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Diversity and ecology of algae and cyanobacteria in the Enguri River, Georgia

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ABSTRACT

Altogether 272 species and infraspecific taxa of algae and cyanobacteria were identified in the Enguri River habitats during 1974-1977, and 2014 field trips. Total list of algal flora including our findings and reference lists is represented by 339 taxa (excluding diatoms) and most of them were bio-indicators. Charophyta, Cyanobacteria and Chlorophyta species were dominated in communities. Altitude play the major role in distribution patterns of algal diversity and ecological groups of water quality indicators.

1. Introduction

Algal diversity in fresh waters can be used as environmental indicators. We assume that the diversity of non-diatom algae in Georgia is still far from complete. Whereas algal diversity in the nearby countries is regularly studied [1-6], the research in the aquatic objects of the southern Caucasian region still remains at an initial stage [7].

The Enguri River and water bodies in its basin were studied sporadically and the results were partly published in regional journals in Russian. The first work concerning the algal flora of the Enguri River basin owned G. S. Philippov [8], in which for the villages Becho and Mestia (Upper Svaneti) were indicated 14 taxa of algae. G. K. Kanchaveli [9,10] was studied algal communities from the Mestia and Maseri villages' area in the Upper Svaneti and reveal 70 taxa of non-diatom algae. R. F. Elanidze [11] published results of complex expedition study with about 20 taxa of algae in the Enguri River basin. Our preliminary results were also published in [12-14] with altogether 160 taxa of non-diatom algae.

We assume that present work can enrich of algal diversity in the Georgia area in particular in the one of the largest Georgian river, the Enguri River, as well as help us to reveal of high altitude environmental factors that regulate of algal species distribution. We have assumed that comparison of species diversity of the river and its tributaries will help in revealing trends of algal diversity under climatic impacts. The main characteristic of the Caucasian region is the high range of altitude and sharp seasonality of climate. The elevation plays a larger role in regulating plant species richness patterns. The altitudinal studies of high plant diversity distribution are very developed especially for the rare species. However, from the standpoint of the factors, which regulate distribution, the study of common species are the most important [15].

The diversity-temperature relationship for the high plants is well-known [16]. Whereas study of altitude-diversity correlation for diverse groups of plants, bryophytes, and lichens is developed [17], it is not clear for freshwater algal communities [7], and we try to clarify this problem in Caucasian region [18].

The studied river basin starts in the high mountains reserves and is mostly transformed and anthropogenically impacted in its lower part near the Black Sea. Methods used to reveal environmental impacts with the help of ecological indicators are: the community structure fluctuation analysis, bio-indication of major impacting factors, and statistical approaches, linking the community structural and functional aspects with environmental fluctuation [19].

The aim of our work was to reveal its floristic diversity in the Enguri River basin habitats, and study their community structure in large amplitude of the environment altitudes from 0 m to 3000 m above sea level (a.s.l.) with help of bio-indication methods and statistics.

2. Material and Methods

2.1. Sampling and laboratory studies

Our material covers almost all types of bodies of water: rivers, lakes, waterfalls, springs, streams, wetlands, pools, mineral springs, wet rocks, etc. We collected 318 algological samples during the period of our study in 1974-1977, and 2014.

Samples were taken from different ecological groups: periphyton, benthos, plankton (using plankton net with gas mesh 25), wet rocks, the surface of stones, stems higher aquatic plants and other items, samples were collected with a scalpel. Large forms of algae – *Spirogyra* and *Cladophora* and some other green filamentous algae were taken by hand.

Algological samples were collected during vegetation period few times by scratching and scooping, placed in 15 ml plastic tubes, and partly fixed with 3% neutral formaldehyde

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solution, as well as partly not fixed and transported to the laboratory in the ice box.

Identification of algae was with using of microscopes MBI-3 and Amplival under magnification 400-800. Species were identified according to international guides and the taxonomy follows the modern taxonomical system [20], which includes the recent taxonomic revision.

To form the full floristic list, we have include species lists from recent papers [8-14].

For species diversity and ecological analysis, we applied the bio-indication methods wildly used in European countries under Framework Directive [21]. Our database for indicator species was published in Barinova et al. [22]. The statistical methods are those recommended by V. Heywood [19] for development of floristic and taxonomic studies namely the GRAPHS program [23] for comparative floristic, and Statistica 12.0 Program for calculation of Distance weighted least squares statistical pallets.

2.2. Description of study site

The Enguri is a river in western Georgia with catchment basin about 4060 km^2. It is 213 km long, with water discharge 39.5 $m^3 s^{-1}$, originates in northeastern Svaneti near the region of Racha on altitude about 3000 m a.s.l. (Figure 1) and plays an important role providing hydroelectric power to the area. It flows on the territory of Western Georgia, taking the start in a few glaciers of the Greater Caucasus. In the upper Svaneti it flows through the basin, and then, turning into narrow gorges, extends near the town of Jvari and enters the territory of Colchis lowland, which flows into the Black Sea [24] (Figure 2). The altitude gradient is about 3000 m. The Enguri River basin is a part of the 433 region “Western Transcaucasia” in the map of the Freshwater Regions of the World [25] (Figure 3).

The climate in the upper part of the river near the Ushguli village is cold and temperate [26]. There is a great deal of rainfall even in the driest month. The temperature here averages 2.5 °C and precipitation averages 983 mm. The driest month is January with 42 mm of precipitation. The greatest amount of precipitation occurs in June, with an average of 131 mm. August is the warmest month with an average of 11.6 °C. The lowest average temperatures in the year occur in January, when it is around -6.7 °C.

Lower reaches of the river placed near the Black Sea where climate is warm and temperate [27]. The average annual temperature is 14.5 °C and the average rainfall is 1831 mm. The driest month is May, with 83 mm of rain. The greatest amount of precipitation occurs in August, with an average of 198 mm. August is the warmest month of the year with averages temperature 23.5 °C. The lowest average temperatures in the year occur in January, when it is around 5.7 °C. As a result, the basin area demonstrate high climatic gradient of its environment and can be used as a model area for climatic regulation of the biodiversity patterns in all eastern part of the Black Sea coast.

3. Results and Discussion

3.1. Diversity and ecology of algae

After processing, 272 species and infraspecies taxa of algae and cyanobacteria were identified in the studied Enguri River system. As a result, the full species list, including our findings and reference lists is represented by 339 taxa (excluding diatoms) in Table 1. Here are also included information on ecology of revealed taxa as a part of our database [22], as well as distribution over the Enguri River basin altitude layers.

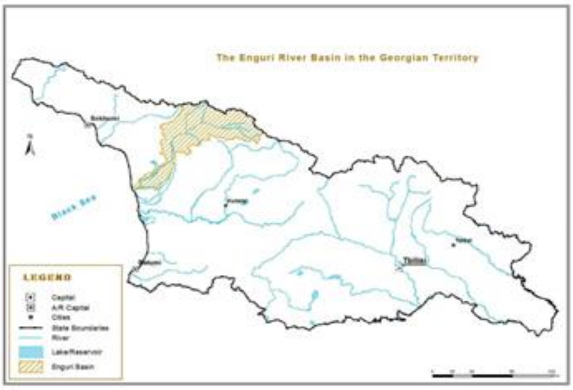

Figure 1. The Enguri River basin in the Georgian territory.

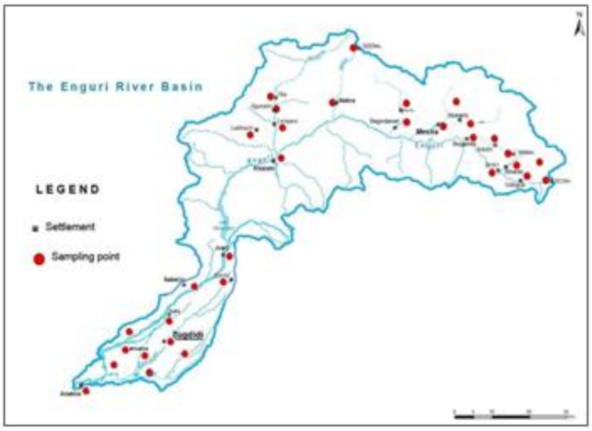

Figure 2. Sampling points in the Enguri River basin.

Figure 3. The Enguri River basin as a part of the 433 region “Western Transcaucasia” in the map of the Freshwater Regions of the World [25].

Because the main part of the river basin waters in the Enguri basin are presented by rivers and streams, the largest number of algae was found in flowing waters (rivers, streams, springs, waterfalls, etc.), where they inhabited and wet and underwater rocks and other substrates. Significantly fewer algae found in a variety of standing water bodies (pools, artificial pools, lakes). Even less diverse was algae of wetlands, and extremely poor were mineral springs and wet soil.

Before diversity analysis, we constructed the Willis curve (Figure 4) to assess how representative the assumed material is. As it was concluded from our many algal floras of Eurasia [5,22], the Willis curve has a hyperbolic shape in sufficiently studied cases. In the case of the Enguri River freshwater flora, the Willis curve approaches hyperbolic shape, thereby

Table 1. Distribution of algal diversity with species ecological preferences (according to [8]) in the Enguri River basin over altitude of its habitat.

