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MANAGING IMPACTS OF DEEP SEA RESOURCE EXPLOITATION

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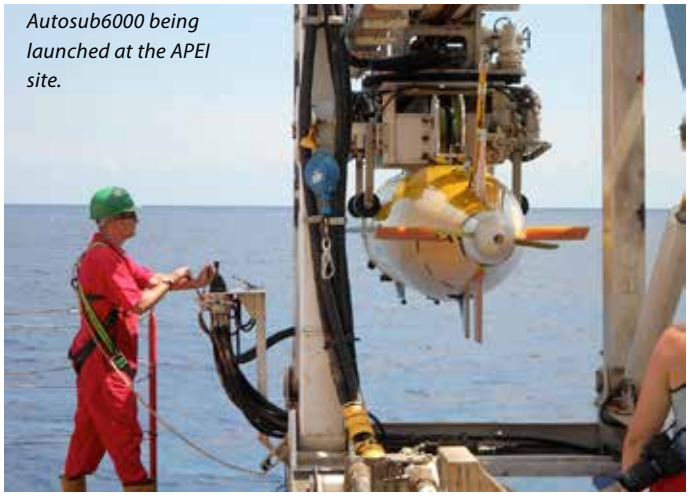
RRS James Cook explores nodule habitats in the Clarion-Clipperton Zone

Dan Jones, JC120 Principal Scientist

The UK Natural Environment Research Council's research vessel RRS *James Cook* has returned from the National Oceanography Centre led JC120 cruise to study the biology and geochemistry of an area of the Clarion Clipperton Zone (CCZ).

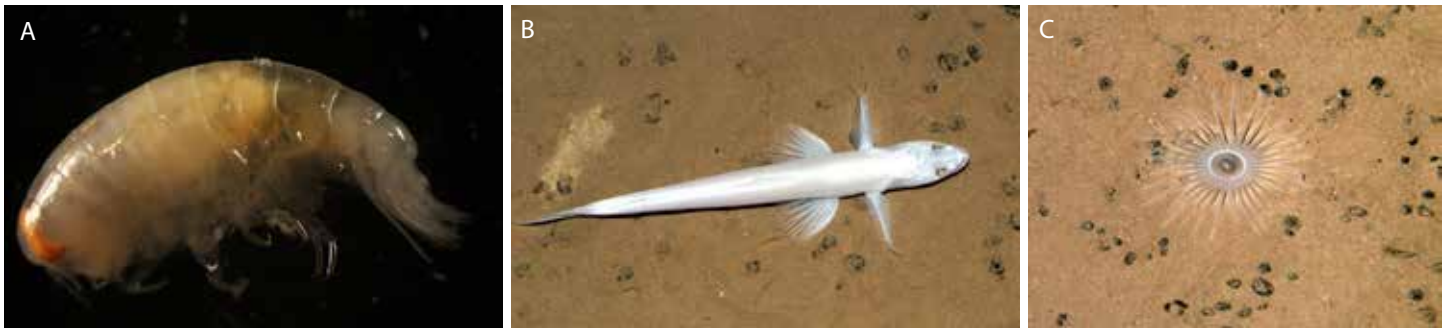
We returned to Manzanillo, Mexico, on 19 May after a 34-day voyage on the RRS *James Cook* out to the north-easternmost Area of Particular Environmental Importance (APEI). The 9 APEIs are large areas, of 400 x 400km (200 x 200km core protected area with an additional buffer zone of 100km), that are set aside by the International Seabed Authority (ISA) and protected from mining activities. In the spatial management plan for the CCZ the APEIs will form the largest of the protected areas. Smaller set-aside areas will also be left within the mining claim areas themselves, but these will be determined later in the mining process. Until this year, the APEIs remained largely unexplored.

During the cruise we gathered a huge dataset on the subsea landscape, biology and geochemistry of the APEI. Our maps of the south-western area (5,500 km^2) of the APEI, created using shipboard bathymetry, revealed an area dominated by a series of ridges and seamounts, which appear typical for the CCZ. We explored several representative areas in much greater detail with acoustic surveys carried out from the NERC AUV Autosub 6000. The resultant maps revealed a surprising amount of topography and landscape variation for an abyssal plain! We also used the AUV to take both forward and downward looking colour photographs from near the seabed. As well as the AUV photos, we took photographs and HD video using a towed camera platform (HyBIS). The cameras were very busy, generating over half a million photographs of the seabed!

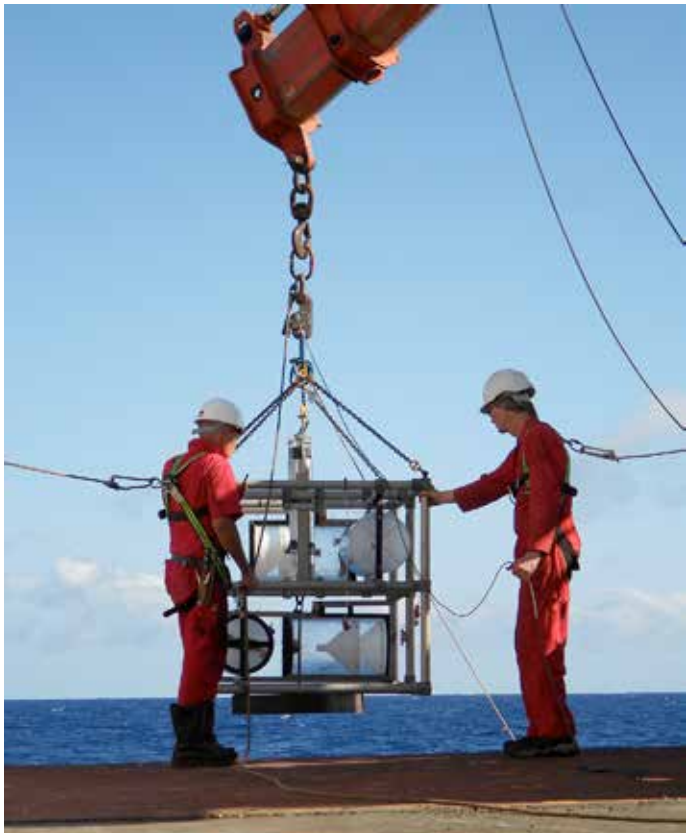


Autosub6000 being launched at the APEI site.

MIDAS has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under Grant Agreement no. 603418. For more information about MIDAS visit the project website at www.eu-midas.net



Above: A) An unidentified amphipod crustacean collected with a baited trap on JC120 in the APEI. B) A deep-sea Lizard fish, Bathysaurus sp., living on the seafloor at the APEI, photographed by Autosub6000. The fish is around 40cm long. C) An unidentified anemone living on the seafloor at the NE APEI in the CCZ captured on camera by Autosub6000. The anemone is around 15cm in diameter.



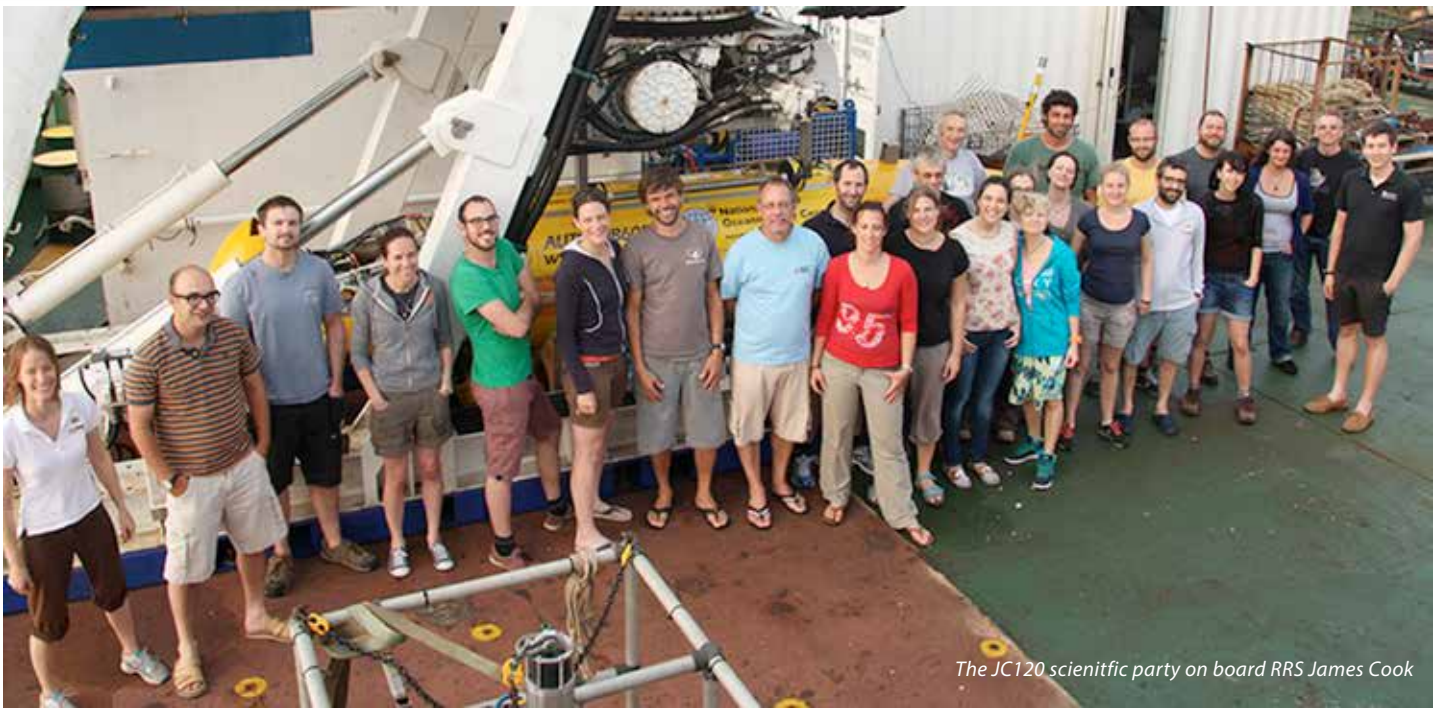
Top image: The JC120 science team watching the arrival of our towed camera (HyBIS) on the seafloor at the Clarion Clipperton Zone. Above: The amphipod trap being launched on JC120. This lander has four baited traps designed to catch small scavengers, such as fish and crustaceans.

