The palaeolimnological potential of diatom assemblages in floodplain lakes of the Danube Delta, Romania: a pilot study

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Abstract

Within the framework of a palaeolimnological pilot study, the potential of sedimentary diatom assemblages for the reconstruction of the eutrophication history was studied in short sediment cores from five shallow lakes located in the Romanian Danube Delta. A total of 234 diatom taxa representing 57 genera could be identified but diatom assemblages are generally predominated by a few species only. Loss on ignition percentages, total diatom abundances and diatom downcore successions largely vary within the single sediment cores and between all five lakes. This suggests the presence of various lake environments within the Danube Delta, each characterized by lake-specific geomorphological, sedimentological, hydrological, and biological conditions. Highly variable depositional conditions are also confirmed by radiocesium measurements in two of the five cores suggesting distinct inter-lake differences in the sedimentation rate. Causes for the great intra-lake and inter-lake variability in diatom downcore successions are difficult to specify and may include changes in the physico-chemical conditions, aquatic vegetation cover, water depth, river influence, turbidity and inter-biotic interactions. However, based on this pilot study, it is likely that the spatial and temporal distribution of sedimentary diatom assemblages in Danube Delta lakes were not triggered by the trophic state. The delta lakes likely became meso- to eutrophic long before 1950, possibly during late-Holocene times.

Introduction

Shallow lakes in floodplains of large rivers display a great variety of different habitats and ecological gradients. One of the largest floodlains in Europe, enclosing hundreds of shallow lakes, is the Danube Delta (Fig. 1). Hydrological characteristics in the delta lakes largely fluctuate caused by seasonal and interannual variability of river and lake water fluxes due to water transport via channels, periodical floodings, and water flow under reed beds (Coops et al., 1999; Buijse et al., 2002). The spatial and temporal variability of hydrological conditions in the floodplain lakes also leads to distinct differences in the plant, fish, zooplankton and phytoplankton communities (Coops et al., 1999; Oosterberg et al., 2000; Nãvodaru et al., 2002).

The Danube Delta drains the 2860 km long Danube River which has its origin near the German village Donaueschingen in the Black Forest and passes eight countries on its way to the Black Sea (Fig. 1). The catchment area of the Danube River is approximately 817 000 km^2 and the delta itself has a surface area of ca. 5800 km^2 (Oosterberg et al., 2000). Although the Danube Delta recently still displays a natural gradient of habitats with characteristic floras and faunas, man-made stress factors like eutrophication and geomorphological impacts became evident since the early 1970's due to dike and channel construction, fish farming, reed harvesting and agricultural activities within
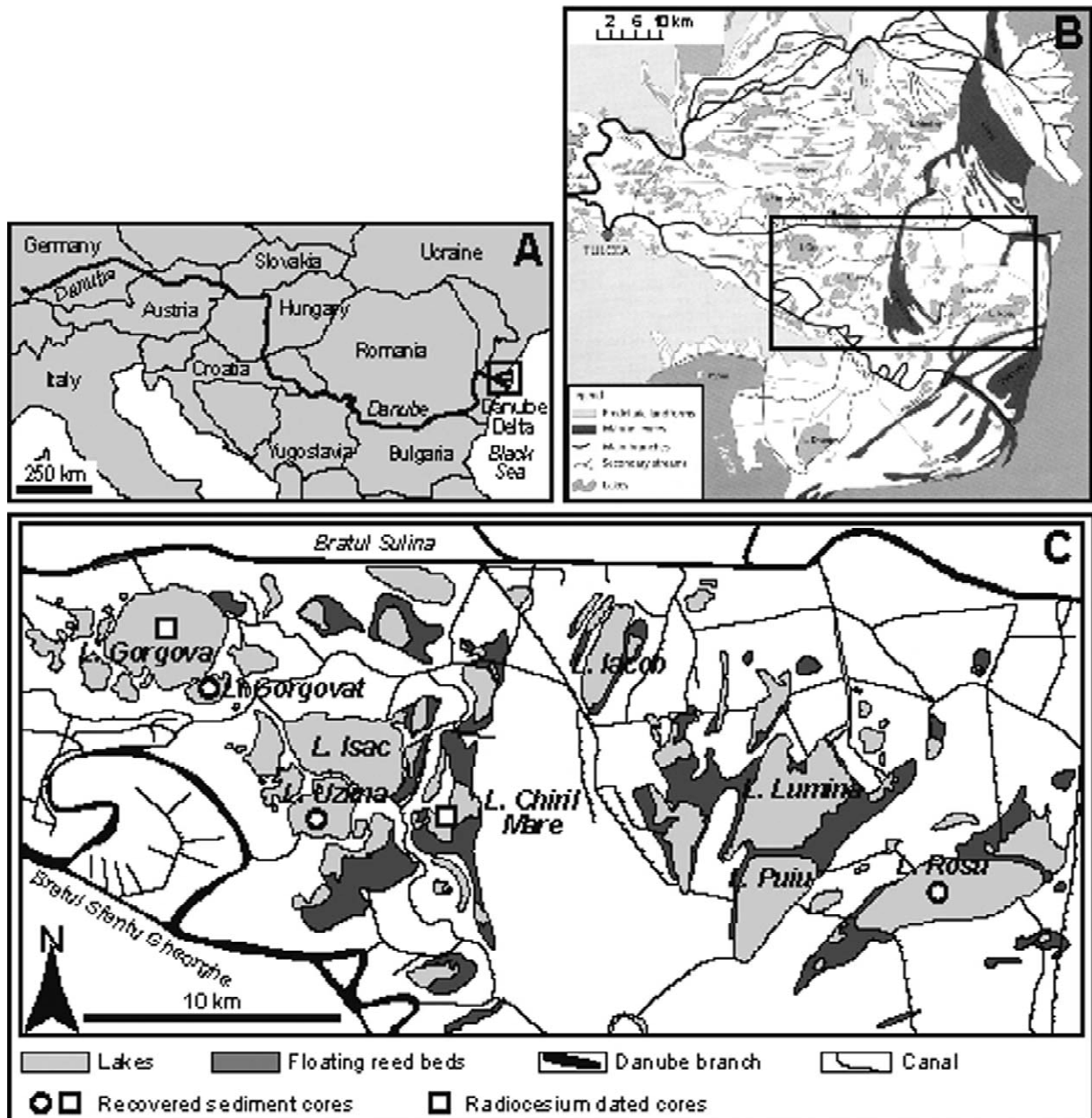
Figure 1. Geographical maps of the study area. (A). The Danube River from the origin to its delta. (B). Morphography of the Danube Delta (taken from Oosterberg et al., 2000). (C). Sampling sites in the Gorgova-Isac and Roşu-Puiu lake complexes.

the delta, and due to contaminated Danube River water influx (Heliotis et al., 1994; Schmidt, 2001).

The present paper summarizes a pilot study on the potential of sedimentary diatom assemblages as an indicator for trophic state changes in Danube Delta lakes during the past 50–100 years. This is the first palaeolimnological study of Danube Delta lakes and questions to be evaluated include (1) the composi-tion and succession of diatom assemblages in five short sediment cores, (2) the time presumably rep-resented by five short sediment cores, and (3) pos-sible palaeoenvironmental implications of the diatom successions.

Diatoms or Bacillariophyceae are since long time used in bioassessments and historical reconstructions as indicators for modern and past changes of ecolo-

Table 1. Core site description in lakes in the Danube Delta. The cores have been analyzed for the diatom succession (*), the loss on ignition percentages (°), and the radiocesium concentration (#)

Sampling date	Location	Water depth [m]	GPS Position [UTM]	Core length [cm]
6 June 2002	Core DD4 * # Lake Chiril Mare	1.60	35 T 0682906 UTM 4995240	38
6 June 2002	Core DD5* ° Lake Uzlina	1.50	35 T 0678010 UTM 4995393	36
8 June 2002	Core DD6* ° Lake Roşu	3.00	35 T 0700836 UTM 4991644	46
9 June 2002	Core DD7 # Lake Gorgova	2.40	35 T 0672171 UTM 5001871	52
9 June 2002	Core DD8* ° Lake Gorgova	2.40	35 T 0672221 UTM 5001761	46
9 June 2002	Core DD9* ° Lake Gorgovaţ	1.20	35 T 0673166 UTM 5000145	48

gical conditions (Stoermer & Smol, 1999). However, our knowledge about diatom assemblages and their palaeolimnological potential in river delta lakes is relatively little. One of the few comprehensive palaeostudies on delta lake diatoms is available from the Mackenzie Delta in Arctic Canada (Hay et al., 2000; Michelutti et al., 2001), which, compared to our study, is based on a much bigger database. Hay et al. (2000) and Michelutti et al. (2001) could show that lake diatom assemblages in the Mackenzie Delta are good indicators for past changes in macrophyte production and river influence.

Also, the knowledge about the diatom flora in lakes of the Danube Delta is rather poor. Whereas there are a relatively good qualitative and quantitative data on modern planktic diatoms (Török, 1998; Tudor & Török, 1999; Ibelings et al., 2000), benthic and epiphytic diatom communities as well as fossil diatom sediment assemblages of the delta lakes are insufficiently studied. Most available literature on non-planktic diatoms is relatively old and, moreover, usually restricted to a description of the identified species (e.g. Moruzi et al., 1960; Moruzi, 1968 and references therein).

