Phytotaxa 222 (2): 111–120
www.mapress.com/phytotaxa/
Copyright © 2015 Magnolia Press

Article

ISSN 1179-3155 (print edition)
PHYTOTAXA
ISSN 1179-3163 (online edition)

http://dx.doi.org/10.11646/phytotaxa.222.2.3

Mallomonas alpestrina sp. nov. (Synurales, Chrysophyceae, Stramenopiles) and its spineless relatives—*Mallomonas alata* group

YVONNE NĚMCOVÁ[1,*], MARTINA PICHRTOVÁ[1] & VOJTĚCH ZEISEK[1,2]
[1]*Department of Botany, Charles University in Prague, Benatska 2, 128 01 Prague, Czech Republic*
[2]*Department of Taxonomy, Institute of Botany, Czech Academy of Science, Zamek 1, Pruhonice, 252 43, Czech Republic*
[*]*Corresponding author (E-mail:ynemcova@natur.cuni.cz)*

Abstract

In this paper, we define the *Mallomonas alata* group and describe *M. alpestrina sp. nov.* from an oligotrophic high mountain glacial lake on the slopes of Haba Xue Shan (Haba Snow Mountain), China. The *Mallomonas alata* group is excluded from the *M. pumilio* group primarily based on the approximately triangular shape of the collar scales, the small hook-like protruded dome, and one considerably broader anterior flange of the body scale. We extend previous research on small species from the section Torquatae with reticulated scale-shield pattern. Molecular genetic data for the *Mallomonas alata* group species are not currently available; therefore, we provide detailed information on scale and scale-case morphology, environmental requirements, and geographical distribution of these species.

Introduction

The genus *Mallomonas* Perty (1852: 170) includes heterokont photosynthetic flagellates covered by overlapping silica scales. A cell contains a single, golden brown, deeply divided plastid. Pigment composition is dominated by the brown pigment fucoxanthin, chlorophyll *a*, and chlorophyll c_2. Currently, *ca*. 180 taxa have been described within the genus *Mallomonas* (Siver 1991, Kristiansen & Preisig 2007) based primarily on the silica scale morphology. However, recently descriptions based on both molecular data and scale morphology have been published (Jo *et al*. 2013, Kim *et al*. 2014). The term *Mallomonas pumilio* group [including *M. alata* Asmund *et al*. (1982: 391) f. *alata*] was introduced by Asmund *et al*. (1982). The group included species with small (7–20 μm) ovoid to ellipsoidal cells from the section Torquatae, which exhibited a reticulated scale-shield pattern with the reticulum meshes enclosing one to several pores at the bottom. Asmund *et al*. (1982) reported that the *Mallomonas pumilio* type [Harris & Bradley (1957: 45)] included two different species. They designated one species (their fig. 4 in Asmund *et al*. 1982) as a lectotype of *Mallomonas pumilio* Harris & Bradley (1957) *emend*. Asmund *et al*. (1982: 387) var. *pumilio*, and described the other as the new species *Mallomonas alata* f. *alata* (their Fig. 3). A new form from a paludal forest in southern Chile, *M. alata* f. *hualvensis* Asmund *et al*. (1982: 394), also was introduced in that paper. Subsequently, *M. alata* f. *hualvensis* was reported from Ontario, Canada (Nicholls 1988) and the Aquitaine Region, France (Němcová *et al*. 2012), which placed its endemic status in dispute.

Detailed revision and elaborate definition of the *Mallomonas pumilio* group based on scale morphology and scale shape analysis was provided by Němcová *et al*. (2013). To evaluate slight differences in scale morphology, landmark-based geometric morphometrics analysis was used. Two new species [*Mallomonas jubata* Němcová *et al*. (2013: 36) and *M. directa* Němcová *et al*. (2013: 40)] and two new varieties [*M. pumilio* var. *dispersa* Němcová *et al*. (2013: 42) and *M. solea-ferrea* var. *irregularis* Němcová *et al*. (2013: 40)] were introduced, and the emended definition of *M. pumilio* var. *pumilio emend*. Němcová *et al*. (2013: 44) was provided. The varieties *Mallomonas pumilio* var. *silvicola* Asmund *et al*. (1982: 391) and *M. pumilio* var. *munda* Asmund *et al*. (1982: 391) were erected to the species level *M. silvicola* Němcová *et al*. (2013: 38) and *M. munda* Němcová *et al*. (2013: 36), respectively. Only species exhibiting collar scales with a well-developed circular to oval dome, harboring smooth curved bristle, were retained in the *M. pumilio* group. Species exhibiting approximately triangular collar scales with a small hook-like protruded dome and body scales with one considerably broader anterior flange (*M. alata* f. *alata* and *M. alata* f. *hualvensis*) were not

Accepted by Saúl Blanco Lanza: 31 Jul. 2015; published: 14 Aug. 2015
Licensed under a Creative Commons Attribution License http://creativecommons.org/licenses/by/3.0

included in the analyses. Recently, the new species *Mallomonas tirolensis* Pichrtová *et al*. (2013: 79), which exhibits similar collar and body-scale morphology, was identified in the eastern Alpine region of North Tyrol, Austria.

