Phytobenthos of the Danube and its tributaries in 2007 (Joint Danube Survey 2)

Jarmila Makovinska[1], Dasa Hlubikova[1], Corina de Hoogh[2] & Matus Haviar[1]

[1]Water Research Institute, Nabr. arm. gen. L.Svobodu 5, 812 49 Bratislava, Slovak Republic
[2]Kiwa Water Research, P.O. Box 1072, 3430 BB Nieuwegein, The Netherland

1. Introduction

Algae are important primary producers in many surface waters of temperate regions. This makes this organism group especially interesting for use as a bioindicator to monitor long-term changes in aquatic ecosystems, especially related to eutrophication. Both phytoplankton and phytobenthos & macrophytes are identified as Biological Quality Elements under the European Water Framework Directive (2000/60/EC), and as such need to be monitored to determine anthropogenic influences on aquatic ecosystems. Especially in rivers, phytobenthos is considered to be a suitable parameter to determine the impact of nutrient pollution, because the organisms are generally sessile and therefore represent the status of realised nutrients at the sampled location.

According to the Water Framework Directive (WFD), a major requirement for good ecological status of rivers and lakes is that "changes do not indicate any accelerated growth of [algae,] phytobenthos or higher forms of plant life resulting in undesirable disturbance to the water balance of organisms present in the water or to the physico-chemical quality of the water…" (annex V 1.2.1/1.2.2). For the supporting physico-chemical quality elements, it is required to estimate the magnitude of all significant point and non-point source pollution (annex II 1.4), including "substances that contribute to eutrophication (in particular nitrates and phosphates)" (annex VIII). However, because the primary focus is on the biological effects resulting from elevated nutrient levels, high nutrient concentrations alone, without the corresponding biological impacts, will not result in the downgrading of the ecological status of the river. In order to meet the requirements of the WFD, information on both biodiversity and biomass for each biological quality element is required. In the Danube, eutrophication is an important anthropogenic pressure threatening the quality of the river water. Therefore, phytobenthos biomass and biodiversity were elaborately investigated during the JDS2.

2. Methods

2.1. Sampling

Sampling of phytobenthos for Joint Danube Survey 2 was based on combination of two standards (EN 13946: Water quality. Guidance standard for the routine sampling and pre-treatment of benthic diatoms from rivers and CEN/TC 230 N 0540: Water quality. Guidance standard for the surveying, sampling and laboratory analysis of phytobenthos in shallow running water). Additionally fluorescence measurements for phytobenthos biomass determinations were performed.

A segment of river that had substrate suitable for sampling was selected. For preference, epilithon was taken from at least five boulders or more than five pebbles at all sampling sites. Where hard substrata were absent epiphyton was sampled following about mentioned EN standard. First of all the measurement of chlorophyll-*a* has been performed at the sampled stones.

After measurement of chlorophyll-a, an area of minimum 10 cm^2 was brushed thoroughly from each stone (as much concentrate sample as possible). The sample has been transferred from tray to sample container and labelled. All field information needed have been recorded to the standardised field protocol.

There were two types of phytobenthos samples. The samples used for benthic diatoms analysis were preserved by formaldehyde (final solution should be 1 - 4 %) because of the long term storage of the samples. Second sample was used for on-board analysis of living non-diatom phytobenthos. Native samples were stored in the refrigerator for analysis. If the macroscopic algae (e.g. *Cladophora*, *Hydrodiction*) were present, separate sample container was used for easier determination. Samples of phytobenthos were taken from euphotic zone, usually up to 1 m depth. At some locations, especially in the lower Danube there were problems to find any suitable substrata due to natural conditions as well as due to increase of the water level.

2.2. Living non-diatom phytobenthos analysis

After sampling the microscopic analysis of living non-diatom phytobenthos has been performed using light microsopy at 400 x – 1000 x magnification. All important determination characteristics of the species were recorded using image analysis. The determination was done as detail as possible using actual determination keys for individual algal groups. Estimation of the quantity of the individual species in the scale 1 – 9 was used.

Based on phytobenthos sampling together with microscopic analysis the estimation of the ratio of cyanobacteria, chlorophyta, diatoms and other algal groups was performed.

2.3. Benthic diatom analysis

The preparation and quantification of samples of benthic diatoms followed the instructions of the EN 14407 (2004). Diatoms were cleaned using 40% hydrogen peroxide (H_2O_2) and permanent slides were mounted using Naphrax. On average, 400 valves were counted on each slide in random transects with lights microscope with DIC (Differential Interference Contrast) at 1000 x magnification. The determination largely followed Krammer & Lange-Bertalot (1986 – 1991), Krammer (1997a, b, 2000, 2002, 2003), Lange-Bertalot (1996, 2001) and Lange-Bertalot & Krammer (1987). Based on diatom inventories, 17 diatom indices were calculated using Omnidia 4.2. (Lecointe & et al., 1999).

2.4. Phytobenthos biomass measurement

Fluorescence measurements for phytobenthos biomass determinations were performed using the Benthofluor® fluorometer (bbe Moldaenke, Kiel, Germany) according to the Aberle et al. (2006). On each of five or more stones five sub-areas were measured, each measurement was done 3 - 4 times to obtain sufficient database of chlorophyll-*a* for statistical analysis. Three main algal groups were distinguished: diatoms, green algae and cyanobacteria. For each of these groups and for total benthic algal biomass, the chlorophyll-*a* level was determined in $\mu g/cm^2$.

3. Results

3.1. Living phytobenthos species diversity

166 samples were collected at 135 sites (124 from the River Danube and 11 from the tributaries). Some of the samples contained diatoms only. Together 52 taxa of non-diatom phytobenthos were identified.

Species diversity of the living phytobenthos was created by species of diatoms (we excluded them, because separate assessment), Cyanobacteria (Cyanophyta), Chlorophyta and Rhodophyta. Cyanobacteria were represented by filamentous species *Heteroleibleinia fontana* (Hansgirg) Anagnostidis et Komarek, *H. kützingii* (Schmidle) Compere, *Homeothrix varians* Geitler, *Lyngbya martensiana* Meneghini ex Gomont, *Oscillatoria limosa* Agardg ex Gomont, *Phormidium retzii* (Agardh) Gomont ex Gomont, *Ph. tergestinum* (Kützing) Anagnostidis et Komarek, which occurred at more than 75 % of samples. Coccal cyanobacteria were often observed as well (mainly *Chroococcus*, *Chamaesiphon* and *Pleurocapsa* species). Planktonic species as e.g. *Pseudanabaena catenata* Lauterborn were also present.

Less species of Chlorophyta occurred at individual sampling stations but usually they were more abundant in the shallow poles of the river (e.g. *Cladophora glomerata* (L.) Kützing, *Hydrodictyon reticulatum* (L.) Lagerheim), *Spirogyra* sp., *Stigeoclonium tenue* (Aghard) Kützing). *Cladophora glomerata* was accompanying water macrophytes very often. Samples of phytobenthos contained also planktonic species.

Red algae *Hildebrandia rivularis* (Liebmann) Aghard was found upstream dam Abwinden-Asten and later upstream dam Greifenstein together with *Bangia atropurpurea* (Roth) Aghard.

3.2. Phytobenthos biomass

In the downstream part of the Danube, it was not possible to find appropriate substrate for measurement of the phytobenthos biomass. Longitudinal trend lines of biomass results of the left and right side of the Danube (including mouth of tributaries) show only slight increase of chlorophyll-a along the river Danube, although the increase in the right site of the river is slightly higher, but still statistically not significant.

Phytobenthos biomass seems to increase downstream as well (Fig.1,2), when comparing the average biomass of the Upper, Middle and Lower Danube (Fig. 1 as well. The differences in biomass between the left and right bank of the river were also not significant for the Upper and Middle Danube (Fig. 2). Because of the sampling problems, this result is not representative for the whole Lower Danube.

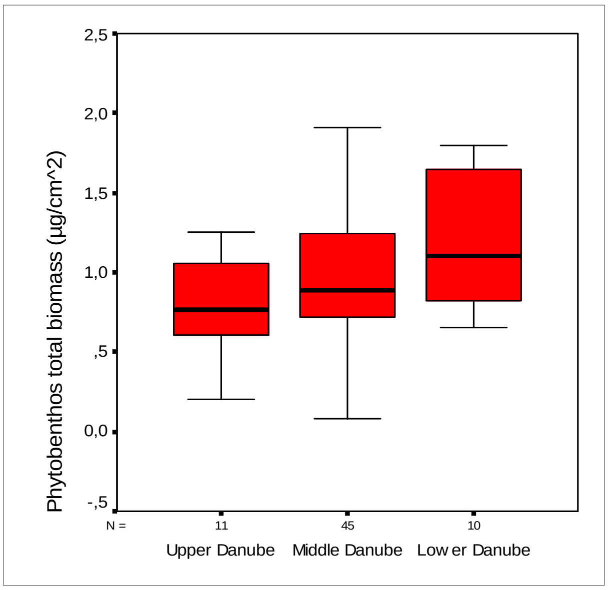

Fig. 1. Phytobenthos biomass in the Upper, Middle and Lower Danube.

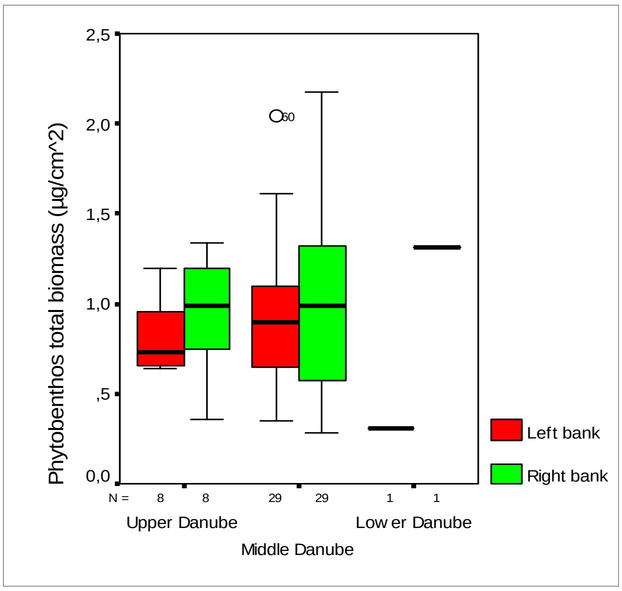

Fig. 2. Phytobenthos biomass - the differences between left and right bank in the Upper, Middle and Lower Danube.

