

Article

Silica-Scaled Chrysophytes of Teletskoye Lake and Adjacent Area with a Description of a New Species from the Genus *Mallomonas*

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Abstract: The silica-scaled chrysophyte flora of some lakes and rivers of the Altai Mountains was investigated by means of electron microscopy. Teletskoye Lake; the Biya, Chulyshman, and Katun Rivers; and small lakes around the area were studied. A total of sixteen taxa were recorded, including eight belonging to *Mallomonas*, five to *Synura*, and three to *Paraphysomonas*. A revision of previously reported taxa of scaled chrysophytes in this region was carried out. One species new to science from the genus *Mallomonas* was found and described. *Mallomonas altaica* sp. nov. belongs to the section *Striatae* and is characterised by scales with ribs covering only the anterior part of the shield and a posterior flange almost completely covered with the secondary siliceous layer. This species was discovered only at Teletskoye Lake.

Keywords: Synurales; Paraphysomonadales; mountain lakes and rivers; new species; *Mallomonas*; *Striatae*; scale ultrastructure; Russia; Altai



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1. Introduction

Chrysophytes are a large, widespread group of predominantly freshwater planktonic, heterokont protists with diverse morphology [1]. A special group of chrysophytes consists of species whose cells are covered with siliceous structures (scales, bristles, and spines). These taxa are represented in different phylogenetic lineages in the orders Paraphysomonadales, Chromulinales, and Synurales [2]. The identification of most taxa of silica-scaled chrysophytes is based on studying the ultrastructure of scales, bristles, and spines using electron microscopy (SEM and TEM). For this group, a species concept based on the ultrastructural features of silica structures is well developed and in good agreement with the molecular data [2–4]. This allows the use of chrysophyte algae with siliceous covers in palaeoecology, biomonitoring, and biogeographical studies [5–7].

Chrysophyte diversity has been studied intensely, but predominantly in certain regions of Europe and North America. Information about chrysophytes in northern Asia is insufficient [8–10]. Most water bodies in these northern areas are difficult to access. Any information about algae from these regions with extreme climatic conditions is very valuable. In Asian Russia, investigations have been conducted in the Taymyr Peninsula [8], the Polar Ural [11,12], the Yenisei River basin [13,14], the Yakutia and Magadanskaya oblasts [9,10,15–17], and the Baikal Lake area [18–20]. Several new taxa of *Mallomonas* and *Synura* have been described in this region, e.g., *Mallomonas striata* Asmund var. *getseniae* Voloshko and *M. striata* var. *balonovii* Voloshko [11]; *M. kuzminii* Gusev and Kulikovskiy [21]; *M. voloshkoe* Gusev, Němcová, and Kulikovskiy [22]; *Synura petersenii* Korshikov emend. Škaloud and Kynclová f. *taymyrensis* Kristiansen [8]; and *S. tiksienensis* Bessudova, Gabyshev, and Likhoshvay [23]. Thus, this region potentially contains many interesting, rare and new species that could be discovered by a detailed study of the water bodies. Mountain

lakes are particularly interesting due to their unique flora, which includes rare and endemic species [24,25].

Here, we describe a new species, *M. altaica* sp. nov., from a mountain lake in Altai and report the associated flora of silica-scaled chrysophytes in this area.

2. Materials and Methods

Samples from the Altai (Altai Republic) were included in this study (Figure 1, Table 1). The Altai samples were collected from Teletskoye Lake and the adjacent area on 27–29 May 2015. Teletskoye Lake is the deepest freshwater body in the southwest of Siberia. It is located in the northeast of the Altai Mountains at an altitude of 434 m above sea level. Part of the water body and its eastern coast are incorporated among the UNESCO World Heritage Sites as part of the “Golden Mountains of Altai” complex [26]. The lake has an elongated shape in the meridional direction, and is 78 km long with a maximum width of 5.2 km. The lake is quite large; its water area is 223 km², and its volume is 40 km³. One of the unique characteristics of this lake is the sparse presence of shallow areas. The littoral area with depths up to 10 m is only 7.8% of the lake area, and the maximum depth is 325 m [27]. The catchment area is 19,500 km², and most of this area has an average elevation of 1940 m, which ensures low mineralisation and organic matter concentrations in the lake. Among the 70 permanent tributaries, the Chulyshman River is the largest, accounting for 75% of the total inflow to the lake. The Biya River is almost the only outflow of Teletskoye Lake (98% of total water runoff) [28]. Teletskoye Lake is characterised by increased external water exchange, in which a complete change of water occurs every 5.81 years [29].