Taxa	05	10	15	20	25	30	Hab	T	Oxy	pH	Sal	Tro	Ref
Cyanobacteria													
Anabaena lapponica Borge f. *lapponica*	-	-	1	-	-	-	P-B	-	-	-	-	-	ka
Anabaena lapponica f. *insignis* Kossinskaya	-	-	1	-	-	-	P-B	-	-	-	-	-	ka
Anabaena laxa A.Braun	-	-	1	-	-	-	-	-	-	-	-	-	k
Anabaena oscillarioides Bory ex Bornet & Flahault	-	-	-	-	1	-	P-B	-	-	-	-	-	k
Anabaena sedovii Kossinskaya	-	-	1	-	-	-	-	-	-	-	-	-	ka
Anabaena sp.	1	1	1	-	-	-	-	-	-	-	-	-	k
Aphanocapsa conferta (West & G.S.West) Komárková-Legnerová & Cronberg	-	-	-	1	-	-	P	-	-	-	i	me	k
Aphanocapsa delicatissima West & G.S.West	1	-	-	-	-	-	P-B	-	-	-	i	m	k
Aphanocapsa grevillei (Berkeley) Rabenhorst	1	1	1	-	-	-	P	-	-	-	hb	-	k
Aphanocapsa incerta (Lemmermann) G.Cronberg & Komárek	-	-	1	-	-	-	P-B	-	-	-	i	me	k,ka
Aphanocapsa muscicola (Meneghini) Wille	1	-	1	1	-	-	B,S	-	aer	-	i	-	k
Aphanocapsa parietina (Nägeli ex Kützing) Nägeli	-	-	1	-	-	-	Ep,S	-	aer	alf	-	-	k
Aphanocapsa planctonica (G.M.Smith) Komárek & Anagnostidis	1	1	1	-	-	-	P	-	-	-	i	o	k
Aphanothece castagnei (Kützing) Rabenhorst	-	-	1	-	-	-	P-B, Ep,S	-	aer	-	-	-	k
Aphanothece saxicola Nägeli	-	-	-	1	-	-	P,S	-	aer	-	i	-	k
Aphanothece stagnina (Sprengel) A.Braun	-	-	1	-	-	-	P-B	-	-	ind	hl	me	k
Calothrix braunii Bornet & Flahault	1	-	1	1	-	-	B,S	temp	st-str	-	-	m	k
Calothrix clavata G.S.West	-	-	-	1	-	-	B,S	-	st-str	-	-	-	k
Calothrix elenkinii Kossinskaja	-	-	1	1	-	-	-	-	-	-	-	-	k
Chondrocystis dermochroa (Nägeli) Komárek & Anagnostidis	-	-	-	1	-	-	B,S	-	aer	-	-	-	k
Chroococcus cohaerens (Brébisson) Nägeli	1	-	1	-	1	-	B,S	-	aer	-	hb	-	k
Chroococcus minor (Kützing) Nägeli	-	-	-	-	1	-	B,S	-	-	-	-	o	k
Chroococcus minutus (Kützing) Nägeli	1	-	1	1	-	1	P-B	-	-	ind	i	o-m	k
Chroococcus turgidus (Kützing) Nägeli	1	1	1	1	-	-	P-B,S	-	aer	alf	hl	-	k
Cyanobacterium cedrorum (Sauvageau) Komárek, Kopecky & Cepák	-	-	1	-	-	-	S	-	-	-	-	-	k
Cyanothece aeruginosa (Nägeli) Komárek	-	-	1	-	-	-	P-B,Ep	-	aer	-	-	-	f
Dactylococcopsis raphidioides Hansgirg	-	-	1	-	-	-	P	-	st-str	-	-	-	f
Geitlerinema splendidum (Greville ex Gomont) Anagnostidis	-	-	-	-	-	-	P-B,S	-	st-str, H2S	-	hl	m	k
Gloeocapsa atrata Kützing	1	1	1	1	-	-	B,S	temp	aer	-	hl	-	k
Gloeocapsa punctata Nägeli	-	-	1	-	-	-	Ep,S	-	aer	-	hl	-	k
Gloeocapsa rupestris Kützing	-	-	-	-	-	-	Ep,S	-	aer	-	-	-	k
Gloeocapsa turgida f. *violacea* (West) Hollerbach	-	-	1	-	-	-	-	-	-	-	-	-	ka
Gloeothece palea (Kützing) Nägeli	-	-	-	-	-	-	Ep	-	aer	-	-	-	k
Hapalosiphon pumilus Kirchner ex Bornet & Flahault	-	1	-	-	-	-	B	-	st	-	-	o	k
Jaaginema pseudogeminatum (G.Schmid) Anagnostidis & Komárek	-	-	1	-	-	-	P-B,S	warm	st-str	-	-	-	k
Keratococcus mucicola (Hustedt) Hindák	-	-	1	-	-	-	-	-	-	-	-	-	f
Leptolyngbya angustissima (West & G.S.West) Anagnostidis & Komárek	1	-	-	-	-	-	B,Ep,S	warm	st-str, aer	-	-	me	k
Leptolyngbya foveolara (Gomont) Anagnostidis & Komárek	-	1	-	-	-	-	B,S	-	aer	-	-	-	k
Leptolyngbya tenuis (Gomont) Anagnostidis & Komárek	1	-	1	-	-	1	B,S	-	st-str	-	i	-	k
Leptolyngbya valderiana (Gomont) Anagnostidis & Komárek	-	-	-	1	-	-	B,S	-	st-str	-	-	o-m	k
Lyngbya martensiana Meneghini ex Gomont	1	-	-	-	-	-	P-B,S	warm	st-str	-	-	o-m	k
Merismopedia glauca (Ehrenberg) Kützing	1	-	1	-	-	-	P-B	-	-	ind	i	o-m	k,e
Merismopedia minima G.Beck	-	-	-	-	1	-	B,S	-	aer	-	-	o	k
Merismopedia punctata Meyen	1	1	-	-	-	-	P-B	-	-	ind	i	me	k
Merismopedia tenuissima Lemmermann	1	-	1	1	-	-	P-B	-	-	-	hl	e	k

Microcoleus amoenus (Gomont) Strunecky, Komárek & J.R.Johansen	1	1	1	1	-	-	P-B,S	-	st-str	-	-	me	k
Microcoleus autumnalis (Gomont) Strunecky, Komárek & J.R.Johansen	1	1	1	1	1	1	B,S	-	st-str	-	-	-	k
Microcoleus caucasicus (Elenkin & Kosinskaja) Strunecky, Komárek & J.R.Johansen	-	-	1	1	-	-	-	-	-	-	-	-	k
Microcoleus vaginatus Gomont ex Gomont	-	-	1	1	-	-	B,S	-	st,aer	-	hl	-	k
Microcystis pulverea (H.C.Wood) Forti	1	1	1	1	-	-	P-B,S	-	-	-	i	-	k
Nostoc commune Vaucher ex Bornet & Flahault	-	-	1	-	-	-	B,S	-	-	-	-	-	f
Nostoc linckia Bornet ex Bornet & Flahault	-	1	1	1	-	-	P-B,Ep	-	-	-	-	-	k,ka
Nostoc paludosum Kützing ex Bornet & Flahault	-	-	1	-	-	-	P-B,S	-	st	-	-	m	k
Nostoc pruniforme C.Agardh ex Bornet & Flahault	-	-	1	1	-	-	P-B,S	-	st	-	-	-	k
Nostoc punctiforme f. *populorum* (Geitler) Hollerbach	-	-	1	-	-	-	-	-	-	-	-	-	k
Nostoc sp.	-	-	-	1	-	-	-	-	-	-	-	-	k
Oscillatoria anguina Bory ex Gomont	1	-	-	-	-	-	B,S	-	-	-	-	o-m	k
Oscillatoria limosa C.Agardh ex Gomont	1	1	-	-	-	-	P-B	-	st-str	-	hl	e	k
Oscillatoria princeps Vaucher ex Gomont	1	-	1	1	-	-	P-B,S	-	st-str	-	-	o-m	k
Oscillatoria sp.	1	-	-	-	-	-	-	-	-	-	-	-	e
Oscillatoria tenuis f. *symplociformis* (Hansgirg ex Forti) Elenkin	-	-	-	-	-	-	P-B,S	-	st-str	-	hl	me	k
Oscillatoria terebriformis f. *amphigranulata* Elenkin & Kossinskaja	-	-	-	1	-	-	-	-	-	-	-	-	k
Phormidesmis molle (Gomont) Turicchia, Ventura, Komárková & Komárek	1	-	-	-	-	-	B,S	-	st-str	-	i	me	k
Phormidium ambiguum f. *novae-semliae* (Schirschov) Elenkin	-	-	1	-	-	-	B,S	etrm	st-str	ind	i	me	k
Phormidium favosum Gomont	1	-	1	1	-	-	B	cool	str	alf	-	o	k
Phormidium grunowianum (Gomont) Anagnostidis & Komárek	1	-	-	-	-	-	P-B,S	etrm	st-str	-	-	o	k
Phormidium irriguum (Kützing ex Gomont) Anagnostidis & Komárek	1	-	-	-	-	-	B,Ep	-	aer	-	-	me	k
Phormidium molle f. *tenue* (Woronichin) Elenkin	1	-	-	-	-	1	B,S	-	st-str	-	i	me	k
Phormidium schroeteri (Hansgirg) Anagnostidis	1	-	1	1	-	-	P-B,S	-	st	-	-	-	k
Phormidium subfuscum Kützing ex Gomont	1	1	1	1	-	-	B,S	-	st-str	-	-	o	k
Phormidium terebriforme (C.Agardh ex Gomont) Anagnostidis & Komárek	-	-	1	-	-	-	P-B,S	etrm	st-str	-	-	o	k
Phormidium tergestinum (Rabenhorst ex Gomont) Anagnostidis & Komárek	1	-	1	-	-	-	P-B,S	-	st-str	-	i	e	k
Phormidium uncinatum Gomont ex Gomont	-	-	1	-	-	-	P-B,S	etrm	st-str	-	i	me	k
Phormidium valderianum var. *tenue* Woronichin	-	-	-	-	-	-	B,S	-	st-str	-	-	o-m	k
Planktothrix rubescens (De Candolle ex Gomont) Anagnostidis & Komárek	-	-	1	-	-	-	-	-	-	-	-	-	ka
Schizothrix calcicola Gomont	-	-	-	1	-	-	B,S	-	aer	-	-	-	k
Schizothrix lenormandiana Gomont	-	-	-	1	-	-	B,S	-	st	-	-	-	k
Schizothrix sp.	1	-	-	-	-	-	-	-	-	-	-	-	e
Scytonema crispum Bornet ex De Toni	-	-	1	-	-	1	B,Ep	-	st-str	-	-	o	k
Scytonema hofmannii C.Agardh ex Bornet & Flahault var. *hofmannii*	-	-	-	1	-	-	S	-	aer	-	-	-	k
Scytonema hofmannii var. *calcicola* Hansgirg	1	-	-	1	-	-	S	-	-	-	-	-	k
Scytonema ocellatum Lyngbye ex Bornet & Flahault	-	-	1	-	-	-	S	-	-	-	-	-	k
Scytonema wolleanum Forti	-	-	-	-	-	-	B,Ep	-	aer	-	-	-	k
Snowella lacustris (Chodat) Komárek & Hindák	1	-	-	1	-	-	P	-	-	-	i	me	k
Spirulina major Kützing ex Gomont	1	-	1	1	1	-	P-B,S	warm	st	-	hl	-	k
Spirulina sp.	-	-	-	1	-	-	-	-	-	-	-	-	k
Stenomitos frigidus (F.E.Fritsch) Miscoe & J.R.Johansen	1	-	-	-	-	-	P-B	cool	st-str	-	i	-	k

