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WORKSHOP ON MARINE SCIENTIFIC RESEARCH IN THE AREA:

ESTABLISHING COLLABORATIVE PLATFORM TO ENHANCE BIODIVERSITY KNOWLEDGE FOR ENVIRONMENTAL MANAGEMENT IN MID-OCEAN RIDGE ECOSYSTEM FOCUSING ON THE INDIAN OCEAN

15 - 17 December 2020; Online

INTRODUCTION

1. In accordance with the UN Convention on the Law of the Sea ("the Convention") and 1994 Agreement relating to the implementation of Part XI of the Convention, the International Seabed Authority (ISA), on behalf of the States Parties to the Convention, is mandated to administer the mineral resources in the Area and to control and organize current exploration activities, as well as future mining activities, in the Area for the benefit of humankind as a whole. The Authority is also mandated to take necessary measures with respect to activities in the Area to ensure effective protection for the marine environment from harmful effects and to adopt appropriate rules, regulations and procedures for, *inter alia*, the prevention, reduction and control of pollution and other hazards to the marine environment, the protection and conservation of the natural resources of the Area and the prevention of damage to the flora and fauna of the marine environment[1].

2. In addition, the Authority is mandated by the Convention to promote and encourage the conduct of marine scientific research in the Area, and coordinate and disseminate the results of such research and analysis when available[2]. The importance of this mission was highlighted by the Strategic Plan of the ISA for the period 2019-2023, adopted by the Assembly at its twenty-fourth session in 2018[3]. Especially through the strategic direction 4 ("Promote and encourage marine scientific research in the Area"), the members of the ISA have established the vision in this regard, which is being implemented according to the High-level Action Plan for 2019-2023 adopted by the Assembly at its twenty-fifth session in 2019[4].

3. In 2017, the United Nations Decade of Ocean Science for Sustainable Development from 2021 to 2030 was proclaimed by the United Nations General Assembly in its resolution 72/73. ISA developed an action plan[5] to formalize and organize its contribution to the implementation of the United Nations Decade, building on the strategic directions, high-level actions and associated outputs set out in the abovementioned Strategic Plan and the High-level Action Plan. The ISA Assembly adopted this action plan in December 2020.

4. In light of the context described above, the ISA secretariat, in collaboration with the China

[1] United Nations Convention on the Law of the Sea, art.145
[2] United Nations Convention on the Law of the Sea, art.143
[3] ISBA/24/A/10, annex, para. 29
[4] ISBA/25/A/15
[5] ISBA/25/A/4, ISBA/26/A/17

Ocean Mineral Resources Research and Development Association (COMRA) and the Hong Kong University of Science and Technology (HKUST), convened an international workshop on Marine Scientific Research in the Area: *Establishing collaborative platform to enhance biodiversity knowledge for environmental management in mid-ocean ridge ecosystem*, via online platform, from 15-17 December 2020. The workshop was conducted in English.

5. The workshop aimed to: (i) review existing efforts in gathering knowledge and information on hydrothermal vent ecosystems in the Indian Ocean, and identify knowledge gaps and priorities for future scientific research; (ii) identify best practices, including technological innovations to address knowledge gaps related to mid-ocean ridge ecosystems in the Indian Ocean through standardization of methodologies, protocols and procedures for environmental monitoring and data sharing; and (iii) explore mechanisms for collaboration among and between contractors, and the scientific community to support long-term observation and monitoring of hydrothermal vent ecosystems in the Indian Ocean, which can inform ISA's future efforts for the protection of marine environment in this region, including the development of a regional environmental management plan.

6. The workshop was attended by 82 participants in their individual expert capacities through an online registration process. The full list of workshop participants is provided in annex I to this report.

ITEM 1. OPENING OF THE WORKSHOP

7. Mr. Michael Lodge, the Secretary General of the ISA, delivered his opening statement through a video message. First, he expressed his gratitude to the Ministry of Natural Resources of China, the China Ocean Mineral Resources Research and Development Association and the Hong Kong University of Science and Technology for their collaboration and support in convening this workshop. He also thanked Dr. Pedro Madureira and Dr. Pei-Yuan Qian for co-chairing this workshop. Mr. Lodge highlighted ISA's mandate to promote and encourage marine scientific research in the Area as well as coordinate and disseminate the results of such research. He also emphasized ISA's duty to strengthen the research capabilities of developing countries, in order to ensure their effective participation in deep-sea exploration and research programmes. The ISA Action Plan for Marine Scientific Research in support of the UN Decade of Ocean Science for Sustainable Development and the ISA Strategic Plan and High-Level Action Plan for 2019-2023 were underlined as important frameworks for advancing scientific knowledge on deep-sea ecosystems and biodiversity. He stressed the importance of enhanced collaboration and coordination among contractors and scientific communities in identifying innovative and financially sustainable solutions to support science-based policy decision-making processes, with a view to ensuring the sustainable development of activities in the Area. He informed the participants that the workshop outputs will contribute to identifying actions necessary to establish a platform for collaboration under ISA to accelerate the progress towards achieving ISA's mandate on marine scientific research in the Area.

8. Mr. Zhanhai Zhang, the representative of the Ministry of Natural Resources of China, delivered his opening statement through a video message. He began by welcoming the participants and congratulating the organization of the workshop. He then noted the Law of the People's Republic of China on Exploration for and Exploitation of Resources in the Deep Seabed Area, which requires Chinese contractors to ensure the protection of the marine environment when carrying out activities under their exploration contracts. He invited the participants to actively share their experience and knowledge to enhance our understanding of the mid-ocean ridges in the Indian Ocean. At the same time, he urged the international community to promote practical cooperation for environmental protection of the mid-ocean ridges in support of the UN 2030 Agenda for Sustainable Development. Lastly, he stated that the Government of PR China supports the work of ISA on the protection of the marine environment and stands ready to collaborate for the advancement of marine scientific research.

9. Mr. Wei Shyy, the President of Hong Kong University of Science and Technology, delivered his opening statement through a video message. He began his speech highlighting that ISA's efforts

have been instrumental in balancing future mineral resource exploitation with sustainable socioeconomic and environmental development. He also emphasized the need to foster closer collaboration among members of ISA, academia, and the industry. He then announced that HKUST has identified ocean science as a research focus area in order to contribute to China's efforts towards ocean conservation, established international research collaboration, and supported young scientists. Lastly, he highlighted the importance of developing ways and means to address knowledge gaps, share best practices, and establish a collaborative platform for the achievement of UN Sustainable Development Goal 14.

ITEM 2. WORKSHOP BACKGROUND, SCOPE AND EXPECTED OUTPUTS

10. Pei-Yuan Qian (HKUST) and Pedro Madureira (member of the LTC) were invited as co-chairs to moderate the workshop deliberation.

11. Under this item, participants had before them the "Draft Action plan of the International Seabed Authority in support of the United Nations Decade of Ocean Science for Sustainable Development" (ISBA/26/A/4).

12. Jihyun Lee (ISA secretariat) provided a presentation on the workshop background, and Luciana Genio (ISA secretariat) provided a presentation on the workshop objectives, scope and expected outputs.

13. Feng Liu (COMRA) delivered a presentation on China's efforts for mid-ocean ridge studies.

14. Summaries of the above presentations are provided in annex II to this report.

15. Participants exchanged their views, insights and suggestions in response to the presentations above. Key points of this discussion are summarized below:

(i) Participants highlighted the need to develop specific means of improving communication, cooperation and coordination between academic researchers and contractors. It was emphasized that such collaborative efforts should be organized and facilitated through practical approaches. Some specific suggestions included announcements of cruise opportunities, sharing of contractors' cruise schedules and locations, and fostering opportunities for cruise participation. In this regard, the InterRidge platform was noted as an example, and cooperation between InterRidge and ISA secretariat was suggested for developing a joint platform with a view to enhance cruise collaboration. Promoting such platform involving a wider range of scientific communities was also raised as a point of consideration.

