



## REPORT OF THE WORKSHOP ON THE REGIONAL ENVIRONMENTAL MANAGEMENT PLAN FOR THE AREA OF THE NORTHERN MID-ATLANTIC RIDGE

25-29 November 2019, Évora, Portugal

### INTRODUCTION

1. The International Seabed Authority (ISA) is the organization through which, 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 (“1994 Agreement”), the States Parties to the Convention administer the mineral resources in the Area, and 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 from activities in the Area 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.<sup>1</sup>
2. Pursuant to this mandate, the Council of ISA (Council), during its seventeenth session in 2012, on the basis of the recommendation of the Legal and Technical Commission (Commission), approved an Environmental Management Plan (EMP) for the Clarion-Clipperton Zone (CCZ).<sup>2</sup> This included the designation of a network of nine “Areas of Particular Environmental Interest” (APEIs) as an integral part of that plan.
3. Building on the experience of CCZ-EMP, the development of regional environmental management plans (REMPs) becomes an essential element of the strategic plan (2019-2023) adopted by the Assembly in 2018 (ISBA/24/A/10), and subsequently a central part in the high level action plan endorsed by the Assembly in 2019 (ISBA/25/A/15). Strategic Direction 3.2 provides that the ISA is to “develop, implement and keep under review regional environmental assessments and management plans for all mineral provinces in the Area where exploration or exploitation is taking place to ensure sufficient protection of the marine environment as required by, *inter alia*, article 145 and part XII of the Convention”.
4. At its twenty-fourth session, in March 2018, the Council took note of a preliminary strategy proposed by the Secretary-General for the development of REMPs for key provinces where exploration activities under contracts are carried out.<sup>3</sup> The Council agreed with the priority areas that had been identified on a preliminary basis as the Mid-Atlantic Ridge, the Indian Ocean triple junction ridge and

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<sup>1</sup> United Nations Convention on the Law of the Sea, art.145.

<sup>2</sup> See ISBA/17/LTC/7; ISBA/17/C/19 and ISBA/18/C/22.

<sup>3</sup> See ISBA/24/C/3.

nodule-bearing province, as well as the North-West Pacific and South Atlantic for seamounts. The implementation of this preliminary strategy has started with the organization of two workshops held in Qingdao in May 2018 (relating to the design of REMPs for the cobalt crust region of the North-western Pacific) and Szczecin in June 2018 (relating to the design of REMPs for polymetallic sulphide deposits on mid-ocean ridges).<sup>4</sup>

5. The Council also considered essential that the development of those plans be carried out under the auspices of the Authority through a transparent and coordinated process in light of its jurisdiction under the Convention and the 1994 Agreement (ISBA/24/C/8). Plans are established by a decision of the Council, on recommendations of the Legal and Technical Commission, and each Contractor “undertakes [...] to comply with [...] the decisions of relevant organs of the Authority”, including those establishing the REMP.<sup>5</sup>

6. In paragraph 19 of its decision during the twenty-fifth session<sup>6</sup>, the Council encouraged the secretariat and the Commission to make progress on the development of regional environmental management plans, in particular where there are currently exploration contracts, while taking note of a report on the implementation of the strategy (ISBA/25/C/13), including a programme of work to develop those plans through a series of workshops planned during 2019-2020.

7. In accordance with the tentative schedule contained in document ISBA/25/C/13, several workshops have been planned to facilitate the review and development of regional environmental management plans. In order to support the organization of these workshops, the secretariat prepared a guidance document<sup>7</sup> to facilitate the development of REMPs, which clarified the roles and responsibilities of ISA organs as well as a series of workshops to be convened by ISA secretariat as scientific and technical process to prepare draft elements for inclusion in the REMPs.

8. With the above background, the ISA, in collaboration with the Atlantic REMP Project (funded by European Union) and the Government of Portugal, convened the Workshop on Regional Environmental Management Plan for the Area of the Northern Mid-Atlantic Ridge (MAR), at the University of Évora, Évora, Portugal, from 25-29 November 2019.

9. The workshop aimed to: (i) review, analyze and synthesize scientific data and information on biogeography; physical, geological and environmental settings; biodiversity, ecosystem features and habitats, along and across the northern MAR, (ii) review current exploration activity within contract areas and distribution of resources (polymetallic sulphides) along the northern MAR, (iii) describe potential areas that could be impacted by exploitation of mineral resources in the Area and would require enhanced management measures, and (iv) discuss framework to address cumulative impacts from exploitation in order to achieve effective protection of the marine environment.

10. The results of this workshop will provide scientific inputs to the forthcoming workshop on the regional environmental management plan for Area of the northern MAR to be held in St. Petersburg, Russia, in 15-19 June 2020, which will focus on identifying specific management approaches and measures for developing draft elements for inclusion in the REMP.

11. The workshop was attended by 46 participants in their individual expert capacities, selected to participate in this workshop in accordance with the selection criteria provided in the workshop

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<sup>4</sup> The report of this workshop is available at <https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/ts22.pdf>.

<sup>5</sup> Annex IV, Section 13.2 (b) in each set of the Authority’s Regulations on prospecting and exploration.

<sup>6</sup> ISBA/25/C/37

<sup>7</sup> [https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/rem\\_p\\_guidance\\_.pdf](https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/rem_p_guidance_.pdf)

announcements<sup>8</sup>, based on nominations submitted by the member States, including sponsoring States and developing countries, contractors, relevant international/regional organizations, scientific institutions and NGOs. The full list of workshop participants is provided in annex I to this report.

### **ITEM 1. OPENING OF THE WORKSHOP**

12. Mr. Michael Lodge, the Secretary General of the ISA, delivered his opening remark via video message. He thanked the Government of Portugal and the University of Évora for hosting the workshop, and the European Commission for providing financial support through its Atlantic REMP project. He also expressed his appreciation to the co-chairs of the workshop for their contribution in shaping the workshop programme and providing local logistic support, and Duke University and CSIRO/Australia for providing their technical support. He highlighted the significant achievements of the Authority in the adoption of a comprehensive exploration code, and in promoting, encouraging and coordinating marine scientific research as part of exploration activities and through the ISA database (DeepData). REMPs are a critical element in the measures to implement the Authority's mandate in ensuring effective protection of the marine environment, in accordance with article 145 of the Convention. As such the Council of the ISA at the 24th session took note of a strategy to develop REMPs through a series of workshops and the results of the workshops will be presented to the Legal and Technical Commission. Likewise, the Council considered it essential that REMPs should be developed under the auspices of the ISA, and approved the priority areas for the development of REMPs, including the northern mid-Atlantic ridge. Finally, he highlighted the importance of this workshop in providing scientific inputs to the development of the REMP in the northern mid-Atlantic ridge, as well as sharing insights that can contribute to overall development of the REMPs.

13. Prof. Ana Costa Freitas, the Rector of the University of Évora, delivered her remark. She welcomed all the participants and thanked the ISA for having accepted the invitation to come to Évora to convene this important workshop on the Regional Environment Management Plan for the Area in the North Atlantic. She highlighted the role of the University of Évora to the knowledge of the Alentejo region. There is a long tradition of exploitation of marbles and polymetallic sulphides along the geological structure known as Iberian Pyrite Belt. The University has contributed with scientific studies and training of qualified human resources to the development of the mineral resource activities over the past thirty years. More recently, geotechnical cartography of the so-called "Marble Zone", which mainly covers the municipalities of Estremoz, Borba and Vila Viçosa, was proposed aiming to identify and characterize the geological risks caused by the geodynamic phenomena. She emphasized that Évora was recognized a world Heritage city from UNESCO in 1986. She is quite happy to see that the name of Évora and its University is also taking part into building the application of the principle of the Common Heritage of Mankind, as envisaged by the United Nations Convention on the Law of the Sea.

14. Dr. Inês Gameiro, on behalf of the Minister Ricardo Serrão Santos of the Ministry of the Sea, delivered the Minister's remark. In his speech, the minister emphasized the role of Portugal in promoting cooperative, multilateral and engaging processes on sustainable oceans, as demonstrated by its engagement on the Agenda 2030 for Sustainable Development, in particular SDG 14, and on the UN Decade of Ocean Science for Sustainable Development, as well as other relevant meetings and actions such as co-organizing the UN Ocean Conference in 2020. The Minister also mentioned a number of initiatives that he led under the OSPAR Convention as well as the ISA regarding environmental management of hydrothermal vent ecosystems in mid-ocean ridges, and several research projects dedicated to the deep-sea chemosynthetic environments in the Mid-Atlantic Ridge. In this context, the Minister welcomed the decision of the Council of the ISA in 2018, in setting the Mid-Atlantic Ridge as

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<sup>8</sup> <https://www.isa.org.jm/workshop/workshop-regional-environmental-management-plan-area-northern-mid-atlantic-ridge>

a priority area for the development of an REMP. He recognized the ambitious goals of the ISA workshop, which highlight the need for investing in knowledge. Part of these objectives are aligned with the Galway and Belém Declarations, and are being addressed in several scientific initiatives undertaken by research institutions under the Ministry of Science and the Ministry of the Sea. He highlighted the need for multi-stakeholder participation in the REMP process and to inform citizens, in keeping with the principle of the Common Heritage of Mankind.

15. Mr. Gonçalo Motta, on behalf of the Ministry of Foreign Affairs, delivered his remark. He welcomed all the participants to Portugal and to Évora. He thanked the University of Évora and the ISA for organizing this important workshop. He also highlighted that these fora provide good opportunities for diplomats to learn with scientists about important steps to improve the knowledge on the deep sea, as well as to promote a sustainable use of the ocean while ensuring the protection of the marine environment. He wished a fruitful discussion to all participants.

16. Dr Magdalena Mihordea, on behalf of the Directorate General of Maritime Affairs and Fisheries of the European Commission, delivered her remarks. She thanked the workshop conveners for the opportunity to observe the workshop and thanked the workshop participants for providing their expert contributions. Dr Mihordea provided the context for cooperation between the European Union (EU) and the Authority, emphasising the need for healthier, cleaner, and better managed oceans for the good of society as a whole, and also as a prerequisite for building a sustainable blue economy. She highlighted the EU's International Ocean Governance Agenda, which seeks to improve the international ocean governance framework; reduce pressures on oceans and seas to create suitable conditions for the blue economy; and strengthen international ocean research and data. She also detailed the policies adopted by the EU to drive a sustainable blue economy, including robust environmental legislation; guidance on sustainable financing of the blue economy; the joint roadmap adopted with UNESCO to accelerate worldwide cross-border cooperation on maritime spatial planning; the transition to sustainable energy systems including offshore renewables; and initiating transatlantic research and innovation cooperation together with countries bordering the Atlantic. She also mentioned the EU activities in relation to deep-sea mining, which seek to ensure that if and when this activity takes place, it does so in line with the EU's commitment to sustainability and with minimal environmental impact. She emphasised that the EU fully supports the work of the International Seabed Authority towards the sustainable development of mining activities of the Area, whilst ensuring the effective protection of the marine environment, in line with its mandate under the UN Convention on the Law of the Sea. She detailed some of the EU's deep-sea mining research, such as assessing environmental impacts and investigating environmental protection measures. This work includes ecological risk assessments of deep-sea ecosystems and vulnerability of deep-sea biodiversity under increasing human stressors. The EU's work within these fields provides the rationale behind its support of the Atlantic REMP Project, which seeks to assist the Authority in its endeavours to develop a Regional Environmental Management Plan for the Mid-Atlantic Ridge. She was happy to note the EU's excellent cooperation with the ISA and hoped that this would yield results that the Authority can use in the process of developing an REMP for the northern Mid-Atlantic Ridge.