Study area

The lakes investigated for this study are located in the Romanian Danube Delta Biosphere Reserve (DDBR) between the Sulina river branch in the north and the Sfantu Gheorghe river branch in the south (Fig. 1). Sediment cores were taken in five shallow lakes: L.

Gorgova, L. Gorgovaţ, L. Uzlina, L. Chiril Mare, and L. Roşu (Table 1). The selected lakes represent an east–west transect within the Danube Delta and are partly also subject to long-term limnological monitoring (Oosterberg et al., 2000). Water depths are between 1.20 and 3.00 metres and the recovered cores have lenghts between 36 and 52 cm. The current limnology of the lakes is determined by the seasonal variabilty of Danube river water discharge. The large network of canals and channels within the Danube Delta supports a quasi-canalization of the water flow from the delta entrance towards the Black Sea. As a result of the seasonal fluctuations of river water fluxes, Danube Delta lakes show a large variability in the light, nutrient and turbidity conditions, and in the occurrence of aquatic vegetation (Coops et al., 1999; Oosterberg et al., 2000). Although lake classification within floodplains is generally difficult, Buijse et al. (2002) defined three types of Danube Delta lakes (Table 2) based on differences in trophic state, topography, vegetation, and zooplankton and fish communities. Based on this classification (Table 2), L. Gorgova and L. Roşu represent type 1-lakes, L. Uzlina is a type 2-lake, and L. Gorgovaţ and L. Chiril Mare are assigned as type 3-lakes.

Materials and methods

Sediment sampling

Lake sediment coring was carried out in June 2002 during a houseboat-based field campaign. A gravity corer (UWITEC Corp., Austria) equipped with PVC tubes (diameter: 6 cm) was used to recover six short sediment cores (Table 1). Five of the six cores were opened longitudinally shortly after recovery onboard the houseboat (the sediment was stiff enough to apply this method), one core was kept for radionuclide measurements. Following lithological description and photographical documentation which revealed only minor stratigraphical disturbances within the entire core sections, one core half was sampled at 1 cm intervals for diatom analysis, the other core half was sampled in 2 cm intervals for physical and geochemical analyses. The intact core and all subsamples were stored in a dark cool place on the houseboat until further investigation.

Table 2. Typology of Danube Delta lakes. 'Low', 'intermediate' and 'high' refer to relative values (after Buijse et al., 2002, modified)

Parameter	Type 1 L. Gorgova, Roşu	Type 2 L. Uzlina	Type 3 L. Chiril Mare, Gorgovaţ
Size	Large	Intermediate	Small
Water depth	Deep	Shallow	Shallow
Substratum	Sand-silt	Clay	Organic
Dominant fish	Indifferent and still-water species	Species indifferent to low velocities	Still-water species
Zooplankton abundance	High	Low	Low
Phytoplankton and cyanobacteria abundance	High	Low	Low
Macrophyte abundance	Low	High	High
Dominant macrophyte species	None	*Potamogeton trichoides*	*Nitellopsis obtusa*
Area of reed belt	Varying	Small	Large
Phosphorus concentration	Low	Low	High
Nitrogen concentration	High	High	Low
Turbidity	Turbid	Clear	Clear

Sedimentation rates and radiocesium measurements

Measurements of cesium radionuclid activities (^{137}Cs) were carried out on two sediment cores in order to obtain estimates of sedimentation rates and to establish a depth-age relationship. Single measurements of the ^{137}Cs activity in freeze-dried, 2 cm thick sediment subsamples from core DD4 recovered in L. Chiril Mare were carried out at the Institute for Inland Water Management and Wastewater Treatment (RIZA) using a High Purity Germanium detector. A second core, core DD7 from L. Gorgova, was analysed on radiocesium activity using the non-destructive, entire-core PHAROS technique at the Nuclear Geophysics Division of the Kernfysisch Versneller Instituut (KVI) at Groningen University. This technique measures entire sediment cores in 2 cm intervals using Bismut-Germanium-Oxide ($Bi_4Ge_3O_{12}$) detectors (see http://ngd.kvi.nl/sediment/pharos for further information).

Loss on ignition (LOI) measurements

LOI measurements were carried out on subsamples of four sediment cores in order to obtain an estimation of the organic carbon and carbonate contents. For this purpose, between 1.5 and 5.0 g of freeze-dried and homogenisized subsamples of originally 2 cm thick intervals have been combusted in a muffle furnace subsequently for 4 h at 550 °C (oxidation of organic matter) and 950 °C (combustion of the carbonate). The weight loss during the oxidations was measured by weighing the subsamples before and after each burning process. The LOI (given as a percentage) was then calculated using the formulas published by Heiri et al. (2001). Although there are several factors affecting the LOI results (e.g. sample size, exposure time, position of samples in the furnace), this relatively cheap and fast method yields a reliable estimation of the organic carbon and carbonate contents in the sediments (Heiri et al., 2001).

Diatom slides

Diatom slides were prepared in 5 cm intervals from freeze-dried bulk sediment which was treated successively with hydrogen peroxide, hydrochloric acid and nitric acid, in order to remove all organic and carbonate components (Cremer et al., 2001). Slides were prepared employing the sedimentation tray method described by Battarbee (1973). Cover-glasses were mounted on slides using the high refraction mountant Naphrax®. Diatom identification and counting was carried out at a magnification of ×1000 using an Olympus BX51 microscope equipped with Nomarski optics. As far as possible, a minimum of 300 valves

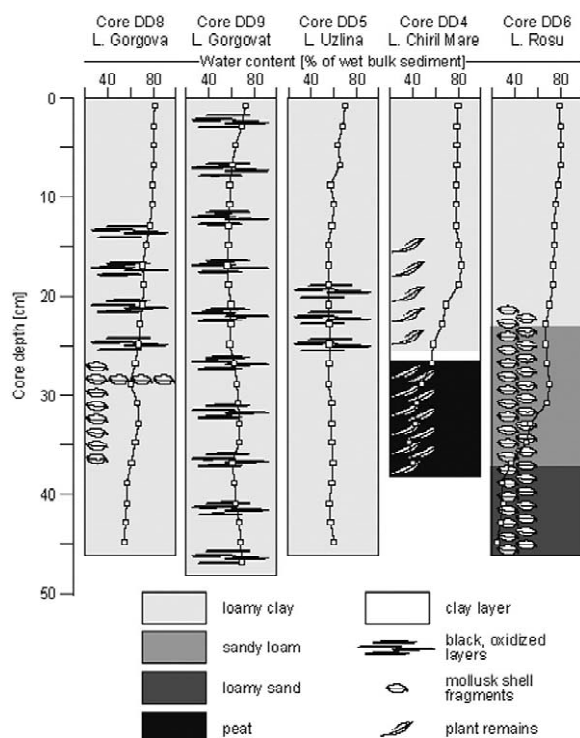*Figure 2.* Lithology and water content in short sediment cores from five Danube Delta lakes.

Figure 3. Radiocesium activities in two selected lake sediment cores from the Danube Delta. The dashed line represents the background ^{137}Cs activity. Methods applied (see also text): core DD4, single measurements using a Germanium detector, measured at the Institute for Inland Water Management and Wastewater Treatment (RIZA, Lelystad, The Netherlands); core DD7, entire-core measurements using the PHAROS detector, measured at the Nuclear Geophysics Division of the Kernfysisch Versneller Instituut (KVI, Groningen, The Netherlands). The inset shows the age-depth relationship in both cores for the past 50 years.

were counted. The identification of diatom species was mainly based on Krammer & Lange-Bertalot (1991, 1999a,b, 2000).

Results and discussion

Lithology, radiocesium (^{137}Cs) concentration and loss on ignition (LOI)

Lithology

The five sediment cores consist mainly of a muddy loamy clay with inserted black oxidized layers (Fig. 2). The basal sections of cores DD4 from L. Chiril Mare and DD6 from L. Roşu are characterized by thick peat and sand layers, respectively. Although it was not the aim of this study to apply complex sedimentological methods, the rough and rather qualitative lithological description of the five cores given in Figure 2 clearly shows that there is a large variety of sedimentological settings present within the Danube Delta lakes. However, whereas the surface deposits in the Danube Delta are comprehensively mapped 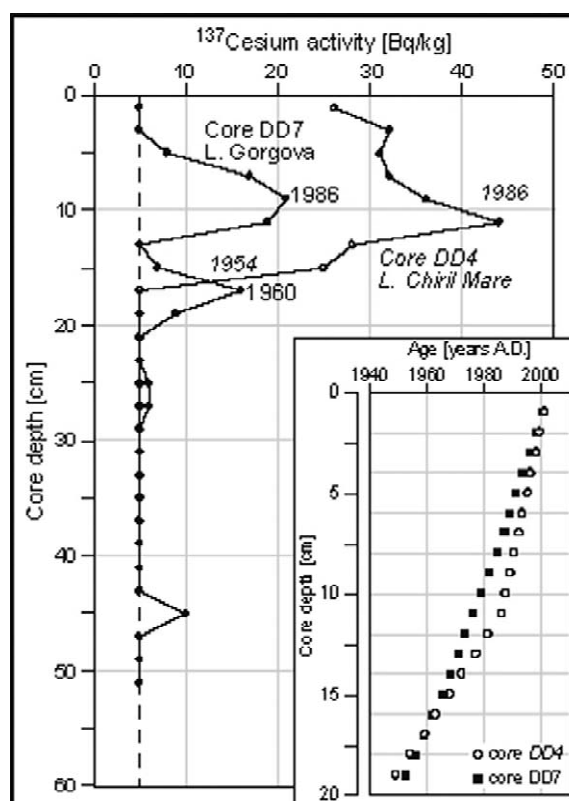(Munteanu & Curelariu, 1996) there is only limited information available on the vertical structure of soils and sediments (e.g. Pfannenstiel, 1950; Ghenea & Mihailescu, 1991), particularly of those representing the past few hundred years. The core lithology is also reflected in the water content which is generally high in the sections consisting of loamy clay and amounts up to 80% of the wet weight (Fig. 2). The basal peat and sand sections in L. Chiril Mare and L. Roşu, respectively, have a distinctly lower water content of 40–50% (Fig. 2).

