Abstracts

Third Nereis Park Conference –

Benthic Processes in a Globally Changing Environment

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INTEGRATIVE SCALE

INFLUENCE OF ANTHROPOGENIC STRESSORS ON BENTHIC PROCESSES, LOCAL AND GLOBAL IMPLICATIONS

HYPOXIA IN THE BALTIC SEA

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Hypoxia, the lack of oxygen in bottom waters, reduces habitat for living resources and enhances phosphorus release from sediments allowing for conditions favorable for the growth of cyanobacteria in the Baltic Sea. Hypoxia creates a vicious cycle that helps sustain eutrophication. Although we know that hypoxia has occurred in the past and probably co-varied with external forces, such as climate change and nutrient fluxes, the relative importance of these two forcing mechanisms is unresolved, which restricts predictions about the Baltic Sea ecosystem response to future climate and anthropogenic stressors. Hypoxia during the last two millennia can also be linked to population growth, technological development and land-use expansion phases, implying that historical trends in hypoxia may not be climate related, but result from anthropogenic impacts. Hypoxia in the coastal zone is also a prevalent problem in the Baltic Sea. Our recent work has identified over 115 sites in the coastal zone with the Baltic having over 20% of all known hypoxic sites in the world! Although it is quite popular in the media to discuss engineering approaches for the remediation of hypoxia, ultimately the only long-term solution to hypoxia in the Baltic Sea is a reduction of nutrient supply.

Anthropogenic impact	Integrative

INFLUENCE OF ANTHROPOGENIC STRESSORS ON BENTHIC PROCESSES, LOCAL AND GLOBAL IMPLICATIONS

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Benthic organisms are involved in basic functional processes influencing energy transfer, carbon cycling, nutrient and elemental cycling, and fate of sediment bound contaminants within ecosystems and benthic-pelagic coupling. Bioturbation has a major influence on the rates of cycling with toxicants and hypoxia/anoxia having a major influence on the rate of bioturbation. The principal effect is to lessen the importance of bioturbation and alter cycling pathways. Estimates of the loss of function for key ecosystem services are in the millions of US dollars/km2/year. Data relative to the effect of hypoxia at local and regional scales on bioturbation will be presented.

Anthropogenic impact	Integrative

BIOTURBATION IN AQUATIC SYSTEMS – A HISTORICAL PERSPECTIVE

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The first reference to bioturbation was made by Darwin about earth worms behaviour. For a long time, bioturbation was mainly considered for fresh-water macrofauna. However, most enthousiasm for the subject appeared in the 1990's in marine environments. In the mean time, terrestrial bioturbation mostly remained descriptive. All quantification techniques started with diffusion-like measurement of bio-reworking effects on *in situ* sediment radionuclides. This method's success led to it's application with several tracers : glass beads, luminophores, microspheres, etc… that required imaginative experimental designs. Short time measurements gave evidence of multiple non locals bio-transports (bioconveying, regeneration in burrows) hiding behind the overall local biodiffusion effects. From the early 2000s onwards, measurements of bio-irrigation and solute fluxes through water/sediment interfaces was promoted. Model performance increased with knowledge about these multiple biotransports. The coupling with geochemistry made the distinction possible between bio- and non biologically related fluxes for particulate and dissolved matter. However, very few models attend to simulate the bioturbation influence at the ecosystem scale. This up-scaling should benefit to bioturbation recognition as a major process in matter cycling and ecosystem resilience.

Macrofauna bioturbation history	Integrative

WHAT IS BIOTURBATION? NEED FOR PRECISE DEFINITION IN AQUATIC SCIENCE

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The term bioturbation is frequently used to describe how living organisms affect the substratum in which they live. Accordingly, Web of Science showed more than 2500 bioturbation hits in

early 2011. A closer look at the literature reveals a different usage of the term both within and between scientific disciplines, such as aquatic science, soil science (pedology) and ichnology. The confusion has been particularly pronounced in aquatic science literature, where it has been used to describe either the redistribution of particles and creation of biogenic structures by burrowing animals or all disturbances, including both particle and water movements, within the substratum caused by animals and plants. In this presentation we assess how the term bioturbation has been used in the literature. Our effort leads to a "new" and hopefully useful definition of bioturbation that is applicable and appreciated within all contemporary scientific disciplines - without compromising past studies. This new and precise definition acts as an "umbrella" term that covers all relevant aspects related to interactions particularly between organisms and sediments in aquatic environments.

Functional biodiversity	Integrative

OCEAN ACIDIFICATION: IMPACTS ON MICROBIAL NITROGEN CYCLING IN MARINE SEDIMENT BURROWS

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Ocean acidification may decrease coastal water pH by 0.3-0.5 units by the year 2100, potentially impacting upon biogeochemical cycling and ecosystem interactions. The mud shrimp Upogebia deltaura creates sediment burrows which are associated with increased bacterial diversity and an increase in denitrification and nitrification rates by 3 and 10 times, respectively. However, U. deltaura is behaviourally sensitive to ocean acidification. This study investigates the impact of decreased seawater pH on the structure, function and diversity of microbial communities inhabiting its burrow. Four shrimp per treatment were established in individual sediment cores before overlying water was acidified to one of five pH treatments (8.10, 7.90, 7.70, 7.35 and 6.80) for 14 weeks. With decreasing pH, there was a significant inhibition of nitrification in the burrow wall, as well as decreased rates of denitrification in bulk sediment. 16S rRNA gene pyrosequencing and Q-PCR analysis of bacterial and archaeal ammonia oxidising (amoA) genes were used to investigate variation in microbial diversity and in the ratio of bacterial:archaeal nitrifiers in sediments. The results indicate that ocean acidification could significantly affect nitrogen cycling within bioturbated sediments; potentially altering biogeochemical interactions between the sediment and water column.

Anthropogenic impact	Integrative

A WELCOME CAN OF WORMS? HYPOXIA MITIGATION BY AN INVASIVE SPECIES

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Hypoxic disturbance is globally one of the major threats to the functioning of benthic communities. Such disturbance can provide an opportunity for invasive species to establish and these species can subsequently become the main drivers of ecological change. There is recent evidence that improved bottom-water oxygen conditions in coastal areas of the Baltic Sea coincide with increased abundances of the invasive polychaetes Marenzelleria spp. Using a reactive-transport model, we demonstrate that the bioirrigation activities of dense Marenzelleria populations have a major impact on sediment phosphorus dynamics and that they may facilitate the switch from a seasonally hypoxic system back to a normoxic system by increasing the sediment's phosphorus retention capacity. The model is used to illustrate mechanisms through which Marenzelleria can act as a driver of ecological change, although hypoxic disturbance or natural population declines in native species may be needed for them to initially establish. Although invasive species are generally considered to have negative ecosystem and economic effects, we here show a potential positive effect of one of the main invaders in the Baltic Sea.

