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CHECKLIST OF ALGAE OF BEREHOVE AND ITS SURROUNDINGS (ZAKARPATTIA REGION, UKRAINE)

Abstract. An analysis of the literature shows that algal studies in Zakarpattia Region has primarily focused on its mountainous part. The Zakarpattia Lowland has been explored much less, and data regarding the algae of Berehove are entirely absent. The aim of this study was to determine the species composition of algae of Berehove and its surroundings, assess the peculiarities of their distribution in various types of aquatic ecotopes, and supplement the data on the algoflora of Zakarpattia. The survey encompassed the Verke River, a series of lentic water bodies (primarily water-filled quarries), and temporary water bodies (puddles). The samples included plankton, squeezes from aquatic plants, periphyton from various substrates, filamentous algal mats, and charophytes. For the first time, a comprehensive list is provided, comprising 227 algal species represented by 231 intraspecific taxa (ist). The taxonomic distribution across divisions is as follows: *Chlorophyta* (61 species/62 ist), *Euglenozoa* (50/52), *Bacillariophyta* (38), *Charophyta* (37/38), *Cyanobacteriophyta* (22), *Heterokontophyta* (15), *Dinoflagellata* (2), *Cryptophyta*, and *Haptophyta* (1 species each). In the Verke River, euglenophytes dominate both in terms of the number and abundance, indicating severe eutrophic conditions. The majority of the identified taxa are considered common or quite common for Ukraine; however, 12 species are categorized as rare. Notably, 45 species (46 ist) represent new records for the flora of the Ukrainian Carpathians.

Keywords: algae, biodiversity, rare species, new records, Berehove, Ukraine

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Introduction

Research on the algal [1] diversity of the Zakarpattia Region began in the mid-20th century with the work of Margit Szabados (1949), who investigated the water bodies of the Ukrainian Carpathians in the modern-day Khust, Rakhiv, and Tiachiv districts and provided the first species list for this region, which included 90 names. However, this initial and subsequent studies primarily focused on the algae of the mountainous part of the Carpathians in general, and its protected areas in particular (Palamar-Mordvintseva, 1978a, 1978b; Massjuk, 1996; Tsarenko et al., 1997; Romanenko, 1998, 2002, etc.).

The algae of the Zakarpattia Lowland remain poorly studied. Data on the species composition of algae in the Berehove District, which situated almost entirely in the Zakarpattia Lowland, are presented in several publications (Moshkova, 1972, 1979; Vetrova, 1979, 1993; Yunger, Moshkova, 1993; Romanenko, 1998, 2002; Kostikov et al., 2001). As for the algae of the town of Berehove and its surroundings, records are available in only a single publication dedicated to the charophyte algae of the Zakarpattia Region (Borysova et al., 2023). Specifically, *Chara globularis* Thuill. and *Nitella mucronata* (A.Braun) Miq. are reported for the water bodies in the surroundings of Berehove.

Thus, despite the high level of knowledge about the algal flora of Ukraine (Tsarenko et al., 2024a), there are still areas for which data on algal diversity are virtually absent. The town of Berehove and its surroundings represent one of such territories. Therefore, we aimed to document the algal species composition of the water bodies of the town of Berehove and its vicinity.

Materials and Methods

The town of Berehove is located in Zakarpattia Region and, according to physical-geographical regionalization, lies in the Transcarpathian Lowland region of the Ukrainian Carpathians (National…, 2007). According to the algofloristic regionalization of Ukraine, it belongs to the Tysa-Latorytsia district of the Carpathian-Danube subprovince (Palamar-Mordvintseva, Tsarenko, 2015; Tsarenko et al., 2024a). This territory is characterized by a significant diversity of natural and anthropogenically transformed water bodies. The main waterway of the city is the Verke River, or Verke Canal, which bilongs to Tysa River basin. The modern hydrological regime of the Verke River is largely transformed by anthropogenic activity. The river waters are used for the water

[1] By algae, we understand "oxygenic photosynthesisers other than embryophyte land plants" (Cavalier-Smith, 2007; Guiry, Guiry, 2026), including *Cyanobacteriophyta*, *Euglenozoa*, and *Dinoflagellata*.

supply of the territories in the Berehove land reclamation system, while the river itself serves as a recipient and diluent for wastewater from the settlements of the basin, creating favorable conditions for the formation of diverse algal communities.

The studies covered various types of water bodies, in particular the Verke River, flooded former quarries, small stagnant water body, and temporary pools (puddles) (Fig. 1).

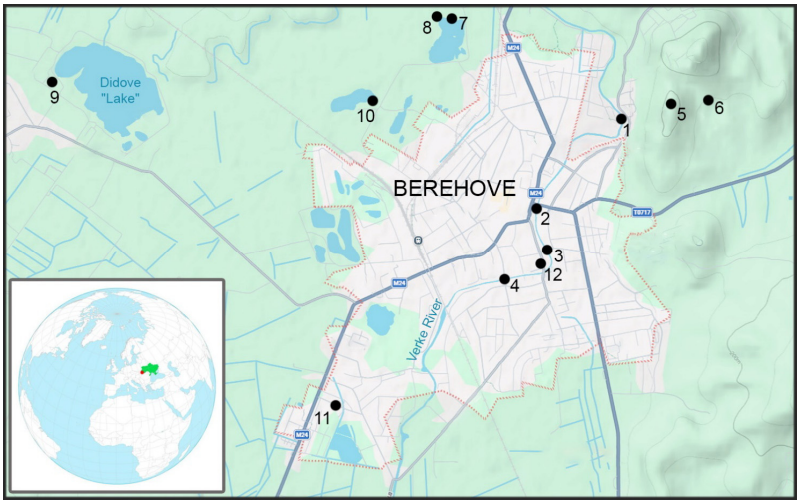


Fig. 1. Map of Berehove with indicated sampling sites.
The numbers of the sampling sites correspond to those in Table 1

The study was based on algal samples collected from water bodies in the town of Berehove and its surroundings in 2017 (collector P.M. Tsarenko) and 2023 (collector O.V. Burova).

