Polish Botanical Journal 51(2): 177–207, 2006

DIATOMS OF THE WYŻYNA KRAKOWSKO-CZĘSTOCHOWSKA UPLAND (S POLAND) – COSCINODISCOPHYCEAE (THALASSIOSIROPHYCIDAE)

Agata Zofia Wojtal & Janina Kwandrans

Abstract. The paper describes centric diatoms of the class Coscinodiscophyceae (Thalassiosirophycidae) identified in materials collected from springs and streams of the Wyżyna Krakowsko-Częstochowska upland in 1993–2005, supplemented by records from related literature. The presence of 20 species belonging to seven genera is confirmed. Among them, taxa new to the Polish diatom flora were observed, including *Thalassiosira duostra* Pienaar, *Skeletonema potamos* (Weber) Hasle and *Cyclotella delicatula* Hustedt, along with several taxa very rarely reported from Poland, such as *Thalassiosira guillardii* Hasle, *Cyclostephanos delicatus* (Genkal) Casper & Scheffler and *C. invisitatus* (Hohn & Hellermann) Theriot, Stoermer & Håkansson, and five species new for the studied area. LM and SEM micrographs document all the species recorded in the materials collected. Comments accompany most of the taxa, and dot maps of the distribution of some species are given.

Key words: Bacillariophyta, Centrales, taxonomy, ecology, springs, running waters, distribution

Agata Zofia Wojtal, Department of Phycology, W. Szafer Institute of Botany, Polish Academy of Sciences, ul. Lubicz 46, PL-31-512 Kraków, Poland; e-mail: wojtal@ib-pan.krakow.pl
Janina Kwandrans, Institute of Nature Conservation, Department of Freshwater Biology, Polish Academy of Sciences, Al. Mickiewicza 33, PL-31-120 Kraków, Poland; e-mail: kwandrans@iop.krakow.pl

Introduction

The Wyżyna Krakowsko-Częstochowska upland is one of the phycologically best-investigated areas in Poland. Recent floristic and taxonomic studies investigated Euglenophyta (Wołowski 1998), Chrysophyceae (Cabała 2002) and diatoms (Wojtal 2001, 2003a, b, 2004; Wojtal & Sobczyk 2006). The initial data on Thalassiosirophycidae identified from the Wyżyna Krakowsko-Częstochowska upland originate from a floristic work by Raciborski (1888), in which *Cyclotella kuetzingiana* Thwaites and *C. operculata* Kützing were reported. Up to now, data on 15 taxa of three genera have been published (Kawecka & Kwandrans 2000; Siemińska & Wołowski 2003). The present study extends the list to 20 species of seven genera. *Cyclostephanos tholiformis* Stoermer, Håkansson & Theriot, *Stephanodiscus hantzschii* Grunow fo. *tenuis* (Hustedt) Håkansson & Stoermer, *S. medius* Håkansson, Håkansson & Theriot and *S. parvus* Stoermer & Håkansson are here included in *Cyclostephanos delicatus* (Genkal) Casper & Scheffler, *Stephanodiscus hantzschi* Grunow, *S. alpinus* Hustedt, and *S. minutulus* (Kützing) Grunow in Cleve et Möller, respectively. All identified taxa are briefly described and documented by LM and SEM photographs, and data on their taxonomy, ecology and distribution are provided.

The occurrence of four of 15 earlier-reported taxa was not confirmed. Without reinvestigation of the material, the identity of the diatom determined as *Cyclotella comta* (Ehrenberg) Kützing by Siemińska (1947), Turoboyski (1962), Kadłubowska (1964) and Hojda (1971) remains uncertain, due to recent changes of the species concept (e.g., Håkansson 2002). The historical report of *Cyclotella astraea* (Ehrenberg) Kützing [= *Stephanodiscus astraea* (Ehrenberg) Grunow] (Siemińska 1947), identified according to the species concept of that time, is also doubtful. The occurrence of the two other species – *Cyclotella* *kuetzingiana* Thwaites (Raciborski 1888; Gutwiński 1895; Turoboyski 1962; Kadłubowska 1964), and *Thalassiosira weissflogii* (Grunow) Fryxell & Hasle (Kawecka & Kwandrans 2000) – is more reliable, but they were not detected in our materials.

The species richness of diatoms of the Thalasiosirophycidae reported so far from the Wyżyna Krakowsko-Częstochowska upland is low, due to the general absence of lakes or water reservoirs, considered to be the habitats most conducive to the growth of most centric diatoms. Another problem involves difficulties in precisely identifying these diatoms. For reliable identification of many taxa such as *Thalassiosira pseudonana* Hasle & Heimdal, *Discostella pseudostelligera* (Hustedt) Houk & Klee and *Stephanodiscus agassizensis* Håkansson & Kling, electron microscopy studies are needed. Even the most common diatom representatives of the Thalassiosirophycidae are characterized by great morphological variability dependent on environmental conditions (e.g., Yang & Duthie 1993; Wunsam *et al.*1995; Håkansson & Chepurnov 1999; Hausmann & Lotter 2002) and the stage of the life cycle (e.g., Håkansson & Chepurnov 1999; Håkansson 2002; Kato *et al*. 2003), and valve heterogeneity is a feature of several genera (e.g., Håkansson 2002; Houk & Klee 2004).

Moreover, recent detailed work suggests that some widespread and common species may constitute a complex of multiple, reproductively isolated sexual species of very similar or even the same frustule morphology, as reported in *Cyclotella meneghiniana* Kützing (Beszteri *et al.* 2005). Until biological and morphological differences are clarified, the presence of certain morphotypes, possibly environmentally induced, could be used for practical purposes, for example in water quality monitoring or palaeoreconstruction.

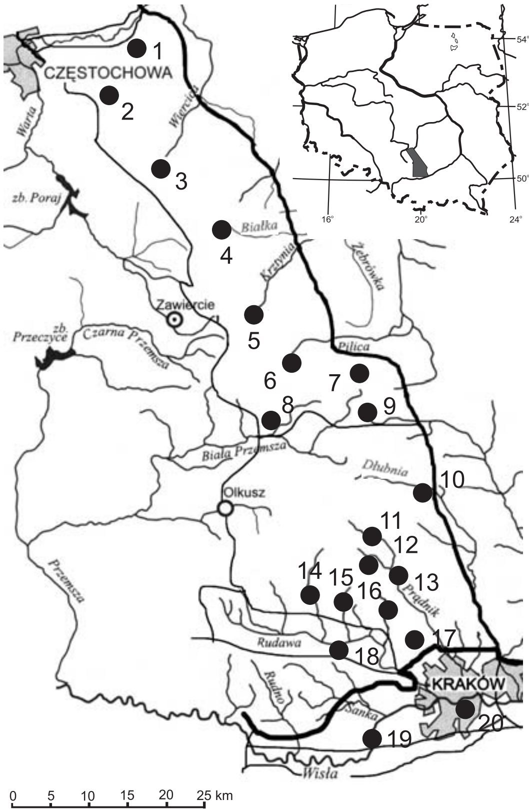


Fig. 1. Distribution of investigated localities: 1 – Wielki Las Reserve, 2 – Kusięta sinkhole, 3 – outflow from Wiercica River springs, 4 – Białka River springs, 5 – Krztynia River springs, 6 – spring in Pilica–Piaski, 7 – spring of Pilica River in Węgrzynów, 8 – Biała Przemsza spring, 9 – Szreniawa River, 10 – Dłubnia spring, 11 – spring of Prądnik River, 12 – fish ponds near Prądnik River, 13 – Prądnik River, 14 – fish ponds on Będkówka stream, 15 – Kobylanka stream and springs, 16 – Kluczwoda stream, 17 – artificial pond in Modlnica, 18 – Rudawa River, 19 – Vistula River, 20 – Vistula River in Kraków.

Study area, material and methods

The Wyżyna Krakowsko-Częstochowska upland extends from the Carpathian foothills in the vicinity of Kraków in the south, to the town of Częstochowa in the north (Fig. 1). The area covers 2650 km^2, extending *ca* 80 km north-south and *ca* 20 km east-west, with average elevation of 350 m a.s.l. (Kondracki 1994). According to the new geographical division of Polish uplands, the area of the Brama Krakowska gate (including Kraków and the Vistula River) is outside the Wyżyna Krakowsko-Częstochowska upland (Kondracki 2000). Because the Vistula River was considered a natural border of the upland for many years (e.g., Dynowska 1983), and consequently included in phycological surveys of the upland (e.g., Wołowski 1998), we incorporated material and literature sources relating to diatoms reported from the upland area as treated by Dynowska (1983).

The southern part of the region is rich in springs and streams, but lies near large, densely populated industrial centers. Most of the waters are eutrophic as a result of human activity, and some of them are also impacted by modification of river channels, construction of weirs or other work (e.g., Kwandrans *et al*. 1998; Kawecka & Kwandrans 2000). The Vistula River carries high loads of organic pollutants and salts (e.g., Dumnicka 1988, 2002; Kawecka & Kwandrans 2000). The northern part of the upland is poor in aquatic habitats.

Water conductivity was moderate, in the range of 292–569 µS cm^{-1}, and pH values generally oscillated around 7, except for the sinkhole in Kusięta and the Vistula River, where in July 2005 conductivity was 112 and 1620 µS cm^{-1}, and pH reached 4.8 and 8.2, respectively.

This paper is based on material collected from the upland in 1993–2005 from 20 localities (Fig. 1, Table 1), supplemented by data from the Iconotheca of Algae of the Department of Phycology, W. Szafer Institute of Botany, Polish Academy of Sciences, the *Catalogue of Polish Procaryotic and Eukaryotic Algae* (Siemińska & Wołowski 2003), and available information published up to 2006 (taxa identified to generic level were not considered). Samples for detailed taxonomic analysis were prepared and cleaned by standard techniques (Krammer & Lange-Bertalot 1986). The density of valve face structures (e.g., costae) per 10 µm on a line tangential to the radius was calculated from the formula $\tau = 10n/\pi D$ (Genkal 1977), where n is the total number of structures, D is valve face diameter, and τ is the number of structures per 10 µm.

Light microscopy observations employed a Nikon Optiphot microscope equipped with differential interference contrast. SEM observations of cleaned, gold-coated material employed a Philips scanning electron microscope. Most of the SEM micrographs were made in the Institute of Metallurgy and Materials Science, Polish Academy of Sciences, and the Laboratory of Field Emission, Scanning Electron Microscopy and Microanalysis at the Institute of Geological Sciences of the Jagiellonian University. The basic determination of a particular diatom taxa's ecology follows Denys (1991), Krammer and Lange-Bertalot (1991) and Van Dam *et al*. (1994). Measurements of conductivity and pH were made *in situ* using a CC-102 conductivity meter and a CC-103 pH meter (Elmetron). The studied material is deposited in the collection of the Department of Phycology, W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

In the list an asterisk (*) precedes the names of species new for the area, and a double asterisk (**) precedes spe-

Table 1. Occurrence of diatoms of the Coscinodiscophyceae recorded at 20 localities (1–20 as on Fig. 1) in Wyżyna Krakowsko-Częstochowska upland.

Species/ Locality	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Thalassiosira duostra															+					
Thalassiosira guillardii																				+
Thalassiosira pseudonana					+	+									+			+		+
Skeletonema potamos																			+	
Skeletonema subsalsum						+	+							+						
Cyclotella atomus			+		+	+			+			+	+	+	+	+	+	+	+	+
Cyclotella delicatula						+														
Cyclotella distinguenda				+		+									+					
Cyclotella meneghiniana	+	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+
Cyclotella ocellata																			+	
Discostella pseudostelligera	+						+		+					+	+			+	+	+
Discostella stelligera	+							+							+		+			
Discostella woltereckii								+											+	
Puncticulata radiosa	+	+			+	+			+									+	+	
Cyclostephanos delicatus												+							+	+
Cyclostephanos dubius																		+		+
Cyclostephanos invisitatus																		+		+
Stephanodiscus alpinus																+				
Stephanodiscus hantzschii				+		+		+		+	+	+		+		+		+	+	
Stephanodiscus minutulus								+				+	+	+	+			+		

cies new for Poland. Species within genera are arranged alphabetically.

RESULTS AND DISCUSSION

*******Thalassiosira duostra*** Pienaar Fig. 2: 1–3.

Valve 10.3–25.7 μm in diameter, areolar pattern fasciculate. Areolae 25–30 per 10 μm on valve face and 20–31 per 10 μm near its junction with the mantle. Areolae with external foramina and internal cribra. On valve face, cribra are circular in outline and slightly domed inwards. Tangential areolar walls present. Diameter of areolar chambers greater than the height of their walls. Marginal fultoportulae (strutted processes) situated in a single ring, 5–10 per 10 μm. Neighboring marginal fultoportulae are separated by 2–3 rows of areole, and have external tubes 0.5–1.2 μm in length and 0.3–0.5 μm in diameter.

GENERAL DISTRIBUTION. Rare, presumably cosmopolitan species, described from the Vaal River in the Republic of South Africa (Pienaar & Pieterse 1990). In Europe known from the Danube River and Iberian Peninsula (Kiss *et al*. 2005). Reported also from Brazil (Torgan *et al.* 2006).

DISTRIBUTION IN POLAND. *Thalassiosira duostra* occurred rarely in materials collected from an anthropogenically altered section of Kobylanka stream. New to the Polish flora.

ECOLOGY. Characterized as a freshwater, probably mesohalobous species present in eutrophic rivers (Pienaar & Pieterse 1990); reported also from polluted, eutrophic or even waste water (Torgan *et al*. 2006). The present data seem to confirm its wide ecological range.

REMARKS. Internal tubes of marginal fultoportulae very short, surrounded by four satellite pores. The recorded specimens have paired valve face fultoportulae located halfway between the valve center and valve margin. One rimoportula (labiate process) is located slightly outside the ring of marginal fultoportulae. The elongated inner slit of the rimoportula is oriented radially.

******Thalassiosira guillardii*** Hasle
Figs 2: 4–5; 3 & 4: 1–3.

Valve 4–14 μm in diameter, areolar pattern fasciculate. Marginal fultoportulae in a single ring spaced regularly 7–8(12) per 10 μm.

GENERAL DISTRIBUTION. A rare, cosmopolitan species. Known from European and Asian waters: Germany, British rivers, Gulf of Finland (Hasle 1978), Danube River (Kiss 1984), Volga Basin (Genkal 1992), Lake Ladoga (Trifonova & Genkal 2006), Lake Baikal and Selenga River in Russia (Popovskaya *et al*. 2002), water bodies of the Iberian Peninsula (Kiss *et al.* 2005), and Tokyo Bay, Japan (Hasle 1978). Reported also from inland waters of the U.S.A. and Canada (Hasle 1978, Stoermer *et al*. 1999).

DISTRIBUTION IN POLAND. *Thalassiosira guillardii* was reported from Poland for the first time from the highly organically polluted and saline Zbiornik Puławski reservoir (Bucka & Wilk-Woźniak 2002; Wilk-Woźniak & Ligęza 2003). This is the second locality of *T. guillardii* in Poland (Fig. 3).

ECOLOGY. Characterized by fairly wide salinity tolerance (Hasle 1978), and observed in eutrophic, anthropogenically altered aquatic habitats.

REMARKS. The central fultoportula is located about halfway between the valve center and valve margin, surrounded by three satellite pores. Features a marginal ring of regularly spaced fultoportulae, each surrounded by four struts. One marginal fultoportula is replaced by a distinctive rimoportula with an elongated inner slit, oriented radially.

→

Fig. 2. 1–3 – *Thalassiosira duostra* Pienaar: 1 – marginal rimoportula and central fultoportulae arrowed, 2 – characteristic wall structure enlarged and arrowed, 3 – enlarged marginal part, 4 & 5 – *T. guillardii* Hasle (5 – detail of marginal area with marginal fultoportulae with four struts), 6–8 – *T. weissflogii* (Grunow) Fryxel & Hasle, specimens from saline waters in Stale, S Poland [7 – detail of central fultoportulae with four struts, and thallassiroid wall structure, 8 – marginal rimoportula (labiate process)]. 1, 4–8 internal view, 2 & 3 – external view; all in SEM. CF – valve face fultoportula, MF – marginal fultoportula, R – rimoportula.