This huge archive of seabed photos will be highly valuable in describing the seabed habitats and megafauna of the area. We saw a surprising diversity of megafauna and found polymetallic nodules across much of the APEI.

Samples of seafloor sediments, animals and overlying water were taken from across the study areato generate a strong multidisciplinary dataset from the area, with information on various sizes of fauna (megafauna, macrofauna, meiofauna and protozoans), the sedimentary environment and its geochemistry and the overlying (and pore) water. We collected cores up to 3 metres deep for geochemical analysis, including assessment of metals, including rare-earth metals, dissolved gasses in the sediments and pore fluids and assessment of the physical characteristics of the sediments. This will give us a much better understanding of the nodule formation mechanisms and the controls on life in the region.

Smaller samples of sediments were taken to assess the biodiversity and community composition of the fauna of the region, quantitatively for many faunal groups. In addition, the team from the Natural History Museum in London, along with some other scientists from elsewhere, collected a range of fauna to add into their database of the fauna of the Clarion-Clipperton Zone with linked photographic, genetic and morphological data from all the species we found. Having an accurate taxonomic database is vital in understanding the connectivity between different areas of the CCZ and will help in ultimately determining how areas disturbed by mining will recover. Finally, we collected some nodules and fauna with trawls over the seafloor.

All these samples give us a strong baseline dataset from the APEI, allowing us to evaluate this area and assess any future changes. We will also be able to make comparisons with the mining claim areas to better understand broad scale patterns. We have worked hard to ensure data are collected in the same way on all the different cruises to the CCZ area to ensure that these comparisons are robust and useful to both science and environmental managers working for the nascent seafloor mining industry.



The JC120 scienitfic party on board RRS James Cook

Genetic flow between abyssal invertebrates across the CCZ

Sergi Taboada, Adrian Glover and Gordon Paterson, Natural History Museum, London

First things first, let me introduce myself. My name is Sergi Taboada and I am a postdoctoral researcher at NHM, working with Adrian Glover and Gordon Paterson. A few months ago, myself and James Bell (Adrian Glover's PhD student) joined the JC120 cruise to survey two areas in the Clarion Clipperton Zone (CCZ) in the Pacific Ocean: an Area of Particular Environment Interest (APEI-4) and one of the UK claim areas for mining manganese nodules. Experts from several institutions were involved in the cruise with the principal aim to characterise the abyssal benthic communities present in the area in order to predict how organisms might be affected by deep-sea mining (see report on p1-2 of this newsletter).

Our task was to collect and preserve the invertebrate fauna living in the seafloor (associated with manganese nodules and in the sediment) in order to identify these organisms using both morphological and molecular approaches. To do so we spent many hours sieving and sorting sediment, photographing and preserving the marine invertebrates that we found. Briefly, from more than 40 deployments we collected ca. 600 invertebrates, specimens that have recently safely arrived at our lab in London. These organisms include sponges, crustaceans, molluscs and annelid worms, and are mostly unknown to science since the habitats in which they occur have been scarcely studied so far.

Specimens from this cruise will be sorted into morphospecies and compared to sample material from other cruises around the CCZ, which has mainly been collected by the Abyssline project. This collaborative effort between MIDAS and Abyssline will allow us to select target species that can be used to assess their genetic connectivity across the CCZ, specifically between reserve areas (APEIs) and mining claims (UK, Singapore and Germany). Genetic flow between target species across and within these areas will be assessed using different molecular mitochondrial and nuclear markers.

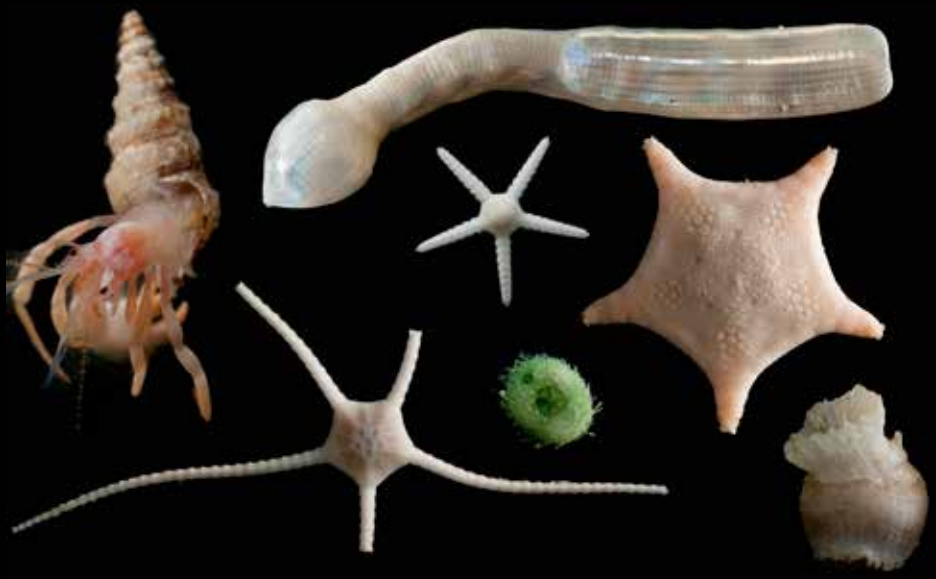
A lot of work is yet to be done since more than 10,000 individuals from the CCZ have been collected, but we are expecting some preliminary results within the next few months. We will keep you posted!

Right: Sergei in the lab on RRS James Cook taking pictures of an annelid worm.

Ecological studies in the Russian claim area on the Mid-Atlantic Ridge: the 37th cruise of the RV Professor Logachev

Tina Molodtsova, Sergey Galkin, Stanislav Kobylanksy and Andrey Gebruk
P.P. Shirshov Institute of Oceanology RAS, Moscow Russia

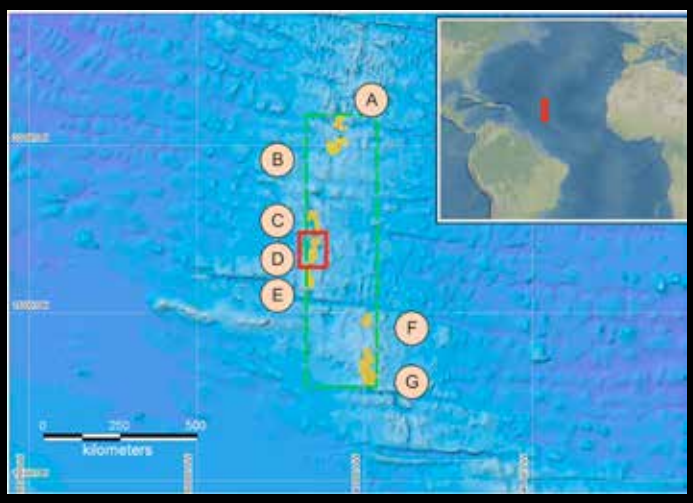
Following the 2012 signing of a 15-year contract between the ISA and the Ministry of Natural Resources and Environment of the Russian Federation for the exploration of polymetallic sulphide ore on the Mid-Atlantic Ridge, three cruises to the claim area with the RV *Professor Logachev* have been accomplished. However, until the most recent cruise there have been no studies of benthic and plankton ecosystems carried out in the area, and only a few biological samples obtained as bycatch from geological equipment (Dobretsova et al., 2013).



