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The impact of sediment removal on the aquatic macroinvertebrate assemblage in a fishpond littoral zone

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ABSTRACT

Bottom sediment removal, a widely used technique in restoration management of standing water bodies, has a strong influence on communities of aquatic organisms. As most information on the impact of sediment removal on the aquatic environment comes from studies on lakes, the aim of this study was to describe macroinvertebrate assemblage succession in a fishpond (Štěpánek fishpond, Bohemian-Moravian highlands, Czech Republic) littoral zone following restoration by sediment removal during the winter of 2003/2004. Semi-quantitative hand net sampling was undertaken one year before (2003) and in each of the following five years (2004–2008) after sediment removal. A significant decrease in both abundance (approx. 90% of individuals) and diversity (approx. 30% of taxa) of macroinvertebrates was detected immediately after pond restoration. The values gradually increased over subsequent years, reaching comparable abundance and diversity three years after sediment removal. A significant shift was recorded in the taxonomic and functional composition of the macroinvertebrate assemblage after sediment removal. Mayfly larvae were the dominant invertebrates before restoration, while chironomid larvae and oligochaetes dominated after sediment removal. Phytophilous taxa, grazers and scrapers, and swimming or diving invertebrates were common in 2003, whilst open-water taxa preferring mud and other mostly inorganic microhabitats, gatherers/collectors, and burrowing/boring invertebrates were relatively common after sediment removal. In 2008, the assemblage reverted towards the situation before sediment removal, probably connected with a lower water level and accelerated macrophyte bed succession. Principal Component Analysis on the species data confirmed the differences in invertebrate taxonomic structure among sampling years. Succession of the fishpond invertebrate assemblage in the years following sediment removal was mainly influenced by fish farming practice and local conditions, i.e. the presence of macrophyte beds, mesohabitat changes following restoration, and the presence of other water bodies in the surroundings.

Key words: fishpond, restoration, macroinvertebrates, succession, biodiversity, functional groups

1. INTRODUCTION

Eutrophic and hypertrophic lakes and ponds require specific management to conserve their main functions, usually involving biomanipulation, drainage or sediment removal. Sediment removal is a common technique in restoration management of standing water bodies around the world. It is used particularly in lakes and ponds with considerable sediment accumulation (especially in areas of soil and nutrient runoff due to inappropriate agricultural land use) in order to reduce internal nutrient loading and for general restoration of the aquatic ecosystem (Moss *et al*. 1986, 1996; Boyd 1995; Pokorný & Hauser 2002; Clemente *et al*. 2005; Ayala *et al*. 2007).

Sediment removal influences both the water body environment and its communities of aquatic organisms. This technique has a proven positive impact on water quality (Pokorný & Hauser 2002) and on reduction of phosphorus released from sediment (Moss *et al*. 1986; Phillips *et al*. 1999; Søndergaard *et al*. 2000), chlorophyll-*a* and blooms of cyanobacteria (Moss *et al*. 1996; Pokorný & Hauser 2002). It also results in increases in phytoplankton diversity (Poulíčková *et al*. 1998; Pokorný & Hauser 2002), increases in the *Daphnia* population (Moss *et al*. 1996) and the re-establishment of aquatic macrophytes generally (Brouwer *et al*. 2002; Van Wichelen *et al*. 2007). In the majority of cases, however, these effects have been only short-term.

On the other hand, negative impacts of sediment removal have also been documented. The displacement of large amounts of sediment has a strong negative influence on populations of animals that are associated with sediments during their life cycle, such as the medicinal leech *Hirudo medicinalis* (Schenková *et al*. 2009) or aquatic turtles and salamanders (Aresco & Gunzburger 2004). These are often removed at the same time as the sediment by heavy machinery. Oberholster *et al*. (2007) described unfavourable succession following restoration through sediment removal and artificial mixing of an urban lake in North America. Post restoration, the lake suffered from cyanobacterial blooms and there was a decrease in the *Daphnia* population.

In general, very little is known about the impact of sediment removal on littoral aquatic invertebrate assemblages. A decrease in both the diversity and density of littoral invertebrates in the season following such inter-

