4.5 PHYTOPLANKTON

4.5.1 Introduction

Eutrophication in rivers is defined as an increase in primary production (algal and plant biomass) due to an elevated nutrient input. High levels of eutrophication lead to negative consequences for the river itself and reservoirs in particular (Wetzel, 1983). They typically include:

- dramatic diurnal changes in oxygen content and pH (elevated oxygen saturation and pH during the day)
- decreased transparency
- lower species diversity, especially in top carnivores
- deterioration in water quality leading to its restricted use value
- deterioration of the amenity value of water

The development of phytoplankton biomass depends on nutrient availability and concentrations, light conditions, flow velocity (residence time) and the “grazing" effect of zooplankton and benthic filter-feeding animals.

Qualitative and quantitative algological investigations were carried out along the Danube and its most important tributaries and side arms as part of JDS. The purpose of this research was to characterize the eutrophication status of the water bodies investigated and reveal longitudinal variations in the trophic state variables along the Danube.

Phytoplankton abundance, chlorophyll-a concentration and concentration of plant nutrients (phosphor and nitrogen) as well as oxygen saturation and transparency (secchi depth) were commonly used as state variables for the characterization of the trophic status of a water body.

Phytoplankton abundance can be measured and expressed as cell/colony numbers (individuum/l) and/or biomass (mg/l). Biomass was gererally measured indirectly, calculated from the density and specific cell volume of particular taxa.

As phytoplankton-biomass is not analysed in routine water quality monitoring, chlorophyll-a concentration is widely used to estimate the primary production of phytoplankton.

4.5.2 Material and Methods

4.5.2.1 Phytoplankton Analyses

The algological methods used in phytoplankton investigations of the Danube are based on the methodological works of Sourinia (1978), Reynolds (1984), Nemeth & Vörös (1986), Wetzel & Likens (1991) and Nemeth (1998).

Unfiltered water samples were taken in parallel with the samples for chemical analyses and fixed with Lugol’s solution, i.e. iodine dissolved in a potassium iodide solution.

100g KI is dissolved in 1 litre of distilled water; then 50g cristalline iodine is dissolved and 100 ml of glacial acetic acid is added. For 200 ml water sample 0.4-0.8 ml Lugol`s iodine is added to give the sample a weak brown colour; then it must be well shaken.

The preserved samples should were kept in the dark at a low temperature.

For quantitative analysis of phytoplankton, the Utermöhl`s inverted-microscope method (UTERMÖHL 1958) was applied using an Opton-type invertoscope fitted with a phase-contrast equipment. Sedimentation chambers 2 ml in volume were used for counting individuals. One or more crossed-diameter transects of the total bottom area was examined under high magnification (objective of x 63). All observed individuals were counted. The average number of individuals/transect was converted into population density unit (individuum/ml).

Population density data were translated into phytoplankton biomass by taking into account differences in the cell size of a particular taxa. For the calculation of the specific cell volumes, simple geometric models (e. g. sphere, ellipsoid, cylinder) or different formulas for more complicated froms (see: Wetzel & Likens 1991, Nemeth 1998) may be used. The appropriate linear dimensions of at least 25 randomly selected individuals should then be measured, and the volume of each of the measured cells calculated, from which the mean cell volume is derived. The mean cell volume should not be calculated from the average linear dimensions of the individual cells (Smayda 1978).

If the linear dimensions were measured in µm, and the mean specific volume in μm^3 assuming a density of 1 (NÉMETH 1998) the specific biomass would be given in pg (10^{-12} g).

If the population density of a particular taxa was determined in $i/ml = 10^3 * i/l$ (i: individuum) and the specific cell volume in $\mu m^3/i$, the biomass of the population of this taxa would be given in $10^3 * \mu m^3/l$

$10^3 * \mu m^3/l \approx 10^3 * 10^{-12} g/l = 10^{-9} g/l = ng/l$

If the specific biomass is expressed in ng/i:

$10^3 * [\ i/l\ ] * [\ ng/i\ ] = 10^3\ ng/l = 10^3 * 10^{-9}\ g/l = 10^{-6}\ g/l = \mu g/l$

Biomass values expressed in µg/l are given as integer.

The biomass of the total population is calculated according to the following expression:

$$B = \sum_{i=1}^{s} b_i{*}N_i = b_1{*}N_1 + b_2{*}N_2 + \dots b_s{*}N_s$$

where B: total biomass
s: the number of species found in the sample (i= 1, 2, ... s)
b_i: specific biomass of the species i
N_i: population density (number of individuals/volume) of the species i

The general systems applied in the qualitative investigation of phytoplankton are based on Bourelly (1966, 1968, 1970) and Van den Hoek al. (1995). For the determination of the particular taxa, the monographs and studies cited in the References were used.

4.5.2.2 Chlorophyll-a Analyses

Samples for chlorophyll-a determination in the Danube were taken together with those for chemical analyses in the middle of the River and near its banks, at 3-5 m depth. In the tributaries, side arms and the Danube Delta arms, the samples, along with those for chemical analyses, were taken only from the middle.

In order to decrease the spatial and temporal variability of Chlorophyl-a content from each sampling site (L,M,R) during the visit to the station (10-20 min) two to three 1-litre samples were taken and well mixed together. An aliquot, 0.5 to 2 litres according to the phytoplankton abundance, was then taken for analysis.

The Chl-a content was analysed according to ISO 10260 by the use of hot extraction. Parallel to the chlorophyll extraction method, the Chl-A content was estimated with a fluorimeter using the method of delayed fluorescence in fresh water samples.

A highly significant correlation ($r^2 = 0, 97$) was found between the extraction method (ISO 10260) and the fluorimetric method .

The reported values represent mean values except where stated otherwise. In case all three points, left, middle and right, were analysed, the mean value for each sampling site was calculated as an average of their values.

For the interpretation of chlorophyll-a concentrations, the assessment system agreed by MLIM-Expert Group and used for TNMN data was used. This system consists of five classes, of which class II represents quality objective:

Quality Class	I	II	III	IV	V
chlorophyll-a (µg/l)	25	50	100	250	>250

4.5.3 Results

261 algal taxa were found during JDS in the plankton of the Danube, its most important tributaries and side arms (Table PPL -1). Taxa determined only at generic or higher taxonomic level as well as several operational taxa (sensu Sokal and Sneath 1973) were also taken into account.

TABLE.PPL-1: List of phytoplankton species found during the JDS

CYANOPHYTA
CHROOCOCCALES
Aphanocapsa holsatica
Chroococcus sp.
Gomphosphaeriaceae spp.
Merismopedia sp., d=1-2um
Microcystidaceae spp.
Microcystis aeruginosa
Microcystis spp.
Chroococcales sp.

OSCILLATORIALES
Lyngbya cf. limnetica
Limnothrix redekei
Oscillatoria cf. agardhii
Oscillatoria spp.
Oscillatoriaceae sp.
Phormidium cf. mucicola
Pseudanabaena limnetica
Pseudanabaena spp.

NOSTOCALES
Anabaena spiroides
Anabaena solitaria f. planctonica
Anabaena spp.
Anabaenopsis elenkinii
Anabaenopsis raciborskii
Anabaenopsis sp.
Aphanizomenon issatschenkoi

EUGLENOPHYTA
Euglena pisciformis
Euglena spp.
Phacus agilis var. agilis
Phacus pyrum var. pyrum
Phacus spp.
Strombomonas deflandrei
Strombomonas verrucosa var. zmiewika
Trachelomonas spp.

CRYPTOPHYTA
Chroomonas sp.
Cryptomonas marssonii
Cryptomonas spp.
Rhodomonas spp.
Cryptophyceae spp.

DINOPHYTA
Dinophyta spp.
Ceratium hirundinella
Gymnodinium sp. (?)
Peridinium spp.

CHRYSOPYCEAE
Chrysococcus spp.
Chrysophyceae sp. (?)
Dinobryon sertularia
Kephyrion rubri-claustri
Kephyrion sp.
Mallomonas sp.
Synura spp.

XANTHOPHYCEAE
Centritractus belenophorus
Centritractus africanus
Dichotomococcus cf. bacillaris
Dichotomococcus curvatus
Goniochloris mutica
Pseudostaurastrum hastatum = Tetredron hastatum
Pleurochloridaceae sp.

DIATOMOPHYCEAE
CENTRALES
Thalassiosiraceae spp.
Aulacoseira ambigua
Aulacoseira granulata var. granulata
Aulacoseira granulata var. angustissima
Aulacoseira subarctica f. recta
Melosira varians
Aulacoseira spp.
Sceletonema sp.

PENNALES
Achnanthes minutissima
Achnanthes spp.
Asterionella formosa
Amphora libyca
Amphora sp.
Cocconeis pediculus
Cocconeis placentula
Cymatopleura solea var. solea
Cymbella helvetica
Cymbella silesiaca
Cymbella sinuata
Cymbella tumida
Diatoma ehrenbergii
Diatoma moniliformis

Diatoma tenuis
Diatoma vulgaris
Gomphonema parvulum
Fragilaria construens f. construens
Fragilaria crotonensis
Fragilaria sp.
Gomphonema parvulum
Hantzschia amphioxys
Navicula capitatoradiata
Navicula cryptocephala
Navicula cryptotenella
Navicula cuspidata var. cuspidata
Navicula lanceolata
Navicula menisculus var. menisculus
Navicula pseudonivalis
Navicula pupula var. pupula
Navicula spp.
Navicula tripunctata
Navicula viridula var. viridula
Nitzschia cf. acicularis
Nitzschia cf. actinastroides
Nitzschia levidensis
Nitzschia cf. palea
Nitzschia reversa
Nitzschia (Lanceolatae) spp.
Nitzschia (Lineares) spp.
Rhoicosphaenia abbreviata
Pennales spp.
Surirella brebissonii
Surirella minuta
Surirella ovata
Synedra cf. acus
Synedra ulna var. ulna
Synedra ulna var. danica
Synedra spp.
Pennales spp.

VOLVOCALES
Chlorogonium sp.
Chlamydomonas simplex
Chlamydomonas braunii
Chlamydomonas monadina
Chlamydomonas proboscigera
Chlamydomonas sp.
Lobomonas ampla
Carteria sp.
Chlorogonium sp.
Pandorina charkowiensis
Pandorina morum
Phacotus sp.
Pteromonas aculeata
Phytomonadina spp.

