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RESEARCH ARTICLE

Diatoms of the lower Vistula River phytoseston

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Abstract. This paper presents the results of research on the phytoseston of the Vistula River along a distance of 163 km. The research was conducted between 1994 and 2010. A total of 218 diatom taxa were identified in the phytoseston. A large number of diatoms were represented by only a few specimens, and, in some cases, only in one of the 312 samples examined. Only nine species had the highest constancy of occurrence in the lower Vistula River; however, mostly periphyton and benthos species predominated the phytoseston in the Vistula River at all of the stations. Most of the species were cosmopolitan. The eutrophic conditions of the Vistula River were confirmed by the great number of eutraphentic diatom taxa. The 86 diatom species identified that have high or very high oxygen requirements confirm that oxygen conditions in the river are good. The ecological potential of the Vistula River was rated based on concentrations of chlorophyll *a*. The worst state, which was moderate, was recorded in 1998 at positions above the dam in Włocławek. Research on the river segment in Toruń in the 2007-2010 period indicated the ecological potential had improved from good to maximum. Despite high anthropogenic pressure and major engineering projects, the Vistula River is characterized by good and maximum ecological potential and great biodiversity.

Keywords: phytoseston, taxonomical composition, Vistula River, biodiversity, long-term study, ecological potential

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Introduction

Diatoms are especially good indicators of environmental conditions, and they are used to monitor environmental changes (e.g., Kelly 2002, Vilbaste et al. 2004, Rakowska and Szczepocka 2011). Mainly sessile diatom assemblages are investigated as indicators, but they are merely one of the elements of the phytobenthos according to the EU Framework Water Directive (2000/60/EC). Previous water quality assessments of the Vistula River have been based almost exclusively on evaluating changes in water chemistry. While such studies are extremely important, they do not identify long-term, well-established changes in water quality, and provide only a temporary image of water quality. According to the requirements of the Water Framework Directive (WFD), only the responses of living organisms permit performing this type of evaluation. Previous phytoplankton studies were conducted along the upper and middle segments of the Vistula River (e.g., Cabejszek et al. 1959, Kyselowa and Kysela 1966, Uherkovich 1970, Hanak-Schmager 1974, Klimowicz 1981, Praszkiewicz et al. 1983). Previous studies from the lower Vistula River focus on changes in all phytoplankton that are limited to one season or a river segment, usually the Włocławek Dam Reservoir (Dembowska 2002a, 2002b, 2005). The present paper is a specific summary of research conducted since 1994 along a segment of river that is

163 km long. The research was conducted at varying frequencies along a few distinct sections of the river. Although comparative analysis of species composition based on all of the results included in different seasons and at different sites is difficult, these data gathered throughout the research period of 1994-2010 will supplement knowledge about the biology of Poland's largest river.

The diatom assemblages in the Vistula phytoseston were presented in the present study because information about the diatom flora in the lower part of Poland's largest river is still incomplete. The aim of this work was to describe diatom diversity primarily through species richness. Spatial and temporal changes in water quality based on diatom species composition in the phytoplankton were analyzed and compared to regular assessments of ecological potential and water quality that were performed formerly based on chemical research.

Material and methods

Study area

The Vistula is the longest river in Poland with a total length of 1068 km and a drainage basin of approximately 194000 km^2 (Głogowska 2000). The Vistula is a lowland river along almost its entire course, and the lower Vistula is the longest segment at 391 km in length between the 550th and 941st km. The average, annual flows ranges from 900 to 1050 m^3 s^{-1}.

The Włocławek Dam Reservoir (WDR) is located between the 618th and 675th km. It was created in 1970 as one of the reservoirs in a cascade on the lower Vistula. It is the largest reservoir in Poland in terms of surface area, and the second largest (after the Solina reservoir) in terms of capacity (Głodek 1985). The Vistula supplies more than 98% of the waters flowing into the reservoir, so the inflow is almost equal to the outflow. The short retention time and its regular shape, considerable length, and narrow width contribute to the fluvial character of the reservoir (Giziński et al. 1993). The WDR has changed the natural character of the river significantly, so the section between the backwater of the reservoir and the station in Nieszawa (21 km below the dam) are classified as heavily modified waters. The river retains its natural character at Wyszogród, Toruń, and Dybowo.

Hydrochemical studies conducted in the Vistula River (Kentzer et al. 1999, Kentzer 2000, Mieszczankin 2009, Kowalkowski et al. 2012, Pastuszek et al. 2012) indicate that the river waters are eutrophic and hypereutrophic.

The Voivodeship Inspectorate of Environmental Protection also performs regular water quality monitoring in the Vistula area studied, and it reported that the waters of the river were unclassifiable because bacteriological pollution was too high. According to physicochemical parameters and chlorophyll *a* concentrations, these Vistula waters were classified as either quality class II or III. According to the latest reports on water quality, the Vistula River is characterized by good ecological potential. The physicochemical parameters allow its waters to be classified as quality class II, which also corresponds to good ecological potential.

Sampling and methods

Qualitative samples of phytoseston were collected between 1994 and 2010. The samples were collected along a 163-km segment of the lower Vistula (Fig. 1) at sites located between Wyszogród (582nd km) and Dybowo (745th km) in the main flow current and in the embankment zone of the lower Vistula. A description of these sites is presented in Table 1.

The material was collected from the surface layer, with a no. 25 plankton net with 55-60 μm mesh sizes and refills of approximately 200 ml of unconcentrated water. A total of 312 phytoseston samples were collected. The following *in situ* parameters were measured at the sampling sites: temperature (T); pH; conductivity (EC); oxygen content (O_2, % O_2). The hydrochemical conditions were also monitored at these stations. Chlorophyll *a* concentrations were determined with the

