Lauterbornia 69: 87-105, D-86424 Dinkelscherben, 2010-05-10

The macroinvertebrate and nematode community from soft sediments in impounded sections of the river Elbe near Pardubice, Czech Republic

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With 3 figures and 7 tables

Keywords: Nematoda, Oligochaeta, Chironomidae, Diptera, Insecta, macroinvertebrates, Elbe, Czech Republic, river, diversity, abundance, biomass, faunistics, soft sediment, impoundment
Schlagwörter: Nematoda, Oligochaeta, Chironomidae, Diptera, Insecta, Makrozoobenthos, Elbe, Tschechien, Fluss, Abundanz, Biomasse, Biozönotik, Faunistik, Feinsediment, Aufstau

In 2005 and 2006, the macroinvertebrate and nematode community from soft sediment areas in impounded sections of the river Elbe in the Czech Republic near Pardubice was investigated. 99 macroinvertebrate taxa, most of them belonging to the Oligochaeta and the Chironomidae, were found with total abundance ranging between 1526 and 6067 ind./m². The total number of nematode taxa was 45, their total abundance varied between 16 726 and 17 235 ind./m². Faunistic aspects, diversity, abundance and biomass are discussed and compared with the community of other impounded rivers.

1 Introduction

Hydro-morphological alterations are among the key pressures on river ecosystems in Central Europe. One of them is the impoundment of rivers for hydroelectric power, shipping or other purposes. Negative effects on the invertebrate communities as a consequence of the reduced flow velocity and the monotonous sediment structure have been described by numerous authors (Herzig 1984, Boon 1988, Penczak & al. 2006).

However, quantitative data on invertebrates from soft sediments in impounded rivers are surprisingly rare, especially from large rivers. The main reasons are the high methodological effort of sampling and difficulties in taxonomy, since the dominant invertebrate groups in soft sediments (Nematoda, Oligochaeta and Chironomidae) belong to the most difficult ones in terms of species determination.

Our study is part of the EU project MODELKEY (511237-GOCE), which aims at investigating the impact of key pollutants on aquatic communities. In this paper, we present quantitative data on the macroinvertebrate and nematode community from soft sediments in impounded sections of the river Elbe in Czech Republic. The paper concentrates on the faunistic aspect in high taxonomic resolution and fills a gap of knowledge about invertebrate communities of heavily modified water bodies as defined in the Water Framework Directive (2000/60/EC WFD).

2 Material and Methods

2.1 Description of the study sites

The river Elbe and its catchment area represent the third largest central European river basin (Prange & al. 2000). The river is situated in the Czech Republic and Germany and is 1094 km long (Fig. 1). It covers a catchment area of 148 268 km² that is inhabited by 24.5 million people (IKSE 2005). The Czech stretch of the Elbe upstream of the Hřensko/Schmilka border settlements covers a basin area of about 50 000 km². Mean discharge at the German-Czech border is 314 m³/s. Between the border and the city of Hradec Králové, the Elbe is regulated and divided into numerous impounded sections (ISKE 2005, Fuksa 2006). The study sites are situated in a river stretch between Hradec Králové and Týnec (Fig. 1), which comprises four impounded sections, each of them 6.63 to 15.89 km long. Water level differences between upstream and downstream of the weirs vary between 2.57 to 3.90 m, the mean slope between Hradec Králové and Přelouč is 0.46 % (IKSE 2005).

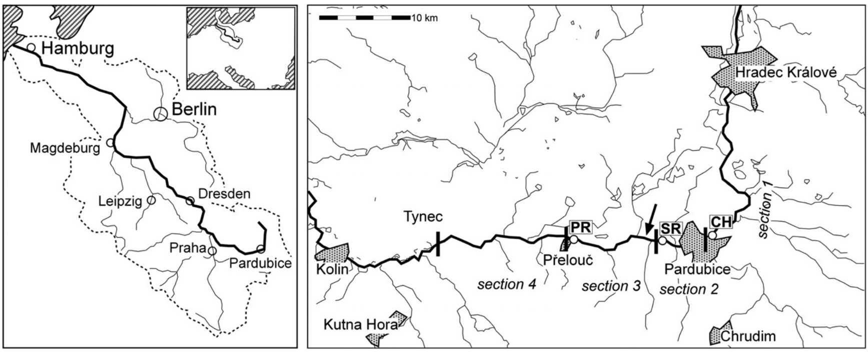

Fig. 1. Sampling locations in the river Elbe near Pardubice. The arrow marks the inflow of industrial sewage. PA, SR, PR = sampling sites

Whereas some sections of the river Elbe still include natural stretches with meanders and torrential zones, the sections near and downstream of Pardubice represent a channelized and impounded river (Fig. 2, 3). Each of the impounded sections includes a fast flowing stretch below the weirs and an almost stagnant

