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Hydraulic conditions over bed forms control the benthic fauna distribution in a lowland river (Spree River, Germany).

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ABSTRACT: We report preliminary results of a detailed hydraulic-ecological study to identify the effects of flow hydrodynamics and morphodynamic processes on the distribution and composition of benthic invertebrates in a lowland river. We examined a riffle-pool-transitional sequence in a meander bend of the Spree River (Germany) and focused on the detailed flow structures over a representative micro-form in a riffle bed-form. Two invertebrate groups dominated the community: Diptera (mainly Chironomini) and amphipods (Dikerogammarus haemobaphes and Chorophium curvispinum). The results suggest that at the meso-habitat scale (i.e. riffle, pool and transitional zone) hydraulic conditions are most intense in the riffle zone, leading to low densities of invertebrates. At the micro-habitat scale (i.e. within the bed-form), the benthic invertebrates peaked in density on the crest where the bed shear stress was a bit lower comparing with the lee-side (mean differences around 33%). This study suggests that benthic macroinvertebrates prefer the benefits from lower hydrodynamic stress and of more stable environmental conditions in the studied meander, providing refuge and probably food.

Keywords: Eco-hydraulic, Benthic fauna, Bed form

1 INTRODUCTION

The term ecohydrology, including the subdiscipline of ecohydraulics, implies research at the interface between the hydrological and ecological sciences (Hannah et al. 2004). However, despite increasing attention to this relatively new discipline it is still in the state of infancy (Zalewski and Robarts 2003). This is probably attributable to the lack of attention ecologists have paid to hydraulics and morphodynamics or hydrologist to biotic interactions (Kemp et al. 2000). Changes in hydro- and morphodynamic condition directly or indirectly influence benthic invertebrates at the scale of individual organisms or assemblages. The past and current studies of the relationship between flow variation and benthic invertebrates includes several aspects such as the flow behaves around invertebrate bodies (Ambühl 1959; Statzner and Holm 1989; Statzner et al. 1991; Schmedtje et al. 1991; Hart et al. 1996; Callaghan et al. 2007), flow requirements and tolerances of invertebrate species (Rempel et al. 2000; Kawamura et al. 2003; Doledec et al. 2007; Rivers-Moore et al. 2007; Blettler et al. 2008; Amsler et al. 2009), near-bed hydraulic conditions and invertebrate microdistribution (Statzner 1981; Davis 1986; Lancaster and Hildrew 1993; Growns and Davis 1994; Merigoux and Doledec 2004), and invertebrate drift in relation to variation in natural flow regime (Statzner 1987; Borchardt 1993; Brittain and Eikeland 1988).

The general characteristics of macroinvertebrate communities (density, taxon richness, evenness) and their taxonomic composition have been demonstrated to vary on spatial scale (Downes et al., 1993; Townsend et al., 1997; Li et al., 2001). Those studies showed that multiscale studies are essential for the identification of characteristic scales at which ecological patterns can be detected in rivers. The variation in functional composition also occurs at very smaller scales where functional composition can vary at pool, riffle, and even within-riffle scales (Boyero 2005; Brooks et al. 2005). Habitat patches defined by flow characteristics and morphological features provide specific food resources and refuge for benthic invertebrates. These patches could be defined at riffle-pool scale (mesohabitat) and still within-bedform over a riffle scale (microhabitat). Then, the distinctive patterns of flow and morphology along fluvial bedform create specific habitat conditions for invertebrate assemblages or, in contrast, to induce individual drift. Hydro- and morphodynamic bedform field investigations are limited both in number and in the detail of measurements because of inherent difficulties involved in obtaining data on bedform-flow interactions within natural rivers (McLean and Smith 1979; Kostaschuk and Villard 1996). Field studies of turbulent flow structure over riverbeds covered by fed forms and dunes were conducted by McLean and Smith (1979), Kostaschuck and Villard (1996), Nikora et al. (1997), Sukhodolov et al. (2006), Holmes and Garcia (2008), between others. However, laboratory investigations on artificial bedforms and dunes have been more frequent. Although there has been intensive research on the influence of physical forces on benthic invertebrates and morphodynamics of dunes and bedforms in respect to hydraulic conditions, the previous studies examined the processes in frame of their own disciplines and separately.