Radiocesium (^{137}Cs) dating

Radiocesium activities in the sediments of L. Gorgova and L. Chiril Mare are summarized in Figure 3. Both sediment cores show rather low radiocesium activities and at least one distinct peak reflecting most

likely the readionuclide fallout as a consequence of the Chernobyl nuclear power plant accident in 1986. The difference in the radiocesium activities between the two cores might be due to the two methods applied for radiocesium determination (see chapter 'Materials and methods'). Core DD7 from L. Gorgova shows also a minor peak between 16 and 18 cm core depth which probably reflects regular atmospheric nuclear weapon tests that started from early 1960s (Fig. 3). This lower peak is not clearly visible in core DD4 from L. Chiril Mare and it might be speculated that the onset of nuclear bomb testing in the early 1950s is reflected in the increase of the radiocesium activity between 15 and 16 cm core depth. Core DD4 was also measured on ^{210}Pb activities which, however, are relatively low and vary between 112 Bq kg^{-1} at 4–6 cm core depth and 7 Bq kg^{-1} at 34–36 cm core depth.

The radiocesium activities measured in cores DD4 and DD7 are by factor three to six lower compared to published values for other lacustrine cores from the Danube Delta (Duliu et al., 1996; Winkels et al., 1998; Dinescu & Duliu, 2001). This could be due to the fact that the results in both cores were not corrected for sediment density and/or that the Bismut-Germanium-Oxide detectors used for core DD7 in the PHAROS technique (see chapter 'Materials and methods') have a lower resolution than the High Purity Germanium detector that was used for core DD4. In general, the concentration of fallout radionuclides in lake sediments depends on various factors including the atmospheric flux to the catchment and the lakes, transport processes between catchment and lakes, the loss via outflow and the residence time of water in lakes (Appleby, 2001), all of which certainly contributed to the observed patterns of radiocesium activity in both cores.

Sedimentation rates calculated for both lakes based on the radiocesium activity are shown in Table 3. The generally low ^{137}Cs activities make it difficult to calculate dates for the two cores with the consequence that the dates given in Figures 3 and 7 should be regarded with some caution but, nevertheless, provide a good estimate of the sedimentation rates. Sedimentation rates are distinctly higher during the past 15 years compared to the older layers. Moreover, the modern sedimentation rate in L. Chiril Mare is clearly higher than the respective rate in L. Gorgova (0.70 cm compared to 0.47 cm per year) but is lower in pre-1986 times (0.20 cm compared to 0.35 cm per year). The sedimentation rates determined in the present study are in the same range as rates calculated for L. Furtuna,

Table 3. Comparison of calculated sedimentation rates from lakes of the Danube Delta

Lake	Period	Sedimentation rate [cm/year]
Cremer et al. (this study)		
L. Gorgova	1986–2002	0.47 ± 0.05
	1960–1986	0.35 ± 0.07
L. Chiril Mare	1986–2002	0.70
	1953–1986	0.20
Duliu et al. (2001)		
L. Matita	1963–1994	ca. 0.15
Dinescu & Duliu (1998)		
L. Furtuna	1930–1996	0.81
L. Lung	1930–1996	0.60
L. Mesteru	1930–1996	0.80
Winkels et al. (1998)		
L. Uzlina	1940–1994	~1
Unnamed lake 1 (western delta)	1940–1994	~5–10
Unnamed lake 2 (western delta)	1940–1994	~5

L. Lung, and L. Mesteru by Dinescu & Duliu (1998) and for L. Uzlina by Winkels et al. (1998) (Table 3), but they are distinctly higher than the rate calculated for L. Matita in the northern Danube Delta (Duliu et al., 1996). On the other hand, Winkels et al. (1998) report significantly higher sedimentation rates between 5 and 10 cm/year from two lakes located in the western part of the Danube Delta.

Radiocesium activities and resulting sedimentation rates in cores DD4 and DD7 suggest a reliable age-depth relationship for the past 50 years (Fig. 3). Taking into account the distinctly varying inter-lake and intra-lake sedimentation rates (Table 3), calculated pre-1950 sedimentation rates and dates would be rather speculative as there are no distinct and reliable time markers preserved. However, the few published radiocesium activities and sedimentation rates suggest variable and dynamic sedimentation processes in the Danube Delta lakes.

Loss on ignition (LOI)
The heterogenous nature of depositional lake environments within the Danube Delta is also confirmed by the LOI measurements carried out on four cores. As mentioned above, the LOI procedure is a low-cost and relatively time-saving method to quantitatively estimate the contents of organic carbon and carbonate in
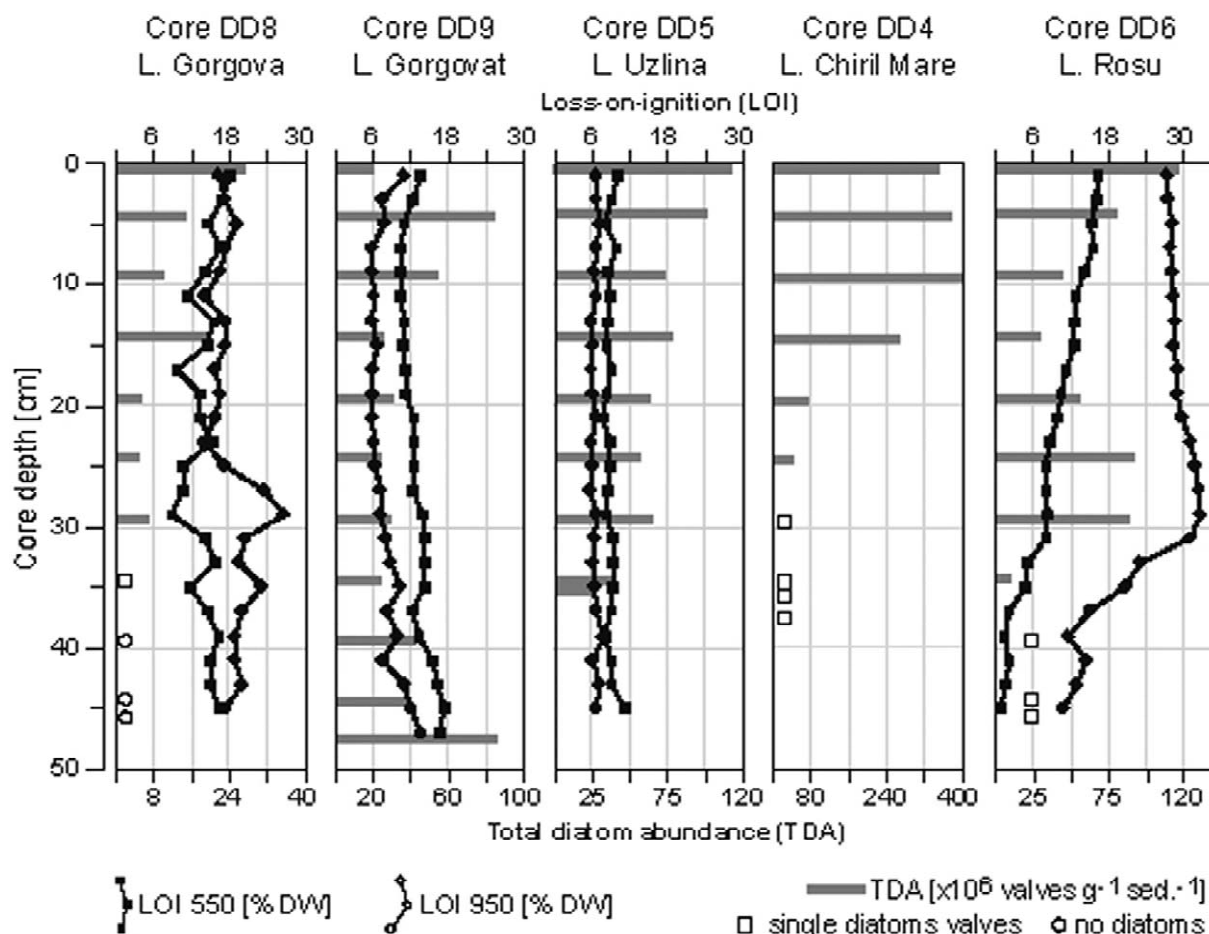
Figure 4. Loss on ignition (LOI) and total diatom abundance (TDA) data in short sediment cores from five Danube Delta lakes.

sediments (Heiri et al., 2001). The LOI curves presented in Figure 4 show disparate trends regarding both the absolute LOI values and the downcore variation between the four sediment cores. Lake Gorgovaţ and L. Uzlina are characterized by LOI 550 values of 12–18% and 6–12%, respectively, and both show LOI 950 values of 6–12% (Fig. 4). The downcore variation of both LOI indicators is relatively low in both cores which may indicate a relatively stable depositional environment in both lakes during the past century.

