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Taxonomic investigations of cyanobacterial and algal flora from the Southern Altai, East Kazakhstan

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Abstract: The study presents results of pilot investigations (2005-2007) of micro-vegetation biodiversity in marginally explored mountain and forest-steppe areas of southern Altai, East Kazakhstan. On the basis of morphological phenotypes and ecological demands a total of 351 taxa of cyanobacteria and algae were identified in the principal biotopes (rivers and streams, backwaters, irrigation channels, lakes, high-tundra periglacial and barren land settings, snow fields, and pedogenic /soil cover/ environments) of the territorial topographic gradient of ca. 400-3900 m a.s.l. Microbiological records display a remarkable taxonomic variability, including several previously undescribed endemic species of algae adapted to locally specific geo-environmental conditions. The present results show a major potential for future systematic phycological studies integrated in the complex nature monitoring and management strategy in protected areas of the Altai. The results also demonstrate a limited impact of modern human activity on the quality of local water sources with only minor present ecological risks in balance with the traditional lifestyles of pastoralist communities.

Key words: cyanobacteria, algae, taxonomy, microflora, biodiversity, southern Altai, East Kazakhstan

1. Introduction

The present state of scientific knowledge on microflora of Kazakhstan is rather limited. Only few articles, concerning local cyanobacteria and algae, have been published to date (e.g., Muzafarov 1965; Ergashev 1974). Although algal and cyanobacterial microflora has been previously studied in Turkmenistan, Uzbekistan, Tajikistan, Kyrgyzstan and the southern Kazakhstan (Obukhova 1952; Vozzhennikova 1953; Kiselev 1955; Muzafarov 1965; Ergashev 1974; Masharipov 1976; Shoyakubov *et al*. 1976), the eastern part of Kazakhstan still belongs to the least researched microbiologically and largely unknown regions of Central Asia.

The key study area is located in the central part of the southern Altai Mountains, East Kazakhstan, belonging to the Paleoarctic biogeographical zone of southern Siberia, well-known for high numbers of unique and endemic species of flora and fauna (Androsova 1977). The principal investigations of cyanobacteria and algae were carried out in the territory of the Katon-Karagay National Nature Park (648 km^2) and the Lake Markakol Nature Protection Zone (455 km^2) as a part of a complex biodiversity mapping of pristine natural areas of East Kazakhstan. Most of the investigated territory (with MAT +1°C) is covered by semi-arid steppes and forest-steppes in river valleys, and by mixed taiga forests, dark coniferous forests and alpine tundra in the mountains, following the topographic gradient above the crystallinic bedrock.

The discussed data result from systematic pilot studies of freshwater and aerophytic flora carried out in the Kazakh zone of the Altai within the framework of ecological and biotic investigations of the broader Altai region, following the studies of cyanobacterial and algal flora in pristine soils of Gorno Altai, Siberia (Chlachula *et al*. 2002; Koutný *et al*. 2003). Since the original species variability of cyanobacteria and algae represents proxy

indicators of water quality, the assembled database derived from the main biotopes/habitats of the local ecosystems (aquatic, terrestrial, air-related and snow-cover related) was also used to assess quality of the main water systems, particularly of the Bukhtarma River with its tributaries, draining the studied territory.

2. Material and methods

2.1. Material sampling and processing

Cyanobacterial and algal flora sampling was performed during the summer seasons of 2005-2007. Approximately 225 aquatic samples were collected from the Bukhtarma and Berel Rivers: their main channels, backwaters and stagnant water pools; irrigation channels, bogs, mountain streams, snow-fields and post-glacial mountain lakes (Jazovo, Dzhindagatuy, Markakol), with the latter biotically compared to the continental lacustrine basins of eastern Kazakhstan (Lakes Zaysan and Kopchegay) (Fig. 1). In addition, aerophytic microvegetation was sampled from exposed rock surfaces and modern pedogenic (soil) horizons. Cyanobacterial and algal flora from the present pastures, past-grazed and non-grazed areas were used for a close contextual taxonomic evaluation (Fig. 2).

The collected biotic material was dried, fixed in 1.5% formaldehyde or kept alive in the Petri dishes with sterile BG11 nutrient medium. Soil samples were placed on agar plots with BG11 nutrient medium in Petri dishes and cultivated under laboratory conditions for 4 weeks. Diatom permanent slides were prepared in compliance with standard procedures (Houk 2003).

Fig. 1. Location map of the study area, East Kazakhstan, with the marked investigated localities

