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MICROALGAE OF PROTECTED LAKES OF NORTHWESTERN UKRAINE

Yuriy Malakhov[1], Olha Kryvosheia & Petro Tsarenko

Abstract. The paper reports the first comprehensive study of microalgal species composition in four lakes of Volhynian Polissya (northwestern Ukraine), in which 271 species (279 intraspecific taxa) of 11 microalgal phyla were identified. Four dominant phytoplankton assemblages were determined for each lake. Bacillariophyta and Charophyta formed more than half (59.2%) of the taxonomic list, accounting for 94 and 66 species respectively. Desmidiaceae was the most diverse family, with 44 species (47 intraspecific taxa) of microalgae. The four lakes are highly dissimilar in species richness and composition, having only 8 (2.9%) species in common. Lake Cheremske had the highest number of algal species – 137 (144). Lake Bile, Lake Somyne and Lake Redychi were much less diverse, with 105, 79 (80) and 75 (78) species respectively. Morphological descriptions, original micrographies and figures are presented for a number of species, including some not previously documented in Ukraine: *Chromulina* cf. *verrucosa* G. A. Klebs, *Eunotia myrmica* Lange-Bert. and *E. tetraodon* Ehrenb. The lakes, which are almost pristine or are recovering, maintain diverse and valuable algal floras, making them important sites in the Pan-European ecological network.

Key words: microalgae, diversity, distribution, phytoplankton, lakes, nature reserves, Volhynian Polissya

Yuriy Malakhov, Olga Kryvosheia & Petro Tsarenko, Department of Phycology, M. G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine, 2 Tereshchenkivska St., 01601, Kyiv, Ukraine; e-mails: yur.malakhov@gmail.com, olja_km@mail.ru, ptsar@ukr.net

Introduction

Phycological and limnological studies in the Polesie region, and particularly in northwestern Polesie, have been carried out for almost a century (e.g., Wolsky 1927; Ernest 1939; Masjuk 1958; Asaul 1962; Tsarenko 1984, 2014a, b; Kovalenko 1997; Kryvenda 2007; Bukhtiyarova 2008; Palamar-Mordvintseva *et al*. 2009). In these studies, most of the researchers' attention was focused on the algal flora and species composition of various lakes in the Svityaz algofloristic area (Palamar-Mordvintseva & Tsarenko 2015). This lake and wetland assemblage is in the Western Bug River Basin and is part of the West Polesie Trilateral Transboundary Biosphere Reserve (Chmelevski *et al*. 2015). With more than 950 recorded species, this reserve is considered to be a hotspot of the country's algal biodiversity (Tsarenko 2014a). The nearby Polish lakes also show high levels of algal diversity, with 341 recorded species of green conjugates alone (Pasztaleniec & Poniewozik 2010; Chmelevski *et al*. 2015). Even with such extensive study, there is room for much more investigation of algal biodiversity in Ukraine and its neighboring countries.

Polesia and its subregion Volhynian Polissya (northwestern Ukraine) form one of several major core areas of the Pan-European Ecological Network for Central and Eastern Europe. Together these core areas maintain ecological coherence and provide important wildlife corridors (Jongman *et al*. 2011). In Ukraine's national econetwork, Volhynian Polissya is part of the Polissian nature corridor, which consists of 16 cores covering more than 847,000 ha (Fig. 1). Each core is in a nature reserve or national park, the highest national conservation categories for protected land (Anonymous 2012). Half of these cores are located just within Volhynian Polissya (Fig. 1: 1–6, 11, 12). Together with the adjacent Pojezierze

[1] Corresponding author

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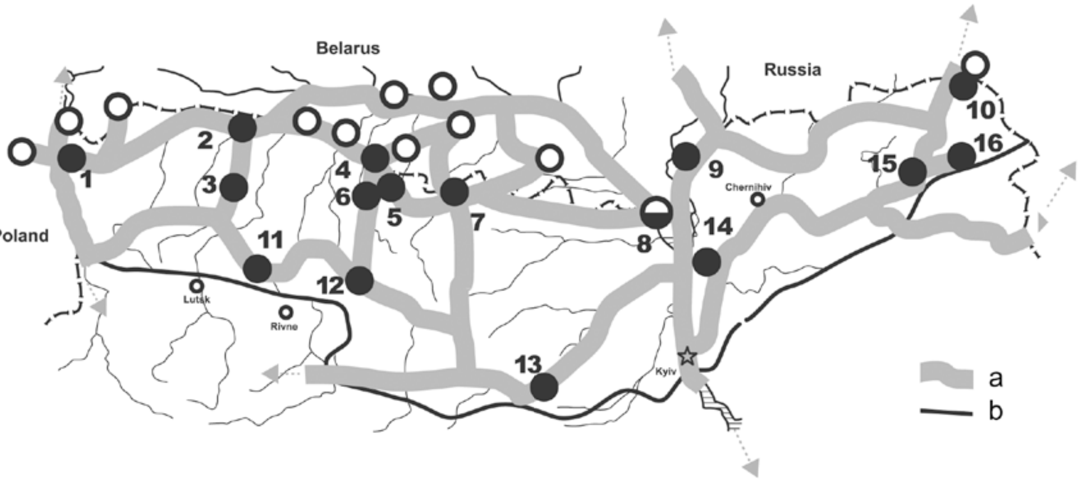


Fig. 1. Scheme of Ukrainian Polissya econetwork (adapted from Anonymous 2012). Major cores of the network: 1 – Shatsk, 2 – Prypyat-Stokhid, 3 – Biloozersko-Cheremske, 4 – Perebrody, 5 – Syra Pohonia, 6 – Somyne, 7 – Ubortsko-Bolotnytske, 8 – Chornobyl, 9 – Dniprovske, 10 – Desnyansko-Starohutske, 11 – Tsuman, 12 – Nadslychanske, 13 – Korostyshiv, 14 – Mizhrichenske, 15 – Mezynsko-Shostkynske, 16 – Verkhnyoesmanske; a – major nature corridors, b – southern border of Polesia region, ● – major econetwork cores in Ukraine, ○ – indicate cores of Polesia econetwork in Poland, Belarus and Russia.

Łęczyńsko-Włodawskie lake district in Poland, the Biloozersko-Cheremske, Perebrody, Prypyat-Stokhid, Shatsk, Somnye and Syra Pohonia cores are recognized as important Ramsar sites (Marushevsky & Zharuk 2006; Chmelevski *et al*. 2015; https://rsis.ramsar.org).