Considering the above explanation, it is promising to study the possible link between hydraulic characteristics, closely related to morphological features, and benthic invertebrate distribution over bedforms. In this preliminary study we examined: i. relationships between morphology, flow and ecology in a sequence riffle -transitional -pool zone over a meander bend, focusing their effect on aquatic benthic invertebrate distribution (mesohabitat scale); ii. structure of flow prevailing over the stoss-side, crests and lee-side of a bedform on a riffle and its effect to spatial distribution of the macroinvertebrates (microhabitat scale).

2 METHODOLOGY

2.1 *Study river reach*

Field investigations have been carried out on the lower Spree River (Germany). The Spree drains an area of about 10000 km^2. The selected river reach is a meander bend located near the Neubrück city, 70km east from Berlin (Figure 1). This meander had a width of 25-30m, 1.5-3.5m of depth, b/h ≈ 10, 170° bend, a radius of 150m, a curvature ratio r/h > 60 and stable banks cover by vegetation. The river reach bed is covered by mobile sand-forming bedforms of ~10-15m in length and ~0.10-0.20m in height.

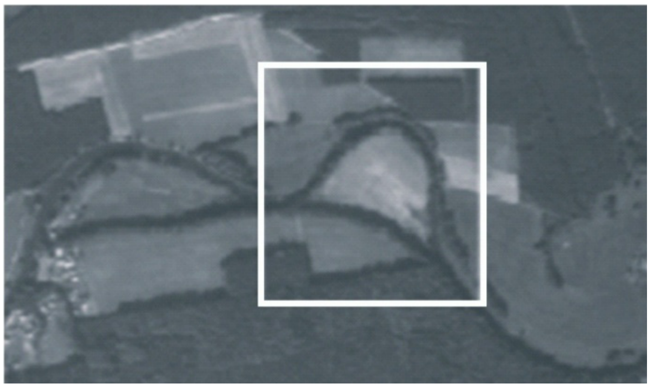

Figure 1. Location of the Neubrück meander bend.

2.2 *Benthic Sampling.*

Four benthic replicates were taken at each sampling point. The benthic samples were obtained with a Surber sampler 200µm net, filtered and fixed in 90% alcohol in the field. A total of five sampling point were selected. Three of them on the riffle zone (over the bed-form), one on the transition zone, and the last on the pool zone. A key point in the sampling procedure was the positioning in order to assure the four samples are taken exactly at the stoss-side, crest and lee-side of the selected bedform. It was attained by diving and checking the corresponding marked places in the line guide at the moment of each sample catch. In all cases the samples were taken in the central part of the channel. In order to know the specific position in the meander, a Total Station was used to check the corresponding coordinates.

The invertebrates were being hand-picked in the laboratory under a 10x stereoscopic microscope, identified and stored in an alcohol solution.

2.3 *Morpho- and hydraulic measurement.*

This study focuses on morpho –hydro and ecological characteristics on the selected bed form, therefore details of the river bed topography over it were surveyed with an acoustic doppler velocimeter (ADV) aligned with the current direction (trough a guide line emplacement). These measurements were performed in a high precision way (each 5 cm). Three velocity verticals were measured along the selected bed form, specifically over the stoss-side, crest and lee-side, by using the same ADV (Figure 2). A total of 15-20 point velocities were recorded at the verticals, closer spaced in the first centimeters from the bottom (each 5 cm). Each point velocity was measured for an interval of 240 seconds. The shear velocity was estimated as the intercept between z/h and u'w'; where z: distance from the bottom, h: depth, u': velocity fluctuation in the flow direction, and w': vertical velocity fluctuation. All hydro-morphological high-quality data were related to those of invertebrate distribution and diversity.

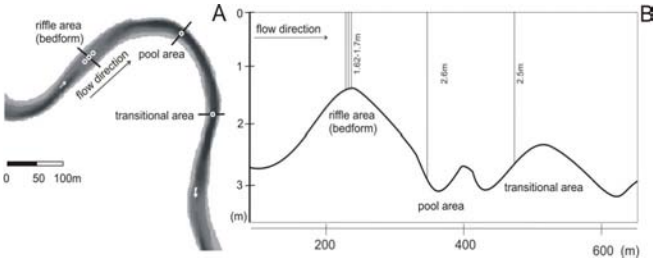

Figure 2. Surveyed meander bend with the location of each benthic station shown by white points. A, plan view of the meander. B, meander profile.