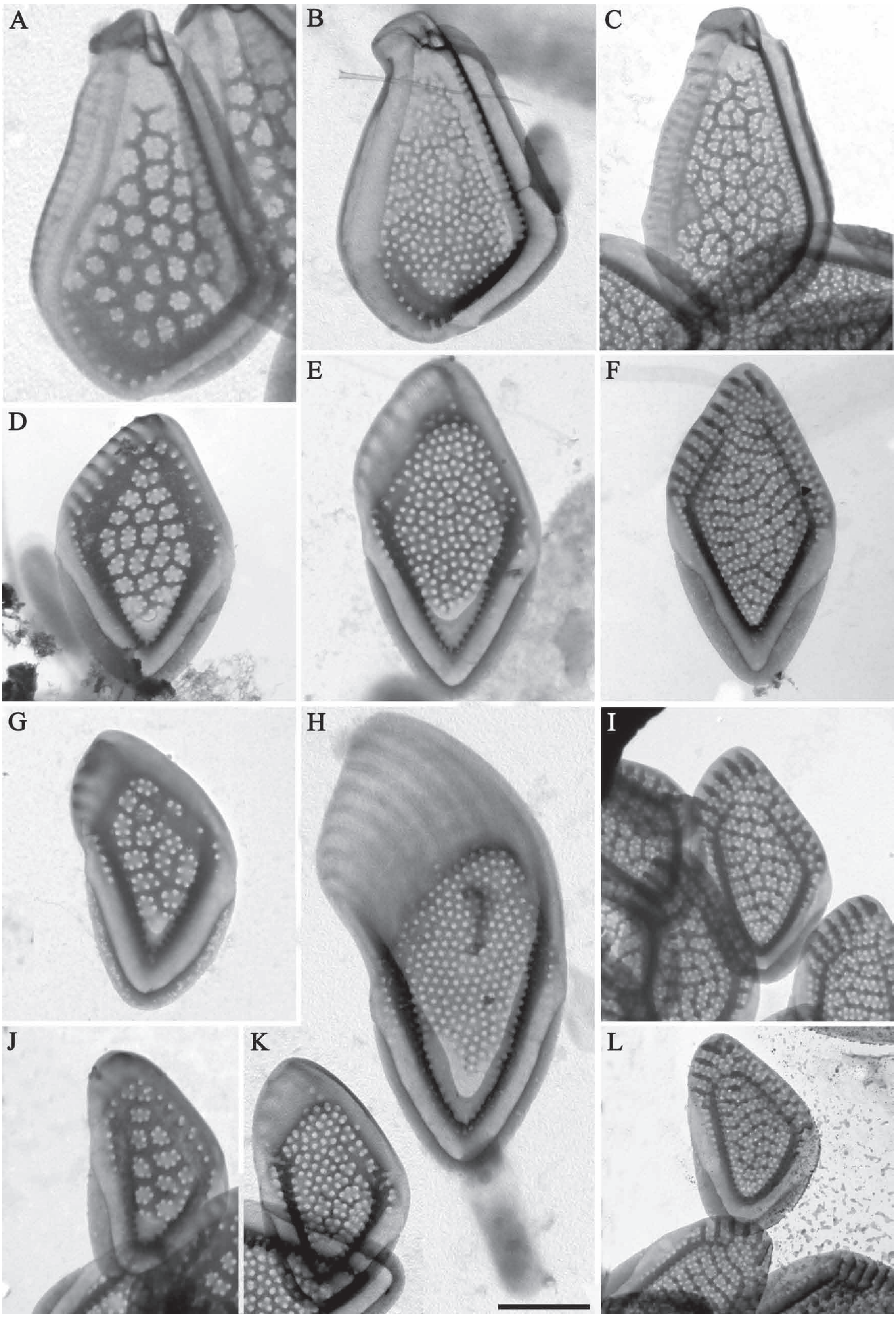

FIGURE 1. A–C. Collar scales in: A. *Mallomonas alata* f. *alata*. B. *Mallomonas alata* f. *hualvensis*. C. *Mallomonas tirolensis*. D–F. Body scales in: D. *Mallomonas alata* f. *alata*. E. *Mallomonas alata* f. *hualvensis*. F. *Mallomonas tirolensis*. G–I. Transitional scales between the rear and the body scales in: G. *Mallomonas*. *alata* f. *alata*. H. *Mallomonas alata* f. *hualvensis* (note the considerably broad anterior flange). I. *Mallomonas tirolensis*. J–L. Rear scales in: J. *Mallomonas alata* f. *alata*. K. *Mallomonas alata* f. *hualvensis*. L. *Mallomonas tirolensis*. Scale bar = 1 μm. A–L are shown at the same magnification.