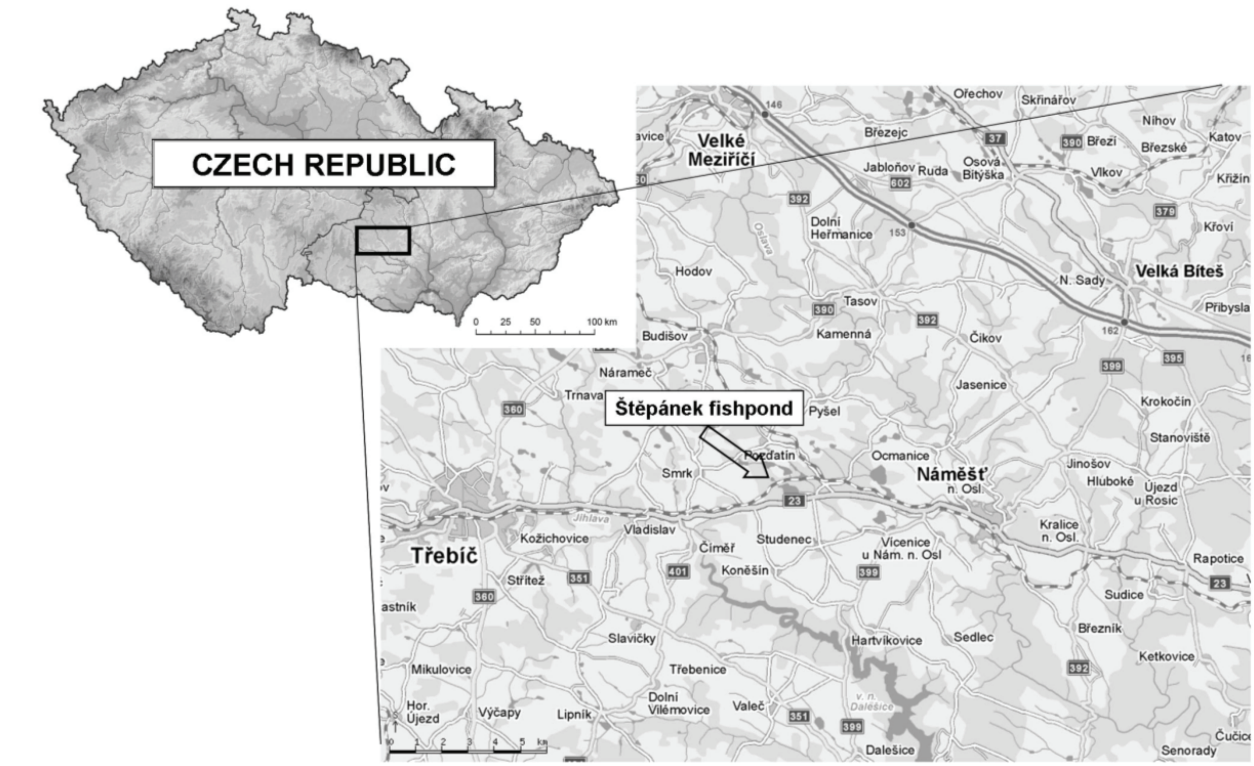

Fig. 1. Location of the Štěpánek fishpond in the Czech Republic (www.mapy.cz).

vention, however, has been documented in central Florida by Butler *et al*. (1992) and in Colorado by Oberholster *et al*. (2007).

Most information available on the impact of sediment removal on aquatic ecosystems relates to studies on lakes. In fishponds that are constructed primarily for aquacultural purposes, sediment removal is the most logical solution for reduction of internal loading (Hejný & Husák 1978; Björk 1988; Brönmark & Hansson 2005), and is commonly associated with increasing the pond fish farming capacity for subsequent years (Boyd 1995). Research on the impact of such intervention on the fishpond aquatic biota is still scanty. The aim of this study, therefore, is to describe aquatic macroinvertebrate succession in the littoral zone of a small fishpond following restoration through sediment removal.

2. MATERIAL AND METHODS

The Štěpánek fishpond is situated in the eastern part of the Bohemian-Moravian highlands (Fig. 1; GPS 49°13'24"N, 16°02'24"E) at an altitude of 450 m a.s.l. This small fishpond (2.2 ha) has one small inflow, though it is almost exclusively supplied with water through precipitation. The pond, which is surrounded by woodland and meadow, has been exploited for fish farming for decades and is usually emptied for a short period only during the yearly autumn pond harvest. Vegetation over most of the pond littoral zone was well developed and dominated by narrow-leaf cattail (*Typha angustifolia*) and reed sweetgrass (*Glyceria maxima*). In 2003, semi-quantitative sampling of littoral aquatic macroinvertebrates was undertaken as a control. During the winter of 2003/2004, the pond was drained completely and the accumulated sediment removed using heavy machinery, i.e. bulldozers removed the organic sediment to a depth of about 1 m and this was loaded onto trucks and carried away. The littoral macrophyte beds were almost completely destroyed. From 2005 on, the pond was stocked with high numbers of common carp (*Cyprinus carpio*), tench (*Tinca tinca*), grass carp (*Ctenopharyngodon idella*) and zander (*Sander lucioperca*). In order to document changes in the macroinvertebrate assemblage following restoration, sampling continued each year between 2004 and 2008.

Sampling always took place in the middle of July, following the same methodology adopted in 2003. Each year, macroinvertebrates were collected via a five-minute sweep with a hand net through the macrophyte stems and the upper layer of sediment along a comparable peripheral distance of approximately 200 m (about 30% of the pond perimeter). A hand net with a 500 mm mesh size was used as this is deemed suitable for the sampling of littoral macroinvertebrates in emergent vegetation (García-Criado & Trigal 2005; Sychra & Adámek 2010). The sampling site was located along the western, shallow bank of the pond, where macrophyte beds were well developed in 2003. Samples were preserved in 4% formaldehyde solution. In the laboratory, macroinvertebrates were determined to the lowest possible taxonomic level.