3 RESULTS

The main recorded benthic groups were Anphipoda, specifically Dikerogammarus haemobaphes (Pontogammaridae) and Chelicorophium curvispinum (Corophiidae), Chironomidae (Chironomini) and, in a lower proportion, Naididae (Oligochaeta) and Bivalvia. Total densities varied between 3103 (stoss-side of bedform) and 9102 ind. m^{-2} (pool area; Table 1). The highest density over the studied bedform was recorded on the crest.

Table 1. Invertebrate densities and principal benthic groups recorded on each sampling stations. Anhp.= Anphipoda; Chir.= Chironomidae; Olig.= Oligochaeta; C.c.= *C. curvispinum; D.h.= D. haemobaphes;* s-s= stoss-side; l-s= lee-side; tran.=transitional zone.

	Density (ind m^{-2})				
	Anph.		Chir.	Olig.	total
	C. c.	*D. h.*			
s-s	1423	110	1330	207	3071
crest	1582	124	2443	493	4643
l-s	373	54	2536	400	3364
pool	501	23	7797	781	9102
tran.	1526	210	5664	478	7879

The detailed recorded morphology of the bedform is shown in Figure 3. This bedform is symmetric with very small sandy forms superimposed which dimensions are 0.2 m high and 20.2 m length.

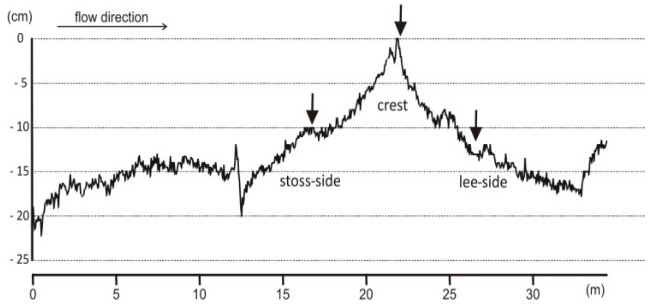

Figure 3. Surveyed bedform. Vertical scales on the right side enable to know the corresponding bedform high. Arrows showing the measurements and sampling stations.

The results of the hydraulic variables measured along the bedform profile are shown in Figure 4 (velocity and shear stress profiles). The lowest bed shear stresses occurred on the crest.

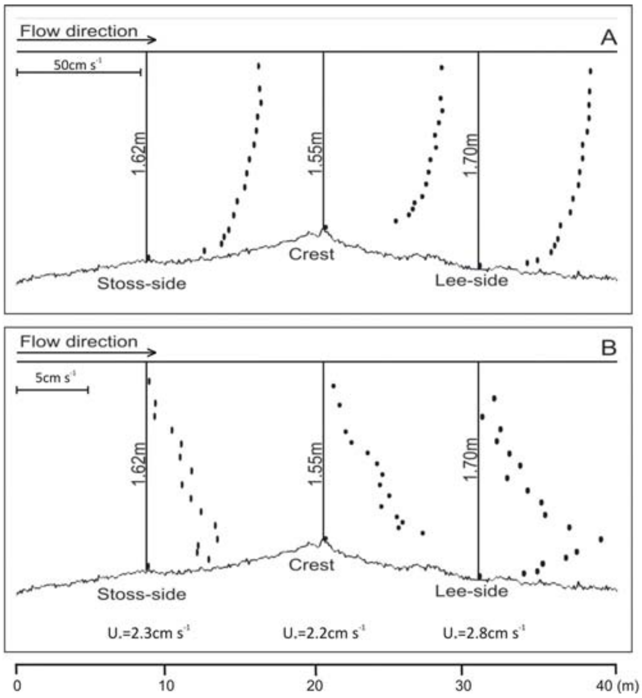

Figure 4. Hydraulic condition measured along the bedform. A, velocity profiles. B, shear velocity profiles and its values.