## **ITEM 2. ADOPTION OF THE AGENDA AND ORGANIZATION OF WORK**

17. After a brief introduction by the workshop co-chairs, Mr. Pedro Madureira and Mr. Gordon Paterson, the participants adopted the agenda and the organization of work, as contained in provisional agenda and annotations to provisional agenda<sup>9</sup>.

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<sup>9</sup> [https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/joint-agd-annot\\_0.pdf](https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/joint-agd-annot_0.pdf)

18. The workshop was organized in plenary and breakout-group sessions. The workshop co-chairs nominated facilitators and rapporteurs for the plenary sessions, based on the expertise and experience of the workshop participants and in consultation with the ISA secretariat, as follows:

- Agenda item 3: Harald Brekke
- Agenda item 4: Rachel Boschen-Rose
- Agenda item 5: Georgy Cherkashov
- Agenda item 6: Phil Weaver/Pat Halpin/Skipton Wolloey

### **ITEM 3. WORKSHOP BACKGROUND, SCOPE AND EXPECTED OUTPUTS**

19. Under this item, participants had before them a background document prepared by the ISA secretariat on “guidance to facilitate the development of Regional Environmental Management Plans”<sup>10</sup>.

20. Jihyun Lee (ISA secretariat) provided a presentation on “Workshop background, including the key results of the relevant previous workshops<sup>11</sup>, and expected outputs: ISA’s approach for the REMP development”.

21. Phil Weaver (Secretariat for Atlantic REMP Project) provided a presentation on “Setting the context for the workshop and proposed geographic scope of the workshop”.

22. Relating to the geographic scope of the workshop, the following points were clarified and noted:

- The geographic scope of this workshop may not necessarily be the same as the geographic scope of the REMP to be developed. The scope of the workshop could cover an area large enough to provide sufficient scientific information, taking into account mineral provinces and biogeography, and recognizing that the MAR is not a single biogeographical region and the subunits need to be considered.
- Existing biogeographical descriptions of the ocean, including northern Atlantic, are based on interpreting the physical data, including geology and depth of the seafloor, and the physical qualities of the covering water, for example the Global Open Oceans and Deep Seabed (GOODS) Biogeographic Classification (UNESCO 2009). There is a critical need to develop biogeographical map of the global ocean incorporating the distribution of the organisms to support the development of the REMP, including through habitat mapping by contractors.
- The potential for future applications for exploration and exploitation contracts in the Area of this region need to be considered in identifying the geographic scope of this workshop, and eventually the planning scope, in order to ensure cost-effectiveness of the overall planning process of the REMP development.
- For the mid-Atlantic ridge, and mid-ocean ridges in general, the planning unit needs to be designed taking into consideration the three-dimensional nature of ecosystem/habitat features and resources distribution, e.g. zonation occurs both in terms of water depth and areal extent.
- Depending on the availability of relevant scientific information/data, distinctive sub-regions can be identified in considering the scope the REMP development.

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<sup>10</sup> [https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/rem\\_p\\_guidance\\_.pdf](https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/rem_p_guidance_.pdf)

<sup>11</sup> <https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/ts22.pdf> (June 2018, Szczecin, Poland); [https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/paris\\_meeting\\_report\\_for\\_webposting.pdf](https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/paris_meeting_report_for_webposting.pdf) (May 2019, Paris, France)

- Models and sub-divisions must be based on the best data and information available. The available scientific information and data vary across the area. It seems that there are more data available on certain aspects (e.g. mammals) to the north of the Azores. Contractors have acquired important data to serve as baselines, which is available from the ISA database. The workshop should identify knowledge gaps and make recommendations as to what further data is needed.

23. For overall data compilation, this workshop covered the full extent of the Northern Mid-Atlantic Ridge region. Figure 1 depicts this area. For specific workshop discussion, the workshop focused on the Area between the limit of the Portuguese ECS in the Azores region (~33°N lat) and the Romanche Fracture Zone in the south (~0° lat).

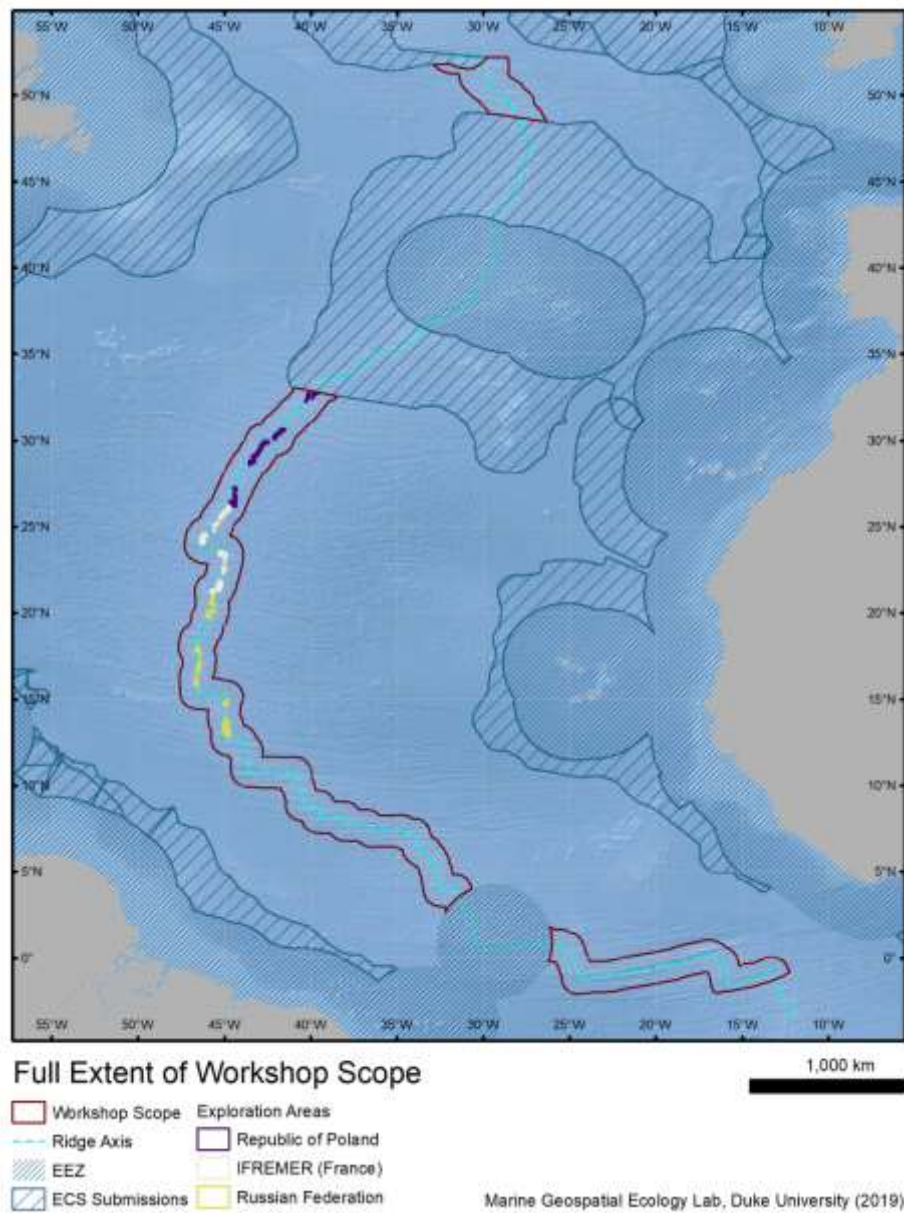


Figure 1. Workshop scope within the Northern Mid-Atlantic Ridge region.

24. Participants then exchanged insights, views and suggestions on the approaches for synthesizing workshop discussion, building on the following presentations:
- Phil Weaver: Scenario Planning for adaptive management
  - Pat Halpin (Technical Support Team): Application of area-based management tools
  - Skipton Woolley (Technical support Team): Quantitative modeling for addressing cumulative impact assessment
25. Summaries of the above presentations are provided in annex II to this report.

**ITEM 4. REVIEW, ANALYSIS AND SYNTHESIS OF RELEVANT SCIENTIFIC DATA/INFORMATION/MAPS RELATING TO BIODIVERSITY AND ECOSYSTEM PATTERNS ALONG THE NORTHERN MID-ATLANTIC RIDGE**

26. Under this item, participants had before them:
- (i) Draft Report on the Regional Environmental Assessment that described geological, biological and environmental characteristics and patterns along and across the northern mid-Atlantic ridge, prepared by the Atlantic REMP Project. The summary description of this report is provided in annex III to this report;
  - (ii) Draft Data Report compiling environmental and biological information, biogeographic classification, and human uses and management areas in 75 GIS layers, prepared by Atlantic REMP Project with technical support by Duke University/MGEL. The summary description of this report is provided in annex IV.
27. The above two reports were introduced to the workshop participants by Phil Weaver & Rachel Boschen-Rose, and Pat Halpin, respectively.
28. Following presentations were also delivered on biodiversity and ecosystem setting, including connectivity:
- Lenaick Menot: Benthic habitats – sediment and rocky
  - Imants G. Priede: Pelagic habitats
  - Cindy Van Dover: Vents and inactive vent communities
29. Participants exchanged their views, insights, and suggestions on, *inter alia*, information contained in the Regional Environmental Assessment Report and Data Report as a scientific basis for developing an REMP and critical data/information gaps. The results of discussion are summarized in annex V to this report.
30. Summaries of the above presentations are provided in annex II to this report, and summary of the plenary discussion is contained in annex V.