(ii) Regarding training opportunities for new oceanographers and young professionals from developing countries, it was noted that the newly established ISA-China Joint Training Research Centre (JTRC) plans to offer training courses, especially to those from developing country member States, in particular small island developing States and the least developed countries.

ITEM 3. OVERVIEW OF CONTRACTOR ACTIVITIES RELATED TO ENVIRONMENTAL MONITORING AND ASSESSMENT IN THE INDIAN OCEAN: KEY RESULTS AND CHALLENGES

16. Under this item, the following participants delivered presentations to provide an overview of contractors' activities in the Indian Ocean highlighting key results and challenges associated with environmental monitoring and assessment in the region:

- Thomas Kuhn (Federal Institute for Geosciences and Natural Resources of Germany,

BGR);

- Zongling Wang (China Ocean Mineral Resources Research and Development Association, COMRA);
- Baban Ingole (Government of India); and
- Yeon Jee Suh (Government of the Republic of Korea)

17. Summaries of the above presentations are provided in annex II to this report.

18. Participants exchanged their views, insights, and suggestions in response to the presentations above. Key points of this discussion are summarized below:

(i) Participants recognized the need for further collaboration among contractors and scientific communities to collect, analyze, and share data, with a view to addressing knowledge gaps and challenges in the context of environmental baseline studies and monitoring of the mid-ocean ridge ecosystems in the Indian Ocean. In particular, participants discussed the spatial and temporal extent of data collected by the contractors to inform the understanding of migration patterns of deep-sea species. According to one of the contractors, the collected data revealed migration of different species at different spatial scales, and further connectivity studies are being carried out to investigate migration patterns of benthic faunal groups.

(ii) Participants also discussed potential ways in which research collaboration under an exploration contract can be extended to other research groups and other contractors for the wider use of the collected data, noting high interest for scientific publication of data by researchers, in particular early career scientists, involved in the exploration activities in the contract areas. As such, sharing of data through scientific publications as well as other forms of cooperation with research and academic institutions have been encouraged by many contractors. It was also emphasized that the data collected by contractors are submitted to ISA's DeepData database and the environmental data are made accessible by public through ISA website.

19. A summary of the plenary discussion under this item is provided in annex IV to this report.

ITEM 4. ENHANCING SCIENTIFIC KNOWLEDGE ON MID-OCEAN RIDGE ECOSYSTEMS WITH A FOCUS ON THE INDIAN OCEAN

20. The following presentations were delivered to inform the discussions under this item:

(i) New approaches to deep-sea polymetallic sulphides exploration
- by Chunhui Tao (Second Institute of Oceanography, China)

(ii) Microbial diversity and function in hydrothermal vent ecosystems of Mid- Indian Ocean Ridge
- by Ken Takai (Japan Agency for Marine-Earth Science and Technology – JAMSTEC, Japan)

(iii) Biogeochemical studies in the South Indian Ocean
- by Natalie C. Harms (University of Hamburg, Germany)

(iv) Understanding connectivity in the Indian Ocean Ridge
- by Florence Pradillon (Institut Français de Recherche pour l'Exploitation de la Mer – IFREMER, France)

(v) DeepData: Platform for sharing environmental data on mid-ocean ridge
- Sheldon Carter (ISA secretariat)

21. Summaries of the above presentations are provided in annex II to this report.

22. Building on the presentations and the results of deliberations under the previous agenda items, participants, at the plenary, discussed the following topics:

- Technology innovation for observation and monitoring, including *in-situ* and *ex-situ* experimentation;
- Standardization of methods, protocols and procedures for monitoring and observation; and
- Data exchange, compilation and analysis, including through DeepData, to support the implementation of ISA's mandate for environmental protection.

23. A summary of the plenary discussion under this item is provided in annex IV to this report.

ITEM 5. DEVELOPING A COLLABORATIVE PLATFORM FOR MARINE SCIENTIFIC RESEARCH IN THE MID-OCEAN RIDGES IN THE INDIAN OCEAN IN SUPPORT OF THE IMPLEMENTATION OF ISA'S MANDATE

24. The following theme presentation was delivered to inform the discussions under this item:

- Collaboration among stakeholders and capacity development of various actors to support environmental management and address knowledge gaps.
  - Wanfei Qiu (ISA secretariat), on behalf of Gordon Paterson (member of LTC)

25. A summary of the presentation above is provided in annex II to this report.

26. Under this item, a panel discussion was organized to discuss ways and means for developing a collaborative platform for marine scientific research in mid-ocean ridges, as guided by the "Draft Action plan of the International Seabed Authority in support of the United Nations Decade of Ocean Science for Sustainable Development" (ISBA/26/A/4), including:

- Joint cruises;
- Joint or complementary research programmes; and
- Opportunities for capacity building.

27. The following panelists were invited for the discussion:

(i) Patrick Halpin (Duke University);

(ii) Gu Wu (ISA-China Joint Training and Research Centre);

(iii) Jon Copley (University of Southampton);

(iv) Dass Bissessur (Mauritius);

(v) Joseph Appiott (Secretariat of the Convention on Biological Diversity, CBD);

(vi) Nic Bax (IOC-UNESCO Global Ocean Observing System, GOOS); and

(vii) Khaira Ismail (Former ISA trainee)

28. Summaries of the panel interventions above are provided in annex III to this report.

29. Following the panel discussion, participants were invited to ask questions and exchange insights and views, in response to the ideas, examples, and experience shared by the panelists. A summary of this discussion is provided in annex IV to this report.

ITEM 6. SUMMARY AND CONCLUSION

30. The workshop co-chairs provided a summary of the workshop results, highlighting the following:

(i) Substantial scientific achievements have been made by contractors, through their exploration activities, and the results have extensively contributed to advancing marine scientific research in the Area and improving our understanding of the mid-ocean ridge ecosystems in the Indian Ocean;

(ii) Many cruises for exploration of mineral resources and environmental baseline studies have been conducted by individual contractors, and the workshop identified the need to promote research collaboration through joint cruises;

(iii) In terms of standardizing research methodologies, there is a need to better understand temporal and spatial variabilities of, *inter alia*:

- Geological processes, including spreading rates, tectonic activities, magmatism, ore-forming systems, sedimentation;
- Physical and chemical oceanographic parameters, especially near-bottom flow dynamics affecting dispersal of animals and chemical mixing in the water column;
- Distribution of vent endemic and non-vent endemic species;
- Life-history traits of key habitat-forming species; and
- Connectivity patterns of benthic species and mid-water migratory species.

(iv) Relative paucity of scientific information on areas beyond the contract areas. This is primarily because most data are generated by the contractors' exploration activities in their contract areas. To address this issue, the workshop highlighted the importance of expanding marine scientific research in the Area, facilitate collaboration between contractors and scientific communities, and linking other available scientific data and information with those collected by contractors.

(v) Need to develop a practical platform for enhanced collaboration on:

- Research cruises;
- Sharing best practices across sectors;
- Sharing findable, accessible, interoperable, and reusable (FAIR) data and information;
- Sharing samples (e.g., specimen) through a network of private and national museum facilities; and
- Training opportunities and capacity development at the institutional level.

(vi) Collaboration could build on the existing processes and initiatives, e.g. InterRidge, Global Ocean Observing System, and Deep-Ocean Observing Strategy.

(vii) Need for convening a range of scientific workshops within the auspices of ISA secretariat in linkage with various forums on marine scientific research, facilitating discussions and promoting collaborations among various stakeholders across different sectors, especially between contractors and scientists.

(viii) Need to avoid "reinventing the wheel, and rather, refine the wheel" by building on the existing activities and facilitating purposeful research activities and scientific collaboration.