The samples included plankton (collected using a plankton net), squeezes from aquatic plants, periphyton from various substrates (including stones, concrete structures, aquatic plants, and submerged wood; collected along with the substrate whenever possible), filamentous algal mats, and charophytes. In total, 27 algal samples were collected in 2023 (the number of samples from 2017 is unknown). During the 2023 sampling, water temperature and pH were measured using a Combo Water Quality Meter 86031. Information on the sampling sites is provided in Table 1.

Table 1. **Sampling sites on water bodies o Berehove and its surroundings**

Site No.	Data	Water bodies	Coordinates		Water temperature, °C *	pH *
			Longitude	Latitude		
1	21.05.2017; 29.06.2023	Verke River, site 1	22.657409	48.214055	22.9	7.12
2	29.06.2023	Verke River, site 2	22.646208	48.205356	21.9	7.04
3	21.05.2017	Verke River, site 3	22.647615	48.202644	–	–
4	29.06.2023	Verke River, site 4	22.642044	48.199909	22.7	7.00
5	27.06.2023	Mine "lake" (former quarry)	22.664079	48.215765	22.8	6.94
6	27.06.2023	Artificial water body, adjacent to the quarry	22.667604	48.216360	25.7	7.63
7	21.05.2017; 27.06.2023	Quarry lake	22.634741	48.223258	25.7	7.98
8	27.06.2023	Bay of the quarry lake	22.633255	48.223500	26.4	7.68
9	28.06.2023	Small stagnant water body near "Lake" Didove	22.582248	48.217552	24.3	8.22
10	28.06.2023	Quarry lake	22.625192	48.216118	24.6	7.75
11	28.06.2023	Temporary pool on an unpaved road	22.619156	48.190792	–	–
12	29.06.2023	Temporary pool	22.646976	48.201894	–	–

* Water temperature and pH were measured only during sampling in 2023.

The fresh material was investigated by Olympus BX 53 light microscope with Nomarski differential interference optics (DIC). Digital photographs were obtained using an Olympus LC30 camera attached to the microscope and processed with cellSens Entry software.

The sample containing *Spirogyra* filaments at the initial stage of conjugation was kept on a windowsill for 10 days until the mature stage of conjugation was reached.

The collected samples also were preserved in a 4% formaldehyde solution and deposited in the Algotheca of the M.G. Kholodny Institute of Botany, NAS of Ukraine.

Algae were identified using the multivolume series "Identification manual of freshwater algae of the Ukrainian SSR" (1938–1993), "Algal flora of continental water bodies of Ukraine" (1986–2005), "Flora of algae of Ukraine" (2009–2016), "Süßwasserflora von Mitteleuropa" (1978–2018), as well as monographs and papers by Z.I. Asaul (1975), P.M. Tsarenko (1990), H. Lange-

Bertalot et al. (2017), H.H. Lilitska (2019), M. Łukomska-Kowalczyk et al. (2015, 2020), and Chaber et al. (2022).

The nomenclature and taxonomic affiliation of algae were verified following the AlgaeBase (Guiry, Guiry, 2026) and "Prodromus of spore plants of Ukraine: algae" (Tsarenko et al., 2024a, 2024b).

Results and Discussion

As a result of the analysis of the collected materials, 227 algae species were identified, represented by 231 intraspecific taxa (ist) from 9 phyla. The highest number of taxa was recorded for the phylum *Chlorophyta* (61 species, 62 ist). A high abundance of *Euglenozoa* (50 species, 52 ist) was notable, indicating high eutrophication of the water bodies (primarily concerning the Verke River). The phylum *Bacillariophyta* was represented by 38 species, *Charophyta* — by 37 species (38 ist), and *Cyanobacteriophyta* — by 22. *Dinoflagellata* included 2 species, while *Cryptophyta* and *Haptophyta* were represented by 1 species each (Table 2).

Table 2. **Taxonomic structure of algal species diversity in water bodies of Berehove and its surroundings**

Phylum	Number of				
	classes	orders	families	genera	species/ist
Cyanobacteriophyta	1	7	10	16	22
Euglenozoa	1	3	3	11	50/52
Heterokontophyta	3	6	7	8	15
Bacillariophyta	4	13	17	24	38
Dinoflagellata	1	2	2	2	2
Cryptophyta	1	1	1	1	1
Haptophyta	1	1	1	1	1
Chlorophyta	4	11	21	42	61/62
Charophyta	2	4	6	11	37/38
Total	18	48	68	116	227/231

In the analysis of species distribution across water body types, only the 2023 data were taken into account. In the Verke River 52 species of algae were found. Almost half of these (24 species) belong to *Euglenozoa*, primarily represented by species of the genera *Lepocinclis* Perty, *Trachelomonas* Ehrenb., and *Euglena* Ehrenb. These taxa reached high abundance, pointing to severe eutrophication of the water body. Nearly all of them (21 species) serve as indicators of β-, β-α, and α-mesosaprobic zones (Barinova et al., 2019).

Although rivers are generally characterized by the predominance of diatoms and green algae, cases where euglenoids become the dominant group do occur and are specifically associated with severe organic pollution and low flow conditions (Conforti et al., 1995; Bauer et al., 2002; Santana et al., 2016). Also, in the Verke River significant growths of the green filamentous alga *Schizomeris leibleinii* Kütz. were recorded which is widely recognized as a reliable bioindicator of organic pollution and high trophic status in freshwater ecosystems (Pereira, Branco, 2007; Peres et al., 2010). Chronic severe organic pollution and low flow rates have been well-known problems for the Verke River in recent decades, which is associated with siltation and the lack of a centralized sewage system in parts of the city. This is also confirmed by the annual results of physicochemical water measurements (Surface..., 2023).

In lentic water bodies, primarily represented by water-filled quarries, 72 algal species (73 ist) were identified. The dominant divisions are *Chlorophyta* (29 species) and *Charophyta* (15 species). The most common species in these water bodies (by frequency of occurrence) were *Epithemia gibba* (Ehrenb.) Kütz., *Aphanochaete repens* A.Braun, *Botryococcus braunii* Kütz., *Cladophora fracta* (O.F.Müller ex Vahl) Kütz., and *Stauridium tetras* (Ehrenb.) E.Hegewald.

