

MASTS VISITING FELLOWSHIP

Project Summary

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Investigating the role of chemical communication between cells involved in microbial biostabilization of marine sediments

This MASTS Fellowship support was used to bring Dr. Alan W. Decho, a professor at the University of South Carolina (USC), to the Scottish Oceans Institute (SOI) at the University of St. Andrews (Scotland) to work in collaboration with Prof. David Paterson (SOI) for four months of scientific research. Decho is an international expert in the role of chemical communication in the ecology of biofilms. The role of biofilms in the environment, and more specifically in the biogenic stabilization of sediments, is one of increasing importance. The interaction between biofilms cells is now recognised as far more complex than first imagined. Chemical signalling (quorum sensing) is a process that allows efficient communication, coordination and resource exploitation among groups of cells inhabiting surfaces. However, the role of these signalling pathways in supporting the biostabilisation of depositional habitats, one of the most direct ecosystem services supplied by natural biofilms, has not been considered. Information gained from the study of cell attachment will be exploited to examine the role of cell-signalling in the production, deposition and physical characteristic of the polymer secretions known to stabilise sediments.

The purpose of our work was to begin investigations of cell-signalling and its potential role in the microbial biogenic stabilisation of marine sediments. The project was novel and designed to generate useful results for the host institution and the MASTS consortium as well as the broader marine scientific community. The study is highly-relevant to MASTS.

Networking with Scottish Researchers.

Several steps were taken to encourage and build interactions between the USA and Scottish researchers. First, a group of MASTS researchers, led by Dr Heather Haynes (HW) and supported by Prof David Paterson (St Andrews), Prof Vlad Nikora (Aberdeen) and Prof Peter Davies (Telford Institute, Dundee) initially met and agreed to request a "biofilm community project" within MASTS. Second, once present (March 10) at SOI (St. Andrews) Decho was invited to meet with various Group members over the course of four months to discuss ongoing research, and to develop initiatives (of SOI) to improve Scottish Ocean technologies (e.g. marine current turbines hydro-power) and ocean resources, and to improve the potential for future research interactions.

(1) A first stop of Dr. Decho was to attend the SOI-MASTS Science Cabaret (held March 27, 2013) at the Edinburgh Natural History Museum. There, he was able to hear short presentations regarding ongoing MASTS projects. He would later take part in workshops, visit laboratories, and give seminars. During these visits, Decho was able to speak to MASTS-supported graduate students and faculty, as well as other Scottish researchers. (2) A second visit included Herriot Watt University

(May 8; Edinburgh), where Decho gave a seminar to faculty, staff, students (both graduate and undergraduate) and had the opportunity to have one-one visits with eight different researchers. Dr. Decho then visited the University of Aberdeen (May 9th), accompanied by Dr. Paterson and a graduate student, to meet with Prof. Vladimir Nikora. Here, interesting discussions took place regarding the roles of biofilms on the water-flow and potential biofouling of marine turbines (for energy generation) off of the Orkney Islands (cf EMEC). Preliminary ideas were generated for proposing studies of the biofouling process on the surfaces of marine turbines. We will continue to develop and refine these ideas in future plans. During the month of June, Decho visited the SAMS (Scottish Association for Marine Science) Laboratory in Argyll, near Oban. There Dr. Decho, along with Dr. Paterson, met with Drs. Karen Alexander, Day and others to have discussions on biofilms, chemical communication and how this area potentially interacts in their ongoing studies. Decho then gave a seminar at SOI (St Andrews) where he covered the roles of bacteria and their biofilm processes, including chemical communication, in broader ocean processes such as sediment stabilization and biofouling (recorded as a webinar).

On a day to day, week to week basis, Professor Decho had the opportunity to interact with the Sediment Ecology Research Group (e.g. attend laboratory meetings, informal talks with students and staff, and observe ongoing research in the lab, and field) at St Andrews which has an international reputation in the field of ecosystem engineering and the impact of biofilm on sediment erosion and transport. During this time, Prof Decho developed a keen interest to learn more about MASTS and potential international linkage to the US.

Laboratory and Field Research. The initial objectives of the research were to:

(1) To identify and quantitatively measure chemical communication signals, called AHLs, from a series of natural marine sediments ranging from non-stabilized (e.g. mud) to highly-stabilized (e.g. mixture of sand/mud) at the Eden Estuary sampling site of the SERG. [A laboratory study was later devised (and conducted) to examine the same process under more-controlled conditions.]

(2) To experimentally disrupt a stabilized-sediment mat, and quantitatively measure changes in the sediment-cohesiveness and accumulations of AHL signals, as recolonization occurred over time.

The extracted signal molecules (AHLs) and confocal microscopy samples were sent to the Decho laboratory in the US for further extraction followed by mass spectrometry analyses, which the lab was already set up to conduct.

Initial Results.

Initial collections of natural sediment mat samples were conducted (Fig 1) . The samples were imaged using low temperature scanning electron microscopy (LTSEM) to provide spatial information on the distribution of the microbiota. The samples were then processed analysed for the detection of chemical signals. However, the initial sampling was unsuccessful because the solvent (i.e. using DCM) that was first used was not sufficient to acquire detection of chemical signals. A second series of sediment samples of sediment mats were collected from the sampling site for a controlled laboratory experiment. Samples were collected then taken to the research laboratory at the University of St. Andrews. There, using flowing seawater and controlled light/dark cycle and tidal cycle conditions, quantitative measurements of sediment cohesiveness (see below) will be conducted, followed by extractions and analyses of quorum sensing signals, called acylhomoserine lactones (AHLs – described below). These mats have been examined for other types of studies by the SERG group.