Anthropogenic impact	Integrative

HORIZONTAL AND VERTICAL PARTICLE BIOTURBATION BY AMPHIURA FILIFORMIS (OPHIUROIDA) IN RELATION TO SUBSURFACE MIGRATION

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Rates of within sediment horizontal migration (DM), and both horizontal (DH) and vertical (DV) particle bioturbation by the ophiuroid Amphiura filiformis were determined in separate mesocosm experiments using diffusion models. The experiments were repeated over several timescales. DV was stable over time, DH became stable after 15 days, while DM was very variable. Mean DH and DV biodiffusion coefficients were 1.16cm2d-1 and 0.92cm2d-1

respectively, while mean DM was an order of magnitude greater than the rates of bioturbation at 11.06cm2d-1. Amphiura filiformis is potentially very mobile within sediments. The disparity between DM and DH in Amphiura filiformis would suggest that the animal causes little detectable reworking when mobile, and that most bioturbation takes place while the animal is stationary and either actively feeding or maintaining its burrow. There was no significant difference between DH and DV. The strong homogenizing effect of horizontal bioturbation may have implications for inter-specific competition and community dynamics, and should be investigated further to ascertain its potential role in controlling ecosystem processes.

Functional biodiversity	Integrative

THINKING OUTSIDE THE CORE: SEARCHING FOR GENERALITY AND SOCIETAL RELEVANCE IN BIODIVERSITY AND ECOSYSTEM FUNCTION

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In recent years, scientific and technological advances have expanded our understanding of the role of sediment dwelling organisms in ecosystem processes. Defining the interactions between organisms and their biogeochemical and hydrodynamic environment can require very detailed measurement and analysis of small-scale processes. While this detail is important to the advancement of benthic ecology, we also need to consider how we might translate such knowledge into the broader realm of seafloor landscapes. In this talk, I want to illustrate potential sources of variability in ecosystem function. My intention is to encourage a more integrated empirical approach to research by emphasising what is gained by field observation compared with controlled experiments. I think considering these issues is important both for the development of the science, but also in the application of that knowledge to fully implement Ecosystem Services frameworks in marine ecosystems.

Functional biodiversity	Integrative

BIOLOGICAL AND BIOGEOCHEMICAL EFFECTS OF DRILL CUTTINGS

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This project studied different effects of water-based drill cuttings, using three different experimental methods: field experiment, mesocosm setup and acute toxicity using bioassays. Offshore drilling activities discharge large amounts of drill cuttings (a mixture of reservoir rocks, drilling mud and added chemicals), which may harm benthic organisms. Because of

environmental concerns of previous drilling with oil-based and synthetic muds, most drilling is performed using water-based drilling muds. Water-based drill cuttings have been assumed to have minor or no negative impact on the marine environment except for sedimentation.

Sediments with water-based drill cuttings in the field and mesocosm studies showed reduced oxygen concentrations and increased oxygen consumption. Mesocosm boxes showed reduction in number of taxa and abundance of macrofauna with increasing thickness of drill cuttings, which was not observed for the natural sediment particles. Bioassays showed that biological effects of water-based drill cuttings are similar to oil-based drill cuttings. Toxicity is the impact factor that can explain biological effects across all methods performed in the project and this factor should be investigated further in future projects.

Anthropogenic impact	Integrative

WILL BIOTURBATING ANIMALS BE AFFECTED BY OCEAN ACIDIFICATION?

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It was initially assumed that, of all the marine habitats, the flora and fauna of sediments would be least affected by Ocean Acidification. This assumption was primarily based on the knowledge that sediment habitats are already subjected to large changes in pH over very small spatial scales, often only millimetres. Consequently, the organisms and processes that existed in this environment were thought to be well equipped to deal with the relatively small changes associated with OA. This assumption is now being challenged and recent evidence suggests that the health and function of key sediment dwelling organisms could be significantly affected, either directly or indirectly, by OA. Given the dominance of sediment habitats in the marine realm and their importance in supporting key biogeochemical processes, which in turn support a number of socially important ecosystem services, the impacts of OA on the health and function of infaunal species could have a global impact. This talk will identify some of the mechanisms by which OA could affect burrowing organisms and will introduce some of the current research initiatives in this area.

Anthropogenic impact	Integrative

OCEAN ACIDIFICATION

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Since the start of the industrial revolution (*circa* 1750), levels of atmospheric carbon dioxide (CO_2) have risen from ≈ 180ppm to a concentration in excess of 380ppm. This increase has been responsible for the incremental warming now seen in terrestrial and marine environments across the globe. However, the total increase in atmospheric CO_2, and the subsequent warming, would have been considerably greater were it not for the oceans acting as a CO_2 sink and taking up more than a third of the made-man CO_2 emitted in the last 250 years. Whilst this is seemingly

good news in the fight against global warming, this rapid influx of CO_2 has significantly altered the chemistry of the planet's surface ocean and coastal seas. Data from long-term observatories and simulations from computer models clearly show that levels of dissolved CO_2 are increasing and the concentration of carbonate ions is decreasing. This is leading to reduced seawater pH and the shoaling of the carbonate compensation depth. All of these chemical reactions, collectively known as "Ocean Acidification" or OA, will have an impact on marine ecosystems; the organisms they contain and the processes they support. This talk will give an in depth look into the potential impacts OA may have on marine organisms.

Anthropogenic impact	Integrative

MICRO SCALE

THE RELATIONSHIP BETWEEN THYASIRID (BIVALVIA: THYASIRIDAE) VENTILATION BEHAVIOR AND SEDIMENT REDOX CYCLES

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Some species of thyasirid clams (Bivalvia: Thyasiridae) living in symbiosis with sulfur-oxidizing bacteria are often dominant in marine coastal environments affected by anthropogenically-driven organic enrichment. These clams have no siphon, but ventilate through an inhalant tube that is constructed using their hyper-extensile foot. They also construct burrow networks, or "pedal tracts", in the sediments beneath the shell presumably to target isolated patches of sulfide, a behavior known as "sulfide mining"; eventually, the surrounding sediments become reoxidized. Thus, thyasirids may help mitigate the effects of organic enrichment. Previous studies using planar optodes to map the distribution of pH in sediments around pedal tracts suggested localized, progressive decreases and increases in pH during the day and night, respectively. Here, the long-term ventilation patterns via the inhalant tube (oxygen uptake and release of hypoxic water) were studied and related with the diurnal redox cycling around pedal tracts, to investigate the relationship between symbiont-associated bivalve behavior and sediment redox processes. These results are important in better understanding both temporal and spatial aspects of sediment oxidation by these bivalves.