On 18 April 2015, the scientific programme of the RV Prof. Logachev's 37th cruise was successfully completed in the Russian claim area. The cruise was conducted by the Polar Marine Geological Survey Expedition with participation from the P.P. Shirshov Institute of Oceanology, Geological Institute and VNIIOceangeology. Fifteen survey blocks (numbers 31 to 45, located between 17°51'N and 16°41'N) have been examined between November 2014 and April 2015.

This spring, and for the first time in the Russian claim area, an ecological survey was performed which included sampling of benthos (Sigsbee trawl 2.0 m), mesoplankton (Multinet Hydro-Bios 0.125 м2, 5 nets, mesh 180 μm) and mid-water fish (Isaac-Kidd midwater trawl). Fish larvae were collected at epipelagic stations using Savilov's pleuston net. Additionally, some epifauna samples were obtained via geological gear (rock dredge, TVgrab and square corer). In the course of the geological survey two new ore fields were discovered on the south-western slope of the seamount on the eastern flank of the MAR rift valley, one at 17°09'N and second at 17°07'N. Video profiling in this area indicated signs of modern hydrothermal activity in the area. Extensive fields of shells of *Bathymodiolus puteoserpentis* and *Thyasira* sp. were recorded and samples of bivalves were taken using the TVgrab and corer. Two midwater trawls (1825-0 m and 2680-0 m), six epipelagic stations and seven Multinet stations (2961-0 m) were also successfully completed in the survey area.

A significant component of the ecological survey focused on the study of benthic non-vent soft sediment fauna. Seven benthic trawls were carried out at depths from 2270 m to 3900 m, with a TV survey performed at each station along the trawl transect. Unfortunately sea conditions were not favourable for TV profiling, so only larger animals could be identified on the video footage.



Above: Blocks 31-45 in the Russian claim area examined in 37th cruise of RV Professor Logachev. Main image: some of the animals collected during the survey within the Russian claim area.

n the absence of ROV no hard substrates were sampled due to rough topography. However, one TV transect was conducted on hard substrate on the western flank of the rift valley. Several patches showed high concentrations of large sessile filter-feeders, including octocorals of the family Isididae, *Metallogorgia melanotrichos* (Chrysogorgidae), *Bathypathes* sp. (Antipatharia) and hexactinellid sponges. Surprisingly high concentrations of drowned pelagic algae *Sargassum* sp. (Phaeophyceae, Fucales) in different states of degeneration were found on both soft and hard substrates, and algae appeared in trawl catches and on video.

A preliminary evaluation of benthos samples revealed ~ 660 specimens of benthic invertebrates and 1141 specimens of fish. Mesoplankton samples have not been processed yet. At least 100 species of benthic invertebrates were collected. The main taxonomic groups in the area include Decapoda (Parapaguridae), Ophiuroidea, Bryozoa and Porifera. The alpha diversity of ichthyofauna is estimated as 48 OTUs from 14 families: Mycthophidae, Chlorophthalmidae, Gonostomatidae, Paralepididae, Sternoptychidae, Melamphaidae, Malacosteidae, Platytroctidae, Omosudidae, Cetomimidae, Gempilidae, Coryphaenidae, Istiophoridae, Aphionidae and Balistidae. *Cetomimus hempeli* (Cetomimidae) and *Barathronus multident* (Aphionidae) were reported for the first time from the tropical Atlantic.

We would like to thank the crew and the scientific team of the 37th cruise of RV Professor Logachev for their highly professional support.

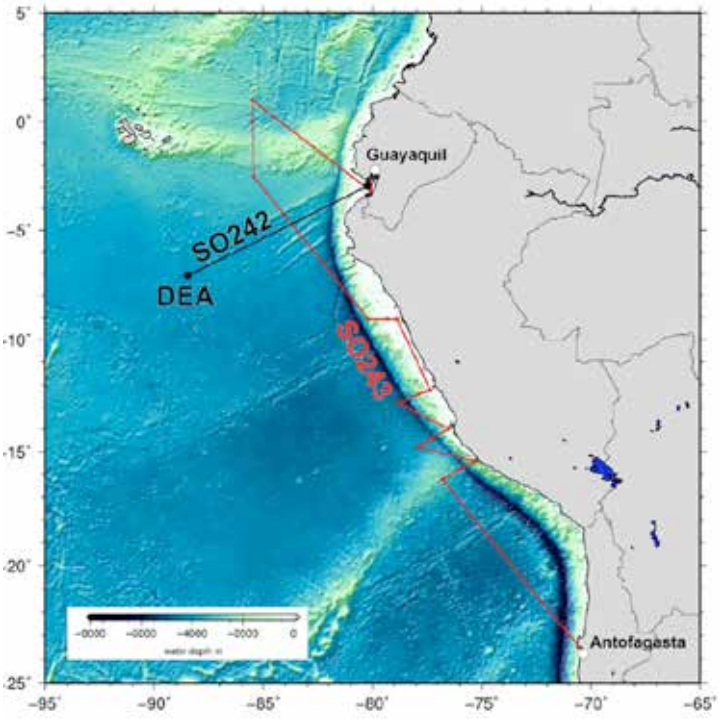
Right: The ecological team (left to right): Stanislav Kobylansky, Sergey Galkin, Tina Molodtsova and Konstantin Soloviov. Below: RV Professor Logachev in Fort-de-France, Martinique. Photo courtesy K. Soloviov.

Revisiting DISCOL: the largest existing experimental disturbance of a nodule ecosystem

RV Sonne cruise SO242, August-September 2015

In August and September 2015, 15 European institutions and 4 SMEs including several MIDAS partners will spend more than two months on board the new German research vessel RV Sonne to carry out investigations in a nodule ecosystem located in the Peru Basin. The work focuses on a circular area of some 2 nautical miles diameter that was disturbed during the first period of deep-sea mining hype a quarter century ago as part of the German project DISCOL (DISturbance and reCOLonization experiment). The disruption of the seafloor at more than 4000 m water depth was created in 1989 by a deep-sea plough harrow towed by the predecessor of the current RV Sonne, and still represents the largest mining-related disturbance experiment worldwide.

The work carried out this summer during two consecutive cruise legs represents the fifth post-impact study and resumes the impact assessment in the area after a 20-year break. The investigations take place within the Pilot Action 'Ecological Aspects of Deep-Sea Mining' initiated by the Joint Programming initiative 'Healthy and Productive Seas and Oceans'. This work assesses the ecological impacts that could arise from commercial mining activities in the deep sea and includes investigations in the Clarion-Cliiperton Zone (CCZ) that were carried out with RV Sonne earlier this spring (see the Spring 2015 issue of the MIDAS newsletter). The activities in the DISCOL experimental area aim to assess the long-term effects and potential recovery of the ecosystem by comparing disturbed sites with adjacent undisturbed sites, plus a combination of recent findings with existing data from earlier studies in the area. Compared to previous investigations, an extensive range of modern techniques is now available for observations, sampling, and sample analyses. These extend the scope of investigations for defining baseline conditions in nodule ecosystems, assessing their natural variability and for addressing potential long term disturbance effects. At the same time the results obtained with state of the art technologies will largely improve our understanding of the benefit of different methods for the monitoring of baseline conditions and impacts in the context of deep-sea mininig.



Planned cruise track and working area of SONNE cruise SO242 and SO243

The plough-harrow apparatus used to disturb the seafloor in 1989. During this experiment, nodules were not recovered but ploughed into the sediment.

State of the art habitat mapping

During the first leg (SO242/1, 28 July - 25 August 2015) the entire disturbed area will be mapped for the first time. GEOMAR's Abyss AUV uses visual and acoustic techniques to assemble a complete habitat map. High-resolution side scan and multibeam data will be acquired and immediately processed to precisely georeference the existing plough tracks and to allow for subsequent AUV image mosaicking surveys at close range to the seafloor. Acquired images are georeferenced on board and stored in the upgraded DIAS database system (DISCOL Image Annotation System) for immediate annotation of characteristics such as fauna,

sediment composition, and Mn-nodule density. This map will serve to identify areas of different disturbance level as an important precondition for the planning of the activities carried out during legs SO242/1 and SO242/2 (28 Aug - 1 October 2015). In certain areas of interest, the overview images collected by the AUV will be complemented with high resolution imaging surveys including videos, stereographic videos, high resolution stills, and hyperspectral images collected with towed platforms and the ROV at close range to the seafloor during both legs.

