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Silica-scaled chrysophytes during spring in the Kis-Balaton Reservoir, Hungary

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As a result of taking water samples in spring 1999, 26 species of silica-scaled chrysophytes were found in the Kis-Balaton Reservoir I, one of the most remarkable aquatic habitats in Hungary. From them, 23 have been identified with certainity, two were questionable and two were identified to genus level. 12 species are new to Hungary and 19 species had not been found in Kis-Balaton before. Most of the species are widely distributed, occurring mainly in eutrophic waters. The most abundant species were *Paraphysomonas vestita*, *Synura petersenii* and *Mallomonas alpina*, all three widely distributed, cosmopolitan species. Beside these, *Mallomonas cratis* and *Mallomonas acaroides* were found to be common members of the vernal flora of silica-scaled chrysophytes in Kis-Balaton. *Mallomonas pseudocratis* has been found only in a few places in the world, while *Mallomonas alata* and *Mallomonas parvula* have bipolar distribution.

Key words: Silica scales, Chrysophyta, taxonomy, phytoplankton, reservoir, Kis-Balaton, Hungary

Introduction

In the middle of the last century, Kis-Balaton (location between Lat. 17°–17°30'N and Long. 46°30'–47°E) was part of Lake Balaton. From that time on, the water-level had been regulated and gradually decreased until 1985. This westernmost part of Lake Balaton was detached from the main body of water in the middle of our century and was named Kis-Balaton, and quickly started to be marshy. A unique bird-habitat was created. After the drainage of the area, the western part of Lake Balaton (the Keszthely bay) received all the inflow of the strongly polluted Zala river without the natural filtration that Kis-Balaton had provided before, so the trophic state of Lake Balaton increased dramatically in the 70s and 80s. Therefore, as part of a new concept to »save« Lake Balaton, the Kis-Balaton Water Protection Reservoir was built in 1985 with the first (18 km^2) inundation of the area. This was an attempt to reconstruct the original, natural conditions of Kis-Balaton itself. Today, the Kis-Balaton Reservoir has international interest due to its unique wildlife.

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The first electron microscopic (EM) records in Hungary of a silica scaled chrysophyte, *Paraphysomonas vestita* were made by HAJDU (1975) about 25 years ago. However, study of the silica-scaled chrysophyte flora of Hungarian waters is very scarce.

Before a second (16 km^2) inundation in the area in 1992, an electron microscope chrysophyte survey of Kis-Balaton was made by KRISTIANSEN and PADISÁK (1992). They identified 8 chrysophyte species as a result of sampling from 20 different parts of the lake on the 9th and 10th of July, 1991. Apart from the investigation in 1991, samples for this or other purposes have been analysed by KISS and KRISTIANSEN (1994) from the Danube River, the Tisza River and Lake Balaton, with seven species from samples of all seasons; PÉTERFI et al. (1998a) from the bog-lake Baláta-tó, with 26 species in spring and summer samples; PÉTERFI et al. (1998b) from the Hortobágy National Park area with 26 taxa during spring and summer.

Therefore, it seemed reasonable to start a larger-scale investigation of the silica-scaled chrysophytes of Hungary, extending to all kinds of water in several different parts of the country. The aim of this study is to give a more complete floristic picture concerning the chrysophyte flora of Kis-Balaton, as a greater number of silica-scaled chrysophyte species usually occur during spring. As a part of a spring 1999 sampling tour in Hungary, one water- and one net-sample were taken at one point of Kis-Balaton Reservoir, to investigate the silica-scaled chrysophytes.

Material and methods

Water- and net-samples were taken from the shore of the open water-surface of Kis-Balaton Reservoir I (Fig. 1), on the 13th of April 1999, after a flood-period caused by rain and melting ice that extended all over Hungary. Water-samples were taken for measuring total nitrogen (TN) and total phosphorus (TP) content. The pH, temperature and conductivity were measured on the spot with portable instruments (pH 97 WP, Milwaukee and HACH conductivity/TDS meter). The samples were fixed with Lugol's iodine-solution. After the Lugol solution was removed, one drop of each sample was put on formvar-, carbon-coated EM grids. After rinsing with distilled water and drying, the specimens were examined in a Jeol JEM-100SX transmission electron microscope (Department of Phycology, Botanical Institute, Copenhagen University). Four grids from water-samples and three from net-samples were prepared.

For measuring TN and TP, we used the Danish description in Limnologisk Metodik (ed.: Copenhagen University, Freshwater Biological Laboratory, 1973).

