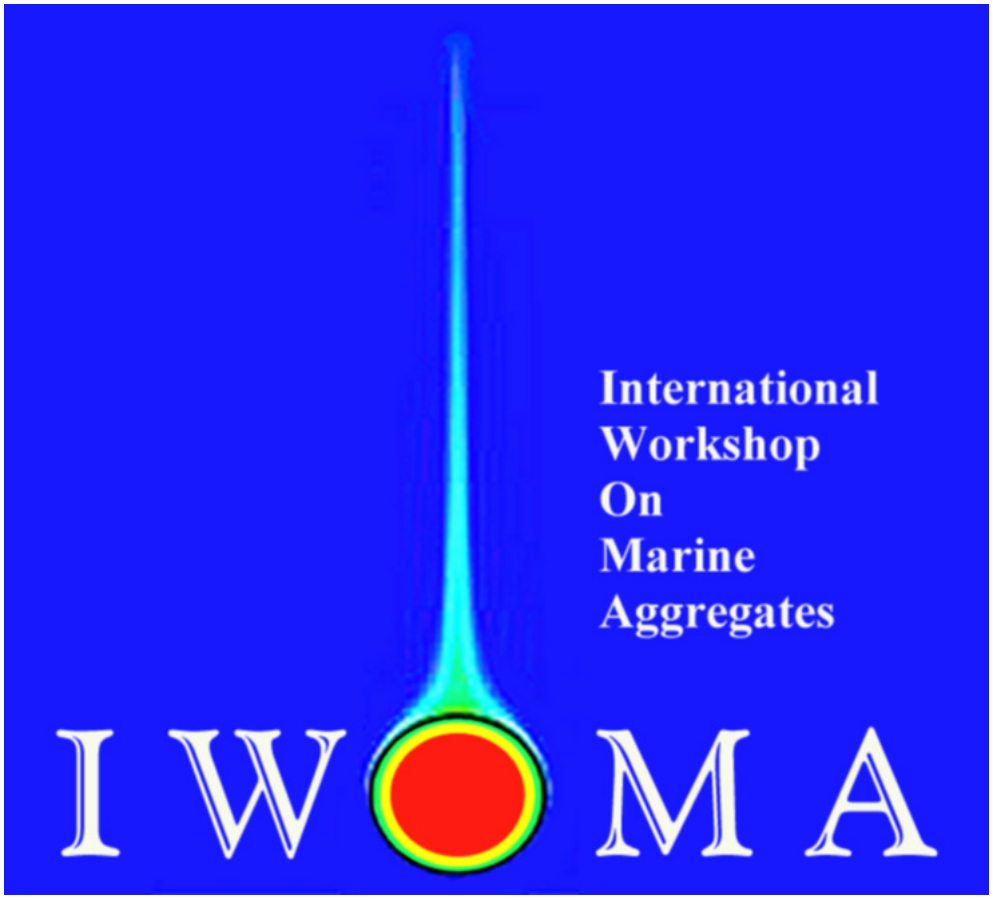

Microbial Dynamics, Small Scale Processes and Mathematical Modeling

December 11+12, 2006

Max Planck Institute for Marine Microbiology
Bremen, Germany

MAX-PLANCK-GESELLSCHAFT

Program and Abstracts

Program

December 11, 2006

9:00-9:30	Registration at the MPI Foyer
9:30-9:45	**Welcome adress** Bo Barker Jørgensen and Arzhang Khalili (MPI Bremen, Germany)
9:45-10:30	**Jackson, George (USA)** Insights into particle concentrations and fluxes
10:30-11:15	**Smetacek, Victor (Germany)** Aggregation and mass sinking of diatom species populations from an iron-fertilized bloom in the Southern Ocean
11:15-12:00	**Lunau, Mirko (Germany)** Mechanisms of aggregation and disaggregation of microaggregates-interplay between sedimentology, hydrodynamic and microbiology
12:00-12:45	**Kiørboe, Thomas (Denmark)** Dynamics of microbisal communities attached to marine snow
12:45-14:00	Lunch break
14:00-14:45	**Passow, Uta (Germany)** Effect of transparent exopolymer particles and minerals in aggregates
14:45-15:30	**Grossart, Hans-Peter (Germany)** Effect of iron availablitiy on colonization rate and ectoenzyme activities of bacteria attached to aggregates
15:30-16:00	Coffe break
16:00-16:45	**Beardsley, Christine (USA)** Shrimp feces: a hot spot for bacteria-mediated organic matter recycling in a recirculating aquaculture system
16:45-17:30	**Simon, Meinhard (Germany)** Microbial ecology of aggregates in shallow turbid and tidally affected system
17:30-18:15	**Schüler, Marga (Germany)** Whole genome analysis of the marine Bacteroidetes Gramella forsetii reveals adaptations to the degradation of polymeric organic matter
18:30	Evening Mixer