Division of the biomass within individual Danube River types (Fig. 3) shows the highest concentrations in the type 7 (Iron Gate Reservoir).

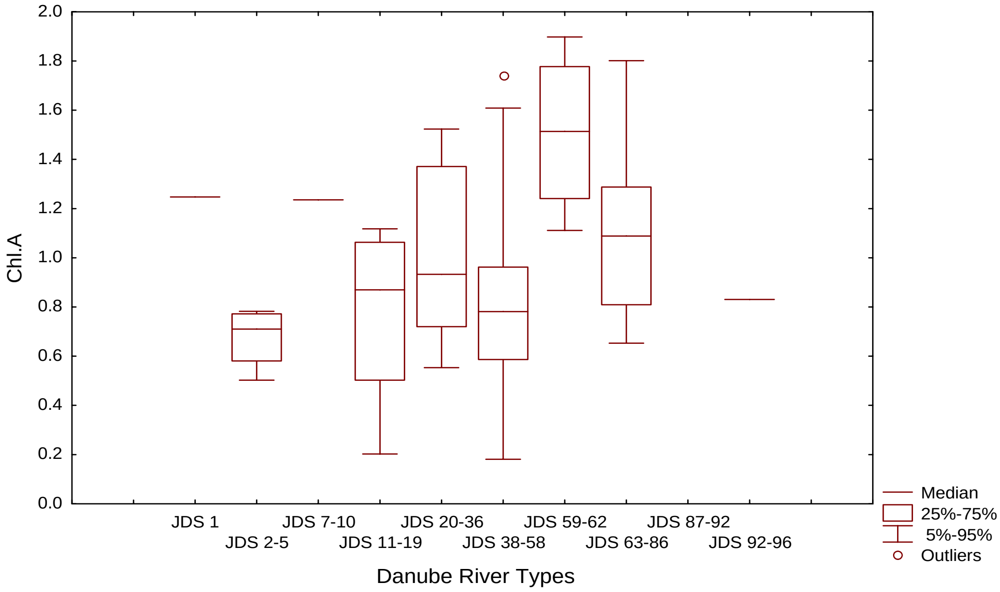

Fig. 3. Phytobenthos biomass division within the individual Danube River types.

The longitudinal profile of the chlorophyll-a biomass on the left side of the Danube and left side tributaries is shown in Fig. 4 and on the right side of the Danube and right side tributaries in the Fig. 5. Figures show the lack of appropriate substrate for measurement of biomass in the Lower Danube section especially in the left side of the Danube and left side tributaries.

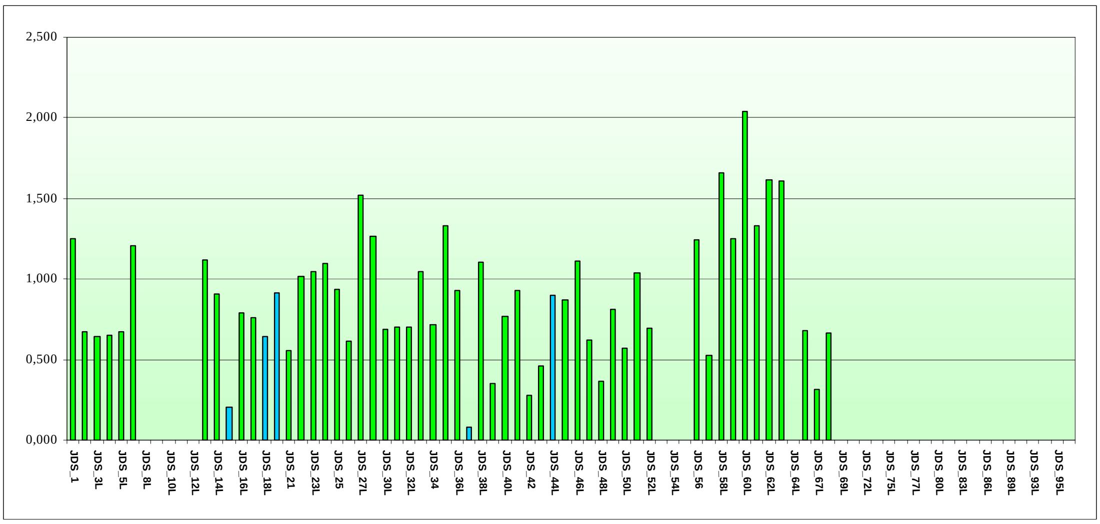

Fig. 4. Chlorophyll_*a* of the phytobenthos in the Danube-left side (green collums) and tributaries (blue collums) - fluorescence measurements (µg.cm2)

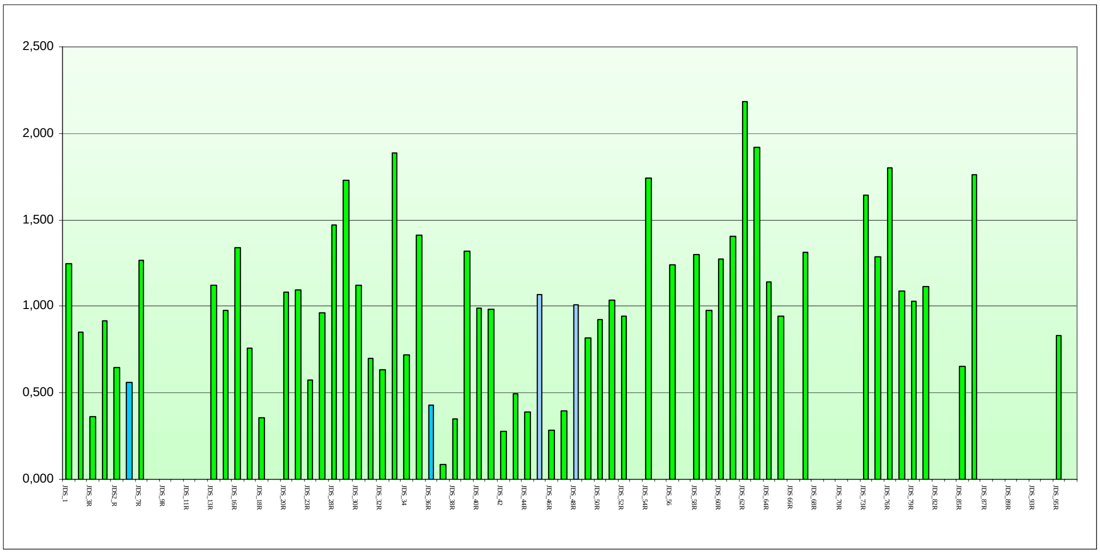

Fig. 5. Chlorophyll_*a* of the phytobenthos in the Danube-right side (green collums) and tributaries (blue collums) - fluorescence measurements (µg.cm2)

But when compare results of phytoplankton and phytobenthos biomass in the JDS2 stations, Middle Danube shows highest variability, Upper and Lower Danube show lower phytoplankton levels, resulting in better growing opportunities for phytobenthos (Fig. 6).

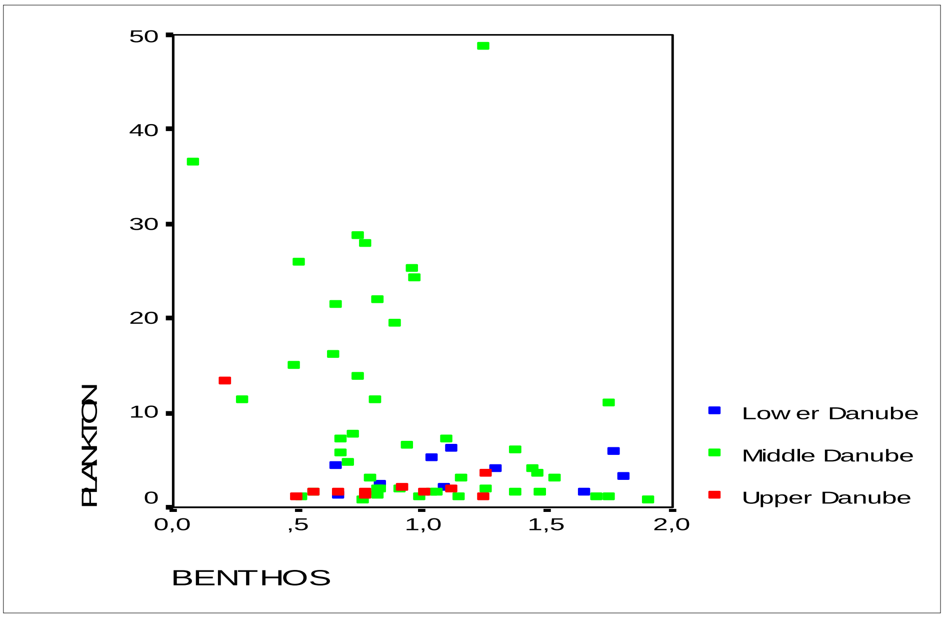

Fig. 6. Phytoplankton and phytobenthos biomass (chlorophyll-a) in JDS2 sampling stations.

Based on phytobenthos sampling together with microscopic analysis the estimation of the ratio of cyanobacteria, green algae, diatoms and other algal groups was performed (Fig. 7). Cyanobacteria and green algae prevailed from the point of view of relative abundance in the most of sampling stations, however at eight JDS 2 stations diatoms created the most abundant group.