Fig. 2: The power plant of Přelouč. The sampling site PR (Fig. 1) is situated about 50 m upstream the weir

Fig. 3: Impoundment of the river Elbe (section 3, cf Fig. 1), about 4 km upstream of Přelouč

stretch upstream of them. The channelized stream is about 20 m wide, the water depth ranges from 0.5 m below the weirs up to 3 m in front of the weirs. Mean discharge MQ at the gauge of Přelouč is about 57 m^3/s, MNQ is 15.9 m^3/s (IKSE 2005). Age and installed capacity of the hydro-electric power plants situated at the end of first three sections (Fig. 1) are:
Pardubice: constructed 1965/72, installed capacity 1.94 MW
Srnojedy: weir constructed 1932/37, power plant 1940/47, installed capacity 2.21 MW
Přelouč: constructed 1921/27, installed capacity 1.84 MW

The macroinvertebrate sampling campaigns concentrated on the sections 1 to 3 with sites denoted as Pardubice (PA), Srnojedy (SR) and Přelouč (PR) as presented in Fig. 1. The three sites are similar in terms of hydro-morphology. The site PR, however, is influenced by effluents of the chemical industry of Srnojedy (Synthesia Co.) together with municipal water treatment plant discharge.

The sediment of the river Elbe is gravel in the flowing sections, whereas sandy silt and clay dominate in the sedimentation areas upstream the weirs. Macrophytes are lacking, but in the riparian zone branches of shrubs and willows hang into the water and provide some structure within the monotone bed profile. Sampling sites were situated in the soft sediment zones in front of the weirs of the impounded river (Fig. 1).

General hydro-chemical data of the Elbe are available from the national monitoring station at Valy, downstream of Pardubice in section 3 (Tab. 1).

Tab. 1: Hydrochemical data from the river Elbe at the national monitoring station of Valy, between Srnojedy and Přelouč (IKSE 2007). All values are annual arithmetic means of single samples or weekly mixed samples (n = 13). Discharge Q, water temperature T, pH, electric conductivity C (25 °C) and oxygen concentration O_2 was measured continuously. Suspended solids SS are given as median in order to compensate for the high seasonal variability (depending on discharge conditions). Acid neutralizing capacity ANC was calculated from the ion balance. Other abbreviations: DOC = dissolved organic carbon, Ca^{2+} = calcium, Mg^{2+} = magnesium, Na^+ = sodium, K^+ = potassium, Cl^- = chloride, SO_4-S = sulfate (as S), TP = total phosphorus, SRP = soluble reactive phosphorus (= orthophosphate o-PO_4-P), TN = total nitrogen, NO_3-N = nitrate (as N), NO_2-N = nitrite (as N), NH_4-N = ammonium (as N), SRSi = soluble reactive silica (= SiO_2-Si), Chl-a = chlorophyll-a

Parameter	Unit	Value	Parameter	Unit	Value
Q	m^3/s	63.6	Cl^-	mg/l	28
T	°C	11.7	SO_4-S	mg/l	21
pH	-log [H+]	7.2	ANC	mmol/l	2.4
C	µS/cm	463	TP	mg/l	0.12
O2	mg/l	10	SRP	mg/l	0.07
SS	mg/l	10	TN	mg/l	6.2
DOC	mg/l	5.5	NO_3-N	mg/l	5.3
Ca^{2+}	mg/l	69	NO_2-N	mg/l	0.076
Mg^{2+}	mg/l	6.5	NH_4-N	mg/l	0.2
Na^+	mg/l	18	SRSi	mg/l	4.25
K^+	mg/l	4.3	Chl-a	µg/l	14.5

2.2 Sampling and sample processing

Sampling campaigns were carried out on 19 May 2005 and on 22 May 2006. From a boat, 10 replicates were taken at each site and date. In 2005, an Ekman grab was used (area of each replicate: 225 cm^2), whereas in 2006 samples were taken with cores (ø 6 cm, each replicate as mixed sample of 3 single cores giving a total area per replicate of 84.8 cm^2). The upper 10 cm layer of each sediment core or grab were transferred into plastic flasks and stored in a 4 % formalin solution.

In the laboratory, all samples were sieved using a 500 μm mesh. Subsamples were produced with a 250 μm mesh in 2005 in order to check for loss of taxa and individuals. Unless explicitly stated, all numbers of taxa richness, abundance and biomass refer to the samples sieved with 500 μm.

Invertebrates were separated from the sediment and counted using a dissecting microscope (25–40 x magnification). As far as possible, identification was done for all major benthic groups on species level, including Chironomidae and Oligochaeta.