In Table 1 the scale densities of the different species on the grids are based on our general observations. The categories set up are the following: few 2–10, many 10–20, very many >20 scales on all the grids together. The numbers, of course, are approximate.

Results and discussion

All together, 26 silica-scaled chrysophyte species were found during a thorough examination of the grids: 1 *Chrysosphaerella*, 7 *Paraphysomonas*, 2 *Spiniferomonas*, 4 *Synura* and 12 *Mallomonas* species (Tab. 1, Figs. 2.1–2.32). The physical and chemical parameters measured and the TN and TP values were as follows: temperature=12.7 °C; pH=8.1; con-

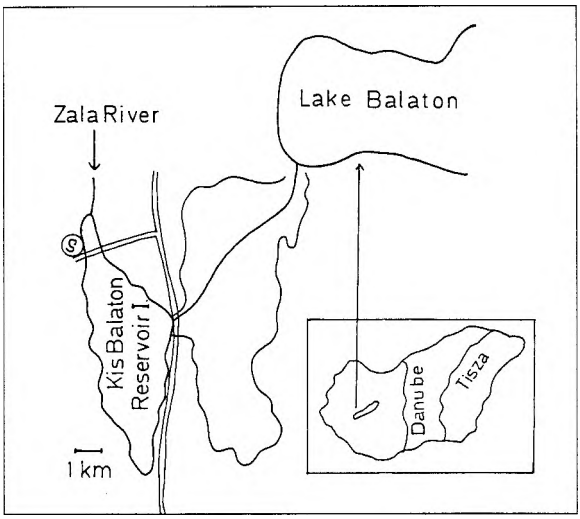

Fig. 1. Map of Kis-Balaton Reservoir, S -sampling station

ductivity (CND)=0.74 $mScm^{-1}$; total dissolved solids (TDS)=0.37 gl^{-1}; TN=323.08 gl^{-1}; TP= 48.57 gl^{-1}.

Taxonomic comments on species found are as follows:

Chrysosphaerella brevispina Korshikov em. Harris et Bradley (Fig. 2.1)
A widely distributed species, typically occurring in cold-water periods, mainly in springtime. It was found in Hungary before in the Hortobágy National Park and in Balăta-tó (PÉTERFI et al. 1998a, b). According to SIVER (1988), it is a pH-indifferent species.

Paraphysomonas corynephora Preisig et Hibberd (Fig. 2.2)
A fairly common species (VØRS et al. 1990), known from Europe. New to Hungary.

Paraphysomonas imperforata Lucas (Fig. 2.3)
A common cosmopolitan species, which has also been described from marine localities. We found it in almost all of the Hungarian lakes we examined to date. Despite this, it has not been recorded in Hungary before.

Paraphysomonas punctata Zimmermann *ssp. punctata* (Fig. 2.4)
It has only been recorded in certain regions of the world, and is primarily known from Europe. *P. punctata* is an interesting species-complex of five subspecies, one (*ssp. hexagona*) has been newly described in Denmark by OLSEN, POULSEN, REUSS and STEINARSDOTTIR (1999). New to Hungary.

Paraphysomonas punctata ssp. simplicior Preisig et Hibberd (Fig. 2.5)
It has only been recorded from a few places in the world, mainly in Europe. This subspecies differs from *P. punctata ssp. punctata* in the lack of distinct regular perforations (PREISIG

and HIBBERD 1982), though the scales have an irregular granulation on the distal side. Probably the scales pictured in this paper show their proximal sides, therefore granulation cannot be seen. New to Hungary.

Paraphysomonas sp. cf. butcheri Pennick et Clarke (Fig. 2.6)
Considering that we found only one single crown-scale, but no plate-scale, it is difficult to identify it with confidence; however it strongly resembles the above mentioned species. It is common, widely distributed and can be found both in marine and freshwater localities (PREISIG and HIBBERD 1982). New to Hungary.

Paraphysomonas sp. cf. circumvallata Thomsen (Fig. 2.7)
This species is primarily known from Europe, and the total global distribution is not known. The narrow margin on the scale is a typical feature of the species. The slight granulation of the central part resembles the distal side of the *P. circumvallata var. mediogranulata* scale (PREISIG and HIBBERD 1982).

Paraphysomonas vestita (Stokes) de Saedeler (Fig. 2.8)
This is a very common species all over the world, occurring mainly in eutrophic waters. The first EM records of the species from Hungary were made by HAJDU (1975).

