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Silica-scaled chrysophytes of Lake Baikal

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The list of silica-scaled chrysophytes of Lake Baikal has been enlarged using electron microscopy. It has been supplemented with 12 species and 2 forms. *Spiniferomonas takahashii* has been observed for the first time in the water bodies of Russia. According to our data, the list of silica-scaled chrysophytes of Lake Baikal includes 25 species and intra-species taxa: *Chrysosphaerella* – 3, *Paraphysomonas* – 2, *Clathromonas* – 1, *Spiniferomonas* – 7, *Mallomonas* – 8 and *Synura* – 4. We have also analyzed their seasonal dynamics and observed algal species that are dominant in spring, summer and autumn.
Key words: silica-scale chrysophytes; Lake Baikal

Introduction

Lake Baikal, one of the most ancient and deepest lakes in the world, is located in the belt of temperate climate, stretching from 51°54’18" to 51°54’30 N and from 126°37'12'' to 126°37'20'' E (Baikal. Atlas, 1995). The lake is of tectonic origin and lies in the deep depression surrounded by mountain ridges. Natural conditions of the lake (Baikal. Atlas, 1995) and phytoplankton composition (Popovskaya, Genkal, Likhoshway, 2016) are not uniform because of the differences in bottom relief, shoreline and large bays.

K.I. Meyer (1930) was the first who had observed silica-scaled chrysophytes in the phytoplankton of Lake Baikal. Those were four species: *Mallomonas caudata* Iwanoff, *M. tonsurata* Teiling, *Synura uvella* Ehrenberg, and *Chrysosphaerella longispina* Lauterborn. Later, O.M. Kozhova (1959) also mentioned them. Then, four more species of these algae were identified in the phytoplankton of Lake Baikal: *M. vannigera* Asmund, *Chrysospaerella conradii* Bourrelly (= *Chrysospaerella brevispina*), *C. baicalensis* Popovskaya, and *Paraphysomonas imperforata* Lucas (Votintsev, Meshcheryakova, Popovskaya, 1975; Popovskaya, 1981; Zagorenko, Kaplina, 1988; Izmestyeva, Kozhova, 1988).

The species of the genus *Mallomonas* observed as *M.* sp. (Votintsev, Meshcheryakova, Popovskaya, 1975; Zagorenko, Kaplina, 1988; Izmestyeva, Kozhova, 1988; Vorobyeva et al., 1992) and the most common in the littoral area of the lake during the ice period (Antipova, 1969; 1974) appeared to be *M. vannigera* (Vorobyeva et al., 1992). It was noted that this species in Lake Baikal differed from the specimens described earlier from other water bodies (Balonov, 1980; Asmund, Kristiansen, 1986) in small size of cells, scales, spines and cysts (Vorobyeva et al., 1992).

Studies of phytoplankton by means of electron microscopy allowed the detection of 7 more silica-scaled chrysophytes: *M. striata* var. *striata* Asmund, *M. alpina* Pascher & Ruttner, *M. acaroides* Perty, *M. crassisquama* (Asmund) Fott, *Spiniferomonas bourrellyi* Takahashi, *S. trioralis* f. *cuspidata* Balonov and *P. vestita* (A.C. Stokes) De Saedeleer (Vorobyeva et al., 1992). Thus, by the beginning of our investigations, 15 species and intra-species taxa of these algae have been known in Lake Baikal.

This work is aimed at revising silica-scaled chrysophytes in Lake Baikal using electron microscopy and studying their distribution depending on hydrochemical parameters of the environment.

Material and methods

We analyzed 75 integral (0-25 m) water samples collected with a sampler at 25 sites in May-June and September 2016 as well as in May-June 2017 according to traditional plan (Tab. 1, Fig. 1).

Table 1. Sampling sites (see Fig. 1)