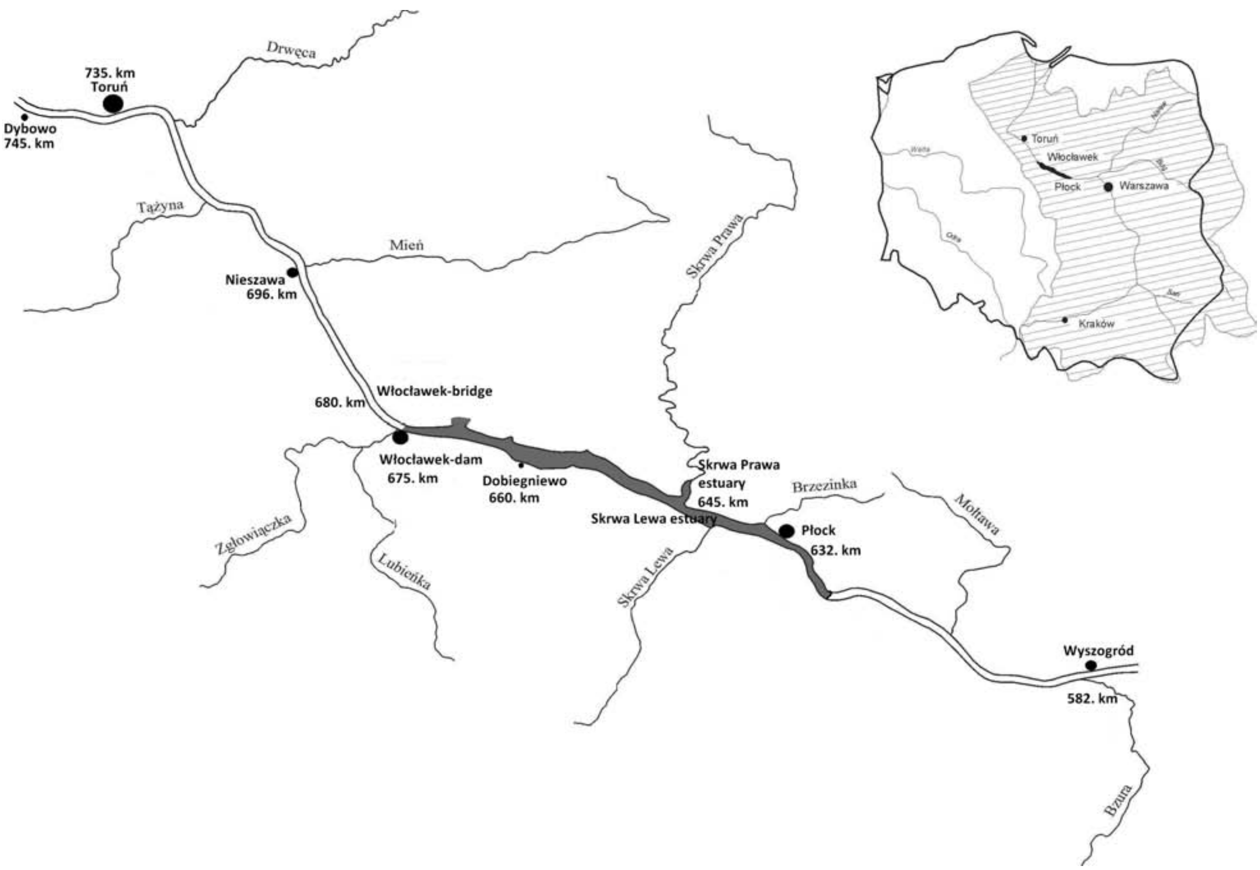

Figure 1. Map of Poland with the Vistula River drainage basin and map of the lower Vistula River segment between Wyszogród and Dybowo; the WDR is the shadowed area.

Table 1
Geographic and morphometric data of investigated sites

Sampling station	Code	River km	Depth (m)	No of samples	Sampling periods
Wyszogród	WY	582	2	6	IV-XI 1998
Płock	PL	632	3-5	47	IV 1994-III 1995; VI 1997-XI 2000; V-X 2006
Skrwa Lewa	SL	640	1-3	3	VII, IX 1997; III 1998
Skrwa Prawa	SP	645	2-4	3	VII, IX 1997; III 1998
Dobiegniewo mainstream	DN	660	8-10	42	VI 1996-X 1996; VII 1998-XI 2000; V-X 2006
Dobiegniewo flood zone	DR	660	4-5	27	VI 1996-X 1996; VII 1998-XI 2000; V-X 2006
Dobiegniewo embankment zone	DB	660	1-2	8	VII 1998-IV 1999
Włocławek dam	WZ	675	12-13	47	IV 1994-III 1995; VI 1997-XI 2000; V-X 2006
Włocławek bridge	WM	680		14	V-X 1996; IV 1998-II 1999
Nieszawa	Ni	696	2	21	IV 1994-III 1995; VI 1997-VIII 1998
Toruń mainstream	To	735	3.5	30	IV 1994-III 1995; 1996; VI 1997-XII97; I-X 1998
Toruń embankment zone		735	1.0	41	IV-X 2007; IV-X 2008; IV-X 2009; VII, VIII 2010
Dybowo	Dy	744-745	3.5	16	III-XI 2003

Table 2
Average concentration of selected environmental variables (according to Kentzer et al. 1999, Kentzer 2000, Mieszczankin 2009, and Dembowska and Napiórkowski, unpublished data). TSI (based on TP, TN, and/or Chl *a*); H – hypertrophy; E – eutrophy; quality class based on chemical indicators supporting biological elements; IFPL – based on Chl *a*, n.d. – no data

