Ecological effects of different shore protection types on the River Elbe, East Germany

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Introduction

The shores of the River Elbe have traditionally been protected by groynes built perpendicularly to the main channel axis. From the ecological point of view, such standard groynes have the disadvantage to minimize the shore dynamics by enhancing accumulation of sand and mud in the groyne fields, so that microhabitats depending on erosion processes disappear. In addition, the shores are regularly flushed by waves due to ships passing by. Consequently, the diversity of the fauna is strongly reduced due to loss of habitat diversity and mechanical disturbance (Carling et al. 1996, Grafahrend-Belau 2003). In order to try to conciliate commercial navigation and preservation of the biodiversity, several alternatives for shore protection have been developed, mainly concerning the shape of the groynes, i.e. "Absenkungsbuhne", "Knickbuhne" (Anlauf 2002) and parallel work (hinterströmtes Parallelwerk). The latter consists of a stony dyke of 800 m length built parallel to the river bank at the small village of Gallin near Lutherstadt-Wittenberg. Depending on the water level in the Elbe, a small amount of water flows behind the parallel work via an upstream inflow opening, and leaves it via a second opening downstream. Hence, this structure prevents any direct impact of ship waves on the shore. However the erosion/accumulation dynamics of sediment in its field is still unknown, as well as its effect on the fauna.

Floods progressively damage the standard groynes. Observed damages are mainly disruptions which lead to the formation of secondary flow channels between two or more adjacent groyne fields. As a consequence, a high erosion/accumulation dynamics of sediment occurs in the field of such broken groynes, which greatly diversifies the mesohabitats. Both the broken groynes and the parallel work exhibit two distinct seasonal phases with contrasting flow velocity conditions: high flow velocities when connected to the main channel (wet phase), and dry groyne fields with only isolated pools remaining when the water level decreases in summer (pool phase).

Our project aims to assess comparatively the ecological effects of the three shore protection types, namely standard groynes, broken groynes and parallel work on species composition, diversity and productivity of benthic macroinvertebrates.

Methods

Three standard groyne fields located at our upstream site near the parallel work (Elbe-km 207) were compared with three former standard groyne fields now protected by the parallel work (Elbe-km 204). In the same way, three broken groynes located more downstream near Havelberg (Elbe-km

425) were compared with three adjacent standard groynes (Elbe-km 424). In summer, the isolated pools in the parallel work and at the broken groynes were compared with two permanent pools corresponding to old side arms located in the flood plain near Havelberg (Elbe-km 447 and 459).

Benthic macroinvertebrates were seasonally collected in May, June, August, October 2003, and in April 2004, based on a mesohabitat specific sampling protocol including seven substrate-types (stones, gravel, sand, mud, roots, macrophytes, dead wood) and three categories of current velocity (0-0.2, 0.2-0.6, > 0.6 m/s). Sand, gravel and mud were sampled quantitatively using a 250 µm size-standardised Surber net, with 3-7 replicates each. Stones were brushed to collect macroinvertebrates and the maximum length in their three dimensions measured. Roots, macrophytes, and dead wood were sampled with a hand net operated during a standard time period of one minute. All benthic macroinvertebrates were identified taxonomically to the species level except Diptera and Oligochaeta. Biomass was determined as dry mass by drying for 24 hours at 75°C. For highly sclerotized and shell protected species ash-free dry mass was determined (5 hours at 500°C).

For the purpose of this study, data from all substrate types of the same sampling site were grouped together, only separating samples from the two different temporal phases. For statistical analyses, 50 species which where recorded exclusively in one sampling site were removed from the matrix in order to overcome the strong dependence of ordination methods on single outlier species (McCune & Grace 2002). Oligochaeta and Chironomidae, which were found in high abundances in all the sampling sites, were also removed from the matrix because they do not contribute any information at this level of identification if found abundant everywhere. We finally obtained a working matrix with a size of 24 sites x 140 taxa. As records originating from hand-net catching were only semi-quantitatives, data were standardised by total site abundance in order to allow comparability between sites. Non-metric multidimensional scaling analysis (NMDS) based on Bray-Curtis similarities was used to ordinate the studied sites. NMDS is an ordination method which avoids the assumption of linear relationships among variables, a situation always occurring in community relationships (Clarke 1993). Search for characteristic species of each shore protection type were done by the SIMPER routine of the software PRIMER. The SIMPER routine allows to identify which species principally explain the difference observed in the assemblages of two dissimilar sets of samples. For that, it analyses the overall percentage contribution of each species to the average dissimilarity between the two groups (Clarke and Gorley 2001).

Results

Ordination of the studied sites using NMDS showed a clear separation of the samples corresponding to the two different temporal phases in the broken groynes and in the parallel work (Fig.1). The samples corresponding to the wet phase of the broken groynes and parallel work are grouped together with the samples of the standard groynes. It can also be clearly seen that the samples are organised along a gradient of intensity of connection with the main channel, in a sequence from permanently connected sites (on the left) to the permanently disconnected sites (on the right). Samples from upstream and downstream sites are separated vertically. In the following, only sites corresponding to the same river section will be compared in order to prevent the influence of differences in faunal assemblages due to the longitudinal zonation.

