

Motivation

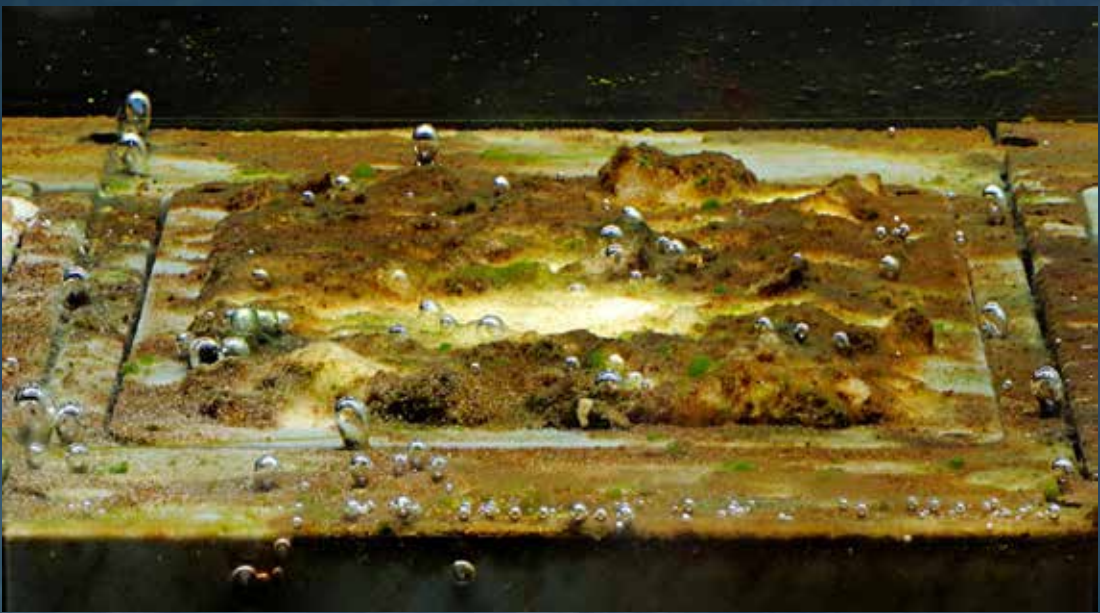
Coastal, estuarine and fluvial environments are vulnerable to future climate change due to **non-linear responses** to shifts in boundary conditions such as rising sea level and more frequent extreme events (i.e. intense rainfall or storm surges). **Biota** are an integral part of these environments, since organisms are often at the interface between water and sediment transport systems. **Flume experiments** provide opportunities to isolate and quantify the impact of different forcing regimes on biota under controlled conditions.