CHLOROCOCCALES
Actinastrum hantzschii
Amphikricos minutissimus
Ankistrodesmus gracilis
Chlorococcales spp., 2-4 um
Chlorococcales sp., 4-8 um
Chlorococcales sp., 4-8x2-4 um, 1-2s
Chlorococcales sp., 8-16x1-2 um, 1-2s
Chlorococcales sp., 8-16 um
Coelastrum astroideum
Coelastrum microporum
Coelastrum morus
Coelastrum reticulatum
Coelastrum spp.
Coenocystis reniformis
Chodatella quadriseta var. quadriseta
Chodatella quadriseta var. brevicauda
Chodatella sp.
Crucigenia cf. mucronata
Crucigenia tetrapedia
Crucigenia sp.
Crucigeniella apiculata
Dicellula geminata
Dicloster acuatus
Dictyosphaerium ehrenbergianum
Dictyosphaerium granulatum
Dictyosphaerium tetrachotomum
Didymogenes anomala
Didymocystis inermis
Didymocystis planctonica
Didymogenes palatina
Diplochloris hortobagyii
Franceia ovalis
Golenkinia radiata
Kirchneriella danubiana
Kirchneriella irregularis var. irregularis
Kirchneriella lunaris
Kirchneriella obesa
Kirchneriella rotunda
Kirchneriella spp.
Lagerheimia ciliata
Lagerheimia genevensis
Lagerheimia longiseta
Lagerheimia wratislawiensis
Micractinium pusillum
Monoraphidium arcuatum
Monoraphidium circinale
Monoraphidium contortum
Monoraphidium dybowskii

Monoraphidium minutum
Monoraphidium spp.
Neodesmus danubialis
Nephrochlamys subsolitaria
Nephrochlamys willeana
Nephrochlamys sp.
Oocystis coronata
Oocystis marssonii
Oocystis spp.
Pediastrum boryanum
Pediastrum duplex var. duplex
Pediastrum duplex var. gracillimum
Pediastrum simplex var. simplex
Pediastrum simplex var. echinulatum
Pediastrum tetras
Pseudoschroederia robusta
Quadricoccus ellipticus
Quadricoccus verrucosus
Scenedesmus acuminatus var. acuminatus f. acuminatus
Scenedesmus acuminatus var. acuminatus f. tortuosus
Scenedesmus acutus var. alternans
Scenedesmus arcuatus var. arcuatus
Scenedesmus arcuatus f. granulatus
Scenedesmus arcuatus var. platydiscus
Scenedesmus armatus var. armatus
Scenedesmus armatus var. bicaudatus
Scenedesmus carinatus
Scenedesmus denticulatus var. denticulatus
Scenedesmus denticulatus var. linearis
Scenedesmus dispar
Scenedesmus dispar var. costato-granulatus
Scenedesmus grahneisii
Scenedesmus gutwinskii forma
Scenedesmus incrassatulus
Scenedesmus intermedius var. intermedius
Scenedesmus intermedius var. bicaudatus
Scenedesmus linearis
Scenedesmus opoliensis
Scenedesmus ovalternus var. graevenitzii
Scenedesmus pannonicus var. pannonicus f. granulatus
Scenedesmus pseudohelveticus
Scenedesmus quadricauda
Scenedesmus serratus
Scenedesmus smithii
Scenedesmus spinosus var. spinosus
Scenedesmus spinosus var. bicaudatus
Scenedesmus spp.
Schroederia setigera
Schroederia spiralis
Schroederia sp.
Siderocelis kolkwitzii
Siderocelis ornata
Siderocelis sp.
Siderocystopsis fusca
Tetrachlorella alternans
Tetrachlorella coronata
Tetrachlorella sp.
Tetraedron caudatum
Tetraedron incus
Tetraedron minimum var. minimum
Tetraedron minimum var. tetralobatum
Tetraedron proteiforme
Tetraedron triangulare
Tetrastrum glabrum
Tetrastrum heteracathum
Tetrastrum péterfii
Tetrastrum punctatum
Tetrastrum staurogeniaeforme
Tetrastrum triangulare
Tetrastrum sp.
Treubaria sp.

ULOTHRICALES
Catena viridis
Elakatothrix sp.
Gloeotila sp.
Koliella longiseta
Koliella sp. (?)
Koliella spp.
Planctonema lauterbornii
Stichococcus pelagicus
Ulotrichales sp.
SUM Ulothricales

DESMIDIALES
Closterium moniliforme
Closterium acutum var. acutum
Closterium acutum var. linea
Closterium spp.
Cosmarium bioculatum
Cosmarium spp.
Staurastrum paradoxum

The longitudinal variations of phytoplankton biomass and chlorophyll-a concentration of the Danube are presented in Figure PPL-1 and Figure PPL-2 respectively. The phytoplankton biomass, chlorophyll-a concentration and selected chemical data are summarized in Table PPL-2.

Table PPL-2. Selected biological and chemical data

sampling sites	rkm	Bio mass ug/l	chl-a ug/l	PO4-P mg/l	total-P mg/l	D. O. mg/l	%
JDS1	2581	1277	5,6	0,049	0,06	8,9	94,0
JDS2	2412	8917	29,6	0,007	0,07	10,9	121,0
JDS3	2358	11061	42,0	0,010	0,09	11,9	136,0
JDS4	2233	12368	38,5	0,055	0,09	10,4	119,0
JDS5			2,1	0,035	0,10	10,2	106,0
JDS6	2204	3765	12,4	0,058	0,09	9,9	107,0
JDS7	2165	3174	12,1	0,058	0,08	10,5	110,0
JDS8	2120	3566	11,2	0,048	0,08	9,5	103,0
JDS9	2095	2738	13,0	0,006	0,07	10,1	110,0
JDS10	2080	3042	10,4	0,003	0,09	9,7	104,0
JDS11	1950	871	6,0	0,016	0,15	8,7	95,0
JDS12	1942	1215	5,0	0,016	0,14	8,9	97,0
JDS13		1433	16,3	0,130	0,22	10,4	125,0
JDS14	1895	2527	11,0	0,003	0,08	9,1	102,0
JDS15	1881	3517	9,2	0,022	0,09	8,6	94,0
JDS16		31609	77,7	0,140	0,32	8,6	100,0
JDS17	1869		11,8	0,042	0,10	8,8	96,0
JDS18	1856	4219	19,5	0,039	0,13	9,0	100,0
JDS19	1852	5808	16,9	0,042	0,10	8,5	94,0
JDS20	1846	5499	18,6	0,032	0,10	8,8	98,0
JDS21	1812	1926	10,7	0,035	0,10	8,5	96,0
JDS22		6005	14,5	0,029	0,08	9,8	110,0
JDS23	1806	4417	15,4	0,042	0,07	9,5	107,0
JDS24		1256	6,2	0,159	0,21	3,0	35,0
JDS25	1768	3831	17,2	0,039	0,08	8,4	96,0
JDS26		4951	11,0	0,058	0,13	7,0	83,0
JDS27		6036	19,8	0,042	0,07	8,8	100,0
JDS28	1719	6416	23,4	0,035	0,09	8,9	106,0
JDS29		4828	22,8	0,149	0,22	8,9	104,0
JDS30		29519	82,3	0,179	0,20	6,1	70,0
JDS31	1707	6849	30,2	0,042	0,09	8,8	100,0
JDS32	1692	7706	33,4	0,026	0,09	9,1	104,0
JDS33		6802	35,0	0,055	0,08	9,9	113,0
JDS34	1659	6897	40,3	0,045	0,09	9,9	119,0
JDS35			37,0	0,032	0,10	11,1	129,0
JDS36		18743	73,1	0,016	0,17	12,4	146,0
JDS37	1632	24048	101,0	0,019	0,10	12,5	145,0
JDS38		20064	46,8	0,032	0,15	9,8	122,0
JDS39	1586	38053	124,0	0,006	0,11	16,3	192,0
JDS40	1560	39926	137,0	0,013	0,11	12,4	145,0
JDS41	1533	34491	113,0	0,009	0,11	14,3	167,0
JDS42		58810	94,1	0,228	0,58	18,9	240,0
JDS43	1481	29767	120,0	0,058	0,43	14,2	170,0
JDS44	1434	39042	102,0	0,019	0,11	12,8	149,0
JDS45	1424	24958	78,7	0,009	0,11	11,9	137,0
JDS46	1384	20832	66,0	0,006	0,13	10,8	125,0
JDS47		23417	67,8	0,006	0,10	10,4	119,0
JDS48	1367	15436	50,0	0,006	0,11	8,2	98,0
JDS49	1337	13718	56,2	0,006	0,12	9,3	106,0
JDS50	1300	11349	37,8	0,033	0,11	9,0	105,0
JDS51	1262	7218	29,0	0,016	0,13	8,6	102,0
JDS52	1252	6238	27,8	0,020	0,11	7,1	84,0
JDS53	1216	6692	15,4	0,026	0,07	7,0	85,0
JDS54		2061	10,7	0,065	0,13	4,9	59,0
JDS55	1200	3341	12,0	0,065	0,12	6,9	81,0

JDS56		539	9,5	0,098	0,12	6,7	81,0
JDS57	1159	3372	9,8	0,058	0,08	7,5	93,0
JDS58	1151	2856	10,7	0,055	0,08	5,7	67,0
JDS59	1132	4100	12,7	0,055	0,08	5,9	70,0
JDS60	1107	4266	11,2	0,071	0,11	5,4	65,0
JDS61		19749	87,6	0,045	0,17	10,2	125,0
JDS62	1097	2036	5,0	0,052	0,08	4,5	53,0
JDS63	1077	806	3,5	0,058	0,08	5,0	59,0
JDS64	1071	837	2,4	0,074	0,08	5,4	65,0
JDS65	1040	403	1,2	0,055	0,07	4,9	57,0
JDS66	954	832	3,8	0,065	0,10	6,0	72,0
JDS67	926	851	3,8	0,088	0,08	5,6	66,0
JDS68	849	339	1,2	0,074	0,08	5,8	68,0
JDS69		455	6,6	0,016	0,08	8,0	99,0
JDS70	834	686	7,1	0,074	0,12	6,2	74,0
JDS71	795	932	3,0	0,081	0,09	6,9	83,0
JDS72	685	1426	7,1	0,085	0,11	8,0	94,0
JDS73	641	1429	6,9	0,082	0,07	8,2	96,0
JDS74			97,9	0,848	0,69	11,7	136,0
JDS75	630	2187	7,8	0,091	0,18	8,2	93,0
JDS76	606	1939	8,9	0,082	0,08	8,2	94,0
JDS77		7003	9,8	0,094	0,13	8,0	91,0
JDS78	603	2801	8,9	0,078	0,14	8,6	97,0
JDS79	579	2557	13,0	0,108	0,12	8,3	98,0
JDS80	550	2447	6,3	0,085	0,13	8,1	92,0
JDS81		3458	27,2	0,196	0,92	7,7	87,0
JDS82	532	3096	12,2	0,163	0,16	8,2	94,0
JDS83	499	2851	10,3	0,078	0,16	8,2	95,0
JDS84			36,7	0,297	0,59	5,1	54,0
JDS85	488	1989	8,7	0,085	0,13	7,0	79,0
JDS86	434	3003	5,9	0,078	0,13	7,0	77,0
JDS87		3697	6,8	0,238	0,61		
JDS88	429	3048	13,3	0,078	0,15	8,3	92,0
JDS89	375	4163	17,3	0,078	0,18	8,3	94,0
JDS90	293	3389	7,0	0,091	0,14	5,2	62,0
JDS91	236	4790	18,9	0,091	0,22	7,1	85,0
JDS92	167	4306	20,0	0,098	0,14	7,2	86,0
JDS93		407	7,1	0,065	0,25	5,8	63,0
JDS94		2279	7,8	0,068	0,31	7,9	83,0
JDS95	132	7371	9,8	0,062	0,17	7,4	86,0
JDS96	18	4468	14,3	0,065	0,16	6,0	71,0
JDS97	0	3505	15,9	0,078	0,18	7,5	85,0
JDS98	0	6198	16,0	0,091	0,19	6,6	77,0
min		**339**	**1,2**	**0,003**	**0,06**	**3,0**	**35,0**
max		**58810**	**137,0**	**0,848**	**0,92**	**18,9**	**240,0**
avg		**8270**	**27,9**	**0,072**	**0,15**	**8,6**	**99,2**