In this study we aimed to fill a gap in knowledge of the algal flora of lakes other than those of Shatsk National Park. Despite the high status and value of these lakes, the microalgal data for them are scarce or even absent. We assessed microalgae species diversity and its conservation value in the protected lakes of the Rivnensky and Cheremsky Nature Reserves, which constitute the Biloozersko-Cheremske and Somyne cores of the Ukrainian Polissya econetwork.

Materials and methods

This study is based on 53 algal samples collected during repeated field trips to the Rivnensky and Cheremsky Nature Reserves in July of 2003–2008 and 2013–2014. Our sampling covered the main aquatic complexes of the reserves: Lake Bile, Lake Somyne, Lake Redychi and Lake Cheremske (Fig. 2). Plankton and benthos samples were taken with a plankton net (64 μm mesh) and a siphon. Periphytic samples were collected together with fragments of aquatic plants or macroalgal filaments. Most of the samples were fixed in 4% solution of formaldehyde, and some were maintained live. We measured water pH immediately after sample collection with an SX 620 portable pH-meter.

Further analyses in the laboratory employed light and scanning electron microscopy. For the study we also established enrichment cultures with and without

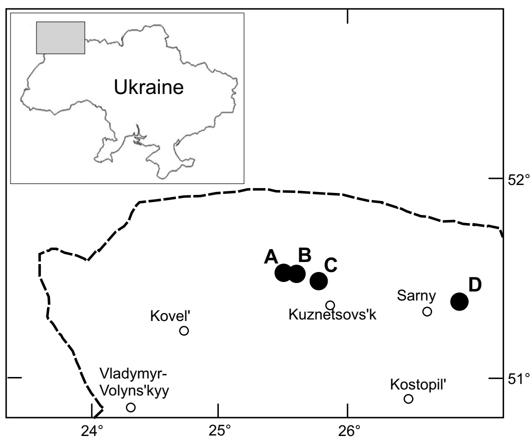


Fig. 2. Sampling locations on map of Ukraine. A – Lake Cheremske, B – Lake Redychi, C – Lake Bile, D – Lake Somyne.

addition of BBM medium (Andersen 2005). Unialgal culturing was continued on sterile solid (1.5% agar) BBM medium in growth chambers (L : D 12 : 12, 3000–4000 lm flux).

Algal colonies on agar plates were examined with an MBS-10 stereomicroscope; separate specimens of microalgae were examined and identified using ZEISS Primo Star (objectives: Plan Achromat 10×, 40×, immersion-oil 100×) and MBI-6 phase-contrast (Plan Achromat 40×, immersion-oil 90×) light microscopes. For identification of diatoms, frustules were cleaned in hot hydrogen peroxide (Prygiel & Coste 2000) and mounted in Naphrax synthetic resin. Cleaned diatom frustules were also examined using a JEM-1230 scanning electron microscope at the M. G. Kholodny Institute of Botany, National Academy of Sciences of Ukraine.

The taxonomic list (see Appendix) follows the system presented in the *Algae of Ukraine* series (Tsarenko *et al*. 2006, 2009, 2011, 2014). Taxonomy of the phylum *Cyanoprokaryota* follows Komárek and Anagnostidis (1998, 2005) and Komárek (2013).

The dendrogram was built in PAST 3.11 (Hammer *et al*. 2001).

Characteristics of sampling sites and study region

Mixed broadleaf and coniferous forest is the most common vegetation type in Volhynian Polissya. Other characteristic features of this region include humid continental climate, the prevalence of lowland relief, and a dense hydrographic network. Another attribute of the region is its many lakes, whose presence is related to the occurrence of karst formations and post-glacial activity (Marynych & Shyshchenko 2005). The majority of Volhynian Polissya lakes show hydrocarbonate and calcium mineralization, with neutral or slightly acidic water (pH = 6.5–7.0). Hydrochemical parameters of the studied lakes are given in Table 1.

Lake Somyne is located in the Rivnensky Nature Reserve (RNR), Rivne oblast (province), Sarny raion (district). The center of the lake is at 51°23′07″N, 26°51′04″E. Its surface area is 61 ha and its maximum depth is 13 m. Lake Somyne is of karst origin (Marushevsky & Zharuk 2006). Its emerged shoreline vegetation is weakly developed. An earthen dike limits the lake's catchment from the western side. The lake is surrounded by mesotrophic swamps on the other three sides. To the north, adjacent wetlands drain directly into the lake, sometimes forming floating vegetation mats on the lake surface. During sampling the lake water was yellowish brown and its turbidity obscured the lake bottom.

Lake Bile is also located in the RNR, Rivne oblast, Volodymyrets raion. The lake center is at 51°29′01″N, 26°45′13″E. Its surface area is 453 ha and its maximum depth is 26 m. This lake is also of karst origin (Marushevsky & Zharuk 2006). It has a large, shallow (2–2.5 m deep) littoral in the north and northeastern parts of the lake, which continues up to 200 m from the shoreline. After that the littoral breaks, with a sudden increase in depth. The shoreline vegetation is sparse. The high transparency of the water allows plant growth at considerable depths (Orlov *et al*. 2009).

Lake Cheremske and Lake Redychi are both located in the Cheremsky Nature Reserve (ChNR), Volyn oblast, Manevychi raion. The center of Lake Cheremske is at 51°31′27″N, 25° 32′12″E. Its surface area is 7.7 ha and its maximum depth is 7 m. The center of Lake Redychi is at 51°31′30″N, 25°35′07″. Its surface area is 14 ha and its maximum depth is 4.5 m. These drainage lakes are of both glacial and karst origin. They were formed in the course of the transformation of a large drainage lake (covering more than 1000 ha) into what is now Cheremske bog. Both lakes are low in plant species richness but a number of nationally rare plants are found there (Konishchuk 2005).

Results and discussion

During our investigation of the lakes we found 271 species, (279 intraspecific taxa) belonging to 137 genera, 74 families, 40 orders, 15 classes and 11 phyla of microalgae (Table 2).

Table 1. Hydrochemical characteristics of the studied lakes.

