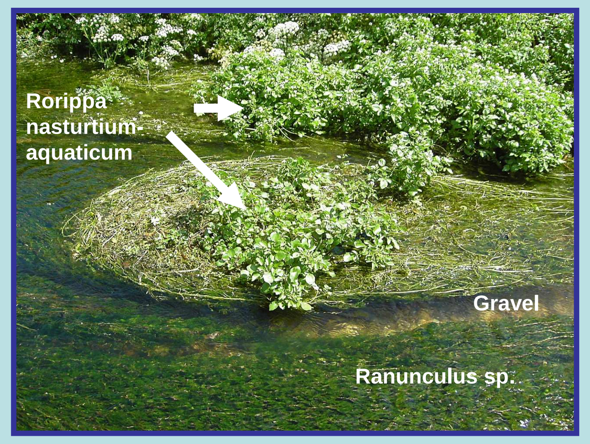
Spatial and temporal variations in the erodibility of fine riverine sediment

Robert C. Grabowski **Queen Mary, University of London, Department of Geography,** r.c.grabowski@gmail.com

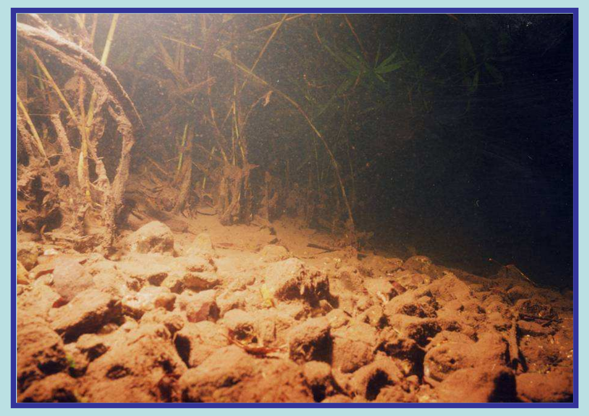
Queen Mary University of London

1) Sediment in chalk streams

- Chalk streams in England are experiencing an increase in fine sediment deposition, linked to changes in land-use practices and reduced baseflow due to groundwater abstraction (i.e. Chalk Stream Malaise)[1].
- Fine sediment accumulates within the gravel bed, under aquatic macrophytes and along margins, where it can negatively impact the ecology, hydrology and anthropogenic uses of the streams[2].
- Fine sediment deposition degrades salmonid spawning grounds[3], reduces surface-groundwater exchange[4], alters nutrient processing in the hyporheic[5] and creates stores of sediment-bound contaminants[6].
- To better gauge the negative impacts of fine sediment on chalk streams, information is needed on the stability of the sediment deposits.



Representative macrophyte community in a chalk stream. Sediment accumulates within the macrophyte beds and along the margins. (Bere Stream, Frome-Piddle Catchment, Dorset). Photo courtesy of G. Davies.



Fine sediment accumulating beneath a macrophyte bed in a chalk stream (Frome-Piddle Catchment). Photos courtesy of L. Baldock.

2) Erodibility

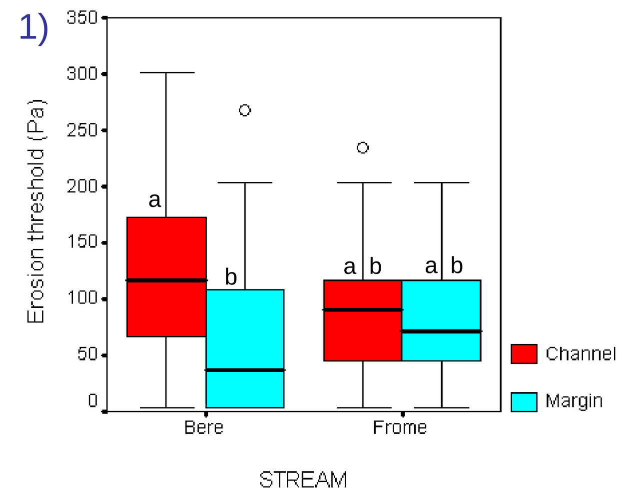
- Erodibility is a measure of the sediment's resistance to erosion by flowing water, e.g. erosion thresholds[7].
- Sediment stability = erodibility + hydrodynamics.
- Erodibility is a characteristic of the sediment itself, determined by the interaction of several key physical, geochemical and biological factors[7].
- To date, few studies have quantified fine sediment erodibility in rivers, and none have examined chalk streams.