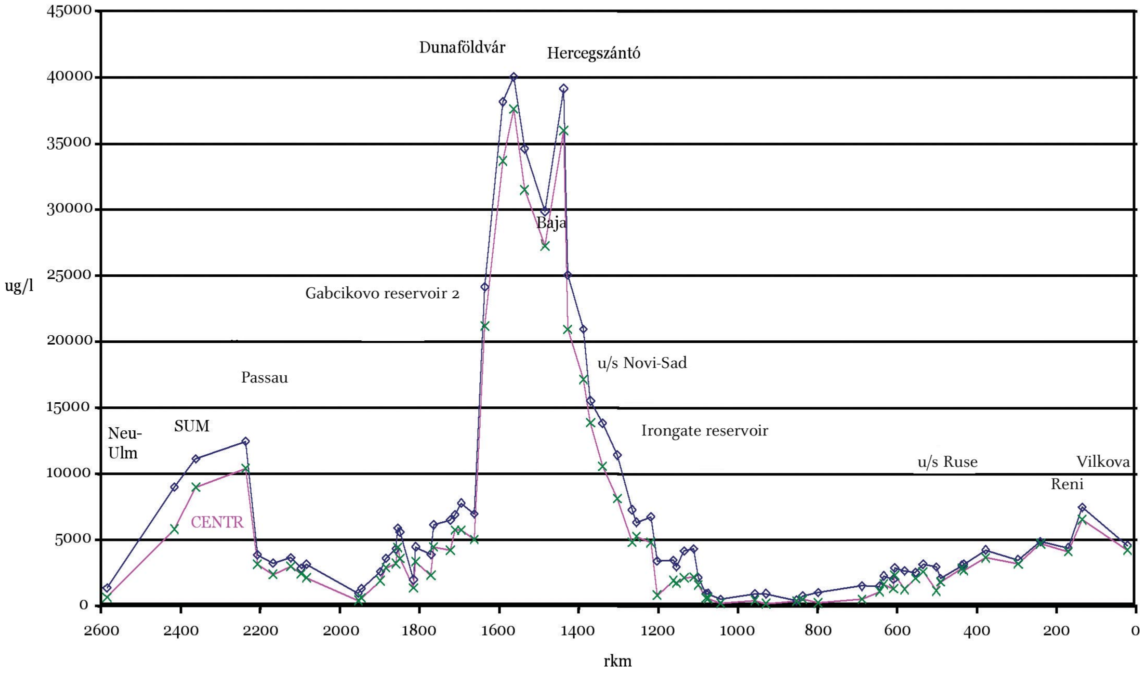

FIGURE PPL-1: Longitudinal variations of phytoplankton biomass (ug/1) in the River Danube

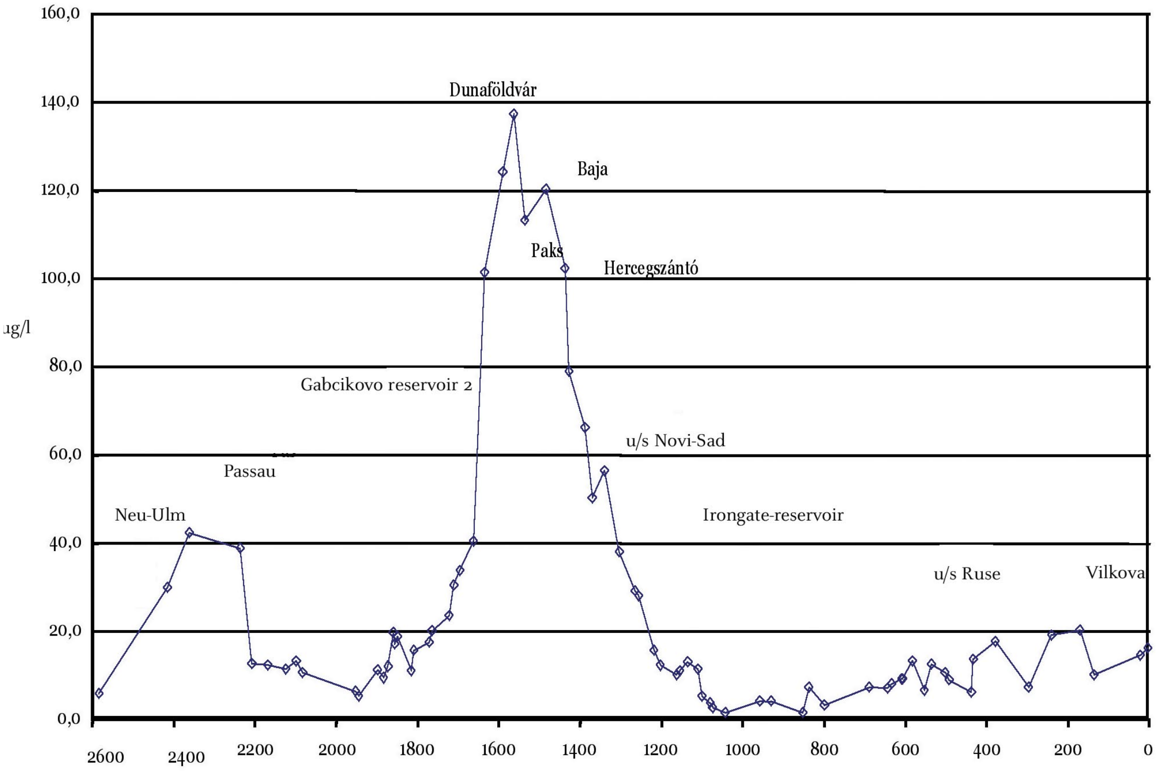

FIGURE PPL-2: Longitudinal variations of chlorophyll-a concentration (ug/1) in the River Danube

4.5.3.1 The Danube

Phytoplankton biomass in the Danube ranged from 0.3 mg/l (JDS 68: upstream of the Timok [Radujevac/Gruia], 849 rkm) to 39.9 mg/l (JDS 40: Dunaföldvár, 1560 rkm).

The concentration of chlorophyll-a varied from 1.2 to 137 µg/l . As already mentioned for the biomass the lowest values were found upstream of the Timok at Radujevac/Gruia km 849 (JDS 68) and the highest values at Dunaföldvár/ km 1560 (JDS 40) .

Longitudinal variations in chlorophyll-a concentrations in the Danube were very similar to the fluctuation in phytoplankton biomass values. The correlation between chlorophyll-a concentration and biomass ($r^2 = 0.87$) can be seen in the Annex – Phytoplankton.

Phytoplankton biomass (µg/l) and relative abundance (%) data according to the main algal groups are summarized in the Annex - Phytoplankton, based on the geo-morphological divisions described in Chapter 3.

The results of phytoplankton biomass in the Danube together with the density of zooplankton are presented in Chapter 4.6, Figure ZPL-1. As can be seen in the graph, the peak of phytoplankton biomass - with a short delay - is followed by the maxima of zooplankton density in the middle section of the Danube. The decrease in phytoplankton is associated with the inncrease in zooplanton density probably due to the grazing effect of zooplankton. The midde part of the diagram in this figure is similar to the graph of Lotka-Volterra's equations (see: Wilson and Bossert 1971) as the time sclale can be replaced by the spatial one.

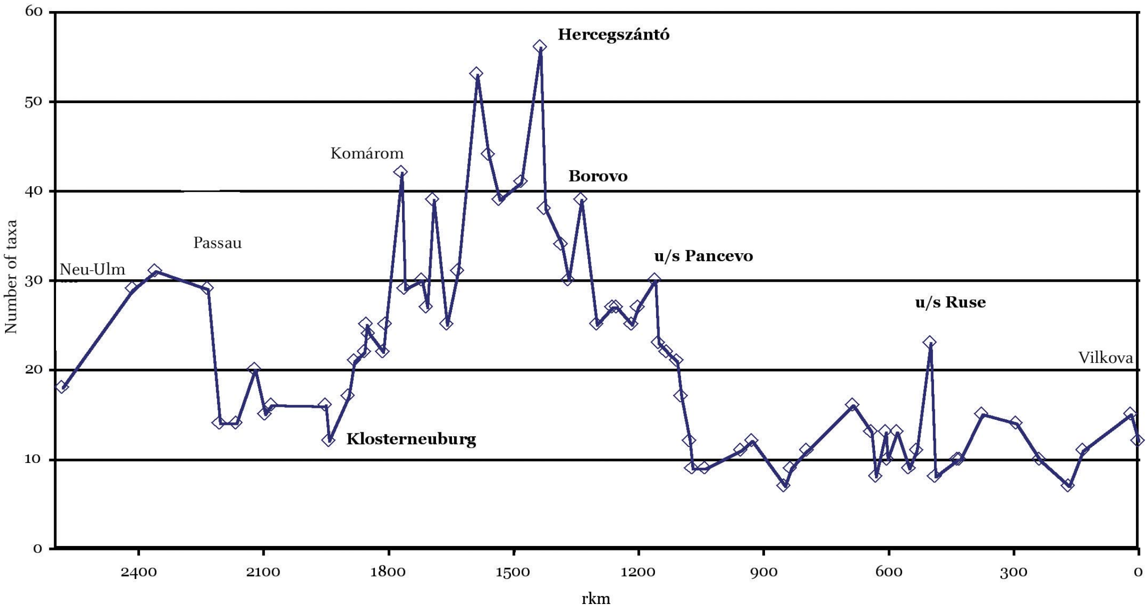

FIGURE PPL-3: Number of dominant taxa

Longitudinal variations in the number of taxa are shown in Fig. PPL-3. When this graph is compared to Fig. PPL-1, it can be seen that the longitudinal variations in phytoplankton biomass are closely related to the variation in the number of taxa. The correlation between the number of taxa and phytoplankton biomass ($r^2 = 0.64$) is shown in the Annex - Phytoplankton

Longitudinal variationsin in the number of taxa according to the hydrogeological reaches of the Danube are shown in Fig. PPL-4. The increase in species richness in the middle and most eutrophicated part of the Danube was caused mainly by the increasing number of Chlorococcales taxa as might have been expected in an eutrophic environment. In general, it was observed throughout the Survey that higher eutrophic situations lead to an increase in phytoplankton diversity in the Danube.

Centrales diatoms were generally dominant in the phytoplankton of the Danube. Variations in the biomass of Centrales taxa (CENTR) along the Danube can also be seen in Fig. PPL-1.

The main taxa identified in the Danube were Thalassiosiracae (*Cyclotella, Cyclostephanos, Stephanodiscus* and *Thalassiosira spp.*). Their relative abundance varied between 10.2 % (JDS 67: Vrbica/Simijan, 926 rkm) and 96.7 % (JDS 91: Giurgeni, 236 rkm) with an average of 70.7 %.

It was observed during JDS if the relative abundance of centric diatoms in the Danube decreased, an increase in the proportion of cryptomonads took place, which happened, for example, in most of the sampling sites of Reach 7.

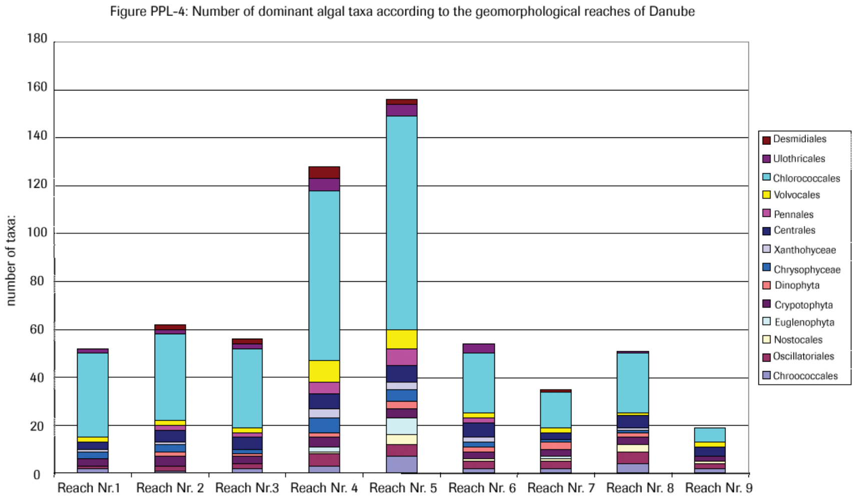

FIGURE PPL-4: Number of dominant algal taxa according to the geomorphological reaches of Danube

The interpretation of phytoplankton data - the variations in their composition and biomass - and data regarding the concentration of chlorophyll-a are based on the proposed nine geomorphological reaches of the Danube.