Site number	Site coordinates	Region	Site
1.	51°40,578 N, 103°52,309 E	Southern Baikal	15 km off Kultuk
2.	51°45,546 N, 104°13,222 E		3 km off Marituy
3.	51°38,710 N, 104°13,715 E		Marituy-Solzan
4.	51°31,428 N, 104°14,417 E		3 km off Solzan
5.	51°49,033 N, 104°54,616 E		3 km off Listvyanka
6.	51°42,262 N, 105°00,720 E		Listvyanka-Tankhoy
7.	51°35,440 N, 105°06,968 E		3 km off Tankhoy
8.	51°46,731 N, 105°22,528 E		Kadilny-Mishikha
9.	52°20,722 N, 106°03,870 E		Kharauz-Krasny Yar
10.	52°39,590 N, 106°50,978 E	Central Baikal	Anga-Sukhaya
11.	53°02,955 N, 107°25,657 E		3 km off Ukhan
12.	52°53,630 N, 107°31,001 E		Ukhan-Tonky
13.	52°44,618 N, 107°38,801 E		3 km off Tonky
14.	53°21,278 N, 108°13,078 E		Khoboy-Krestovy
15.	53°27,245 N, 108°44,387 E		Barguzin Bay
16.	53°38,063 N, 108°07,495 E		Akademichesky Ridge
17.	53°42,564 N, 109°06,384 E		Chivyrkuy Bay (5 m depth)
18.	54°16,860 N, 108°44,473 E	Northern Baikal	Zavorotny-Sosnovka
19.	54°31,829 N, 108°42,310 E		3 km off Elokhin
20.	54°27,052 N, 109°04,164 E		Elokhin-Davsha
21.	54°22,754 N, 109°25,314 E		3 km off Davsha
22.	55°20,966 N, 109°14,635 E		3 km off Baikalsk
23.	55°19,487 N, 109°28,707 E		Baikalskoye-Turali
24.	55°17,537 N, 109°42,947 E		3 km off Turali
25.	55°42,876 N, 109°36,573 E		7 km off Nizhneangarsk

The samples were fixed in the Lugol solution and then settled (Kuzmin, 1975). For more precise identification of small-cell algae and their scales, we also collected 10-15 ml water samples and filtered them through a Whatman filter with a diameter of 13 mm and with pore diameter 1 µm, dried at room temperature, coated with gold and examined on a scanning electron microscope Philips SEM 525M. For transmission electron microscopy (TEM), the sample was put on grids with a diameter of 3 mm with a formvar film, dried at room temperature and analyzed on a LEO 906E.

The abundance of chrysophytes was estimated from a number of scales found on the filter: very rarely (1) – from 2 to 25 scales; rarely (2) – from 26 to 50 scales; often (3) – from 51-150 scales, and abundantly (4) – over 150 scales.

Potentiometric and Winkler methods were used for measuring pH and oxygen, respectively (Wetzel & Likens, 1991). Hydrochemical parameters were measured in the 0 and 25 m layers, temperature in the surface layer (0 m) except one site in Chivyrkuy Bay (7 m).

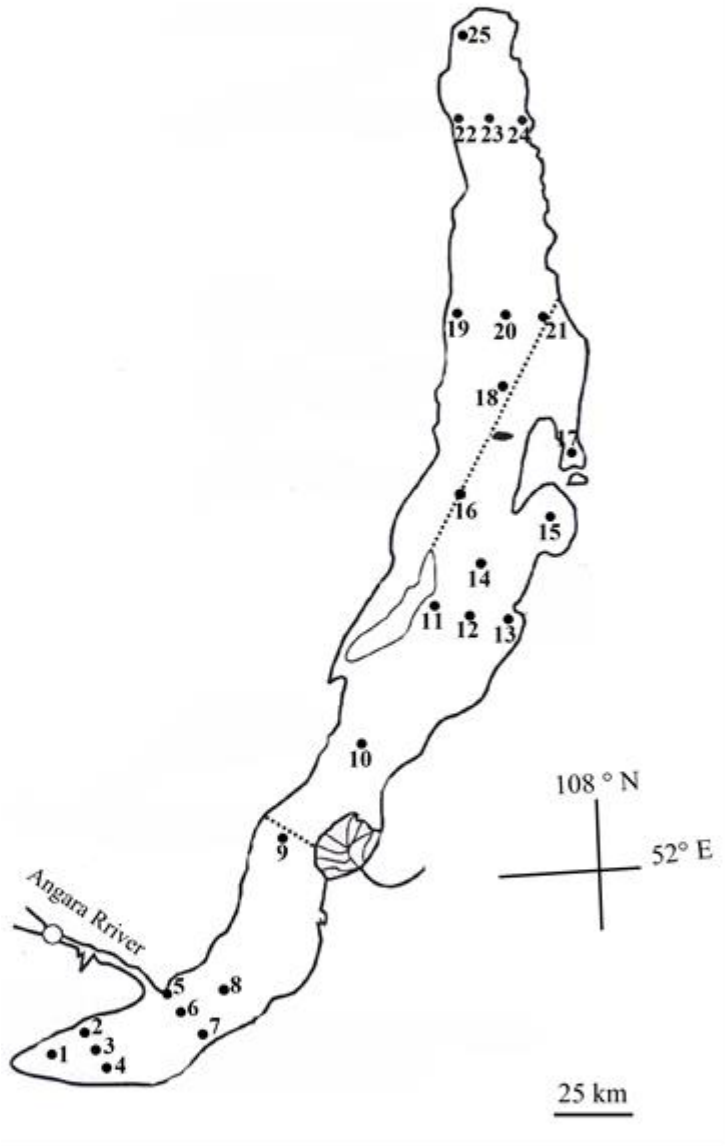

Fig. 1. Sampling scheme. A dashed line shows borders of the lake: Southern, Central and Northern Baikal

Study region

Water of Lake Baikal is of low mineralization: total ions are approximately 96 mg/L with the prevalence of bicarbonate ions and calcium. Concentrations of major ions are constant at all depths and around the water area during all seasons (Grachev et al., 2004) except the areas near the mouths of the lake tributaries.