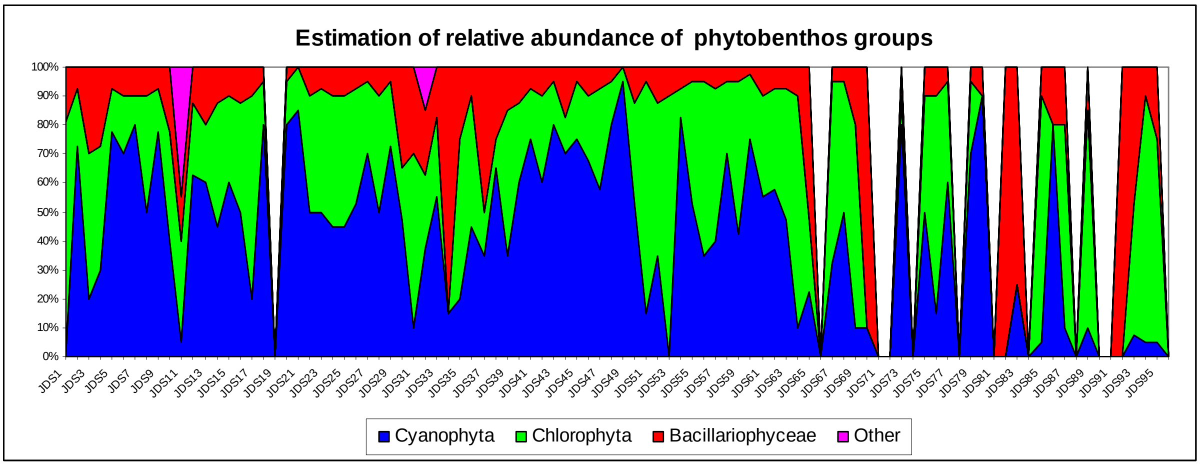

Fig. 7. Ratio of the individual phytobenthos groups of cyanobacteria (Cyanophyta), diatoms (Bacillariophycea) and green algae (Chlorophyta) estimated in the living samples for each sampling site, the 'other' group includes Rhodophytes (JDS11) and bacteria (JDS32).

The same ratio was done by fluorescence measurements. The match of ratio by fluorescence measurements and estimation based on sampling and microscopy was 30% only. The reason is that fluorescence overestimates cyanobacteria, while results based on sampling and microscopy overestimates diatoms.

3.3. Benthic diatoms

Altogether 166 benthic diatom samples were collected at 135 sampling sites (124 from the River Danube and 11 from the tributaries). In total, 391 diatom taxa were identified in 160 samples. 6 diatom samples were not analyzed due to prevailing detritus and the absence of diatom community, mostly coming from the Danube delta.

Benthic diatom assemblages were in most of the collected samples dominated by pennate diatoms, representing the typical benthic community. However, at several sites there was a high percentage of centric primarily planktonic taxa detected in the benthic samples, that usually get to phytobenthos secondarily by sedimenting from the plankton, indicating the low current of the flow and high proportion of sediment in the bottom of the river. This was the case of the sampling sites influenced by Velika Morava tributary (upstream Velika Morava - km 1107, Velika Morava – km 1103, downstream Velika Morava - 1097), were the relative abundance of the centric diatom *Cyclotella meneghiniana* reached more than 70%.

3.3.1. Species diversity

In total, 200 diatom taxa appeared at more than 1 sampling location and among these, 75 taxa were found with frequency higher than 20%. Only 13 diatom taxa showed frequency of occurrence higher than 50%, 11 out of these species were among the most abundant as well. Comparing the relative abundance of the dominant species, only 21 species obtained the average relative abundance at all sites higher than 1%. Evaluating the percentage of dominance and frequency, there are 23 diatom species considered as the most frequent and abundant during JDS 2 and are listed in Table 1. Within the dominant representatives *Navicula recens* (Lange-Bertalot) Lange-Bertalot was assessed as the most common diatom species in the River Danube during JDS2 showing 21% of average relative abundance among all examined sampling sites and was identified in 139 samples.

Table 1. The most frequent and abundant diatom taxa.

Name of taxa	**Dominance (%)**	**Frequency (%)**
Navicula recens (Lange-Bertalot) Lange-Bertalot	22,90	83,73
Navicula tripunctata (O.F.Müller) Bory	7,53	74,10
Cocconeis placentula Ehrenberg var.*lineata* (Ehrenberg) Van Heurck	4,34	68,07
Cyclotella meneghiniana Kützing	4,28	42,17
Amphora pediculus (Kützing) Grunow	3,55	68,07
Nitzschia inconspicua Grunow	3,53	38,55
Navicula viridula (Kützing) Ehr. var. *rostellata* (Kützing) Cleve	3,41	66,27
Navicula cryptotenella Lange-Bertalot	2,96	71,08
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot	2,81	62,65
Amphora copulata (Kützing) Schoeman & Archibald	1,95	61,45
Navicula capitatoradiata Germain	1,93	57,23
Luticola goeppertiana (Bleisch in Rabenhorst) D.G. Mann	1,79	24,70
Diatoma vulgaris Bory 1824	1,63	36,75
Navicula erifuga Lange-Bertalot	1,61	53,01
Eolimna minima (Grunow) Lange-Bertalot	1,35	43,98
Navicula antonii Lange-Bertalot	1,28	51,20
Nitzschia palea (Kützing) W.Smith	1,15	42,17
Reimeria uniseriata Sala, Guerrero & Ferrario	1,14	39,76
Cocconeis pediculus Ehrenberg	1,08	37,35
Nitzschia amphibia Grunow f.amphibia	1,02	34,34
Gyrosigma nodiferum (Grunow) Reimer	1,02	40,96
Navicula germainii Wallace	0,99	50,00
Ulnaria ulna (Nitzsch.) Compère	0,59	54,82

Concerning the changes and differences in the species diversity, the species composition was very similar among the sampling sites showing slight changes in the species distribution along the longitudinal profile and more significant but random changes depending on another variables than the longitudinal gradient.

Results of the cluster analysis (complete linkage) based on the species composition and species abundance are shown at Fig. 8 and generally refer to significantly high similarity of most of the samples. However, comparing the groups of clusters with the regard to the longitudinal profile of the flow, it is possible to differentiate at least two groups of samples. The samples coming from the upper Danube up to the beginning of the middle Danube (from Germany, station upstream Iller up to Slovakia, station Bratislava) are grouped in the cluster F and samples from the middle and lower Danube downstream station Bratislava are grouped in clusters B-E roughly separating types 1-4 from types 5-8. Moreover, there are several clusters separated independently on the Danube typology: cluster A, which represent sites in the Irongate region and cluster Modry with the lowest similarity level among the whole dataset. This cluster includes various samples from different sites, which all however content high percentage of solids and detritus, with apparently unrepresentative and disturbed diatom community and very low species diversity (less than 20 taxa at site).

Apart of these two most significantly different groups of sites, there are several more samples showing significant deviations in the diatom communities, or appearing on the boundaries of the main clusters either distributed randomly among the whole datasets. All of these samples show considerably higher level of dissimilarity and correspond to the sites influenced by the tributaries. The highest differences in the species composition and abundance were detected downstream Yantra (cl), Sava and Olt.

When judged through the species composition, the separation of clusters is mostly based on the percentage or presence and absence of *Navicula recens* in diatom samples, as this species was present in 139 out of 166 diatom samples. *N. recens* is a common eutraphenthic diatom species occurring in rivers with high trophic level and indicating high content of phoshorus (Potapova et al. 2004). Populations of *N. recens* were usually accompanied by other eutraphentic species such as *Navicula amphiceropsis* Lange-Bertalot & Rumrich, *Navicula erifuga* Lange-Bertalot and *Navicula rostellata* Kützing.

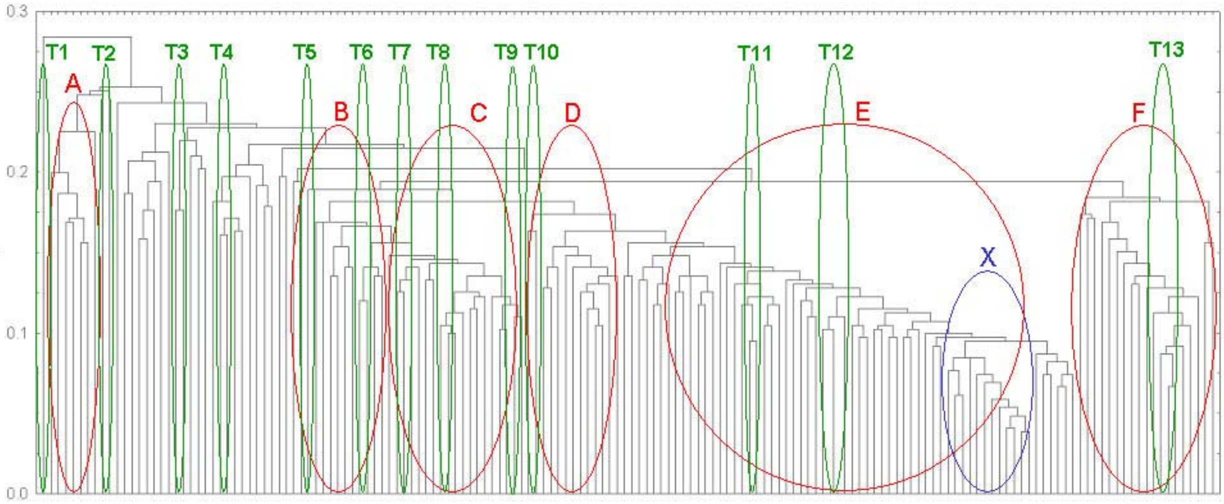

Figure 8. Dissimilarity of diatom samples. In spite of large similarity of samples, there are significant differences between the River Danube (A-F) and some tributaries (T1: Drava, T2: Morava, T3: Sio, T4: Drava, T5: Yantra, T6: Iskar, T7: Tisza, T8: Sava, T9: Adony, T10: Vah, T11: Olt, T12: Yantra, T13: Velika Morava). Samples with high content of detritus and with low abundance of diatoms are grouped in cluster X. Several groups of clusters can be separated representing specific regions or river parts:

A: Iron Gate region (Irongate reservoir (Tekija/Orsova) JDS41 – Irongate II JDS44, type 5,6),
B: Hungary/Croatia region (Paks JDS36 – Dalj JDS44, type 5,6),
C: Serbia, Tisza-Sava region (Dalj JDS44 - Sava JDS51, type 6),
D: Slovakia/Hungary region (Vah JDS21 - Paks JDS36, type 5),
E: downstream Irongate region (Upstream Timok JDS65 – Russenski Lom JDS81, type 8),
F: upper/middle Danube region (Upstream Iller JDS1 – Bratislava JDS17, type 1,2,3,4)

Most of samples grouped in clusters B, C, D and E were typical by diatom communities dominanted or subdominated by *Navicula. recens*, showing specific deviations in the species composition as a consequence of the influence of tributaries. Interestingly, there was a significant difference in the abundance of *N recens* in between the riverbanks. Only rarely the relative abundance of the taxa corresponded in between the two banks. In the river part between Ilok/Backa Palanka (rkm 1300) and upstream Olt (rkm 606), the abundance of the taxa was regularly significantly lower on the right river bank than on the left river bank, sometimes even absent in the sample from the right bank even if in the sample from the left bank it was dominant (e.g. Upstream Olt: rkm 606, Banatska Palanka/Bazias : 1071, Downstream Velika Morava: rkm 1097, Upstream Pancevo/Downstream Sava: rkm 1159). Regarding the ecological optima of the species, its presence in the sample can significantly change the final result of water quality evaluation towards the worst quality. On the other hand, such differences in species composition make the interpretation of data and statistical analysis quite complicated and only hardly interpretable, as the same river station has two sampling sites with completely different diatom communities.

Cluster E, mostly includes sites downstream Irongate region (rkm 849 – rkm 498), with diatom communities dominated or subdominated by *Amphora pediculus* (Kützing) Grunow, *Cocconeis placentula* Ehrenberg var. *lineata* (Ehr.)Van Heurck, *Diatoma vulgaris* Bory 1824, *Navicula cryptotenella* Lange-Bertalot, *Navicula tripunctata* (O.F.Müller) Bory and *Reimeria uniseriata* Sala Guerrero & Ferrario, whilst the largest differences correspond to sites influenced by particular tributaries Olt (T11) and Yantra (T12) (Fig. 8).

Clusters B, C, D are typical by communities with prevailing abundance of *N. recens*, or co-dominated by *N. amphiceropsis, N. erifuga, N. rostellata, N. tripunctata*, showing significant differences in species composition of tributaries (Fig. 8: T6-T16).

Cluster A represents sites in the Irongate region, with divers diatom communities and with generally higher number of taxa at sites (usually more than 50-60 taxa per sample). These sites were mostly dominated by mesotraphentic and eutraphentic species such as *Gyrosigma nodiferum* (Grunow) Reimer, *Navicula rostellata*, *Nitzschia amphibia* Grunow, *Nitzschia inconspicua* Grunow, and *Navicula recens* as well.

Cluster F separated from the group of clusters B, C, D and E differs significantly from other groups of samples by presence of representatives of the genus *Luticola* D.G. Mann, which were found in most of the samples of the upper Danube, however in different abundances. L. goeppertiana was in general the most abundant and most frequent. This species is commonly present in eutrophic up to hypertrophic rivers and appears in high concentrations of nutrients (Potapova et al. 2004). The highest abundance of the taxa was detected at Geisling power plant, Germany, rkm 2354 (more than 50% of relative abundance) and at Medvedov, Slovakia, rkm 1806 (almost 50% of relative abundance) indicating hypetrophic conditions at sites. Abundance of the species at other sampling sites varied usually up to 5% of relative abundance, but never reaching such a high proportions in the benthic community as detected in Geisling and Medvedov. Morevover, after the Medvedov sampling site the species only rarely occurred at sites and usually in low abundances.

To conclude the results of the species composition evaluation based on clustering, clear separation of single Danube types is hardly possible. The species composition at sampling sites was changing gradually, mostly depending on confluence of tributaries (apart of others abiotic descriptors), whilst the largest differences in the species structure in general were revealed between particular tributaries, e.g. Drava, Yantra, Sava and Velika Morava (Fig. 8).

There were several taxa with unknown species identity, so far identified to the genera level, such as *Luticola* sp. and *Navicula* sp. that reached the relative abundance higher than 5%. Identification of the taxa will be further verified in detail and the taxa will be examined in SEM in order to clarify their species identity.

With the regard to autecological preferences of the most frequent and dominant species, the sites were mostly and generally dominanted by eutrophentic species e.g. *Amphora pediculus* (Kutzing) Grunow, *Eolimna minima (Grunow) Lange-Bertalot, Navicula tripunctata* (O.F.Müller) Bory, *Navicula viridula* (Kutz.) Ehr. var.*rostellata* (Kutz.) Cleve, *Luticola goeppertiana* (Bleisch in Rabenhorst) D.G. Mann, *Navicula recens* (Lange-Bertalot), *Navicula erifuga* Lange-Bertalot, *Nitzschia inconspicua* Grunow, *Nitzschia clausii* Hantzsch and *Nitzschia palea* (Kutzing) W.Smith referring to beta mesosaprobic to polysaprobic conditions. However, except of the indicators of high trophic status also taxa referring to better than eutrophic conditions where found quite common and sometimes even dominating at sites, such as *Cocconeis placentula* Ehrenberg var. *lineata* (Ehr.) Van Heurck, *Cocconeis pediculus* Ehrenberg, and *Rhoicosphenia abbreviata* (C.Agardh) Lange-Bertalot. Inspite of their “positive” indicator values (Van Dam et al. 1994, Lecointe et al., 1999), their use in water quality evaluation is somehow questionable and unreliable, while they are all considered as pioneer species, tolerating high levels of disturbance at sites and usually indicating unstable and disturbed environment rather than water quality (Kelly et al. 2007). Interestingly different community, was found downstream Yantra, with oligotraphentic diatom species, e.g. *Diatoma mesodon* (Ehrenberg) Kützing and *Meridion circulare* (Greville) C.A.Agardh var. *circulare*. Most of the detected the taxa within all sampling sites were alcaliphilous.

3.3.3. First records

Regarding the long history in floristic studies on diatoms in Danubian countries it is extremely difficult if ever possible to precisely and correctly summarize the first records of diatoms for the Danube in general. Moreover, in case of diatoms, the references on first records are hardly interpretable, because they do not describe the spread of the taxa (except for some few examples of invasive species), or presence in previously not occupied regions, but they usually and mostly refer to the lack of diatom studies in the examined region as well as to the lack of scientific and effective publications or missing relevant determination literature during the previous diatom studies. Therefore we consider the highlighted information on first records as hardly significant and unusable for further studies.

This is supported by the results of evaluation of first records of diatoms identified during JDS2 in Slovak part of the Danube and Slovak tributaries. After detailed compilation of published data of diatoms in

Slovakia, there are 12 diatom taxa, considered as first records for Slovakia: *Achnanthidium eutrophilum* (Lange-Bertalot) Lange-Bertalot, *Gomphonema insigniforme* Reichardt & Lange-Bertalot, *Gomphonema parvulum* var. *parvulum* f. *saprophilum* Lange-Bertalot & Reichardt, *Gomphonema pumilum* var. *rigidum* Reichardt & Lange-Bertalot, *Navicula amphiceropsis* Lange-Bertalot & Rumrich, *Navicula antonii* Lange-Bertalot, *Navicula cataracta-rheni* Lange-Bertalot, *Navicula germainii* Wallace, *Nitzschia filiformis* (W.M.Smith) Van Heurck sensu lato, *Reimeria uniseriata* Sala Guerrero & Ferrario.

However, all these species are common in European rivers, as well as in Slovakia and have already been previously detected in the River Danube and also in other Slovak rivers during the regular monitoring of diatoms since 2003, but none of the records have yet been validly published. Within these taxa, *N. amphiceropsis* and *N. germainii* have been regularly found in the river Danube and the Morava tributary and have been only rarely present in other lowland rivers in Slovakia (unpublished data). Species such as, *G. parvulum* v. *parvulum f. saprophilum*, *Navicula antonii*, *N. cataracta-rheni, Nitzschia filiformis* and *Reimeria uniseriata* are common and abundant in the Slovak part of the River Danube as well as in other river types and rivers in Slovakia (unpublished data). *A. eutrophilum*, however, has not been found in the Slovak Danube so far, but it is a specific case, as the identification of this taxa can pose problems and the species could be easily overlooked during previous studies. Apart of the Danube, the species has already been recorded in several other lowland rivers in eastern Slovakia before (unpublished data).

3.3.4. Diatom indices

Based on diatom inventories, 17 diatom indices were calculated using Omnidia 4.2. (Lecointe & et al., 1999). Results of calculations are shown in Tab. 2.

Table 2. Summary of diatom indices values. CEE (Descy & Coste 1990), DES (Descy 1979), EPI-D (Dell' Uomo et al. 1999), GDI (Rumeau & Coste 1988), (Prygiel & Coste 1996), IBD (Lenoir & Coste 1996), IPS (Coste in CEMAGREF 1982), L&M (Leclercq & Maquet 1987), SHE (Schiefele & Schreiner 1991), SID (Rott et al. 1999) SLA (Sládeček 1986), TID (Rott et al. 1999), TDI (Kelly & Whitton 1995), WAT (Watanabe et al. 1986), IDAP (Prygiel & Coste 1996), IDP (Prygiel & Coste 1996).