Lake	Conductivity µS/cm^{-1}	pH	Dissolved O_2 mg/l^{-1}	NH_4^+ mg/l^{-1}	NO_2^- mg/l^{-1}	NO_3^- mg/l^{-1}	PO_4^{3-} mg/l^{-1}	Fe^{3+} mg/l^{-1}
Redychi	63	6.46	9.5	0.20	<0.01	<0.01	–	1.1
Cheremske	70	6.16–6.50	9.7	0.22	<0.01	<0.01	–	1.2
Somyne	(76)–102–160	(5.50)–6.67–(7.10)	–	0.64–(2.2)	<0.01	0.01–2.01	0.049	(0.5)–1.0–3.0
Bile	95	7.34–(8.50)	9.6	0.45	<0.03	2.01	–	1.5

Bacillariophyta (94 species) and Charophyta (66 species) form the basis of the algal species composition of all of the studied waterbodies, accounting for more than half (59.2%) of the taxonomic list. Chlorophyta and Cyanoprokaryota contribute less to the diversity of the lakes: 53 (19.6%) and 28 (10.3%) species respectively.

Among the principal families, Desmidiaceae showed the most diversity, adding 44 species (47 intraspecific taxa) to the taxonomic list.

Other noteworthy families are Pinnulariaceae (15 species, 18 intraspecific taxa), Cymbellaceae (10 species), Gomphonemataceae (10 species), Eunotiaceae (9 species) and Fragilariaceae (7 species) – Bacillariophyta; Selenastraceae (12 species) and Scenedesmaceae (9 species) – Chlorophyta; Closteriaceae (13 species, 14 intraspecific taxa) – Charophyta; and Euglenaceae (10 species, 11 intraspecific taxa) – Euglenophyta. The basis of algal diversity of the investigated lakes consists of desmids, pennate diatoms, and coccoid green and euglenoid algae. Lake Cheremske yielded the highest number of algal species (137 species, 144 intraspecific taxa). The species diversity of Lake Bile appeared to be lower (105 species). Lake Somyne (79 species, 80 intraspecific taxa) and Lake Redychi (75 species, 78 intraspecific taxa) showed low algal species richness.

Jaccard similarity coefficient calculations showed the four lakes to be floristically distinct rather than similar (Fig. 3). Lake Cheremske and Lake Redychi showed the highest similarity (0.37); Lake Cheremske and Lake Bile were the most distant pair (0.11). Lake Bile and Lake Somyne were also distant (0.19). Such low Jaccard coefficients indicate specific species compositions and heterogeneity of habitat conditions. The four waterbodies had only 8 species (2.9%) in common: *Stephanodiscus hantzschii* Grunow, *Cyclotella meneghiniana* Kütz., *Gomphonema acuminatum* Ehrenb., *Cocconeis placentula* Ehrenb., *Brachysira vitrea* (Grunow) R. Ross, *Navicula radiosa* Kütz., *Oedogonium* sp. ster. and *Aphanochaete repens* A. Braun.

During microscopic examination, the majority of microalgae species occurred sporadically, with a few being dominant or fairly abundant. Basing on these observations, we identified dominant species assemblages in the phytoplankton of the researched lakes.

For Lake Bile, pelagic samples showed that the chroococcoid cyanoprokaryotes were fairly diverse, with *Aphanocapsa planctonica* (G. M. Sm.) Komárek & Anagn., *Coelosphaerium kuetzingianum* Nägeli, *Snowella lacustris* (Chodat) Komárek & Hindák and *Woronichinia naegeliana* (Unger) Elenkin present. The occasional findings of *Aphanothece endophytica* (West & G. S. West) Komárk.-Legn. & Cronberg in colonial mucilage of *Woronichinia naegeliana* were especially

Table 2. Taxonomic spectrum of algal flora of the studied lakes.

Phylum	Quantity					% of total species number
	classes	orders	families	genera	species (int. taxa)	
Cyanoprokaryota	1	3	9	23	28 (28)	10.33%
Euglenophyta	1	1	2	5	11 (12)	4.06%
Chrysophyta	1	3	5	7	8 (8)	2.95%
Xanthophyta	1	2	3	2	4 (4)	1.85%
Eustigmatophyta	1	1	1	1	1 (1)	0.37%
Bacillariophyta	3	13	24	40	94 (97)	34.69%
Dinophyta	1	2	2	2	2 (2)	0.74%
Cryptophyta	1	1	1	1	2 (2)	0.74%
Glaucocystophyta	1	1	1	1	1 (1)	0.37%
Chlorophyta	2	9	20	37	54 (54)	19.56%
Charophyta	2	4	6	18	66 (70)	24.35%
Total	15	40	74	137	271 (279)	100.00%

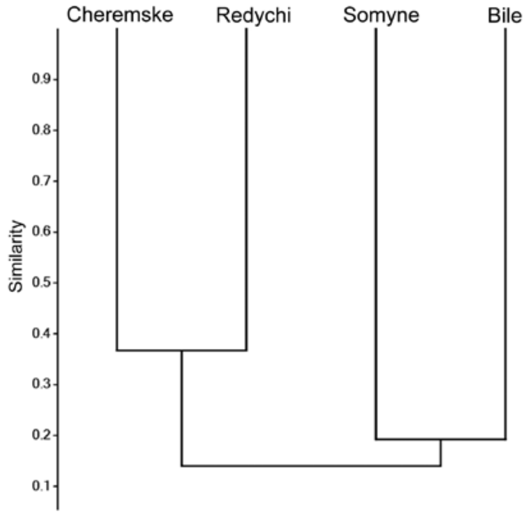


Fig. 3. Jaccard similarity dendrogram, built by single-linkage clustering.