Anthropogenic impact	Micro/Meso

FIRST EXPERIMENTAL ASSESSMENT OF STEP LENGTH AND RESTING TIME DISTRIBUTIONS USING IMAGE ANALYSIS: A MECHANISTIC STUDY OF SEDIMENT REWORKING BY THE DEPOSIT-FEEDING BIVALVE ABRA ALBA

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According to continuous time random walk (CTRW) model, sediment reworking performed by a given organism is driven by two parameters: Step length (distance of particle displacement during an individual reworking event); and resting time (time duration between two consecutive displacements of a single sediment particle). Estimates of these two parameters are scarce and derived from modeling. New developments in image analysis however allow for their direct experimental assessment. A new experimental approach involving, thin aquaria, luminophores, high frequency image acquisition and sophisticated image processing techniques allowing for the direct assessment of step length and resting times has been developed. Based on the results of 48 hours long experiments conducted at different water temperature and with or without the addition of fresh phytoplankton detritus, we will show how this new approach allows for a better assessment of: (1) the spatio-temporal distributions of step length and resting times, and (2) the effects of temperature and organic matter availability on step length and resting time in the deposit-feeding bivalve Abra alba.

Novel tools and techniques	Micro

REVEALING HIGH RESOLUTION TWO-DIMENSIONAL IN SITU EXTRACELLULAR ENZYME ACTIVITY IN MARINE SEDIMENTS BY USE OF PLANAR FLUOROSENSORS

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Bacteria release extracellular enzymes to digest insoluble organic polymers before transporting the products back into their cells. Previous studies using traditional methods involving detailed sectioning or dissection of sediment cores, followed by homogenization, and measurement of exoenzyme activity after addition of a fluorogenically labeled substrate, have demonstrated enhanced extracellular enzyme activities in bioturbated sediments and near biogenic structures compared with non-bioturbated zones. Here we describe the continued development of novel transparent planar sensor foils for resolving two-dimensional sub-millimeter scale enzyme activity patterns over large areas (~ 100 cm2). These fluorosensor foils allow direct visualization and measurement of organic matter/microbial 'hot spots' in relation to physical and biogenic structures. Examples of real-time proteolytic enzyme (Leucine-aminopeptidase) activity patterns are shown.

Novel tools and techniques	Micro/Integrative

LOOKING FOR NEW BIOTURBATION TERRITORIES: EFFECTS OF BIOTIC INTERACTIONS ON LITTER DECOMPOSITION AND BIOTURBATION

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In order to investigate the effects of macro-invertebrates on particular organic matter dynamics in forest streams, in the frame of laboratory experiments, two ecosystem functions have been examined concomitantly: (i) decomposition of submerged plant litter as the main energy source to aquatic food webs, (ii) bioturbation that controls sediment and organic matter distribution. By manipulating the presence/absence and density of gammarids (shredders) and odonata larvae (predators), we were able to quantify density-dependent surface sediment reworking by the different species, up to 230 cm2.y-1 and 2200 cm2.y-1, for Gammarus spp. (at 1900 ind.m-2) and Cordulegaster boltonii (at 90 indiv. m-2) respectively. Leaf decomposition was also found dependent of the density of the shredder species as experimentally controlled or modified by predation. Preliminary results also suggest that the predation and sediment reworking activities by the odonata larvae may somehow be linked. Further efforts will be devoted to assessing the relative importance of trophic (density-mediated) and non-trophic (trait-mediated) interactions in controlling both ecosystem functions.

Functional biodiversity	Micro

STIMULATED MICROBIAL PAH MINERALIZATION AROUND MACROFAUNAL BURROWS IN ARCTIC MARINE SEDIMENTS

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Bacteria mineralize polycyclic aromatic hydrocarbons (PAHs) in marine sediments. Macrofauna-microbe interactions likely drive contaminant fate since bioturbation redistributes all sedimentary compounds. We investigated the role of the burrowing polychaete *Arenicola marina* in regulating PAH distribution, bacterial community structure (BCS) and bacterial PAH mineralization potential (PAH-MP) in intertidal Greenland sediments from surface, burrow, and bulk layers collected at PAH contaminated and pristine sites. DNA based BCS was identified using PCR-DGGE on the *rpoB* gene. Sediment oxygen demand, nitrification potential, nitrogen, carbon, and PAH content were also determined.

PAH levels were non-detectable at the pristine site, while levels were high (3,5 μg g DW^{-1}) at the contaminated site. PAHs in *A. marina* burrows were double those in surface sediments, while bulk PAHs were moderate, indicating continuous bioturbation. Bacterial PAH-MP correlated with PAH exposure, being highest in surface and burrow sediments. BCS differed

among sites and among compartments. Burrow BCS were distinct and resembled those from surface sediments more than those from the bulk. This investigation is the first describing detailed PAH distribution in the field in relation to natural bacterial PAH-MP.

Anthropogenic impact	Micro/Meso

LINKING OXYGEN DYNAMICS AND POREWATER TRANSPORT IN SEDIMENTS INHABITED BY THE INVASIVE POLYCHAETE MARENZELLERIA VIRIDIS

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The polychaete Marenzelleria viridis is an invasive species in Europe where it apparently occupies habitats similar to Nereis diversicolor. Recent studies suggest that invasion of M. viridis replacing N. diversicolor may change the biogeochemical functioning of estuarine sediments by increasing sulfate reduction and thereby sulfide production. Also, irrigation by M. viridis enhances percolation of more anoxic, nutrient and sulfide rich porewater towards the sediment-water interface, which can affect redox conditions and change the microbial activity and community structure along the primary interface. The reasons behind this are still unclear. By combining planar optodes, imaging techniques, microsensors and dye experiments we investigated the impact of M. viridis on sediment oxygenation, nitrogen cycling and sulfide distribution.
The study demonstrates the strengths of combining novel and well-proven micro-sensor and imaging techniques for elucidating biogeochemical functioning of bioturbated systems.

