Annales Universitatis Paedagogicae Cracoviensis
Studia Naturae, 9: XX–XX, 2024
ISSN 2543-8832
DOI: 10.24917/25438832.9.x

[1]Wojciech W. A. Kowalski, [2]Hanna Szymańska

[1]Independent Researcher, Kadetów 14/2 St., 71-227 Szczecin; Department of Botany and Nature Conservation, West Pomeranian University of Technology in Szczecin, J. Słowackiego 17 St., 71-434 Szczecin, Poland; e-mail: wojciech.wakowalski@wp.pl

[2] Independet Researcher, 21 Pobondzie St., 16-406 Rutka Tartak; Faculty of Biology, Department of Biological and Chemical Research Center, University of Warsaw, 101 Żwirki and Wigury St., 02-089 Warsaw, Poland

Actinotaenium globosum (Bulnh.) Först. ex Comp. (=*Cosmarium globosum* Bulnh.) and *Staurastrum avicula* Bréb. in the plankton of the Wigry Lake.

Materials for phycoflora of the Wigry National Park

Abstract

The paper presents information on the occurrence of mesotrophic taxa of the order Desmidiales in the Wigry Lake (north-eastern Poland). The morphology of the cells and the photographic and drawing documentation made it possible to classify them into three taxonomic units, which are: *Actinotaenium globosum* (Bulnh.) Först. ex Comp., *Staurastrum avicula* Bréb. var. *avicula* Ralfs and S. *avicula* Bréb. var. *exornatum* Messik. – the last variety has not yet been recorded in the phycoflora of Polish. The size of the cells and the submicroscopic ornamentation of their walls as well as the features of the shape of the internal organisation of the protoplast are consistent with the data. The identified taxa occur in large numbers in the plankton of the bay and waters of the Wigry Lake.

Keywords: Desmidiales, Masurian Lake District, phytoplankton, Poland
Received: [2024.05.27]
Accepted: [2024.08.19]

Introduction

The occurrence and dynamic development of the population of one taxon and sometimes accompanying species with similar habitat requirements is a consequence of the physico-chemical-biological factors defined in the aquatic environment. They are an important parameter, the scope of which prefers the requirements and favours the development of a specific taxonomic composition of phycoflora.

One of the places of occurrence of interesting species of phycoflora is the channel Wigry Lake, located in north-eastern Poland, in the Podlaskie Voivodeship (Fig. 1).

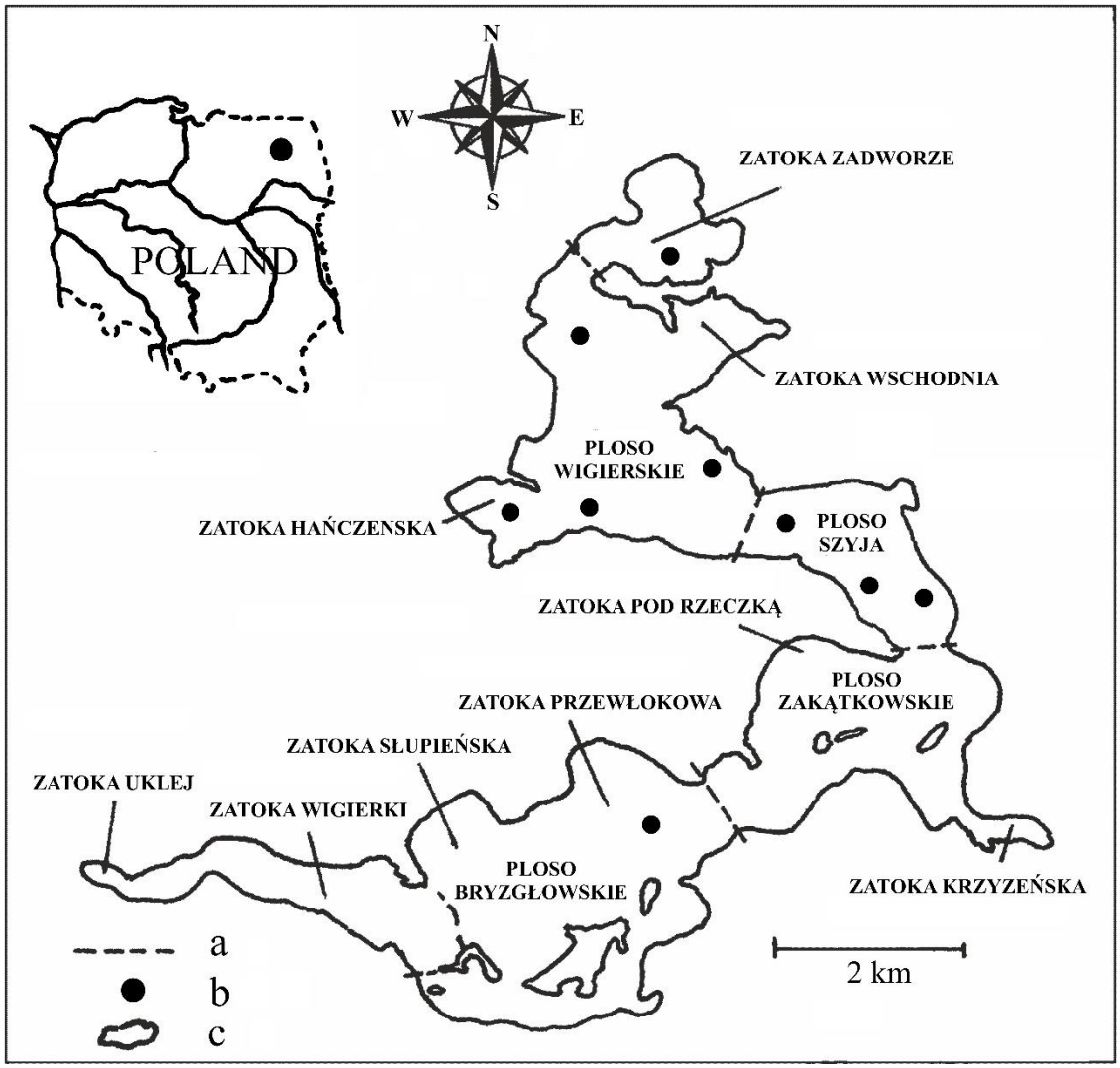

Fig. 1. Phytoplankton research sites in the Wigry Lake basin: a – boundaries of the lake ploses, b – sample areas (study area), c – islands (the shape of the lake basin was developed based on IRŚ data); "zatoka" means bay

This lake is located on the border of the East Suwałki Lakeland and the Augustów Plain (Masurian Lake District). The area of Wigry Lake is about 2115 hectares, and its average depth is 15.4 meters – maximum depth up to 74.2 meters. Wigry Lake is one of the deepest and largest lakes in Poland (Choiński, 1991).

Research on the lake's phytoplankton dates back to the beginning of the 19th century. The first information about planktonic algae in Wigry Lake and neighbouring lakes appeared in the work of Heyneman (1902), a Russian zoologist, and Schröder (1917), a German phytoplankton researcher. Schröder analysed three samples collected in the summer of 1916

from the Wigry Plos southwest of the monastery, identifying 33 species of planktonic algae. In the interwar period, research on the algae flora was conducted by Wołoszyńska (1922).

More detailed research was performed by Wisłouch (1926). These researches included material collected in the years 1924-1925 and concerned summer phytoplankton of Wigry Lake collected from six sites, including Uklei Bay (6 samples), Wigry (1 sample), Wigry under Wysokim Wegielem (1 sample), Wigry pod monastery (1 sample), Wigry at the mouth of Czarna Hańcza (1 sample), Northern Plos near the village of Tartak (1 sample). Wisłouch identified a total of 40 taxa in the collected materials. The greatest taxonomic diversity occurred in the Uklei Bay – 36 taxa. In samples from other sites, from 6 to 14 taxa were found.