The Analysis of variance (ANOVA) revealed statistical differences in the benthic density between the bedform stations and the transitional - pool area (Figure 5). The application of the LSD Fisher post-hoc test supports this statement.

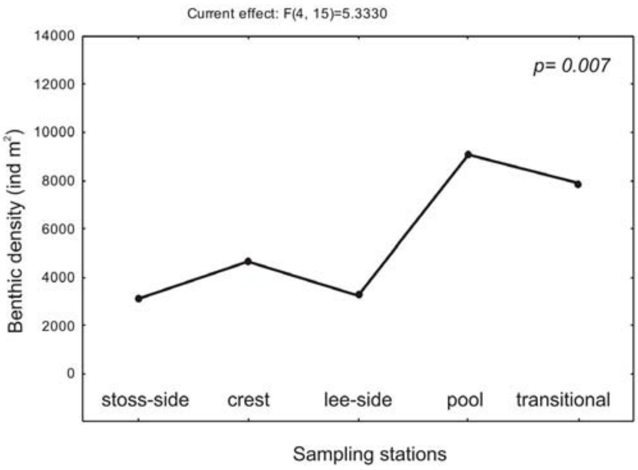

Figure 5. ANOVA results (circle= mean).

In spite of the variations of total benthic densities between the corresponding crest and lee-side were no statistically significant, a highest density was recorded on the crest. The opposite situation was recorded on the lee-side, i.e. the lowest benthic densities (mean differences around 33%). The Figure 6 shows the results of the box plot analysis revealing the same tendency and a highest benthic variability recorded over the crest.

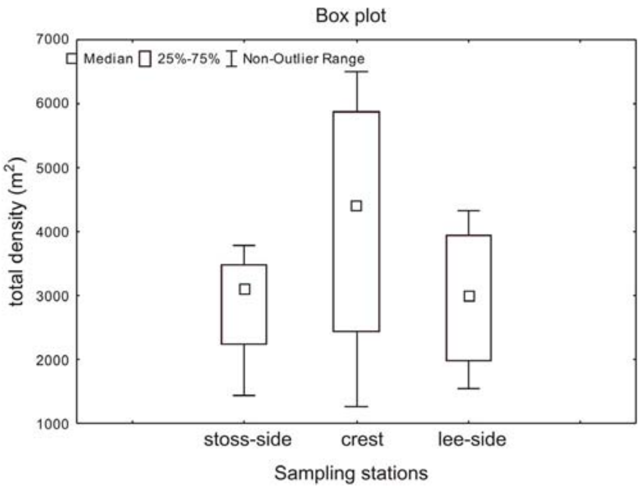

Figure 6. Box plot of the median of density distribution at each sampling point on the bedform (s-s: stoss-side; cr: crest; l-s: lee-side).

4 DISCUSSION AND CONCLUSION

4.1 *Meso-habitat scale (i.e. riffle -transitional - pool zone).*

Considerably higher densities of benthic invertebrates were recorded on pool and transitional zone on the Neubrück meander. The sequence riffle - transitional -pool zone of the central strip of the meander behave as 'hydraulic biotopes' (following the definition advanced by Wadeson, 1994) at a mesohabitat scale. The riffle area is subjected to stronger hydraulic conditions (larger bed shear stresses) than transitional or pool area. As a consequence, considerably lower densities of benthic macro invertebrates were recorded on the riffle.

4.2 *Micro-habitat scale (i.e. within bedform).*

Differences in benthic densities were also found at microhabitat scales (although no statistical differences), i.e. within-bedform scale. The global hydraulic conditions varied a bit between the stoss-side, crest and lee-side of bedform. The highest densities were found in the crest (depositional zone) where the lowest bed shear stresses occur. On the other hand, the smallest densities were recorded on the stoss-side and lee-side of the bedform. Apparently, the organisms prefer the crest of this kind of bedform.

It was shown in this study that a stratified benthic macroinvertebrates distribution may be found in a meander of a small lowland river. Multi-scale approaches are needed if a comprehensive understanding linking hydro- and morphodynamics processes with benthic organisms on meanders is desired, i.e. location of the sampling stations (riffle, transitional or pool area) and the position along the selected area (i.e. bedform over a riffle) should be all due accounted. However, considering the preliminary character of this study further investigations are necessary.

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