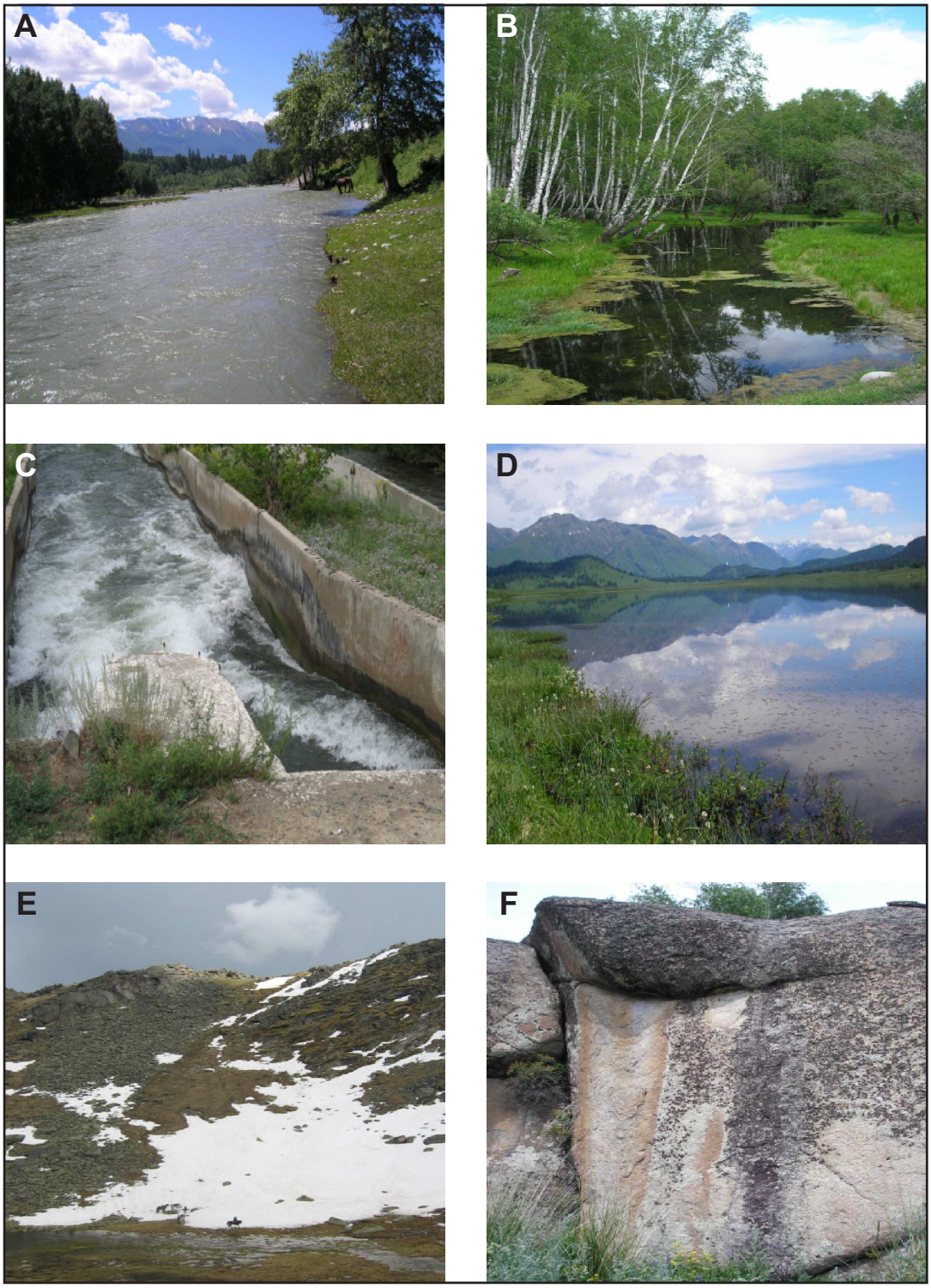

Fig. 2. The investigated Southern Altai biotopes
Explanations: A – Bukhtarma River, B – backwaters, C – irrigation channels (Zaysan Basin), D – Lake Jazovo, E – snow fields and barren lands (alpine Altai settings), F – aerophytic vegetation of cyanobacteria (black spots)

2.2. Taxonomic identification

Taxonomic identification of Conjugatophyceae and Charophyta followed Poljanskiy (1955), Krasnoperova (1970, 1971), Krasavina (1974), Hollerbach & Krasavina (1975), Rundina (1977); diatoms were determined according to Krammer & Lange-Bertalot (1986, 1988, 1991a, 1991b) and Krammer (1997a, 1997b, 2000, 2003). Identification of particular morphotypes is based on the cited literature (Geitler 1932; Elenkin 1936-1949; Starmach 1972; Komárek & Anagnostidis 1999, 2005; Houk 2003). Although contemporary taxonomic literature was applied, determination of several taxa was uncertain or unfeasible, suggesting existence of some still undescribed endemic microflora taxa, adapted to local, highly specific geo-environmental conditions.

The taxonomical classification of algae was applied according to Lee (2008).

3. Results and discussion

The total number of the currently determined taxa includes: Cyanobacteria (82), Rhodophyta (1), Dinophyta (3), Heterokontophyta: Chrysophyceae (4), Bacillariophyceae (171), Xanthophyta (4), Chlorophyta (87) and Charophyta (3). Identification of some species turned out to be rather problematic. Only 88% of Bacillariophyceae, 28% of Cyanophyta and 24% of Chlorophyta were identified to a specific level. Great numbers of undetermined Cyanophyta (20) and Chlorophyta (15) taxa suggest the presence of new genera or species. The occurrence distribution of particular taxa is summarized in Table 1.

Algal flora was strongly affected by low temperatures of mountain waters, mainly of glacial origin. Therefore, algal species typical for the spring season occurred most frequently in the studied samples. The principal investigated biotopes are represented by rivers and streams, backwaters, irrigation channels, lakes, aerophytic tundra settings (barren lands, snow fields) and pedogenic environments of the present soil cover (Fig. 2).

3.1. Rivers and Streams

Both indifferent species and indicator taxa of clean and cold water conditions (*Hydrurus foetidus* (Vill.) Trev., *Ulothrix* sp., *Microspora* sp. and *Meridion circulare* (Grev.) Ag. predominated in the samples from the fluvial environments (river valleys).