December 12, 2006

9:00-9:45	**Ploug, Helle (Germany)** Microsensor studies of mass transfer to sinking aggregates
9:45-10:30	**Li, Xiaoyan (Hong Kong)** Investigation of the hydrodynamic behaviour of marine aggregates using particle image velocimetry (PIV)
10:30-11:00	Coffe break
11:00-11:45	**Thoms, Silke (Germany)** Parameterization of coagulation processes in the formation of transparent exopolymer particles (TEP)
11:45-12:30	**Khalili, Arzhang (Germany)** Modeling exchange processes around and through a sinking porous sphere
12:30-14:00	Lunch break
14:00-15:30	**Final Open Discussion**
15:30	**End of Workshop**

Abstracts

In order to appearance of speakers in the program

Jackson, George A.

Insights into particle concentrations and fluxes from coagulation models

Coagulation theory can be applied with a differing levels of complexity to describe particle dynamics in the ocean. At its simplest, it predicts a maximum particle concentration. Results from recent iron experiments re consistent with these. More elaborate calculations yield predictions for particles size distributions which can also be compared to observations. Particle size spectra can also be combined with our understanding of how animals detect particles to predict the relative success of different feeding strategies. Big unknowns remain.

Smetacek, Victor

Aggregation and mass sinking of diatom species populations from an iron-fertilized bloom in the Southern Ocean

Higher surface production is generally reflected in higher organic carbon content of the underlying sediments. The bulk of the accumulating carbon is believed to be exported by aggregation and sinking of intact cells and chains in the aftermath of diatom blooms. Less is known about the factors triggering the sinking process and the mechanisms of aggregate formation. We studied the growth and demise of individual diatom species populations during an in situ phytoplankton bloom induced by artificial iron fertilization (EIFEX: European Iron Fertilization Experiment). A massive flux event, which appeared as spikes in vertical transmissometer profiles and was confirmed by discrete water-column sampling, started on day 26 during which about half the suspended particulate organic carbon was exported out of the surface mixed layer. A significant fraction of the sinking particles reached the sea floor at 3700 m depth within 10 days. These speeds can only be reached by prior formation of large aggregates. The species composition of the diatoms in the deep water column indicated that some species sank out quantitatively, others seemed to have been entrained in the sinking aggregates and yet others escaped entrainment and sinking and continued growth in the surface layer after the sinking event. Species of the long-spined diatom genus Chaetoceros appear to have played a major role in the aggregate formation and sinking event. The results of the experiment suggest that large-scale fertilization of the Southern Ocean could well function as one of several strategies to combat ongoing global warming and surface ocean acidification.

Lunau, Mirko

Mechanisms of aggregation and disaggregation of microaggregates-interplay between sedimentology, hydrodynamic and microbiology

Tidalflat ecosystems exhibit pronounced tidal currents that cause high loads of suspended matter (SPM) and intense sedimentation. Up to date most environmental studies from these areas were limited to hydrographical, geochemical or sedimentological issues while microbiological processes were seldom taken into account. In order to compare the role of microbial activity versus physical forcing for aggregation and disaggregation processes we conducted a comprehensive study in a
backbarrier tidal flat area of the German Wadden Sea. Specific hypothesis regarding the significant importance of microbiological processes in this highly dynamic environment were derived from field work. In order to verify these hypothesis we used an experimental setup in the lab and followed aggregate dynamics and - size, bacterial activity (aminoacid uptake) and spatial distribution of bacteria at different physical forcings. The results indicate that bacteria are significantly involved in aggregation processes and biogeochemical cycling of e.g. trace metals and organic matter. Furthermore, changes in physical conditions were reflected by the rapid adaptation of bacterial activity as well as by colonization of aggregates.