Station	Sampling periods	pH	EC ($\mu S\ cm^{-1}$)	TP ($mg\ l^{-1}$)	$P\text{-}PO_4$ ($mg\ l^{-1}$)	TN ($mg\ l^{-1}$)	Nmin ($mg\ l^{-1}$)	Chl *a* ($\mu g\ l^{-1}$)	TSI	Class of purity	IFPL
WY	IV-XI 1998	7.3	n.d.	0.24	0.09	2.7	1.65	94.5	H	II	IV
PL	IV 1994-III 1995	n.d.	n.d.	0.27	0.09	3.4	1.86	n.d.	H	II	-
	IV-XI 1998	8.9	n.d.	0.22	0.07	2.8	1.70	92.1	H	II	IV
	VI 1997-XI 2000	n.d.	n.d.	0.23	0.06	2.6	0.77	n.d.	H	II	-
	V-X 2006	8.7	625	0.35	0.05	4.7	0.53	65.5	H	II	III
SL	VII, IX 1997; III 1998	9.2	670	0.33	0.16	n.d.	1.54	n.d.	H	II	-
SP	VII, IX 1997; III 1998	9.0	570	0.38	0.15	n.d.	1.73	n.d.	H	II	-
DN	VI 1996-X 1996	8.4	n.d.	n.d.	0.07	5.3	n.d.	n.d.	H	II	-
	V-X 2006	8.4	638	0.32	0.09	5.3	1.27	36.9	H	II	II
DR	VI 1996-X 1996	8.3	n.d.	n.d.	0.09	6.1	0.82	n.d.	H	II	-
	V-X 2006	8.2	618	0.29	0.07	6.1	0.97	33.9	H	II	II
WZ	IV 1994-III 1995	n.d.	n.d.	0.26	0.15	3.4	2.24	n.d.	H	II	-
	IV-XI 1998	8.4	n.d.	0.19	0.11	2.5	1.69	63.2	H	I	III
	V-X 2006	8.3	655	0.33	0.09	6.5	1.13	17.2	H	II	I
WM	V-X 1996	8.9	n.d	n.d.	0.12	2.8	1,68	n.d.	H	I	-
	IV-XI 1998	8.1	n.d.	0,23	0.12	2.8	1.92	49.5	H	II	II
Ni	IV 1994-III 1995	n.d.	n.d.	0.29	0.16	3.0	2.27	n.d.	H	II	-
	IV-XI 1998	8.4	n.d.	0.20	0.13	2.4	1.68	45.3	H	I	II
To	IV 1994-III 1995	n.d.	n.d.	0.26	0.13	3.0	1.88	n.d.	H	II	-
	IV-XI 1998	8.1	n.d.	0.26	0.09	2.2	1.89	48.3	H	II	II
	IV-X 2007	8.2	643	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d	-
	IV-X 2008	8.3	567	n.d.	0.09	n.d.	0.93	21.2	E	n.d	I
	IV-X 2009	8.3	585	n.d.	0.05	n.d.	1.08	19.9	E	n.d	I
	VII, VIII 2010	8.5	508	n.d.	n.d.	n.d.	n.d.	28.8	E	n.d	II
Dy	III-XI 2003	7.8	1062	0.24	0.08	n.d.	n.d.	n.d.	H	II	-

spectrophotometric method according to Nusch (1980). The results of the remaining chemical studies (Table 2) were taken from Kentzer et al. (1999), Kentzer (2000) and Mieszczankin (2009). The mean Trophic State Index was estimated based on chlorophyll *a* and/or total phosphorus (TP) and total nitrogen (TN) concentrations (Carlson 1977, Kratzer and Brezonik 1981). The ecological potential at stations between the 632nd and 696th km was estimated according to Picińska-Fałtynowicz and Błachuta (2011).

The diatoms were identified either by boiling the samples in 30% hydrogen peroxide, or using a cold mixture of sulfuric and nitric acids to remove protoplasts and organic admixtures contained in the material. Permanent preparations were made from this material in the synthetic resins Styrax (Gum Storax) or Naphrax. The diatoms were identified based on cell wall structure under a light microscope (Nikon Alphaphot-2) at a magnification of 1000x in bright light and phase contrast. Diatom taxa were identified using the keys by Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), Lange-Bertalot (2001) and Pliński and Witkowski (2009). The percentage of similarity among the diatom communities was assessed with a multivariate statistical package (MVSP 3.2, Kovach Computing Services). The classification of diatoms according to their life-forms, trophic preferences, oxygen requirements, and the degree to which they were endangered was based on the literature (Krammer and Lange-Bertalot 1986, 1988, 1991a, Denys 1991, Van Dam et al. 1994, Rakowska 2001, Siemińska et al. 2006).

Results and discussion

The results of the research on the physicochemical properties of the lower Vistula River waters are presented in Table 2. The river water was characterized by alkaline pH that varied between 7.8 and 9.2. The concentration of nutrients is characteristic of hypertrophic waters. The average concentration of total phosphorus was the highest at station SP in the 1997/1998 period (0.38 mg l^{-1}), and the lowest value of this parameter was recorded at station WZ (0.19 mg l^{-1}). The average concentration of total nitrogen was the highest in the flood area of the WDR at station DR at over 6 mg l^{-1}. At almost all research stations, water quality was class II, which corresponds to good ecological potential.

Fluctuations in the concentration of chlorophyll *a* (Table 2) reflect changes in phytoplankton development and indicates improved water quality. The highest concentration of chlorophyll *a* (94.5 μg l^{-1}) was recorded in Wyszogród in 1998. A similarly high value was recorded in Płock in the same year. The comparison of the Vistula River's ecological potential at various sites based on chlorophyll *a* concentration revealed that the worst condition (poor) was at Wyszogród and Płock. Stations downstream from the dam were characterized by much lower chlorophyll *a* values: the ecological potential of waters at stations WM, Ni, and To improved to good according to IFPL (Picińska-Fałtynowicz and Błachuta 2011). In the 2007-2010 period, a marked reduction in chlorophyll *a* concentrations was observed in Toruń as compared to that determined in 1998; thus, the ecological potential improved to maximum, and only in 2010 the ecological potential decreased to good, probably because of a vast summer flood. The Trophic State Index (Carlson 1977, Kratzer and Brezonik 1981) calculated from the concentration of nutrients and chlorophyll *a* indicated hypertrophy throughout the investigated segment of the river.

Throughout the long-term research on phytoplankton in the lower Vistula River the occurrence of nearly 500 proeukaryotic and eukaryotic phytoplankton species was confirmed. Diatoms were the largest group of species in the phytoplankton, which comprised 218 taxa and constituted as much as 44% of the entire species composition. The most numerous genera in terms of species richness were *Navicula* (20 species), *Nitzschia* (12), and *Cymbella* (11). Only nine diatom species were constant throughout the study area at a frequency in the samples exceeding 80%, as follows: *Aulacoseira granulata* (Ehrenberg) Simonsen; *Cyclotella meneghiniana* Kützing; *C. radiosa* (Grunow) Lemmermann; *Stephanodiscus hantzschii* Grunow (in Cleve et Grunow); *Actinocyclus normanii* (Gregory ex Greville) Hustedt; *Asterionella formosa* Hassal; *Fragilaria crotonensis* Kitton; *Staurosirella pinnata* (Kützing) Williams et Round; *Cocconeis placentula* Ehrenberg.

