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New diatom species recorded in the waters of southern and south-eastern Poland

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ABSTRACT

Rivers, streams and small water bodies constitute important refugia for rare and poorly known diatom taxa, their diatom diversity remains insufficiently documented yet. The aim of this study was to document the occurrence, spatial distribution and selected ecological characteristics of diatom taxa newly recorded in Poland. The study was conducted between 2017 and 2025 at selected sites in rivers and streams of southern and south-eastern Poland, as well as in small water bodies located in the UMCS Botanic Garden in Lublin and in the village of Ruda. Water temperature, pH and electrolytic conductivity were measured at the investigated sites, and available physicochemical data were used to characterise the habitats of the recorded taxa. Nineteen diatom taxa previously unrecorded in Poland were identified. Most taxa were recorded at low abundance, with several represented by single valves, which limited the possibility of defining their ecological preferences. The highest number of new records was associated with the Kisielina River, where several taxa occurred under eutrophic, alkaline or potentially wastewater-impacted conditions, including *Sellaphora saprotolerans*, *Neidium quadrinflatum*, *Gomphonella linearoides* and *Tryblionella aerophila*. Particularly noteworthy was the record of *Frustulia pumilo*, previously known mainly from South America, which considerably extends its documented geographical range. The results expand the known diatom flora of Poland by 19 taxa and demonstrate that rare and previously overlooked species occur in a broad spectrum of aquatic habitats. The occurrence of several new records in the Kisielina River indicates that eutrophic and anthropogenically influenced waters may harbour a substantial, but still underestimated, diversity of rare diatoms. At the same time, the low abundance, microhabitat specificity and taxonomic difficulties associated with several taxa, often requiring SEM examination, highlight the importance of detailed taxonomic surveys for improving knowledge of diatom diversity and distribution.

Keywords: Bacillariophyta, biogeography, ecological preferences, new records for Poland, freshwater diatoms, rare taxa.

INTRODUCTION

Poland's water resources are highly diverse, and the Carpathians are distinguished by relatively large surface water resources. The variability of runoff in Carpathian rivers is very high compared to rivers in other regions of Poland. The Carpathian area belongs for the most part to the Vistula River basin and thus to the Baltic Sea catchment. The rivers are fed primarily by precipitation, snowmelt, and groundwater drainage. The largest amounts of water runoff occur in the high-mountain regions (the Tatras), and the smallest within the foothills. The greatest variability in flows is characteristic of the rivers of the Low Beskids and the foothills located to their north. An increase in runoff occurs from west to east, and the differences result from both climatic

conditions and geological structure. In the eastern part of the Carpathians, the considerable influence of a continental climate is evident, and the flysch formations are usually poorly water-bearing shales, while the channel beds often incise into solid rock. All these factors are unfavorable to stable runoff (Dobija, 1981; Dynowska, 1995). Considering the overall water conditions in the Carpathians, two macroregions are distinguished – western and eastern. The area where the research was conducted belongs to the eastern macroregion, which includes the basins located east of the Biała Tarnowska River. They are characterized by snow-and-rain feeding and high runoff in the winter half-year, especially during the spring months. The foothill area is classified as the so-called "type of relatively slow water circulation," in which there is low recharge from precipitation, small groundwater resources, and springs with low yield and small discharge (Ziemońska, 1973; Dynowska, 1991, 1995).

Rivers and streams in southern and southeastern Poland are habitat to many diatom species. Among photosynthetic microorganisms, diatoms are one of the most rapidly developing groups. They occur in various types of aquatic environments; however, the biology and ecology of these organisms still remain insufficiently understood, as do the factors influencing their diversity and geographical distribution (Round et al., 2007; Vanormelingen et al., 2008).

Diatomological research in south-eastern Poland has been carried out in various types of habitats (mainly aquatic environments, but also soil and epiphytic habitats among mosses) for over fifteen years (Noga et al., 2014b). Initially, studies on diatom diversity combined with water quality assessment based on the indicative role of these microorganisms were conducted in the Wisłok River and its tributaries (e.g. Noga, 2012; Pajączek et al., 2012; Noga et al., 2013b,c), and subsequently in the San (Noga et al., 2013d, 2014c; Kochman-Kędziora et al., 2022), Wisłoka (Noga et al., 2016) and Biała (Noga et al., 2015) rivers. During research conducted in 2013–2025 in southern and south-eastern Poland, numerous diatom taxa new to Poland were identified, many of them known from only a few localities worldwide (Noga et al., 2013a, 2014a,d, 2017b, 2024; Noga, 2019; Noga and Rybak, 2017, 2019; Bysiek et al., 2025; Bartyńska et al., 2026). Taxa new to science were also described (Stanek-Tarkowska et al., 2016; Noga et al., 2017a; Rybak et al., 2023).

The objective of this study is to document and characterize the spatial distribution of diatom taxa new to Poland, identified in the Kisielina and Kłopotnica rivers, in the Olchowaty Stream, and in water pools in the Botanical Garden in Lublin as well as in a small forest in the village of Ruda, together with their ecological and morphological characteristics.

STUDY AREA

During research conducted in the years 2017–2025, the occurrence of diatom taxa new to Poland was found in the Kisielina and Kłopotnica rivers, in the Olchowaty Stream, as well as in small water bodies located in the Botanical Garden in Lublin and in a small forest in the village of Ruda.

The Kisielina River is a tributary of the Vistula, over 40 km long, rising on the northern slopes of the Wilkówka hill (340.7 m a.s.l.). It flows through built-up rural areas, arable fields and grasslands. The sources of the Kisielina are located in a small forest; the middle section flows through a large forest complex (the Radłów Forest), while the lower section runs through agriculturally used areas (Przybysz-Ławnicka et al., 2008, 2010). A detailed description of the area through which the Kisielina River flows, together with a map showing the locations of the sampling sites, was presented by Noga and co-authors in a 2025 publication.

The Kłopotnica River is a small watercourse about 15 km long, with a catchment area of 47.5 km² (mainly forested in character). It rises on the slopes of Magura Wątkowska (780 m a.s.l.) and is a left-bank tributary of the Wisłoka River. Kłopotnica has the character of a mountain river with a swift current and a stony bottom, especially in its upper section (Bors et al., 2011), where research sites were designated. Two sites were located within the Magura National Park and one in the park's buffer zone. The study area covered the upper, 3-kilometre, shaded section of the river.

The Olchowaty Stream (approximately 7 km long) is a right-bank tributary of the Osława River. The source of the stream is located at an altitude of about 920 m a.s.l., at the foot of Chryszczata. In the upper section of the stream, the significant role of headward and bed erosion shaping the steepness of the slopes is visible. In the upper course there are also two small lakes (1.44 ha and 0.45 ha), which formed more than 100 years ago as a result of a

landslide triggered by prolonged rainfall (Gorczyca et al., 2011; Forest Management Plan, 2015). One of the ponds was located in the area of the Botanical Garden in Lublin, in the south-western part (Mountain Plants Section, the so-called Alpine Garden). The garden is situated in the valley of the Czechówka River and includes a section of its valley (www1). The pond is a small water body (3 m × 5 m, about 0.6 m deep), supplied by a stream that is part of a cascade built in the Alpine Garden (the stream serves as a backup water source for the pond and two other ponds located in the garden, using water from a deep well).

A group of three water ponds (one in a forest and two in arable fields) was located within a small forest and among cultivated fields in the village of Ruda (about 70 km north-west of Rzeszów). The three ponds were distributed over an area of about one kilometre. They were small water bodies (8–15 m (up to 20 m) in diameter, with depth varying depending on the season and the amount of precipitation: 0.25–1.5 m), fed mainly by atmospheric precipitation and, to a lesser extent, by runoff from nearby arable fields. The forest pond was shaded, while the other two, situated among the cultivated fields, were exposed to sunlight. The bottoms of the ponds were silted or sandy.

METHODS

The research was conducted in the years 2017–2025 at designated sites in rivers and streams of southern and south-eastern Poland, as well as in small water bodies (ponds) located in the UMCS Botanic Garden in Lublin and in the village of Ruda (Table 1).

Samples for research in rivers and streams were collected from stones, mud, and submerged aquatic plants (depending on their availability at the sites), always in spring and autumn. Material from the pond in the Botanical Garden in Lublin was collected from near shore sediments overgrown with green algal mats (Chlorophyta, including *Cladophora* sp. and *Spirogyra* sp.), whereas material from ponds in the village of Ruda was collected from bottom mud. Directly in the field, water temperature, pH, and electrolytic conductivity were measured. In addition, a small amount of water was collected for chemical analyses, which were performed in the laboratory of the University of Rzeszów (Thermo Scientific DIONEX ICS–5000+DC ion chromatograph).

The collected materials were preserved in a 4% formalin solution and then prepared and processed according to methods used in diatomological studies (Kawecka, 1980). To obtain empty diatom frustules, part of the sample was subjected to maceration in chromic acid, and then the material was rinsed with distilled water in a centrifuge (at 2500 rpm for 5 minutes). Microscope slides were mounted in the synthetic resin Pleurax.

Diatoms were identified using a Carl Zeiss Axio Imager A2 light microscope equipped with a Zeiss AxioCam HRc camera, at 1000× magnification, according to the following identification keys: Krammer (2000), Lange-Bertalot et al. (2017), Reichardt (2018), Werum et al. (2024).

The abundance of a given species was determined by counting specimens in randomly selected microscope fields of view until a total of approximately 300 cells was obtained. The most abundant were considered to be those species which share in a given sample exceeded 5%.

