EXPERIMENTAL STUDY ON THE INTERACTION BETWEEN FRESHWATER MUSSELS, SEDIMENT AND HYDRAULICS

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Many freshwater mussels in Europe are on the endangered species list. However, the reasons for their decline are unclear. Water quality is a factor but not necessarily the determining one. This paper reports on a pre-study which investigated the effects of hydraulics and sediment as further components. We first describe the experimental set-up, then present the results, and finally draw our conclusions. The study, which was conducted at the Oskar-von-Miller-Institute at Technische Universität München (TUM), strongly indicates that there is an interaction between the mussels and the sediment, and between the mussels and the hydraulics. We therefore recommend that longitudinal studies are conducted to investigate these effects in more detail.

1 INTRODUCTION

The behavior of mussels in rivers, and the effects and interactions resulting from this behavior is still a relatively under-researched area. What previous studies there are focus mainly on the biological behavior of the mussels [1], the transport of larvae in the flow [2], or the effects of the environment on the mussels themselves; for example, the effect of sound on mussels [3], or light on mussels [4].

Our experiments had two different foci. One was hydraulically based, and the other related to the expected interaction between mussels and sediment. The assumption was that mussels have the same effect on the current as a beveled stone of comparable size, and how they arrange themselves in the flume in relation to the flow direction is of interest since whether or not they are clustered together might affect their ability to procreate. Ambühl [5] and Constantinescu *et al.* [6] used artificial mussels in their experiments to evaluate the flow structure around single mussels. The migration of mussels in a natural waterbody shows that they migrate to the banks and the shore area [7]. Schwalb *et al.* found that mussels move sporadically and in groups [7] in a natural river. Our experiment confirmed this finding for behavior in the flume. We expected that this migration of mussels would have an effect on the sediment.

To the best of our knowledge, no studies to date have investigated the effects of hydraulics and sediment on mussel behavior. As the results found in nature [7] and with artificial mussels [6] can be achieved also in a lab flume and with real mussels, we assume that further experiments can be done under controlled laboratory conditions. In such experiments in a lab, e.g. more different velocities could be evaluated with respect to the behavior of the mussels and the flow structures around different individuals using detailed measuring equipment.

2 MATERIALS AND METHODS

2.1 Experimental set-up

The flume used for the experiments is made basically of concrete and glass. The width of the flume is 0.5 m, the flow length was about 12 m (Fig. 1).
The discharge in the flume can be controlled with a Magnetic Flow Meter (MFM) located at the inlet of the flume. The water was taken from river Obernach to create a less artificial surrounding, so the behavior of the mussels is not negatively influenced by an unnatural water quality. For the same reason the sandy sediment was composed with a grain size distribution comparable to small rivers, the natural habitat of *Unio pictorum*, with a maximum grain size of 4 mm.

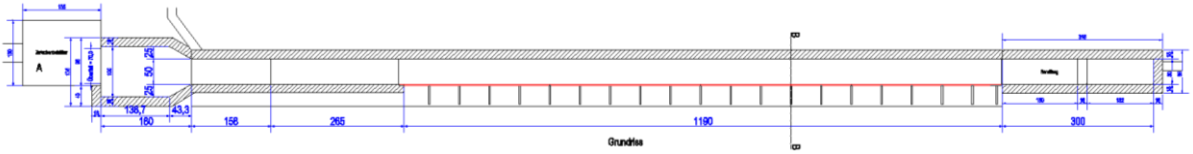

Figure 1. Plan view of the flume, the flow direction is from left to right. The MFM is located at position A (left), the mussels are situated beginning of cross-section B-B. The glass wall is on the right side orographically.

The flow velocity during most of the time was kept stable with an average value of 0.1 – 0.2 m/s. Only for the hydraulic experiments the velocity was varied up to 0.3 m/s and kept stable on this value for about six hours. These velocity values follow the different flow velocities in the study of Schwalb *et al.* [7].

The behavior of the *Unio pictorum* was monitored with optical tracking over a period of two month without any intervention. The effects of their migration on the sediment were observed, scanned with a Kinect system and evaluated as a 3D model. Also the interaction with the flow was measured using Particle Image Velocimetry (PIV), a measurement technique to collect information about the turbulent structures and the velocities around the mussels.

The mussels used in the experiment were adult *Unio pictorum* from a mussel farm with a size of 5-10 cm. This species was chosen due to comparability with other studies [6] including *Unio pictorum*. At the beginning of the experiment the mussels where positioned at the last third of the flume in a raster of three mussels in y-direction (perpendicular to the main flow direction) and four mussels in x-direction (parallel to the main flow direction). As the mussels have to be set into the flume anyway this method made it easier to value the first movements.