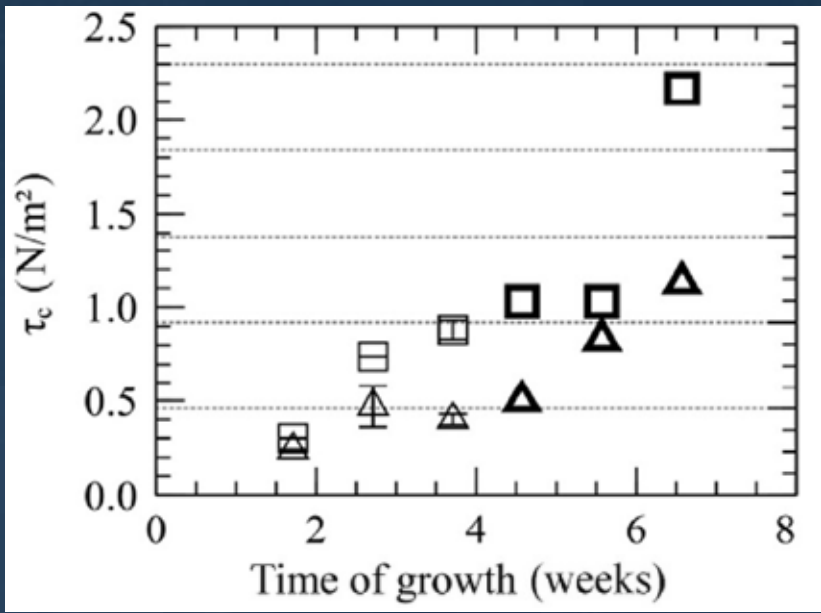
1. Natural biofilms

- **Considerable influence on sediment stability and erodibility**
 - > Primarily due to secretion of extracellular polymeric substances (EPS) by micro-organisms
 - > Reported five-fold increase in critical bed shear stress compared to uncolonised sites
- **Evaluate growth behaviour and sediment stabilising capacity**
 - > Saline, brackish and freshwater environments
 - > Obtain growth and sediment stability reference curves
 - + Minimum timescales in maturing a biofilm to assist with scaling of time
 - + Quantify added sediment stability
 - > Measurements include sediment stability, EPS and chlorophyll-a concentrations
- **Test resilience and recovery following climate-change related stresses**
 - > Droughts (simulating longer periods of low flow)
 - > Floods (simulating increased storminess and flood risk)
 - > Increased salinity (simulating sea-level rise)

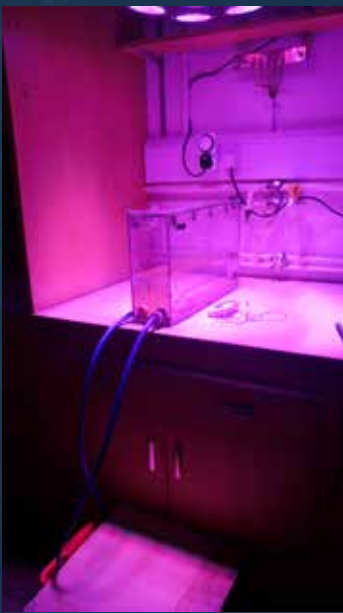
BUT: large variability in space and time and takes long (weeks to months) to grow (see box 2)



A 3-week old biofilm grown under controlled lab conditions. Gerbersdorfer & Wieprecht (2015)



Biofilm growth resulting in biostabilisation of substrate and higher bed shear stresses. Thom et al. (2014)