In the studied temporary water bodies (puddles on a dirt road), only *Microcoleus amoenus* (Gomont) Strunecky, Komárek et J.R.Johansen was found, which formed films across the entire bottom of the puddles.

The majority of the identified taxa found in the water bodies of Berehove and its surroundings are either widespread (140 species, 142 ist, or 61.7% of the total species diversity) or moderately distributed (48 species, 49 ist, or 21.1%) in Ukraine, while 12 species are considered rare. Among the rare taxa, one species — *Cosmarium cyaneilacustre* Lilitskaya — was described as new to science in 2012 and was previously known only from two lakes in Kyiv (Lake Synie and Lake Holube) (Lilitskaya, 2012). Thus, our finding represents the second record since its original description. For species such as *Phacus anacoelus* A.Stokes and *Chrysococcus triporus* B.Mack, revealed locality represents the second record in Ukraine. They were previously known from the Horikhuvatski (Lilitskaya et al., 2017) and Palladinski (Lilitskaya, 1998) ponds in Kyiv, respectively. For an additional nine species, up to five localities are known in Ukraine. All rare species are indicated in Table 3. Some of them are shown in Fig. 2.

Among the identified species, 45 species (46 ist) are reported for the first time for the Ukrainian Carpathians. Such a large number of species new to the region can be attributed to the insufficient study of the Ukrainian Carpathians in general, and the Zakarpattia Lowland in particular, since most of these species are not rare for the territory of Ukraine as a whole.

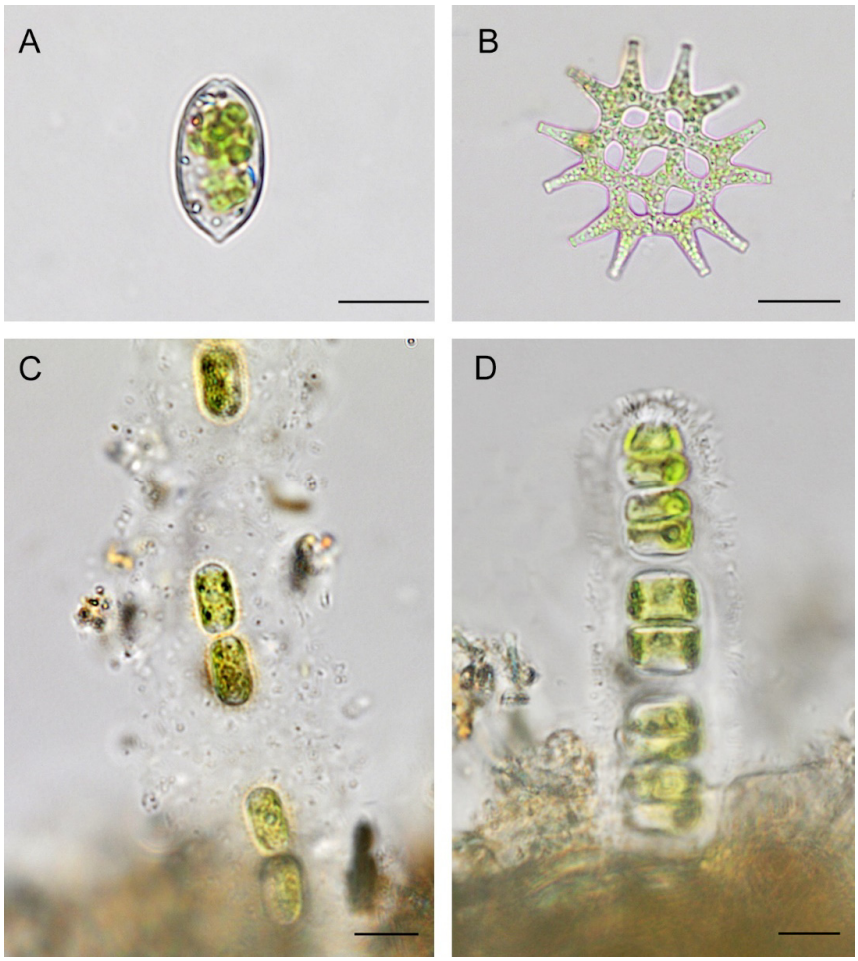


Fig. 2. Some rare species found in the water bodies of Berehove and its surroundings: A: *Lepocinclis cylindrica* (Korshikov) W.Conrad; B: *Lacunastrum gracillimum* (West et G.S.West) H.A.McManus; C: *Geminella interrupta* Turpin; D*: Ulothrix mucosa* Thuret. Scale 10 µm (A, C, D), 20 µm (B)

The species most frequently found in the water bodies of Berehove include *Microcoleus amoenus*, *Euglena deses* (O.F.Müller) Ehrenb., *Monomorphina pyrum* (Ehrenb.) Mereschk., *Trachelomonas hispida* (Perty) F.Stein, *T. volvocina* (Ehrenb.) Ehrenb., *Lepocinclis acus* (O.F.Müller) B.Marin et Melkonian, *L. fusiformis* (H.J.Carter) Lemmerm., *Epithemia gibba*, *Botryococcus braunii*, *Stauridium tetras*, *Coelastrum microporum* Nägeli, *Closterium moniliferum* Ehrenb. ex Ralfs, *Staurastrum tetracerum* Ralfs ex Ralfs.

Oedogonium spp. and *Spirogyra* spp. were also frequently encountered, predominantly in a sterile state. Only once *Spirogyra* filaments were observed at an early stage of conjugation — in the sample from Mine "lake" (former quarry)

collected 27 June 2023. After maintaining this sample on a windowsill for ten days, mature spores were obtained, allowing for species identification. This species was identified as *Spirogyra majuscula* Kütz. (Fig. 3).