Since 1992, the lake's plankton has been studied by Hutorowicz et al. (1992). These studies included the algal flora of sites located from Plos Północny to Uklei Bay. In the study, the authors determined the total biomass of phytoplankton and nanoplankton as well as the biomass and percentage of taxonomic units, indicating the dominant groups. A summary of the research results was presented by Tomaszewicz (1996). Since 1996, research on lake phytoplankton Wigry Lake was implemented by: Szeląg-Wasilewska, Gołdyn (1996), Hutorowicz (1999, 2000), Krzywosz, Hutorowicz (1999), Grabowska, Górniak (2005), Hutorowicz, Łukarska-Czyżew (2005), Owsianny, Grabowska (2007) and others. In the years 2012-2014, Szymańska carried out in-depth research on the flora of planktonic algae in Wigry Lake. They included samples collected from spring to autumn in different parts of the lake. In the collected research material, approximately 200 taxa representing various taxonomic units were identified. However, the research results have not been published.

The main aim of this study was to present interesting taxa of the Desmidiales order from the genera *Actinotaenium* and *Staurastrum* recorded in the phycoflora of the Lake Wigry. The description of these species and their varieties was also aimed at (1) – drawing attention to the different terminology used in algological studies for the same species and unifying the taxonomic position of the species *Actinotaenium globosum* (Bulnh.) Först. ex Comp. (=*Cosmarium globosum* Bulnh.); (2) – mass development – "bloom" (flos-aqae) of both taxa in the waters of the lake, dominated by *A. globosum*, classified as a taxon of mesotrophic habitats; (3) – recording the occurrence of a variety of *Staurastrum avicula* Bréb. var. *exornatum* Messik, which has not yet been registered in the flora of algae in Poland, and is also very rare in Europe.

Material, methods

The material for the study was collected with a plankton net from near-surface waters of Wigry Lake in the zone of the frontal formation of macrohydrophyte communities and pelagic waters in May, July-November, 2012, and 2013. The research points marked on the map (Fig. 1) are sampling areas. In addition, the cells of planktonic forms inhabiting the wadding clusters of filamentous algae thallus floating in the water depths were washed out. The inspiration to undertake such research was the taxonomic recognition of epiphytic forms of the genera *Oedogonium* sp. div and *Bulbochaete* sp. div, from the order Oedogoniales, class Chlorophyceae.

The research material was collected from the water layer at a depth of approximately 0.5 m using a 5 l Patalas Scoop. The collected sample was concentrated on a plankton net no. 25. At the same time, plankton occurring in periphyton inhabiting the shoots of various species of aquatic plants in the euphotic layer of the lake were collected. A preliminary in-vital analysis of the material was performed in the laboratory, and then the samples were fixed with lactophenol. The determinations were made using Nikon microscope equipment with a photographic attachment at the Department of Plant Systematics and Geography, Faculty of Biology, University of Warsaw (Poland). The drawing documentation was developed based on the designed microscopic image. The laboratory prepared photographic (H. Szymańska) and drawing (W.W.A. Kowalski) documentation of the cells dominating the phytoplankton of two interesting taxa from the order Desmidiales.

Mesotrophic habitat preferences of identified taxa were determined based on information contained in basic monographic studies (Förster, 1982; Lenzenweger, 2003). Materials provided by the Directorate of the Wigry National Park were also used, i.e. the Protection Plan for the Wigry National Park and the Natura 2000 area "Ostoja Wigry" (*Plan ochrony… Natura 2000*), a report on the protection of water resources and ecosystems. Ecological and physicochemical parameters in Wigry Lake waters were compiled based on data from 2012 by Górniak et al. (2014). This report includes data from 1925 to 2012. The attached table shows the lowest and highest values of the tested parameters and the location of the test site (Tab. 1).

Based on the information contained in https://www.algaebase.org (Guiry, Guiry, 2024), the taxonomic position of *Cosmarium globusom* Bulnh. was verified – the species name is currently considered a synonym of *Actinotaenium globusom* (Bulnh.) Först. ex Comp.

Tab. 1. The values of the lowest and highest analysed parameters obtained in the summer of 2012 for surface waters in the bays and fields of the Wigry Lake (Górniak et al., 2014)

Smallest parameter value	Research position	Parameter value highest	Research position
1. Visibility of Sechi's puck [m]			
2.5	Plos Wigry	3.4	Bryzgiel Bay
2. Water pH			
8.6	Zadworze Bay	8.9	Krzyżańska Bay
3. Concentration of phosphorus compounds [mgP/m3]			
8.4	Zadworze Bay	33.5	Krzyżańska Bay
4. Total phosphorus concentration [mgP/m3]			
30.4	Krzyżańska Bay ★ Plos Szyja	62,5	Northern Plos
5. Mineral nitrogen concentration – ammonium ions [mgN/m3]			
49	Krzyżańska Bay	228	Plos Szyja
6. Summer nitrate concentration [mgN/m3]			
78	Plos Szyja	238	Uklejowa Bay
7. Concentration of dissolved organic carbon compounds [DOC mg/dm3]			
2.32	Słupiańska Bay	8.75	Plos Szyja
8. Concentration of chlorophyll *a* in the epilimnion			
0.65	Zadworze Bay	4.09	Krzyżanska Bay
9. Iron concentration [µg/dm3]			
12	Krzyżańska Bay★ Słupiańska Bay	259	Bryzgiel Bay

★ - for posts with identical post

Result and short discussion

Notes on the ecology and occurrence of *Actinotaenium* and *Staurastrum*

The species composition of phytoplankton in freshwaters depends on many factors that change during the growing season. The consequence of these transformations is a change in habitat conditions. Eurotypical, low stenotopic species that live within a narrow range of habitat variability have a high tolerance to changes in one or more factors. Plankton with a taxonomic composition dominated by cells representing *Actinotaenium globusom* and *Staurastrum avicula* (its varieties) occurred in both growing seasons throughout Lake Wigry (Fig. 1-2), except for the extreme western part the Uklej Bay. It was particularly numerous in the northern, most eutrophicated part of the reservoir, especially in autumn.

The growing season of the observed taxa begins in summer, but the occurrence of dominant species in July-August is rare, and cell division stages were rarely observed. The optimal dynamic development of the basic taxa observed occurs in the second half of September and the first half of October. Cell divisions are very dynamic during this period, especially in the Northern Plos, less numerous in the meso-eutrophic Szyja Plos and other parts of the reservoir.