Macroinvertebrate taxa were determined using the following identification keys (selected): Sperber (1950), Wachs (1967), Brinkhurst (1971), Wiederholm (1983, 1986), Moller Pillot (1984a, 1984b), Rivosecchi (1984), Steinlechner (1987), Pitsch (1993), Sauter (1995), Gittenberger & al. (1998), Glöer & Meier-Brook (2003), Vallenduuk (1999), Vallenduuk & Moller Pillot (1999), Klink (2002), Killeen & al. (2004), Neu & Tobias (2004), Bauernfeind & Humpesch (2001), Glöer (2002), Hölzel (2002), Janecek (2003), Langton & Visser (2003), Timm & Veldhuijzen van Zanten (2003), Eiseler (2005), Wilson & Ruse (2005), Lechthaler & Car (2005), Lechthaler & Stockinger (2005), Orendt (2008).

Nematodes were separated from subsamples, which were taken from cores without sieving. The sediment was rinsed into centrifugation tubes and centrifuged for 5 min at 800 g. After discarding the supernatant, sediment was mixed with a colloidal silica suspension (Ludox TM 50; Sigma-Aldrich, Munich, Germany) that was adjusted to a density of 1.13 g/cm^3 with deionized water. After centrifugation for 15 min at 800 g, the supernatant was filtered through a 10 μm gaze that retained all nematodes. The extraction steps were repeated three times. Less than 10 % of the total number of extracted nematodes were found in the third extraction step. The retained organisms were rinsed into Petri-dishes, where they were counted using a dissecting microscope (25–40 x magnification). From each sample approximately 100 nematodes were transferred and prepared in glycerol (Seinhorst 1959). Nematodes were determined under the microscope to species level (1250 x magnification; Leitz, Dialux).

The biomass of macroinvertebrates was determined in different ways:
1) For Tubificidae, Lumbriculidae and Chironomidae, length-mass-relationships from Lindegaard (1992), Burgherr & Meyer (1997) and Salbrechter (2001) were used (Tab. 2). A regression originally derived from *Limnodrilus profundicola* (Verrill) was also applied to large specimens of Enchytraeidae, since a comparison with data from Lindegaard (1992) showed a good correspondence of the regression results.
2) Some large animals and bulks of small animals of a few groups (Hydrozoa, Bivalvia, Ephemeroptera and Trichoptera) were weighed directly on a balance as "formaldehyde fresh mass" (FM) after removing the formaldehyde solution with a filter paper. Fresh mass was converted to dry mass (DM) assuming a FM: DM factor of 6 (Waters 1977). No correction for weight loss due to storage in formalin was made.

For evaluation of these two different ways of biomass determination, the biomass of a subsample of *Limnodrilus hoffmeisteri* Claparéde specimens was calculated in both ways. The difference of individual biomass was about 8 % (dry mass from length-mass-regression: 311 μg, dry mass converted from formaldehyde fresh mass: 338 μg), suggesting a good compliance of the two methods.
3) Due to their small size, some Oligochaeta (mainly Naididae) and all Nematoda and microcrustaceans (Copepoda, Ostracoda, Anomopoda) were not weighed directly, nor could they be measured under the microscope with reasonable effort. For these taxa, biomass was roughly estimated using species-specific values for the mean individual body mass. They were derived from literature data (Girtler 1987, Traunspurger 2002) as well as own estimations, which are related to the Tubificidae and Chironomidae calculations, and range from 0.67 μg DM/ind. for nematodes to 108 μg DM/ind. for *Stylaria lacustris* Linnaeus.

Tab. 2: Length-mass-regressions for Oligochaeta using equations from Salbrechter (2001), Lindegaard (1992) and Burgherr and Meyer (1997). Regression for Oligochaeta: $M = a\ D_W^b$, with M = dry mass [mg] in Salbrechter (2001) and ash free dry mass [mg] in Lindegaard (1992), and D_W = diameter [µm] of 8th segment of living Oligochaeta in water. D_W was derived using the equation $D_W = 0.86\ D_B + 79.05$ (from Salbrechter 2001), with D_B = diameter [µm] of 8th segment of formaldehyde preserved animals in Berlese mounts. Regression for Chironomidae: $M = a + b\ L$, with M = dry mass [mg] and L = total length (measured from labrum to procercus) [mm]. * regression originally for *Limnodrilus profundicola* only, ** regression originally for *Stylodrilus heringianus* Claparède

Taxa	a	b	reference
Limnodrilus, Potamothrix, Tubifex, large Enchytraeidae	0.00254	1.85	Salbrechter (2001) *
Spirosperma ferox Eisen	1.673	3.482	Lindegaard (1992)
Psammoryctides barbatus (Grube)	0.00782	1.77	Salbrechter (2001)
Lumbriculidae	5.61	2.709	Lindegaard (1992) **
Chironomidae	–6.67	2.63	Burgherr and Meyer (1997)

3 Results and discussion

3.1 Species composition

Dominating oligochaete taxa were *Limnodrilus hoffmeisteri*, *L. claparedeanus* Ratzel, juvenile *Limnodrilus* sp., unidentified Tubificidae and the Naididae *Vejdovskiella intermedia* (Bretscher). *Limnodrilus* species are among the most common Oligochaeta in polluted waters (Tab. 3). Their dominance in the soft sediments of the polluted river Elbe is thus not surprising. They can be found more frequently in sandy sediments than other tolerant Tubificidae species such as *Tubifex tubifex* (Müller), *Psammoryctides barbatus* (Grube) and some *Potamothrix* species (Brinkhurst 1961, Wachs 1967).