Spiniferomonas cornuta Balonov (Fig. 2.9)
A quite rare species, it was also found in Germany by HICKEL and MAAß (1989) in a mesotrophic lake with low conductivity. However it is a common species in Iceland (Svava Steinarsdottir pers. com.). New to Hungary.

Spiniferomonas trioralis Takahashi (Fig. 2.10)
A widely distributed, cosmopolitan species. In Hungary it has only been found in Kis-Balaton (KRISTIANSEN and PADISÁK 1992).

Synura echinulata Korshikov (Fig. 2.11)
Widely distributed, found in oligotrophic to eutrophic water. It has been found in several Hungarian localities (KISS and KRISTIANSEN 1994, PÉTERFI et al. 1998a).

Synura petersenii Korshikov (Figs. 2.12–14)
A common, cosmopolitan species. The most widely distributed one of the genus. There are reports from many places in Hungary (KRISTIANSEN and PADISÁK 1992, KISS and KRISTIANSEN 1994, PÉTERFI et al. 1998a, b).

Synura spinosa? Korshikov (Fig. 2.15)
We found a single apical scale that makes the identification questionable, because of the similarity with the *S. curtispina* scale (Tab. 1). Basal scales are needed to identify the species with security. However, the relatively long spine and the surface of the scale rather resembles *S. spinosa*. There are previous Hungarian records of *S. spinosa* from Hortobágy and Balaton-tó (PÉTERFI et al. 1998a, b)

Synura uvella Stein (Figs. 2.16–17)

A widely distributed species, occurring mainly in eutrophic waters. The first EM records of the species in Hungary were made by PÉTERFI et al. (1998a, b). There are several light microscopic records that are dubious. According to SIVER (1988) it is a pH-indifferent species, though KRISTIANSEN (1975) found it to be more common in alkaline waters.

Mallomonas acaroides Perty em. Ivanov (Figs. 2.18–19)

A widely distributed species, occurring mainly under eutrophic conditions. Based on EM investigations it was found with certainty in several places in Hungary (KRISTIANSEN and PADISÁK 1992, KISS and KRISTIANSEN 1994, PÉTERFI et al. 1998a, b).

Mallomonas akrokomos Ruttner in Pascher (Fig. 2.21)

A widely distributed, cold-water species. There are previous records from Hungary by PÉTERFI et al. (1998 a, b). It can be found in a wide range of environmental conditions and trophic gradients (SIVER and MARSICANO 1996).

Mallomonas alata Asmund, Cronberg et Dürrschmidt (Fig. 2.22)

This species has a bipolar distribution, occurring both in the southern and northern temperate regions, but not in the tropics (KRISTIANSEN and VIGNA 1996). It was also found in Greenland (KRISTIANSEN 1994). In Hungary it was found in the bog-lake Baláta-tó (PÉTERFI et al. 1998a).

Mallomonas alpina Ruttner in Pascher (Figs. 2.23–24)

A cosmopolitan species, occurring over a wide range of environmental conditions. This species was also found in the Hortobágy National Park (PÉTERFI et al. 1998b)

Mallomonas annulata (Bradley) Harris (Fig. 2.25)

This species has a worldwide, but more or less scattered distribution (WEI and KRISTIANSEN 1994), mostly occurring in temperate regions (HANSEN and KRISTIANSEN 1997), with a relatively broad pH-range and preference for cold water (PÉTERFI et al. 1998a). It had the biggest tolerance for trophic gradients among the Synurophyceae species that SIVER and MARSICANO (1996) used to construct the trophic inference model. It occurs mostly under mesotrophic conditions according to PÉTERFI et al. (1998b); however SIVER and MARSICANO (1996) found the optimum within eutrophic conditions. It was previously found in Hungary by PÉTERFI et al. (1998a, b).

Mallomonas caudata Ivanov em. Krieger (Fig. 2.20)

A widely distributed species, in slightly alkaline, eutrophic waters, occurring mainly in the summer (PÉTERFI et al. 1998a). According to SIVER and MARSICANO (1996), it is present over a relatively wide trophic gradient, with an optimum in mesotrophic conditions. It is known to be a pH-indifferent species (SIVER 1988). A common member of spring and summer phytoplankton of most fishponds and reservoirs of the Hortobágy, and has also been recorded from the Danube River and from Baláta-tó (KISS and KRISTIANSEN 1994, PÉTERFI et al. 1998a, b).