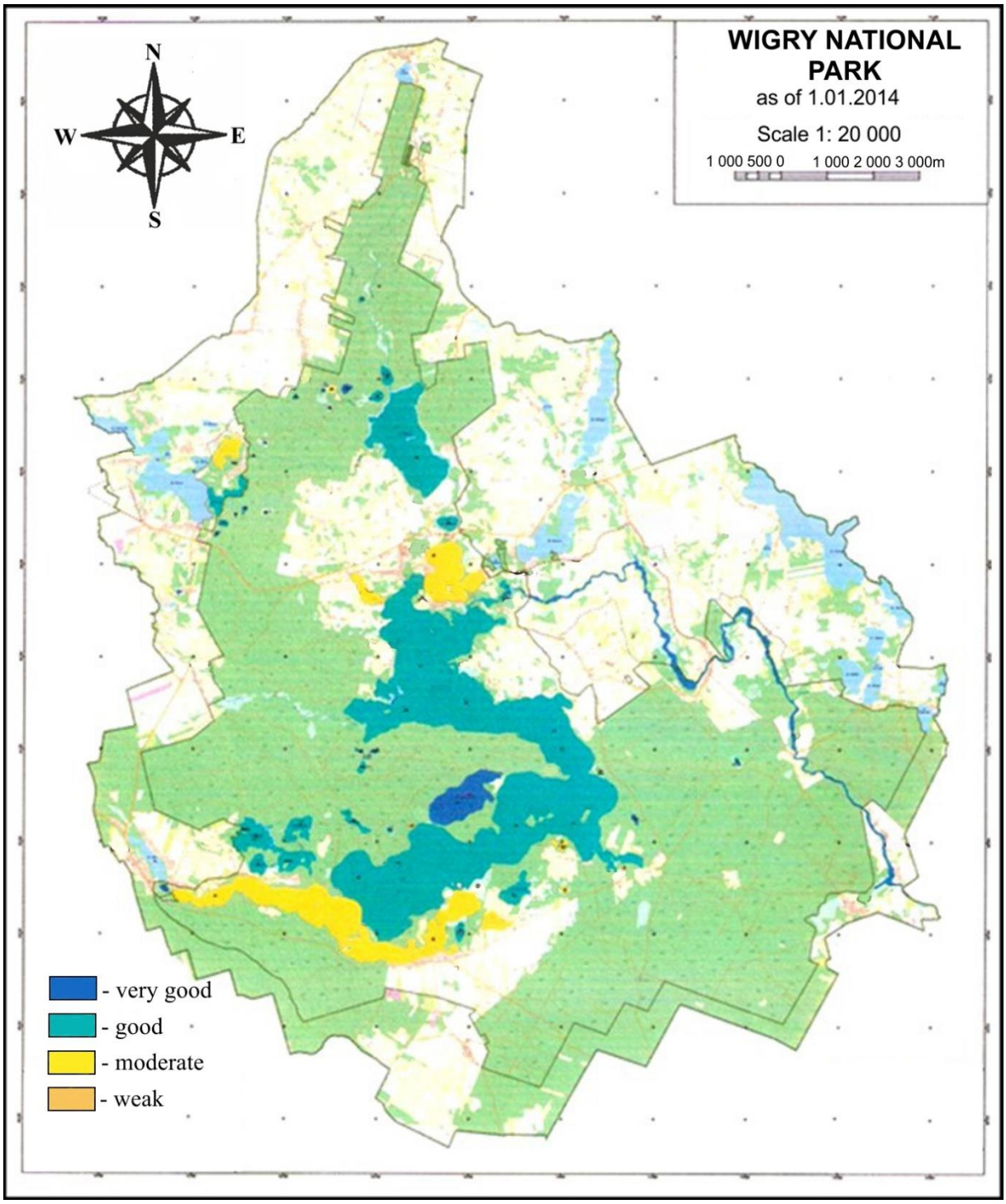

Fig. 2. The ecological state of aquatic ecosystems in the Wigry National Park (Source: *Mapa stanu ekologicznego* … (2014) – changed)

In November, numerous cells of the analysed taxa, also dividing, occur in the southern part of Plos Szyja and the eutrophicated Hańcza Bay (the mouth of the Czarna Hańcza River). In addition to living and dividing cells, there are dying cells throughout the basin at that time.

Taxonomic position of algae occurring in the plankton of the Wigry Lake

The most numerous inhabitants of periphyton and plankton formations in lake waters are: Wigry were: *Actinotaenium globosum* (Bulnheim) K.Förster ex Compère and S*taurastrum avicula* Brébisson var. *avicula* Ralfs – a variety of the typical and very rare *Staurastrum avicula* Brébisson var. *exornatum* E.Messikommer (1929).

Actinotaenium globosum (Bulnh.) Först. ex Comp. Fig. 3A–C, Fig. 4–5 – Appendix 1

Basionym: *Cosmarium globosum* Bulnh. 1861. in Hedwigia, p.52, vol.9, f.S

Synonyms: *Calocylindrus strangulatus* Cooke &Wills in Cooke, Brit. Desm. 1887, p.128, vol. 44, f. 10; West, Alg. N. Yorks, 1889, p.293; *Dysphinctium globosum* (Bulnh.) Hansg. Prodr. Algenfl. Böhm. 1888, p.243; De Toni, Syll. Alg. 1889, p. 880; Heimerl, Desm. alp. 1891, p. 593; *Dysphinctium strangulatum* De Toni, Syll. Alg.1889, p. 887; *Cosmarium globosum* Bulnh. form Borge, Süssw. Chlorine. Archang. 1894, p.23, vol.2, f.20; *Dysphinctium globosum* (Bulnh.) Hansgirg (1886), *Pleurotaeniopsis strangulatus* (Cooke et Wills) Espenschied 1903, S.104, t.2, f.26; Migula, 1907, Algen. Teil I, S. 399, T.24B, F.6; *Cosmarium moliniforme* (Turp.) Ralfs bei Bernard 1908, S.90, T.6, F.119; *Dysphinctum cucurbita* (Bréb.) Reinsch forma. A. Reinsch, 1807, S.178; *Cosmarius globosum* Bulnh. form Wolle, 1884, S.60, T.15, F.20; Wolle, Bethlehem, Pa., 1892, S. 65, T.18, F.20; Scott, Grönblad, Croasdale. Journal bot Fenn., 1965, S.44, T.8, F.20.

In the algological literature, the species was mentioned under various taxonomic names listed in AlgaeBase (Guiry, Guiry, 2024).

Description: Cells formed from two symmetrical, spherical half-cells, flattened at the base of their connection. The tops of the semi-cells are regularly rounded or slightly flattened. Cell length 30.8–31.7 μm, width 20.6–24.5 μm, lg.: br. 1.48–1.59. Isthmus 16.4–17.3 μm wide. The sine is broadly exposed, almost semi-circular, narrowed in the inner part, gently indented, and rounded in the top part. In the apical view, the cells are definitely round, with a diameter of 20.6–24.5 μm. Dividing cells of similar size, long 32.4–32.5 μm, wide 21.7 μm. Before the stem cells divide, their division line is marked in the isthmus zone. Each half-cell with one large spherical pyrenoid with a diameter of 9.8–11.0 μm. Chloroplasts, viewed from the apical side, clearly star-shaped and six-pointed. from the front side with 3 longitudinal ribs. Cell wall, colourless, smooth.

Occurrence and ecologies: *Actinotaenium globosum* (Bulnh.), Kurt Förster ex Compère it is classified as a cosmopolitan thymoplankton taxa, often found in acidic to moderately acidic waters (pH 4.0–6.7), in large lakes, in small water reservoirs, peat bogs, and swamps. A species

with a moderately arctic and subarctic range, also found in large African lakes and Amazonian streams Föerster (1982). Lenzenweger (2003) defines it as a taxon associated with biotopes, mesotrophic habitats of transitional and low peat bogs, the coastal zone of heath peat bogs, wet slopes and alpine ponds.

Distribution in Poland: In Polish phycological literature, the species is classified and presented as two separate taxa. It is given as *Cosmarium globosum* Bulnh. by, among others: Tomaszewicz (1970,1988), Kadlubowska (1952, 1961) and fo. brevior (Schröder, 1898) and fo. *minor* Sosnowska-Półtoracka (1966, 1974). In the study devoted to algae from the family Mesotaeniaceae and the order Desmidiales in the "Bagno Przerębiec" peat bog (Lesiak, 1984, 1990; Lesiak, Sitkowska, 1984), the taxon is listed under the name *Actinotaenium globosum* (Bulnh.) Först. ex Comp. The species' localities are also given: Eichler (1890), Sieminiak (1984a, 1984b), Siemińska, Siemińska (1967), Szklarczyk-Gazdowa (1956, 1965, 1966).

General distribution: Wet, West (1908) define the occurrence of the species as recorded in various parts of the world, both in Europe and the continents of both Americas, Australia, eastern Africa and southeast Asia. Lenzenweger (2003) includes the taxon in the genus *Actinotaenium* Teiling, describing it as frequently occurring.

Taxonomy:

The taxonomy of this species presented in various monographic studies on the species is not clearly defined. This applies especially to the form of the chloroplast. The original description – the basonym of the taxon was presented by Bulnh. (1861). In various modern studies, the species is classified as a species of the genus *Actinotaenium* sp. (Kossinskaja, 1952; Compére, 1976; Förster, 1982; Lenzenweger, 2003) or is considered a species of the genus *Cosmarium* sp. (Krieger, Gerloff, 1969, and others). The final taxonomic position as *Actinotaenium globosum* (Bulnh.) Först. ex Comp. (=*Cosmarium globosum* Bulnh.) is presented at AlgaeBase (Guiry, Guiry, 2024).

Abundant population of *A. globosum* in mid-lake plankton is accompanied by *Staurastrum avicula* Bréb. cells. In the phytoplankton material, the species appears mainly as a typical variety, *S. avicula* Bréb. var. *avicula* Ralfs, often occurring in various water reservoirs. It is extremely rare a variety of *S. avicula* Bréb. var. *exornatum* Messik. so far recorded in the Polish phycoflora (Tab. 2).