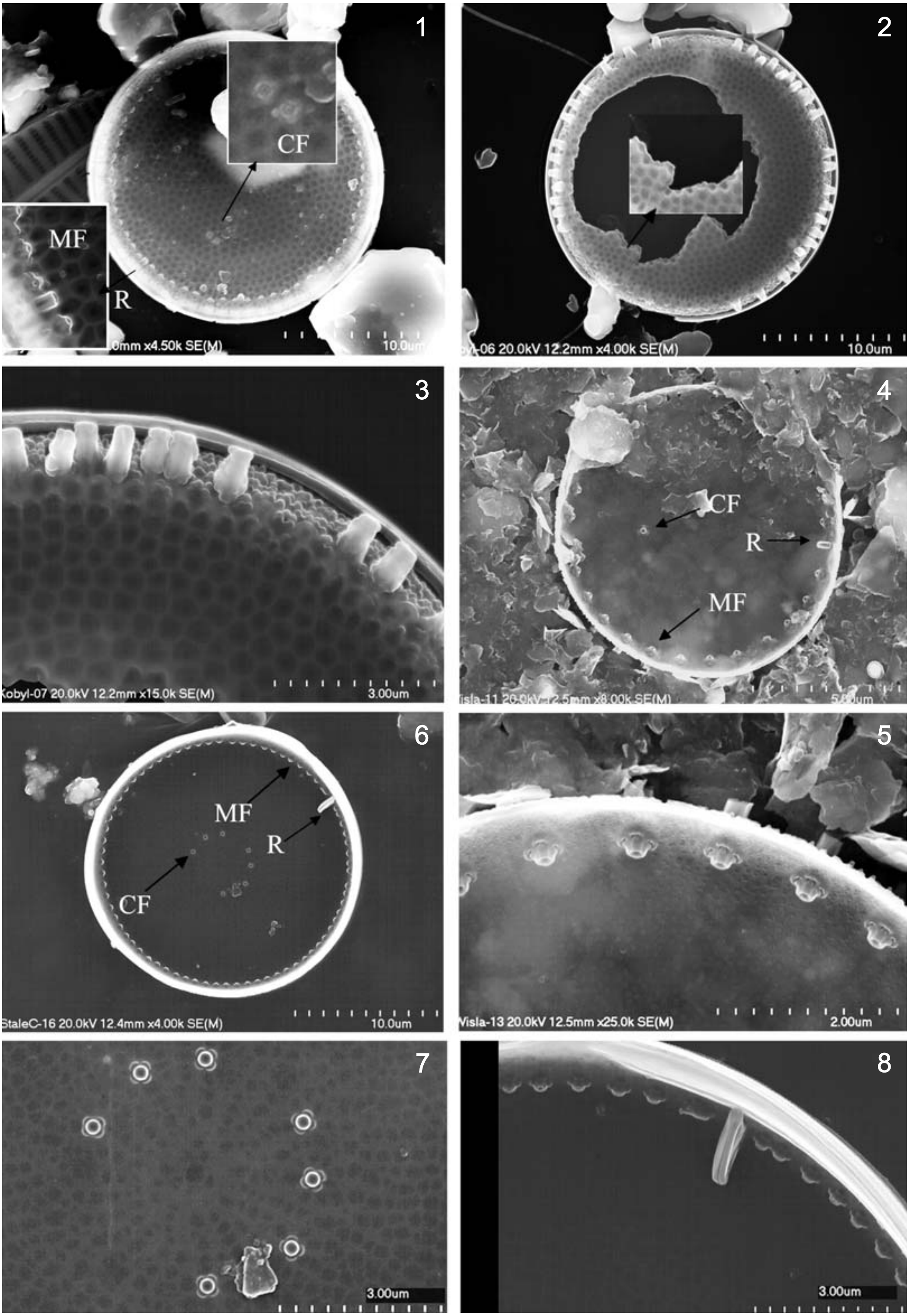

1
CF
MF
R
2
20.0kV 12.2mm x4.00k SE(M)
10.0um
3
obyl-07 20.0kV 12.2mm x15.0k SE(M)
3.00um
4
CF
R
MF
6
MF
R
CF
StaleC-16 20.0kV 12.4mm x4.00k SE(M)
10.0um
5
Wisla-13 20.0kV 12.5mm x25.0k SE(M)
2.00um
7
3.00um
8
3.00um

Fig. 3. Distribution of *Thalassiosira guillardii* Hasle in Poland.

Thalassiosira pseudonana Hasle & Heimdal Figs 4: 8 & 7: 20–25

Cyclotella nana Hustedt

Valves flat, very weakly silicified, 3.5–6.0 μm in diameter. Marginal fultoportulae in a single ring, spaced regularly, are the most distinctive structures under light microscopy.

GENERAL DISTRIBUTION. Probably a cosmopolitan species.

DISTRIBUTION IN POLAND. The distribution of *T. pseudonana* is not exactly known. It seems to be widespread and not rare, but overlooked or misidentified. Reported from the Zbiornik Puławski reservoir (Bucka & Wilk-Woźniak 2002; Wilk-Woźniak & Ligęza 2003), several rivers of southern Poland (data unpublished), and the Vistula River (Bucka 2000; Kawecka & Kwandrans 2000).

ECOLOGY. Planktonic (Krammer & Lange-Bertalot 1991), alkaliphilous, brackish/freshwater taxon, hypereutraphentic, α-mesosaprobous, strictly aquatic (Van Dam *et al.* 1994).

REMARKS. Morphological studies of *C. nana* Hustedt undertaken by Hasle and Heimdal (1970) resulted in the transfer this species to the genus *Thalassiosira.* It is believed to have an extremely wide tolerance spectrum (Hasle & Heimdal 1970) and a wide range of morphological variability (Hasle 1976; Kiss 1984). The observed valves are devoid of a central fultoportula, conforming to earlier observations of the species from other freshwater environments (Hasle 1976; Kiss 1984), and lack an irregular siliceous ring in the center of the valve face. In small, weakly silicified valves the most distinctive structures are marginal fultoportulae. According to Kiss (1984) the more silicified valves have discernible short costae in the marginal area. However, specimens with heavily silicified costae much more resemble the small valves without a stellate pattern of *Discostella pseudostelligera* (Hust.) Houk & Klee (Kiss 1984, Krammer & Lange-Bertalot 1991). Some specimens identified as similar to *T. pseudonana* (Fig. 7: 23–25) differ in possessing a distinct narrow striated valve face area.

*****Skeletonema potamos*** (Weber) Hasle *in* Hasle & Evensen Fig. 4: 9

Microsiphonia potamos Weber, *Stephanodiscus subsalsus* (A. Cleve) Hustedt.

Cells rectangular in girdle view, in sibling pairs or joined into 3–5-cell colonies. *Skeletonema potamos* possesses sibling cells less closely spaced than those of *S. subsalsum*, because of their usually longer spines (Fig. 4: 9), domed valve faces, and distinct pseudosulcus.

GENERAL DISTRIBUTION. Cosmopolitan, relatively rare, reported from different kinds of inland water bodies (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. Species new to the Polish flora.

ECOLOGY. Nanoplanktonic, tolerating waters of elevated conductivity, also known from brackish waters, eutraphentic species (Krammer & Lange-Bertalot 1991). Alkaliphilous, fresh/brackish water taxon, hypereutraphentic, β-mesosaprobous, strictly aquatic (Van Dam *et al.* 1994).

REMARKS. Although this species was not reported from Poland earlier, its distribution is presumably much wider. The small dimensions and weakly silicified valves of *S. potamos* and *S. sub-*

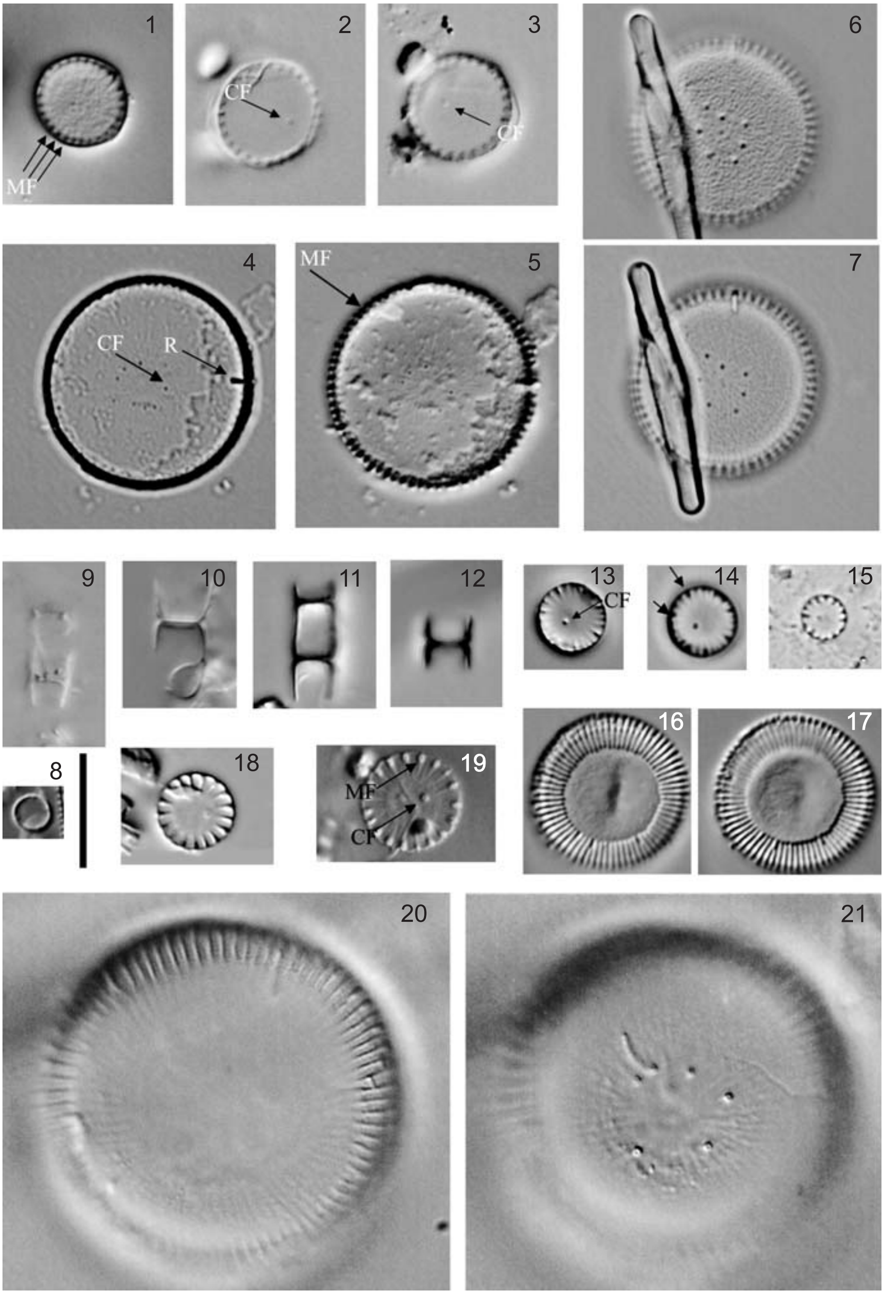


Fig. 4. 1–3 – *Thalassiosira guillardii* Hasle. 4–7 – *T. weissflogii* (Grunow) Fryxell & Hasle, (specimens from saline waters in Stale, S Poland), 8 – *T. pseudonana* Hasle & Heimdal, 9 – *Skeletonema potamos* (Weber) Hasle, 10 – *S.* cf. *subsalsum*, 11 & 12 – *S. subsalsum* (Cleve-Euler) Bethge, 13–15 – *Cyclotella atomus* Hustedt, 16 & 17 – *C. distinguenda* Hustedt, 18–21 – *C. meneghiniana* Kützing (20 & 21 – initial cell); all in LM; scale bar = 10 µm. CF – valve face fultoportula, MF – marginal fultoportula, R – rimoportula.

salsum make them easy to overlook or misidentify when they occur in low numbers.

Skeletonema subsalsum (Cleve-Euler) Bethge
Figs 4: 10–12 & 5

Melosira subsalsa Cleve-Euler

Tiny and weakly silicified cells, rectangular in girdle view, in closely spaced sibling pairs, due mainly to having flat valve faces and the lack of a pseudosulcus.

GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. *Skeletonema subsalsum* was reported from three localities near shore waters of the Baltic Sea (Ringer 1966, Pliński 1979, Edler *et al.* 1984) and from the Vistula River in Kraków (Kawecka & Kwandrans 2000).

ECOLOGY. Cosmopolitan species, known from waters of moderate ion concentration (Krammer & Lange-Bertalot 1991). Brackish/freshwater taxon, strictly aquatic (Van Dam *et al.* 1994).

REMARKS. It can be distinguished from *S. potamos* by the lack of a pseudosulcus in sibling cells and flat valve faces. The presence of *S. subsalsum* in the heavily polluted Vistula River may be related to salinization of the environment.

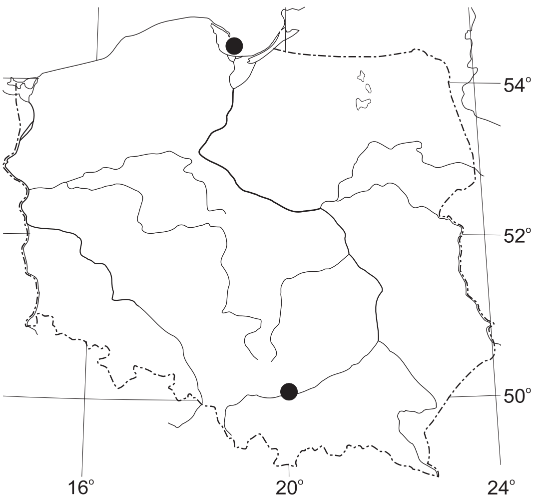


Fig. 5. Distribution of *Skeletonema subsalsum* in Poland.

Cyclotella atomus Hustedt
Figs 4: 13–15 & 6: 1–6

Valves 3.5–8 μm in diameter. Central area of valve face almost flat (Fig. 6: 1) or tangentially undulated (Fig. 6: 2), with one central fultoportula. Marginal area composed of 13.5–20 striae per 10 μm, with every second, third or fourth stria appearing thicker than the others (Fig. 4: 14).

GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. A common species. So far reported only once from the area studied (Kawecka & Kwandrans 2000). *Cyclotella atomus* is one of the most common species in the material studied (Table 1).

ECOLOGY. Euplanktonic (Denys 1991), Brackish/freshwater taxon, eutraphentic, α-mesosaprobous, strictly aquatic (Van Dam *et al.* 1994), tolerates higher ion concentrations (Krammer & Lange-Bertalot 1991).

REMARKS. The observed specimens possessed a central fultoportula with three struts, and a diagonally positioned rimoportula (Fig. 6: 3 & 4). Another important morphological feature of the species is the position of marginal fultoportulae struts (Sabater & Klee 1990; Håkansson & Clarke 1997). The observed specimens possessed marginal fultoportulae, with two struts each, above and below internal openings (Fig. 6: 5 & 6). Specimens with a horizontally positioned rimoportula (Sabater & Klee 1990, Håkansson & Clarke 1997) were not found. Some of the observed specimens have a marginal area with a distinct border (closed chambers, Fig. 6: 2), a feature attributed to *C. atomus* var *gracilis.* Because these two taxa can be reliably distinguished only by EM analyses, and co-occur, we treated the two varieties together.

****Cyclotella delicatula** Hustedt
Figs 7: 14–19 & 8: 1–7

Valves 4.5–12.0 μm in diameter. Central area of valve face almost flat. According to Scheffler *et al.* (2003) most valves have striae of the same length except where the rimoportula is inserted.

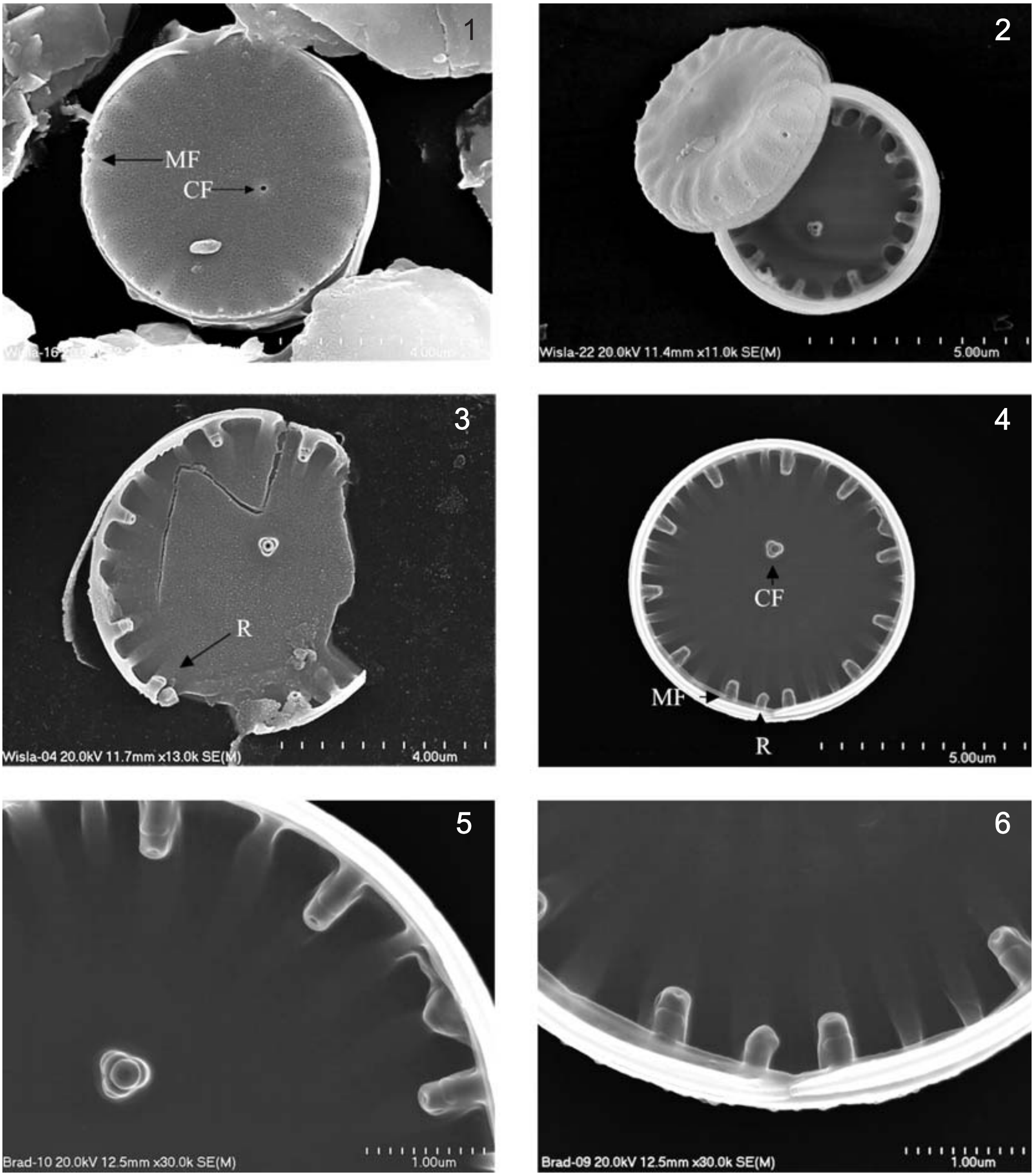


Fig. 6. *Cyclotella atomus* Hustedt. 1 – external view, 2 – external and internal views of one-frustule valves, 3–6 – internal view, all in SEM. CF – valve face fultoportula, MF – marginal fultoportula, R – rimoportula.