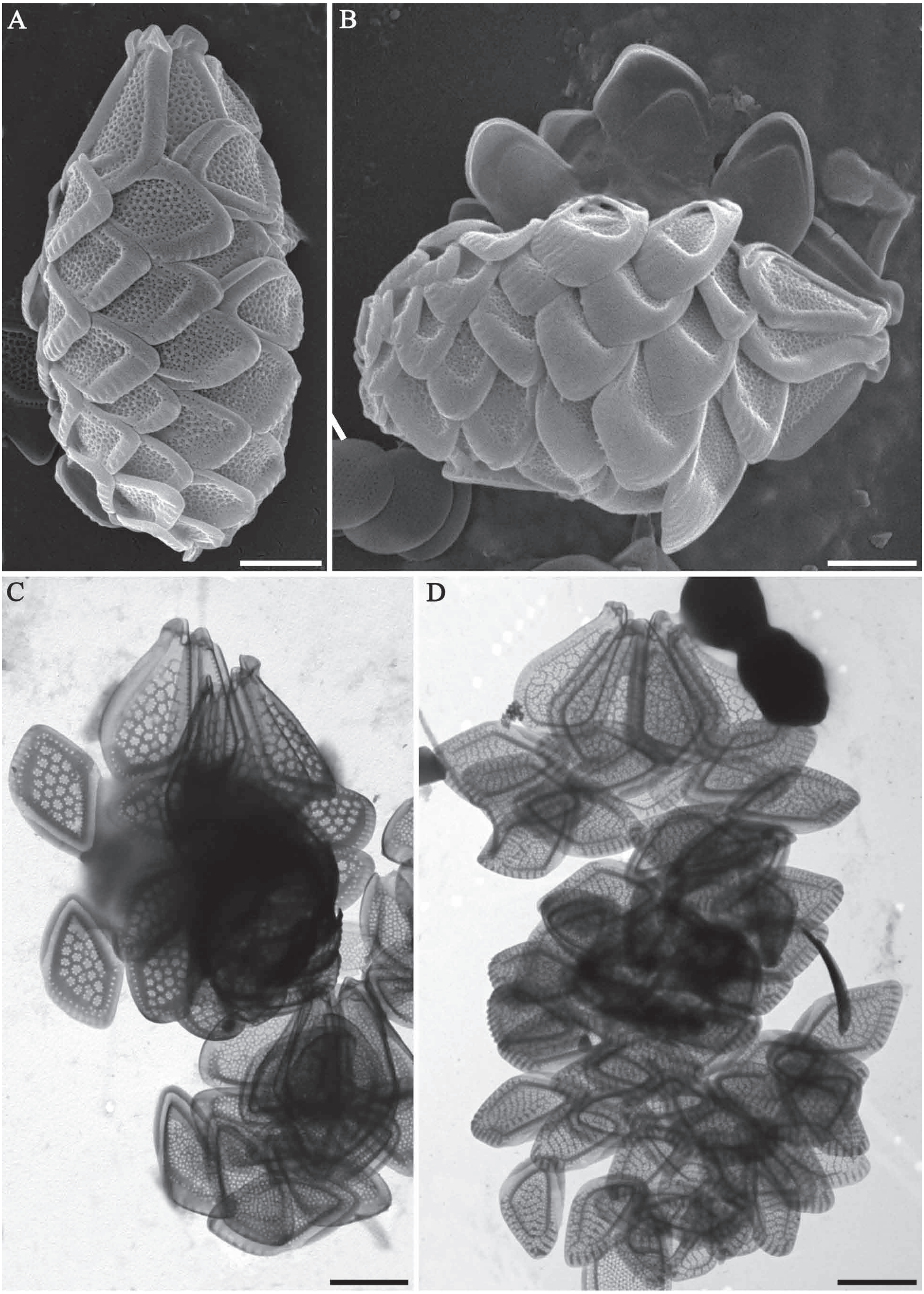

FIGURE 2. A. Whole-cell armor of *Mallomonas alata* f. *alata* in a scanning electron microscope (SEM) micrograph. B. *Mallomonas alata* f. *hualvensis*, whole cell in SEM. C. A combined micrograph of whole-cell armors of *M*. *alata* f. *alata* (upper part) and *M*. *alata* f. *hualvensis* (lower part) in a transmission electron microscope (TEM) micrograph. D. Whole-cell armor of *M*. *tirolensis* in TEM. Scale bar = 2 μm.

The purpose of this paper is to define the *Mallomonas alata* group and describe *M. alpestrina sp. nov*. We extend previous research on small species from the section Torquatae with reticulated scale-shield pattern. Molecular genetic data are not currently available; therefore, we provide detailed information on scale and scale-case morphology, environmental requirements, and geographical distribution of the *Mallomonas alata* group species.

Materials and Methods

The new species *Mallomonas alpestrina* was identified in one of many glacial lakes (4192 m a.s.l.) on the slopes of Haba Xue Shan (Haba Snow Mountain), Zhongdian (Shangri-La County, Deqen Tibetan Autonomous Prefecture, Northwestern Yunnan), China. The lake is located in a long narrow valley and it follows the shape of the valley; the lake length from SE to NW is *ca*. 225 m and it reaches *ca*. 73 m at the widest point. The lake depth is not known. However, as this glacial lake lies in a deep valley, it may be tens of meters deep. The lake is surrounded by steep subalpine rocky slopes dominated by various grasses and shrubs (mostly *Rhododendron* spp.). The species description is based on surface sediment samples obtained by syringe suction from the upper sediment layers, which were fixed with Lugol's solution.

Samples containing other species were collected using a plankton net (20 µm mesh). *Mallomonas alata* f. *alata* was sampled in Zeller Loch, Germany (Fig. 1A), Basco Pantano near Policoro, Italy (Fig. 1D), Aquitaine, France (Figs 1G, J; Figs 2A, C). *M. alata* f. *hualvensis* was sampled in Aquitaine, France. *Mallomonas tirolensis* samples were from North Tyrol, Austria.

The Lugol-fixed samples were washed by repeated centrifugation in deionized water. Drops of fresh or washed samples were dried onto Formvar-coated transmission electron microscopy (TEM) grids (Nováková *et al*. 2004). The TEM grids were examined with a JEOL 1011 transmission electron microscope. Photomicrographs were obtained using a Veleta CCD camera equipped with image analysis software (Olympus Soft Imaging Solution GmbH). For scanning electron microscopy (SEM), the Formvar-coated grid (already observed in TEM) was mounted onto an SEM stub with double-sided adhesive carbon tape, coated with gold for 5 min with a Bal-Tec SCD 050 sputter coater (which formed a 3-nm thick gold layer), and observed with a JEOL 6380 LV scanning electron microscope. Typification of the new species is based on the illustrations published in this study, because it was impossible to preserve specimens showing the features attributed to the taxon (ICN art. 40.5).