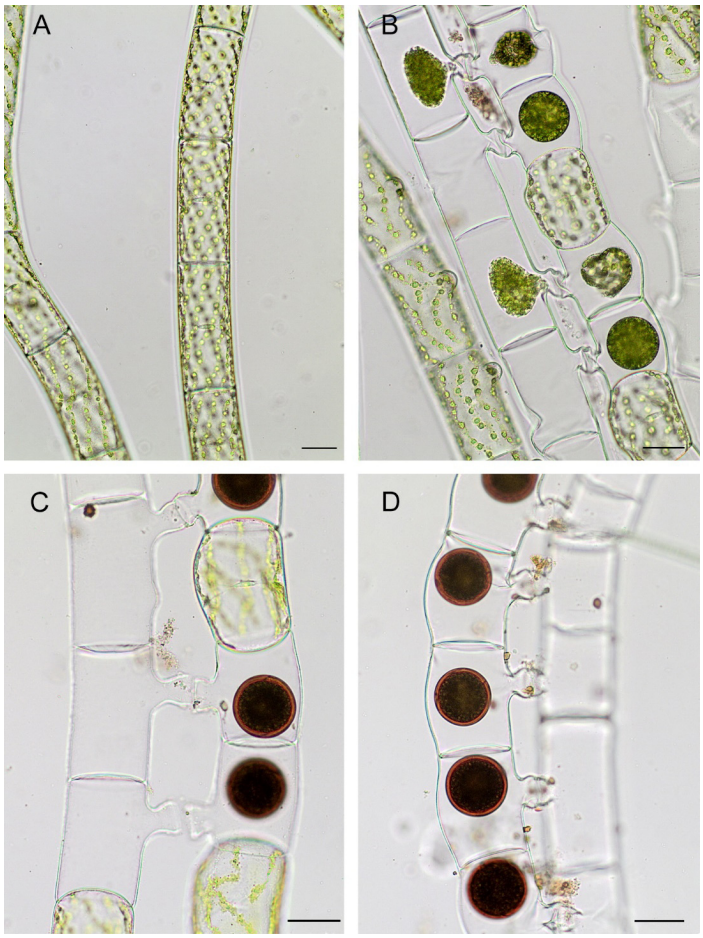


Fig. 3. *Spirogyra majuscula* Kütz. A: vegetative filaments; B: filaments at an early stage of conjugation; C, D: filaments at a mature stage of conjugation with mature zygospores. Scale 50 µm

It is quite common in Ukraine (Tsarenko et al., 2024b). However, an analysis of the literature shows that most of them dated late 19th and early 20th centuries. In the case of zygnematalean algae, this does not indicate a decline in their distribution, but rather the difficulty of detecting filaments at the conjugation stage during routine field collections. Therefore, every such finding merits attention.

Table 3 presents a list of the identified algae species. For species recorded in 2023, their localities are provided. For species identified in 2017, the exact localities are unknown.

Table 3. **List of algae species identified in the water bodies of Berehove**

Taxa	Locality*
CYANOBACTERIOPHYTA Oren, Mareš et Rippka	
CYANOPHYCEAE Schaffner	
PSEUDANABAENALES Komárek et Anagn.	
Pseudanabaenaceae Anagn. et Komárek	
Limnothrix redekei (Goor) Meffert[2]	2017
SYNECHOCOCCALES Hoffmann, Komárek et Kaštovský	
Synechococcales familia incertae sedis	
Jaaginema geminatum (Schwabe ex Gomont) Anagn. et Komárek	1
LEPTOLYNGBYALES Strunecký et Mareš	
Leptolyngbyaceae Komárek et al.	
Phormidesmis mollis (Gomont) Turicchia, S.Ventura, Komárková et Komárek	5
OSCILLATORIALES Schaffner	
Oscillatoriaceae (Gray) Kirchner	
Oscillatoria limosa C.Agardh ex Gomont	8, 10
O. princeps Vaucher ex Gomont	2, 4
O. tenuis C.Agardh ex Gomont	2017, 4
Phormidium ambiguum Gomont	5
P. chalybeum (Mertens ex Gomont) Anagn. et Komárek	2017
P. terebriforme (C.Agardh ex Gomont) Anagn. et Komárek	2017
Microcoleaceae Komárek et al.	
Lyngbya aestuarii Liebman ex Gomont	8, 9
Lyngbya sp.	2017
Microcoleus amoenus (Gomont) Strunecky, Komárek et J.R.Johansen	1, 11, 12
Planktothrix planctonica (Elenkin) Anagn. et Komárek[2]	2017
COLEOFASCICULALES Strunecký et Mareš	
Wilmottiaceae Strunecký et Mareš	
Anagnostidinema amphibium (Gomont) Strunecký, Bohunická, J.R.Johansen et Komárek	1
CHROOCOCCALES Schaffner	
Microcystaceae Elenkin	
Aphanocapsa grevillei (Berkeley) Rabenh.	9
A. incerta (Lemmerm.) G.Cronberg et Komárek	2017

Merismopedia tranquilla (Ehrenb.) Trevisan	6
Microcystis pulverea (H.C.Wood) Forti	2017
Snowella lacustris (Chodat) Komárek et Hindák	2017
Chroococcaceae Rabenh.	
Chroococcus minutus (Kütz.) Nägeli	8
NOSTOCALES Borzi	
Rivulariaceae Bornet et Flahault	
Calothrix brevissima G.S.West	8
Nostocaceae Eichler	
Nostoc paludosum Kütz. ex Bornet et Flahault	5, 10
EUGLENOZOA (EUGLENOPHYTA)	
EUGLENOPHYCEAE Schoenichen	
PLOEOTIALES Cavalier-Smith	
Entosiphon sulcatus (Dujard.) F.Stein	2017, 4
HETERONEMATALES Bütschli	
Anisonemataceae Kent	
Peranema trichophorum (Ehrenb.) F.Stein	2017
EUGLENALES Bütschli	
Euglenaceae Dujardin	
Colacium vesiculosum Ehrenb.	1
Cryptoglena pigra Ehrenb. [2]	2017
Euglena agilis H.J.Carter	2017, 1
E. deses (O.F.Müller) Ehrenb.	2017, 2, 4
E. gracilis G.A.Klebs	2017
E. granulata (G.A.Klebs) F.Schmitz	2017
E. obtusa F.Schmitz [2]	2
E. sanguinea Ehrenb.	1
E. texta (Dujard.) Hübner	2017
E. viridis (O.F.Müller) Ehrenb.	5
Euglenaformis proxima (P.A.Dang.) M.S.Bennett et Triemer	2017
Euglena spp.	2017
Euglenaria caudata (E.F.W.Hübner) Karnkowska-Ishikawa et E.W.Linton	2017
Monomorphina pyrum (Ehrenb.) Mereschk.	2017, 2, 4
Trachelomonas abrupta Svirenko	2017
T. armata (Ehrenb.) F.Stein	2
T. caudata (Ehrenb.) F.Stein	2017
T. cylindracea (Playfair) T.G.Popova [1, 2]	2017
T. granulosa Playfair	1
T. hispida (Perty) F.Stein	2017, 2, 4
Trachelomonas intermedia P.A.Dang. f. Intermedia	2017, 2
T. intermedia f. chachinae (Skvortzov) T.G.Popova [2]	2017