RESULTS

The studied waters were most often characterized by an alkaline reaction; only in the upper reaches of the Kisielina River and the Olchowaty Stream was the pH close to neutral or slightly acidic. The upper courses of the rivers and streams were also distinguished by low values of electrolytic conductivity, whereas the highest conductivity values (nearly 700 µS/cm) were

Table 1. Study duration, number of sampling sites, and seasonal coverage in the investigated aquatic environments

Watercourses	Study years	Number of seasons	Number of sites
Kisielina	2023	2	7
Kłopotnica	2019	2	3
Olchowaty	2017, 2021	2	5
Small pond in Lublin	2025	2	1
Small ponds in Ruda	2017, 2019	4	3

recorded in a water pond located in the Botanical Garden in Lublin. The highest NO_3^- values were measured in the waters of the Kisielina River and in the pond in Lublin, while the remaining chemical parameters were rather low. The waters of the Kłopotnica River were the richest in calcium ions (Table 2).

Studies carried out in the years 2017–2025 made it possible to distinguish 19 diatom species (Figs 1-110) that had not previously been recorded in Poland (Table 3). These species occurred singly at the investigated sites; some of them, such as *Frustulia pumilo*, *Pinnularia infirma* and *Stauroneis blazenciciae*, were found at the sites as single specimens. Only *Sellaphora labernardierei* (Figs 34-48, 102, 103) was dominant at one site, in a small forest pond in the spring of 2017 (abundance: 8.5%).

DISCUSSION

Over nearly ten years of research carried out in southern and south-eastern Poland, the presence of 19 diatom species previously unrecorded from Poland was found in various types of waters. Half of them belongs to three genera commonly identified in such waters, i.e. *Sellaphora, Gomphonema* and *Fragilaria,* and most of them prefer eutrophic conditions (Mertens et al., 2025). *Sellaphora auldreekie*, *S. bisexualis* and *S. saprotolerans* were distinguished from the *S. pupula* complex, which occurs in freshwater, eutrophic habitats (Lange-Bertalot et al., 2017). *Sellaphora bisexualis* was described on the basis of the morphological features of specimens that originated exclusively from eutrophic ponds and lowland lakes, and developed in the epipelon of nearshore muddy sediments. Genetic studies showed that specimens from Great Britain and from Australia have exactly the same barcode sequence, and on this basis it was concluded that *S. bisexualis* is characterized by a wide distribution range (Mann et al., 2008, 2009). In the material studied it occurred very rarely, as single specimens and only at one site in the Kisielina River.

Sellaphora saprotolerans is associated with highly nutrient-rich waters, from eu- to hypertrophic. It is most frequently identified in sites heavily loaded with municipal and industrial wastewater, but not exceeding β-mesosaprobic conditions. It occurred much more frequently and abundantly in the years 1960–1990; in later years – along with the improvement in water quality – the species was observed increasingly rarely (Lange-Bertalot et al., 2017). In our study, *S. saprotolerans* occurred only in the Kisielina River, primarily in material collected from the mud. It developed mostly in the middle reach, less often in the lower reach, i.e. at sites where the highest NO_3^- values were recorded (Noga et al., 2025). At no site was it a dominant species, and its share in the diatom assemblage did not exceed 1%.

An interesting species is *Sellaphora labernardierei*, which is distinctive due to its different autecology compared to other species of the genus *Sellaphora*. Probably because of its very small size (in the material examined: 6.6–16.2 µm in length, most observed valves <10 µm), it was only described in 2016 from France. The species occurred in mineral and slightly acidic waters with a high nitrate content (Beauger et

Table 2. Values of physicochemical parameters of waters measured at the designated sites (1: Kisielina River, 2: Kłopotnica River, 3: Olchowaty Stream, 4: a small pond in the Botanical Garden in Lublin, 5: small mid-forest and mid-field ponds in the village of Ruda); T – temperature, EC – conductivity

Sites	1	2	3	4	5
T [°C]	1.5-16.0	11.2-15.4	7.5-17.2	9.7-15.5	11.0-23.0
pH	6.2-7.2	7.8-8.0	5.9-7.4	7.1-7.9	6.1-7.9
EC [µS/cm]	115-320	247-355	75-224	310-697	132-435
Cl^- [mg/l]	10.55-28.94	0.70-2.52	0.28-1.37	10.14-20.08	0.41-19.22
SO_4^{2-} [mg/l]	20.33-45.63	19.35-26.71	5.75-25.54	8.81-24.05	<0.001-50.01
NO_3^- [mg/l]	2.31-8.09	<0.01-1.25	0.57-3.24	2.15-7.00	<0.001-1.42
PO_4^{3-} [mg/l]	<0.001	<0.001	<0.001	<0.001	<0.001
NH_4^+ [mg/l]	0.02-0.20	<0.001-0.13	0.27-0.48	<0.001	<0.001-0.91
Mg^{2+} [mg/l]	3.22-11.86	3.70-5.84	1.06-4.62	13.47-19.95	0.91-8.70
Ca^{2+} [mg/l]	16.36-38.84	20.21-32.13	8.21-25.34	20.87-25.20	5.82-24.63

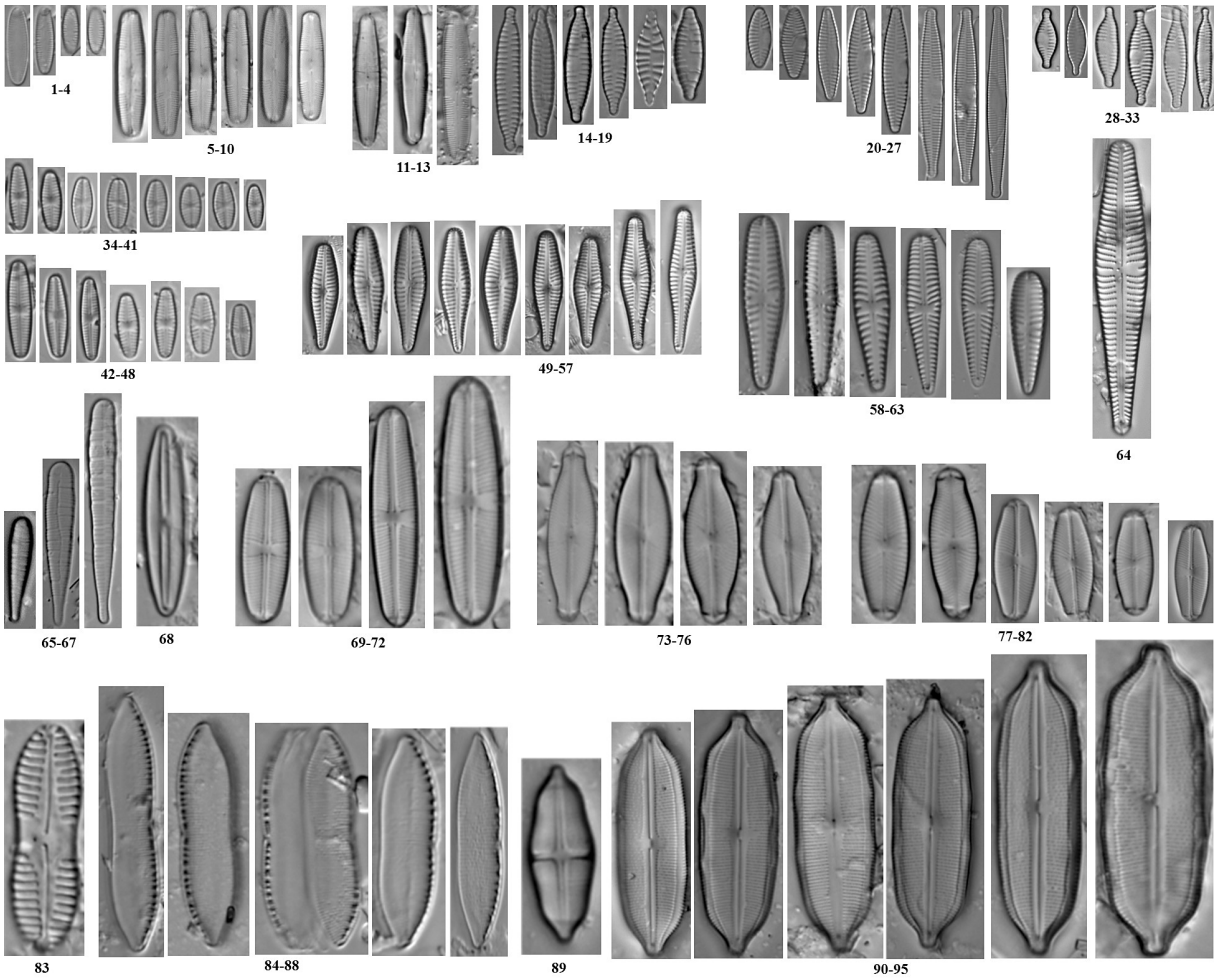
Table 3. Morphological and ecological characterization of diatom species new to Poland, including their global distribution and occurrence in the studied waters (the Kisielina and Kłopotnica rivers, the Olchowaty Stream, and small ponds); Square brackets contain the frustule dimensions [length × width; number of striae (s) and, if present, fibulae (f) per 10 µm]; habitat types are given in parentheses in capital letters: stone (S), moss (M), mud (MU), plant-including grasses and other submerged aquatic plants (P)