Synechococcus elongatus (Nägeli) Nägeli	-	-	1	-	-	-	P-B,S	-	aer	-	-	m	k
Woronichinia compacta (Lemmermann) Komárek & Hindák	-	-	-	-	-	-	P-B	-	-	-	-	o-m	k
Ochrophyta (Xanthophyceae)													
Ophiocytium cochleare (Eichwald) A.Braun	-	-	-	1	-	-	P-B	-	-	-	oh	-	k
Ophiocytium lagerheimii Lemmermann	-	-	-	-	-	-	-	-	-	-	-	-	k
Ophiocytium parvulum (Perty) A.Braun	-	-	-	1	-	-	B	-	-	-	oh	-	k
Tribonema aequale Pascher	-	1	1	1	1	-	B	-	-	-	-	-	k
Tribonema ambiguum Skuja	-	-	1	-	-	-	-	-	-	-	-	-	k
Tribonema elegans Pascher	-	-	1	1	-	-	B	-	-	-	-	-	k
Tribonema gayanum Pascher	-	-	1	-	-	-	-	-	-	-	-	-	ka
Tribonema minus (Wille) Hazen	-	-	1	1	-	-	B	-	-	-	i	-	k
Tribonema sp.	1	-	-	-	-	-	B	-	-	-	-	-	e
Tribonema spirotaenia Ettl	-	-	1	-	1	-	-	-	-	-	-	-	k
Tribonema subtilissimum Pascher	1	-	-	1	-	-	B	-	-	-	i	-	k
Tribonema viride Pascher	-	1	-	1	-	-	P-B	-	-	-	i	-	k
Tribonema vulgare Pascher	-	1	1	-	1	-	P-B	-	-	-	i	-	k
Vaucheria sp.	1	1	1	1	-	-	-	-	-	-	-	-	k
Ochrophyta (Eustigmatophyceae)													
Chlorobotrys simplex Pascher	-	-	1	-	-	-	-	-	-	-	-	-	k
Ochrophyta (Chrysophyceae)													
Hydrurus foetidus (Villars) Trevisan	-	1	1	1	-	1	B	-	-	-	-	-	k
Miozoa (Dinophyceae)													
Chimonodinium lomnickii var. *wierzejskii* (Woloszynska) S.C.Craveiro, A.J.Calado, N.Daugbjerg, G.Hansen & Ø.Moestrup	-	-	1	-	-	-	P	-	-	-	-	-	ka
Glaucophyta													
Glaucocystis nostochinearum Itzigsohn	-	-	1	-	-	-	-	-	-	-	-	-	ka
Euglenophyta													
Euglena fenestrata Elenkin	1	-	-	-	-	-	-	-	-	-	-	-	k
Euglena gracilis G.A.Klebs	-	1	-	-	-	-	P-B	etrm	st	ind	oh	-	k
Euglena pavlovskoënsis (Elenkin & Poljanski) T.G.Popova	-	1	-	-	-	-	P-B	-	st-str	ind	-	-	k
Euglena spirogyra Ehrenberg	1	-	-	-	1	-	P-B	-	-	-	-	-	k
Euglena viridis (O.F.Müller) Ehrenberg	1	-	-	1	1	-	P-B,S	etrm	st-str	ind	mh	-	k
Euglenaformis proxima (Dangeard) M.S.Bennett & Triemer	1	-	-	-	-	-	P-B	etrm	st-str	ind	mh	-	k
Phacus limnophilus (Lemmermann) E.W.Linton & A.Karnkowska-Ishikawa	1	-	-	-	-	-	P-B	etrm	st-str	-	-	-	k
Phacus orbicularis K.Hübner	1	-	-	-	1	-	P-B	-	st-str	ind	i	-	k
Phacus pleuronectes (O.F.Müller) Nitzsch ex Dujardin	-	-	1	-	1	-	P-B	-	st-str	ind	i	-	k,ka
Phacus sp.	1	-	-	-	-	-	-	-	-	-	-	-	e
Trachelomonas abrupta Svirenko	-	1	-	-	-	-	-	etrm	-	-	-	-	k
Trachelomonas acanthostoma A.C.Stokes	-	-	1	-	-	-	-	-	-	-	-	-	ka
Trachelomonas alisoviana Skvortzov	-	-	1	-	-	-	-	-	-	-	-	-	ka
Trachelomonas intermedia f. *umbilicophora* T.G.Popova	-	-	1	-	-	-	-	-	-	-	-	-	ka
Trachelomonas stokesiana T.C.Palmer	-	-	1	-	-	-	-	-	-	-	-	-	ka
Trachelomonas volvocina (Ehrenberg) Ehrenberg var. *volvocina*	-	-	-	-	1	-	B	etrm	st-str	ind	i	-	k
Trachelomonas volvocina var. *subglobosa* Lemmermann	1	-	-	-	-	-	-	-	-	-	-	-	k
Chlorophyta													
Acutodesmus acuminatus (Lagerheim) P.M.Tsarenko	1	-	1	1	1	-	P-B	-	st-str	ind	i	-	k
Ankistrodesmus falcatus (Corda) Ralfs	-	-	-	1	-	-	P-B	-	st-str	-	hb	-	k
Botryosphaerella sudetica (Lemmermann) P.C.Silva	-	-	1	-	-	-	-	-	-	-	-	-	ka
Chlamydomonas caudata Wille	-	-	1	-	-	-	P	-	-	-	-	-	f
Chlamydomonas nivalis (F.A.Bauer) Wille	-	-	1	-	-	-	-	-	-	-	-	-	f
Chlorella vulgaris Beyerinck	-	-	1	-	1	-	P-B, pb,S	-	-	-	hl	-	k
Chloromonas nivalis (Chodat) Hoham & Mullet	-	-	1	-	-	-	-	-	-	-	-	-	f
Cladophora fracta (O.F.Müller ex Vahl) Kützing	1	-	-	-	-	-	P-B	-	st-str	-	-	-	k