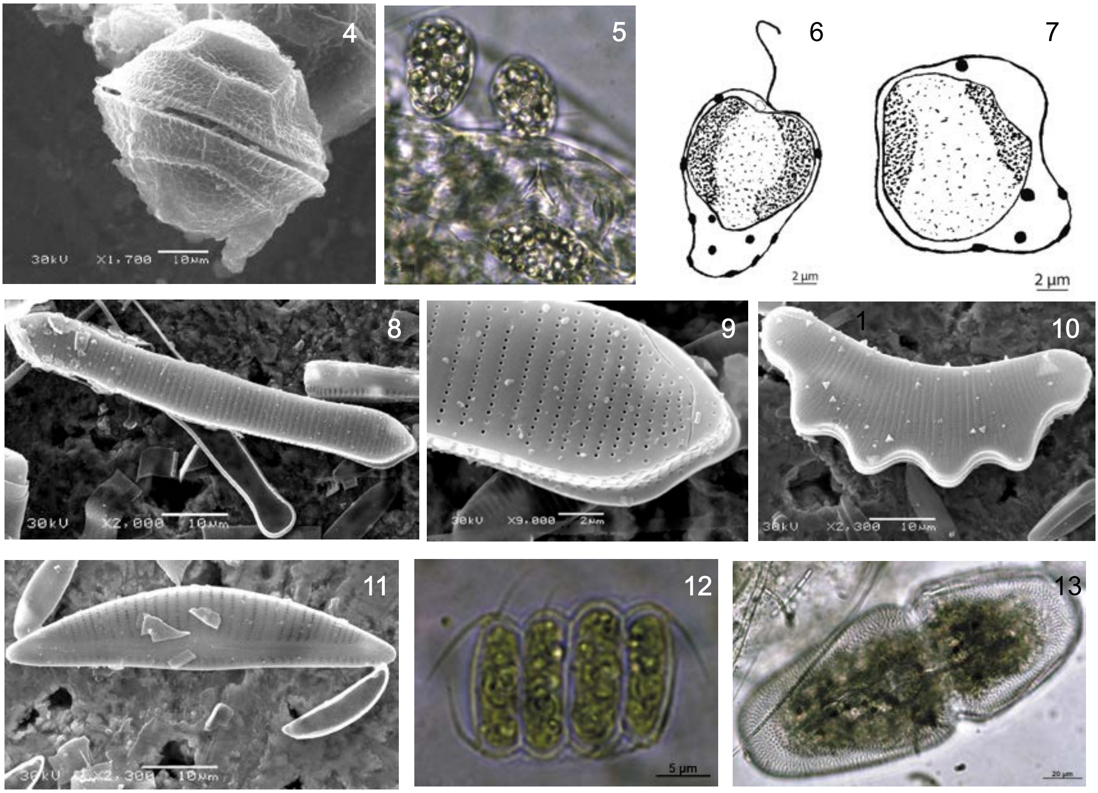
interesting, as its presence indicates clear water (Komárek & Anagnostidis 1998; Kovalenko 2009). Second most frequent in the Lake Bile phytoplankton was the group of diatom species *Tabellaria flocculosa* (Roth) Kütz., *Fragillaria crotonensis* Kitton, *Eunotia pectinalis* (Kütz.) Rabenhorst and *Navicula radiosa*. Among the less frequent but still typical findings were the unicellular thecate dinoflagellate *Ceratium hirundinella* (C. Agardh) Kütz. and the chrysophycean colonial *Dinobryon divergens* O. E. Imhof. The shallow littoral of the lake showed different species composition patterns and overall greater microalgal abundance than the lake's pelagial. In the shallows, the cyanoprokaryotic diatom community was complemented by desmid and coccoid green specimens. We suggest that the increased development of microalgae in the shallow near-shore zone can be explained by the elevated concentrations of biogenic nutrients that flow from the lakeshore and become trapped there.

Pelagic samples from Lake Somyne were conspicuously poor, both qualitatively and quantitatively. The most frequent findings were the dinoflagellates *Ceratium hirundinella* and *Peridinium gatunense* Nygaard (Fig. 4). These species can be considered the absolute dominants of the lake's phytoplankton. Massive development of *P. gatunense* was previously observed in lakes of Ukrainian Polissya (Kapustin 2013). This species is known to cause massive blooms, particularly in lentic ecosystems of oligotrophic and mesotrophic lakes such as Lake Kinneret in Israel (Hickel & Pollingher 1988; Krakhmalnyi *et al.* 2014). According to Oda and Bicudo (2006), peak development of *P. gatunense* occurs during periods of evident limnological stress such as nutrient depletion, allowing this species to take advantage of reduced competition. Our observation of high abundance of *P. gatunense* in July samples suggests that Lake Somyne may experience stress during warm summer months, but further study of the lake's hydrology is needed to verify this.

In addition to dinoflagellates, we frequently observed scattered specimens of cyanoprokaryotes (*Aphanocapsa planctonica*), diatoms [*Acanthoceras zachariasii* (Brun) Simonsen, *Tabellaria flocculosa*, *Navicula radiosa*, *Brachysira vitrea*], chrysophytes (*Pseudokephiryon poculum* W. Conrad) and green algae [*Monoraphidium arcuatum* (Korschikov) Hindák, *M. contortum* (Thur.) Komárk.-Legn., *Kirchneriella obesa* (West) Schmidle]. We also found the epizoic euglenid *Colacium cyclopicola* (Gickl.) Woron. & T. G. Popova (Fig. 5) in the microscopic crustacean plankton relatively frequently. Palustrine parts of the lake were marked by the presence of *Euglena gracilis* G. A. Klebs, *Trachelomonas volvocina* Ehrenb., *T. volvocina* var. *punctata* Playfair, *Phacus* spp. (Euglenophyta); *Ophiocytium* spp. (Xanthophyta); *Cocconeis* spp., *Pinnularia* spp. and *Ulnaria* spp. (Bacillariophyta).

The low algal diversity of the material from Lake Somyne may be explained in part by weak water mineralization. The elevated content of humic substances originating from the adjacent swamps may be another factor limiting algal growth in the lake. The yellowish brown coloration of the lake water indicates high content of humic compounds, which typically causes water acidification, although the average pH 7.1 recorded at the time of sampling does not mark Lake Somyne as acidic.

The pelagic phytoplankton communities of Lake Cheremske and Lake Redychi can also be



Figs 4–13. 4 – *Peridinium gatunense* Nygaard from Lake Somyne; 5 – *Colacium cyclopicola* (Gickl.) Woron. & T. G. Popova from Lake Bile; 6 & 7 – monad form (6) and amoeboid form (7) of *Chromulina* cf. *verrucosa* G. A. Klebs from Lake Somyne; 8 & 9 – *Eunotia myrmica* Lange-Bert. from Lake Redychi; 10 – *E. tetraodon* Ehrenb. from Lake Redychi; 11 – *Encyonema vulgare* Krammer from Lake Somyne; 12 – *Desmodesmus magnus* (Meyen) P. Tsarenko from Lake Bile; 13 – *Actinotaenium turgidum* (Bréb. *ex* Ralfs) Teiling *ex* Růžička & Pouzar from Lake Bile.