ITEM 7. CLOSURE OF THE WORKSHOP

31. The workshop concluded at 9:30 a.m. (Jamaica; GMT-5) on Thursday, 17 December 2020.

Annex I

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Annex II

SUMMARIES OF PRESENTATIONS

Agenda Item 2. Workshop background, scope and expected outputs

Workshop background – *by Jihyun Lee (ISA secretariat)*

She began her presentation by highlighting key mandates of ISA that provide the context for this workshop. At the core of ISA's mandates under the UN Convention on the Law of the Sea lies the protection of the marine environment from harmful effects that may arise from activities in the Area. The Convention also mandates ISA to promote and encourage the conduct of marine scientific research in the Area and to coordinate and disseminate the results of such research and analysis when available. In efforts to successfully implement these mandates, ISA developed an Action Plan in support of the UN Decade of Ocean Science for Sustainable Development, in line with the ISA Strategic Plan for period 2019-2023 and its High-Level Action Plan. The Action Plan identified six strategic research priorities (SRPs), including addressing the need to advance our knowledge of deep-sea ecosystems; standardizing the taxonomy and other methodologies for deep-sea biodiversity assessment; facilitating technological innovation; enhancing understanding of potential impacts of activities in the Area; promoting information and data sharing; and strengthening capacity development. . In this regard, contractors' obligations under their exploration contracts to collect environmental baseline data and monitor impacts of their exploration activities are noteworthy. The collected data will be primary input to the environmental impacts assessment as part of the applications for future exploitation contracts and will also enhance our understanding of marine ecosystem and the predictability of impacts of activities in the Area at both temporal and spatial scales. Data collected by contractors on mineral resources and environmental parameters are compiled and organized in DeepData since its launch in 2019. The environmental data of DeepData are publicly available and will support the discussions related to the protection of the marine environment, in particular the development of regional environmental management plans. ISA provides multidisciplinary learning opportunities through various programmes offered by contractors and the secretariat, in collaboration with ISA members and partners. It is also expected that the recently established ISA-China joint training and research center (JTRC) will effectively enhance ISA's efforts towards strengthening scientific capacity of ISA members.

Workshop scope and expected outputs – *by Luciana Genio (ISA secretariat)*

Under the mandate given by the United Nations on the Law of the Sea, the ISA is responsible for regulating the activities in the Area, which encompass more than 50 percent of the ocean's seafloor extending beyond the limits of national jurisdiction. In the context of the workshop background presented by the Secretariat, discussions will be centered on the scientific knowledge and collaborative efforts needed to advance the understanding of mid-ocean ridge ecosystems, focusing on the Indian Ocean. Understanding how deep-sea species are distributed and interact with the marine environment requires holistic scientific approaches that integrate results from multi- and interdisciplinary studies, which are the building blocks of the environmental baseline work undertaken by the ISA contractors along with the mineral resource exploration activities. Currently, there are four exploration contracts for polymetallic sulphides located in the Central, Southwest, and Southeast Indian ridges. The progress made and scientific achievements obtained by ISA contractors and other scientific experts in this region will be presented. In this context, the workshop aims to identify coherent, collaborative and scientifically robust ways to enhance biodiversity knowledge. In particular, the workshop will focus on providing an overview of current scientific knowledge and information available and identify priority areas for marine scientific research. It also aims to discuss best practices, including technological innovations for addressing knowledge gaps as well as standardized methodologies, protocols and procedures for environmental monitoring and data sharing. Finally, the workshop aims to explore ways for collaboration among and between contractors and

the scientific community to support long-term observations and monitoring of hydrothermal vent ecosystems in the Indian Ocean. The expected outcomes include identifying means for enhanced collaboration among contractors and scientific groups, for instance through joint and complementary initiatives such as cruises and other research programmes and discuss further opportunities for capacity development. The meeting will also allow to strengthen the scientific basis to support the implementation of ISA's mandate for the protection of the marine environment and re-enforce ISA's contribution to implementation of scientific initiatives aligned with the Strategic Plan and High-level action plan for the period of 2019-2023 and the ISA's Action Plan in support of implementation of UN Decade of Ocean Science for Sustainable Development.

Overview on China's efforts for the studies on mid-ocean ridges – ***by Feng Liu (China Ocean Mineral Resources Research and Development Association, COMRA)***

In his presentation, Mr. Feng gave a brief introduction to COMRA's progress in mid-ocean ridge studies. He stated that the government of China has adopted the Law on Exploration for and Exploitation of Resources in the Deep Seabed with related environmental requirements to guide the activities of contractors sponsored by China. He reviewed the history and progress of COMRA since its establishment in 1991. Under the ISA contract for the exploration of polymetallic suphides in the Indian Ocean, COMRA has carried out exploration activities and multiple environmental surveys. As a result, 18 hydrothermal anomaly areas and 8 mineralized areas have been identified. In addition, COMRA has also funded ongoing research on characterization of biological communities, including spatial and temporal changes in vent communities and connectivity, which has led to the discovery of 1 new genus and 15 new species. Mr. Liu also introduced COMRA's training programme, which has provided 47 training opportunities, including 18 related to mid-ocean ridge research. COMRA has also funded PhD studies for students from developing countries. Future efforts on capacity building and marine scientific research will be enhanced through the ISA-China Joint Training and Research Center.

Agenda Item 3. Overview of contractor activities related to environmental monitoring and assessment in the Indian Ocean – key results and challenges

Overview of BGR activities related to environmental monitoring and assessment within its Indian Ocean license area: key results and challenges – ***by Thomas Kuhn et al. (Federal Institute of Geosciences and Natural Resources of Germany, BGR)***

On the 6th of May 2015 the ISA and the Federal Institute for Geosciences & Natural Resources (BGR) signed a contract for the exploration of seafloor massive sulphides in the Indian Ocean close to the Rodriguez Triple Junction. During the first five-year period, BGR has conducted six exploration cruises in its contract area and approximately half of the ship time and the financial budget were dedicated to environmental baseline studies. These studies include physical and chemical oceanography, sedimentation processes and sediment geochemistry, geology, as well as biodiversity investigations. In this regard, BGR cooperates with universities and research institutions, supports master and doctoral programs and carries out additional scientific research outside its contract area.

Physical oceanography studies aim to understand the overall processes driving and modulating surface productivity, particulate matter transport and sedimentation. Sediment trap moorings additionally equipped with current meters, as well as vertical CTD casts and water samples, are used for these investigations. The moorings have been installed in five different clusters over the entire contract area enabling the development of water mass models for this part of the Indian Ocean water column. Hydrothermal plume detection and investigation formed another part of the oceanographic program. Apart from detection of hydrothermal fields, plume investigations add to the global dataset of hydrothermal activity along mid-ocean ridges. Most recent multibeam-echosounder systems can provide information on water column features simultaneously with seafloor mapping. Thus, acoustic water column imaging (WCI) data were

gathered during all BGR expeditions and the information from WCI can be used by biologists for biomass assessments consisting of schools of fish, layers of zooplankton and other pelagic organisms.

The geochemistry and microbial composition of sediments and pore water at different sites in a hydrothermal field are other components of BGR's environmental baseline studies. Sediments in active and inactive sites are an integral part of a hydrothermal system. They not only record the hydrothermal activity over time, but also contain an essential stock of the meiofauna of the hydrothermal system. High-resolution sampling of sediments was obtained with short push cores (about 30 cm length) operated with ROV manipulators.

The analysis of dissolved metal contents in seawater has been the main task of chemical oceanography studies. For this purpose, BGR adopts so-called passive samplers. These simple and cheap devices measure the bio-available fraction of dissolved metals in seawater over time and thus, not only enable to overcome the limitations of conventional sampling tools but also allow to better meet the requirements of environmental monitoring during any mining activity.

