

ON THE TRAIL OF THE HUNGARIAN SILICA-SCALED CHRYSOPHYTES: A HISTORICAL REVIEW

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Abstract: Silica-scaled chrysophytes form a unique group of protists and have significant contribution to ecosystem services (provisioning, supporting, regulating, and cultural services). In Hungary, scientific research on silica-scaled chrysophytes actually began in the early 1990s, since has undergone rapid development. Professor Judit Padisák, a leading figure in Hungarian hydrobiology and limnoecology, played a key role in this field. The development of Hungarian research was made possible not only by her personal scientific commitment, but also by her national and international cooperation efforts. Therefore, the present paper summarises the history of Hungarian research on silica-scaled chrysophytes in honour of Professor Judit Padisák's passion and scientific works.

Key words: chrysophyceae, history, Hungary, Judit Padisák, recent flora

INTRODUCTION

Chrysophytes belong to the superkingdom of Eukaryota, clade of Stramenopiles, phylum of Ochrophyta, and class of Chrysophyceae (KRISTIANSEN and ŠKALOUD 2017, SCHOCH *et al.* 2020) forming many genetically and morphologically distinct lineages. Within this algal group, there are many species with siliceous coverage (scale, spine, bristle) including *Chrysosphaerella*, *Lepidochromonas*, *Mallomonas*, *Neotessella*, *Paraphysomonas*, *Polylepidomonas*, *Spiniferomonas*, and *Synura* (KAPUSTIN and GUSEV 2019, KRISTIANSEN and PREISIG 2007, KRISTIANSEN and ŠKALOUD 2017). This ultrastructure is the basis of the well-developed taxonomic system for species differentiation, and their consistent and reliable studies (KRISTIANSEN 2005, ŠKALOUD *et al.* 2013a). The species number is continuously changing year by year due to the newly described species worldwide (Fig. 1). Currently, approximately 350 taxa of silica-scaled chrysophytes are described (GUIRY and GUIRY 2025), but this number certainly does not reflect their real species richness, which has been probably underestimated and far from complete.

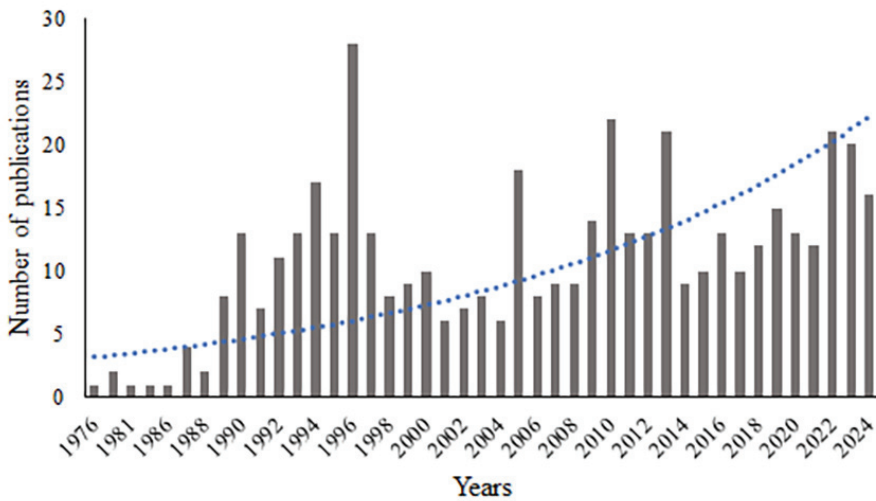


Fig. 1. The number of publications describing new taxa of silica-scaled chrysophytes – involving fossil and recent taxa – on the basis of the “Web of Science” database (searching for keywords of ‘new’, ‘species’, ‘silica-scaled’ at July 31, 2025) and its temporal trend (dotted line).

