REPORT OF THE WORKSHOP ON ENHANCING IMAGE-BASED BIODIVERSITY ASSESSMENTS TO ADVANCE DEEP-SEA TAXONOMY

12-14 October 2021, 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 mankind 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 required 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 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 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. In December 2020, the ISA Assembly adopted the Action plan of the International Seabed Authority in support of the United Nations Decade of Ocean Science for Sustainable Development[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.

4. Among six strategic research priorities identified in the action plan, the following priorities highlight the importance of expanding deep-sea knowledge base and standardizing taxonomic information: i) advancing scientific knowledge and understanding of deep-sea ecosystems, including biodiversity and ecosystems functions, in the Area; and ii) standardizing and innovating methodologies for deep-sea biodiversity assessment, including taxonomic identification and description, in the Area.

[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/26/A/17

5. In pursuance of the strategies and priorities identified above, ISA, in collaboration with the Ministry of Oceans and Fisheries of the Republic of Korea (MOMAF) and the National Marine Biodiversity Institute of Korea (MABIK), organized an online workshop on Deep-sea Taxonomic Standardization: strategic approaches for collaboration, from 15-16 September 2020. The workshop successfully identified key needs, priorities, and collaborative approaches for increasing deep-sea taxonomic knowledge, which are being further developed and consolidated into a roadmap to promote effective integration of deep-sea taxonomic information into ISA's efforts for protection of the marine environment.

6. Building on the results of the abovementioned workshop on deep-sea taxonomic standardization, ISA, in collaboration with MOMAF and MABIK, organized an online workshop on Enhancing Image-based Biodiversity Assessments to Advance Deep-sea Taxonomy from 12-14 October 2021. In response to the needs and priorities identified during the previous workshop, this workshop aimed to identify technical means and key elements for a standardized model necessary to facilitate effective sharing and use of image data within the context of ISA, with a view to enhancing deep-sea species identification and quantification, as well as increasing capacity and literacy in deep-sea taxonomy.

7. The workshop was conducted in two separate sessions: technical session for invited experts from 12-13 October 2021 and open session for registered participants on 14 October 2021. The technical session focused on topics related to: i) archiving and utilizing images for the development of species identification methods and facilitation of machine learning for automatic image recognitions on which future Artificial Intelligence-powered tools can rely; ii) standardizing image annotation methodologies and tools; iii) improving methods for image acquisitions and analyses; and iv) innovating image data products and outreach activities using deep-sea taxonomy image platform. The open session focused on: i) providing updates on the results of the technical session; ii) presenting the short-, medium- and long-term priority actions, identified by the previous taxonomic standardization workshop in 2020, for the effective integration of deep-sea taxonomic knowledge into ISA's work on the protection of the marine environment; and iii) exploring potential ways and means to enhance collaboration among members and stakeholders of ISA, including the scientific community, contractors, and decision-makers, for effective generation, use and sharing of deep-sea taxonomic information.

8. Drawing on the results of this workshop, the ISA secretariat can start developing a practical model of sharing images, as well as optimizing and standardizing the application of images for biodiversity assessments, in support of the work of ISA. Likewise, the workshop provided an opportunity to members, contractors, and other relevant stakeholders of ISA in exploring collaborative approaches on innovating image-based deep-sea species identifications, increase the awareness of associated methodologies, and promote capacity-building efforts in the field of deep-sea taxonomy.

9. Part I of the workshop (technical session) was attended by 46 invited experts. A total of 128 participants attended Part II of the workshop (open session) in their individual expert capacities through online registration. The full list of workshop participants is provided in annex I to this report.

I. PART I: TECHNICAL SESSION

A. OPENING OF THE WORKSHOP

10. The Secretary General of the International Seabed Authority, a representative of the Ministry of Ocean and Fisheries (MOMAF) of the Republic of Korea, and a representative of the National Marine Biodiversity Institute of Korea (MABIK), opened the workshop at 6:00 a.m. (Jamaica; GMT-5) on Tuesday, 12 October 2021.

11. Mr. Michael Lodge, the Secretary General of ISA, began his statement by welcoming the

participants. He expressed his appreciation to the Ministry of Oceans and Fisheries of the Republic of Korea and the National Marine Biodiversity Institute of Korea (MABIK) for sponsoring the organization of workshop and collaborating on the design of the workshop programme. He thanked Ms. Kerry Howell (Chair), and speakers and panelists for their scientific and technical contribution to the workshop. He then highlighted the relevance of ISA's mandates given by the UN Convention on the Law of the Sea, particularly on the protection of the marine environment from potential harmful effects that may arise from activities in the Area. He also emphasized ISA's unique role to promote and encourage marine scientific research in the Area and underlined the importance of advancing deep-sea taxonomy in generating biodiversity data, necessary to establish an effective regulatory framework for activities in the Area. The ISA Action Plan in support of the UN Decade of Ocean Science for Sustainable Development was introduced as one of the key frameworks within which ISA's efforts towards promoting marine scientific research are being developed, including standardization and innovation of methodologies for deep-sea biodiversity assessment as one of the six strategic research priorities. Lastly, Mr. Lodge highlighted ISA's previous activities in the field of deep-sea taxonomy, including a series of taxonomic standardization workshops organized since 2013. In particular, he underlined the most recent workshop held in September 2020 that identified key needs, priorities, and collaborative approaches to advance deep-sea taxonomy. These are being consolidated in the form of a roadmap to guide future ISA's activities in facilitating effective integration of deep-sea taxonomic information for the protection of the marine environment.

12. Mr. Sang Keun Song, the Deputy Minister for Marine Policy Office, Ministry of Oceans and Fisheries, Republic of Korea, began his statement by thanking His Excellency, Mr. Michael W. Lodge, the Secretary-General of ISA, as well as Dr. Sun-Do Hwang, the President of the National Marine Biodiversity Institute of Korea, for co-organizing this workshop. He also thanked Ms. Kerry Howell for chairing the workshop and all presenters and participants for their support and contributions. Mr. Song highlighted that the ISA workshop on deep-sea taxonomic standardization held in September 2020 successfully established an important basis for enhancing the collective efforts to advance deep-sea taxonomy, which led to the organization of the present workshop focusing on image-based biodiversity assessment. He emphasized the importance of increasing the utility of image data for effective deep-sea biodiversity assessments, as well as the need to further promote sharing of the best available scientific information among experts and the public for their adequate understanding and active engagement in the work of ISA. Lastly, he noted the ongoing collaboration between the Government of the Republic of Korea and other governments in promoting ocean data and knowledge sharing, as well as its willingness to further collaborate with members and stakeholders of ISA on advancing deep-sea taxonomic research.

13. Mr. Sun-Do Hwang, president of the National Marine Biodiversity Institute of Korea (MABIK), began his statement by thanking His Excellency, Mr. Michael W. Lodge, the Secretary-General of ISA, as well as Mr. Sang Keun Song, the Deputy Ministry of the Ministry of Oceans and Fisheries of the Republic of Korea, for their continuous support and collaboration in advancing deep-sea taxonomy within the context of ISA. He then thanked Ms. Kerry Howell for chairing the workshop and all presenters and participants for their support and contributions to the organization of the workshop. He highlighted the successful outcomes of the ISA workshop on deep-sea taxonomic standardization held in September 2020, including the organization of this workshop. He also emphasized the importance of enhancing image-based biodiversity assessments and MABIK's collaboration with Korea's Ministry of Oceans and Fisheries on digitalizing ocean data and information, particularly in the field of taxonomy. He underlined MABIK's expertise in using marine information systems and its experience in implementing various outreach activities for public engagement. Lastly, he affirmed MABIK's willingness to continue collaborating with ISA and other stakeholders in accelerating the collective efforts towards advancing deep-sea taxonomy.

B. WORKSHOP BACKGROUND, SCOPE AND EXPECTED OUTPUTS

14. The workshop was organized in plenary sessions introduced by selected panelists. The workshop chair, Kerry Howell (University of Plymouth, UK), moderated the workshop deliberation.

15. Under this item, participants had before them following documents: (i) action plan of the International Seabed Authority in support of the United Nations Decade of Ocean Science for Sustainable Development; and (ii) report of the Workshop on Deep Sea Taxonomic Standardization: Strategic Approaches for Collaboration (15-16 September 2020).

16. Luciana Genio (ISA secretariat) delivered a presentation on workshop background, scope and expected outputs.

17. Workshop participants noted the followings:

a) This workshop addresses one of the six strategic research priorities identified in the ISA Action Plan in support of the UN Decade of Ocean Science for Sustainable Development, focusing on standardization and innovation of methodologies for deep-sea biodiversity assessment, including taxonomic identifications and description in the Area.

b) ISA has undertaken various activities to address standardization of methods and analysis for biodiversity assessments, including technical studies, a series of workshops, as well as the biodiversity synthesis for the Clarion Clipperton Zone region. Notably, the virtual workshop on taxonomic standardization in September 2020 discussed strategic collaborative approaches to advance deep-sea taxonomic knowledge and highlighted the importance of taxonomic identifications based on image data and the need to establish reference image libraries.

c) Building on the results of these activities, this workshop aims to identify technical means and key elements for a standardized model necessary to facilitate effective sharing and use of image data within the context of ISA. It is expected that the workshop will support members, contractors, and other relevant stakeholders of ISA in exploring opportunities to collaborate on innovating methods and tools for image-based deep-sea species identifications, effectively sharing images and image-based assessments, and promoting capacity-building efforts in the field of deep-sea taxonomy.