Figure 1. Geographical position of the studied area. Sample sites are marked by asterisks. (1) Teletskoye Lake, station 1; (2) Teletskoye Lake, station 2; (3) Chulyshman River; (4) Teletskoye Lake, station 3, Kyga Bay; (5) Teletskoye Lake, station 4, mouth of the Kokshi River; (6) Teletskoye Lake, station 5; (7) Unnamed lake 1 near the Biya River; (8) Unnamed lake 2 near the Biya River; and (9) Biya River.

Table 1. Basic characteristics of the localities (Cond.—specific conductance, $\mu\text{S cm}^{-1}$, T—temperature, $^{\circ}\text{C}$).

	Name	Coordinates	pH	Cond.	T
1	Teletskoye Lake, station 1	N51° 33.691', E87° 38.921'	7.3	98	5
2	Teletskoye Lake, station 2	N51° 21.900', E87° 44.951'	n/a	n/a	n/a
3	Chulyshman River	N51° 21.884', E87° 44.964'	7.8	196	10
4	Teletskoye Lake, station 3, Kyga Bay	N51° 21.336', E87° 50.870'	7.3	109	11
5	Teletskoye Lake, station 4, mouth of Kokshi River	N51° 34.518', E87° 41.146'	7.3	91	7
6	Teletskoye Lake, station 5	N51° 34.660', E87° 41.069'	8.3	91	13
7	Unnamed lake 1 near the Biya River	N51° 46.917', E87° 15.528'	7.9	70	23
8	Unnamed lake 2 near the Biya River	N51° 47.045', E87° 16.120'	7.3	33	23.4
9	Biya River	N51° 47.154', E87° 14.938'	7.5	91	10
10	Katun River	N50° 59.409', E86° 15.634'	7.9	108	10

Samples were collected using a plankton net with a 20 μm mesh. For electron microscopy studies, an aliquot of each sample was washed three times by repeated centrifugation with deionised water. Drops of each washed sample were dried directly onto stubs for scanning electron microscopy (SEM) or grids for transmission electron microscopy (TEM) or digested for 4–5 min in sulphuric acid with potassium dichromate before mounting. For SEM studies, samples were dried onto aluminium stubs, coated with gold for 10 min with a JEE-4X (JEOL) sputter coater, and observed with a JEOL 6510 LV scanning electron microscope. For TEM studies, samples were dried onto formvar-coated grids (EMS FF200-Cu-50, Electron Microscopy Sciences, Hatfield, USA) and observed with a JEM-1011 transmission electron microscope. Specific conductance, pH, and temperature were measured using a Hanna HI 9828 (Hanna Instruments, Inc., Smithfield, RI, USA), and are represented in Table 1.

3. Results

During studies of Teletskoye Lake, adjacent small water bodies, and the Biya, Chulyshman, and Katun Rivers in the Altai Mountains, 16 taxa were observed (Table 2, Figures 2–4). Eight taxa belong to the genus *Mallomonas*, while the others are species of the genera *Synura* (five) and *Paraphysomonas* (three). In Teletskoye Lake, 11 taxa were observed. In other lakes and rivers, between two and five taxa of silica-scaled chrysophytes were found.

During our investigation, we found scales of *Mallomonas* that differed in ultrastructure from the known species. Below, we give a formal description of this species.

***Mallomonas altaica* sp. nov.** Gusev and Martynenko (Figure 2).

Description: Scales are $3.6\text{--}4.2 \times 1.9\text{--}2.2 \mu\text{m}$ in size, oblong and oval in shape, with weak lateral incurvings. Scales possess a posterior rim, a posterior flange, a V-rib, anterior ribs and flanges, and a dome. The dome is smooth and subcircular, or it has several weakly developed ribs. The shield is marked with 9–17 regularly spaced transverse ribs in the anterior part. The posterior part of the shield near the angle of the V-rib is smooth. Base plate pores are irregularly distributed on the shield. Three to four large pores are located in the angle of the V-rib. The anterior flanges are narrow, with five to eight closely spaced struts on each side. The anterior submarginal ribs are well developed. The V-rib on the scales is rounded, slightly hooded, and bears internal struts. The posterior rim is smooth. The posterior flange is covered with a secondary siliceous layer and bears numerous struts (usually more than 30, well visible on SEM images) and scattered base-plate pores. Bristles and cysts were not observed.

Holotype specimen: Portion of a single cluster of cells on SEM stub No. A20 deposited at the Herbarium of the Papanin Institute for Biology of Inland Waters, RAS, Borok (IBIW). E.S. Gusev collected material from Teletskoye Lake in the Republic of Altai, Russia, on 27 May 2016. Figure 2A illustrates a representative scale from the holotype specimen.

Type Locality: Teletskoye Lake, Republic of Altai, Russia. Latitude/Longitude: N51° 21.336', E87° 50.870'.