Trachelomonas lacustris Drežep. [2]	2
T. nigra Svirenko[2]	2017
T. oblonga Lemmerm.	2017
T. ornata Skvortsov	2017
T. planctonica Svirenko	2017
T. volvocina (Ehrenb.) Ehrenb. var. *volvocina*	2017, 1, 5, 10
T. volvocina var. *subglobosa* Lemmerm.	2017
T. volvocinopsis Svirenko [2]	2017
Phacaceae J.I.Kim, Triemer et W.Shin	
Lepocinclis acus (O.F.Müller) B.Marin et Melkonian	2017, 1, 2
L. cyclidiopsis M.S.Bennett et Triemer [2]	6
L. cylindrica (Korshikov) W.Conrad [1, 2]	1
L. fusiformis (H.J.Carter) Lemmerm.	1, 2, 4, 5
L. globulus Perty	2017, 1
L. hispidula (Eichwald) Daday [2]	2017
L. ovum (Ehrenb.) Lemmerm.	2017
L. oxyuris (Schmarda) B.Marin et Melkonian	2017, 1
L. spirogyroides B.Marin et Melkonian [2]	2017, 4
L. steinii (Lemmerm.) Lemmerm.	2017, 1
L. tripteris (Dujard.) B.Marin et Melkonian	2017, 4
Phacus acuminatus A.Stokes	2017
P. anacoelus A.Stokes [1, 2]	2017
P. circumflexus Pochmann	2, 4
P. cordatus (Pochmann) Zakryś et Łukomska [1, 2]	2
P. curvicauda Svirenko	2017
P. monilatus (A.Stokes) Lemmerm. [2]	1, 5
P. orbicularis Hübner	2017
P. pleuronectes (O.F. Müller) Nitzsch ex Dujard.	2017
P. triquetrus (Ehrenb.) Dujard.	2017
HETEROKONTOHYTA Moestrup, R.A.Andersen et Guiry	
CHRYSOPHYCEAE Pascher	
CHROMULINALES Pascher	
Dinobryaceae Ehrenb.	
Dinobryon cylindricum O.E.Imhof	2017
D. divergens O.E.Imhof	2017
D. sertularia Ehrenb.	2017
D. sociale var. *americanum* (Brunnth.) H.Bachm.	2017
Epipyxis borgei (Lemmerm.) D.K.Hilliard et B.C.Asmund [1, 2]	5
CHRYSOSACCALES Bour.	
Chrysococcaceae Lemmerm.	
Chrysococcus triporus B.Mack [1, 2]	2017
Stylococcaceae Lemmerm.	
Lagynion scherffelii Pascher [2]	8
SYNURALES R.A.Andersen	

Mallomonadaceae Diesing	
Synura sp.	2017
MISCHOCOCCALES F.E.Fritsch	
Sciadiaceae Gobi	
Ophiocytium capitatum Wolle[2]	5
O. gracillimum Borzi[2]	4
TRIBONEMATALES Pascher	
Tribonemataceae G.S.West	
Tribonema affine (Kütz.) G.S.West	4
T. viride Pascher	2017
T. vulgare Pascher	2, 4
EUSTIGMATOPHYCEAE D.J. Hibberd et Leedale	
EUSTIGMATALES D.J. Hibberd	
Chlorobotryaceae Pascher	
Characiopsis falx Pascher [2]	8
Characiopsis sp.	8
BACILLARIOPHYTA Karsten	
MELOSIROPHYCEAE Kociolek, Ashworth et A.J.Alverson	
MELOSIRALES R.M.Crawford	
Melosiraceae Kütz.	
Melosira varians C.Agardh	2017
Melosira sp.	2017
THALASSIOSIROPHYCEAE Kociolek, Ashworth et A.J.Alverson	
STEPHANODISCALES Nikolaev et Harwood	
Stephanodiscaceae I.V.Makarova	
Stephanocyclus meneghinianus (Kütz.) Kulikovskiy, Genkal et Kociolek	2017
THALASSIOSIRALES Glezer et I.V.Makarova	
Thalassiosiraceae M.Lebour	
Lindavia radiosa (Grunow) De Toni et Forti	2017
FRAGILARIOPHYCEAE Round	
FRAGILARIALES P.C.Silva	
Fragilariaceae Kütz.	
Fragilaria crotonensis Kitton	2017
Fragilaria sp.	2017, 10
Ulnaria acus (Kütz.) Aboal	5
U. biceps (Kütz.) Compère	2017
U. capitata (Ehrenb.) Compère	2017
U. ulna (Nitzsch) Compère	4
Ulnaria sp.	2017
Tabellariaceae Kütz.	
Asterionella formosa Hassall	2017
Diatoma spp.	2017
BACILLARIOPHYCEAE Haeckel	
BACILLARIALES Hendey	