	SLA	DESCY	LMA	SHE	WAT	TDI	GDI	CEE	IPS	IBD	IDAP	EPI-D	IDP	SID	TID
MIN	5,8	1,4	3,6	3,7	1,5	48,0	4,2	3,9	4,0	3,2	5,5	3,6	3,9	4,9	2,6
MAX	13,9	19,9	15,3	17,6	18,9	99,5	14,9	18,3	18,6	18,3	17,4	16,1	15,8	15,5	14,6
AVERAGE	10,8	15,5	11,8	12,0	11,4	79,3	11,4	10,8	11,5	9,6	11,2	9,9	10,6	11,9	5,9
MEDIAN	10,8	16,2	12,0	12,1	11,5	80,0	12,0	11,1	11,3	9,4	11,6	9,6	10,7	11,9	5,7
ST. DEV	1,5	3,4	2,0	1,9	3,2	8,6	1,9	3,0	2,6	2,8	2,9	2,0	1,6	1,4	1,5

Differences in values of diatom indices are quite apparent (Tab. 2), but not surprising, as each index includes different taxa databases and was developed in specific region or with different purpose. Therefore, use of indices for water quality evaluation without previous detailed testing of its suitability in studied region or river type should be avoided and is not recommended (Rott et al. 2003). However, testing of indices is conditioned by availability of data from several sampling occasions especially with the regard of the chemical parameters, as results of on single sampling performed at the same time than diatom sampling can include significant sources of uncertitude and must not correspond with the structure of diatom community. Regarding the broad applicability of IPS index (Ács et al. 2004, Eloranta & Andersson 1998, Gomá et al. 2004, Hlubikova et al. 2007, Kelly et al. 1995, Kwandrans et al. 1998, Prygiel & Coste 1993, Vilbaste 2004), as it is not possible to perform reiable testing of diatom indices based on JDS2 data, IPS index was selected for preliminary assessment of ecological status as shown at Fig. 9.

IPS (Coste in Cemagref 1982) „Specific Pollution Sensitivity Index“ was developed in France as a national assessment index (Prygiel et al., 2002) for detection of total water pollution. Indicator taxa are divided into 5 classes according their sensitivity to pollution and into 3 classes according indicative weight. IPS was tested and selected as an appropriate tool for water quality evaluation in Britain (Kelly et al. 1995), France (Prygiel & Coste 1993) Finland (Vilbaste 2004), in Hungary (Acs et al., 2004, Van Dam et al. , 2005), Poland (Kwandrans et al 1998, Luxembourg, in Slovakia (Hlubikova et al. 2007) and in Spain (Gomá et al. 2004). The applicability of the index in many different European regions is great advantage, when judged through WFD, because the same metric used in more countries facilitates the intercalibration of national assessment methods and for this purpose, the IPS was successfully used as intercalibration metric of diatoms within intercalibration exercise of Central Baltic Geographical Intercalibration Group. On the other hand, IPS was developed on large database and involves large number of diatom taxa in the calculation and includes most of the species of the OMNIDIA database. This feature can explain why IPS successfully works in many countries rather than other indices.

Based on results of IPS calculation, Values of IPS index seem to decrease downstream indicating the longitudinal increase of pollution (organic, nutrient and general degradation). Comparing the IPS values in different parts of the longitudinal profile, there are 4 groups of sites distinctly separated (Fig. 9) depending on the level of pollution; showing best quality at sites from Upstream Iller (Germany - JDS 1) to Greifenstein (Austria – JDS 11) (Group 1); showing change of water quality in the manner of higher level of pollution in the part between Klosterneuburg (Austria - JDS 12) to Batina (Croatia – JDS 40) (Group 2); showing worst level of pollution at sites from Upstream Drava (Croatia – JDS 41) up to Starapalanka – Ram (Croatia JDS - 58); and showing large variability of index values at sites downstream Banatska Palanka/Bazias probably due to multiple factors that besides pollution form the structure of benthic diatom communities and thus significantly increase the uncertainty of diatom-based assessment (Group 4).

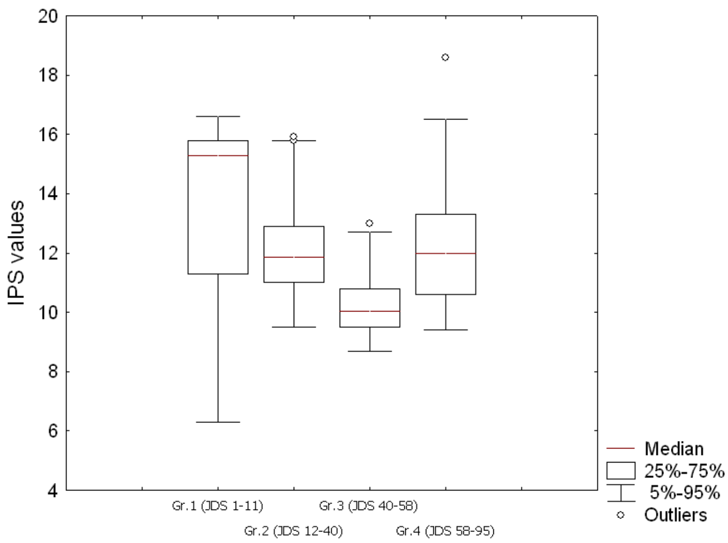

Figure 9. Comparison of IPS values in upper, middle and lower Danube. Different parts of the River Danube are grouped in 4 groups according to different intervals of IPS: Gr. 1: JDS1 - 11, Gr. 2: JDS12 – 40, Gr. 3: JDS 40 – 58, Gr. 4: JDS 58-95.

3.3.5. Indication of ecological status assessment

For the classification of the sites within the water quality classes, type-non specific classification scheme of IPS of Coste in Cemagref (1982), where 5 classes of sensitivity of IPS index are used for water quality evaluation, (Lecointe & et al., 1999) was first applied. Results of water quality assessment of the Danube and its tributaries based on this classification system show the worst quality in the Danube at Geisling (left side) and the Hron tributary (Fig. 10). According to this results most of other sites of the Danube and tributaries varied within the class II – III.

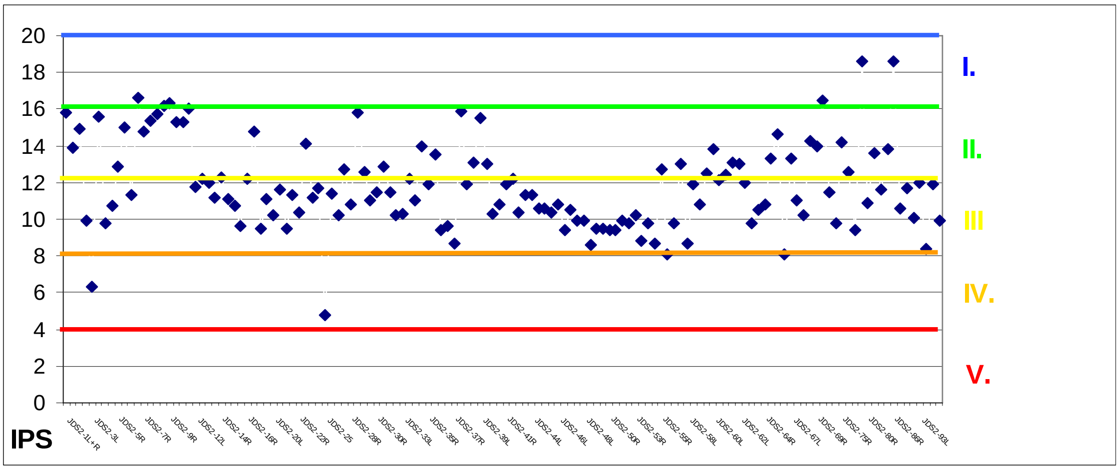

Figure 10. Assessment of water quality of the Danube and the tributaries based on 5 class scale of sensitivity of IPS index (Coste in Cemagref, 1982) to the pollution.

In order to indicate the ecological status using type specific classification scheme, the Slovak classification system for diatom-based assessment was used. Slovak classification system (Hlubiková et al. 2007) is based on multimetric index comprising three separate diatom indices: IPS (Coste in Cemagref 1982) „Specific Pollution Sensitivity Index“, CEE (Descy & Coste 1991) „Descy & Coste Index“ and EPI-D (Dell'Uomo et al. 1999) „Diatom-based Eutrophication/Pollution Index“. For EQR calculation average value of the three diatom indices is used in order to compensate the differences in the applicability or sensivity of particular indices depending on the taxa included in the calculation or particular changes of the indication potential of species in different regions and river types. This assessment system was proposed for natural river types, including large rivers at altitudes below 200 m a.s.l. in Hungarian lowland. Reference values and class boundaries for this river type were derived by modelling based on the results of diatom analyses from approximately 450 diatom samples covering the whole pollution gradient and river typology in Slovakia (from the worst up to reference conditions) (Bartik et al. 2006).

Final EQR values of individual JDS2 stations using the Slovak classification scheme for lowland rivers (Fig.11) vary within all classes, although most of the results refer to moderate and poor ecological status (class III – IV).