characterized as low in species abundance and diversity. Despite their proximity and similar morphology, they differ in dominant species complexes. Lake Cheremske is dominated by *Trachelomonas volvocina*, *Tabellaria flocculosa* and *Gomphonema acuminatum*, while Lake Redchyi is dominated by *Tabellaria fenestrata* (Lyngb.) Kütz., *T. flocculosa* and *Cocconeis placentula*. This difference may be due to differences in the ecological amplitudes of particular species, or to hydroecological conditions such as flow level, temperature regime, or the presence or absence of groundwater discharge. As in Lake Somyne, the palustrine parts of both lakes showed higher shares of particular algal phyla (Chlorophyta, Xanthophyta, Charophyta, Bacillariophyta) in the dominant species assemblages. The most distinctive algal complex was recorded in samples from the periphyton of vascular plant associations: *Gomphonema acuminatum*, *Eunotia bilunaris* (Ehrenb.) Mills., *E. pectinalis*, *Navicula radiosa*, *Pinnularia subcapitata* W. Greg., *Tabellaria flocculosa*, *Mougeotia* sp. ster., *Oedogonium* sp.ster., *Palmodictyon viride* Kütz., *Ophiocytium capitatum* Wolle, *Quadrigula korschikovii* Komárek, *Cylindrocystis brebissonii* (Menegh. *ex* Ralfs) De Bary, *Closterium acutum* Bréb., *C. juncidum* Ralfs, *Staurastrum boreale* West & G. S. West and *Xanthidium cristatum* Bréb *ex* Ralfs. This peculiar species composition is characteristic of the adjacent swamps. Its presence in the lakes demonstrates the strong influence of the swamp on the lakes' water.

We also recorded 69 microalgal taxa that are new (*) or rare (**) for the Ukrainian algal flora. Morphological descriptions, original photomicrographs and figures for some of them are presented below.

CHRYSOPHYTA

Chromulinaceae Engler

***Chromulina** cf. **verrucosa** G. A. Klebs Figs 6 & 7

COLLECTING SITE: Lake Somyne.

Cells oval, truncated at anterior, slightly excavated at attachment of flagella. Cells metabolic, especially at posterior end. Cell shape rounded to oval or oblong, with appendage at posterior end. Observed cells may also persist in amoeboid state for a relatively long time. Periplast covered with large, irregular verrucae. One flagellum nearly equal to cell length visible by LM. Cells contain single, large, trough-shaped, yellowish brown chloroplast. One small contractile vacuole located at anterior end of cell near base of flagellum. Cell length 16.5 µm, width 12 µm.

Specimens of *Ch.* cf. *verrucosa* were found in enrichment cultures from Lake Somyne. This species is also known from Central Europe (Germany) and European Russia (Guiry & Guiry 2016; Matvienko 1965). Freshwater species, planktic in lentic waters.

BACILLARIOPHYTA

Eunotiaceae Kütz.

***Eunotia myrmica** Lange-Bert. Figs 8 & 9

Eunotia formica sensu Hustedt, *E. formica* sensu Mölder & Tynni

COLLECTING SITE: Lake Redychi.

Valves slightly bent to almost linear. Central part of valve slightly inflated on dorsal and ventral sides. Ends of valve weakly capitate with cuneate to acuminated punctate apices. Terminal parts of raphe bent towards dorsal margin. Length of valves 63.4–101.3 µm, width 8.4–7.5 µm. Striae density 10 in 10 µm in central part of valve, 13–14 in 10 µm at apices. Areolae density 26 in 10 µm. Freshwater species.

The cognate taxon *E. formica* Ehrenb. was previously known from Ukrainian Polissya (Radzymovsky & Polischuk 1970; Moshkova & Vodopian 1975) and lakes of the Ukrainian Carpathians (Konenko *et al*. 1965; Tsarenko *et al*. 2009). Taking into account the revision of the *E. formica* complex (Lange-Bertalot *et al*. 2011), however, we recognize *E. myrmica* as a newly registered species in Ukraine. It is also known from Arctic Russia, Scandinavia, Canada and northern USA (Lange-Bertalot *et al*. 2011).

***Eunotia tetraodon** Ehrenb. Fig. 10

Eunotia serra var. *diadema* (Ehrenb.) Patrick, *E. serra* var. *tetraodon* (Ehrenb.) Norpel

COLLECTING SITE: Lake Redychi.

Valves highly convex, with four regular undulations on dorsal side. Apices wider than undulations, bluntly rounded. Terminal parts of raphe shifted closer to apices, bent towards dorsal margin. Length of valves 49.5–50.1 µm, width 13.6–16.9 µm. Striae radial, of two types: complete (passing through whole breadth of valve) and short (present only on dorsal margin, more numerous on undulations, filling gaps between full-length striae). Striae density 10 in 10 µm in central part of valve, 14–16 in 10 µm at apices. Areolae density 22–23 in 10 µm. Freshwater benthic species, acidophilic, xeno-oligosaprobic.

The cognate species *Eunotia serra* was previously reported from Ukrainian Polissya (Topachevsky & Oksiyuk 1960) and the steppe zone (Vladimirova & Litvinova 1964; Tsarenko *et al*. 2009). In light of the recent genus revision and reconsideration of some intraspecific taxa as separate species (Lange-Bertalot *et al*. 2011), we regard our finding of *E. tetraodon* as the first report for Ukraine. This species has a Holarctic distribution, found mostly in boreal-alpine habitats of Eurasia and North America (Lange-Bertalot *et al*. 2011).

Cymbellaceae Grev.

****Encyonema vulgare** Krammer Fig. 11

COLLECTING SITES: Lake Somyne, Lake Cheremske and Lake Redychi.

Valves dorsoventral, semi-lanceolate, with arcuate dorsal margin. Ventral margin slightly convex in central area, sometimes becoming linear. Apices broadly rounded. Length of valves 51.2–45.4 µm, width 11.1–12.3 µm, length/width ratio 4.6. Raphe linear, positioned laterally. Axial field narrow, shifted to ventral side and parallel to dorsal margin. Central field absent or indistinctly delineated. Striae radial, converging at ends of ventral side, 10–11 in 10 µm. Areolae density 25 in 10 µm.

This alga usually is found in oligotrophic waterbodies with low electrolyte content. This is the second finding in Ukraine (Kryvosheia & Kryvenda 2015) and the first for Ukrainian Polissya. *Encyonema vulgare* was also reported from Poland, northwestern and southeastern USA, Colombia and China (Guiry & Guiry 2016).

Chlorophyta

Scenedesmaceae Oltm.

** ***Desmodesmus magnus*** (Meyen) P. Tsarenko Fig. 12

Collecting sites: Lake Bile and Lake Somyne.

Coenobia consists of four cylindrically oval cells with rounded poles and slightly convex external margin. Cell poles have linearly symmetric and bent spines. Cell length 14.5 µm, width 4.5 µm.

