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Macrozoobenthos response to environmental degradation in a heavily modified stream: Case study the Upper Elbe River, Czech Republic

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Abstract: Benthic macroinvertebrates are an important indicator of river health. However, their response upon water quality development downstream the pollution outlets considerably depends on the environmental habitat characteristics. Three successive stretches, each of them providing three different mesohabitats in stillwater (S), torrential (T) and riparian (R) zones were selected for evaluation of the impact of altered metapotamal river bed morphology (channelization) and chemical determinants of water quality on the Upper Elbe River. In downstream direction, the stretches are separated by weirs and characterized as a low polluted low modified natural stream (N), a low polluted channelized stream (C) and a channelized polluted stream (CP). Altogether, 111 benthic macroinvertebrate taxa were recorded in the Pardubice hotspot between Němčice and Přelouč. Despite different levels of stream bed and water quality degradation, micro- and mesohabitat characteristics appeared to be the most important factors determining the diversity of macrozoobenthos in riffle (substrate size structure) and in shoreline (macrophyte community composition and structure) mesohabitats. The diversity of macroinvertebrate communities was highest in riparian mesohabitats compared to stillwater and torrential ones. Saprobic indices increased in downstream direction, thus indicating the decline of water quality.

Key words: macrozoobenthos; pollution; channelization; degradation; the Elbe River

Introduction

In running waters, benthic macroinvertebrates (macrozoobenthos) are considered as one of the best indicators of habitat quality, very conventionally called as “river health”, and this is why they are widely used for water quality assessments (e.g., Hellawel 1986; Rosenberg & Resh 1993; Chessman 1995; Wright 1995). The effort to separate the anthropogenic stress effects from differences related to natural conditions (Rossaro & Pietrangelo 1993) is recently obvious especially in connection with the WFD monitoring programmes (e.g., Rollaufs et al. 2004; Helešic 2006).

The Elbe River and its catchment area belong to one of the largest central European river basins. The river is situated in a landscape heavily modified by various anthropogenic influences. Numerous agricultural, settlement and industrialized areas are spread along the Elbe River and its tributaries. In majority, the river bed has been channelized and the stream serves also for boat navigation.

Recently, many industrial plants have been closed down but still many of them continue operating and some of them discharge their incompletely treated wastes directly into the Elbe River. On the other hand, several river stretches and their biota have recovered significantly due to the reduced pollution from industrial and municipal sources. However, the biological diversity in the Elbe River is still under strong pressure from various anthropogenic impacts, the effects of which are usually combined. Main pressures arise from hydro-morphological degradation and pollution by effluents of industrial activities as well as diffuse pollution (run-off) from agriculture. The area of this study – a metapotamal section of the Elbe River near Pardubice – has been recognized as one of the most polluted and modified river stretches in the Czech Republic (Prange et al. 2000).

The aquatic biota of the Elbe River in the Czech Republic has been investigated only occasionally, although it represents a very important example of degraded and heavily modified riverine ecosystems. The influence of main pollution sources in the Czech part of the Elbe River (including Pardubice hotspot) upon various fish physiological biomarkers, like yolk protein precursors and estrogenic disruptors, heavy metal and pesticide residues contents etc., was studied by Kružíková et al. (2008) and Randák et al. (2006, 2009). They re-

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vealed a significant negative influence of, among others, Synthesia Pardubice Co. upon the load of pollutants in the Elbe River presenting a significant risk to aquatic organisms.

Within the EU project MODELKEY (511237-GOCE), the river section between Němčice and Přelouč was selected as a so called "Pardubice hotspot" for investigating the impacts of key pollutants and morphological habitat degradation upon the aquatic communities (Brack et al. 2005). In this paper, we provide a comparison of different anthropogenic pressures upon basic composition of the invertebrate community in soft sediments of stillwater upweir zones, in hard sandy-gravel-stony substrate of torrential zones and in emersed and hanging down riparian vegetation along the banks of this river section. Its objective was to compare the diversity and response of macrozoobenthos assemblages colonizing different mesohabitats upstream and downstream of the chemical and municipal pollution from the Pardubice town under conditions of morphological river habitat degradation (river channelization).