Striae of almost equal length (Fig. 7: 14–15, internal view) to quite different lengths (Fig. 7: 17–19, external view), 16–18 per 10 μm. Marginal fultoportulae situated at every fifth costa, and one valve face fultoportula surrounded by two satellite pores (Fig. 8: 6–7).

GENERAL DISTRIBUTION. A rarely reported species described from a small groundwater lake in Austria. Known also from the Iberian Peninsula (Kiss *et al.* 2005), Russia (Genkal & Stenina 2005), Great Lakes in the U.S.A. and Canada (Fritz *et al.* 1993; Stoermer *et al.* 1999; Barbiero & Tuchman

2004). The lack of information for determination of *Cyclotella delicatula* in the most commonly used keys (Scheffler *et al.* 2003) could be the main reason for infrequent data on its distribution.

DISTRIBUTION IN POLAND. This is the first record from Poland.

ECOLOGY. Uncertain. *Cyclotella delicatula* has been recorded at only one locality – Pilica–Piaski spring. Its abundance in calcium-rich eutrophic waters may suggest the ecological requirements of this taxon.

REMARKS. The valves are weakly silicified with branched striae, and marginal fultoportulae spaced irregularly even in one valve (Fig. 8: 6). Neighboring marginal fultoportulae are separated by five, six or seven costae. The valves of specimens identified as *Cyclotella* cf. *delicatula* were without central area fultoportulae and possessed coarsely structured areolation (Fig. 8: 4). They were observed in the same material as *C. delicatula*.

Cyclotella distinguenda Hustedt

Figs 4: 16–17 & 11: 1–4

Frustulia operculata sensu Kützing 1834, non Agardh, *Cyclotella operculata* auct. non (C.A. Agardh) Brébisson, *C. tecta* Håkansson & Ross.

Valves 10–32 μm in diameter. Valve face with 12–14 striae per 10 μm. Central area tangentially undulated. No valve face fultoportula.

GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. Reported mainly from northern Poland (e.g., Hustedt 1948; Marciniak 1973, 1979; Kaczmarska 1976, 1977; Bogaczewicz-Adamczak 1988; Bińka *et al.*1988; Cieśla & Marciniak 1982; Bąk *et al.* 2006) and central Poland (Rakowska 2001). Observed also in rivers of southern Poland (unpublished data). *C. operculata* Kützing was identified from the Wyżyna Krakowsko-Częstochowska upland by Raciborski (1888) and Gutwiński (1895).

ECOLOGY. Euplanktonic (Denys 1991) or tychoplanktonic of benthic origin, known from the pelagial zone of lakes, alkaliphilous species, tolerating waters of elevated conductivity, Brackish/freshwater taxon, strictly aquatic (Krammer & Lange-Bertalot 1991; Van Dam *et al.* 1994).

REMARKS. Central area (both elevated and depressed part) covered by more or less distinctive wrinkles. Valves with striae, which consist of three rows of areolae along the whole length of striae (two rows of coarser areolae and one row of much finer areolae). Internal opening of rimoportula positioned diagonally on the valve face/mantle junction. Marginal fultoportulae openings situated (interiorly) just above every (second) third–fourth rib.

Cyclotella meneghiniana Kützing

Figs 4: 18–21; 7: 1–13; 9: 1–8 & 10: 1–5

Surirella melosiroides Meneghini

Valves 5–45 μm in diameter. Central area flat or tangentially undulate. Marginal area with 6–10 striae per 10 μm. In the central area, one to several valve face fultoportulae surrounded by three satellite pores. One rimoportula present with an external slit-like opening, and internally with a stalked labium often bent toward the costa (Fig. 10: 2 & 4).

GENERAL DISTRIBUTION. A widespread species (Krammer & Lange-Bertalot 1991; Håkansson 2002).

DISTRIBUTION IN POLAND. One of the most commonly reported centric diatoms. In the area studied it is known from the Vistula River (Turoboyski 1962; Pudo 1977; Kawecka & Kwandrans 2000), the Pilica River (Kadłubowska 1964), springs of Kobylanka stream (Skalna 1969), and the Będkówka (Kubik 1970) and Sanka streams (Hojda 1971). One of the most common species in the materials studied (Table 1).

ECOLOGY. Tychoplanktonic of benthic origin (Denys 1991), brackish/freshwater, eutraphentic, α-meso- to polysaprobous, indicator of poor water quality, aquatic and subaerophytic (Van Dam *et al*. 1994; Prygiel & Coste 2000). According to Krammer and Lange-Bertalot (1991) it is common

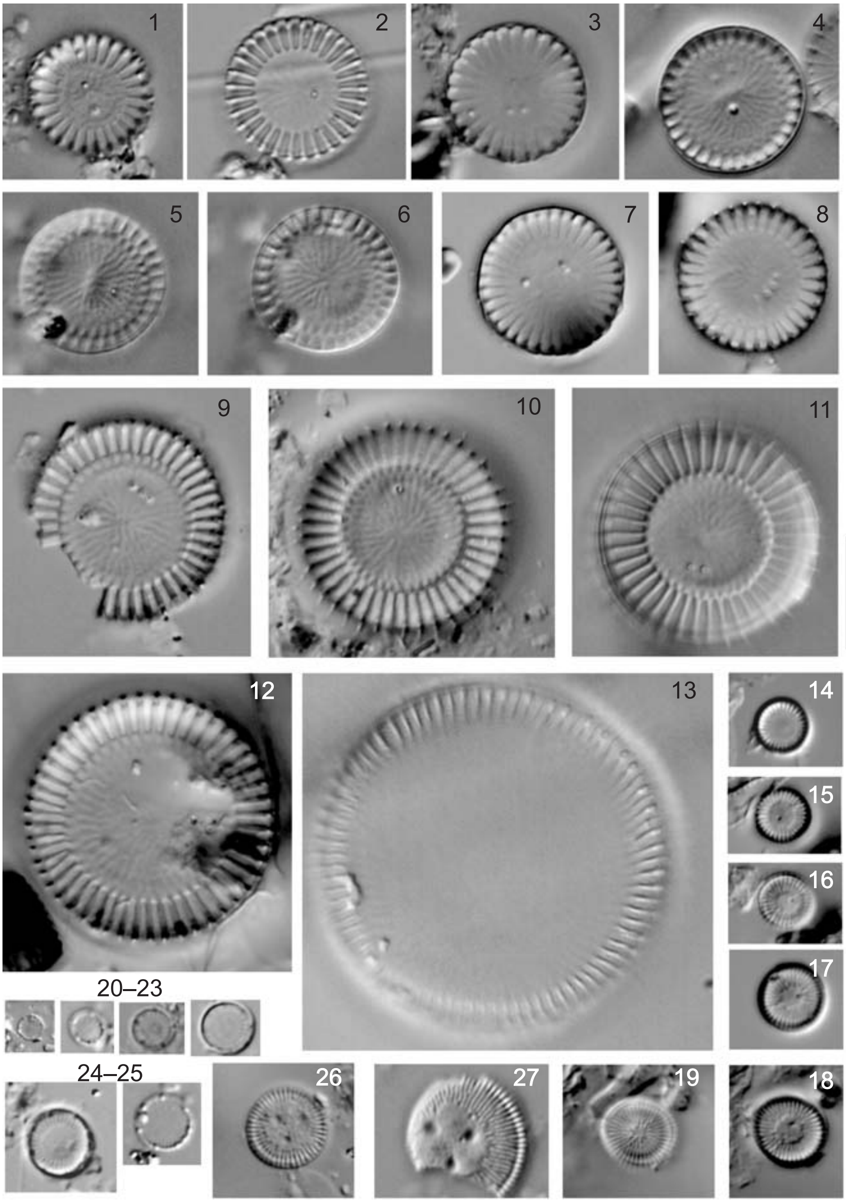


Fig. 7. 1–13 – *Cyclotella meneghiniana* Kützing (13 – initial cell), 14–19 – *C. delicatula* Hustedt, 20–22 – *Thalassiosira pseudonana* Hasle & Heimdal, 23–25 – *T.* cf. *pseudonana,* 26 & 27 – *C. ocellata* Pantocsek; all in LM; scale bar = 10 μm.

in ditches and puddles and also in rivers and eutrophic lakes. *Cyclotella meneghiniana* possibly belongs to the group of species considered "super tramps", such as *Nitzschia palea* (Kützing) W. Smith. Diatoms of this group can grow in a variety of habitats, but only when not in a highly competitive situation (Patrick & Roberts 1979). In highly eutrophic and polluted (saline) waters *C. meneghiniana* can develop large populations, when presumably freed of competition.

REMARKS. *Cyclotella meneghiniana* is a species with a very wide range of morphological variability (Håkansson 2002). Its morphology certainly is environmentally induced (e.g., presumably by ion concentration) and dependent on the life cycle stage (e.g., Håkansson & Chepurnov 1999; Håkansson 2002), as in other common centric diatoms such as *Stephanodiscus alpinus* Hust. (Theriot *et al*. 1987), *S. minutulus* (Kobayasi *et al*. 1985) or *S. hantzschii* Grunow (Geissler 1986). In the highly polluted and saline Vistula River we observed the mass occurrence of *Cyclotella meneghiniana* and recorded very fine silicified valves with various numbers of valve face fultoportulae (sometimes the valves of one frustule differed in number), and initial cells. The morphology of the observed initial cells (Figs 7: 13 & 10: 1–5) was similar to that of initial cells of *C. meneghiniana* found in monoclonal cultures by Håkansson and Chepurnow (1999). They also show close similarities to Meyer and Håkansson's (1997) description of *Cyclotella wulfiae*.

***Cyclotella ocellata** Pantocsek Fig. 7: 26–27.

Valves 8–20(25) µm in diameter. Marginal area consists of 13–15 striae of different lengths per 10 µm. In central area are three to five papillae and corresponding depressions (*orbiculus depressus*).

GENERAL DISTRIBUTION. Probably a cosmopolitan species (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. This species is relatively frequently reported (e.g., Rakowska 1996; Siemińska & Wołowski 2003). Because of its great morphological variability, however, some information in references probably concerns similar related species. This is the first record of *C. ocellata* for the area studied.

ECOLOGY. Euplanktonic (Denys 1991) or tychoplanktonic of benthic origin, alkaliphilous, freshwater species, meso-eutraphentic, oligosaprobous, strictly aquatic (Van Dam *et al*. 1994, Krammer & Lange-Bertalot 1991).

REMARKS. The species is known to have great morphological plasticity, but is characterized by specific features (e.g., *orbiculus depressus*). Heterovalvy (epivalve is morphologically different from hypovalve) is a common feature in *C. ocellata* populations (Cremer *et al*. 2005). Under a different concept of morphological variability limits, *C. comensis* Grunow, *C. krammeri* Håkansson and *C. rossi* Håkansson are unified (Hegewald & Hindakova 1997; Cremer *et al.* 2005), whereas Håkansson (2002) treated these taxa as separate species.

Discostella pseudostelligera (Hustedt) Houk & Klee Fig. 12: 1–3 & 13: 1–9

Cyclotella pseudostelligera Hustedt

Valves 4–6 µm in diameter. Marginal area (1/4–1/3 the area of the valve face) with 16–20 striae per 10 µm. Frustules heterovalvate. On valves with stellate pattern in the central area, dichotomically divided costae and more distinctive striae.

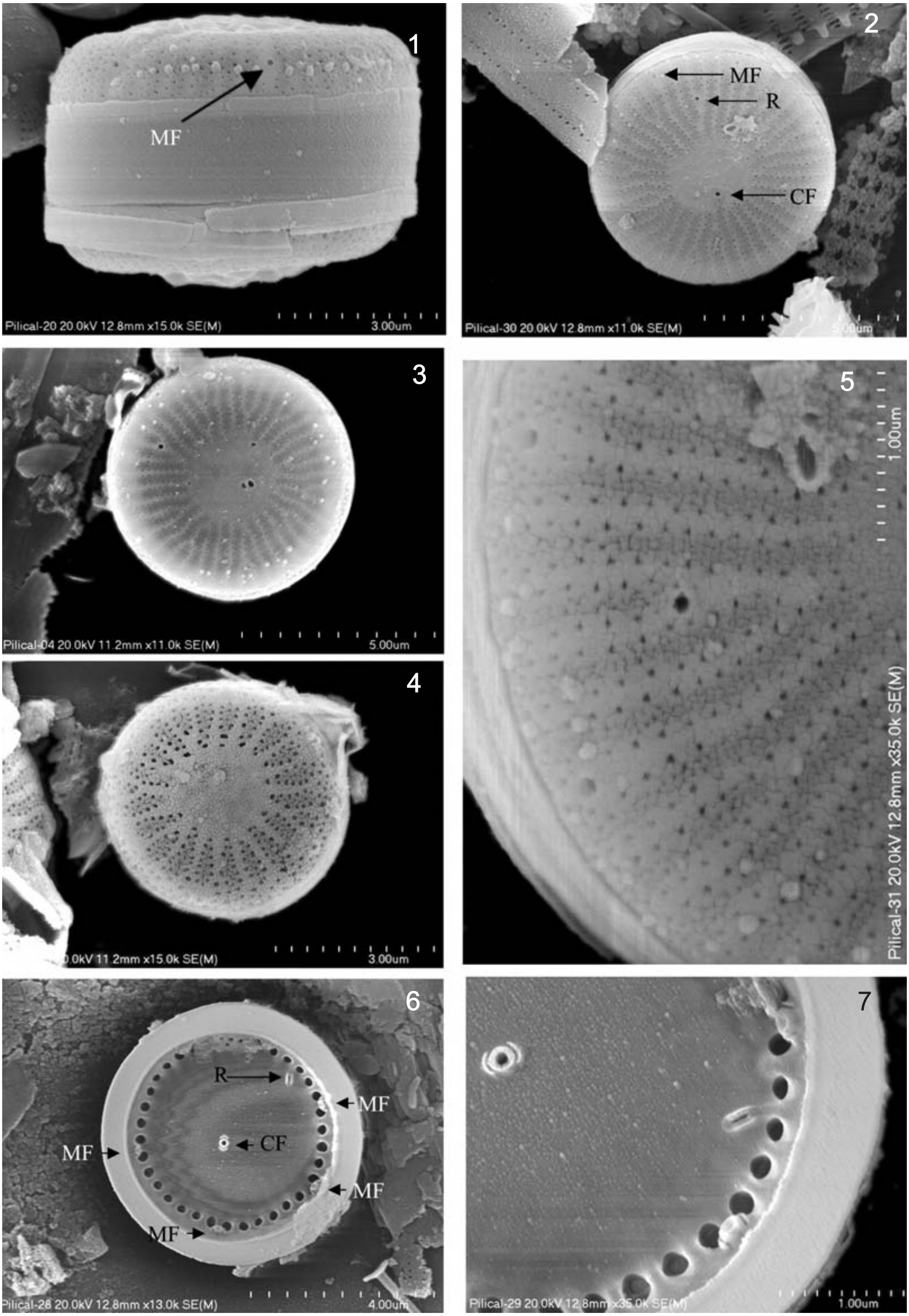
GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).