Occasional specimens of *D. magnus* were found in enrichment cultures from Lake Somyne and in samples from shallows of Lake Bile. It is a regionally rare protected species (Konishchuk *et al.* 2010). This freshwater alga occurs in the plankton and periphython of lakes and ponds. The species range is disjunctive and includes Eurasia, Africa, South America and Oceania (Guiry & Guiry 2016).

Charophyta

Desmidiaceae Ralfs

** ***Actinotaenium turgidum*** (Bréb. *ex* Ralfs) Teiling *ex* Růžička & Pouzar Fig. 13

Collecting site: Lake Bile.

Cells large, ellipsoidal, slightly constricted. Apices obtusely rounded to truncated. Finely porous, scrobiculate cell wall. Cell length 182 µm, width 76 µm.

Specimens of *A. turgidum* occurred very rarely (1–2 cells per slide) in samples from the shallow littoral of Lake Bile. This species is rare for the algal flora of Volhynian Polissya (Palamar-Mordvintseva *et al.* 2009). Benthic, planktic (tychoplanktic) in lakes, swamps and streams; mesosaprobic. The species range includes Europe, South Asia, South America, Australia and Oceania (Guiry & Guiry 2016).

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APPENDIX. Taxonomic list of algal flora of the studied lakes. A – lake Bile, B – Lake Somyne, C – Lake Cheremske, D – Lake Redychi; * – new for Ukrainian flora, ** – rare in Ukrainian flora.

Taxon / Lake	A	B	C	D
CYANOPROKARYOTA				
Anabaena sp.	+			
Aphanocapsa planctonica (G. M. Sm.) Komárek & Anagn.	+	+		
***Aphanothece endophytica* (West & G. S. West) Komárk.-Legn. & Cronberg	+			
A. microscopica Nägeli	+			
A. minutissima (West) Komárk.-Legn. & Cronberg	+			
Chroococcus minimus (Keissler) Lemmerm.		+		
C. turgidus (Kütz.) Nägeli	+		+	
Coelosphaerium kuetzingianum Nägeli	+			
Cyanothece aeruginosa (Nägeli) Komárek			+	
Dolichospermum flos-aquae (Bréb. *ex* Bornet & Flahault) Wacklin, Hoffman & Komárek	+			
D. spiroides (Klebhan) Wacklin, L. Hoffmann & Komárek			+	
Geitlerinema splendidum (Grev. *ex* Gomont) Anagn.	+			
Gloeocapsa gelatinosa Kütz.	+			
***Gloeothece subtilis* Skuja		+		
Gloeotrichia pisum Thuret *ex* Bornet & Flahault	+			
Hapalosiphon pumilus Kirchner *ex* Bornet & Flahault		+		
**cf. *Leptolyngbya gloeophila* (Borzi) Anagn. & Komárek	+			
Merismopedia punctata Meyen	+	+		
Microcystis cf. *smithii* Komárek & Anagn.	+			
Nostoc punctiforme (Kütz.) Hariot			+	
Oscillatoria tenuis C. Agardh *ex* Gomont			+	+
Pseudanabaena catenata Lauterborn	+			
***Rivularia aquatica* (De-Wild.) Geitl.	+			
Snowella lacustris (Chodat) Komárek & Hindák	+			

APPENDIX. *Continued.*

Taxon / Lake	A	B	C	D
Spirulina cf. *robusta* Welsh	+			
Stenomitos frigidus (F. E. Fritsch) Miscoe & J. R. Johansen		+		
Synechocystis aquatilis Sauv.			+	
Woronichinia naegeliana (Unger) Elenkin	+			
EUGLENOPHYTA				
*******Colacium cyclopicola* (Gickl.) Woron. & T. G. Popova	+	+		
***Distigma curvatum* Pringsh.			+	+
Euglena ehrenbergii G. A. Klebs			+	+
E. gracilis G. A. Klebs		+	+	
E. pisciformis G. A. Klebs			+	+
E. proxima P. A. Dang.			+	
E. tripteris (Duj.) G. A. Klebs			+	+
Phacus pleuronectes (Ehrenb.) Dujard.		+		
P. pyrum (Ehrenb.) F. Stein		+		
Trachelomonas rugulosa F. Stein		+		
T. volvocina Ehrenb. var. *volvocina*		+	+	+
T. volvocina var. *punctata* Playfair		+		
CHRYSOPHYTA				
**Chromulina* cf. *verrucosa* G. A. Klebs		+		
***Dynobrion cylindricum* var. *palustre* Lemmerm.		+		
D. divergens O. E. Imhof	+	+	+	
Epipyxis utriculus var. *pusilla* Averintsev		+		
Lagynion scherffelii Pascher		+		
***Lepochromulina calyx* Scherff.		+		
***Pseudokephyrion poculum* W. Conrad		+		
Synura uvella Ehrenb. *emend.* Korschikov			+	+
XANTOPHYTA				
***Bumilleria angustata* (Starmach) Matv. & Dogadina	+			
Ophiocytium capitatum Wolle			+	
O. maius Nägeli		+		
O. parvulum (Perty) A. Braun		+		
EUSTIGMATOPHYTA				
Vischeria helvetica (Vischer & Pascher) Hibberd			+	
BACILLARIOPHYTA				
Acanthoceras zachariasii (Brun) Simonsen		+		
Achnanthidium exiguum (Grunow) Czarn.				+
Amphora ovalis (Kütz.) Kütz.	+			
Aulacoseira granulata (Ehrenb.) Simonsen		+		
Brachysira vitrea (Grunow) R. Ross	+	+	+	+
Caloneis silicula (Ehrenb.) Cleve	+			
***Cavinula scutelloides* (W. Sm.) Lange-Bert.	+			
Cocconeis pediculus Ehrenb.	+	+		
C. placentula Ehrenb. var. *placentula*	+	+	+	+
Craticula buderi (Hust.) Lange-Bert.	+			
Cyclotella meneghiniana Kütz.	+	+	+	+
C. stelligera Cleve & Grunow		+		
Cymatopleura solea (Bréb.) W. Sm.	+			
***Cymbella aspera* (Ehrenb.) Cleve		+		
C. cymbiformis C. Agardh	+			