On the other hand, the LOI records in L. Gorgova and L. Roşu show distinct downcore variability. Whereas the LOI 550 in L. Gorgova uniformly varies between 12 and 18%, there is a shift in the LOI 950 visible at 25 cm core depth with distinctly increased values below this level (Fig. 4). This observation is in accordance with the lithology of core DD8 showing distinctly identifiable layers of mollusk shell fragments between 27 and 37 cm core depth (Fig. 2).

Clearest trends are represented in core DD6 from L. Roşu of which LOI 550 record gradually decreases from 18% present in the clayey top layer of the core towards 1% in the sandy bottom core part (Fig. 4). An even more obvious trend is visible in the carbonate record of core DD6: the LOI 950 values fluctuate around 30% in the upper 30 cm of the core and shift towards values around 12% in the interval 30–40 cm depth. This LOI pattern might match with the lithology of core DD6 (Fig. 2) which shows a relatively high sand proportion below 25 cm core depth and, moreover, a clearly lower water content in the basal core section. However, we do not have any good explanation for the distinct decrease in LOI 950 below 30 cm in core DD6 despite the presence of high proportions of mollusk shells (Fig. 2) which would suggest an increased carbonate content.

In summary, the results of the LOI measurements are in good accordance with the lithological findings

of the sediment cores and they confirm the diversity of depositional lake environments within the Danube Delta.

Composition of the diatom flora

The present work is the first comprehensive study of the modern and historical diatom flora from lakes located in the Romanian Danube Delta. A total of 234 diatom taxa representing 57 genera could be identified in modern lake sediments from the Danube Delta. All taxa are listed in Appendix I according to current taxonomical literature. The high number of genera reflect the recent trend of splitting up almost all diatom genera based on new micromorphological, physiological and genetical insights due to improved microscopic and molecular techniques.

Downcore diatom assemblages

Diatoms are present throughout sediment cores DD9 (L. Gorgovaţ) and DD5 (L. Uzlina) indicating a continuous depositional environment in both lakes. On the other hand, the bottom core layers in L. Gorgova, L. Chiril Mare, and L. Roşu show only minor diatom content or even are completely barren, thus indicating events that have possibly prevented a continuous sedimentation (Fig. 4). The total diatom abundance (TDA) shows no uniform trend in all five sediment cores. The maximum TDA values vary between 400×10^6 valves g^{-1} dry sed. in core DD4 from L. Chiril Mare and 28×10^6 valves g^{-1} dry sed. in core DD8 from L. Gorgova (Fig. 4), thus representing inter-lake variability in sedimentation patterns and possibly also diatom bioproductivity. There are also remarkable TDA fluctuations visible within the single cores. Whereas in the cores from L. Gorgova, L. Uzlina, and L. Chiril Mare the TDA decreases with core depth, the cores from L. Gorgovaţ and L. Roşu are characterized by clearly increased TDA values in both the top and bottom core layers (Fig. 4). These findings demonstrate that the productivity conditions in the lakes may have changed drastically over the time represented by these cores.

Figures 5 and 6 summarize the diatom downcore succession based on the relative abundance of single diatom species. The graphs show all taxa that achieve a relative abundance of 5% in at least one subsample. The number of taxa that meet this criterion ranges between 15 taxa in core DD6 from L. Roşu and just seven taxa in core DD4 from L. Chiril Mare. The diatom downcore succession patterns are briefly described hereafter:

Lake Gorgova (core DD8, Fig. 5). There is a clear boundary in this core at 20 cm core depth: below this boundary, between 20 and 30 cm core depth, the diatom assemblage is dominated by *Staurosira construens* Ehrenberg and varieties (see Appendix 1) and *Staurosirella pinnata* (Ehrenberg) Williams et Round, whereas above this layer *Aulacoseira granulata* (Ehrenberg) Simonsen, *Nitzschia solita* Hustedt and *Stephanodiscus hantzschii* Grunow and associated species are most abundant. There is a clear maximum in the relative abundance of *Cocconeis placentula* Ehrenberg in the topmost layer.

Lake Gorgovaţ (core DD9, Fig. 5). As in core DD8, there is a clear shift in the composition of the diatom assemblage at 25 cm core depth. Below this layer *S. construens* and *S. pinnata* are the predominating species, whereas above this boundary *A. granulata*, *Cyclotella meneghiniana* Kützing and the *S. hantzschii* group are most abundant. The topmost layer shows maximum relative abundance of *C. placentula* and *Fragilaria vaucheriae* (Kützing) Petersen.

Lake Uzlina (core DD5, Fig. 5). In this core the diatom assemblage below 18 cm core depth is predominated by *A. granulata*, *Aulacoseira subarctica* (Müller) Harworth and the *S. hantzschii* group. Above this boundary, *C. placentula*, *F. vaucheriae* and *Thalassiosira visurgis* Hustedt have highest relative abundance. Both *Cyclostephanos invisitatus* (Hohn et Hellerman) Theriot, Stoermer et Håkansson and *C. meneghiniana* occur in relatively high abundances throughout the core but do not show any distinct trends.

Lake Chiril Mare (core DD4, Fig. 6). There are only seven species in core DD4 that meet the 5% criterion. The complete core, except for the sequence between 24 and 30 cm core depth, is clearly dominated by the three fragilarioid species *Pseudostaurosira brevistriata* (Grunow) Williams et Round, *S. construens*, and *S. pinnata*. The interval between 24 and 30 cm is characterized by increased relative abundance of *A. granulata*, *Epithemia adnata* (Kützing) Brébisson and *E. turgida* (Ehrenberg) Kützing. Furthermore, the *S. hantzschii* group occurs in increased relative abundance in the uppermost 5 cm of the core.

Lake Roşu (core DD6, Fig. 6). This core shows the highest number of species that occur at a relative abundance of 5% in at least one subsample. The core can roughly be subdivided into three intervals. The basal layer up to 35 cm core depth is predominated by *S. pinnata*, *P. brevistriata* and two species of the genus *Amphora*. The interval between 10 and 30 cm core depth shows highest relative abundance
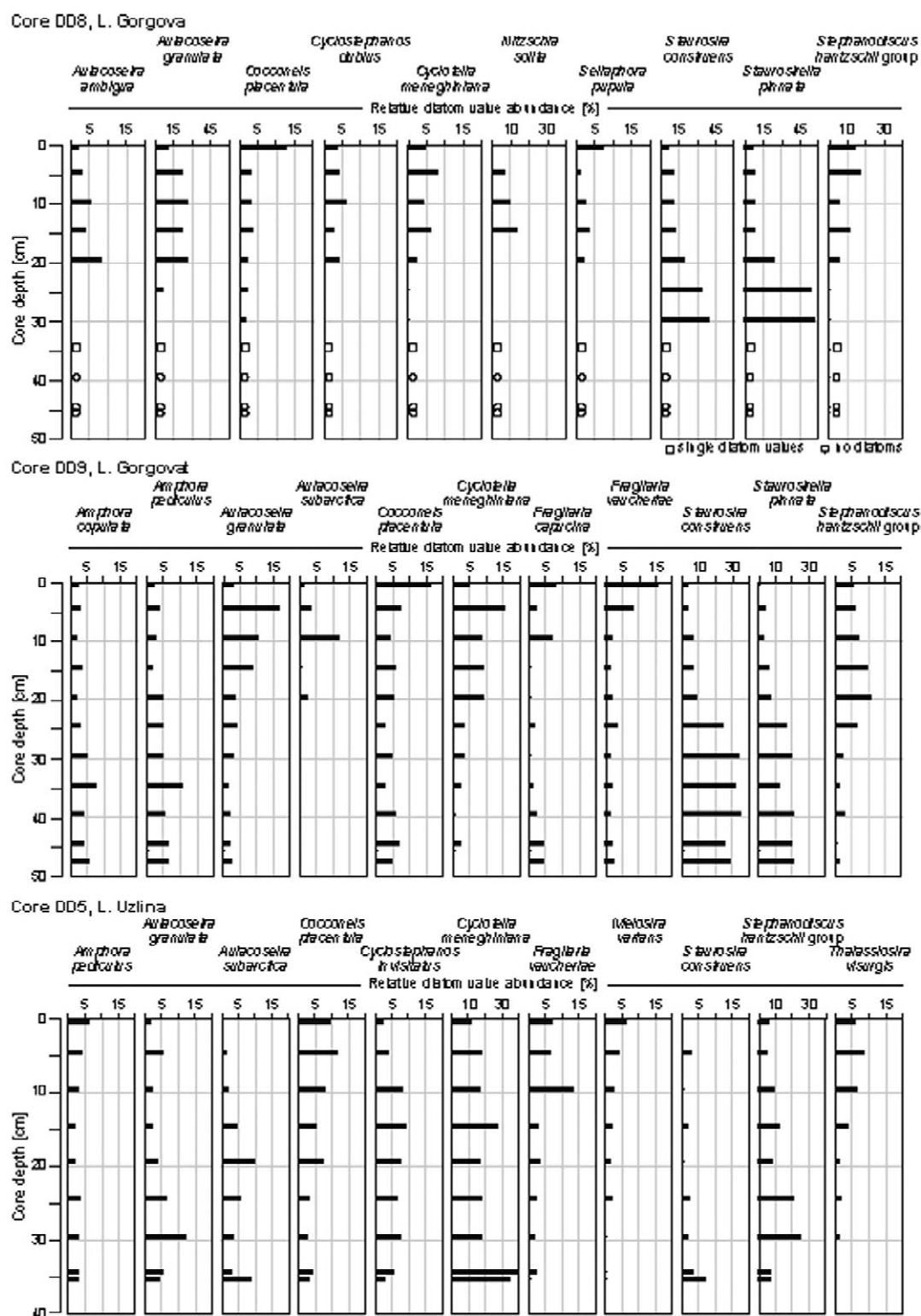
Figure 5. Composition of diatom assemblages in short sediment cores from L. Gorgova, L. Gorgovaţ, and L. Uzlina. All taxa are considered that achieve a minimum of 5% relative abundance in at least one subsample. The *Stephanodiscus hantzschii* group also includes *S. minutulus* and *S. parvus*.