Cladophora glomerata (Linnaeus) Kützing	1	1	-	-	-	-	P-B	-	st-str	alf	i	-	k
Cladophora sp.	1	-	-	-	-	-	-	-	-	-	-	-	e
Closteriopsis longissima (Lemmermann) Lemmermann	-	-	1	-	-	-	P	-	st-str	-	i	-	f
Coelastrella levicostata Korshikov	-	-	1	-	-	-	-	-	-	-	-	-	ka
Coelastrum microporum Nägeli	1	-	-	-	-	-	P-B	-	st-str	ind	i	-	k
Coelastrum sphaericum Nägeli	1	-	-	1	-	-	P-B	-	st-str	-	i	-	k
Coleochaete scutata Brébisson	-	-	1	-	-	-	B	-	-	-	-	-	ka
Cryodactylon antarctica Kol	-	-	1	-	-	-	P-B	-	st-str	-	hl	-	f
Desmococcus olivaceus (Persoon ex Acharius) J.R.Laundon	-	-	1	-	-	-	B,S	-	-	-	i	-	f
Desmodesmus communis (E.Hegewald) E.Hegewald	1	-	-	-	-	-	P-B	-	st-str	ind	i	-	e
Draparnaldia glomerata (Vaucher) C.Agardh	-	-	-	1	-	-	B	-	-	-	-	-	k
Draparnaldia mutabilis (Roth) Bory	-	-	1	-	-	-	B	-	-	-	-	-	k
Enteromorpha sp.	1	-	-	-	-	-	-	-	-	-	-	-	e
Eremosphaera gigas (W.Archer) Fott & Kalina	-	-	1	-	-	-	-	-	-	-	-	-	k
Fusola viridis J.W.Snow	-	-	1	-	-	-	-	-	-	-	-	-	ka
Gonium pectorale O.F.Müller	1	-	-	-	-	-	P	-	st	-	i	-	e
Heleochloris pallida Korshikov	-	-	1	-	-	-	-	-	-	-	-	-	ka
Hydrodictyon reticulatum (Linnaeus) Bory	1	-	-	-	-	-	P-B	-	st	-	-	-	k
Microspora quadrata Hazen	1	1	1	1	-	-	B	-	-	-	-	-	k
Microspora stagnorum (Kützing) Lagerheim	1	-	-	-	-	-	B	-	st	-	-	-	k
Microspora tumidula Hazen	1	-	1	-	-	-	-	-	-	-	-	-	k
Monoraphidium griffithii (Berkeley) Komárková-Legnerová	1	-	-	-	1	-	P-B	-	st-str	-	i	-	k
Mucidosphaerium pulchellum (H.C.Wood) C.Bock, Proschold & Krienitz	-	-	1	-	-	-	P-B	-	st-str	ind	i	-	ka
Neocystis lacustris (Chodat) Hindák	-	-	1	-	-	-	-	-	-	-	-	-	f
Nephrocytium lunatum West	-	-	1	-	-	-	P-B	-	st	-	-	-	ka
Oedogonium sp.	1	1	1	1	1	1	B	-	-	-	-	-	k,e
Pandorina morum (O.F.Müller) Bory	1	-	-	1	-	-	P	-	st	-	i	-	k,e
Pediastrum braunii Wartmann	-	-	1	-	-	-	P	-	-	-	-	-	k
Pediastrum duplex Meyen	1	-	-	-	-	1	P	-	st-str	ind	i	-	k
Pediastrum integrum f. *glabrum* Raciborski	-	-	1	-	-	-	P	-	-	-	-	-	k
Pseudopediastrum boryanum (Turpin) E.Hegewald var. *boryanum*	1	-	1	1	-	-	P-B	-	st-str	ind	i	-	k,e
Pseudopediastrum boryanum var. *longicorne* (Reinsch) Tsarenko	-	-	1	-	-	-	P-B	-	st-str	ind	i	-	k
Pteromonas angulosa (H.J.Carter) Lemmermann	-	-	1	-	-	-	P	-	st	-	-	-	ka
Radiococcus polycoccus (Korshikov) I.Kostikov, T.Darienko, A.Lukesová & L.Hoffmann	1	-	-	-	-	-	P	-	-	-	i	-	k
Rhizoclonium hieroglyphicum (C.Agardh) Kützing	-	-	-	-	-	-	B	-	st-str	-	hl	-	k
Scenedesmus acuminatus (Lagerheim) Chodat	1	-	-	-	1	-	P	-	-	-	i	-	k
Scenedesmus ellipticus Corda	1	-	1	1	1	-	P-B,S	-	st-str	-	-	-	k
Scenedesmus obtusus Meyen var. *Obtusus*	1	1	1	1	-	-	P-B	-	st-str	-	-	-	k
Scenedesmus obtusus var. *apiculatus* (West & G.S.West) Tsarenko	1	-	-	-	-	-	P-B	-	st-str	-	-	-	k
Scenedesmus quadricauda (Turpin) Brébisson var. *quadricauda*	1	-	1	-	1	-	P	-	-	ind	i	-	k
Scenedesmus quadricauda var. *africanus* Fritsch	1	-	-	-	-	-	P	-	-	ind	i	-	k
Sphaerocystis schroeteri Chodat	1	-	1	-	-	-	P	-	-	ind	i	-	k,ka
Stauridium tetras (Ehrenberg) E.Hegewald	1	-	1	-	-	-	P-B	-	st-str	ind	i	-	k,ka,e
Stigeoclonium tenue (C.Agardh) Kützing	1	-	1	1	1	-	B	-	st-str	-	-	-	k
Tetradesmus lagerheimii M.J.Wynne & Guiry	-	-	1	-	-	-	-	-	-	-	-	-	ka
Tetradesmus obliquus (Turpin) M.J.Wynne	1	-	-	1	-	-	P-B	-	st-str	ind	i	-	k
Tetraspora gelatinosa (Vaucher) Desvaux	1	-	-	-	-	1	P	-	-	-	-	-	k
Ulothrix moniliformis (Kützing) Kützing	-	-	1	-	-	-	B	-	-	-	-	-	k
Ulothrix oscillarina Kützing	1	-	-	-	1	-	-	-	-	-	-	-	k

Ulothrix sp.	1	-	-	-	-	-	-	-	-	-	-	-	e
Ulothrix tenerrima (Kützing) Kützing	1	1	1	1	1	-	B	-	st	-	i	-	k
Ulothrix tenuissima Kützing	1	-	1	1	-	-	B	-	st	-	i	-	k
Ulothrix zonata (F.Weber & Mohr) Kützing	1	1	1	1	1	1	P-B	-	st-str	ind	i	-	k,e
Volvox globator Linnaeus	1	-	-	-	-	-	P	-	-	-	-	-	k
Charophyta													
Actinotaenium cucurbita (Brébisson ex Ralfs) Teiling	-	1	1	1	1	1	P-B	-	aer	acf	-	o	k
Actinotaenium globosum (Bulnheim) Kurt Förster ex Compère	-	1	-	-	-	-	P-B	-	-	acf	-	o-m	k
Actinotaenium phymatosporum (Nordstedt) Kouwets & Coesel	-	-	-	1	-	-	B	-	-	acf	-	o-m	k
Actinotaenium silvae-nigrae (Rabanus) Kouwets & Coesel	-	-	1	-	-	-	-	-	-	-	-	-	ka
Actinotaenium spinospermum (Joshua) Kouwets & Coesel	1	-	1	-	-	-	B	-	-	acf	-	m	k
Actinotaenium turgidum (Brébisson ex Ralfs) Teiling	-	1	1	-	-	-	B	-	-	acf	-	m	k,ka
Closterium acerosum Ehrenberg ex Ralfs	1	1	1	1	1	-	P-B	-	st-str	ind	i	e	k,ka
Closterium acerosum var. *elongatum* Brébisson	1	-	-	1	1	-	P-B	-	-	ind	hl	me	k
Closterium acerosum var. *minus* Hantzsch	1	-	-	-	-	-	B	-	-	ind	hl	me	k
Closterium baillyanum (Brébisson ex Ralfs) Brébisson var. *baillyanum*	-	-	1	-	-	-	B	-	-	ind	-	o-m	ka
Closterium baillyanum var. *alpinum* (Viret) Grönblad	-	-	1	-	-	-	B	-	-	acf	-	o-m	ka
Closterium calosporum Wittrock	-	-	1	-	-	-	B	-	-	acf	-	m	k
Closterium closterioides (Ralfs) A.Louis & Peeters var. *closterioides*	-	-	1	1	-	-	B	-	-	acf	-	o-m	k
Closterium closterioides var. *intermedium* (J.Roy & Bisset) Ruzicka	-	-	1	1	-	-	B	-	-	acf	-	o-m	k
Closterium delpontei (Klebs) Wolle	-	-	1	-	-	-	-	-	-	-	-	-	ka
Closterium dianae Ehrenberg ex Ralfs f. *dianae*	-	-	1	-	-	-	P-B	-	st-str	acf	-	m	ka
Closterium dianae f. *intermedium* Kossinskaya	-	-	1	-	-	-	-	-	-	-	-	-	ka
Closterium jenneri Ralfs	-	-	1	-	-	-	P-B	-	-	acf	-	m	ka
Closterium kuetzingii Brébisson	-	-	1	-	-	-	P-B	-	st	acf	i	m	k
Closterium lanceolatum Kützing ex Ralfs	-	-	1	-	-	-	B	-	st	ind	-	e	k
Closterium leibleinii Kützing ex Ralfs	1	1	-	-	-	-	P-B	-	st-str	ind	-	e	k
Closterium littorale F.Gay	1	1	1	1	-	-	P-B	-	-	ind	-	e	k
Closterium lunula Ehrenberg & Hemprich ex Ralfs	-	-	1	-	-	-	B	-	-	ind	-	m	ka
Closterium moniliferum Ehrenberg ex Ralfs	1	1	1	-	-	-	P-B	-	st-str	ind	i	me	k,e
Closterium parvulum Nägeli	1	-	1	1	1	-	P-B	-	-	ind	i	m	k,ka
Closterium peracerosum F.Gay	1	-	1	1	-	-	P-B	-	st-str	ind	-	e	k
Closterium rostratum Ehrenberg ex Ralfs	-	-	1	-	-	-	B	-	aer	ind	-	m	k,ka
Closterium siliqua West & G.S.West	-	-	1	-	-	-	P	-	st-str	-	-	-	ka
Closterium sp.	1	-	-	-	-	-	-	-	-	-	-	-	e
Closterium strigosum var. *elegans* (G.S.West) Willi Krieger	-	-	1	-	-	-	B	-	-	ind	-	e	k
Closterium striolatum var. *erectum* Klebs	-	-	1	-	-	-	-	-	-	-	-	-	ka
Closterium tumidulum F.Gay	1	-	1	-	-	-	P-B	-	-	acf	-	o-e	k
Closterium venus Kützing ex Ralfs	-	-	-	1	-	-	P-B	-	-	ind	-	me	k
Cosmarium angulosum Brébisson var. *angulosum*	-	-	1	-	-	-	B	-	-	ind	-	m	k
Cosmarium angulosum var. *concinnum* (Rabenhorst) West & G.S.West	-	-	-	1	-	-	B	-	-	acf	-	m	k
Cosmarium biretum Brébisson ex Ralfs	-	-	-	-	-	-	P-B	-	-	ind	-	me	k
Cosmarium blyttii var. *novae-sylvae* West & G.S.West	-	-	-	-	1	-	B	-	-	acf	-	o-m	k
Cosmarium botrytis Meneghini ex Ralfs	1	1	1	-	1	-	P-B	-	st-str	ind	i	m	k
Cosmarium botrytis var. *subtumidum* Wittrock	1	-	1	-	-	-	P-B	-	-	ind	i	-	k
Cosmarium caelatum Ralfs	-	-	1	1	-	-	B,aer	-	aer	ind	-	m	k,ka
Cosmarium calcareum Wittrock	1	1	1	-	-	-	-	-	-	-	-	-	k
Cosmarium connatum Brébisson ex Ralfs	-	-	1	1	-	-	B	-	-	acf	-	m	k