Appendix. *Continued.*

Taxon / Lake	A	B	C	D
C. lanceolata (C. Agardh) Ehrenb.	+			
****C. subcistula** Krammer	+	+		
****Cymbopleura cuspidata** (Kütz.) Krammer	+			+
Diploneis ovalis (Hilse) Cleve	+			
Encyonema caespitosum Kütz.	+			
***E. neogracile* Krammer			+	
***E. silesiacum* (Bleisch) D. G. Mann	+			+
***E. vulgare* Krammer		+	+	+
Epithemia adnata (Kütz.) Bréb.	+		+	+
E. frickei Krammer	+			
E. sorex Kütz.	+			
E. turgida (Ehrenb.) Kütz.				+
Eunotia arcus Ehrenb.				+
E. bilunaris (Ehrenb.) Schaar.		+	+	+
***E. flexuosa* (Bréb. & Kütz.) Kütz.	+		+	+
***E. minor* (Kütz.) Grunow		+	+	+
**E. myrmica* Lange-Bert.				+
***E. naegelii* Migula		+		
E. pectinalis (Kütz.) Rabenh.	+		+	+
***E. sylvahercynia* Nörpel, Van Sull & Lange-Bert.			+	+
**E. tetraodon* Ehrenb.				+
Fragilaria capucina var. *vaucheriae* (Kütz.) Lange-Bert.	+			
F. crotonensis Kitton	+	+		
Frustulia disjuncta Lange-Bert.			+	+
***F. krammeri* Lange-Bert. & Metzeltin			+	+
F. vulgaris (Thwaites) De Toni			+	
Gomphonema acuminatum Ehrenb.	+	+	+	+
G. angustatum (Kütz.) Rabenh.			+	
G. augur Ehrenb.				+
***G. brebissonii* Kütz.	+			
G. capitatum Ehrenb.				+
G. coronatum Ehrenb.		+	+	+
G. gracile Ehrenb.		+	+	+
G. parvulum Kütz.	+		+	+
G. truncatum Ehrenb.	+	+	+	
Halamphora veneta (Kütz.) Levkov				+
Hantzschia amphioxys (Ehrenb.) Grunow	+			
Lemnicola hungarica (Grunow) Round & Basson				+
Navicula cryptotenella Lange-Bert.	+		+	
N. radiosa Kütz.	+	+	+	+
N. reinhardtii (Grunow) Grunow	+			
N. viridula (Kütz.) Ehrenb.	+			
***N. vulpina* Kütz.	+	+		
Neidium ampliatum (Ehrenb.) Krammer	+			
N. bisulcatum (Lagerst.) Cleve				+
N. dubium (Ehrenb.) Cleve	+			
Nitzschia amphibia Grunow	+			+
N. fonticola (Grunow) Grunow				+
Pinnularia brebissonii (Kütz.) Rabenh.			+	

APPENDIX. *Continued.*

Taxon / Lake	A	B	C	D
**P. *complexa* Krammer			+	+
**P. *flexuosa* Cleve			+	+
**P. *gracillima* Greg.			+	+
P. microstauron (Ehrenb.) Cleve				+
P. nodosa (Ehrenb.) W. Sm. var. *nodosa*	+			
**P. *nodosa* var. *pseudogracillima* A. Mayer			+	+
**P. *parvulissima* Krammer			+	+
**P. *polyonca* (Bréb.) W. Sm. var. *polyonka*			+	+
**P. *polyonca* var. *similis* Krammer			+	+
**P. *rhombarea* Krammer			+	+
**P. *stidolphii* Krammer			+	+
**P. *subanglica* Krammer			+	+
P. subcapitata W. Greg		+	+	+
**P. *subrupestris* Krammer var. *subrupestris*			+	+
**P. *subrupestris* var. *cruciata* Krammer			+	+
P. viridis (Nitzsch) Ehrenb.		+	+	+
Placoneis placentula (Ehrenb.) Mereschk.	+			
Planothidium frequentissimum (Lange-Bert.) Lange-Bert.		+		
Reimeria sinuata (W. Greg.) Kociolek & Stoermer	+			
Rhopalodia gibba (Ehrenb.) O. Müll.	+			+
Rossithidium linearis (W. Sm.) Round & Bukht.		+	+	
Sellaphora pupula (Kütz.) Mereschk.	+			
Stauroneis anceps Ehrenb.	+		+	
S. gracilis Ehrenb.			+	
Staurosirella pinnata (Ehrenb.) D. M. Williams & Round	+			
Stephanodiscus hantzschii Grunow	+	+	+	+
Surirella linearis W. Sm.	+			
Tabellaria fenestrata (Lyngb.) Kütz.		+	+	+
T. flocculosa (Roth) Kütz.	+	+	+	+
Tabularia fasciculata (C. Agardh) D. M. Williams & Round		+		
Ulnaria acus (Kütz.) Aboal	+	+		
U. biceps (Kütz.) Compère	+	+		
U. ulna (Nitzsch) Compère	+			
DINOPHYTA				
Ceratium hirundinella (C. Agardh) Kütz.	+	+		
***Peridinium gatunense* Nygaard		+		
CRYPTOPHYTA				
Cryptomonas marssonii Skuja *emend.* Hoef-Emden & Melkonian		+		
**C. *obovata* Skuja			+	
GLAUCOCYSTOPHYTA				
***Glaucocystis nostochinearum* Itzigs.			+	+
CHLOROPHYTA				
***Acanthococcus aciculiferus* Lagerh.			+	
Acutodesmus dimorphus (Turpin) P. Tsarenko	+	+		
A. pectinatus (Meyen) P. Tsarenko			+	
Ankistrodesmus falcatus (Corda) Ralfs	+			
A. fusiformis Corda *ex* Korschikov	+	+	+	
Aphanochaete repens A. Braun	+	+	+	+
***Asterococcus limneticus* G. M. Sm.	+	+		