Tab. 1. Definition of microhabitats, feeding groups and type of locomotion used in the analyses and their representatives according to the Asterics software (AQEM consortium 2008).

Term	Definition	Representatives
Microhabitat pelal	mud; grain size <0.063 mm	some tubificids, some aquatic beetles, some chironomids
Microhabitat argyllal	silt, loam, clay; grain size <0.063 mm	some oligochaetes, some chironomids
Microhabitat psammal	sand; grain size 0.063-2 mm	some tubificids, some chironomids
Microhabitat akal	fine to medium-sized gravel; grain size 0.2-2 cm	some oligochaetes, some chironomids
Microhabitat lithal	coarse gravel, stones, boulders; grain size >2 cm	some leeches, some Diptera
Microhabitat phytal	algae, mosses and macrophytes including living parts of terrestrial plants	aquatic snails, naidids, some leeches, mayfly nymphs, some water bugs, some aquatic beetles, some Diptera
Microhabitat POM	particulate organic matter, such as woody debris, CPOM, FPOM	some oligochaetes, some water bugs, some dragonfly nymphs, some aquatic beetles, some chironomids
Grazers and scrapers	feeders on endo- and epilithic algal tissues, biofilm, partially POM and tissues of living plants	aquatic snails, some naidids, mayfly nymphs, some chironomids
Gatherers/collectors	feeders on sedimented FPOM, detritus	oligochaetes, mayfly nymphs, some water bugs, some chironomids, some Diptera
Predators	feeders on live prey	some leeches, some water bugs, dragonfly nymphs, some aquatic beetles, some chironomids, some Diptera
Swimming/diving	actively moving in water column	naidids, some mayfly nymphs, water bugs, some aquatic beetles, some Diptera
Sprawling/walking	actively moving on substrates	aquatic snails, naidids, leeches, dragonfly nymphs, some aquatic beetles, some chironomids, some Diptera
Burrowing/boring	making a hole or tunnel dug into the ground	some oligochaetes, some chironomids, some Diptera
(semi) Sessil	permanently attached to substrate	some oligochaetes, some leeches, some chironomids

Tab. 2. Main characteristics of the littoral macroinvertebrate assemblage, macrophyte beds, fish stock and water level at the Štěpánek fishpond during the years 2003-2008. Note: Joint taxa = percentage of taxa occurring before sediment removal recorded afterwards; Eudominant groups = taxa with relative abundances higher than 10%; Macrophyte beds = relative proportion of the pond perimeter comprising macrophyte beds; Fish species and age: C = common carp, GC = grass carp, T = tench, Z = zander, 1-3 = fish age in years; Usual water level = water level in fully filled pond).

	12.7.2003	20.7.2004	16.7.2005	18.7.2006	21.7.2007	12.7.2008
No. of individuals	3499	346	927	3349	2072	1186
No. of taxa	44	32	33	41	21	48
Joint taxa (%)	100	38.6	50.0	52.3	25.0	45.5
Eudominant groups (more than 10%)	Ephemeroptera Heteroptera Hirudinida	Chironomidae Oligochaeta	Chironomidae Hydrachnellae Oligochaeta	Oligochaeta Ephemeroptera	Oligochaeta Heteroptera Chironomidae	Heteroptera Chironomidae Ephemeroptera
Macrophyte beds (%)	28.9	3.4	16.7	11.0	5.0	28.5
Dominant macrophytes	*Typha angustifolia* *Glyceria maxima* *Schoenoplectus* sp.	species of exposed bottoms *Glyceria maxima*	*Phalaris arundinacea* *Typha latifolia* *Glyceria maxima*	*Glyceria maxima* *Typha latifolia*	*Glyceria maxima* *Typha latifolia*	*Typha latifolia* *Glyceria maxima*
Fish stock ($kg.ha^{-1}$)	180.0	0.0	965.0	973.9	835.2	870.0
Fish species and age	C2	0	C2,GC3	C1-2,T1,Z1	C2,T2	C2,T2,GC1,Z1
Difference from usual water level	0	0	0	0	-1 m	-0.75 m

At each sampling, the rate of aquatic vegetation succession (dominant macrophyte taxa, proportion of macrophyte beds on the pond perimeter) and water level were also monitored. Data on fish stock (see Tab. 2) were provided by the local fish farming association (MO MRS Náměšť nad Oslavou).

Principal Component Analysis (PCA) was employed to identify the most important gradients in the species data. Environmental data were fitted ex-post to the PCA ordination axes as passive variables. Both analyses and graphs were produced using Canoco for Windows (Version 4.5; ter Braak & Šmilauer 2002) and Microsoft Excel. All taxa were assigned to feeding and microhabitat preference groups using Asterics software (version 3.1.1; AQEM consortium 2008; Tab. 1).