18. Summary of the above presentation is provided in annex II to this report.

C. IMAGE DATA FLOW: ARCHIVING, CATALOGUING, PROCESSING, AND SHARING IMAGE DATA AND INFORMATION

19. Under this item, Kerry Howell (University of Plymouth, UK) delivered a presentation on the image data workflow for biodiversity assessments highlighting challenges faced by those generating and using these data.

20. Workshop participants noted the followings:

a) The workflow of image-based data, as illustrated in annex III, comprises the following steps: (i) collection of images/videos and associated data, (ii) storage of raw images/videos and data, and onward use for non-scientific purposes (e.g., education and outreach), (iii) quality control and cleaning of images/videos and data, (iv) analysis of image-based data to extract biodiversity information, and (v) storage of annotated and biological data.

b) Different gear types produce different qualities of images/videos, which affects the ability to discriminate animals in the imagery. This leads to challenges in comparing biodiversity data across surveys. The lack of systemic archiving of raw data files makes image-based data rarely findable, accessible, interoperable, or reusable (FAIR). In addition, data are not

currently machine readable due to the lack of common formats and standards for naming and archiving imagery and metadata files. Common standards and tools to support image analyses are also lacking. Quality control procedures are not standardized in image-based data analysis. Effective storage of processed data needs to be considered to support the development of deep-learning, artificial intelligence (AI)-based tools to accelerate the annotation process.

21. Summary of the above presentation is provided in annex II to this report.

22. Participants exchanged their insights and views, in response to the presentation, including some points that are summarized below, *inter alia*:

a) The need for standardization was noted at the various steps of image data workflow for biodiversity assessments, including acquisition of benthic, pelagic, and specimen images, metadata reporting templates, reference image catalogues, image annotations, and quality control processes.

b) The importance of quality control and assurance was emphasized for ensuring consistency among image-based surveys, enabling scientifically robust compilation, synthesis, and analysis of image data for effective environmental management, including the development and implementation of regional environmental management plans (REMPs). Possible modalities for quality control of image data were discussed, including periodic regional workshops to gather relevant experts, in close linkage with the REMP processes for relevant mineral provinces.

c) The challenges of a globally declining taxonomic skill base were highlighted, associated with the difficulty of identifying animals in image data and limited access to taxonomic expertise. Targeted training for both para-taxonomists and traditional taxonomists is needed, as well as enhanced collaboration among them.

D. IMAGE ACQUISITION: NEEDS AND REQUIREMENTS FOR BIOLOGICAL IMAGE SURVEYS AND LABORATORY STUDIES

23. Under this item, the following experts from various backgrounds and expertise shared in a panel discussion their ideas and insights on different approaches to image acquisition:

a) Daniel Jones (National Oceanography Centre, UK) on image surveys of benthic communities;

b) Dhugal Lindsay (Japan Agency for Marine-Earth Science and Technology, Japan) on image surveys of pelagic communities; and

c) Daniela Zeppilli (L'Institut Français de Recherche pour L'Exploitation de la Mer, France) on microscopic observations, including 3-dimensional imagery.

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

25. Participants exchanged their views, insights and suggestions in response to the panel discussion, including some points that are summarized below, *inter alia*:

a) Video data are important for assessing pelagic communities as they allow to capture behavioral features that are critical for species identification, while still images are generally sufficient for benthic communities. The quality required for pelagic video data varies according to gear type, with very high quality (8K resolution[6]) for towed camera,

[6] 8000 pixels (7680 x 4320)

and lower resolution (4K resolution[7] or even High Definition[8] (HD)) for Remotely Operated Vehicles. For benthic surveys, it was suggested that video or imagery acquisition should be at 1-3 meter above the seafloor, although specific requirements will vary depending on the particular purpose of data collection.

b) Specific guidance is required for *ex-situ* images of physical specimens taken in offshore laboratories. This should draw from existing initiatives, such as the ongoing efforts across networks of natural history museums[9] to standardize digitization, archival, and exchange of physical specimens, including specimen images. Photographs as well as 3-dimensional scans of physical specimens would also be effective for validation of taxonomic identifications by expert taxonomists, avoiding the potential loss of valuable physical specimens, including small infauna specimens and morphotypes.

c) The documentation of best practices for image acquisition was suggested for compilation into the Ocean Best Practices System[10] of IOC-UNESCO, building on existing guidelines and manuals for image-based survey and specimen imagery. Some examples of existing guidelines were provided including, *inter alia*:

- ISO (International Organization for Standardization) recommendations for the gathering of image-based data at seafloor where epifauna and benthopelagic fauna with a minimum dimension of 1 cm are used as a proxy for the status of the biological community: ISO 23731:2021.
- New technical committee for standardization in the field of biodiversity (under development): ISO TC 331.
- Field manuals developed by the Marine Biodiversity Hub for Australian waters[11].
- ISA draft guidelines for the establishment of baseline environmental data[12]; section on megafauna imagery provides specific guidance on image acquisition.

E. INFRASTRUCTURE NEEDS FOR IMAGERY DATA ARCHIVING AND EXCHANGE

26. Under this item, the following experts from various backgrounds and expertise shared in a panel discussion their ideas and insights on infrastructure needs for imagery data archiving and exchange:

a) Sheldon Carter (ISA secretariat) on the ISA DeepData database;

b) Pieter Provoost (IOC-UNESCO) on the Ocean Biodiversity Information System (OBIS) database; and

c) Kakani Katija (Monterey Bay Aquarium Research Institute, USA) on the FathomNet database.

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

28. Participants exchanged their views, insights and suggestions in response to panel discussion. including some points that are summarized below, *inter alia*:

a) Several possible ways for storage and sharing of large amounts of image and video data

[7] 4000 pixels (3840 x 2160)
[8] 1080 pixels (1920 x 1080)
[9] E.g., in Europe: https://www.dissco.eu/, in USA: https://www.idigbio.org/
[10] https://www.oceanbestpractices.org
[11] https://www.nespmarine.edu.au/field-manuals-marine-sampling-monitor-australian-waters.
[12] https://isa.org.jm/files/files/documents/expected _scope_and_standard_of_baseline_data_collection.pdf

were identified, including *inter alia*: (i) cloud-based storage and the use of persistent Uniform Resource Locators (URLs) and Digital Object Identifiers (DOIs); (ii) storage of high resolution data on external hard drives, with a subset of lower resolution (compressed) data stored online; (iii) use of tags in video data to extract relevant sections; and (iv) storage and sharing of annotated data via platforms like FathomNet. It was noted that the ISA DeepData database can potentially increase its storage capacity (hardware) with the ability to create interoperable links with other databases.

b) Development and implementation of data use policies is needed to protect valuable taxonomic information, where this may be required/desired.

c) Detailed and standardized metadata are critical for effective archiving, sharing and use of imagery data. It was noted that ISA's DeepData reporting templates were recently updated in alignment with accepted international standards such as the Darwin Core for biological information; these templates are living documents and will continue to be updated as needed to incorporate new standards. Examples of existing metadata templates and developing standards were provided, including *inter alia*:

- World Ocean Database (WOD)[13];
- Audubon Core (akin to Darwin core for specimens)[14];
- Ecological Metadata Language (EML)[15];
- Image FAIR Digital Objects (iFDOs)[16];
- Dublin Core[17];
- NASA PDS4[18];
- Integrated Marine Observing System (IMOS)[19]; and
- ISO 23731, 23732, 23734. Further guidelines for image metadata reporting may be submitted to the new ISO standard for biodiversity (ISO TC 331).

d) It was also noted that *ex-situ* specimen imagery needs to be linked with *in-situ* imagery.

e) File naming conventions are needed to support machine readability of image data. As contained in ISO 23731 standard, filenames for archived images should include a unique identifier for the cruise/survey/platform, the date and time of the first frame in the format YYYYMMDD-HHMMSS, and a camera identifier, separated by hyphens (e.g., PLATFORM-YYYYMMDD-HHMMSS-CAMERA1-01.mov[20]).

F. IMAGE ANNOTATIONS: STANDARD REFERENCE CATALOGUE

29. Under this item, the following experts shared in a panel discussion their ideas and insights on different software for image annotations and classification:

[13] World Ocean Database | National Centers for Environmental Information (NCEI) (noaa.gov);
[14] Audubon Core - Audubon Core (tdwg.org). Note: It is possible to provide input to Audubon core terms.
[15] Ecological Metadata Language (EML) (ecoinformatics.org). Note: dataset level metadata.
[16] Overview - FAIR marine images (marine-imaging.com). Note: a set of metadata fields grouped by core, capture and content information.
[17] DCMI: Home (dublincore.org)
[18] PDS: What Is PDS4? (nasa.gov)
[19] IMOS AUV Images Viewer (aodn.org.au)
[20] Example developed during the Marine Imaging Workshop, organized by Ocean Networks Canada, Victoria, in 2019, (https://marine-imaging-workshop.com/miw_2019.html).

a) Timm Schoening (GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany) on *Biigle* and other annotation tools;

b) Candice Untiedt (Commonwealth Scientific and Industrial Research Organization, Australia) on *CATAMI* classification scheme; and

c) Kirsty McQuaid (Plymouth University, UK and the South African National Biodiversity Institute, South Africa) on *SMarTaR-ID* framework.