Novel tools and techniques	Micro

REDOX OSCILLATIONS IN BIOTURBATED SEDIMENTS

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Over the last few years we have investigated some of the most important bioturbating infaunal groups with respect to their hydraulic activity and the related porewater advection and oxygen dynamics. Despite species specific traits, the investigated crustaceans, bivalves, and polychaetes all engage in hydraulic behaviors that cause intermittent bidirectional transport of water away and towards the organisms. As a consequence, the sediment surrounding the burrows as well as the sediment surface experience frequent oscillations between oxic and anoxic conditions on the scale of minutes. In this talk we will visualize this dynamic nature of the geochemical conditions and present quantitative analysis of the species-, and sediment-specific oscillatory character and the scale of impact. The disruption of stable geochemical conditions by hydraulically active organisms is expected to have important implications for the distribution and activity of the associated (microbial) community and may explain the diversity of biogeochemical processes performed in bioturbated sediments.

Functional biodiversity	Micro

NITRIFIER AND DENITRIFIER COMMUNITY COMPOSITION IN MARINE SEDIMENTS

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Marine sediments comprise a complex environment on many scales, containing both physical and chemical heterogeneities and complex gradients. Given the great diversity of microbes present in sediments, and the wide range of their metabolic capabilities for biogeochemical transformations, it is expected that microbial communities should exhibit structure in relation to the observed environmental features. In this presentation, I will explore the evidence for such structure and for relationships between microbial community structure and

biogeochemical function. Processes in the nitrogen cycle in particular are sensitive to oxygen gradients because of the wide redox range of inorganic N compounds and the differing oxygen sensitivities of microbial metabolisms responsible for different steps in the pathways. Thus we hypothesize that nitrifying and denitrifying microbial assemblages might be structured in time and space in response to oxygen gradients, both within bulk sediments and around biotic structures such as burrows. Although there is ample evidence for chemical and physical microenvironments in sediments, there is less evidence for microbial community structure on the same scale. This failure to detect microscale structure may result from the versatility and resilience of natural microbial assemblages combined with experimental limitations in the methods currently used to investigate microbial communities.

Novel tools and techniques	Micro

COLORIMETRIC DGT AND DET: SIMPLE, LOW COST METHODS TO DETERMINE 2-DIMENSIONAL POREWATER SOLUTE DISTRIBUTIONS WITH MILLIMETER RESOLUTION

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The presence of plant roots, faunal burrows and non-uniform distributions of organic matter and mineral particles induces small-scale heterogeneity in the distribution of sediment porewater solutes. However, conventional methods are not able to measure these small-scale 2D variations. Colorimetric Diffusive Gradient in Thin film (DGT) and Diffusive equilibration in Thin Film (DET) represent simple, low cost methods to map the distribution of porewater solutes at millimetre resolution. Moreover, multiple analyte specific DET's and DGT's can be combined within single sediment probes to allow determination of solute co-distributions over the same sediment area.

The talk will outline the theory of colorimetric DET and DGT techniques, their advantages and limitations, and give an overview of the sulfide DGT, and phosphate, Mn(II) and Fe(II) DET methods developed within our research group. Data from field and mesocosm deployments of single and multiple analyte probes will be presented to demonstrate the power of these methods, the high degree of heterogeneity present in sediments, the strong interactions which exist between analyte distributions and the important role of "hot spots" of microbial activity to overall sediment biogeochemistry.

Novel tools and techniques	Micro/Meso

MESO SCALE

EFFECTS OF THE INVASIVE POLYCHAETE, MARENZELLERIA VIRIDIS, ON THE FATE OF SEDIMENT ASSOCIATED POLLUTANTS – A MICROCOSM STUDY WITH 14C-LABELLED PYRENE

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The deep burrowing, invasive spionid polychaete, Marenzelleria spp. (3 sibling species), is rapidly expanding its range in the Baltic Sea ecosystem, increasing the depth of the bioturbated zone dramatically relative to the native benthic community. One concern is the effect of this invasion on the fate of deeply buried sediment-associated pollutants in the historically polluted Baltic Sea. We report here the results of an experimental microcosm study examining the fate of 14C radiolabelled pyrene (a 4-ring PAH) in sediment microcosms with and without Marenzelleria viridis. We also investigated the impact of depositing labile organic matter (seston) on the sediment surface. Worms clearly enhanced the release of pyrene and degradation metabolites from the sediment to the overlying water in all cases, mostly due to the initial flushing of sediments during burrow establishment. Surprisingly, there was no clear effect of worms on the mineralization of pyrene to CO2, where a complicated interaction between bioturbation and the presence of labile organic matter was observed. Furthermore, the ultimate fate of the increased release of sediment-associated pyrene and its metabolites to the water is unknown.

Anthropogenic impact	Meso

4D VISUALISATION AND QUANTIFICATION OF BIOLOGICALLY DRIVEN ADVECTIVE FLOW

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In the last decades, medical imaging techniques such as computer aided tomography (CT scan) have been used in soil and sediment science to provide excellent 3D visualization and measurement of biogenic structures. This step forward has opened the window to non destructive measures of geometric properties within the sediment. When combined with positron emission tomography (PET-CT scan), it is possible to visualize and quantify fluid transport in vivo and in real time. This presentation introduces the potential use of the PET-CT scan technique for the measurement of spatial and temporal irrigation patterns created by ventilating fauna in the sediment. As an example, we will present a 4D picture (space and time) of the porewater advective flow induced by the lugworm (*Arenicola marina*), and compare the results obtained with PET-CT scan and more traditional methods.

Novel tools and techniques	Meso/Micro

MONITORING OF SANDY NEARSHORE RIPPLE MARKS, THEIR EVOLUTION AND ROLE AS BENTHIC HABITAT

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Sandy ripple marks are a common phenomenon at shallow water coasts. These bedforms characterize a habitat with numerous endo- and epibenthic organisms like e.g. *M. arenaria* or *A. marina*, which are strongly influenced by sediment transport processes around them. These processes and the response of the organisms are in the focus of research at the intersection of geoscience, marine biology and coastal engineering.
In order to perform a bedform monitoring, a customized underwater photogrammetry-system was build, and deployed at a study site some 350 m offshore Rostock-Warnemünde, which is characterized by weak longshore currents (<0.3 m/s) and microtidal conditions. Thus, sea and swell are the main driving factors for sediment transport at this location.
Every day, about 20 image pairs of the sea floor are taken, which can be processed to 3D-models or anaglyph images. Shifts of morphology and mass can be observed and quantified, as well as be correlated to the governing local sea state conditions. Furthermore, the density of population of *M. arenaria* or *A. marina* and their reaction to transport processes can be investigated.