Taxa	Ecology and distribution	References
Achnanthidium zhakovschikovii Potapova [6.8-12.5 × 3.1-3.4; s: 21-26] Figs 1-4, 96, 97	The species occurs in calcium-rich waters with neutral pH, low levels of organic matter and nutrients. It developed abundantly (about 13%) on *Cladophora* thalli, and less abundantly on stones. Worldwide distribution: Germany, France, Russia. Distribution in Poland: the Olchowaty Stream (S, M), the Kłopotnica River (S).	Potapova 2006 Ector & Hlŭbiková (2010) Peeters & Ector (2018) Doege et al. (2022) Chavaux et al. (2025)
Caloneis langebertalotii Van de Vijver, Ector & Jarlman [20.1-24.2 × 4.1-4.6; s: 24-28] Figs 5-10	The species has been described from eutrophic waters with an alkaline reaction. Worldwide distribution: Sweden. Distribution in Poland: the Olchowaty Stream (S, M), the Kłopotnica River (S, M).	Van de Vijver et al. (2012)
Caloneis langebertalotioides Reichardt [26.0-31.1 × 5.0-5.2; s: 21-26] Figs 11-13	The species was recorded in a ditch with almost stagnant water (abundance <1%) and among mosses in spring areas in the German part of the Alps. Worldwide distribution: Germany. Distribution in Poland: the Kisielina River (P); recently, a single specimen was identified in a municipal fountain in Rzeszów (MU).	Reichardt (2012, 2018) Cantonati et al. (2022) Werum et al. (2024) Bartyńska et al. (2025)
Fragilaria deformis (W. Smith)Van de Vijver & Ector [14.3-18.8 × 4.9-5.2; s: 14-15] Figs 28-33	An epilithic species, observed in weakly mineralized rivers with low conductivity, neutral pH, and low concentrations of nitrates, nitrites, and ammonia; a eutrophic species. Worldwide distribution: Spain, France, Germany, Austria, the Netherlands, Serbia. Distribution in Poland: the Olchowaty Stream (M), the Kłopotnica River (S, M).	Delgado et al. (2015) Peeters & Ector (2017) Reichardt (2021) Van de Vijver et al. (2021) Mertens et al. (2025) Vlaović et al. (2025)
Fragilaria irregularis Chudaev, Jüttner & Van de Vijver [11.7-25.1 × 3.9-4.9; s: 10-11] Figs 14-19	Species first described from the small mountain river Adegoy River (Krasnodar Territory, Russia). Worldwide distribution: Russia. Distribution in Poland: the Olchowaty Stream (S, M), the Kłopotnica River (S).	Chudaev et al. (2021)
Fragilaria sandellii Van de Vijver & Jarlman [11.8-15.3 × 4.7-5.1; s: 16-18] Figs 20-27, 98	A freshwater species found in a small river with slightly alkaline pH and low electrolytic conductivity which, according to Mertens and co-authors (2025), prefers neutral pH. Worlwide distribution: Sweden, France, the Netherlands, Canada. Distribution in Poland: the Kisielina River (P), the Olchowaty Stream (S, M).	Van de Vijver et al. (2012) Peeters & Ector (2017) Skibbe et al. (2022) Mertens et al. (2025)
Frustulia pumilo Lange Bertalot & U. Rumrich [21.5 × 4.3; s: prążki niewidoczne w LM] Fig. 68	Species recorded in the Andes on extremely rare rocks and in a tributary of a pond at an elevation of about 800 m a.s.l. Worlwide distribution: in the Andes in Ecuador, the northern part of South America (Brazil, Colombia). Distribution in Poland: the Kisielina River (MU)	Rumrich et al. (2000) Montoya-Moreno et al. (2013) Moresco & Rodrigues (2016) Dunck et al. (2018)
Gomphonema compactum Reichardt [23.5-25.3 × 5.9-7.2; s: 12] Figs 49-57, 105-110	Species described from Germany, from fish ponds where it occurred abundantly (over 6%) with dominance of G. parvulum (over 50%); it prefers neutral pH and eutrophic conditions. Worldwide distribution: Germany, the Netherlands. Distribution in Poland: the Kisielina River (S, P), the Kłopotnica River (M), a small pond in the Botanical Garden in Lublin (MU, P).	Reichardt (2018) Werum et al. (2024) Mertens et al. (2025)
Gomphonella linearoides (Levkov) R. Jahn & N. Abarca [25.4-25.8 × 5.0-6.0; s: 11-12] Figs 58-63	The species was described from Lake Ohrid and springs in Macedonia as occurring rarely in communities of epiphytic diatoms or in calcareous, oligotrophic springs with a medium electrolyte content. Mertens and co-authors (2025) considered this species to be alkaliphilic and eutrophic. Worldwide distribution: Macedonia, Germany, the Netherlands, Turkey, China. Distribution in Poland: the Kisielina River (S, P).	Levkov & Williams (2011, 2012), Levkov et al. (2016a) (Reichardt 2018) Solak et al. (2021) Luo et al. (2024) Mertens et al. (2025)
Gomphonema zellense Reichardt [33.1–64.4 × 7.5–11.1; s: 7-9] Fig. 64	The species was first described from Germany, from moderately eutrophic waters. Under similar trophic conditions and in high-carbonate waters it occurred in Macedonia. According to Mertens et al. (2025), the taxon prefers pH close to neutral and meso-eutrophic conditions. Worlwide distribution: Germany, Macedonia, Serbia, the Netherlands, France, China, and Australia. Distribution in Poland: the Olchowaty Stream (S, M), the Kłopotnica River (S, M).	Reichardt (1999, 2018), Ector & Hlúbiková (2010) Levkov et al. (2016a) Vidaković et al. (2018) John (2020) Wang & You (2024) Mertens et al. (2025)
Meridion infirmatum Reichardt [25.6-31.7 × 5.6-5.9; s: 18] Figs 65-67	A species of unknown ecology, first described from Germany, from a marshy ditch; also recorded in small streams or ditches (rarely). Worlwide distribution: Germany. Distribution in Poland: the Kisielina River (MU, S).	Reichardt (2018, 2020) Cantonati et al. (2023) Werum et al. (2024)

Table 3. Cont. Morphological and ecological characterization of diatom species new to Poland, including their global distribution and occurrence in the studied waters (the Kisielina and Kłopotnica rivers, the Olchowaty Stream, and small ponds); Square brackets contain the frustule dimensions [length × width; number of striae (s) and, if present, fibulae (f) per 10 μm]; habitat types are given in parentheses in capital letters: stone (S), moss (M), mud (MU), plant-including grasses and other submerged aquatic plants (P)

Taxa	Ecology and distribution	References
Neidium quadrinflatum Reichardt [10.9-41.8 × 5.0-13.3; s: 14-18] Figs 90-95, 101	A species first described from Germany, near Treuchtlingen, also recorded in the Althmühl and defined as a taxon of unknown ecology; Mertens and co-authors (2025) considered it alkaliphilic, eutrophic, and preferring β-mesosaprobic conditions. Worldwide distribution: Germany, the Netherlands. Distribution in Poland: the Kisielina River (MU, P, S).	Reichardt (2018) Werum et al. (2024) Mertens et al. (2025)
Pinnularia infirma Krammer [24.0 × 6.3; s: 10] Fig. 83	A species of unknown ecology; Mertens and co-authors (2025) considered it an oligotrophic taxon. Worldwide distribution: Germany, the Netherlands, Great Britain and Ireland, China, North and South America, as well as Australia and New Zealand. Distribution in Poland: the Kisielina River (MU).	Krammer & Lange-Bertalot (1986), Schnittler (1996) Krammer (2000) Mauch & Schmedtje (2003) Whitton et al. (2003) Montoya-Moreno et al. (2013), Li & Qi (2014) Reavie (2022), John (2025) Mertens et al. (2025)
Sellaphora auldreekie D.G. Mann & S.M. McDonald [21.0-25.5 × 6.8-7.1; s: 21-22] Figs 73-76	A species known from eutrophic ponds, it was separated from the *Sellaphora pupula* complex, which occurs in freshwater eutrophic habitats. Mertens and co-authors (2025) also described this taxon as alkaliphilous and eutrophic, preferring α-mesosaprobic conditions. Worldwide distribution: Great Britain, the Czech Republic, Germany, Japan, China, Mongolia, Russia. Distribution in Poland: the Kisielina River (MU, P).	Mann et al. (2004, 2008) Lysáková et al. (2007) Dorofeyuk & Kulikovskiy (2012), Kihara et al. (2015) Hofmann et al. (2018) Reichardt (2018) Genkal & Eremkina (2023) Glushchenko et al. (2023) Luo et al. (2024) Mertens et al. (2025)
Sellaphora bisexualis D.G. Mann & K.M. Evans [18.9-31.7 × 6.6-6.8; s: 19-22] Figs 69-72	The species was found in epilithon samples from lowland ponds and lakes growing in the epipelon of marginal mud. Worlwide distribution: Great Britain, Germany, Australia, Japan, the Netherland. Distribution in Poland: the Kisielina River (MU, P).	Mann et al. (2009) Kihara et al. (2015) Reichardt (2018) Werum et al. (2024) Mertens et al. (2025)
Sellaphora labernardierei Beauger, C.E.Wetzel & Ector [6.6-16.2 × 3.1-3.6; s: 19-24] Figs 34-48, 102, 103	A species first described from France, observed in a ditch, along riverbanks, and at a mineral spring; it prefers mineral waters with high nitrate concentrations and a slightly acidic pH. Worldwide distribution: France, Germany, the Netherlands. Distribution in Poland: Kisielina River (K), a mid-forest pond in the village of Ruda (MU).	Beauger et al. (2016, 2020, 2022), Cantonati et al. (2022) Mertens et al. (2025)
Sellaphora saprotolerans Lange-Bertalot, G. Hofmann & Cantonati [16.1-21.3 × 5.9-6.9; s: 20-22] Figs 77-82, 99, 100	The species does not have a precisely defined ecology; it has been separated from the *Sellaphora pupula* complex. In Central Europe it occurs in rivers heavily polluted with industrial and municipal wastewater. Worldwide distribution: Germany, the Netherlands, Russia, China. Distribution in Poland: Kisielina River (MU, P, S).	Lange-Bertalot et al. (2017) Hofmann et al. (2018) Genkal & Eremkina (2023) Werum et al. (2024) Wang & You (2024)
Stauroneis blazenciciae Levkov, Tofilovska, Jovanovska, Cvetkoska & Metzeltin [16.6 × 6.0; s: 20] Fig. 89	The species was described from a shallow, oligotrophic mountain lake of postglacial origin, as well as from small mountain streams and peat bogs on Mt. Jablanica and in the Shara Mountains (about 1900 m a.s.l.). Worldwide distribution: Bosnia & Herzegovina. Distribution in Poland: Kisielina River (S).	Levkov et al. (2016b)
Tryblionella aerophila (Hustedt) D.G. Mann [21.6-31,6 × 6.0-7.3; s: 25-26; f: 8-10] Figs 84-88, 104	The species occurs frequently under aerophytic conditions among mosses and on soils; it has also been observed on embankments along forest streams. It prefers neutral pH and meso-eutrophic conditions. Worldwide distribution: Great Britain and Ireland, Germany, the Netherlands, India, North America, Hawaii, New Zealand. Distribution in Poland: Kisielina River (S, P, MU).	Ettl & Gärtner (1995) Whitton et al. (2003) Kociolek (2005) Harper et al. (2012) Miscoe et al. (2016) Gupta & Das (2020) Mertens et al. (2025)