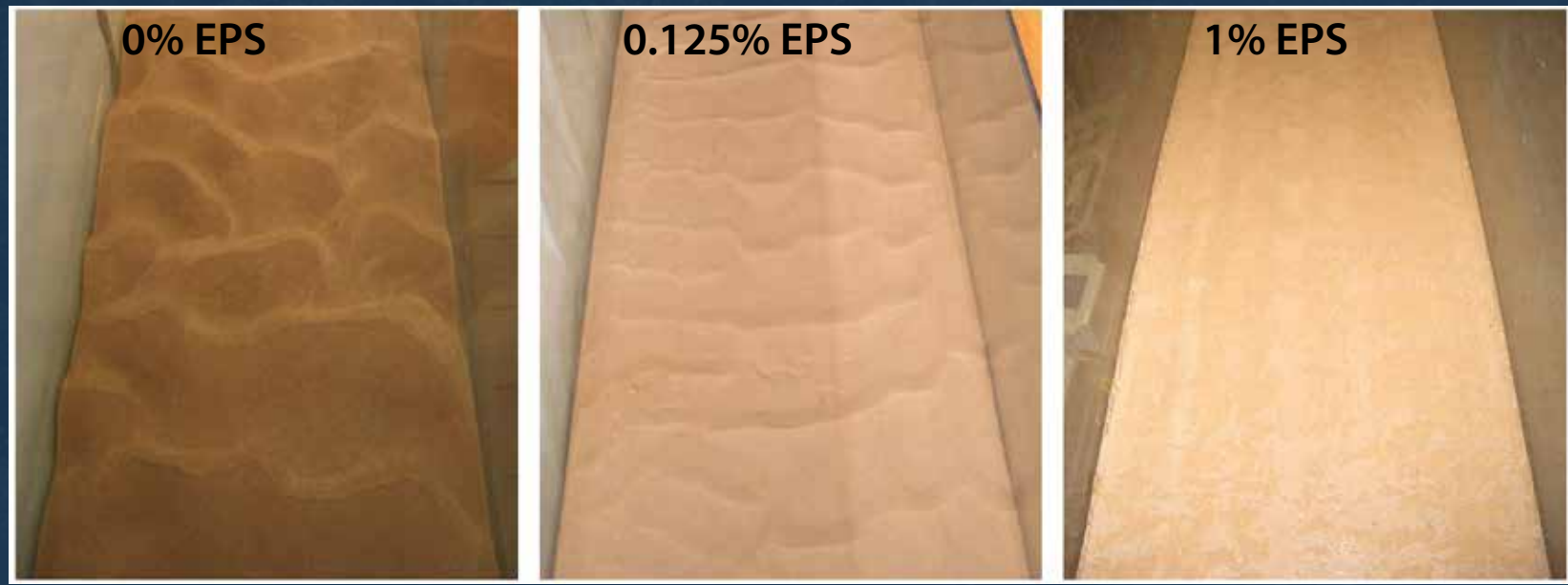


Setup of biofilm growth exp. at University of Hull

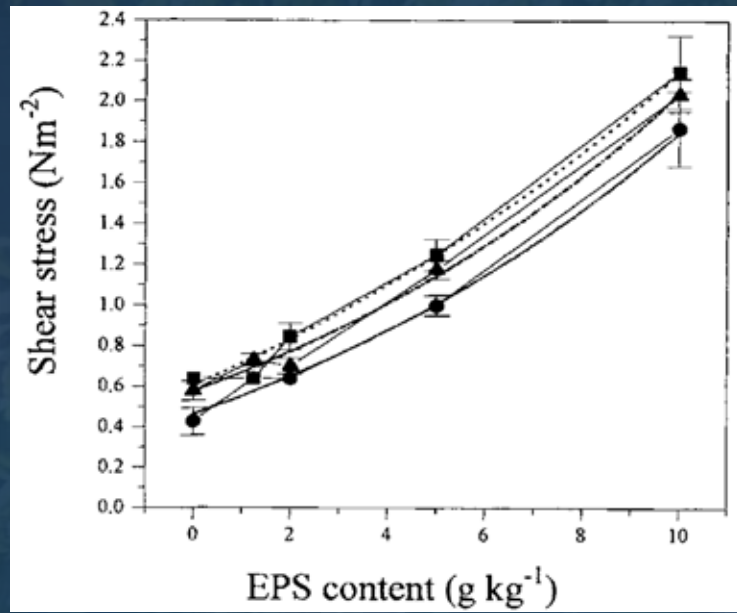
2. Chemical surrogates

- **Use of chemical surrogates in the laboratory as a proxy for naturally occurring EPS**
 - > Ability to introduce biological cohesion in a *fast* and *controlled manner*
 - > Wide application of Xanthan gum
 - > Other surrogates available and potentially useful: Agar, Carrageenan, Alginic acid
- **Protocol development for application focussing on:**
 - > Preparation procedure [dry mix vs. wet mix]
 - > Relation between EPS content and sediment stability for a range of surrogates
 - > The ability to de-activate and re-activate the surrogates
 - > Potential winnowing of the effect of the surrogates [timescales and degree of]
- **Standardised test setups**
 - > Riverbank erosion
 - > Delta sedimentation

BUT: unsure how well surrogates mimic sediment stabilising behaviour of natural EPS and small-scale vegetation (see box 3)



Bedform characteristics with different proportions of Xanthan gum (EPS). Malarkey et al. (2015)



As EPS content increases the erosion threshold increases. Tolhurst et al. (2002)

3. Flood sequencing in rivers

- **Resilience of riverscapes to projected changes in hydrologic forcing**
 - > Higher magnitude floods
 - > Prolonged periods of low flow and drought
- **Simulation of a range of hydrological regimes**
 - > Magnitude and duration of flood events
 - > Interval between consecutive flood events
 - > Progressive increases in flood frequency and magnitude
 - > Explore fast-forwarding of time: comparison of 1 in 10 year flood to 10 consecutive yearly floods
- **Explore interactions with riverine biota**
 - > Represented by surrogate vegetation (alfalfa) or EPS surrogates
 - > Apply different degrees of biota [vegetation density or EPS content]
 - > Growth and recovery of biota as a function of flood interval