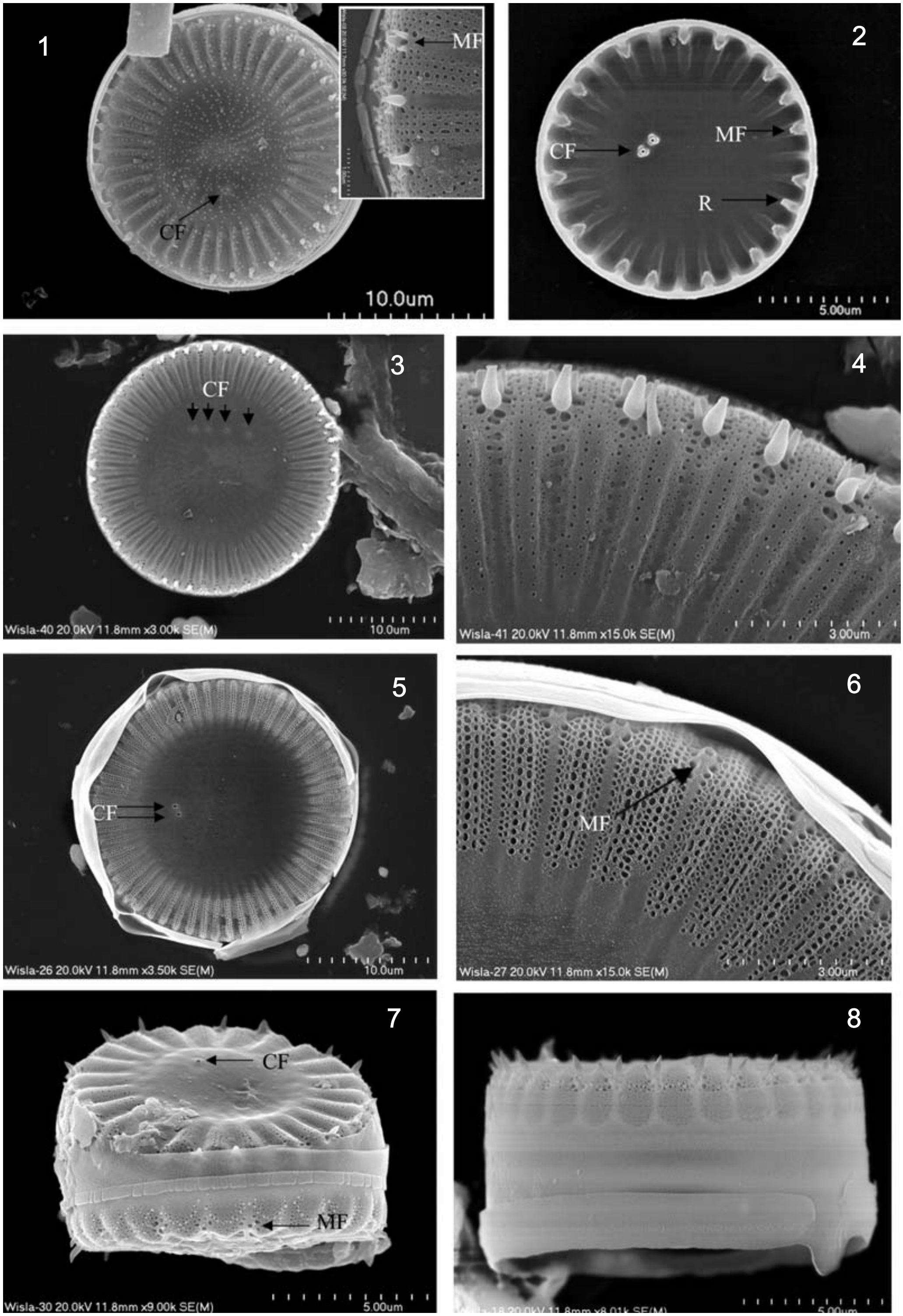
DISTRIBUTION IN POLAND. The species is regarded as cosmopolitan but there are not enough published data to estimate its real distribution. Although there is only one record of the species from the Vistula River in Poland (Kiss & Pająk 1994), probably it is not rare but either overlooked or not identified to the species level. Observed in the Wyżyna Krakowsko-Częstochowska upland: Vistula, Szreniawa, Dłubnia (Kawecka & Kwandrans 2000) and Rudawa rivers (Bucka 2000), and in several rivers and reservoirs in southern Poland (unpublished data).

ECOLOGY. Defined as euplanktonic (Denys 1991) or tychoplanktonic of benthic origin, Brackish/freshwater taxon, eutraphentic, α-meso-

→

Fig. 8. *Cyclotella delicatula* Hustedt (1–3 & 5–7) and *C.* cf. *delicatula* (4). 1–5 – valves in external view, 6 & 7 – valves in internal view; all in SEM. (1 – frustule with very slight tangential undulation, girdle view, 7 – valve face fultoportulae with two struts). CF – valve face fultoportula, MF – marginal fultoportula, R – rimoportula.


1
MF
Pilical-20 20.0kV 12.8mm x15.0k SE(M)
3.00um
2
MF
R
CF
Pilical-30 20.0kV 12.8mm x11.0k SE(M)
3
Pilical-04 20.0kV 11.2mm x11.0k SE(M)
5.00um
4
0.0kV 11.2mm x15.0k SE(M)
3.00um
5
1.00um
Pilical-31 20.0kV 12.8mm x35.0k SE(M)
6
R
MF
CF
MF
MF
MF
Pilical-28 20.0kV 12.8mm x13.0k SE(M)
4.00um
7
Pilical-29 20.0kV 12.8mm x35.0k SE(M)
1.00um


1
MF
CF
10.0um
2
MF
CF
R
5.00um
3
CF
Wisla-40 20.0kV 11.8mm x3.00k SE(M)
10.0um
4
Wisla-41 20.0kV 11.8mm x15.0k SE(M)
3.00um
5
CF
Wisla-26 20.0kV 11.8mm x3.50k SE(M)
10.0um
6
MF
Wisla-27 20.0kV 11.8mm x15.0k SE(M)
3.00um
7
CF
MF
Wisla-30 20.0kV 11.8mm x9.00k SE(M)
5.00um
8
5.00um

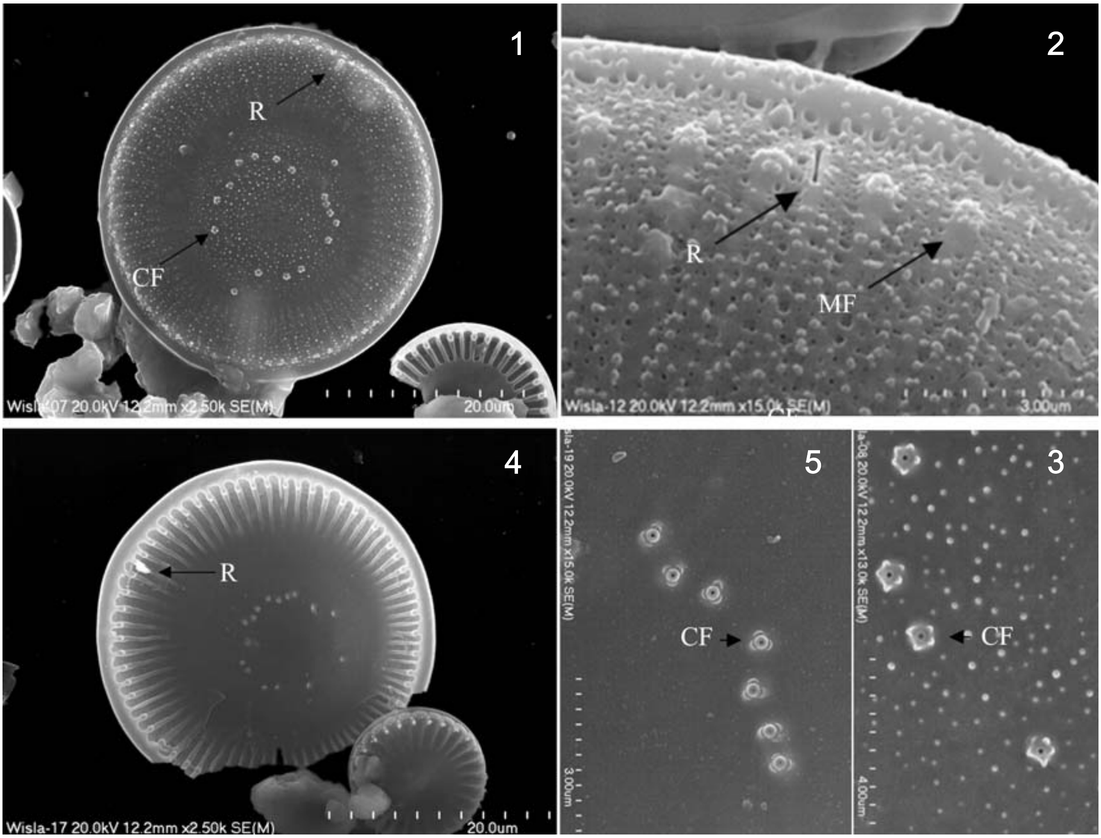


Fig. 10. 1–5 – initial cells of *C. meneghiniana* Kützing: 2 – enlarged marginal part, detail with external opening of the rimoportula, 3 – external view of central fultoportulae, 5 – internal view of valve face fultoportulae. 1–3 – external view, 4 & 5 – internal view; all in SEM.

saprobous, considered an indicator of moderate water quality (Prygiel & Coste 2000). Neutrophilous, α-mesosaprobous, eutraphentic, strictly aquatic species (Van Dam *et al*. 1995). Wunsam *et al*. (1995) characterized *D. pseudostelligera* as an inhabitant of waters of low conductivity (lower than for *D. stelligera*). Also reported from more eutrophic environments (Siver *et al*. 2005). These preference/tolerance limits conform with our findings in numerous rivers in southern Poland (Kwandrans & Wojtal 2006).

REMARKS. Valves with a stellate pattern concentrically elevated, colliculate, with "teeth-shaped" external openings of marginal fultoportulae (Fig. 13: 1 & 4). Valves devoid of stellate pattern, with flat central part of the valve face (Fig. 13: 4). Internally with small, sessile rimoportulae and marginal fultoportulae openings surrounded by two struts situated on the valve face/mantle junction (Fig. 13: 5). The smallest, weakly silicified valves without stellate pattern are very difficult to identify by

←

Fig. 9. *Cyclotella meneghiniana* Kützing. 1 & 7 – valve with tangential undulation of central area, 2, 3 & 5 – valves with different numbers of central fultoportulae, 2 – valve with two central fultoportulae, with three struts each, 8 – girdle view of valve. 1, 3–8 – valves in external view, 2 – valve in internal view; all in SEM. CF – valve face fultoportula, MF – marginal fultoportula, R – rimoportula.

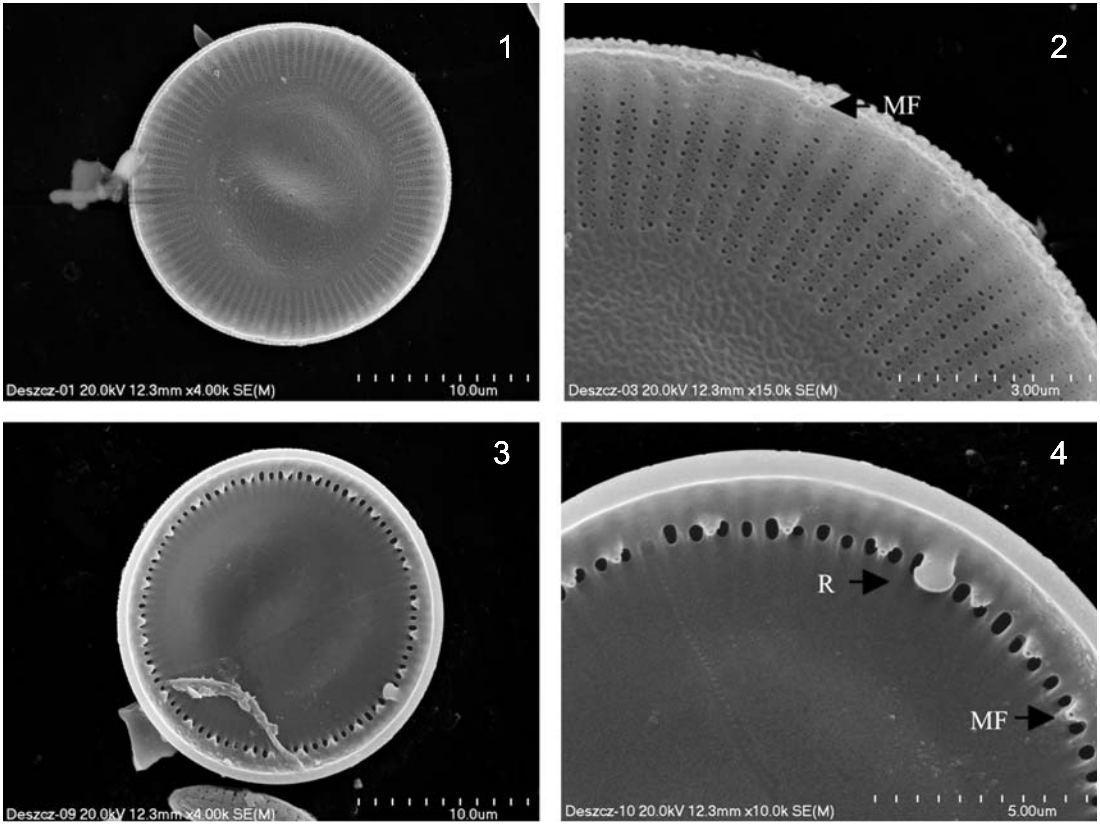


Fig. 11. *Cyclotella distinguenda* Hustedt. 1 & 2 – external view, 3 & 4 – internal view of valves; all in SEM. (1 – valve with tangential undulation, 2 – marginal area structure; every fascicle consists of two rows of coarser areoles and one row of distinctively finer areoles, 4 – marginal area with fultoportulae and rimoportula in position oblique to valve fascicle). CF – valve face fultoportula, MF – marginal fultoportula, R – rimoportula.

LM, and could be confused with *Thalassiosira pseudonana.*

Discostella stelligera (Cleve & Grunow) Houk & Klee Fig. 12: 10–11

Cyclotella meneghiniana var. ?*stelligera* Cleve & Grunow *in* Cleve, *Cyclotella stelligera* Cleve & Grunow *in* Cleve.

Frustules heterovalvate (central area with and without stellate pattern), 15–40 μm in diameter. Marginal area with 11–14 striae per 10 μm. Concentrically undulated marginal fultoportulae situated between costae. Valves with stellate pattern possess a narrow hyaline area between the ornamented marginal and central areas of the valve face.

GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. According to data published up to 1990 (see Siemińska & Wołowski 2003), apparently quite common in Poland. From the Krakowsko-Częstochowska upland *D. stelligera* was reported from the area studied by Turoboyski (1962) and Pudo (1977) from the Vistula River, and by Kadłubowska (1964) from the Pilica River.

ECOLOGY. Euplanktonic (Denys 1991) or tychoplanktonic of benthic origin, Brackish/freshwater taxon. According to Wunsam *et al*. (1995) *D. stelligera* prefers waters of lower conductivity.