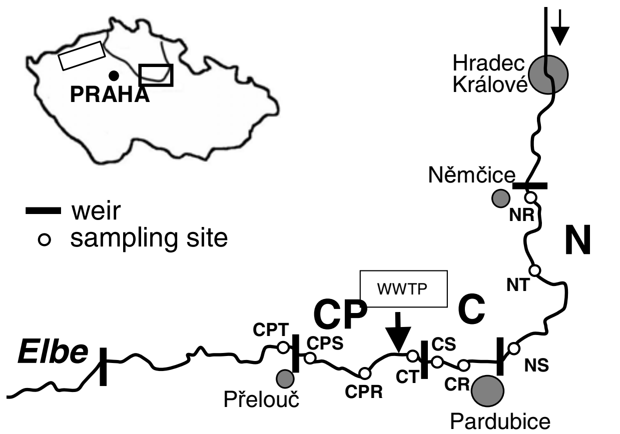

Fig. 1. "Pardubice hotspot" section of the Upper Elbe River with the stretches under study. Abbreviations: WWTP – waste water treatment plant, N – "natural" river stretch, C – channelized river stretch, CP – channelized polluted river stretch, S – stillwater zone, T – torrential zone, R – riparian zone.

Study sites

The Elbe River is situated in the Czech Republic and Germany and is 1,094 km long. Its catchment area upstream the Přelouč location corresponds to 6,432 km^2 with the mean discharge at the Přelouč gauge (lowest downstream profile of surveyed river section) of about 57 m^3 s^{-1} with minimum discharge of 15.9 m^3 s^{-1} (IKSE 2005).

Between the German-Czech border and the city of Pardubice, the Elbe River is regulated and divided into numerous impounded sections (IKSE 2005). The sites of interest in this study (Fig. 1) were situated in three stretches separated by the weirs (3.00 to 3.90 m high) between Němčice (50°5′34.55″ N, 15°48′20.75″ E) and Přelouč (50°2′26.70″ N, 15°33′47.30″ E), each of them being 6.63 to 15.89 km long and with volumes of 1.4 to 1.88 billion m^3.

Whereas the section of the Elbe River upstream Pardubice still includes partly natural river with meanders and torrential zones, the sections at Pardubice and downstream represent a channelized river with generally fluviatile character. The basic hydraulic conditions on the two last mentioned downstream stretches (C and CP – Fig. 1) can be assumed to be comparable except for the level of pollution. All stretches include fast flowing zones below the weirs and almost stagnant stillwater zones upstream them. The mean width of the stream here is about 20 m. Generally, the water depth ranges from 0.5 m downstream the weirs up to 3 m in front of the weirs.

For the purpose of the study, three subsequent stretches were selected. The upper one between the Pardubice weir and Němčice was characterized as a low polluted stream with more or less natural river bed (N), the middle stretch was modified to channelized river bed (C) with slight municipal pollution, whilst the lowest stretch was a channelized river downstream of the outlet of heavy industrial and municipal pollution (CP). Each of the three stretches under study covered three comparable mesohabitats – stillwater (S), torrential (T) and riparian (R) zones. For more detailed substrate traits and basic physico-chemical determinants of individual sampled mesohabitats (zones) during sampling events see Tables 1–3.

The macroinvertebrate sampling campaigns concentrated on the above mentioned stretches with the aim to compare the changes in longitudinal gradient from slightly (natural N – "unpolluted", "unchannelized") to heavily (polluted – P, channelized – C) modified river environment. The most important input of pollution was supposed to affect the river assemblage downstream of Srnojedy, where

Table 1. Substrate traits and physico-chemical determinants of stillwater (S) mesohabitats during sampling events in the natural (N), channelized (C) and channelized polluted (CP) river stretch.

Mesohabitat		NS	CS	CPS
O_2 concentration	mg L^{-1}	13.18	14.05	11.86
O_2 saturation	%	126.8	139.5	115.7
pH		7.32	7.10	7.19
Conductivity	mS m^{-1}	30.6	32.3	34.7
Current velocity	m s^{-1}	0	0.21	0.13
Mean depth	cm	148	174	311
Substrate	%	mud 100	mud 100	mud 100
Deterioration		minor	channelization	channelization pollution

Table 2. Substrate traits and physico-chemical determinants of torrentile (T) mesohabitats during sampling events in the natural (N), channelized (C) and channelized polluted (CP) river stretch.

Mesohabitat		NT	CT	CPT
O_2 concentration	mg L^{-1}	10.97	11.61	12.94
O_2 saturation	%	118.3	113.3	133.3
pH		7.34	7.17	7.14
Conductivity	mS m^{-1}	30.7	32.4	34.4
Current velocity	m s^{-1}	0.74	0.24	0.74
Mean depth	cm	21	27	16
Dominating substrate		sand-gravel	pebbles	pebbles
<2 cm	%	80		
2–20 cm	%	20	10	30
20–40 cm	%		40	70
40–60 cm	%		50	
Deterioration		minor	channelization	channelization pollution

Table 3. Substrate traits and physico-chemical determinants of riparian (R) mesohabitats during sampling events in the natural (N), channelized (C) and channelized polluted (CP) river stretch.