Previous scientific studies in the upper and middle segments of the Vistula River reported that diatoms were the most species-rich group of algae (Starmach 1938, in Krzeczkowska-Wołoszyn 1991, Cabejszek et al. 1959, Kyselowa and Kysela 1966, Hanak-Schmager 1974, Klimowicz 1981, Praszkiewicz et al. 1983, Tyszka-Mackiewicz 1983). The presented research revealed that the phytoseston in the lower course of the Vistula River is of a similar species composition as in other sections of the river. Only the papers by Uherkovich (1970) and Kowalczewski et al. (1985) report that green algae were the largest group of species; this stemmed from the fact that the diatoms were not identified to the species level. The phytoplankton of many other large European rivers also comprises diatoms (e.g., Yang et al. 1997, Piirsoo 2001, Tavernini et al. 2011, Stanković et al. 2012). The largest group of diatom species (164) in the lower Vistula phytoseston were cosmopolitan forms.

Almost half of the identified diatom species (105) was listed at all the stations. The greatest number of species (167), was noted at the Włocławek station,

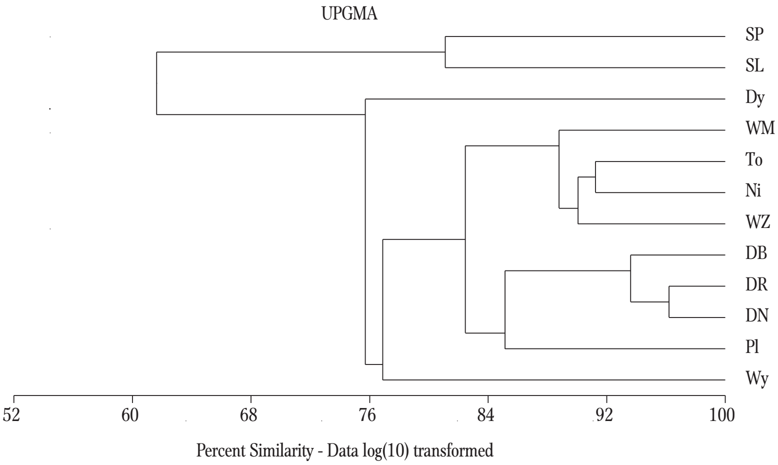

Figure 2. Similarity of diatom communities in the Vistula River between Wyszogród and Dybowo.

which represents the lower part of the WDR. The lowest number of species (131) was recorded at Dybowo, which was only sampled in one year, and had specific chemical conditions (Table 2). The EC value at this site indicates large amounts of chloride ion pollution (Mieszczankin 2009). Such high values were significantly different from those at other stations, the values at which were always lower than 1000 μS l^{-1}. A similarly low number of taxa (133) was found in the central part of the WDR, at the Dobiegniewo station. Less dynamic waters reduce the adhesion of settled diatoms. While some diatom species were recorded only at one station; most of them were noted only once; thus, their relationship with the station seems to be doubtful. Only *Pleurosira laevis* (Ehrenberg) Compére in Toruń and *Fragilaria construens* var. *exigua* (W. Smith) Schulz in Dybowo occurred several times. The percentage similarity indicates differences among stations (Fig. 2). The samples from Wyszogród, the inflows of the Skrwa Lewa and the Skrwa Prawa, and from Dybowo were separated from the remaining stations. The small number of samples taken from these stations was the reason for the dissimilarity (Table 1).

Most of diatom species observed in the Vistula waters had been moved from sedentary habitats. Their presence reflects the strong current of the river waters. Only 33 typically planktonic species (eu- and tychoplankton) comprised just 15% of the diatom taxonomic composition (Fig. 3). The largest groups with respect to life-form were species from benthic and periphytic communities (154 taxa). These were released into the water column when they detached from substrates. The high velocity of the flowing water causes sessile algae to break off from substrates and drift into the pelagic zone. Although quantitative research was not the purpose of this paper, for a complete description of diatoms in the Vistula River, it is necessary to quote the results of the research by Dembowska (2002a, 2002b, 2005) and Kentzer et al. (2010). In quantitative terms, periphytic and benthic diatoms did not play any major role in the phytoplankton.

Slower water flow improves conditions for the development of plankton species as it accelerates suspended matter sedimentation. The slower the water flow is, the more apparent dependence on trophic conditions becomes. The taxonomic composition of phytoplankton in stagnant, or lentic, waters primarily reflects the abundance of nutrients, whereas factors associated with directed water currents are important in lotic waters. The hydrological properties of rivers often modify physical conditions such as water temperature, light conditions, the amount of suspended matter, and biological properties, mainly the presence or absence of effective filtrating organisms (Napiórkowski et al. 2006, Kentzer et al. 2010).

The majority of the diatoms identified are eutraphentic (91) species (Fig. 4), but the presence of 12 taxa that are indicators of oligotrophic and

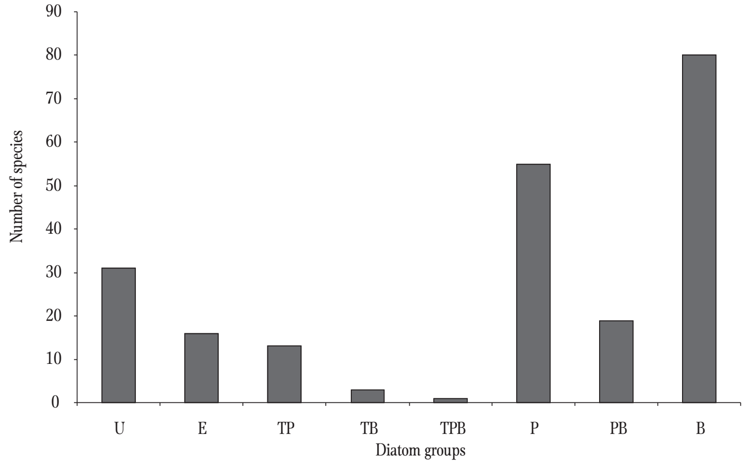

Figure 3. Diatom life-form groups (according to Denys 1991). U – unknown, E – euplanktic, TP – tycho- peryphytic origin, TB – tycho-benthic origin, TPB – tycho- peryphytic and benthic origin, P – peryphytic, PB – peryphytic and benthic, B – benthic.