Water conductivity in the lake varies from 108 to 110 mS/m (Grachev et al., 2004). We should note unique peculiar feature of Lake Baikal – high concentration of oxygen at all depths up to its maximum 1637 m (Weiss, Carmack, Koropalov, 1991; Shimaraev, Domysheva, Gorbunova, 1996; Grachev et al., 2004). Seasonal variations of oxygen content are observed only in the upper water layer of 100-200 m. Its maximal content (ca. 14.5 mg/L) is associated with the under-ice development of phytoplankton in March-April. After ice breaking, oxygen concentration decreases up to 9 mg/L and changes insignificantly with depth because of the water warming. During the autumn water cooling, the concentration rises up to the winter maximum. The content of nutrients in Lake Baikal is not high. Their concentrations increase with depth reaching ca. 2 mg/L of silicon, 0,60 mg/L of nitrate and 0,070 of phosphate in the near-bottom layer (Shimaraev, Domysheva, 2002). Seasonal variations of nutrients are mainly observed in the upper 100-m water layer with their two maxima (January-February and mid June-July) and two minima (April and August-September) (Votintsev, 1961; Grachev et al., 2004).

Hydrochemical parameters during investigations coincided with the data of long-term observations. Water temperature in spring was low (1.8-3.7 °C), and only in May-June it exceeded 6 °C at two sites (13 and 17). In September, water temperature rose to 12-14 °C, however at two sites (6 and 20) it was lower than 10 °C, and at site 23 only 5.21 °C. In spring and autumn, the pH values varied insignificantly at all sites – about 8, oxygen concentrations was ca 13 mg/L in spring and in autumn between 9,70 and 11,86 mg/L.

Results

Silica-scaled chrysophytes

We detected 25 species and intra-specific taxa of silica-scaled chrysophytes in Lake Baikal: *Chrysosphaerella* – 3, *Paraphysomonas* – 2, *Clathromonas* – 1, *Spiniferomonas* – 7, *Mallomonas* – 8 and *Synura* – 4 (Tabs 2, 3; Figs 2-4).

Table 2. List of species and intra-specific taxa of silica-scaled chrysophytes in Lake Baikal observed in May-June. Site numbers correspond to sites in Fig. 1. Abundance was estimated according to the following scale: (3) frequent, (2) rare and (1) very rare

		Southern Baikal									Central Baikal								Northern Baikal							
		Site number																								
#	**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
1.	*Chrysosphaerella baicalensis*	**3**	**3**	1	**3**	1	1	1	–	–	–	–	–	2	–	–	–	1	–	–	–	–	–	–	–	–
2.	*C. brevispina*	–	–	–	–	–	–	–	–	–	1	1	1	1	1	1	**3**	1	2	1	2	2	**3**	**3**	**3**	2
3.	*C. coronacircumspina*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4.	*Paraphysomonas a.*	–	1	–	1	1	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
5.	*P. gladiata*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6.	*Clathromonas takahashii*	1	2	1	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7.	*Spiniferomonas abrupta*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
8.	*S. bourrellyi*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9.	*S. cornuta*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
10.	*S. septispina*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11.	*S. takahashii*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12.	*S. trioralis* f. *trioralis*	1	1	–	1	–	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
13.	*S. trioralis* f. *cuspidata*	1	1	1	1	–	–	–	1	–	–	–	–	1	–	–	–	2	–	–	–	–	–	–	–	–
14.	*Mallomonas acaroides*	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
15.	*M. alpina*	2	1	1	1	–	1	–	1	–	–	–	–	1	–	–	–	1	1	–	–	–	–	–	–	–
16.	*M. crassisquama*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
17.	*M. mangofera*	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
18.	*M. striata* var. *striata*	1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
19.	*M. striata* var. *getseniae*	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20.	*M. tonsurata*	1	2	1	2	–	1	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
21.	*M. vannigera*	1	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22.	*Synura glabra*	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–	–	–
23.	*S. heteropora*.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
24.	*S. petersenii*	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
25.	*S. uvella*	–	–	–	–	–	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
	Total taxa	**9**	**7**	**5**	**8**	**2**	**3**	**1**	**5**	**–**	**1**	**1**	**1**	**13**	**1**	**1**	**1**	**9**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**

Chrysosphaerella baicalensis Popovskaya (Fig. 2 A, B).