Cosmarium costatum Nordstedt	-	-	1	-	-	-	-	-	-	acf	-	m	k
Cosmarium crenatum Ralfs ex Ralfs	-	-	-	-	-	-	B,aer	-	aer	ind	-	m	k
Cosmarium cucumis Corda ex Ralfs	-	-	1	-	-	-	B	-	-	acf	-	m	k
Cosmarium cymatium (West & G.S.West) Willi Krieger & Gerloff	1	-	-	-	-	-	P-B	-	st-str	ind	hb	me	k
Cosmarium davidsonii J.Roy & Bissett	-	-	1	-	-	-	B,aer	-	aer	acf	-	m	k
Cosmarium elegantissimum P.Lundell	-	-	1	-	-	-	-	-	-	acf	-	m	ka
Cosmarium galeritum Nordstedt	-	-	1	-	-	-	B	-	aer	ind	-	m	k
Cosmarium garrolense J.Roy & Bisset	1	1	1	-	1	1	B,aer	-	aer	acf	-	m	k
Cosmarium granatum Brébisson ex Ralfs	1	-	-	-	-	-	B	-	st-str	ind	i	m	k
Cosmarium hammeri var. *protuberans* West & G.S.West	-	-	1	-	-	-	-	-	-	acf	-	m	k
Cosmarium holmiense var. *hibernicum* (West) Schmidle	-	-	-	-	1	-	B,aer	-	aer	acf	-	m	k
Cosmarium impressulum Elfving	-	1	1	-	-	-	B	-	-	ind	hb	m	k
Cosmarium laeve Rabenhorst var. *laeve*	1	1	1	1	1	1	P-B	-	st-str	ind	hb	me	k
Cosmarium laeve var. *octangulare* (Wille) West & G.S.West	1	-	-	-	-	-	P-B	-	-	ind	-	me	k
Cosmarium lundellii var. *ellipticum* West & G.S.West	-	-	1	1	-	-	-	-	-	acf	-	m	k
Cosmarium margaritatum (P.Lundell) J.Roy & Bisset f. *margaritatum*	-	-	1	-	-	-	B	-	-	acf	-	m	k
Cosmarium margaritatum f. *minus* (Boldt) West & G.S.West	-	-	-	-	-	-	-	-	-	-	-	m	k
Cosmarium meneghinii Brébisson ex Ralfs	1	-	1	1	1	-	B	-	-	ind	-	me	k
Cosmarium nitidulum De Notaris	-	-	1	-	-	-	-	-	-	acf	-	m	k
Cosmarium notabile Brébisson var. *notabile*	1	-	1	1	-	-	B,aer	-	aer	acf	-	o-m	k
Cosmarium notabile var. *medium* (Gutwinski) Willi Krieger & Gerloff	-	-	-	1	-	-	B,aer	-	aer	acf	-	o-m	k
Cosmarium notabile var. *subnotabile* (Wille) Coesel	-	-	-	1	-	-	B,aer	-	-	-	-	m	k
Cosmarium obtusatum (Schmidle) Schmidle	1	1	1	1	-	-	B	-	-	ind	i	me	k
Cosmarium pachydermum var. *aethiopicum* (West & G.S.West) West & G.S.West	-	-	1	-	-	-	B	-	-	acf	-	m	k
Cosmarium parvulum var. *nordstedtii* K.Förster	-	-	-	-	-	-	P-B	-	-	ind	i	m	k
Cosmarium porteanum W.Archer	1	-	-	-	-	-	B	-	-	ind	i	m	k
Cosmarium punctulatum Brébisson var. *punctulatum*	-	-	-	1	-	-	P-B	-	-	ind	hb	m	k
Cosmarium punctulatum var. *subpunctulatum* (Nordstedt) Børgesen	1	-	1	-	-	-	B	-	-	ind	-	me	k
Cosmarium pyramidatum Brébisson ex Ralfs	-	-	1	1	-	-	B	-	-	acf	-	o-m	k
Cosmarium reniforme (Ralfs) W.Archer	1	-	-	-	-	-	P-B	-	st-str	ind	hb	me	k
Cosmarium sexnotatum var. *tristriatum* (Lütkemuller) Schmidle	1	-	-	-	-	-	B	-	-	acf	-	m	k
Cosmarium sp.	1	-	-	-	-	-	-	-	-	-	-	-	e
Cosmarium speciosum var. *rostafinskii* (Gutwinski) West & G.S.West	1	-	1	1	1	-	B,aer	-	-	acf	-	m	k
Cosmarium speciosum var. *simplex* Nordstedt	-	-	-	1	1	-	B,aer	-	aer	acf	-	m	k
Cosmarium subbroomei Schmidle	-	-	1	-	-	-	B	-	-	alf	-	me	k
Cosmarium subcostatum Nordstedt	1	1	1	1	1	-	P-B	-	-	ind	i	e	k
Cosmarium subcrenatum Hantzsch	-	1	1	1	1	-	B,aer	-	aer	acf	-	m	k
Cosmarium subcucumis Schmidle	-	-	1	1	1	-	B	-	-	acf	-	m	k
Cosmarium subtumidum Nordstedt	-	-	-	1	-	-	B	-	-	acf	-	o-m	k
Cosmarium tauricum Palamar-Mordvintseva	-	-	1	-	-	-	-	-	-	-	-	-	ka
Cosmarium tetragonum (Nägeli) W.Archer	-	-	1	-	-	-	-	-	-	acf	-	m	k
Cosmarium tetraophthalmum Brébisson ex Ralfs	-	-	1	-	-	-	P-B	-	st-str	ind	-	m	k
Cosmarium thwaitesii Ralfs	-	-	-	-	-	-	B	-	-	acf	-	m	k
Cosmarium tinctum Ralfs	-	-	1	1	-	-	B	-	-	acf	-	o-m	k
Cosmarium trachypleurum var. *minus* Raciborski	-	-	1	-	-	-	B	-	-	acf	-	m	k
Cosmarium tumens Nordstedt	1	-	-	-	-	-	-	-	-	-	-	-	k

Cosmarium undulatum var. *minutum* Wittrock	-	-	1	-	-	-	P-B	-	-	acf	-	m	k
Cosmarium undulatum var. *wollei* West	-	-	1	-	-	-	P-B	-	-	acf	-	m	k
Cosmarium vexatum West	-	-	-	-	1	-	B	-	-	ind	-	m	k
Cosmarium viride f. *minus* West	-	-	1	-	-	-	-	-	-	-	-	-	ka
Desmidium quadrangulatum Ralfs ex Ralfs	-	-	1	-	-	-	-	-	-	acf	-	m	ka
Desmidium swartzii C.Agardh ex Ralfs	-	-	1	-	-	-	B	-	-	ind	i	m	ka
Euastrum ansatum Ehrenberg ex Ralfs var. *ansatum*	-	-	1	-	-	-	P-B	-	-	acf	-	o-m	k,ka
Euastrum ansatum var. *rhomboidale* F.Ducellier	-	-	1	-	-	-	B	-	-	acf	-	o-m	ka
Euastrum bidentatum Nägeli	-	-	-	1	-	-	P-B	-	-	ind	hb	m	k,ka
Euastrum binale var. *sectum* (W.B.Turner) Willi Kreiger	-	-	1	-	-	-	P-B	-	-	acf	-	o	ka
Euastrum crassicole Lundell	-	-	-	1	-	-	B	-	aer	acf	-	o-m	k
Euastrum dubium Nägeli var. *dubium*	-	-	1	-	-	-	P-B	-	-	acf	hb	o-m	k
Euastrum dubium var. *ornatum* Woloszynska	1	-	-	-	-	-	B	-	-	acf	-	o-m	k
Euastrum dubium var. *tritum* West & G.S.West	-	-	-	1	-	-	-	-	-	-	-	-	k
Euastrum gayanum De Toni	-	-	-	1	-	-	B	-	-	acf	-	m	k
Euastrum humerosum var. *affine* (Ralfs) Raciborski	-	-	1	-	-	-	B	-	-	acf	-	o-m	ka
Euastrum incrassatum Nordstedt	-	-	1	-	-	-	-	-	-	-	-	-	ka
Euastrum insulare (Wittrock) J.Roy	-	-	1	-	-	-	P-B	-	-	acf	hb	o-m	ka
Euastrum luetkemuelleri F.Ducellier	-	-	1	-	-	-	-	-	-	acf	-	o-m	ka
Euastrum oblongum Ralfs	-	-	1	1	-	-	B	-	-	acf	-	m	k
Euastrum sublobatum Brébisson ex Ralfs	-	-	1	-	-	-	-	-	-	-	-	-	ka
Euastrum turneri West	-	-	1	-	-	-	B	-	-	acf	-	m	ka
Euastrum verrucosum var. *alatum* Wolle	-	-	1	-	-	-	-	-	-	-	-	-	k
Euastrum verrucosum var. *Porsoloviense* V. Poljansky	1	-	-	-	-	-	-	-	-	-	-	-	k
Euastrum verucosum Ehrenberg var. *Verucosum*	1	-	-	-	-	-	P-B	-	-	acf	hb	m	k
Hyalotheca dissiliens Brébisson ex Ralfs	-	-	1	-	-	-	P-B	-	-	ind	hb	m	ka
Micrasterias papillifera Brébisson ex Ralfs f. *papillifera*	-	-	1	-	-	-	B	-	-	acf	-	m	ka
Micrasterias papillifera f. *glabra* J. Dick	-	-	1	-	-	-	-	-	-	-	-	-	ka
Micrasterias radiosa var. *murrayi* (West & G.S.West) Croasdale	-	-	1	-	-	-	B	-	-	-	-	-	ka
Micrasterias thomasiana var. *notata* (Nordstedt) Grönblad	-	-	1	-	-	-	B	-	-	acf	-	o-m	ka
Micrasterias truncata Brébisson ex Ralfs var. *Truncata*	-	-	1	1	-	-	B	-	-	acf	-	o-m	k,ka
Micrasterias truncata var. *Semiradiata* (Kützing) Wolle	-	-	1	-	-	-	B	-	-	acf	-	o-m	ka
Mougeotia sp.	1	1	1	1	1	1	B	-	-	-	-	-	k
Penium cylindrus Brébisson ex Ralfs var. *cylindrus*	-	-	1	-	-	-	B	-	-	acf	-	o-m	k,ka
Penium cylindrus var. *attenuatum* Raciborski	-	-	1	-	-	-	B	-	-	-	-	-	k
Penium margaritaceum Brébisson	1	-	-	1	-	-	B	-	-	ind	-	o-m	k
Penium polymorphum (Perty) Perty	-	-	1	-	-	-	B	-	st	acf	-	o-m	k,ka
Penium spirostriolatum J.Barker	1	-	1	-	-	-	B	-	-	acf	-	o-m	k,ka
Pleurotaenium trabecula Nägeli var. *trabecula*	1	-	1	1	-	-	P-B	-	-	ind	i	me	k,ka
Pleurotaenium trabecula var. *crassum* Wittrock	1	-	-	-	-	-	B	-	-	ind	-	m	k
Spirogyra decimina (O.F.Müller) Dumortier	1	-	-	-	-	-	B	-	-	-	-	-	k
Spirogyra dubia Kützing	1	-	-	-	-	-	B	-	st	-	-	-	k
Spirogyra sp.	1	-	1	1	1	-	B	-	-	-	-	-	k,e
Staurastrum aculeatum Meneghini ex Ralfs	-	-	1	-	-	-	B	-	-	acf	-	o-m	k
Staurastrum alternans Brébisson	1	-	1	-	1	-	B	-	-	ind	-	o-m	k
Staurastrum dilatatum Ehrenberg ex Ralfs var. *dilatatum*	1	-	1	1	-	-	P	-	-	-	-	-	k
Staurastrum dilatatum var. *hibernicum* (West & G.S.West) West & G.S.West	-	-	1	-	-	-	P	-	-	-	-	-	k