Targeted sampling for investigations of sediment fauna and geochemistry

TV-guided multi-corers, gravity corers, and ROV pushcores will recover sediments for geochemical analyses from undisturbed areas and areas that were disturbed with the plough harrow in 1989. Geochemical conditions will be compared to observations during the last visit in 1996 and to model-based predictions of recovery of geochemical zonation. Biological sampling with box corer, multi-corer, ROV pushcores and epibenthic sled will be used by scientists from the Senckenberg Institute, Gent University, RBINS, Aveiro University, MPI Bremen and others to assess to what extent the benthic communities have changed or recovered since the original disturbance in 1989, and if motile fauna have increased since the last observations in 1996. In addition to taxonomic studies and abundance measurements, state-of-the-art genetic fingerprinting will be employed to identify multicellular organisms as well as microbes. These sample-based investigations of benthic communities will be accompanied by assessments of megafauna and larger macrofauna based on imaging surveys (GEOMAR, MPI Bremen, IMAR and others).

Sediment biogeochemistry and ecosystem functioning

Biogeochemical processes in the reactive top layer of the sediments will be addressed based on sediment cores and in situ studies. Sample-based investigations include state-of-the-art pore water and solid phase geochemical investigations, as well as shipboard biogeochemical incubations with labelled substrates (GEOMAR, JUB, AWI, MPI Bremen, NIOZ). In situ seafloor studies will be carried out by MPI, IRIS, NIOZ, Gent University, Southampton University, IMAR, Aveiro University. ROV modules and other autonomous instruments such as landers will be used to investigate chemical gradients in the uppermost sediment layer and to quantify solute fluxes across the sediment-water interface. Autonomous and ROV-manipulated benthic chambers and microcosms allow for in situ experiments that will investigate the transfer of organic matter and energy in benthic food webs and the fate of contaminants that are released upon seafloor disturbance. Most of these investigations were not possible with the technologies available during earlier post-impact studies. Instead of comparisons to previous data, the studies will therefore be carried out at sites with different levels of disturbance, either from the original large-scale disturbance or from small-scale experimental manipulations carried out during the cruise (e.g., nodule removal, coverage with settling fines from suspension plumes).

Processes in the benthic boundary layer

Lander- and mooring-based systems will be used for monitoring physical parameters close to the bottom and in the lower water column. These measurements will enable a better estimate of sediment plume distribution and the covering of the seafloor with resettling fines. Three systems - the DOS lander from GEOMAR, the BoBo lander and a thermistor string mooring (both from NIOZ) - will be deployed. The landers are equipped with ADCP, CTDs, sediment traps, and a stereographic time-lapse camera system. Additional measurements will be carried out by moored and CTD-based turbidity sensors, by sampling of suspensate plumes with ROV-based pumps and by filtration of bottom waters with in situ pumps (AWI, JUB, MARUM, MPI Bremen, Kiel University and others). All these measurements target the fate of dissolved and particulate constituents from sediments that are re-suspended deliberately upon localised disturbances as well as unintentionally during sampling activities. The results obtained during the expeditions will serve for the validation of models that assess the indirect impact on the area surrounding the actual mining site.

You can follow the progress of the RV Sonne expedition from 28 July 2015 via the OceanBlogs website at www.oceanblogs.org/eadsm or follow the link from the front page of the MIDAS website.

RV Sonne awaiting departure in the port of Guayaquil, Ecuador. Image courtesy J. Greinert.

A multidisciplinary approach to locate polymetallic nodules and understand deep-sea environments in the GSR concession

François Charlet[1], Ellen Pape[2], Carmen Juan[3], Nick Eloot[4], Michel Hoffert[5], Lucien Halleux[4], Ann Vanreusel[2], David Van Rooij[3] and Kris Van Nijen[1]

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Introduction

On 14 January 2013, a contract was signed between the International Seabed Authority (ISA) and Global Sea Mineral Resources (GSR) for the exploration of polymetallic nodules in the Clarion-Clipperton Fracture Zone (CCFZ) in the NE Pacific Ocean. The assigned area is situated around 125°W and 15°N and covers over 75,000 km^2 divided over three areas named B2, B4 and B6 (Fig. 1). Pursuant to the contract between ISA and GSR, the first exploration cruise took place in the summer of 2014 (cruise GSRNOD14A). Most of the scientific research and laboratory analyses are being performed by Belgian universities: the Marine Biology Research Group and the Renard Centre of Marine Geology (RCMG) of Ghent University, and the Department of Geology of the Catholic University of Leuven.

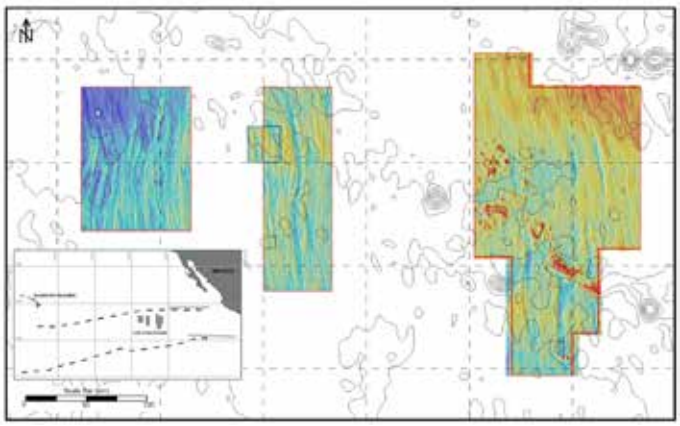

Figure 1: The GSR License Area, in the NE Pacific Ocean, superimposed on the newly acquired bathymetric data.

The presence of polymetallic nodules (and thus the presence of valuable elements such as Mn, Fe, Cu, Co and Ni) in the GSR concession area was established during extensive research in the 1970s and 1980s, but little detailed historical information is available about their spatial distribution and abundance (Bischoff and Piper, 1979). DOMES C (Deep Ocean Mining Environmental Study) is the only small-scale area, partially situated in the GSR concession, which was intensely studied during the second half of the 1970s.

Methods

In designing the investigation of its concession, GSR considered the experience of past and present concession holders in the CCFZ (e.g. OMA, IFREMER, UKSR, BGR…) in order to optimise both local and global assessment of the potential mining areas within the CCFZ boundaries.

All operations performed during GSRNOD14A were executed on board the R/V Mt. Mitchell (Fig. 2). The ship is equipped with a hull-mounted multibeam echo-sounder system (MBES; Kongsberg EM120), a winch and an A-frame that enable box coring and dredging operations.

GSR used the MBES system, capable of surveying large areas. Box-coring was used to begin assessing nodule abundance, characterise the nature of the sediment, determine major and trace elements, calibrate the geophysical data and compose the first biological samples. In addition, a dedicated dredging program provided nodules in sufficient quantities for geochemical and metallurgical analyses. All collected field measurements are part of an extensive identification of the current environmental status of the GSR Concession area, as a straightforward baseline reference record of the local ecosystem.

Figure 2: Vessel and equipment used during GSRNOD14A: (A) Winch used for sampling, (B) camera equipment mounted on box-corer, (C) camera equipment mounted on dredge, (D) 50x50x50cm box-corer, (E) Sippican and launching system, (F) MBES acquisition, (G) R/V Mt. Mitchell and (H) dredge.

A GoPro® camera and light system, mounted on both the box-corer and dredge, provided seafloor images. The images were used to (1) confirm the in-situ nodule coverage, (2) observe potential problems during sampling operations and (3) observe deep-sea life and traces thereof.

Results

Topography

The EM120 echo-sounder from Kongsberg was used to generate a 75-metre resolution bathymetric map for the three parts of the GSR concession. The acquisition (using QINSy software) and on-board processing (using CARIS HIPS and SIPS software) took 25 days in total. Further processing and analysis were carried out with ArcGIS software and associated tools (Spatial Analyst and 3D Analyst). The intensity of the reflected signal of the sea bottom (backscatter) was used to identify (1) rocky areas, (2) areas with nodules and (3) areas with bare mud (Kuhn et al., 2011; de Moustier, 1985).