Kiørboe, Thomas

Marine snow associated microbial communities: dynamics and significance

Rich microbial communities develop on and around suspended particles in pelagic environments. Their activity may account for a significant fraction of the microbial activity in the water column and they enhance the degradation of sinking particles, thus retarding vertical material fluxes in the ocean. A combination of simple mechanistic models and experiments are used to explore the dynamics of these communities. The description considers the hydrodynamic environment of sinking aggregates, motility behaviour and colonization of bacteria and flagellates, growth and detachment of particle-attached microbes, and trophic interactions. The models and experiments are capable of describing some gross features of particle attached microbial communities, such as how the abundances of attached microbes scale with particle size, but there are many open and unresolved questions. These include the similarity or difference of particle-attached and free microbes; the interaction between the dynamics of the particles (as they form and degrade) and the dynamics of the microbes; and the significance for ocean carbon fluxes of these microbial communities.

Passow, Uta

Effects of transparent exopolymer particles and minerals for aggregation and sinking

The transfer to depth of particulate organic carbon (POC) via the biological pump is an important, but not well understood component of the marine carbon cycle. The flux of carbon to the seafloor represents a balance between sinking velocity and loss rate of POC (microbial degradation, grazing etc.). Thus many organisms, their detritus or feces only reach depths below 1000 m via fast sinking aggregates. The sinking velocities of aggregates vary with the size, density and porosity of the aggregates. Transparent exopolymer particles (TEP) and minerals (biogenic or lithogenic), two particle types which consist of only small amounts of organic carbon, both impact POC flux appreciably by impacting size, porosity and density of aggregates. TEP act as the glue necessary to stick particles together forming large aggregates, which due to their size sink substantially faster than individually component particles. TEP are, however, positively buoyant and increasing amounts of TEP decrease the sinking velocity of aggregates. Minerals, like calcium carbonate, opal and clays have been suggested to determine POC flux by increasing the density of aggregates (ballast hypothesis). However, minerals may also lead to fragmentation of aggregates.

Grossart, Hans Peter

Effect of iron availability on colonization rate and ectoenzyme activities of bacteria attached to aggregates

On the one hand, marine snow aggregates are microbial hotspots that support high bacterial abundance and activities and on the other hand they are important vehicles for deep-sea carbon sequestration. Lately, there have been many attempts to increase carbon sequestration by large-scale iron fertilization for combat of global warming. However, all these studies ignore how iron addition may affect the interactions between the ambient bacterial communities and aggregates. Therefore, we conducted laboratory experiments to study the effects of iron availability on particle colonization behaviour, motility and enzymatic activities of four strains of marine bacteria. Iron depletion reduced the particle colonization rate by 1.7 to 43.1%, which could be attributed to reduced swimming speeds in two of the four strains. Protease activity was not affected by iron availability and attached bacteria had higher cell-specific protease activities than their free counterparts. In addition, we compared the cell-specific protein production (BPP) and protease activity between free-living and attached bacteria on model aggregates (agar spheres). Natural bacterial assemblages attached to aggregates had 3-fold higher BPP and 2-orders of magnitude higher protease activity than their free-living counterpart. These observations could be explained by preferential colonization of the agar spheres by bacteria with inherently higher metabolic activity and/or individual bacteria increasing their metabolism upon attachment to surfaces. Therefore, in subsequent experiments, we tested whether bacteria could up- and down-regulate their metabolism while on and off an aggregate. Protease activity of attached bacteria was 10-20 times higher than that of free-living bacteria, indicating that the individual strains could increase their protease activity within a short time (2 h) upon attachment to surfaces. Our results suggest that iron addition in iron-limiting oceanic regions will alter the behaviour of the ambient bacterial communities and intensify particle colonization by bacteria. Together with increased enzymatic activities upon bacterial attachment to surfaces, this may accelerate particle dissolution as well as disintegration and, hence, reduce the overall particle fluxes to the deep sea.

Beardsley, Christine

Shrimp feces: a hot spot for bacteria-mediated organic matter recycling in a recirculating aquaculture system

Although bacteria associated with marine fecal pellets have long been known to play major roles in oceanic carbon, nitrogen, and phosphate cycling, microbial ecology studies in marine aquaculture systems are only recently emerging and knowledge on microbial pathways, processes and their regulation in these systems is still insufficient. Particularly in closed, i.e., recirculating aquaculture systems (RAS), an understanding of the endemic microbial structure and their processes and interactions is crucial for the system's functioning and successful management. In this study, we investigated microbial pathways in feces of shrimp (Litopenaeus vannamei) from RAS with respect to carbon and nitrogen fluxes and their partitioning between the shrimp and microbes. Results from controlled small scale experiments showed that shrimp feces had high concentrations of bioavailable dissolved and particulate organic matter (OM), of which large quantities were quickly released into the water. Shrimp gut derived bacteria efficiently utilized this OM. They grew within the feces at a rate of 2*1010 cells*g-1*h-1 and also rapidly colonized the water. Most importantly, these fecal bacteria processed the excreted OM by hydrolytic ectoenzymatic activity in way that lead to an increase in the protein concentration in the feces and thus they increased the nutritional value of the feces for the coprophageous shrimp. This potential of fecal bacteria to quantitatively influence carbon and nitrogen pathways and turnover rates in shrimp RAS demands an integrative view of nutrient-shrimp-microbe interactions and, if included in future aquaculture operations, this could be a step towards sustainable aquaculture.