Mesohabitat		NR	CR	CPR
O_2 concentration	mg L^{-1}	11.88	13.04	13.29
O_2 saturation	%	116.7	125.9	131.9
pH		7.29	7.14	7.10
Conductivity	mS m^{-1}	26.8	30.7	35.9
Current velocity	m s^{-1}	1	0.24	0.24
Mean depth	cm	21	27	16
Riparian vegetation				
Glyceria	%		100	40
Phalaris	%	80		40
Urtica	%			10
Typha	%			5
Salix	%	20		5
Deterioration		minor	channelization	channelization pollution

the effluent outlet of the chemical industry (Synthesia Pardubice Co.), together with municipal water treatment plant discharge, is located (the WWTP arrow on Fig. 1). The company emits a strongly chemically smelling effluent, which produces a plume that is visible over a long distance downstream. General hydro-chemical data of the Elbe River are available from the national monitoring station at the Valy site (downstream Pardubice) which is located in the channelized and heavily polluted (CP) river stretch (Table 4).

Material and methods

Sampling and sample processing

Sampling campaigns were carried out in October 2005. The sediment samples in stillwater zones of the Elbe River (S) were collected from the boat by rope operated Ekman grab (225 cm^2) in three replicates. The upper 20 cm layer of each sediment grab sample was sieved using a 500 μm mesh, transferred into plastic flasks and stored in a 4% formaldehyde solution. In the laboratory, invertebrates were separated from the sieved sediment and counted using a dissecting microscope (25–40 fold magnification). As far as possible, identification was done for all major benthic groups on the species level.

Samples from riffle torrential (T) zones were collected using 3-minute "kick sampling" with hand net (20 × 30 cm, 500 µm mesh). Phytophilic macroinvertebrates from the emersed and hanging down riparian vegetation (R) were collected by 3-minute sweep netting from the boat using the same hand net. Collected samples from both torrential substrates and riparian plants were sieved and processed as mentioned above for soft sediments.

Data processing and statistics

Species richness and the EPT (Ephemeroptera/Plecoptera/Trichoptera) ratio were assessed and Shannon's diversity (H') index was calculated (Begon et al. 1990). Saprobic index (SI) of macrozoobenthos was determined according to the Czech National Standard ČSN 75 7716 (1998).

Detrended canonical correspondence analysis (DCA), based on abundance of individual macrozoobenthos taxa, was used to ordinate taxa, mesohabitats and their environmental parameters (ter Braak & Prentice 1988). The faunal data were $\log(x + 1)$ transformed prior to the analysis. Cluster analysis was used to group sites according to the macrozoobenthos taxa, using binary Jaccard index (presence/absence data) for distance measuring. All analyses were carried out using CANOCO software (version 4.5; ter Braak & Šmilauer 2002).

Table 4. Hydrochemical data from the Elbe River at the national monitoring station of Valy, between Srnojedy and Přelouč (IKSE 2007).

Q	T	pH	C	O_2	SS	DOC
$m^3\ s^{-1}$	°C	–log [H^+]	$\mu S\ cm^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$
63.6	11.7	7.2	463	10	10	5.5
Ca^{2+}	Mg^{2+}	Na^+	K^+	Cl^-	SO_4-S	ANC
$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mmol\ L^{-1}$
69	6.5	18	4.3	28	21	2.40
TP	SRP	TN	NO_3-N	NO_2-N	NH_4-N	Chl-a
$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$mg\ L^{-1}$	$\mu g\ L^{-1}$
0.12	0.07	6.2	5.3	0.076	0.20	14.5

Explanations: 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 not given as arithmetic mean, but 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 N, NO_2-N = nitrite N, NH_4-N = ammonium N, Chl-*a* = chlorophyll-*a*.

Table 5. Taxa richness on the mesohabitats under study.

Zone	Stillwater			Torrential			Riparian		
River strech	NS	CS	CPS	NT	CT	CPT	NR	CR	CPR
Total number of taxa	13	14	15	22	13	27	22	24	37
Number of EPT taxa	0	0	0	5	6	5	10	4	5
EPT/total number of taxa (%)	0	0	0	22.7	46.2	18.5	45.5	16.7	13.5
EPT/total number of ind (%)	0	0	0	49.6	52.4	43.6	22.2	19.4	27.7
Shannon-Wiener index	2.06	2.00	2.51	1.95	2.36	1.98	2.19	2.89	2.97
Saprobic index	1.98	1.75	2.46	1.97	2.01	2.01	2.28	2.37	2.34

For abbreviations see Fig. 1 caption.