Despite the relatively low taxon number compared to other algal groups, silica-scaled chrysophytes are unique organisms and they have significant contribution to many ecosystem services (reviewed by LENGYEL *et al.* 2023): supporting (e.g. primary production, biogeochemical cycling), regulating (e.g. water purification), provisioning (e.g. production of biochemicals), and cultural services (e.g. inspiration source). Despite their huge importance, silica-scaled chrysophytes still represent a pretty much neglected algal group compared to others (e.g. diatoms), thus there is a need for their more detailed research in the future.

BIOGEOGRAPHICAL IMPORTANCE

Silica-scaled chrysophytes have special ecophysiological characteristics (KRISTIANSEN and ŠKALOUD 2017, SANDGREN 1988, SANDGREN *et al.* 1995). They do not have enzymes that would enable them to use hydrogen carbonate as a carbon source and absorb phosphate from alkaline waters. They are nutritionally opportunistic. Furthermore, they have flagellates enabling them to have ‘wobbly’ movement. On the basis of these characteristics, their distribution can be very limited and restricted to slightly acidic habitats with medium-high humic content, and low exposure to wind. With the exception of certain areas, this type of water is typically rare worldwide, occurring mostly in isolated locations.

Consequently, many species have well-defined geographic distribution types, such as bipolar, cosmopolitan, pantropic, endemic, etc. (KRISTIANSEN 2001*a, b*, KRISTIANSEN and VIGNA 1996).

In Hungary, this kind of aquatic habitats (Fig. 2) is likely to be scarce for geochemical reasons, but the country is in a special biogeographical borderline situation. Nordic species appear in large numbers in early spring, whilst tropical species are typical in summer. Changes in species distributions may indicate climate change processes, therefore the research of Hungarian silica-scaled chrysophytes may be of great importance for our future.



Fig. 2. A typical habitat of silica-chrysophytes situated in Hungary (a small brownish forest lake in Mt Kab).

HUNGARIAN RESEARCH

Before 1990 – The beginnings

The earliest publication dates back to 1865 (MARGÓ 1865), which reported the presence of the species *Synura uvella*. After that, plenty of references were published about the Hungarian flora of silica-scaled chrysophytes recording altogether 32 taxa (reviewed by KRISTIANSEN and PADISÁK 1992, collected in the database “Flora et Iconographia Algarium Hungariae” (BUCZKÓ and RAJCZY 1998)). Nevertheless, all these studies are based on light microscopy (LM), thus

the real identity of the species is highly debatable. Therefore silica-scaled chrysophytes had remained virtually unknown in Hungary until the late 1980s, as their accurate and reliable identification required electron microscopy (EM), which was only available to a limited extent at that time.

Hungarian research using transmission electron microscopy was started by Lajos HAJDU (1975), who firstly recorded the presence of *Paraphysomonas vestita*. Later, the periphytic algal flora in the River Danube was studied, which also resulted in the verification of further three species of silica-scaled chrysophytes, such as *Mallomonas tonsurata*, *Synura glabra*, and *S. petersenii* (ÁCS and KISS 1991, KISS 1987).

Between 1990 and 2000 – The pioneering phase

This period was characterised by intensive researches exploring the hidden flora of silica-scaled chrysophytes using electron microscopy. Surveys were conducted in many parts of the country including approximately 100 aquatic habitats. Judit Padisák's research represented a significant milestone in these investigations. One of her major studies on this topic was published jointly with Professor Kristiansen in 1992. They recorded altogether eight taxa from the Kis-Balaton Water Protecting reservoir, including three new Hungarian occurrences (*Chrysosphaerella annulata*, *Spiniferomonas trioralis*, *Synura curtispina*). Shortly afterwards, seven taxa were found by investigating the algal flora in the River Danube, River Tisza, Eastern Main Canal, and Lake Balaton (KISS and KRISTIANSEN 1994). As a result of this extended survey, *Synura echinulata* was newly recorded.