Results

Description of the Mallomonas alata group

The *Mallomonas alata* group includes small species (approximately 10 µm) with ovoid to ellipsoid cells prolonged in the anterior part, which is formed primarily by six collar scales. The collar scales are approximately triangular with a small hook-like protruded dome. The proximal border (rim) and the submarginal rib serve as a track to position the overlapping collar scale. No group members were observed to have bristles attached to the dome. There is one considerably broader anterior flange in the body scale. The body scales form a precisely organized scale-case; the broader flanges are exposed to the surface, whereas the shorter flanges are more or less overlapped by adjacent body scales. The rear scales are asymmetrical; the side bearing a broad flange extension is always shorter than the other side. No spines on the rear scales were observed, except for the newly described *Mallomonas alpestrina*, in which diminutive spines were occasionally found. The shield of all scale types is covered by a regularly arranged reticulum with different numbers of pores (1–25) surrounded by short ridges of reticulum. Four taxa have met the description criteria and have been included in the *Mallomonas alata* group: *M. alata* f. *alata*, *M. alata* f. *hualvensis*, *M. tirolensis*, and *M. alpestrina sp. nov*. The diagnostic features of these species are summarized in Table 1.

TABLE 1. Diagnostic features of *Mallomonas alata* species group.

	Collar scale			Body scale				
	Size (μm)	Ventral flange	Shield pattern /No. of pores at the bottom of each mesh	Shield pattern / no. of pores at the bottom of each mesh	Broader anterior flange	Shorter anterior flange	Posterior subm. rib	Posterior flange
M. apestrina	4.5 × 2.9	smooth	rosette-like with central papilla / 20–25	rosette-like with central papilla / 20–25	*ca*. 5 ridges, wavy appearance, 2–3 pores	several groups of 2–3 pores	internal struts	smooth
M. alata f. *alata*	3.9–4.5 × 2.5–3.0	wavy	annular groups / 5–8	annular groups / 5–8	6–8 ridges, wavy appearance, one row of large pores	one row of large pores	smooth	smooth
M. alata f. *hualvensis*	3.5–4.0 × 2.1–2.7	smooth	usually single pores / 1–(3)	single pores	8–10 ridges, wavy appearance, no pores	smooth	smooth	smooth
M. tirolensis	3.4–4.0 × 2.1–2.6	wavy	irregularly shaped mash / (4)–8–(20)	two rows of pores / often 4	8–10 pronounced ridges, continuous to the shield	similar pattern as on the shield	smooth	smooth

Mallomonas alata f. *alata* (Figs 1A, D, G, J; Fig. 2A, C; upper part of the micrograph) is widely distributed with numerous records all over the world (Kristiansen 2002), including New Zealand (Dürrschmidt 1986). The species is tolerant to a wide range of ecological conditions (Němcová *et al*. 2003). In Europe, the frequency of occurrence is highest in water bodies with pH 6.5–7.0 (46% of all records, 31 in total) and conductivity 60–260 μS·cm^{-1} (60% of all records, 42 in total; Škaloud *et al*. 2013). *Mallomonas alata* f. *hualvensis* (Figs 1B, E, H, K; Figs 2B, C; lower part of the micrograph) was described from Chile, with subsequent descriptions in North America (Nicholls 1988) and Europe (Péterfi *et al*. 1998, Barreto 2005, Siver *et al*. 2005, Němcová *et al*. 2012). There are no records from subtropical and tropical regions. We may consider a bipolar distribution of the species in temperate regions of both hemispheres. Water conductivity and pH ranged from 19−240 μS·cm^{-1} and 5.5−7.1, respectively (50% of all records, 4 in total; were from pH 6.5–6.8; Škaloud *et al*. 2013). *Mallomonas tirolensis* (Figs 1C, F, I, L; Fig. 2D) was identified in two lakes in North Tyrol, Austria (pH 8.2 and 8.1, and conductivity 371 and 414 μS·cm^{-1}; Pichrtová *et al*. 2013). *Mallomonas alpestrina* (Figs 3A–I) is known only from the type locality, the oligotrophic high mountain glacial lake, Haba Xue Shan (Snow Mountain), China (this article). Records of *Mallomonas alpestrina*, *M. alata* f. *hualvensis* and *M. tirolensis* accompanied by environmental conditions are summarized in Table 2.

TABLE 2. Records of *Mallomonas alpestrina*, *M. alata* f. *hualvensis* and *M. tirolensis*.