**ITEM 5. REVIEW OF CURRENT EXPLORATION ACTIVITY WITHIN CONTRACT AREAS AND DISTRIBUTION OF RESOURCES (POLYMETALLIC SULPHIDES) ALONG THE NORTHERN MID-ATLANTIC RIDGE**

31. Under this item, participants had before them the Draft Report on Regional Environmental Assessment that reviewed current exploration activities within contract areas and distribution of resources (polymetallic sulphides) along the northern mid-Atlantic ridge, prepared by the Atlantic REMP Project.
32. The following theme presentations were also delivered:

- Georgy Cherkashov (LTC member): Geological setting and prospects for resource exploitation
  - Pedro Madureira (LTC member): Considerations for developing an REMP from geological/resources perspectives
  - Andreas Thurnherr : Potential mining impacts
33. Participants exchanged their views, insights, and suggestions on, *inter alia*:
- Relinquishment of PMS contract areas, which may increase the spatial portfolio available for REMPs. It was clarified that the ‘Recommendations for the guidance of contractors on the relinquishment of areas under exploration contracts for polymetallic sulphides or cobalt-rich ferromanganese crusts’ (ISAB/25/LTC/8) mainly focus on ensuring a managed and coordinated approach among different contractors, and that which parts of the contract area would be returned to the Area is ultimately the decision of contractors. The REMP process could explore how to make use of the relinquished areas.
  - Monitoring is a key to understanding the potential environmental impacts of future activities within contract areas.
  - Potential scope of the REMPs. It was highlighted that there is no one-size-fits-all approach to the design of the REMP. The scope of the REMP needs to be based on science, taking into account the differences among regions.
  - Scientific basis for the design of the REMP, including the identification of ecosystem features that should be given priority when considering management measures.
  - Availability of scientific information for describing important habitats through coarse or fine scale planning approaches, including habitats within the contract areas.
34. Summaries of the above presentations are provided in annex II to this report.

**ITEM 6. SCENARIO PLANNING OF ENVIRONMENTAL REQUIREMENTS IN SUPPORT OF THE APPLICATION OF AREA-BASED MANAGEMENT TOOLS, INCLUDING AREAS OF PARTICULAR ENVIRONMENTAL INTERESTS (APEIs), AND ADDRESSING CUMULATIVE IMPACTS**

35. Building on the theme presentations delivered and ensuing plenary discussion, the workshop participants focused on, through plenary and break-out sessions, three distinct but complementary approaches to REMP planning. These approaches include (1) qualitative modeling for assessing cumulative impacts; (2) area-based management tools (ABMT); and (3) adaptive management. These complementary approaches rely on distinct objectives, methods of analysis, data requirements, and spatial and temporal domains of implementation (Figure 1.). In general, cumulative impacts assessment is intended to be implemented at a bioregional scale linking pressures, impacts and risks through the development of qualitative models. Area-based management tools are intended to be implemented at a defined management scale and may rely on a variety of fine-scale, coarse scale and regional scale tools to identify specific sites or broader habitat areas in need of increased precaution or protection. Adaptive management is intended to be implemented during exploration and exploitation phases and provide measures and procedures to be implemented if sensitive habitats or features are encountered during operations.

36. At the plenary, workshop co-chairs suggested approaches for break-out sessions held in three groups, including the steps and timeframe to produce outputs under this agenda item. Workshop co-chairs appointed Phil Weaver, Pat Halpin and Skipton Woolley as facilitators to moderate the workshop discussion under this agenda item.



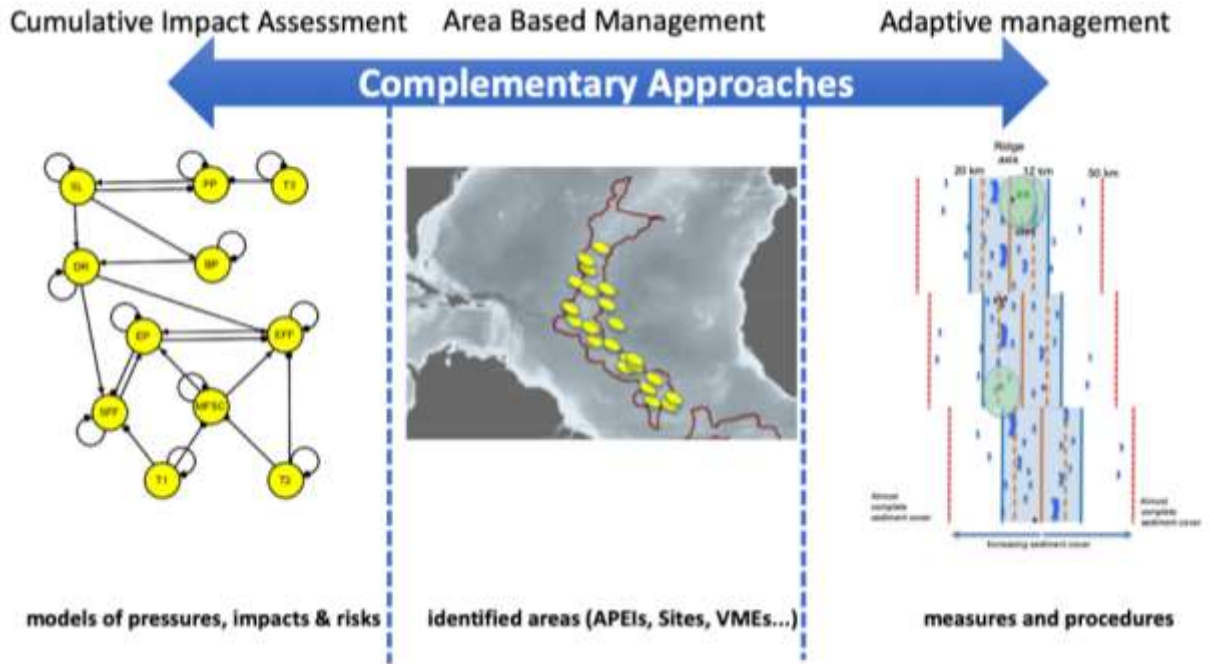


Figure 1. Complementary approaches to designing REMP

37. Workshop co-chairs also briefed the workshop participants on overall goals, objectives and guiding principles for the development of the REMP, as contained in ISA publications and documents (e.g. ISA workshop reports, CCZ-EMP, draft regulations, etc.). The workshop participants highlighted the importance of providing scientific basis for designing environmental goal and objectives for the development of an REMP. Preliminary consideration of environmental goals and objectives, as presented by the workshop co-chairs, provided a useful basis for group discussion at the present workshop. Likewise it was noted that further elaboration of these goals and objectives could provide a basis for wider discussion at the forthcoming workshop in St Petersburg, which will focus on environmental management measures. As such, it was also noted that any discussion regarding management goals and objectives of an REMP will take place in this forthcoming workshop.

38. In order to facilitate group discussion, some groups identified possible environmental goals and objectives, among the list provided by the workshop co-chair with some modifications, as guiding basis for their group work. Some groups identified preliminary set of environmental goals, for example. To ensure the protection of the environment, including rare or fragile ecosystems, and preservation of ecological balance of the marine environment, consistent with the legal framework of the International Seabed Authority, throughout the deep-sea mining process. In addition preliminary set of environmental objectives considering scientific requirements were identified, for example – minimise pollution and the loss of habitat as well as living resources as a consequence of mining activities; maintain (i) biodiversity at regional scale (i.e. genetic diversity, species richness, habitat or community types), (ii) the ability of populations to replace themselves (i.e. via connectivity and the preservation of suitable habitat), (iii) ecosystem structural complexity, function and subsequent services (recognizing that many are yet to be discovered) along the northern MAR, and (iv) the adaptive (providing resilience) and evolutionary potential for biota to cope with change; preserve multiple representative and unique marine ecosystems that occur in a bioregion sufficient to counter uncertainty, natural variation and the possibility of catastrophic events.

39. Participants were then split into three groups to undertake focused-discussions in break-out sessions:

- Groups 1: Active hydrothermal vent communities
- Group 2: Inactive hydrothermal vent communities/Hard substrate
- Group 3: Mid-water fauna/Sediment

40. The set of questions considered during the break-out session are described in annex VI to this report.

41. Each group reported at the plenary the results of the break-out session, which was followed by plenary discussion and exchange of views on the results of the group discussion.

42. Results of the group discussion during the break-out session and the plenary under this agenda item are summarized in annexes VII, VIII, IX to this report.

43. Upon the request of the plenary, the following presentation was also provided by Arne Myhrvold regarding technological development opportunities to support the implementation of the REMP - Minimising potential environmental impact of a project through engineering in the project development phase. A summary of this presentation is provided in Annex II.

## **ITEM 7. SUMMARY OF THE WORKSHOP**

44. Participants considered and provided comments to the draft report of the workshop prepared and presented by the workshop co-chairs, with the support of the secretariats and rapporteurs.

45. As requested by the workshop participants, and with support from the group facilitators, the workshop co-chairs prepared a co-chairs' summary as presented below.

Forty-six international experts took part in the workshop organised by the International Seabed Authority (ISA), in collaboration with the European Commission through its Atlantic REMP project and the Government of Portugal. Information was exchanged through background documents prepared before the meeting in particular a draft report on Regional Environmental Assessment and a draft Data Report. These documents summarised the current state of knowledge and data available relating to the objectives of the workshop. In addition, a guidance document – *Guidance to facilitate the development of Regional Environmental Management Plans (REMPs)* – provided a background to the process and objectives of the workshop within the framework of the ISA.

Discussions in Évora focused on providing the scientific basis for an REMP, the goals, objectives and knowledge gaps as well as identifying key sites and areas which would require enhanced management to achieve effective protection of the marine environment. Sessions included presentations which provided participants with the scientific and technical aspects of management tools and approaches, the ecological and geological settings, and contractors exploration activities.

Most of the discussions took place in discrete expert groups bringing together a range of disciplines, mainly focused on biology, geology and oceanography. These breakout groups were organised along ecological themes – active vents; inactive vents and hard surfaces; and pelagic and sediment. The groups then discussed key questions posed by three different but complementary approaches: adaptive management, area-based management tools, and qualitative modelling for assessing cumulative impacts. Each of the groups had a facilitator and rapporteur. In addition, each of the approaches also had a rapporteur. In this way the discussions of the workshop were captured, consolidated and presented in this

report. Periodically the groups came together in a plenary session to summarise the progress made. In this way most of the workshop questions were addressed and significant progress was made in developing input into the next workshop to be held in 2020 in St. Petersburg, Russia. In particular areas in need of enhanced protection and management were categorised such as active vents, fracture zones as well as areas identified by modelling approaches which were identified as needing enhanced precaution. The cumulative impact modelling exercises highlighted the potential impacts of mining activities on different components of the ecosystem, underlining the need for an REMP. Finally, adaptive management approaches based on various mining scenarios suggested how management measures could be applied to achieve effective protection of the marine environment in areas where mining would take place. A considerable amount of work was undertaken by the participants in the five workshop days.