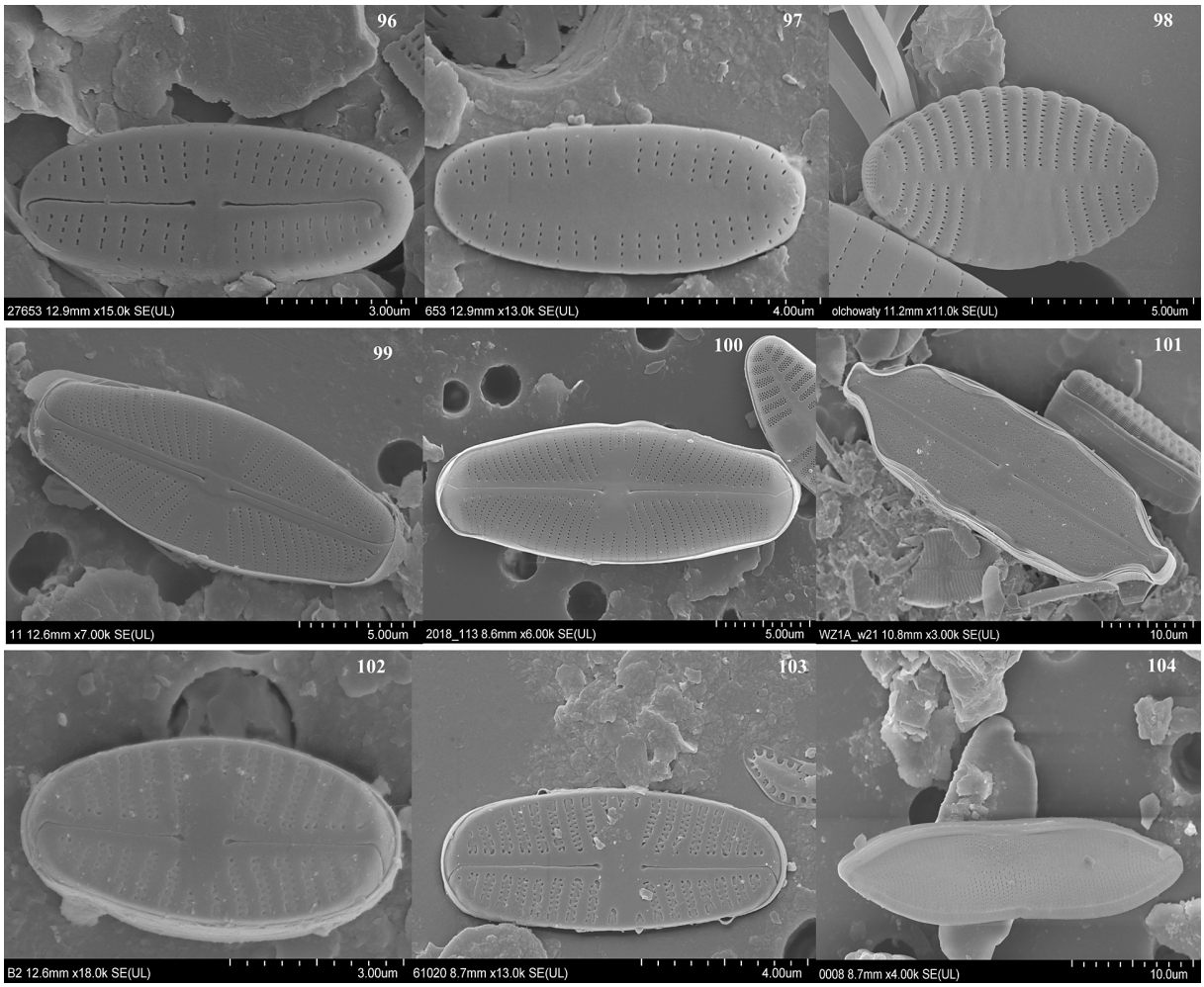
al., 2016). The authors of this paper consider that correct identification of this species is possible only after a detailed analysis of material in SEM, because the valves of *S. labernardierei* are very similar in size and shape to other small species of the genus *Sellaphora*, especially *S. saugerresii* (Desmazières) C.E. Wetzel & D.G. Mann. During the research conducted in S and SE Poland, only a single specimen was found in the Kisielina River (during SEM analysis of the material), whereas in material collected from muddy bottom sediments in a small, forest pond, the species was one of the dominants in spring 2017. The water at this site was characterized by



Figs 1-95. LM photographs: 1-4 *Achnanthidium zhakovschikovii*, 5-10 *Caloneis langebertalotii*, 11-13 *Caloneis langebertalotioides*, 14-19 *Fragilaria irregularis*, 20-27 *Fragilaria sandellii*, 28-33 *Fragilaria deformis*, 34-48 *Sellaphora labernardierei*, 49-57 *Gomphonema compactum*, 58-63 *Gomphonella linearoides*, 64 *Gomphonema zellense*, 65-67 *Meridion infirmatum*, 68 *Frustulia pumilo*, 69-72 *Sellaphora bisexualis*, 73-76 *Sellaphora auldreekie*, 77- 82 *Sellaphora saprotolerans*, 83 *Pinnularia infirma*, 84-88 *Tryblionella aerophila*, 89 *Stauroneis blazenciciae*, 90-95 *Neidium quadrinflatum*

an alkaline reaction (pH 7.9), rather low conductivity (189 µS/cm), and a NO_3^- ion concentration of 0.50 mg/l. The values of the remaining chemical parameters were low. These are therefore conditions different from those under which *S. labernardierei* was first described from France (Beauger et al., 2016).

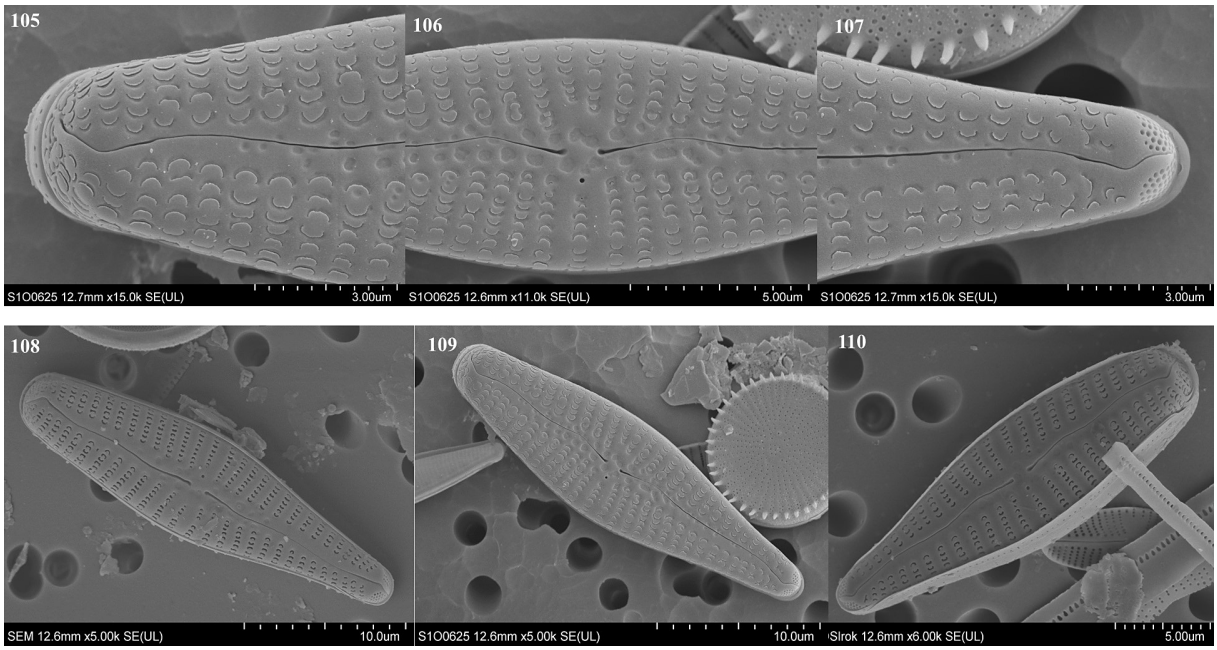
Two species of the genus *Gomphonema* also prefer eutrophic or mesotrophic waters. They occurred rarely at the studied sites, in the form of single valves. *Gomphonema zellense* developed in the Olchowaty stream under mesotrophic conditions and at neutral pH, as reported in the literature (Reichardt, 1999; Levkov et al., 2016a). Single valves were also found in the Kłopotnica River, although there the reaction was always alkaline (pH 7.8–8.0). The second species – *Gomphonema compactum* – was only described in 2018 from eutrophic fish ponds in Germany (Reichardt, 2018). The species occurred very rarely in the lower, heavily silted section of the Kisielina River, which was densely overgrown with vegetation. Single valves were also found in the Kłopotnica River among mosses growing on stones. More valves of *G. compactum* were identified in a small water body in the Botanic Garden in Lublin, which was abundantly overgrown with mats of green algae (mainly of the genera *Spirogyra* and *Cladophora*). The water in the pond had high conductivity values (310–697 µS/cm) and NO_3^- ion concentrations (2.15–7.00 mg/l). The above information confirms that the recently described *Gomphonema compactum* prefers eutrophic conditions and a reaction close to neutral, as



Figs 96-104. SEM photographs: 96, 97 *Achnanthidium zhakovschikovii*, 98 *Fragilaria sandellii*, 99, 100 *Sellaphora saprotolerans*, 101 *Neidium quadrinflatum*, 102, 103 *Sellaphora labernardierei*, 104 *Tryblionella aerophila*

defined by Mertens and co-authors (2025). Our research has shown that it is more frequently observed in standing than in flowing waters, and in habitats densely overgrown with vegetation.