2.2 The Hydraulic Measurements

Two weeks after inserting the mussels in the flume the measurements of the interaction between the flow and mussels were conducted. We used a standard PIV system (2D). The system is a combination of a Neodym-YAG laser with a CMOS camera of ILA (Intelligent Laser Applications GmbH). With this method a camera is taking double pictures of an area in the flow illuminated by the laser, the so called laser sheet. The particles in the water flow through this sheet with a certain velocity. This velocity can be evaluated calculating the displacement of the single particles between each pair of pictures.

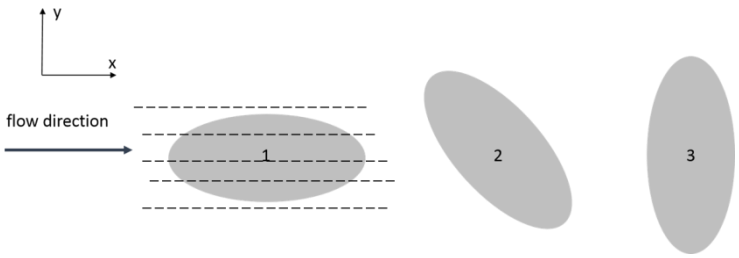

Figure 2. Schematic view of the three positions of the probed mussels: parallel to the flow (1), inclined to flow (2) and at right angle to the flow (3). This view is not a scale model.

Mussels in three different positions (Fig. 2) were used for the measurements of the turbulence and the flow velocity in the near field of each mussel. The laser sheets were positioned beside the mussel as well as around the mussel´s shell as shown exemplarily in Fig. 2 with the dashed lines. The measurements were conducted for two different flow velocities (0.12 m/s and 0.3 m/s). These velocities are comparable to the lower and the highest flow velocities of the study of Schwalb *et al.* [7].

2.3 Sediment Observations

The mussels started immediately to rearrange. As the diameter of the material was rather small the mussels could relocate the soil material easily. The effects on the sediment as depression and elevation of certain areas were measured using a standard Windows Kinect system. This system works as a laser scanner. It puts a laser-grid on the surface and detects the distance between the device and the grid. While moving the scanner over the surface it is possible to rearrange the constructed mesh and even close small holes in the data set. The result of such a

measurement is a point cloud. This can be covered, using programs such as MeshLab, with a mesh to generate a 3D object.

The scanner is not able to penetrate the water surface very deeply as the red laser is not strong enough, but the mussels cannot be dried up at any time. Therefore comparative measurements were executed in advance to identify such water depth which is appropriate for a scan with a sufficient data point amount and mesh quality. This is a depth of 5 cm. As an additional possibility to enhance the data quality, the flow was stopped during the measurements. Thus we avoided waves on the surface and subsequently high refraction rates of the laser.

3 RESULTS AND DISCUSSION

The results of the experiments show a good accordance to the literature ([6] and [7]). Although the number of mussels in our experiments was quite small, the results are in good accordance with the data found for the behavior in the natural field site [7]. Approx. 75 % of the mussels moved within the first week after the rearrangement. 95% of the mussels showed a shoreward displacement. 20% of the mussels were moving in long tracks within a short time period (over 2 m/day). Also these long distance movements took place within 15 cm of the walls. The smaller mussels (5-7 cm) dug themselves under the surface of the sediment, the bigger ones protrude mainly from the sediment and therefore caused an effect on the flow. The effect can be compared with a slanting stone in the flow as shown with an artificial mussel in the study of Constantinescu *et al.* [6]. Especially for the mussels perpendicular to the flow direction the velocity behind the mussels decreases clearly and simultaneously the turbulence intensity increased (Fig. 3).