Mallomonas cratis Harris et Bradley (Figs. 2.26–27)
It has a wide, almost bipolar distribution, mainly in temperate regions (KRISTIANSEN 1995). New to Hungary.

Mallomonas parvula Dürrschmidt (Fig. 2.29)
Like *M. alata*, it also has a bipolar distribution (KRISTIANSEN and VIGNA 1996). HICKEL and MAAß (1989) found it in shallow eutrophic and mesotrophic lakes in Northern Germany and also in brackish water. New to Hungary.

Mallomonas pseudocratis ?v Dürrschmidt (Fig. 2.30)
Only a few single scales were found. This species has been reported only from a few parts of the world, from the temperate region (Southern Chile, DÜRRSCHMIDT 1983; Tasmania, CROOME and TYLER 1985) as well as from the tropics (Sri Lanka, DÜRRSCHMIDT and CRONBERG 1989. India, WUJEK and SAHA 1996). The scale structures of *M. pseudocratis* and *M. cratis* are very similar. According to the first description of the species by DÜRRSCHMIDT (1983), a number of features distinguish it from *M. cratis*. These are among others: the ribs on the dome are longitudinal or oblique, but never U-shaped; there is a wing-like structure that overhangs the anterior flange; there are no teeth along the edge of the hood, in the angle of the V-rib; there are no struts on the anterior flange as prolongations of the ribs, though there can be hints of struts; there is uniformity in the appearance of all body scales. *M. cratis* was a fairly common species. In samples of one of the ponds from the same area (in Lengyeltóti) *M. cratis* and *M. pseudocratis*-like scales were found together in the same assembly of scales, obviously belonging to the same cell. DÜRRSCHMIDT (1983 Fig. 2) shows a group of the same type of *M. pseudocratis* scales staying in regular rows. In our samples from Lengyeltóti, however, only a few *M. pseudocratis*-like scales were placed together with more *M. cratis* scales, and transitional forms were also observed in a row. Unfortunately in the samples from Kis-Balaton only single *M. pseudocratis*-like scales were found. Thus the taxonomic relationships of the species need further investigation. *M. pseudocratis* is new to Hungary.

Mallomonas schwemmlei Glenk (Fig. 2.28)
This species has a wide distribution in the Northern Hemisphere. Although the single scale we found is partly hidden, the anterior flanges, which are important for the identification, can be seen. *Mallomonas dickii* and *Mallomonas doignonii* both have similar scales with a ribbed pattern, but there is a well-defined difference: the anterior submarginal ribs of *M. schwemmlei* are dissimilar, because on one side there is a membrane-like outgrowth (ASMUND and KRISTIANSEN 1986). New to Hungary.

Mallomonas striata Asmund (Fig. 2.31)
Widespread, cosmopolitan species. New to Hungary.

Mallomonas tonsurata Teiling em. Krieger (Fig. 2.32)
A cosmopolitan species, found mostly in eutrophic, alkaline waters. Beside Kis-Balaton, it was also found in the river Danube, in Lake Balaton and on Hortobágy (KISS and KRISTIANSEN 1994, PÉTERFI et al. 1998b).

As a result of a summer sampling in 1991 KRISTIANSEN and PADISÁK (1992) found 8 species of silica-scaled chrysophytes in Kis-Balaton. In addition to this – except *Chrysosphaerella annulata* – 19 further species were found during our investigation in spring 1999. The affiliation of the only *Synura spinosa* – or *Synura curtispina*-like scale is questionable. *Chrysosphaerella annulata* has a scattered occurrence in both temperate and tropical regions (HANSEN 1996). It was not found in the spring-samples, which could be due to its preference for warmer water. Table 1 contains a list of the species found during spring. The most abundant species were *Paraphysomonas vestita*, *Synura petersenii* and *Mallomonas alpina,* all three are widely distributed and cosmopolitan, occurring mainly under eutrophic conditions (KRISTIANSEN and PADISÁK 1992). However, the measured TN and TP values represent different trophic states according to the guidelines of FRINK and NORVELL (1984). 323.08 μg l^{-1} of TN indicates mesotrophic but 48.57 μg l^{-1} of TP eutrophic conditions. *S. petersenii* is present throughout the year; it sometimes even forms water-blooms in autumn and winter in backwaters of the Danube (KISS and KRISTIANSEN 1994). These three species and two others – *Mallomonas acaroides* and *Mallomonas cratis* – were the most common silica-scaled chrysophytes in Kis-Balaton in April 1999. The optimal pH value (8.0–8.1) for both *Mallomonas alpina* and *M. acaroides* (SIVER 1988) was present in

Tab. 1. List of silica-scaled chrysophytes found during the spring sampling of Kis-Balaton Reservoir (April 1999), with the new findings.