Results

Altogether, 111 taxa of benthic macroinvertebrates were recorded in the Pardubice hotspot between Němčice and Přelouč (Appendix 1). The number of taxa in stillwater mesohabitats (24 in total) amounted to 13, 14 and 15 in NS, CS and CPS, respectively (Table 5). Their numbers in the torrential zone (48 taxa in total) were lowest in CT (13 taxa), whilst highest figures were recorded in CPT with 26 taxa. The downstream increasing gradient was recorded in riparian phytophilic macroinvertebrate assemblages (56 taxa in total) with lowest taxa richness in NR (23 taxa) and highest one in CPR (38 taxa).

The numbers of EPT taxa were almost identical in all three torrential zones ranging between 5 and 6, whilst in the riparian zone, the highest figures appeared in the natural section with 10 taxa. Their numbers declined downstream to 4 and 7 in CR and CPR, respectively. No EPT taxa were recorded in stillwater soft sediments (Table 5). Their proportion with respect to the total numbers of taxa recorded was highest in the CT and NR mesohabitats with approximately 45% share, whilst in the other mesohabitats it fluctuated around and rather below 20%. The contribution of EPT individuals to the total number of individuals was considerably higher in torrential zones (43.8–54.2%) compared to riparian assemblages (21.5–30.9%).

Shannon's index values fluctuated between approximately 2 and 3 with certain increasing tendency downstream. The downstream increase was most obvious in torrential mesohabitats with 2.19, 2.89 and 2.97 in NT, CT and CPT, respectively. Generally, the diversity of the torrential assemblages was slightly higher (H' 2.19–2.97) than that of macrozoobenthos in soft sediments (H' 1.95–2.36) and riparian mesohabitats (H' 1.91–2.72).

The values of saprobic index increased downstream with the environmental deterioration gradient from 1.98 to 2.46, 1.97 to 2.01, 2.28 to 2.34 in stillwater, torrential and riparian zones, respectively.

Detrended canonical correspondence analysis (DCA) separated mesohabitats into three distinct zone groups, each represented by typical macroinvertebrate assemblage (Fig. 2). First axis differentiate stillwater assemblages on the mesohabitats NS, CS and CPS, represented e.g. by some oligochets (*Limnodrilus hoffmeisteri* Claparède, 1862, Tubificidae g. sp.) and chironomids [*Paratendipes* gr. *albimanus* (Meigen, 1818), *Procladius* sp., *Microchironomus tener* (Kiefer, 1918)] and the assemblages on lotic mesohabitats that were characterized, e.g., by presence of EPT taxa. Second axis, corresponding with oxygen saturation and current velocity, differentiate assemblages of riparian mesohabitats (NR, CR, CPR), represented typically by dragonfly larvae (*Platycnemis pennipes* Pallas, 1771, Coena-

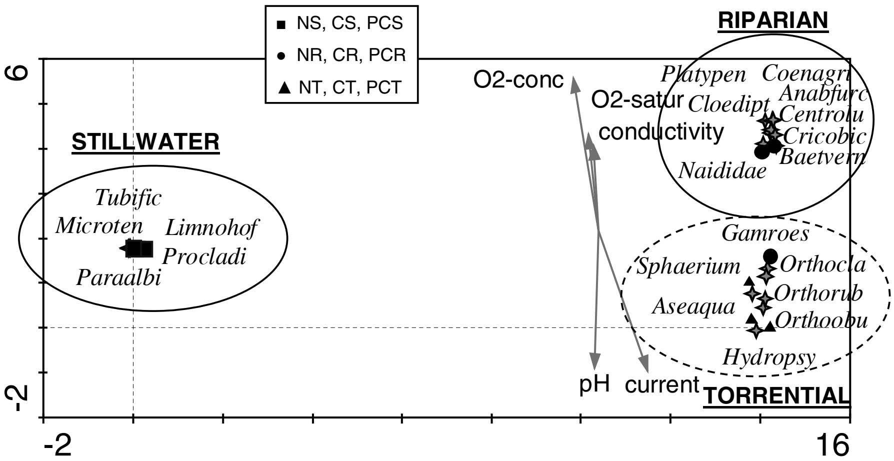

Fig. 2. The DCA ordination plot with samples and investigated environmental factors performed on taxa abundances. Note: First and second principal components are shown. Taxa are represented by their abbreviations: Tubific – Tubificidae g. sp., Limnohof – *Limnodrilus hoffmeisteri*, Naididae – Naididae g. sp., Sphaerium – *Sphaerium* sp., Aseaqua – *Asellus aquaticus* (L., 1758), Gamroes – *Gammarus roeselii*, Baetvern – *Baetis vernus*, Centrolu – *Centroptilum luteolum*, Cloedipt – *Cloeon dipterum*, Coenagri – Coenagrionidae g. sp., Platypen – *Platycnemis pennipes*, Anafurc – *Anabolia furcata*, Hydropsy – *Hydropsyche* sp., Cricobic – *Cricotopus bicinctus* (Meigen, 1818), Microten – *Microchironomus tener*, Orthocla – Orthocladiinae g.sp., Orthoobu – *Orthocladius obumbratus* Johannsen, 1905 sensu Langton & Visser (2003), Orthorub – *Orthocladius rubicundus* Meigen, 1818, Paraalbi – *Paratendipes* gr. *albimanus*, Procladi – *Procladius* sp. For mesohabitat abbreviations see Fig. 1 caption.

