Pirin-planina.- Sbornik na Bulgarskata Akademiya na Naukite 20: 1–128 (In Bulgarian, French and Russian summ.).

Book:

Valkanov D. E., Draganova P. M. & Tsvetkova B. B. 1978. Flora of Bulgaria. Algae. Izd. Narodna Prosveta, Sofia, 642 pp. (In Bulgarian)

Valkanov D. E., Draganova P. M. & Tsvetkova B. B. 1978. Flora of Bulgaria. Algae. Izd. Narodna Prosveta, Sofia, 642 pp. (In Bulgarian, English summ.)

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HINDÁK F. 1996. Klúč na určovanie nerozkonárených vláknitých zelených rias (Ulotrichineae, Ulotrichales, Chlorophyceae) [Key to unbranched filamentous green algae (Ulotrichineae, Ulotrichales, Chlorophyceae)].- Bull. Slov. Bot. Spol., Bratislava, Suppl. 1: 1–77 (In Slovakian).

Footnotes should be avoided.

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