3. RESULTS

The littoral habitats of the Štěpánek fishpond were markedly disturbed by the sediment removal in the winter of 2003/2004. During these operations, the beds of narrow-leaf cattail and reed sweetgrass were destroyed; only very restricted beds of reed sweetgrass and vegetation of the exposed fishpond bottoms being recorded inside and along the pond edge in 2004. Restoration of the macrophyte beds was very slow over subsequent years. Following a hot and dry summer in 2007, however, water level was low and macrophyte succession accelerated. In 2008, reed sweetgrass and broad-leaf cattail (*Typha latifolia*) beds were well developed and were comparable to 2003 (Tab. 2).

Altogether, more than 11 000 individuals of 99 macroinvertebrate taxa were recorded between the years 2003 and 2008 (see Appendix 1). The highest abundance (3 499 individuals) and second highest taxa richness (44 taxa) were recorded in 2003, before sediment removal. After intervention, a significant decrease in both abundance and diversity was recorded, amounting to 346 individuals and 32 taxa, respectively. Total

Tab. 3. Total abundance of higher taxa, number of lower taxa and relative abundance of temporal (aquatic insects) and permanent (gastropods, oligochaetes, leeches, crustaceans and water mites) fauna.

	2003	2004	2005	2006	2007	2008
	Number of individuals / number of taxa					
Gastropoda	245 / 3	5 / 2	25 / 2	84 / 3	0 / 0	111 / 2
Oligochaeta	347 / 5	70 / 6	159 / 5	1872 / 5	1048 / 5	13 / 3
Hirudinida	377 / 5	1 / 1	6 / 2	154 / 4	8 / 1	6 / 3
Hydrachnellae	22 / 1	10 / 1	212 / 1	334 / 1	4 / 1	66 / 1
Ephemeroptera	1915 / 2	10 / 2	19 / 2	392 / 2	0 / 0	272 / 2
Heteroptera	430 / 6	15 / 4	13 / 4	240 / 6	788 / 5	347 / 10
Chironomidae	120 / 10	228 / 11	451 / 9	224 / 10	212 / 6	322 / 12
Others	43 / 13	7 / 6	42 / 9	47 / 11	12 / 4	49 / 16
	Relative abundance (%)					
Permanent	28.35	24.86	43.37	73.24	51.16	16.53
Temporal	71.65	75.14	56.63	26.76	48.84	83.47

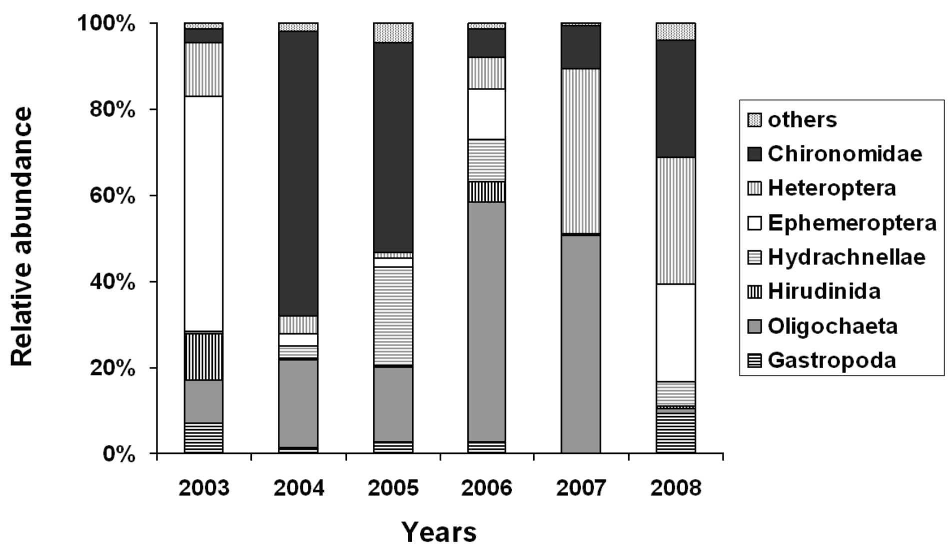

Fig. 2. Relative abundance of higher macroinvertebrate taxa.

macroinvertebrate abundance was approximately 10 times lower in 2004. Over the next two years (2005-2006), abundance increased again to 3 349 individuals (41 taxa) by 2006, but was followed by a second decline over 2007-2008 (Tab. 2). The number of invertebrate taxa fluctuated between sampling years. While a decrease in number of taxa was detected immediately following pond restoration, values comparable with 2003 were found in 2006 and 2008 (Tab. 2).

A significant shift in assemblage composition was recorded following sediment removal. Mayfly larvae (mainly *Cloeon dipterum*) were the dominant invertebrates in 2003, while chironomid larvae (e.g., *Cricotopus* gr. *sylvestris*, *Glyptotendipes* sp. or *Microtendipes* gr. *chloris*) dominated in 2004-2005 and oligochaetes (e.g., *Ophidonais serpentina*, *Stylaria lacustris*, *Dero digitata* or *Limnodrilus* sp.) in 2006-2007. A relatively balanced assemblage was documented in 2008, with mayfly nymphs, aquatic bugs (mainly Corixidae) and chironomid larvae as the dominant macroinvertebrate groups (Tab. 3; Fig. 2).