Comparison of the number of site-specific species (standardised by the sampling surface) among the sites revealed that the broken groynes harbour much more site-specific species per unit area than the standard groynes, which especially colonise the temporary pools (0,78 versus 0,03 species/m^2). 80% of these site-specific species were Coleoptera. In contrast, the parallel work harbours only a

slightly higher number of site-specific species than the standard groynes (0,48 versus 0,35 species/m^2).

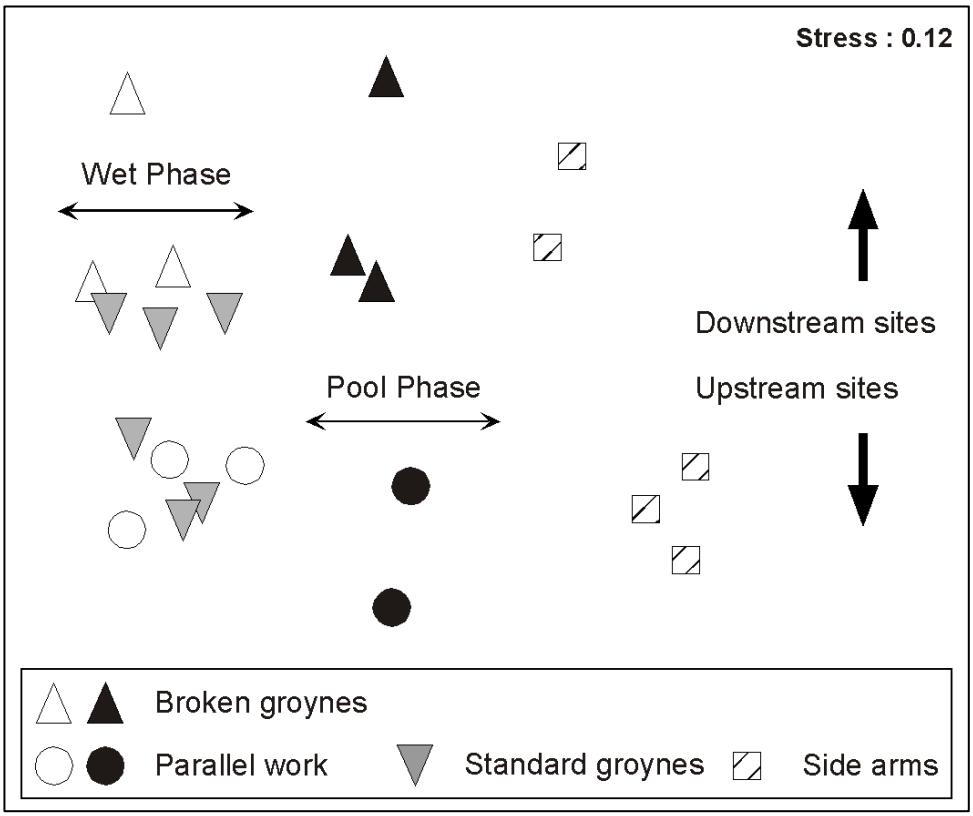

Fig.1: NMDS Plot based on the similarity of the benthic macroinvertebrate assemblages. Black symbols: pool phase, white symbols: wet phase.

Seven characteristic species, of which some are highly stenoecious, were identified by the SIMPER routine in the isolated pools in the broken groyne fields, while only one characteristic species, the Ponto-Caspian invader *Corophium curvispinum*, was identified in the standard groynes downstream (Table 1). Among the characteristic species for isolated pools, *Cloeon dipterum, Sigara striata* and *S. lateralis* are stenotopic species inhabiting macrophytes and roots, and *Caenis pseudorivulorum* is a typical potamobionte species seen as a relict from the main channel. In opposite, only three characteristic taxa were selected by the SIMPER routine for the isolated pools in the parallel work versus seven taxa for the nearby standard groynes. Among them, *Hydropsyche contubernalis*, *Procloeon bifidum* and *Baetis fuscatus* are highly indicative for lotic habitat conditions.

The number and abundance of invasive species colonising the isolated pools of the broken groyne fields and in the parallel work appeared lower than the number of invasive species colonising the standard groynes. Two neozoans, the American invader *Gamarus tigrinus* and *Physella acuta* from South-Western Europe were recorded in the isolated pools and three Ponto-Caspian invaders, *Corophium curvispinum*, *Dikerogammarus tigrinus* and *Jaera istri* were recorded in the standard groynes, also in much higher frequencies and abundances as shown by their respective percentage of contribution to the average similarity between replicates (Table 1).

Compared diversity among sites, using the log series α diversity index (Fisher et al. 1943) showed two contrasted patterns between the downstream and the upstream studied sites (Fig.2A). In broken groynes, isolated pools are hot spots of diversity which mainly contribute to the global biodiversity of the site. Diversity is almost two times higher in the broken groynes than in the standard groynes.