	Records	Sampling year	pH	Conductivity (μS·cm^{-1})	Temp. (°C)	Coordinates	References
M. apestrina	Asia, China unnamed lake between villages Haba and Haba Xue Shan	2012	-	-	-	27° 20.798’ N 100° 4.582’ E	This paper
M. alata f. *hualvensis*	South America, Chile pond near the town Villarrica	1979	6.5	39	12	-	Asmund *et al*. (1982)
	North America, Canada Pond 1, Galway Twp.	1988	-	-	-	44° 48.033’ N 78° 29’ W	Nicholls (1988)
	Europe, Hungary bog-lake Baláta-tó	1998	-	-	-	-	Péterfi *et al*. (1998)
	Europe, Hungary pond in Visegrád mountains	1999	6.8	240	10.5	-	Barreto (2005)
	Europe, Russia Vorkuta tundra, pond Vorgashor	2002	5.5	-	8.0	67° 35’ N 63.47’ E	Siver *et al*. (2005)
	Europe, Russia Kharbey, small pond	2003	-	19	19.7	67° 32.437’ N 62° 58.78’ E	Siver *et al*. (2005)
	Europe, Russia Vash.-Kharbey, small pond	2003	-	39	14.9	67° 53.208’ N 62° 11.802’ E	Siver *et al*. (2005)
	Europe, France pool close to Lac du Bousquet	2010	7.1	178	-	44° 30.032’ N 0° 37.853’ W	Němcová *et al*. (2012)
	Europe, France enclosed bay of Étang de Cazaux	2010	6.8	236	-	44° 26.456’ N 1° 11.299’ W	Němcová *et al*. (2012)

...cotinued on the next page

TABLE 2. (Cotinued)

	Records	Sampling year	pH	Conductivity (μS·cm^{-1})	Temp. (°C)	Coordinates	References
	Europe, Czech Republic Velke Darko Pond						Škaloud *et al*. (2013)
	Europe, Germany Reeckkanal	2011	7.9	511	11.5	53° 30.385' N 12° 38.043' E	Škaloud *et al*. (2013)
M. tirolensis	Europe, Austria Möserer See	2012	8.2	371	5.8	47° 18.864' N 11° 8.652' E	Pichrtová *et al*. (2013)
	Europe, Austria Seefelder See (Wildsee)	2012	8.1	414	7.1	47° 19.344' N 11° 11.52' E	Pichrtová *et al*. (2013)

Taxonomy

Mallomonas alpestrina **Němcová & Zeisek, *sp. nov*. (Fig. 3A–I)**

Three types of scale are discerned, including collar, body, and rear scales; however, a continuous transition between body and rear scales is evident. Collar scales (4.5 × 2.9 μm) are approximately triangular with rounded distal part. The submarginal rib is well developed at the dorsal and posterior ends of the scale, but totally reduced along the ventral edge. The submarginal rib is reinforced by internal struts, which appear striated in TEM images. The ventral flange is broad and smooth. The triangular hook-like dome is small, and protrudes above the surface of the other scales. The proximal border (rim) encircles only the dorsal part of the collar scale; together with the submarginal rib, they serve as tracks to fit the neighbouring collar scale in place. The scale shield is covered by a regularly arranged reticulum, large groups of pores (up to 20–25) are surrounded by short ridges of reticulum, and there is a thickened part (papilla) in the middle of each pore group (Fig. 3A). Domeless body scales (3.5–3.9 × 1.9–2.1 μm) are rhombic and extremely asymmetrical (Figs 3C, F). There is a smooth transition between posterior submarginal ribs and anterior flanges/submarginal ribs. Posterior submarginal ribs are striated (or bear internal struts, see Fig. 3D for detail). One of the anterior flanges is considerably broader and shorter, strengthened by ribs providing a wavy appearance. The other flange is penetrated by several groups of pores positioned along the anterior submarginal rib, but it lacks cross ribs (Figs 3B, E). The posterior flange is narrow and smooth. The proximal border (rim) encircles approximately one-third of the scale. Reticulation of the shield is similar to that of the collar scales. The rear scales ((2.0) 2.4–2.7 × 1.5–1.6 μm) are asymmetric, with one anterior flange considerably longer than the other, and the longer one bears 2−3 ribs (Figs 3G–I). The distal rear scales are almost rounded and bear a diminutive spine (Fig. 3I). Bristles are not observed; the species probably does not produce bristles. The cyst is unknown. The cell dimensions are unknown.

Type:—CHINA. Northern Yunnan: Diqin county, Zhongdian, unnamed lake on the slopes of Haba Xue Shan (Haba Snow Mountain), close to Haba village, 27° 20.798' N 100° 4.582' E, 4192 m a.s.l., *V. Zeisek*, *8 September 2012* (holotype: Fig. 3B).

Etymology:—The epithet refers to the occurrence of the species in a glacial lake at high elevation.

Habitat:—Oligotrophic high mountain lake.

Distribution:—China, the species was only found in the type locality.

Discussion

The *Mallomonas alata* group is excluded from the *M. pumilio* group primarily based on the approximately triangular shape of the collar scales and the small hook-like protruded dome without attached bristles. One anterior flange of the body scale is considerably broader. Harris (1970) considered *M. alata* collar scales to be an immature form of *M. pumilio* collar scales. Asmund *et al*. (1982) disputed this "immature scales" theory, and delimited *M. alata* f. *alata* as a separate species. A scale is formed endogenously within a silicon deposition vesicle (SDV); its shape cannot be changed after silicification and extrusion to the cell surface (Leadbeater 1990). However, slight changes in scale shape and proportions during scale biogenesis inside the SDV are inducible by shifts in environmental conditions such as temperature (Řezáčová-Škaloudová *et al*. 2010, Pichrtová & Němcová 2011) and pH (Němcová & Pichrtová 2012). Insufficiently silicified scales are often reported in dense cultures where a deficiency of diluted SiO_2 may occur (Němcová *et al*. 2010). In natural populations, insufficiently silicified scales may be released after cell death if the process of silicification has not been completed. However, complete alteration of the dome after scale release to the cell surface would be inconsistent with the scale construction principles. All *Mallomonas alata* group members share the same dome structure. Based on the dome shape (no cavity develops on the inner scale surface), we presume an absence of bristles in the *Mallomonas alata* group. Harris (1970) reported a single, short, delicate bristle (see p. 77, Plate 1, Fig. 3 in Harris 1970). However, after close inspection of the image, we conclude that this structure likely represents a dorsal submarginal rib.