REACH 1: NEU-ULM (JDS 1) – PASSAU (JDS 4)

The biomass of phytoplankton measured during JDS showed an increase from 1,3 mg/l at Neu-Ulm to 12.4 mg/l at Passau, upstream of the confluence with the Inn. Similarly, chlorophyll-a concentration changed from 5.6 to 38.5 µg/l reaching a local maximum (42.0 µg/l) at Regensburg (JDS 3), which still allows water quality to be classified as class II.

The number of phytoplankton taxa found in Reach 1 varied from 18 to 31 (mean 27).

The relative abundance of centric diatoms increased steadily from 45.5 % to 83.5 %, parallel with a gradual decrease in the relative abundance of cryptomonads (18.5 to 3.4 %).

REACH 2: JOCHENSTEIN (JDS 6) – HAINBURG (JDS 15)

Downstream of the confluence with the Inn, which is characterzed by cloudy glacier waters, the biomass decreased significantly and values ranged from 0.9 to 3.8 mg/l with an average of 2.7 mg/l. There was no indication of a significant longitudinal increase in biomass in this Reach. Chlorophyll-a concentrations oscillated between 5.0 and 13.0 μg/l (class I).

The number of phytoplankton taxa found in this Reach was between 12 to 21 (mean 16).

The relative abundance of centric diatoms varied from 38.5 to 85.9 % with an average value of 69.6 %. In the case of low percentages of diatoms (39 – 45%) found at Greifenstein (JDS 11) and Klosterneuburg (JDS 12), higher amounts of Dinophytes (22- to 39%) could be observed.

REACH 3: GABCIKOVO RESERVOIR (JDS 18-20)

Compared to the previous Reach, phytoplankton biomass in Reach 3 was slightly higher and varied between 4.2 and 5.8 mg/l with an average of 5.2 mg/l. Chlorophyll-a concentrations ranged from 16.9 to 19.5 μg/l.

The number of phytoplankton taxa found in this Reach varied from 22 to 25 (mean 24).

The relative abundance of dominant centric diatoms varied from 64.1 to 74.9 % with an average of 71.1 %.

REACH 4: SAP (JDS 21) – UPSTREAM OF BUDAPEST (JDS 34)

Biomass values ranged from 1.9 to 7.7 mg/l with a mean of 5.5 mg/l. As can be seen from Fig. PPL-1., there was an increase in biomass between Sap and Budapest. Chlorophyll-a concentration gradually increased between Sap and Budapest from 10.7 (class I) up to 40.3 μg/l (class II).

22 to 42 (mean 30) phytoplankton taxa coud be found at the sampling sites of this Reach.

The relative abundance of centric diatoms varied from 59.4 to 82.6 % with a mean of 70.8 %. Chlorococcal green algae reached their highest relative abundance of 16.7 % at Sturovo/Eztergom.

REACH 5: DOWNSTREAM OF BUDAPEST (JDS 37) – BELGRADE (JDS 55)

Phytoplankton biomass ranged from 3.3 (JDS 55: Belgrade) to 39.9 mg/l (JDS 40: Dunaföldvár) with a mean value of 21.0 mg/l. The highest biomass value for the whole of the Danube was reported at Dunaföldvár.

At the same time, chlorophyll-a concentration varied between 12.0 (JDS 55: Belgrade), which translates into water quality class I, and 137.0 µg/l (JDS 40: Dunaföldvár) - another record value for the whole of the Danube - indicating class IV.

The biomass considerably decreased downstream throughout the 360 river kilometers stretch of the Danube between Dunaföldvár and Belgrade. This seemed to be due the the grazing effect of zooplankton which increased significantly and reached its highest level downstream of Novi-Sad (see Chapter 4.6, Fig. ZPL-1).

The section of the Danube between Budapest and Hercegszántó was during JDS found to be the most eutrophicated part of the River. Oxygen (hyper-)saturation ranged from 145 to 192 % with an average of 161 % indicating a highly eutrophic situation.

The highest number of phytoplankton taxa was found in this Reach. It varied between 24 and 56 (mean 36).

Centric diatoms were dominant in phytoplankton between Budapest (JDS 37) and Stari Slankamen (JDS 53). The composition of phytoplankton was considerably altered at Belgrade where Centrales reached 22.8 %, Pennales 25.2 %, Cryptophyta 18,6%,Volvocales 12.8 % and the Chlorococcales 11.1 %.

REACH 6: UPSTREAM OF PANCEVO (JDS 57) – IRON GATE RESERVOIR (JDS 66)

Phytoplankton biomass in this Raech was low and varied between 0.4 (JDS 65: Iron Gate reservoir) and 4.2 mg/l (JDS 60: u/s Velika Morava) with an average of 2.2 mg/l. Chlorophyll-a concentrations ranged from 1.2 (JDS 65: Iron Gate reservoir) to 12.7 µg/l (JDS 59: Grocka).

Phytoplankton taxa steadily decreased along this Raech, ranging from 30 to 9 (mean 17).

Centric diatoms generally dominant the phytoplankton group; their proportion relative to the total biomass varied between 32.9 and 72.0 % with an average value of 53.8 %. The relative abundance of Cryptophyta ranged from 9.9 to 39.4 %. The lowest values for diatoms of 33 and 40% respectively were found at the two sampling sites in the Iron Gate reservoir (JDS 65 and 66), which is related to the high percentages of Cryptophyta (26 – 40%).

REACH 7: VRBICA/SIMIJAN (JDS 67) – D/S ZIMNICEA/SVISHTOV (JDS 80)

The biomass of phytoplankton ranged from 0.3 (JDS 68: upstream of the Timok at Radujevac/Gruia) to 2,8 mg/l (JDS 78: downstream Olt) with a mean value of 1.6 mg/l. The biomass increased slightly along this Reach.

The highest transparency could be observed in the Danube downstrem of the Iron Gate and upstream of the Timok with values of 2,8 m sechhi depth. Chlorophyll-a concentration varied between 1.2 (JDS 68: upstream of the Timok at Radujevac/Gruia) and 13.0 µg/l. (JDS 79: downstream of Turnu-Magurele/Nikopol).

The number of phytoplankton taxa found in this Reach varied from 8 to 16 (mean 11).

Centric diatoms showed high variations (10.2% to 82.2 %), and so did Cryptophyta (7.0% to 44.1%). The average share of centric diatoms and Cryptophyta were 55.9% and 22.9 % respectively.

At Calafat (JDS 71), Oscillatoriales reached 32 % percent of the total phytoplankton biomass.

REACH 8: D/S JATRA (JDS 82) – RENI (JDS 95)

The biomass of phytoplankton varied between 2.0 (JDS 85 downstream of Ruse/Giurgiu) and 7,4 mg/l (JDS 95, Reni-Chilia/Kilia arm) with an average of 3.8 mg/l. Chlorophyll-a concentration ranged from 5.9 (JDS 86: upstream of the Arges) to 20.0 µg/l (JDS 92, Braila).

Between eight and 15 (mean 12) phytoplankton taxa were found in this Reach.

Centric diatoms again dominated the phytoplankton; their share varied between 80,0% and 96.7 % with the exception of the sampling site upstream of the Ruse (JDS 83) At this site, Centrales accounted for only 38% of the biomass while Oscillatoriales blue-green algae and pennate diatoms reached the relative abundance of 24.6 and 14.6 % respectively.

REACH 9: DANUBE DELTA ARMS (JDS 96-98)

Phytoplankton biomass ranged from 3.5 (JDS 97: Sulina arm) to 6,2 mg/l (JDS 98: Sf. Gheorghe arm) with an average of 4.7 mg/l. Chlorophyll-a concentration varied between 14.3 and 16.0 µg/l.

10 to 15 (mean 12) phytoplankton taxa were found in this Reach.

The phytoplankton was dominated by centric diatoms. Their share of the total phytoplankton biomass varied between 89.2 and 93.9 % with a mean value of 91.9 %.

4.5.3.2 Side-arms and Tributaries of the Danube

Phytoplankton biomass and relative abundance data are summarized in the Annex - Phytoplankton.

The biomass and composition of phytoplankton in several side-arms were highly similar to the structural characteristics of the main arm. Biomass values were 6.0 and 6.8 mg/l in the Old Danube at Ásványráró (JDS 22) and in the upstream end of Szentendre side-arm (JDS 33) respectively. The concentrations of chlorophyll-a were 14.5 or 35.0 µg/l.

The relative abundance of dominant centric diatoms were 67.2 and 85.5 % respectively. Phytoplankton biomass and chlorophyll-a concentrations were 1.3 mg/l or 6.2 µg/l in the Moson Danube arm (JDS 24). The phytoplankton was dominanted by chlorococcal green algae (45.3 %) which seem to influence also the downstream phytoplankton composition in the Danube from Komarno/Komarom to Iza/Szony (JDS 25, 27 and 28). The relative abundance of the following taxa was higher than 10 %: piko algae (12.7 %), Flagellatae (10.9 %), Cryptophyta (14.6 %), Centrales (12.9 %). The high proportion of piko algae and flagellates belonging to different taxonomic groups are indicative of a high level of organic pollution. This is also underlined by very low oxygen values (35 % saturation).

The Ráckeve-Soroksár Danube was characterized by high phytoplankton biomass and chlorophyll-a concentration. Biomass values were 18.7 and 20.0 mg/l; chlorophyll-a concentration was 73,1 (indicating class III) at the arm-start (JDS 36) and 46,8 µg/lat the arm-end (JDS 38).

Centric diatoms were dominant at the arm-start (76.3 %) while at the arm-end the phytoplankton was dominated by cryptomonads (47.8 %) and the share of centric diatoms reached 32.6 %.

Extreme differences were recognized in the biomass and composition of phytoplankton in the following tributaries.

The biomass of phytoplankton and chlorophyll-a concentration were 1.4 mg/l and 16.3 µg/l respectively in the Schwechat River (JDS 13) . Chlorophyll-a biomass ratio (1.14 %) was higher than the usual mean values published by Nemeth and Vörös (1986). Phytoplankton biomass was extremly rich in Desmidiales species. The cumulative relative abundance of *Closterium moniliforme* and *Cosmarium spp.* was 28.3 %. The proportion of centric diatoms, chlorococcal greens, pennate diatoms and piko-algae was 23.7, 18.2, 13.5 and 11.0 % respectively.

High phytoplankton biomass (31.6 mg/l) was observed in the Morava River (JDS 16) with chlorophyll-a concentration of 77.7 µg/l (indicating class III) . Centric diatoms were dominant (52.4 %) in phytoplankton. The relative abundance of green algae was 28.9 % (Volvocales: 9.3 %, Chlorococcales: 17.5 %, Desmidiales: 2.1 %).

In comparison to the Morava, the biomass and chlorophyll-a concentration in the Vah River (JDS 26) were much lower, i.e. 5.0 mg/l and 11.0 µg/l respectively. The relative abundance of dominant centric diatoms was 64.5 %.

In the Hron River (JDS 29), the biomass of phytoplankton and chlorophyll-a concentration were 4.8 mg/l and 22.8 µg/l respectively. The relative abundance of the following taxa was higher than 10 %: Centrales (35.6 %), Chlorococcales (31.2 %) Cryptophyta (15.7 %).

A high phytoplankton biomass and chlorophyll-a concentration were measured in the Ipoly River (JDS 30) respectively 29.5 mg/l and 82.3 µg/l (indicating class III). The phytoplankton was dominated by centric diatoms (82.5 %). The sampling site at the Ipoly is also characterised by a low flow, low transparency, high organic pollution and the highest species diversity of zooplankton among all JDS stations.