The species was observed predominantly in Southern Baikal with its abundance in May-June at sites 1 and 2. Single specimens were detected in September. In Northern Baikal, it was registered rarely (Tabs 2, 3).

C. brevispina Korshikov (Fig. 2 C, D).

This species was observed often in May-June 2017 predominantly in Central and Northern Baikal (Tab. 2).

C. coronacircumspina Wujek et Kristiansen (Fig. 2 E).

This species was observed in September in Southern and Central Baikal and described for the first time. Maximal abundance was registered in September at sites 12 and 17. Single specimens were found in Northern Baikal (Tab. 3).

Paraphysomonas acuminata acuminata Scoble & Cavalier-Smith (Fig. 2 F).

This species was described for the first time. Single specimens of the species were registered in May-June predominantly in Southern and Central Baikal (Tab. 2).

P. gladiata Preisig & Hibberd (Fig. 2 H).

This species was described for the first time. Single specimens were detected in the plankton of Northern Baikal in autumn (Tab. 3).

Clathromonas takahashii Cronberg et Kristiansen (Fig. 2 G).

This species was mentioned for the first time. Maximal abundance was observed in May-June at sites 2 and 4. It was not registered in Central and Northern Baikal (Tab. 2).

Spiniferomonas abrupta Nielsen (Fig. 3 D, E).

This species was described for the first time in Lake Baikal. Single specimens were detected at site 17 in May-June, and in September at sites 1, 2 and 13 (Tab. 2, 3).

S. bourrellyi Takahashi (Fig. 2 I).

The species was observed in Central Baikal in September at sites 17 and 20 (Tab. 3).

S. cornuta Balonov (Fig. 2 L).

Single specimens of this species were registered for the first time in Lake Baikal in May-June at site 17. In September, the species was observed around the entire water area of the lake (Tab. 2, 3).

S. septispina Nicholls (Fig. 2 J, K).

This species was observed for the first time in Lake Baikal. Maximal abundance was observed in September in Central Baikal at sites 8, 12, 13 and 17). In Southern Baikal, it was observed rarely (Tab. 3).

Table 3. List of species and intra-specific taxa of silica-scaled chrysophytes in Lake Baikal observed in September. Site numbers correspond to sites in Fig. 1. Abundance was estimated according to the following scale: (4) abundant, (3) frequent, (2) rare and (1) very rare

		Southern Baikal									Central Baikal								Northern Baikal							
		Site number																								
#	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1.	*Chrysosphaerella baicalensis*	1	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2.	*C. brevispina*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3.	*C. coronacircumspina*	2	2	1	2	2	2	2	2	2	2	1	**3**	2	2	–	1	**3**	1	1	2	1	–	1	–	–
4.	*Paraphysomonas a. acuminata*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5.	*P. gladiata*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	1	–	–	–	–
6.	*Clathromonas takahashii*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7.	*Spiniferomonas abrupta*	2	2	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–
8.	*S. bourrellyi*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	2	–	–	–	–	–
9.	*S. cornuta*	2	2	2	–	2	2	–	2	–	2	–	2	2	–	–	–	2	–	–	–	1	–	1	–	–
10.	*S. septispina*	–	–	–	–	–	–	–	2	–	–	–	2	2	–	–	–	2	–	–	–	–	–	–	–	–
11.	*S. takahashii*	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–
12.	*S. trioralis* f. *trioralis*	**4**	**4**	**4**	**3**	**3**	**4**	2	**4**	**3**	**3**	1	**3**	**4**	2	1	1	**3**	**3**	1	**3**	1	1	1	–	1
13.	*S. trioralis* f. *cuspidata*	**4**	**4**	**4**	**3**	**3**	**4**	**3**	**4**	**4**	**3**	2	**3**	**4**	2	1	1	**3**	**3**	1	**3**	1	1	1	1	–
14.	*Mallomonas acaroides*	–	–	–	–	–	2	–	–	–	–	2	–	–	2	**3**	–	**3**	1	1	–	1	–	–	–	–
15.	*M. alpina*	1	2	–	–	–	1	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16.	*M. crassisquama*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
17.	*M. mangofera*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18.	*M. striata* var. *striata*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19.	*M. striata* var. *getseniae*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20.	*M. tonsurata*	–	–	–	–	–	1	–	–	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–
21.	*M. vannigera*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22.	*Synura glabra*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23.	*S. heteropora*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24.	*S. petersenii*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25.	*S. uvella*	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Total taxa	**7**	**7**	**4**	**3**	**4**	**7**	**3**	**6**	**3**	**5**	**4**	**6**	**6**	**4**	**3**	**4**	**7**	**4**	**5**	**5**	**6**	**2**	**4**	**1**	**1**