Bacillariaceae Ehrenb.	
Hantzschia amphioxys (Ehrenb.) Grunow	2017
Nitzschia acicularis (Kütz.) W.Smith	8
Nitzschia spp.	2017, 1, 4
CYMBELLALES D.G.Mann	
Cymbellaceae Kütz.	
Brebissonia lanceolata (C.Agardh) R.K.Mahoney et Reimer [2]	2017
Cymbella aspera (Ehrenb.) Cleve	2017
Cymbella sp.	2017
Placoneis sp.	2017
Gomphonemataceae Kütz.	
Gomphonema pseudoaugur Lange-Bert.	1
Rhoicospheniaceae J.Chen et H.Zhu	
Rhoicosphenia abbreviata (C.Agardh) Lange-Bert.	8
DIADESMIDALES Kociolek, Ashworth et A.J.Alverson	
Diadesmidaceae D.G.Mann	
Diadesmis confervacea Kütz.	2017
EUNOTIALES P.C.Silva	
Eunotiaceae Kütz.	
Eunotia spp.	2017
MASTOGLOIALES D.G.Mann	
Amphipleuraceae Grunow	
Amphipleura pellucida (Kütz.) Kütz.	2017
Stauroneidaceae D.G.Mann	
Craticula ambigua (Ehrenb.) D.G.Mann	2017, 10
NAVICULALES Bessey	
Naviculaceae Kütz.	
Navicula cryptocephala Kütz.	2017
N. lanceolata Ehrenb.	8
N. radiosa Kütz.	2017
Navicula spp.	2017
Pleurosigmataceae Mereschkowsky	
Gyrosigma acuminatum (Kütz.) Rabenh.	6
SELLAPHORALES Kociolek, Ashworth et A.J.Alverson	
Pinnulariaceae D.G.Mann	
Pinnularia sp.	2017, 10
SURIRELLALES D.G.Mann	
Surirellaceae Kütz.	
Amphora ovalis (Kütz.) Kütz.	2017
Amphora sp.	2017, 8
Epithemia gibba (Ehrenb.) Kütz.	2017, 5, 8, 10
E. sorex Kütz.	2017
Epithemia turgida (Ehrenb.) Kütz.	2017
Surirella librile (Ehrenb.) Ehrenb.	2017

DINOFLAGELLATA Fensome et al.	
DINOPHYCEAE F.E. Fritsch	
GONYAULACALES Taylor	
Ceratiaceae Kof.	
Ceratium hirundinella f. *austriacum* (Zederb.) H.Bachm. [2]	2017
PERIDINIALES Macalister	
Peridiniopsidaceae Gottschling et al.	
Parvodinium cunningtonii (Lemmerm.) Pandeirada, Craveiro, Daugbjerg, Moestrup et A.J.Calado [2]	2017
CRYPTOPHYTA	
CRYPTOPHYCEAE Pascher emend. Cavalier-Smith	
CRYPTOMONADALES Engler	
Cryptomonadaceae Ehrenb.	
Cryptomonas ovata Ehrenb. [2]	2017
HAPTOPHYTA	
COCCOLITHOPHYCEAE Rothmaler	
COCCOLITHALES Schwarz emend. Edvardsen et Eikrem in Edvardsen et al.	
Hymenomonadaceae Senn	
Hymenomonas roseola F.Stein [2]	2017
CHLOROPHYTA	
CHLORODENDROPHYCEAE Massjuk	
CHLORODENDRALES F.E.Fritsch	
Chlorodendraceae Oltm.	
Tetraselmis cordiformis (H.J.Carter) F.Stein [2]	2017
ULVOPHYCEAE (J.V.Lamour.) Stewart et Mattox	
CLADOPHORALES Haeckel	
Cladophoraceae Wille in Warm.	
Cladophora fracta (O.F.Müller ex Vahl) Kütz.	8, 10
Rhizoclonium hieroglyphicum (C.Agardh) Kütz.	8
ULOTRICHALES Borzi	
Ulotrichaceae Kütz. emend. Borzi	
Ulothrix mucosa Thuret [1, 2]	8
TREBOUXIOPHYCEAE Friedl	
CHLORELLALES H.C. Bold et Wynne	
Chlorellaceae Brunnth.	
Dictyosphaerium ehrenbergianum Nägeli	2017
Geminella interrupta Turpin [1, 2]	8
Gloeotila protogenita Kütz. [2]	8
Mucidosphaerium pulchellum (H.C.Wood) C.Bock, Proschold et Krienitz	2017
Oocystaceae Bohlin	
Neglectella solitaria (Wittr.) Stenclová et Kaštovský [2]	2017
Oocystis lacustris Chodat	2017
TREBOUXIALESFriedl	
Botryococcaceae Wille	

Botryococcus braunii Kütz.	6, 8, 10
Trebouxiales incertae sedis	
Lemmermannia tetrapedia (Kirchner) Lemmerm.	6
CHLOROPHYCEAE Wille in Warming	
OEDOGONIALES G.S.West	
Oedogoniaceae de Bary ex Hirn	
Bulbochaete sp.	10
Oedogonium spp.	2017, 1, 4, 6, 7, 8, 10
VOLVOCALES Oltm.	
Chlamydomonadaceae G.M.Sm.	
Carteria sp.	2017
Chlamydomonas reinhardtii P.A.Dang. [2]	2017
Volvocaceae Cohn	
Colemanosphaera charkowiensis (Korshikov) H.Nozaki, T.K.Yamada, F.Takahashi, R.Matsuzaki et T.Nakada	2017
Pandorina morum (O.F.Müller) Bory	2017, 10
Pleodorina illinoisensis Kofoid	2017
CHAETOPHORALES Wille sensu Stewart et Mattox	
Aphanochaetaceae (Printz) Bourr.	
Aphanochaete repens A.Braun	8, 9
Fritschiellaceae Caisová et Melkonian	
Stigeoclonium sp.	1, 2, 4
Schizomeridaceae G.M.Sm.	
Schizomeris leibleinii Kütz. [2]	2, 4
Uronemataceae Caisová et al.	
Uronema confervicola Lagerh.	4
CHAETOPELTIDALES O'Kelley, S.Watanabe et Floyd	
Hydrocytiaceae Barcytė et M.Eliáš	
Hydrocytium acuminatum (A.Braun) A.Braun	2, 8
SPHAEROPLEALES Luerssen	
Characiaceae (Nägeli) Wittrock	
Characium sp.	1
Hydrodictyaceae Dumort.	
Lacunastrum gracillimum (West et G.S.West) H.A.McManus [1, 2]	6, 10
Pediastrum duplex Meyen	2017
Pseudopediastrum boryanum (Turpin) E.Hegewald var. *boryanum*	2017
P. boryanum var. *longicorne* (Reinsch) P.M.Tsarenko	10
Stauridium tetras (Ehrenb.) E.Hegewald	2017, 6, 10
Tetraëdron minimum (A.Braun) Hansg.	2017, 10
Mychonastaceae Fuciková, P.O.Lewis et L.A.Lewis	
Mychonastes anomalus (Korshikov) Krienitz, C.Bock, Dadheech et Proschold	2017
Nephrocytiaceae Garcia, Bagatini et Štenclová	
Nephrocytium agardhianum Nägeli [2]	2017