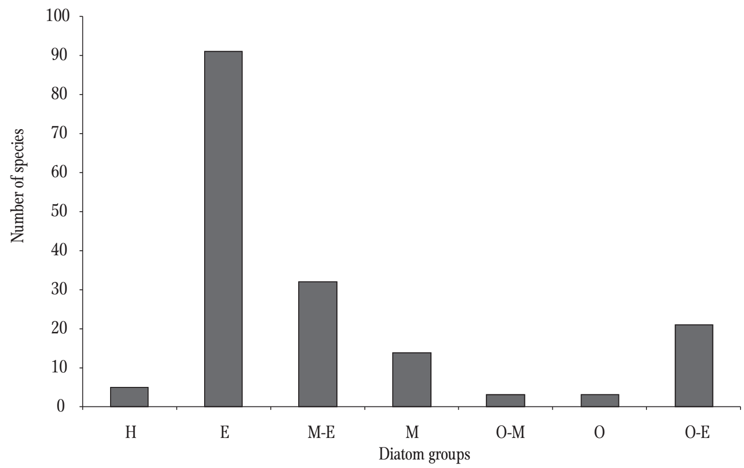

Figure 4. Diatom groups by trophic requirements (according to van Dam et al. 1994). H-hypertrophic, E-eutrophic, M-E-meso-eutrophic, M-mesotrophic, O-M-oligo-mesotrophic, O-oligotrophic, O-E- wide range of occurrence under various trophic conditions.

oligo-mesotrophic conditions was found (Table 3). Eutrophic and hypereutrophic conditions in the Vistula River (Kentzer et al. 1999, Kentzer 2000, Mieszczankin 2009, Kowalkowski et al. 2012, Pastuszek et al. 2012) were reflected in the presence of large numbers of diatom taxa characteristic of eutrophic (over 40% taxa) and meso-eutrophic (almost 15%) waters. Gradual improvement in water quality, although slow, has been noted recently in the chemical composition of the water. The contents of total nitrogen and total phosphorus are used to determine class I and II i.e. maximum and good ecological potential (Regulation 2011). These water conditions favor the development of diatoms that prefer clear waters, which is why taxa occurring in oligotrophic and oligomesotrophic conditions were present. For example, *Ellerbeckia arenaria* (Moore) Crawford, which is considered to be an indicator of oligotrophic conditions (according to Van Dam et al. 1994), was noted only twice in the 1990s at Wyszogród and Włocławek, while in recent years it has been noted at Toruń frequently.

Lower reaches of rivers where water flow is slow and conditions are highly trophic are usually characterized by lower oxygen concentrations compared to those in upper reaches where oxygen concentrations are usually constant and close to 100%. Similarly to eutrophic lakes, oxygen supersaturation can occur locally in lower river reaches with low water flow velocity and in subsurface water layers when

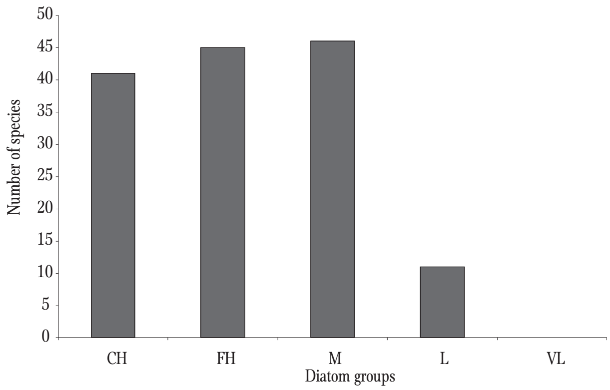

Figure 5. Diatom groups by oxygen requirements (according to van Dam et al. 1994). CH – continuously high, FH – fairly high, M – moderate, L – low, VL – very low.

photosynthesis conditions are favorable. Simultaneously, oxygen concentrations in benthic water layers can be low because of decomposing organic matter. Over half of the taxa identified had at least moderate oxygen requirements, while 86 diatom species had high or very high oxygen requirements (Fig. 5). The most frequent among them (Table 3) were noted throughout the Vistula River segment studied. These results concur with the findings of Kentzer and Giziński (1995) that the WDR contains less oxygen compared to free-flowing river waters, although oxygenation in the reservoir seldom drops to dangerously low levels. Nonetheless, the author links decreased oxygen concentrations not as much with a deceleration in flow velocity as to reduced phytoplankton quantity, which, in turn, results in lower oxygen production during photosynthesis. Phytoplankton is deposited in the WDR, which increases the amount of degradable organic matter, which consequently further increases oxygen absorption.

Vistula River conditions are suitable for the development of many diatom species, including those identified as endangered in Poland (Table 3). Based on the Red List of Algae in Poland by Siemińska et al. (2006), 31 diatom species identified in the current study are included: ten of these taxa are classified as vulnerable – V (Appendix, Photo 1-8, 13-15), two taxa are in the category of indeterminate risk – I (Appendix, Photo 9-10, 36), and the largest taxa group (19 species) are classified as rare – R (Appendix, Photo 11-12, 16-35, 37-39). Most of the taxa identified in the current study that are included on the Red List of Algae occurred sporadically. Only *Sellaphora bacillum* (Ehrenberg) D. Mann and *Geissleria decussis* (Østrup) Lange-Bertalot et Metzeltin were recorded frequently, while *Pseudostaurosira brevistriata* (Grunow) Williams et Round was noted very often. It is difficult to understand why the authors of the Red List of Algae in Poland included some of the species on this list, and this pertains to several species which occur very often in different types of waters in Poland (Rakowska 2001, Siemińska and Wołowski 2003). Additionally, *Didymosphaenia geminata* (Lyng.) H. Schmidt. (Appendix, no. 40), which is regarded as an invasive, alien species, was present in the phytoseston.

Long-term monitoring was performed at the Toruń station, where samples were collected in 1994-1998 and 2007-2010. Cluster analysis (Fig. 6) indicates that the most similar groups of diatoms were noted in 1994/95 and 1996, while the most different were noted in 1998, when the highest number of diatom species (139) was noted in the phytoplankton. The large number of species identified result from the as many as 15 samples, which were collected as often as weekly in summer 1998. The similarity among samples collected in 1997 and 2010 is probably a consequence of summer floods in both of these years, while similarity in the 2007-2009 period stemmed from performing sampling in the embankment zone. Long-term observations also indicate a change in phytoseston quantity.