Epithet: The species name is derived from “Altai”, the area from which it was described.

Distribution: This species was found in the type locality only. The pH was 7.3 at the time of collection, the temperature was 11 °C, and the specific conductance was 109 $\mu\text{S cm}^{-1}$.

Among other *Mallomonas* taxa, *M. crassisquama* (Figure 3f,g) was found in all studied localities except the Biya River. *Mallomonas elongata* (Figure 3h–j) was also frequently found but was absent only in the Katun River and unnamed lake 2. Other taxa were registered rarely (Table 2). *Mallomonas annulata* (Figure 3e), *M. altaica*, and *M. pechlaneri* (Figure 3k,l) were observed in one locality only.

Several morphotypes of the *Synura petersenii sensu lato* species complex were observed. We provide descriptions of morphotypes observed in our samples.

Synura petersenii Korshikov emend. Škaloud and Kynčlová (Figure 3o,p): Body scales elongated, $4.5\text{--}4.6 \times 2.3\text{--}2.6 \mu\text{m}$. The keel is ornamented by rather small pores (diameter 46–69 nm). The ratio between scale and keel width varies from 3.0 to 3.6. The basal plate is ornamented by numerous small pores (diameter 21–29 nm). The diameter of the large pores in the anterior part varies from 0.36 to 0.43 μm . Numerous struts (28–29), often interconnected by transverse folds, regularly extend from the keel to the edge of the scales. The species is a widely distributed taxon and has been confirmed in many regions of the world [30], including localities in Russia [31–33].

***Synura* sp. 1** (Figure 4a,b): Body scales are elongated, $3.2\text{--}3.6 \times 1.8\text{--}2.6 \mu\text{m}$. The keel is ornamented by pores with a diameter of 53–72 nm. The ratio between scale and keel width varies from 3.4 to 3.8. The basal plate is ornamented by numerous small pores (diameter 16–29 nm). The diameter of the large pores in the anterior part ranges from 0.18 to 0.35 μm . Struts (20–22) regularly extend from the keel to the edge of the scales, with no well-developed interconnections by transverse folds.

This morphotype corresponds to *Synura americana* Kynčlová and Škaloud, but we are cautious to make this identification without confirmation by molecular data for a population so remote from its confirmed habitats.

***Synura* sp. 2** (Figure 4c–f): Body scales are elongated, $4.2\text{--}5.1 \times 2.2\text{--}2.7 \mu\text{m}$. The keel is ornamented by pores with a diameter of 59–80 nm. The ratio between scale and keel width varies from 2.8 to 4.3. The basal plate is ornamented by numerous pores with a diameter of 30–48 nm. The diameter of the large pores in the anterior part varies from 0.30 to 0.43 μm . Numerous struts (26–30) regularly extend from the keel to the edge of the scales and are rarely interconnected by transverse folds. This morphotype has large body scales. Based on scale size, the number of struts, and the diameter of the base plate and keel pores, it can be compared with *S. borealis* Škaloud and Škaloudová and *S. hibbernica* Škaloud and Škaloudová. However, *S. hibbernica* has elongated body scales and specific apical scales with a long spine. The body scales of *S. borealis* usually have an anteriorly widened keel, while on most body scales of *Synura* sp. 2, the keel is narrow.

***Synura* sp. 3** (Figure 4g): Body scales are elongated, $4.4 \times 2.3 \mu\text{m}$. The keel is wide in the anterior part and ornamented by pores with a diameter of 57–80 nm. The ratio between scale and keel width is 2.6. The basal plate is ornamented by numerous pores with a diameter of 36–48 nm. The diameter of the large pores in the anterior part is 0.38 μm . Numerous struts (26), interconnected by transverse folds, regularly extend from the keel to the edge of the scale. These scales are similar to those of *S. petersenii sensu stricto*, but there are larger base plate pores and a wider keel.

***Synura* sp. 4** (Figure 4h): Elongated apical scale, wide oval shape, $3.8 \times 2.3 \mu\text{m}$. The keel is wide and ornamented by large pores with a diameter of 70–96 nm. The ratio between scale and keel width is 2.6. The basal plate is ornamented by numerous small pores with a diameter of 28–31 nm. The diameter of the large pores in the anterior part of the scales is 0.40 μm . Numerous struts (23) regularly extend from the keel to the edge of the scales and are not interconnected by transverse folds. This morphotype differs from

those described above in terms of the diameter of the pores of the basal plate and keel; however, due to the presence of only one scale, it is difficult to determine the group of species to which it may belong.

Several morphotypes of *Paraphysomonas* were observed.