Tab. 3: Taxa list and abundance of macroinvertebrates [ind/m^2] from the river Elbe at Pardubice (PA = Pardubice, SR = Srnojedy, PR = Přelouč) in spring 2005 and spring 2006. Since the mean abundances of major groups were calculated separately as geometric means they differ from the sums of the geometric means of the single taxa

	PA 2005	SR 2005	PR 2005	PA 2006	PR 2006
HYDROZOA			1		
Hydrozoa Gen. sp.			1		
BIVALVIA	1	23	3		2
Unio pictorum (L.)		2	<1		1
Pisidium henslowanum (Sheppard, 1823)	<1		<1		
Pisidium moitesserianum (Paladilhe, 1866)		4			
Pisidium sp.	<1	1	2		
Pisidium supinum (Schmidt, 1851)		<1			
Pisididae Gen. sp.		1			
Sphaerium sp.					1
OLIGOCHAETA	1565	3095	2093	61	470
Lumbriculidae Gen. sp.		<1			
Total Lumbriculidae		<1			
Enchytraeidae Gen. sp.				1	
Total Enchytraeidae				1	
Amphichaeta leydigii Tauber, 1879	<1		1		
Amphichaeta sannio Kallstenius, 1892			<1		
Chaetogaster diastrophus (Gruithuisen, 1828)			<1		
Naididae gen. sp.		1	<1		
Nais bretscheri Michaelsen, 1899	3		4		
Nais communis Piguet, 1906	<1	1	3		
Nais elinguis Müller, 1773	4		4		
Nais pseudobtusa Piguet, 1906		1			
Nais simplex Piguet, 1906			<1		
Ophidonais serpentina (Müller, 1773)	2	3	1		1
Paranais frici Hrabe, 1941		1			
Pristina proboscidea Beddard, 1869			1		
Stylaria lacustris (Linnaeus, 1767)	1				1
Uncinais uncinata (Orsted, 1842)		9	2		
Vejdovskiella intermedia (Bretscher, 1896)	20	13	39	1	
Total Naididae	121	196	96	1	2
Aulodrilus limnobius Bretscher, 1899	1	1			
Aulodrilus pluriseta (Piguet, 1906)	1	3	1		
Ilyodrilus templetoni (Southern, 1909)		2	<1		
Limnodrilus claparedeanus Ratzel, 1868		3	110		2
Limnodrilus hoffmeisteri Claparéde, 1862	231	562	416	7	31
Limnodrilus sp.	732	1575	22	1	11
Potamothrix hammoniensis (Michaelsen, 1901)	<1	10	4	1	3
Spirosperma ferox Eisen, 1879					1
Tubificidae Gen. sp.	116	186	39	5	12
Total Tubificidae	1267	2663	1260	55	409
Oligochaeta cocoons	6	75	243		2
ACARI: Hydrachnidia indet.		3	1	1	1