From the following years, research shifted its focus from biodiversity aspects to ecological assessments, and studies began on linking species to environmental parameters (pH, conductivity, nutrient content, etc.). Judit Padisák was the centre of these researches, too, who contributed significantly to bringing Hungarian research of silica-scaled chrysophytes into line with international trends through many co-operations. Two prominent figures of these international relations were Leontin Stefan Péterfi (Babeş-Bolyai University, Romania) and Laura Momeu (Institute of Biological Research, Romania). As part of the early major collaborations, permanent and temporary lakes of Hortobágy (PÉTERFI *et al.* 1998a), as well as the bog-lake called 'Baláta-tó' located in the southeastern part of the country (PÉTERFI *et al.* 1998b) were studied. These investigations led to the discovery of 26–26 taxa, among them a total of 25 were considered new for Hungary (listed in Appendix 1). As further novelty, many of the records were new not only for the country, but also for the Carpathian Basin (e.g. *Mallomonas corymbosa*) or even for Europe (e.g. *Mallomonas scalaris*; PÉTERFI *et al.* 1998a, b). Additionally, a huge variability in species with different habitat preferences was also found with a special attention to

the occurrences of two tropical/subtropical species (*Mallomonas cyathellata* and *M. portae-ferreae*). Overall, a broader interest of habitat specific case-studies than local ones was concluded due to their surprisingly rich flora and their potential importance in understanding mechanisms in the field of phycogeography.

After 2000 – The broadening research

As a consequence of the previous findings, larger-scale investigations were started to explore different types of aquatic habitats. In light of this, the Kis-Balaton Reservoir was re-examined first (BARRETO *et al.* 2000), which resulted in greater species richness than it was previously found (KISS and KRISTIANSEN 1994). Altogether 20 taxa were new for this habitat and 12 taxa for Hungary (listed in Appendix 1). Within the framework of another international cooperation, samples collected from different types of habitats (e.g. backwaters, fishponds, small lakes) in various areas of Hungary between 1995 and 1996 were reanalysed (PADISÁK *et al.* 2000). As a result, 20 silica-scaled taxa were recorded without any new Hungarian occurrence. Subsequently, 33 localities were studied in 1999 in order to give floristical overview about the Hungarian flora. This comprehensive research yielded

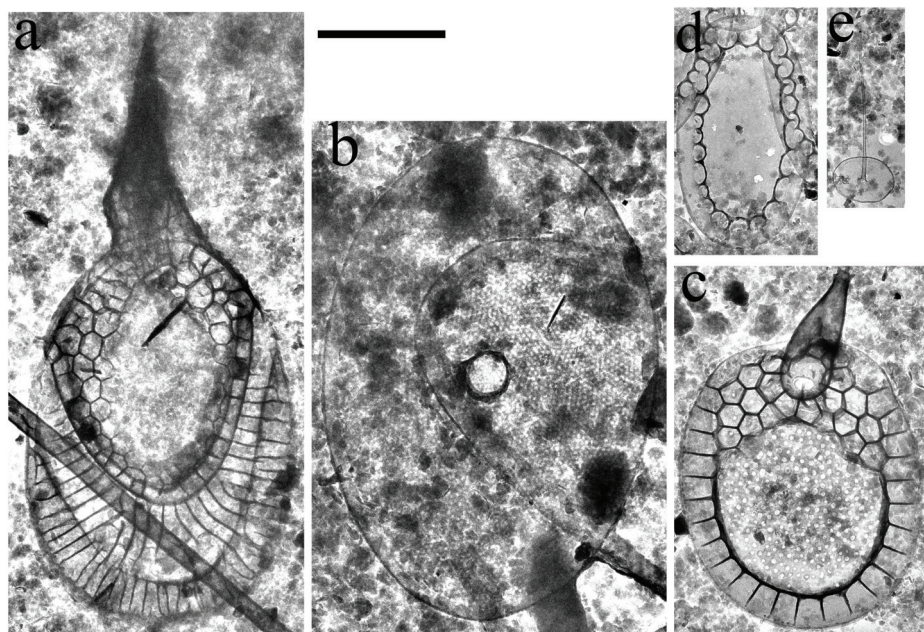


Fig. 3. Transmission electron microscope (TEM) microphotographs of some characteristic silica-scaled chrysophytes found in Hungary. Silica scale of *Mallomonas insignis* (a), *Neotessella lapponica* (b), *Synura uvella* (c), *Chrysosphaerella brevispina* (d), *Pharaphysomonas vestita* (e). Scale bar: 2 μ m.