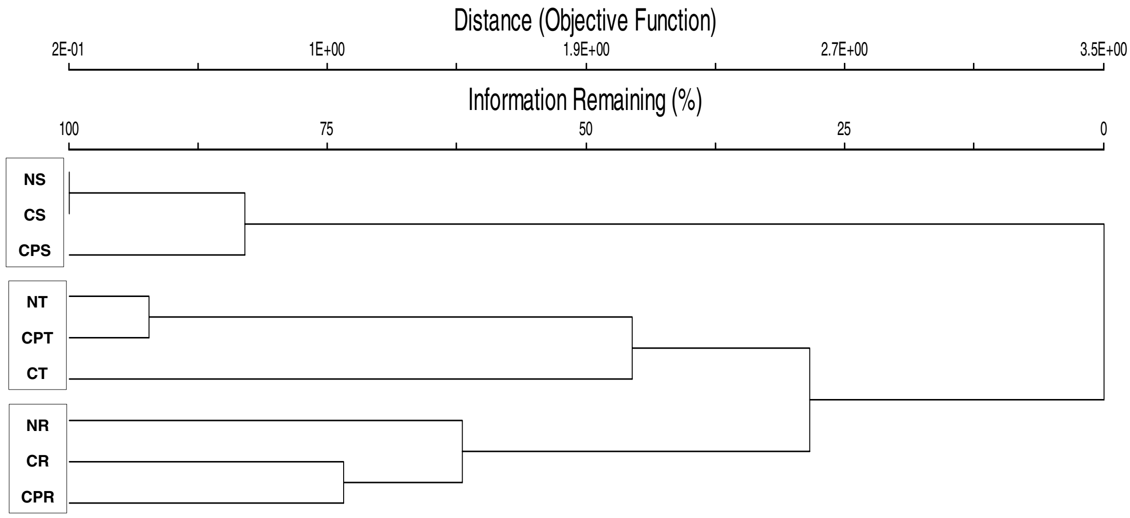

Fig. 3. Cluster analysis (UPGMA, Jaccard index) of samples on each mesohabitat. For abbreviations see Fig. 1 caption.

grionidae g. sp.), mayfly larvae [*Cloeon dipterum* (L., 1761) *Baetis vernus* Curtis, 1834, *Centroptilum luteolum* (Müller, 1776)], caddisfly larvae (*Anabolia furcata* Brauer, 1857), phytophilic oligochetes (Naididae) and others from those of torrential mesohabitats (NT, CT, CPT) represented by *Gammarus roeselii* Gervais, 1835, *Sphaerium* sp., caddisfly (*Hydropsyche* sp. juv.) and chironomid larvae of the family Orthocladiinae. The first axis of DCA explained 25.2% and second one 16.7% (both altogether then 41.9%) of the total variance. Similarly, cluster analysis, based on presence/absence data (Jaccard index) clearly separated the three mesohabitat types (Fig. 3).

Discussion

The invertebrate assemblages in three different mesohabitats (stillwater mud, riparian vegetation and torrential gravel) of the Elbe River in the study area consisted of 111 taxa (Appendix 1). This figure is comparatively high regarding the fact that some surveyed sites were located on a polluted and modified (channelized) river. Moreover, sampling was restricted to a certain period of the year (October) and higher taxa richness could be expected with additional sampling in other seasons. Obviously, the sampling strategy based on the survey of three different mesohabitats also contributed to relatively high final figures. In fact, only one taxon (*Tanytarsus* sp.) was recorded on all mesohabitats. No other taxa were found to be common for either stillwater muddy and torrential riffle and/or for muddy and riparian plant substrate. This finding is in a good agreement with the conclusions of Brabec et al. (2004) who proved that the lotic and lentic habitats in a river differ in taxonomic composition, ecological traits and biotic indices of macrozoobenthos. On the other hand, 16 taxa were recorded as affined to both torrential and riparian mesohabitats, the majority of them belonging to the families Chironomidae and Naididae. Besides them, also the amphipod *Gammarus roeselii* was recorded quite numerously in both riparian plant and torrential stony mesohabitats. Thus, habitat (S, T, R) preferences determined macrozoobenthos assemblage composition, overwhelming potential influence of the river stretch modification and degradation (N, C, CP). Also Pinel-Alloul et al. (1996) conluded that sediment grain size is to be considered as one of the most significant ecological variables to explain variation in macroinvertebrate communities.