	PA 2005	SR 2005	PR 2005	PA 2006	PR 2006
EPHEMEROPTERA	1		1	2	2
Baetis vernus Curtis, 1834					1
Caenis horaria (L.)				1	
Caenis luctuosa (Burmeister, 1839)			1		
Caenis macrura Stephens, 1835	1			1	
Ephemera vulgata L., 1758					1
MEGALOPTERA			<1		
Sialis sp.			<1		
TRICHOPTERA	<1			2	
Hydroptila sp.				2	
Oxyethira sp.	<1				
DIPTERA CHIRONOMIDAE	2978	2764	1075	1095	1098
Chironomidae Gen. sp.		<1		3	2
Chironomini Gen. sp.	1		1		
Chironomus plumosus agg.	1	1			
Chironomus sp.	27	5	11	40	11
Cladopelma laccophila gr.	5				1
Cladopelma lateralis gr.	<1				
Cladotanytarsus mancus gr.	3	1	1	1	2
Corynoneura antennalis Kieffer, 1921	1				
Corynoneura sp.	<1		<1		
Cricotopus laetus Hirvenoja, 1973	1				
Cricotopus sp.			<1	1	
Cryptochironomus defectus/rostratus				2	
Cryptochironomus rostratus Kieffer, 1921			1		
Cryptotendipes sp.	8	27	39	7	3
Cryptotendipes usmaensis (Pagast, 1931)	<1				
Dicrotendipes nervosus (Staeger, 1839)	<1				
Eukiefferiella sp.					1
Harnischia sp.			3		
Microchironomus tener (Kieffer, 1918)	841	419			1
Orthocladiinae COP sp.		1		2	
Orthocladiinae Gen. sp.	<1		<1		
Orthocladius (Eu.) sp.			<1		
Parachironomus arcuatus gr.	1	1			
Paracladius conversus (Walker, 1856)				73	28
Paracladopelma camptolabis gr.				1	
Paralauterborniella nigrohalteralis (Malloch, 1915)			3	39	49
Paratendipes albimanus gr.	1141	1387	335	77	2
Phaenopsectra sp.			<1		
Polypedilum albicorne (Meigen, 1838)					2
Polypedilum cultellatum Goetghebuer, 1921	1		<1		
Polypedilum scalaenum gr.	203	118	116	54	219
Polypedilum sp.	<1		1		
Potthastia gaedii gr.	8	4	12		
Procladius (H.) sp.	142	442	56	36	11
Prodiamesa olivacea (Meigen, 1818)	6	<1	21	3	33
Pseudorthocladius sp.	<1				
Pseudosmittia sp.	<1				
Rheocricotopus sp.			1		
Rheotanytarsus sp.	<1				
Stempellinella minor (Edwards, 1929)			2		
Tanypus punctipennis Meigen, 1818	1	5			
Tanytarsus ejuncidus (Walker, 1856)	<1	3	4		
Tanytarsus sp.	2	3	15		
Thienemanniella sp.	<1				
Thienemannimyia carnea (Fabricius, 1805)			<1		
Thienemannimyia/Rheopelopia sp.			1		
DIPTERA OTHER FAMILIES	4		1	3	2
Ceratopogoninae Gen. sp.	1		1	1	1
Dolichopodidae Gen. sp.	1				
Chelifera sp.	1				
Diptera indet.	1			1	1
Muscidae Gen. sp.	1				
Prosimulium sp.				1	
Simulium (s.str.) sp.				1	
Pachygaster sp.			<1		
Total macroinvertebrates	4694	6067	3339	1526	1823

Among Chironomidae, *Paratendipes albimanus* gr., *Microchironomus tener* (Kieffer), *Polypedilum scalaenum* gr. and *Procladius* sp. prevailed (Tab. 3). *Paratendipes albimanus* (Meigen) is a rather tolerant species occurring in moderately polluted rhithral to potamal rivers (Moog 2002), but also in the littoral zone of oligotrophic Alpine lakes (unpubl. data). *M. tener* is found typically in potamal rivers (Evrard 1994) and meso- to eutrophic lakes (Rossaro 1984, Wolfram 1996, Prat & Rieradevall 2006). It occurs predominantly on sandy sediments and seems to find suitable environmental conditions in reservoirs of large rivers. It is reported from reservoirs also by other authors (Potter & Learner 1974, Zinchenko 1992, Kuijpers & al. 1992). Also *P. scalaenum* agg. is typically found in sandy, riverine habitats. The range of distribution of this species extends, however, more towards faster flowing river stretches (hyporhithral – epipotamal) than is the case for *M. tener*.

The most dominant nematode species was *Eumonhystera filiformis* (Bastian), with other species of this genus co-dominating. *E. filiformis* is widely distributed and can dominate the nematode community in very different habitats such as lowland rivers (Gagarin 2009), small carbonate streams (Beier & Traunspurger 2003a, 2003b), glacial-fed streams in the high Alps (Eisendle 2008) and the littoral of lakes (Peters & Traunspurger 2005). Other taxa with arithmetic mean abundance larger than 1000 ind./m^2 were *Diplogaster* sp., Diplogasteridae Gen. sp., *Monhystera paludicola* de Man and Rhabditidae Gen. sp. (Tab. 4).

Tab. 4: Taxa list and abundance of nematodes [ind./m^2, arithmetic mean] from the river Elbe at Pardubice (PA = Pardubice, PR = Přelouč) in spring 2006