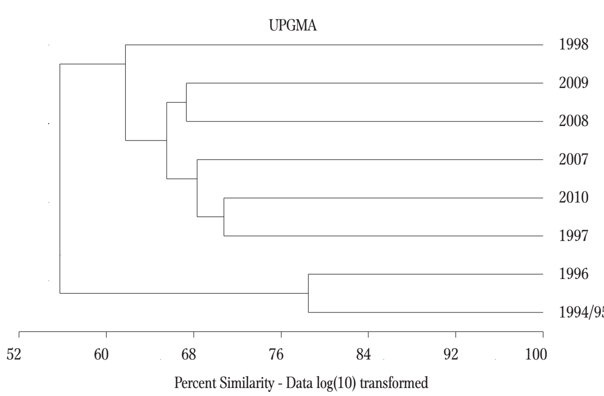

Figure 6. Similarity of diatom communities in the Vistula River at the Toruń station between 1994-2010.

Table 3

Ecological indicator species of diatoms in the Vistula River (trophic and oxygen conditions according to Van Dam et al. 1994; taxa from Red List by Siemińska et al. 2006)

Ooligotrophic and oligo-mesotrophic conditions	Hhigh and very high oxygen conditions	Vulnerable taxa	Taxa of indeterminate risk	Rare taxa
Achnanthes coarctata (Brébisson) Grunow	*Pseudostaurosira brevistriata* (Grunow) Williams et Round	*Achnanthidium exiguum* (Grunow) Czarnecki	*Ulnaria oxyrhynchus* (Kützing) M. Aboal	*Achnanthes coarctata* (Brébisson) Grunow
Amphora inariensis Krammer	*Navicula tripunctata* (O.F.Müll.) Bory	*Cymbella aspera* (Ehrenberg) Peragallo	*Neidium dubium* (Ehrenberg) Cleve	Aneumastus tusculus (Ehrenberg) D. Mann et Stickle
Caloneis undulata (Greg.) Krammer	*Navicula reinhardtii* (Grun.) Grun. in Cleve et Möll	*Cymbella ehrenbergii* Kützing		*Caloneis permagna* (Bailey) Cleve
Cymbella aspera (Ehrenberg) Peragallo	*Amphora ovalis* (Kütz.) Kütz.	*Fragilaria reicheltii* (Voigt) Lange-Bertalot		*Cocconeis placentula* var. *klinoraphis* Geitler
Cymbopleura amphicephala (Nägeli) Krammer	*Gomphoneis olivacea* (Hornemann) Dawson ex Ross et Sims	*Neidium ampilatum* (Ehrenberg) Krammer		*Cymbella helvetica* Kützing
Cymbopleura subaequalis (Grunow) Krammer	*Rhoicosphaenia abbreviata* (C. Agardh) Lange-Bert.	*Pinnularia microstauron* (Ehrenberg) Cleve,		*Cymbella lanceolata* (Ehrenberg) Kirchn
Diploneis elliptica (Kützing) Cleve	*Nitzschia recta* Hantz. in Rabenh.	*Sellaphora bacillum* (Ehrenberg) D. Mann		*Cymbopleura subaequalis* (Grunow) Krammer
Ellerbeckia arenaria (Moore) Crawford	*Nitzschia linearis* (Agardh) W. Smith,	*Stauroneis phoenicenteron* (Nitzsch) Ehrenberg		*Diploneis oblongella* (Naegeli ex Kützing) Ross
Entomoneis paludosa (W. Smith) Reimer	*Cymatopleura elliptica* (Bréb.) W. Smith.	*Surirella bifrons* Ehrenberg		*Geissleria decussis* (Østrup) Lange-Bertalot et Metzeltin
Fragilaria capucina var. rumpens (Kützing) Lange-Bertalot		*Surirella elegans* Ehrenberg		*Geissleria schoenfeldii* (Hustedt) Lange-Bertalot et Metzeltin
Neidium ampilatum (Ehrenberg) Krammer				*Gomphonema affine* Kützing
N. bisulcatum (Lager.) Cleve				*Navicula digitoradiata* (Greg.) Ralfs in Pritch.
Pinnularia borealis Ehrenberg				*Navicula cincta* Ehrenberg
Surirella bifrons Ehrenberg				*Navicula menisculus* Schumann
				Neidium bisulcatum (Lager.) Cleve
				Pseudostaurosira brevistriata (Lands) Williams et Round
				Staurosira bidens (Heiberg) Lands
				Surirella brebissonii Krammer et Lange-Bertalot
				Surirella crumena Brébisson ex Kützing

At the Toruń station, chlorophyll *a* concentrations decreased significantly in the 2007-2010 period as compared with those in 1998 (Table 2), and these values, expressed as ZCH according to Picińska-Fałtynowicz and Błachuta (2011), permit concluding that ecological potential improved from good in 1998 to maximum in the 2007-2009 period. However, the flood in 2010 caused a the ecological condition to worsen slightly to good potential.

In conclusion, diatoms are usually studied as a component of settled algal communities. The present research shows that these organisms, as a component of large river phytoplankton, are extremely important, and that they can be used as indicators of trophic and ecological conditions in large rivers. One of the characteristic of the lower reaches of large rivers is considerable fertility. These conditions were present in the studied area of the Vistula River, and they were indicated by high concentrations of nutrients. The trophic state index (TSI) characterized Vistula waters as eutrophic or even hypertrophic. A large number of taxa characteristic for eutrophic conditions confirms the high trophic state of Vistula waters, which was determined based on hydrochemical analysis. River waters are well mixed, which contributes significantly to improved oxygenation and self-cleansing capabilities. The diatom species composition of the phytoseston indicates that oxygen conditions prevailing in the lower Vistula reaches were good. The waters of this river also provide good habitats for the development of rare and vulnerable species. The last period of research conducted in Toruń indicated there had been a marked improvement in water quality, which allowed classifying the Vistula at this site as being of maximum or good ecological potential. The present studies indicate that river waters with a high nutrient contents and which are under heavy anthropogenic pressure and major river engineering projects (dam reservoirs, regulated river beds) can be of good or even maximum ecological potential.