Simon, Meinhard

Microbial ecology of aggregates in shallow turbid and tidally affected systems

In shallow turbid and tidally effected systems the hydrodynamic, physico-chemical, geochemical and biological conditions for aggregation are quite different from pelagic environments. In the latter, rather constant hydrodynamic and physico-chemical conditions prevail and differential settling is a major factor for aggregation of phytoplankton-derived particulate organic matter. In the former systems, these conditions change dramatically within a tidal cycle and resuspension and shear are other important factors which have profound consequences for aggregation and microbial processes during aggregation and for biogeochemical cycling of matter and elements. During intense investigations of aggregation dynamics in the German Wadden Sea and in experimental systems during the recent years it turned out that microbes and in particular heterotrophic bacteria are actively involved in aggregation. The highly variable hydrodynamic forcing not only affects aggregation during a tidal cycle but also the mobility and activity of the bacteria, leading to greatly changing substrate uptake and growth patterns during such regularly occurring cycles. The contribution will present results from the field and experimental studies highlighting the active role of heterotrophic bacteria and the significance of hydrodynamic forcing for aggregation in such highly dynamic ecosystems.

Schüler, Marga

Whole genome analysis of the marine Bacteroidetes 'Gramella forsetii' reveals adaptations to the degradation of polymeric organic matter

Members of the Bacteroidetes, formerly known as the Cytophaga-Flavobacteria-Bacteroides (CFB) phylum, are among the major taxa of marine heterotrophic bacterioplankton frequently found on macroscopic organic matter particles (marine snow). In addition, they have been shown to represent also a significant part of free-living microbial assemblages in nutrient-rich micro-environments. Their abundance and distribution pattern in combination with enzymatic activity studies has led to the notion that organisms of this group are specialists for degradation of high molecular weight compounds in both the dissolved and particulate fraction of the marine organic matter pool. This implies a major role of Bacteroidetes in the marine carbon cycle, and it seems highly interesting to explore the extent to which the genome contents of members of this group reflect general and special capabilities consistent with their anticipated role in the process of organic matter remineralization. Recently, we completed the analysis of the first genome (3.8 Mb) of a marine member of the Bacteroidetes, ‘Gramella forsetii’ KT0803, a North Sea isolate phylogenetically affiliated with the Flavobacteria. The predicted proteome disclosed several traits which in joint consideration suggest a clear adaptation of this marine Bacteroidetes representative to the degradation of high molecular weight organic matter, such as a substantial suite of genes encoding hydrolytic enzymes, a predicted preference for polymeric carbon sources and a distinct capability for surface adhesion. Currently, we are establishing a whole genome DNA microarray for comparative expression profiling, to investigate the organism’s response to varying nutrient qualities and quantities, and to follow the expression of specific hydrolytic activities.

Ploug, Helle

Microsensor studies of mass transfer to sinking aggregates

Small-scale flow and diffusion within and around marine snow are key processes determining coagulation and remineralization of particles in the ocean. The relative importance of interstitial flow and diffusion, however, is still poorly quantified within marine snow. In the present study, aggregates formed from diatom cultures in roller tanks were used as a model of marine snow. The fractal dimension (D3) of aggregates was 1.16 +/- 0.13 and thus similar to reported values for field-sampled marine snow. The wet volume fraction occupied by transparent exopolymer particles (TEP) in aggregates varied between 0.02 and 0.11, and it was on average 7.2-fold larger than that occupied by cells. The exchangeable porewater content occupied 87 to 98% of the aggregate volume. Diffusivity was directly measured within aggregates using a diffusivity microsensor. The average apparent diffusivity of gases within 1 to 8 days old aggregates ranged between 0.90 to 0.95 times that of the free diffusion coefficient in sea water. The average sinking velocity was 91+/- 36 m d-1 for an average aggregate size of 2.8+/-0.9 mm. Two independent models based on measured cell and aggregate size, porosity, and sinking velocity as well as small-scale oxygen gradients and total oxygen exchange indicated that maximum interstitial flow was 8 µm s-1, equal to 1% of sinking velocity. Diffusion accounted for 67% of total oxygen exchange between the aggregates and the surrounding sea water.