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

31. Participants exchanged their views, insights and suggestions in response to the panel discussion, including some points that are summarized below, *inter alia*:

a) Aligning efforts among software developers to ensure standard formats of data inputs and outputs is crucial to enhance inter-operability among image annotation tools. For instance, there is ongoing work for standardizing video annotations on Squidle into Darwin Core format, while VARS software allows users to choose the export format. Another example of online video annotation tool – Tator[21] - was indicated for considering a common export format that would be accepted by the wider community. The development of a 'translation tool' was suggested to facilitate linking annotation fields by different users/systems. Some research institutions (e.g., IFREMER) have initiated this effort on an *ad hoc* basis, but a standardized approach would be needed for wider accessibility of the data. OBIS was suggested as a platform to export image annotation data, although Darwin Core is limited to contain annotation information. Other controlled vocabularies (e.g., *CATAMI*, *SMarTaR-ID*, EUNIS) could be extended to OBIS, aligned with annotation tools.

b) It was noted that standard image reference catalogues are needed for species identifications, considering inter-operability across taxonomic and morphological classifications. For example, Squidle has a translation scheme linking WoRMS catalogue of taxonomic names and *CATAMI* classification scheme, and it also allows creation of new labels. The use of multiple classification schemes in one annotation (e.g., multiple labelling trees available in *Biigle*) was also suggested as a possible way to standardize identifications across image annotators. Currently some annotation tools allow adding multiple names in the *Comments* field, as in Squidle.

c) Regarding the use of open nomenclature, guidelines for handling temporary names (which may be non-scientific) are provided by OBIS, but those names must be linked to a scientific name to the lowest possible taxonomic rank, because WoRMS (the taxonomic backbone of OBIS) only accepts formally published names; further details for the standardization of open taxonomic nomenclature for image-based identifications are available in a recent peer-reviewed publication[22]. The development of a search function in OBIS for temporary names was suggested.

d) Mechanisms to assign uncertainty in image-based species identifications should be considered, such as assigning fuzzy labels (e.g., 50% chance being morphospecies 1, 50% chance being morphospecies 2). The need to establish a set of standardized modifiers to accompany the chosen classification system was indicated. Intercalibration workshops for comparing image-based species identifications among different annotators were also

[21] www.tator.io
[22] doi:10.3389/fmars.2021.620702

considered important for standardizing vocabularies and crosswalks between annotation tools and classification schemes.

e) The need to standardize color correction and initial processing of imagery data prior to image analysis was emphasized. Similarly, consideration should be given to standardize the use of scale bars or lasers for size measurements and biomass estimates; scaling of oblique videos/images can be solved by use of stereo cameras.

f) The importance of quality control and assurance of image-based identification was highlighted, although access to qualified expert taxonomists is limited. Modalities for training image annotators with expert taxonomists were suggested, for instance by allocating specific funds for these training activities under research grants, as well as within the ISA contractors training program. Dedicated training courses and training materials (e.g., video tutorials, identification guidelines) were also suggested to enhance image annotation capacity. Course fees and paid access to training resources (e.g., Skillshare platform[23]) were suggested to financially support taxonomic expertise. Mechanisms to support members of developing States were also discussed (e.g., reduced fees). Increasing the number of qualified taxonomists and annotators would also contribute to developing a quality assurance process based on accreditation of imagery identifications. This would ensure the quality of data that is used for decision making processes, as well as for further development of automated tools using artificial intelligence. The certification of identification skills would however require accredited training to be developed, for example through the Ocean Teacher Global Academy.

G. IMAGE DATA PRODUCTS: KEYS, GUIDES, AND OUTREACH MATERIALS

32. Under this item, the following experts from various backgrounds and expertise shared in a panel discussion their ideas and insights on various image data products:

a) Kamila Mianowicz (Interoceanmetal Joint Organization, Poland) on Atlas of Megafauna;

b) Adrian Glover (Natural History Museum, UK) on DeepSea ID and Clarion-Clipperton Zone (CCZ) species list; and

c) Youngdawng Moh and Jinwook Back (National Marine Biodiversity Institute of Korea, Republic of Korea) on image platform for public outreach.

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

34. Participants exchanged their views, insights and suggestions in response to the panel discussion, including some points that are summarized below, *inter alia*:

a) Specific tags or labels should be used to store selected images with identified value for media products, public engagement, and deep-sea literacy projects. Several examples of imagery use and existing resources for public education and outreach were provided, including deep-sea image guides[24], 3-dimensional models[25] and virtual reality reconstructions of deep-sea specimens and habitats;

[23] www.skillshare.com
[24] MBARI's Deep-Sea Guide
[25] MBARI (@mbari) - Sketchfab

b) A citizen science platform[26] for image annotations has also been developed for hydrothermal vent systems and is expected to be expanded to other deep-sea ecosystems. The Deep Ocean Education Project[27] was also listed among existing initiatives for deep-sea literacy.

H. SUMMARY AND CONCLUSION

35. The workshop chair provided a summary of the workshop results, including ways and means for effective and standardized generation, use and sharing of image data and information to support image-based biodiversity assessments and advance deep-sea taxonomy. Key points are summarized below, *inter alia*:

a) Image-based surveying and monitoring is a very powerful noninvasive methodology for investigating the deep-sea environment. Deep-sea imagery has become an essential tool, providing a different perspective on deep-sea ecosystems, from those obtained from traditional sampling methods such as trawling and coring. However, deep-sea image-based biodiversity assessments face many challenges at every step in the process of the image data workflow: image data acquisition, storage, processing, analysis, archiving and reporting.

b) Survey designs considering specific scientific goals are of utmost importance during the image acquisition phase. The compilation of existing guidelines and manuals for image acquisition into the Ocean Best Practice System of IOC-UNESCO was suggested to facilitate the standardization of deep seafloor and water column image-based surveys. Existing initiatives for museum specimen digitalization were also noted to provide guidance for imaging physical specimens, including at-sea and in-land laboratories.

c) Regarding infrastructure needs for imagery data archiving and exchange, possible next steps include the implementation of metadata reporting standards to ensure data are Findable, Accessible, Interoperable and Reusable (FAIR) and the development of the ISA DeepData database for storage of raw data as well as annotated metadata for wider use, including machine-learning datasets and artificial intelligence developments. The recently launched FathomNet provides an example of possible ways to store and share annotated data.

d) Aligning efforts among software developers to standardize data inputs/outputs formats is crucial for interoperability of data produced by the different annotation tools. Another important step is the intercalibration of image-based identifications. This can be achieved by hosting regional workshops related to different mineral provinces, in close linkage with the REMP process, to standardize image references catalogues (and annotations), including morphological and taxonomic classification schemes. The need to develop a pool of taxonomic expertise and platform for knowledge exchange was highlighted, as well as the development of training materials and the identification of trainers among taxonomic experts. An accredited quality assurance/quality control (QA/QC) process for annotated data was also considered of key importance to ensure data quality.

e) Deep-sea imagery and videos are a valuable resource, not only for generating biodiversity data but also as an educational tool and public outreach. The development of specific tags to identify and store imagery and video for non-scientific purposes (e.g., media products, education, etc.) was suggested. Data use policies and protection of ownership were considered important in the development of various products and initiatives for wider

[26] Deep Sea Spy (ifremer.fr)
[27] Deep Ocean Education Project | A Hub For Underwater Resources

dissemination of deep-sea images and videos. Several examples of ongoing activities were shared, including 3-dimensional models and games.

36. The workshop participants expressed appreciation to the chair for her able steering of the workshop deliberation and excellent summary, the ISA secretariat and MABIK for organizing the workshop, and the Government of the Republic of Korea for financially sponsoring the workshop, and called for a continuous support for this important initiative.

I. CLOSURE OF THE WORKSHOP

37. The workshop was closed at 10:00 a.m. (Jamaica; GMT-5) on Wednesday, 13 October 2021.

II. PART II: OPEN SESSION (14 OCTOBER 2021)

A. OPENING OF THE WORKSHOP

38. The Secretary General of the International Seabed Authority, a representative of the Ministry of Ocean and Fisheries (MOMAF) of the Republic of Korea, and a representative of the National Marine Biodiversity Institute of Korea (MABIK), opened the workshop at 6:00 a.m. (Jamaica; GMT-5) on Thursday, 14 October 2021. Their opening messages are summarized in section I.A above.

B. WORKSHOP BACKGROUND, SCOPE AND EXPECTED OUTPUTS

39. The workshop was organized in plenary sessions introduced by selected speakers and panelists. The workshop chair, Kerry Howell (University of Plymouth, UK), moderated the workshop deliberation.

40. Under this item, participants had before them following documents: (i) action plan of the International Seabed Authority in support of the United Nations Decade of Ocean Science for Sustainable Development; and (ii) report of the Workshop on Deep Sea Taxonomic Standardization: Strategic Approaches for Collaboration (15-16 September 2020).