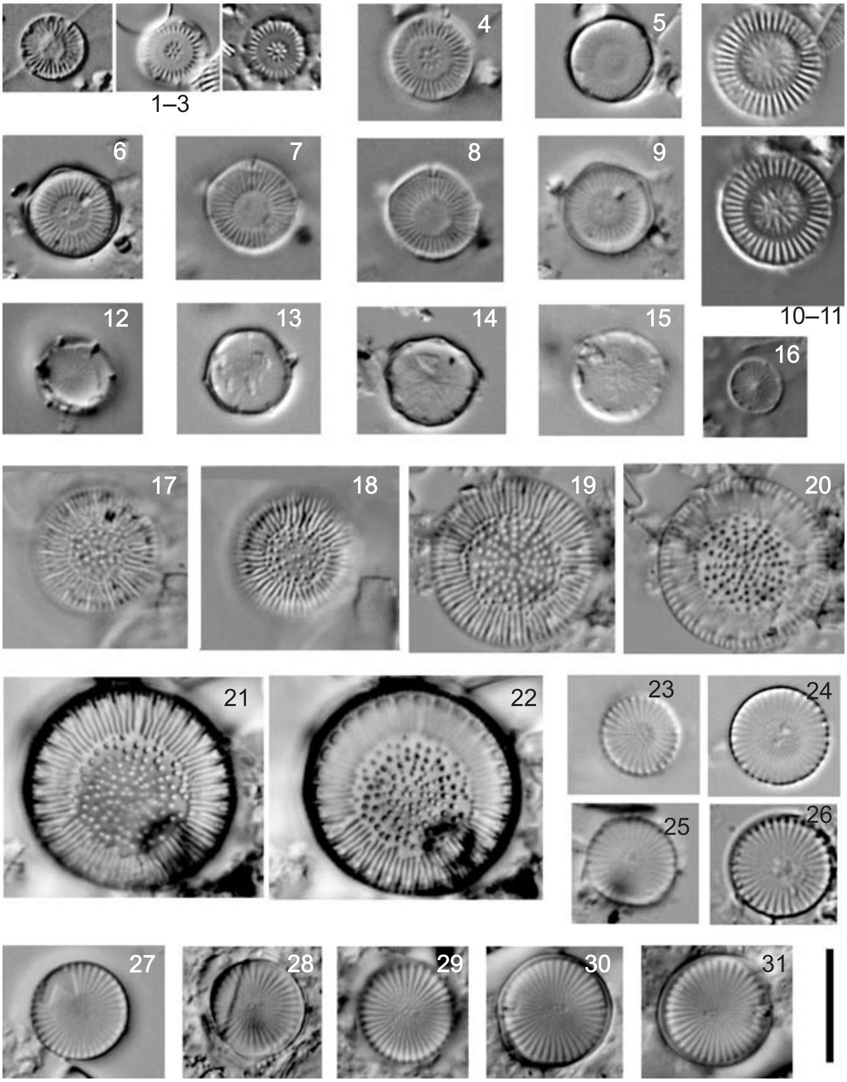


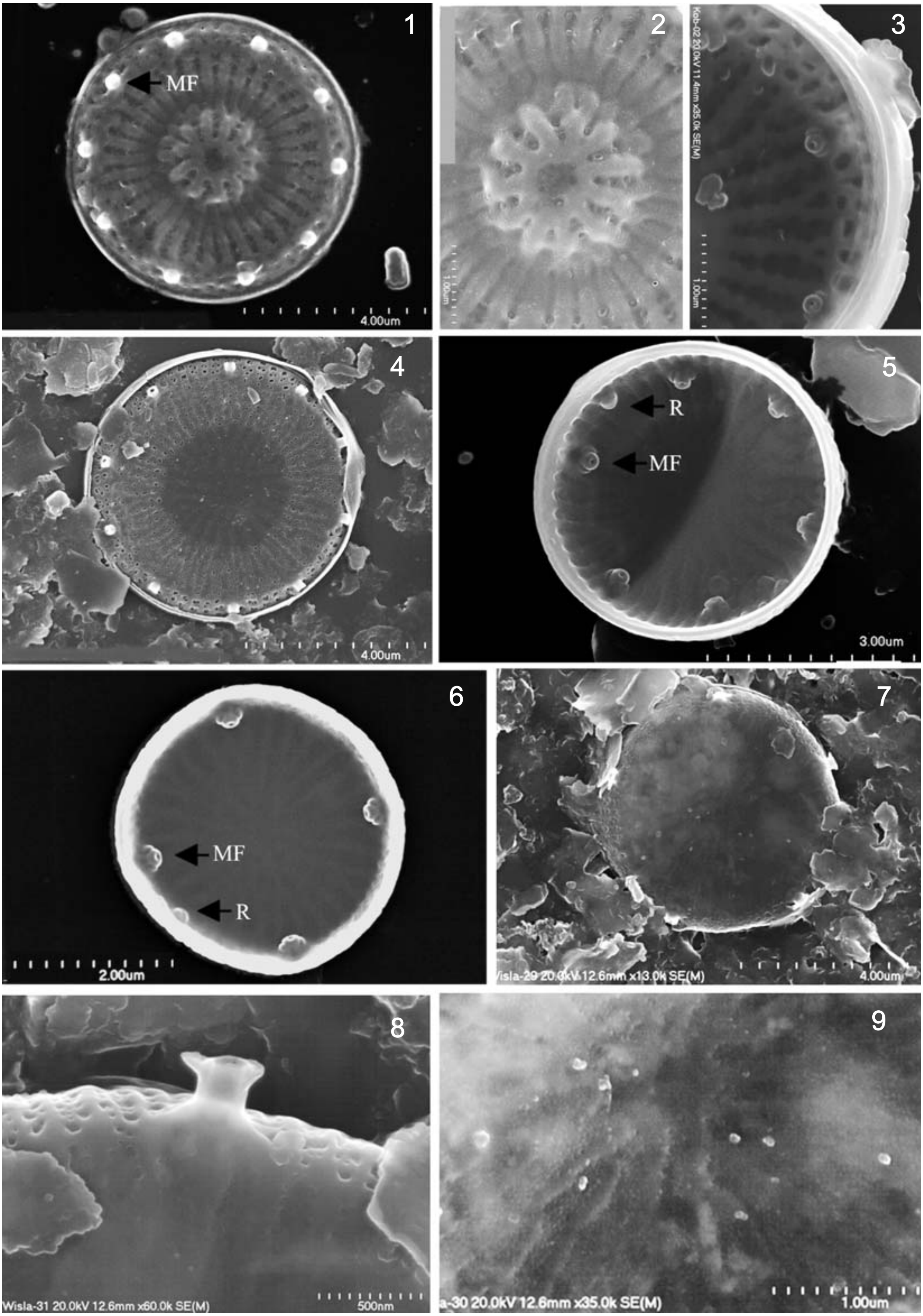
Fig. 12. 1–3 – *Discostella pseudostelligera* (Hustedt) Houk & Klee. 4–9 – *D.* cf. *woltereckii* (Hustedt) Houk & Klee, 10 & 11 – *D. stelligera* (Cleve & Grunow) Houk & Klee, 12–16 – *D. woltereckii* (Hustedt) Houk & Klee, 17–22 – *Puncticulata radiosa* (Lemmermann) Håkansson, 23–27 – *Cyclostephanos* cf. *delicatus* (Genkal) Casper & Scheffler, 28–31 – *C.* cf. *delicatus*; all in LM; scale bar = 10 µm.

REMARKS. Recorded specimens possessed distinctive coarse striation and central stellate pattern. In our materials *D. stelligera* was less common than *D. pseudostelligera*. Generally it occurred in eutrophic waters less polluted than the Vistula, Rudawa or Prądnik rivers, where *D. pseudostelligera* was not rare and sometimes common.

****Discostella woltereckii*** (Hustedt) Houk & Klee
Figs 12: 4–9 & 12–16; 14 & 15: 1–3

Cyclotella woltereckii Hustedt.

Valves of dichotomous pattern, 4.7–12 µm in diameter. Central area of different sizes from very small (Fig. 12: 16) to larger (Fig. 12: 15), formed by striae running towards the valve center. Marginal


1
MF
4.00um
2
3
4
4.00um
5
R
MF
3.00um
6
MF
R
2.00um
7
Wisla-29 20.0kV 12.6mm x13.0k SE(M)
4.00um
8
Wisla-31 20.0kV 12.6mm x60.0k SE(M)
500nm
9
a-30 20.0kV 12.6mm x35.0k SE(M)
1.00um

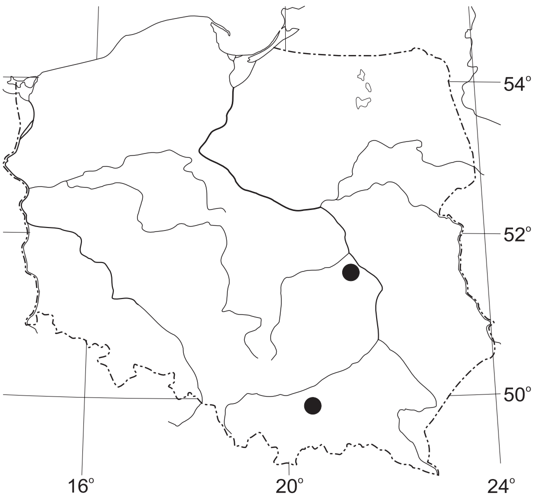


Fig. 14. Distribution of *Discostella woltereckii* (Hustedt) Houk & Klee in Poland (one dot may represent more than one locality).

area with 19–21 longer striae per 10 µm running deep towards the valve center, and much shorter ones inserted among them (Fig. 15: 1–3).

GENERAL DISTRIBUTION. *D. woltereckii* was described by Hustedt from Java in 1942, also known from Europe (Wunsam *et al*. 1995, Hübener (1999).

DISTRIBUTION IN POLAND. The species was reported from Poland only twice (Fig. 14.), from reservoirs in central Poland (Bucka & Wilk-Woźniak 2002) and a dam reservoir in southern Poland (Wojtal *et al.* 2005).

ECOLOGY. Tychoplanktonic of benthic origin, cosmopolitan, brackish/freshwater taxon. Wunsam *et al*. (1995) gave lower conductivity preferences for this species, but the physical and chemical parameters of water where *D. woltereckii* was identified are much more like those reported by Hübener (1999); we found it in an alkaline eutrophic lake of moderate and high conductivity.

REMARKS. The observed specimens show irregular radial striation, with shorter striae inserted between longer ones. Central area almost absent or very small, raised (Fig. 12: 16) or rather flat (Figs. 12: 15 & 15: 1). External openings of marginal fultoportulae wing-shaped (Fig. 15: 2 & 3). Similar ornamentation of *D. woltereckii* was characterized as a dichotomous valve pattern by Klee and Houk (1996). Some specimens determined here as *D.* cf. *woltereckii* (Fig. 12: 4–9) show some similarities to *D. pseudostelligera*. Among these weakly silicified valves we did not find valves with the stellate pattern considered typical for *D. woltereckii*, consisting of larger puncta with several small puncta between them at the margin of the pattern (Klee & Houk 1996). The marginal area of these specimens is built of dichotomously branched striae. Because valves typical for *D. woltereckii* occurred in the same samples, possibly the valves determined as *D.* cf. *woltereckii* represent the stellate pattern morphological form of the species.

Puncticulata radiosa (Lemmermann) Håkansson
Figs 12: 17–22 & 15: 4–7

Cyclotella comta var. *radiosa* Grunow *in* Van Heurck 1882.

Valves concentrically undulated, 7–25 µm in diameter. Externally, central area concentrically elevated, slightly colliculate, with external openings of central fultoportulae (smaller puncta) and areolae (bigger puncta) (Fig. 15: 4). External openings of rimoportulae at end of shortened striae (Fig. 15: 4). Inside valves with slit-like openings of rimoportulae positioned radially (Fig. 15: 5, 7) or diagonally, situated beneath alveolar chambers (towards central part of valve face). Marginal fultoportulae openings situated (interiorly) on valve mantle, above every third to fourth rib (Fig. 15: 5).

←

Fig. 13. 1–9 – *Discostella pseudostelligera* (Hustedt) Houk & Klee. 1 & 4 – "teeth-shaped" fultoportulae, 2 – central area structure, 3 – marginal fultoportulae with two struts, situated between dichotomically divided costae, 4 – heterovalvy (cf. Fig. 13: 1), 5 & 6 – internal view of valve with six and four marginal fultoportulae, respectively, and marginal rimoportula, 7–9 – *Discostella* cf. *pseudostelligera* (Hustedt) Houk & Klee (7 & 8 – wing-shaped marginal fultoportulae, 9 – fine-structured central area). 1, 2, 4, 7–9 external view, 3, 5 & 6 – internal view; all in SEM. CF – valve face fultoportula, MF – marginal fultoportula, R – rimoportula.

GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. The distribution of *P. radiosa* seems to be underestimated. Reported from the area studied from the Vistula River (Kawecka & Kwandrans 2000) and the Rudawa River (Kawecka & Kwandrans 2000).

ECOLOGY. Euplanktonic (Denys 1991), alkaliphilous, brackish/freshwater species, eutraphentic, β-mesosaprobous, strictly aquatic species (Van Dam *et al.* 1994).

REMARKS. Particular morphotypes may develop in response to certain trophic states or life stages of the cell, within a large range of morphological variability.

***Cyclostephanos delicatus** (Genkal) Casper & Scheffler Figs 12: 23–31 & 16: 15–20.

S*tephanodiscus delicatus* Genkal, *Cyclostephanos tholiformis* Stoermer, Håkansson & Theriot

Center of valve face elevated or depressed, 6.9–13.8 μm in diameter. Valves with slightly excentric valve face fultoportulae. The striated marginal area consists of 11.5–17 striae per 10 μm. According to Casper and Scheffler (1990) and Dreßler and Hübener (2006), marginal fultoportulae possess two or three struts (cowlings) and one central face fultoportula with two struts.

GENERAL DISTRIBUTION. A widespread species in the Northern Hemisphere (e.g., Stoermer *et. al.* 1987, Casper & Scheffler 1990, Medioli & Brooks 2003, Kharitonov 2005, Dreßler & Hübener 2006).

DISTRIBUTION IN POLAND. Reported so far only from a dam reservoir in southern Poland (Wojtal *et al.* 2005) and from the Zalew Szczeciński lagoon (Bąk *et al*. 2006).

ECOLOGY. Available data suggest that the species can inhabit eutrophic and polluted calcium-rich waters (e.g., Casper & Scheffler 1990, Dreßler & Hübener 2006), including waters with elevated salts concentrations (Kharitonov 2005).

REMARKS. A recent morphological study of *Stephanodiscus delicatus* revealed that this species is conspecific with *Cyclostephanos tholiformis* (Dreßler & Hübener 2006). Some specimens identified as *Stephanodiscus* cf. *delicatus* possess an annulus in the center of the valve (Fig. 12: 28–31), a feature known from North American populations of *C. tholiformis* (Stoermer *et. al*. 1987), and weakly silicified valves with finer ornamentation and gradual undulation of the valve face area.

****Cyclostephanos dubius*** (Fricke) Round *in* Theriot *et al.* 1987 Figs 15: 8 & 16: 1–11

Cyclotella dubia Fricke, *Stephanodiscus dubius* (Fricke) Hustedt.

Center of valve face strongly concentrically undulate, 4–35 μm in diameter. Valves with variable numbers of spines at the valve face/mantle junction. Striated marginal area consists of 12–18 striae per 10 μm.

GENERAL DISTRIBUTION. Probably a cosmopolitan species (Krammer & Lange-Bertalot 1991).

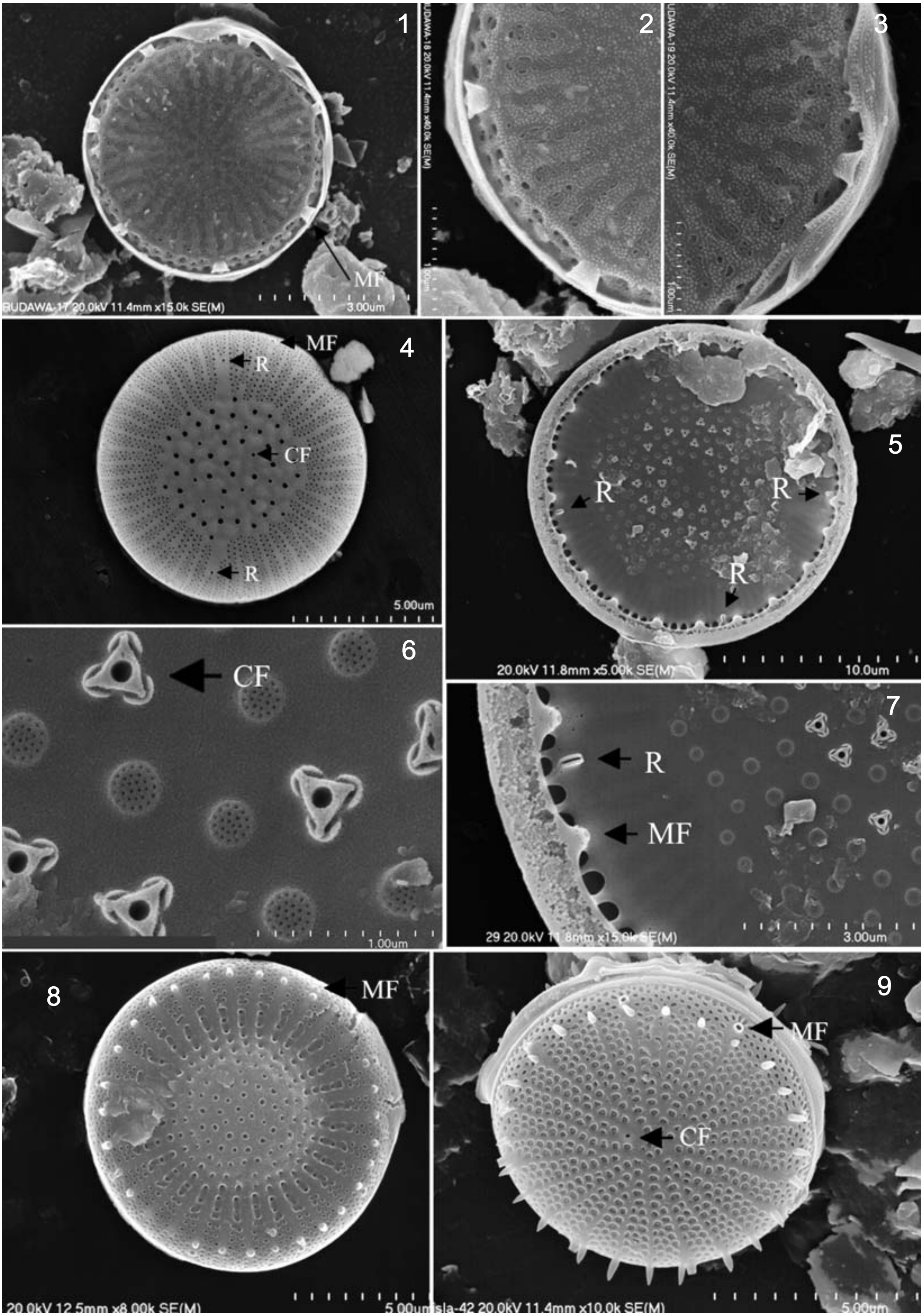
DISTRIBUTION IN POLAND. Commonly reported species.