Table 1: Characteristic species and their percentage of contribution for the four studied sites. Neozoan species are underlined.

Broken Groynes - Isolated Pools	
Cloeon dipterum	11%
Gammarus tigrinus	8,7%
Caenis pseudorivulorum	6,2%
Physella acuta	5,9%
Helophorus sp.	5,5%
Sigara striata	4,1%
Sigara lateralis	2,7%

Standard Groynes Downstream	
Corophium curvispinum	28%

Parallel Work - Isolated Pools	
Ceratopogonidae	20%
Physella acuta	16%
Cloeon dipterum	14%

Standard Groynes Upstream	
Dikerogammarus villosus	14%
Helobdella stagnalis	10%
Jaera istri	5,7%
Micronecta minutissima	4,5%
Hydropsyche contubernalis	3,8%
Procloeon bifidum	3,7%
Baetis fuscatus	3,4%

In opposite, diversity in the parallel work was higher during the wet phase, when connected to the main channel of the River Elbe, but global diversity there was slightly lower than in the standard groynes. Productivity, expressed as ash free dry mass of macroinvertebrates per m² were also compared among sites (Fig. 2B). In both broken groynes and parallel work, isolated pools are hot spot of productivity. However, in the broken groynes most of the productivity occurs during the pool phase while the parallel work is more productive than the standard groynes, even during the wet phase.

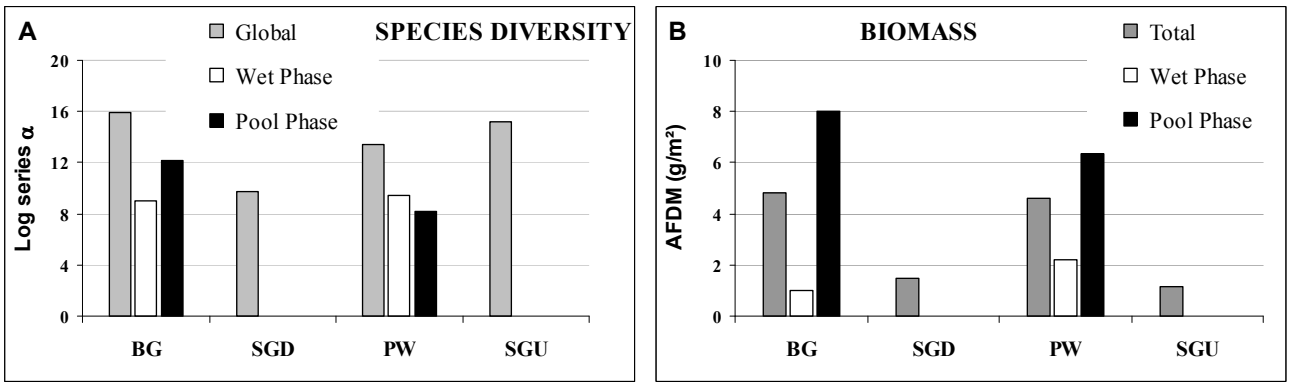

Fig.2: Among sites comparison of A) species diversity and B) productivity. BG: Broken groynes, SGD: Standard groynes downstream, PW: Parallel work, SGU: Standard groynes upstream.

Discussion

The occurrence during summer and autumn of isolated pools in the broken groyne fields and parallel work clearly enhanced the ecological quality of these sites. There, a high productivity was recorded due to higher temperature, high autochthonous primary production, and good availability of food. The high diversity and abundance of site-specific water beetles species recorded in the pools,

which are known to be early colonisers of newly created standing water areas, indicates constant colonisation along the time period. The high biodiversity recorded in the isolated pools of the broken groyne fields was related to the multiplicity of mesohabitat-types occurring there, as shown by the three identified characteristics species *C. dipterum, S. striata* and *S. lateralis*, which are known to need complex substrate to hide, as macrophytes and roots. In contrast, these habitats are poorly represented in the standard groynes due to permanent flushing by the waves and higher morphological uniformity. The low diversity recorded in the isolated pools of the parallel work may possibly be attributed to its recent construction, with attractive mesohabitats as macrophytes and woody debris still being absent. Another reason might be that the parallel work is disconnected from the Elbe main channel early in spring already. As a rougher flow regime would favour sediment dynamics, a diversification of the mesohabitats in the isolated pools is to be expected in that case. Also, colonisation by typical rheophilic species as observed in the standard groynes will be possible. This suggests that biodiversity could be even higher if the secondary flow behind the parallel work would be increased by a larger and deeper inflow opening, which would hardly affect navigation in the main channel. Similar conclusions have already been drawn from studies on the rivers Main, Danube, Elbe and Severn (Carling et al. 1996). Thus, it can be expected that parallel work groyne fields might become, as the isolated pools in the broken groynes, an important in-channel habitat contributing to high biodiversity in the River Elbe. Also, dynamic habitats appeared to be less colonized by neozoans.

In summary, it seems that the ecological conditions for invertebrates in the shore habitats of the River Elbe could be considerably improved by alternative ways of shore protection, without significant obstruction of navigation.

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