Dominating macrozoobenthos groups in the soft sediments of stillwater impounded zones were chironomids and oligochets, 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).

In torrential zones, several species of leeches (Hirudinea) were recorded in CPT, whilst on other mesohabitats they occurred only sporadically. This mesohabitat provided, probably due to higher organic loading and several upstream impoundments, good conditions for collectors, represented by numerous occurrences of *Hydropsyche* sp. (Trichoptera) and *Sphaerium* sp. (Bivalvia). As prognosed in the River Continuum Concept – (Vannote et al. 1980) conception, increasing organic loading results in changes in proportional representation of individual food strategists in favour of collectors and filtrators at the expense of scrapers.

The occurrence of invasive North-American spiny-cheek crayfish *Orconectes limosus* Rafinesque, 1817 was also documented on the CT mesohabitat. The absolute numbers of benthic macroinvertebrates collected by time-limited 3-min kick-sampling in CPT mesohabitat were approximately twice to ten times higher than in the NT and CT samples, respectively (Appendix 1).

Riparian zone was predominantly colonized by phytophilic macroinvertebrates. Besides chironomids, also phytophilic larvae of damselflies [*Platycnemis pennipes*, Coenagrionidae g. sp., *Calopteryx splendens* (Harris, 1825), *Ischnura* sp.], mayflies (*Cloeon dipterum*, *Centroptilum luteolum*) and caddisflies (*Anabolia furcata*) prevailed in samples collected from riparian vegetation. As for the torrential zone, their density in samples collected by sweep sampling along the banks were twice to four times higher in CPR samples (most polluted and modified section) compared to NR and CR samples, respectively. This complies with the finding of Zalewski et al. (2001), who stressed the importance of the riparian ecotone for stream habitat restoration.

Despite increasing degradation of the Elbe River environment in the downstream gradient from more or less natural stretch (N) through channelized slightly polluted (C) to channelized and heavily polluted (CP) stretches, the indicators of water quality and diversity of the macrozoobenthos assemblages did not show any significant signs of degradation both in stillwater soft sediments (S), torrential stony habitat (T) and riparian vegetation (R). However, the degradation in dowstream gradient was obvious from figures of mercury content in chub [*Leuciscus cephalus* (L., 1758)] muscles (Kružíková et al. 2008) which was by approx. 10–90% higher in fish from the Valy site (CP stretch) as compared to Němčice site (N stretch). Paradoxically, the taxa richness and diversity indices increased downstream being lowest in the "natural" upstream stretch (N) and highest in the most modified downstream CP stretch. Despite no considerable differences were found in the "simple" metrics like taxa richness, diversity etc., certain dissimilarities could be revealed when analyzing the data on species level. Also the results of Pinel-Alloul et al. (1996) show that taxon-based and biotic index approaches emphasize different aspects of macroinvertebrate community structure and do not fully agree in ranking the sites according to their environmental quality as defined chemically.

As already presented in many previous studies (e.g., Ormerod & Edwards 1987; Soldán et al. 1998), benthic macroinvertebrates reflect very sensitively various undesirable impacts of human activities upon aquatic ecosystem health. Based on evaluation of 124 sites in streams of the Morava, Vltava and Vlára catchments in the Czech Republic, Adámek & Jurajda (2001) proved that invertebrate taxa richness and diversity followed a unimodal pattern along water pollution and habitat degradation gradients, with maximum values at medium pollution and low richness and diversity values at both ends of the gradient. This pattern was more pronounced in water pollution determinants (saprobic index) than in the determinants of morphological habitat degradation (channelization). Significant relationships between abiotic (BOD, nutrients) and biotic (saprobic index of macrozoobenthos) indicators of organic enrichment were identified also by Brabec et al. (2004). On the other hand, the morphological man-made modifications of the river channel were found to be the main factor negatively affecting lowland river macroinvertebrates and their biodiversity under conditions of homogenous (low) pollution loading (Horsák et al. 2009). Their results indicate that the biggest threat to benthic macroinvertebrate diversity of lowland rivers comes from channelization.

The numbers of taxa in the Upper Elbe River increased in the downstream gradient of the Pardubice hotspot with increasing habitat degradation both from water quality and morphological degradation points of view. Their highest figures were recorded in the CP stretch both for stillwater, torrential and riparian mesohabitats.