Biodiversity baseline studies have been realized to gather data on species composition, distribution, and abundance of different pelagic and benthic communities from mega-, macro- and meiofauna, demersal scavengers, and plankton. These studies have also covered different seafloor habitats such as active, inactive and non-vent areas. In parallel, ecological and connectivity investigations have been conducted– these are important components to monitor changes in the biodiversity along the contract area and to evaluate the resilience of biological communities. These data will inform the ability to mitigate impacts and predict recovery in future mining events. To obtain samples of fauna from different habitats we use Remotely Operated Vehicles equipped with a variety of tools and we try as much as possible not to affect the sampled area. This strategic sampling program provides the data to assess potential environmental impacts of exploration and future exploitation activity in the BGR contract area, an important element of the environmental management plan.

Geochemical, taxonomical, biological, ecological, and molecular data of all samples and species studied, combined with bibliography and information on the habitats are deposited in global databases to be accessed by the scientific community. Results of our environmental investigations have been or will be published in science journals or presented at international conferences. BGR contractor is willing and open for further co-operation in the Indian Ocean and welcomes any suggestions and proposals by both other contractors and the science community.

Environmental monitoring and assessment in the Indian Ocean – *by Zongling Wang (China Ocean Mineral Resources Research and Development Association, COMRA)*

This presentation summarized the key results and challenges of environmental monitoring and assessment in the Indian Ocean by China Ocean Mineral Resources Research and Development Association (COMRA). COMRA's research activities focused on the Southwest Indian Ridge (SWIR) and Carlsberg Ridge (CR). Sediments, water and biological samples were obtained near the vent fields. The variation of temperature and pCO_2 were found to be good indicators of hydrothermal vents. The near-vent sediment was rich in several metals, such as Cu, Zn, Ni etc. Low chlorophyll a biomass and high planktonic diversity were found in the upper water column. The bacteria involved in sulfur cycling were abundant in the vent communities, revealing differences in microbial communities from those in the water column. Uniqueness and connectivity of hydrothermal vent fauna were analyzed. A new morphotype of scaly-foot snails was found in Tiancheng vent field. The analysis of population connectivity and gene flow of scaly-foot snails showed no genetic barrier between Tiancheng and Central Indian Ridge populations. At Carlsberg Ridge the vent fauna was more similar to that on the CIR and characterized by *Rimicaris* kaire, and that two new species of worms were discovered. However, the Longqi population seemed to be isolated from the rest. Such connectivity pattern was further confirmed by haplotype network analysis of three other dominant species.

A brief introduction of compiled scientific information for the workshop was given. The document contained published scientific data from western Indian Ocean, which included environmental data, biological data, and biogeographic classification in the Area. Oceanographic data such as temperature,

salinity, ocean currents and concentrations of chlorophyll a, as well as the location of fracture zones were compiled. The exact location of 11 active vent fields currently found in the western Indian Ocean and the available chemical parameters were also included in the compilation. The distribution of Vulnerable Marine Ecosystem (VME) indicators, for example, deep-sea corals and sponges from Ocean Biodiversity Information Systems were described. The biogeographic data focused on four major biogeographic classification systems. In addition, a number of relevant published scientific papers were summarized and listed as additional data resources.

Lastly, some scientific knowledge gaps were identified and the following questions were raised: Is there connection between active and inactive vents? What is the bottom current direction? What are the chemical gradients and speciation changes with increasing distance from hydrothermal vents? What is the spatiotemporal succession of vent fauna and larval dispersal patterns? Mr. Wang highlighted the importance of in-situ surveys, numerical modeling, multi-disciplinary studies, and international cooperation for the future work in filling these gaps.

The compiled information on the hydrothermal vent fields along the mid-ocean ridge in the west Indian Ocean prepared by a group of Chinese experts led by Prof. Pei-Yuan Qian with support of COMRA and HKUST was made available to the participant during the workshop.

Environmental baseline studies for exploration of polymetallic sulphides in the Indian Ocean – *by Baban Ingole (Government of India)*

With a primary objective to establish environmental baseline conditions for the exploration of hydrothermal sulphides, comprehensive environmental and oceanographic data were collected from the Indian contact area (i.e., Central Indian Ridge-CIR and Southwestern Ridge-SWIR). The physical data of the water column were collected by using SBE 19 plus having conventional sensors along with FLNTURD (fluorescence and turbidity sensors) and dissolved oxygen (DO). At the bottom depth (below 3,500 m), the potential temperature profiles observed much colder waters at SWIR, less saline and higher dissolved oxygen content compared to those in the CIR regions. The surface temperature values varied from 20 to 26°C and values for bottom water were in the range of 0.98 to 1.5°C. The surface salinity was ~35. 2 PSU and bottom values were varied from 34.69 to 34.73 PSU. Turbidity values at all the baseline stations were within the mean range. The annual observations showed that below 2,000m water depth physical characteristics were well maintained. Dissolved inorganic nutrients estimated at seven EIA stations followed a general trend with surface depletion and mid-depth nutrients enrichment around 1,200-1,300m water depth, which is attributed to the degradation of organic matter and subsequent release of nutrients to the water column. The concentrations of nitrite were low at all the sampling stations. Silicate profile showed enrichment with water depths, suggesting benthic supply of silicate from bottom sediments. DO concentration showed a minimum value at around 1,200-1,300m water depth, which could be related to the sinking of organic matter and their degradation. Inter-annual comparisons indicated low temporal variations in dissolved nutrients in the study region. The top 200-meter water column was rich in nekton and largely comprised larval forms of fishes, shrimps and cephalopods. The zooplankton samples were represented by highly diverse plankton communities with the dominance of calanoid copepods. The meroplankton sample largely consisted of larval stages of the larger macro-and megafauna and was dominated by crustaceans, followed by cnidarians, molluscs, and echinoderms. The detailed morphological and molecular analysis of bacteria and benthic fauna revealed the presence of new bacterial (*Alteromonas pelagimontana* sp. nov; *Alcanivorax* sp. nov) and macrobenthic (*Geodia* sp.nov; *Isodictya* sp.nov.) species in the study area. Thus, the data generated under this program not only will help in developing a Regional Environmental Management Plan in the region but also will be very useful in assessing the genetic diversity and connectivity of vent associated biota.

Overview of exploration activities related to environmental monitoring of assessment in the Indian Ocean by the Republic of Korea: key results and challenges – *by Yeon Jee Suh (Government of the*

Republic of Korea)

The exploration contract for polymetallic sulphides in the Indian Ocean was granted in June 2014 by the International Seabed Authority (ISA) for the Republic of Korea as the sponsoring state of the Ministry of Oceans and Fisheries. Since then, the Korea Institute of Ocean Science and Technology (KIOST) have been carrying out environmental baseline studies, including an investigation of physical and chemical properties in the water column, spatial and vertical distribution of zooplankton community, and spatial distribution and composition of interstitial meiobenthic and megafaunal community in the contract area. In 2017, KIOST discovered four new hydrothermal vent fields on the Central Indian Ridge, including the Onnuri Vent Field (OVF) which is a low temperature diffusive vent with a distinct community composition (<40% similarity between OVF and other vent fields). Scientific papers on the discovery of the OVF, identification of new species, and the vent ecosystem have recently been published by the KIOST scientists and their collaborators. From 2021 to 2024, KIOST plans to install moorings with current meters and sediment traps for long-term monitoring of current and sinking particles, continue surveying the water column, and delve further into studies on biodiversity and biogeography using video cameras and remotely operated vehicles. KIOST is well aware of the importance of the international collaboration in ocean science and capacity development of developing States. In light of this, KIOST would like to extend collaboration with other contractors and scientific communities and further contribute to promoting the participation of developing States to improve productivity in discovery and management of deep-sea biodiversity.