#### **ITEM 8. OTHER MATTERS**

46. Under this item, workshop participants expressed their appreciation for the collaboration between ISA and InterRidge, including the information provided by InterRidge's Vent Database for this workshop. Participants also welcomed potential future collaboration between InterRidge and ISA, including through establishing a working group by InterRidge to focus on topics relevant to ISA.
47. Workshop participants agreed that they would submit comments and suggestions, if any, on draft report on Regional Environmental Assessment and draft Data Report, so that revised versions could be made available for future ISA process.

#### **ITEM 9. CLOSURE OF THE WORKSHOP**

48. The workshop was closed at 3.30 p.m. on Friday, 29 November 2019.

*Annex I*  
**List of Participants**

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7. Ms. Ana Colaço  
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<sup>12</sup> This participant indicated that she would not associate herself with this report.

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## *Annex II*

### **Summary of Theme Presentations**

#### ***Presentations delivered under agenda item 3.***

#### **Workshop background, including the key results of the relevant previous workshops, and expected outputs: ISA's approach for the REMP development**

**by Jihyun Lee (ISA secretariat)**

Development of REMPs is an essential element in the measures undertaken by the ISA to ensure protection of the marine environment, in line with its mandate under article 145 of the Convention, and occupies a central part the ISA's Strategic Plan and high-level action plan for the period 2019-2023. REMPs are established by a decision of the Council, on recommendations of the Legal and Technical Commission (LTC). In its decision contained in ISBA/24/C/8, the Council considered essential that the development of REMPs is carried out under the auspices of the Authority and encouraged the Secretariat and LTC to make further progress.

In this context, a guidance to facilitate the development of REMPs has been prepared by the Secretariat to enable a common understanding on the REMP process. The launch of ISA database DeepData, building on environmental baseline studies conducted by the contractors over the past decades as part of their exploration activities, would provide important scientific platform supporting the development of REMPs by providing environmental data, together with scientific information and data from other sources.

As part of the strategy to develop REMPs in priority regions, as mandated by the Council, this workshop builds on results of previous ISA workshops, including the Szczecin workshop in 2018, and will focus on scientific synthesis of data and information in support of the application of area-based management tools, adaptive management and addressing cumulative impacts. In particular, it will provide scientific inputs to the workshop to be held in Russia in 2020, which aims to identify management measures and draft elements for inclusion in the development of the REMP in the MAR for the consideration by the LTC.

#### **Setting the context for the workshop and proposed geographic scope of the workshop**

**by Phil Weaver (secretariat of Atlantic REMP Project)**

REMPs have a clear role within the decision-making process of the ISA but are also beneficial to contractors in reducing uncertainty in the planning process, reducing environmental impacts of their activities, reducing the need to retrofit environmental controls at a later date and improving investor confidence. Mining polymetallic sulphides is different to mining polymetallic nodules or cobalt crusts in that the deposits are three-dimensional and individual mines will cover a relatively small area and potentially be in place for several years. In the North Atlantic contractor blocks are closely aligned with the Mid-Atlantic Ridge, where new oceanic crust is generated. The ridge forms an elevated area of the ocean floor where rocky habitats are common and hydrothermal vents and their globally unique ecosystems are located. Moving away from the ridge axis by just a few tens of kilometres, the seabed becomes blanketed by sediments and any resources are difficult to locate. Mining is therefore likely to be concentrated within 20-30 km of the ridge axis and any impacts are more likely to be associated with rocky substrate fauna and potentially hydrothermal vent communities.

A likely scenario is that there will be relatively few large mines in the North Atlantic, although the mining process may create plumes of sediment-laden water that could impact habitats within some kilometres of the mine sites, depending on the technology to be developed and applied. Cumulative impacts from multiple mines or from widespread plumes could become a critical element of management concern. Water returned to the ocean from dewatering of the mined ore when it reaches the surface vessel may also cause impacts on midwater fauna. Adaptive management approaches need to be in place within the REMP to address uncertainties relating to the performance of mining equipment and the total amount of mining so that sensitive habitats are not seriously impacted.

The area to be considered by the workshop was proposed for the plenary discussion. A number of geographic provinces have been proposed for the North Atlantic, each covering very large areas and, for the benthic provinces, also covering large depth ranges. Each province includes a range of habitats. The ridge axis lies mainly in the bathyal province that covers the depth range of 800-3000 m or a proposed variant of this - the lower bathyal province that covers the depth range 800-3500 m. The Area of the Atlantic Ocean includes a section of the ridge axis from the southern end of the Icelandic extended continental shelf claim to the northern end of the Portuguese extended continental shelf claim (north of the Azores) and also extends from the southern end of the Portuguese extended continental shelf claim to the Equator exclusive of the Brazilian Exclusive Economic Zone (EEZ) around the islands of St Peter and St Paul. The contract areas extend from the southern end of the Portuguese extended continental shelf claim to around 12°N.

## **Scenario planning**

### **By Phil Weaver**

Scenario planning is an important first step towards understanding the scientific information needed to support adaptive management for an activity. In the context of seafloor massive sulphide mining on the Mid-Atlantic Ridge (MAR), a likely scenario is that there will be relatively few large mines in the North Atlantic, depending on ore tonnage and grade within contracted blocks. The mining process may create plumes of sediment-laden water that could impact habitats within some kilometres of the mine sites, depending on the technology to be developed and applied, and the local physical oceanographic conditions. Cumulative impacts from multiple mines or from widespread plumes could become a critical element of management concern. Water returned to the ocean from dewatering of the mined ore when it reaches the surface vessel may also cause impacts on midwater fauna.

Adaptive management approaches need to be in place within the REMP to address uncertainties relating to the performance of mining equipment and the total amount of mining so that sensitive habitats are not seriously impacted. Discussion of mining scenarios will help to identify the types of potential sensitive habitats, communities or species along the MAR, and the scientific evidence needed to determine if these meet either existing or future criteria for enhanced environmental management.

## **Approaches for spatial planning**

### **by Pat Halpin (Technical Support Team)**

This presentation provides an overview of spatial planning approaches and discusses the relationship between spatial approaches and non-spatial approaches. There is a need to build on previous workshop results, including the 2018 Szczecin REMP workshop, which concluded that REMP planning should include “...the primary goal of facilitating seabed mining while maintaining biodiversity, protecting unique and representative habitats, and preserving ecosystem function through both area-based management tools (ABMTs) and non-ABMTs (e.g. management measures).”

The potential interaction between broad scale cumulative impacts analysis, area-based management and fine scale adaptive management approaches are discussed. A description of criteria-based approaches is provided, noting that the selection of areas for protection in spatial planning is often based on criteria that must be interpreted through quantitative regional analysis, qualitative scientific expert judgment, or a combination of these approaches. These criteria may be based on attributes or properties of individual species, ecological communities, habitats or broader ecosystems. These criteria may focus on the inherent attributes of the species/habitat or could focus on the vulnerability of the species/habitat to disruption or damage. The differences between site level and network level criteria are also discussed.

There are two scales of application of ABMTs: a coarse filter approach targeting the representation of broad ecosystem features and gradients; and a fine filter approach targeting unique sites that may be of particularly high values or at particularly high risk. The current interpretation of APEIs is an example of a coarse filter approach; this type of ABMT could be augmented with fine scale sites in need of protection. The type of APEIs described for the CCZ region may need to be adapted to suit the needs of the Mid-Atlantic Ridge region. A purposefully configured mixed portfolio combining large areas to protect and buffer intact gradients of habitats augmented with specific sites in need of protection may provide the most flexibility to satisfy both mining interests and protection needs. A mixed portfolio could include areas of increased precaution, or other categories of use in addition to closure areas. Some areas could require more intensive mapping, monitoring or potential remediation.

Defining the appropriate biogeographic spatial extent of a REMP is a fundamental step in the planning process. Defining tractable evaluation criteria for assessing different ABMT network configurations (size, spacing, placement) will also be key to REMP planning. Increased spatial precision will require increased data coverage and detail, which have implications for adaptive management. It is likely that an adaptive management approach will be required to anticipate changes in data and knowledge, new technologies, and contract area relinquishment.

## **Approaches for addressing cumulative impact assessment**

### **By Skipton Woolley**

Understanding the effects of cumulative impacts in a region is a multitiered process, which requires the description of the distribution of key ecosystems, key effects on the ecosystems and then understanding how these components interact. Spatial data on the distribution of ecosystems for Mid-Atlantic Ridge, including environmental, physical, biological characteristics will be used to understand how active vent, inactive vent, benthic and mid-water habitats could respond to cumulative effects of pressures from potential deep-sea mining activities.

Conceptual models represent a working hypothesis about how an ecosystem works. They should a) identify the important components and processes in the system; b) document assumptions about how these components and processes are related; c) identify the linkages between these components/processes and anthropogenic pressures; and d) identify knowledge gaps or other sources of uncertainty.

Conceptual models come in many different forms including simple narrative descriptions, schematic diagrams, box-and-arrow flowcharts, or even cartoons that pictorially illustrate physical and biological processes and the effects of anthropogenic pressures. Even though there are many forms of conceptual models, they all have common elements and can be constructed using a common set of steps:

1. Identify bounds of the system of interest
2. Identify key model components, subsystems, and interactions
3. Identify natural and anthropogenic stressors (pressures)

#### 4. Describe relationships of stressors, ecological factors, and responses

Conceptual models need to portray the ecological system at a level of resolution that is useful to the purposes of the risk assessment, striking a balance between simplicity and complexity. They should not seek to represent the entire system with myriad components and processes; rather the goal should be to encompass the relevant subsystem, which includes the components of the system that are the focus of the risk assessment, the associated processes and variables that act to maintain and regulate them, and the natural and anthropogenic pressures or concerns.

#### *Presentations delivered under agenda item 4.*

##### **Draft Report on Regional Environmental Assessment of the Mid-Atlantic Ridge**

**By Phil Weaver and Ms Rachel Boschen-Rose (secretariat of Atlantic REMP Project)**

This presentation provides an overview of the Draft Report on Regional Environmental Assessment document (REA) that provides a synthesis of available information relating to the environment of the northern Mid-Atlantic Ridge (MAR) from south of Iceland to the equator. The draft REA includes chapters on the geological environment, physical oceanography and biology. An account is also provided of the existing exploration contract areas for polymetallic sulphides on the MAR, and potential cumulative impacts. Details on the draft REA are provided in annex III to this report.

##### **Draft Data Report compiled for the workshop**

**By Pat Halpin**

This presentation reviews the compilation of scientific data and information prepared for the workshop and presented in the document entitled “Data Report: Workshop on the Regional Environmental Management Plan for the Area of the Northern Mid-Atlantic Ridge.” Details on the draft Data Report are provided in annex IV to this report.