Novel tools and techniques	Meso

LINKS BETWEEN DIVERSITY OF BENTHIC FAUNA, NUTRIENT FLUXES AND HYPOXIA – A FIELD STUDY ACROSS A HYPOXIC GRADIENT

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Hypoxia in coastal environments is a growing problem globally as well as in the Baltic Sea. It is a complex problem because the increasing spatial distribution of hypoxia is partly due to the increasing coastal eutrophication, and hypoxia in turn increases the release of nutrients from the sediments. Therefore, in order to more efficiently manage eutrophication an improved understanding of feedback mechanisms between hypoxia, the diversity and functioning of benthic fauna, and the internal nutrient loading from the sediments is very important.

We conducted a coastal field study in the Tvärminne-area in the western Gulf of Finland, northern Baltic Sea. Samples were collected from nine sites (8-33 m depth) describing a gradient of different bottom-water oxygen concentrations in an area of very fine muddy sediments. Nutrient fluxes were measured across the sediment-water interface by incubating intact sediment cores. For instance, the efflux of phosphate from the sediment increased significantly when the oxygen concentration decreased and the influence of the strong gradient both in bottom-water oxygen concentration and in benthic faunal diversity, abundance and biomass on nutrient dynamics was remarkable.

Functional biodiversity	Meso

FEEDING BEHAVIOUR OF AN OXYPODID CRAB, MACROPHTHALAMUS JAPONICUS, AND ITS EFFECTS ON ORGANIC MATTER REMOVAL FROM AN INTERTIDAL SEDIMENT OF THE HAN RIVER ESTUARY, KOREA

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The objective of this study is to elucidate the feeding behavior of an oxypodid crab, Macrophthalmus japonicus, the most dominant macrofauna in Korean mud flat, and to clarify its role in organic matter removal from the intertidal sediments. The crab's feeding behavior,

variations of oxygen penetration depth and Chl a concentration in their feeding substratum, and the removal rate of organic carbon and nitrogen in their feeding pellets were investigated during the daytime ebb on a mud flat of the Han river estuary, Korea. The feeding behavior of Macrophthalmus japonicus was relatively dependent on air temperature and oxygen penetration depth was affected by their activities of probing the substratum with chelae for feeding and movement. Organic carbon and nitrogen concentrations of the feeding pellets decreased down to 60% due to their feeding. It was calculated that organic carbon and nitrogen were removed at the rate of 1.89 mmol C m-2 h-1 and 0.24 mmol N m-2 h-1, respectively. C/N ratio increased to 18% in feeding pellets compared with that of non-feeding sediments. Depletion of 15N in the pellet (5.99 permil) compared to that in the sediment (7.21 permil) further implied that the crab removed N in the sediment. Overall results indicated that carbon removal by the feeding of Macrophthalmus japonicus was comparable to 50% of anaerobic C mineralization in the sediments, and the crab feeds on nitrogen selectively in order to meet their nitrogen requirements.

Functional biodiversity	Meso

SMALL LARVAE – LARGE IMPACT
IMPACTS OF MACROZOOBENTHOS ON HYDRODYNAMIC AND BIOGEOCHEMICAL PROCESSES AT THE SEDIMENT-LAKE INTERFACE

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Several macrozoobenthos species such as *Chironomus plumosus* pump water through their burrows since they need oxygen for respiration and feed on plankton. We developed measurement techniques for macrozoobenthos burrows with small diameters and are able to characterize and quantify the flow through the burrows. For Lake Müggelsee we estimated that its chironomid population pumps once per week a water volume equivalent to the whole lake volume through the sediment. For sure there is a tremendous impact on the water quality by such intense filtration activity but impacts are still non-quantified. The flow through the burrows induces flow through the surrounding sediment and with positron emission tomography we are able to visualize and measure that flow. The flow through the burrows and the surrounding sediment alters the redox zonation and biogeochemical turnover in the sediment. We focus our research on phosphate and elements closely coupled to phosphate biogeochemistry since P is the limiting nutrient for primary production in most freshwater ecosystems and an excess of P causes eutrophication. With a novel pore water sampling technique we could visualize the spatial

pattern of pore water concentrations and with a P fractionation of the burrow walls we could identify biogeochemical changes of the sediment composition.

Novel tools and techniques	Meso

FUNCTIONAL CLASSIFICATION OF BENTHIC MACROFAUNA USING IMAGING OF LUMINOPHORES AND MULTIVARIATE ANALYSIS

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Significant efforts have been devoted to 1) understand feedbacks between biogeochemical signals and the behaviour of benthic fauna, and 2) to experimentally quantify the importance of bioturbation by individual species and faunal communities for element cycling.
This work presents a general procedure for classification of macrofaunal reworking using multivariate analysis on proxys for sediment transport. The transport of fluorescent particles (luminophores) added to the surface sediment was monitored by imaging during a two week experiment with several common bioturbating marine species:
The multivariate analysis of reworking proxies not only revealed groups of species with similarities in particle reworking behaviour, but also the overall importance of individual proxies (e.g. Db, ORC, depth of luminophore penetration) and faunal properties (e.g. biomass, biovolume) for the overall classification.
The study suggests that imaging of particle displacement in combination with multivariate analysis provide a powerful and general tool for functional classification of benthic macrofauna.

Functional biodiversity	Meso/Integrative

CONVEYOR-BELT DEPOSIT FEEDING BY THE POLYCHAETE HETEROMASTUS FILIFORMIS

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The depths and rates of deposit mixing by the cosmopolitan marine annelid Heteromastus filiformis was investigated in prepared microcosms and intact cores from Great Bay, NH, USA

using 137Cs tracer layers. The cores were placed in aquaria at 14.4 or 24.4 oC and a gamma detector periodically scanned the microcosms to permit observation of the bioturbation-induced particle movement. The results indicate that the worms typically fed head down in the sediment at depths up to 16 cm and that biodiffusive mixing was absent regardless of worm density. The per individual feeding rate of 2.28 x 10-3 yr-1 was invariant over worm densities of 2,500-10,000 individuals m-2. In natural box cores during the first 143 days of incubation the downward velocity of 137Cs-labeled surface sediments was 1.31 ± 0.16 cm yr-1 and 2.47 ± 0.32 cm yr-1 for cores incubated at 14.4 ºC and 24.4 C, respectively, yielding a Q10 of 1.87. Downward velocities of high temperature incubations accelerated after this time, likely reflecting increased worm growth at the elevated temperature. Low temperature incubations were unchanged after day 143.