Nephrocytium lunatum West	2017
Scenedesmaceae Oltm.	
Coelastrum astroideum De Not.	6
C. microporum Nägeli	2017, 5, 10
Comasiella arcuata (Lemmerm.) E.Hegewald, M.Wolf, Al.Keller, Friedl et Krienitz	2017
Desmodesmus abundans (Kirchner) E.Hegewald	10
D. armatus (Chodat) E.Hegewald	2017
D. bicaudatus (Dedusenko) P.M.Tsarenko	5, 10
D. brasiliensis (Bohlin) E.Hegewald	1
D. communis (E.Hegewald) E.Hegewald	2017
D. intermedius (Chodat) E.Hegewald[2]	2017
D. magnus (Meyen) P.M.Tsarenko[2]	10
D. microspina (Chodat) P.M.Tsarenko	1
D. opoliensis var. *carinatus* (Lemmerm.) E.Hegewald	10
D. protuberans (F.E.Fritsch et M.F.Rich) E.Hegewald	10
D. serrato-pectinatus (Chodat) P.M.Tsarenko	2017
D. subspicatus (Chodat) E.Hegewald et A.W.F.Schmidt	1
Tetradesmus dimorphus (Turpin) M.J.Wynne	2017
T. obliquus (Turpin) M.J.Wynne	6, 8
Selenastraceae Blackman et Tansley	
Ankistrodesmus arcuatus Korshikov	4, 5
A. fusiformis Corda	2017
A. spiralis (W.B.Turner) Lemmerm.	2017
Kirchneriella obesa (West) West et G.S.West	10
Messastrum gracile (Reinsch) T.S.Garcia	2017
Monoraphidium contortum (Thuret) Komárk.-Legn.	2017
M. griffithii (Berkeley) Komárk.-Legn.	5, 8
M. irregulare (G.M.Smith) Komárk.-Legn.	2017, 5
M. tortile (West et G.S.West) Komárk.-Legn. [2]	2017
Raphidocelis sigmoidea Hindák [2]	5
Selenastrum bibraianum Reinsch	4
CHAROPHYTA	
ZYGNEMATOPHYCEAE Round ex Guiry	
ZYGNEMATALES Bessey	
Zygnemataceae Kütz.	
Mougeotia sp.	5, 10
Zygnema sp.	2017, 10
SPIROGYRALES S. Hess et J. de Vries	
Spirogyraceae Bessey	
Spirogyra majuscula Kütz. [2]	5
Spirogyra spp.	2017, 2, 4, 5, 6, 10
DESMIDIALES Bessey	
Closteriaceae Bessey	

Closterium kuetzingii Bréb.	2017, 4
C. leibleinii Kütz. ex Ralfs	4
C. moniliferum Ehrenb. ex Ralfs	2017, 1, 2, 4
Closterium parvulum Nägeli	2017
C. pritchardianum W.Archer	2017
C. venus Kütz. ex Ralfs	4
Desmidiaceae Ralfs	
Cosmarium adoxum West et G.S.West [2]	2017
C. bioculatum Bréb. ex Ralfs	2017
C. botrytis Menegh. ex Ralfs	10
C. cyaneilacustre Lilitskaya [1]	2017
C. granatum Bréb. ex Ralfs f. *granatum*	10
C. granatum f. crassum Y.V.Roll	10
C. laeve Rabenh.	2017
C. neodepressum G.J.P.Ramos et C.W.N.Moura [2]	2017
C. punctulatum Bréb.	2017
C. regnellii Wille	10
C. reniforme (Ralfs) W.Archer	2017
C. subgranatum (Nordst.) Lütkem.	4
C. subprotumidum Nordst.	10
C. subtumidum Nordst. [2]	2017
C. turpinii Bréb.	2017
Cosmarium spp.	2017
Euastrum spinulosum Delponte [1, 2]	10
Sphaerozosma vertebratum Bréb. ex Ralfs	2017
Staurastrum boreale West et G.S.West	2017
S. dispar Bréb. [2]	2017
S. gracile Ralfs ex Ralfs	10
S. muticum Bréb. ex Ralfs	10
S. ralfsii var. *depressum* (J.Roy et Bisset) Coesel et Meesters	2017
S. tetracerum Ralfs ex Ralfs	2017, 6, 10
Staurastrum spp.	2017
Peniaceae Haeckel	
Penium margaritaceum Bréb. ex Ralfs	2017
CHAROPHYCEAE Mig. emend. Mattox et Stewart	
CHARALES Dumort.	
Characeae S.F.Gray	
Chara globularis Thuiller	7
Nitella mucronata (A.Braun) Miquel	2018 (Borysova et al., 2023), 6, 10

* The locality number (1–12) corresponds to the sampling site numbers in Table 1. Since the exact localities for the species identified in 2017 are unknown, they are designated as "2017".
"2018 (Borysova et al., 2023)" refers to a locality in the vicinity of Kidosh Village, a forest lake, 48.211861, 22.667056, dated 24.09.2018, collected by A.B. Gromakova, as specified in O.V. Borysova et al. (2023).
[1] – rare species; [2] – species new to the Ukrainian Carpathians.