Three species of the genus *Fragilaria* were recorded that are new for Poland, including one – *F. deformis* – classified as eutrophic by Mertens et al. (2025). This species was originally described under the name *Synedra deformis* W. Smith (1856), and was later transferred to the genus *Fragilaria* as *Fragilaria deformis* (W. Smith) Van de Vijver & Ector, comb. nov. (Van de Vijver et al., 2020). A year later, Van de Vijver et al. (2021) demonstrated that the species described in 2015 as *Fragilaria candidagilae* by Delgado et al. (2015) shows no morphological differences from *F. deformis* and is therefore the same species, with the name *F. candidagilae* being its heterotypic synonym. Delgado et al. (2015) observed this species in poorly mineralised rivers with neutral pH and low conductivity. In our study, the species occurred under similar conditions in the Olchowaty stream, whereas in the Kisielina River it developed at alkaline reaction (pH around 8). Single valves of *F. deformis* were most frequently found in material collected from mosses, less often from stones. *Fragilaria irregularis* co-occurred with *F. deformis* at the same sites, under mesotrophic conditions, with an alkaline or near-neutral reaction. Little is known about the ecology of this species, as it was only described in 2021 from a mountain river in Russia (Chudaev et al., 2021), and this is so far the only recorded locality of this species. *Fragilaria sandellii* – the third species of the genus *Fragilaria* – occurred very rarely in the Olchowaty stream and in the Kisielina River. Mertens et al. (2025) classified



Figs 105-110. SEM photographs: *Gomphonema compactum*

it as preferring neutral pH, whereas Van de Vijver et al. (2012) described it from a small river with low conductivity and slightly alkaline pH. Unfortunately, based on the single valves of *F. sandellii* identified in our study, it is not possible to expand the information on the ecological preferences of this species.

The waters of the Kisielina River also turned out to be a habitat for other species classified as eutrophic and alkaliphilic (Mertens et al., 2025), namely *Neidium quadrinflatum* and *Gomphonella linearoides*. Little is known about the ecology of *Neidium quadrinflatum*, which was described recently from Germany (Reichardt, 2018). It occurs rarely in Europe. Previously, it was included in the *N. dubium* complex, as *N. dubium* fo. *constricta* sensu Hustedt or *N. dubium* var. *constricta* Hustedt. The species often co-occurs with *N. dubiosum* Reichardt and *N. cuneatiforme* Levkov (Reichardt, 2018; Werum et al., 2024). Due to the characteristic, three-undulate valve margins, it can be relatively easily identified within a diatom assemblage. In the Kisielina River it occurred singly at several sites in the middle and lower course, while single specimens were also identified in the lower course of the San River in the years 2023–2024 (Bąk, unpublished data).

Gomphonella linearoides was described under the name *Gomphonema linearoides* Levkov and separated from the *Gomphonema olivaceum* (Hornemann) Brébisson complex (Levkov and Williams, 2011). In Macedonia it was observed rarely in calcareous springs and in Lake Ohrid, among epiphytic diatoms (Levkov et al., 2016a), whereas in the Netherlands it was classified as an eutrophic species (Mertens et al., 2025). Single valves of *G. linearoides* were observed in the lower course of the Kisielina River, also under eutrophic conditions. A much wider distribution characterizes the next species – *Tryblionella aerophila*. It is known not only from Europe (Krammer and Lange-Bertalot, 1988; Ettl and Gärtner, 1995; Whitton et al., 2003; Mertens et al., 2025), but also from other continents, including Asia (Gupta and Das, 2020) and North America (Kociolek, 2005; Miscoe et al., 2016), as well as from New Zealand (Harper et al., 2012). It is an aerophilic species, often occurring on soil and among mosses (Krammer and Lange-Bertalot, 1988; Ettl and Gärtner, 1995), and is meso-eutrophic (Mertens et al., 2025). In our study it was found only in the middle course of the Kisielina River, where it occurred sporadically under eutrophic or meso-eutrophic conditions.

Some species, identified in this study as new to Poland, were found in the analyzed material only as single specimens, and all of them occurred in the Kisielina River. *Stauroneis blazenciciae* was recently described as new to science from small streams and a lake, as well as peat bogs in the Shara Mountains in Bosnia and Herzegovina (Levkov et al., 2016b).

Pinnularia infirma was also recorded as a single specimen; however, in contrast to the previous species, it has been reported from most continents (Krammer, 2000; Mauch and Schmedtje, 2003; Whitton et al., 2003; Montoya-Moreno et al., 2013; Li and Qi, 2014; Reavie, 2022; John, 2025; Mertens et al., 2025). Despite such a wide distribution, little is still known about the ecology of this species and it is usually mentioned only in species lists. According to Mertens and co-authors (2025), it is an oligotrophic species.

The most noteworthy and apparently novel record is that of *Frustulia pumilo*, originally described from the Andes (Rumrich et al., 2000) and, until now, reported exclusively from South America (Montoya-Moreno et al., 2013; Moresco and Rodrigues, 2016; Dunck et al., 2018). In addition to a single specimen found in the Kisielina River, several frustules of this species were also observed during 2013–2014 in streams of the Low Beskids in southern Poland (Peszek, 2018, unpublished data).

The *Meridion infirmatum* is also an interesting species, which occurred rarely in the upper course of the Kisielina River. A single specimen was also recorded in the Osława River (a tributary of the San, SE Poland) (Lis, unpublished data). *Meridion infirmatum* was first described from small swampy ditches in Germany (Reichardt, 2018), and so far the only known localities of this species are in Germany (Reichardt, 2020; Cantonati et al., 2023).

In Kisielina, one more species was identified that has not previously been reported from Poland – *Caloneis langebertalotioides*. Recently, a single specimen of this species was also found in a fountain within the city of Rzeszów (Bartyńska et al., 2025). The species was first described from ditches with nearly stagnant water in Germany by Reichardt (2012) and, as the author notes, it had probably previously been included in the broad *Caloneis bacillum* complex. In addition, single specimens have been found in predominantly marsh habitats fed by springs. To date, the species is known only from Germany (Reichardt, 2018; Cantonati et al., 2022). Based on the single specimens recorded in Kisielina, it is not possible to broaden the information on the ecological preferences of this species.

A second species of the genus *Caloneis* – *C. lange-bertalotii* – was described from Sweden, from a small eutrophic river with an alkaline reaction close to pH 8, and this remains the only known locality to date (Van de Vijver et al., 2012). Under different trophic conditions (from oligo- to mesotrophic), it was identified in the upper course of the Kłopotnica River and in the Olchowaty Stream. It always occurred as single specimens on stones and among mosses growing on stones, at alkaline pH (Kłopotnica River) or pH close to neutral (Olchowaty Stream).

Similarly, the last of the species discussed – *Achnanthidium zhakovschikovii* – occurred singly in the Olchowaty Stream (at all sites from the headwaters to the mouth, on stones and sporadically among mosses) and in the upper course of the Kłopotnica River (very rarely and only on stones). The species was first described from rivers of Northwestern Russia, from waters with neutral pH and rich in calcium (Potapova, 2006). To date, it has also been reported from France (Ector and Hlůbiková, 2010; Peeters and Ector, 2018; Chavaux et al., 2025) and Germany (Doege et al., 2022). In our study, the species was observed at shaded sites, under oligo- to mesotrophic conditions, β-mesosaprobic conditions, and at pH ranging from slightly acidic to alkaline (Olchowaty Stream: 5.9–7.4; Kłopotnica River: 7.8–8.0). The studied waters were characterized by low to moderate concentrations of Ca^{2+} ions, which varied seasonally (8.21–32.13 mg/L). Due to the small size of the frustules, *A. zhakovschikovii* is difficult to identify and may be overlooked, especially when it occurs very rarely and cell dimensions are very small (<10 µm).

The identification of 19 diatom taxa not previously reported from Poland demonstrates that the national inventory of diatom diversity remains incomplete and that infrequent or morphologically very similar to others may be under-detected even in comparatively well-characterized regions. Accordingly, continued, hypothesis-driven sampling across a broad spectrum of habitat types, coupled with high-resolution morphological examination, is required to detect overlooked diversity, refine species distributional ranges, and develop more robust ecological characterizations of rare freshwater diatom taxa.