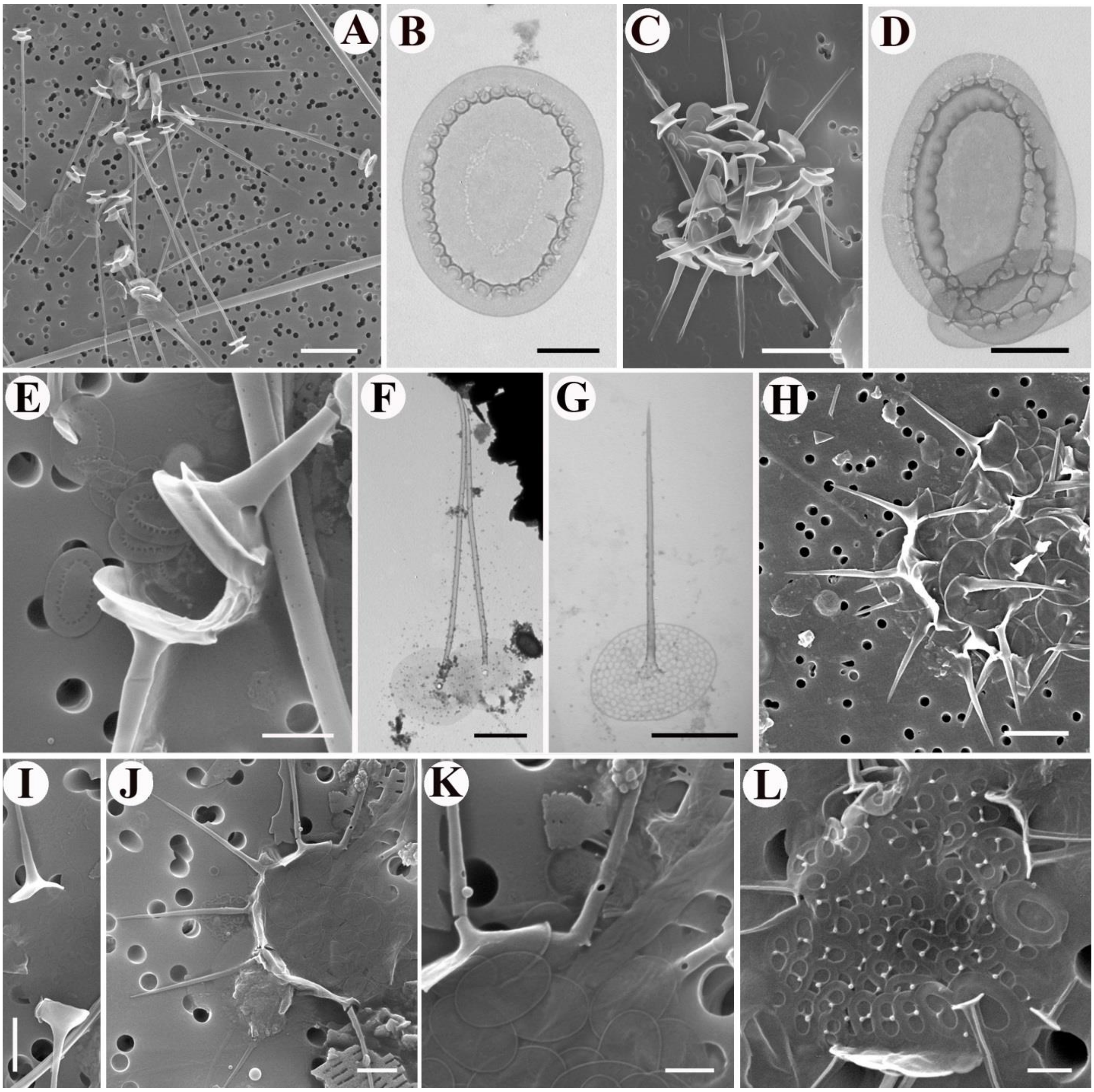

Fig. 2. SEM (A, C, E, H-L), TEM (B, D, F, G). Scales and spines of silica-scaled chrysophytes of Lake Baikal:
A, B – *Chrysosphaerella baicalensis*; C, D – *C. brevispina*; E – *C. coronacircumspina*; F – *Paraphysomonas acuminata acuminata*; G – *Clathromonas takahashii*; H – *P. gladiata*; I – *Spiniferomonas bourrellyi*; J, K – *S. septispina*; L – *S. cornuta.* Scale bars: B – 0.5 nm; D, F-H, K, L – 1 µm; E, I, J – 2 µm; A, C – 10 µm.