Species name	scale-density on the grids	new to Kis-Balaton	new to Hungary
Chrysosphaerella brevispina	1 spine-scale, few plate-scales	+	
Paraphysomonas imperforata	few scales	+	+
Paraphysomonas corynephora	few scales	+	+
Paraphysomonas punctata ssp. punctata	few scales	+	+
Paraphysomonas punctata ssp. simplicior	few scales	+	+
Paraphysomonas sp. cf. butcheri	1 single crown-scale	+	+
Paraphysomonas sp. cf. circumvallata	few scales	+	+
Paraphysomonas vestita	very many scales		
Spiniferomonas cornuta	few scales	+	+
Spiniferomonas trioralis	few scales		
Synura echinulata	1 single scale	+	
Synura petersenii	very many scales		
Synura spinosa?	1 single scale	+	
Synura uvella	few scales	+	
Mallomonas acaroides	many scales		
Mallomonas akrokomos	few scales	+	
Mallomonas alata	1 single scale	+	
Mallomonas alpina	very many scales		
Mallomonas annulata	few scales	+	
Mallomonas caudata	1 single scale	+	
Mallomonas cratis	many scales	+	+
Mallomonas parvula	few scales	+	+
Mallomonas pseudocratis?	few scales	+	+
Mallomonas schwemmlei	1 single scale	+	+
Mallomonas striata	few scales	+	+
Mallomonas tonsurata	few scales		

