Testing the Battin model of downstream fluvial change in organic matter, biofilms and microbial habitats: the role of stream power and sediment distribution

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Abstract: Organic carbon in rivers is a major source of energy to fuel ecosystems, and most streams outgas carbon dioxide to the atmosphere via processing of organic matter by micro-organisms. Battin et al (*Nature Geoscience* 2008 p.95) hypothesized that catchments are meta-ecosystems 'to include the acclimation of microbial communities in downstream ecosystems that enable them to exploit energy that escapes from upstream ecosystems, thereby increasing the overall energy utilization'. This project aims to carry out the first field test of the Battin model by integrating measurements of (a) more sensitive estimators of channel carbon storage locations and biofilm dynamics in relation to (b) changing stream power distributions (a key measure of fluvial energy) and biological controls, in a series of rivers in western and upland Britain. Stream power is a key control of fluvial processes, and we further hypothesize that such microbial communities must adapt to changing stream power, channel hydraulics, associated bed stability and sediment load, which partly controls light availability. We have developed a new methodology (CASSP) to derive stream power values at high resolution down entire rivers (Barker, Lawler et al., 2009). Often, flood power peaks in mid-catchment: this supports our earlier simulations, but contradicts previous models. The student, as part of the Water Sciences group, will assess the impact of such physical energy peaks on organic matter, benthic biofilms, microbial habitats and ecosystem function, measured using novel characterization techniques. See full project outline at: www.gees.bham.ac.uk

References:

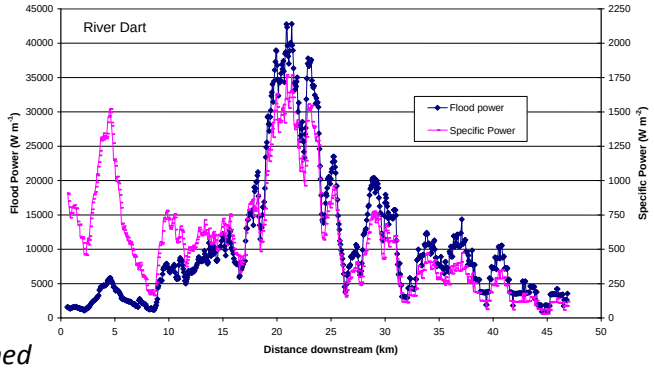
Barker, Lawler et al 2009. Longitudinal distributions of river flood power. *Earth Surf. Proc. L*, 34, 280–290

Battin et al 2008. Biophysical controls on organic carbon fluxes in fluvial networks. *Nature Geoscience* 1: 95-100

Organic carbon in rivers is a major source of energy to fuel stream ecosystems, and most rivers outgas carbon dioxide to the atmosphere due to the processing of organic matter by micro-organisms (Cole et al 2007). Interestingly, Battin et al (2008, *Nature Geoscience,* p95) hypothesized that river catchments are meta-ecosystems 'to include the acclimation of microbial communities in downstream ecosystems that enable them to exploit energy that escapes from upstream ecosystems, thereby increasing the overall energy utilization'. Such microbial communities must therefore adapt to changing stream hydraulics and associated bed stability, sediment load, carbon quality and fluxes. However, the Battin et al model is conceptual, and has not yet been rigorously validated in the field, so we know little of its potential applicability. Therefore, this project aims to carry out the first field test of the Battin model by integrating (a) more sensitive estimators of channel carbon storage locations and biofilm dynamics in relation to (b) changing stream power distributions (a key measure of fluvial energy) and sediment controls, in a series of rivers in western and upland Britain measurements. Also, we have recently derived at Birmingham the first high-resolution stream power datasets for 34 river systems, using our new CASSP (CAtchment-Scale Stream Power) methodology (Barker, Lawler et al., 2009): these will be used to test such conceptual models of interactions between stream biota and channel hydraulics at basin scales.

Our Water Sciences group, which includes leading physical hydrologists, geomorphologists and hydroecologists, is well-placed to carry out this study.

Stream power is a strong control of fluvial and ecological processes, including channel erosion, sediment fluxes and habitat development. Until recently, however, very little was known about the spatial structure of flood power distributions at river catchment scales. The new CASSP methodology, already applied to 34 UK rivers (Barker et al., 2009), allows, for the first time, full spatial structures of ***flood power*** to be delivered at an unsurpassed 60m spatial resolution along entire rivers. It can also be applied to drainage networks, too, to allow testing for system fractality. In half of the basins, we found that flood power peaked in mid-catchment (e.g. see R. Dart power distribution in Figure): this key result supported our theoretical DOCPROBE simulations but, crucially, *contradicted earlier models which assumed simple monotonic increases or decreases in stream power.* Therefore, it is clear that we now need to assess the impact of such recently-discovered mid-catchment peaks in stream energy (in addition to channel hydraulics, bed stability and sediment load which partly controls light availability) on organic matter, benthic biofilms, microbial habitats and ecosystem function along river continua (e.g. storage/retention in fluvial systems).



This novel and timely PhD proposal links our expertise in the fields of river channel hydraulics at the catchment scale, especially stream power distributions (Barker, Lawler et al. 2009), sediment flux (Lawler et al, 2006) and the quantification and characterization of dissolved organic matter at catchment scales. These stream power variables will be used to predict hydraulic and geomorphological variables which impact on organic carbon quality, storage and fluxes, including specific microbial and biofilm activities. The student will be trained through Masters modules and dedicated specific research skills training including experimental design, water, sediment and biota assessment monitoring/sampling techniques, data QA protocols, and novel stream power characterization and modeling techniques. The strong focus on both field, lab, numerical and conceptual model-development research will significantly to enhance the training and career prospects for the student, especially within pure/applied research, water resource management, pollution control and environmental consultancy.

Example References:

Barker DM, **Lawler** DM et al 2009. Longitudinal distributions of river flood power. *Earth Surface Processes and Landforms,* **34:** 280–290

Battin TJ et al 2008. Biophysical controls on organic carbon fluxes in fluvial networks. *Nature Geoscience,* 1: 95-100

Cole JJ et al 2007. Plumbing the global carbon cycle: waters & carbon budgets. *Ecosystems* 10: 171-184

Ledger ME, Harris RML, Armitage PD & Milner AM 2009. Realism of model ecosystems: an evaluation of physicochemistry & macroinvertebrate assemblages in … streams. *Hydrobiologia*, 617, 91-99

Applications are welcomed from strong students in Geography, Ecology, Environmental Science or relevant discipline. Please contact the supervisors (d.m.lawler@bham.ac.uk; m.e.ledger@bham.ac.uk); or Gretchel Coldicott, Postgraduate Administrator (g.coldicott@bham.ac.uk). Tel: +44-121-414-6935/5532.