S. takahashii Nicholls (Fig. 3 F).

This species was registered for the first time in Russia. Single specimens were found only in September in Central Baikal (sites 10 and 16) (Tab. 3).

S. trioralis* f. *trioralis Takahashi (Fig. 3 C).

The form was registered for the first time in Lake Baikal ubiquitously around the entire water area of the lake. Maximal abundance of this species was observed in Southern and Central Baikal in September. However, in Northern Baikal it was found rarely (Tabs 2, 3).

S. trioralis* f. *cuspidata Balonov (Fig. 3 A, B).

The form was registered ubiquitously around the entire water area of the lake. Maximal abundance of this species was observed in Southern and Central Baikal in September. However, in Northern Baikal it was found rarely (Tabs 2, 3).

Mallomonas acaroides Perty (Fig. 3 I, J).

The species was observed predominantly in September with its maximal abundance in Central Baikal at sites 15 and 17 (Tab. 3).

M. alpina Pascher & Ruttner (Fig. 3 G, K).

The species was registered in Southern and Central Baikal in May-June and September and rarely in Northern Baikal (Tabs 2, 3).

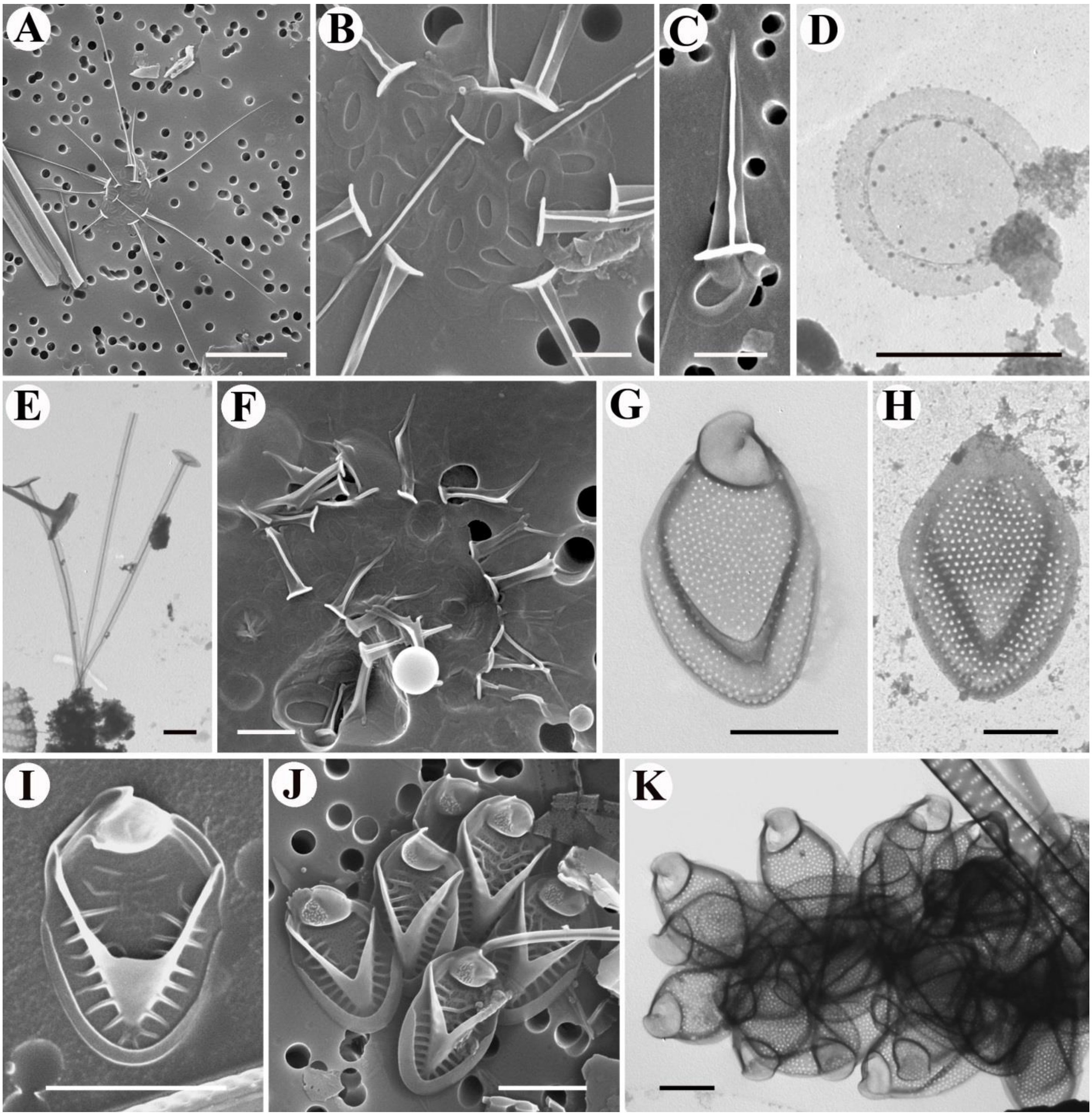

Fig. 3. SEM (A-C, F, I, J), TEM (D, E, G, H, K). Scales and spines of silica-scaled chrysophytes from Lake Baikal: A, B – *S. trioralis* f. *cuspidata*; C – *S. trioralis* f. *trioralis*; D, E – *S. abrubta*; F – *S. takahashii*; G, L – *Mallomonas alpina*; H – *M. tonsurata*; J, K – *M. acaroides*. Scale bars: B-E, H – 1 µm; F, G, K – 2 µm; I, J – 4 µm; A – 10 µm.

S. takahashii Nicholls (Fig. 3 F).

This species was registered for the first time in Russia. Single specimens were found only in September in Central Baikal (sites 10 and 16) (Tab. 3).

S. trioralis* f. *trioralis Takahashi (Fig. 3 C).

The form was registered for the first time in Lake Baikal ubiquitously around the entire water area of the lake. Maximal abundance of this species was observed in Southern and Central Baikal in September. However, in Northern Baikal it was found rarely (Tabs 2, 3).

S. trioralis* f. *cuspidata Balonov (Fig. 3 A, B).

The form was registered ubiquitously around the entire water area of the lake. Maximal abundance of this species was observed in Southern and Central Baikal in September. However, in Northern Baikal it was found rarely (Tabs 2, 3).

Mallomonas acaroides Perty (Fig. 3 I, J).

The species was observed predominantly in September with its maximal abundance in Central Baikal at sites 15 and 17 (Tab. 3).

M. alpina Pascher & Ruttner (Fig. 3 G, K).

The species was registered in Southern and Central Baikal in May-June and September and rarely in Northern Baikal (Tabs 2, 3).