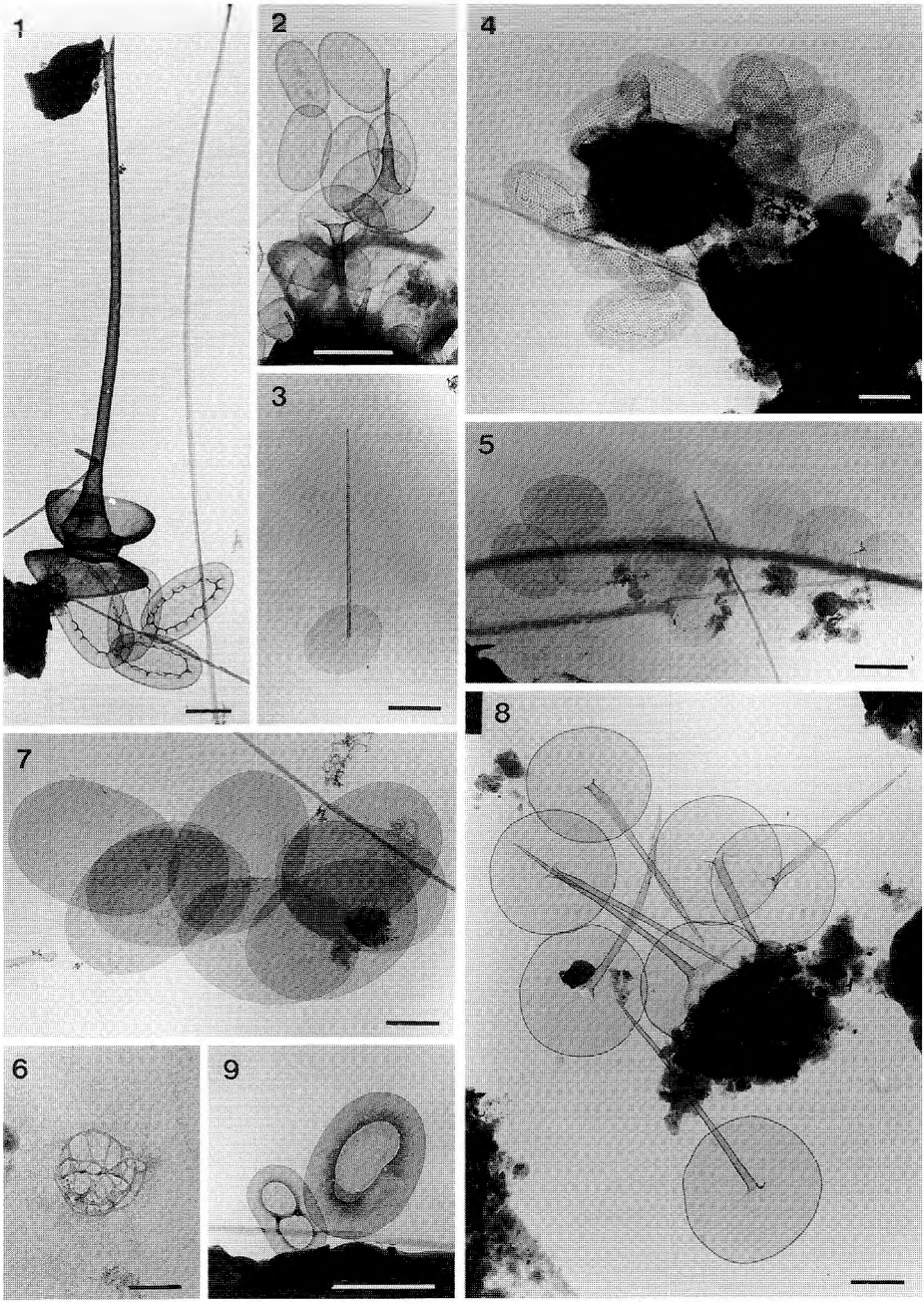

Fig. 2. (1–9). Type of scales. 1-*Chrysosphaerella brevispina*, plate-scales and spine-scale; 2-*Paraphysomonas corynephora*, plate-scales and spine-scales; 3-*Paraphysomonas imperforata*; 4-*Paraphysomonas punctata* ssp. *punctata*; 5-*Paraphysomonas punctata* ssp. *simplicior*; 6-*Paraphysomonas* sp. cf. *butcherii*, crown scale; 7-*Paraphysomonas* sp. cf. *circumvallata*; 8-*Paraphysomonas vestita*; 9-*Spiniferomonas cornuta*, two types of scales. The scale-bars indicate 1 μm, except Fig. 2.6, where it is 0.25 μm.