Agenda Item 4. Enhancing scientific knowledge on mid-ocean ridge ecosystems in the Indian ocean

New approaches to deep-sea polymetallic sulphide exploration – ***by Chunhui Tao (Second Institute of Oceanography, China)***

Hydrothermal circulation systems around the world have been developed along mid-ocean ridges at different spreading rates. Most of them are tectonically and magma-controlled and have great potential for metal mineralization. Mid-ocean ridges are currently the frontier of geoscience and life sciences. Along the ~60,000 km of global mid-ocean ridge system, there are quite a few “black smoker” hydrothermal fields of above 300°C temperature. According to the InterRidge database, 304 vent fields have been visually confirmed, and the location of 362 more active fields were inferred from the results of the systematic water column plume surveys. Our main concerns are how to find more sulphide deposits, how large the deposits could be, and what the associated potential environmental issues are. In this regard, we can conduct the mineral introspective mapping, which is mainly based on the mineral introspective model, including magma and topography. This method will help us understand the area and improve local prediction. Second, with the help of prospecting factor and detecting technology, we could delineate the anomalies along the mid-ocean ridge for the plume, alteration, fauna and more. Finally, we can use various tools like TV, ROV, HOV to verify if the observed anomalies are related to vents or sulphides.
This presentation also described the plume/geochemical tracing work and several effective geophysical approaches to explore the polymetallic sulphides, such as transient electromagnetic, controlled-source electromagnetic, and self-potential and reflection seismic. It was also highlighted in the presentation that many of these instruments can be mounted on Autonomous Underwater Vehicles (AUVs) and thus survey a larger area than Human Operated Vehicles resulting in the detection of more vents. Furthermore, seafloor drilling was highlighted as a more accurate method for exploring the sulphide ore bodies. This has been well practiced in the TAG and Solawa areas. In the Yuhuang deposit on SWIR, 30% copper-bearing sulphide cores were obtained after drilling, which initially revealed good resource prospects. Next, the presentation described an approach to long-term monitoring of hydrothermal systems, including heat sources, fluid circulate channels, and mineralization processes, as well as the vent environment. This is mainly to identify the heat source and its circulation mechanism. The OBSs and numerical simulation was used for this activity. Lastly, the presentation highlighted the importance of strengthening international cooperation to effectively detect the inactive and off-axis polymetallic sulphide deposits, and identify the

way to balance the resource exploitation and the environmental protection.

Microbial diversity and function in hydrothermal vent ecosystems of Middle Indian Ocean Ridge – *by Ken Takai (Japan Agency for Marine-Earth Science and Technology, JAMSTEC)*

Historically speaking, the Indian Ocean is one of the least explored oceans for research on deep-sea hydrothermal systems. The first seafloor deep-sea hydrothermal activity was discovered in 2000 at the Central Indian Ridge (CIR) near the Rodrigues Triple Junction (RTJ) by a Japanese team with R/V Kairei and ROV Kaiko. Since then, 13 major active seafloor hydrothermal systems have been found in various mid-ocean-ridge systems of the Indian Ocean, such as the Carlsberg Ridge, Central Indian Ridge (CIR), Southeastern Indian Ridge (SEIR) and Southwestern Indian Ridge (SWIR). However, among these newly discovered deep-sea hydrothermal systems, not so many for detailed studies have been conducted on microbial diversity and function associated with hydrothermal fluids and mineral deposits. The limited information on the chemolithotrophic microbial community development in the Indian Ocean hydrothermal systems suggest no apparent biogeographical characteristics of microbial diversity and function specific to the Indian Ocean. To further understand the global biogeographic connectivity and evolutionary process of deep-sea hydrothermal vent-endemic microbial communities, new studies on the Indian Ocean hydrothermal systems and the associated microbial communities will provide key insights. It was also suggested that the composition of microbial communities can somehow be predicted from the fluid composition according to McCollom-Shock's prediction which states that the thermodynamic energy potentials dictates chemolithotrophic energy metabolism. However, other parameters such as pH are not accounted for in this model.

Biogeochemical studies in the South Indian Ocean – *by Natalie C. Harms (University of Hamburg, Germany)*

Oligotrophic subtropical gyres cover ~75% of the ocean's surface and are predicted to expand under global warming, and thus will become even more important for global marine nitrogen and carbon cycles. The oligotrophic subtropical gyre of the Indian Ocean, however, is one of the least explored ocean regions. Our investigations provide new field data on the nutrient distribution and its isotopic composition related to the different water masses of the South Indian Ocean. Furthermore, we present first data ever measured on sediment trap derived sinking particulate matter fluxes in the low productive Indian Ocean gyre. Nutrient distribution in the Indian Ocean subtropical gyre (IOSG) are predominantly influenced by the typical flow-system of the subtropical gyres that lead to deep thermo-, pycno- and nutriclines in the centre and thus form strongly stratified and nutrient-depleted surface waters. We combined water mass distributions based on physical water column data with nutrient measurements and stable isotope data to verify nitrogen sources and transformation processes in the IOSG and across its boundaries. Our results indicate that nutrient distribution and the nitrate isotopic composition are affected by water masses of antarctic and subantarctic origin converging and mixing with water masses from the southern equatorial Indian Ocean and the Arabian Sea. In a second step, we present a five-year series of sediment trap experiments that provide new information on the nature of organic carbon fluxes, their controlling factors and on the temporal gyre variability. Due to the nutrient limited conditions in the IOSG, we measured the lowest ever-recorded particulate organic carbon fluxes (~0.2 g m^{-2} $year^{-1}$ at 2,600–3,500 m water depth) worldwide. Furthermore, surface sediment samples collected during 2015 and 2018 reveal sedimentation rates of ~0.23 cm per 1,000 years and provide new information on the final organic carbon storage in the pelagic sediments of the Indian Ocean gyre. Based on primary production rates, sinking particulate matter fluxes and surface sediments, we estimated that only ~0.01% of the initial primary production in the euphotic zone reaches the sea floor and can be stored in the deep-sea sediments. Take-home messages are 1) the South Indian Ocean is characterized by a single subtropical gyre that deepens the nutricline reducing primary productivity; 2) the South Indian Ocean has one of the lowest particulate organic matter (POC) flux in the world due to its lower primary productivity and only 0.01% of the surface primary production reaches the seafloor; and 3) biological processes are stimulated by the Subantarctic Mode water (SAMW)

and Red-Sea_Persian Gulf Intermediate Water (RSPGIW) which both inject nutrients (including nitrogen) to the system.

Understanding connectivity in the Indian Ocean ridge – *by Florence Pradillon (Institut Français de Recherche pour l'Exploitation de la Mer – IFREMER, France)*

Connectivity describes the degree to which spatially separated populations exchange individuals. For most marine benthic species, this exchange of migrants occurs during their planktonic larval stages. Connectivity is one of the main drivers of colonization processes through the supply of new settlers, population's demography, species persistence through time and space, and community dynamics and diversity. It has thus been recognized as an essential biological parameter for the development of area-based management tools, ensuring sustainability of marine ecosystems facing anthropogenic impacts. However, assessing connectivity is not straightforward, which may explain the difficulties in translating its estimates into metrics that can effectively inform management strategies. Multiple biological and physical processes operate in connectivity, including reproduction and spawning, larval biology, currents, settlement on the bottom and recruitment into benthic populations. Different approaches are available to estimate connectivity, each with its own limitations due to the fact that each address some of the processes operating in connectivity. This makes the combination of different approaches desirable to achieve accurate and contemporary connectivity estimates. Bio-physical modelling has recently been increasingly used to simulate the trajectories of larvae from vent populations along ridges and detect regions of high connectivity or dispersal barriers. However, accurate predictions of larval transport require empirical data on species reproductive and larval traits.
The exploration of roughly 16,500 km of the Indian Ocean spreading system is recent, and relatively few vent living communities are currently known, among over 300 active vents potentially existing along the Central Indian ridge (CIR), the Carlsberg ridge, the Southeast Indian ridge (SEIR) and the Southwest Indian ridge (SWIR). Current reports, including the recent results of environmental baseline studies of ISA contractors on the diversity of vent communities at these sites, list more than 70 macrofaunal species, among which, emblematic taxa such as *Rimicaris kairei* shrimps, *Bathymodiolus marisindicus* mussels, *Alviniconcha marisindica* snails, *Chrysomallon squamiferum* snails, *Neolepas* barnacles, *Austinograea rodriguezensis* crabs, *Marianactis anemones*, etc. Variability in faunal composition was observed across vent fields, but several taxa exhibit large geographic distribution areas, sometimes spanning several ridges. Their connectivity patterns were inferred from genetic studies based the COI mitochondrial gene. For most studied species, low genetic structuration was observed suggesting high dispersal capabilities. A connectivity break was however identified for the snail *C. squamiferum*, along the SWIR between the Longqi and Tiancheng vent fields. Further exploration and discovery of new populations along Indian ridges, not only in contract areas, will allow to refine connectivity estimates. In addition, the collection of empirical data on reproductive traits, larval biology, as well as current regimes near the bottom is needed to better interpret genetic connectivity estimates and parameterize bio-physical models simulating larval dispersal.