M. crassisquama (Asmund) Fott (Fig. 4 A).

Single specimens of the species were observed only in Central Baikal (site 17) in May-June and September (Tabs 2, 3).

M. mangofera K.Harris & D.E.Bradley (Fig. 4 B).

This species was described for Lake Baikal for the first time. Single specimens were observed in Southern Baikal (site 13) (Tab. 2).

M. striata* var. *striata Asmund (Fig. 4 D).

The variation was registered rarely in Southern and Central Baikal in May-June (Tab. 2).

M. striata* var. *getseniae Voloshko (Fig. 4 C).

The variation was observed rarely in Southern Baikal in May-June. Earlier, it was named as *M. striata* var. *striata* (Vorobyeva et al., 1992) (Tab. 2).

M. tonsurata Teiling (Fig. 3 H).

The species was detected in May-June and in September in Southern and Central Baikal. The maximal abundance was registered at sites 2 and 4. In Northern Baikal, it was observed rarely (Tabs 2, 3).

M. vannigera Asmund (Fig. 4 E, F).

The species was observed rarely in May-June in Southern and Central Baikal (Tab. 2).

Synura glabra Korshikov (Fig. 4 G).

Single specimens of this species were observed for the first time in Central Baikal in May-June at site 17 (Tab. 2).

S. heteropora Skaloud, Skaloudová & Procházková in Skaloud et al. (Fig. 4 I, J).

Single specimens of this species were observed for the first time in Central Baikal at sites 13 and 17 in May-June (Tab. 2).

S. petersenii Korshikov (Fig. 4 K, L).

Single specimens of this species were registered for the first time in Central Baikal in May-June at site 13 (Tab. 2).

S. uvella Ehrenberg (Fig. 4 H).

This species was observed rarely in Southern and Central Baikal in May-June at site 17 (Tab. 2).

M. caudata, *P. vestita* and *Chrysosphaerella longispina* observed in earlier studies were not registered in this investigation. We think that these species were observed with light microscopy probably by mistake (Meyer, 1030; Kozhova, 1959).

Discussion

Spatial distribution and seasonal dynamics of silica-scaled chrysophytes in Lake Baikal

The highest diversity of silica-scaled chrysophytes was observed in the southern and central basins of Lake Baikal. In spring and summer, their abundance is low due to the dominance of large diatoms in this period as well as to low water temperature that limits their growth. The following species develop intensely in spring and summer: *Chrysosphaerella baicalensis*, *C. brevispina*, *Clathromonas takahashii*, *Mallomonas alpina* and *M. tonsurata*. These species are observed more often as a whole cell. It should be noted that *C. brevispina* was observed only in May-June of 2017, whereas *C. baicalensis* was detected only in May-June of 2016 (Tab. 2).