Li, Xiaoyan

Investigation of the Hydrodynamic Behaviour of Particles and Marine Aggregates Using Particle Image Velocimetry (PIV)

The hydrodynamic behaviour of particles has a significant influence on the interactions and the kinetics of flocculation between suspended particles. However, characterisation of the hydrodynamics of particles and particle aggregates in water is rather difficult because of the small scale of the hydraulic field, a wide range of particle sizes and the dynamic situation of moving particles. In this laboratory study, an advanced visualisation technique in particle image velocimetry (PIV) was employed to investigate the hydrodynamic properties of settling particles in water. The experiments were conducted in a settling column filled with a suspension of fluorescent polymeric beads as seed tracers. A laser light sheet was generated by the PIV setup to illuminate a thin vertical planar region in the settling column, while the motions of particles were recorded by a high speed CCD camera. The PIV technique was able to capture the trajectories of the tracers when a large particle settled through the tracer suspension, which gave the direct flow information, e.g., streamlines, surrounding the settling particles. Three types of particles, including large solid spheres, flocs of standard microspheres, and marine diatom aggregates, have been characterised for their hydrodynamic behaviours. The PIV laboratory results indicate directly the curvilinear feature of the streamlines around falling particles. The rectilinear collision model largely overestimates the collision areas of the settling particles. However, the available curvilinear model underestimates the collision potentials by one order of magnitude or two for the solid spheres. The collision areas of the microsphere flocs are more than an order of magnitude greater than the similarly-sized solid spheres. Marine aggregates appear to be highly porous and fractal, which allows streamlines to penetrate into the aggregate interior. The permeable feature of marine aggregates can significantly enhance the collisions and flocculation between the aggregates and other small particles including algal cells in water.

Thoms, Silke

Parameterization of coagulation processes in the formation of transparent exopolymer particles (TEP)

Two different mechanisms have been proposed for the TEP formation, spontaneous self-assembly [1] and particle coagulation [2]. The term "self-assembly" is rather broad and applies to spontaneous aggregation and formation of ordered structures when pre-existing components (separate or distinct parts of a disordered structure) are mixed in correct proportions. The process is reversible and involves systems that are at global or local thermodynamic equilibrium. "Self-assembly" is thus not synonymous with "formation" of structures during an irreversible growth process in a steady state out of the thermodynamic equilibrium. For a kinetic growth process such as coagulation, the components must be able to move with respect to one another. If the components stick together irreversible when they collide, they form fractal-like aggregates rather than micelles, bilayers or other regular structures usually formed by self-assembly. A coagulation of complex pre-existing components can involve self-assembling processes if the components are able to equilibrate between aggregated and non-aggregated states, or to adjust their positions relative to one another in the space of an aggregate. Chin et al. (1998) demonstrated the formation of self-assembled nano-aggregates under laboratory conditions. However, the particle size spectra and the fractal geometry of TEP observed in more natural environment suggest a kinetic growth process, where TEP is formed via coagulation of either individual acidic polysaccharides (PCHO) or self-assembled precursors. In a recent study, the cascade from the exudation of PCHO by algal cells to the formation of TEP was successfully described with a simple two-size-class model for PCHO coagulation [3]. This simple parameterization of the complex coagulation process is useful to take into account PCHO-TEP dynamics into higher scale ecosystem models [4]. In this study, the parameterization of PCHO-TEP dynamics is derived on the basis of the analytical solution of a forced Smoluchowski equation for particle coagulation.

Khalili, Arzhang

Modeling exchange processes around and through a sinking porous sphere.

Mathematical modeling has become a strong tool to analyze marine related problems. During sinking aggregates undergo a process of exchange of flow and nutrients with the ambient water. Aggregates have been, so far, considered as a solid object (sphere). Even this simple model has revealed significant issues. Here, a further development is provided by taking the aggregates as porous bodies. The mathematical model combining the phenomena within and outside the aggregate provides a tool to discuss all possible situations observed in the reality via modifying the boundary and interface conditions. A comparison is given between the exchange processes for solid and porous aggregates.

Program Organization	Assistance and Secretary	Logo design and layout
Prof. Dr. Arzhang Khalili	Ulrike Tietjen	Heiko Löbner