At higher altitudes (above 1700 m a.s.l.), the algal and cyanobacterial communities were replaced by lichens. Kiselev (1955), Muzafarov (1965) and Ergashev (1974) found similar taxa in the majority of river channels in Turkmenistan, Uzbekistan, Tajikistan, Kyrgyzstan and the southern part of Kazakhstan, apart from the commonly represented taxa of *Oedogonium* sp., *Zygnema* sp., *Nostoc verrucosum* Valch. ex Born. and Flah., in addition to various types of *Phormidium* sp.

As unusual aspect is the absence of species *Prasiola fluviatilis* (Sommer.) Aresch. ex Lag., which was commonly recorded in river settings of Uzbekistan, Kyrgyzstan and Tajikistan (Muzafarov 1965). Another surprising fact is an almost complete absence of rhodophytes (except for several specimens of *Lemanea fluviatilis* (L.) C. Ag. found near Lake Markakol), despite frequent records of *Batrachospermum moniliforme* Roth, *Chantransia chalybea* (Roth) Fries and *Lemanea fluviatilis* from the broader Central Asia and *Bangia atropurpurea* (Roth)

Table 1. Summarizing table of the cyanobacterial and algal taxa (Southern Altai, East Kazakhstan)

Cyanophyta	
Total number of taxa	82
Number of taxa identified to the specific level	18%
Potential new species or genera	29%
Rhodophyta	
Determined taxa (1)	*Lemanea fluviatilis*
Dinophyta	
Determined taxa (3)	*Peridinium bipes, Peridinium cinctum, Woloszynskia* sp.
Heterokontophyta: Chrysophyceae	
Determined taxa (4)	*Dinobryon* sp., *Hydrurus foetidus* (2), *Synura* sp
Heterokontophyta: Bacillariophyceae	
Total number of taxa	171
Number of taxa identified to the specific level	82%
Potential new species or genera	5%
Taxa typical of Central Asia	*Encyonema persilesiacum* var. *ata-tau, Cymbella stuxbergii, Synedra goulardii*
Xanthophyta	
Total number of taxa	7 (from genera *Ophiocytium, Tribonema, Vaucheria*)
Chlorophyta	
Total number of taxa	86
Number of taxa identified to the specific level	19%
Potential new species or genera	15%
Charophyta	
Determined taxa (3)	*Chara* sp., *Chara* aff. *vulgaris* 1 and *Chara* aff. *vulgaris* 2

C. Ag. recorded in analogous habitats in Kazakhstan (Muzafarov 1965; Ergashev 1974). This phenomenon might reflect various geo-environmental factors, e.g. changes in pH or light conditions.

Mono-specific populations of cyanobacteria from Hydrococcaceae and some unidentified species of *Tapinothrix* Sauv. were attached to exposed surfaces of cobbles in mountain streams. The presence of the genera *Chaetophora* Schrank, *Draparnaldia* Bory and *Stigeoclonium* Kütz. is typical of springs and streams emptying the local Altai mountain lakes. Brown-coloured macroscopic mats of *Meridion circulare* (Bacillariophyceae) dominated in humid and forested high mountain areas. An unknown *Cladophora* Kütz. species and a population of *Chara vulgaris* s.l. were found in smaller mountain streams at lower altitudes (700-1000 m a.s.l.). The above mentioned *Cladophora* species is specific in its morphology and is not identical with the common *Cladophora* species from Central Asia (Kiselev 1955; Muzafarov 1965). The occurrence of *Chara vulgaris* s.l. in rapid streams is rather unexpected due to its tight relation to torrential biotopes (Muzafarov 1965; Krasavina 1974; Hollerbach & Krasavina 1975).

The collected diatom taxa may be generally regarded as "cosmopolitans" characteristic of standing water biotopes, with the occurrence of some species recorded exclusively in Kazakhstan, e.g. *Encyonema persilesiacum* var. *ata-tau* Krammer (Krammer 1997a). Although the total number of the found diatom species did not exceed 36 for rivers and 53 for streams, a high occurrence of the currently undetermined species suggests great microflora variability in the Altai.

3.2. Backwaters

The species composition of the Altai backwater and palustrine biotopes is rather unique. Bacillariophyta, Chrysophyta and Chlorophyta were recorded from all sampling locations, most of them with the characteristic spring season appearance. The genera of *Phormidium* Kütz. ex Gom., *Synura* Ehren., *Fragilaria* Lyngb., *Meridion* Ag., *Chaetophora, Draparnaldia*, *Mougeotia* Ag. and *Zygnema* Ag. dominated in the samples.

The *Fragilaria* and *Meridion* species formed typical mats, brown-coloured around margins, while *Chaetophora*, *Draparnaldia* and some unidentified and evidently undescribed endemic genera, most probably related to the Chaetophorales group, occurred in river valley oxbow lakes. These genera represented the dominant microvegetation component of this particular Altai biotope.

3.3. Irrigation channels

Irrigation channels are considered to be a specific anthropogenic type of biotopes with a distinctive cyanobacterial and algal flora (Muzafarov 1965; Ergashev 1974). Some modern irrigation channels were previously studied in the Almaty region, SE Kazakhstan (Ergashev 1974). Micro-vegetation records from two presently abandoned irrigation channels near the Dzhambul village, the Katon-Karagay region in East Kazakhstan, are included in the presented study.