3) Methodology

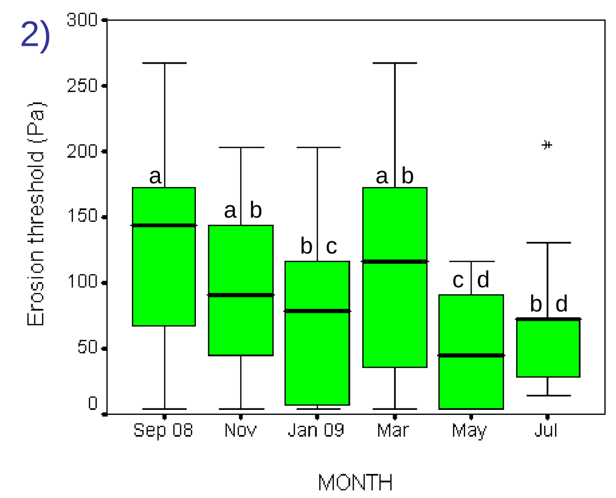
- A yearlong field survey was conducted in 2 chalk streams (Bere Stream and River Frome, Dorset) to investigate the erodibility of surficial fine sediment deposits (stratified random survey design).
- Paired sediment cores and *in situ* cohesive strength measurements (CSM) were taken in areas of sediment accumulation, e.g. macrophyte beds and margins, in each stream reach (n = 20). As a part of this study, a calibration was derived to convert CSM-derived erosion thresholds to critical shear stress[8].
- Sediment cores were analysed in the laboratory for particle size (absolute and effective), bulk density, organic content, cation and metal concentrations (e.g. SAR), colloidal carbohydrates, and chlorophyll-a.
- Data analysis included Kruskal-Wallis and Mann-Whitney U test to compare groups, and regression trees, linear regression and mixed effects modelling to determine the key sediment properties.

3) Erodibility varies over space and season

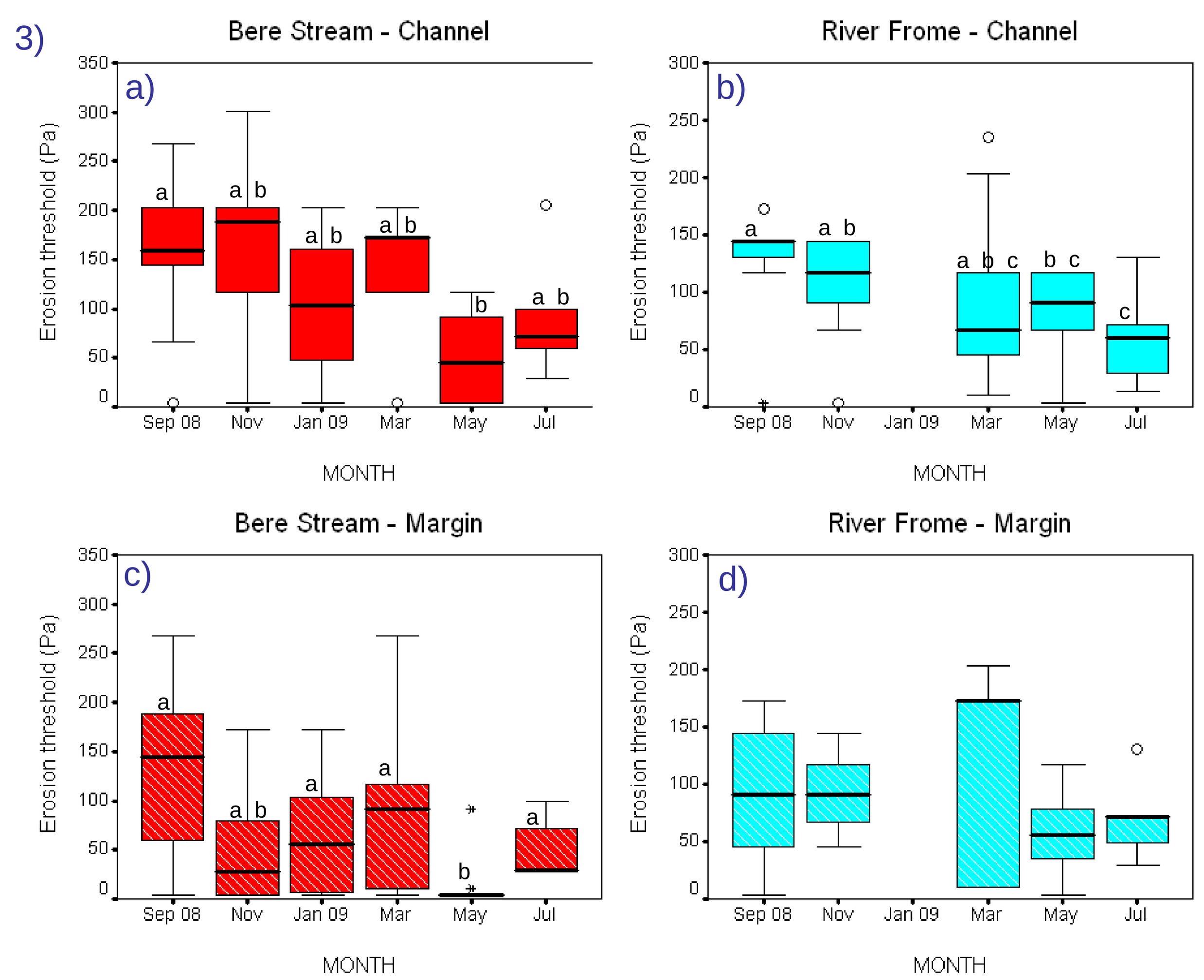
- Erosion thresholds were highest in the mid-channel of the Bere Stream (Fig. 1).
- No significant difference in erosion thresholds between rivers (Fig. 1).