A shift in the invertebrate assemblage was also evident as regards functional grouping. Phytophilous taxa, grazers and scrapers, and swimming or diving invertebrates were common in 2003. The abundances of these groups decreased strongly in the years following sediment removal, with taxa preferring mud (pelal) and other mostly inorganic microhabitats (argyllal, psammal, akal, and lithal), gatherers/collectors, and burrowing/boring invertebrates being relatively more common following sediment removal (Fig. 3). In 2008, a decline in the abundance of these taxa and a new increase in the relative number of grazers and scrapers was recorded. The ratio between abundances of permanent and temporal taxa remained unchanged after pond restoration. In most years, aquatic insects (temporal fauna) were more abundant; aquatic snails, oligochaetes and leeches (permanent fauna) only being more abundant in the years 2006-2007 (Tab. 3).

Species-data based PCA confirmed differences in the taxonomic structure of the invertebrate assemblage between the sampling years described. The first PCA

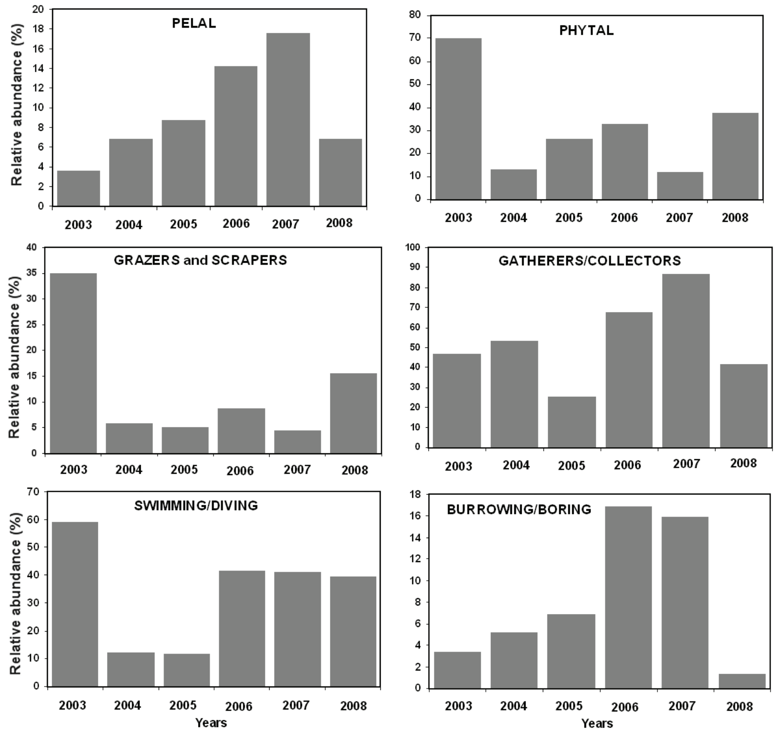

Fig. 3. Relative abundance of the main functional invertebrate groups based on microhabitat and food preference and type of movement.

axis explained 63.1% of total variance, and the second axis 25.3%. In 2003, before sediment removal, phytophilous taxa such as the mayfly *Cloeon dipterum*, the snail *Gyraulus albus* or leeches such as *Hemiclepsis marginata* and *Helobdella stagnalis* were the dominant invertebrates. Chironomid larvae and oligochaetes were more common in 2004-2005 and 2006-2007, respectively. Finally, in 2008, the corixids *Micronecta scholtzi* and *Sigara falleni* and the snail *Radix auricularia* were most abundant (Fig. 4). The sample scores on the first PCA axis were strongly positively correlated with the occurrence of phytal preferring taxa, grazers and scrapers, and sprawling/walking invertebrates; while the occurrence of burrowing/boring invertebrates and gatherers/collectors was positively correlated with the second axis (Fig. 5).

4. DISCUSSION

Aquatic macroinvertebrates living in fishpond littoral zones are a very important link in the pond food chains. Such invertebrates display life strategies that enhance long-term survival in rapidly changeable pond littoral conditions (Ward 1992; Dvořák & Imhof 1998). During sediment removal operations, littoral macrophyte beds and the upper layer of organic sediment, which represent important habitats for phytophilous and bottom-dwelling macroinvertebrates, are completely destroyed and/or removed. Moreover, the upper sediment layer contains the greater part of the plant and invertebrate egg bank, from which the restored sites would normally be recolonised (Combroux *et al*. 2002; Gleason *et al.* 2004). Invertebrate recolonisation following sediment removal, therefore, would be comparable with the relatively rapid colonisation of a newly created water body, where most taxa appear during the first season, followed by a decrease in diversity and the dominance of a few taxa only in subsequent seasons (Solimini *et al*. 2003; Ruhí *et al*. 2009). Indeed, Butler *et al.* (1992) observed high invertebrate diversity in the second year after sediment removal from a lake in Florida, USA, and a rapid decrease the following season. The results of such studies, however, are in opposition with the results of our research.