Cyanobacterial and algal flora formed mats of a pale brown and green colour alongside channels. Some interesting species of *Calothrix* Ag. ex Born. et Flah., *Ammatoidea* W. West and G. S. West, *Leptolyngbya* Anagn. & Kom., and two types of *Phormidium*, *Chlorogloea microcystoides* Geitl. was recorded, as well as an unknown taxon of green filamentous algae, approximately comparable to *Stigeoclonium* without subsidiary branches.

In contrast, Ergashev (1974) distinguished *Hydrocoleus brebissonii* Kütz., *Lyngbya aestuarii* (Mert.) Lieb. ex Gom., *Microcoleus chthonoplastes* (Mert.) Zanar. ex Gom., *Plectonema terebrans* Born. and Flah., *Phormidium molle* (Kütz.) Gom., *Ph. uncinatum* Gom. ex Gom. (cyanobacteria) and *Chantransia chalybea*, *Cladophora glomerata* Pilg., *Stigeoclonium subuligerum* Kütz. from similar biotopes. The *Trentepohlia jolithus* (Lin.) Wallr., previously reported from a special wooden apparatus (chigir) in irrigation channels in the Almaty region (Ergashev 1974), was not recorded in the investigated area of East Kazakhstan.

The number of gathered diatom species was the lowest (29) from the surveyed southern Altai biotopes. An interesting finding is the unexpected presence of *Cymbella helmckei* Krammer, until now observed only in Lake Balaton, Hungary (Krammer 2002), and two unknown *Pinnularia* Ehren. taxa (*Pinnularia* sp.1 and sp.2) from stream biotopes.

3.4. Lakes

The algal species composition observed in the Altai lakes is rather unique and is worth studying in detail. Most of the investigated freshwater lakes (Kopchegay, Dzhindagatuy, Markakol and Zaysan) have some general environmental similarities to the better-investigated saline/brakish Lake Balchash in central Kazakhstan (a large water extent with a stony and sandy lake bottom and littoral vegetation).

Green macroscopic algal taxa – *Oedogonium* Link, *Zygnema*, *Mougeotia*, *Cladophora* and a group of Charophyta have been mostly documented in large Kazakh lakes (Muzafarov 1965; Krasavina 1974; Hollerbach & Krasavina 1975; Rundina 1977). During our research only populations of *Chara vulgaris* s.l. were found. In contrast, Krasavina (1974), Hollerbach & Krasavina (1975) described the presence of numerous species of Charophytes (*Ch. intermedia* A. Br., *Ch. tomentosa* Linn., *Ch. schaffneri*, *Ch. foetida* A. Br., *Ch. altaica* A. Br. emend. Hollerb. or *Ch. aspera* Willd., *Nitella tenuissima* (Desv.) Kütz., *N. hyalina* (De Cand.)

C. Ag., *Nitellopsis obtusa* (Desv.) J. Groves and the *Tollypela nidifica* population) from various regions of Kazakhstan.

The total number of the found diatom taxa (115) and the overall species diversity were much higher in the lake ecosystems than for the rest of the mapped Altai biotopes. The number of unidentified taxa (7) did not reach their absolute and proportional quantity as in the local biotopes of streams and rivers (11 out of 70 taxa). Algal flora of the two closely investigated lakes varies considerably within the general species composition described above, but also between each other. Glacial water sources distinguished the lakes from other studied lacustrine basins. The geo-biological substrate and the presence of macrophytes are the other most differentiating factors. The Jazovo Lake (N 49°33′28.1″; E 86°18′9.9″; 1659 m a.s.l.) is a shallow, peaty lake with a sandy bottom located in a mountain valley. The macrophytic species *Comarum palustre* L., *Menyanthes trifolia* L. and *Warnstorfia exannulata* (Schimp. in B.S.G.) Loeske dominate in the littoral zone. The bottom of the lake is covered by vegetation of *Chara vulgaris* s. l. Major components of mats attached to macrophytes include *Bulbochaete* sp., *Oedogonium* sp., *Nostoc linckia* (Roth) Born., *Tolypothrix* sp., *Aulosira* sp., *Chaetosphaeridium* sp., *Dichothrix* sp., *Tetraspora* sp., *Tetrastrum* sp., *Aulacoseira valida* (Grun.) Krammer, *Diatoma* cf. *mesodon* (Ehrenb.) Kütz., *Epithemia* cf. *adnata* (Kütz.) Bréb., *Gomphonema acuminatum* Ehrenb., *Gomphonema truncatum* Ehrenb., *Meridion circulare* and *Pinnularia borealis* Ehrenb.

„The Mountain lake" (N 49°11′02″; E 86°38′11″; 2528 m a.s.l.) is a small, shallow lake with a perennial filling source of glacial water, originating in ice-fields on the plateaus of the Southern Altai Range (ca. 4000 m a.s.l.). An unknown species from the genus *Stigeoclonium* grew predominantly on the shale bedrock. *Draparnaldia* sp., *Tetraspora* sp. and cyanobacteria *Phormidium retzii* (Ag.) Gom. ex Gom., *Tolypothrix* sp., *Tapinothrix* sp., *Stichosiphon* cf. *sansibaricus* (Hieron.) Dr. and Daily, *Hassallia* sp., *Komvophoron* sp., *Chamaesiphon* cf. *incrustans* Grun. in Rabenh., *Microchaete* cf. *uberrima* N. Carter and *Merismopedia glauca* (Ehren.) Kütz. were dominant on stones in inflow and outflow settings. *Woloszynskia* sp., *Peridinium bipes* F. Stein (Dinophyta) and *Cosmarium* cf. *tetraophtalmum* Bréb. ex Ralfs (Conjugatophyceae) were repeatedly identified in plankton.