Novel tools and techniques	Meso

CONSEQUENCES OF RAPID AND SEVERE CO2 INDUCED SEAWATER ACIDIFICATION ON BENTHIC ECOSYSTEM FUNCTION

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Whilst a range of biological effects associated with ocean acidification have been documented within the context of long term environmental change, the short term ecological consequences of rapid acidification caused by leakage from subsea carbon capture infrastructure have received little attention. In this study representative benthic invertebrate species were exposed to seawater acidified with carbon dioxide gas (pH 6.5) to mimic the effects of leakage from a subsea CO2 storage site for a period of 96hrs. Nutrient regeneration was measured, as was bioturbation, a key process which mediates this function. We show that the activity of individual species can change rapidly with acidification and this can lead to dramatic changes in ecosystem function. Our findings demonstrate that whilst exposure to severe seawater acidification may not be lethal in the short-term, it can have immediate functional consequences that cannot be detected using post-hoc environmental impact assessments that rely on taxonomic inventories.

Anthropogenic impact	Meso

CONTEXT-DEPENDENT EFFECT OF BIOTURBATION ON HYDRAULIC CONDUCTIVITY AND PARTICULATE ORGANIC MATTER DEGRADATION IN RIVER SEDIMENTS

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The present paper aimed to investigate how physical characteristics of the sedimentary habitat modulate the ability of bioturbators to influence hydrologic exchanges and organic matter processing at water-sediment interface of rivers. An experimental procedure was developed at the laboratory, using slow filtration columns in which we recreated two sedimentary habitats by adding a layer of fine (low permeability) or coarse (high permeability) particles at the top of a highly permeable gravel-sand matrix. For each habitat, we measured the influence of tubificid worms (Tubifex tubifex) as common bioturbators on physico-chemical (sediment reworking, permeability, hydraulic conductivity and water chemistry) and microbial (abundances, activities) characteristics. We also measured breakdown rates of buried leaf litter as ecological process mediated by microbes. Results showed that T. tubifex had a low influence on hydraulic water exchanges in highly permeable sedimentary systems. Consequently, tubificid worms did not affect microorganisms developed on buried leaves and leaf litter breakdown. In contrast, T. Tubifex had a very significant influence in habitat with low permeability, in which they counteracted the adverse effect of fine sediment deposits on water exchanges. By increasing the transport of water and dissolved oxygen in river sediments through bioturbation, tubificid worms stimulated the activities of microbes developed on leaves and then leaf litter breakdown. Finally, our study demonstrates that the contribution of bioturbation on ecological processes occurring in river sediments cannot be quantified without assessing the complex interactions between bioturbation activities and habitat characteristics.

Functional biodiversity	Meso

INFLUENCE OF BIOTURBATION ON DENITRIFICATION AND DISSIMILATORY NITRATE REDUCTION TO AMMONIUM (DNRA) IN FRESHWATER SEDIMENTS

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Intensive agriculture lead to increased nitrogen fluxes (mostly as nitrate, NO3-) to aquatic ecosystems, which in turn creates ecological problems including eutrophication and associated harmful algal blooms. These problems have focused scientific attention on understanding the controls on nitrate reduction processes such as denitrification and dissimilatory nitrate reduction to ammonium (DNRA). Bioturbation activities of benthic organisms interact with the microbial communities involved in nitrogen cycling. Our objective was to determine the effects of bioturbating invertebrates (tubificid oligochaetes) on denitrification and DNRA in freshwater

sediments. A mesocosm experiment was used to determine how tubificid density and increasing NO3- concentrations (using N15 isotope tracing) interact to affect N cycling and associated microbial communities. Preliminary results suggest that increased fauna densities and NO3- concentrations correlate with increased rates of denitrification and DNRA. Further analysis will explore if these rates are related to increased gene copies (measured by quantitative PCR on N cycling functional genes). These results enhance our knowledge and understanding of the interactions among anthropogenic impacts, benthic fauna, and microbial community in affecting N cycling in aquatic environments.

Anthropogenic impact	Meso

IMPACTS OF THE INVASIVE POLYCHAETE MARENZELLERIA VIRIDIS ON ORGANIC MATTER PROCESSING AND NUTRIENT CYCLIG IN ESTUARINE SEDIMENTS

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The invasive polychaete Marenzelleria viridis has in recent decades been recorded in increasing densities in Europe and may become a problem with respect to nutrient cycling and associated effects on ecosystem functioning. M. viridis has a special mode of ventilation (i.e. muscular and ciliary) and the resulting irrigation efficiently transports porewater solutes from deeper sediment zones to the surface. In this study we investigated the effects of M. viridis irrigation on organic matter remineralization and nutrient dynamics in sediments from Odense Fjord, Denmark. A laboratory experiment with sandy sediment inhabited by M. viridis (1200 ind m-2) was conducted for 8 weeks. Fluxes of O2, CO2 and nutrients between water and sediment were monitored every 2-5 days. Porewater solutes (ammonium, sulfide and CO2) were measured after 0, 4 and 8 weeks. There was clear evidence that M. viridis impacted fluxes and porewater solutes when compared to defaunated controls. Furthermore, the results indicate that M. viridis irrigation may stimulate anaerobic microbial and geochemical processes at all sediment depths.

Anthropogenic impact	Meso

A COMPARATIVE STUDY ON SOLUTE AND PARTICLE TRANSPORT BY THE THREE SIBLING SPECIES OF MARENZELLERIA SPP. IN THE BALTIC

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Since the 1980`s the invasive spionid polychaetes of the genus Marenzelleria spp., consisting of the three sibling species M. neglecta, M. viridis and M. arctia has been found in the Baltic Sea. Because of the difficulties in species identification, little

is known about species dependent sediment reworking and solute transport, though size and burrowing depth of the organisms indicate substantial differences.
To investigate the potential differences among closely related species, tracer (luminophores, bromide) and nutrient fluxes were experimentally investigated in mesocosms (4 replicates). Polychaetes were identified to species level using a molecular genetic key.
Maximum irrigation depth in M. arctia cores was small (12.8 ± 1.7 cm) compared to controls (8 ± 1.0 cm). M. neglecta (21.2 ± 4.0 cm) and M. viridis (32.8 ± 3.5 cm) reached considerably deeper. Solute transport based on Br--inventories in the sediment was enhanced by the factor 1.8 in M. arctia, 4.4 in M. neglecta and 5.6 in M. viridis treatments compared to controls.
These findings and their relation to nutrient fluxes will be further explored by modelling coefficients α, Db and r.