- Median erosion threshold decreased significantly over the study period for both streams (Fig. 2).

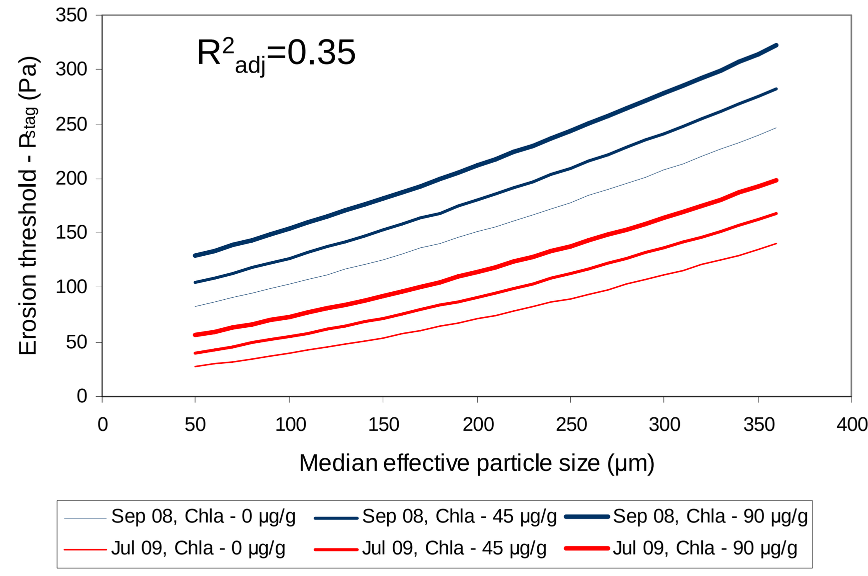


- Erosion thresholds decreased over time for fine sediment located in the mid-channel (Fig. 3 a, b).
- Erosion thresholds fluctuated more over time in the margins (Fig 3 c, d).



5) What sediment properties are responsible for the variations in erodibility?

- Two sediment properties were identified as statistically significant explanatory variables for the spatial and temporal variations in erosion thresholds.
  - Effective particle size: the median size of natural flocs and aggregates.
  - Chlorophyll-a: a proxy for the photo-autotrophic microbial community biomass (e.g. diatoms).
- There was a significant temporal component unexplained by the measured variables.



6) Conclusions

- The erodibility of fine sediment deposits varies significantly over space and time in chalk streams.
  - Sediment found within the middle of the channel had greater erosion threshold than in the margins (Bere Stream).
  - Erodibility varies significantly over the course of the year. Median erosion thresholds decreased over the study period (ca. 2x), though patterns varied by location within the stream.
- Variations are primarily explained by two sediment properties, a physical and a biological one, effective particle size and chlorophyll-a.
- The existence of significant spatial and temporal variations in erodibility has important implications for the dynamics of sediment and sediment-bound contaminant transport in river basins.

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