Only a single scale of *Paraphysomonas* sp. 1 (Figure 4i) was found. The base plate is round, 1.4 µm in diameter, with a dense rim. The spine is 3.4 µm long and tapering to an attenuated blunt tip. This specimen is most similar in morphology and size to *Paraphysomonas varia* Scoble and Cavalier-Smith, which is known from the tropics [4,34]. However, one scale is not enough to accurately identify this morphotype. *Paraphysomonas* sp. 1 is also similar to *P. cambrispina* Scoble and Cavalier-Smith and *P. stylata* var. *limnetica* Scoble and Cavalier-Smith. However, unlike *Paraphysomonas* sp. 1, *P. cambrispina* has shorter spines tapering to an oblique dull tip, while *Paraphysomonas stylata* var. *limnetica* has longer spines gently tapering completely to a tip.

Paraphysomonas sp. 2 (Figure 4j,k) has one type of spine scale. The spine is 4.2–5.8 µm long, gently tapering from a wide base to the tip, and there is a round base plate with a thickened margin of 2.1–2.8 µm. The scales resemble those of *P. vulgaris* Scoble and Cavalier-Smith but are larger (2.1–2.8 vs. 1.8–2.2 µm) and have a longer spine (4.2–5.8 vs. 3.1–4.5 µm). It is very likely our scales represent an undescribed *Paraphysomonas* species.

Paraphysomonas sp. 3 (Figure 4l) has one type of spine scale. The spine is 4.8–5.8 µm long, gently tapering from an inflated base to the tip, and there is a round base plate with a thickened margin of 2.4–2.5 µm. This morphotype is similar to *Paraphysomonas* sp. 2 but distinctly distinguished by the inflated base of the spine.

Table 2. List of silica-scaled chrysophytes found in this study; “+” indicates the presence of a taxon.

Taxon	Sample Sites *									
	1	2	3	4	5	6	7	8	9	10
<i>Mallomonas acaroides</i> Perty emend. Iwanoff			+		+	+				
<i>M. alpina</i> Pascher and Ruttner emend. Asmund and Kristiansen				+	+	+	+			+
<i>M. altaica</i> sp. nov.				+						
<i>M. annulata</i> (D.E. Bradley) K. Harris				+						
<i>M. crassisquama</i> (Asmund) Fott	+		+	+	+	+	+	+		+
<i>M. elongata</i> Reverdin	+	+		+	+	+	+		+	
<i>M. pechlaneri</i> Nemcová and Rott						+				
<i>M. tonsurata</i> Teiling emend W. Krieger			+				+	+		
<i>Synura petersenii</i> Korshikov emend. Škaloud and Kynčlová				+				+	+	
<i>S. sp. 1</i>		+								
<i>S. sp. 2</i>						+				
<i>S. sp. 3</i>										+
<i>S. sp. 4</i>										+
<i>Paraphysomonas</i> sp. 1						+				
<i>P. sp.2</i>							+			
<i>P. sp.3</i>			+					+		

* Sample site designations are presented in Table 1.

