FIELD EXPERIMENTS TO ASSESS THE LINKS BETWEEN BED-MATERIAL ENTRAINMENT AND INVERTEBRATE DRIFT IN GRAVEL-BED RIVERS

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1. INTRODUCTION

Patches of fine material (Figure 1) play an important role in sediment transport in gravel-bed rivers (Laronne et al., 2001; Garcia et al., 2007). They are particularly important in contributing material in the early stages of flood events and may be the dominant source of bedload transported during small and medium sized events. Moreover, entrainment of fine material can trigger mass drift of benthic invertebrates (Gibbins et al., 2007a, 2007b). Thus, patch sediment entrainment is of ecological relevance.

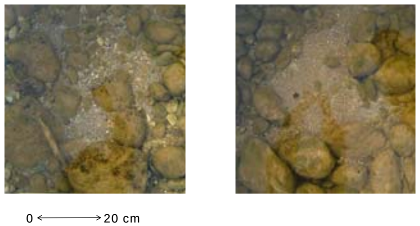

Figure 1: Patches of fine sediment in a gravel-bed river (Ribera Salada, NE Spain).

2. PATCH ENTRAINMENT

Sediment entrainment from patches of fine material in gravel-bed rivers is poorly known. Bedload studies have largely neglected the process of incipient motion from patches, primarily due to technical constraints on sampling. Historically, basket samplers (e.g. Helley-Smith) have been the most frequently used direct technique for collecting bedload data. However, this technique may underestimate the quantity of fine material moving across the bed due, for example, either to 'blockage' or what has been termed 'perching' (Vericat et al., 2006). Moreover, manual samplers require the operator to have the predictive capacity to be in place during the early stages of flood events when incipient bedload transport occurs. Automated sampling devices such as Birkbeck pit-traps can address this limitation, although as they have relatively high detection thresholds, they provide limited insight into conditions or episodes of very low bedload transport.

Garcia et al. (2007) present one of very few studies describing entrainment and low bedload transport from patches of fine material in upland gravel-bed rivers. Using video observations, they confirmed that within-patch grain instability, followed by within-patch gyratory step-and-rest motion, followed in turn by general sediment motion, are the three phases of sediment entrainment in patches. We designed and built a novel flume to quantitatively assess the phases of fine sedimnt entrainment from patches. The flume (Figure 2) was designed to re-create hydraulic conditions in the field such as attained during early stages of flood events. The flume allows manipulation of conditions in situ, rather than in a laboratory flume setting where experimental artefacts can confound interpretation of geomorphological and ecological responses.

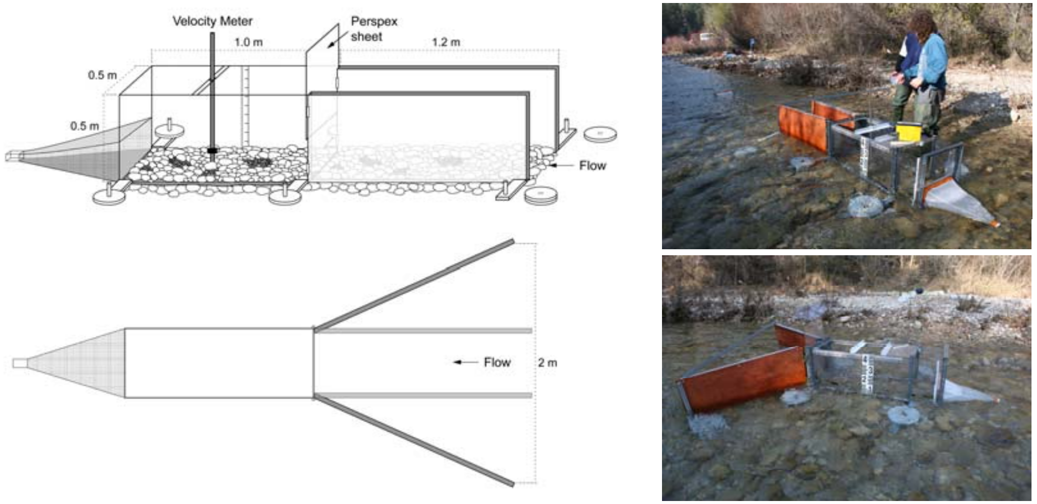

Figure 2: The portable flume: flume characteristics and dimensions, plan view of the flume with the doors in the normal position and with doors opened, increasing discharge and altering hydraulic conditions (diagram from Vericat et al. 2007). Photographs illustrate both operations.

3. FLUME OPERATIONS

1) The flume encompasses individual patches; the bottom is open, isolating experimental patches of stream bed from the rest of the channel. A net is fitted tightly to the full width of the flume its downstream end, capturing bedload material and any animals mobilised (Figure 2).
2) Hinged doors are fitted to the upstream end of the flume: a) in the normal position they run parallel to the sides of the flume, and so flow conditions are not manipulated; while b) when they are opened, the doors funnel water from a 2 m wide section of channel into the flume, increasing flume discharge and altering basic hydraulic conditions (Figure 3).
3) To produce further increases, at the upstream end of the flume a Perspex sheet can be slide vertically in, creating a near-bed jet of water inside the flume. This increases velocity and boundary shear stress.