Our results indicate that both the diversity and abundance of littoral invertebrates in the Štěpánek fishpond decreased strongly after sediment removal (by about 90% of individuals and 30% of taxa) and gradually increased again over subsequent years. The differences in the response of invertebrate assemblages observed is probably due to differences between the conditions found in natural lakes and the semi-natural conditions prevalent in fishponds, where fish farming management practices have a considerable influence on the continuity of natural succession. According to previous studies, early colonisers, such as chironomid larvae (Danell & Sjöberg 1982; Layton & Voshell 1991; Butler *et al.* 1992; Brown *et al.* 1997; Solimini *et al.* 2003) are the most abundant group in the two years following sediment removal; the rapid colonisation of aquatic bugs and beetles, which are usually among the first colonisers

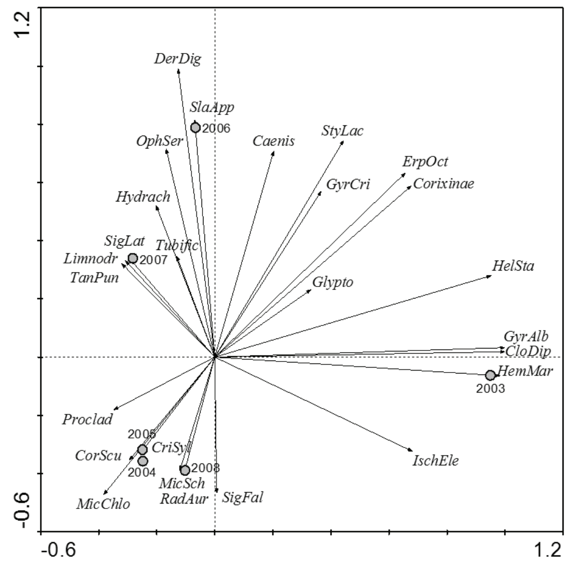

Fig. 4. PCA ordination plot with samples and most abundant macroinvertebrate taxa (more than 40 captured individuals). For species codes see Appendix.

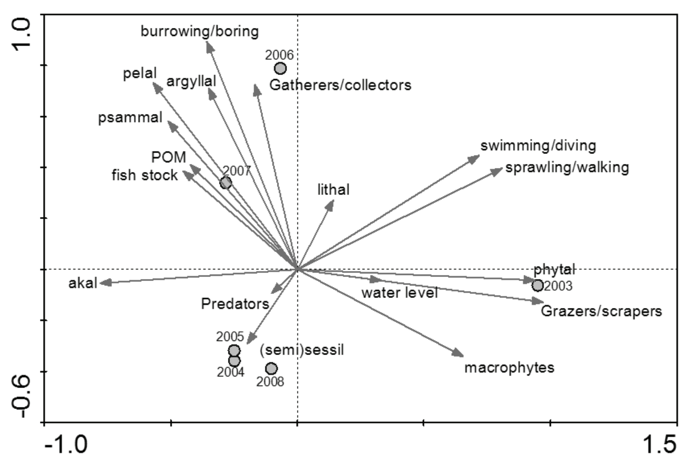

Fig. 5. PCA ordination plot with samples, monitored factors (macrophytes, fish stock, water level) and functional macroinvertebrate groups (according to Asterics software).

(Popham 1964; Danell & Sjöberg 1982; Layton & Voshell 1991; Jeffries 1994), being inhibited by high fish stock and the absence of macrophytes.

The relatively balanced ratio between temporal and permanent fauna before and after sediment removal, as well as the presence of approximately half the previous permanent taxa (gastropods, oligochaetes) suggests that their eggs or cocoons were not completely removed with the sediments as such taxa are usually slow to colonise new sites (Danell & Sjöberg 1982; Brown *et al*. 1997). The presence of other water bodies in the surrounding area plays an important role for recolonisation of such taxa (Barnes 1983; Brady *et al.* 2002) and such could well be the case for the Štěpánek pond, which is located within a system of nearby fishponds.

The absence of littoral macrophytes, and their subsequent gradual development, appeared to be the most important factor influencing invertebrate assemblage succession following sediment removal at the study site. Due to their structural complexity and importance as a substrate for periphyton, macrophyte beds serve both as living space and as a refuge against fish predation for many aquatic invertebrates. Their presence in the littoral zone, therefore, greatly increases invertebrate diversity (Dvořák & Imhof 1998; Petr 2000; Solimini *et al*. 2003). Sediment removal at the Štěpánek pond resulted in a decrease in both abundance and diversity of a number of groups usually associated with macrophyte beds, with the greatest negative impact being recorded in grazers and scrapers (e.g., some snails), phytal preferring taxa (e.g., snails, some leeches, mayfly nymphs, aquatic bugs and beetles, some dipterans) and actively swimming/diving invertebrates (e.g., aquatic bugs and beetles). Oberholster *et al*. (2007) similarly recorded a decline in scrapers and shredders (especially isopods and caddis fly larvae) after removal of lake bottom sediment in Colorado. In the years following restoration, constantly high water level and high stock with grass carp were probably important factors negatively influencing aquatic macrophyte bed regeneration in the Štěpánek pond, a process described in detail by Hroudová & Zákravský (1999) and Zákravský & Hroudová (2007).