ECOLOGY. Euplanktonic (Denys 1991), alkalibiontic, brackish/freshwater species, eutraphentic, α-mesosaprobous, strictly aquatic species (Van Dam *et al*. 1994). Considered an indicator of poor water quality (Prygiel & Coste 2000).

REMARKS. The species is characterized by great morphological variability, related to the degree of valve silicification. The fine or coarse structure of valves, the presence or absence of spines, and the areolation pattern may be environmentally and ontogenically dependent.

⟶

Fig. 15. 1–3 – *Discostella woltereckii* (Hustedt) Houk & Klee. 2 & 3 – marginal wing-shaped fultoportulae, 4–7 – *Puncticulata radiosa* (Lemmermann) Håkansson (5–7 – marginal fultoportulae at every fourth costa, scattered central fultoportulae with three struts), 8 – *Cyclostephanos dubius* (Fricke) Round, 9 – *C. invisitatus* (Hohn & Hellerman) Stoermer, Theriot & Håkansson. 1–4, 8 & 9 – external view, 5–7 – internal view; all in SEM. CF – valve face fultoportula, MF – marginal fultoportula, R – rimoportula.


1
MF
BUDAWA-17 20.0kV 11.4mm x15.0k SE(M)
3.00um
2
3
4
MF
R
CF
R
5.00um
5
R
R
R
20.0kV 11.8mm x5.00k SE(M)
10.0um
6
CF
1.00um
7
R
MF
3.00um
8
MF
20.0kV 12.5mm x8.00k SE(M)
5.00um
9
MF
CF
20.0kV 11.4mm x10.0k SE(M)
5.00um

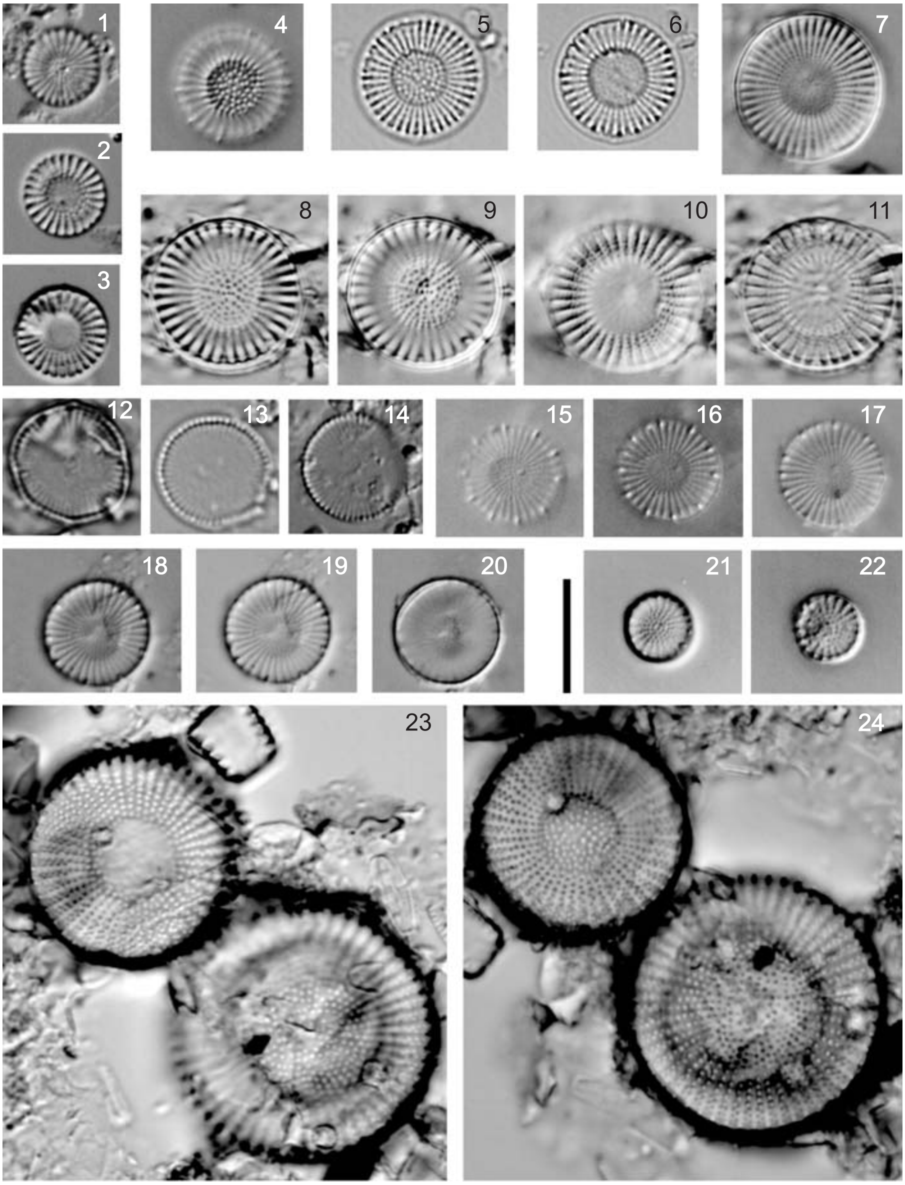


Fig. 16. 1–11 – *Cyclostephanos dubius* (Fricke) Round, 12–14 – *C. invisitatus* (Hohn & Hellerman) Stoermer, Theriot & Håkansson, 15–20 – *C.* cf. *delicatus* (Genkal) Casper & Scheffler, 21 & 22 – *Stephanodiscus minutulus* (Kützing) Grunow *in* Cleve & Möller, 23 & 24 – *S. alpinus* Hustedt; all in LM; scale bar = 10 μm.

*****Cyclostephanos invisitatus*** (Hohn & Hellerman) Stoermer, Theriot & Håkansson

Figs 15: 9; 16: 12–14 & 17

Stephanodiscus invisitatus Hohn & Hellerman, *Stephanodiscus hantzschii* var. *striator* Kalbe

Valves flat, 6–14 μm in diameter. Striated marginal area consists of 15–20 striae per 10 μm.

GENERAL DISTRIBUTION. Probably a cosmopolitan species (Krammer & Lange-Bertalot 1991).

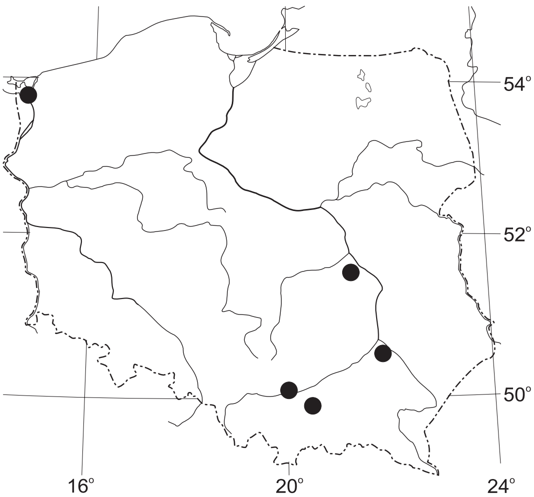


Fig. 17. Distribution of *Cyclostephanos invisitatus* (Hohn & Hellerman) Stoermer, Theriot & Hakansson in Poland (one dot may represent more than one locality).

DISTRIBUTION IN POLAND. *C. invisitatus* was reported from the Rawka River (Rakowska 1984), the heavily polluted Zbiornik Puławski reservoir (Bucka & Wilk-Woźniak 2002), a dam reservoir in southern Poland (Wojtal *et al.* 2005), and the Zalew Szczeciński lagoon (Bąk *et al.* 2006). Presumably much more widespread.

ECOLOGY. Not well known. Cosmopolitan, planktonic (Krammer & Lange-Bertalot 1991), known from waters of moderate and higher trophy and moderate alkalinity (e.g., Siver *et al.* 2005).

REMARKS. The representatives in the material studied were weakly silicified, with fine ribs, most distinctive near the valve margin.

Stephanodiscus alpinus Hustedt

Figs 16: 23–24 & 19: 20–24

Valves 7.5–32 µm in diameter, with central part strongly undulate concentrically. Striated area consists of (6)8–11 striae per 10 µm. Valve face fultoportula near center or absent (Håkansson 2002).

GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. Known from the Zbiornik Puławski reservoir (Bucka & Wilk-Woźniak 2002, Wilk-Woźniak & Ligęza 2003) and Zalew Szczeciński lagoon (Bąk *et al.* 2006). From the Wyżyna Krakowsko-Częstochowska upland reported so far only from Kluczwoda stream (Nawrat 1993).

ECOLOGY. Planktonic, cosmopolitan (Krammer & Lange-Bertalot 1991). *Stephanodiscus alpinus* was originally believed to prefer low temperatures. Further data indicated that it tolerates slight nutrient enrichment (Stoermer & Yang 1970). The data from Poland may suggest a much wider range of ecological tolerance, including heated, polluted and saline waters (Bucka & Wilk-Woźniak 2002), polluted brackish waters (Bąk *et al.* 2006) and subaerophytic localities overgrown by *Vaucheria* sp. in the Kluczwoda stream (Nawrat 1993). Misidentification is also possible. Records of its occurrence in a wide environmental spectrum may imply broad tolerance limits or may be the result of incorrect reporting of separate but similar taxa.

REMARKS. Some specimens (Fig. 19: 22–24) resemble *Stephanodiscus medius* Håkansson, a species known from Canada. During our study they occurred only once, in the same sample with *Stephanodiscus alpinus.*

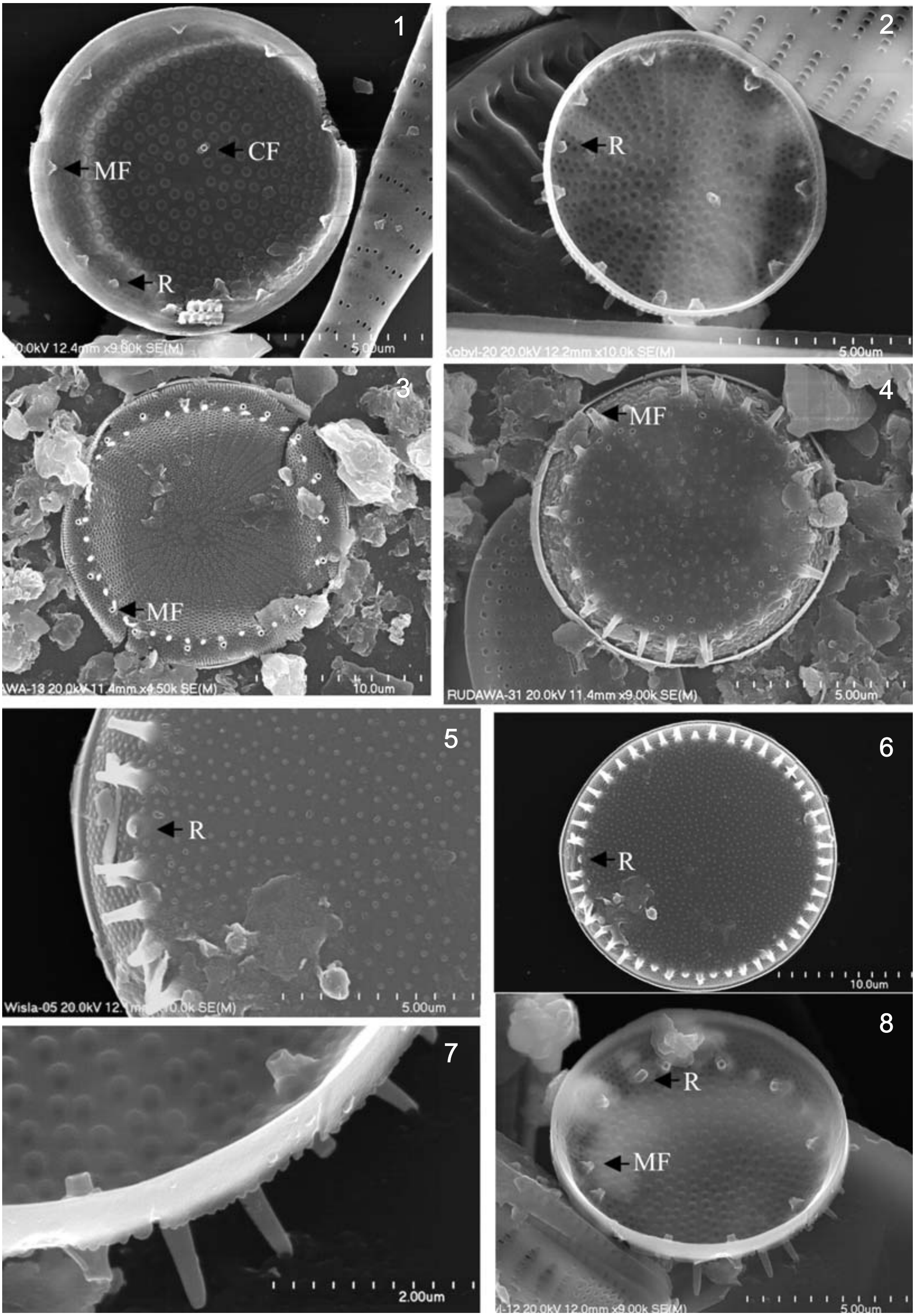
Stephanodiscus hantzschii Grunow

Figs 18: 3–8 & 19: 1–9

Cyclotella operculata sensu Hantzsch *in* Rabenhorst, non *Frustulia operculata* Agardh, non *Cyclotella operculata* Kützing, *Stephanodiscus tenuis* Hustedt, *S. hantzschii* Grunow fo. *tenuis* (Hustedt) Håkansson & Stoermer.

Valves flat, 5–30 µm in diameter. Striated area consists of 8–12 striae per 10 µm. Spines at every interfascicle (at valve face/mantle junction). Mantle fultoportulae beneath every third to fifth spine. One rimoportula between spines (Fig. 18: 5–6). Valve face fultoportula absent. Observed specimens possessed valves with a clear areolar pattern (Fig. 18: 3, 6) as well as irregularly shaped and variously oriented short fissures and slits scattered across the valve face (Fig. 18: 4).

GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).


1
CF
MF
R
5.00um
2
R
Kobyl-20 20.0kV 12.2mm x10.0k SE(M)
5.00um
3
MF
10.0um
4
MF
RUDAWA-31 20.0kV 11.4mm x9.00k SE(M)
5.00um
5
R
5.00um
6
R
10.0um
7
2.00um
8
R
MF
5.00um

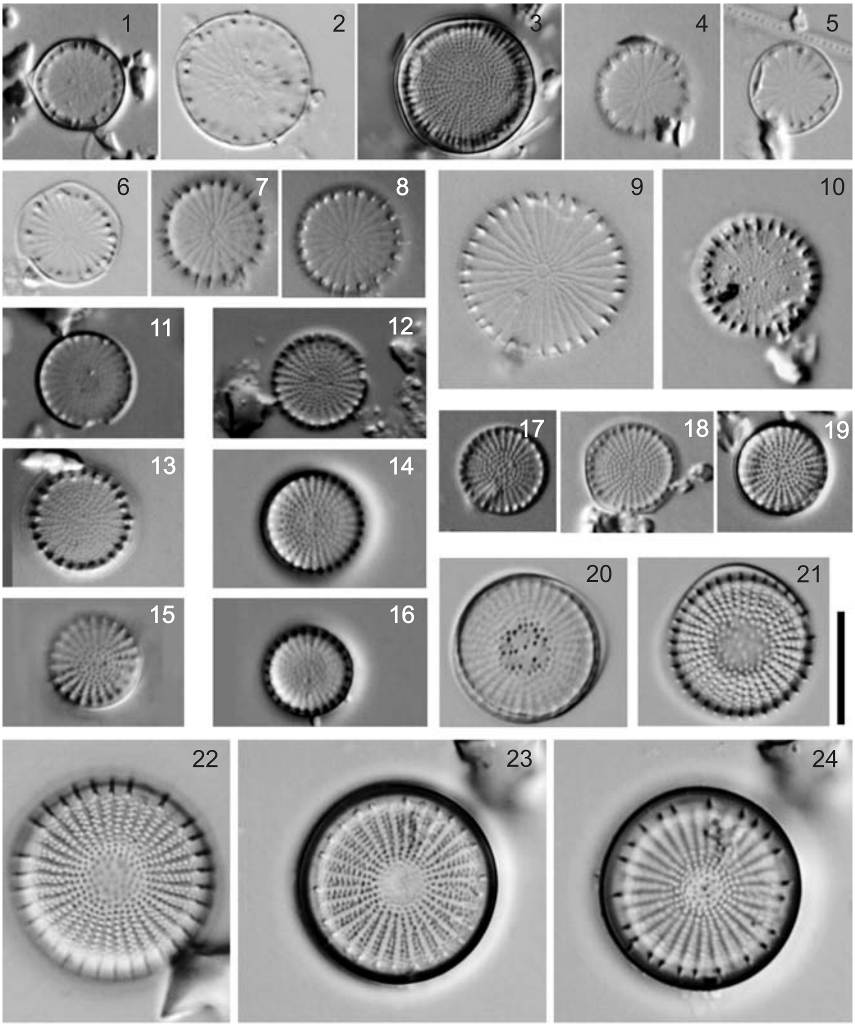


Fig. 19. 1–9 – *Stephanodiscus hantzschii* Grunow (4–9 – morphotypes regarded as *S. hantzschii* Grunow fo. *tenuis* Håkansson & Stoermer), 10 – *S.* cf. *hantzschii* (initial cell?), 11–19 – *S. minutulus* (Kützing) Grunow, 20–21 – *S.* cf. *alpinus* Hustedt, 22–24 – *S. alpinus* Hustedt; all in LM; scale bar = 10 µm.