APPENDIX. *Continued.*

Taxon / Lake	A	B	C	D
Bulbochaete sp. ster.	+	+		
Characium cf. *acuminatum* A. Braun	+			
Chlamydomonas oblonga E. G. Pringsh.		+		
Chlorella vulgaris Beij.		+		
Chlorococcum lobatum (Korschikov) F. E. Fritsch & John		+		
Coelastrum microporum Nägeli	+			
Crucigeniella irregularis (Wille) P. Tsarenko & D. M. John				
Desmodesmus armatus (Chodat) E. Hegew.	+	+		
*******D. magnus* (Meyen) P. Tsarenko	+	+		
D. protuberans (F. E. Fritsch & Rich) E. Hegew.				+
Dictyosphaerium sp.	+			
Echinosphaeridium nordstedtii Lemmerm.			+	
Elakatothrix genevensis (Reverd.) Hindák			+	
Eudorina elegans Ehrenb.			+	+
Kirchneriella lunaris (Kirchn.) Moeb.			+	
K. obesa (West) Schmidle		+		
Microspora sp.		+		
Microthamnion kuetzingianum Nägeli *ex* Kütz.			+	
M. strictissimum Rabenh.		+	+	
Monoraphidium arcuatum (Korschikov) Hindák		+	+	
M. contortum (Thur.) Komárk.-Legn.		+	+	+
M. griffithii (Berk.) Komárk.-Legn.			+	
M. minutum (Nägeli) Komárk.-Legn.	+			
M. tortile (West & G. S. West) Komárk.-Legn.		+		
Mychonastes homosphaera (Skuja) Kalina & Punčoch.	+	+		
Oedogonium sp. ster.	+	+	+	+
Oocystis parva West & G. S. West	+			
O. solitaria Wittr.			+	+
Palmodictyon lobatum Korschikov			+	
P. varium (Nägeli) Lemmerm.			+	
***P. viride* Kütz.			+	+
Pandorina morum (O. F. Müller) Bory			+	+
***Parachlorella kessleri* (Fott & Novákova) Krienitz *et al.*		+		
Phacotus coccifer Korschikov			+	+
Pseudocharacium obtusum (A. Braun) Petry-Hesse		+		
Pseudopediastrum boryanum (Turpin) E. Hegew.	+			
Quadrigula korschikovii Komárek	+		+	
Scenedesmus ellipticus Corda	+			
S. obtusus var. *apiculatus* (West & G. S.West) P. Tsarenko				+
S. parvus (G. M. Sm.) Bourr.		+		
Selenastrum bibraianum Reinsch			+	+
S. gracile Reinsch			+	+
Sorastrum spinulosum Nägeli	+			
Stauridium tetras (Ehrenb.) E. Hegew.	+			
Stigeoclonium sp.		+		
Tetraëdron minimum (A. Braun) Hansg.	+	+		
T. regulare Kütz.			+	
CHAROPHYTA				
Actinotaenium cucurbita (Bréb.) Teil. *ex* Růžička & Pouzar			+	

APPENDIX. *Continued*.

Taxon / Lake	A	B	C	D
*******A. turgidum* (Bréb. *ex* Ralfs) Teiling *ex* Růžička & Pouzar	+			
*******A. wollei* (West & G .S. West) Teiling *ex* Růžička & Pouzar			+	
Closterium acutum Bréb.			+	
C. dianae Ehrenb. *ex* Ralfs			+	
*******C. dianae* var. *minus* Hieron.			+	
C. gracile Bréb. *ex* Ralfs			+	
C. incurvum Bréb.			+	
C. juncidum Ralfs			+	
C. kuetzingii Bréb.			+	
C. lineatum Ehrenb.			+	
C. moniliferum Ehrenb. *ex* Ralfs	+			
*******C. praelongum* Bréb.			+	
*******C. regulare* Bréb.			+	
C. setaceum Ehrenb. *ex* Ralfs		+		
C. striolatum Ehrenb. *ex* Ralfs			+	
C. venus Kütz. *ex* Ralfs			+	
Coleochaete scutata Bréb.			+	+
*******Cosmarium arctoum* Nordst.			+	
C. debaryi Arch.			+	
C. depressum (Nägeli) P. Lundell			+	
*******C. difficile* Lütkem.			+	
*******C. elegantissimum* P. Lundell			+	
C. humile (Gay) Nordst.			+	+
C. margaritatum (P. Lundell) Roy & Bisset	+			
C. meneghinii Bréb.	+			
C. moniliforme Ralfs	+			
C. pachydermum P. Lundell			+	
C. portianum W. Archer			+	
C. pseudopyramidatum P. Lundell			+	+
C. punctulatum (Bréb. *ex* Ralfs) Pal.-Mordv.			+	
C. pygmaeum W. Archer	?		+	
C. pyramidatum Bréb.			+	+
C. subcostatum Nordst.			+	+
C. subprotumidum var. *gregorii* Roy & Biss.			+	
Cosmoastrum muticum (Bréb. *ex* Ralfs) Pal.-Mordv. *ex* Petlov.			+	
C. punctulatum (Bréb. *ex* Ralfs) Pal.-Mordv.			+	
*******C. retusum* var. *boreale* (West & G. S. West) Pal.-Mordv.			+	
C. teliferum (Ralfs) Pal.-Mordv.			+	
Cylindrocystis brebissonii (Menegh. *ex* Ralfs) De Bary			+	
C. crassa De Bary			+	
Euastrum ansatum Ralfs			+	
E. denticulatum (Kirchn.) Gay	+		+	
Haplotaenium minutum (Ralfs) Bando			+	
Klebsormidium nitens (Menegh.) Lokhorst	+			
Netrium digitus (Ehrenb. *ex* Ralfs) Itzigs. & Rothe		+	+	
*******Octacantium bifidum* (Bréb.) Compère			+	
Penium cylindrus Bréb. *ex* Ralfs			+	
*******Spondylosium planum* (Wolle) West & G. S. West	+			
*******Staurastrum aculeatum* [Ehrenb.] Menegh. *ex* Ralfs			+	

APPENDIX. *Continued*.

Taxon / Lake	A	B	C	D
**S. *boreale* West & G. S. West			+	+
S. cyrtocerum Bréb. *ex* Ralfs			+	
S. furcatum var. *aciculiferum* (West) Coesel			+	
***S. furcatum* var. *spinosum* (Wittr. & Nordst.) Petlov.			+	
S. gracile Ralfs *ex* Ralfs	+			
***S. gracile* var. *nanum* Wille			+	
S. margaritaceum (Ehrenb.) *ex* Ralfs			+	+
S. cf. *oxyacanthum* W. Archer	+			
S. polymorphum Bréb. *ex* Ralfs *emend*. Nordst. *ex* Grönblad			+	+
***Staurodesmus corniculatus* (P. Lundell) Teiling	+			
S. incus (Bréb. *ex* Ralfs) Teiling			+	
***S. pterosporus* (P. Lundell) Bourr.			+	
Tetmemorus brebissonii (Menegh.) *ex* Ralfs			+	
T. laevis (Kütz.) *ex* Ralfs			+	
***T. laevis* var. *minutus* (De Bary) Willi Krieg.			+	
***Tortitaenia obscura* (Ralfs) Brook			+	
T. trabeculata (A. Braun) Brook			+	
Xanthidium antilopaeum (Bréb.) *ex* Kütz.			+	
X. cristatum Bréb. *ex* Ralfs			+	