Nevertheless, the values of saprobic indices increased in direction downstream, proving a slight deterioration of water quality. This tendency was most evident in the stillwater zones, where the saprobic index increased from 1.98 in NS to 2.46 in CPS mesohabitats. The increase of the saprobic index in torrential and riparian mesohabitats was not very pronounced – from 1.97 to 2.01 in NT and CPT and from 2.28 to 2.34 in NR and CPR. Both mesohabitats provide good environmental conditions for the occurrence of taxa indicating lower saprobic loading like, e.g., *Ancylus fluviatilis* Müller, 1774, *Siphlonurus aestivalis* (Eaton, 1903), *Rhyacophila* sp. and *Polycentropus flavomaculatus* (Pictet, 1834) in CPR and CPT mesohabitats.

The occurrence of EPT taxa was recorded only in riparian and torrential mesohabitats. Their higher proportion with respect to total numbers of macrozoobenthos taxa and individuals was generally recorded in torrential zones than in riparian ones. However the riparian mesohabitat in "natural" section (NR) provided better conditions for EPT taxa, since their share on total taxa number was higher there (43.5%) than in the torrential mesohabitat (NT 22.7%). Six, one and three mayfly, stonefly and caddisfly taxa, respectively, were recorded in the NR phytophilic macroinvertebrate assemblage. Among them, the rheophilic *Heptagenia coerulans* Rostock, 1877, *Isoperla* sp. and *Rhyacophila* sp. were not registered in the torrential zone (NT). Significantly more EPT-taxa are known from the freely flowing section of the Elbe River in Germany downstream the Czech border (Beilharz et al. 2004). They documented a considerable (almost tenfold) increase in EPT taxa numbers in 1989–2000 as a result of reduction of external load (mainly oxygen-consuming and xenobiotic substances).

In accordance with formerly mentioned evaluations (Adámek & Jurajda 2001) and findings of other studies (Rollaufs et al. 2004), the highest diversity of benthic macroinvertebrates in lowland rivers corresponds to β-saprobic conditions (SI around 2) which was found in the upper river stretch (N). Thus, a decline in biodiversity rather than the observed increase might be expected in the downstream gradient of the Elbe River. However, the conclusions of Adámek & Jurajda (2001) were done using data from rather smaller streams. The optimum level of organic pollution (saprobity) for macrozoobenthos biodiversity is possibly higher than in the Elbe River at Pardubice. According to the grading pattern of morphological habitat degradation used by Adámek & Jurajda (2001), the individual stretches corresponded to their habitat degradation score 1.8 (NT), 2.5 (CT) and 2.5 (CPT). The highest biodiversity for lowland rivers according to these authors, based on evaluation of stream channelization, riffles/pools ratio and submersed and riparian vegetation occurrence, was found for the habitat degradation score 2.7, which is also in a good accordance with the values corresponding to the CT and CPT stretches (2.5). Thus it seems that despite increasing degradation of the river water quality in the downstream gradient of the Němčice – Přelouč section of the Elbe River, the physical environmental factors (current, substrate) were the driving elements for increasing diversity of benthic macroinvertebrates.

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Apendix 1. List of individual taxa, their occurrence and total numbers recorded. For abbreviations see Fig. 1 caption.

Zone	Stillwater			Torrential			Riparian		
Taxon/Site	NS	CS	CPS	NT	CT	CPT	NR	CR	CPR
Lumbriculidae g. sp.				1					
Aulodrilus pluriseta (Piguet, 1906)	5								
Limnodrilus hoffmeisteri Claparède, 1862	8	8	8						
Limnodrilus claparedeanus Ratzel, 1868			6						
Limnodrilus sp. juv.	7	7							
Potamothrix hammoniensis (Michaelsen, 1901)	5								
Tubificidae g. sp. juv.	7	5	7						
Amphichaeta leydigi Tauber, 1879			4						
Nais bretscheri Michaelsen, 1899			3						
Uncinais uncinata (Orsted, 1842)		5							
Stylaria lacustris (L., 1767)							1	1	1
Pristina proboscidea Beddard, 1896			6						
Vejdovskyella intermedia (Bretscher, 1896)			6						
Ophidonais serpentina (Müller, 1773)			5						
Naididae g. sp.						5		1	18
Enchytreidae g. sp.									1
Erpobdella monostriata (Lindenfeld et Pietruszynski, 1890)						1			
Erpobdella octoculata (L., 1758)						4			
Helobdella stagnalis (L., 1758)						1			
Hemiclepsis marginata (Müller, 1774)						1			
Glossiphonia complanata (L., 1758)						1			
Piscicola geometra (L., 1758)					1		1		
Acroloxus lacustris L., 1758								1	
Ancylus fluviatilis Müller, 1774						2			
Bithynia tentaculata (L., 1758)						2			
Pisidium sp.						1			
Sphaerium sp.						68			
Gammarus fossarum Koch, 1835					1				
Gammarus roeselii Gervais, 1835				1	4				36
Asellus aquaticus (L., 1758)						16			
Orconectes limosus (Rafinesque, 1817)					1				