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REFERENCES

1. Bartyńska, K., Bąk, W., Noga, T. & Poradowska, A. (2025). Fountains – elements of urban architecture and biodiversity „micro-reserves". *Polish Journal for Sustainable Development*, 29(2), 7-20. https://doi.org 10.15584/pjsd.2025.29.2.1
2. Bartyńska, K., Noga, T. & Poradowska, A. (2026). Forest reservoirs in southeastern Poland as habitats of diatom species new to Poland. *Journal of Ecological Engineering*, *27*(1), 392-402. https://doi.org/10.12911/22998993/209871
3. Beauger, A., Voldoire, O., Wetzel, C.E., Allain, E., Millan, F., Breton, V., Kolovi, S. & Ector, L. (2020). Biodiversity and ecology of diatoms in mineral springs of the area of Sainte Marguerite (Saint-Maurice-ès-Allier, Massif central, France). *BIOM - Revue scientifique pour la biodiversité du Massif central 1*(1), 21-34. BIOM/https://doi.org/10.18145/biom.v1i1.250
4. Beauger, A., Wetzel, C.E., Voldoire, O., Garreau, A. & Ector, L. (2016). *Sellaphora labernardierei* (Sellaphoraceae, Bacillariophyta), a new epilithic species from French spring and four new combinations within the genus Sellaphora. *Phytotaxa*, *260*(3), 235-246. https://doi.org/10.11646/phytotaxa.260.3.3
5. Beauger, A., Wetzel, C.E., Allain, E., Bertin, C., Voldoire, O., Breton, V., Baker, L.-A., Kolovi, S., Biron, D. & Ector, L. (2022). *Chamaepinnularia salina* (Bacillariophyta), a new diatom species from French mineral springs. *Phytotaxa*, *538*(1), 55-73. : https://doi.org/10.11646/phytotaxa.538.1.5
6. Bors, P., Gładysz, K., Książkiewicz, J. & Sochacka, I. (2011). *A guide to the Nature Path Folusz*. In: Gładysz, K. (Ed.), Magurski Park Narodowy, Krempna, 40 pp. (in Polish with English summary).
7. Bysiek, A., Noga, T., Kosiński, K. & Poradowska, A. (2025). New European locality of *Gomphonema varians* E. Reichardt & Levkov and first record in Poland. *Journal of Ecological Engineering*, *26*(12), 214-220. https://doi.org/10.12911/22998993/207505
8. Cantonati, M., Bilous, O., Spitale, D., Angeli, N., Segadelli, S., Bernab, D., Lichtenwöhrer, K., Gerecke, R. & Saber, A.A. (2022). Diatoms from the spring ecosystems selected for the long-term monitoring of climate-change effects in the Berchtesgaden National Park (Germany). *Water*, *14*(38), 1-22. https://doi.org/10.3390/w14030381
9. Cantonati, M., Casoria, C., Gerecke, R., Bilous, O.P., Maisto, G., Segadelli, S., Spitale, D., Steinbauer, A., Vogel, S. & Saber, A.A. (2023). Diatom indicators of fluctuating/intermittent discharge from springs in two Bavarian Nature Conservation Areas. *Diversity*, *15*, 915. https://doi.org/10.3390/d15080915
10. Chavaux, R., Guiglion, G., Wetzel, C.E., Pottiez, M., Van de Vijver, B. & Ector, L. (2025). *Atlas des diatomées des plans d'eau français*. Office français de la biodiversité – Direction régionale Auvergne Rhône-Alpes. Lyon: 397 pp. (in French).
11. Chudaev, D.A., Jüttner, I. & Van de Vijver, B. (2021). *Fragilaria irregularis* sp. nov. a new araphid species (Fragilariaceae, Bacillariophyta) from the River Adegoy, Krasnodar Territory, Russia. *Phytotaxa*, *508*(2), 221-228. https://doi.org/10.11646/phytotaxa.508.2.11
12. Delgado, C., Novais, M.H., Blanco, S. & Almeida, S.F.P. (2015). Examination and comparison of *Fragilaria candidagilae* sp. nov. with type material of *Fragilaria recapitellata, F. capucina, F. perminuta, F. intermedia* and *F. neointermedia* (Fragilariales, Bacillariophyceae) *Phytotaxa, 231*(1). https://doi.org/10.11646/phytotaxa.231.1.1
13. Dobija, A. (1981). Seasonal variability of runoff in the Upper Vistula catchment (down to Zawichost). *Zeszyty Naukowe UJ, Prace Geograficzne, 53*, 51-112. (in Polish).
14. Doege, A., Hofmann, G., Kroker, J., Paul, G. & Paul, M. (2022). *Artenliste der Algen Sachsens Vorkommen, Taxonomie und Autökologie. [2]*. Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie, Dresden, 489 pp. (in German).
15. Dorofeyuk, N. & Kulikovskiy, M. (2012). *Diatoms of Mongolia. Biological resources and natual condiitons of Mongolia. Proceedings of Joint Russian-Mongolian Complex Biological Expedition. Vol. LIX.* Institute of Ecology and Evolition RAN, Moscow, 367 pp. (in Russian).
16. Dunck, B., Junqueira, M.G., Bichoff, A., Vieira da Silva, M., Pineda, A., Magro de Paula3, A.C., Zanco, B.F., Moresco, G.A., Iatskiu, P., Bortolini, J.C., Rodrigues de Souza, Y., Train, S., Rodrigues, L.C., Jati, S. & Rodrigues, L. (2018). Periphytic and planktonic algae records from the upper Paraná river floodplain, Brazil: an update. *Hoehnea*, *45*(4), 560-590. https://doi.org/10.1590/2236-8906-03/2018
17. Dynowska, J. (1991). *Water balance*. In: Dynowska, J. and Maciejewski, M. (Ed.), Upper Vistula River Basin, Part I., PWN, Warszawa – Kraków, pp. 223-227 (in Polish).
18. Dynowska, J. (1995). *Waters*. In: Warszyńska, J. (Ed.), The Polish Carpathians – nature, man and his activities. Uniwersytet Jagielloński, Kraków, pp. 49-68 (in Polish with English summary).
19. Ector, L. & Hlúbiková, D. (2010). *Atlas des diatomées des Alpes-Maritimes et de la Région Provence-Alpes-Côte d'Azur*. Centre de Recherche Public Gabriel Lippmann, Belvaux, Luxembourg, 393 pp.
20. Ettl, H. & Gärtner, G. (1995). *Syllabus der Boden-, Luft- und Flechtenalgen*. Gustav Fischer Verlag, Stuttgart, 721 pp. (in German).
21. Genkal, S.I. & Eremkina, T.V. (2023). Diatom

algae of reservoirs of different types in the Middle Urals (Sverdlovsk Oblast, Russia). *Inland Water Biology*, *16*(3), 385-393. https://doi.org/10.1134/S1995082923030082

22. Glushchenko, A., Genkal, S., Kuznetsova, I. & Kulikovskiy, M. (2023). Taxonomy and Distribution of the genus *Sellaphora* Mereschowsky (Bacillariophyceae: Sellaphoraceae) in Aquatic Ecosystems of Mongolia. *Plants*, *12*, 3611. https://doi.org/10.3390/plants12203611
23. Gorczyca, E., Izmaiłow, B., Krzemień, K. & Wrońska-Wałach, D. (2011). The state of the art of the studies on the Bieszczady Mts. geomorphology. *Roczniki Bieszczadzkie*, *19*, 299-317. (in Polish with English summary).
24. Gupta, R.K. & Das, S.K. (2020). *Algae of India Volume 4. A checklist of Indian diatoms. Salt Lake.* Botanical Survey of India Ministry of Environment, Forests & Climate Change Government of India, Kolkata, 327 pp.
25. Harper, M.A., Cassie Cooper, V., Chang, F.H., Nelson, W.A. & Broady, P.A. (2012). *Phylum Ochrophyta: brown and golden-brown algae, diatoms, silicioflagellates, and kin*. In: Gordon, D.P. (Ed.), New Zealand inventory of biodiversity. Volume 3. Kingdoms Bacteria, Protozoa, Chromista, Plantae, Fungi. Canterbury University Press, Christchurch, pp. 114-163.
26. Hofmann, G., Lange-Bertalot, H., Werum, M. & Klee, R. (2018). *Rote Liste und Gesamtartenliste der limnischen Kieselalgen (Bacillariophyta) Deutschlands*. In: Metzing, D. et al. (Eds), Rote Liste gefährdeter Tiere, Pflanzen und Pilze Deutschlands. Band 7: Pflanzen [Naturschutz und Biologische Vielfalt 70(7): 601-708]. Landwirtschaftsverlag, Münster (in German).
27. John, J. (2020). *Diatoms from arid Australia: taxonomy and biogeography. The diatom flora of Australia Volume 3*. Koeltz Botanical Books, Schmitten – Oberreifenberg, 578 pp.
28. John, J. (2025). *Diatoms from Tropical Australia: taxonomy and biogeography. The diatom flora of Australia Volume 4*. Koeltz Botanical Books, Schmitten, 669 pp.
29. Kawecka, B. (1980). Sessile algae in european mountains streams. 1. The ecological characteristics of communities. *Acta Hydrobiol., 22*, 361-420.
30. Kihara, Y., Tsuda, K., Ishii, C., Ishizumi, E. & Ohtsuka, T. (2015). Periphytic diatoms of Nakaikemi Wetland, an ancient peaty low moor in central Japan. *Diatom*, *31*, 18-44. https://doi.org/10.11464/diatom.31.18
31. Kochman-Kędziora, N., Noga, T., Rybak, M. & Peszek, Ł. (2022). How to assess a water quality using microorganisms? A case study based on the diatoms developing in San River in the city of Przemyśl. *Rocznik Przemyski*, *58*(3), 75-98. (in Polish with English summary).
32. Kociolek, J.P. (2005). A checklist and preliminary bibliography of the Recent, freshwater diatoms of inland environments of the continental United States. *Proceedings of the California Academy of Sciences. Fourth Series*, *56*(27), 395-525.
33. Krammer, K. (2000). The genus *Pinnularia*. In: Lange-Bertalot, H. (Ed.), Diatoms of the European inland waters and comparable habitats. Volume 1. A.R.G. Gantner Verlag K.G., Ruggell, 703 pp.
34. Krammer, K. & Lange-Bertalot, H. (1986). *Bacillariophyceae. 1. Teil: Naviculaceae* In: Ettl, H., Gerloff, J., Heynig, H. & Mollenhauer, D. (Eds), Süsswasserflora von Mitteleuropa, 2/1. Gustav Fisher Verlag, Jena. 876 pp.
35. Krammer, K. & Lange-Bertalot, H. (1988). *Bacillariophyceae. 2. Bacillariaceae, Epithemiaceae, Surirellaceae*. In: Ettl, H., Gerloff, J., Heynig, H. & Mollenhauer, D. (Eds), Süsswasserflora von Mitteleuropa, 2/2, Gustav Fischer Verlag, Jena, 610 pp.
36. Lange-Bertalot, H., Hofmann, G., Werum, M. & Cantonati, M. (2017). Freshwater benthic diatoms of Central Europe: over 800 common species used in ecological assessments. English edition with updated taxonomy and added species. In: Cantonati, M. et al. (Eds), Koeltz Botanical Books, Schmitten-Oberreifenberg, 942 pp.
37. Levkov, Z. & Williams, D.M. (2011). Fifteen new diatom (Bacillariophyta) species from Lake Ohrid, Macedonia. *Phytotaxa*, *30*, 1-41. https://doi.org/10.11646/phytotaxa.30.1.1
38. Levkov, Z. & Williams, D.M. (2012). Checklist of diatoms (Bacillariophyta) from Lake Ohrid and Lake Prespa (Macedonia), and their watersheds. *Phytotaxa*, *45*, 1-76. DOI: 10.11646/phytotaxa.45.1.1
39. Levkov, Z., Mitic-Kopanja, D. & Reichardt, E. (2016a). *The diatom genus Gomphonema in the Republic of Macedonia*. In: Lange-Bertalot, H. (Ed.), Diatoms of Europe. Diatoms of the European inland waters and comparable habitats. Volume 8. Koeltz Botanical Books, Oberreifenberg, 552 pp.
40. Levkov, Z, Tofilovska, S., Jovanovska, E., Cvetkoska, A. & Metzeltin, D. (2016b). Revision of the *Stauroneis smithii* Grunow (Bacillariophyceae) species complex from Macedonia. *Botanica Serbica*, *40*(2), 167-178. DOI: 10.5281/zenodo.162215
41. Li, J.Y. & Qi, Y.Z. (2014). *Flora algarum sinicarum aquae dulcis Tomus XIX Bacillariophyta Naviculaceae (II)*. Science Press, Beijing, 149 pp.
42. Ludwig, G. & Schnittler, M. (1996). Rote Liste gefährdeter Pflanzen Deutschlands. *Schriftenreihe für Vegetationskunde*, *28*, 1-744.
43. Luo, F., You, Q.-M., Yu, P. & Wang, Q.-X. (2024). *Diatoms in Hengduan Mountains, China [Research*