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Figure 6. Composition of diatom assemblages in short sediment cores from L. Chiril Mare and L. Roşu. All taxa are considered that achieve a minimum of 5% relative abundance in at least one subsample. The *Stephanodiscus hantzschii* group also includes *S. minutulus* and *S. parvus*.
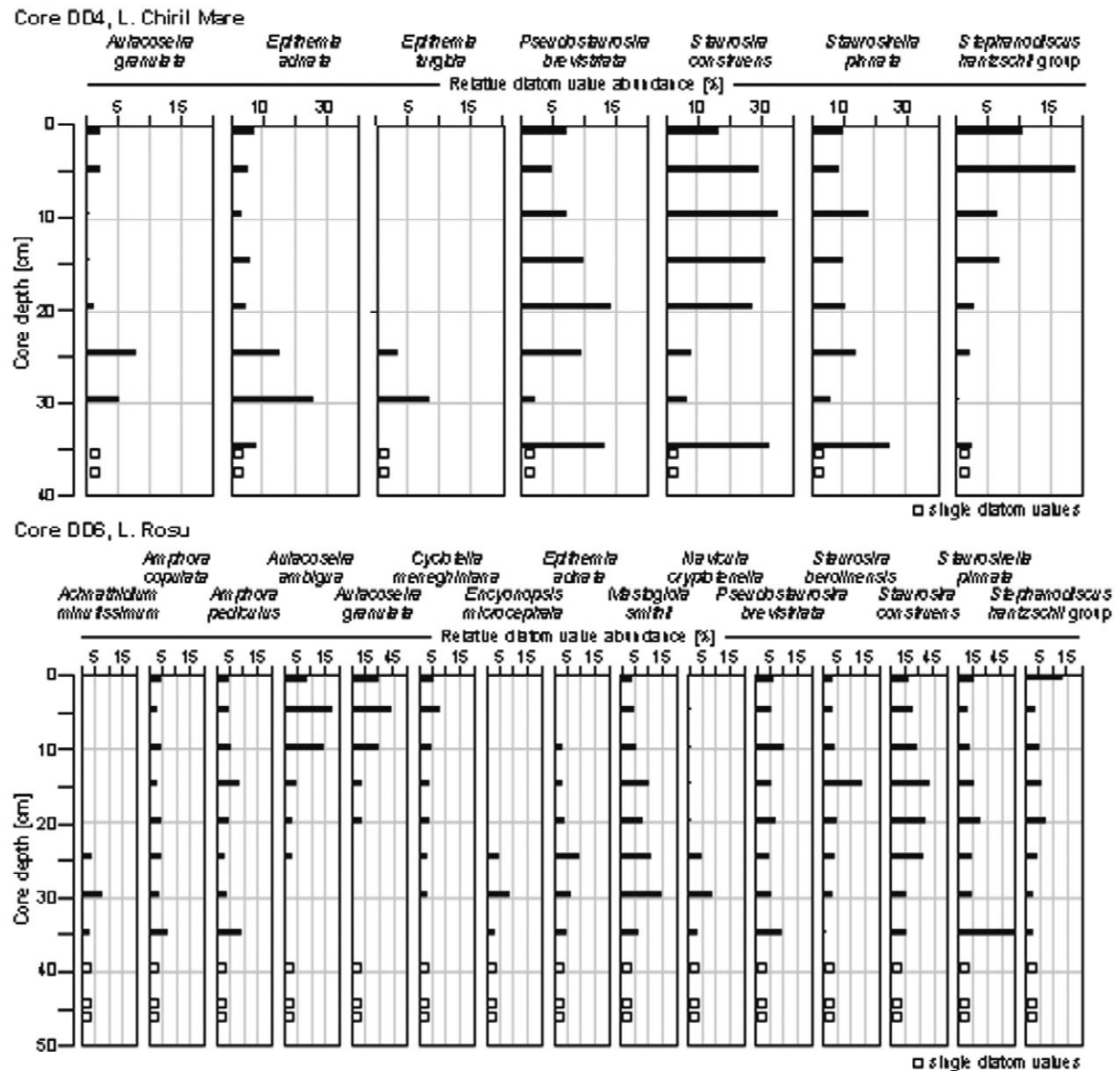
of *S. construens*, *S. pinnata* and *Mastogloia smithii* Thwaites. The uppermost layer (0–10 cm) is characterized by the predominance of *A. granulata* and *A. ambigua* (Grunow) Simonsen.

A comparison of the diatom assemblages in the five sediment cores reveals significant differences with regard to the species composition, thus reflecting local, lake-specific limnological conditions. An inter-lake diatom comparison is best possible looking at the three species that do occur in significant relative abundance

in all five cores (Fig. 7): *A. granulata*, *S. construens* and the *S. hantzschii* group. Figure 7 shows clear differences in the occurrence of the three species in pre- and post-1960 times. On the other hand, there is no clear inter-lake trend visible that could be related to the geographical location of the lakes in the Danube Delta. *Staurosira construens*, for example, a cosmopolitan benthic and epiphytic diatom species, shows highest relative abundance in pre-1960 times in L. Gorgova and L. Gorgovaţ and in post-1960 times in
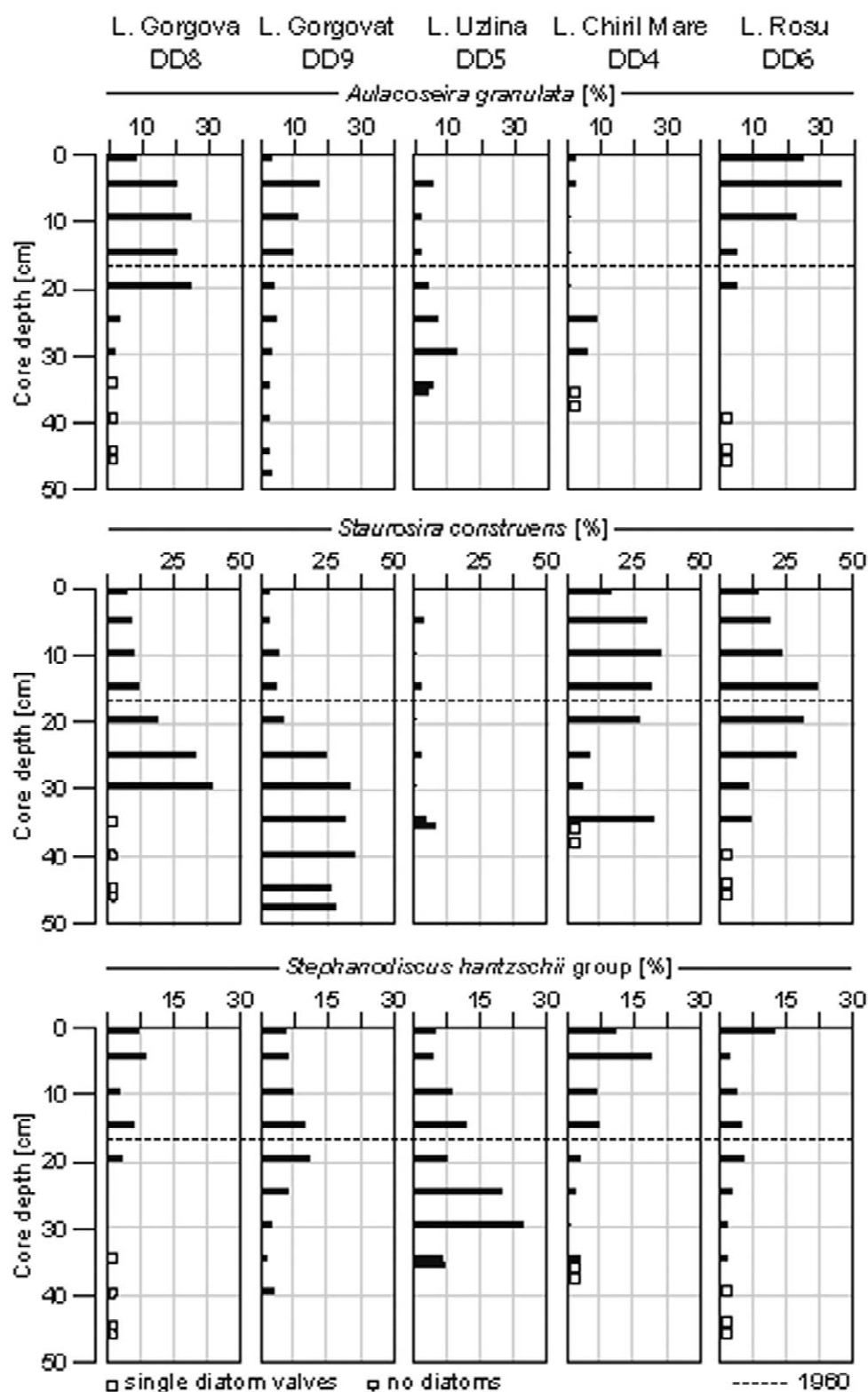
Figure 7. Comparison of short sediment cores from five Danube Delta lakes regarding the downcore relative abundance of the three diatom taxa frequently occurring in all lakes. The dashed line marks the year 1960 based on radiocesium determination in cores DD4 and DD7 (see Fig. 3). The *Stephanodiscus hantzschii* group also includes *S. minutulus* and *S. parvus*.