The general bathymetry shows a succession of ridges and valleys with a north-south orientation, slightly curved to the NNE or NNW, with water depths generally ranging between 4,000m and 5,000m (vertical resolution: 50m). The overall depth increases from east to west. Seamounts are present in all three areas; over 90% are situated in B6, where they form a SE-NW alignment (Fig. 1), and occasionally reaching elevations greater than 1,000m.

Nodules

The box-corer and dredge (a sledge with a 2-inch mesh inside) were deployed to obtain nodules (Fig. 3). For each batch of nodules, shape, dimension, weight, volume, and density were determined and measured on a representative sample (40 to 50 units), based on the descriptive methodology established by Hoffert (2008). Video imagery obtained during the deployment of both types of sampling devices is currently being analysed. The tests for geochemical composition are being conducted on representative nodule samples taken from the box-corer. So far, as expected, Mn is the dominant element found in the polymetallic nodules collected during GSRNOD14A. Little difference is seen compared to historical data for Mn, Fe, Cu, Co and Ni. Nodule abundance (in kg/m^2) will be estimated from box-corer samples and seafloor images (Fig. 4).

The box-corer sediment samples were subsampled for further biological, sedimentological, geochemical and geotechnical analysis on shore.

Figure 3: The dredge (left) and a size-sorted sample of nodules (right) obtained during cruise GSRNOD14A .

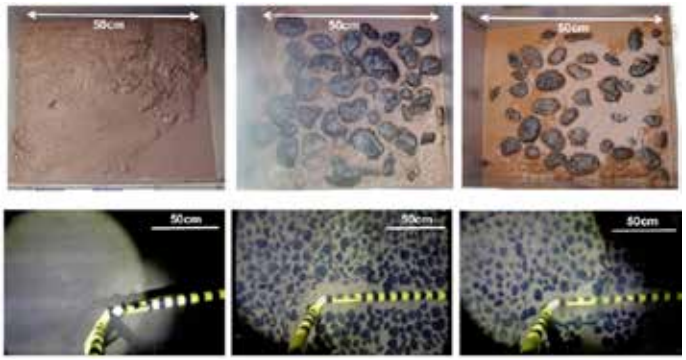

Figure 4: Box-corer samples and seafloor images taken during GSRNOD14A. Seafloor images are video stills taken just before or after impact, which give an idea of the in-situ surface concentra-tion and burial depth of the nodules.

Biology

Sediment subsamples were taken for the analysis of macro- and meiofauna, granulometry and the sedimentary content of organic carbon, nitrogen and total organic matter. Several nodules were collected from the box-cores for more detailed nodule fauna investigations.

Macrofaunal abundances (Size: >250 µm / range: 152-576 individuals m^{-2}) fell within the range of abundances documented in other historical reports from the CCFZ and other nodule-bearing sites (Hecker & Paul, 1979; Borowski & Thiel, 1998; Ingole et al. 2001). Nematodes dominated the macrofaunal samples (Fig. 5); other abundant taxa were copepods, tanaidaceans and ostracods.

Meiofaunal abundances (size: 32–1000 µm / range: 42.7-107.6 individuals 10 cm^{-2}) were in the range of abundances reported in other meiofaunal studies from the CCFZ and other nodule-bearing sites (Renaud-Mornant & Gourbault, 1990: Radziejewska, 2006; Mahatma, 2009). Nematodes dominated; copepods and nauplii were the second most abundant meiofaunal groups, which is consistent with previously published data on meiofauna from polymetallic nodule areas in the NE Pacific (Snider et al., 1984) including the CCFZ (Radziejewska, 2006; Mahatma, 2009).

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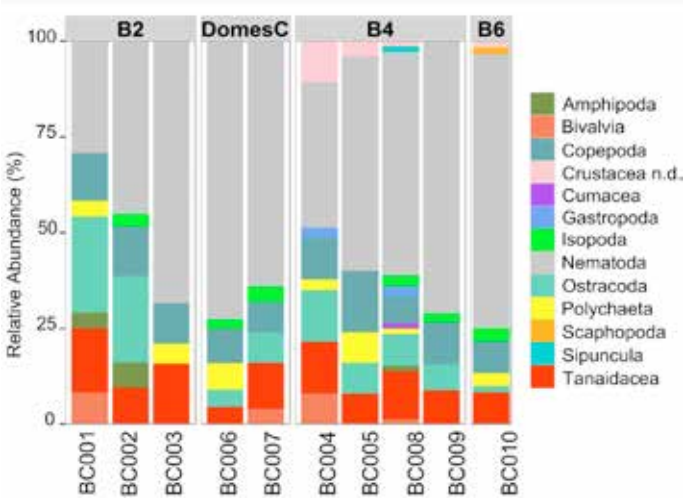

Figure 5: Macrofaunal taxon composition (0-10 cm) per box-core. Boxcores are grouped per zone. (Marine Biology Research Group, Ghent University).

Meiofaunal abundance only correlated with sediment environmental parameters, whilst macrofauna numbers correlated with nodule size and sediment nitrogen content. Meiofaunal and macrofaunal taxon composition did not display a relationship with any of the nodule parameters or sediment environmental variables. Furthermore, macrofaunal and meiofaunal taxon richness correlated inversely. Sediments with bigger nodules were characterised by lower meiofaunal taxon richness, whereas macrofaunal taxon richness correlated negatively with the sediment carbon-to-nitrogen ratio. Preliminary findings from the study of nodule epifauna suggest a diverse epifauna that is likely to be mainly of protozoan origin.

Although the main focus was on the benthos, ship-board observations of seabirds, marine mammals and other large pelagic fauna were also conducted. Planned further biological analyses include (1) finalisation of the analyses of nodule fauna, and (2) the identification of nematodes to lower taxonomical level. The results of the latter will be used to create a nematode atlas of the GSR concession, which may aid in establishing connectivity and heterogeneity in CCFZ.

Sediment

Box-corer samples from the upper sediment (up to 40 cm depth) were sub-sampled and analysed with various non-intrusive and intrusive techniques. The CT scan cross-sections show intensive bioturbation characterised by burrows of different sizes, shapes and varying abundance affecting the whole sediment sample in all the sub-cores (Fig. 6). Magnetic susceptibility, wet bulk density, color spectrophotometry (using Geotek Multi-Sensor Core Logger) and the chemical composition of sediment cores (using X-ray fluorescence spectroscopy, XRF) were also analysed to detect and better understand downcore variations in composition and properties of sediment, as well as detecting contacts in the sediment column (mostly bioturbated, but also sharp, undulated and gradational) that suggest the presence of sedimentary hiatuses.

Geotechnical analysis of the upper sediment gives shear strength values below 5 kPa, and a bulk density of about 1.6 g/cm^3. The upper 10 centimeters is more fluid. This depth-related density increase, measured with vane tests, is also confirmed by CT scanning (Fig. 6).

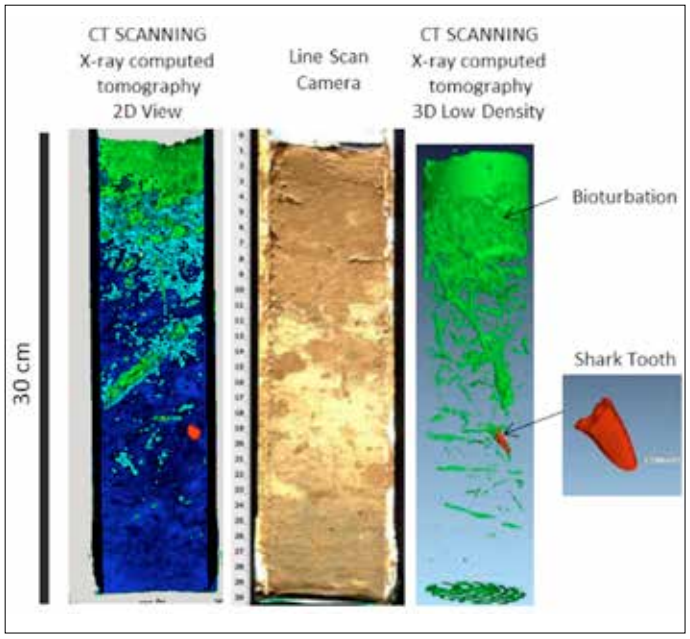

Figure 6: Examples of a sub-core analysed by Computed Tomography (CT scan - color scale is not given) compared to real sediment color (obtained with Geotek line scan camera). Low density values on top (light green) increase downcore (dark blue). The red spot (very high density) corresponds to the presence of a shark tooth covered by manganese buried in the sediment. Low density patches, corresponding to bioturbation, have been individualised in 3D (RCMG – Ghent University)

Most sediment samples contain a large fraction of silt (63 to 2µm), in which the grain-size curves are characterised by a bimodal distribution, with models located around the limit. The mean sediment grain size ranges between 11 and 19µm (silt fraction). Optical microscope observations of sediment subsamples indicate the sediment is mostly constituted by clay minerals together with planktonic or-ganisms (foraminifera, radiolarians…), as well as spicules, feldspars, quartz, volcanic glasses, and Fe-Mn oxy-hydroxides (Fig. 7).