Tab. 2. Comparison of the characteristics of two analysed varieties of *Staurastrum avicula* Bréb. based on bibliographic data

Parameters of the compared varieties	*Staurastrum avicula* varieties	
	avicula Ralfs	*exornatum* Messik.
Cell length	30–45 [µm] 28–40 [µm] With spikes 22.5–34.5 [µm] Palamar-Mordvintseva (1982)	30–36 [µm] Coesel, Meesters (2007) 35.8–36.0 [µm]✶,
Cell width	35–55 [µm] Coesel, Meesters (2007), With spikes 30-45 [µm], width without spines 30–45 [µm], Lenzenweger (1997)	37–42 [µm] with spines 48.5–50.8 Coesel, Meesters (2007) breadth without spines 35.0–28.5 [µm],
Istmus	8,5–11 [µm] 9–11 [µm] Palamar-Mordvintseva (1982) 12–15 [µm] Lenzenweger (1997) 7–8.6 [µm] Hirano (1959)	No data in the literature 9.8–10.1 [µm] ✶
Sinus	sine usually linear, wide open at the end, or wide open with a sharp peak. Sinus open and acute-angled Palamar-Mordvintseva. (1982)	No data in the literature length spines 5.5–9.8 [µm]✶
Half-cells	Semicells in rough outline bovol-shaped, as a rule with two spines et each apical angle. Semiceiis in apical view (2-)3(-4) angular with concave to almost straidht sides, angles terminating in one or two spines Coesel, Meesters (2007) The semi-cells are triangular in shape, the tops of the cells are rounded. Palamar-Mordvintseva (1982)	Differs from the type variety only in the ornamentation of the cell wall. This consists of widened, elongated warts, some of which also have teeth on them and which are particularly noticeable in the parietal view in the form of two intramarginal rows parallel to the sides, parietal mites with coarse pores. Lenzenweger (1997) Semi-cells with two pairs of spines of different lengths
Ornamentation	Cell wall finely granulate, the granules around the angles arranged in concentric series , the granwules near the semicell centre may be much reduced Palamar-Mordvintseva (1982)	Differs from nominate variety in that the granules on the semicell body are partly fused to produce emarginated verrucae Coesel, Meesters (2007)
Habitat of the taxon	A species of mesotrophic habitats Coesel, Meesters (2007), Lenzenweger (2003)	A species of mesotrophic habitats Coesel, Meesters (2007), Lenzenweger (2003)

✶ – parameters of cells noticed in Wigry Lake plankton

Staurastrum avicula Bréb. var. ***avicula*** Ralfs, Fig. 3Da–Db, Fig. 6A–C – Appendix 1

Basionym: *Staurastrum papillosum* Kirch.

Synonym: *Rhaphidiastrum avicula* (Bréb.) Pal.-Mordv. (1982)

Description: In terms of shape, size. the ornamentation of cell walls, as well as the form of chloroplasts and pyrenoids of the cell do not differ from the descriptions of the nominal species. Height of cells with spines 34.0–35.2 μm, without spines 33.2–33.7 μm, width with spines 57.2–58. 6 μm, without thorns 35.9–39.3 μm, lg.:br. 0.59–0.61 μm. Isthmus 13.1–13.3 μm wide.

Occurrence and Oekologie: Lenzenweger (2003) classifies the taxon as a species associated with mesotrophic waters. Wayda (2023) found its occurrence in polyhumic reservoirs of the Górski Gorce massif (Southern Poland).

Distribution in Poland: In the Polish algological literature *Staurastrum avicula* Bréb. var. *avicula* Ralf is recorded relatively often from the waters of dam reservoirs, fish ponds, oxbow lakes, and less often from peat bog ecosystems. In the Catalog of Polish Prokaryotic and Eukaryotic Algae (Siemińska, Wołowski, 2003), until the publication of the last update, 12 localities of the typical species and 9 localities concerning its varieties and forms are given. These include *S. avicula* var. *aciculiferum* West and *S. avicula* var. *subarcuatum* (Wolle) West & G.S.West.

General distribution: Taxon rather common in Holocen peat pits elsewhere less common. (Coesel, Meesters, 2007). According to Kosinskaja (1982), on a wide ecological scale, cosmopolitan, It occurs in the flora of peat bogs, swampy places, in ponds, in the plankton of lakes, mainly in the coastal littoral, streams, and in rice fields. Widely distributed, including: Asia, Europe, North America, Brazil, Faroe Islands, Greenland (Hirano, 1959).

Staurastrum avicula Bréb. var. ***exornatum*** Messik. Fig. 3E, Fig. 6D–E – Appendix 1

Basionym: *Staurastrum avicula* Bréb. var. *exornatum* Messik.

Description: cell length 35.8–36.0 μm, breadth with spines 48.5–50.8 μm, breadth without spines 35.0–28.5 μm, length spines 5.5–9.8 μm, breadth of isthmus 9.8–10.1μm. Semi-cells with two pairs of spines of different lengths. The variety differs from the nominal taxon by a different structure of the upper surface of the half-cells. Granulation is formed by consolidating them and shaping them in the form of rows of irregular shapes arranged perpendicular to the edges of the cell. The ornamentation covers the entire marginal zone of the half-cells. The size of the cells is similar to the dimensions of the nominal species.

Occurrence: due to the lack of detailed information in the algological literature regarding the spread and ecology of the variety, its occurrence cannot be determined at this stage.

Distribution in Poland: the variety has not been recorded in the Polish flora so far. Its occurrence was not shown in the *Catalogue of Polish Prokaryotic and Eukaryotic Algae* (Siemińska, Wołowski, 2003) prepared at the Department of Algology of the Institute of Botany of the Polish Academy of Sciences.

General distribution: the taxon was originally described by Messikomer (1929) from a mesotrophic lake in Switzerland. Included in monographic studies by Coesel (1997) and Coesel, Meesters (2007). The available published phycological information lacks data on its distribution and occurrence.

Acknowledgements

We would like to thank PhD Hanna Werblan-Jakubiec, then Director of the Botanical Garden of the University of Warsaw, and Mr. Włodzimierz Winiarski, an employee of the Botanical Garden, for their help in collecting the scientific material used to prepare this work. We would also like to thank the Directorate of the Wigry National Park for providing materials on the ecological state of Lake Wigry.

Conflict of interest

The author declare no conflict of interest related to this article.

References

Bulnheim, O. (1861). *Beiträge zur Flora der Desmidien Sachsen. I.* Ibid., 2, 50–52. [In German]

Choiński, A. (1991). *Katalog jezior Polski.* Cz. 2, Pojezierze Mazurskie. Poznań: Wydawnictwo Naukowe UAM. [In Polish]

Coesel, P.F.M. (1997). *De Desmidiaceeën van Nederland*. Deel 6, Fam. Desmidiaceae (4). Wetensch. Meded. KNNV nr. 220, Utrecht, pp. 88. [In Dutch]

Coesel, P.F.M., Meesters K.J. (2007). *Desmids of the Lowlands. Mesotaeniaceae and Desmidiaceae of the European Lowlands.* KNNV Publishing. Zeist, the Netherlands. p. 352.

Compére, P. (1976). *Observations taxonomiques et nomenclaturals sur quelques Desmidiées (Chlorophyta) de la région du lac Tchad (Afrique central).* Ibid., 45, 455–4700. [In French]

Cooke, M.C. (1887). *British Desmids. A supplement to British Fresh-Water Algae*. 7–10. p. 97–205 + 1–14, London.