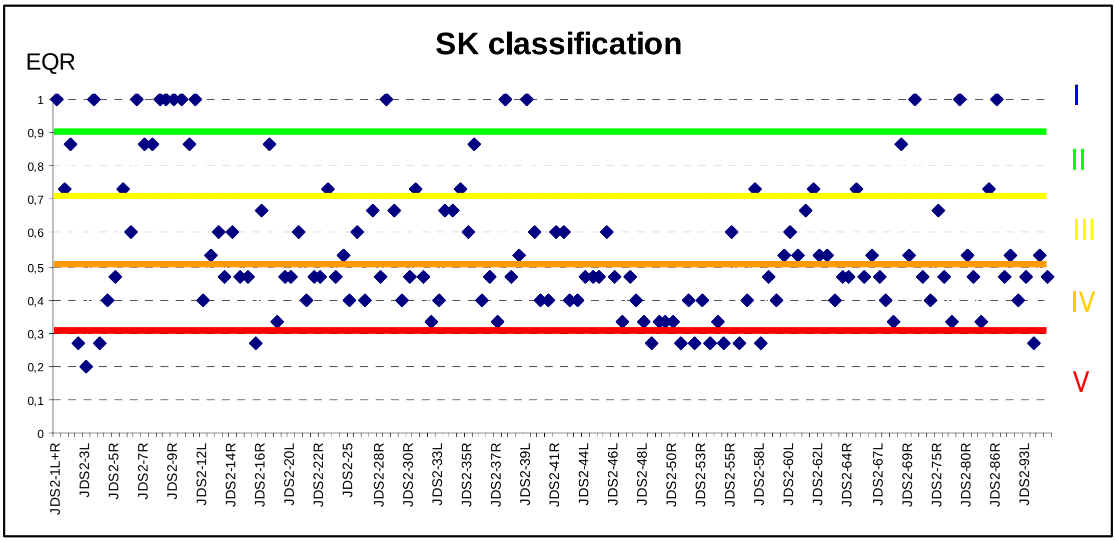

Figure 11. Indication of the ecological status of the Danube and the tributaries based on Slovak classification system according to the phytobenthos (benthic diatoms).

3.4. Comparison of the data from JDS1 and JDS2

Species diversity of the phytobenthos (including diatoms) was higher in JDS2 (443) in comparison to the JDS1 (340). It was caused by the fact that during JDS2 living samples have been analysed and probably by the use of semi-quantitative sampling method.

Fluorescence measurement of the phytobenthos biomass (concentration of the chlorophyll-a) was done first time during JDS2.

Indication of the ecological status based on phytobenthos was done first time in JDS2 as well. In the year 2001 (JDS1) member states were in the phase of preparation of the classification schemes according to the WFD requirements and they were not finalized that time.

4. Conclusions

- In total, 443 taxa were identified.
- In spite of large similarity of diatom samples, there are significant differences between the River Danube and some tributaries. 6 groups of clusters could be separated representing specific regions or river parts.
- With the regard of autecological preferences of the most frequent and dominant species, the sites were mostly dominanted by eutrophic to hypertrophic species referring to beta mesosaprobic up to polysaprobic conditions. Most of the diatom taxa were alcaliphilous.
- Phytobenthos biomass was measured for first time in the JDS2, therefore it is not possible to compare it with previous results.
- Ithere was an evidence of slight increase of chlorophyll-a along the river Danube (at individual stations and Upper, Middle and Lower Danube as well), but still statistically not very significant.
- Comparing the results of phytoplankton and phytobenthos biomass, Middle Danube shows highest variability, Upper and Lower Danube show lower phytoplankton levels, resulting in better growing opportunities for phytobenthos.
- Moreover, evaluation of JDS1 data was done based on Saprobic index only, while within JDS2 17 different diatom indices (trophic, saprobic and general pollution and degradation indices) were calculated.
- Regarding the broad applicability of IPS index, it was selected for preliminary assessment of water quality. Values of IPS index seemed to decrease downstream indicating the longitudinal increase of pollution. Comparing the IPS values in different parts of the longitudinal profile, 4 groups of sites were separated depending on the level of pollution, showing worst water quality in the part between stations Upstream Drava (Croatia – JDS 41) up to Starapalanka – Ram (Serbia JDS – 58).
- Additionaly, ecological status of sites was evaluated using the Slovak classification scheme based on averaging of IPS, CEE and EPI-D indices indicating moderate and poor ecological status at most of the sites.

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6. List of taxa of the phytobenthos of JDS2

TAXA
Chroococcales sp. div.
Chroococcus sp.
Chroococcus minutus (Kutzing) Nageli
Chamaesiphon incrustans Grunow in Rabenhorst
Chamaesiphon polonicus (Rostafinski) Hansgirg
Cyanophanon minutus Geitler
Merismopedia elegans A. Braun in Kutzing
Pleurocapsa sp.
Pleurocapsa minor Hansgirg
Arthrospira sp.
Arthrospira jenneri Stizenberger ex Gomont
Calothix sp.
Homeothrix sp.
Homoeothrix varians Geitler
Heteroleibleinia kuetzingii (Schmidle) Compere
Heteroleibleinia fontana (Hansgirg) Anagnostidis et Komarek
Jaaginema sp.
Jaaginema geminatum (Meneghini ex Gomont) Anagnostidis et Komarek
Lyngbya sp.
Lyngbya martensiana Meneghini ex Gomont
Oscillatoria sp.
Oscillatoria limosa Agardh ex Gomont
Oscillatoria princeps Vaucher ex Gomont
Oscillatoria tenuis Agardh ex Gomont
Plectonema sp.
Pseudanabaena sp.
Pseudanabaena catenata Lauterborn
Pseudanabaena galeata Bocher
Phormidium sp.
Phormidium amoenum Kurzing ex Anagnostidis et Komarek
Phormidium autumnale (Agardh) Trevisan ex Gomont
Phormidium corium Gomont
Phormidium chalybeum (Mertens ex Gomont) Anagnostidis et Komarek
Phormidium incrustatum Gomont ex Gomont
Phormidium kuetzingianum (Kirchner) Anagnostidis et Komarek
Phormidium nigrum (Vaucher ex Gomont) Anagnostidis et Komarek

Phormidium retzii (Agardh) Gomont ex Gomont
Phormidium tergestinum (Kutzing) Anagnostidis et Komarek
Pseudophormidium phormidioides (Hansgirg ex Forti) Anagnostidis et Komarek
Pseudophormidium tenue (Thuret ex Gomont) Anagnostidis et Komarek
Siphononema sp.
Chlorophyceae sp.div.
Pleurococcus sp.
Hydrodictyon reticulatum (L.) Lagerheim
Ulothrix tenuissima Kutzing
Microspora sp.
Stigeoclonium tenue (Agardh) Kutzing
Cladophora glomerata (L.) Kutzing
Enteromorpha intestinalis (L.) Link
Spirogyra sp.
Hildenbrandtia rivularis (Liebmann) J.Aghardh
Bangia atropurpurea (Roth) C. Aghardh
Aulacoseira ambigua (Grun.) Simonsen
Achnanthes biasolettiana Grun. var. thienemannii (Hustedt) Lange-Bertalot
Achnanthidium lineare W.Smith
Amphora copulata (Kütz.) Schoeman & Archibald
Achnanthidium atomoides Monnier, Lange-Bertalot & Ector
Achnanthidium atomus (Hustedt) Monnier, Lange-Bertalot & Ector
Achnanthidium biasolettianum (Grunow in Cl. & Grun.) Lange-Bertalot
Achnanthidium exiguum (Grunow) Czarnecki
Achnanthidium eutrophilum (Lange-Bertalot) Lange-Bertalot
Achnanthidium latecephalum Kobayasi
Achnanthidium macrocephalum (Hust.) Round & Bukhtiyarova
Achnanthidium minutissima (Kütz.) Czarn.var. affinis (Grun.) Bukht.
Achnanthidium minutissimum (Kütz.) Czarnecki
Adlafia minuscula var. muralis (Grunow) Lange-Bertalot
Achnanthidium pyrenaicum (Hustedt) Kobayasi
Achnanthidium saprophila (Kobayasi et Mayama) Round & Bukhtiyarova
Achnanthidium straubianum (Lange-Bertalot) Lange-Bertalot
Achnanthes exilis Kützing
Asterionella formosa Hassall
Achnanthes J.B.M. Bory de St. Vincent
Amphora inariensis Krammer
Achnanthes inflata (Kützing) Grunow
Achnanthes minutissima Kützing var.jackii (Rabenhorst) Lange-Bertalot
Amphora montana Krasske
Amphora C.G. Ehrenberg ex F.T. Kützing

Aulacoseira muzzanensis (Meister) Krammer
Actinocyclus normanii (Greg. ex Grev.) Hustedt morphotype normanii
Amphora normanii Rabenhorst
Amphora oligotraphenta Lange-Bertalot
Amphora ovalis (Kützing) Kützing
Amphora pediculus (Kützing) Grunow
Aulacoseira alpigena (Grunow) Krammer
Aulacoseira granulata (Ehr.) Simonsen var.angustissima (O.M.) Simonsen
Aulacoseira granulata (Ehr.) Simonsen
Aulacoseira G.H.K. Thwaites
Aulacoseira pseudodistans Lange-Bertalot 'manuskriptnamen'
Aulacoseira subarctica (O.Müller) Haworth
Amphora veneta Kützing
Bacillaria paxillifera (O.F. Müller) Hendey var.paxillifer
Cymbella excisa Kützing var. excisa
Cyclotella atomus var. gracilis Genkal & Kiss
Craticula ambigua (Ehrenberg) Mann
Caloneis amphisbaena (Bory) Cleve fo.amphisbaena
Cyclotella atomus Hustedt
Caloneis bacillum (Grunow) Cleve
Cymbopleura cuspidata (Kützing) Krammer
Cyclotella cyclopuncta Håkansson & Carter
Cymbella compacta Østrup
Cyclotella comensis Grunow in Van Heurck
Cyclostephanos dubius (Fricke) Round
Cymatopleura elliptica (Brébisson) W.Smith var.elliptica
Cyclostephanos invisitatus (Hohn & Hellerman) Theriot Störmer & Håkansson
Cymbella kappii (Cholnoky) Cholnoky
Cymbella lanceolata (Agardh ?) Agardh var.lanceolata
Caloneis macedonica Hustedt
Cyclotella meduanae Germain
Cyclotella meneghiniana Kützing
Craticula molestiformis (Hustedt) Lange-Bertalot
Craticula minusculoides (Hustedt) Lange-Bertalot
Cymbella neocistula Krammer var.neocistula Krammer
Cocconeis neodiminuta Krammer
Cyclotella ocellata Pantocsek
Cocconeis pseudolineata (Geitler) Lange-Bertalot
Cyclotella pseudostelligera Hustedt fo.diminuta Manguin
Cocconeis pediculus Ehrenberg
Cocconeis placentula Ehrenberg var. placentula