41. Luciana Genio (ISA secretariat) delivered a presentation on workshop background, scope and expected outputs.

42. Summary of the above presentation is provided in annex II to this report.

C. ENHANCING IMAGE-BASED BIODIVERSITY ASSESSMENTS TO ADVANCE DEEP-SEA TAXONOMY

43. The workshop chair briefed the workshop participants on the key results of Part I of the workshop, as summarized in Part I.H above.

44. Participants exchanged their insights and views, in response to the presentation, including some points that are summarized below, *inter alia*:

a) In face of the recognized global shortage of deep-sea professional taxonomists and limited job opportunities, it is necessary to develop capacity in deep-sea taxonomy. Capacity building and training in image-based taxonomic identifications should consider both remote (e.g., video tutorials) and in-person training modalities, including access to physical specimens for observation of morphological features that are difficult to recognize in imagery data. Training opportunities should be varied to consider different levels of capacity development needs (e.g., post-graduate studies under the ISA contractor training program, ISA-IFREMER postdoc fellowship) and flexible to allow wider participation of candidates

with different time availability (e.g., employed, and unemployed participants). Training may also be required for specific taxa (e.g., copepods or deep-sea fish), as well as for use and analysis of image-based biodiversity data to support environmental monitoring and impact assessments.

b) Reviewing and updating the list of professional taxonomists, originally collated through the International Network for scientific investigation of Deep-sea ecosystems (INDEEP) initiative, would be a first step to establish a network of deep-sea taxonomic expertise to provide community support in image-based, as well as traditional taxonomy.

c) Development of morphological keys that align with taxonomic classification, following the example of the SMarTaR-ID project, is needed to bridge the gaps between image-based and specimen-based identifications. These will aim to be multi-entry keys, rather than dichotomous, to ease identification in cases where important morphological features may be obscured in images. It was noted that aligning morphology and taxonomy may not always be possible, and in such cases new morphological keys that don't necessarily align with traditional taxonomy may be required to support image-based identification. The inclusion of open nomenclature (i.e., temporary names that have not been formally published) in the WoRMS database is currently being considered by its Steering Committee.

d) Standardization of image acquisition, both *in-situ* and *ex-situ* was emphasized, and the documentation of best practices into the Ocean Best Practices System of IOC-UNESCO was suggested to support delivery of consistent data sets. Involving taxonomists at the image acquisition phase was considered important to ensure that imagery would support species identifications. Details of the image acquisition workflow (e.g., set up used in offshore laboratory specimen imagery) should be recorded (through photographs, notes, protocols, etc.) as part of metadata associated with image data.

e) It was noted that image surveys could focus on priority taxa to be determined based on scientific criteria such as the value for assessing ecosystem change. An example for identifying those priority taxonomic groups that are likely to be informative for biodiversity monitoring and impact assessment was provided for the Australian Integrated Marine and Coastal Regionalization process[28].

D. ROADMAP TO PROMOTE EFFECTIVE INTEGRATION OF DEEP-SEA TAXONOMIC INFORMATION INTO ISA'S EFFORTS TOWARDS FACILITATING ACTIVITIES IN THE AREA IN AN ENVIRONMENTALLY RESPONSIBLE MANNER

45. Under this item, Luciana Genio (ISA secretariat) delivered a presentation to introduce the short-, medium- and long-term priority actions, identified by the previous taxonomic standardization workshop in 2020, for the effective integration of deep-sea taxonomic knowledge into ISA's work on the protection of the marine environment in the Area.

46. Participants exchanged their insights and views, in response to the presentation, including some points that are summarized below, *inter alia*:

a) It was noted that the ISA Sustainable Seabed Knowledge Initiative (SsKi) will provide the framework to implement the priority actions for taxonomic standardization , across all mineral provinces where exploration is currently taking place.

[28] OHara_D4_M7_RPv5_Expanding our Spatial Knowledge to Support Best Practice Reviews.pdf (nespmarine.edu.au)

b) It was clarified that while SsKi aims to contribute to the UN Decade of Ocean Science for Sustainable Development and the global knowledge base through scientific research associated with mineral exploration activities, in line with ISA's mandate to promote marine scientific research in the Area, it is not a prerequisite for ISA's regulatory functions in relation to regional or local environmental baselines.

47. Summary of the above presentation is provided in annex IV to this report.

E. IDENTIFYING PARTNERS, DONORS, AND RELEVANT INITIATIVES FOR THE EFFECTIVE GENERATION, USE AND SHARING OF DEEP-SEA TAXONOMIC INFORMATION

48. Under this item, the following experts delivered presentations on ongoing and future initiatives that will contribute to the effective implementation of collaborative activities to advance deep-sea taxonomy:

a) Ward Appeltans (IOC-UNESCO);

b) Tammy Horton (World Register of Marine Species);

c) Muriel Rabone (Natural History Museum of UK);

d) Daniela Zeppilli (L'Institut Français de Recherche pour L'Exploitation de la Mer); and

e) Aurore Maillet (European Commission).

49. Participants exchanged their insights and views, in response to the presentation, including some points that are summarized below, *inter alia*:

a) The importance of linking and cross-referencing *in-situ* imagery, *ex-situ* specimen imagery and voucher specimens in registered collections was highlighted to assist taxonomic identifications. Likewise, the importance of building robust environmental DNA libraries and linking these to images was emphasized. These efforts should align with other global initiatives such as the Darwin Tree of Life[29] and Earth Biogenome[30] to avoid duplication and strengthen synergies.

b) The growing number of new species described in the Clarion Clipperton Zone, one of the most sampled deep-sea regions, demonstrates the value of scientific research being undertaken through collaborative activities among ISA contractors and scientific communities. It also highlights the need to expand such collaborative efforts to other regions. Within the context of ISA Action Plan in support of UN Decade of Ocean Science for Sustainable Development, including through SsKi, ISA can continue to make its efforts to establish a partnership framework to support science-industry collaborations globally, in a transparent and inclusive manner, including developing States members of ISA.

50. Summaries of the above presentations are provided in annex IV to this report.

F. SUMMARY AND CONCLUSION

51. The workshop chair provided a summary of the workshop results, including suggested approaches to promote coherent, collaborative and scientifically robust ways and means for enhancing taxonomic knowledge of biodiversity in the Area. Key points are summarized below, *inter alia*:

[29] Darwin Tree of Life – Reading the genomes of all life: a new platform for understanding our biodiversity
[30] Earth BioGenome Project

a) Taxonomic identification of deep-sea species is a topic that has attracted much interest in recent years and is fostering innovative developments of automated technologies such as those based in imagery. There are several challenges to be addressed at the various stages of image and video data workflow for enhanced accessibility and interoperability of data, to support scientifically and statistically robust biodiversity assessments.

b) During the technical session of this workshop (see Part I of this report), current developments in image data acquisition, archiving, processing, and reporting have been shared and possible means to improve data standardization were suggested through collaborative activities drawing on existing initiatives. Use of deep-sea imagery data beyond scientific purposes was highlighted and examples of education and public engagement activities were provided.

c) The need to support training and capacity building in image-based deep-sea taxonomy was also emphasized, not only to assist with standardization of images annotations but also to ensure quality control and assurance of datasets that can be used for artificial-intelligence based methodologies for species identifications. A series of activities were suggested, including web-based and in-person training opportunities.

d) Short, medium, and long-term collaborative efforts to address priorities for deep-sea taxonomic standardization will make a critical contribution to ISA's work on the protection of the marine environment in the Area. A global partnership framework is being established in the scope of ISA's Sustainable Seabed Knowledge Initiative (SsKi), providing the financial and technical means to advance deep-sea biodiversity knowledge in line with the strategic research priorities identified in the ISA's Action Plan in support of the UN Decade of Ocean Science for Sustainable development.

G. CLOSURE OF THE WORKSHOP

52. The workshop was closed at 10:00 a.m. (Jamaica; GMT-5) on Thursday, 14 October 2021.

Annex I

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Annex II

SUMMARY OF THEME PRESENTATIONS

PART I: TECHNICAL SESSION (12-13 OCTOBER 2021)

Presentations delivered under agenda item 2

Workshop background, scope and expected outputs

By Luciana Genio (ISA Secretariat)

Protection of the marine environment from harmful effects which may arise from activities in the Area is at the core of ISA's mandates. ISA also has the duty 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 line with the ISA's Strategic Plan and High-Level Action Plan for the period of 2019-2023, the ISA Assembly in 2020 adopted the ISA Action Plan in support of UN Decade of Ocean Science for Sustainable Development to formalize ISA's contribution to the UN Decade. This workshop addresses one of the six strategic research priorities identified in the action plan, focusing on standardization and innovation of methodologies for deep-sea biodiversity assessment, including taxonomic identifications and description in the Area.

ISA has undertaken several activities to address standardization of methods and analysis for biodiversity assessments, including technical studies, a series of intercalibration workshops, and the biodiversity synthesis for the Clarion Clipperton Zone region. In particular, ISA hosted a virtual workshop on taxonomic standardization in September 2020 to discuss strategic collaborative approaches for advancing deep-sea taxonomic knowledge. Addressing requirements of taxonomic identifications based on image data, and the need to establish reference image libraries were identified as a key priority for enhancing deep-sea species identification and quantification, as well as increasing capacity and literacy in deep sea taxonomy.