De Toni, G.B. (1889). *Sylloge algarum omnium hucusque cognitarum*. Vol. 1. Sylloge Chlorophycearum. – p. 129+1315. Patavii. [In Latin]

Eichler, B. (1890). Spis desmidyj zebranych w okolicach Międzyrzeca. Catalogue des Desmidiées recuellies aux environs de Międzyrzec. *Pamiętnik Fizjograficzny, 10(III),* 83–92. [In Polish]

Förster, K. (1982). *Conjugatophyceae: Zygnemales und Desmidiales (excl. Zygnemataceae).* Huber-Pestalozzi G. Das Phytoplankton des Süßwassers. Systematik und Biologie. 8 Teil, 1. Hālfte. Stuttgart, ss. 543. [In German]

Górniak, A. S, Ejsmont- Karabin, J., Krzywosz, T., Zieliński, P., Kłonowska-Olejnik, M., Rybak, J.I., Żukowska–Stolc, J., Cudowska, A., Karpowicz, M., Więcko, A., Pietryczuk, A. (2014). *Plan ochrony dla Wigierskiego*

Parku Narodowego i obszaru Natura 2000 „Ostoja Wigierska". Operat ochrony zasobów i ekosystemów wodnych. Warszawa, Białystok, Olsztyn, Suwałki: Konsorcjum Narodowa Fundacja Ochrony Środowiska i Taxus SI. s. 1–162. [In Polish]

Grabowska. M., Górniak. A. (2005). Letni fitoplankton wybranych sucharów Wigierskiego Parku Narodowego. *Rocznik Augustowsko–Suwalski, 4,* 99–104. [In Polish]

Guiry, M.D., Guiry, G.M. (2024). *AlgaeBase*. World-wide electronic publication, University of Galway. https://www.algaebase.org; searched on 12 sierpnia 2024.

Heimerl, A. (1891). Desmidiaceae alpinae. Beiträge zur Kenntnis der Desmiadiceen der Grenzgebietes non Salzburg und Steiermark. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien, 41,* 587–609. [In German]

Heyneman, B.A. (1902). Izsledovanije oziera Wigry w biologiczeskom i rybovodnom otnoszenijach. *Iż. Nikolskogo Rybovodnago Zavoda, 7(6),* 1–39. Petersburg. [In Russian]

Hirano, M. (1959). Flora desmidiarum japonicarum. V. *Contributions from the Biological Laboratory, Kyoto University*, 7, 226–301.

Hutorowicz,, A. (1999). Zbiorowisko fitoplanktonu jako wskaźnik eutrofizacji jeziora Wigry. W: B. Zdanowski, M. Kamiński, A. Martyniak (red.), *Funkcjonowanie i ochrona ekosystemów wodnych na obszarach chronionych*. Olsztyn: Instytut Rybactwa Śródlądowego. s. 279–288. [In Polish]

Hutorowicz, A. (2000). Morphologic variability of Dinophyceae from the genus *Ceratium* in a mesotrophic lake Wigry (Poland). *Polish Journal of Ecology, 48(1),* 89–95.

Hutorowicz, A., Łukawska-Czyżew, A. (2005). Bruzdnice z rodzaju *Ceratium* w planktonie roślinnym Jeziora Wigry (Pojezierze Suwalskie). W: K. Gwoździński (red.), *Bory Tucholskie. Zasoby i ich ochrona*. Łódź: Uniwersytet Łódzki. s.101–111. [In Polish]

Hutorowicz, A., Spodniewska, I., Krzywosz, W. (1992). Fitoplankton w jeziorach Wigierskiego Parku Narodowego. W: B. Zdanowski (red.), Jeziora Wigierskiego Parku Narodowego. Stan eutrofizacji i kierunki ochrony. *Zeszty Naukowe „Człowiek i Środowisko", 3,* 79–99. [In Polish]

Kadłubowska, J.Z. (1952). Desmidiées de la tourbiére de Marysin III (Łódź) (Desmidiaceae torfowiska na Marysinie III (Łódź)). *Acta Societatis Botanicorum Poloniae, 21(*3*),* 425–434. [In French]

Kadlubowska, J.Z. (1961). Glony zbiorników wodnych Łodzi i okolicy. – Algae fund in water reservoirs in Łódź and neighbourhood. *Łódzkie Towarzystwo Naukowe, Wydz. III, 71*, 1–164. [In Polish]

Kosinskaja, E.K. (1952). *Mezotenievye i gonatozigovye vodorosli. Mesotaeniales et Gonatozygales*. Flora Spor. Rast. SSSR, 2(1), p. 163. Moskva-Leningrad. [In Russian]

Krieger, W., Gerloff, J. (1969). *Die Gattung Cosmarium*., Weinheim: lif. 3-4: 241–410. [In German]

Krzywosz, W., Hutorowicz, A. (1999). Fitoplankton jeziora Wigierskiego Parku Narodowego. W: B. Zdanowski, M. Kamiński, A. Martyniak (red.), *Funkcjonowanie i ochrona ekosystemów wodnych na obszarach chronionych*. Olsztyn: Instytut Rybactwa Śródlądowego. 351–359. [In Polish]

Lenzenweger, R. (1996). *Desmid iaceenflora von Österreich. Biblioteka Phycologica, J. Cramer in der Gebrüder Borntraeger Vorlagsbuchhandlung*. Berlin-Stuttgart. Band 101, Teil :1–162. [In German]

Lenzenweger, R. (2003). *Desmidiaceenflora von Österreich. Biblioteka Phycologica, J. Cramer in der Gebrüder Borntraeger Vorlagsbuchhandlung.* Berlin-Stuttgart. Band 111, Teil 4: 1–218. [In German].

Lesiak, T. (1984). Wykaz taksonów z rodziny Mesotaeniaceae i rzędu Desmidiales torfowiska Bagno Przerębiec. List of taxa from Mesotaeniaceae familie and Desmidiales ordung im Przerębiec Peabog. *Acta Universitatis Lodziensis. Folia Botanica*, *3*, 321–342. [In Polish]

Lesiak, T. (1990). Dalsze badania glonów z rodziny Mesotaeniaceae i rzędu Desmidiales na torfowisku „Bagno Przerębiec". Część I. (Further studies on algae from the Mesotaeniaceae family and the Desmidiales order on the peat bog „Przerębiec Swamp". Part I). *Acta Universitatis Lodziensis. Folia Botanica*, *7*, 165–295. [In Polish]

Lesiak, T., Sitkowska, M. (1984). Desmidiaceae wschodniej części torfowiska Bagno Przerębiec. Desmidiaceae of the eastern part on the Przerębiec Beg. *Acta Universitatis Lodziensis. Folia Botanica*, *2*, 183–202. [In Polish]

Mapa stanu ekologicznego ekosystemów wodnych (2014). Zał. 14. Wigierski Park Narodowy PLH 200004 Ostoja Wigierska. Opracowano w ramach realizacji projektów: POIS.05.03.00-00-275/10

Messikommer, E. (1929). Beiträge zur Kenntnis der Algenflora des Kantons Zürich. IV: Die Algenvegetation der Moore am Pfëffikersee. *Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich*, *74*, 139–162. [In German]

Owsianny, P.M., Grabowska, M. (2007). New Dinophyta species records for the Wigry National Park (Poland) with an checklist of all reported species for the park. W: *Materiały – streszczenia. XXVI Międzynarodowa Konferencja Fykologiczna*. Nałęczów-Lublin 2007. [In Polish]

Palamar-Mordvintseva, G.M. (1982). *Opredelitel' presnovodnykh vodorosley SSSR. Zelenyye vodorosli. Klass Kon'yugaty. Poryadok Desmidiyevyye* [Manual for identification of the freshwater algae of the USSR. Desmidiales]. Vol. 11(2). Leningrad: Nauka Leningradskoe Otdelenie. [In Russian]

Plan ochrony Wigierskiego Parku Narodowego i obszaru Natura 2000 Ostoja Wigierska, współfinansowanego ze środków Programu Operacyjnego Infrastruktura i Środowisko, w ramach działania 5.3 priorytetu V, 61/2013/Wn-10/OP-IN-PS/D, dofinansowany ze środków Narodowego Funduszu Ochrony Środowiska [In Polish]

Schröder, B. (1898). Neue Beiträge zur Kenntnis der Algen des Riesengebirges. *Forschungsberichte aus der Biologischen Station zu Plön, 6(1*), 9–47. [In German]

Schröder, B. (1917). Schwebepflanzen aus dem Wigrysee bei Suwałki in Polen. *Berichte der Deutschen Botanischen Gesellschaft, 35(3),* 256-266. [In German]