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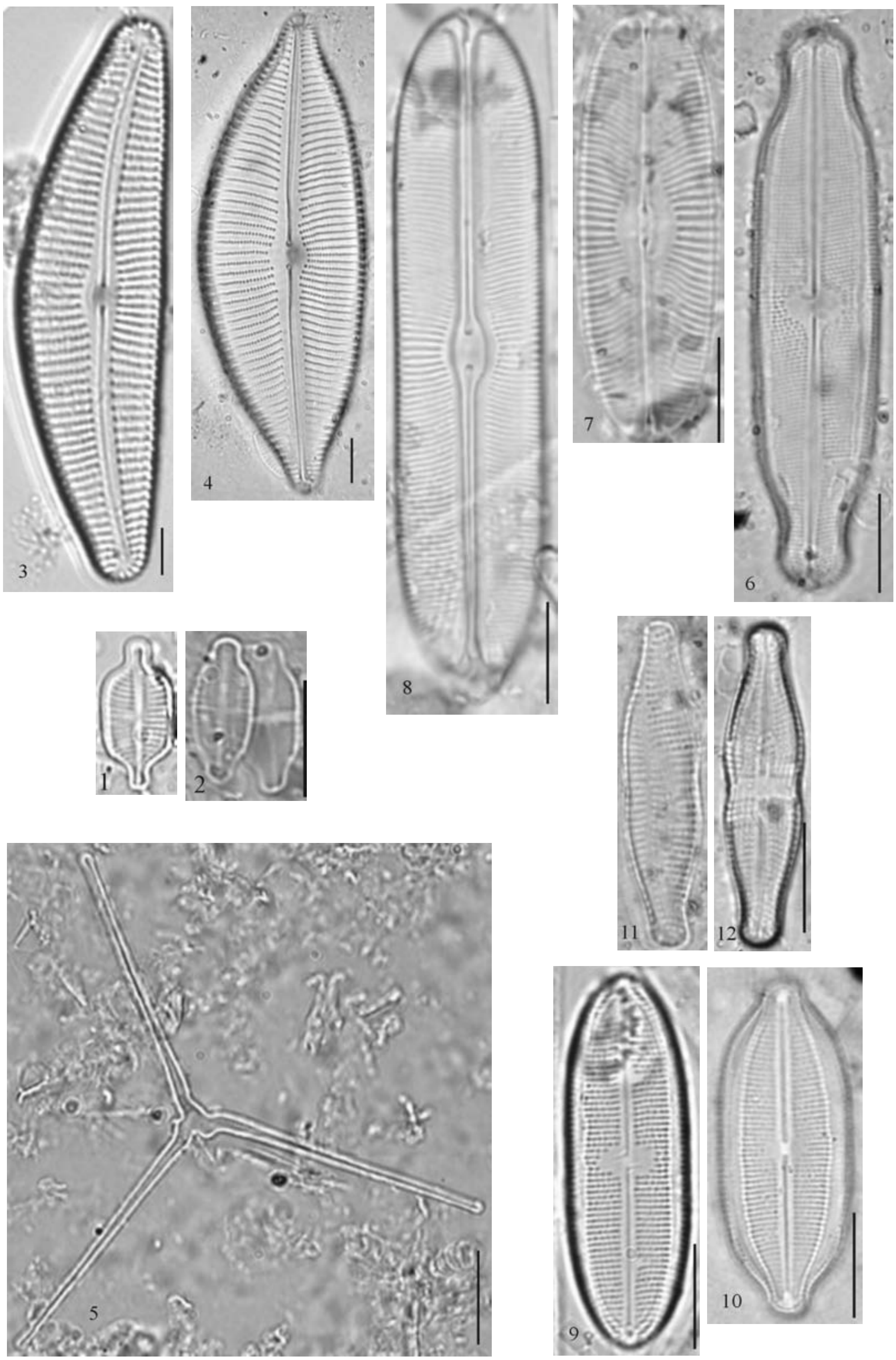
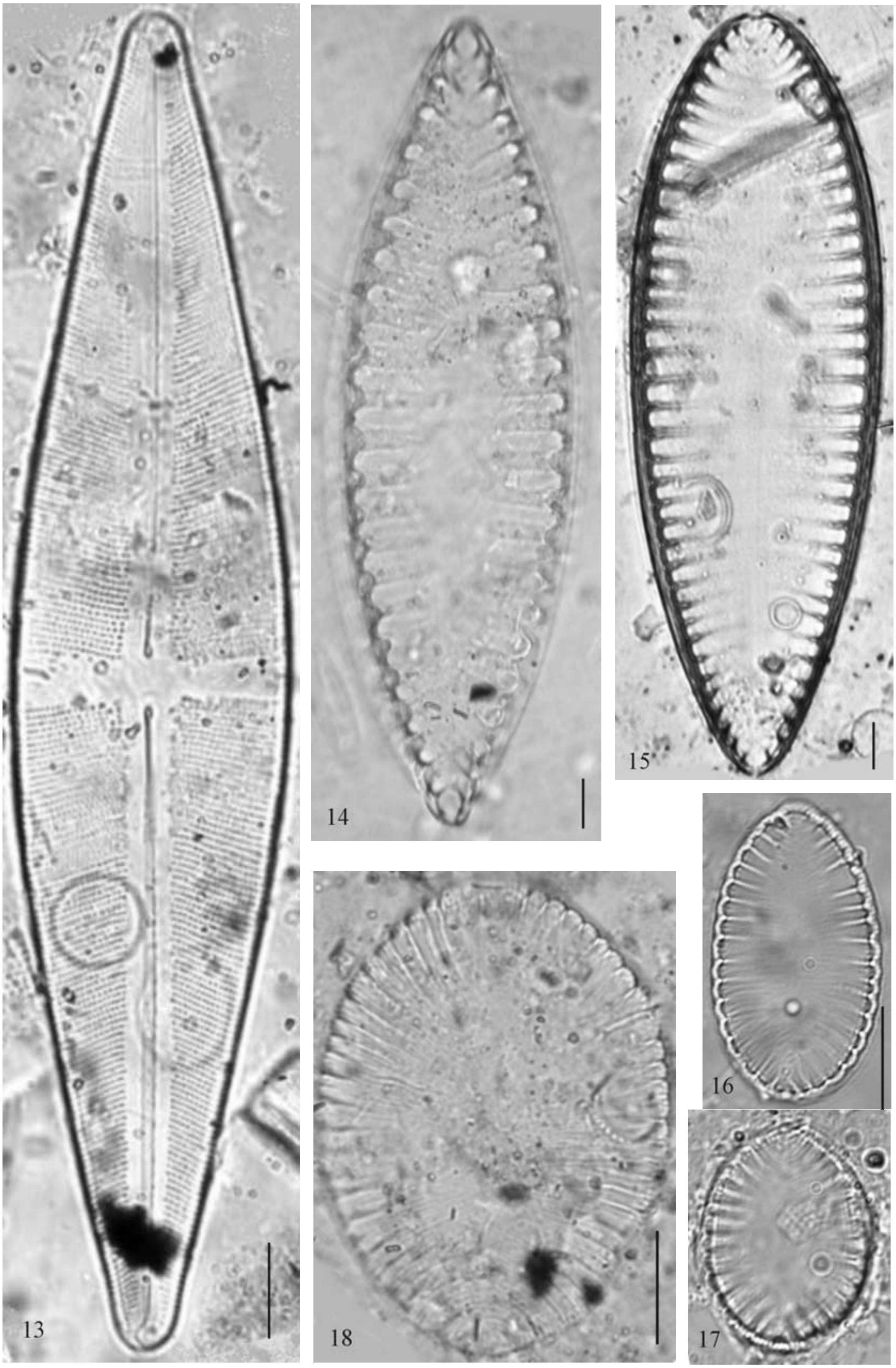
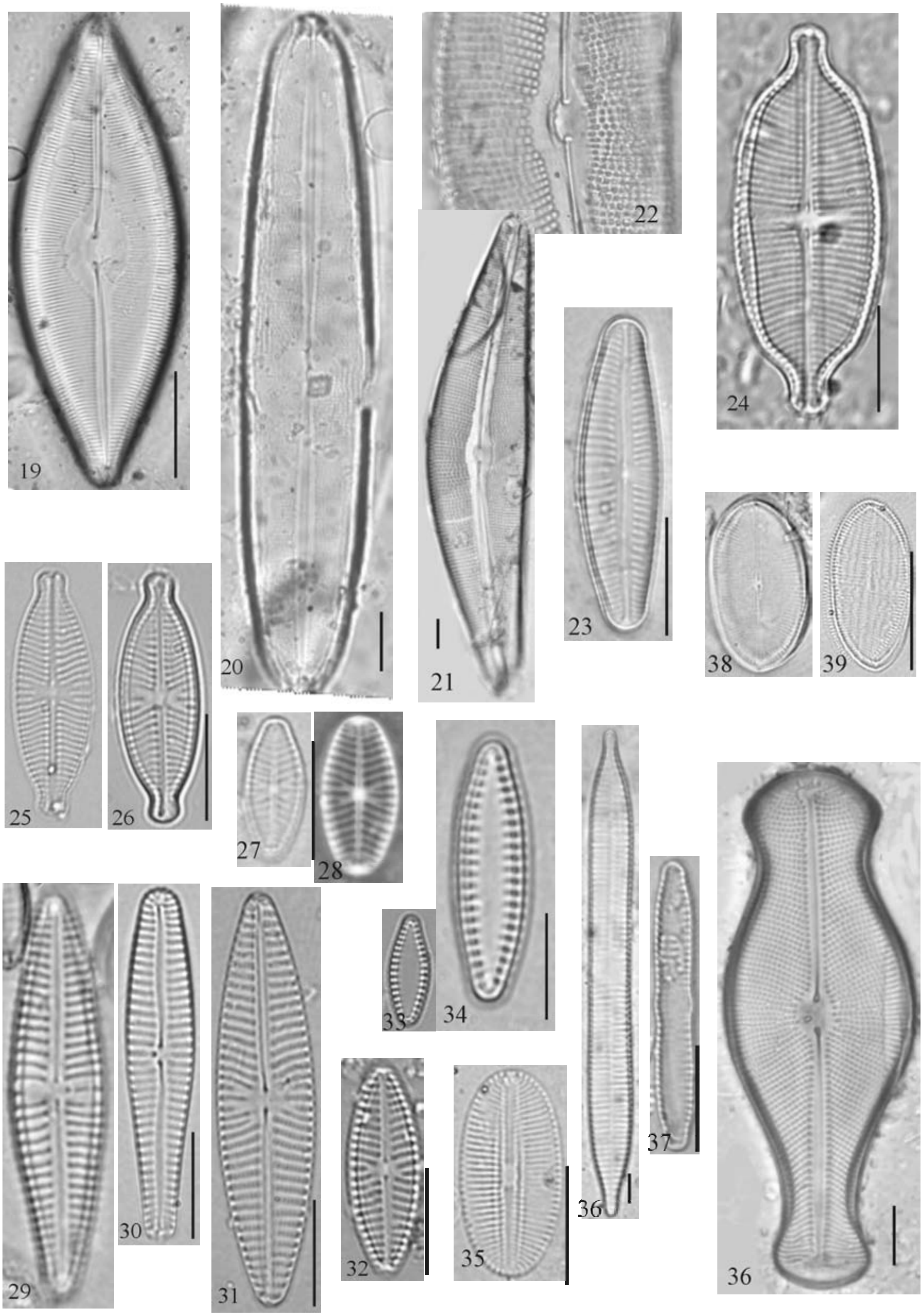
Appendix