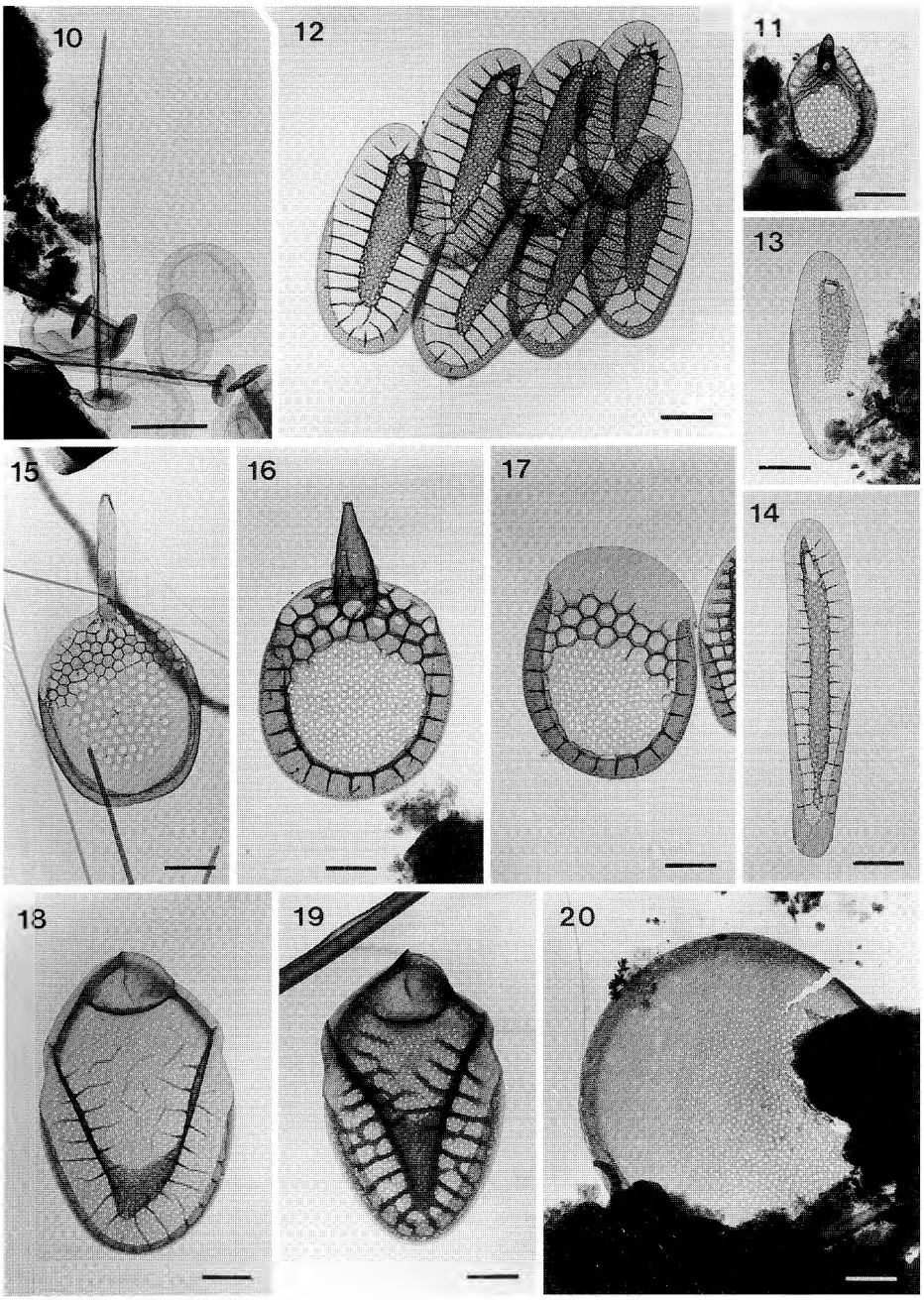

Fig. 2. – continued (10–20). 10-*Spiniferomonas trioralis*, plate-scales and spine-scales; 11-*Synura echinulata*, apical scale; 12-*Synura petersenii*, scales with spine, 13-*Synura petersenii*, weakly silicified scale, 14-*Synura petersenii*, basal scale; 15-*Synura spinosa*?, apical or body scale; 16-*Synura uvella*, apical or body scale, 17-*Synura uvella*, basal scale; 18-*Mallomonas acaroides*, weakly silicified scale, 19-*Mallomonas acaroides*, heavily silicified scale; 20-*Mallomonas caudata*. The scale-bars indicate 1 μm.