Apendix 1. (continued)

Zone	Stillwater			Torrential			Riparian		
Taxon/Site	NS	CS	CPS	NT	CT	CPT	NR	CR	CPR
Baetis fuscatus (L., 1761)				2			2		
Baetis vernus Curtis, 1834							14	10	11
Centroptilum luteolum (Müller, 1776)							1	1	17
Cloeon dipterum L., 1761									17
Caenis luctuosa (Burmeister, 1839)							1		
Caenis sp. juv.				1			2		
Siphlonurus aestivalis (Eaton, 1903)									6
Heptagenia coerulans Rostock, 1878				1	4		1		
Isoperla sp.juv.							1		
Gomphus vulgatissimus (L., 1758)									1
Ischnura pumilio (Charpentier, 1825)					1			3	3
Ischnura elegans (Vander Linden 1820)									3
Ischnura sp.juv.								1	
Calopteryx splendens Selys et Hagen, 1850							3	2	8
Enallagma cyathigerum (Charpentier, 1840)								1	
Platycnemis pennipes (Pallas, 1771)								7	39
Coenagrionidae g. sp.								9	16
Aphelocheiurus aestivalis (Fabricius, 1794)				2	1				
Ilyocoris cimicoides L., 1758								2	
Corixa sp.									2
Ranatra linearis L., 1758									1
Hydropsyche incognita Pitsch, 1993						5			
Hydropsyche sp. juv.				59	3	86			
Ecnomus sp.					1				
Hydroptila sp.								1	
Plectrocnemia sp. juv.					1				
Psychomia pusilla (F., 1781)				1	1				
Cyrnus trimaculatus (Curtis, 1834)									1
Halesus digitatus/tesselatus									5
Holocentropus sp. juv.					1	5			
Rhyacophila sp.						2	1		
Polycentropus flavomaculatus (Pictet, 1834)						1			
Anabolia furcata Brauer, 1857							1	2	29
Oecetis notata (Rambur, 1842)							1		
Limnophila sp.				3					
Tipula lateralis Meigen 1804				1					
Tipula sp.				1	1				
Brilia flavifrons (Johannsen, 1905)									1
Chironomini g. sp.						1		2	5
Chironomus sp.			2						
Cladopelma gr. *laccophila*	2								
Corynoneura sp.									1
Cricotopus bicinctus (Meigen, 1818)							2	6	9
Cricotopus gr. *sylvestris*								3	3
Cryptotendipes sp.	2	3	2						
Dicrotendipes sp.									1
Eukiefferiella gracei (Edwards, 1929)				1			2		
Glyptotendipes sp.						1			
Microchironomus tener	33	14							
Micropsectra sp.						1			
Microtendipes gr. *tenellus*						1			
Orthocladius obumbratus Johannsen, 1905				12		5	17		1
Orthocladius rubicundus (Meigen, 1818)				7		3	19		2
Orthocladius ashei/rivicola				1			1		
Orthocladiinae g. sp.				22		10	37	4	25
Paratendipes gr. *albimanus*	11	43	11						
Paratrichocladius rufiventris (Meigen, 1830)						1		3	10
Phaenopsectra sp.									2
Polypedilum scalaenum (Schrank, 1803)	1	2	1						
Polypedilum gr. *convictum*									2
Polypedilum gr. *laetum*								2	
Potthastia gr. *gaedii*	2	1	2						
Procladius sp.	3	16	3						
Prodiamesa olivacea (Meigen, 1818)		1							
Rheocricotopus fuscipes (Kieffer 1909)							1	2	3
Stictochironomus sp.				1					
Synorthocladius semivirens (Kieffer, 1909)									1

Apendix 1. (continued)

Zone	Stillwater			Torrential			Riparian		
Taxon/Site	NS	CS	CPS	NT	CT	CPT	NR	CR	CPR
Tanypus punctipennis Meigen, 1818		1							
Tanypodinae g. sp.							1	1	1
Tanytarsus sp.	1	3	1	1		1			2
Tanytarsus ejuncidus (Walker, 1856)		1							
Thienemannimyia/Rheopelopia							1		
Thienemanniella sp.				1					
Tvetenia discoloripes/verralli				1					
Ceratopogonidae g. sp.									1
Simuliidae g. sp.				8			3	3	
Antocha vitripennis (Meigen, 1830)						1			
Limnius sp.				1					
Laccophilus minutus (L., 1758)								4	3
Platambus maculatus (L., 1758)									1