Cocconeis placentula Ehrenberg var.euglypta (Ehr.) Grunow
Cocconeis placentula Ehrenberg var.lineata (Ehr.) Van Heurck
Caloneis permagna (J.W.Bailey) Cleve
Craticula accomoda (Hustedt) Mann
Craticula cuspidata (Kützing) Mann
Cymbella subaequalis Grunow
Cymatopleura solea (Brébisson) W.Smith var.apiculata (W.Smith) Ralfs
Cyclostephanos delicatus (Genkal) Kling & Håkansson
Caloneis schumanniana (Grunow) Cleve
Caloneis silicula (Ehr.) Cleve
Cymatopleura solea (Brébisson) W.Smith var.solea
Cymbella turgidula Grunow 1875 in A.Schmidt & al. var. turgidula
Cymbella tumida (Brébisson) Van Heurck
Cyclotella wuethrichiana Druart & Straub
Cyclotella F.T. Kützing ex A de Brébisson
Cymbella C.Agardh 1830
Cymbella species
Diploneis boldtiana Cleve
Diadesmis confervacea Kützing
Diadesmis contenta (Grunow ex V. Heurck) Mann
Diatoma ehrenbergii Kützing
Diploneis elliptica (Kützing) Cleve
Diadesmis gallica Wm. Smith
Didymosphenia geminata (Lyng.) Schmidt morphotyp geminata Metz&Lange-bertalo
Diatoma mesodon (Ehrenberg) Kützing
Diatoma moniliformis Kützing
Diploneis parma Cleve
Discostella pseudostelligera (Hustedt) Houk et Klee
Discostella stelligera (Cleve et Grun.) Houk & Klee
Denticula tenuis Kützing
Diatoma vulgaris Bory 1824
Encyonema caespitosum Kützing
Encyonema minutum (Hilse in Rabh.) D.G. Mann
Encyonema reichardtii (Krammer) D.G. Mann
Encyonema silesiacum (Bleisch in Rabh.) D.G. Mann var.lata Krammer
Encyonema subminutum Krammer & Lange-Bertalot
Encyonema ventricosum (Agardh) Grunow morphotype 1
Encyonema ventricosum (Agardh) Grunow
Eolimna minima (Grunow) Lange-Bertalot
Eunotia pectinalis (Dyllwyn) Rabenhorst var.pectinalis

Encyonema prostratum (Berkeley) Kützing
Eolimna subminuscula (Manguin) Moser Lange-Bertalot & Metzeltin
Encyonema silesiacum var.distinctepunctatum Krammer
Encyonema silesiacum (Bleisch in Rabh.) D.G. Mann
Epithemia turgida (Ehr.) Kütz. var.granulata (E.) Brun
Eunotia C.G. Ehrenberg
Encyonema vulgare Krammer var. vulgare
Fragilaria arcus (Ehrenberg) Cleve var. arcus
Fragilaria bidens Heiberg
Fragilaria capucina Desmazières var.capucina
Fragilaria capucina Desmazières var.capitellata (Grunow) Lange-Bertalot
Fragilaria capucina Desmazières var.distans (Grunow) Lange-Bertalot
Fragilaria capucina Desmazières var.mesolepta (Rabenhorst) Rabenhorst
Fragilaria capucina Desm. var. perminuta (Grunow) Lange-Bertalot
Fragilaria crotonensis Kitton
Fragilaria capucina Desm. ssp. rumpens (Kütz.) Lange-Bert. ex Bukht.
Fragilaria capucina Desmazières var.vaucheriae (Kützing) Lange-Bertalot
Fragilaria gracilis üstrup
Fallacia lenzi (Hustedt) Lange-Bertalot
Fragilaria martyi (Héribaud) Lange-Bertalot
Fragilaria pulchella (Ralfs ex Kütz.) Lange-Bertalot (Ctenophora)
Fallacia pygmaea (Kützing) Stickle & Mann ssp.pygmaea Lange-Bertalot
Fragilaria H.C. Lyngbye
Frustulia rhomboides (Ehr.) De Toni var.amphipleuroides (Grunow) De Toni
Fistulifera saprophila (Lange-Bertalot & Bonik) Lange-Bertalot
Fallacia subhamulata (Grunow in V. Heurck) D.G. Mann
Fallacia tenera (Hustedt) Mann in Round
Fragilaria ulna (Nitzsch.) Lange-Bertalot var.acus (Kütz.) Lange-Bertalot
Frustulia vulgaris (Thwaites) De Toni
Fragilaria zeilleri Héribaud var.elliptica Gasse
Gomphonema acuminatum Ehrenberg
Gomphonema angustum Agardh
Gomphonema augur Ehrenberg
Gomphonema capitatum Ehr.
Gomphonema clavatum Ehr.
Gomphonema clevei Fricke
Geissleria decussis (Østrup) Lange-Bertalot & Metzeltin
Geissleria Lange-Bertalot & Metzeltin
Gomphonema exilissimum (Grun.) Lange-Bertalot & Reichardt
Gomphonema gracile Ehrenberg
Gomphonema insigniforme Reichardt & Lange-Bertalot

Gomphonema lagenula Kützing
Gomphonema micropus Kützing var. micropus
Gomphonema minutum (Ag.) Agardh f. minutum
Gyrosigma nodiferum (Grunow) Reimer
Gomphonema olivaceum (Hornemann) Brébisson var. olivaceum
Gomphonema olivaceolacuum (Lange-Bert. & Reichardt) Lange-Bert. & Reichardt
Gomphonema C.G. Ehrenberg
Gomphonema species
Gomphonema parvulum (Kützing) Kützing var. parvulum f. parvulum
Gomphonema parvulum var.parvulum f.saprophilum Lange-Bert.&Reichardt
Gomphonema pumilum var. elegans Reichardt & Lange-Bertalot
Gomphonema parvulum var.exilis Grunow
Gomphosphenia grovei M.Schmidt var.lingulata (Hustedt) Lange-Bertalot
Gomphonema pumilum var. rigidum Reichardt & Lange-Bertalot
Gomphonema productum (Grunow) Lange-Bertalot & Reichardt
Gomphonema pumilum (Grunow) Reichardt & Lange-Bertalot
Gomphonema parvulius Lange-Bertalot & Reichardt
Gyrosigma scalproides (Rabenhorst) Cleve
Gomphonema tergestinum Fricke
Gomphonema transsilvanica (Pantocsek) Krammer
Gomphonema truncatum Ehr.
Gyrosigma acuminatum (Kützing) Rabenhorst
Gyrosigma attenuatum (Kützing) Rabenhorst
Gyrosigma parkerii (Harrison) Elmore
Gomphonema zellense Reichardt
Hantzschia amphioxys (Ehr.) Grunow in Cleve et Grunow 1880
Hantzschia amphilepta (Grunow) Lange-Bertalot
Hippodonta arkonensis Lange-Bert.Metzeltin & Witkowski
Hippodonta capitata (Ehr.) Lange-Bert.Metzeltin & Witkowski
Hippodonta costulata (Grunow) Lange-Bertalot Metzeltin & Witkowski
Hippodonta hungarica (Grunow) Lange-Bertalot Metzeltin & Witkowski
Hippodonta linearis (üstrup) Lange-Bertalot Metzeltin & Witkowski
Hippodonta Lange-Bertalot. Metzeltin & Witkowski
Hippodonta lueneburgensis (Grunow) Lange-Bertalot Metzeltin & Witkowski
Cymbella helvetica Kützing
Karayevia clevei (Grun. in Cl. & Grun.) Round & Bukhtiyarova
Kolbesia gessneri (Hust.) Aboal
Kolbesia ploenensis (Hust.) Kingston
Luticola cohnii (Hilse) D.G. Mann
Luticola goeppertiana (Bleisch in Rabenhorst) D.G. Mann
Lemnicola hungarica (Grunow) Round & Basson

Luticola mutica (Kützing) D.G. Mann
Luticola nivalis (Ehrenberg) D.G. Mann
Luticola D.G. Mann
Luticola ventriconfusa Lange-Bertalot
Mayamaea atomus var. permitis (Hustedt) Lange-Bertalot
Meridion circulare (Greville) Agardh var.constrictum (Ralfs) Van Heurck
Meridion circulare (Greville) C.A.Agardh var. circulare
Melosira varians Agardh
Navicula amphiceropsis Lange-Bertalot & Rumrich
Nitzschia acidoclinata Lange-Bertalot
Nitzschia acula Hantzsch
Nitzschia agnita Hustedt
Nitzschia amphibia Grunow f.amphibia
Navicula antonii Lange-Bertalot
Navicula J.B.M. Bory de St. Vincent
Nitzschia brunoi Lange-Bertalot
Nitzschia brevissima Grunow
Neidium bisulcatum (Lagerstedt) Cleve var.subampliatum Krammer
Navicula cari Ehrenberg var.linearis (Østrup) Cleve-Euler
Navicula cari Ehrenberg
Navicula catalanogermanica Lange-Bertalot & Hofmann
Navicula cryptotenelloides Lange-Bertalot forme teratogene
Navicula cincta (Ehr.) Ralfs in Pritchard
Nitzschia clausii Hantzsch
Nitzschia capitellata Hustedt in A.Schmidt & al.
Navicula capitatoradiata Germain
Navicula cryptocephala Kützing
Navicula cryptotenella Lange-Bertalot
Navicula cryptotenelloides Lange-Bertalot
Navicula cataracta-rheni Lange-Bertalot
Navicula caterva Hohn & Hellerman
Nitzschia dissipata (Kützing) Grunow var.dissipata
Nitzschia dissipata (Kützing) Grunow var.media (Hantzsch.) Grunow
Neidium dubium (Ehrenberg) Cleve
Neidium productum (W.M.Smith) Cleve
Navicula erifuga Lange-Bertalot
Navicula exilis Kützing
Nitzschia forfica Cholnoky 1968 p71 f.124
Nitzschia filiformis (W.M.Smith) Van Heurck var. filiformis
Nitzschia fonticola Grunow in Cleve et Müll.er
Navicula geitleri Hustedt