Areas of interest for nodules

Sampling locations, selected with both bathymetric and backscatter charts, were chosen in a variety of environments, including valleys, crests, plateaus and large plains with different backscatter values and topographic settings to ground-truth both topographic setting and backscatter values.

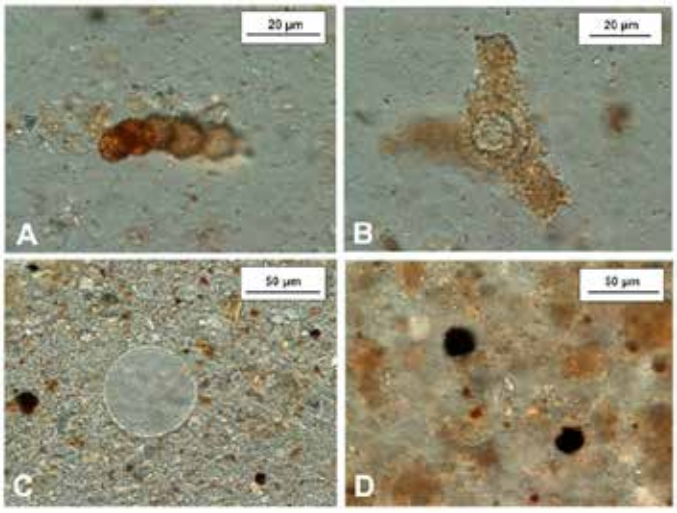

Figure 7 – (A) Examples of Foraminifera, (B) Radiolaria, (C) radial diatoms and (D) Fe-Mn oxyhydroxides observed with an optical microscope (RCMG – Ghent University).

The main purpose of the pilot sampling was to confirm our methodology for both a technical-economical assessment on nodule detection and identification of operational areas of interest, which is also applied by other concession holders. From a technical-economical point of view, areas of interest for nodules are defined by (1) flat topography, (2) high abundance of nodules (kg/m^2) and (3) relatively compacted surficial sediment layer. GSR has now roughly identified, inside the concession, several "potential" zones for further investigation for the upcoming GSR exploration cruises.

Together with this initial technical assessment on deep sea mining activities, first steps have been taken to identify the environmental baseline, i.e., the reference status of the local ecosystem, in order to analyse potential environmental effects in a proper reference framework.

Prospects (GSRNOD15A)

A combination of (1) broad- and fine-scale acoustic measurements, (2) video imagery, (3) ground-truthing (multi-core and box-core) and (4) water sampling will be used in the next GSR Expedition Cruise GSRNOD15A. This cruise plans to combine high-resolution geophysical surveys near the seabed (MBES, SSS, SBP, Camera…), sediment, nodule and water sampling, using box-corer, multi-corer, dredge and CTD equipment.

More detailed in-situ measurements will be acquired by using a geotechnical probe to generate accurate density profiles of the upper sediment layer.

For the upcoming cruises, deployment of deep-sea current meter and Acoustic Doppler Current Profiling (ADCP) equipment will contribute to the understanding of local deep-sea currents and enable the development of a realistic model of sediment transport.

Again, a close collaboration and interaction with other international concession holders in the CCFZ will be set up in order to generalise and agree upon a common reference framework (both technical and environmental) on deep-sea mining activities in the zone of interest.

Conclusions

GSRNOD14A was the first exploration cruise successfully executed by GSR in the framework of its contract with the ISA. This cruise demonstrated the efficiency of a multi-disciplinary approach, combining biological, geological, geophysical, geochemical and geotechnical research.

The collected detailed field records identify and describe an integrated picture of the concession area, as a proper reference base for the further assessment of environmental effects on the local ecosystem.

Environmental, technical engineering, financial and legal aspects are the main factors controlling the global feasibility of nodule mining. Only a fully integrated as-sessment inspired by a transparent cooperation between science and industry, as already implemented by GSR in this first exploration cruise, is the most efficient way to develop sustainable nodule mining in the deep sea.

GSRNOD14A initiated this project spirit and has provided a solid reference base for the next development steps in deep-sea mining activities.

Acknowledgements

Global Sea Mineral Resources would like to acknowledge everyone involved in the GSRNOD14A cruise, in the data processing and in the reporting phase.

We would particularly like to thank the captain and crew of the RV Mount Mitchell, the Global Seas personnel, the TerraSond survey team, G-Tec geologists and cartogra-phers, scientists and technicians from Ghent University (Marine Biology Research Group & RCMG) and the Catho-lic University of Leuven (KUL). A special thanks goes out to our DEME shareholders, who strongly believe in our deep-sea project.

[see over for references]

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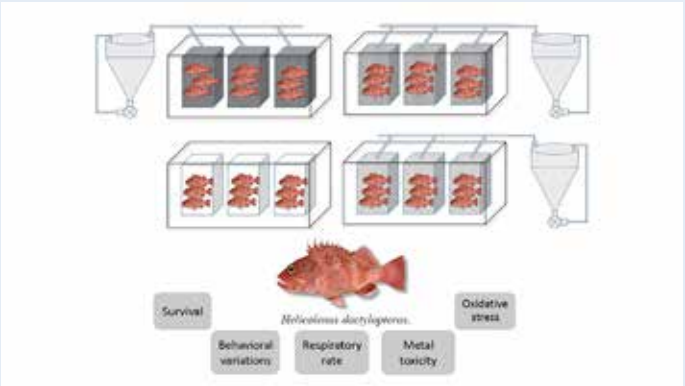
Testing the effects of sediment plumes on bluemouth rockfish

Members of the MIDAS team at IMAR University of Azores are preparing laboratory experiments to test the effects of mining-related sediment plumes on the physiology and behavior of the bluemouth rockfish *Helicolenus dactylopterus*. This work is a continuation of the previous trials on deep-sea corals and mussels in assessing the impacts of deep-sea mining on benthic organisms.

Bluemouth is a commercially important fish that occurs in areas with interest for deep-sea mining and in nearby seamounts. This benthic fish was demonstrated to be site-attached with an extremely low degree of horizontal movement. Tag and recapture programs have shown fish to be recaptured in the exact same location 15 years before, while recent telemetry studies have also shown no movement of adult fish. Therefore, it is likely that bluemouth rockfish would be affected by deep-sea mining sediment plumes.

In this experiment, bluemouth rockfish will be exposed to three different concentrations of sediment particles for 30 days. We will collect information on fish survival and behavioral variations such as modifications on movement patterns and foraging. Additionally, respiratory rates, metal toxicity levels and oxidative stress biomarkers will be used as indicators of physiological modifications at experimental conditions.

The sediment particles used in this experiment were obtained by grinding sedimentary rocks collected at the hydrothermal vent field Lucky Strike, and particle size matches the range expected by Seafloor Mining Tools excavation and by dewatering processes, according to MIDAs industry partner IHC Mining B.V. Bluemouth rockfish will be collected from the nearby seamounts using hooks and line and acclimatised to captive conditions. The seawater system was designed in close collaboration with R. Bannister, (Institute of Marine Research, Norway).



Towards the development of a Strategic Environmental Management Plan (SEMP) for deep seabed mineral exploitation in the Atlantic basin

A scoping workshop to consider issues relevant to an Atlantic SEMP took place in Horta, Azores, Portugal on 1-3 June 2015. The workshop was attended by 39 participants from 11 nationalities, and was informed by two remote presentations. The workshop and its preparation were kindly sponsored by the European Commission's Directorate-General for Maritime Affairs and Fisheries, the Government of the Azores, the Pew Charitable Trusts, the Deep Sea Conservation Coalition, the Kaplan Fund and Oceans5.

At a strategic level, the challenge is to plan for environmentally sustainable exploitation at the scale of an ocean basin, balancing economic benefits of mineral extraction with conservation of marine ecosystems, whilst taking appropriate account of other maritime activities. In terms of its geographic scope, the workshop focused on the Area in the North and South Atlantic, in particular the Mid Atlantic Ridge (MAR) and the Rio Grande Rise (RGR). A Pre-Workshop Data report was compiled to support and inform the workshop. This report collated available information from available publications, biogeographic databases, experts, online libraries and habitat suitability models. Data had been sourced from major repositories including OBIS, Pangaea, and EMODnet as well as other portals. Some data were not yet available and some further work to finalise the data report was envisaged. Data availability was skewed to the northern part of the MAR. The workshop agreed that extra effort to obtain data known to exist is desirable and a selection of sources and possible updates were highlighted.