Photographs. 1-2. *Achnanthidium exiguum*, 3. *Cymbella aspera*, 4. *C. ehrenbergii*, 5. *Fragilaria reicheltii*, 6. *Neidium ampilatum*, 7-8. *Sellaphora bacillum*, 9-10. *Neidium dubium*, 11-12. *Achnanthes coarctata* (scale bar 10 μm).



Photographs. 13. *Stauroneis phoenicenteron*, 14. *Surirella bifrons*, 15. *S. elegans*, 16-17. *S. brebissonii*, 18. *S. crumena* (scale bar 10 μm).



Photographs. 19. *Caloneis permagna*, 20. *Neidium bisulcatum*, 21-22. *Cymbella lanceolata*, 23. *Cymbopleura subaequalis*, 24. *Aneumastus tusculus*, 25-26. *Geissleria decussis*, 27-28. *G. schoenfeldii*, 29-30. *Gomphonema affine*, 31. *Navicula digitoradiata*, 32. *N. menisculus*, 33-34. *Pseudostaurosira brevistriata*, 35. *Diploneis oblongella*, 36. *Ulnaria oxyrhynchus*, 37. *Staurosira bidens*, 38-39. *Cocconeis placentula* var. *klinoraphis*, 40. *Didymosphaenia geminata* (scale bar 10 µm).