Taxa	PA 2006	PR 2006
Achromadora ruricola (de Man, 1880)	364	174
Achromadora tenax Cobb, 1913	0	131
Aglenchus sp.	0	131
Aphelenchoides sp.	364	82
Aporcelaimellus sp.	0	174
Bursilla monhystera (Butschli, 1873)	0	131
Coslenchus costatus (de Man, 1921)	0	307
Cuticularia sp.	0	59
Diplogaster sp.	727	1039
Diplogasteridae Gen. sp.	0	1169
Diplogasteritus sp.	1091	153
Diploscapter coronatus (Cobb, 1893)	364	612
Eucephalobus cf striatus Thorne, 1937	0	59
Eumonhystera barbata Andrássy, 1981	364	0
Eumonhystera dispar (Bastian, 1865)	1091	3557
Eumonhystera filiformis (Bastian, 1865)	2182	4921
Eumonhystera longicaudatula (Gerlach & Riemann ,1973)	0	405
Eumonhystera pseudobulbosa (von Daday, 1896)	1091	440
Eumonhystera simplex (de Man, 1880)	1091	534
Eumonhystera sp. 1	364	35
Eumonhystera vulgaris (de Man, 1880)	1454	526
Eumonhystera sp. 3	1818	1466
Filenchus vulgaris (Brzeski, 1963)	364	285
Hemicycliophora typica de Man, 1921	0	131
Heterocephalobus elongatus (de Man, 1880)	0	59
Hirschmaniella gracilis (de Man, 1880)	0	225
Monhystera paludicola de Man, 1880	727	1582
Monhystera wangi Wu & Hoeppli, 1932	0	76

Taxa	PA 2006	PR 2006
Mononchus tunbridgensis Bastian, 1865	364	0
Panagrolaimus sp.	0	592
Plectus aquatilis Andrássy, 1985	0	248
Plectus opisthocirculus Andrássy, 1952	0	82
Plectus sp.	0	305
Prismatolaimus sp.	0	131
Prodorylaimus sp.	0	59
Psilenchus aestuarius Andrássy ,1962	0	59
Rhabditidae Gen. sp.	1454	1147
Tobrilus diversipapillatus (Daday, 1905)	0	166
Tobrilus sp.	364	0
Tripyla affinis de Man, 1880	364	0
Tripyla cf glomerans Bastian, 1865	0	59
Tylenchus sp.	364	111
Tylenchidae Gen. sp. 1	364	225
Tylenchidae Gen. sp. 2	0	209
Tylenchorhynchus dubius (Buetschli, 1873)	0	117
Total Nematoda	16726	21972

3.2 Taxa richness and diversity

Total taxa richness of macroinvertebrates in the soft sediment zones was 99 (including taxa at higher taxonomic rank; 76 taxa identified on species or species group level), ranging from 31 to 55 at single sites and dates (Tab. 5). Chironomidae (in total 46 taxa, 25 identified on species or species group level) and Oligochaeta (in total 27 taxa, 21 identified on species level) were the major benthic groups richest in taxa (Tab. 3). The use of a lower mesh size (250 μm) in a subset of the samples in 2005 did not significantly change the taxa richness. Only two Naididae species (*Vejdovskyella comata* (Vejdovsky) and *Nais pardalis* Piguet) were found exclusively in the fraction 250–500 μm. Theoretical taxa richness, calculated using the non-parametric species richness estimators Chao2 and second-order jackknife (Colwell 2005), was much higher than the observed one, ranging from 52 to 91 in 2005 and from 41 to 51 in 2006, respectively. Diversity varied only slightly at the sites studied. Shannon index of diversity *H'* ranged from 1.85 to 2.32, evenness was 0.46 to 0.66. Inspite of lower taxa richness in 2006 as compared with 2005, diversity and evenness did not significantly differ between the two sampling campaigns.

Tab. 5: Taxa richness *S*, diversity *H'* and evenness *E* of the soft sediment macroinvertebrate community in the river Elbe at Pardubice (PA = Pardubice, SR = Srnojedy, PR = Přelouč) in spring 2005 and spring 2006. *N* = total number of individual determined in the samples, *S* = observed taxa richness, *H'* = Shannon index of diversity (based on natural logarithm), *E* = Evenness, *Jack2* = (non-parametric) second-order Jackknife estimate of total taxa richness, *Chao2* = Chao's (non-parametric) estimate of total taxa richness (in brackets: 95% confidence limits)

Site/Year	N	S	H'	E	Jack2	Chao2
PA 2005	1175	53	1.837	0.463	91	82 (66–120)
SR 2005	1497	40	1.851	0.502	58	52 (44–80)
PR 2005	975	55	2.315	0.578	81	69 (60–93)
PA 2006	419	29	2.231	0.663	51	49 (35–104)
PR 2006	509	31	1.947	0.567	49	41 (34–68)

Taxa richness of nematodes ranged from 20.2 to 26.0 per sample. Total taxa richness was 21 at site Pardubice and 41 at Přelouč (in total: 45). The difference can be accounted to different sample sizes (in terms of identified nematode specimens). Rarified to n <50 (less than 50 specimens), taxa richness is similar: with n = 30 taxa richness is 14 at both sites, with n = 50 taxa richness is 17 at PA and 18 at PR. With n >50, an increasing number of rare taxa was found at Přelouč. Correspondingly, Shannon index of diversity was nearly the same at PA (2.83) and PR (2.87), but evenness was higher at PA (0.930) than at PR (0.773).