This workshop aims to identify technical means and key elements for a standardized model necessary to facilitate effective sharing and use of image data within the context of ISA. The various steps of the image data workflow, from acquisition, to archival and exchange, processing and annotations, and the creation of image data products for multiple users will be the focus of the expert deliberations. The workshop is expected to support members, contractors, and other relevant stakeholders of ISA in exploring opportunities to collaborate on innovating methods and tools for image-based deep-sea species identifications, effectively sharing images and image-based assessments, and promoting capacity-building efforts in the field of deep-sea taxonomy.

Presentations delivered under agenda item 3

The challenges faced in using image and video data

By Kerry Howell, University of Plymouth, UK

The workflow of image-based data comprises the following steps: (i) collection of images/videos and associated data, (ii) storage of raw images/videos and data, and onward use for non-scientific purposes (e.g., education and outreach), (iii) quality control and cleaning of images/videos and data, (iv) analysis of image-based data to extract biodiversity information, and (v) storage of annotated and biological data. Each step in this pathway presents challenges to those who generate and use these data. Different images and videos produced by different gear types can undermine the ability to discriminate animals in the imagery, which lead to challenges in comparing biodiversity data across surveys. Raw data files from survey cruises are not usually archived in a systematic manner and may only be archived locally by individual researchers or institutions undertaking the surveys. Therefore, image-based data are rarely

findable, accessible, interoperable, or reusable (FAIR). There are no common naming formats for imagery and metadata files, no common folder structures for archiving, no common metadata standards, and so data are not currently machine readable.

In addition, there are no common standards around the analysis process, and there are no common standards for naming morphotaxa due to the lack of global morphotaxa/species reference library. Different software is currently available and used for imagery annotation, and there are currently no agreed quality control procedures in image-based data analysis. Quality control for data generated by different observers is needed, as well as to check if identifications are accurate and conform to yet to be agreed standards. At the final step, effective storage of processed data needs to be considered. Annotated data is very useful for training both humans and machines, and well-archived annotated datasets can be used to support the development of deep-learning, artificial intelligence (AI)-based tools to speed up the annotation process. At present there is no global database to archive this sort of data, often consisting of temporary names or morphotaxa information. This workshop aims to address the challenges associated with each of these steps in the collection, use and storage of image-based data, and identify possible ways forward considering new innovations.

Presentations delivered under agenda item 4

Image surveys of benthic communities

By Daniel Jones and Erik Simon-Lledó, National Oceanography Centre (NOC), UK

Image-based assessments are increasingly common. Imaging is a relatively quick, quantitative, and non-destructive approach for assessing benthic megafaunal communities. Effective survey requires clear scientific objectives, of which several are highlighted in the Legal and Technical Commission of ISA's guidance of contractors for the assessment of the possible environmental impacts arising from exploration activities in the Area (ISBA/25/LTC/6/Rev.1). The most common objective, "assessments of abundance, biomass, species structure and diversity of megafauna," highlights three primary requirements, each with multiple considerations. These are: 1) unbiased estimates of the sample population under investigation; 2) consistent results that are comparable between and within surveys; and 3) results at the appropriate level of accuracy and precision for the assessments required. For 1) it is important to define an appropriate sampling design, identify the sample population and obtain unbiased and independent estimates of it. For 2) it is important to be consistent in the size of organisms assessed (often megafauna is considered >10mm in size), the taxonomic resolution and the morphospecies identified (both within and between surveys). Finally, for 3) the sample unit size (single images are very rarely an effective sampling unit) and the number of replicates is important. These requirements are different for different parameters (e.g., abundance, biomass, species structure, etc.) and influence the potential for testing changes, for example those associated with monitoring of mining disturbance. Once these considerations are documented it is easier to select appropriate imaging methodologies. In our experience, benthic assessments are more straightforward with downward looking still images. In the Clarion Clipperton Zone (CCZ) for example, thousands of high-quality photographs usually need to be obtained by whatever platform can do this effectively. Software platforms for image annotation such as BIIGLE facilitate this laborious task as well as greatly improve the potential for quality control. The use of standardized image catalogues is also important, such as the catalogue developed by NOC for the CCZ.

Imaging surveys of pelagic communities

By Dhugal Lindsay, Japan Agency for Marine-Earth Science and Technology, Japan

Cameras and lights on crewed submersibles, remotely operated vehicles (ROVs) or towed camera systems are invariably optimized for imaging benthic organisms. Lights are normally directed in the

same direction as the cameras for furthest light penetration and therefore maximum range. The highly reflective seafloor is much brighter than the marine snow particles between it and the camera, allowing clear images of benthos to be obtained. Altimeter data and/or spaced laser beams provide an estimate of organism sizes. Such a set-up is sub-optimal for imaging-based surveys of midwater fauna. Many larger midwater organisms are gelatinous and reflect light poorly, due to either transparency as with jellyfish, or light-absorbing pigments as with many fish. It is also much harder to successfully target a 1-cm diameter, translucent jellyfish with a laser-based sizing system than it is to hit somewhere on the seafloor. Imaging needs and requirements for midwater surveys include side lighting for highest contrast, high resolution to see fine details, and fast frame rates to use behavior to help with species identifications. Image files should ideally be recorded at 10- or 12-bit depth with lighting that seems a little dark to the human eye using low image/file compression rates that preserve the various shades of black to record the mostly transparent or black-pigmented animals against their black background. An example of an acceptable setup would be video at >4K resolution, 60 frames per second recorded in Progressive recording mode, Apple PreRes 4:2:2 codec. This combination facilitates species identification, but for quantification, imaging needs are even greater. Since a laser pointer system does not work in midwater, high-resolution stereo video cameras, synchronously recorded, are needed for organism size and population density calculations. Many smaller animals cannot be imaged by video cameras. Instruments that give size-accurate images, such as shadowgraph cameras or the Underwater Visual Profiler (UVP) can be useful for, for example, attached to a CTD rosette for collecting quantitative data on plankton and marine snow, while sampling water for eDNA analyses and gathering environmental data (temperature, salinity, oxygen, etc.). All imaging systems need to be synchronized, preferably to Greenwich Mean Time (GMT), to combine image datasets for the same "packet" of water. Environmental data parameters and platform/camera metadata (e.g., depth, altitude, zoom ratio, etc.) should be logged at each instrument's native rate and pinned to GMT, rather than logged at the rate of the slowest instrument. Net-caught plankton should be imaged by a system that allows accurate size measurements, such as the ZooScan plankton scanner, and curated in a system such as EcoTaxa, in addition to preserving and storing the physical samples.

Microscopic observations, including 3D imagery

By Daniela Zeppilli, Valentin Foulon and Catherine Borremans, L'Institut Français de Recherche pour L'Exploitation de la Mer, France

Meiofauna communities (i.e., small organisms living in the sediments) comprise some of the most diverse groups of organisms on Earth and possibly one of the best bio-indicators in the context of the rapid increase of anthropogenic pressures in the deep sea. However, due to their very small size and their huge diversity, only a small part of the diversity of this group has been described and knowledge of their biology and ecology is fragmented. Furthermore, the lack of reference genetic information in public depositories makes the use of rapid fingerprinting techniques limited for this important benthic compartment. In the last decades, new technological developments in different imaging fields (e.g., electronic, industrial processes or biomedical) using different kinds of microscopy and camera (e.g., Brightfield, Confocal, Axio Zoom, SEM, Flow imaging, etc.) have allowed 3D-imaging of very small entities with a very high-resolution. All these technologies can also be adapted and used for recognition of small organisms. The combination of very high-resolution imaging with assistance of artificial intelligence classification by convolutional neural networks can allow identification of small organisms at a pace with which human eyes and brains cannot compete. Additionally, the synergy of staining techniques (such as Fluorescence in-situ hybridization) and microscopy can allow the visualization of biological features, providing important functional information associated to species identifications. Development of a standardized method for ecological and biodiversity surveys, in the context of deep-sea mineral exploration and future exploitation, need further development of images acquisition automation, including on one hand high-resolution imaging associated with genetic assignment, widely shared in open access depositories, and on the other hand the development of faster low-resolution

imaging associated with eDNA/metabarcoding approaches.