DeepData: Platform for sharing environmental data on mid-ocean ridges – *by Sheldon Carter (ISA secretariat)*

During this presentation, Mr. Carter briefly introduced to the ISA DeepData database and how it has been designed to play its role as a platform for sharing environmental data on the mid-ocean ridge. This was done by first highlighting the ISA's commitment in Strategic Direction 4 of the ISA strategic plan for the period of 2019-2023 to promote and encourage marine scientific research in the Area. Data gathered during contractors' exploration activities are stored in DeepData and disseminated through the dedicated platform on the ISA website.
Mr. Carter then informed participants of the five pillars on which the ISA Data Management Strategy is built upon. The first pillar is data identification, which addresses what, where, when and how marine

scientific data within the Area are captured and made available to various user groups. The second pillar is the storage of data and addresses the medium through which data are archived, and the third focuses on where data are made available for public use and presented in a user-friendly manner that promotes open and transparent data access. The fourth pillar seeks to integrate the data to form synergies with other data providers for increased knowledge of the deep seabed. The final pillar addresses data governance, which highlights the rules and policy guidelines that have been implemented to facilitate the delivery of the above-mentioned data management components and make environmental data available to the global community in a safe and transparent manner.

AGNEDA ITEM 5: Developing a collaborative platform for marine scientific research in the mid-ocean ridges in the Indian ocean in support of the implementation of ISA's mandate

Collaboration among stakeholders and capacity development of various actors to support environmental management and address knowledge gaps – *by Wanfei Qiu (ISA secretariat)*

Ms. Qiu presented key messages from a recent ISA workshop on the development of a regional environmental management plan (REMP) for the Area of the Northern Mid-Atlantic Ridge[6]. Several collaborative activities were identified for addressing monitoring and research priorities, such as future workshops for prioritization of knowledge gaps and development of impact thresholds. Understanding of plumes and technology for plume reduction, as well as technology development for future exploitation, multi-scale and long-term environmental monitoring were discussed. The need to undertake risk analyses, mapping and modelling at the regional scale, and data intercalibration exercises for regional comparative analysis were recognized, along with further research on structural properties critical for ecosystem function, taxonomy and biogeography, connectivity and larval studies, and migratory corridors. In addition, sharing of cruise information and opportunities to participate in such cruises was also identified as cross-cutting actions that could contribute towards multiple monitoring and research priorities**.** It was also considered important to identify thresholds and essential biological variables for monitoring at a range of spatial and temporal scales, which could guide the design of joint monitoring programmes and activities. Ms. Qiu also highlighted priority capacity development activities that were discussed at the abovementioned REMP workshop, including further opportunities for early career scientists, raising awareness of decision-makers and funding bodies on the work of ISA, and implementation of a programmatic approach to capacity development.

[6] See the details of workshop at https://www.isa.org.jm/event/workshop-remp-area-northern-mid-atlantic-ridge

Annex III

SUMMARIES OF PANEL INTERVENTIONS

Patrick Halpin (Duke University)

Marine scientific research (MSR) in the Area conducted in consideration of information useful for regional environmental management planning (REMP) could be a way to focus research activities and catalyze collaboration. It is important for scientific communities to consider purposeful ways to prioritize research for complementarity and enhanced collaboration. One of the most effective ways to achieve this is to establish clear goals. Three key topics for the REMP planning include area-based management tools (ABMTs), adaptive management processes, and cumulative impacts. In particular, ABMTs are focused around: 1) sites in need of protection that use *vulnerable marine ecosystem (VME) criteria*; 2) areas in need of protection that use *significant area criteria*; and 3) representativity and connectivity areas that are selected using *network-based criteria*. Applying these criteria as a goal could help researchers focus their studies that can answer more practical questions. The *VME criteria* can be defined as criteria for protection at the site level, which are based on vulnerability and fragility of various species. In this regard, research could focus on species responses to environmental change, identification of vulnerable life history traits, and species mapping, etc. *Significant area criteria* are used for defining important areas for protection at the regional level, which include the vulnerable criteria and additional characteristics, such as the uniqueness, biological productivity, and naturalness of areas, etc. To this end, we need to develop species distribution models, identify endemic versus under-sampled species, and regional patterns of habitats, species distribution and productivity. More broadly, to identify representative and network areas of particular significance, four main criteria are considered: 1) representativity; 2) connectivity; 3) replication; and 4) adequacy. This especially requires a lot of synthetic research on comprehensive mapping, species characterization, near-bottom currents and larval distribution, source-sink dynamics between populations, sensitivity analysis at various scales, and habitat representation within regions, etc. With these criteria in mind, researchers can identify complementary and cooperative research activities that can be conducted across different groups of scientists and contractors, and thus better mobilize resources and inform the policy-making process.

Gu Wu (ISA-China Joint Training and Research Centre)

Ms. Gu introduced the work of ISA-China Joint Training and Research Center (JTRC). The JTRC was established through a Memorandum of Understanding signed between the ISA and the Ministry of Natural Resources of China in October 2019. Its mission is to enhance capacity building and advance marine scientific research in developing States, foster cooperation in marine scientific research and technology development, and to promote the participation of developing States in activities in the Area. Ms. Gu also briefed participants about the research carried out by the National Deep Sea Center of China in 2014 and 2015 on the mid-ocean ridge in the Indian Ocean, and explored ways through which the JTRC could contribute to further advance marine scientific research and environmental management in the Indian Ocean. Such contributions can include training courses on polymetallic sulphide resources and hydrothermal vent ecosystems, joint research cruises in Indian Ocean, and establishing a platform for facilitating joint research and dissemination of research results. In her final remarks, Ms. Gu stated that future work of the JTRC will be carried out under the guidance of its Steering Committee.

Jon Copley (University of Southampton)

Building a productive relationship between Marine Scientific Research (MSR) in the Area and contractor activities requires an understanding of differences between the research questions of each domain. Research conducted by contractors addresses specific goals, such as collecting samples and data that provide baseline patterns of biodiversity distribution and ecosystem function in their contract area. Contractor research activities typically involve applying established ecological understanding, using

reliably proven techniques and approaches, and often building on existing regional data. In contrast, MSR in the Area needs to address fundamental research questions that advance understanding of geological, geochemical, oceanographic and ecological processes to be successful in obtaining funding from national science agencies. The questions that drive MSR are seldom region-specific, e.g.: "What is the role of mid-ocean ridge topography in mixing global thermohaline circulation?", and questions from different disciplines need to be targeted to build multidisciplinary programmes that justify the use of facilities such as research ships and deep-submergence platforms. The underpinning of contractor research activities by MSR is reasonably well-established, as contractors are sometimes also members of the academic community, and published studies and data from MSR are available as context for contractors. The underpinning of MSR by contractor activities, for example contributing to the development of new MSR programmes in the Area, is less clear. The InterRidge organization provides channels for rapid dissemination of discoveries by contractors to the academic community, through its InterRidge News publication. Its Working Group system offers a forum for collaborative development of new MSR programmes at mid-ocean ridges, and its bursary schemes support capacity development. Contractor findings could contribute to development of MSR programmes targeting specific regions such as the Indian Ocean, while greater understanding of fundamental processes such as dispersal and connectivity, often needed by contractors, will depend on wider MSR efforts in the Area.