Navicula germainii Wallace
Navicula gregaria Donkin
Nitzschia hantzschiana Rabenhorst
Nitzschia heufleriana Grunow
Navicula hintzii Lange-Bertalot
Nitzschia angustata Grunow
Nitzschia archibaldii Lange-Bertalot
Nitzschia bulnheimiana (Rabenhorst) H.L.Smith
Nitzschia frustulum (Kützing) Grunow var.frustulum
Nitzschia fruticosa Hustedt
Nitzschia graciliformis Lange-Bertalot & Simonsen
Nitzschia gracilis Hantzsch
Nitzschia lacuum Lange-Bertalot
Nitzschia inconspicua Grunow
Nitzschia intermedia Hantzsch ex Cleve & Grunow
Nitzschia perminuta (Grunow) M.Peragallo
Nitzschia pusilla (Kützing) Grunow
Nitzschia solita Hustedt
Nitzschia subtilis Grunow in Cleve et Grunow
Nitzschia A.H. Hassall
Navicula jakovljevicii Hustedt
Navicula kotschyi Grunow
Navicula lanceolata (Agardh) Ehrenberg
Nitzschia liebetruthii Rabenhorst var.liebetruthii
Nitzschia linearis (Agardh) W.M.Smith var.linearis
Nitzschia levidensis (W.Smith) Grunow var.salinarum Grunow in Van Heurck
Navicula lundii Reichardt
Nitzschia luzonensis Hustedt
Navicula menisculus Schumann var. menisculus
Navicula margalithii Lange-Bertalot
Nitzschia microcephala Grunow in Cleve & Moller
Navicula notha Wallace
Navicula novaesiberica Lange-Bertalot
Nitzschia paleacea (Grunow) Grunow in van Heurck
Nitzschia palea (Kützing) W.Smith
Nitzschia pseudobacata Cholnoky
Navicula phyllepta Kützing
Navicula pseudonivalis Bock
Nitzschia perspicua Cholnoky
Navicula radiosa Kützing
Navicula recens (Lange-Bertalot) Lange-Bertalot

Nitzschia recta Hantzsch in Rabenhorst
Navicula reinhardtii (Grunow) Grunow in Cl. & Müll.er
Navicula reichardtiana Lange-Bertalot var. reichardtiana
Navicula salinarum Grunow in Cleve et Grunow var.salinarum
Nitzschia salpaespinosae Lange-Bertalot
Nitzschia sublinearis Hustedt
Navicula subplacentula Hustedt
Navicula streckerae Lange-Bertalot & Witkowski
Navicula schroeteri Meister var. schroeteri
Nitzschia sigma (Kützing) W.M.Smith
Nitzschia sigmoidea (Nitzsch) W. Smith
Nitzschia sinuata (Thwaites) Grunow var.tabellaria Grunow
Navicula slesvicensis Grunow
Nitzschia sociabilis Hustedt
Nitzschia solgensis Cleve-Euler
Navicula splendicula Van Landingham
Nitzschia subacicularis Hustedt in A.Schmidt et al.
Navicula symmetrica Patrick
Navicula trophicatrix Lange-Bertalot
Navicula tenelloides Hustedt
Nitzschia terrestris (Petersen) Hustedt
Navicula thiennemanii Hustedt
Nitzschia tryblionella var. maxima Grunow in Cleve & Grun.
Navicula tripunctata (O.F.Müller) Bory
Navicula trivialis Lange-Bertalot var. trivialis
Nitzschia tubicola Grunow
Nitzschia umbonata (Ehrenberg) Lange-Bertalot
Navicula upsaliensis (Grunow) Peragallo
Navicula vandamii Schoeman & Archibald var. vandamii
Naviculadicta laterostrata Hustedt
Navicula (dicta) seminulum (Grunow) Lange Bertalot
Navicula veneta Kützing
Nitzschia vermicularis (Kützing) Hantzsch
Navicula viridula (Kützing) Ehrenberg
Navicula viridula (Kütz.) Ehr. var.rostellata (Kütz.) Cleve
Nitzschia wuellerstorfii Lange-Bertalot
Nitzschia angustatula Lange-Bertalot
Nitzschia linearis (Agardh) W.M.Smith var.tenuis (W.Smith) Grunow
Opephora mutabilis (Grunow) Sabbe & Vyverman
Orthoseira G.H.K. Thwaites
Pinnularia borealis Ehrenberg var. borealis

Pinnularia Brébissonii (Kütz.) Rabenhorst var. Brébissonii
Psammodictyon constricta (Gregory) D.G. Mann
Placoneis constans (Hustedt) Cox
Placoneis elginensis (Greg) Cox
Placoneis exigua (Gregory) Mereschkowsky
Placoneis gastrum (Ehr.) Mereschkowsky
Pinnularia inconstans Mayer
Pinnularia C.G. Ehrenberg
Placoneis C. Mereschkowsky 1903
Psammothidium lauenburgianum (Hustedt) Bukht. et Round
Planothidium engelbrechtii (Choln.) Round & Bukhtiyarova
Planothidium frequentissimum (Lange-Bertalot) Lange-Bertalot
Planothidium Round & Bukhtiyarova
Pinnularia microstauron (Ehr.) Cleve var. microstauron
Psammothidium montanum (Krasske) Mayama
Placoneis placentula (Ehr.) Heinzerling
Parlibellus protracta (Grunow) Witkowski Lange-Bertalot & Metzeltin
Pseudostaurosira parasitica (W.Smith) Morales
Placoneis pseudanglica (Lange-Bertalot) Cox
Pseudostaurosira parasitica var. subconstricta (Grunow) Morales
Puncticulata radiosa (Lemmermann) H'kansson
Planothidium rostratum (Østrup) Lange-Bertalot
Psammothidium subatomoides (Hustedt) Bukht.et Round
Pseudostaurosira brevistriata (Grun.in Van Heurck) Williams & Round
Placoneis symmetrica (Hustedt) Lange-Bertalot
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot
Puncticulata comta (Ehr.) H'kansson
Pinnularia viridis (Nitzsch) Ehrenberg var.viridis morphotype 1
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot
Reimeria sinuata (Gregory) Kociolek & Störmer
Reimeria uniseriata Sala Guerrero & Ferrario
Surirella angusta Kützing
Staurosira acutirostrata (Metz.& Lange-Bert.) Metzeltin & Lange-Bertalot
Surirella Brébissonii var.Kützingii Krammer et Lange-Bertalot
Surirella Brébissonii Krammer & Lange-Bertalot var.brébissonii
Surirella brightwellii W.Smith var.brightwellii
Staurosira construens (Ehr.) var. binodis (Ehr.) Hamilton
Staurosira construens Ehrenberg
Staurosira construens Ehr. f.subsalina (Hust.) Bukhtiyarova
Sellaphora bacillum (Ehrenberg) D.G.Mann
Staurosira elliptica (Schumann) Williams & Round

Synedra fasciculata Kützing
Stephanodiscus hantzschii Grunow in Cl. & Grun. 1880
Surirella linearis W.M.Smith
Stephanodiscus medius H'kansson
Stephanodiscus neoastraea Håkansson et Hickel
Sellaphora nyassensis (O.Müller) D.G. Mann
Stephanodiscus parvus Störmer et Håkansson
Sellaphora pupula (Kützing) Mereschkowksy
Staurosira pinnata Ehrenberg
Staurosira leptostauron Ehrenberg ?
Stauroneis smithii Grunow
Surirella suecica Grunow
Staurosira venter (Ehr.) Cleve & Moeller
Synedra tabulata (Agardh) Kützing var. tabulata
Stephanodiscus C.G. Ehrenberg
Stephanodiscus invisitatus Hohn et Hellermann
Staurosirella lapponica (Grun.in Van Heurck) Williams & Round
Staurosirella berolinensis (Lem.) Bukhtiyarova
Stephanodiscus minutulus (Kützing) Cleve & Moller
Stephanodiscus tenuis Hustedt
Surirella capronii Brébisson in Kitton
Surirella minuta Brébisson
Surirella sp. nov. (muellerthalensis)
Surirella P. J.F. Turpin
Surirella tenera Gregory
Synedra C.G. Ehrenberg
Tryblionella apiculata Gregory
Thalassiosira bramaputrae (Ehr.) Håkansson & Locker
Tryblionella calida (grunow in Cl. & Grun.) D.G. Mann
Tryblionella debilis Arnott ex O'Meara
Thalassiosira duostra Pienaar
Tabellaria flocculosa (Roth) Kützing
Tryblionella hungarica (Grunow) D.G. Mann
Tryblionella levidensis Wm. Smith
Tryblionella littoralis (Grunow in Cl. & Grun.) D.G. Mann
Thalassiosira pseudonana Hasle et Heimdal
Thalassiosira weissflogii (Grunow) Fryxell & Hasle
Ulnaria biceps (Kützing) Compère
Ulnaria ulna (Nitzsch.) Compère