In general, functional and taxonomic shifts in the macroinvertebrate assemblage were connected with changes in the littoral habitat of the pond. Sediment removal changes both the physical and chemical characteristics of the bottom soil (Yuvanatemiya & Boyd 2006); restored sites tending to have more inorganic substrates and/or bottom lacking in macrophytes as compared with undisturbed sites with more vegetation and organic matter (Hejný & Husák 1978; Butler *et al*. 1992). At the Štěpánek pond, the relative abundance of invertebrates preferring pelal and some inorganic substrates and burrowing/boring taxa (especially some oligochaetes and chironomid larvae) gradually increased in the years after sediment removal. A similar shift from phytophilous to more open-water taxa was also documented under natural conditions by Oberholster *et al*. (2007) for invertebrates and Tugend & Allen (2004) for fish assemblages, following restoration of a lake littoral zone.

Invertebrate assemblage succession in the five years following sediment removal was also influenced by variations in local conditions. For example, the development of littoral vegetation was accelerated by lower water level in 2007. Subsequently, by 2008, the macrophyte beds had re-established to level existing before pond restoration (as found by Hroudová & Zákravský 1999). Similarly, the relative abundances of phytophilous invertebrates and grazers and scrapers had also increased and the relative abundances of pelal preferring invertebrates and burrowing/boring taxa decreased. Such relatively rapid changes in the pond ecosystem indicate an unsteady state for aquatic plant and invertebrate assemblages in pond littoral zones. In general, we can conclude that macroinvertebrate abundances in fishpond littorals can change year-by-year due to both specific management intervention and local environmental conditions. On the other hand, assemblage diversity is also significantly related to taxa composition in the previous year (see Brady *et al*. 2002).

This pilot study demonstrated several shortcomings. Future research on the impact of sediment removal on fishpond littoral macroinvertebrate assemblages must be supported by more detailed sampling during the growing season and by monitoring of changes in physical and chemical conditions at the micro- and mesohabitat levels. Further detailed research is also recommended on the complex impact of sediment removal on aquatic macrophytes, macrozoobenthos and zooplankton in fishponds. Results of this and similar studies are important, especially in connection with management measures on carp fishponds, as they bring fish farming issues into closer harmony with the conservation of threatened wetland ecosystems, and *vice versa*.

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APPENDIX

Macroinvertebrate taxa and number of individuals captured at the Štěpánek fishpond between 2003 and 2008 (species codes as used in Fig. 4).

	Species code	12/07/2003	20/07/2004	16/07/2005	18/07/2006	21/07/2007	12/07/2008
Gastropoda							
Lymnaea stagnalis (Linnaeus, 1758)		1					
Radix auricularia (Linnaeus, 1758)	*RadAur*						81
Gyraulus albus (O.F. Müller, 1774)	*GyrAlb*	221	4	4	44		30
Gyraulus crista (Linnaeus, 1758)	*GyrCri*	23	1	21	38		
Hippeutis complanatus (Linnaeus, 1758)					2		
Oligochaeta							
Ophidonais serpentina (Müller, 1774)	*OphSer*		27	124	432		9
Stylaria lacustris (Linnaeus, 1767)	*StyLac*	201	5	14	368		
Dero digitata (Müller, 1774)	*DerDig*	136	14	8	1016	652	
Nais variabilis Piguet, 1906				6			2
Slavina appendiculata (Udekem, 1855)	*SlaApp*				48		
Limnodrilus sp.	*Limnodr*	2	15	7		352	2
Limnodrilus hoffmeisteri Claparede, 1862			3			4	
Limnodrilus udekemianus Claparede, 1862		2					

(continued)

Appendix. Continuation.