The phytoplankton biomass of 58.8 mg/l in the Sió-canal (JDS 42) was the highest value among the tributaries. Chlorophyll-a concentration was also very high (82.3 µg/l). The eutrophic status was also underlined by high nutrient concentrations, an oxygen (hyper-)saturation of 240%, pH of 8,81 and very high zooplankton abundance.

The relative abundance of the dominant centric diatoms was 65.0 %. The share of chlorococcal green algae was 11.4 %.

Although nutrient concentrations were low, phytoplankton biomass and chlorophyll-a concentration in the Drava River (JDS 47) were at 23.4 mg/l and 67.8 µg/l respectively much higher than expected. The relative abundance of the dominant centric diatoms was 51.4 %. The share of pennate diatoms (mainly Fragilaria crotonensis) and chlorococcal green algae was 24.2% and 15.2 % respectively.

At 2.1 mg/l and 10.7 µg/l respectively, phytoplankton biomass and chlorophyll-a concentration in the Tisza River (JDS 54) was much lower compared to the Drava. The phytoplankton was dominated by centric diatoms, whose share in the total biomass was 70.5 %. The relative abundance of cryptomonads was 18.6 %.

In the Sava River (JDS 56), a very low biomass value was observed (0.54 mg/l). The concentration of chlorophyll-a was 9.5 µg/l. The chlorophyll-a content of phytoplankton biomass was unusally high (1.76 %) compared to the values reported in literature. The most striking feature of the phytoplankton structure was a high relative abundance of piko-algae (38.2 %). The high proportion of piko-algae is usually associated with low biomass values (see Annex - Phytoplankton). The relative abundance of chlorococcal green algae and cryptomonads was 44.3% and 11.6 % respectively.

A large biomass of phytoplankton and chlorophyll-a concentration was found in the Velika Morava (JDS 61) with 19.7 mg/l and 87.6 mg/l chl-a respectively. The relative abundance of the dominant centric diatoms was 71.2 %.

In the Timok River, an extremely low biomass value was estimated (0.46 mg/). The concentration of chlorophyll-a was 6.6 µg/l. The chlorophyll-a content of phytoplankton biomass (1.45 %) was higher than the usual mean values published in literature. A high proportion (31.4 %) of piko-algae was observed in this water body. The relative abundance of centric diatoms and chlorococcal green algae was 40.0% and 27.9 % respectively.

Despite the fact that the transparency of 0,8 m in the Iskar River (JDS 74) was the highest measured in the tributaries in the lower Danube section, 97,9 µg/l was the highest chlorophyll-a concentration found during JDS. Phytoplankton biomass was not analysed. The eutrophic situation was underlined by high nutrient concentrations (0,67 mg/l Ptot); oxygen saturation was 136%.

Compared to the Iskar, the biomass of phytoplankton and chlorophyll-a concentration in the Olt River (JDS 77) were at 7.0 mg/l and 9.8 µg/l respectively very low. The phytoplankton biomass was rich in Dinophyta-species (54.9 %), chlorococcal blue green algae (13.8 %) and centric diatoms (11.9 %).

The biomass of phytoplankton and chlorophyll-a concentration in the Jantra River (JDS 81) were 3.5 mg/l or 27.2 µg/l (indicating class II) although nutrient concentrations were very high (0,196 mg/l PO4-P and 0,92 mg/l Ptot). The relative abundance of the following taxa were higher than 10 %: Oscillatoriales (25,7 %), Centrales (24.1 %), Dinophyta (13.8 %), Cryptophyta (13.6 %), Chlorococcales (12.4 %).

In the Russenski Lom River (JDS 84), chlorophyll-a concentration reached 36,7 µg/l. Phyoplankton biomass was not analysed. Compared to other tributaries of the Danube like the Morava and the Drava these values are relatively low, although the Russenski Lom was highly polluted with biodegradable substances and nutrients and oxygen saturation was only 53 %.

Despite the fact that the Arges River (JDS 87) is highly polluted as well, only low chlorophyll-a concentrations of 6,8 µg/l could be observed. Biomass was not calculated for this river.

Minimal biomass values (0.41 mg/l) were measured in the Siret River (JDS 93) with chlorophyll-a concentration of 7.1 µg/l although phosphorous concentrations were elevated. The chlorophyll-a content of phytoplankton biomass was unusally high (1.74 %). The phytoplankton were dominanted by diatoms (Centrales 60.9 %, Pennales: 15.9 %). The relative abundance of piko-algae was high (19.5 %). It was stated above that a strong presence of piko-algae is usually associated with low biomass values.

The same situation (high pollution – low biomass) could be observed in the Prut River (JDS 94), where phytoplankton biomass and chlorophyll-a concentration were 2.3 mg/l and 7.8 µg/l respectively. The phytoplankton was dominated by diatoms (Centrales 44.2 %, Pennales: 34.8 %).

4.5.4 Summary and Conclusions

261 phytoplankton taxa were found during JDS in the plankton of the Danube, its most important tributaries and side arms.

Phytoplankton biomass in the Danube ranged from 0.3 mg/l upstream of the Timok at Radujevac/Gruia to 39.9 mg/l at Dunaföldvár. In general, high biomass values indicating eutrophic conditions in the Danube were found in the Hungarian stretch of the Danube downstream of Budapest.

The concentration of chlorophyll-a varied from 1.2 to 137 µg/l with the minimum and maximum values at the same sites as already mentioned for biomass.

Longitudinal variations of chlorophyll-a concentrations in the Danube were generally very similar to the fluctuation in phytoplankton biomass values.

Comparing longitudinal variations of phytoplankton biomass in the Danube with the density of zooplankton it can be seen that the peak of phytoplankton biomass was - with a short delay - followed by maximum values of zooplankton density in the middle section of the Danube. The decrease in phytoplankton is associated with an increase in zooplanton density probably due to the grazing effect of zooplankton.

The longitudinal variations of phytoplankton biomass is also related to the variation of taxa number.

The increase in species richness in the middle and most eutrophicated part of the Danube was caused mainly by the increasing number of Chlorococcales taxa as might have been expected in an eutrophic environment.

In general, it was observed during JDS that higher levels of eutrophication lead to an increase of phytoplankton diversity in the Danube.

The biomass and composition of phytoplankton of several side-arms were mostly very similar to the structural characteristics in the main arm.

Concerning the tributaries, the highest values of phytoplankton biomass/chl-a concentrations were found in the Iskar, the Velika Morava, the Ipoly and the Sio where the eutrophic status was usually underlined by high nutrient concentrations and oxygen-hypersaturation.

Despite the fact that the Jantra, the Rusenski Lom, the Arges, the Siret and the Prut were also highly polluted with nutrients or biodegradable organic matter, phytoplankton biomass was unexpectedly low probably due to retarding or toxic effects.

In contrast, much higher amounts of phytoplankton biomass could be observed in the Drava even though it contained comparably only low concentrations of nutrients.

Concerning the method used to analyse chlorophyll-a concentrations, a highly significant correlation ($r^2 = 0, 97$) was found between the extraction method (ISO 10260) and the fluorimetric method.

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4.6 ZOOPLANKTON

4.6.1 Introduction

In the course of the Joint Danube Survey in August-September 2001, zooplankton samples were collected at 98 sampling sites in the Danube and at the points of confluence with its tributaries. Taxonomic identification of Rotatoria and Crustacea (Cladocera, Copepoda) species was made in filtered samples. Species composition and individual abundance were determined for each sampling site and served as a basis for biological water quality assessment of the River and its tributaries. Results are compared to similar surveys conducted previously.

The comprehensive survey „Zooplankton of the Danube" compiled by Naidenov in 1998 states that the first zooplankton investigations were conducted at the beginning of the century on the joint Austrian-Hungarian Danube section (Steuer 1901, Kottasz 1913, Jungmayer 1914). These were followed by many other studies in the Danubian countries.

Plankton communities are expected to develop only in large-flow rivers with the exception of their upper section. The development of riverine plankton depends on the following conditions: necessary flow (average flow min. 200-300 m^3/s) and water depth, a given flow velocity (max. 0,4 m/s), turbulence, suspended solids content, required length of the river section and stagnant waters hydraulically connected to the main arm. If the river flow is high and water level fluctuations are large, but do not have the necessary depth, zooplankton will be destroyed due to frictions against the riverbank, riverbed and plants.

Suspended solids could through friction damage the plankton species that do not have a hard shell and cause clogging of the filtering apparatus. In rivers with large suspended particles, usually fine-filtering, settling and predatory Rotatoria species, and Copepoda nauplius and Copepodit larvae survive.

Zooplankton communities can only develop in rivers exceeding the length of about 500-700 km because the growth of the species takes some time. The shorter the generation time the larger the population size and larger populations are more likely to survive lotic conditions. Generation time of Rotatoria is about 3-7 days, and largely depends on temperature. In the case of Cladocerans, generation time is about one week, while for Copepods it is about one month. According to calculations presented by Naidenov (1998), travel time from Kelheim (2414 rkm) to the estuary is 26 days, meaning that passive swimmers of Rotatoria are able to reproduce 4-9 times, Cladoceran 1-2 times and Copepods only once. The total zooplankton biomass is likely to grow 600 times due to the population growth in which the contribution of Rotatoria biomass can reach as high as 90%, provided that the elimination of biomass is disregarded in the meantime.

As far as population growth is concerned, tributaries, temporal runoff and islands play a crucial role in it. Qualitative and quantitative composition of zooplankton could be highly influenced by the effects of the confluence of a species-poor canal and water diversion devices, respectively closures. According to Wawrik (1968) and Naidenov (1991), the formation of autochtonous potamoplankton is inhibited.

All this is true of the Danube and was confirmed during JDS .

4.6.2 Methods

The list of Rotatoria and Crustacea taxa comprises only plankton species that were identified from the water body in each case. Tychoplanktonic species determined and indicated in the species list were drifted to the sample accidentally.

Water samples were taken from the water surface. In each case, 50 liters of water were filtered through 70 μm mesh size plankton net. The collected material was quantitatively transferred to sample storage bottles. The filtrate was conserved on-site by using Lugol solution so that the color of the liquid was close to „cognac".

4.6.2.1 Sampling sites

Samples were taken at all JDS sampling sites except at sites number 17, 35, 43, 54, 67 and 87.

4.6.2.2 Qualitative Investigations

Many Rotatoria taxa could be determined on the basis of their masticatory organs. Preparation was conducted by putting under the microscopic cover slide a drop of hypochloric acid that corrodes the body fluids of the animal and makes masticatory organs visible.

Dissection of Cladocera and Copepoda crustacean was also conducted under stereoscopic microscope in 9%-os glycerin solution. Dissected body parts were arranged on the slide and covered. Identification of the species required the use of 200-400 magnification.

Based on the individual abundance values in a unit of water volume, zooplankton taxon lists were prepared for each sampling site. On the basis of this, average individual numbers were ranked according to the following scale:

+	only one individuum
1	2-20%
2	21-40%:
3	41-60%:
4	61-80%:
5	81-100%:

Following this, a synthetic species list was prepared for each sampling site where the percentage contribution to average species composition was considered.

The occurrence of species was indicated on species lists according to the following codes:
Rare occurrence (+) = only in one investigation or in 2-20% of the investigations;
Frequent occurrence (++) = in 21-40% of the investigations;
Dominant (+++) = in 41-100% of the investigations (GULYÁS 1979).

Frequently occurring or dominant species are indicated in taxa lists by bold-italics letter type (Table ZPL-1).

Species determination was based on the following taxonomic literature: BANCSI 1986, 1988, NOGRADY 1993, SEGERS 1995, KOSTE 1978, KUTIKOVA 1970 (Rotatoria), FLÖSSNER 1972, GULYÁS 1974, GULYÁS és FORRÓ 1999, MANUJLOVA 1964 (Cladocera), DÉVAI 1977, DUS-

SART 1967, 1969, EINSLE 1993, GULYÁS és FORRÓ 2001 (Copepoda).