Presentations delivered under agenda item 5

Image and video data management in ISA DeepData database

By Sheldon Carter, ISA secretariat

In 2019, ISA launched its database called "ISA Deep Seabed and Ocean Database" (DeepData[32]). DeepData is an integrated database system designed to serve as a geospatial data management system. It holds centralized data of public and private information on marine mineral resources and environmental baseline data acquired by the ISA contractors during their exploration activities. The environmental data, including biological, physical, and geochemical parameters of the seafloor and water column ecosystems, is accessible to the public. The GIS capabilities of the system allow users to navigate a map and identify the specific location at which samples were observed. The contractors are required to submit the metadata and results of their sample analysis from exploration surveys in contract areas, using the digital reporting templates recommended by the Legal and Technical Commission. The relationship between sample information, station information and the photo/video file name details is established in the metadata template. The photo and video file names are also recorded in both the environmental and geological reporting templates, associated with the results of the biological, geochemical and geological analysis. The DeepData website acts as a storage medium for photo and video files along with their associated metadata, and it has the capability to provide annotated photo and video files and make them available for user download. However, the major challenge faced is the absence of metadata to complement the photo and video gallery ISA currently has in its possession, without which it has proven difficult to make these files quarriable on the DeepData website. Currently DeepData can only associate one image to each sample/result, but the ability to visualize multiple photos for each sample (by simply scrolling through each photo of the sample) has been discussed as an upgrade of the database. The need to further annotate the current photo and video inventory and facilitate sharing such files with a broader range of members of the scientific community was highlighted.

Imagery data in the Ocean biodiversity Information System (OBIS)

By Pieter Provoost, IOC-UNESCO

The Ocean Biodiversity Information System (OBIS) is a network of over thirty regional and thematic nodes promoting open access to marine biodiversity data and the use of biodiversity data standards and vocabularies. OBIS collaborates on community biodiversity data standards with Biodiversity Data Standards (TDWG) and the Global Biodiversity Information Facility (GBIF). Central to this is the Darwin Core body of standards, which includes a glossary of terms, as well as guidelines for sharing data aligned with these terms using different file formats. Datasets are organized in core and extension tables and packaged together with metadata documents in so called Darwin Core Archives. Darwin Core Archives typically do not contain media files, but rather URLs linking occurrences to image or video resources hosted elsewhere. There are several options for referencing images and including image metadata in biodiversity datasets. While it is possible to add image URLs in the associated *Media* field in the occurrence core, dedicated Darwin Core extensions such as the *Simple Multimedia* extension or the *Audobon Media Description* extension allow for more rich image metadata to be included. Some recent additions to the *Audubon Media Description* extension make it particularly suited for sharing image and video annotations. The extension now includes the fields *xFrac*, *yFrac*, *widthFrac*, *heightFrac*, *startTimestamp*, and *endTimestamp*, which allow for the definition of spatial and temporal regions of interest within media resources.

[32] http://data.isa.org.jm

FathomNet – A global underwater image database for enabling artificial intelligence in the ocean

By Kakani Katija, Monterey Bay Aquarium Research Institute, USA

Ocean-going platforms are integrating high-resolution camera feeds for observation and navigation, producing a deluge of visual data. The volume and rate of this data collection can rapidly outpace researchers' abilities to process and analyze them. Recent advances in artificial intelligence and machine learning enable fast, sophisticated analysis of visual data, but have had limited success in the ocean due to lack of dataset standardization, insufficient formatting, and aggregation of existing, expertly curated imagery for use by data scientists. To address this need, we have created FathomNet, a public platform that makes use of existing, expertly curated data that is built on FAIR data principles and uses community-recognized Darwin CORE archive data formats. FathomNet has over 160k localizations of 1.4k midwater and benthic classes, and contains more than 70k iconic and non-iconic views of marine animals, underwater equipment, debris, etc. All submitted annotation data are licensed under a Creative Commons Attribution - No Derivatives 4.0 International License; images are licensed under a Creative Commons Attribution - Non Commercial - No Derivatives 4.0 International license, and all of the images may be used for training and development of machine learning algorithms for commercial, academic, non-profit, and government purposes. In addition to the database and website, FathomNet includes an ecosystem of services with instructional guides, code, and machine learning models aggregated on GitHub. Additional terms of use involve contributing enrichments, where the user contributes to the FathomNet ecosystem either by defining workflows, sharing trained models, contributing data, or validating existing data, and restricting use to benevolent purposes in ways that are consistent with UN Sustainable Development Goals. As FathomNet continues to develop and incorporate more image data from other oceanographic community members, this effort will enable scientists, explorers, policymakers, storytellers, and the public to understand and care for our ocean.

Presentations delivered under agenda item 6

Image annotation tools

By Timm Schoening, GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany

Image annotation is the process of manually or automatically adding semantic information to image data (photos or videos). The manual process is highly labor intensive, hence efficient software tools are required to make the workload of annotating big image data sets feasible. Several such tools have evolved for the marine image domain over the past years. Three of these tools are prominently used and actively developed: VARS, Squidle and BIIGLE. BIIGLE[33] at present appears to be the most actively developed, most widely used and most efficient tool for the task. It enables photo and video annotation, annotation of entire images or annotation of pixel regions within images by points, polygons or many other shapes. It features quality assurance and control functionality for creating robust and verified annotations, has an open artificial intelligence backend to incorporate automated image analysis methods, provides reference image catalogues, and is connected to the World Register of Marine Species (WoRMs) catalogue of marine names and the Collaborative and Annotation Tools for Analysis of Marine Imagery (CATAMI) classification scheme. It is web-based and thus enables world-wide access to images and annotations, where access to the data can be managed by the data owners. To achieving FAIRness of the entire marine image analysis workflow, BIIGLE is currently being extended to adhere to Findable, Accessible, Interoperable and Reusable (FAIR) principles itself to become a key tool in the image data workflow. Metadata standards like Audubon and those incorporated in SmartarID (Dublin Core and Darwin Core standards), will be available for ingest in, and export from BIIGLE in the near future. Furthermore, BIIGLE will be the first software tool to provide the most comprehensive marine

[33] www.biigle.de

image metadata standard (image FAIR digital objects – iFDOs: www.marine-imaging.com/fair) as a means to not only capture technical and semantic metadata of images, but also scientific information on the accessibility, reusability and interoperability of images and annotations created by BIIGLE.

The CATAMI classification scheme

Candice Untiedt, Commonwealth Scientific and Industrial Research Organization, Australia

Imagery is being increasingly used in deep-sea surveys due to the ethical concerns of using extractive sampling in sensitive habitats and the ability of image-based methods to sample larger areas, collecting qualitative and quantitative data. Despite these advantages, one of the main challenges of using imagery as the source of biodiversity data is the difficulty in accurately identifying fauna. This has led to the development of alternative, often morphological-based classification schemes for the identification and annotation of marine fauna from imagery. The Collaborative and Annotation Tools for Analysis of Marine Imagery and video (CATAMI) classification scheme was developed in Australia, through a collaborative and consultative process including scientists, taxonomists, managers and image annotators. It comprises a hierarchy of standardized, descriptive terms, each with a definition and unique numerical code, Codes for Australian Aquatic Biota (CAAB), for annotating faunal units in imagery. The CATAMI scheme is designed to be useable by non-experts and thus classification within groups is based on morphology, which aligns well with taxonomy in some Phyla. In a recent study, we developed a dual annotation method in which we used both a specific taxonomic identifier and a standard morphological identifier (CATAMI) together to annotate black corals and octocorals, effectively generating two separate data sets with differing resolutions and applications. In an effort to move closer towards global standardization, the use of a standardized classification of morphospecies (e.g., CATAMI) would be beneficial, together with a taxonomic scheme to classify fauna from imagery. This has the advantages of generating standardized annotations suitable for sharing across various research groups and regionally specific, high resolution taxonomic biodiversity data. It also enables flexibility to apply multiple morphotypes to the same operational taxonomic unit, thus accommodating the morphological plasticity and variability inherent in several faunal groups.

SMarTaR-ID: Creating a global standardized marine taxon reference image database

By Kirsty McQuaid, Kerry Howell, Jaime Davies and the SMarTaR-ID Team

SMarTaR-ID is a community-driven project aimed at standardizing reference image catalogues for image-based fauna identification. The current lack of standardization has led to problems with observer bias, merging datasets and application to fields like artificial intelligence. SMarTaR-ID provides a solution whereby image catalogues from different individuals, institutions or nations are standardized to one common reference catalogue. This ensures that across research groups, morphospecies identified in imagery are assigned consistent Operational Taxonomic Units (OTUs), which are unique identifiers. The workflow proposed by SMarTaR-ID involves: 1) submission of reference catalogues to SMarTaR-ID using a standard template; 2) review, quality control and standardization of the catalogue to align with SMarTaR-ID OTUs; 3) merger of quality-controlled images with the main database; 4) supply of images to the web interface; and finally, 4) export of end products as required. The web interface of SMarTaR-ID allows users to search images of different animal groups, using both taxonomic and morphological filters, to identify animals in their own data sets and apply the standardized OTUs. This is supported by information pages for each OTU, which can be downloaded and contain details on morphological features to support identification. The end products will include an e-guide, which can be downloaded for use at sea, links to image annotation software like BIIGLE, and training materials to support image-based identification. Importantly, SMarTaR-ID strives to move beyond just a reference image catalogue to also provide materials such as morphological keys and guides for various taxa. These morphological classification keys are produced by taxonomists and relate to taxonomy as far as is

possible. SMarTaR-ID is first being applied to the North Atlantic, with a beta launch planned for late 2021. Standardization of catalogues in the South Atlantic and Indian Ocean are also under development, with expansion to other areas planned.