Dass Bissessur (Mauritius)

The various training programmes and opportunities offered by ISA and the contractors to developing states are a good initiative to promote marine scientific research in this field. Young scientists are given the opportunity to acquire a minimum knowledge and the capability to converse and discuss with specialists in the field. First, the procedures for selecting scientists from the developing countries for training could be better adapted to their level of knowledge in marine science, depending on their scientific background and expertise. Second, the current training programme is a one-time and short-term capacity building initiative. It could be enhanced by developing it into a continuous long-term programme. Third, for the given trainings to be more effective and valuable, a follow up process could be put in place between ISA, the contractor, and the developing States. A lack of opportunities to maintain and further develop the capacity of trainees after the conclusion of the programme has been observed. Indeed, it is the developing State's responsibility to further train and build capacity of its scientists in the field. However, ISA and the contractors could adopt a more pro-active approach to facilitate this process. For example, former ISA trainees could be invited to participate in MSR or exploration expeditions in their region, even if it is within their country's jurisdiction. They could also be assigned to carry out a specific research activity to contribute to the advancement of marine science in the region. Also, effective collaboration between ISA, the contractors, and institutions from the developing States (for instance the Department for Continental Shelf, Maritime Zones Administration and Exploration in Mauritius) could be established by sharing of staff, scientists, and technicians, as well as various resources, including technology. For instance, dedicated laboratories and research facilities could be set up in the developing State's institution(s), with the sponsorship of ISA and the contractors. The creation of this joint lab would enable effective collaboration and long-term commitment from all for deep-sea research and allow the members from developing States to actively participate in the activities. In addition, this joint research lab could serve as a regional research lab for the activities and would greatly benefit the contractors as they would have a local facility for the preparation of the expeditions (pre-cruise) and the management of collected data and samples (post-cruise).

Joseph Appiott (Secretariat of the Convention on Biological Diversity)

Work under the Convention on Biological Diversity (CBD) not only provides important avenues of collaboration relevant to marine scientific research and facilitating the application of research findings, but also provides lessons and insights related to collaboration in marine scientific research. First, global targets on biodiversity set by governments require increasing information related to biodiversity and ecosystems and necessitate further cross-sectoral collaboration in scientific research. In particular, CBD Parties are

negotiating the post-2020 global biodiversity framework (as the successor to the Aichi Biodiversity Targets), which will contain a new set of global goals for biodiversity. The post-2020 framework, expected to be adopted by CBD Parties in 2021, will likely reflect targets with higher ambition in order to reverse trends in biodiversity loss and will require more robust information to implement and monitor. Second, work under the CBD to facilitate the description of ecologically or biologically significant marine areas (EBSAs) not only contributes to work under the ISA on the development of Regional Environmental Management Plans (REMP), but could also inform future areas of focus for research and illustrates the importance of translating science outputs into information that can directly inform policy. Third, the Sustainable Ocean Initiative Global Dialogue with Regional Seas Organizations and Regional Fishery Bodies, a global platform to facilitate regional-scale collaboration, provides a potential platform to support REMP planning and implementation, as well as illustrating the importance of focusing collaboration around areas of mutual interest and shared goals.

Nic Bax (IOC-UNESCO Global Ocean Observing System)

The physical and biogeochemical communities routinely provide reports on the ocean's status because they have agreed what to measure, how to measure it and how to report it, as well as the process for sharing data so that a truly global picture emerges. This has led to significant investment in ocean monitoring including fleets of profiling robots in all ocean basins. In contrast, only seven percent of the global surface ocean is covered by active, long-term, systematic biological observations, and only a third of these programmes share their data openly. The biological community is currently failing to provide the information that global leaders need to track progress against major international agreements, including the UN Sustainable Development Goals and the Convention on Biological Diversity's post-2020 Global Biodiversity Framework. We all have heard of FAIR and open data, and there is progress on **F**indable, **A**ccessible and **I**nteroperable. However, without the elements that make data **R**eusable we would still not have progressed very far. This applies whether our goal is to monitor the world ocean, or the cumulative impacts of human exploitation in an individual ocean basin or in a single mid-ocean ridge. To provide reusable data we need as a community to agree on standards, document and use best practices, employ spatially balanced statistical design (even in exploratory phases), improve our consistency and collaboration. The Intergovernmental Oceanographic Commission (IOC-UNESCO) is supporting Reusable data through the Essential Ocean Variables of the Global Ocean Observing System, the Ocean Biodiversity Information System, the International Best Practices Portal, and the Deep Ocean Observing Strategy (under GOOS). They are closely linked to GEOs Marine Biodiversity Observation Network and reporting through UNEP-WCMC. In summary, we should recognize that long-term monitoring is not the same as exploration or even research. However, with improved rigour, especially employing documented best practices, spatially balanced statistical designs and FAIR data, baseline exploration and research data can become the first data point in a possible time series and become more and more valuable over time.

Khaira Ismail (Former ISA Trainee)

The range of training programmes offered by contractors via the International Seabed Authority serves as a potential starting point to enhance stakeholders' collaborative effort. Further to the pre-existing training program, which is to encourage personnel involvement from developing States in mineral exploration activities, the collaborative platform should promote efficient partnerships to ensure effective communication between policymakers, stakeholders, and scientists. In establishing the collaborative platform to enhance knowledge for environmental management in the Indian Ocean, it is important to appoint a national focal representative to facilitate communication on activities being carried out, sharing of research findings and data. It is also important to focus on long term collaboration, and the collaborative effort should be driven by specific goals. Each member State, especially those who have a keen interest in exploring the Indian Ocean, should have a focal representative with expertise specifically in environmental or scientific knowledge of the mid-ocean ridge ecosystem in the Indian Ocean. Such practice could ensure efficient contribution from all parties interested in exploring the high seas, not just limited to a member

State with the capacity and facilities to explore the high seas. The platform should also focus on long term collaboration, not only for a few individuals but aiming for institutional collaboration. It could include joint funding or matching grants between contractors with developing countries. The outcome of the collaboration could not only answer a specific research question, but also aim for capacity building to produce master or PhD graduates. Mentorship for developing institutions from established institutions in deep-sea research will enhance the chance to gather more biodiversity knowledge for environmental management in the mid-ocean ridge of the Indian Ocean. Another best practice that could be incorporated to gather more biodiversity knowledge is to design the collaborative platform with shared goals. This will allow structured scientific planning and avoiding redundancy in data collection and overlapping research questions.

Annex IV

SUMMARY OF THE PLENARY DISCUSSIONS

I. Addressing knowledge gaps and challenges in the context of environmental baseline studies and monitoring of the mid-ocean ridge ecosystems in the Indian Ocean

1. Participants reiterated the importance of ISA's mandate to promote and encourage the conduct of marine scientific research in the Area as well as disseminating the results of such research. The data generated from the environmental baseline studies conducted in contract areas were highlighted as valuable contributions to enhancing scientific knowledge in the Area. In addition, it was emphasized that ISA's work on advancing marine scientific research should take place actively in the Area, building on the scientific advancement undertaken by contractors in the contract areas.