In Ukraine, the study of algae in urbanized water bodies is conducted in great detail, but this primarily concerns the water bodies of megacities (Kyiv, Kharkiv, Odesa). Regarding small towns, generalized research results have been published for Pereiaslav-Khmelnytskyi (Gerasymova, Tsarenko, 2010), whereas for medium and large cities, such data are available for Kamianets-Podilskyi (Levanets, Manturova, 2004) and Vinnytsia (Tsarenko et al., 2006). A comparison of the total number of identified species reveals that the algal species diversity in Berehove is quite high (227 species/231 ist) and almost equals that of Vinnytsia (248/257). For Pereiaslav-Khmelnytskyi, 146 species (152 ist) are reported, and for Kamianets-Podilskyi — 40 species (which are excluded from further analysis due to the low recorded species diversity) (Table 4).

Table 4. **Taxonomic structure of algal species diversity in water bodies of selected Ukrainian towns and cities**

	Number of species/ist			
Phylum	Berehove	Vinnytsia	Pereiaslav-Khmelnytskyi	Kamianets-Podilskyi
Cyanobacteriophyta	22	26	12	11
Euglenozoa	50/52	31/32	21	2
Heterokontophyta	15	8	8	–
Bacillariophyta	38	51	33	12
Dinoflagellata	2	5	1	–
Cryptophyta	1	3	–	–
Haptophyta	1	–	–	–
Rhodophyta	–	–	–	2
Chlorophyta	61/62	116/124	64/69	13
Charophyta	37/38	8	8	–
Total	**227/231**	**248/257**	**147/152**	**40**

Examining the taxonomic composition, the dominant phyla in the water bodies of both Vinnytsia and Pereiaslav-Khmelnytskyi are *Chlorophyta*, *Bacillariophyta*, and *Euglenozoa*. A distinctive feature of Berehove is the rank of *Euglenozoa*, which occupies the second position in the spectrum of leading taxa after *Chlorophyta*, along with an approximately equal number of *Bacillariophyta* and *Charophyta* species. The number of *Euglenozoa* species in Berehove significantly exceeds that of other cities; this is attributed to the chronic severe organic pollution of the Verke River, which has been discussed above. Furthermore, the number of *Charophyta* species is substantially higher in Berehove. These are primarily represented by the genera *Cosmarium* Corda ex Ralfs (15 species, 16 intraspecific taxa), *Staurastrum* Meyen ex Ralfs (7), and *Closterium* Nitzsch ex Ralfs (6), which thrive predominantly among aquatic plants in stagnant water bodies.

Thus, our research demonstrates that although phycologists primarily focus on the water bodies of megacities or, conversely, protected nature areas, studying the algae of small towns is important as well. On the one hand, small towns often face acute issues of chronic organic pollution due to the lack of centralized sewage systems and the discharge of domestic wastewater into surface waters, which is reflected in the algal species composition. On the other hand, the presence of rare species highlights the value of small-town water bodies as reservoirs of biodiversity.

Conclusions

As a result of the study, the algal species composition in the water bodies of Berehove and its surroundings has been determined for the first time. It comprises 227 species (represented by 231 ist) belonging to 9 phyla. The highest number of species was recorded for *Chlorophyta* (61 species/62 ist), *Euglenozoa* (50/52), *Bacillariophyta* (38), *Charophyta* (37/38), and *Cyano-bacteriophyta* (22 species). Such a high representation of euglenophytes indicates a high level of eutrophication in the city's water bodies, particularly in the Verke River, where euglenophytes dominate over representatives of other phyla in terms of both species number and abundance.

Of the identified species, 12 are rare for Ukraine. Among them *Cosmarium cyaneilacustre* is reported from its second locality since the original description, while two other species (*Phacus anacoelus* and *Chrysococcus triporus*) are recorded for the second time for Ukraine. Fourty-five species (46 ist) are first cited for the Ukrainian Carpathians, reflecting a lack of algological studies in the area.

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ETHICS DECLARATION

The authors declare that they have no conflict of interest.

Declaration of AI and Ai-assisted technologies in the writing process

During the preparation of this work, the authors used AI on Google Search (Gemini) for translation and linguistic editing of the manuscript. Following the use of this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Чек-лист водоростей міста Берегове та його околиць (Закарпатська обл., Україна)

Аналіз літературних даних показав, що дослідження водоростей Закарпаття переважно стосувалося гірської частини регіону. Закарпатська низовина досліджена значно менше, а відомості щодо водоростей м. Берегове повністю відсутні. Метою даної роботи було

встановлення видового складу водоростей водойм м. Берегове та його околиць, особливостей їхнього поширення у водоймах різного типу та доповнення відомостей про альгофлору Закарпаття. Дослідженнями охоплені р. Верке, низка стоячих водойм (переважно кар'єрів, заповнених водою) та ефемерні водойми (калюжі). Відбирали планктон, вижимки з водних рослин, перифітон з різних субстратів, розростання нитчастих водоростей та харофітові водорості. Вперше наводиться список, що містить 227 видів водоростей, представлених 231 внутрішньовидовим таксоном (ввт). За відділами вони розподіляються наступним чином: *Chlorophyta* (61 вид/62 ввт), *Euglenozoa* (50/52), *Bacillariophyta* (38), *Charophyta* (37/38), *Cyanobacteriophyta* (22), *Heterokontophyta* (15), *Dinoflagellata* (2), *Cryptophyta* та *Haptophyta* (по 1 виду). У р. Верке евгленові водорості переважають за кількістю та рясністю таксонів, що свідчить про евтрофні умови. Більшість виявлених таксонів відносяться до значно і помірно поширених в межах України, 12 видів є рідкісними. 45 видів (46 ввт) наводяться уперше для Українських Карпат.

К л ю ч о в і с л о в а : водорості, біорізноманіття, рідкісні види, нові знахідки, Берегове, Україна

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