##### **Biodiversity and ecosystem setting, including connectivity – Benthic habitats (sediment and rocky)**

**By Lénaïck Menot and Tina Molodstova**

The non-vent benthic fauna is here defined as the fauna that do not rely on energy or chemicals from active or inactive hydrothermal vents at any stage of its life cycle. The non-vent fauna may be indirectly impacted by particles plumes spreading from a mined area as well as directly impacted by the removal of the sedimentary pile over SMS deposits. The non-vent fauna of the Mid-Atlantic Ridge (MAR) is mostly known from the MAR-ECO and ECO-MAR projects, which sampled the northern part of the MAR, from the Azores up to 60°N. Published data on the non-vent fauna south of the Azores are scattered across the taxonomic literature. A review of 24 taxonomic papers focusing on the non-vent MAR fauna suggested that about 15% of the species found on the MAR are endemic to the MAR. A review of ecology papers highlighted two latitudinal shifts in species composition. The first shift is located at 60°N and 1000 m depth. It matches with the boundary between two water masses. The second shift in community composition is located at the Charlie Gibbs Fracture Zone. It matches with the polar front and could be due to variations in primary productivity, north and south of the front. Beyond latitude, community composition has been shown to vary according to depth and from both side of the MAR. The MAR indeed could act as a barrier to dispersal for species with low dispersal ability such as peracarid crustaceans. Species turnover on the MAR was finally enhanced at local scale by the complexity of the topography, the heterogeneity of the substratum and the diversity of biogenic structures from pteropod thanatocoenose to sponge grounds and aggregation of corals. These latter

biogenic structures may qualify as non-vent Vulnerable Marine Ecosystems (VME) on hard substrates due to their functional significance, structural complexity, fragility and slow recovery. On soft sediments, the rare and fragile enteropneusts are another example of a potential VME indicator taxa. The discovery of new VMEs on the Mid-Atlantic Ridge is however to be expected due to the low sampling effort towards non-vent fauna to date.

### **Biodiversity and ecosystem setting, including connectivity – Pelagic habitats (sediment and rocky)**

**By Imants G. Priede**

Pelagic habitats encompass the water column from the ocean surface down to 50m above the bottom. Sunlight sufficient for photosynthesis and growth of phytoplankton is confined to the upper 200m providing food for the entire oceanic food chain. The water column beneath 200m is populated by nekton, free-swimming fish, shrimps and cephalopods that occur in such vast abundance that they are detectable by ships' echosounders as acoustic deep-scattering layers (DSL). The DSL is globally estimated to contain up to 10 Gt of fish, equivalent to 100 times the global fish catch.

The nekton of the DSL migrate to the surface at night to feed on the rich food resources and then descend at dawn. This diel vertical migration acts as a biological pump transporting food into the ocean interior. The nekton is dominated by small plankton-feeding fishes and shrimps which in turn are preyed upon by larger squids, octopuses, dragonfishes, gulper eels and other predators. The DSL nekton is a massive food resource for a variety of predators including sperm whales, sharks, tunas and birds diving from the surface and near bottom interceptor predators. The DSL nekton tends to concentrate over the Mid-Atlantic Ridge in a layer of 200m thickness above the seafloor.

There are latitudinal trends in biodiversity from low diversity in Sub-Arctic waters in the north to highest diversity at mid latitudes 20-40°N. Surveys have recorded 205 fish species, 64 shrimp species and 41 cephalopod species over the North Mid Atlantic Ridge of which 35-50% are circum-global indicating a high level of connectivity with other oceans. In addition to super-abundant dominant species the fauna also includes many rare, highly adapted deep-sea species often known from only a few specimens.

### **Active, inactive, and extinct sulphide occurrences: Biodiversity and ecosystem setting, including connectivity**

**By Cindy Lee Van Dover**

Active sulphide ecosystems (hydrothermal vents) are well-recognized in their global uniqueness for the microbial, chemoautotrophic base of their food webs and for novel adaptations by vent organisms to extremes of physical, chemical, and biological conditions. They are living libraries of evolution.

While there may be more than 1000 active sulphide ecosystems distributed globally, the active sulphide habitat is extremely rare, occupying in entirety an area on the order of 50 km<sup>2</sup>, by one estimate. Biodiversity and other characteristics of active vent ecosystems differ from one site to another, driven in part by variations in supporting geology and geochemistry. Recent scientific contributions relating to connectivity indicate that there may be multiple biogeographic subregions within major biogeographic provinces, highlighting the need for biogeographic patterns incorporating biodiversity information to support the development of the REMP.

Far less studied are sulphide occurrences where fluid flow has ceased. Recent reviews strive to provide a standard terminology and contexts for inactive sulphides. A key finding from experimental drilling is that inactive sulphides may become reactivated; what is not known is the extent to which reactivating a 'dormant' sulphide habitats modifies fluid flow in the occurrences of any nearby active sulphide

habitats, potentially impacting the productivity and biodiversity of the hydrothermally active sulphide ecosystem.

While microbial succession occurs as sulphide systems transition from active to inactive, there are few quantitative studies of the autotrophic capacity of microbial communities associated with inactive sulphide habitats. Nor are there more than a few published quantitative studies of the macrobiota of inactive sulphide forming systems and their trophic relationships to sulphide microbes and (or) pelagic particulate organic material. Some inactive sulphide habitats clearly host dense populations of suspension-feeding invertebrates, other sulphide habitats appear to be barren. There are a few anecdotal notes suggesting the presence of invertebrate taxa endemic to inactive sulphide forming systems, but compelling evidence for endemism remains to be brought forward.

Some potential environmental risks associated with mining activity at inactive sulphide habitats may be unique to this mineral resource and will need to be taken into account during the process of determining environmental impacts.

#### ***Presentations delivered under Agenda Item 5.***

#### **Geological setting, distribution, potential resources and prospects for exploitation of SMS deposits**

**By Georgy Cherkashov**

The distribution of SMS deposits along the MAR demonstrates high variability in distance between separate sites, ranging from ten to over one hundred kilometers. Current resource estimation of SMS deposits in the North Atlantic is not reliable. Potential resources could be increased dramatically by 2-3 times as a result of extension of the exploration area across the rift valley up to 20 km, or could be decreased as a result of drilling SMS deposits outcropping on the sea floor. Due to the absence of an economic model for SMS mining, it is not possible to determine the level of resources which could be commercially interesting for future exploitation. The suggested profitable level of annual production of polymetallic nodules (3 million tonnes per year) is not applicable for SMS, and there should be specialized studies on the suggested profitable level for SMS annual production.

Uncertainties regarding SMS distribution and resources include the following aspects:

- Before drilling all estimations of SMS tonnage have a preliminary character
- Uneven metal grade distribution within SMS deposits does not allow a reliable evaluation of metal resources
- Without feasibility studies any financial model has a preliminary character
- Feasibility study could not be executed before test mining which is not conducted yet

#### **Considerations for developing a REMP from geological/resources perspectives**

**By Pedro Madureira**

Geologists are used to interpret geological maps on land and to identify targets to apply geophysical methods for resource assessment. At the deep sea, this objective is relatively easy to achieve in the case of the polymetallic nodules that lie at the surface of the seabed. However, in the case of polymetallic sulphides the resource assessment is much harder to accomplish due to the extension that these deposits can reach below the seafloor. The discovery of active vents is facilitated by the presence of a hydrothermal plume that changes the physico-chemical properties of the surrounding ocean water. The search for inactive and extinct sites is more demanding and usually performed by electromagnetic



surveys. Notwithstanding the crucial role of drilling in the case of polymetallic sulphides resources assessment, the search for these potential targets has an important role in the strategy followed by contractors in the early stages of their contracts for exploration. In fact, according to paragraph 2 of Regulation 27 of the exploration regulations for polymetallic sulphides, by the end of the eighth year from the date of the contract, the contractor shall have relinquished at least 50 per cent of the original area allocated to it. By the end of the tenth year from the date of the contract, the contractor shall have relinquished at least 75 per cent of the original area allocated to it. Therefore, after this time period, the area available for exploration under the contract does not exceed 2,500 km<sup>2</sup>. According to paragraph 1 of the same regulations, areas to be relinquished shall be defined by the contractor in the form of sub-blocks comprising one or more cells of a grid as provided by the Authority. In the 25<sup>th</sup> Session of the ISA, the Legal and Technical Commission assisted the Secretariat in defining a grid made of cells of 1 km<sup>2</sup> within each exploration block. The final area of exploration allocated to a Contractor after this relinquishment process may be characterized by a patchy pattern that should be considered in the scientific approach aimed to develop a feasible and effective regional environmental management plan.

## **Potential Mining Impacts**

**By Andreas Thurnherr**

In this presentation, he discussed potential physical impacts from deep-sea mining, with a particular emphasis on the impacts of pollutant plumes. The main categories of mining effects include i) seabed alteration and dense particle plumes created by the mechanical excavators, ii) plumes of particles and dissolved substances released into the water column at depth both intentionally (tailings and wastewater discharge) and from potential leakage, iii) noise and light pollution, especially on the seafloor and at the sea surface, as well as iv) possible nutrient enrichment in the upper ocean where deep water mixed with minerals is released near the surface.

While sedimentation from particle plumes can be highly destructive the dispersal potential of plume particles is limited by their settling time scales, with smaller particles having the largest dispersal potential. Solute plumes, on the other hand, have potentially unlimited dispersal potential. While intuitively reasonable, assessments of dispersal potential based on advection by mean currents and particle settling underestimate the true spatial extent of mining impacts because the underlying model accounts neither for re-suspension of particles nor for the effects of eddy diffusion, which often causes omni-directional horizontal dispersal (i.e. including in the mean-flow up-stream direction) in the deep ocean. The potential mining sites along the northern Mid-Atlantic Ridge are all found in the rift valley, which is topographically separated from the open ocean and has its own system of currents and upwelling. Some of the implications of the rift-valley setting for dispersal of mining plumes are also addressed.

## ***Presentations delivered under Agenda Item 6.***

### **Minimising potential environmental impact of a project through engineering in the project development phase**

**By Arne Myhrvold**

It is important to have a systematic management of environmental aspects in developing and designing project concept, to integrate environmental objectives into design details of a exploration/exploitation project, and in particular to ensure that the development concept, including location and physical layout, and the design of facilities, equipment, systems and processes minimise environmental adverse impacts during the installation and operational phases. In the early phase of a project, it is important to identify potential environmental risk factors to a project, including a systematic review of the concept(s) and

main systems to identify and assess the environmental aspects and identify mitigation measures. Examples include:

- Minimise creation of seabed mining plume
- Minimise volume of returned water
- Minimise particle content in returned water plume
- Treat returned water
- Minimise need to lift ore (subsea processing)
- Avoid interfering with SOFAR channel (Sound Fixing and Ranging)
- Minimise use of light

In this early phase of deep sea mining industries, it is also important to identify and assess potential technology gaps and opportunities. As the project is matured and prior to the selection of a development concept, the pros and cons of the different concepts should be assessed.