Sieminiak, D. (1984a). Glony epipeliczne w przybrzeżnych częściach zbiornika Przeczyc i sąsiadujących odcinkach rzeki Czarna Przemsza (Górny Śląsk). 1. Glony w strefie stale zalanej (Epipelic alga In marginal parts of the Przeczyce reservoir and of neighbouring sectors of the River Czarna Przemsza. (Upper Silesia). 1. Algae in permanently flooded zone). *Acta Hydrobiologica*, *25–26(1)*, 51–66. [In Polish]

Sieminiak, D. (1984b). Glony epipeliczne w przybrzeżnych częściach zbiornika Przeczyc i sąsiadujących odcinkach rzeki Czarna Przemsza (Górny Śląsk). 2. Glony w okresowo zanurzonej strefie (Epipelic alga In marginal parts of the Przeczyce reservoir and of neighbouring sec tors of the River Czarna Przemsza (Upper Silesia). 2. Algae in periodically emergent zone). *Acta Hydrobiologica*, *25–26(2)*, 135–144. [In Polish]

Siemińska, A., Siemińska, J. (1967). Flora i fauna w rejonie Zespołu Gospodarstw Doświadczalnych PAN i Zbiornika Goczałkowickiego na Śląsku. Flora and fauna In the region of the Experimental Farms of the Polish

Academy of Sciences and of Goczałkowice Reservoir., Silesia. *Acta Hydrobiologica*, *9(1–2)*, 1–109. [In Polish]

Siemińska, J., Wołowski, K. (2003). *Catalogue of Polish procariotic and eukaryotic Algae. Katalog glonów prokariotycznych i eukariotycznych Polski. Biodiversity of Poland. Różnorodność biologiczna Polski.* W. Szafer Institute of Botany, Polish Akademy of Sciences. Kraków. Vol. 5: ss. 251 [In Polish].

Sosnowska-Półtoracka, J. (1966). Plankton roślinny jeziora Sukiel (Phytoplankton of Lake Sukiel). *Zeszyty Naukowe Wyższej Szkoły Rolniczej w Olsztynie*, *21(511)*, 711–731. [In Polish]

Sosnowska-Półtoracka, J. (1974). Plankton communities of three Mazurian lakes and chlorophyll content in their phytoplancton (Zbiorowiska planktonowe trzech jezior mazurskich i zawartość chlorofilu w ich fitoplanktonie). *Mongraphiae Botanicae*, *42*, 1–152.

Starmach, K. (1963). Rośliny słodkowodne. Wstęp ogólny i zarys metod badania. W: *Flora słodkowodna Polski*, t. I. Warszawa-Kraków: PWN. [In Polish]

Szeląg-Wasielewska, E., Gołdyn, R. (1996). Struktura wielkościowa fitoplanktonu trzech jezior Wigierskiego Parku Narodowego. *Fragmenta Floristica et Geobotanica, Ser. Polonica*, *3*, s. 277–287. [In Polish]

Szklarczyk-Gazdowa, C. (1956). Phytoplankton of the dam-reservoir at Kozłowa Góra in the years 1951–1953. (Plankton roślinny zbiornika zaporowego w Kozłowej Górze w latach 1951–1953). *Acta Societatis Botanicorum Poloniae*, *25(3)*, 537–578.

Szklarczyk-Gazdowa, C. (1965). Plankton wybranych stawów rybnych dorzecza górnej Wisły ze szczególnym uwzględnieniem zielenic. Plankton of certain fish ponds In the Upper Vistula Basin. *Mongraphiae Botanicae*, *19*, 85–147. [In Polish]

Szklarczyk-Gazdowa, C. (1966). Plankton niektórych stawów we Wrotnowie koło Oświęcimia ze szczególnym uwzględnieniem zielenic. Plankton In some ponds at Wrotnów near Oświęcim (southern Poland) with special consideration of the Green alga. *Fragmenta Floristica et Geobotanica Polonica*, *12(2)*, 217–232. [In Polish]

Tomaszewicz, G.H. (1970). Desmidiaceae from old beds of the Bug (Desmidie starorzeczy Bugu). *Acta Societatis Botanicorum Poloniae*, *39(2)*, 217–242.

Tomaszewicz, G.H. (1988). Desmids of the transitional bogs of the Middle Mazowsze Land (Desmidie torfowisk przejściowych Niziny Środkowomazowieckiej). *Mongraphiae Botanicae*, *70*, 3–86.

Tomaszewicz, G.H. (1996). Flora glonow Wigierskiego Parku Narodowego. *Fragmenta Floristica et Geobotanica, Ser. Polonica*, *3*, 239–259. [In Polish]

Wayda, M. (2023). Desmids of Gorce Mts. Geobotanical studies. *Plant and Fungal Systematics*, *68(1)*, 1–206. https://doi.org/10.35535/pfsyst-2023-0001

West, W. (1888). *Fresh-water Algae*. In: F.A. Lees, The Flora of West Yorkshire. London, 745–777.

Wisłouch, S. 1926. O letnim fitoplanktonie jezior Wigierskich. *Archiwum Hydrobiologii i Rybactwa*, *1(1–2)*, 79–114. [In Polish]

Wołoszyńska, J. (1922). II. Pierwszy przyczynek do znajomości glonów Litwy. *Rozprawy i Wiadomości z Muzeum im. Dzieduszyckich*, *5/6*, 63–127, 4 tables, plates 3–4. [In Polish]

