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Physical Geography

Microalgae play King Canute!

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Introduction

King Canute sat on the beach and tried to stop the tide coming in. Pretty stupid, he drowned! But in a different way, microalgae, single celled photosynthetic organisms less than 200 microns in size, are helping to stop sea level rise from eroding out coasts. The problem is that global warming is heating up not just the Earth's atmosphere, but also the seas and oceans. It also may be starting to melt the ice caps and glaciers that store up huge amounts of freshwater, which when melted flows in to the sea. Heating up the world's oceans means that the water expands and sea levels rise, the process is simply termed, thermal expansion. The Intergovernmental Panel for Climate Change (IPCC) consists of bodies of scientists who analyse all the available data for predicting the effects of climate change. They produce complex models called Scenarios, in which sea level rise is just one of the many of the models outputs. Some versions of these models predict increases in sea level over the next 100 years in the order of up to, or over 1m in the UK. And that's a big problem around the coast, where increased sea level means an increase in the waves and currents that are eroding our coastline.

It's a particular problem for soft coastal sediments in places such as estuaries. Here the soft muds can be easily eroded by the sea. In turn the muddy areas with coastal plants, saltmarshes, also get eroded and in turn important coastal areas such as farmland, coastal developments and even towns can be at risk from being eroded away by the seas energy. Coastal managers try and stop this, often by building costly sea defences such as concrete sea walls. A more natural process is to use biology to buffer the seas energy and reduce the amount of erosion that occurs. One way of doing this is called Managed realignment. This means allowing a natural coastal habitat to be formed, consisting of mudflats and saltmarsh, which in turn buffer the seas energy and stop it eroding further inland. This management relies on the natural dynamic balance in coastal systems. But how do mudflats and saltmarshes become stable enough to cope with the sea's energy? How do mudflats resist being eroded and help facilitate the formation of saltmarsh? Scientists have been working on this for some time, and have shown that it's microalgae and plants that help stabilise coastal muddy sediments.

Figure 1: Examples of severe storms on the Severn Estuary, adapted from Hovey et al 2010.

Findings

The microalgae

If you look at the surface of a mudflat in an estuary it just looks like bare mud. But it's not, it's covered by thousands or millions of tiny single celled organisms called diatoms. These are microalgae. They can photosynthesise, which means they use the sunlight to make their own organic carbon from inorganic carbon dioxide. The organic carbon is in the form of sugars to start with, produced in the dark reactions of photosynthesis, the Calvin Cycle. For the diatoms, these sugars are especially important as they help the small cells move. In fact every tidal cycle, the diatoms migrate. As the tide goes out, they migrate up through the mud to the surface where they can photosynthesise in the light. Then, before the tide comes back in, they migrate back down into the mud. The migration is only very small, maybe 3 or 4 hundred microns or a few millimetres at the most, but for cells that are 10 to 200 microns long, that's quite far. The cells migrate using a sticky polymer made up mostly from sticky sugars such as mannose, arabanose and many others. They can glide through the polymer that they excrete into the mud forming a surface layer called a biofilm, a sticky matrix of cells, mud particles and the polymer. This polymer is called Colloidal Extracellular Polymeric Substance or cEPS for short. Studies have shown that it's the migration movements of the diatoms that leads to the production of the sticky polymer and hence the formation of the biofilm on the surface of the mudflats in estuaries.

The polymer

This polymer, produced by the diatoms plays an important role in stabilising the mudflats. Our studies have shown that, when the tide goes out the sticky polymer dries out slightly in the muddy sediment and binds tightly to the clay particles. This forms the biofilm which is like a thin film over the muddy clay sediment and increases its strength. When the tide comes back in, the matrix of the biofilm can more greatly resist the hydrodynamic forces of the water and as a result is less likely to be eroded. We have shown this with measurement of the critical erosion threshold of the sediment. Many devices have been used, such as Cohesive Strength Meters, an expensive water pistol that fires a very precise water jet at the mud to measure how much force is needed to erode it, through to large circulating flumes that move hundred or even thousands of litres of water over large areas of muddy sediment. Work has shown that there is a critical velocity of water movement needed to produce enough force, the critical shear stress, to erode the sediment. This critical velocity (U* measured in cm s-1) or shear stress (τ, Nm-2) increases proportional to not only the amount of diatoms present (the microalgal biomass) but also as a factor of the polymer (cEPS) that the diatoms produce. This process is called biostabilisation.

Succession

The microalgae and their polymers are the start of the process of stabilising the coastal soft sediments in estuaries. By stabilising the mudflats, they enable a succession of higher plants to colonise. Pioneer species such as Salicornia and grasses such as Spartina grow in the mud, with their roots stabilising the sediment further and trapping more sediment to slowly build up the layers into a saltmarsh with many other species of plant, such as sedges and rushes. In turn there forms a natural barrier to the seas energy that buffers the waves and reduces the amount of coastal erosion that occurs. The microalgae have started the process that leads to reducing the effects of sea level rise. Not quite stopping the tide coming in, but not bad for microscopic cells.

Conclusions

The studies of diatoms living and growing in the surface of coastal muddy sediments, such as those in estuaries, has shown that these microscopic cells migrate vertically following a tidal rhythm.

- To enable the diatoms to move, they excrete a sticky polymer composed of sugars we call, colloidal extracellular Polymeric Substance.
- This polymer serves an important ecosystem service by biostabilising the muddy clay sediments and in turn raises the level of energy needed to erode the mudflat.
- This biostabilisation in turn likely helps the formation of coastal saltmarshes which act as an important buffer of the seas energy, which is ever increasing as part of sea level rise.

References

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- Perkins, R.G. , Sun, H., Watson, J., Player, M.A., Gust, G. and Paterson, D.M. 2004. In-line laser holography and video analysis of eroded floc from artificial and estuarine sediments. Env. Sci. Technol. 38: 4640 – 4648. (4.630; 28)

Further information

- Mud flats: http://www.geography-site.co.uk/pages/physical/coastal/mudflats.html