The assessment and selection of technologies should be in accordance to the mitigation hierarchy - 1. avoid; 2. minimise/reduce; 3. compensate/remedy, and the principle of applying the Best Available Technique(s) (BAT).

The main elements of this process are summarized in table below:

Early phase /exploration	Engineering phase
<p>Do an early phase risk assessment</p> <ul style="list-style-type: none"> <li>• Identify relevant risk factors and assess relevant mitigating actions</li> <li>• Need sufficient understanding of ecosystem</li> <li>• Need sufficient understanding of impacts from operations</li> </ul>	<p>Establish environmental objectives</p> <p>Review and rank the different concepts</p> <p>Best Available Technique (BAT) assessment</p> <p>Establish relevant environmental performance requirements</p>
<p>Understand the environmental regulations</p>	

A clear set of regulations for exploitation, supported by standards and guidelines, would provide a framework for the contractors, thereby supporting technology development both regarding “exploitation technology” to minimise environmental impact as well as technology to increase the biological knowledge and understanding.

### *Annex III*

## **Summary of Draft Report on the Regional Environmental Assessment of the Mid-Atlantic Ridge**

### ***Purpose***

1. The Draft Report on the Regional Environmental Assessment (REA)<sup>13</sup> provides an aggregation and synthesis of existing information relating to the northern Mid-Atlantic Ridge (MAR). Compilation of this existing information at the regional scale has three main purposes: i) To provide the regional environmental context of the MAR, including for future Environmental Impact Assessments (EIAs) to be conducted by Contractors; ii) To facilitate the identification of ‘data gaps’ with respect to specific geographical locations or environmental components where further information is required; and iii) To support the identification of locations where environmental management measures may be required to provide enhanced protection and preservation of the marine environment.

### ***Preparation and scope***

2. The REA of the MAR was prepared by the Atlantic REMP project, which is supported by the European Union. The document was coordinated by Seascope Consultants, and includes contributions from nine authors, all of whom are experts in their respective fields. The information contained within the REA is from public sources, consisting of published scientific papers, biogeographic databases and online libraries.

3. The REA sets the scene for discussions on developing the REMP by providing a synthesis of available information. A geological overview includes a description of the MAR, including the location of vents and a description of the formation of ore bodies at vent sites. The location of contract areas is provided together with an assessment of resource potential based on limited available information. Mention is made of available technology for locating ore bodies and an example of recent test mining for polymetallic sulphides is provided. Potential impacts from mining are discussed, including the effect of plumes. An account of the physical oceanography is provided at both regional and local scales, which is essential to determine the spread of plumes.

4. Understanding and managing cumulative impacts forms an important component of REMPs, and information is provided on the types of potential impacts, for example from multiple activities of the same type (mining) or from multiple different causes.

5. The biological section is structured to reflect the content which is expected to be required in the Environmental Impact Statements (EIS) to be submitted to Authority, as detailed in the Draft ISA Regulations for Exploitation (ISBA/25/C/WP.1, Annex IV). The template for EIS within ISBA/25/C/WP.1 spans the surface (0 – 200m water depth), mid-water (200m – 50m above seafloor) and benthic (seafloor and 50m above seafloor) environments. To reflect this, the REA includes all three divisions of the marine environment.

6. The geographical coverage of the REA is broader than the Area in the North Atlantic or the MAR as a feature. This is to provide the regional context for REMP development, which requires a basin-scale understanding of the North Atlantic physical and biological environments. To address this scope, the REA compiles information from the southern boundary of the Icelandic Extended Continental Shelf (ECS) claim on the MAR to the Equator. The REA does not define the specific geographic scope to be covered by the REMP in the North Atlantic, as this will be determined through the processes of the Authority.

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<sup>13</sup> <https://ran-s3.s3.amazonaws.com/isa.org/jm/s3fs-public/files/documents/readraft.pdf>

7. An attempt has been made to cover the range of biological components included within the EIS template of ISBA/25/C/WP.1, and the required aspects of their biology, such as regional distribution, temporal variation, trophic relationships, ecosystem function, connectivity, and resilience and recovery. In general, the most information is available for the regional distribution of biological components. Typically, there is less information available for temporal variation and trophic relationships. Far less information is available regarding ecosystem function, connectivity, and resilience and recovery. Generally, there is more biological information available for the section of the MAR south of Iceland but North of the Azores than there is South of the Azores to the Equator. Where information is limited or absent on biological components, or aspects of their biology, this is identified within the text.

#### ***Future use and development***

8. The REA is not an exhaustive account of the physical and biological environment of the northern MAR but provides an informative first assessment, which it is anticipated will be updated as more information becomes available. Aspects not addressed within this version of the document, including Chemical Oceanography, and certain sub-divisions of the Biological section, can be provided in the next iteration, which will be completed following comments from the Évora workshop participants.

## *Annex IV*

### **Summary of Draft Data Report on the Mid-Atlantic Ridge**

Relevant datasets and analyses for the Northern Mid-Atlantic region were compiled by the Marine Geospatial Ecology Lab, with financial support from the Atlantic REMP Project, which is sponsored by the European Commission. These data were compiled in a document entitled Data Report<sup>14</sup>: Workshop on the Regional Environmental Management Plan for the Area of the Northern Mid-Atlantic Ridge. The baseline data layers developed for this workshop are developed from open access data sources to provide consistency between regional efforts, along with many datasets specific to the Northern Mid-Atlantic region. More than 100 data layers were collated and prepared for this workshop.

The Mid-Atlantic Ridge (MAR) extends right from the Arctic Ocean to beyond South Africa. For the purposes of this report on the Northern Mid-Atlantic Ridge, data were collected or generated for areas between 57°N and 9°S and basin-wide in an east/west direction. The extent of the data report does not define the geographic scope that will be covered by the Northern Mid-Atlantic REMP.

The report covers five general types of data: (1) environmental data; (2) biological data; (3) biogeographic classifications; (4) human uses; and (5) areas defined for management and/or conservation objectives.

The environmental data layers include bathymetric and physical substrate data, oceanographic features, and remotely sensed data.

The biological data portion of the report covers a variety of data sources to include data and statistical indices compiled by the Ocean Biogeographic Information System, habitat prediction models, satellite tracks of sea turtles, sharks, and marine mammals, and Important Bird Areas. This portion of the report also presents data from the ISA Deep Data Portal for two of the claim areas.

The biogeographic data focuses on major biogeographic classification systems, including Global Open Ocean and Deep Seabed abyssal and bathyal classifications and Longhurst marine provinces.

The human uses section of the report covers fishing efforts, shipping and vessel densities, mining exploration areas, and the cumulative human impacts on the world's oceans.

Areas defined for management and/or conservation objectives include Regional Fisheries Management Organizations, VME closed areas to bottom fishing, marine protected areas, and Convention on Biological Diversity Ecologically or Biologically Significant Areas. In addition to data layers, the report identifies a number of published scientific papers that list additional data resources. Additionally, there are likely a significant number of scientific datasets and papers for the Northern Mid-Atlantic region that were not located in internationally accessible sites. It is recommended that workshop participants rely on local experts to help identify critical regional datasets and analyses that could be identified to supplement their efforts. Data layers that were not included in this version of the data report can be included in a future version, following comments from workshop participants.

Specific information on individual data layers is provided in detail in the data report.

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<sup>14</sup> <https://ran-s3.s3.amazonaws.com/isa.org/jm/s3fs-public/files/documents/datareport-19nov-lowres.pdf>

*Annex V*

***Summary of discussion on review, analysis and synthesis of relevant scientific data/information/maps relating to biodiversity and ecosystem patterns along the northern mid-Atlantic ridge***

1. Participants noted that both the Regional Environmental Assessment (REA) document and the Data Report are draft documents, which will be updated incorporating any comments from the workshop participants. As living documents, it is anticipated that these documents will be further updated in the future as additional information becomes available.
2. Additional aspects which participants suggested could feature in the revised version of the REA document included information on the habitat provided by natural hydrothermal vent plumes, which originate in the benthic environment but extend into the mid-water environment; and the location of permanent infrastructure on the seafloor, such as submarine cables, in the context of the cumulative impacts chapter.
3. The importance of high-resolution bathymetry was noted by participants, as these data would be needed to identify and spatially define benthic habitats. High resolution bathymetric information may be concentrated in locations where detailed scientific research has been conducted and may be absent for large portions of the Mid-Atlantic Ridge (MAR) which are not as well studied. Participants suggested determining the extent to which the MAR has been mapped with high resolution bathymetry would help identify gaps in knowledge of the MAR topography.
4. Environmental parameters which determine the regional distribution of species on the MAR were discussed, including the distance between suitable habitat, currents, topography of the seafloor, and depth. It was noted that very little information is available on the near-bottom currents, which due to local topography can be highly variable.
5. Participants considered water depth to be particularly important in structuring both benthic and pelagic communities, and suggested that further consideration may be needed regarding how to address depth zonation on the MAR. Depth zonation occurs between the MAR ridge axis top, flanks, axial valley and the abyssal plain. Latitudinal changes in average depth also occur along the MAR, with shallower sites in the North and deeper sites in the South. For spatially discrete habitat, such as active vents, it may be difficult to differentiate between the influences of depth and latitude on species distributions, considering that the average depth of the MAR has an inverse relationship with latitude.
6. The topography of the MAR was also considered important in structuring biological communities, such as the high biomass of pelagic nekton observed within the deep-scattering layer over the MAR and within the bottom 200m of the water column overlying the MAR. It was noted that the MAR axial valley may also structure benthic communities through influencing the food regime and currents. However, there have not been any studies comparing the biological communities of the axial valley to those occurring in other ridge habitats, such as the crest and flanks.
7. The importance of long-term observatories on the MAR for monitoring and characterizing temporal variability in benthic communities was noted by participants. In this context, data and information collected from the EMSO-Azores non-cabled seafloor multidisciplinary observatory located at 37°N (Lucky Strike vent field) established in 2010 were considered particularly valuable.
8. Participants noted that more information is available on the biological environment between the southern extent of the Iceland Extended Continental Shelf (ECS) submission and the northern extent of the Portugal (Azores) ECS submission, compared with the MAR between the southern extent of the Portuguese ECS submission and the Equator. This is reflected in the greater number of scientific publications available for the North compared to the South.

9. Participants noted that very little is known about inactive sulphide habitat on the MAR. It was also noted that there are several data gaps which are common to multiple MAR habitats. These shared knowledge gaps included:

- a. Complete species distribution information, including local variation in abundance, centers of distribution, and whether species are truly endemic or just under-sampled;
- b. Connectivity of populations, as determined through genetic studies and biophysical modelling; and
- c. Fauna life history characteristics, including larval dispersal distances and development mode.

