ESTUARIES

# Bugs 'n' mud – a sticky problem

Sharon Stephens
Mal Green
Conrad Pilditch

*The seabeds of our estuaries are inhabited by an array of organisms, including the more obvious crabs, worms and shellfish. But what about the bugs – or, more specifically, the microbes – and why should we be interested in them?*

What do muddy water, shoreline erosion, mass kills of shellfish, and siltation of marinas and navigation channels have in common? No, it's not bugs (they come soon), it's sediment transport – the erosion, movement and deposition of sediments. Sediment transport affects just about every physical and biological feature of our harbours and estuaries. Hence, the ability to accurately predict sediment transport is a key tool in the maintenance of the integrity of these valued coastal areas. For example, if we know that land erosion associated with forest clearfelling is going to eventually result in a layer of mud on a particularly sensitive estuarine habitat, then we can take steps to protect that habitat. For example, appropriate sedimentation ponds could be established between the site of tree-felling and the estuary.

## Microbes in sediment

Although great strides are being made in understanding estuarine sediment transport and in transferring that knowledge to predictive models, progress has been limited by a demonstrably wrong assumption: that the movement of sediment is not affected by biological processes. (The critic would explain this situation by pointing out that biology introduces all kinds of complexities – mathematical and physical – into sediment-transport models, and so it is usually put in the "too-hard basket".)

Enter the microbes and their mucous secretions that they use for attachment and locomotion in a sediment world. These mucous secretions bind grains of sediment, potentially making its erosion more difficult. Microbes can therefore be viewed as "sediment stabilisers". Herein lies our interest in bugs 'n' mud: a more accurate picture of the forces needed to start erosion – taking microbial processes into account – can be used to build more accurate sediment-transport models, which in turn can be applied in real-world problems with more confidence.

How have we gone about it? The first hurdle was to find a way to measure something we cannot see with the naked eye. Microbes in abundance are often noted as green-brown patches on the estuary floor, but even then we cannot count them. We can, however, collect small samples of sediment and estimate microbial activity using proxies: the amount of chlorophyll *a* (a light-capturing pigment used in photosynthesis) and carbohydrate in the samples. These are indicators for microbial biomass and sediment mucous content, respectively. Both measurements are necessary because different species of microbes produce different amounts of mucous, hence measurements of chlorophyll *a* and carbohydrate will not necessarily correlate.


A rippled seabed with prominent diatom mat between the ripple crests. (Scale: approx. 10 cm between crests)

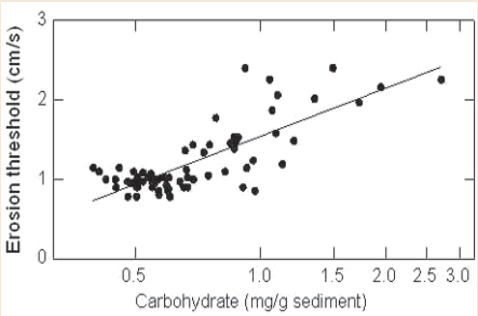
## Mud stabilisers

As well as microbial abundance and sediment mucous content, we can also measure erosion threshold (see "Measuring sediment erosion..."). So it is now possible to determine how effective bugs are at stabilising seabed sediment. This has involved making many measurements in different kinds of estuaries – sandy vs. muddy and sheltered vs. exposed. We expect the type and number of microbes to differ between sandy and muddy sediments. Thus the amount of mucous produced and therefore the degree of sediment binding will differ both within and between estuaries. In addition there will be variability through time because seasonal changes in both weather and macrofauna are likely to affect microbial communities.

***Sharon Stephens is a University of Waikato PhD student based at NIWA in Hamilton, under the supervision of Conrad Pilditch (Department of Biological Sciences, University of Waikato) and Mal Green (NIWA Hamilton). Her study is funded by a FRST Bright Future Scholarship (Top Achiever Doctoral) and is a part of NIWA's FRST-funded programme Effects of Sediments on Estuarine and Coastal Ecosystems (C01X0024). The Sea Carousel project and Mal Green's participation in that work were sponsored by the Geological Survey of Canada (Atlantic).***

(Macrofauna are animals larger than 0.5 mm, which live in the seabed. They include worms and shellfish.) Our fieldwork is ongoing.