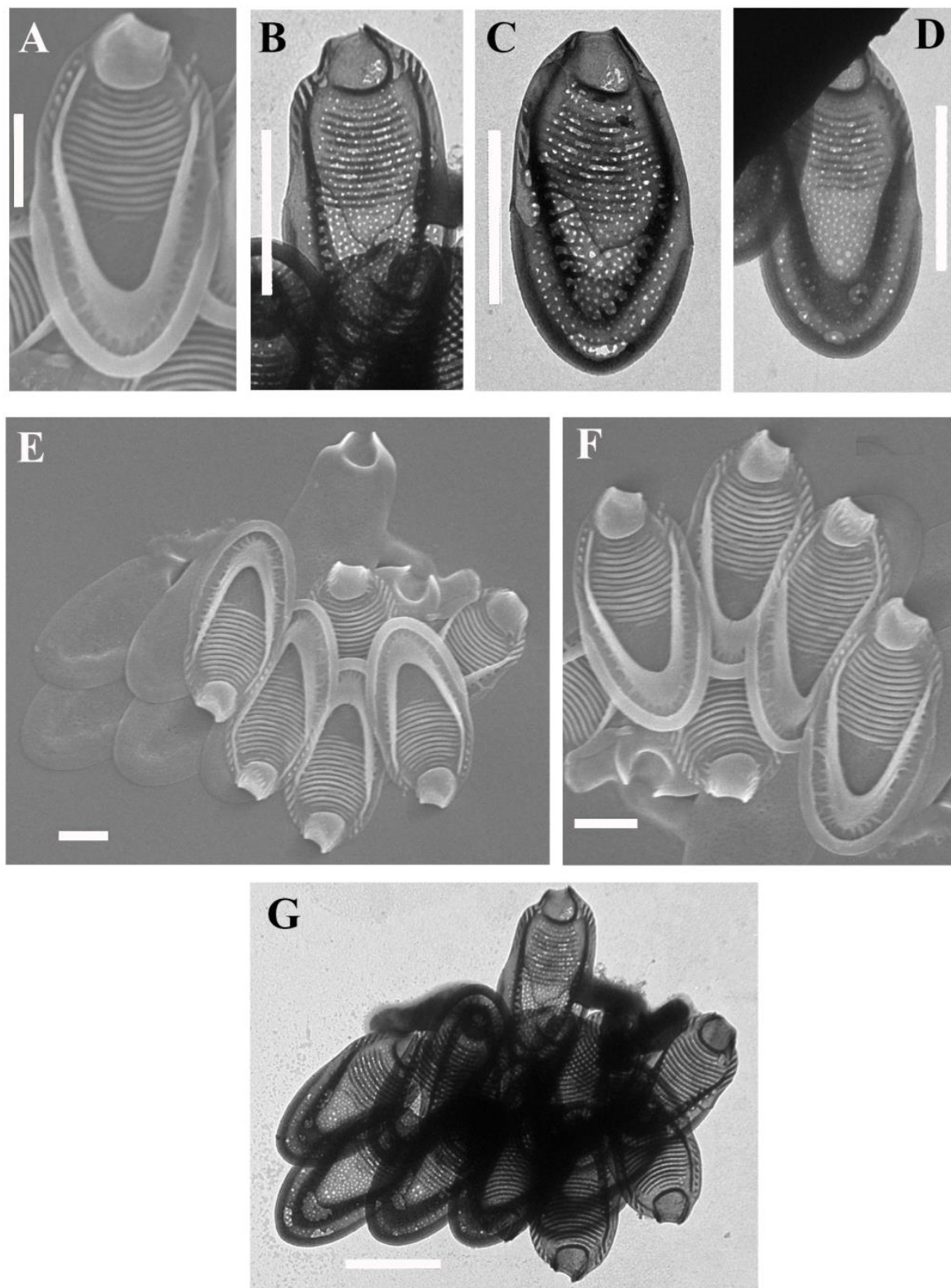


Figure 2. *Mallomonas altaica* sp. nov. (A) Body scale, SEM; (B–D) body scales, TEM; (E) group of scales, illustrating an upper surface and bottom surface view, SEM; (F) group of body scales at higher magnification, SEM; and (G) group of body scales, TEM. Scale bars: (B–D,G): 2 μ m; (A,E,F): 1 μ m.