The peak of chrysophyte growth in Lake Baikal is observed in autumn (Tab. 3) when vegetation of large diatoms decreases and water temperature is higher than in spring. In September, we observed *C. coronacircumspina*, *S. bourrellyi*, *S. septispina*, *S. cornuta* and *M. acaroides* with the dominance of *S. trioralis* f. *trioralis* and *S. trioralis* f. *cuspidata*.

Studying samples taken on filters during the cruise around Lake Baikal in september 2016, 3 morphotypes were identified by scales to species among 20 stomatocyst morphotypes: Stomatocyst 156 Zeeb & Smol, 1993 – *Chrysosphaerella coronacircumspina*; Stomatocyst 223 Firsova & Likhoshway, 2006 – *Spiniferomonas trioralis*; Stomatocyst 302 Firsova, 2006 – *Spiniferomonas septispina* (Firsova, Bessudova, Likhoshway, 2017).

In this study we demonstrated that in Lake Baikal vegetative cells and silicious scales are more frequent than dormant stomatocysts. Several cells of these species had not had stomatocyst; it points to the fact that september could be a time when the dormant phases of these species are being formed.

Biogeographic distribution

The following rare taxa or taxa with limited distribution were observed in Lake Baikal: *C. takahashii*, *Spiniferompnas abrupta*, *S. septispina*, *S. takahashii*, *P. a. acuminata*, *M. striata* var. *getseniae*.

C. takahashii were observed earlier in Vashutkiny and Kharbeiskiye lakes (Siver et al., 2005), in Lake Ladoga (Voloshko, Gavrilova, Gromov, 2002) and in Labynkyr and Vorota lakes (Yakutia) (Bessudova et al., 2016). *Spiniferompnas abrupta* was registered in Russia only in these Yakutian lakes (Bessudova et al., 2016). *S. septispina* was observed earlier in Russia in the lakes of the Polar Urals (Voloshko, 2010). *S. takahashii* is a rare species with scattered distribution. It was observed in North America (Siver, 1988; Siver, Wujek, 1999) and North Europe (Nemcová et al., 2016). *M. striata* var. *getseniae* is considered to be an endemic species in the north of Russia (Voloshko, 2013). It was also found on the Taymyr Peninsula (Kristiansen, Duwell, Wegeberg, 1997) and in aquatic ecosystems of the Polar Urals (Voloshko, 2010).

Specific morphology of some chrysophytes of Lake Baikal

During our investigations, we have found a number of morphological peculiar characteristics of chrysophytes from Lake Baikal. For example, *M. acaroides* possesses two types of scales: the first type is scales whose morphology is characteristic of *M. acaroides* (the scales are wider and relatively large) (Fig. 3 I); the scales of the second type are of a narrower elongated form with an acute V-rib, thicker ribs on the posterior flange and rough large-pore reticulum on the shield like in *M. crassisquama* (Fig. 3 J). It is likely that both *M. acaroides* and *M. striata* are changeable species. Earlier, Kristiansen et al. (1995) described in detail the scales with similar morphology from the volcanic lake Pingo (Greenland). The author also cited a number of references in which there were microphotographs of a similar morphotype in samples collected from other regions of the world (Fott, 1962; Kristiansen, 1979; Wee, 1982; Kristiansen, Tong, 1989; Kristiansen, Tong, Olrik, 1990). In Russia, scales of *M. acaroides* with similar morphology were found in the Lower Yenisei basin (Bessudova et al., 2016).

All cells of *Spiniferompnas cornuta* found in Lake Baikal have 3 types of scales: (1) large with one lacuna, (2) with two lacunas and two processes and (3) two lacunas and one process. The cells of *S. cornuta* have two types of scales (Siver, 1988; Voloshko, 2013).

Chrysosphaerella baicalensis is similar to *C. brevispina* but different in some morphological characteristics. The spine length in *C. baicalensis* can reach 35 μm, whereas that in *C. brevispina* from Lake Baikal is 11-15 μm. Basal plates of spines in *C. baicalensis* are of similar diameter. The thickness of a spine is the same along its entire length contrary to *C. brevispina* whose spine base is a little wider than its apex.

Hence, according to our data, Lake Baikal houses 25 species and intra-specific taxa of silica-scaled chrysophytes. These are mainly widespread taxa. Their highest diversity was observed in the southern and central basins of Lake Baikal. Maximal abundance and species diversity was observed in autumn.

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