The invertebrate fauna of soft sediments in the study area of the river Elbe is comparatively poor in taxa. Invertebrate groups with rheophilic species are lacking (Plecoptera) or occur only in low abundance (Ephemeroptera, Trichoptera). Dominating macrobenthic groups in the soft sediment zones of the impounded river are Chironomidae and Oligochaeta, which usually prevail in the invertebrate community of impounded rivers (e.g. Herzig 1984, 1989, Tittizer 1997) or in muddy-sandy riparian zones and slowly flowing side arms of lowland rivers (van den Brink & van der Velde 1991, Csányi & al. 1994, Zauner & al. 2001).

The sampling sites can, of course, not be regarded as representative for the whole river section between Hradec Králové and Týnec, since sampling was restricted to the soft sediment zones. Higher species richness and especially a higher proportion of EPT-taxa can be found in the riparian zones and in the short torrential river stretches below the weirs of the river Elbe near Pardubice (Adámek & al. 2007). Significantly more EPT-taxa are also known from the freely flowing section of the Middle and Upper Elbe in Germany (Beilharz & al. 2002).

The low diversity at the study sites with Chironomidae and Oligochaeta dominating is clearly owing to the hydro-morphological pressure in the impounded river. A low structural heterogeneity, as found in the uniform soft sediment areas upstream of the weirs, is typically correlated with a reduced faunal diversity (Mackay & Waters 1986, Baekken & al. 1984, Boon 1988, Harding 1992, Parz-Gollner & Herzig 2000).

A comparison of taxa richness and abundance of Oligochaeta and Chironomidae with other large lowland rivers or impounded streams is difficult, since these two groups are frequently not identified on species level. In the muddy riparian zone of the upper Danube in Austria and in soft sediment zones of the Danube below Vienna, a lower taxa richness of Chironomidae was found, while the number of Oligochaeta taxa was actually comparable to the present study (Reckendorfer 2000, Zauner & al. 2001). In the Dutch section of the river Rhine, 37 Oligochaeta taxa were recorded (Schmelz 1994). The values of diversity among nematodes, however, compare well with numbers found in other temperate rivers, whereas evenness was higher than in the most other rivers (Tab. 6).

Tab. 6: Diversity (Shannon-Index *H'*) and evenness *E* of nematode communites in various temperate rivers

River (country)	Site	H'	E	reference
Elbe (D)	Alte Elbe	1.35		Heininger & al. 2007
Mur (A)		2.37	0.52	Kirchengast 1984
Elbe (D)	Fahlberg List	2.64		Heininger & al. 2007
Elbe (CZ)	Pardubice	2.83	0.93	this study
Elbe (CZ)	Přelouč	2.87	0.77	this study
Carrega Wood (I)		2.50–2.90	0.49–0.59	Zullini & Ricci 1980
Rhine (D)		2.99	0.56	Bongers & Van de Haar 1990
Seveso (I)		2.50–3.97	0.55–0.68	Zullini 1976
Körsch (D)		3.28	0.81	Beier & Traunspurger 2003b
Mississippi (USA)		3.71	0.82	Anderson 1992
Krähenbach (D)		3.96	0.65	Beier & Traunspurger 2003a
Danube (A)		4.20	0.74	Eder 1983

3.3 Total abundance and biomass

Macroinvertebrate abundance varied between 1526 and 6067 ind./m² (Tab. 3). Dominating major groups were Tubificidae and Chironomidae. Whereas Chironomidae abundance showed little variability (1076–3020 ind./m²), Oligochaeta abundance strongly decreased from spring 2005 (1565–3095 ind./m²) to spring 2006 (61–470 ind./m²) (Tab. 3). Tubificidae and Chironomidae dominated not only in abundance, but also in terms of biomass (Tab. 7). However, due to higher individual biomasses of Tubificidae in 2006, total Oligochaeta biomass was higher than Chironomidae biomass at Přelouč inspite of the much lower abundance.