Presentations delivered under agenda item 7

Atlas of Megafauna

By Kamila Mianowicz, Interoceanmetal Joint Organization, Poland

The online Atlas of Megafauna[34] results from the study undertaken by the Interoceanmetal Joint Organization (IOM) aimed to determine abundance, composition structure and distribution pattern of deep-sea megafauna in the exploration block H22 of IOM contract area in the Clarion-Clipperton Zone. This forms part of the baseline research on deep-sea biological communities conducted in accordance with the relevant Recommendations of the Legal and Technical Commission. Pictures of the seabed were taken during the IOM-2014 cruise in the contract area. Overall, almost 44,000 individuals were recognized and identified by a para-taxonomist on more than 32,000 images of seabed from 9 photo-profiles of a total length of more than 580 km. Only 544 organisms belonging to 30 taxonomic groups were included in the Atlas. The main criterion was image quality. Taxonomic identification was done to the lowest possible taxonomic category but, since the identification was performed by a para-taxonomist, the current status of taxonomic identification is "lowest ID stet." or "lowest ID indet." In the following year we plan: 1) to identify all stet. organisms; 2) to ensure that all taxonomic names are in accordance with global best practices (namely Darwin Core), therefore we seek collaboration and cooperation with external experts; 3) to supplement imagery data with metadata; and 4) to identify and publish selected images from the IOM-2019 cruise.

Deep Sea ID

By Adrian Glover, Natural History Museum, UK

The Deep Sea ID[35] is an iOS and Android application (App) that can be downloaded from the mobile App Store (search for Deep Sea ID). Its backbone is the thematic database World Register of Deep-Sea Species (WoRDSS) that is hosted by the World Register of Marine Species (WoRMS), currently containing over 28,000 deep sea species. Essentially, it is the App version of the WoRDSS website, with the unique feature of including many beautiful images of deep-sea species, particularly screen grabs, images from ROVs, as well as specimen photographs of macrofauna and megafauna. The App's interface is very user-friendly, allowing users to scroll easily through the taxonomic hierarchy of organisms. With a very efficient search function, a list of organisms is quickly populated upon entering the first few letters of an organism's name. The Deep Sea ID App is useful for verifying the accuracy of spellings, confirming the taxonomic rank an organism belongs to, and the position in the phylogenetic tree, as well as viewing vernacular names. These features are accessible both online and offline, which make it useful for at-sea work. While the application is operative, further development (upgrade to version 1.3) is envisaged, for which financial support is being sought. The updated version would be compatible across all devices, reflect an updated database sourced from WoRMS, and include 200 (already sourced) new images. It is anticipated that a future version (v 1.5) would be released over time providing users with new images and improved features.

Image Platform for Public Outreach

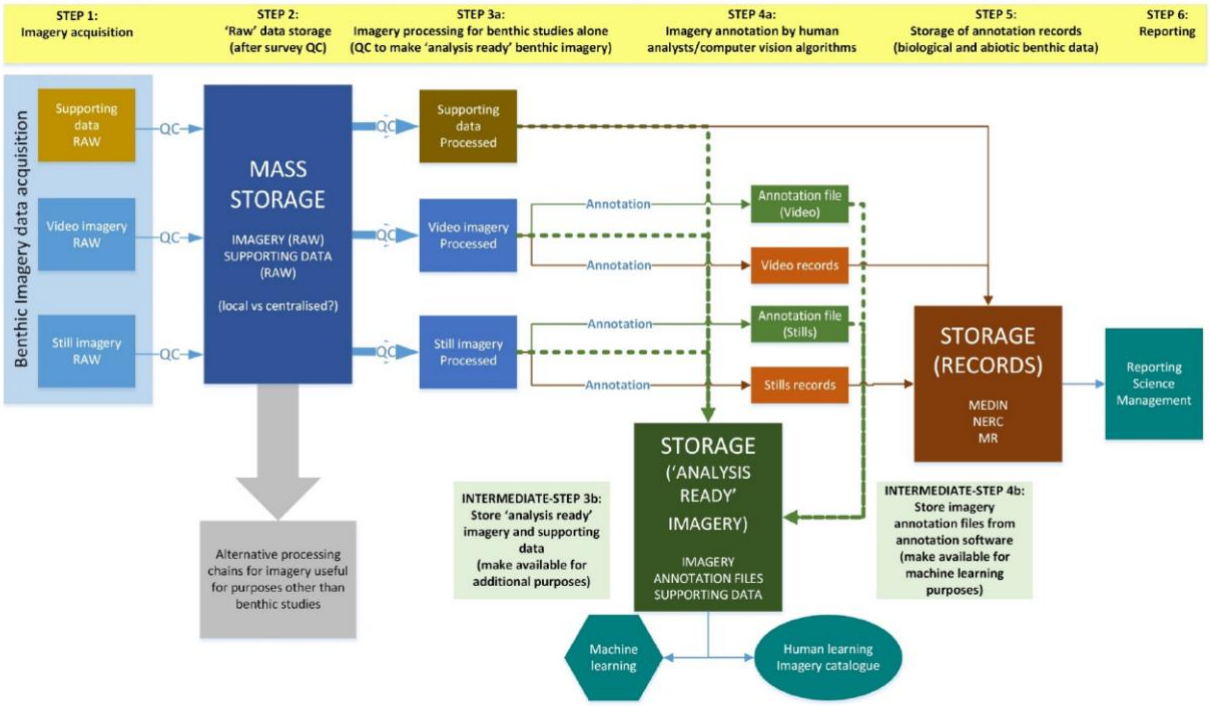
By Youngdawng Moh and Jinwook Back, National Marine Biodiversity Institute of Korea (MABIK), Republic of Korea

[34] https://iom.gov.pl/environmental-research/megafauna-atlas/
[35] http://www.marinespecies.org/deepsea/app.php

Public outreach is a key activity of MABIK, as set in the Act on Establishment and Articles of Association of the Institute. Promoting public outreach helps to establish a shared recognition of a certain social problem among the members of society, which can lead to a policy demand and initiate a new policy process. The motivation for MABIK's digital image platform for public outreach included its geographical disadvantage, lack of awareness due to its short history, and travel restrictions because of COVID-19 pandemic, which have limited public access to its museum. Several challenges were encountered while building an image platform for public outreach, including scoping and assessing the public's demands, as well as establishing internal protocols for image resolution, naming and categorization of files, assigning responsibility for the uploading process, image ownership, among others. Also, the effectiveness of the delivery method (e.g., YouTube, MABIK website, etc.) also needed to be considered for increased impact. If one would apply MABIK's experience to build a deep-sea image platform for public outreach, it would be crucial to first identify a legal basis. Article 244 of UNCLOS could provide this legal basis, since it requires States and competent international organizations to publicize and disseminate knowledge, as well as actively promote the flow of scientific data and information. The fact that the public in general cannot directly access the deep sea could be another supporting argument for a deep-sea image platform for public outreach. It is important to bear in mind that there will be more far-reaching challenges than those accounted by MABIK. A larger number and wider diversity of the public would need to be considered and would possibly require a more elaborate process for collaboration among institutions, including establishing protocols for image sharing (e.g., ownership, image size, resolution, etc.) and securing financial support.

Annex III

IMAGE DATA WORKFLOW FOR BIODIVERSITY ASSESSEMENTS



Modified from Figure 3, JNCC Report 686, Proposed benthic imagery data flows v0.2 (Van Rein, Snaith, Postlethwaite, Lear)

Annex IV

SUMMARY OF THEME PRESENTATIONS

PART II: OPEN SESSION (14 OCTOBER 2021)

Presentations delivered under agenda item 4

Roadmap to facilitate the integration of taxonomic knowledge into ISA's efforts for protection of the marine environment in Area

By Luciana Genio, ISA Secretariat

Robust scientific basis established with the best available data is essential to effectively develop and implement environmental management tools and approaches. To this end, the ISA secretariat is preparing a roadmap to facilitate the integration of taxonomic knowledge into ISA's efforts for protection of the marine environment in Area, drawing on the results of the previous ISA workshop on deep-sea taxonomic standardization, held in September 2020. Enhanced data sharing, innovative tools, networks of experts and organizations, as well as dedicated capacity building and literacy initiatives on deep-sea taxonomy, are among the priority actions to advance taxonomic knowledge and its effective use for the protection of marine environment. The geographic scope of these actions extends to all mineral provinces and deep-sea habitats where current exploration is taking place, as well as potential future exploitation activities, in close linkage with the REMP process. A range of relevant organizations and scientific institutions have been engaged to develop technical and financial collaboration (see below presentations under agenda item 5) for the operationalization of the proposed priority actions. These partnerships were established within the framework of the Sustainable Seabed Knowledge Initiative (SsKi), which has been designed by the ISA secretariat, together with relevant scientific groups and stakeholders for advancing the knowledge of deep-sea environments and ecosystems in support of ISA's mandates. SsKi aims to support the generation of new biodiversity data and development of innovative and cost-effective methodologies for faster and more accurate biodiversity assessments. This initiative will also support capacity-building initiatives at both individual and institutional levels on deep-sea taxonomy research and facilitate cross-sectoral collaboration and holistic efforts to enhance global knowledge underpinning effective protection of the marine environment in the Area.