4.6.2.3 Quantitative Investigations

Condensed samples were prepared in two ways. In the first case, when only few animals were collected in the filtrate of the water sample, the animals were counted in the whole sample. The settled sample was first decanted and the remaining water was removed by a pipette equipped with filtering material at the one end and a rubber ball at the other end for suction. By the completion of the removal of this water, a few drops of water were backwashed from the pipette to the sample by pressing the rubber ball in order to backwash the animals potentially adhered to the surface of the filter material at the tip of the pipette. The settled material remaining at the bottom of the sample storage bottle was further settled for 30 minutes, then covered with cover glass and the enumeration of the individuals of taxa was made considering the full bottom of the compartment.

In case of high zooplankton densities, dilution was applied using measuring cylinders of known volume. An aliquot part was transferred into 5 ml counting chambers, and settled. The enumeration of animals was conducted in Utermöhl-type plankton microscope by counting the whole bottom of the compartment. Abundance values were calculated on the basis of the known volumes of filtered and diluted sample, and the volume and surface of the counting chamber. Abundance values are given in individuum/m^3 referring to the original sample.

Investigations were conducted with an Utermöhl-type inversed microscope using a 5- ml chamber. Species which require previous preparation and dissection for determination were selected from the sample and prepared under a stereoscopic microscope by using various magnification ranges for identification.

TABLE ZPL-1. Occurrence of Rotatoria and Crustacea species in the Danube section between Regensburg-Tulcea and in tributaries (August-September 2002)

Taxa	Dominant
ROTATORIA	
Anuraeopsis fissa (Gosse, 1851)	+
Ascomorpha ecaudis Zacharias, 1893	+
Asplanchna brightwelli Gosse, 1850	++
A. priodonta Gosse, 1850	+
A. sieboldi (Leydig, 1854)	+
Asplanchnopus multiplex (Schrank, 1753)	+
Bdelloidea sp.	+++
Brachionus angularis angularis Gosse, 1851	+++
B. angularis f. bidens Plate, 1886	++
B. budapestinensis budapestinensis Daday, 1885	+++
B. calyciflorus calyciflorus Pallas, 1766	+++
B. calyciflorus f. anuraeiformis Brehm, 1909	+++
B. calyciflorus f. dorcas Gosse, 1851	++
B. calyciflorus f. spinosus Wierzejski, 1891	++
B. diversicornis diversicornis (Daday, 1883)	+
B. falcatus Zacharias, 1898	+
B. leydigii leydigii Cohn, 1862	+
B. leydigi tridentatus Zernov, 1901	+
B. quadridentatus quadridentatus Hermann, 1783	+
B. quadridentatus var. brevispinus Ehrb., 1832	++
B. quadridentatus var. cluniorbicularis Skorikov, 1894	+
B. quadridentatus var. rhenanus Lauterborn, 1893	+
B. rubens Ehrb., 1838	+
B. urceolaris (O.F.Müller, 1773)	++
Cephalodella gibba (Ehrb., 1832)	+
Cephalodella sp.	+
Collotheca atrochoides (Wierzejski, 1893)	+
Cupelopagis vorax (Leydi, 1857)	+
Dichranophorus sp.	+
Elosa worallii Lord, 1891	+
Euchlanis dilatata Ehrb., 1832	++
E. lyra Hudson, 1886	+
E. proxima Myers, 1930	+
E. triquetra Ehrb., 1838	+
Filinia longiseta (Ehrb., 1834)	++
F. longiseta var. limnetica (Zacharias, 1893)	+
F. terminalis (Plate, 1886)	+
Kellikottia longispina (Kellikott, 1879)	+
Keratella cochlearis cochlearis (Gosse, 1851)	+++
K. cochlearis var. tecta (Gosse, 1851)	+++
K. irregularis (Lauterborn, 1898)	++
K. quadrata (O.F.Müller, 1786)	++
K. quadrata var. frenzeli (Eckstein, 1895)	+
K. tropica (Apstein, 1907)	+
K. valga (Ehrb., 1934)	+
Lecane brachydactyla (Stenroos, 1898)	+
L. (Monostyla) bulla (Gosse, 1886)	++
L. clara (Bryce, 1892)	+
L. (Monostyla) closterocerca (Schmarda, 1859)	+
L. luna (O.F.Müller, 1776)	+
L. (Monostyla) lunaris (Ehrb. 1832)	+
L. (Monostyla) psammophila (Wiszniewski, 1932)	+
L. (Monostyla) scutata (Harring et Myers, 1926)	+
Lepadella ovalis (O.F.Müller, 1786)	+
L. patella (O.F.Müller, 1786)	+

Lophocharis oxysternon (Gosse, 1851)	+
Monommata longiseta (O.F.Müller, 1786)	+
Mytilina mucronata mucronata (O.F.Müller, 1773)	+
Notholca acuminata (Ehrb., 1832)	+
N. labis Gosse, 1887	+
N. squamula (O.F.Müller, 1786)	+
Notommata sp.	+
Platyas quadricornis (Ehrb., 1832)	+
Polyarthra major Burckhardt, 1900	+
P. vulgaris Carlin, 1943	**+++**
Pompholyx sulcata Hudson, 1885	**++**
Rotaria sp.	+
Synchaeta oblonga Ehrb., 1831	**++**
S. pectinata Ehrb., 1832	**++**
S. stylata Wierzejski, 1893	+
Synchaeta sp.	+
Testudinella patina (Hermann, 1783)	+
Trichocerca birostris (Carlin, 1943)	+
T. dixon-nutalli (Jennings, 1903)	+
T. elongata (Gosse, 1886)	+
T. longiseta (Schrank, 1802)	+
T. pusilla (Lauterborn, 1898)	**++**
T. rattus (O.F.Müller, 1776)	+
Trichotria curta (Skorikov, 1914)	+
CLADOCERA	
Alona guttata Sars, 1862	+
A. karelica Stenroos, 1897	+
A. quadrangularis (O.F.Müller, 1785)	+
A. rectangula Sars, 1862	+
Bosmina (Eubosmina) coregoni Baird, 1857	+
Bosmina (Bosmina) longirostris (O.F.Müller, 1785)	**+++**
B. (B.) longirostris var. cornuta (Jurine)	**++**
B. (B.) longirtostris var. pellucida Stingelin	**++**
Ceriodaphnia quadrangula (O.F.Müller, 1875)	+
Chydorus sphaericus (O.F.Müller, 1776)	+
Daphnia cucullata Sars, 1862	**++**
D. galeata Sars, 1864	**++**
D. longispina O.F.Müller, 1785	+
Diaphanosoma brachyurum (Liévin, 1848)	**++**
Disparalona rostrata (Koch, 1841)	**++**
Graptoleberis testudinaria (Fischer, 1848)	+
Iliocryptus agilis Kurz, 1878	+
Iiocryptus sordidus (Liévin, 1848)	+
Leptodora kindtii (Focke, 1844)	+
Macrothrix hirsuticornis Norman et Brady, 1867	+
M. laticornis (Fischer, 1848)	+
Moina brachiata (Jurine, 1820)	**++**
M. macrocopa (Straus, 1820)	+
M. micrura Kurz, 1874	**++**
Pleuroxus aduncus (Jurine, 1820)	+
P. trigonellus (O.F.Müller, 1785)	+
Sida crystallina (O.F.Müller, 1776)	+
COPEPODA	
Calanoida	
Eudiaptomus gracilis (Sars, 1863)	+
Eudiaptomus sp.	+
Eurytemora velox (Lilljeborg, 1853)	+
Cyclopoida	
Acanthocyclops robustus (Sars, 1873)	**+++**
A. vernalis (Fischer, 1853)	+

Cyclops sp.	+
Diacyclops bicuspidatus (Claus, 1857)	++
Eucyclops macruroides (Lilljeborg, 1901)	+
E. serrulatus (Fischer, 1851)	+
Macrocyclops albidus (Jurine, 1820)	+
Megacyclops viridis (Jurine, 1820)	+
Mesocyclops leuckarti (Claus, 1857)	++
Thermocyclops crassus (Fischer, 1853)	+++
T. oithonoides (Sars, 1863)	+

Key: + - Rare, ++ - frequently occuring, +++ - dominant

4.6.3 Results

4.6.3.1 Total JDS Reach

79 Rotatoria, 27 Cladocera and 14 Copepoda - altogether 120 species - were analysed in the Danube and its tributaries during JDS (Table ZPL-1 and Annex - Zooplankton). Most of the species are of planktonic life form but numerous tychoplanktonic elements were also identified. The latter were washed to the plankton from the bottom, the aqueous vegetation, or the tributaries. The number of zooplankton taxa found at the JDS sampling sites varied between 4-26 in the Danube and between 6-30 in the tributaries. A gradual increase was observed in the Danube along the longitudinal section in the downstream direction.

The dominance of the following taxa is characteristic for this river section: *Brachionus angularis angularis, B. budapestinensis budapestinensis, B. calyciflorus, Keratella cochlearis cochlearis, K. c. var. tecta, Polyarthra vulgaris, Bosmina (Bosmina) longirostris, Acanthocyclops robustus, Thermocyclops crassus*. These species are typical for nutrient rich, polytrophic waters where large individual abundance may occur. These JDS results are comparable to the results of many years of investigations. In certain river sections even more taxa were found to be dominant. These will be discussed in details in the particular discussion of zooplankton communities.

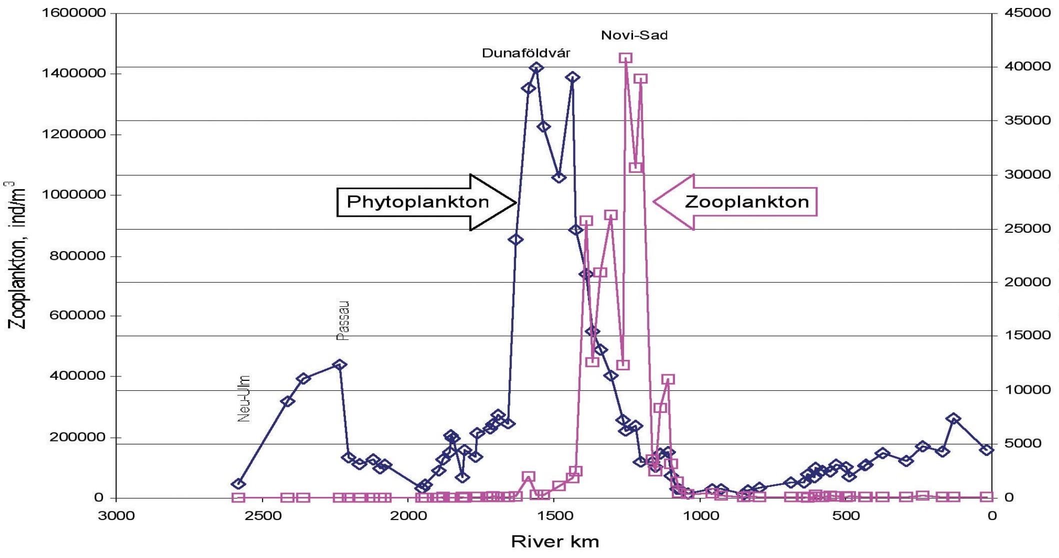

FIGURE ZPL-1: Variation in phytoplankton biomass and zooplankton population density along the Danube River found during JDS.

The following species could be found only rarely: *Brachionus falcatus, Collotheca atrochoides, Cupelopagis vorax, Lecane brachydactyla, L. (Monostyla) psammophila, L. (Monostyla) scutata, Monommata longiseta, Trichotria curta* (Rotatoria), *Alona guttata, A. karelica, Graptoleberis testudinaria* (Cladocera).