3.5. Aerophytic biotopes (barren soils, snow fields)

Large populations of *Stigonema minutum* Hassall ex Born. et Flah., *Stigonema* sp. and *Chlorogloea* sp. were documented on surfaces of large stones near the village of Arshaty, the upper Bukhtarma river valley (N 49°17′53″; E 86°33′9,4″; 1201 m a.s.l.). Local cyanobacteria commonly form black, spot-like colonies. *Symplocastrum* sp. and *Eucapsis* sp. populations were recorded, isolated from the barren tundra soils. Persisting snow fields situated at altitudes above 2000 m a.s.l. display in places a reddish colouration, caused by the presence of *Chlamydomonas nivalis* (Bauer) Wille.

3.6. Soil biotopes

The diversity of the main soil types distributed in the broader Altai region reflects the geomorphic and geological context of the specific biotopes with chernozemic, luvisolic, brunisolic, gleysolic and regosolic soil types, corresponding to (parkland-)steppe, seasonally water-saturated steppe, boreal taiga forest, coniferous forest and alpine tundra, respectively (Chlachula 2007). According to studies from other areas, the influence of grazing/pasture on soil micro-vegetation is evident (e.g. Evans & Johansen 1999; Johansen & Shubert 2001; Johansen *et al.* 2001; Türk & Gärtner 2001). Nevertheless, no clear difference was recorded within the investigated territory in the species composition between the cultivated samples originating from the intensively and extensively grazed areas of East Kazakhstan. The present results are consistent with the conclusions of the research focused on soil microflora in Tajikistan (Melnikova 1956). Additional systematic data should define in detail the particular microflora composition range within the specific soil types.

4. Summary and conclusions

The first results of the microflora (cyanobacteria and algae) studies from unexplored mountain areas of the southern Altai and the adjacent forest-steppe and steppe regions of East Kazakhstan display a remarkable taxonomic variability reflecting the unique diversity of local natural environments. Several newly recorded and so far undescribed (or unknown) taxa of algae show a major potential for future systematic studies. The current results also indicate a limited impact of a direct as well as indirect human activity on the local environments (water sources) and minor ecological risks due to the present exploitation of natural resources, both reflecting the traditional historical lifestyles (pastoralism and forestry) practiced by the local Kazakh communities. Only a minor part of the recorded algal species is indifferent to water pollution and is common in clean running as well as stagnant waters. A marginal frequency of the recorded algal taxa is characteristic of anthropogenically polluted waters, thus suggesting an overall pristine and clear regional environment. The present results have been incorporated in the complex biodiversity and ecology management studies of the protected natural areas of the Altai-Sayan Eco-region – the Katon Karagay Nature Park in particular.

Although the present pilot microbiological study was strictly based on morphological determination according to the standard and regionally specific floras, the unique biodiversity of the investigated territory of central Eurasia is rather evident in respect to the overall number of the unclassified endemic micro-vegetation taxa. Future taxonomic investigations, comprising additional contextual ecological and molecular biological data, will further provide a better understanding of the documented cyanobacterial and algal diversity and functioning of the present Altai ecosystems.

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Appendix. List of identified cyanobacterial and algal taxa