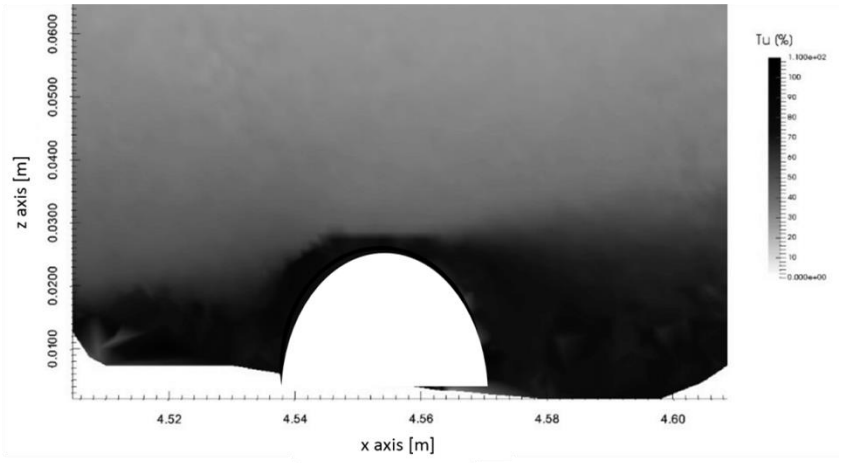

Figure 3. The effect of the mussel positioned at right angles to the flow on the turbulence intensity measured with the PIV. The darker the black the higher the turbulent intensity.

In general we can assume that the characteristics of the mussels are comparable to a stone of the same diameter and form as the artificial mussels are [6]. However the mussels are able to arrange parallel to the flow. In all the rearrangements, except for single mussels, all arranged either parallel (60%) or inclined (40%) (position 1 and 2 in Fig. 2). These results could be achieved for both flow velocities (0.12 m/s and 0.3 m/s).
A more clear effect in interaction with the flow appeared in combination with the sediment interaction. The migration paths showed clear marks in the soil material (Fig. 4).

Due to the low flow velocity (0.12 m/s) the changes were stable and could be observed during all the experiment. The total elevation changes could reach up to 10 cm between the lowest point and the highest point of the affected area. As approx. 25% of the mussels changed their places often and covered a long distance the area looks quite furrowed. As described, the mussels preferred to take the path with less flow resistance so the furrows are not parallel to the flow (Fig. 4). For the velocity of 30 cm/s the furrows collapsed and the bottom structure was getting smoother again. These results can be evaluated using the different 3D models of the point clouds measured and combine the results of the different measurements. The sediments observations confirmed that the migration of mussels cause a motion of the sediments of three times the width of one mussel and an affected depth of 3 cm on average.

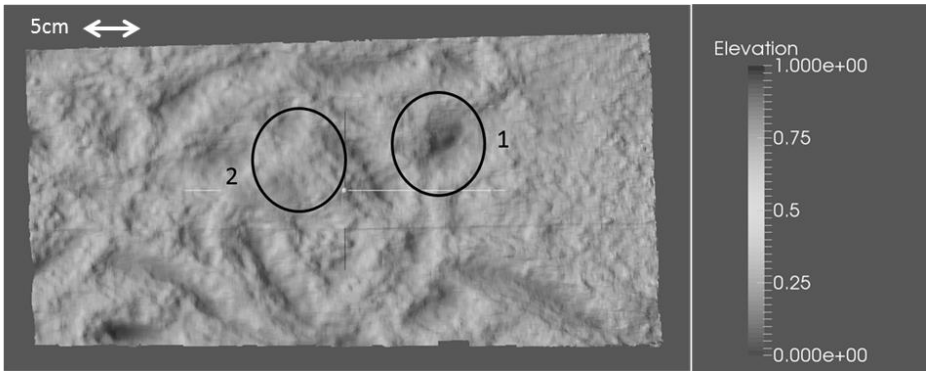

Figure 4. The effect of the mussels on the sediment after one week of observation. The shown detail has a length of approx. 1 m. The dark grey areas (1) show the depressions in the sediment, the lighter grey areas (2) the elevation.

4 CONCLUSION

The results have to be split, on the one hand the flow influences the mussels, how they arrange in the current and how far, often and fast they move. On the other hand the mussels also influence their neighborhood. The mussels themselves and also the elevations in the soil increase the turbulence intensity in the flume. The raised material is eroded again, so slowly and only slightly but clearly, existing rearrangement processes of the sediment take place. As the flume was operated with natural river water it could be observed, that the fine particles in the water, like clay, settled especially in these furrows. These areas are not that exposed to the flow so the shear stress is lower and the erosion of the clay happens less easily. Thus the upper layer of the sediment is mixed up and the composition can change very slowly. The effect of the mussels on the sediment, even if it is not detectable in a very short term observation, can be seen as obviously present. Although in this set up only very few mussels could be used, and the flume has for instance not the size of a natural river bed, the behavior of the mussels showed a very good accordance with studies carried out in the field site [6].
The study is ongoing with the evaluation of the data using the quadrant analysis method given by Pokrajac *et al.* [8]. This should give us a more detailed insight into the spatial disturbances of the time-averaged velocity field around the mussels. Also there is a deeper evaluation of the changes of the bed ongoing using different methods of cloud comparison.

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