many outstanding results published in 2001 and 2005. Firstly, three new taxa on a global scale were described from the Visegrád Mts, which is unique and outstanding in terms of Hungarian research (BARRETO 2001). Up to date, the distribution of *Mallomonas formosa* and *M. cucullata* is solely known from Hungary, whilst *M. tubulosa* was recorded from France and the Czech Republic too (ŠKALOUD *et al.* 2013b). As another significant aspect, this study explored many different areas (e.g. Mátra, Visegrád and Pilis Mountains) and habitat types (e.g. groundwater ponds, forest ponds, quarry ponds, swamps) which had previously been unknown in terms of silica-scaled chrysophytes research (BARRETO 2005). Overall, Sára Barreto's research contributed to the knowledge of Hungarian flora with 38 new findings and description of their ecological requirements. The latest research was conducted in 2013 and focused on the survey of small forest ponds located in Mt Kab in the Transdanubian Mts (PADISÁK *et al.* 2015). As a result, a particularly rich flora was discovered including 35 taxa with five new occurrences. Thereby, the Hungarian flora of silica-scaled chrysophytes was extended and currently consists of 98 taxa (Fig. 3, Appendix 1, electronic supplement).

Future perspectives

Research on silica-scaled chrysophyte algae is a classic example of how a new methodological paradigm (EM) emerges in the scientific life of a country. Significant progress has been made in data collection, mapping and morphotype analysis, thus we have moved from an initial taxonomic gap to an internationally comparable body of knowledge that is also recorded in a famous electronic database. The post-2010 era has been characterised internationally by the spread of molecular taxonomy based on DNA sequencing. Given the biodiversity of the Hungarian flora discovered so far, these methods could be pioneering in the future in finding more hidden species.

CONCLUSIONS

Although the species list is far from complete, the research results summarised in the present paper highlight Hungary's richness in silica-scaled chrysophyte algae. The series of national examples all prove that most of the aquatic habitats studied are particularly important in terms of biodiversity. All the anthropogenic activities (e.g. land-use), future climate change, and increasingly frequent extreme weather events can lead to dramatic loss in their biodiversity, and, consequently, in the ecosystem function and services they maintain. Furthermore, Hungarian flora may also play a prominent role in the research of biogeographical patterns and species distributions. For these reasons, further detailed research is strongly necessary.

* * *

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Összefoglaló: A szilíciumpikkelyes flagelláták a protiszták egyedi csoportját alkotják, amelyek jelentős szerepet játszanak az ökoszisztéma-szolgáltatásokban (ellátó, támogató, szabályozó és kulturális). Magyarországon a szilíciumpikkelyes flagelláták tudományos kutatása csak az 1990-es évek elején kezdődött el igazán, majd gyors fejlődésen ment keresztül. Prof. Dr. Padisák Judit, a magyar hidrobiológia és limnológia kiemelkedő alakja kulcsszerepet játszott ebben a folyamatban. A magyar kutatások fejlődését nemcsak személyes tudományos elkötelezettsége, hanem hazai és nemzetközi kapcsolatépítései is lehetővé tették. Jelen tanulmány célja, hogy összefoglalja a szilíciumpikkelyes flagelláták magyarországi kutatásának történetét, tisztelegve Prof. Dr. Padisák Judit szenvedélyes és tudományos munkássága előtt.

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Appendix 1 – available elctronically at <http://publication.nhmus.hu/studbot/bannales.php?volume=56>

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