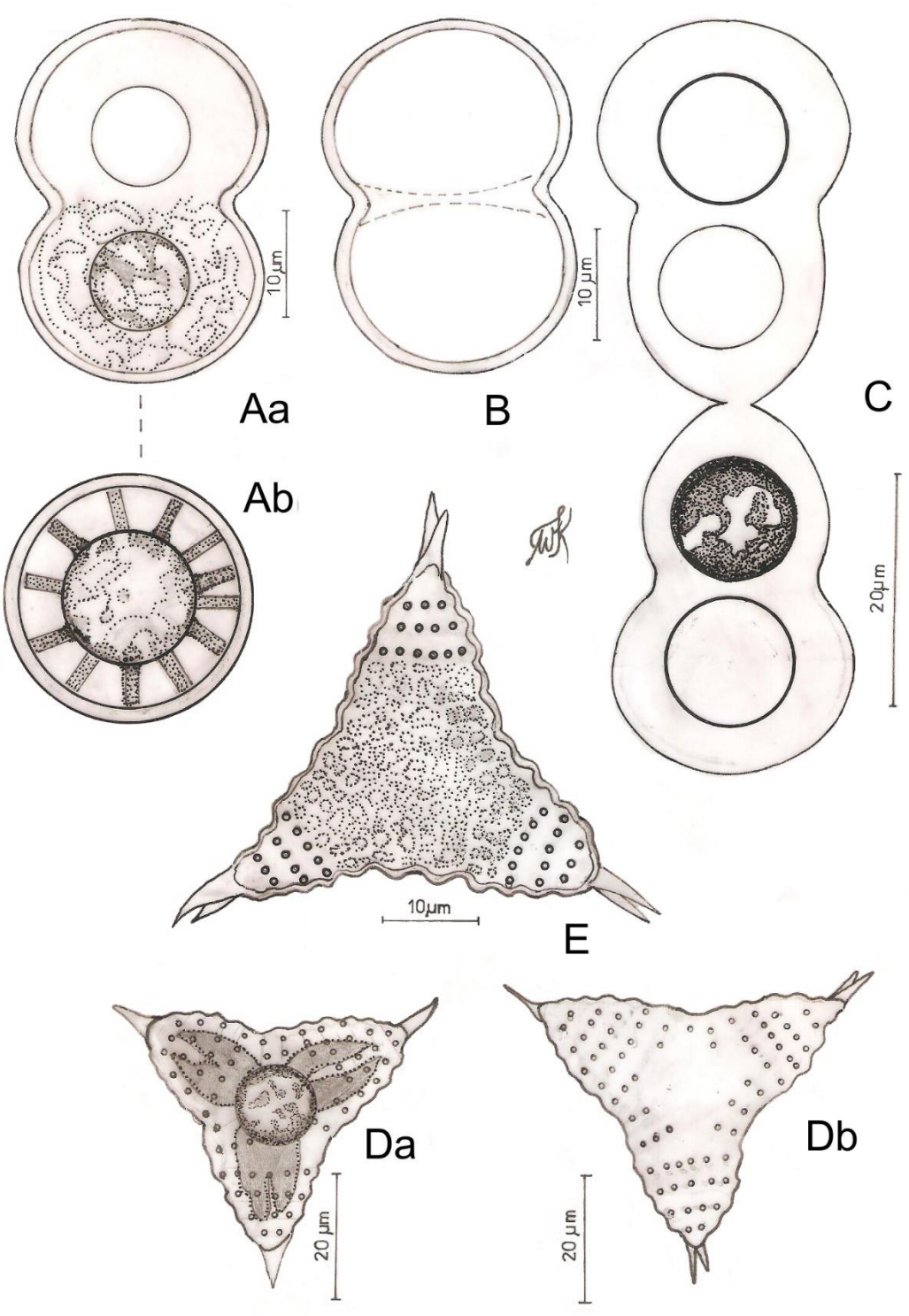

Fig. 3. *Actinotaenium globosum* **(**Bulnh.) Först. ex Comp. (=*Cosmarium globosum* Bulnh.): cell with pyrenoids and chloroplast – Aa, star-shaped six-pointed chloroplast with pyrenoid in each half-cell (apical view) – Ab; cell wall without protoplast – B; vegetative cell division – C; *Staurastrum avicula* Bréb. var. *avicula* Ralfs: protoplast with pyrenoid (apical view) – Da, apical surface ornamentation – Db; *Staurastrum avicula* Bréb. var *exornatum* Messik. ornamentation of the apical surface – E (Drawings. Wojciech. W. A. Kowalski)

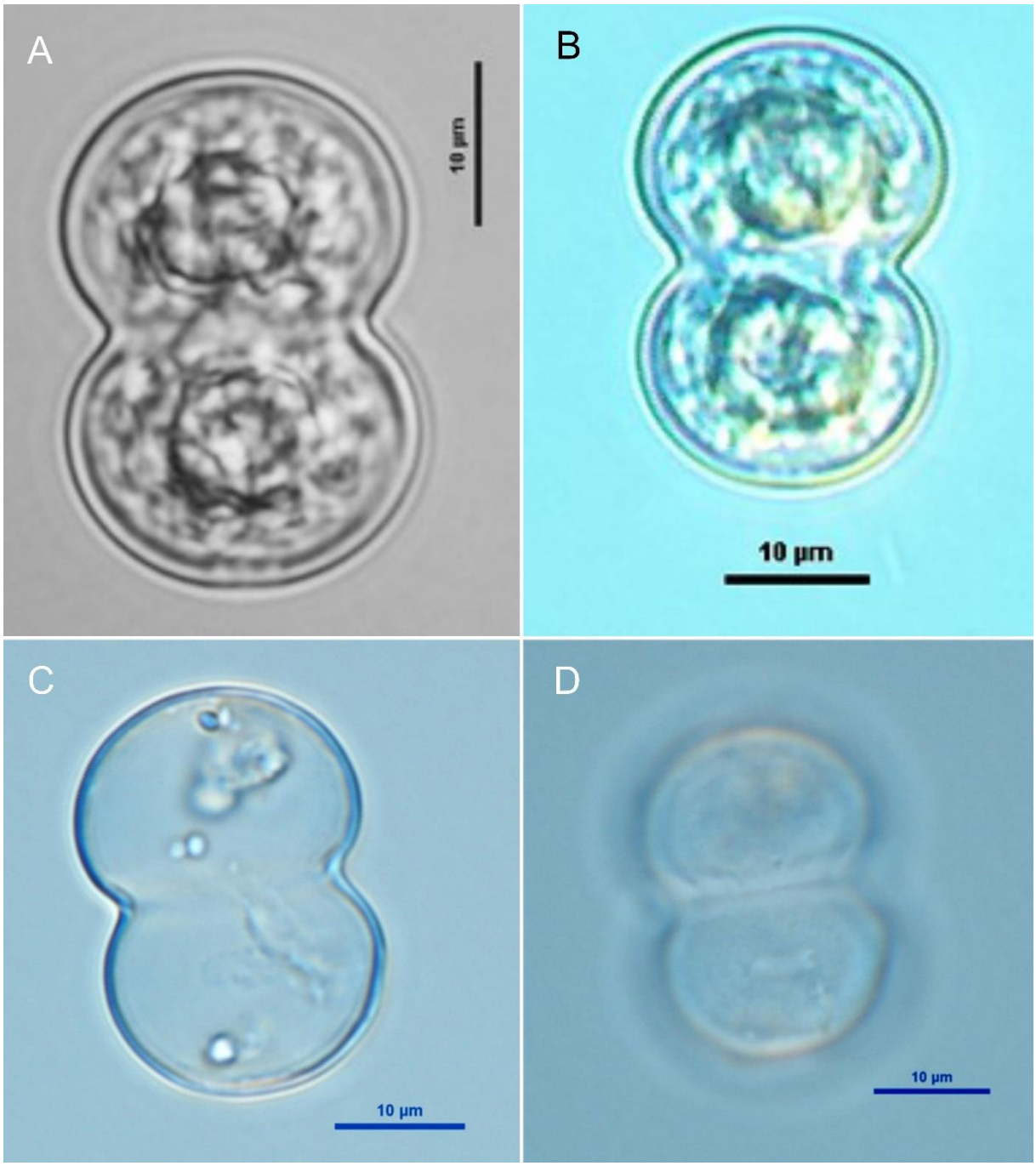

Fig. 4. *Actinotaenium globosum* (Bulnh.) Först. ex Comp. (=*Cosmarium globosum* Bulnh.): cell with chloroplast and pyrenoid – A,B; cells without a protoplast – C, D (Photo. Hanna Szymańska)