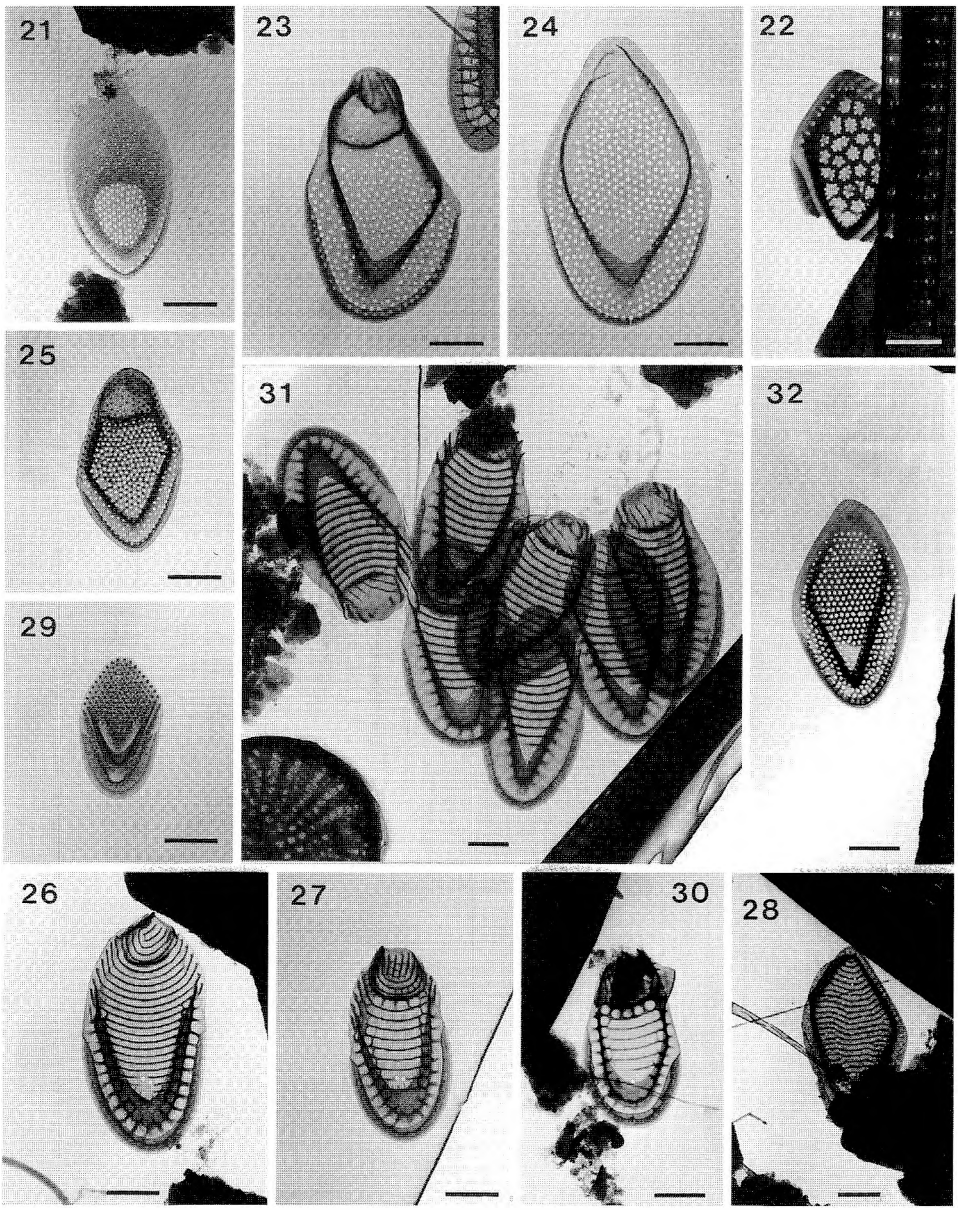

Fig. 2. – continued (21–32). 21-*Mallomonas akrokomos*, body scale; 22-*Mallomonas alata*, body scale; 23-*Mallomonas alpina*, dome-bearing apical scale, 24-*Mallomonas alpina*, domeless body scale; 25-*Mallomonas annulata*, dome-bearing body scale; 26, 27-*Mallomonas cratis*, two different types of scales; 28-*Mallomonas schwemmlei*, body scale; 29-*Mallomonas parvula*, body scale; 30-*Mallomonas pseudocratis*, body scale; 31-*Mallomonas striata*, body scales; 32-*Mallomonas tonsurata*, domeless body scale. The scale-bars indicate 1 μm.

Kis-Balaton. *S. petersenii* and *M. acaroides* (together with *S. curtispina*), were found in almost all the rivers and lakes that have been studied for this purpose in Hungary (KRISTIANSEN and PADISÁK 1992, KISS and KRISTIANSEN 1994, PÉTERFI et al. 1998a, b). *Mallomonas akrokomos* and *Mallomonas annulata* have a preference for colder water, which might explain why they were not found in the summer samples of Kis-Balaton. *M. akrokomos* is mostly reported from slightly acidic water bodies, but SIVER (1988) found pH 8 as its top border of occurrence. *Paraphysomonas imperforata, P. vestita* and *Spiniferomonas trioralis* are very common species all over the world. However, *P. imperforata* has never been recorded, not only from Kis-Balaton but even from Hungary. We assume that this is due to the scales having been overlooked, since the scales of *P. imperforata* and *P. vestita* might look very similar at a superficial glance. *Mallomonas tonsurata* and *Mallomonas striata* are also cosmopolitan species. Nevertheless, this is the first record of *M. striata* from Hungary. This might be due to the fact that this species is somewhat alkaliphilous having a pH preference of 7.8 (SIVER 1988) and in the previous Hungarian investigations pH – if measured – was always less than 7. *Paraphysomonas punctata* was represented with two subspecies, from them *P. punctata ssp. simplicior* is quite rare. *Spiniferomonas cornuta, Mallomonas pseudocratis* and *Mallomonas schwemmlei* also contribute to the special character of the habitat, as there are not very many reports of them on a world scale. *M. pseudocratis* has only been reported from Southern Chile, Tasmania, Sri Lanka and India (DÜRRSCHMIDT 1983, CROOME and TYLER 1985, DÜRRSCHMIDT and CRONBERG 1989, WUJEK and SAHA 1996). However, the identification of this species might be questionable according to our observations of other samples, as mentioned in the description.

Kis-Balaton seems to be not only one of the most special bird-areas, but the home of many species of silica-scaled chrysophytes. A spring sample was needed to get a more complete picture of the habitat concerning these algae, as was also emphasised in the previous investigation.

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