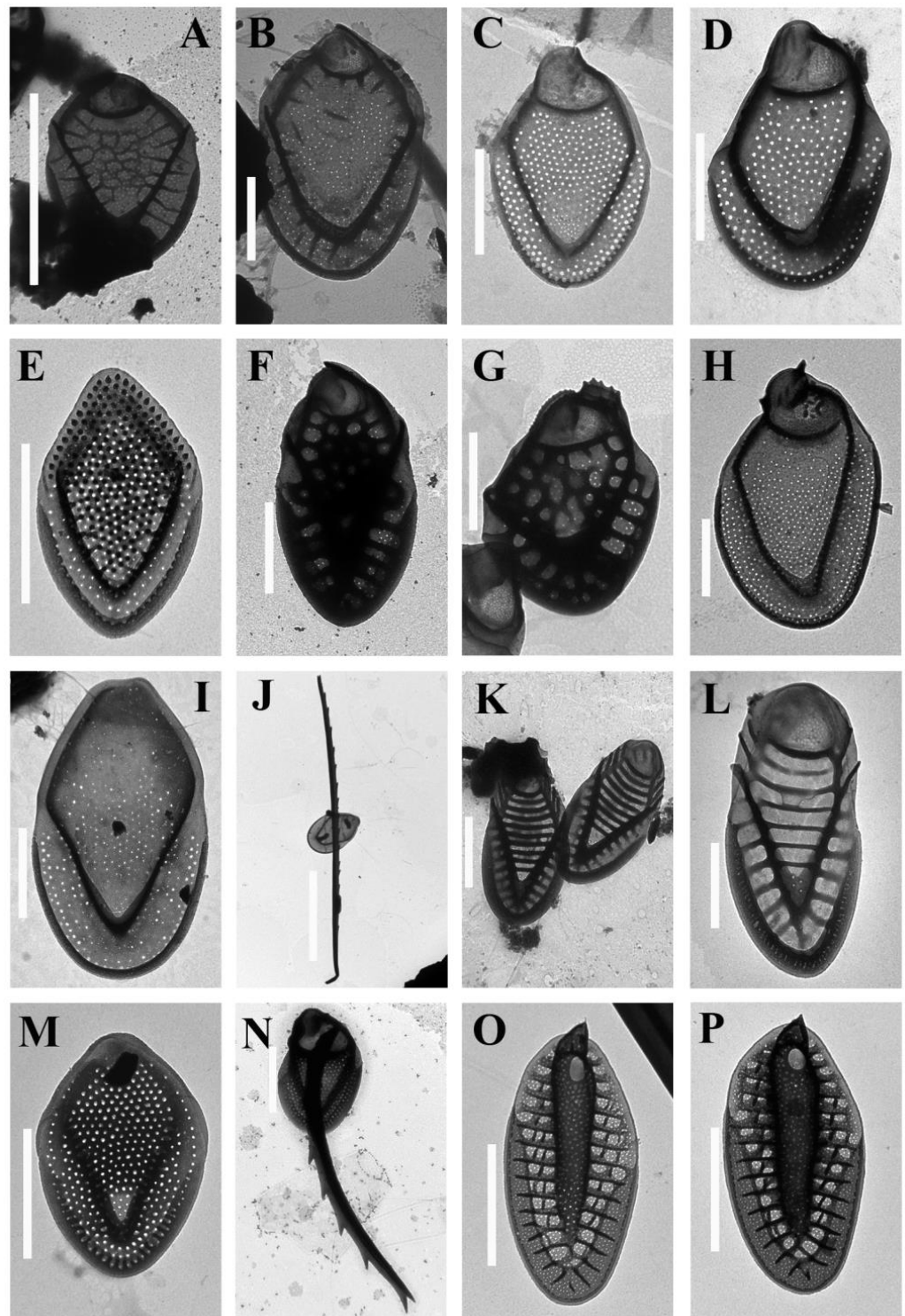


Figure 3. *Mallomonas* and *Synura* taxa from Teletskoye Lake and adjacent area, TEM. (A,B) *Mallomonas acaroides*, body scales; (C,D) *Mallomonas alpina*, body scale (C) and apical scale (D); (E) *Mallomonas annulata* body scale; (F,G) *Mallomonas crassisquama*, body scale (F) and apical scale (G); (H–J) *Mallomonas elongata*, domed body scale; (H), domeless body scale (I) and bristle (J); (K,L) *Mallomonas pechlaneri*, body scales; (M,N) *Mallomonas tonsurata*, domeless body scale (M) and domed scale with bristle (N); and (O,P) *Synura petersenii*, body scales. Scale bars: (J): 10 µm; (A): 5 µm; (B–I,K,M–P): 2 µm; and (L): 1 µm.

