Shaken and stirred: getting a taste of mining impacts on deep-sea sediments

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Mining of polymetallic nodules from soft sediments in international waters may begin within the next couple of years. There is no doubt that this will remove any nodule-attached fauna from the mined area along with their substrate, which needs millions of years to return. But what about the organisms thriving in the sediments below, which even the most selective nodule collector will affect? As the open ocean floor develops at a very slow rate, nodule mining will easily disrupt a habitat that has taken thousands of years to form. Usually, the highest abundances of organisms are found in this top layer of the seabed where most food is supplied as fresh particles from the overlying waters. Particularly variable geochemical conditions in the surface sediments offer a wide range of microhabitats that host a huge variety of microorganisms and representatives of many different animal phyla.

The deep seafloor is still poorly studied and numerous questions as to the biodiversity and spatial distribution of deep-sea soft-bottom communities remain unsolved. With respect to mining impacts, questions on the organisms' potential to withstand disturbances and recolonise as well as the timescales to reform stable communities need to be considered as a prerequisite for any impact assessment and management plan. With the present rush for deep-sea mineral resources we may lose unique ecosystems that we are only beginning to understand and which potentially provide relevant services for mankind, such as carbon sequestration, recycling of nutrients and supply of genetic biodiversity for biotechnology applications.

How to assess mining impacts on sediment ecosystems

Disturbance experiments are key in assessing and predicting impacts of mining and other anthropogenic activities on deep-sea ecosystems but typically require major efforts and huge funds. The largest experiment of this kind was the DISturbance and re-COLonization experiment (DISCOL) carried out in the late 1980s in the south-eastern tropical Pacific. Though far from reaching realistic industrial scales, DISCOL involved the ploughing of an 11 km^2 area of the seabed. However, much smaller disturbances may be adequate if specific questions are posed, with the additional benefit of reduced efforts and more easily controlled experimental conditions. MIDAS partner institution Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) in Bremerhaven, Germany developed the so-called 'Integrated Sediment Disturber' (ISD) - an autonomous instrument that is able to expose deep-sea sediments to different levels of physical perturbation to study the impact on small scale organisms and sediment functions.

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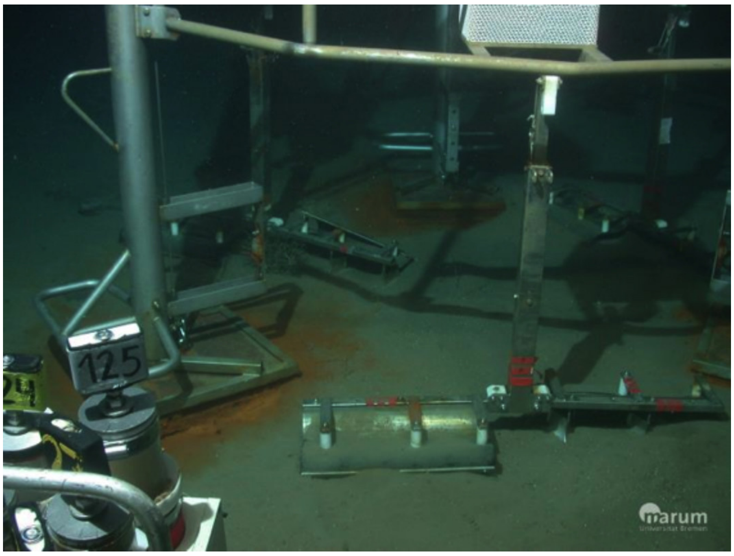