L. Chiril Mare; there is no clear trend visible in the core from L. Roşu and *S. construens* is only of minor importance in L. Uzlina. *Aulacoseira granulata*, a cosmopolitan tychoplanktonic species, shows highest occurrence in post-1960 sediments of L. Gorgova and L. Roşu whereas the *S. hantzschii* group, consisting also of cosmopolitan planktic diatoms, does particularly occur in pre-1960 sediments of L. Uzlina and post-1960 times in L. Chiril Mare (Fig. 7).

The variability of the sedimentary diatom distribution patterns is also supported by the phytoplankton occurrence. Phytoplankton surveys carried out in 1997 and 1998 in 13 selected lakes of the Danube Delta show that there is a large seasonal and interannual variability in the composition of the diatom communities (Ibelings et al., 2000). In both years, diatoms together with blue-green algae were the most abundant algae, based on cell number counts in water samples. However, the occurrence of blooms and the genera and species that were most abundant, were different from year to year. For example, L. Roşu had a combined diatom–blue-green algae bloom in July 1997, whereas in 1998 there was a diatom bloom in April and blue-green algae did not occur at all (Ibelings et al., 2000).

In summary, the diatom downcore assemblages demonstrate first, that there are no general trends and gradients visible in the species composition of the delta lakes, and second, as a consequence, that the modern distribution pattern of diatom communities must be triggered by a variety of lake-specific hydrological conditions. Furtheron, it is rather evident that the modern spatial distribution of diatom communities within the Danube Delta is not reflected in the lake classification system suggested by Buijse et al. (2002) (Table 2), meaning that the different diatom communities cannot be assigned to a certain lake type. This suggests that the lake ecosystems within the Danube Delta are enormously dynamic and variable and, therefore, it might be problematic to arrange them in a consistent classification system.

Potential of diatom assemblages as indicator for past environmental changes

More or less distinct changes in the diatom species composition are visible in all investigated cores (Figs 5, 6 and 7). The diatom downcore successions show that environmental changes undoubtedly must have been present during the past century. However, because the modern limnology and the interplay between biotic and abiotic factors in the delta lakes are not yet completely understood, it is difficult to specify those environmental changes that could have been responsible for the observed changes in the diatom assemblages. Possible causes for the observed spatial and temporal distribution pattern of diatom assemblages could be diverse and may include, for example, changes in lakewater quality, the presence of submerged vegetation, turbidity, physico-chemical conditions, water depth and inter-biota relationships (e.g. grazing).

Past changes in trophic state

The main focus of this pilot study was to check whether the diatom assemblages have the potential for reconstructing the eutrophication history of the delta lakes. Diatom assemblages are since long time used as indicators for historical changes in the trophic state of lakes (see Hall & Smol, 1999, for a review) and there are several case studies available from various regions in Europe that demonstrate lake eutrophication and restoration trends over the past 120 years (e.g. Lotter, 1998). Lakes within the Danube Delta are also believed to have suffered substantial eutrophication since the 1960s although the available data that could confirm this are relatively poor. The average total phosphorus concentration in the delta lakes ranges from 80 to 150 μg/l stating that most lakes recently are eutrophic or even hypertrophic (Oosterberg & Bogdan, 2000). Whereas the inter-lake variability in the total phosphorus content is relatively small, there is considerable seasonal variation within single lakes. This trend is also visible in other parameters, e.g. the nitrogen, chlorophyll and suspended solid concentrations (Oosterberg & Bogdan, 2000).

In order to estimate the potenial of the delta lake diatom assemblages for a reconstruction of past eutrophication trends, the trophic state of all relevant diatom species has been compiled (Table 4). The trophic affinities were taken from van Dam et al. (1994) who listed the freshwater diatoms of the Netherlands and their autecological preferences based on own observations and literature data. The most abundant diatoms occurring in the sediments of the delta lakes are meso- to eutraphentic, some even hypertraphentic taxa (Table 4). Considering the predominance of these diatom taxa in all five sediment cores (Figs 5 and 6), it becomes clear that the investigated lakes must have been meso- to eutrophic throughout the timespan reflected by the cores.

Table 4. Trophic affinities of the most abundant diatom species in lake sediments from the Danube Delta (compiled after van Dam et al., 1994)

Species	Trophic state	Ecology
Achnanthidium minutissimum	Oligo-eutraphentic	Benthic
Amphora copulata	Eutraphentic	Benthic
Amphora pediculus	Eutraphentic	Benthic
Aulacoseira ambigua	Eutraphentic	Planktic
Aulacoseira granulata	Eutraphentic	Planktic, tychoplanktonic
Aulacoseira subarctica	Oligo-mesotraphentic	Planktic
Cocconeis placentula	Eutraphentic	Benthic
Cyclostephanos dubius	Eutraphentic	Planktic
Cyclostephanos invisitatus	? Hypereutraphentic	Planktic
Cyclotella meneghiniana	Eutraphentic	Tychoplanktonic
Encyonopsis microcephala	Meso-eutraphentic	Benthic
Epithemia adnata	Meso-eutraphentic	Benthic
Epithemia turgida	Meso-eutraphentic	Benthic
Fragilaria capucina	Mesotraphentic	Benthic
Fragilaria vaucheriae	Eutraphentic	Benthic
Mastogloia smithii	Eutraphentic	Benthic
Melosira varians	Eutraphentic	Planktic
Navicula cryptotenella	Oligo-eutraphentic	Benthic
Nitzschia solita	Eutraphentic	Benthic
Pseudostaurosira brevistriata	Oligo-eutraphentic	Benthic
Sellaphora pupula	Mesotraphentic	Benthic
Staurosira berolinensis	Hypereutraphentic	Planktic
Staurosira construens	Meso-eutraphentic	Benthic
Staurosirella pinnata	Oligo-eutraphentic	Benthic
Stephanodiscus hantzschii	Hypereutraphentic	Planktic
Stephanodiscus minutulus	Hypereutraphentic	Planktic
Stephanodiscus parvus	Hypereutraphentic	Planktic
Thalassiosira visurgis	No Information available	Planktic

The meso- to eutraphentic nature of the most abundant diatom taxa throughout the entire sediment cores indicates that eutrophication likely took place much earlier than the 1950s. There are a few arguments that might support the hypothesis that waters in the Danube Delta are meso- to eutrophic since very long time. The Danube Delta has always been the terminus of the Danube River which drains vast regions of eastern Europe and consequently, constantly received a surplus of nutrients. This 'natural eutrophication process' has been certainly strongly amplified since humans started to cultivate the land in the catchment of the Danube River. Early human impact certainly included agricultural activities (e.g. ploughing of fields) which led to an increase of land erosion and consequently, enhanced nutrient supply. An intensification of these processes, possibly due to increased popoulation since the Greek and Ro-

man periods, might have led to meso- to eutrophic conditions in the Danube Delta since that time. Nevertheless, it is rather likely that the nutrient input into the Danube Delta was highest during the past 50 years due to increased population and industrial activities. However, changes from meso- to eutrophic and from eu- to hypertrophic conditions are hardly reflected in the diatom assemblages.

Conclusions

The studied sediment cores from five shallow lakes in the Danube Delta reveal a diverse diatom flora and large spatial and temporal variations in both the occurrence and species composition of the diatom assemblages.

However, at present, it is rather unclear how the spatial and temporal distribution of phytoplankton and periphyton communities in Danube Delta lakes is controlled. The available database of limnological parameters is still relatively little and does not include all lakes in the study area and, consequently, has to be enlarged during future monitoring campaigns. The sedimentary diatom successions likely do not reflect eutrophication trends in the delta lakes indicated by the aspect that all abundant diatoms in the downcore assemblages are meso- to eutraphentic species. Most likely, the delta lakes as the 'end of the pipe' of the Danube River are meso- to eutrophic since late-Holocene times.

The present investigation clearly emphasizes the view that each of the Danube Delta lakes is a unique mini-ecosystem with local and lake-specific geomorphological, hydrological, sedimentological and biological conditions.