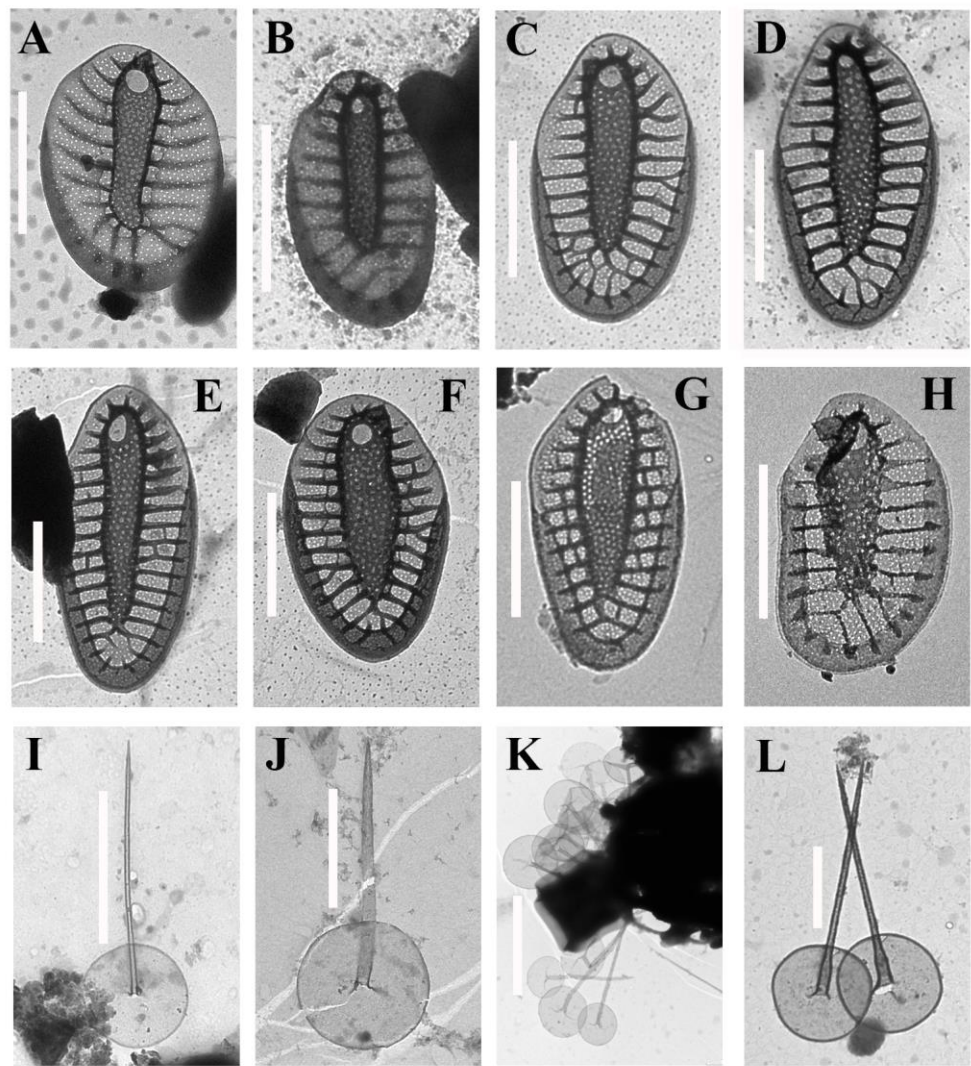


Figure 4. *Synura* and *Paraphysomonas* taxa from Teletskoye Lake and adjacent area, TEM. (A,B) *Synura* sp. 1, body scales; (C–F) *Synura* sp. 2, body scales; (G) *Synura* sp. 3, body scale; (H) *Synura* sp. 4, body scale; (I) *Paraphysomonas* sp. 1; (J,K) *Paraphysomonas* sp. 2; and (L) *Paraphysomonas* sp. 3. Scale bars: (K): 5 µm; (A–J,L): 2 µm.

4. Discussion

The study of the phytoplankton in Teletskoye Lake started at the beginning of the 20th century, and the plankton have been described as extremely poor, except for diatoms [35]. Subsequent studies made it possible to identify in the lake flora 492 species from Bacillariophyta, Chlorophyta, Chrysophyta, Dinophyta, Euglenophyta, Cryptophyta, Xanthophyta, and Cyanobacteria [36]. Among chrysophytes several genera were reported, including *Dinobryon* Ehrenberg, *Chrysococcus* Klebs, *Kephyrion* Pascher, *Mallomonas* Perty, and *Pseudokephyrion* Pascher [36,37]. Silica-scaled chrysophytes, according to previous studies, were represented by nine species and one variety: *Mallomonas globosa* J. Schiller, *M. producta* (Zacharias) Iwanoff, *M. elegans* Lemmermann, *M. elongata*, *M. ploesslii* Perty, *M. crassisquama*, *M. alpina*, *M. caudata* Iwanoff, *M. vannigera* Asmund, and *M. striata* var. *serrata* K. Harris and D.E. Bradley [36,37]. These records need to be revised. *Mallomonas globosa*, *M. producta*, *M. elegans*, and *M. ploesslii* were identified by light microscopy only [38,39]. They are dubious taxa due to the lack of electron microscopy studies, thus a lack of species descriptions of the ultrastructure of the scales and bristles. Moreover, *Mallomonas globosa* is considered a member of the other chrysophycean genus, *Spiniferomonas* [1]. *M. crassisquama* was identified only with a type of stomatocyst found in Teletskoye Lake [40] and was

not confirmed with illustrations of scales. The rest of the known species were identified based on electron microscopy: *M. alpina*, *M. caudata*, *M. elongata*, *M. striata* var. *serrata*, and *M. vannigera* [36,37]. The identification of *M. striata* var. *serrata* (Figure 2b in [36]) should be changed to *M. pechlaneri* due to the presence of smooth bristles with bifurcated tips and scale ultrastructure. Recently, *Mallomonas pechlaneri* was recorded in Teletskoye Lake by other researchers [22]. In addition, more than 70 morphotypes of chrysophycean stomatocysts were found in the phytoplankton of Teletskoye Lake [36,37,40]. This suggests that there are many more chrysophycean species in the phytoplankton of the lake than previously thought.

Our data made it possible to supplement the list of silica-scaled chrysophytes in Teletskoye Lake and the adjacent area with four *Mallomonas* and one *Synura* species. The presence of *M. crassisquama* in the lake phytoplankton was confirmed. In addition, four morphotypes from the genus *Synura* (*Synura petersenii* species complex) and three from the genus *Paraphysomonas* were found. *Synura petersenii* is a complex of closely related cryptic and pseudocryptic taxa that requires molecular methods for correct identification [2,30,41–43]. We could not correctly identify these morphotypes down to the species level without molecular data, but we consider it important to publish their images for further analysis of the diversity of chrysophytes in this region. Correct identification of *Paraphysomonas* also requires molecular data [4]. Thus, we provide images of the morphotypes found with comments on their similarity to known morphotypes. This is the first record of taxa from this genus in Teletskoye Lake.