Next is the number crunching, with the aim of finding a biological predictor of erosion threshold. We are looking for good relationships between the indicators of microbial activity and erosion threshold (see graph below). Indicators with the best prediction potential are being incorporated into sediment-transport models.




A good relationship between bed sediment carbohydrate (indicating mucous content) and erosion threshold, Okura estuary, east coast, 25 km north of Auckland. Incorporating this relationship into a sediment-transport model of the estuary could provide more accurate simulations of turbidity, sedimentation and siltation.

Sound simple? Well of course things are never as clear-cut as they seem, and this study is no exception. Because of disturbances, the presence of microbes does not guarantee sediment binding. For example, storm waves may break apart sediment bound together by microbes, leaving behind the microbes (and the associated indicator) but with no binding effect. To understand this type of stabilisation–disturbance relationship, we are also measuring erosion threshold and microbial activity before, during and after storms. Another complication is that the animals living in the sediment can interfere with stabilisation by feeding on microbes. We are using experiments in enclosures to investigate these interactions.

Our results have shown that microbes can increase erosion threshold by up to a factor of three compared with abiotic sediments. A pattern emerges: microbial abundance and sediment mucous content increase as sediment grain-size grades from coarse sand to fine mud. In tandem with this change, there is an increase in the erosion threshold over that for equivalent abiotic sediment. This indicates a quantifiable link between sediment stability and microbial activity.

It's time to retrieve this one from the too-hard basket! ■

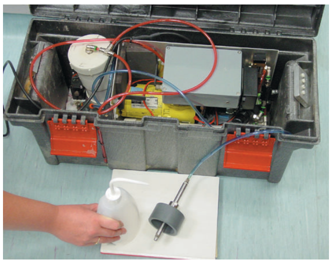
## Measuring sediment erosion threshold: the toolkit

### Laboratory instrument: Waikato recirculating flume

The Waikato flume is 7.25 m long and 50 cm wide with flow up to 30 cm deep. Cores of estuarine bed sediment are inserted through the base so that they are flush with the flume floor. They are then exposed to increasing flow speeds. We note the instant at which surface sediment grains are first dislodged by the flow. The flow speed at this time is used to calculate the sediment erosion threshold.

Unfortunately, the physical characteristics of the sediment cores (e.g., grain packing, water content) may be altered during transport of the core to the lab. Therefore we complement the laboratory flume with field instruments...

### Field instrument 1: Cohesive strength meter (CSM)

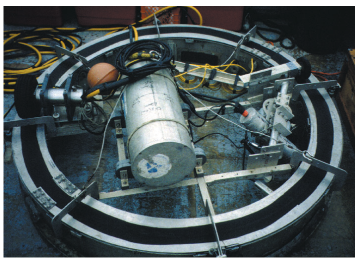


The CSM is portable, easy-to-use and gives quick readings. It fires a jet of water at the sediment surface in short pulses. The force of the jet is progressively increased until the erosion threshold is crossed. The CSM is used to survey sediments throughout estuaries and at different times of the year to assess spatial and temporal variability in sediment erodibility.

### Field instrument 2: NIWA submersible in-situ flume

The NIWA submersible in-situ flume gives more detailed results than the CSM. It is shaped like an inverted "U", and is equipped with optical backscatter sensors, photodetectors, a water sampler and a current meter. As in the Waikato recirculating flume, water is accelerated through the flume by a propeller. Since the NIWA flume has no bottom, measurements can be made on undisturbed in-situ bed sediments that are exposed to the accelerated flow along the length of the inverted "U".

## An application to fish farms



NIWA scientists participated in a series of North American experiments along Maine's rocky shoreline using the in-situ "Sea Carousel" annular flume, an instrument developed by the Geological Survey of Canada (Atlantic). The purpose of these experiments was to measure the erosion threshold of waste (a combination of unused food and fish faeces) that accumulates below fish farms. The results are being used by GSC (Atlantic) to refine models that predict dispersal of waste by waves and currents and associated effects on the coastal ecosystem.