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Appendix 1. List of diatom species identified in short sediment cores from lakes in the Danube Delta. Common synonyms are in angle brackets

1.	*Achnanthes conspicua* Mayer
2.	*Achnanthes* sp. [cf. *A. johncarteri* Lange-Bertalot et Krammer]
3.	*Achnanthes rupestoides* Hohn [further study justify suggest transfer to *Psammothidium*]
4.	*Achnanthidium exiguum* (Grunow) Czarnecki [*Achnanthes exigua* Grunow]
5.	*Achnanthidium minutissimum* (Kützing) Czarnecki [*Achnanthes minutissima* Kützing]
6.	*Actinocyclus normanii* fo. *subsalsa* (Juhlin-Dannfelt) Hustedt
7.	*Amphora commutata* Grunow
8.	*Amphora copulata* (Kützing) Schoemann et Archibald [*Amphora libyca* Ehrenberg]
9.	*Amphora* sp. [cf. *A. inariensis* Krammer]
10.	*Amphora ovalis* (Kützing) Kützing
11.	*Amphora pediculus* (Kützing) Grunow
12.	*Amphora veneta* Kützing
13.	*Anomoeoneis sphaerophora* (Ehrenberg) Pfitzer
14.	*Asterionella formosa* Hassall
15.	*Aulacoseira ambigua* (Grunow) Simonsen
16.	*Aulacoseira crenulata* (Ehrenberg) Thwaites
17.	*Aulacoseira granulata* (Ehrenberg) Simonsen
18.	*Aulacoseira italica* (Ehrenberg) Simonen)
19.	*Aulacoseira* sp. [cf. *A. laevissima* (Grunow) Krammer]
20.	*Aulacoseira* sp. [cf. *A. muzzanensis* (Meister) Krammer]
21.	*Aulacoseira* sp. [cf. *A. pfaffiana* (Reinsch) Krammer]
22.	*Aulacoseira subarctica* (Müller) Harworth
23.	*Brachysira styriaca* (Grunow) Ross [*Anomoeoneis styriaca* (Grunow) Hustedt]
24.	*Brachysira vitrea* (Grunow) Ross [*Anomoeoneis vitrea* (Grunow) Ross]
25.	*Caloneis amphisbaena* (Bory) Cleve
26.	*Caloneis bacillum* (Grunow) Cleve
27.	*Caloneis silicula* (Ehrenberg) Cleve
28.	*Cocconeis neothumensis* Krammer
29.	*Cocconeis pediculus* Ehrenberg
30.	*Cocconeis placentula* var. *euglypta* Ehrenberg
31.	*Cocconeis placentula* var. *lineata* (Ehrenberg) Van Heurck
32.	*Cocconeis placentula* var. *placentula* Ehrenberg
33.	*Craticula cuspidata* (Kützing) Mann
34.	*Cyclostephanos dubius* (Fricke) Round
35.	*Cyclostephanos invisitatus* (Hohn et Hellerman) Theriot, Stoermer et Håkansson
36.	*Cyclotella* sp. [cf. *C. atomus* Hustedt]
37.	*Cyclotella* sp. [cf. *C. bodanica* var. *affinis* (Grunow) Cleve-Euler]
38.	*Cyclotella krammeri* Håkansson
39.	*Cyclotella meneghiniana* Kützing
40.	*Cyclotella ocellata* Pantocsek
41.	*Cyclotella pseudostelligera* Hustedt
42.	*Cyclotella schumannii* (Grunow) Håkansson
43.	*Cyclotella stelligera* Cleve et Grunow
44.	*Cymatopleura solea* var. *apiculata* (W. Smith) Ralfs
45.	*Cymatopleura solea* var. *solea* (Brébisson) W. Smith
46.	*Cymbella affinis* Kützing
47.	*Cymbella amphicephala* Naegeli [further study may justify transfer to *Encyonopsis*]
48.	*Cymbella cistula* (Ehrenberg) Kirchner
49.	*Cymbella cuspidata* Kützing
50.	*Cymbella cymbiformis* var. *cymbiformis* Agardh

Appendix 1. Continued

51.	*Cymbella cymbiformis* var. *nonpunctata* Fontell
52.	*Cymbella ehrenbergii* Kützing
53.	*Cymbella helvetica* Kützing
54.	*Cymbella hustedtii* Krasske
55.	*Cymbella leptoceros* (Ehrenberg) Kützing
56.	*Cymbella prostrata* (Berkeley) Cleve
57.	*Cymbella proxima* Reimer
58.	*Denticula kuetzingii* Grunow
59.	*Diatoma tenuis* Agardh
60.	*Diatoma vulgaris* Bory
61.	*Diploneis elliptica* (Kützing) Cleve
62.	*Diploneis marginestriata* Hustedt
63.	*Diploneis ovalis* (Hilse) Cleve
64.	*Ellerbeckia* sp. [cf. *E. arenaria* (Moore) Crawford]
65.	*Encyonema caespitosum* Kützing [*Cymbella caespitosa* (Kützing) Brun]
66.	*Encyonema minutum* (Hilse) Mann
67.	*Encyonema silesiacum* (Bleisch) Mann [*Cymbella silesiaca* Bleisch]
68.	*Encyonopsis cesatii* (Rabenhorst) Krammer [*Cymbella cesatii* (Rabenhorst) Grunow]
69.	*Encyonopsis microcephala* (Grunow) Krammer [*Cymbella microcephala* Grunow]
70.	*Epithemia adnata* (Kützing) Brébisson
71.	*Epithemia argus* (Ehrenberg) Kützing
72.	*Epithemia frickei* Krammer
73.	*Epithemia smithii* Carruthers
74.	*Epithemia sorex* Kützing
75.	*Epithemia turgida* var. *granulata* (Ehrenberg) Brun
76.	*Epithemia turgida* var. *turgida* (Ehrenberg) Kützing
77.	*Eunotia arcus* Ehrenberg
78.	*Eunotia bilunaris* (Ehrenberg) Mills
79.	*Eunotia* sp. [cf. *E. exigua* (Brébisson) Rabenhorst]
80.	*Eunotia formica* Ehrenberg
81.	*Eunotia* sp. [cf. E. *glacialis* Meister]
82.	*Eunotia* sp. [cf. E. *implicata* Nörpel]
83.	*Fallacia pygmaea* (Kützing) Mann
84.	*Fallacia subhamulata* (Grunow) Mann
85.	*Fragilaria capucina* var. *capucina* Desmazières
86.	*Fragilaria capucina* var. *mesolepta* (Rabenhorst) Rabenhorst
87.	*Fragilaria crotonensis* Kitton
88.	*Fragilaria dilatata* (Brébisson) Lange-Bertalot
89.	*Fragilaria fasciculata* (Agardh) Lange-Bertalot
90.	*Fragilaria nanana* Lange-Bertalot
91.	*Fragilaria parasitica* var. *parasitica* (W. Smith) Grunow
92.	*Fragilaria parasitica* var. *subconstricta* Grunow
93.	*Fragilaria ulna* var. *acus* (Kützing) Lange-Bertalot [futher studies may justify transfer to *Ulnaria*]
94.	*Fragilaria vaucheriae* (Kützing) Petersen [*Fragilaria capucina* var. *vaucheriae* (Kützing) Lange-Bertalot]
95.	*Geissleria decussis* (Østrup) Lange-Bertalot et Metzeltin [*Navicula decussis* Østrup]
96.	*Geissleria schoenfeldii* (Hustedt) Lange-Bertalot et Metzeltin [*Navicula schoenfeldii* Hustedt]
97.	*Gomphonema acuminatum* Ehrenberg
98.	*Gomphonema amoenum* Lange-Bertalot
99.	*Gomphonema angustum* Agardh
100.	*Gomphonema* sp. [cf. *G. augur* Ehrenberg]
101.	*Gomphonema clavatum* Ehrenberg

Appendix 1. Continued

102.	*Gomphonema dichotomum* Kützing
103.	*Gomphonema gracile* Ehrenberg
104.	*Gomphonema grovei* var. *lingulatum* (Hustedt) Lange-Bertalot
105.	*Gomphonema minutum* (Agardh) Agardh
106.	*Gomphonema olivaceum* (Hornemann) Brébisson
107.	*Gomphonema parvulum* (Kützing) Kützing
108.	*Gomphonema truncatum* Ehrenberg
109.	*Gyrosigma acuminatum* (Kützing) Rabenhorst
110.	*Gyrosigma attenuatum* (Kützing) Rabenhorst
111.	*Gyrosigma nodiferum* (Grunow) Reimer
112.	*Gyrosigma parkerii* (Harrison) Elmore
113.	*Hannaea arcus* (Ehrenberg) Patrick
114.	*Hantzschia amphioxys* (Ehrenberg) Grunow
115.	*Hippodonta capitata* (Ehrenberg) Lange-Bertalot, Metzeltin et Witkowski [*Navicula capitata* Ehrenberg]
116.	*Hippodonta costulata* (Grunow) Lange-Bertalot, Metzeltin et Witkowski [*Navicula costulata* Grunow]
117.	*Hippodonta subcostulata* (Hustedt) Lange-Bertalot, Metzeltin et Witkowski [*Navicula subcostulata* Hustedt]
118.	*Karayevia clevei* (Grunow) Round et Bukhtiyarova [*Achnanthes clevei* Grunow]
119.	*Karayevia laterostrata* (Hustedt) Kingston [*Achnanthes laterostrata* Hustedt]
120.	*Kolbesia nitidiformis* (Lange-Bertalot) Lange-Bertalot [*Achnanthes nitidiformis* Lange-Bertalot]
121.	*Kolbesia ploenensis* (Hustedt) Kingston [*Achnanthes ploenensis* Hustedt]
122.	*Mastogloia elliptica* Agardh
123.	*Mastogloia smithii* var. *lacustris* Grunow
124.	*Mastogloia smithii* var. *smithii* Thwaites
125.	*Melosira varians* Agardh
126.	*Meridion circulare* (Greville) Agardh
127.	*Navicula* sp. [cf. *N. angusta* Grunow]
128.	*Navicula bacilloides* Hustedt [further studies may justify transfer to *Sellaphora*]
129.	*Navicula capitatoradiata* Germain
130.	*Navicula cari* Ehrenberg
131.	*Navicula cincta* (Ehrenberg) Ralfs
132.	*Navicula concentrica* Carter
133.	*Navicula* sp. [cf. *N. constans* Hustedt]
134.	*Navicula cryptocephala* Kützing
135.	*Navicula* sp. [cf. *N. cryptotenella* Lange-Bertalot]
136.	*Navicula graciloides* Mayer
137.	*Navicula gregaria* Donkin
138.	*Navicula menisculus* Schumann
139.	*Navicula meniscus* Schumann
140.	*Navicula oblonga* Kützing
141.	*Navicula perminuta* Grunow
142.	*Navicula* sp. [cf. *N. praeterita* Hustedt]
143.	*Navicula pseudoventralis* Hustedt
144.	*Navicula radiosa* Kützing
145.	*Navicula reinhardtii* Grunow
146.	*Navicula rhynchocephala* Kützing
147.	*Navicula slesvicensis* Grunow
148.	*Navicula tenelloides* Hustedt
149.	*Navicula tripunctata* (O.F. Müller) Bory
150.	*Navicula trivialis* Lange-Bertalot
151.	*Navicula viridula* (Kützing) Ehrenberg
152.	*Neidium ampliatum* (Ehrenberg) Krammer