Some interesting species from the genus *Mallomonas* were found in our study, primarily from the section *Striatae*. The most interesting record is a new species to science, *Mallomonas altaica*, which belongs in this section due to the presence of ribs on the shield [44]. This section encompasses 15 taxa, according to Kristiansen and Preisig [1], and seven more taxa have been described recently [11,22,25,45–47]. Many taxa in this section, such as *Mallomonas striata* var. *striata* Asmund, *M. striata* var. *serrata* Harris and Bradley, *M. flora* Harris and Bradley, *M. cratis* Harris and Bradley, *M. pseudocratis* Dürschmidt, and *M. asmundiae* (Wujek and van der Veer) Nicholls, are widely distributed [1]. However, there are some very rare taxa with limited distribution in this section. In this study, we describe another very rare species from a mountain lake.

The main distinctive features of *Mallomonas altaica* are the ribs, which cover only the anterior part of the shield, and the posterior flange, which is almost completely covered with a secondary siliceous layer. Within the section *Striatae*, *Mallomonas altaica* is most similar to *M. cratis* and *M. marina* Jeong, (Kim, Jo, Kim, Siver, and Shin) by the oblong oval scales. However, the shield on the scales of *M. cratis* and *M. marina* is completely covered with numerous curved transverse ribs, anterior ribs are absent or short, and the dome is covered by concentric U-shaped ribs. Other species are well distinguished by the shape of the scales, and the shield on the scales is completely covered with transverse ribs.

Mallomonas pechlaneri is another rare taxon from the section *Striatae*. It was recently discovered in two North Tyrol alpine lakes [25] and in highland water bodies of the East Sayan Mountains [22]. It seems that this species is restricted to oligotrophic mountain lakes and has a wide distribution across Eurasia.

It is noteworthy that several taxa from this section have recently been described in other mountain water bodies of northern Asia. *Mallomonas striata* var. *getseniae* and *M. striata* var. *balonovii* from the Polar Urals were described [11]. The rank of these taxa should be raised to the species level. *M. voloshkoe*, from a high-altitude lake in the Barguzin Mountains (Transbaikalia area), was described. It can be concluded that many rare or endemic taxa from the section *Striatae* have been found in oligotrophic mountain water bodies with low mineralization, temperature, and nutrient concentration.

The low diversity of silica-scaled chrysophytes is comparable with similar estimates made in studies of oligotrophic mountain lakes. Studies of high-altitude lakes in North Tyrol (Austria) revealed 27 taxa at 12 sites, with species richness varying from one to nine [25]. The diversity of silica-scaled chrysophytes in water bodies located at lower

altitudes in the same area revealed 46 taxa in 22 localities, with species richness varying from four to thirty, but for most localities, the number of taxa found did not exceed ten [24]. A small number of taxa of scaled chrysophytes were also observed in ultra-oligotrophic lakes in North America [6] and Newfoundland [48]. In other cold-water oligotrophic mountain lakes in Siberia, the diversity of silica-scaled chrysophytes was also low. In the lakes of the Polar Urals, between one and sixteen taxa were recorded [12]. When studying the mountain lakes of Yakutia, quite a small number of taxa were also found: in Labyntyr Lake—twenty-three, in Vorota Lake—fifteen [17], and in Toko Lake—six [9]. Only 10 taxa were found in Lake Frolikha (Transbaikal area) [49]. Even in such a large lake as Baikal, only 25 taxa were found in plankton in the open part [18,19].

Mountain lakes are habitats for many rare species of chrysophytes. Recently, a number of new species to science of chrysophytes have been described from mountain water bodies of different origins in Eurasia. In addition to the previously mentioned species from the genus *Mallomonas* from the section *Striatae*, also described were *Mallomonas tirolensis* Pichrtová, Němcová, Škaloud, and Rott from the Alps in Europe [25]; *M. kuzminii* from the Barguzin Mountains in the Transbaikal area, Russia [21]; *M. alpestrina* Němcová and Zeisek from Haba Snow Mountain, China [50]; and *Synura morusimila* Pang and Wang from the Great Xing'an Mountains [51]. In the mountainous regions of China, a rich flora of chrysophycean cysts has also been identified, including many morphotypes new to science [52]. Thus, studies of the mountain lakes of Asia and, in particular, the eastern territories of Russia are very promising in this regard and should be intensified.

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