Distribution in Poland. One of the most commonly reported centric diatom species. From the area studied it was reported from the Pilica River (Kadłubowska 1964), Wyżyna Krakowsko-Częstochowska upland streams (Kłonowska 1986) and the Vistula River (Kawecka & Kwandrans 2000). One of the most common species in the materials studied (Table 1).

Ecology. Euplanktonic (Denys 1991), alkalibiontic, brackish/freshwater species, eutraphentic, α-mesosaprobous to polysaprobic, strictly

←

Fig. 18. 1 & 2 – *Stephanodiscus minutulus* (Kützing) Grunow, central fultoportula with two struts, 3–8 – *S. hantzschii* Grunow (3–6 – valves at different stages of wall silicification, 8 – central area without fultoportula). 1, 2, 7 & 8 – internal view, 3–6 – external view; all in SEM. CF – valve face fultoportula, MF – marginal fultoportula, R – rimoportula.

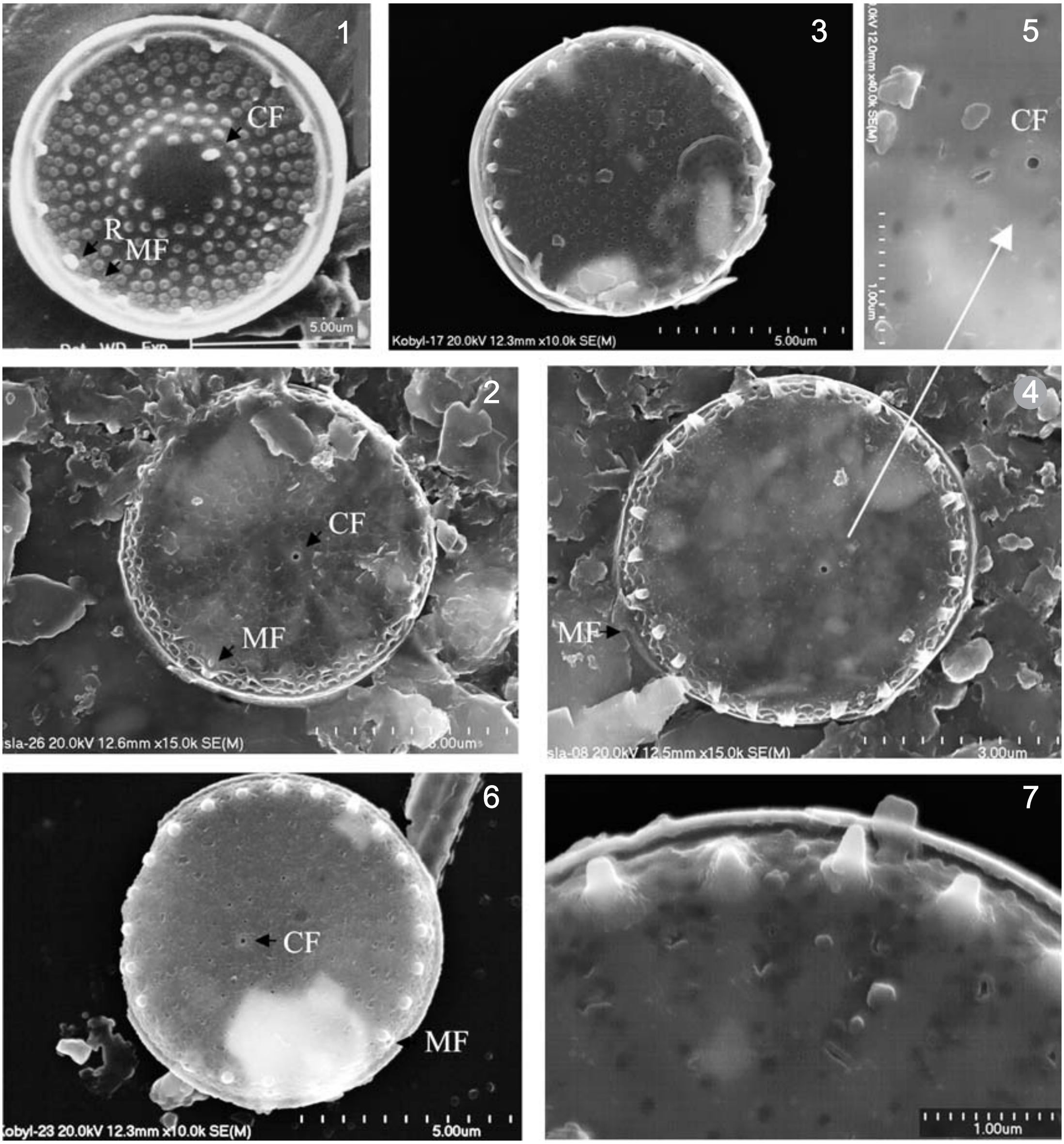


Fig. 20. *Stephanodiscus minutulus* (Kützing) Grunow *in* Cleve & Möller 1 – internal view, 2–7 – external view; all in SEM. CF – valve face fultoportula. (1–7 – valves at different stages of silicification, valve face fultoportula at excentric position). MF – marginal fultoportula, R – rimoportula.

aquatic species (Van Dam *et al*. 1994). In our samples it was present in material collected from eutrophic waters.

REMARKS. *Stephanodiscus tenuis* was described by Hustedt (1939) as a separate species, then was included in *S. hantzschi* as a form (Håkansson & Stoermer 1984). The annulus (central rosette) was regarded as a diagnostic feature of this taxon, but this structure is also present in other *Stephanodiscus* species, and may be more related to the life cycle stage (Håkansson 2002). Our observations conform with the available literature reports. The species is characterized by great morphological variability dependent on environmental conditions and the life cycle stage (e.g., Håkansson 2002).

GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. Commonly reported species.

ECOLOGY. Alkalibiontic, brackish/freshwater, hypereutraphentic species (Van Dam *et al*. 1994). In the materials studied it occurred in meso- and eutrophic waters.

Stephanodiscus minutulus (Kützing) Grunow *in* Cleve & Möller

Figs 16: 21–22; 18: 1–2; 19: 11–19 & 20: 1–7.

Cyclotella minutula Kützing, *Stephanodiscus astraea* var. *minutulus* (Kützing) Grunow *in* Van Heurck, *S. rotula* var. *minutulus* (Kützing) Ross & Sims, *S. rugosus* Siemińska & Chudybowa, *Stephanodiscus parvus* Stoermer & Håkansson.

Valves 5–11 µm in diameter. Striated area consists of 13–15 striae per 10 µm. Valves with various degrees of undulation were observed (e.g. Fig. 20).

GENERAL DISTRIBUTION. A cosmopolitan species (Krammer & Lange-Bertalot 1991).

DISTRIBUTION IN POLAND. Commonly reported from Poland. In the area studied, known from the Vistula River (Kawecka & Kwandrans 2000).

ECOLOGY. Tychoplanktonic of epontic origin (Denys 1991), known from waters with elevated ion concentrations (Krammer & Lange-Bertalot 1991).

REMARKS. The positions of the valve face fultoportulae were regarded as features differentiating *S. minutulus* (heterotopic position) from *S. parvus* (slightly excentric position) (Håkansson 2002), but both positions were observed in type material of *S. minutulus* (Klee & Casper 1997). Different morphotypes with various degrees of undulation of the valve face and various areolation patterns probably develop in response to environmental conditions and population growth rates (Kobayasi *et al.* 1985, (Håkansson 2002). Occluded, flap-like, slit-like or typical areoles are organized in regular patterns or scattered on the valve face. This great variability led Siemińska and Chudybowa to describe the new species *S. rugosus* in 1979, from one lake of the Masurian Lakeland. Detailed investigations of the stability of features considered diagnostic of *S. rugosus* revealed them to be of no taxonomic value, and that taxon was synonymized with *S. minutulus* (Genkal & Håkansson 1990).

ACKNOWLEDGMENTS. We are grateful to Dr. Mirko Dressler, Dr. Vaclav Houk, Dr. Thomas Hübener and Rolf Klee for discussions and suggestions, to Professor Pertii Eloranta for critically reading the manuscript, to Professors Jadwiga Siemińska, Andrzej Witkowski and Konrad Wołowski for providing access to their personal libraries, to Anna Łatkiewicz for producing the SEM images, and to our colleagues and friends for their help in gathering needed literature. This work was supported in part by the Polish Ministry of Education and Science, grant P04G 09826.

REFERENCES

BARBIERO R. P. & TUCHMAN M. L. 2004. The deep chlorophyll maximum in Lake Superior. *Journal of Great Lakes Research* **30**(Suppl. 1): 256–268.

BĄK M., WITKOWSKI A. & LANGE-BERTALOT H. 2006. Diatom flora diversity in the strongly eutrophicated and β-mesosaprobic waters of the Szczecin Lagoon, NW Poland, southern Baltic Sea. In: N. OGNJANOVA-RUMENOVA & K. MANYLOV (eds), *Advances in Phycological studies, Festschrift in Honour of Prof. Dobrina Teminskova-Topalova*, pp. 293–317. Pensoft Publishers & University Publishing House, Sofia – Moscow.

BESZTERI B., ACS E. & MEDLIN L. 2005. Conventional and geometric morphometric studies of valve ultrastructural variation in two closely related *Cyclotella* species (Bacillariophyta). *Eur. J. Phycol*. **40**(1): 89–103.

BIŃKA K., MARCINIAK B. & ZIEMBIŃSKA-TWORZYDŁO M. 1988. Palynologic and diatomologic analysis of the Masovian Interglacial deposits in Adamówka (Sandomierz Lowland). *Kwartalnik Geologiczny* **31**: 453–474.

BOGACZEWICZ-ADAMCZAK B. 1988. Diatomeen aus den Sedimenten von Dziekanowice (kurze Information). *Acta Palaeobot*. **28**: 56–58.

BUCKA H. 2000. Diversity of flora and fauna in running waters of the Province of Cracow (southern Poland) in relation to water quality. 6. Characteristics of rivers on the basis of phytoseston communities. *Acta Hydrobiol*. **42**(3/4): 95–122.

BUCKA H. & WILK-WOŹNIAK E. 2002. A monograph of cosmopolitan and ubiquitous species among pro- and eukaryotic alga from water bodies in southern Poland. Zakład Biologii Wód im. K. Starmacha PAN, Kraków (in Polish).

CABAŁA J. 2002. Chrysophyceae stomatocysts from Budzyń peat bog (Kraków-Częstochowa Upland, Poland). *Polish Bot. J.* **47**(1): 21–35.

CASPER J. & SCHEFFLER W. 1990. *Cyclostephanos delicatus* (Genkal) Casper et Scheffler comb. nov. from waters in the northern part of Germany. *Arch. Protistenk.* **138**: 304–312.

CIEŚLA A. & MARCINIAK B. 1982. Development of Late Glacial lacustrine deposits at Niechorze (Western Pomerania) in the light of diatomological and geochemical data. *Kwartalnik Geologiczny* **26**: 191–215 (in Polish).

CREMER H., WAGNER B., JUSCHUS O. & MELLES M. 2005. A microscopical study of diatom phytoplankton in deep crater Lake El'gygytgyn, Northeast Siberia. *Algol. Stud.* **116**: 147–169.

DENYS L. 1991. A check-list of the diatoms in the Holocene deposits of the western Belgian coastal plain with a survey of their apparent ecological requirements. I. Introduction, ecological code and complete list. *Professional Papers of the Geological Survey of Belgium* **246**: 1–41.

DRESSLER M. & HÜBENER T. 2006. Morphology and ecology of *Cyclostephanos delicatus* (Genkal) Casper et Scheffler (Bacillariophyceae) in comparison with *C. tholiformis* Stoermer, Hakanssson & Theriot. *Nova Hedwigia* **82**(3–4): 409–434.

DUMNICKA E. 1998. Habitat preferences of invertebrate (especially Oligochaeta) in a stream. *Acta Hydrobiol*. **36**: 91–101.

DUMNICKA E. 2002. Upper Vistula River: response of aquatic communities to pollution and impoundment. X Oligochaete taxocens. *Polish Journal of Ecology* **50**(2): 237–247.

DYNOWSKA I. 1983. Springs within the Upland of Cracow-Wieluń and Miechów. *Studia Ośrodka Dokumentacji Fizjograficznej* **11**: 1–244 (in Polish with English summary).

EDLER L., HÄLLFROS G. & NIEMI Å. 1984. A preliminary check-list of the phytoplankton of the Baltic Sea. *Acta Bot. Fenn*. **128**: 1–26.

EHRENBERG C. G. 1845. Vorläfige zweite Mittheilung über die weitere Erknntnis der Beziehgen des kleinsten Lebens zu den vukanisischen Massen der Erde. *Ber. Akad. Wiss. Berlin.* (1845): 133–157.

FRITZ S. C., KINGSTONE J. C. & ENGSTROM D. R. 1993. Quantitative trophic reconstruction from sedimentary diatom assemblages: a cautionary tale. *Freshwater Biology* **30**: 1–23.

GEISSLER U. 1986. Experimental investigations of the variability of frustule characteristics of several freshwater diatoms. 2. The influence of different salt concentrations on some valve structures of *Stephanodiscus hantzschii* Grunow. In: M. RICARD (ed.), *Proceedings of the 8th International Diatom Symposium, Paris, August 27 – September 1, 1984*, pp. 59–66. Koeltz Scientific Books, Koeningstein.

GENKAL S. I. 1977. On the method of calculation of some taxonomically significant structural elements of the valve in the diatoms of the family Thalassiosiraceae Lebour emend Hasle (Bacillariophyta). *Bot. Zhurn.* **62**: 848–851 (in Russian).

GENKAL S. I. 1992. Atlas of plankton diatoms of the Volga river. Gidrometeoizdat, Sankt Petersburg (in Russian).

GENKAL S. I. 1993. Large-celled undulate species of the genus *Stephanodiscus* Ehr. in USSR reservoirs: morphology, ecology and distribution. *Diatom Res.* **8**(1): 45–64.

GENKAL S. I. & HÅKANSSON H. 1990. The problem of distinguishing the newly described diatom genus *Pseudostephanodiscus*. *Diatom Res.* **5**(1): 15–23.

GENKAL S. I. & STENINA A. S. 2005. Interesting records of centric diatoms in reservoirs of the Malozemelskaya Tundra (Russia). *International Journal on Algae* **7**(4): 363–373.

GUTWIŃSKI R. 1895. Prodromus florae algarum Galiciensis. *Rozpr. Akad. Umiejętn., Wydz. Mat.-Przyr.* **28**: 274–449.

HÅKANSSON H. 2002. A compilation and evaluation of species in the genera *Stephanodiscus, Cyclostephanos* and *Cyclotella* with a new genus in the family Stephanodiscaceae. *Diatom Res.* **17**: 1–139.

HÅKANSSON H. & CHEPURNOV V. 1999. A study of variation in valve morphology of the diatom *Cyclotella meneghiniana* in monoclonal cultures: effect of auxospore formation and different salinity conditions. *Diatom Res.* **14**(2): 251–272.

HÅKANSSON H. & CLARKE K. B. 1997. Morphology and taxonomy of the centric diatom *Cyclotella atomus*. *Nova Hedwigia* **65** (1–4): 207–220.

HÅKANSSON H. & KLING H. 1989. A light and electron microscope study previously described and new *Stephanodiscus* species (Bacillariophyceae) from Central and Northern Canadian Lakes, with ecological notes on the species. *Diatom Res.* **4**(2): 269–288.

HÅKANSSON H. & STOERMER E. F. 1984. Observations on the Type Material of *Stephanodiscus hantzschii* Grunow in Cleve & Grunow. *Nowa Hedwigia* **39**: 477–495.