Functional biodiversity	Meso

SPATIAL DISTRIBUTION OF ALITTA VIRENS BURROWS STUDIE BY AXIAL TOMODENSITOMETRY IN TWO SALT MARSHES IN THE BAIE DES CHALEURS, QUÉBEC

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Relationships between macrofaunal behaviour, sediment characteristics, and the spatial organization of biogenic structures remain poorly understood, albeit important for understanding bioturbation impacts. Using axial tomodensitometry (CT-scan), we studied the spatial distribution of burrows in two salt marshes (Gulf of St. Lawrence, Canada) dominated by the gallery-diffuser Alitta virens. Cores were collected, and sediment and burrow characteristics were quantified on both scanned and transversely sectioned cores. Relative abundances of mud and organic matter were greater in the more sheltered site, as were the number, space and volume occupied by biogenic structures, and their regularity of spacing along a vertical plane. In both marshes, mean tomographic intensity (TI, a function of sediment density) significantly increased with depth, whereas the number of burrows and the biogenic space occupied significantly decreased with depth. TI is also correlated with number of structures, biogenic space and organic matter content, confirming that sediment density is important in controlling biological parameters within the whole core. The analysis reveals a strong intra-site variability, with a significant site effect, suggesting that abiotic factors (hydrodynamism, sedimentary composition) affect the distribution of A. virens burrows.

Novel tools and techniques	Meso

INFLUENCE OF NATURAL ABUNDANCES OF THE COCKLE (CERASTODERMA EDULE) ON WATER/SEDIMENT AND AIR/SEDIMENT FLUXES

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The cockle (Cerastoderma edule; Mollusca, Bivalvia) is locally abundant in sandy sediments on the French coast of the English Channel. The species is usually found in dense patches of several hundreds of individuals surrounded by areas of lower densities. In the present study, we estimated the influence of natural abundances of cockles on sediment fluxes. Sediment cores were collected on a sandflat of the Eastern English Channel, brought back to the laboratory and incubated in darkness for the estimation of O2 and nutrient fluxes at the water/sediment interface, and CO2 fluxes at the air/sediment interface. Cockles densities ranged from 0 to 900 ind.m-2, corresponding to a maximum biomass (AFDW) of 134 g.m-2. Fluxes at both interfaces were not directly related neither to the density, nor to the biomass of cockles. Accompagnying species (the Gastropod Hydrobia ulvae and Amphipods of the genus Bathyporeia) were also abundant; though representing a weak biomass, their presence with the dominating cockle seemed to be critical in the resulting sediment fluxes, underlying the importance of species interactions, and thus biodiversity, in the functionning of intertidal systems.

Functional biodiversity	Meso

EFFECT OF DRILL CUTTINGS ON SEDIMENT REWORKING OF TWO BENTHIC SPECIES

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Drill cuttings (a mixture of reservoir rocks and drilling mud) are discharged from offshore drilling activities, and when settling on the seabed, benthic organisms may be affected. While numerous studies have documented effects of drill cuttings on the benthic community level, the present study for the first time investigated effects of drill cuttings on the sediment reworking activity. The experiment was conducted with the bivalve Abra nitida and the brittle star Amphiura filiformis using thin aquaria, luminophores, time lapse photography and image analysis. Due to lack of an appropriate bioturbation model for A. filiformis, sediment reworking activity was measured as total amount of luminophores transported below the sediment-water interface and maximum penetration depth. Both species showed a marked reduction in the total

downwards transportation of luminophores in drill cuttings treatments compared to controls with added natural sediments, and A. nitida also showed a reduced maximum penetration depth. To conclude, the study showed that drill cuttings have the potential to reduce the sediment reworking activity, and such effects are not detected with standard benthic monitoring based on community composition.

Anthropogenic impact	Meso

CAN SEDIMENT REWORKING BY ARENICOLA MARINA PREVENT THE REESTABLISHMENT OF EELGRASS?

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Eelgrass (Zostera marina) used to dominate the vegetation in Odense Fjord, Denmark, and before 1983 it covered >17 km2 of the shallow fjord. Decades of excessive nutrient loading has, however, decreased the eelgrass distribution and at present the cover is only ~2 km2. The state of low eelgrass coverage has not changed despite significant improvements of water quality in the past >10 years. Since lugworms, Arenicola marina, have invaded many of the former eelgrass areas, we hypothesized that the lack of eelgrass recovery is coupled to the activity of lugworms. This was investigated by a combined field and laboratory approach. At a study site where eelgrass used to dominate, we performed a seasonal study of lugworm population dynamics and reworking activity. Furthermore, direct interactions between lugworms and eelgrass were investigated in laboratory experiments. Our results indicate that lugworms have negative impact on eelgrass recovery, since sediment reworking by lugworms buries eelgrass seeds and seedlings. Significant impacts occur even at low lugworm density (< 5 m-2) and can, at least partly, explain the lack of eelgrass recovery in Odense Fjord.

Anthropogenic impact	Meso

IMPACTS OF INCREASING STRESS ON BENTHIC ECOSYSTEM FUNCTIONING

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Disturbance of seafloor ecosystems results in changed or impaired biodiversity. Still, how differences in disturbance dynamics might alter ecosystem functioning is poorly understood. Oxygen deficiency is a widespread threat to benthic communities, with well-established, negative impacts on the benthic fauna. However, few studies have assessed in situ how benthic communities subjected to different degrees of oxygen deficiency alter their contribution to ecosystem functioning. We studied changes in benthic ecosystem functioning by artificially inducing oxygen deficiency of increasing and repetitive durations in sub-tidal sandy habitats. Responses in benthic community structure and function were quantified, and benthic chamber incubations were used for measuring responses in sediment nutrient fluxes. Increased stress reduced benthic biodiversity and impaired the structural and functional composition of the community. Alterations in benthic traits indicated a reduction in the community bioturbation potential. Consequences for ecosystem function were seen as altered sediment oxygen and nutrient fluxes. Although the effects of oxygen deficiency on ecosystem functioning seem to be habitat-specific, our study indicates that the level of stress alters the way benthic communities contribute to ecosystem processes.