10. Consideration was given as whether ongoing environmental survey efforts within the three exploration contract areas south of the Portuguese ECS submission could alter the current views on endemism of MAR biota. Additional sampling effort may discover that species which were thought to be endemic have broader distributions than previously realized. Equally, further sampling may discover new species which have not been recorded elsewhere and so are considered endemic. The role of genetic data in confirming species identifications and so helping to define regional distribution patterns was noted.

11. Detailed discussion was held regarding active vent habitats on the MAR. Topics of discussion included:

- a. Community structure, which is highly variable between sites, reflecting the local environmental conditions, geological setting, fluid geochemistry, biotic interactions, and relatively large distances between sites compared to fast-spreading ridges. This makes it very difficult to select representative sites, as each site has different community structure;
- b. Population connectivity, which may exhibit a linear stepping-stone pattern, although this is not known for the majority of species. Source-sink dynamics between populations are also unknown;
- c. Fauna life history characteristics, which are not well known, although at some sites hydrographic models and population structure indicates that some vent fauna populations may have high levels of larval self-recruitment. Whether vent fauna larvae are constrained by the topography of the axial valley is not known;
- d. Faunal succession and recolonization following disturbance, which is not well characterized for the MAR, as there is little natural disturbance compared to fast-spreading ridges such as the East Pacific Rise, where successional sequences are better characterized.

12. Considering the data gaps identified during discussion, it was suggested that a more precautionary approach may be required until further information becomes available. With additional information, it may be possible to be more adaptive, and to develop quantitative thresholds.

13. The low level of knowledge on the distribution, biology and ecology of many Mid-Atlantic Ridge species may require : (i) managing areas large enough to capture the heterogeneity of habitats that sustain these communities, heterogeneity being driven by e.g. depth gradient, slope, cross-axis variations in geomorphological features and allow for the self-maintenance of populations of these species within the managed areas; and (ii) replicating those areas to capture the biogeographic units within the region, these biogeographic units being driven by large variations in surface primary productivity, water masses and large topographical discontinuities that may represent potential barriers to dispersal.

Annex VI

Set of questions for break-out session under agenda item 6

<b>Groups 1: Active hydrothermal vent communities</b>		
<i>Scenario Planning for Adaptive Management</i>	<i>Spatial Planning</i>	<i>Addressing cumulative impacts</i>
<p>How close do other vents need to be located to preserve connectivity?</p> <p>How do you define thresholds for identifying active vent communities?</p> <p>How similar are communities on adjacent vents?</p> <p>How do we define thresholds for plume impacts?</p> <p>Can you suggest specific technical approaches for limiting plume extent?</p> <p>How to manage unpredicted events?</p>	<p><b><i>For fine scale planning</i></b></p> <p>Can we describe known (fine scale) sites in need of protection?</p> <p>What types of relevant criteria can be used for the above description at finer and coarse scales (e.g. FAO VME criteria)?</p> <p>What size and spacing criteria can be used?</p> <p>What data gaps exist and how can they be resolved?</p> <p>How do we conduct spatial decisions with sparse data (precautionary approaches etc.)?</p> <p><b><i>For coarse scale planning</i></b></p> <p>Can we describe (coarse scale) potential areas for APEIs to protect representative ecosystem components and gradients?</p> <p>What network criteria should be used to evaluate representation, connectivity, replication and adequacy? What data gaps exist and how can they be resolved?</p> <p>How do we conduct spatial decisions with sparse data (precautionary approaches etc.)?</p>	<p>What are the bounds of the system of interest?</p> <p>What is the relevant scale of each system?</p> <p>What are the key model components, subsystems, and interactions of the ecosystem?</p> <p>Identify what are the natural and anthropogenic stressors (pressures) within each described system</p> <p>What are the relationships of stressors, ecological factors, and responses?</p> <p>What parts of the system do we lack key information? and how would be learn about these key components?</p> <p>How to define thresholds for cumulative impact from multiple mining activities per xx km of ridge length?</p>
<b>Group 2 : Inactive hydrothermal vent communities/ Hard substrate</b>		
<i>Scenario Planning for Adaptive Management</i>	<i>Spatial Planning</i>	<i>Addressing cumulative impacts</i>
<p>What are the significant habitats?</p> <p>How close do other equivalent habitats need to be located to preserve</p>	<p><b><i>For fine scale planning</i></b></p> <p>Can we describe known (fine scale) sites in need of protection?</p> <p>What types of relevant criteria</p>	<p>What are the bounds of the system of interest?</p> <p>What is the relevant scale of each system?</p> <p>What are the key model</p>



<p>connectivity?</p> <p>How close do other inactive vents need to be located to preserve connectivity?</p>	<p>can be used for the above description at finer and coarse scales (e.g. FAO VME criteria)?</p> <p>What size and spacing criteria can be used?</p> <p>What data gaps exist and how can they be resolved?</p> <p>How do we conduct spatial decisions with sparse data (precautionary approaches etc.)?</p> <p><b><i>For coarse scale planning</i></b></p> <p>Can we describe (coarse scale) potential areas for APEIs to protect representative ecosystem components and gradients?</p> <p>What network criteria should be used to evaluate representation, connectivity, replication and adequacy? What data gaps exist and how can they be resolved?</p> <p>How do we conduct spatial decisions with sparse data (precautionary approaches etc.)?</p>	<p>components, subsystems, and interactions of the ecosystem?</p> <p>Identify what are the natural and anthropogenic stressors (pressures) within each described system</p> <p>What are the relationships of stressors, ecological factors, and responses?</p> <p>What parts of the system do we lack key information? and how would be learn about these key components?</p> <p>How to define thresholds for cumulative impact from multiple mining activities per xx km of ridge length?</p>
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**Group 3 : Mid-water fauna/Sediment**

<b><i>Scenario Planning for Adaptive Management</i></b>	<b><i>Spatial Planning</i></b>	<b><i>Addressing cumulative impacts</i></b>
<p>Are there any significant assemblages?</p> <p>How do we define thresholds for plume impacts (particles and toxicity)?</p> <p>How do you define thresholds for significant mining impact?</p> <p>Can you suggest technical approaches to for managing plume impacts (Ship to barge returned water and dewatering plume)?</p> <p>Do the plumes have an effect on mammals and reptiles and</p>	<p><b><i>For fine scale planning</i></b></p> <p>Can we describe known (fine scale) sites in need of protection?</p> <p>What types of relevant criteria can be used for the above description at finer and coarse scales (e.g. FAO VME criteria)?</p> <p>What size and spacing criteria can be used?</p> <p>What data gaps exist and how can they be resolved?</p> <p>How do we conduct spatial decisions with sparse data (precautionary approaches etc.)?]</p>	<p>What are the bounds of the system of interest?</p> <p>What is the relevant scale of each system?</p> <p>What are the key model components, subsystems, and interactions of the ecosystem?</p> <p>Identify what are the natural and anthropogenic stressors (pressures) within each described system</p> <p>What are the relationships of stressors, ecological factors, and responses?</p>

<p>migratory species?</p> <p>Will the static mining vessel attract birds and impact their feeding behavior or migratory ability?</p>	<p><b><i>For coarse scale planning</i></b></p> <p>Can we describe (coarse scale) potential areas for APEIs to protect representative ecosystem components and gradients?</p> <p>What network criteria should be used to evaluate representation, connectivity, replication and adequacy?</p> <p>What data gaps exist and how can they be resolved?</p> <p>How do we conduct spatial decisions with sparse data (precautionary approaches etc.)?</p>	<p>What parts of the system do we lack key information? and how would we learn about these key components?</p> <p>How to define thresholds for cumulative impact from multiple mining activities per xx km of ridge length?</p>
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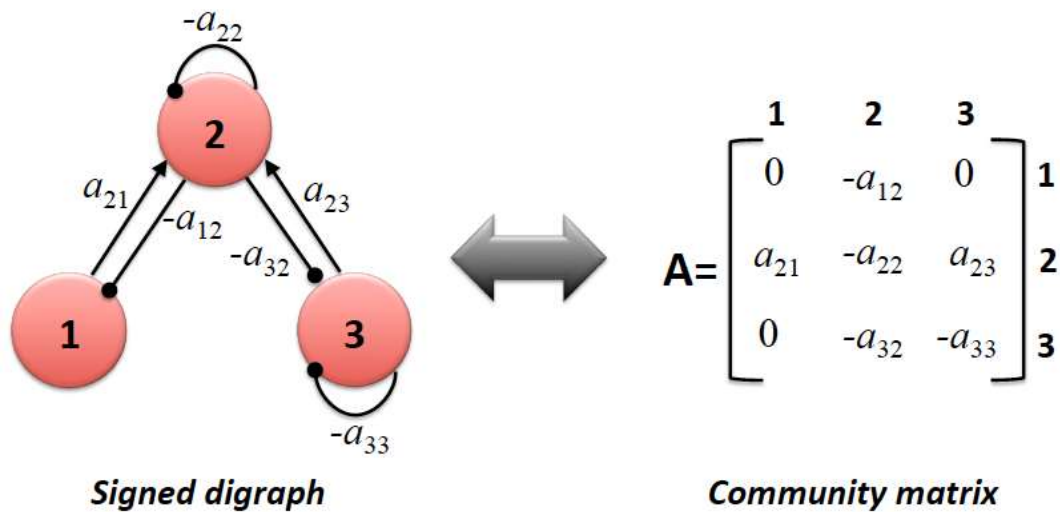
**Results of workshop discussion on qualitative modeling for cumulative impact assessment**

**I. Approaches taken for the qualitative mathematical modeling for addressing cumulative impact<sup>15</sup>**

1. Qualitative mathematical models represent a working hypothesis about how an ecosystem works. They should: a) identify important components and processes in the system; b) document assumptions about how these components and processes are related; c) identify the linkages between these components/processes and anthropogenic pressures; and d) identify knowledge gaps or other sources of uncertainty.
2. Steps or tasks in constructing qualitative mathematical models include identifying:
  - bounds of the system of interest
  - key model components, subsystems, and interactions
  - natural and anthropogenic stressors (pressures)
  - relationships of stressors, ecological factors, and responses
  - clear knowledge gaps in the system.
3. Qualitative mathematical models come in many different forms including simple narrative descriptions, schematic diagrams, box-and-arrow flowcharts, or even cartoons that pictorially illustrate physical and biological processes and the effects of anthropogenic pressures. Even though there are many forms of conceptual models, they all hold common elements and can be constructed using a common set of steps.
4. Qualitative mathematical models need to portray the ecological system at a level of resolution that is useful to the purposes of the risk assessment, striking a balance between simplicity and complexity. They should not seek to represent the entire system with myriad components and processes; rather the goal should be to encompass the relevant subsystem, which includes the components of the system that are the focus of the risk assessment, the associated processes and variables that act to maintain and regulate them, and the natural and anthropogenic pressures or concern.
5. A qualitative mathematical model is implemented through a partial specification of the system. In a partially specified system, only the qualitative nature of the relationships between variables must be specified. Under this approach, the effect of one variable on another can be specified only through the sign of its effect, e.g. positive (+), negative (-) or no (0) effect. Qualitative modelling is based on representing the qualitative nature of the relationships shared between system components and variables (Puccia & Levins 1991). This approach sacrifices precision in model details and predictions but gains a causal understanding of a system that is pertinent to a broad range of contexts and applications (Justus 2005, 2006).
6. Signed flow graphs are a method of qualitative modelling first used by Mason (1953) in working on electrical circuits; this approach was later extended and developed into qualitative mathematical models for application in ecology and biology by Richard Levins (1974, 1975, 1998, Puccia & Levins 1985). This method is based on the analysis of system structure using signed directed graphs (hereafter signed digraphs).