HASLE G. R. 1978. Some freshwater and brackish water species of the diatom genus *Thalassiosira* Cleve. *Phycologia* **17**: 263–292.

HASLE G. R. & HEIMDAL B. R. 1970. Some species of the centric diatom genus *Thalassiosira* studied in the ligth and electron microscopes. *Beih. Nova Hedwigia* **31**: 559–581.

HAUSMANN S. & LOTTER A. F. 2002. Morphological variation within the diatom taxon *Cyclotella comensis* and its importance for qualitative temperature reconstructions. *Freshwater Biology* **46**: 1323–1333.

HEGEWALD E. & HINDÁKOVÁ A. 1997. Variabilität von einer natürlichen Population und von Klonen des *Cyclotella ocellata*-Komplexes (Bacillariophyceae) aus dem Gallbergweiher, Noerdwestdeutschland. *Algol. Stud.* **86**: 17–37.

HOJDA K. 1971. Diatoms of the upper course of the stream Sanka (Cracow-Częstochowa Upland). *Fragm. Florist. Geobot*. **17**(3): 445–454 (in Polish with English summary).

HOUK V. & KLEE R. 2004. The stelligerioid taxa of the genus *Cyclotella* (Kützing) Brébisson (Bacillariophyceae) and their transfer into the new genus *Discostella* gen. nov. *Diatom Res.* **19**(2): 203–228.

HÜBENER T. 1999. Morphology and ultrastructure of a population of *Cyclotella woltereckii* Hustedt (Bacillariophyceae) in Northern Germany. *Nova Hedwigia* **68**(3–4): 469–476.

HUSTEDT F. 1942. Süβwasser-Diatomeen des indomalayischen Archipels und der Hawai-Inseln. Nach dem Material der Wallacea-Expedition. *Int. Rev. Ges. Hydrobiol. Hydrogr*. **42**: 1–252.

HUSTEDT F. 1948. Die Diatomeenflora diluvialer Sedimente bei dem Dorfe Gaj bei Konin im Warthegebiet. *Schweizerische Zeitschrift für Hydrolgie* **11**(1/2): 181–209.

KACZMARSKA I. 1976. Diatom analysis of Eemian profile in fresh-water deposits at Imbramowice near Wrocław. *Acta Palaeobot*. **17**: 3–34.

KACZMARSKA I. 1977. Comments on the flora of diatoms (Bacillariophyceae) from Eemian freshwater sediments at Imbramowice near Wrocław. *Acta Palaeobot*. **18**: 35–60.

KADŁUBOWSKA J. Z. 1964. Diatoms of the river Pilica and their importance in the water pollution evaluation. Part II. Microflora of the river Pilica. *Zeszyty Naukowe Uniwersytetu Łódzkiego* **2**(16): 93–150.

KATO M., TANIMURA Y., FUKOSAWA H. & YASUDA Y. 2003. Intraspecific variation during the life cycle of a modern *Stephanodiscus* species (Bacillariophyceae) inferred from the fossil record of Lake Suigetsu, Japan. *Phycologia* **42**(3): 292–300.

KAWECKA B. & KWANDRANS J. 2000. Diversity of flora and fauna in running waters of the Province of Cracow (southern Poland) in relation to water quality. 3. Benthic cyanobacteria and algae communities. *Acta Hydrobiol*. **42**(3/4): 145–173.

KHARITONOV V. G. 2005. Members of the Centrales (Bacillariophyta) in waterbodies of Beringia. *Bot. Zhurn.* **90**(3): 336–350 (in Russian).

KISS K. T. 1984. Species of the Thalassiosiraceae in Budapest Section of the Danube. Comparison of samples collected in 1956–63 and 1979–83. In: M. RICARD (ed.), *Proceedings of the 8th International Diatom Symposium*, *Paris, August 27 – September 1, 1984*, pp. 23–31. Koeltz Scientific Books, Koeningstein.

KISS K. T. & PAJAK G. 1994. Seasonal changes of diatoms in the plankton of the Vistula River, above and below the Goczałkowice Reservoir, Poland. In: P. KOCIOLEK (ed.), *Proceedings of the 11th International Diatom Symposium*. *Memoirs of the California Academy of Sciences* **17**: 583–597.

KISS K. T., ÁCS É & KOVÁCS A. 1994. Ecological observation on *Skeletonema potamos* (Weber) Hasle in the River Danube, near Budapest (1991–1992, daily investigations). *Hydrobiologia* **289**(1–3): 163–170.

KISS K. T., ÁCS É., ECTOR L., MIRACLE R. M., MORATA S. M., VINCENTE E. & CAMBRA J. 2005. Investigation of centric diatoms from Iberian rivers and lakes Hungarian Algological Meeting 23–27 May 2005, Abstracts. http://falco.elte.hu/ALGA/alga/15HAMabstracts.htm.

KLEE R. & CASPER J. 1997. Once more: Kützing´s Type Material of *Stephanodiscus minutulus* (Kütz.) Grunow (Bacillariophyceae) from "Lüneburg" – a Reinvestigation. *Arch. Protistenk.* **148**: 53–63.

KLEE R. & HOUK V. 1996. Morphology and Ultrastructure of *Cyclotella woltereckii* Hustedt (Bacillariophyceae). *Arch. Protistenk.* **147**: 19–27.

KLING H. & HÅKANSSON H. 1988. A light and electron microscope study of *Cyclotella* species (Bacillariophyceae) from central and northern Canadian Lakes. *Diatom Res.* **3**(1): 55–82.

KŁONOWSKA M. 1986. The food of some mayfly (Ephemeroptera) nymphs from the stream of the Kraków-Częstochowa Jura (Southern Poland). *Acta Hydrobiol*. **28**(1/2): 181–197.

KOBAYASI H., KOBAYASHI H. & IDEI M. 1985. Fine structure and taxonomy of the small and tiny *Stephanodiscus* Bacillariophyceae) species in Japan 3. Co-occurrence of *Stephanodiscus minutulus* (Kütz.) Round and *S. parvus* Stoermer & Hakansson. *Jap. J. Phycol.* **33**(4): 293–300.

KONDRACKI J. 1994. Geografia fizyczna Polski. Państwowe Wydawnictwo Naukowe, Warszawa.

KONDRACKI J. 2000. Geografia regionalna Polski. Państwowe Wydawnictwo Naukowe, Warszawa.

KRAMMER K. & LANGE-BERTALOT H. 1986. Bacillariophyceae. 1. Naviculaceae. In: H. ETTL, J. GERLOFF, H. HEYNING & D. MOLLENHAUER (eds), *Süßwasserflora von Mitteleuropa* **2**(1). G. Fischer Verlag, Stuttgart – New York.

KRAMMER K. & LANGE-BERTALOT H. 1991. Bacillariophyceae. 3. Centrales, Fragilariaceae, Eunotiacae. In: H. ETTL, G. GÄRTNER, J. GERLOFF, H., HEYNING & D. MOLLENHAUER (eds), *Süßwasserflora von Mitteleuropa* **2**(3). Gustav Fischer Verlag, Stuttgart – Jena.

KUBIK B. 1970. The occurrence of Bacillariophyceae in three springs of Będkówka stream (Cracow-Częstochowa Jurassic region) Southern Poland. *Fragm. Florist. Geobot.* **16**: 549–561(in Polish with English summary).

KWANDRANS J. & WOJTAL A. 2006. Classification of water valuation of rivers. In: R. ŻUREK (ed.), *Ichthyofauna and ecological status of Vistula, Raba, Dunajec and Wisłoka Rivers,* pp. 158–192. Institute of Nature Conservation, Polish Academy of Sciences, Kraków (in Polish).

KWANDRANS J., ELORANTA P., KAWECKA B. & WOJTAN K. 1998. Use of benthic diatom communities to evaluate water quality in rivers of southern Poland. *Journal of Applied Phycology* **10**: 193–201.

MARCINIAK B. 1973. The application of the diatomological analysis in the stratigraphy of the late glacial deposits of the Mikołajskie Lake. *Studia Geologica Polonica* **39**: 1–157.

MARCINIAK B. 1979. Dominant diatoms from Late Glacial and Holocene lacustrine sediments in Northern Poland. *Beih. Nova Hedwigia* **64**: 411–426.

MEDIOLI B. E. & BROOKS G. R. 2003. Diatom and thecamoebian signatures of Red River (Manitoba and North Dakota) floods: Data collected from the 1997 and 1999 spring freshets. *Journal of Paleolimnology* **29**: 353–386.

MEYER B. & H. HÅKANSSON 1997. *Cyclotella wulfiae*, a new diatom from a brackish lake in Germany. *Diatom Res.* **12**: 279–285.

NAWRAT B. 1993. Autumn-winter diatoms settled on *Vaucheria* filaments in Kluczwoda stream near Cracow. *Fragm. Florist. Geobot.* **38**(2): 715–736 (in Polish with English summary).

PATRICK R. & ROBERTS N. A. 1979. Diatom communities in the Middle Atlantic States, U.S.A. *Beih. Nova Hedwigia* **64**: 265–283.

PIENAAR C. & PIETERSE A. J. H. 1990. *Thalassiosira duostra* sp. nov., a new freshwater centric diatom from the Vaal River, South Africa. *Diatom Res.* **5**(1): 105–111.

PLIŃSKI M. 1979. Kierunki zmian strukturalnych w fitoplanktonie estuariów Bałtyku południowego. *Zeszyty Naukowe, Rozprawy i Monografie, Uniwersytet Gdański* **15**: 1–136.

POPOVSKAYA G. I., GENKAL S. I. & LIKHOSHWAY E. V. 2002. Diatoms of the plankton of Lake Baikal. Atlas and key. Nauka, Novosibirsk (in Russian).

PRYGIEL J. & COSTE M. 2000. Guide Méthodologique pour la mise en oeuvre de l'Indice Biologique Diatomées. NF T 90-354. Etude Agences de l'Eau-Cemagref Bordeaux, March 2000, Agences de l'Eau.

PUDO J. 1977. Periphyton of the river Vistula in the region of heated water discharges from the power plant at Skawina. *Acta Hydrobiol.* **19(**2): 123–143.

RACIBORSKI M. 1888. Materyjały do flory glonów Polski. *Spraw. Komis. Fizjogr.* **22**: 80–122.

RAKOWSKA B. 1984. Algae of the River Rawka. *Acta Univ. Lodzi., Folia Bot.* **3**: 283–320 (in Polish with English summary).

RAKOWSKA B. 1996. The benthic diatom community of a reservoir after the exploitation of brown coal in Konin (Central Poland). *Algol. Stud.* **82**: 103–106.

RAKOWSKA B. 2001. Study on diatom diversity in water ecosystems of Polish Lowlands. Wydawnictwo Uniwersytetu Łódzkiego, Łódź (in Polish with English summary).

RINGER Z. 1966. Borders of occurrence of plant species depending on salinity according to Polish investigations in the southern Baltic and in the Firths of Vistula and Szczecin. *International Council for the Exploration of the Sea, Baltic-Belt Seas Committee* **3**: 1–7.

SABATER S. & KLEE R. 1990. Observations on centric diatoms of the river Ebro phytoplankton, with special interest on some small *Cyclotella. Diatom Res.* **5**(1): 141–154.

SCHEFFLER W., HOUK V. & R. KLEE 2003. Morphology, morphological variability and ultrastructure of *Cyclotella delicatula* Hustedt (Bacillariophyceae) from Hustedt material. *Diatom Res.* **18**: 107–121.

SIEMIŃSKA J. 1947. The winter flora of diatoms in the ponds of the Fishery Experimental Station of the Jagiellonian University at Mydlniki by Cracow. *Arch. Hydrobiol. Rybactwa* **13**: 181–220 (in Polish with English summary).

SIEMIŃSKA J. & WOŁOWSKI K. 2004. Catalogue of Polish procaryotic and eukaryotic algae. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

SIVER A., HAMILTON P. B., STACHURA-SUCHOPLES K. & KOCIOLEK J. P. 2005. Diatoms of North America: The Freshwater Flora of Cape Cod, Massachusetts, U.S.A. In: H. LANGE-BERTALOT (ed.), *Iconographia Diatomologica. Annotated Diatom Iconographs* **14**: 1–463. A.R.G. Gantner Verlag Kommanditgesellschaft, Ruggell.

SKALNA E. 1969. The occurrence of Bacillariophyceae in three springs of Kobylanka stream (Cracow-Częstochowa Jurassic region). *Fragm. Florist. Geobot.* **15**(2): 245–254 (in Polish with English summary).

STOERMER E. F. & YANG J. J. 1970. Distribution and Relative Abundance of Dominant Plankton Diatoms in Lake Michigan. *Great Lakes Research Division, Institute of Science and Technology, University of Michigan, Ann Arbor, MI, GLRD Special Report* **16**: 1–64.

STOERMER E. F., HÅKANSSON H. & THERIOT E. 1987. *Cyclostephanos* species newly reported from North America: *C. thioliformis* sp. nov. and *C. costatilimbus* comb. nov. *Brit. Phycol. J.* **22**: 349–358.

STOERMER E. F., KREIS R. G. JR. & ANDRESEN N. A. 1999. Checklist of diatoms from the Laurentian Great lakes. II. *Journal of Great Lakes Research* **25**: 515–566.

THERIOT E., STOERMER E. F. & HÅKANSSON H. 1987 Taxonomic interpretation of the rimoportula of freshwater genera in the centric diatom family Thalassiosiraceae. *Diatom Res.* **2**(2): 251–265.

TORGAN L. C., VIEIRA A. H., GIROLDO D. & DOS SANTOS C. B. 2006. Morphological irregularity and small cell size in *Thalassiosira duostra* maintained in culture. In: A. WITKOWSKI (ed.), *Proceedings of 18th International Diatom Symposium 2004 Międzyzdroje, Poland*. Biopress Ltd., Bristol (in press).

TRIFONOVA I. & GENKAL S. 2006. Planktonic diatoms of the Order Thalassisirales Glezer et Makarova (Centrophyceae) from Lake Ladoga, its tributaries, and some lakes in its catchment. In: A. WITKOWSKI (ed.), *Proceedings of 18th International Diatom Symposium 2004 Międzyzdroje, Poland.* Biopress Ltd., Bristol (in press).

TUROBOYSKI L. 1962. Einführende Untersuchungen über das Vorkommen von Kieselalgen in der Wisła in Kraków. *Ekol. Polska, Ser. A* **10(**9): 273–284 (in Polish with German summary).

VAN DAM H., MERTENS A. & SINKELDAM J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *Netherlands Journal of Aquatic Ecology* **28**: 117–133.

VAN HEURCK H. 1880–1887. Synopsis des Diatomées de Belgique. Texte, Atlas. Ducaju and Cie., Anvers.

WILK-WOŹNIAK E. & LIGĘZA S. 2003. Phytoplankton-nutrient relationships during the early spring and the late autumn in a shallow and polluted reservoir. *Oceanological and Hydrobiological Studies* **32**(1): 75–87.

WOJTAL A. 2001. New or rare species of the genus *Navicula* (Bacillariophyceae) in the diatom flora of Poland. *Polish Bot. J.* **46**(2): 161–167.

WOJTAL A. 2003a. Diatoms of the genus *Gomphonema* from karstic stream in the Kraków-Częstochowa Upland. *Acta Soc. Bot. Poloniae* **73**(3): 213–220.

WOJTAL A. 2003b. Diatoms of the families Amphipleuraceae and Brachysiraceae from the Kraków-Częstochowa Upland (S Poland). *Polish Bot. J.* **48**(1): 55–61.

WOJTAL A. 2004. New or rare species of the genera *Achnanthidium* and *Psammothidium* (Bacillariophyceae) in the diatom flora of Poland. *Polish Bot. J.* **49**(2): 215–220.

WOJTAL A. & SOBCZYK Ł. 2006. Composition and structure of epilithic diatom assemblages in a hardwater stream (S Poland). *Algol. Stud.* **119**: 105–125.

WOJTAL A., WOŹNIAK-WILK E. & BUCKA H. 2005. Diatoms (Bacillariophyceae) of the transitory zone of Wolnica Bay (Dobczyce dam reservoir) and Zakliczanka stream (Southern Poland). *Algol. Stud.* **115**: 1–35.

WOŁOWSKI K. 1998. Taxonomic and environmental studies on Euglenophytes of the Kraków-Częstochowa Upland (Southern Poland). W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków.

WUNSAM S., SCHMIDT R. & KLEE R. 1995. *Cyclotella*-taxa (Bacillariophyceae) in lakes of the Alpine region and their relationship to environmental variables. *Aquatic Sciences* **57**(4): 360–386.

YANG J. R. & DUTHIE H. C. 1993. Morphology and ultrastructure of tertological forms of the diatoms *Stephanodiscus niagarae* and *S. parvus* (Bacillariophyceae) from Hamilton Harbour (Lake Ontario, Canada). *Hydrobiologia* **269/270**: 57–66.

Received 3 March 2006