on diatoms in Hengduan Mountains, China]. Shanghai Science and Technology Press, Shanghai, 592 pp.

44. Lysáková, M., Kitner, M. & Poulícková, A. (2007). The epipelic algae of fishponds of Central and Northern Moravia (The Czech Republic). *Fottea, 7*(1), 69-75. https://doi.org/10.5507/fot.2007.006
45. Mann, D.G., Thomas, S.J. & Evans, K.M. (2008). Revision of the diatom genus *Sellaphora*: a first account of the larger species in the British Isles. *Fottea*, *8*, 15-78. DOI: 10.5507/fot.2008.002
46. Mann, D.G., Evans, K.M., Chepurnov, V.A. & Nagai, S. (2009). Morphology and formal description of *Sellaphora bisexualis* sp. nov. (Bacillariophyta). *Fottea*, *9*, 199-209. https://doi.org/10.5507/fot.2009.021
47. Mann, D.G., McDonald, S.M., Bayer, M.M., Droop, S.J.M., Chepurnov, V.A., Loke, R.E., Ciobanu, A. & du Buf, J.M.H. (2004). The *Sellaphora pupula* species complex (Bacillariophyceae): morphometric analysis, ultrastructure and mating data provide evidence for five new species. *Phycologia*, *43*(4), 459-482. https://doi.org/10.2216/i0031-8884-43-4-459.1
48. Mauch, E. & Schmedtje, S. (2003). *Taxaliste der Gewässerorganismen Deutschlands zur Kodierung biologischer Befunde. Informationsberichte des Bayerischen Landsamtes für Wasserwirtschaft Heft 01/03*. Bayerisches Landesamt für Wasserwirtschaf, München, 388 pp. (in German).
49. Mertens, A., van der Wal, J., Verweij, G., Pex, B., van Dulmen, H. & Van Dam, H. (2025). A revised list of diatom ecological indicator values in The Netherlands. *Ecological Indicators*, *172*. 113219. https://doi.org/10.1016/j.ecolind.2025.113219.
50. Miscoe, L.H., Johansen, J.R., Kociolek, J.P. & Lowe, R.L. (2016). *Investigation of the cave diatom flora of Kanuai, Hawaii: an emphasis on taxonomy and distribution. I.* In: Miscoe, L.H., et al. (Eds), The diatom flora and cyobacteria from caves on Kauai, Hawaii. Taxonomy, distribution, new species. Bibliotheca Phycologica, Vol. 120. J CRamer, Stuttgart, pp. 3-74.
51. Montoya-Moreno, Y., Sala, S., Vouilloud, A., Aguirre, N. & Plata-Díaz, Y. (2013). Lista de las diatomeas de ambientes continentales de Colombia. *Biota Colombiana*, *14*(2), 13-78. DOI: 10.21068/bc.v14i2.282
52. Moresco, C. & Rodrigues, L. (2016). Checklist of periphytic diatoms in streams of the Pirapó River basin, Parana state, Brazil. *Check List*, *12*(1), 1823. https://doi.org/10.15560/12.1.1823
53. Noga, T. (2012). *Diversity of diatom communities in the Wisłok River (SE Poland)*. In: Wołowski, K. et al. (Eds), Phycological Reports: Current advances in algal taxonomy and its applications: phylogenetic, ecological and applied perspective. Institute of Botany Polish Academy of Sciences, Krakow, pp. 109-128.
54. Noga, T. (2019). Valuable habitats of protected areas in south Poland – a source of rare and poorly known diatom species. *Acta Societatis Botanicorum Poloniae*, *88*(1), 3595. https://doi.org/10.5586/asbp.3595.
55. Noga, T. & Rybak, M. (2017). First record of *Pinnularia subinterrupta* Krammer & Schroeter in Poland – a rare species in Europe. *Biodiv. Res. Conserv.*, *45*, 17-21. https://doi.org/10.1515/biorc-2017-0002
56. Noga, T. & Rybak, M. (2019). A new site for *Luticola vanheurckii* Van de Vijver & Levkov (Bacillariophyta) – the second record from Europe. *Biologia*, *74*, 149-152. https://doi.org/10.2478/s11756-018-0161-z
57. Noga, T., Rybak, M. & Ector, L. (2017a). Description of *Stauroneis saprophila* sp. nov. (Bacillariophyta), a new diatom species from anthropogenic environment. *Phytotaxa*, *327*(3), 269-275. https://doi.org/10.11646/phytotaxa.327.3.6
58. Noga, T., Skubisz, L. & Poradowska, A. (2024). Pogórze Przemyskie Landscape Park complex as a habitat for rare and new to Poland *Pinnularia* species. *Journal of Ecological Engineering*, *25*(2), 203-214. https://doi.org/10.12911/22998993/176320
59. Noga, T., Stanek-Tarkowska, J., Pajączek, A. & Peszek, Ł. (2013a). New records of *Geissleria declivis* (Hust.) Lange-Bert. (Bacillariophyceae) in Europe, the first in Poland. *Oceanological and Hydrobiological Studies*, *42*(4), 480-485. https://doi.org/10.2478/s13545-013-0104-9
60. Noga, T., Peszek, Ł., Stanek-Tarkowska, J. & Pajączek, A. (2014a). The *Pinnularia* genus in south-eastern Poland with consideration of rare and new taxa to Poland. *Oceanological and Hydrobiological Studies*, *43*(1), 77-99. https://doi.org/10.2478/s13545-014-0120-4
61. Noga, T., Stanek-Tarkowska, J., Rybak, M. & Kochman-Kędziora, N. (2017b). Morphology of *Reimeria ovata* (Hust.) Levkov & Ector in comparison with similar *Reimeria* species. *Oceanological and Hydrobiological Studies*, *46*(1), 123-131. https://doi.org/10.1515/ohs-2017-0013
62. Noga, T., Bysiek, A., Kosiński, K. & Poradowska, A. (2025). Diatom communities of the Kisielina River: assessment of water quality based on diatom indices. *Journal of Ecological Engineering*, *26*(1), 308-321. https://doi.org/10.12911/22998993/195358
63. Noga, T., Stanek-Tarkowska, J., Peszek, Ł., Pajączek, A. & Kowalska, S. (2013b). Use of diatoms to assess water quality of anthropogenically modified Matysówka stream. *Journal of Ecological Engineering*, *14*(2), 1-11. https://doi.org/10.5604/2081139X.1043166
64. Noga, T., Stanek-Tarkowska, J., Pajączek, A., Peszek, Ł. & Kochman, N. (2013c). Ecological characteristics the diatoms of river Wisłok using

their role of indicators for assessing water quality. *Journal of Ecological Engineering*, *14*(3), 18-27. https://doi.org/10.5604/2081139X.1066219