Staurastrum dispar Brébisson	-	-	1	-	-	-	B	-	-	ind	-	m	k
Staurastrum extensum (Nordstedt) Coesel & Meesters	-	-	1	1	1	-	B,aer	-	aer	acf	-	m	k
Staurastrum granulosum Ralfs	-	-	-	-	-	-	-	-	-	ind	-	m	k
Staurastrum hexacerum Wittrock	-	-	1	-	-	-	P	-	-	acf	-	m	k
Staurastrum hibernicum West	-	-	1	-	1	-	B	-	-	acf	-	m	k
Staurastrum hirsutum Ehrenberg ex Ralfs var. *hirsutum*	-	-	-	-	1	-	B	-	-	acf	-	o-m	k
Staurastrum hirsutum var. *muricatum* (Brébisson ex Ralfs) Kurt Förster	-	-	-	1	-	-	B	-	st-str	acf	-	o	k
Staurastrum pilosum Brébisson	-	-	-	1	-	-	P-B	-	st-str	acf	-	m	k
Staurastrum punctulatum Brébisson var. *punctulatum*	1	1	1	1	1	-	P-B	-	st-str	ind	i	o-m	k
Staurastrum punctulatum var. *subproductum* West & G.S.West	-	-	-	-	1	-	P-B	-	st-str	ind	i	o-m	k
Staurastrum pyramidatum West	-	-	1	-	-	-	B	-	-	acf	-	o-m	k
Staurastrum ralfsii (West & G.S.West) Coesel & Meesters	1	-	-	-	-	-	B	-	-	acf	-	m	k
Staurastrum spongiosum Brébisson ex Ralfs	-	-	-	1	-	-	B,aer	-	aer	acf	-	o-m	k
Staurastrum teliferum Ralfs var. *teliferum*	-	-	1	-	-	-	P	-	-	acf	-	m	ka
Staurastrum teliferum var. *gladiosum* (W.B.Turner) Coesel & Meesters	-	-	1	-	-	-	P	-	-	acf	-	m	ka
Staurastrum turgescens De Notaris	1	-	1	1	-	-	-	-	-	acf	-	m	k
Xanthidium antilopaeum Kützing	-	-	1	-	-	-	P-B	-	-	ind	i	m	k
Zygnema sp.	1	1	1	1	1	1	B	-	-	-	-	-	k
Total No of Species	110	45	212	104	50	15							

Note: Altitude of habitats, a.s.l. (05 – 0-500 m, 10 – 500-1000 m, 15 – 1000-1500 m, 20 – 1500-2000 m, 25 – 2000-2500 m, 30 – 2500-3000 m); Substrate (Sub) – substrate preferences (P – planktonic, P-B – plankto-benthic, B – benthic, Ep – epiphyte, S – soil); Temperature (T) – temperature preferences (cool – cool-water, temp – temperate, eterm – eurythermic, warm – warm-water); Oxygenation (Oxy) – streaming and oxygenation (st – standing water, str – streaming water, st-str – low streaming water, aer – aerophiles, H_2S - anoxia); Salinity (Hal) – halobity degree (hb – oligohalobes-halophobes, i – oligohalobes-indifferent, mh – mesohalobes, hl – halophiles); Acidity (pH) – pH degree (alf – alkaliphiles, ind – indifferents; acf – acidophiles); Trophy (Tro) – trophic state (o – oligotraphentic; om – oligo-mesotraphentic; m – mesotraphentic; me – meso-eutraphentic; e – eutraphentic; o-e – oligo- to eutraphentic (hypereutraphentic)); Saprobity S (Sap) – degree of saprobity (x – xenosaprobes, x-o – xeno-oligosaprobes, o-x – oligo-xenosaprobes, x-b – xeno-betamesosaprobes, o – oligosaprobes, o-b – oligo-betamesosaprobes, b-o – beta-oligosaprobes, b – betamesosaprobes, b-a – beta-alphamesosaprobes, o-a – oligo-alphasaprobes, a – alphamesosaprobes, p-a – poly-alpha-mesosaprobes, i – i-eusaprobes). References: k – own data, ka – [9,10], f – [8], e – [11].

confirming that the material is sufficiently known for making the taxonomic and ecological analysis feasible. The Willis proportion is as well close to hyperbolic for the Georgian Reserves algal diversity [7].

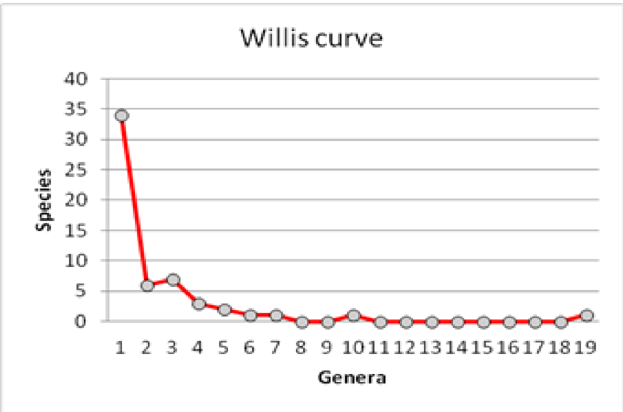

Figure 4. Willis Curve for the algal flora of the Aragvi River basin: number of species per genera (such as: one genus with 34 species; two genera with 6 species; tree genera with 7 species etc.).

The taxonomic structure of algal communities of the Enguri River basin is represented in Table 2. Of nine taxonomic divisions represented in the flora, the Charophyta is the most species rich with 154 taxa (Tables 1,2, Figure 4) in which genera *Cosmarium* with 19 taxa, and *Closterium* with 10 taxa are prevail. Followed Cyanobacteria (89 taxa) and Chlorophyta (62 taxa) and altogether these three Divisions represent the majority of studied flora. It is very interesting characteristic of the regional algal diversity a high representation of charophyte algae in freshwater algal flora, most of which are from *Cosmarium* and *Closterium* genera such in the Aragvi River [18].

Table 2 and Figure 5 show distribution of studied taxa over altitude of habitats. Can be seen that Charophyta species richness was increased up to 2500 m a.s.l. and then partly replaced with green algae and cyanobacteria. In the uppermost habitats in altitude about 2600 m the Chrysophyte algae such as *Hydrurus foetidus* is rather represented in communities. Similar tendency in algal community change under climatic impact of high mountains we revealed in the Aragvi River basin flora [18].

To infer the major factors of the alpha-diversity forming process we compared the taxonomic structure of algal floras and bio-indication results from different altitude layers of the river basin. As can be seen from Table 2, altitude gradient of the different parts of the river is rather sharp and varied from 0 m to about 3000 m a.s.l. Can be seen that taxonomical diversity varied between 130 species near the river mouth in Colchis and 15 species in the upper high mountains habitats, which is highest altitude.