2. Participants were informed that results of contractors' environmental baseline studies are reported through the submission of annual reports to ISA as part of contractor's obligations, which are reviewed by the Legal and Technical Commission to ensure the compliance of their activities with the regulations. All data collected from the studies are stored in the ISA's DeepData database, of which environmental data are accessible to the public. The challenge is to synthesize these data into information useful for regional environmental assessment, regional environmental management planning, environmental impact assessments and environmental management. ISA secretariat is making efforts to develop a compendium of contractors' work to increase awareness on the key contribution of contractors to the marine scientific research. In this regard, participants also identified the need to synthesize scientific outputs from the work of contractors together with other scientific findings to help identify priority areas for future research collaboration.

3. Participants underscored the need for moving beyond exploratory data collection to a more scientifically designed data collection that can purposefully inform regional environmental management planning. It was also suggested that a joint sampling effort by the contractors to gather environmental data in the same area could improve resource efficiency for the collection, sharing, and synthesis of the data.

4. With respect to the data integration at the regional level, participants were informed that this is being carried out under the framework of the regional environmental management planning process in the form of regional environmental assessment reports. These reports aim to combine the data collected by contractors and those published by scientific communities through peer-reviewed literatures. In addition, maps are being produced at the regional scale through the integration of geospatial information. ISA can facilitate further collaboration between contractors and scientific communities to improve data integration and analysis in a broader scientific context.

5. Participants discussed the possibility of using water column data gathered by the contractors for monitoring pelagic species, especially those migratory species. It was noted that contractors carry out plankton studies and water column imaging using multibeam ecosounder (MBES) system that can help detect schools of fish and zooplankton in the water column. Collaboration between contractors and fisheries biologists and ecologists was suggested to advance knowledge on this topic. Moreover, most contractors collect plankton samples with different nets, so they can potentially gather samples of larvae at various stages and thus help address knowledge gaps on larval dispersal patterns in the mid-ocean ridges.

6. Participants identified the need to understand linkages between the three different ridge systems in the Indian Ocean, which can influence the resilience of species to disturbances.

7. Estimates of resource potentials within contract areas are difficult to obtain without detailed drilling campaigns. BGR provided provisional estimates of about 35 million tons of ore, computed based on analyses of surface outlines, mound thicknesses and scientific evidence from well-

known, drilled PMS deposits (i.e., Solwara, PNG). The natural variation of PMS on the seabed and the existing knowledge gaps may require detailed drilling programmes of the subseafloor down to 20-30m depth to further refine the resource estimations.

II. Enhancing scientific knowledge on mid-ocean ridge ecosystems with a focus on the Indian ocean

1. Participants discussed different technologies needed for research on larval dispersal and connectivity in the vent fields:

    a. Barcode markers are often used to measure larval dispersal, but imageries can also be used for automatic recognition of planktonic forms in the water column. Given that not all species disperse via larvae and not all larvae have a planktonic stage, it is important to also consider other factors, for example, habitat suitability and composition of vent fauna, to better understand the connectivity between vent habitats. Using environmental DNA (eDNA) is a good approach and a combination of research on morphologies and genetics of larvae would be beneficial for effective use and interpretation of eDNA data. In addition, there have been studies of markers on individual vent species using tools such as geochemical fingerprinting, in order to understand their behavior and patterns of their larval distribution.

    b. It is important to understand the spatial and temporal patterns of species' reproductive cycle, and collaboration between contractors and scientists on this topic would be beneficial considering different seasons and altitudes that need to be investigated. It is also important to consider source-sink dynamics to better understand connectivity between habitats.

    c. In addition to research on larval dispersal, larval settlement needs to be further investigated. Studying soundscape in the vent fields could offer an important clue, as the larvae may use sound as a settlement cue. This may be included in contractors' monitoring schemes. For instance, sound of different vents may be measured to identify different frequencies produced by the black smokers in the Area, which can then be considered for future research and mining operations.

    d. Participants highlighted that more knowledge on reproductive biology and larval behaviors is required to implement a systematic monitoring approach.

    e. Participants stressed the importance of a reference database of genetic and morphological characteristics of larvae, in order to conduct effective research on larval dispersal and connectivity using technologies mentioned above.

2. As contractors collect similar types of data using similar methods, and all these data are stored in the ISA DeepData database, a scientific review and analysis on, for instance, connectivity over the entire mid-ocean ridge in the Indian Ocean, can be facilitated by ISA secretariat, following the example of similar research conducted in the Clarion-Clipperton Zone.

III. Developing a collaborative platform for marine scientific research in the mid-ocean ridges in the Indian ocean in support of the implementation of ISA's mandate

1. Participants underlined the importance of collaboration between contractors and scientists in sharing data and samples. For example, sharing of seabed imageries (e.g., ROV dive images) obtained by contractors and depositing biological samples in museums for further research was highlighted as best practices that can be encouraged and facilitated by ISA. However, the long period of time required for specimens to be filed in museum collections and the country-specific

policies for transporting samples were highlighted as major challenges for the development of a streamlined procedure for sample sharing. Close collaboration between local repository institutions and contractors was underscored as key to facilitate the transfer of samples and improve resource efficiency.

2. Participants also emphasized the importance of establishing long-term collaboration for facilitating the exchange of data and knowledge as well as capacity building on marine scientific research, including through ISA's collaboration with member States, contractors and scientific institutions.

3. Participants highlighted the importance of ISA's continued work on organizing workshops on marine scientific research, such as the present workshop, involving a variety of stakeholders and scientists, on a more regular basis. In addition, ISA could actively engage with scientists by, for example, organizing sessions at international scientific conferences. ISA could also promote participation of contractors in these occasions to provide a platform for contractors and scientists to discuss and explore opportunities for collaboration.

4. The ISA Action Plan in support of the UN Decade of Ocean Science for Sustainable Development will provide a framework under which cooperation among contractors and between contractors and scientific communities is facilitated in a systematic way. It was noted that cooperation among interested contractors on specific topics could be also useful.

5. Regarding the possibility of integrating data and information collected by scientific communities into the DeepData database, participants were informed that the ISA secretariat is currently working towards linking the DeepData with other international databases, such as the Ocean Biodiversity Information System (OBIS) under IOC-UNESCO, to enhance biodiversity data sharing and accessibility. In addition, the ISA secretariat is discussing potential collaboration with the International Hydrographic Organization (IHO) to facilitate sharing of bathymetric data collected by contractors as contribution to global seafloor mapping. Through such collaborations, the ISA aims to further develop the DeepData into an interconnected network of scientific data, while ensuring operational efficiency and avoiding data redundancy.

6. Participants emphasized the importance of sharing best practices, especially on research designs, as an important step for making the existing and future research efforts more relevant, applicable, and replicable. In this regard, participants noted a need to develop a strategy to sample the world's deep oceans in a systematic way. In addition, InterRidge's code of conduct for research on the mid-ocean ridges, aimed at promoting sharing of data, samples, and knowledge, was brought to the attention as a good example for catalyzing discussions. Some participants suggested InterRidge to create a working group aimed at producing a unified set of best practices for sampling mid-ocean ridges.

7. Collaboration on interpretation and analysis of scientific data is critical to effective integration of science into policy and engagement with a broader range of stakeholders in various sectors. For example, the Convention on Biological Diversity's Sustainable Ocean Initiative Global Dialogue was highlighted as an important process to facilitate cross-sectoral collaboration for a holistic assessment of the marine environment at the regional scale.

8. With respect to enhancing capacity building and stakeholder involvement in marine scientific research, participants identified the lack of continued research opportunities for beneficiaries of capacity-building programmes after they return to their home countries as a challenge and emphasized the importance of institutional capacity development. It was highlighted that long-term commitment from member States is a prerequisite to address this issue. Establishing research laboratories at institutions in developing countries where local scientists can work with contractors was suggested as a possible way to strengthen capacity at the institutional level.

9. Participants identified facilitating research mentorships as a potential way to enhance collaboration. For example, the Deep-Sea Biodiversity Society (DSBS) has an active mentoring

programme designed to increase the diversity of scientists in deep-sea research.