Individual abundance of zooplankton communities varied significantly, between 280 –1383600 ind./m^3 in the Danube (Fig. ZPL-2) and 1140 – 799640 ind./m^3 in its tributaries (Fig. ZPL-3). These values are largely in line with former studies conducted in the summer period. High individual abundance indicates eutrophic, polytrophic conditions of nutrient enrichment in slowly running rivers and lakes.

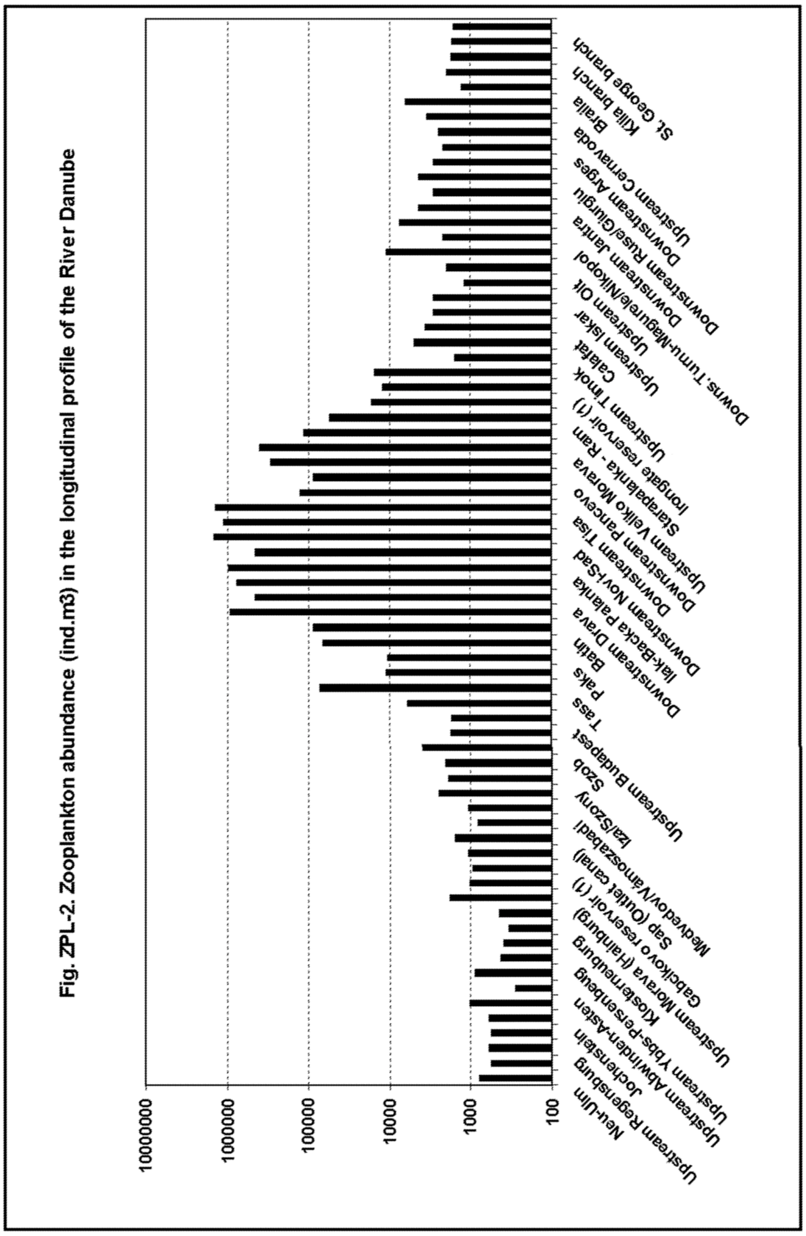

FIGURE ZPL-2: Zooplankton abundance (ind.m^3) in the longitudinal profile of the River Danube

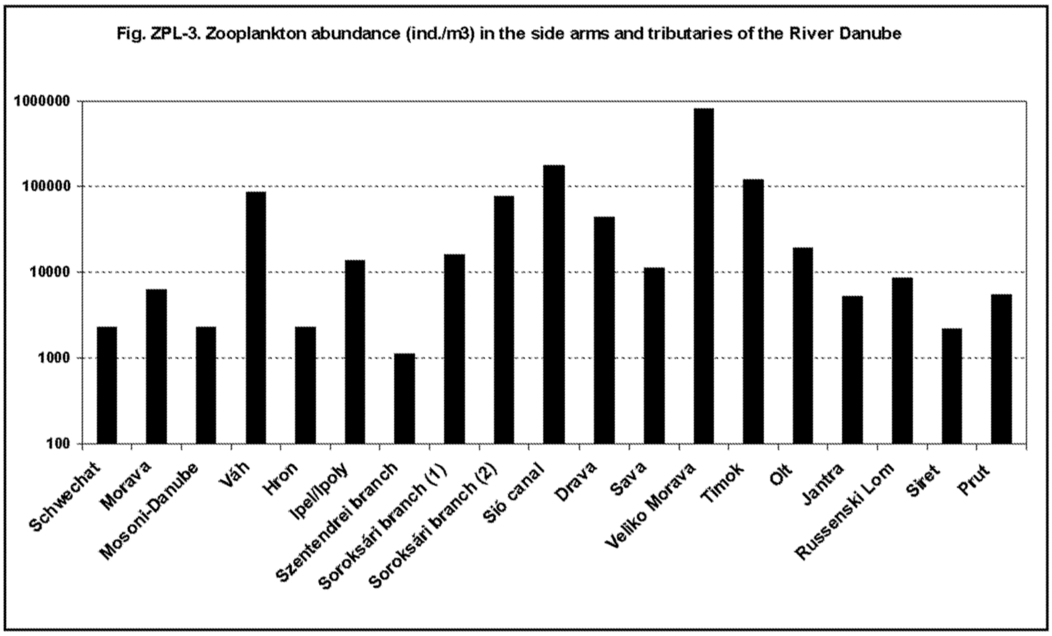

FIGURE ZPL-3: Zooplankton abundance (ind.m^3) in the side arms and tributaries of the River Danube

4.6.3.2 Geo-morphological Reaches

Reach 1:

Only 35 Rotatoria and Crustacea taxa were identified between Neu-Ulm and the confluence point of Inn (2581-2225 km) . The number of taxa varied between 8-17.

Dominant species were B*rachionus angularis angularis, B. calyciflorus, Keratella cochlearis cochlearis, Synchaeta oblonga*. Additionally the following taxa were also identified as frequently occurring *Lecane (Monostyla) bulla, Pompholyx sulcata, Bosmina (Eubosmina) coregoni and Bosmina (Bosmina) longirostris. Copepoda nauplius* and *copepodit larvae* were also identified in each sample. Amongst the rare species the occurrence of *Euchlanis lyra, Monommata longiseta* and *Trichotria curta* has to be mentioned (see Fig ZPL-2 and Annex - Zooplankton).

The individual abundance value was low with measured values of 560 – 780 ind.per m^3. The probable reason for this might be the higher flow velocity of the river and the small amount of available nutrient as it is indicated by the relatively low algal biomass values (1277-1238 μ/l). (see Fig ZPL-2).

Reach 2:

Investigation of the Danube section between the confluence points of the Inn and the Morava (2225-1880 km) revealed the occurrence of 45 Rotatoria and Crustacea taxa. At Hainburg (upstream of the Morava River - JDS 15) the Danube is particularly rich in species. The taxa number varied between 4-21.

The dominant species included: *Brachionus angularis angularis, B. budapestinensis budapestinensis, B. calyciflorus, Keratella cochlearis cochlearis, K. c. var. tecta and Bosmina (Bosmina) longirostris* and those frequently occurring included *Keratella irregularis, Lecane (Monostyla) bulla, Synchaeta spp. Disparalona rostrata*. Rare species were *Cupelopagis vorax* and *Elosa worallii.*

Individual abundance values were highly similar to those in Reach 1 with the exception of the already mentioned site at Hainburg (280-1790 ind./m^3).

The Schwechat has to be mentioned separately because its species spectrum and dominance of certain species indicated eutrophic, organic pollution (2300 ind./m^3), but a high number of vermin cysts and large-size *Closterium acerosum* (Desmidiales) alga species was also determined. (see Fig.ZPL-3 and Annex-Zooplankton).

Reach 3:

Investigations between the confluence of the Morava and Gabcikovo Reservoir (1880-1846 rkm) comprised sampling sites on the territory of the Gabcikovo Reservoir and the downstream canal at Szap, where altogether 31 taxa were identified. The taxa number per sampling site varied between 14 -18.

The dominant species were identical to those dominating the previous Danube sections, i.e.: *Brachionus angularis angularis, B. budapestinensis budapestinensis, B. calyciflorus, Keratella cochlearis cochlearis, K. c. var. tecta, Bosmina (Bosmina) longirostris*. Frequently occurring species were almost identical but complemented with *Polyarthra vulgaris* and *Thermocyclops oithonoides* species.

Individual abundance values increased considerably ranging between 940-1560 ind./m^3 This is probably due to the effects of impoundment, decreased flow velocity and higher nutrient resource availability for filter-feeders. Phytoplankton biomass also increased to 5808 µg/l, (see Fig ZPL-1).

The mouth of the Morava River was dominated by species indicating eutrophic and polluted water (predominantly Rotatoria) with abundance values of 6200 ind./m^3. Very large mass of Microcystis blue-green algae was also observed at this point in the net samples, underlining the eutrophic situation. In spite of this, the occurrence of some rare species was also recorded *(Lecane (Monostyla) closterocerca, L. (Monostyla) psammophila).*

Reach 4:

The number of species identified in the Danube between Gabcikovo and Budapest (1846-1659 km) varied between 17-19, and their abundance ranged between 940-1560 ind./m^3 These values as well as the dominant and frequently occurring species were practically identical to the ones determined in the Gabikovo Reservoir. Interestingly, in this reservoir both the individual numbers of zooplankton and the algal biomass values were only slightly elevated (Fig ZPL-1).

Amongst the rare species, the following were prominent: *Asplanchnopus multiplex, Collotheca atrochoides, Euchlanis triquetra, Trichocerca elongata*, and some other taxon that was never found in the Upper Danube section: *Asplanchna brightwelli, Brachionus diversicornis, B. quadridentatus, Filinia longiseta, Keratella torpica, Trichocerca pusilla, Chydorus sphaericus, Daphnia galeata, Moina micrura, Eucyclops macruroides, E. serrulatus, Mesocyclops leuckarti*. (see Annex -Zooplankton). A gradual increase in individual abundance values is observed along this longitudinal section (see Fig. ZPL-2).

Considering the left side tributaries, the water of the Vah River can be classified as polytrophic as indicated by the high individual number of zooplankton (84400 ind./m^3). Under favorable conditions, large populations of Rotatoria and Crustacea species are formed which consist only of a few, often only one species. Contrary to the results of the previous studies, only 10 taxa were identified from the Hron River during JDS. Individual numbers (2300 ind./m^3) are characteristic to this part of the river. However, the Ipoly River showed an unusually rich species composition (30 species), with large individual numbers (13840 ind./m^3) composed of some eutrophic Rotatoria genera (*Brachionus, Euchlanis, Keratella, Synchaeta*). The probable explanation for this is the back bulking effect of the main arm of the Danube resulting in stagnant water conditions in this tributary (see Fig. ZPL-3 and Annex- Zooplankton).

Reach 6:

The taxon numbers in the Danube between Budapest and Beograd/confluence with the Sava (1659-1202 km) varied between 14-26; and altogether 66 Rotatoria and Crustacea taxa were identified in the filtered samples.