The most reached altitude layer was placed between 1000 and 1500 m a.s.l. with 211 species. We can reveal what happened with alpha diversity in the basin if seeing to the relief of this layer: here is deep canyon with low settled area and without some tributaries. It can be confirmed by species richness increasing in the walleyes and plateau of the river basin. The lower part of the river basin is also under anthropogenic impact of industry and agriculture in the Colchian lowland.

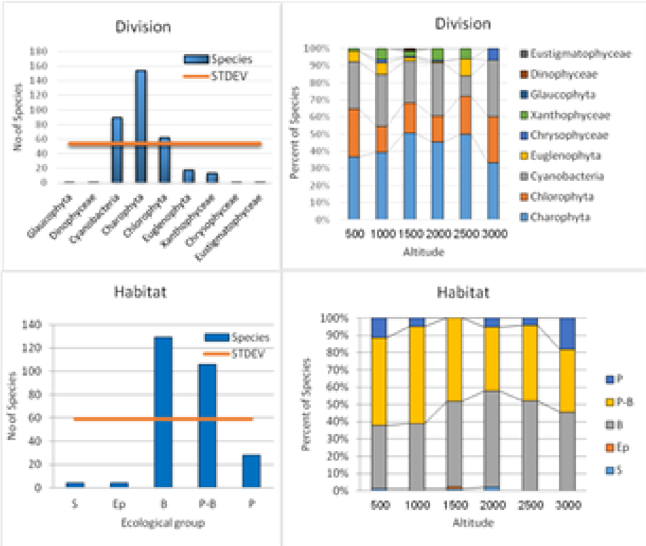

Figure 5. Distribution of indicator species of algae from the Enguri River basin over taxonomic Division, altitude, and ecological groups of substrate preferences (habitats).

In high mountain habitats of closely related regions such as Turkey [28,29] and Israel [5,30] the algal floras are, as a whole, enriched by non-diatom algae and species richness increased with altitude. Our results are demonstrated decreasing of species richness with altitude but in above mentioned floras were studied diatoms also whereas we analyzed non-diatom part of flora only. When we can take the non-diatoms, the revealed patterns are the same. Therefore, Charophyta, Cyanobacteria, and Chrysophyta species play the most important role in the freshwater communities on the high mountain habitats. Species diversity of non-diatom algae in the Enguri River basin has similar distribution with the Aragvi River basin [18], and the Swat River algal flora in Hindu Cush Mountains [31]. It allows us to assume that riverine algal communities have similar regulation of its diversity by high mountains climatic factors.

3.2. Bio-indication of the studied river environment

We use bio-indication methods in purpose to characterize of the stream water quality and ecosystem sustainable. As can be seen in Table 1 and Figure 5, revealed diversity was occupied all types of substrates from plankton to soil. Benthic algae prevail and slightly replace the plankto-benthic inhabitants with altitude. Interesting that role of planktonic species was sufficient in lower and upper parts of the Enguri basin.

Figure 6 demonstrated that water oxygenation was high with low-streaming water inhabitants and aerophiles prevailing in communities. Role of low-oxygenated water indicators was decreased with altitude. In the same time,

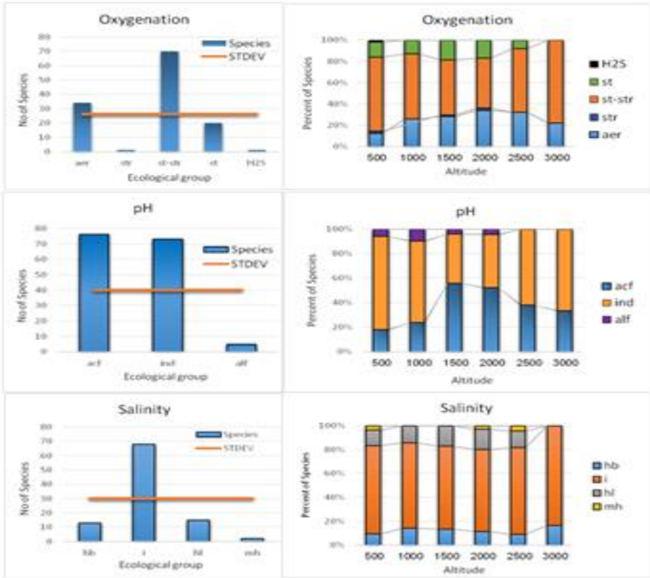

Figure 6. Distribution of indicator species of algae from the Enguri River basin over altitude and ecological groups of water oxygenation, pH, and salinity.

Indicators of water pH (Figure 6) were mostly indifferents with increasing of acidophilic species in the middle part of the river nasin in altitude about 1000-2000 m a.s.l. Alkaliphilic species diversity was low and deceased with altitude.

Salinity indicators were mostly indifferents with decreasing of halophiles in altitude (Figure 6) that marked waters as very fresh.

Trophic state indicators were diverse, represented mostly by mesotrophic and oligotrophic species that increased with altitude (Figure 7).

Organic pollution was reflects in saprobity indicators (Table 1). The indicators were grouped into classes of water quality according rank of saprobity indices in which are belonged species indicators. Can be seen (Figure 7), that water quality was mostly of class II and III with increasing of indicators of class II in the middle part of the river in altitude 1500-2000 m a.s.l.

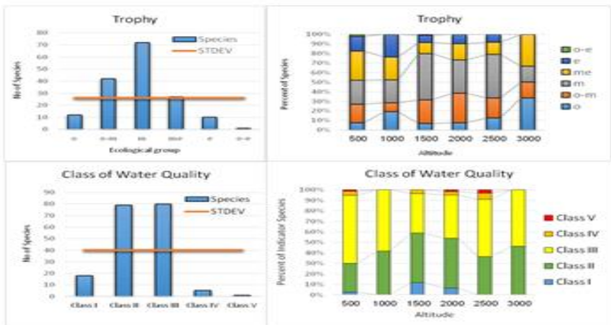

Figure 7. Distribution of indicator species of algae from the Enguri River basin over altitude and ecological groups of water trophic state, and Class of water quality.

Table 2. Distribution of algal and cyanobacterial species from the Enguri River over taxonomic Division and altitude of habitats.

Division	500	1000	1500	2000	2500	3000	Total
Charophyta	47	18	106	47	25	5	154
Chlorophyta	37	6	37	16	10	4	62
Cyanobacteria	36	14	51	32	6	5	89
Euglenophyta	8	3	5	1	5	0	17
Chrysophyceae	0	1	1	1	0	1	1
Xanthophyceae	2	4	8	7	4	0	13
Glaucophyta	0	0	1	0	0	0	1
Dinophyceae	0	0	1	0	0	0	1
Eustigmatophyceae	0	0	1	0	0	0	1
Total in altitude	130	46	211	104	50	15	339

The same tendency was revealed in the Aragvi River basin with increasing of water organic pollution from the upper part of the river to the mouth [18], the Swat River in Pakistan [31], and Songhua River in China [32] where algal community was mostly represented by green algae.

3.3. Comparative floristics

Comparative floristic approach provide for the grouping of algal communities in respect to their taxonomic similarity. Similarity tree of floristic composition that constructed for the Enguri River communities (Figure 8), showing three species diversity clusters at the similarity level 50%. Cluster 1 includes communities of habitats on altitude 0-500 and 1500-2000 m a.s.l. where in the flat valleys or coastal lowland is placed mostly of settlements of this part of Georgia. Cluster 2 comprises habitats in the valley near the sammit of the Enguri River with its largest tributary the Nenskra River. Cluster 3 includes habitats in the canyon area in the middle part of the basin on altitude of 500-1000 m a.s.l. as well as uppermost localities on altitude pper than 2000 m a.s.l.

The dendrite of taxonomic overlap (Figure 9) shows that the algal flora of the middle parts of the basin on the altitude about 1500-2000 m a.s.l. can represent of floristic core in which other floristic parts are included. Core is represents the basin area in which settlements and turism are developed and flow into multiple streams such as Nakra, Dolra, and Mulkhura with the Mestia. Figure 10 show that 1500-2000 m a.s.l. flora is peculiar and shared species on 15-43% from other floras of the basin.

The Dendrogram of Terentiev pleads comparison (Figure 11) highlights the strongest connection between communities from habitats on altitude 0-500 and 1000-2000 m a.s.l.

We calculated surface of trends pattern for each taxonomic Division distribution over total species richness and altitude of habitats with method of Distance weighted least squares (Figure 12). Statistical pallets of the Enguri River basin Charophyta (a) species distribution over altitude of habitats and total species number in communities show that its diversity enriched in species number on the lowermost habitats but decreased with altitude. The similar trend has Chlorophyta (b), Euglenophyta (e), and Dinophyceae (f) species. Cyanobacteria (c) and Chrysophyceae (d) species have opposite trend with increasing in altitude. Remarkable, that the statistically calculated surfaces have prognostic properties. It can be used if communities from other altitudes will study.

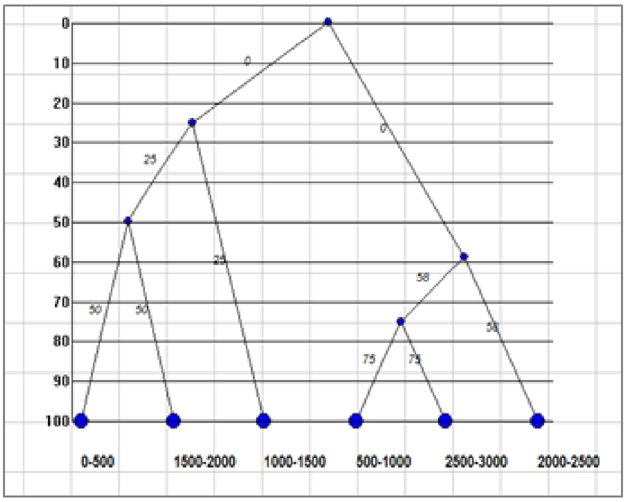

Figure 8. Dendrogram of comparative floristic of algal species of the Enguri River basin over altitude of habitats.