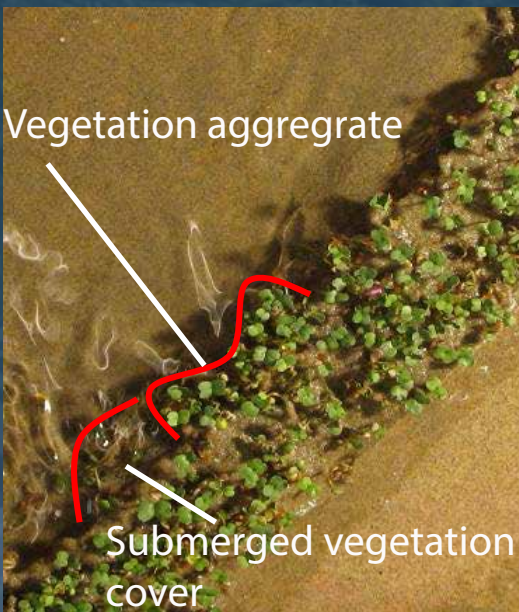
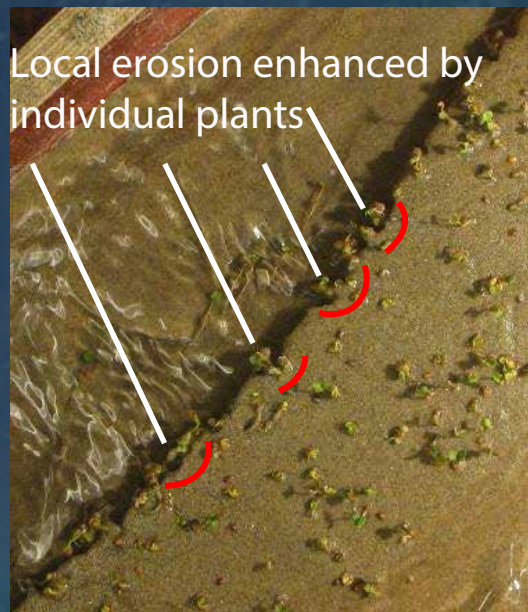
A braided river experiment with small-scale alfalfa vegetation in the Total Environment Simulator at the University of Hull. In future experiments riverine biota may be represented by chemical surrogates or alfalfa, depending on the outcomes of auxiliary tests (see also boxes 2 and 4).

4. Biota and variability

- **Does the variability in the results increase when biota are introduced?**
 - > Smooth morphologies and regular behaviour for (non-cohesive) systems
 - + Riverbank erosion
 - + Coastline retreat
 - > Rugose morphologies and irregular behaviour for biota-dominated systems
 - > Existence of multiple steady states (sediment-dominated vs. biota-dominated)
- **Implications for natural systems as well as representing biota in models**
 - > How many replicates are needed to capture behaviour?
 - > Uncertainty in outcomes of *Building with nature* solutions (green engineering)
- **Address by small-scale tests**
 - > Flume experiments on riverbank erosion and coastline retreat
 - > Numerical model runs to explore more scenarios and to analyse at natural dimensions



Effect of vegetation density on riverbank erosion. A smooth riverbank characterised by regular erosion for low densities and a rugose bank with irregular erosion for higher densities.



Contrasting effects of vegetation on bank erosion. Van de Lageweg et al. (2010)

Future experimental requirements

- ✓ **Accurate representations of biota across a range of spatial and temporal scales**
 - > Protocol development to replicate biological processes and interactions
- ✓ **Simulate complex forcing regimes**
 - > Representation of short-term variability in forcing superimposed on longer term trends
- ✓ **Identification and isolation of responses**
 - > Monitor and isolate the impact of progressive changes in forcing from the event-scale