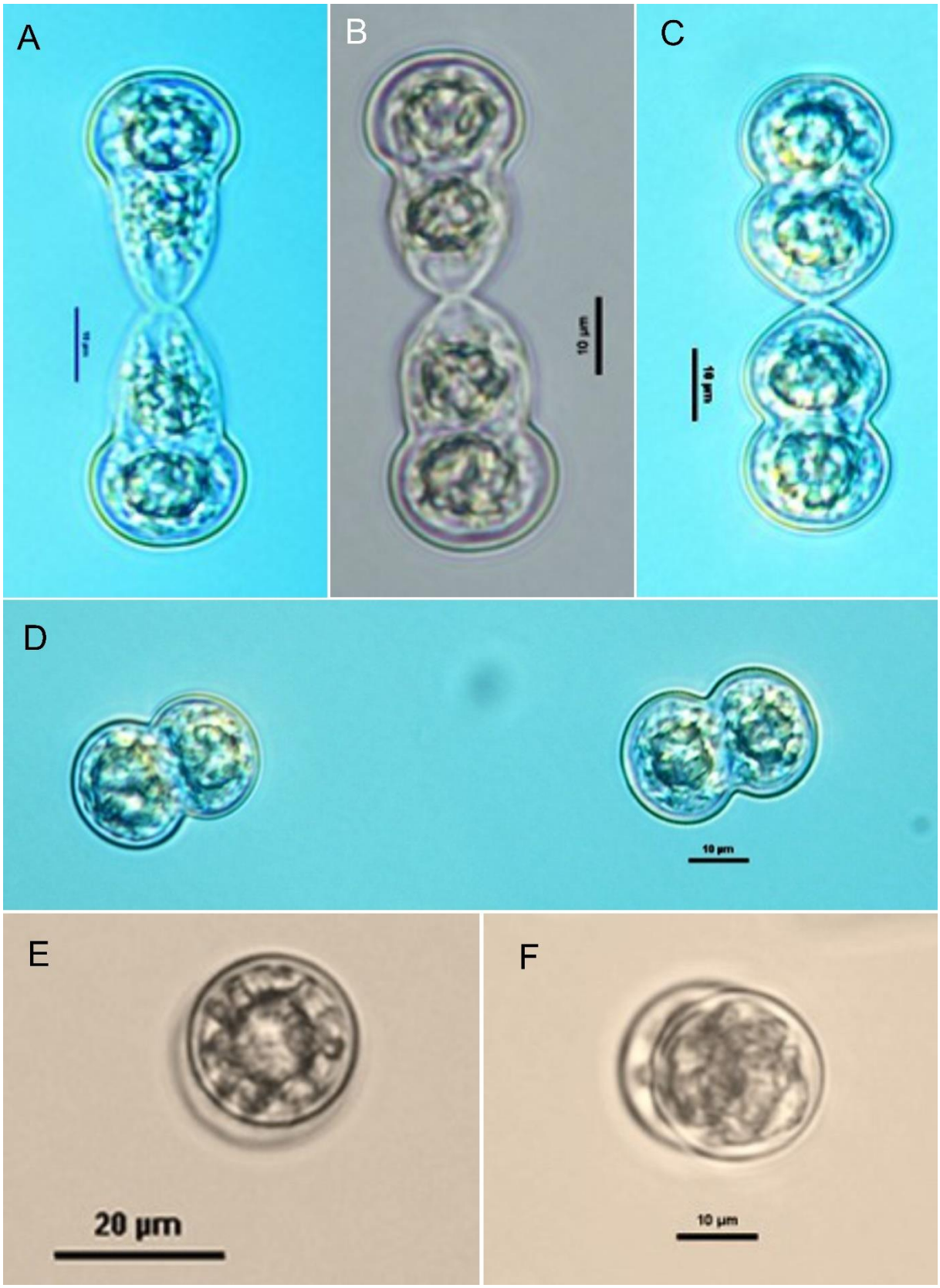

Fig. 5. *Actinotaenium globosum* (Bulnh.) Först. ex Comp. (=*Cosmarium globosum* Bulnh.): subsequent stages of vegetative cell division – A, B, C; young cells formed after division – D; protoplast with chloroplast and pyrenoid (top side of the cell) – E, F (Photo. Hanna Szymańska)

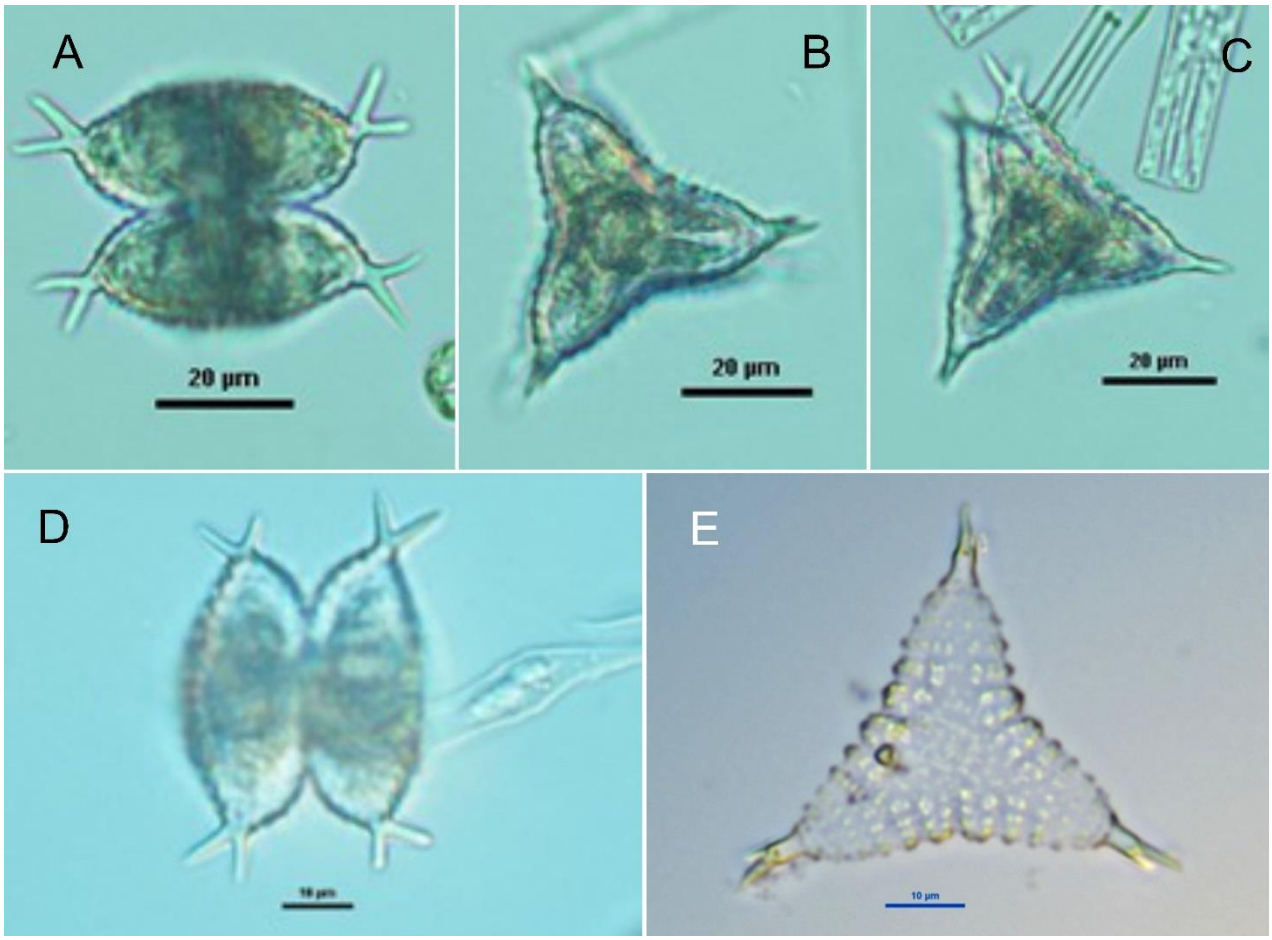

Fig. 6. *Staurastrum avicula* Bréb. var. *avicula* Ralfs: front part of the cell – A; the top part of the cell with the chloroplast and pyrenoid – B, C; *Staurastrum avicula* Bréb. var. *exornatum* Messik.: cell in side view – D; sculpture of the apical part of the cell – E (Photo. Hanna Szymańska)

Actinotaenium globosum (Bulnh.) Först. ex Comp. (=*Cosmarium globosum* Bulnh.) i *Staurastrum avicula* Bréb. w planktonie ekosystemu Jeziora Wigry. Materiały do fykoflory Wigierskiego Parku Narodowego

Streszczenie

W pracy przedstawiono informacje na temat występowania taksonów mezotroficznych z rzędu Desmidiales w ekosystemach Jeziora Wigry (Północna Polska). Morfologia komórek oraz dokumentacja fotograficzna i rysunkowa pozwoliła na zaklasyfikowanie ich do trzech jednostek taksonomicznych, którymi są: *Actinotaenium globosum* (Bulnh.) Först. ex Comp., *Staurastrum avicula* Bréb. var. *avicula* Ralfs oraz *S. avicula* Bréb. var. *exornatum* Messik., która to odmiana nie została jeszcze odnotowana w fikoflorze Polski. Wielkość komórek i submikroskopowa dekoracja ich ścian oraz cechy kształtu i organizacji wewnętrznej protoplastu są zgodne z danymi zawartymi w bibliografii (Coesel, Meesters, 2007). Zidentyfikowane taksony występują licznie w planktonie wód różnych części analizowanego jeziora.

Słowa kluczowe: Desmidiales, Pojezierze Mazurskie, Polska, fitoplankton

Information on the authors

Wojciech W.A. Kowalski

The author is a specialist in the field of algology. His research interests concern both single species of algae and whole groups of marine and freshwater algae, with particular emphasis on rare and endangered taxa. A special taxonomic group of interest are the taxa associated with the ecosystems of peat bogs, as well as freshwater red algae. Now, he is retired researcher from the West Pomeranian University of Technology in Szczecin.

Hanna Szymańska

She is a specialist in the field of algology. Interested in species of planktonic algae, especially from the order Oedogoniales. Retired employee of the University of Warsaw.