To provide context for the workshop, a series of plenary presentations encompassed complementary exercises, current understanding about the mining footprint and the state of knowledge of Atlantic ecosystems. These included an explanation of the process of setting up Areas of Particular Environmental Interest (APEIs) in the Clarion-Clipperton Fracture Zone and the 2010 Dinard Workshop deliberations and outcomes that developed guidelines for the conservation of vent and seep ecosystems (see ISA Technical Study No. 9). Whilst design principles for these ecosystems mirror those for the CCZ, specific natural management units based on genetic connectivity and specific taxa represent a key difference. A recent expert workshop in Norway had considered the balance of protection needed between active and inactive vents.

The workshop recognised the need for adaptive management, acknowledging that compared to the Atlantic the CCZ is a 'simpler system' and the main ecological drivers for CCZ-EMP are surface productivity, bottom depth and seamount distribution. As for the CCZ, protection should be proportionate to anticipated mining activity and in line with persistence of direct and indirect adverse environmental impacts.

In summary, the workshop:

- Reviewed existing science-based goals for the development of an Atlantic SEMP, building on those agreed for the CCZ-EMP and proposed by the DINARD Workshop. A preliminary set of conservation and management objectives as defined by the workshop were accepted as an initial list that could be evolved into a more hierarchical set of goals and objectives;
- Reviewed existing policy and regulations in the context of deep-sea mining including management measures already adopted by other competent international organisations;
- Identified the categories of information required for environmental management and adequacy of available baseline information;
- Proposed guidelines for APEIs/Preservation Reference Zones (PRZs) for sulphides and crusts giving particular attention to active and inactive vents, fracture zones and water column features. A key consideration was to formulate mineral deposit and Atlantic-specific design principles to guide GIS-based optimisation in order to recommend best locations for and spacing between APEIs and/or PRZs;

[Continued over...]

- Considered the nature, distribution and intensity of all human uses and likely interactions with mining; and
- Identified knowledge gaps and considered how to fill them in the context of a proposed roadmap.

High-level outcomes were presented to the ISA and the workshop agreed a further process is needed. To that end a roadmap was elaborated, proposing a series of further scientific meetings considered necessary to establish a more robust basis upon which to base an Atlantic SEMP.

The workshop also recognised that the ISA has exclusive competence for management of mining-related activities in the Area, and it would be for the ISA to further develop, recognise and adopt any SEMP. Thus the roadmap proposed also seeks to articulate with ISA meetings and any SEMP-related initiatives suggested by the Legal and Technical Commission of the ISA. Workshop participants wished to work with and alongside the ISA to achieve an Atlantic SEMP.

In July, at the 21st Session of the International Seabed Authority, the ISA Legal and Technical Commission (hereafter the Commission) '*supported the rationale for an environmental management plan for the Mid-Atlantic Ridge. It noted that a robust scientific case would be developed by the [SEMPIA] workshop participants over the coming years and it was expected that a report would be submitted for consideration and development by the Commission in 2017*'.

Furthermore, a subsequent Decision by the ISA Council '*Encourages the Commission and the Secretariat to make progress on the development of environmental management plans in other international seabed area zones, in particular where there are currently contracts for exploration, in line with the suggestion made by the United Nations General Assembly in paragraph 51 of its Resolution 69/245*'.

International Seabed Authority convenes its 21st Session

6-25 July 2015, Kingston, Jamaica

David Billett, Deep Seas Environmental Solutions

The International Seabed Authority Assembly in session. Image courtesy ISA.

The ISA's 21st Session convened in Kingston on 6-25 July 2015, during which the Legal and Technical Commission met and presented its report to the ISA Council. You can find a copy of the report in 7 different languages by going to the ISA website and searching for the document ISBA/21/C/16. You will find this in the Council papers of the 21st Session,which can be accessed directly from the ISA home page (www.isa.org.jm).

The report contains details of the status of contracts for exploration, the training programmes being planned, details of new templates for the annual reporting of data and expenditure, general comments on the annual reports of contractors, a new application for the exploration of polymetallic nodules in the Clarion Clipperton Zone (CCZ) by China Minmetals Corporation, progress in the review of the environmental management plan for the CCZ, advice on the developing environmental management plan for the Mid Atlantic Ridge, the latest work on the draft regulations for the exploitation of mineral resources in the Area, including high priority issues to be addressed in the next 12 to 18 months, the data management strategy of the ISA, details of ISA workshops held during 2014, including the standardisation

of taxonomic and sampling methods for macrofauna in the CCZ, procedures and criteria for the extensions of contracts for exploration.

Whilst there is talk of a workshop in 2016 on the implementation of the CCZ environmental management plan, it is possible this may be delayed bearing in mind the recent cruises organised by MIDAS and the Joint Programming Initiative to the CCZ and other nodule areas, especially as these cruises sampled within the 'Areas of Particular Environmental Interest' (APEIs), which were set up by the ISA in 2012 to preserve regional biodiversity. The recent workshop held in the Azores on an environmental management plan for the Mid Atlantic Ridge in international waters (see report on page 13) was also discussed and the ISA is aware that a good science case is being worked on by the workshop participants and that this case may be presented to the ISA in 2017 for the consideration and further development by the Legal and Technical Commission.

The 21st Session was marked also by a number of side events organised during lunchtime periods, including one by MIDAS (see below). The amount of data on which to base good environmental decisions is growing rapidly, both from contractors and the science community. The way in which scientists from Europe collaborate successfully (notably those in MIDAS), and who work for contractors and generate novel science, is particularly noteworthy. Useful suggestions on taxonomy and sampling approaches for macrofauna were made at the ISA workshop in Korea in November 2014 (see the Spring 2015 edition of the MIDAS Newsletter). The workshop recommendations are now available as an ISA Briefing Paper 01/2015 via the ISA website. The recommendations will be taken up when the LTC updates the '*Recommendations for the guidance of contractors on the possible environmental impacts arising from exploration of marine minerals in the Area*' in 2016.

MIDAS side event at the ISA 21st Session

Kingston, Jamaica, 15 July 2015

MIDAS held a side event at the ISA during their annual meeting in July 2015, attracting an audience of 68 people many of whom were members of the ISA's Legal and Technical Commission. MIDAS Coordinator Phil Weaver presented an outline of the MIDAS project and stressed that results would be freely shared with the ISA and full support given in the development of its regulatory framework. Examples of some of the scientific work and policy activities of MIDAS were then presented by Prof. Pedro Martinez Arbizu (Senckenberg Institute) and Prof. David Johnson (Seascape), respectively.

Pedro Martinez Arbizu presented some first results of the last international cruise to the CCZ. The aim of the cruise was to study the potential impacts of deep-sea polymetallic mining to the species communities living at the seafloor and the timescales of ecosystem recovery after mining. Molecular methods have been used to assess the species distribution and genetic connectivity between populations at distant sites in the CCZ.

David Johnson presented an overview of the workshop towards a Strategic Environmental Management Plan in the Atlantic, held in the Azores in June (see workshop report on p13 of this newsletter). This workshop collated and visualised multiple data sets, scoped potential conservation and management objectives, and considered design parameters for Areas of Potential Environmental Interest. Experts discussed data availability and adequacy. Prof. Johnson emphasised that this is the start of an adaptive process that he hoped the ISA would take ownership of once the science is more mature.

Left: MIDAS representatives Phil Weaver, Pedro Martinez and David Johnson at the International Seabed Authority's 21st Session in Kingston, Jamaica.

GESAMP International Workshop on the Impacts of Mine Tailings in the Marine Environment

10-12 June 2015, Lima, Peru

By David Johnson, Seascape Consultants

The Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) organised this information exchange workshop, which was co-funded and co-organised by the DOSI-DSTP MITE-DEEP Project (funded by the Norwegian Research Council and INDEEP). The workshop built on a London Convention/London Protocol (LC/LP) review of Deep-Sea Tailings Placement (Vogt, 2012), information gathered by a LC/LP Correspondence Group in 2013 and a national initiative by Chile in 2014.