The dominant species included: *Brachionus angularis angularis, B. budapestinensis budapestinensis, B. calyciflorus, Keratella cochlearis cochlearis, K. c. var. tecta, Polyarthra vulgaris, Bosmina (Bosmina) longirostris, Acanthocyclops robustus*. Frequently occuring species were: *Asplanchna* *brightwelli, Brachionus quadridentatus, B. urceolaris, Lecane (Monostyla) bulla, Synchaeta oblonga, S. pectinata, Trichocerca pusilla, Diacyclops bicuspidatus, Mesocyclops leuckarti, Thermocyclops crassus. Mesocyclops leuckarti*. It is rather interesting that no new rare species were found during this investigation.

Individual numbers varied between 1700-1452200 ind./m^3, especially downstream of Budapest and point of confluence with the Drava, and increased considerably in the region of Novi Sad and Beograd. The reasons for this lie in lower flow velocity, high organic material load of the waste waters and high availability of food for the filter-feeder zooplankton species. This lead to an increase in the individual numbers of Rotatoria communities in particular (see Fig.ZPL-2,3 and Annex-Zooplankton).

The highest algal biomass values (6897-39926 µg/l) and the highest values of zooplankton individual abundance were measured in this particular Danube section. It is very interesting that the increase in algal biomass started already in the region of Tass (1586 rkm) and continued all the way to Hercegszántó (1434 rkm) close to the Hungarian-Yugoslavian border. From this point on, a gradual decrease of phytoplankton biomass was observed towards the Danube Delta. The individual number of zooplankton started to increase significantly from the Hercegszántó region and reached its maximum between the confluence points with the Drava and the Tisza (1384-1200 km), where algal biomass decreased to the range of 832-3341 µg/l (Fig ZPL-1). This phenomenon is the result of grazing/filtering by zooplankton. It is also noted, that on this river stretch the filtered samples contained large volumes of *Microcystis, Fragilaria, Melosira algae* that are, however, not available for filter-feeder types of zooplankton due to their size.

Another interesting observation was that in the Danube between 1379 km (Osijek) and 1071 km (Banatska Palanka/Bazias) very large phytoplanktic communities - like algal-bloom – were formed by a few algal species (*Fragilaria, Melosira, Pediastrum, Microcystis spp*) formed. The identification and counting of zooplankton were extremely difficult due to the large number of algae in the filtered samples.

The dominant species were the following: *Brachionus angularis angularis, B. budapestinensis budapestinensis, B. calyciflorus, Keratella cochlearis cochlearis, K. c. var. tecta, Polyarthra vulgaris, Bosmina (Bosmina) longirostris, Disparalona rostrata, Acanthocyclops robustus*. Frequently occurring species included, among others: *Asplanchna brightwelli, Brachionus quadridentatus, B. urceolaris, Synchaeta oblonga, S. pectinata, Diacyclops bicuspidatus, Mesocyclops leuckarti, Thermocyclops crassus*.

The species composition of communities changed significantly. The predatory *Asplanchna brightwelli* became frequent while the *Synchaeta* species disappeared from Ilok-Backa Palanka (1300 rkm) from the plankton. The number of Crustacea species, especially Cladocerans, increased. The occurrence of tychoplanktonic Disparalona rostrata species became dominant in this stretch. The thermophylic planktic species *Diaphanosoma brachyurum* occurred more and more frequently at many sampling sites. Rare species were represented by only a few members: *Asplanchna sieboldi, Brachionus falcatus, Eurytemora velox*.

The results of quantitative investigations support the above outlined pattern. In spite of the high taxon number, the characteristic species of eutrophic stagnant waters occured almost exclusively. The highest individual numbers were measured in this particular river stretch near Novi Sad and the confluence with the Tisza River.

Considering the tributaries in the Hungarian part of the Danube, the confluence of the Moson arm was rich in species, similar to former observations (26 species), with doubled individual numbers compared to the main arm of the Danube. This is the result of the stagnant character of the river and the back-swelling effect of the main arm.

Species composition and individual number of zooplankton in the Szentendrei-arm was found to be similar to the main arm due to the similar flow conditions (17 species, 1140 ind./m^3).

No water transport happened in the Ráckevei-Soroksári Danube during the investigation period. As a result, large individual numbers were analysed at both sluices of this side arm (Kvassay sluice and Tassi sluice), 15850 and 77020 ind./m^3 respectively. Both sampling sites reported a low taxon number (13 species). The stagnant water of this arm is highly polluted with significant volumes of treated and raw wastewater. This has resulted in the development of large amounts of dominant Rotatoria and Crustacea taxa - a characteristic of polytrophic waters. A similar situation was found in the confluence section of the Sió Canal, with the difference that the taxon number was higher (20). At this sampling site, the highest zooplankton density in the Hungarian section was identified (173700 ind./m^3). Dominant and frequently occurring species were identical to those observed in the Ráckevei-Soroksári arm of the Danube (See Fig. ZPL-3 and Annex - Zooplankton).

Reach 7:

Downstream of Pancevo (1161 rkm), zoopankton abundance value drastically decreased with especially low values (max. 15960 and min. 1540 ind./m^3) in the 122-km-long river section between Banatska Palanka/Bazias -Timok (Radujevac/Gruia), where the algal biomass also decreased. In the Iron Gate Reservoir, neither the species number nor the individual abundance values were higher than in the upstream stretches. Algal biomass was also low (403-832 µg/l) in this section (Fig. ZPL-1).

Concerning the Danube's tributaries in Reach 7, an extremely large amount of Fragilaria crotonensis diatom population was observed in the filtered samples of the Drava. The dominant zooplankton species were the following: *Brachionus calyciflorus, Keratella cochlearis cochlearis, K. c. var. tecta, Polyarthra vulgaris, Synchaeta oblonga, S. pectinata*. It is rather interesting that among the Crustaceans no high individual number species were found. The other interesting result was that the Rotatoria species *Brachionus angularis* and *B. budapestinensis*, which were dominant at all other sampling sites, were lacking here. According to the results of quantitative investigations, the individual numbers were high but significantly lower than in the Danube itself (44100 ind./m^3).

In the Sava, large numbers of *Fragilaria crotonensis* were found. Dominant species were identical to those found in the Drava, except for two *Synchaeta* species. However, at only 11220 ind./m^3 abundance was low.

In contrast to this, a low number of taxa (12) was found in the Velika Morava, with large amounts of *Melosira granulata*. Dominant zooplankton species were identical to those observed in the Sava. The extremely high individual number (799640 ind./m^3) was almost entirely formed by *Brachionus* and *Keratella Rotatoria* species.

Reaches 8 and 9:

In the joint Romanian-Bulgarian and Romanian Danube stretch (Jantra-Reni, 537-135 rkm) and further downstream in the Delta, both species number (8-19) and abundance values (1160-10660 ind./m^3) were significantly lower than in the upstream part of the Danube.

The dominance of the species also changed. As far as Calafat (795 rkm), *Brachionus angularis angularis, B. calyciflorus, B. urceolarisa, Keratella cochlearis cochlearis, K. c. var. tecta, Acanthocyclops robustus* were dominant.

Downstream of this site, *Brachionus calyciflorus* disappeared from the samples and once reappeared with elevated frequencies downstream of the confluence of the Arges (434 rkm). This river section is characterised by the dominance of the following species: *Brachionus angularis angularis, B. calyciflorus, Keratella cochlearis cochlearis, K. c. var. tecta, Polyarthra vulgaris, Bosmina (Bosmina) longirostris, Disparalona rostrata, Acanthocyclops robustus, Thermocyclops crassus*. The small number of species and their individual abundance might be due to the high content of suspended solids in the river downstream of the Arges confluence, which made the determination and counting of the animals nearly impossible, and required several-fold dilution.

The occurrence of some rare species has to be mentioned: *Dipleuchlanis propatula, Elosa worallii, Trichocerca longiseta, Alona karelica, Pleuroxus trigonellus, Eurytemora velox* in this Reach. These species usually occur in eutrophicated waters polluted with organic loads.

A mass appearance of *Melosira granulata* and *Microcystis aeruginosa* algal species was observed in the filtered samples of the Olt and the Jantra tributaries. Both species number (10 and 9) and zooplankton abundance were low (19200 and 5160).

Dominant species of the Olt river were: *Keratella cochlearis cochlearis, K. c. var. tecta, Daphnia cucullata, D. galeata, Acanthocyclops robustus, Thermocyclops crassus*. In contrast to this, only B*rachionus angularis angularis, Keratella cochlearis var. tecta and Bosmina (Bosmina) longirostris* were found in the Jantra.

Rotatoria and Crustacea communities of the Rusenski Lom were similar to those found in the above mentioned two tributaries. The Siret and the Prut were both poor in species (10 and 11 species), and low in their abundance (2180 and 5500 ind./m^3). Dominant species were more or less the same: *Brachionus angularis angularis, Pompholyx sulcata, Bosmina (Bosmina) longirostris, Disparalona rostrata, Mesocyclops leuckarti*. No occurrence of rare species was recorded in these rivers (see Fig. ZPL- 1,2 and Annex-Zooplankton).

4.6.4 Summary and Conclusions

A total of 120 species - 79 Rotatoria, 27 Cladocera and 14 Copepoda – were identified in the Danube and its tributaries during JDS.

The number of zooplankton taxa found at JDS sampling sites varied between 4-26 in the Danube and 6-30 in its tributaries. A gradual increase was observed as one moved downstream.

Individual abundance of the zooplankton communities varied largely, i.e. between 280 –1383600 ind./m3 in the Danube and 1140 – 799640 ind./m^3 in its tributaries. A high individual abundance indicated eutrophic-polytrophic conditions of nutrient enrichment in slowly running rivers.

The dominant species of Rotatoria and Crustacea plankton in the Danube River section between Neu Ulm and Tulcea were: *Brachionus angularis angularis, B. budapestinensis budapestinensis, B. calyciflorus, Keratella cochlearis cochlearis, K. c. var. tecta Bosmina (Bosmina) longirostris, Acanthocyclops robustus*. In the Yugoslavian and Romanian part of the Danube, this was complemented by *Polyarthra* *vulgaris, Disparalona rostrata, and Thermocyclops crassus species*. Nauplius and kopepodite larvae of Copepods were present in great numbers in almost every sample.

The occurrence of many rare species was recorded especially in the German, Austrian, Slovakian and Hungarian part of the Danube. The highest species richness was found in the Hungarian and Yugoslavian sections of the River.

Neither the number of species, nor their individual numbers were significantly elevated in the reservoirs of the Danube.

The lowest individual numbers were measured in the German, Austrian, Romanian and Bulgarian stretches of the River.

The highest individual numbers were registered downstream of Budapest and in the Yugoslavian part of the Danube near Novi Sad, and between the confluence points with the Tisza and the Sava rivers. These results are not in accordance with those generated by previous investigations during which record individual numbers were observed further downstream in the Romanian, Bulgarian and Ukrainian stretches of the River and in the Danube Delta.

Comparison of phytoplankton biomass and zooplankton individual abundance showed low values for the Danube from Neu-Ulm to Tass, as well as in the Iron Gate Reservoir and the Danube Delta. In the upper Danube section, this is the result of a higher flow velocity; in the lower section it is due to the higher content of suspended solids.

In the slow-flowing, highly eutrophicated stretch of the Danube River between Tass and the confluence with the Tisza, large populations of zooplankton were observed where the algal biomass decreased in parallel. The potential reason for this is the filtering effect of zooplankton (grazing effect!).

The effect of the tributaries on the Danube, which is reflected in a changed species composition and an increase in zooplankton density, has been proved in many cases.

Species composition and abundance values of Rotatoria and Crustacea vary a lot in the tributaries. In highly eutrophicated water bodies polluted with organic loads the number of species is usually lower, but large populations are formed by one or only few species.

4.6.5 References

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