65. Noga, T., Kochman, N., Peszek, Ł., Stanek-Tarkowska, J. & Pajączek, A. (2014b). Diatoms (Bacillariophyceae) in rivers and streams and on cultivated soils of the Podkarpacie Region in the years 2007–2011. *Journal of Ecological Engineering*, *15*(1), 6-25. https://doi.org/10.12911/22998993.1084168
66. Noga, T., Stanek-Tarkowska, J., Pajączek, A., Kochman, N. & Peszek, Ł. (2014c). Ecological assessment of the San River water quality on the area of the San Valley Landscape Park. *Journal of Ecological Engineering*, *15*(4), 12-22. https://doi.org/10.12911/22998993.1125453
67. Noga, T., Stanek-Tarkowska, J., Kochman, N., Peszek, Ł., Pajączek, A. & Woźniak, K. (2013d). Application of diatoms to assess the quality of the waters of the Baryczka stream, left-side tributary of the river San. *Journal of Ecological Engineering*, *14*(4), 8-23. https://doi.org/10.5604/2081139X.1055818
68. Noga, T., Stanek-Tarkowska, J., Peszek, Ł., Pajączek, A., Kochman, N. & Zubel, R. (2014d). New localities of rare species *Kobayasiella okadae* (Skvortzov) Lange-Bert. and *K. tintinnus* Buczkó, Wojtal & Jahn in Europe – morphological and ecological characteristics. *Oceanological and Hydrobiological Studies*, *43*(4), 374-379. https://doi.org/10.2478/s13545-014-0000-0
69. Noga, T., Stanek-Tarkowska, J., Pajączek, A., Peszek, Ł., Kochman-Kędziora, N. & Irlik, E. (2015). The use of diatoms (Bacillariophyta) to assess water quality of Biała Tarnowska River. *Inżynieria Ekologiczna*, *42*, 17-27. https://doi.org/10.12912/23920629/1973 (in Polish with English summary).
70. Noga, T., Stanek-Tarkowska, J., Peszek, Ł., Pajączek, A., Kochman-Kędziora, N. & Ligęzka, R. (2016). The use of diatoms to assess the water quality of the Wisłoka River in the Dębica City and surrounding area. *Oceanological and Hydrobiological Studies*, *45*(2), 191-201. DOI: 10.1515/ohs-2016-0018
71. Pajączek A., Musiałek M., Pelczar J. & Noga T. (2012). *Diversity of diatoms Bacillariophyceae) in the Mleczka River, Morwawa River and Rożanka stream (tributaries of the Wisłok River, SE Poland), with particular reference to threatened species*. In: Wołowski, K., Kaczmarska, I., Ehrman, J.M. & Wojtal, A.Z. (Eds), Current advances in algal taxonomy and its applications: phylogenetic, ecological and applied perspective. W. Szafer Institute of Botany, Polish Academy of Sciences, Krakow, pp. 129-151.
72. Peeters, V. & Ector, L. (2017). *Atlas des diatomées des cours d'eau du territoire Bourguignon. Volume 1. Centriques, Araphidées*. Direction Bourgogne Régionale de l'Environnement, de l'Aménagement et du Logement Bourgogne-Franche-Comté, Dijon, 309 pp. (in French).
73. Peeters, V. & Ector, L. (2018). *Atlas des diatomées des cours d'eau du territoire bourguignon. Volume 2*. Direction Régionale de l'Environnement, de l'Aménagement et du Logement Bourgogne-Franche-Comté, Dijon, 271 pp. (in French).
74. Peszek, Ł. (2018). *The diversity of diatom communities and their use in water quality assessment for the Upper Wisłoka River and selected tributaries (Lower Beskid, Magura National Park)*. Uniwersytet Rzeszowski, Rzeszów, PhD thesis.
75. Forest Management Plan. (2015). *Environmental Impact Assessment Forecast. Regional Directorate of State Forests in Krosno*, Komańcza Forest District. Forest Management and Geodesy Office, Przemyśl, 438 pp.
76. Potapova, M. (2006). *Achnanthidium zhakovschikovii* sp. nov. (Bacillariophyta) and related species from rivers of Northwestern Russia. *Nova Hedwigia, 82*(3-4), 399-408. https://doi.org/10.1127/0029-5035/2006/0082-0399
77. Przybysz-Ławnicka, M., Mierzwa, M., Brzeziński, D., Kuldanek, A., Bielaszka, K., Fastnacht, K. & Piwowarczyk, J. (2008). *Study of conditions and directions of spatial development of the Radłów commune*. MGGP S.A. Spatial Planning Office, Tarnów, *55*, 180 (in Polish).
78. Przybysz-Ławnicka, M., Mierzwa, M., Brzeziński, D., Bielaszka, K., Fastnacht-Kundzierewicz, K., Szymakowicz, E., Gębiś., A., Kosiaty, P., Kuldanek, A. & Szwed, B. (2010). *Study of the Conditions and Directions of Spatial Management of Dębno Municipality* MGGP S.A. Spatial Planning Office, Tarnów, 214 pp. (in Polish).
79. Reavie, E.D. (2022). Symmetric biraphid diatoms (largely non-*Navicula*) from the Laurentian Great Lakes. *Diatom Research*, *37*(4), 351-409. https://doi.org/10.1080/0269249X.2022.2096121
80. Reichardt, E. (1999). *Zur Revision der Gattung Gomphonema. Die Arten um G. affine/insigne, G. angustatum/micropus, G. acuminatum sowie gomphonemoide Diatomeen aus dem Oberoligozän in Böhmen*. In: Lange-Bertalot, H. (Ed.), Iconographia Diatomologica 8. Annotated Diatom Micrographs. A.R.G. Gantner Verlag K.G., Königstein, Germany, 203 pp.
81. Reichardt, E. (2012). Neue Diatomeen (Bacillariophyceae) aus dem Gebiet der Stadt Treuchtlingen. *Berichte der Bayerischen Botanischen Gesellschaft*, *82*, 19-32. (in German with English summary).
82. Reichardt, E. (2018). *Die Diatomen in Gebiet der Stadt Treuchtlingen. Band 1 i 2*. Bayerische Botanische Gesellschaft, München, 1184 pp. (in German).

83. Reichardt, E. (2020). Diatomeen in Karstquellen im Naturpark Altmühltal. *Berichte der Bayerischen Botanischen Gesellschaft, 90*, 147-176. (in German with English summary).

84. Reichardt, E. (2021). Die Diatomeen im Gebiet der Stadt Treuchtlingen. 2. Nachtrag. *Berichte der Bayerischen Botanischen Gesellschaft, 91*, 195-224.

85. Round, F.E., Crawford, R.M. & Mann, D.G. (2007). *Diatoms: biology and morphology of the genera*. Cambridge University Press, Cambridge, 760 pp.

86. Rumrich, U., Lange-Bertalot, H. & Rumrich, M. (2000). *Diatoms of the Andes. From Venezuela to Patagonia/Tierra del Fuego and two additional contributions*. In: Lange-Bertalot, H. (Ed.), Phytogeography-Diversity-Taxonomy. Iconographia Diatomologica. Vol. 9. Koeltz Scientific Books, Königstein, Germany, 673 pp.

87. Rybak, M., Czarnota, P. & Noga, T. (2023). Study of terrestrial diatoms in corticolous assemblages from deciduous trees in Central Europe with descriptions of two new *Luticola* D.G.Mann taxa. *PhytoKeys*, *221*, 1-40. https://doi.org/10.3897/phytokeys.221.95248

88. Skibbe, O., Abarca, N., Forrest, F. & Werner, P. (2022). Exploring diatom diversity through cultures – a case study from the Bow River, Canada. *Journal of Limnology*, *81*(2095), 227-255. DOI: 10.4081/jlimnol.2022.2095

89. Solak, C., Wojtal, A., Rybak, M. & Yılmaz, E. (2021). Distribution of *Didymosphenia, Gomphonema* and *Gomphosphenia* diatoms (Bacillariophyta) in Turkish inland waters. *Oceanological and Hydrobiological Studies*, *50*(2), 198-219. https://doi.org/10.2478/oandhs-2021-0018

90. Stanek-Tarkowska, J., Wetzel, C.E., Noga, T. & Ector, L. (2016). Study of the type material of *Navicula egregia* Hustedt and descriptions of two new aerial *Microcostatus* (Bacillariophyta) species from Central Europe. *Phytotaxa*, *280*(2), 163-172. https://doi.org/10.11646/phytotaxa.280.2.6

91. Van de Vijver, B., Jarlman, A., De Haan, M. & Ector, L. (2012). New and interesting diatom species (Bacillariophyceae) from Swedish rivers. *Nova Hedwigia*, *141*, 237-253.

92. Van de Vijver, B., Mertens, A. & Ector, L. (2020). Analysis of the type material of *Synedra deformis* W.Sm. and *Synedra vaucheriae* var. *deformis* Grunow (Fragilariaceae, Bacillariophyta). *Cryptogamie, Algologie, 41*(13), 137-149. https://doi.org/10.5252/cryptogamie-algologie2020v41a13

93. Van de Vijver, B., Hürlimann, J., Williams, D.M., Levkov, Z., Wetzel, C.E. & Ector, L. (2021). *Fragilaria subrecapitellata* (Fragilariaceae, Bacillariophyta), a new diatom species from Switzerland. *Diatom Research, 36*(2), 119-131.

94. Vanormelingen, P., Verleyen, E. & Vyverman, W. (2008). The diversity and distribution of diatoms: from cosmopolitanism to narrow endemism. *Biodivers Conserv*., *17*, 393-405. https://doi.org/10.1007/s10531-007-9257-4

95. Vidaković, D.P., Jakovljević, O.S., Predojević, D.D., Radovanović, S.M., Subakov-Simić, G.V., Lazović, V.M. & Krizmanić, J.Ž. (2018). An updated list of Serbian diatom flora: new recorded taxa. *Archives of Biological Science*, *70*(2), 259-275. https://doi.org/10.2298/ABS170606043V

96. Vlaović, L., Krizmanić, J., Pantović, J. & Vidaković, D. (2025). The hidden biodiversity of diatoms (Bacillariophyceae) of Stara Planina Mountain waterfalls (Serbia). *Biologia 80*(10), 2719-2731. https://doi.org/10.1007/s11756-025-02044-w

97. Wang, Q.X. & You, Q.M. (2024). *Atlas of common diatoms in the Lower Yangtze River*. Science Press, Beijing, 177 pp. (in Chinese).

98. Werum, M., Reichardt, E., Dreßler, M., Werner, P. & Lange-Bertalot, H. (2024). *Ergänzungsband Diatomeen im Süßwasser-Benthos von Mitteleuropa*. Koeltz Scientific Books, Schmitten, 625 pp. (in German).

99. Whitton, B.A., John, D.M., Kelly, M.G. & Haworth, E.Y. (2003). *A coded list of freshwater algae of the British Isles. Second Edition*. Worldwide Web electronic publication.

100. Ziemońska, Z. (1973). Hydroghaphic conditions in the Polish West Carpathians. *Prace Geograficzne, 103*, 1-127. (in Polish with English summary).

101. www1: https://www.umcs.pl/pl/dzial-roslin-wodnych-i-bagiennych,4313.htm (12.08.2026).