Industrial submarine tailings disposal (STD), also known as deep-sea tailings placement (DSTP), is distinct from industrial riverine tailings disposal and artisanal tailings disposal. Tailings are the solid fraction of unrecoverable and uneconomic metals, minerals, chemicals, organics and process water discharged normally as a slurry to a final storage area. Mining operations generating tailings include metals (copper, silver, gold), iron, rutile, graphite and pigments. Previously GESAMP has noted governance gaps associated with characterisation of the receiving environment (for example, tailings may be placed on land but process water discharged at depth via pipeline) and knowledge gaps including the behaviour of slurries, physical smothering effects, ecotoxicological effects and recovery times. Currently at least 16 mines in eight countries discharge tailings into the deep ocean, with further applications pending. Commodities of these different operations vary but most discharge rates (measured in tons / year) are substantial. For example, in Chile each potential ton of copper generates 100 tons of tailings.

The rationale behind DSTP is that it is cheap; in theory at least it avoids land-use conflicts, engineering constraints, the need for long-term maintenance and attendant risks. It is also assumed that the tailings movement in the marine environment mimics natural sediment movements. Some of the environmental risks that have been highlighted include faunal smothering; larger than predicted deposition footprint of slurry and deposition in different areas than predicted; benthic habitat alteration; release of toxic metals and process chemicals; spills; inclusion of other waste streams, and nanoparticles. Best practice has focused on design an operation involving de-aeration, discharge below the euphotic zone and mixed layer, and choosing low-energy depositional environments for discharge.

The Lima workshop sought to provide a synthesis of current understanding of the impacts of marine disposal of mine tailings, to inform the development of future policy and regulatory mechanisms, and to develop partnerships for further work. Expert presentations were given by representatives from government, the mining industry, scientific community, engineers and NGOs. In Chile, for example, the importance of the mining sector to the national GDP was emphasised. Surface impoundments are the most common storage method for mine tailing disposal and recovery rates for tailings are around 92-94%. Dominant chemical compounds in the silt are silicate particles, which are considered inert and harmless for the environment. Experiences from Chile, Indonesia, Mexico, New Zealand, Norway, Peru, PNG and Togo were shared together with modelling information and rehabilitation studies. Participants recognised that many of the environmental challenges and unknowns for deep-sea mining, such as plume behaviour, are similar to those faced by DSTP.

As a result the workshop identified a substantial list of issues relating to discharge of mine tailings into deep-sea marine receiving environments. For example, there is a need to develop standard sediment and aquatic toxicity tests that use species from deeper water. This is further complicated by considerations such as test temperatures, different exposure pathways, pressure variation, and the need for chronic studies with variable exposure regimes and scenarios.

GESAMP will now consider the possibility of forming a Working Group to develop preliminary guidance and recommendations as well as addressing priority knowledge gaps. One expert suggested the need to generate basic information and knowledge as a first step before socialising the process; implementing an appropriate regulatory framework; adapting operational practices to the regulatory framework; and developing and implementing plans for closure and monitoring.

Reference: Vogt, C. (2012) International Assessment of Marine and Riverine Disposal of Mine Tailings. Report presented to the London Convention/London Protocol, International Maritime Organisation.

EcoDeep-SIP Workshop: The crafting of seabed mining ecosystem-based management

29 June -1 July 2015, Embassy of France in Japan, Tokyo

By Lenaick Menot, Ifremer

In the framework of both a Strategic Innovation Promotion Programme project for the development of new-generation research protocol for submarine resources led by JAMSTEC and the JAMSTEC/Ifremer collaborative project EcoDeep, a workshop was hosted by the French Embassy in Tokyo to address the ecosystem-based management of seabed mining. The main aim of the workshop was to provide recommendations regarding the development of protocols and new technologies for the assessment and mitigation of environmental impacts potentially arising from massive sulphide mining.

Above: Working group debriefing in plenary session

For two and a half days, scientist, engineers, representatives from the industry as well as national (Cook Island), regional (SPC/SOPAC) and international (ISA) regulatory bodies worked on these issues. In addition to mineral extraction and particle plumes, the noise produced by the riser system has been identified as a potentially very significant impact as it may cross the deep sound channel and strongly interfere with marine mammals. Discussions on indicators for the monitoring of environmental impacts identified the need to consider ecological functions and their values as ecosystem services.

Recommendations were made on technological developments to mitigate potential impacts as well as to monitor the impacts. The industry is indeed already working on solutions to minimise the intensity of sound-related and plume-related environmental impacts. Emphasis was placed on the need to develop non-invasive monitoring tools for functional groups, such as nested scales of imageries, from larvae to megafauna, as well as to test the relevance and applicability of the 'omics' technologies for the monitoring of ecosystem structures and functions.

Call for precautionary approach in the regulation of DSM

A team of international scientists and legal experts has recently published a paper in *Science* magazine calling for a precautionary approach in the design and implementation of regulatory frameworks for the exploitation of deep-sea minerals. In particular, they highlight the need for the ISA to provide appropriate and timely environmental protection of deep-sea ecosystems in regions potentially affected by mining, and consider including provisions for MPA networks embedded in regional environmental management plans. MIDAS provided input to this paper via co-author Kristina Gjerde.

Managing mining of the deep seabed

Contracts are being granted, but protections are lagging

Reference:

L.M. Wedding, S.M. Reiter, C.R. Smith, K.M. Gjerde, J.N. Kittinger, A.M. Friedlander, S.D. Gaines, M.R. Clark, A.M. Thurnherr, S.M. Hardy, L.B. Crowder (2015) Managing mining of the deep seabed. Science volume 349, Issue 6244, p144-145. DOI: 10.1126/science.aac6647. Published 10 July 2015.

ISA Areas of Particular Environmental Interest (APEI) in the Clarion-Clipperton Fracture Zone: Offsetting to Fund Scientific Research

David Johnson and Maria Adelaide Ferreira have published a short paper in the International Journal of Marine and Coastal Law 30 (2015) making the case for an APEI Trust Fund. The purpose of such a Fund would be to fund systematic scientific surveys needed to validate their role as environmental 'reference zones'. The authors argue that contributions by seabed mining contractors to such a fund would qualify as a biodiversity offset and support an aggregate offset approach as a payment for privately retained revenue of exploiting irreplaceable commons. With the financial regime for deep-sea mining still under active debate this article is timely. It is available at: http://booksandjournals.brillonline.com/content/journals/10.1163/15718085-12341367;jsessionid=22h9v46u5576v.x-brill-live-03

New faces: Welcome to MIDAS!

Daphne Cuvelier
Instituto do MAR, University of the Azores

In early June, Daphne was appointed as a postdoctoral research fellow within the MIDAS project. She joined the multidisciplinary MIDAS team at IMAR in the Azores, and will be mainly contributing to work packages 6 (Recovery and resilience) and 8 (Developing protocols and standards).

Daphne has a lot of experience in working with imagery, time series and numerical ecology at deep-sea vents. She carried out her PhD within the FP6 MarBEF project on the temporal variations of the hydrothermal vent communities of the Lucky Strike vent field on the Mid-Atlantic Ridge. Since then she has continued to work on deep-sea chemosynthetic environments using both imagery and sampling, including a colonisation experiment. Daphne was one of the first to work with the deep-sea observatories during her post-doc studies at Ifremer, during which the dynamics and rhythms of hydrothermal fauna in the North-East Pacific and Atlantic were analysed in high resolution and linked with in situ recorded environmental variables.

The knowledge she has gathered on community dynamics and ecosystem functioning will be put to use in estimating potential restoration actions in the deep sea and, among others, in working with artificial colonisation substrates.

Sergio Taboada,
Natural History Museum, UK

Sergi is a just-landed postdoc at the Natural History Museum in London, who will be studying the molecular connectivity between target macrofaunal invertebrates across the Clarion-Clipperton Zone (CCZ), specifically between reserve areas (APEIs) and mining claims.

Sergi conducted his PhD at the University of Barcelona, focusing on the chemical ecology, bioactivity and biodiversity of Antarctic marine benthic invertebrates. After that, he spent three years working on the biodiversity and phylogenetics of benthic invertebrates from Antarctica and the Mediterranean Sea. Sergi has contributed to the knowledge of annelid polychaetes and nemerteans with 10 new species, and has described many marine soft-bottom invertebrate communities from different environments. He is specialised in the study of polychaetes associated with mammal bones, and was a member of the team who were first to describe *Osedax* (bone-eating worms) from the Southern Ocean. More recently, Sergi has been involved in studies to establish the molecular connectivity and phylogeography of Atlanto-Mediterranean marine invertebrates.

In MIDAS, Sergi will be working on the genetic connectivity of benthic marine invertebrates commonly found across the CCZ - you can read more about this in the article on page 3.

The MIDAS newsletter is published quarterly. The deadline for articles for the Autumn 2015 issue is Friday 16 October - please email vikki.gunn@seascapeconsultants.co.uk with your contributions.