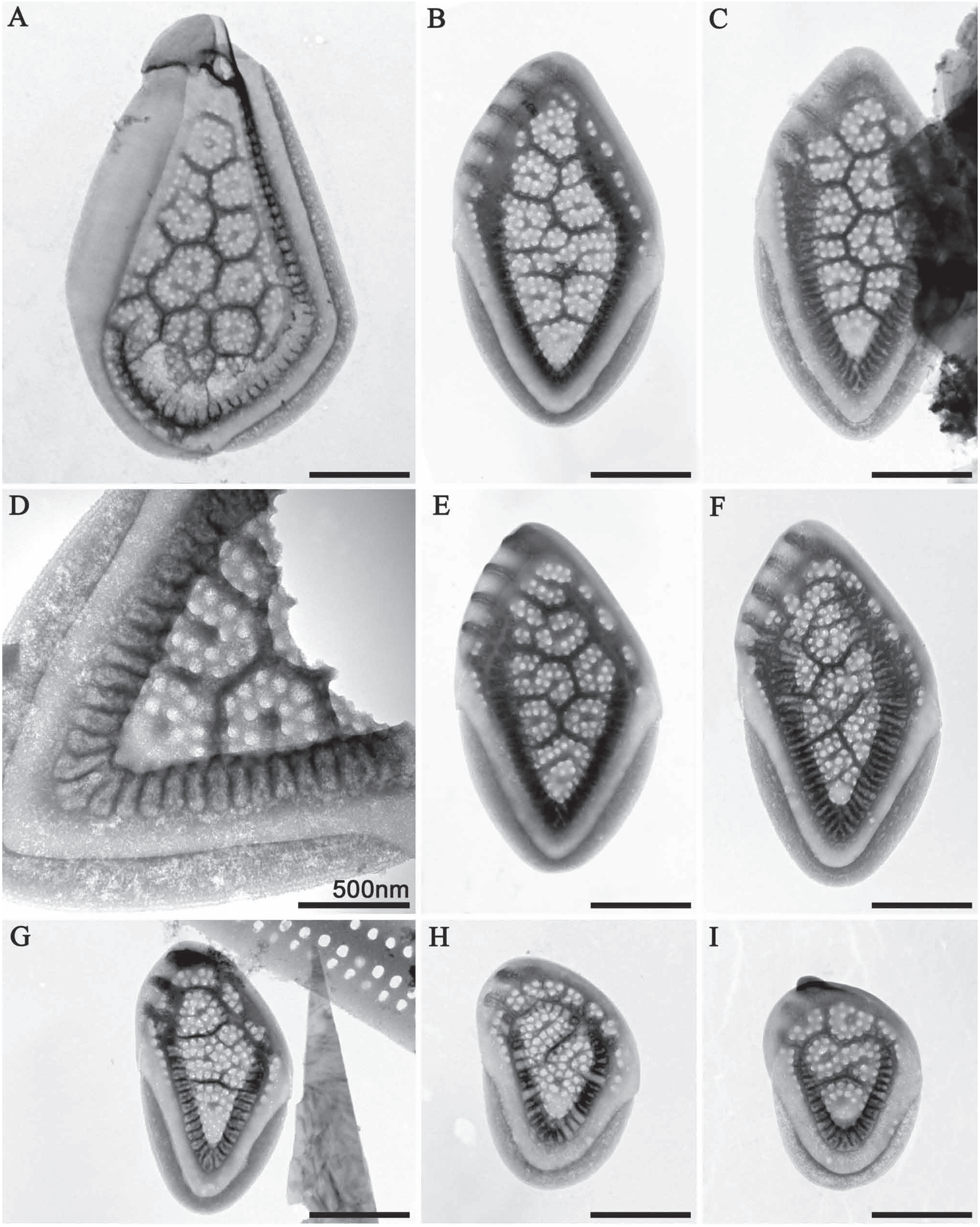

FIGURE 3. *Mallomonas alpestrina sp. nov*. A. A collar scale. B–C. Body scales. D. Detail of body scale; note short ridges of reticulum surrounding large groups of pores. E–F. Asymmetrical body scales with one anterior flange considerably broader and shorter than the other. G–I. Rear scales. I. A rear scale bearing a diminutive spine. Scale bars = 1 µm, if not stated otherwise.