Cyanophyta

Amatoidea sp., *Anabaena* cf. *catenula* Born. et Flah., *Anabaena* sp. 1, *Aphanocapsa* sp., *Aphanothece* sp. 1, *Aphanothece* sp. 2, *Aulosira* sp., *Calothrix* sp. 1, *Calothrix* sp. 2, *Calothrix* sp. 3, *Clastidium* sp., *Cylindrospermum* sp., *Dichothrix* sp., *Eucapsis* sp., *Fischerella* sp., *Gloeocapsa* sp., *Godlewskia* sp., *Hassallia* sp., *Heteroleibleinia* sp., *Hormoscilla pringsheimii* Anagn. et Kom., *Hydrococcaceae* gen.et.sp.dir., *Chamaesiphon* cf. *incrustans* Grun. in Rabenh., *Chlorogloea* microcystoides Geitl., *Chlorogloea* sp. 1, *Chlorogloea* sp. 2, *Chroococcidiopsis* sp., *Komvophoron* sp. 1, *Komvophoron* sp. 2, *Leptolyngbya* cf. *foveolarum* (Rabenh. ex Gom.) Anagn. et Kom., *Leptolyngbya* sp. 1, *Leptolyngbya* sp. 2, *Leptolyngbya* sp. 3, *Leptolyngbya* sp. 4, *Lyngbya* sp. 1, *Lyngbya* sp. 2, *Lyngbya* sp. 3, *Lyngbya* sp. 4, *Lyngbya* sp. 5, *Merismopedia glauca* (Ehren.) Kütz., *Microchaete* cf. *uberrima* N. Carter, *Microchaete* sp., *Microcoleus* sp., *Nodularia willei* Gard., *Nodularia* sp., *Nostoc commune* Vauch. ex Born. et Flah., *Nostoc* cf. *linckia* (Roth) Born., *Nostoc linckia* (Roth) Born., *Nostoc* sp. 1, *Nostoc* sp. 2, *Nostoc* sp. 3, *Nostoc* sp. 4, *Oscillatoria* sp., *Phormidium* aff. *autumnale* (C. Ag.) Gom., *Phormidium ambiguum* Gom., *Phormidium autumnale* (C. Ag.) Gom., *Phormidium* cf. *californicum* Dr., *Phormidium paulsenianum* Boye-Petersen, *Phormidium retzii* typ 1 (Ag.) Gom. ex Gom., *Phormidium retzii* typ 2 (Ag.) Gom. ex Gom., *Phormidium* sp. 1, *Phormidium* sp. 2, *Phormidium* sp. 3, *Phormidium* sp. 4, *Pseudanabaena galeata* Böch., *Spirulina* cf. *subsalsa* Oerst. ex Gom., *Spirulina* sp., *Stigonema informe* Kütz. ex Born. et Flah., *Stigonema* cf. *minutum* Hassall ex Born. et Flah., *Stigonema* sp., *Stichosiphon* cf. *sansibaricus* (Hieron.) Dr. & Daily, *Symplocastrum* sp., *Tapinothrix* sp. 1, *Tapinothrix* sp. 2, *Tapinothrix* sp. 3, *Tolypothrix* sp. 2, *Tolypothrix* sp. 1, *Tolypothrix* sp. 2, *Tolypothrix* sp. 3, *Tolypothrix* sp. 4, *Tolypothrix* sp. 5, *Trichormus* sp., *Xenococcus* sp.

Rhodophyta

Lemanea fluviatilis (L.) C. Ag.

Dinophyta

Peridinium bipes F. Stein, *Peridinium cinctum* (O.F. Müll.) Ehren., *Woloszynskia* sp.

Heterokontophyta: Chrysophyceae

Dinobryon sp., *Hydrurus foetidus* (Vill.) Trev., *Synura* sp. 1, *Synura* sp. 2

Heterokontophyta: Bacillariophyceae

Achnantheiopsis delicatula (Kütz.) Lange-Bert., *Adlafia minuscula* var. *minuscula* (Grun.) Lange-Bert., *Achnanthes laevis* var. *laevis* Østrup, *Achnanthes lapidosa* var. *lapidosa* Krasske, *Achnanthidium biasolettianum aff. var. thienemannii* (Hust.) Round et Bukht., *Achnanthidium minutissimum* var. *jackii* (Rabenh.) Czarn., *Achnanthidium minutissimum* var. *minutissimum* (Kütz.) Czarn., *Achnanthidium* sp. 1, *Amphora* cf. *inariensis* Krammer, *Amphora* cf. *libyca* Ehrenb., *Amphora montana* Krasske, *Amphora ovalis* (Kütz.) Kütz., *Amphora pediculus* (Kütz.) Grun., *Aulacoseira alpigena* (Grun.) Krammer, *Aulacoseira* cf. *canadensis* (Hust.) Simonsen, *Aulacoseira valida* (Grun.) Krammer, *Brachysira procera* Lange-Bert. et G. Moser, *Brachysira styriaca* (Grun.) R. Ross, *Caloneis* sp. 1, *Cavinula pseudoscutiformis* (Hust.) D.G. Mann et A.J. Stickle, *Cavinula cocconeiformis* (Greg. ex Greville) D.G. Mann et A.J. Stickle, *Cocconeis pediculus* Kütz., *Cocconeis placentula* Ehrenb., *Cocconeis placentula* var. *lineata* (Ehrenb.) P. Cleve, *Cyclotella bodanica* var. aff. *lemanica* (O. Müller) Bachman, *Cyclotella ocellata* Pant., *Cyclotella radiosa* (Grun.) Lemm., *Cymatopleura solea* (Bréb.) W. Smith, *Cymbella affinis* Kütz., *Cymbella cymbiformis* Ag., *Cymbella helmckei* Krammer, *Cymbella lacustris* (Ag.) Cleve, *Cymbella lanceolata* var. *lanceolata* (Ag.) Ag., *Cymbella* sp. 1, *Cymbella stuxbergii* (Cleve) Cleve, *Cymbella tumida* (Bréb.) Van Heurek, *Cymbopleura cuspidata* (Kütz.) Krammer, *Cymbopleura lapponica* (Grun.) Krammer, *Cymbopleura naviculiformis* (Auersw.) Krammer, *Diatoma mesodon* (Ehrenb.) Kütz., *Diatoma* sp. 1, *Diatoma tenuis* Ag., *Diploneis* sp. 1, *Dydimosphaenia geminata* (Lyngb.) M. Schmidt, *Encyonema* cf. *lange-bertalotii* Krammer, *Encyonema minutum* (Hilse) D.G. Mann, *Encyonema persilesiacum* var. *ata-tau* Krammer, *Encyonema silesiacum* (Bleisch) D.G. Mann, *Encyonopsis microcephala* (Grun.) Krammer, *Epithemia adnata* (Kütz.) Bréb., *Epithemia* cf. *adnata* (Kütz.) Bréb., *Epithemia* sp., Epithemiaceae sp. 1, *Eunotia bilunaris* (Ehrenb.) Mills, *Eunotia implicata* Nörpel et al., *Eunotia minor* (Kütz.) Grun., *Eunotia muscicola* var. *tridentula* Nörpel et Lange-Bert., *Eunotia* sp. 1, *Eunotia* sp. 2, *Fallacia monoculata* (Hust.) D.G. Mann, *Fragilaria arcus* (Ehrenb.) Cleve, *Fragilaria arcus* var. *recta* Cleve, *Fragilaria capucina* var. *amphicephala* (Grun.) Lange-Bert., *Fragilaria capucina* var. *distans* (Grun.) Boye-Petersen, *Fragilaria capucina* var. *gracilis* (Ŕstrup) Hust., *Fragilaria capucina* Dezmaziéres, *Fragilaria* cf. *capucina* Dezmaziéres, *Fragilaria* cf. *virescens* (Ralfs) D.M. Williams et Round, *Fragilaria* sp. 1, *Fragilaria* sp. 2, *Fragilaria tenera* (W. Sm.) Lange-Bert., *Fragilaria vaucheriae* (Kütz.) Petersen, *Gomphoneis olivacea* (Hornem.) Dawson ex Ross et Sims, *Gomphoneis* sp., *Gomphonema acuminatum* Ehrenb., *Gomphonema angustatum* (Kütz.) Rabenh., *Gomphonema angustum* C. Ag., *Gomphonema* cf. *pumilum* (Grun.) Reichardt et Lange-Bert., *Gomphonema clavatum* Ehrenb., *Gomphonema micropus* Kütz., *Gomphonema parvulum* var. *exilissimum* Grun., *Gomphonema parvulum* var. *parvulum* f. *saprophilum* Lange-Bert. et Reichardt, *Gomphonema sarcophagus* Greg., *Gomphonema* sp. 1, *Gomphonema truncatum* Ehrenb., *Gomphonema ventricosum* Greg., *Gyrosigma attenuatum* (Kütz.) Rabenh., *Hantzschia amphioxys* (Ehrenb.) Grun., *Hippodonta capitata* (Ehrenb.) Lange-Bert., Metzeltin et Witkowski, *Luticola mutica* var. *mutica* (Kütz.) D.G. Mann, *Melosira varians* Ag., *Meridion circulare* (Grev.) Ag., *Navicula broetzii* Lange-Bert. et Reichardt, *Navicula capitatoradiata* Germain, *Navicula* cf. *stankovicii* Hust., *Navicula constans* Hust., *Navicula cryptocephala* Kütz., *Navicula cryptotenella* Lange-Bert., *Navicula explanata* Hust., *Navicula germainii* Wallace, *Navicula lanceolata* (Ag.) Ehrenb., *Navicula pseudolanceolata* Lange-Bert., *Navicula radiosa* Kütz., *Navicula reichardtiana* Lange-Bert., *Navicula rhynchocephala* Kütz., *Navicula* sp. 1, *Navicula* sp. 2, *Navicula veneta* Kütz., *Neidium ampliatum* (Ehrenb.) Krammer, *Neidium bisculatum*