Tab. 7: Biomass [mg/m² dry mass] of macroinvertebrates from the river Elbe at Pardubice (PA = Pardubice, SR = Srnojedy, PR = Přelouč) in spring 2005 and spring 2006. Since the mean abundance of major groups was calculated separately as geometric means they differ from the sum of the geometric means of the families

Taxa	PA 2005	SR 2005	PR 2005	PA 2006	PR 2006
Hydrozoa			<1		
Bivalvia	1	29	3		5
Bivalvia excl. Unio	1	5	1		1
Oligochaeta	159	320	273	15	128
Enchytraeidae				<1	
Lumbriculidae		<1			
Naididae	5	10	5	<1	1
Tubificidae	147	295	233	15	117
Oligochaeta cocoons	1	8	19		1
Acari		1	<1	<1	<1
Ephemeroptera	1		<1	1	2
Megaloptera			<1		
Trichoptera	<1			1	
Diptera	258	346	115	123	97
Chironomidae	254	346	114	113	84
other families	1		<1	2	1
Total	427	1787	586	204	655
Total excl. Unio	427	701	420	204	334

Abundance were much higher in soft sediment zones of the Danube than in the Elbe near Pardubice, with >50 000 ind./m² in the muddy riparian zone of the upper Danube (Zauner & al. 2001) and in the flood plain below Vienna (Reckendorfer 2000). An abundance of up to 690 000 ind./m² was found in an impoundment of the river Danube in Lower Austria, where Oligochaeta dominated with up to 96 % of total abundance (Parz-Gollner & Herzig 2000). High abundance values were also reported from shifting sand areas in Canadian lowland rivers, with Chironomidae abundance ranging from 12 000 to 78 000 ind./m² (Soluk 1985). In impounded side arms of the Hungarian Danube, however, Csányi & al. (1994) found macroinvertebrate densities of 444–18 000 ind./m² (average about 4000 ind./m²), which is within the same order of magnitude as the numbers found in the Elbe. Also densities in the impounded sections of the river Main (Germany) ranged from about 2500 to about 11 500 ind./m² (Schleuter & Tittizer 1988).

The differences in abundance can only be partly explained by the different mesh size used by the authors (e.g., 100 μm used by Parz-Gollner & Herzig 2000). Also in terms of biomass, which is much less affected by mesh size, the values from the Austrian section of the Danube are clearly higher (2.5–76 g dw/m² on sandy to muddy sediment, Parz-Gollner & Herzig 2000) than in the Elbe near Pardubice (0.2–1.8 g dw/m²) and comparable with numbers in eutrophic ponds or lakes. Biomass values on soft sediment zones of medium to large rivers range between 0.1 and 5.8 g dw/m² (Baekken & al. 1984, Benke & al. 1984, Rabeni & Hoel 2000), which is more alike the situation in the stretch of the river Elbe studied here.

The large variation in total abundance and biomass of macroinvertebrates reflects the complexity of the environmental conditions, which influence and characterize the invertebrate communities in rivers. One of the important environmental factors is the discharge regime, which probably affected the faunal assemblage of the river Elbe especially in 2006. The low abundance in that year may result from a strong flood event in early spring 2006. At the beginning of April 2006 a maximum discharge of 636 m³/s (i.e., >HQ10) was measured at the gauge station of Přelouč (IKSE 2007). That this is a recognizable flood event becomes clear if the maximum monthly means are compared between 2005 and 2006. In 2006 it was considerably higher with 225 m²/s (April) than in 2005 with 133 m²/s in March (Czech Hydrometeorological Institute 2008).

Total abundance of nematodes at the two sites sampled in 2006 was almost the same (PA 16 726 ind./m², PR 17 235 ind./m²) (Tab. 4). They are comparable to values that were found in other parts of the river Elbe. In the German section, Heininger & al. (2007) found mean abundance values of 98 and 183 ind./100 ml in Fahlberg List (polluted site, km 319.4) and Alte Elbe (reference site, km 252.0), which corresponds to 19 800 and 36 600 ind./m², respectively. Nematode abundance found in other temperate rivers were 80 000–230 000 ind./m² on sandy-silty sediments of the river Mississippi (Anderson 1992), 1000–90 000 ind./m² on sandy sediment of the river Danube (Tockner & Bretschko 1996), 40 000–400 000 ind./m² on coarse and sany sediment of the river Necker (Eisenmann & al. 1998), and 3700–120 000 ind./m² on stones and gravel of the river Körsch (Beier & Traunspurger 2003b).

4 Conclusion

The species composition of invertebrates in soft sediment areas of impounded sections of the river Elbe is comparatively poor. The dominant species are typical of sandy habitats in the lower potamal region and in the littoral of lakes, but seem to find optimal conditions in river impoundments. Inspite of the reduced diversity, a high taxonomic effort is required for a thorough description of the invertebrate community, since Oligochaeta, Chironomidae and Nematoda prevail both in terms of taxa richness and abundance. Future work is necessary to work out differences between impounded rivers that belong to different bioregions and river types.

Acknowledgements

The presented work was supported by the European Commission through the Integrated Project MODELKEY (Contract-No. 511237-GOCE). We would like to thank Jiří Huml and Zdenka Valová (IVB Brno) for their invaluable help during the sampling campaign, and Wolfram Stockinger and Philipp Wenzl for analysing selected groups of macroinvertebrates.

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Received: 2009-09-29
Accepted: 2010-01-28