All described species of the *Mallomonas alata* group have small cells (*ca*. 10 μm). The length and width of the collar scales are very similar in all investigated species. It is not sufficient to measure the length of a body scale for morphological characterization, because the length is influenced by the broadness of the anterior flange. Broadness of the anterior flange differs according to the scale position within the scale-case, which is most pronounced in *Mallomonas alata* f. *hualvensis* (Fig. 2B). In the *Mallomonas pumilio* group, differences in body-scale shape were captured using landmark-based geometric morphometrics (GM) analysis (Němcová *et al*. 2013). However, GM methods are not applicable in the *M*. *alata* group because of the extremely variable body-scale shape. By contrast, the scale-shield pattern on both collar and body scales embodies a stable character that can be used to distinguish the taxa. The shield pattern (Table 1) varies from single pores (*M. alata* f. *hualvensis*) to groups of 20–25 pores surrounded by short ridges of reticulum (*M. alpestrina*). We considered raising *M. alata* f. *hualvensis* to the species level. However, there is a weak glimpse of reticulation on the shield of some body scales and samples from various geographical locations differ by the broadness of the anterior flange [*e.g*. *M. alata* f. *hualvensis* from Chile, their fig. 29 in Asmund *et al*. (1982), has got narrower anterior flange compared to the *M. alata* f. *hualvensis* from Aquitaine, France]. That is why we finally decided to keep the taxon as a forma. More information is needed on the scale structure from different populations.

The taxon that is most similar to *M. alpestrina* (in addition to other species from the *M. alata* group) is *M. roscida*, which was described from New Zealand (Dürrschmidt 1986: 104). Scales of both taxa have the shield similarly ornamented by a regularly arranged reticulum. Large groups of pores (up to 20–25) are surrounded by short ridges of reticulum with a thickened papilla in the middle of each pore group. The anterior flanges in *M. roscida* are equally broad. Numerous and regularly spaced transverse struts radiate bilaterally from the anterior submarginal rib. By contrast, one of the anterior flanges in *M. alpestrina* is considerably broader than the other, and there is not a distinct anterior submarginal rib. Moreover, *M. roscida* exhibits *M. pumilio*-group-type collar scales with distinctly ornamented domes.

Although *M. alata* f. *alata* is widely distributed, *M. alata* f. *hualvensis* could be considered as a bipolar species that occurs in temperate regions of both hemispheres. The biogeography and ecology of *M. tirolensis* and *M. alpestrina* are unknown. *Mallomonas alpestrina sp. nov*. is described from an oligotrophic high mountain glacial lake (4192 m a.s.l.). It was associated with a rich community of widely distributed silica-scaled chrysophytes, including *Synura conopea* Škaloud *et al*. (2012: 325), *Mallomonas annulata* (Harris & Bradley 1960: 764) Harris (1967: 187), and *M. papillosa* Harris & Bradley (1957: 44). This result indicated that the environmental conditions in the lake were not extreme.

Although all described species of the *Mallomonas alata* group have the same cell size and shape, there are great differences in the record frequencies. We may consider the growth rate, number of propagules (stomatocysts), ecological amplitude, dispersal ability, and biogeographical pattern (Siver & Lott 2012) of the species as factors that drive its abundance in natural localities.

Acknowledgements

This study was supported by Grant P506/13/23274 from the Czech Science Foundation and by Institutional Funds of Charles University in Prague. Collection of *Mallomonas alpestrina* was supported by Grant ME10143 from Ministry of Education, Youth and Sports of the Czech Republic. We acknowledge Miroslav Hyliš for professional technical assistance. We also thank to the reviewers for constructive comments on the manuscript and Saúl Blanco Lanza for editorial corrections.

References

Asmund, B., Cronberg, G. & Dürrschmidt, M. (1982) Revision of the *Mallomonas pumilio* group (Chrysophyceae). *Nordic Journal of Botany* 2: 383–395.
http://dx.doi.org/10.1111/j.1756-1051.1982.tb01204.x

Barreto, S. (2005) The silica-scaled chrysophyte flora of Hungary. *Nova Hedwigia Beiheft* 128: 11–41.

Dürrschmidt, M. (1986) New species of the genus *Mallomonas* (Mallomonadaceae, Chrysophyceae) from New Zealand. *In*: Kristiansen, J. & Andersen, R.A. (Eds.) *Chrysophytes*. *Aspects and problems*. Cambridge University Press, Cambridge, pp. 87–106.

Harris, K. (1967) Variability in *Mallomonas*. *Journal of General Microbiology* 46: 185–191.