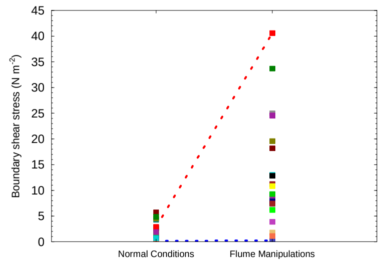

Figure 3: Range of shear stress recorded during the experiments, where V1: no manipulations and V2: flow manipulations. Red and blue dashed lines shows the maximum and minimum increments respectively.

4. RESUTLS

Field experiments using the flume were carried out in the Ribera Salada River (NE Iberian Peninsula), an upland unmodified stream in the Ebro basin (see photographs in Figure 2). Manipulations (opening flume's doors) produced a mean increase in velocity over 120% over the patches, with velocity >2 m s^{-1} in some cases. During the flow manipulations boundary shear stress increased considerably: the maximum increment observed wasd from 2 N m^{-2} to 40 N m^{-2} (Figure 3). Bedload transport was not recorded when the doors were in the normal position (parallel to the sides of the flume), but when doors were opened manipulated flow conditions resulted in entrainment of material from patches (Figure 4a). The maximum bedload transport rate created by the manipulations was close to 7 g $m^{-1}s^{-1}$, a value typically attained during the early stages of floods in the study section of the Ribera Salada. Median bedload material ranged from 0.5 to 2 mm (mean D_{50}= 1.4 mm), being coincident with median patch material particle size (0.6-2.2 mm, mean D_{50}= 1.6 mm, Figure 1). The maximum particle size entrained during the experiments was of 41 m. The number of animals captured in the net during the experiments indicated that a marked increase in the loss of animals from the bed occurs at the point when sediment becomes unstable and bedload transport is initiated (Figure 4b). Calculations suggest that at the highest shear stresses created by the experiments (i.e. 40 N m^{-2}), patches of fine material may be denuded of animals within a 30 minute period. The preliminary experiments in the Ribera Salada demonstrate the potential of the flume to study patch entrainment and sediment transport in patchy rivers, as well as to provide insights into the ecological consequences of these physical processes.

5. CONCLUSIONS

This portable flume has the potential to offer new insights into low bedload transport conditions, the implication of them for invertebrate drift and associated hydraulic controls. It permits controlled flow manipulation in natural river channels. Although the design of the flume can be improved upon, it can be used to address questions related to incipient bedload transport, which conventional approaches such as Helley-Smith sampling or pit traps may be unable to do.

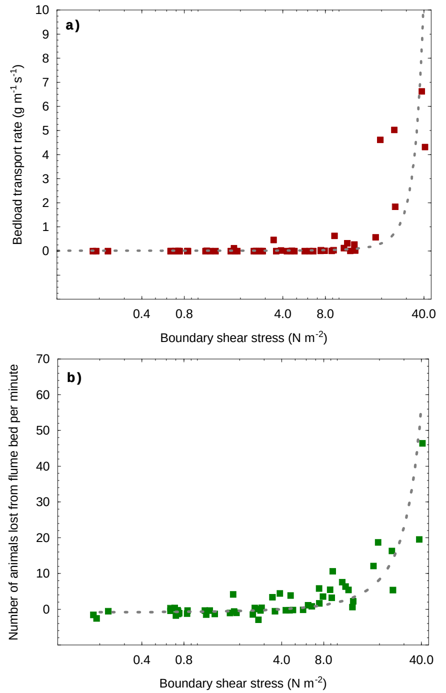

Figure 4: Relationship between boundary shear stress and (a) bedload transport rate and (b) number of animals lost from the river-bed. In each case an exponential curve provided the best fit to the data. The breakpoint in the relationship between shear stress and number of animals (identified using Spline analysis) occurred at 8 to 10 N m-2 and is coincident with that for sediment entrainment.

6. REFERENCES

Garcia C., H. Cohen, I. Reid, A. Rovira, X. Ubeda, and J.B. Laronne (2007), Processes of initiation of motion leading to bedload transport in gravel-bed rivers, *Geophysical Research Letters* 34 (6).

Gibbins, C.N., D. Vericat, R.J. Batalla, and C.M. Gomez (2007a), Shaking and moving: low rates of sediment transport trigger mass drift of stream invertebrates, *Can J Fish Aquat* Sci 64 (1), 1-5

Gibbins, C.N., D. Vericat, and R.J. Batalla (2007b), When is stream invertebrate drift catastrophic? The role of hydraulics and sediment transport in initiating drift during flood events, *Freshwater Biology* 52, 2369-2384.

Laronne J.B., C. Garcia, and I. Reid (2001), Mobility of patch sediment in gravel-bed streams: patch character and its implications for bedload, in *Gravel-bed Rivers V*, edited by M.P., Mosley, pp. 249-289, New Zealand Hydrological Society, Wellington, NZ.

Vericat, D., M. Church, and R.J. Batalla (2006), Bedload bias: Comparison of measurements obtained using two (76 and 152 mm) Helley-Smith samplers in a gravel-bed river, *Water Resources Research* 42, 1-13.

Vericat, D., Batalla, R.J. and Gibbins, C.N. (2007): A new tool to study links between sediment transport and invertebrate drift, *Eos Trans. AGU* 88(41), 410

Fall 2007 AGU Meeting, San Francisco: Abstract H51H-0874