	Species code	12/07/2003	20/07/2004	16/07/2005	18/07/2006	21/07/2007	12/07/2008
Tubificidae gen. sp. juv.	*Tubific*	6				36	
Aulodrilus pigueti Kowalewski, 1914						4	
Cognettia sphagnetorum (Vejdovský, 1878)					8		
Lumbriculus variegatus (Müller, 1774)			6				
Hirudinida							
Theromyzon tessulatum (O.F. Müller, 1774)		4					2
Hemiclepsis marginata (O.F. Müller, 1774)	*HemMar*	105					
Alboglossiphonia hyalina (O.F. Müller, 1774)					2		
Helobdella stagnalis (Linnaeus, 1758)	*HelSta*	213		3	88	8	3
Piscicola geometra (Linnaeus, 1758)		3			4		1
Erpobdella octoculata (Linnaeus, 1758)	*ErpOct*	52	1	3	60		
Crustacea							
Argulus foliaceus (Linnaeus, 1758)					2		
Acari							
Hydrachnellae gen. sp.	*Hydrach*	22	10	212	334	4	66
Ephemeroptera							
Cloeon dipterum (Linnaeus, 1761)	*CloDip*	1893	4	15	324		255
Caenis sp.	*Caenis*	22	6	4	68		17
Heteroptera							
Ilyocoris cimicoides (Linnaeus, 1758)					2		
Notonecta glauca Linnaeus, 1758							2
Notonecta viridis Delcourt, 1909							17
Notonecta sp. juv.		2					5
Plea minutissima Leach, 1817		1		1	2		
Micronecta scholtzi (Fieber, 1860)	*MicSch*					10	216
Sigara lateralis (Leach, 1817)	*SigLat*					460	13
Sigara falleni (Fieber, 1848)	*SigFal*	11	9			6	60
Sigara striata (Linnaeus, 1758)		7	1		6		
Paracorixa concinna (Fieber, 1848)			1			8	
Callicorixa praeusta (Fieber, 1848)							2
Corixinae gen. sp. juv.	*Corixinae*	404	4	10	226	304	29
Gerris lacustris (Linnaeus, 1758)							1
Gerris odontogaster (Zetterstedt, 1828)		5		1	2		
Gerris sp. juv.				1	2		2
Megaloptera							
Sialis lutaria (Linnaeus, 1758)		1			2		
Odonata							
Platycnemis pennipes (Pallas, 1771)		4					
Coenagrion sp.					6		17
Ischnura elegans (Vander Linden, 1820)	*IschEle*	15		10	5		12
Libellula depressa Linnaeus, 1758			1				1
Coleoptera							
Haliplus fluviatilis Aubé, 1836							1
Haliplus sp. juv.		2	3				6
Noterus crassicornis (O.F. Müller, 1776)				6	2		1
Noterus sp. juv.		3					
Laccophilus minutus (Linnaeus, 1758)							1
Rhantus frontalis (Marsham, 1802)							1
Graphoderus sp. juv.		1					1
Helophorus granularis (Linnaeus, 1761)		1					2
Coelostoma orbiculare (Fabricius, 1775)							1
Anacaena lutescens (Stephens, 1829)							1
Laccobius sp. juv.						4	
Enochrus sp. juv.					2		
Hydrobius fuscipes (Linnaeus, 1758) juv.							1
Hydrophilus sp. juv.		1					
Lepidoptera							
Cataclysta lemnata (Linnaeus, 1758)		2			8		
Chironomidae							
Camptochironomus gr. *tentans* Fabricius, 1805		6		2		4	
Cladotanytarsus sp.							1
Clinotanypus nervosus (Meigen, 1818)			1				
Corynoneura gr. *scutellata* Winnertz, 1846	*CorScu*			94			1
Corynoneura sp.			1		1		

(continued)

Appendix. Continuation.

	Species code	12/07/2003	20/07/2004	16/07/2005	18/07/2006	21/07/2007	12/07/2008
Cricotopus gr. *sylvestris* (Fabricius, 1794)	*CriSyl*	2	10	176	91		274
Cryptochironomus sp.			1	2			
Dicrotendipes sp.							4
Endochironomus sp.		1		10	4		1
Glyptotendipes sp.	*Glypto*	84	13	112	106		28
Chironominae sp. juv.						2	
Chironomus plumosus (Linnaeus, 1758)		6					
Metriocnemus cf.							1
Microtendipes gr. *chloris* (Meigen, 1818)	*MicChlo*	1	101	52	8		
Nanocladius cf. *bicolor* Zetterstedt, 1838					2		
Parachironomus sp.			2		9		1
Polypedilum gr. *nubeculosum* (Meigen, 1804)			18	2			5
Polypedilum sp.					1		
Procladius (*Holotanypus*) sp.	*Proclad*	4	67			36	
Tanypodinae sp. juv.		7				2	
Tanypus kraatzi (Kieffer, 1912)		2			1	20	4
Tanypus punctipennis Meigen, 1818	*TanPun*		13			148	1
Tanytarsus sp.			1				
Thienemannimyia gr.				1			
Xenopelopia sp.		7			1		1
other Diptera							
Dixella amphibia (De Geer, 1776)				11			1
Chaoborus crystallinus (De Geer, 1776)		7		7			
Ceratopogonidae gen. sp. juv.			1	2		4	
Anopheles gr. *maculipennis* Meigen, 1818							2
Culex modestus Ficalbi, 1890					8		
Culex sp. juv.					12		
Scaptomyza sp.			1				
Muscidae gen. sp. juv.			1				
Paramormia sp.						4	
Odontomyia sp.				4			
Stratiomyidae gen. sp. juv.		5		1			
Sciomyzidae gen. sp. juv.		1		1	2		

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