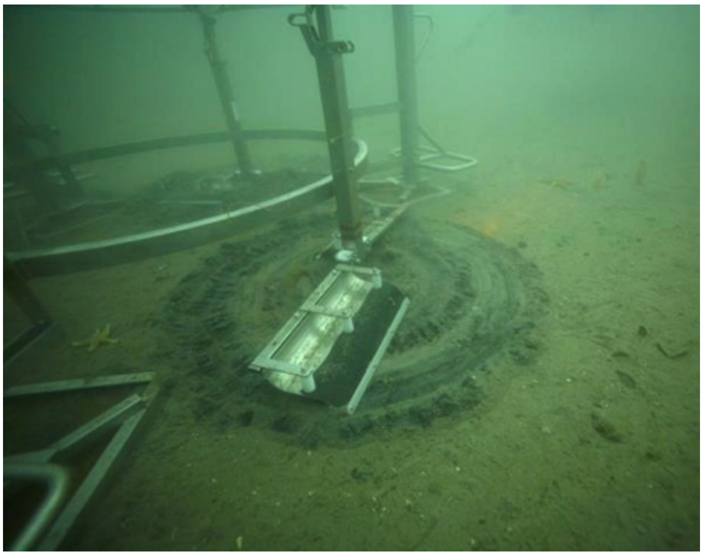

Above left: The Autonomous Sediment Disturber upon deployment at HAUSGARTEN off Svalbard. In the lower left corner push cores used for sampling by a remotely operated vehicle are visible. Image: MARUM at Bremen University and Thomas Soltwedel, AWI. Above right: The rotating plough-like unit disturbing sediments in a shallow water deployment to assess impacts on small sediment fauna and functions. Image: Thomas Soltwedel, AWI.

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Sediment disturber experiment in the Arctic

AWI will focus on an ISD deployment at HAUSGARTEN west of Svalbard, one of the very few sustained long-term deep sea ecosystem observatories. There are no plans to mine this area, yet existing long-term time series at the site facilitate impact studies as natural variations are known. During a one-year deployment, the ISD system disturbs three approx. 1 m^2 areas by means of rotating plough-like units. Sediment samples are obtained from the disturbed patches and nearby reference areas. These are used to investigate abundances and biodiversity of microorganisms and the sub-millimetre representatives of higher life (meiofauna) by means of microscopy and genetic fingerprinting techniques. Vertical oxygen profiles are obtained with microsensors in order to assess sediment oxygen demand. This serves as a parameter of the overall organic matter degradation of the sediments which represents a key function of seafloor communities. Previous short-term ISD studies in shallow waters off southern France and Scotland showed strong and complex impacts of disturbance on all investigated chemical and biological ecosystem components. Established vertical gradients (e.g., in terms of organic matter or organism abundances) were disrupted and sediment oxygen uptake bounced up due to the sudden bottom-water exposure of reduced sediments from deeper layers. In contrast to most other groups of meiofauna, nematodes seemed to resist or even profit from the disturbance, and increased in abundance. Based on these findings we expect that the small-scale deep-sea disturbance study will provide valuable information on potential mining impacts on sediment ecosystems in the deep ocean.

Further reading

Jacob et al. (2013) Biogeography of Deep-Sea Benthic Bacteria at Regional Scale (LTER HAUSGARTEN, Fram Strait, Arctic); www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0072779

Soltwedel, T. et al. (2005) HAUSGARTEN: Multidisciplinary Investigations at a Deep-Sea, Long-Term Observatory in the Arctic Ocean, Oceanography 18(3):46–61; www.tos.org/oceanography/archive/18-3_soltwedel.html

Soltwedel, T. et al. (2008) An "Integrated Sediment Disturber" (ISD) to study the impact of repeated physical perturbations on sediment geochemistry and the small benthic biota, Limnol. Oceanogr.: Methods 6: 307-318; www.aslo.org/lomethods/free/2008/0307.html

IMAR sets up atmospheric and pressurised lab experiments

The Institute of Marine Research at the Department of Oceanography and Fisheries, University of Azores has set up laboratory experiments at LabHorta, aiming simulate the deposition of particles from mining-related sediment plumes onto deep-sea benthic organisms. Physiological response studies will be performed to understand the short-term impact of sediment burial and toxicity on the hydrothermal vent mussel *Bathymodiolus azoricus* and the cold-water coral *Dentomuricea* sp..

The trials will be conducted under both atmospheric pressure and hydrostatic pressure using the IPOCAMP pressure vessel. Collaboration between IMAR/DOP-UAz and the Université Pierre et Marie Curie has enabled the adaptation of IPOCAMP for the planned trial. By bringing together UPMC's technical know-how in pressure vessel specifications and the scientific expertise of researchers at IMAR/DOP-UAz it is now possible to mimic the same aquarium sediment deposition conditions at pressurised conditions. Studies will include (i) measurements of survival and organism-level key physiological functions (e.g. respiratory metabolism); (ii) energy budgets (elemental and biochemistry); (iii) evaluation of antioxidant enzyme activity and quantification, and (iv) differential expression of immune and antioxidant genes.

Above: The laboratory setup at LabHorta, designed to investigate the short-term impacts of sediment burial on the cold-water coral Dentomuricea *sp. (top and bottom right) and the hydrothermal vent mussel* Bathymodiolus azoricus *(bottom left). Images courtesy IMAR/DoP-UAz.*