While these initial results were disappointing (to the investigators), a second series of experiments are planned between Decho and the SERG. The SERG will re-conducted the field sampling, making all field measurements needed (e.g. sediment cohesiveness, PAM fluorescence, etc) under low-tide conditions, then samples collected and returned to the laboratory for sediment analyses including

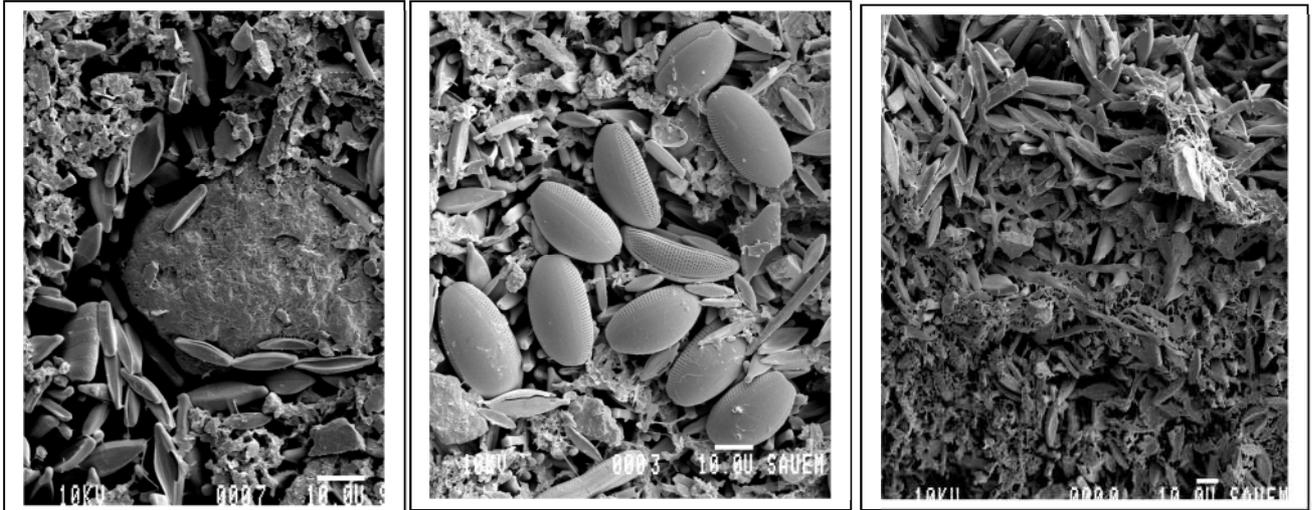


Figure 1: Transient biofilm from the Eden Estuary sites (courtesy of Ms Julie Hope and Mr Irvine Davidson), Left: Sandy site, grain and diatoms, Centre: The diatom, *Amphora* spp from mixed site: Right: Fracture face of transient biofilm showing depth of diatom biofilm.

low-temperature scanning electron microscopy. A subset of samples will be then sent to Decho's laboratory at USC for *confocal scanning laser microscopy (CSLM)* and *quorum sensing signal analyses*. Both Decho and Paterson anticipate that this second study will result in publishable results regarding the role of microbial chemical communication in sediment stabilization processes. We expect that the project results will spawn further research ideas and cooperation among the proposed MASTS Biofilm group. This cooperation is ongoing.

Overall Logistics during the MAST Fellowship.

The work was conducted at the University of St Andrews, in collaboration with Prof. Paterson's laboratory. This is because of their extensive background in sediment stability studies and their abilities to measure sediment stability *in situ* (i.e. in natural environments) using a specifically engineered device called a 'Cohesive Strength Meter', which was designed and constructed by the Paterson laboratory. The project took place during a University sabbatical period, for Decho at the University of South Carolina. [Decho was also provided supplementary support from a Fulbright Senior Research Fellow grant, which covered travel and some modest living expenses].

Communication of Results

We will strive for publication in the highest regarded peer-reviewed journals in our profession. Decho will give seminars will give at his, and other US Universities, and also acknowledge MASTS in his presentation of results at national and international meetings. Decho is in the process of writing a 'general interest' science article to his state newspaper (in Columbia, SC, USA) to raise awareness of his sabbatical experience, and of Scotland and its interesting marine resources. I will be happy to work with our University representative, and the MAST personnel to highlight my work to whatever extent possible. I expect that this will provide an important bridge for information to future researchers and potential applicants to the MAST program. Any publications including press articles, the financial support of MASTS will be acknowledged.

Significance of Work in Relation to the State of the Field, and Potential Benefits.

The results of this study will be the first to examine the role of chemical communication in the sediment stabilization process. The results will provide a new understanding of how the exact mechanisms of stabilization are acquired by the microbial system, and provide a platform of results upon which to base future work. It is anticipated that my proposed project involving the role of

bacterial chemical communication in understanding sediment stabilization will provide a novel, but underexplored aspect in understanding the stabilization of marine sediments.

A Final Note.

Finally, the PI (Decho) would like to report that my stay at the SOI (St. Andrews) was an excellent research and life experience. David Paterson, and Mark James, and their research teams are to be commended for providing excellent accommodations, office space, access to the University library, and laboratory facilities, which made my stay comfortable, efficient and enjoyable. Decho, upon his return to the US, has already given talks to colleagues to illustrate his interesting sabbatical experience, the research facilities present in St. Andrews and other SOI locations, and the relatively unrealized (to many US researchers) potential for marine research that is present in Scotland. It is hoped that this will encourage future US researchers to approach SOI faculty with research ideas, and ultimately interact and develop collaborative research goals.