Functional biodiversity	Meso

MACRO SCALE

DIAGENETIC CYCLING OF SI IN SHALLOW WATER CARBONATE DEPOSITS: ROLE OF PLANT RHIZOSPHERES AND BIOTURBATION

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Silica cycling in shallow water carbonate sediments is potentially strongly regulated by mangroves (Rhizophora), seagrasses (Thalassia, Syringodium), and benthic macrofauna. Sampling sites within ray feeding pits, seagrass beds, and mangrove prop roots off South Bimini, Bahamas revealed low dissolved Si and biogenic Si, with ranges (upper ~ 15 cm) of ~ 10 – 200 microM (seagrass bed average ~ 10 microM) and 5 – 35 micromol Si/g respectively. Ammonification and silica dissolution rates attenuated sharply with depth. Solute and solid phase concentrations and reaction rate distributions are consistent with a subsurface transport sink at ~ 5 to 10 cm, and rapid recycling of Si within the surface litter and root zone (dissolved Si turnover times ~ 1.5 – 2 d in seagrass beds). Planar optode measurements of O2 distributions revealed dynamic rhizosphere interactions with subsurface deposits consistent with the intense recycling of Si. The dissolved Si distributions found in Bimini deposits constrasts with far higher concentrations typical of carbonate sediments in Florida Bay, Florida. Si, incorporated as

phytoliths, may be an important limiting nutrient governing seagrass and mangrove production in offshore carbonate systems.

Functional biodiversity	Macro

FUNCTIONAL BIODIVERSITY ALONG A LAND-OCEAN CONTINUUM: THE ROLE OF BIOGENIC STRUCTURES IN CONTROLLING BIOGEOCHEMICAL FLUXES AT THE SEDIMENT WATER INTERFACE

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Over the past few years, considerable attention has focused on the influence of functional biodiversity on benthic fluxes. Although experimental research has shown that burrows can control solute fluxes, their effects on biogeochemical processes in the field are poorly known. In this study we characterized biogenic sedimentary structures and their effect on benthic fluxes along a natural land-ocean continuum. Field sites were located in the Elorn estuary (France, Brittany), which has a regular input pattern of nutrients due to agricultural activities. Two lots of sediment cores were sampled at three stations along the salinity gradient: one was used to examine biogenic structures (using Cat-Scan) and another for biogeochemical measurements in overlying and interstitial waters. Results showed inhabited and irrigated burrows up to 20 cm deep at upstream and midstream sites where benthic fluxes were higher and porewater profiles were strongly modified. We will present model and computational improvements for image processing which allow analyses of biogenic structures. The quantitative effect of these structures on benthic fluxes will be discussed.

Functional biodiversity	Macro/Integrative

SEDIMENT PROFILE IMAGING – THE SCANDINAVIAN APPROACH

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Sediment profile imaging (SPI) has a history back to the early 70's, however, it was during the 90's with the introduction of digital SLR cameras and image analysis software's that the use of the method expands. This could be tracked in the publication rate of scientific papers where SPI have been used.

The sediment profile camera work as an upside-down periscope penetrating the sediment surface and looking horizontally into the sediment. The image is about 17 cm wide and with a typical penetration depth of 15 cm. Sediment profile image analysis according to the benthic habitat quality index (BHQ) is based on sediment surface structures, subsurface structures and the measurement of the apparent redox potential discontinuity (RPD).

This paper focuses on the interpretation of features observed in SPIs and the analysis of SPIs according to the BHQ-index. Examples from a wide range of applications of the use of SPI in Scandinavian waters are given.

Novel tools and techniques	Macro

ANIMAL-SEDIMENT RELATIONS ALONG A DISTURBANCE GRADIENT ASSESSED BY IN SITU TIMELAPSE SEDIMENT PROFILE IMAGERY

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Animal sediment relations were examined at three sites along a disturbance gradient using time-lapse sediment profile imagery (tSPI). Habitat quality, measured as apparent redox potential discontinuity, increased with distance seaward because of estuarine, physical and anthropogenic disturbance effects. Subsurface burrowing activity was higher in the less disturbed sites. The rate of change of shape of the sediment water interface was highest at the disturbed site because of the presence of unconsolidated spoil material. Rates of reduction of burrow in-fill and prism drag down material were calculated. Linear modelling revealed that reduction rates were significantly effected by time, depth in the sediment profile and the interaction of time and depth. Macrofaunal indices did not discriminate between habitat quality at these sites because of the occurrence of a few individuals from tolerant species at the disturbed site that may have been transported as bedload. In this study, these species did not produce a measurable effect in terms

of bioturbating activity. Observation of the activities of macrofauna in situ allows an informed assessment of ecosystem functioning and habitat quality to be made.

Anthropogenic impact	Macro

DOES BOTTOMTRAWL FISHERY HAVE AN IMPACT ON THE BENTHIC FAUNA IN KATTEGAT?

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The diversity of benthic fauna in all Danish waters has long been declining. The decline is not confined to areas with hypoxia or anoxic sediments, thus eutrofication is ruled out as solitary cause. The question is now, what else is causing the decline? This study aims to focus on bottomtrawl fishery as a possible explanation for the declining benthic diversity.
The trawl activity in the Kattegat area is logged with VMS (vessel monitoring system). Available data for both Danish (’05-’09) and Swedish (’07-’09) vessels were analysed with a GIS program. Data showed intensive bottom trawl activities and the spatial distribution was correlated with both bathymetric data and sediment characteristics.
A distinction of the most disturbed habitat was made by analyzing the preferred trawl-depth together with sediment characteristics. The benthic community within these distinct habitats was found generally to have a low diversity. In order to correlate the diversity and species composition with trawl activity, analysis of the spatial distribution were carried out in the GIS programme. Functional diversity was also studied and correlated with trawl disturbance.

Anthropogenic impact	Macro

OF HOLES AND DEPRESSIONS ON THE GREAT BARRIER REEF COAST – AND A PHYSICIST’S TOOLBOX TO STUDY THEM

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Like any other coastline of the world, the Great Barrier Reef’s coast and seafloor is riddled with holes and depressions created by burrowing animals. We present an overview over studies of tidal irrigation of crustacean burrows in mangrove forests, and of mysterious (and not so mysterious) biogenic holes and mounds on the seafloor, surrounding coral reefs and shipwrecks.

The important role of crustacean burrows to the health of mangrove forests will be discussed, and the role of seafloor bioturbators as habitat engineers for coral assemblages will be demonstrated.

A geophysical toolbox will be presented, which includes (a) centimeter-scale geoelectric methods to locate macroscopic burrows and investigate water flux through burrows, (b) mass balance of the natural radionuclide 222Rn to determine water exchange between mangrove forests and creeks (forest-scale) and (c) high resolution 3D mapping of the seafloor with multibeam echosounders to study the morphology of bioturbation features in greater than diving depth (decimeter to kilometer scale).

Novel tools and techniques	Macro/Meso

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