var. *subampliatum* Krammer, *Nitzschia acicularis* (Kütz.) W. Sm., *Nitzschia* aff. *perminuta* (Grun.) Perag., *Nitzschia amphibia* Grun., *Nitzschia angustata* Grun., *Nitzschia angustiforaminata* Lange-Bert., *Nitzschia* cf. *agnita* Hust., *Nitzschia* cf. *capitelata* Hust., *Nitzschia* cf. *communis* Rabenh., *Nitzschia* cf. *gracilis* Hantzsch, *Nitzschia dissipata* var. *dissipata* (Kütz.) Grun., *Nitzschia dissipata* var. *media* (Hantzsch) Grun., *Nitzschia fonticola* Grun., *Nitzschia frustulum* var. *frustulum* (Kütz.) Grun., *Nitzschia gessneri* Hust., *Nitzschia heufleriana* Grun., *Nitzschia linearis* var. *linearis* (Ag.) W. Sm., *Nitzschia linearis* var. *subtilis* (Grun.) Hust., *Nitzschia palea* (Kütz.) W. Smith, *Nitzschia palea* f. *major* Rabenh., *Nitzschia palea* var. *minuta* Bleisch, *Nitzschia pura* Hust., *Nitzschia recta* Hantzsch, *Nitzschia sinuata* var. *delongei* (Grun.) Lange-Bert., *Nitzschia* sp. 1, *Nitzschia sublinearis* Hust., *Nitzschia vitrea* Norman, *Pinnularia biceps* var. *biceps* Greg., *Pinnularia borealis* Ehrenb., *Pinnularia* cf. *viridiformis* Krammer, *Pinnularia pseudacuminata* Metzeltin et Krammer, *Pinnularia* sp. 1, *Pinnularia* sp. 2, *Pinnularia* sp. 3, *Pinnularia subcapitata* Greg., *Planothidium frequentissimum* (Lange-Bert.) Round et Bukht., *Psammothidium* cf. *bioretii* (Germain) Bukht. et Round, *Psammothidium* cf. *chlidanos* (M. H. Hohn et Hellerman) Lange-Bert., *Psammothidium* cf. r*ossii* (Hust.) Bukht. et Round, *Psammothidium subatomoides* (Hust.) Bukht. et Round, *Pseudostaurosira brevistriata* (Grun.) D. M. Williams et Round, *Reimeria sinuata* (Greg.) Kociolek & Stoermer, *Rhoicosphaenia abbreviata* (Ag.) Lange-Bert., *Sellaphora pupula* var. *mutata* (Krasske) Poulin, *Sellaphora pupula* var. *pupula* (Kütz.) Mereschk., *Sellaphora seminulum* (Grun.) D. G. Mann, *Stauroneis anceps* Ehrenb., *Stauroneis* cf. g*racilis* Ehrenb., *Stauroneis smithii* Grun., *Stauroneis* sp. 1, *Staurosira construens* f. *construens* Ehrenb., *Staurosirella leptostauron* (Ehrenb.) D. M. Williams et Round, *Staurosirella pinnata* var. *pinata* (Ehrenb.) D. M. Williams et Round, *Stephanodiscus* cf. *neoastrea* HÍk. et B. Hickel, *Stephanodiscus* sp., *Surrirella minuta* F. Meister, *Synedra goulardii* Bréb. ex Cleve et Grun., *Synedra ulna* (Nitzsch) Ehrenb., *Tabellaria floculosa* (Roth) Kütz., *Tabellaria* sp.1, *Tetracyclus glans* (Ehrenb.) Mills, *Ulnaria acus* (Kütz.) Aboal