Presentations delivered under agenda item 5

The Ocean Biodiversity Information System (OBIS) and connection with ISA's Deepdata database

By Ward Appeltans, Intergovernmental Oceanographic Commission (IOC) of UNESCO

For the past 21 years, the Intergovernmental Oceanographic Commission (IOC) of UNESCO has been building a central global data platform that provides free access to the world's ocean biodiversity and biogeographic data. The OBIS system has grown by 20 million records last year and will grow even more rapidly in the coming years, with new innovative observing technologies being put in place, such as environmental DNA and automated imaging devices. OBIS is one of the main building blocks for the development of an integrated ocean observing system, aimed to develop the key indicators to report on the health of our ocean and its natural resources. As such, OBIS is already one of the primary sources of information to support activities under the Convention on Biological Diversity (CBD), and assessments under the UN regular process and the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES). In May 2021, the International Seabed Authority (ISA) joined the OBIS network of 32 regional/thematic OBIS nodes, which connects OBIS with the thousands of data providing institutions and scientists. The ISA OBIS node offers additional capabilities for combining, visualizing, and analyzing deep-sea biodiversity data. However, the available options in OBIS for

storing metadata related to image-based observations is still limited. Currently, it only supports the use of a link to an online image using the DarwinCore term "associated media". Future Darwin Core extensions (e.g., simple multimedia and Audubon media description extensions) are in development by the Biodiversity Information Standards group (TDWG), which OBIS will follow closely and contribute to, for ensuring that (meta)data from images can also be published in OBIS using internationally supported community standards.

World Register of Marine Species (WoRMS)

By Tammy Horton, Chair of the Steering Committee of WoRMS

The World Register of Marine Species (WoRMS)[36] provides "an authoritative classification and catalogue of marine names", openly accessible to all[37]. Use of WoRMS names can help ensure taxonomic consistency for the International Seabed Authority (ISA), by providing the most up-to-date name of the species encountered in faunal surveys. Taxonomic expert editors are the driving force of WoRMS. They are supported by the Data Management Team at VLIZ in Belgium and this collaboration is fundamental to the success of WoRMS. Discussions have been held between WoRMS and the ISA secretariat to develop collaborative activities. WoRMS have recommended the use of its nomenclature as a global standard to provide a robust and standardized taxonomy, have provided advice on the use of its tools such as 'Taxon Match', and discussed the incorporation of Open Nomenclature[38] into the ISA Deepdata database. Formal partnership is still being discussed but is likely to be focused on the following main collaborative activities: 1) ensure the quality of deep-sea taxonomic information through a periodic scientific review (two-way comparison between DeepData and the World Register of Deep-Sea Species: WoRDSS); 2) facilitate the development of toolkits (e.g., WoRDSS keys and guides, Deep-sea ID app;) for enhanced use of taxonomic information generated from activities in the Area; and 3) develop training and sensitization activities for providers and users of taxonomic data related to activities in the Area, with a view to standardizing the data, enhancing data sharing, and raising the awareness of deep-sea biodiversity. The collaboration between WoRMS and the ISA secretariat will include seeking financial support to prioritize this work. With these aims in mind, WoRMS look forward to a productive collaboration with the ISA secretariat, which will improve access to high quality taxonomic information for the deep-sea globally.

Getting to the bottom of it: current state of biodiversity knowledge for the CCZ

By Muriel Rabone and Adrian Glover, Natural History Museum of London, UK

Although exploration activities for polymetallic nodule mining have been underway in the Clarion-Cliperton Zone (CCZ) since the 1970s, there is a well-documented lack of biodiversity knowledge for the region. These knowledge gaps urgently need addressing for effective environmental management of the CCZ. With the launching in 2019 of the ISA DeepData database, the key repository of contractor's data, and a large body of data recently published in the scientific literature, it is timely to review the baseline taxonomic data currently available for the CCZ. In this study, done in collaboration with the ISA secretariat and the financial support of PEW Charitable Trusts, benthic metazoan taxonomic records published in DeepData, from all faunal size classes, have been analyzed together with records available

[36] www.marinespecies.org

[37] Horton et al. (2017). Improving nomenclatural consistency: a decade of experience in the World Register of Marine Species. Eur. J. Taxon. 389: 1-24. (https://hdl.handle.net/10.5852/ejt.2017.389); Vandepitte *et al.* (2018). A decade of the World Register of Marine Species – General insights and experiences from the Data Management Team: where are we, what have we learned and how can we continue? PLoS ONE 13(4): e0194599

[38] Horton, T. et al. (2021). Recommendations for the standardisation of open taxonomic nomenclature for image-based identifications. Frontiers. (https://doi.org/10.3389/fmars.2021.620702)

in other databases (OBIS and GBIF) and the published literature. Over 40,000 records have been published on ISA DeepData database from 25 cruises, over 2,000 on OBIS and GBIF, and over 4,000 in the literature from about 47 cruises. The literature reviewed consisted of 123 publications containing taxonomic information published since 2000, including 166 new species descriptions, 28 new genera and 3 new families. The majority of the CCZ taxonomic literature has been published in the last decade, particularly the last 5 years. New species were mainly arthropods and annelids, but significant numbers of species have been described for nematodes, bryozoans, and sponges. The compilation of a CCZ checklist is in progress, which will include 848 named species records from all published sources (including potential pelagic species for which names are currently being reviewed). Approximately 20-25% of species recorded from the CCZ are new. Regarding known names, over 4,000 morphospecies were recorded in the databases, particularly DeepData and the literature, highlighting that many species are yet to be described. Chao1 species richness estimates are over 5,000, with a species accumulation curve being far from asymptote, indicating that species-level sampling is far from complete and that there are many species still to described in the region. These findings provide a biodiversity knowledge basis that can be iteratively improved, as new biodiversity data from the CCZ region is collected.

Biodiversity underestimation in our blue planet: artificial intelligence REVOLUTION in benthic taxonomy - the BLUE REVOLUTION project

By Daniela Zeppilli, Abdesslam Benzinou, Catherine Borremans, Valentin Foulon, L'Institut Français de Recherche pour L'Exploitation de la Mer, France, and the BLUE REVOLUTION team

In face of the growing anthropogenic pressures on marine ecosystems, there is a scientific and moral obligation to find ways for accelerating biodiversity description. The BLUE REVOLUTION project will develop in-situ/onboard/in-the-field methods (holographic microscopy and 3D-fluorescence imaging) linked with classification tools for high throughput analysis, using accurate automated taxonomic classification based on artificial intelligence. These methods will enable generation of quantitative, genetic, and functional data of benthic communities at speeds unseen before. The project will also develop a standardized method for building open-access reference libraries/data repositories of benthic diversity together with fast and reliable tools for rapid and accurate impact assessments and biodiversity surveys. The project will provide training and education opportunities for the next generation of benthic taxonomists/ecologists to develop skills in species identification, including strong hypothesis-based research programs, as well as the ability to employ cutting-edge techniques. The BLUE REVOLUTION developments will be particularly useful for assessing deep-sea ecosystems (owing to the reduction of animal size with increasing water depth) and monitoring a wide range of human impacts including the future exploitation of mineral resources. With the support of the International Seabed Authority, an 18-month postdoctoral fellowship has been announced, within the framework of the BLUE REVOLUTION project, for candidates from developing States members of ISA. The position will focus on developing and testing new methods and technologies of 3D-imaging techniques for the identification of meiofauna organisms of deep-sea ecosystems found in areas currently being explored for mineral resources.

Enhancing Knowledge of Deep-Sea Ecosystems – Sustainable Seabed Knowledge Initiative (SsKi)

By Aurore Maillet, European Commission, Belgium

Within the context of ISA, the Sustainable Seabed Knowledge Initiative (SsKi) is being developed in alignment with the sustainable development goals (SDGs) of the United Nation's 2030 Agenda, more specifically SDG14 – Life Below Water. The outcomes of SsKi will also be relevant for several intergovernmental discussions on preservation of the marine environment by the Convention on Biological Diversity, the Intergovernmental Conference on an internationally legally binding instrument on the conservation and sustainable use of marine biological diversity of areas beyond national

jurisdiction (BBNJ), as well as fulfilling regulatory mandates by the International Seabed Authority (ISA). The initiative is also well aligned with the European Union's (EU) policy framework, through the EU's Green Deal, which spans many fields of the green transition, as well as its precautionary principle, and affirms that additional research and knowledge is needed in order to clearly demonstrate no serious harm to the environment, before marine mineral exploitation in the Area begins. It is against this premise that the European Commission (EC) has funded other initiatives aimed at identifying and mitigating the impacts of future deep seabed mining to the marine environment, developing environmentally friendly mining technologies, and assisting ISA to develop regional environmental management plans (REMPs) for the Area of the northern Mid-Atlantic Ridge. The main research program of the EU, Current Horizon Europe, spans over 7 years and involves the dedication of 14 million euros to the monitoring and supervising system for exploration and future exploitation activities in the deep-sea. EU collaboration with ISA on SsKi initiative will focus on identification of new species, the development of species identification Apps and Toolkits, as well as underwater image reference libraries with a pilot test in the Mid-Atlantic Ridge area. Bringing together the collective efforts from ISA members, contractors, and independent scientists, SsKi will benefit from the best available expertise in an inclusive and transparent manner.