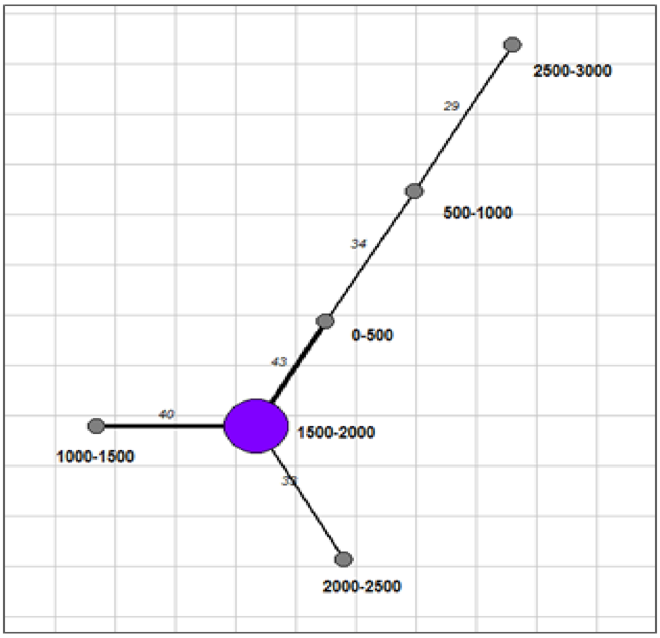

Figure 9. Dendrite of taxonomic overlap of algal species of the Enguri River basin over altitude of habitats.

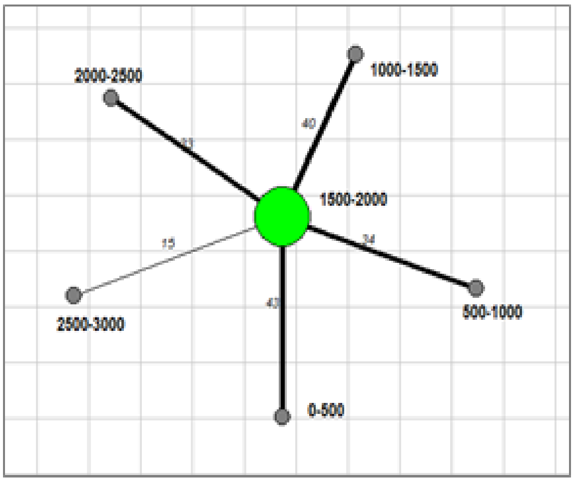

Figure 10. Dendrogram of comparative floristic of algal species of the Enguri River basin over altitude of habitats.

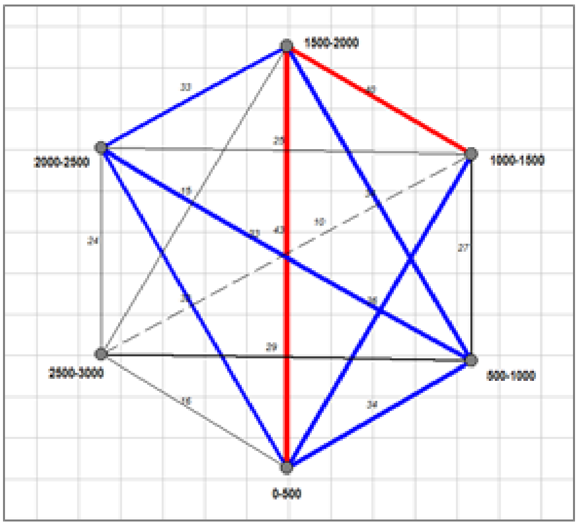

Figure 11. Dendrogram of Terentiev pleads comparison of algal species of the Enguri River basin over altitude of habitats. The relationships that over 40% marked by red, over 30% marked by blue. The most correlated communities lines marked by bold.

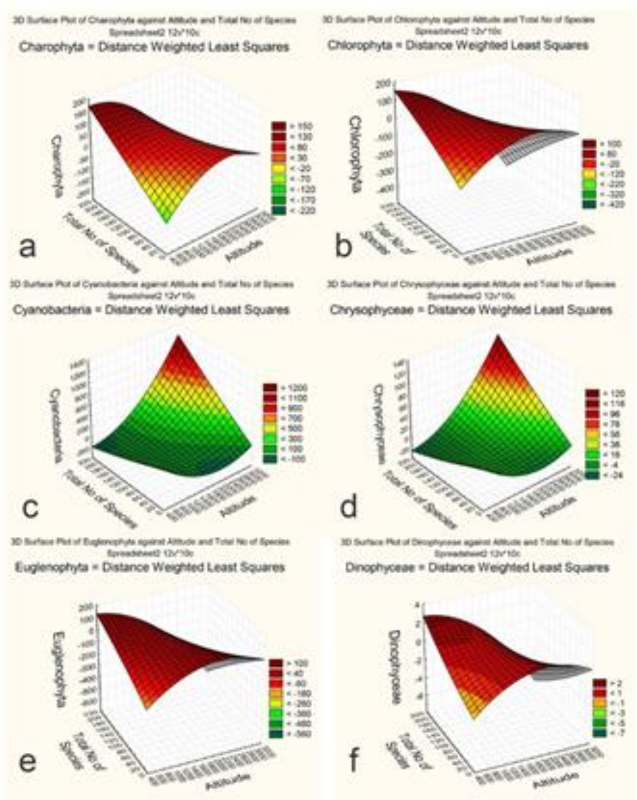

Figure 12. Distance weighted least squares statistical pallets of the Enguri River basin algal species distribution over altitude of habitats and total species number in communities. Charophyta (a), Chlorophyta (b), Cyanobacteria (c), Chrysophyceae (d), Euglenophyta (e), Dinophyceae (f).

This result is similar to our calculation of algal diversity distribution altitude in the Georgian Natural Reserves [7] but opposite for the Aragvi River communities [18]. It can be related with climatic control of algal diversity in the territory of Georgia in compare of territory of single river basin. The analysis, thus, reveals a strong altitude control over the major diversity estimates in the Enguri River.

3.4. Infraspecies variation

Infraspecies variation is important property of biodiversity that was studied in respect of major factors, which are dependent to climatic variables such as altitude [7] or latitude [30,33] of freshwater habitats. Relationship higher/lower taxa ratio for vascular plants can characterize floristic region. Diversity ratios in Asian floras parity is more due to the temperate-tropical taxa [34]. We create the Index of infraspecies variation, which in Georgian Natural Reserves algal flora is rather low, and changed in a small range between 1.01-1.15 [7]. That can be if only few species of the total species list of each reserve are divided into taxonomic varieties.

We calculated Infraspecific variation index for the Enguri River basin as ratio of number of species and infraspecies to number of species. Index varied between 1.05 and 1.22 in the different altitude communities. Average value of index is 1.15 that is in the same range as in the Georgian Natural Reserves [7]. Yet in the Enguri River, algal species of the total species list are divided into taxonomic varieties for 13 species into two and for three species into three variations. They are *Cosmarium notabile*, *Euastrum dubium*, and *Euastrum verrucosum* that varied in habitats below 2000 m a.s.l. Infraspecies variation index show that algal species polymorphism in the Enguri River basin communities increased with increasing of altitude habitats. That allows us to conclude that species of the high mountain ecosystems of the Enguri River have trend to be more polymorphic in altitude.

4. Conclusion

We studied floristic diversity of non-diatom algae the Enguri River basin and compared it to what is known about freshwater algae of the National Georgian reserves and the Aragvi River. About 241 species are mostly represented in the first time for the Enguri River by our study. Altogether 339 species are listed after extensive sampling and revision of the previously described materials. Charophyte species prevail in studied algal flora. Bio-indication characterize the Aragvi River waters as temperate, moderately oxygenated, fresh, neutral water affected by a low to moderate level of organic pollution. The pattern of diversity distribution depends on altitude and local climatic conditions. Whereas Cyanobacteria and Chrysophyta species are richest in high mountain habitats, Charophyta, green algae, dinophytes, and euglenoids avoid high mountain habitats and have negative correlation with altitude. These results can usable as indicator of environmental changes in the mountainous areas. The floristic core of basinal algal flora is represented by communities on the altitude about 1500-2000 m a.s.l. in which placed the most attractive and populated areas under the Caucasus Mountains.

The number of infraspecies per species variation was correlated positively with altitude, and therefore, species of the high mountain ecosystems in the Enguri River have a trend to be most polymorphic.

This type of biodiversity distribution can serve as a regional peculiarity of the Georgian river basins. Similar trends was revealed in algal diversity pattern of nearby floras in western coast of the Black Sea such as Moldova [4,35] Romania [36], and high mountain habitats of Turkey [29,37]. Here non-diatom algae as in mountainous Georgia and in the Aragvi River in particular enrich algal floras. It is controversial with the Turkish coast freshwater floras where the diatoms are ubiquitously prominent [3,37-42]. Remarkable that algal community in the Enguri River is more species rich that in the above mentioned nearby Black Sea coastal rivers of Turkey, which also flow from mountainous areas.

As a conclusion, our analysis reveals a strong altitude control and hence climatic factors for algal diversity distribution in the Enguri River basin one of largest rivers in Georgia.

Acknowledgment

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