Appendix 1. Continued

153.	*Neidium binodis* (Ehrenberg) Hustedt
154.	*Neidium iridis* (Ehrenberg) Cleve
155.	*Nitzschia acuminata* (W. Smith) Grunow
156.	*Nitzschia amphibia* Grunow
157.	*Nitzschia angustata* (W. Smith) Grunow
158.	*Nitzschia angustatula* Lange-Bertalot
159.	*Nitzschia* sp. [cf. *N. capitellata* Hustedt]
160.	*Nitzschia constricta* (Gregory) Grunow
161.	*Nitzschia dissipata* (Kützing) Grunow
162.	*Nitzschia dubia* W. Smith
163.	*Nitzschia fonticola* (Grunow) Cleve et Möller
164.	*Nitzschia frustulum* (Kützing) Grunow
165.	*Nitzschia graciliformis* Lange-Betalot et Simonsen
166.	*Nitzschia heufleriana* Grunow
167.	*Nitzschia hungarica* Grunow
168.	*Nitzschia levidens* (W. Smith) Grunow
169.	*Nitzschia linearis* (Agardh) W. Smith
170.	*Nitzschia littoralis* Grunow
171.	*Nitzschia palea* (Kützing) Smith
172.	*Nitzschia paleacea* Grunow
173.	*Nitzschia recta* Hantzsch
174.	*Nitzschia sigmoidea* (Nitzsch) W. Smith
175.	*Nitzschia* sp. [cf. *N. solita* Hustedt]
176.	*Nitzschia subacicularis* Hustedt
177.	*Nitzschia* sp. [cf. *N. supralitorea* Lange-Bertalot]
178.	*Nitzschia vermicularis* (Kützing) Hantzsch
179.	*Orthoseira* sp. [cf. *O. roeseana* (Rabenhorst) O'Meara]
180.	*Pinnularia* sp. [cf. *P. appendiculata* (Agardh) Cleve]
181.	*Pinnularia divergens* W. Smith
182.	*Pinnularia gibba* Ehrenberg
183.	*Pinnularia streptoraphe* Cleve
184.	*Placoneis elginensis* (Gregory) Cox [*Navicula elginensis* (Gregory) Ralfs]
185.	*Placoneis gastrum* (Ehrenberg) Mereschkowsky [*Navicula gastrum* (Ehrenberg) Kützing]
186.	*Placoneis placentula* (Ehrenberg) Heinzerling [*Navicula placentula* (Ehrenberg) Grunow]
187.	*Placoneis pseudanglica* (Lange-Bertalot) Cox [*Navicula pseudanglica* Lange-Bertalot]
188.	*Planothidium biporomum* (Hohn et Hellerman) Lange-Bertalot [*Achnanthes lanceolata* ssp. *biporoma* (Hohn et Hellerman) Lange-Bertalot]
189.	*Planothidium frequentissimum* (Lange-Bertalot) Round et Bukhtiyarova [*Achnanthes lanceolata* ssp. *frequentissima* Lange-Bertalot]
190.	*Planothidium lanceolatum* (Brébisson) Round et Bukhtiyarova [*Achnanthes lanceolata* (Brébisson) Grunow]
191.	*Planothidium* sp. [cf. *P. oblongellum* (Østrup) Van de Vijver] [*Achnanthes oblongella* Østrup]
192.	*Planothidium rostratum* (Østrup) Round et Bukhtiyarova [*Achnanthes lanceolata* ssp. *rostrata* (Østrup) Lange-Bertalot]
193.	*Psammothidium chlidanos* (Hohn et Hellerman) Lange-Bertalot [*Achnanthes chlidanos* Hohn et Hellerman]
194.	*Psammothidium helveticum* (Hustedt) Bukhtiyarova et Round [*Achnanthes helvetica* (Hustedt) Lange-Bertalot]
195.	*Psammothidium ventralis* (Krasske) Bukhtiyarova et Round [*Achnanthes ventralis* (Krasske) Lange-Bertalot]
196.	*Pseudostaurosira brevistriata* (Grunow) Williams et Round [*Fragilaria brevistriata* Grunow]
197.	*Reimeria sinuata* (Gregory) Kociolek et Stoermer
198.	*Rhoicosphenia abbreviata* (Agardh) Lange-Bertalot
199.	*Rhopalodia gibba* var. *gibba* (Ehrenberg) O. Müller
200.	*Rhopalodia gibba* var. *minuta* Krammer

Appendix 1. Continued

201.	*Rhopalodia gibba* var. *parallela* (Grunow) H. et M. Peragallo
202.	*Sellaphora bacillum* (Ehrenberg) Mann [*Navicula bacillum* Ehrenberg]
203.	*Sellaphora pupula* (Kützing) Mereschkowski [*Navicula pupula* Kützing]
204.	*Sellaphora seminulum* (Grunow) Mann [*Navicula seminulum* Grunow]
205.	*Skeletonema* sp. [cf. *S. subsalsum* (Cleve-Euler) Bethge]
206.	*Stauroneis phoenicenteron* (Nitzsch) Ehrenberg
207.	*Staurosira berolinensis* (Lemmermann) Lange-Bertalot [*Fragilaria berolinensis* (Lemmermann) Lange-Bertalot]
208.	*Staurosira* sp. [cf. *S. circula* Van de Vijver et Beyens]
209.	*Staurosira construens* var. *binodis* (Ehrenberg) Hamilton [*Fragilaria construens* var. *binodis* (Ehrenberg) Grunow]
210.	*Staurosira construens* var. *construens* Ehrenberg [*Fragilaria construens* var. *construens* (Ehrenberg) Grunow]
211.	*Staurosira construens* var. *exigua* (W. Smith) Lange-Bertalot [*Fragilaria construens* var. *exigua* (W. Smith) Schulz]
212.	*Staurosira construens* fo. *subsalina* (Hustedt) Bukhtiyarova [*Fragilaria construens* var. *subsalina* Hustedt]
213.	*Staurosira construens* var. *venter* (Ehrenberg) Hamilton [*Fragilaria construens* var. *venter* (Ehrenberg) Grunow]
214.	*Staurosirella lapponica* (Grunow) Williams et Round
215.	*Staurosirella leptostauron* Ehrenberg (*Fragilaria leptostauron* Ehrenberg]
216.	*Staurosirella pinnata* (Ehrenberg) Williams et Round [*Fragilaria pinnata* Ehrenberg]
217.	*Stephanodiscus alpinus* Hustedt
218.	*Stephanodiscus hantzschii* Grunow
219.	*Stephanodiscus medius* Håkansson
220.	*Stephanodiscus minutulus* (Kützing) Cleve et Möller
221.	*Stephanodiscus neoastraea* Håkansson et Hickel
222.	*Stephanodiscus parvus* Stoermer et Håkansson
223.	*Stephanodiscus* sp. [cf. *S. binderanus*] (Kützing) Krieger
224.	*Surirella bifrons* Ehrenberg
225.	*Surirella brebissonii* Krammer et Lange-Bertalot
226.	*Surirella gracilis* Grunow
227.	*Surirella linearis* var. *helvetica* (Brun) Meister
228.	*Surirella linearis* var. *linearis* W. Smith
229.	*Surirella minuta* Brébisson
230.	*Surirella robusta* Ehrenberg
231.	*Thalassiosira visurgis* Hustedt
232.	*Thalassiosira weissflogii* (Grunow) Fryxell et Hasle
233.	*Ulnaria biceps* (Kützing) Compère [*Fragilaria biceps* (Kützing) Lange-Bertalot]
234.	*Ulnaria ulna* var. *ulna* (Nitzsch) Compère [*Fragilaria ulna* (Nitzsch) Lange-Bertalot]