Xanthophyta

Ophiocytium sp., *Tribonema* sp. 1, *Tribonema* sp. 2, *Tribonema* sp. 3, *Tribonema* sp. 4, *Vaucheria* sp. 1, *Vaucheria* sp. 2

Chlorophyta

Ankistrodesmus spiralis (W.B. Turn.) Lemm., *Ankistrodesmus* sp. 1, *Ankistrodesmus* sp. 2, *Aphanochaete* sp., *Apiocystis* sp., *Bulbochaete* sp., *Haematococcus* cf. *pluvialis* Flotow em. Wille, *Chaetophora* sp. 1, *Chaetophora* sp. 2, *Chaetopsphaeridium* sp., *Chlamydomonas nivalis* (Bauer) Wille, *Chlorella vulgaris* Beij., *Chlorella* cf. *vulgaris* Beij., *Chlorella* sp. 1, *Chlorella* sp. 2, *Chlorella* sp. 3, *Cladophora* sp. 1, *Cladophora* sp. 2, *Cladophora* sp. 3, *Cladophora* sp. 4, *Cladophora* sp. 5, *Closterium* sp. 1, *Closterium* sp. 2, *Coelastrum microporum* Näg. in A.Braun, *Cosmarium* cf. *botrytis* Menegh. ex Ralfs, *Cosmarium moniliferum* (Bory) Ehrenb. ex Ralfs, *Cosmarium* cf. *reniforme* (Ralfs) W. Arch., *Cosmarium* cf. *tetraophthalmum* Bréb. ex Ralfs, *Cosmarium* sp. 1, *Cosmarium* sp. 2, *Cosmarium* sp. 3, *Desmococcus* sp., *Desmodesmus* sp. 2, *Desmodesmus* sp. 3, *Dictyosphaerium* sp. 2, *Draparnaldia* cf. *acuta* (C. Ag.) Kütz., *Draparnaldia* cf. *glomerata* (Vauch.) C. Ag., *Draparnaldia* sp., *Ecdysichlamys* sp., *Euastrum* sp. 1, *Euastrum* sp. 2, *Microspora* sp. 1, *Microspora* sp. 2, *Microspora* sp. 3, *Microspora* sp. 4, *Microspora* sp. 5, *Microthamnion* cf. *strictissimum* Rabenh., *Monoraphidium obtusum* (Korsh.) Kom.-Legn., *Mougeotia* sp. 1, *Mougeotia* sp. 2, *Mougeotia* sp. 3, *Oeogonium* sp. 1, *Oeogonium* sp. 2, *Podohedra* sp. *Pseudococcomyxa* sp., *Scenedesmus acutus* var. *acutus* Meyen, *Scenedesmus quadricauda* (Turp) Bréb. in Bréb. et Godey, *Scenedesmus* sp. 1, *Scenedesmus* sp. 2, *Scenedesmus* sp. 3, *Spirogyra* sp. 1, *Spirogyra* sp. 2, *Spirotaenia* sp., *Staurastrum* cf. *aciculiferum* (G.S. West) O.F. Andersson, *Staurastrum* cf. *eurycerum* H.L. Skuja, *Staurastrum* cf. *lunatum* Ralfs, *Staurastrum* sp., *Stigeoclonium* sp. 1, *Stigeoclonium* sp. 2, *Stigeoclonium* sp. 3, *Stigeoclonium* sp. 4, *Stichococcus* sp. 1, *Stichococcus* sp. 2, *Tetraspora* cf. *gelatinosa* (Vauch.) Desv., *Tetraspora* sp. 1, *Tetraspora* sp. 2, *Tetraspora* sp. 3, *Tetrastrum* sp., *Ulothrix* cf. *zonata* (Weber & Mohr) Kütz., *Ulothrix* sp., *Zygnema* sp., green heterofilamentous alga 1, green heterofilamentous alga 2, green heterofilamentous alga 3, green coccoid alga 1, green coccoid alga 2, green sarcinoid alga

Charophyta

Chara sp., *Chara vulgaris* s.l. 1 L., *Chara vulgaris* s.l. 2 L.