http://dx.doi.org/10.1099/00221287-46-2-185
Harris, K. (1970) Imperfect forms and the taxonomy of *Mallomonas*. *Journal of General Microbiology* 61: 73–76. http://dx.doi.org/10.1099/00221287-61-1-73
Harris, K. & Bradley, D.E. (1957) An examination of the scales and bristles of *Mallomonas* in the electron microscope using carbon replicas. *Journal of the Royal Microscopical Society* 76: 37–46. http://dx.doi.org/10.1111/j.1365-2818.1956.tb00438.x
Harris, K. & Bradley, D.E. (1960) A taxonomic study of *Mallomonas*. *Journal of General Microbiology* 22: 750–777. http://dx.doi.org/10.1099/00221287-22-3-750
Jo, B.Y., Shin, W., Kim, H.S., Siver, P.A. & Andersen, R.A. (2013) Phylogeny of the genus *Mallomonas* (Synurophyceae) and descriptions of five new species on the basis of morphological evidence. *Phycologia* 52: 266–278. http://dx.doi.org/10.2216/12-107.1
Kim, H.S., Kim, J.H., Shin, W. & Jo, B.Y. (2014) *Mallomonas elevata* sp. nov. (Synurophyceae), a new scaled Chrysophyte from Jeju Island, South Korea. *Nova Hedwigia* 98: 89–102. http://dx.doi.org/10.1127/0029-5035/2013/0138
Kristiansen, J. (2002) The genus *Mallomonas* (Synurophyceae) - A taxonomic survey based on the ultrastructure of silica scales and bristles. *Opera Botanica* 139: 1–218.
Kristiansen, J. & Preisig, H.R. (2007) Chrysophyte and Haptophyte algae. Part 2: Synurophyceae. *In: Süßwasserflora von Mitteleuropa*. Spektrum Akademie Verlag, Heidelberg, pp. 1–252.
Leadbeater, B.S.C. (1990) Ultrastructure and assembly of the scale case in *Synura* (Synurophyceae Andersen). *British Phycological Journal* 25: 117–132. http://dx.doi.org/10.1080/00071619000650111
Němcová, Y. & Pichrtová, M. (2012) Shape dynamics of silica scales (Chrysophyceae, Stramenopiles) associated with pH. *Fottea* 12: 281–291.
Němcová, Y., Neustupa, J., Nováková, S. & Kalina, T. (2003) Silica-scaled chrysophytes of the Sumava National Park and the Trebonsko UNESCO Biosphere Reserve (Southern Bohemia, Czech Republic). *Nordic Journal of Botany* 22: 375–383. http://dx.doi.org/10.1111/j.1756-1051.2002.tb01387.x
Němcová, Y., Neustupa, J., Kvíderová, J. & Řezáčová-Škaloudová, M. (2010) Morphological plasticity of silica scales of *Synura echinulata* (Synurophyceae) in crossed gradients of light and temperature - a geometric morphometric approach. *Nova Hedwigia Beiheft* 136: 21–32.
Němcová, Y., Kreidlová, J., Kosová, A. & Neustupa, J. (2012) Lakes and pools of Aquitaine region (France) - a biodiversity hotspot of Synurales in Europe. *Nova Hedwigia* 95: 1–24. http://dx.doi.org/10.1127/0029-5035/2012/0036
Němcová, Y., Kreidlová, J., Pusztai, M. & Neustupa, J. (2013) *Mallomonas pumilio* group (Chrysophyceae/Stramenopiles) – a revision based on the scale/scalecase morphology and geometric morphometric data. *Nova Hedwigia Beiheft* 142: 27–49.
Nicholls, K.H. (1988) Additions to the *Mallomonas* (Chrysophycceae) flora of Ontario, Canada, and a checklist of North American *Mallomonas* species. *Canadian Journal of Botany* 66: 349–360. http://dx.doi.org/10.1139/b88-056
Nováková, S., Němcová, Y., Neustupa, J., Řezáčová, M., Šejnohová, L. & Kalina, T. (2004) Silica-scaled chrysophytes in acid peat bogs of Bohemian Switzerland (Czech Republic) and Saxonian Switzerland (Germany). *Nova Hedwigia* 78: 507–515. http://dx.doi.org/10.1127/0029-5035/2004/0078-0507
Péterfi, L.S., Padisák, J., Momeu, L. & Borics, G. (1998) Silica-scaled chrysophytes from the bog-lake Baláta-tó, SW Hungary. *Nordic Journal of Botany* 18: 727–733. http://dx.doi.org/10.1111/j.1756-1051.1998.tb01555.x
Perty, M. (1852) *Zur Kenntniss kleinster Lebensformen: nach Bau*, *Funktionen*, *Systematik*, *mit Specialverzeichniss der in der Schweiz beobachteten*. Jent & Reinert, Bern, 228 pp.
Pichrtová, M. & Němcová, Y. (2011) Effect of temperature on size and shape of silica scales in *Synura petersenii* and *Mallomonas tonsurata* (Stramenopiles). *Hydrobiologia* 673: 1–11. http://dx.doi.org/10.1007/s10750-011-0743-z
Pichrtová, M., Němcová, Y., Škaloud, P. & Rott, E. (2013) Silica-scaled chrysophytes from North Tyrol (Austria) including a description of *Mallomonas tirolensis* sp. nov. *Nova Hedwigia Beiheft* 142: 69–85.
Řezáčová-Škaloudová, M., Neustupa, J. & Němcová, Y. (2010) Effect of temperature on the variability of silicate structures in *Mallomonas kalinae* and *Synura curtispina* (Synurophyceae). *Nova Hedwigia Beiheft* 136: 55–70.
Škaloud, P., Kynčlová, A., Benada, O., Kofroňová, O. & Škaloudová, M. (2012) Toward a revision of the genus *Synura*, section Petersenianae (Synurophyceae, Heterokontophyta): morphological characterization of six pseudo-cryptic species. *Phycologia* 51:

303–329.
http://dx.doi.org/10.2216/11-20.1

Škaloud, P., Škaloudová, M., Pichrtová, M., Němcová, Y., Kreidlová, J. & Puzstai, M. (2013) www.chrysophytes.eu – a database on distribution and ecology of silica-scaled chrysophytes in Europe. *Nova Hedwigia Beiheft* 142: 141–146.

Siver, P.A. (1991) *The biology of Mallomonas*. *Morphology*, *taxonomy*, *ecology*. Kluwer Academic Publishers, Dordrecht, 230 pp.
http://dx.doi.org/10.1007/978-94-011-3376-0

Siver, P.A. & Lott, A.M. (2012) Biogeographic patterns in scaled chrysophytes from the east coast of North America. *Freshwater Biology* 57: 451–466.
http://dx.doi.org/10.1111/j.1365-2427.2011.02711.x

Siver, P.A., Voloshko, L.N., Gavrilova, O.V. & Getsen, M.V. (2005) The scaled chrysophyte flora of the Bolshezemelskaya tundra (Russia). *Nova Hedwigia Beiheft* 128: 125–149.