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<sup>15</sup> This background information was provided by Mr.Skipton Wolloey (CSIRO/Australia) who facilitated the breakout session under agenda item 6, focusing on addressing cumulative impacts.



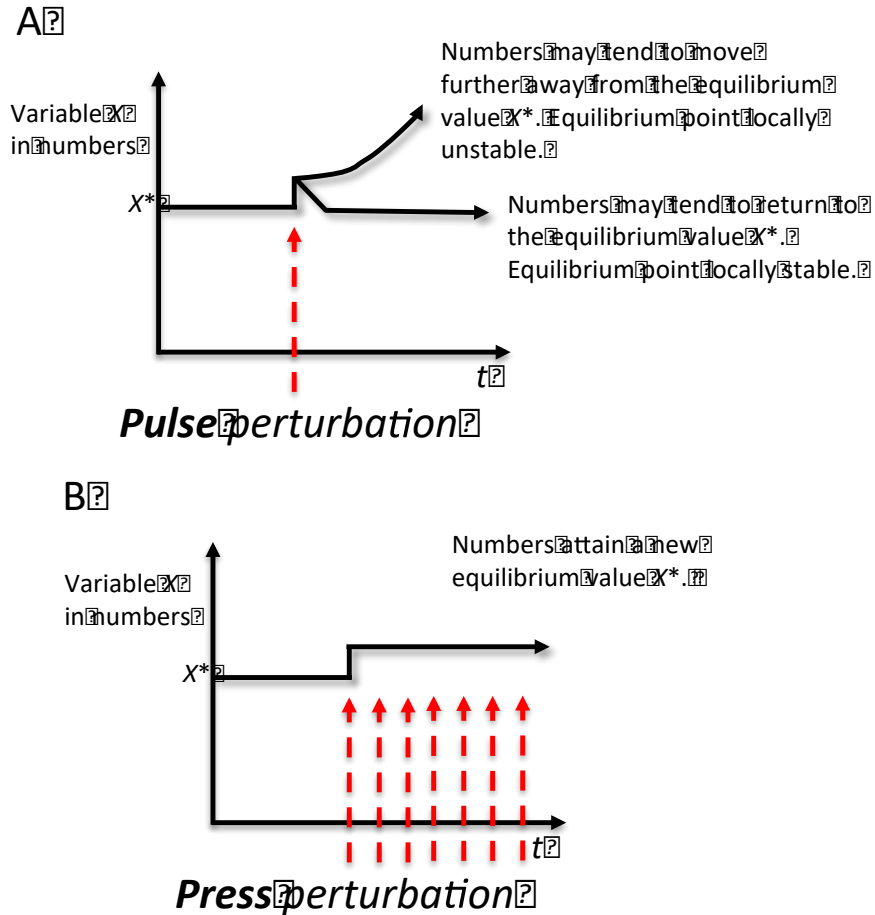
**Figure 1:** Three-variable system represented by a signed digraph and equivalent community matrix. The nodes represent variables 1, 2 and 3. Arrowhead and filled circle ending edges correspond to direct positive and negative effects respectively. The coefficients  $a_{ij}$  in the digraph show the correspondence of each direct effect with the elements of the community matrix. The numbers 1, 2 and 3 in each row and column of the community matrix correspond to variables 1, 2 and 3 of the system.

7. A signed digraph is a graphical representation of variables and their interactions, where the nodes or vertices of the graph represent the system variables, and the directed edges, represent both the sign and the direction of the direct effect of one variable on another, i.e. a positive (+), a negative (-) or a null (0) effect. Figure 1 shows a system of three variables. Edges ending in arrowheads correspond to positive direct effects while edges ending in filled circles represent negative direct effects. In figure 1 there are two positive direct effect from variable 1 to variable 2 and variable 3 to variable 2, and two negative direct effect from variable 2 to variable 1 and variable 2 to variable 3. Arrows originating and ending in the same variable are self-effects. Self-effects can be negatives as in the self-damping variables (as the one shown at variable 2 and variable 3).

8. The structure of the signed digraph is a graphical representation of the community matrix (Levins 1968), which is a matrix that contains the interactions between variables in a dynamic system at equilibrium. In the community matrix the direct effects between variables are represented through the interaction coefficients  $a_{ij}$  in the matrix, which represents the direct effect of variable  $j$  (column) on variable  $i$  (row). Figure 1 shows the equivalence of a signed digraph and a community matrix for a three-variable system. Coefficients with their sign on the digraph correspond to those in the community matrix.

9. Based on the qualitative structure of a system detailed in a signed digraph or community matrix, one can assess the scope or potential for a system to be stable, and if it is stable, then how it will respond to a perturbation that shifts the system to a new equilibrium. Under a sudden and small pulse perturbation, a stable system will return to its former equilibrium (Fig. 2A), but if the system is unstable, then it will either be attracted to a new equilibrium in which abundances or values of the variables are

shifted to different levels, or even the system may collapse, leading to the extinction of one or more components.



**Figure 2.** In A and B are depicted the trajectories of variable  $X$  through time. In A, the red dashed arrow indicates the time at which variable  $X$  is perturbed by a small increase in  $X$  at equilibrium. In B red dashed arrows indicate the sustained (press) perturbation on  $X$  driven by an increase in the growth rate of  $X$ .

10. A sustained change in a system parameter, or a press perturbation, will displace the system to a new equilibrium point (Fig. 2B). This occurs through a change in the growth rate of one or more target variables, which then creates a series of direct and indirect effects that are transmitted to other variables through the system's links. Based on the structure of interactions of the system, one can predict changes in the equilibrium abundances and rate of turnover in model variables.

11. Once we have a clear description of the interaction structure based on the direct effects of the system, we can disentangle relations between variables that can be key when evaluating system response to perturbations.

12. Qualitative mathematical models can be created almost entirely from the description of processes and narratives. The scope and bounds of the studied system or problem is first defined, and the components of interest are then identified. Variables are chosen with respect to the problem that motivated the formulation of the model. In establishing the relationships between variables, one asks 'what is the direct influence of one variable on another', and 'what else in the system determines the

creation or destruction of a variable'. In addition to biological variables, this can also include physical and environmental factors as well as social and economic processes.

13. Workshops with experts and literature reviews are a well-known source of system description. Once we have specified each component of the model system we can represent it as a signed digraph. And while narratives can set the limits and structure of the model system, it is important to note that loop analysis rests on dynamical systems theory. It was Richard Levins (1974) who showed a partial equivalence between a system of differential equations, a matrix, and a digraph. Through equations we can find or elucidate interactions that are not clearly defined through a verbal description, frequently the case for self-damping of a variable, or interactions that become apparent through mathematical derivation, as is the case of interaction modifications (Dambacher and Ramos-Jiliberto 2007).

## II. Results of group discussions

14. In this workshop, a conceptual qualitative modelling approach based on expert knowledge was used to assess cumulative impacts on the MAR ecosystems resulting from anthropogenic pressures that derive from mining activities and other human and natural impacts in the region. Based on the principles described above for conceptual qualitative modelling, group of experts in break-out session were invited to describe the key components of the different communities found in mid-ocean ridge habitats, *inter alia* active and inactive sulphide systems, other hard substrates (e.g. basalts), surrounding sediments and water column. The inferred types of interactions among the different components focused mostly on trophic relationships. However, death/birth types of interactions were also discussed in the scope of larval ecology, which plays a key role for maintaining connectivity (e.g. see active sulphide systems section below).

15. Potential mining impacts deriving from multiple deep-sea mining pressures (e.g. noise, light, particle and chemical plumes, etc.) have been discussed in the literatures and reviewed in the Draft Regional Environmental Assessment (e.g. Van Dover et al. 2014, Sharma 2015; Christiansen et al. 2019). However, the relationships between anthropogenic stressors and biotic/abiotic components as well as ecological factors and responses (i.e. negative or positive response), are yet unknown for specific deep-sea organisms and/or particular taxa found in the MAR habitats.

16. It should be noted that the work undertaken during this workshop consisted of an initial attempt to apply the qualitative modeling approach to explore cumulative impacts. Since the participants had limited time at the workshop to consider all available information and provide comprehensive expert judgement, the group discussions reflect a preliminary analysis. Further analyses, test and validation of model outputs will be required to improve the models, resolve redundancies and other inconsistencies in the model outputs.

17. Nevertheless, experts agreed that the modeling approach was useful to structure their thinking and identify key knowledge gaps, and with better preparation (e.g. prior engagement of workshop participants for their expert inputs), a future workshop focused on modeling cumulative impacts would be helpful in the context of REMP development. As a conceptual exercise, this approach contributes to identifying risks, monitoring, and moving towards adaptive management.

18. A summary of major considerations and key points raised by the experts, as well as knowledge gaps are presented. As an example to illustrate model outputs, the preliminary results of model simulations for the pelagic/sediments working group are described. As mentioned above, further test and validation of these results is warranted.

### Active sulphide ecosystems

19. The expert group initiated the description of the conceptual active sulphide ecosystem using a simple model from the literature (Bergquist et al., 2007) while noting that other ecosystem configurations have been developed which take into account the different contributions of *in situ* primary production (PP) and surface water PP (e.g. Bell et al., 2017).

20. Deep-sea mining pressures, ecosystem components and interactions among them were discussed as summarized in Table 1. Experts highlighted that the most important components at an active vent ecosystem are the symbiont hosts, who act as ecosystem engineers. They also emphasized the need to include a larval component to account for the potential impacts that may affect dispersal propagules, which would have strong implications for recovery and resilience of the ecosystem. Identifying the source population is considered of high importance because losing it would create more serious impact on metapopulation dynamics than the loss of sink population.

21. For this preliminary analysis, experts considered that:

- Particle plume includes overburden and other particles;
- Particle plumes were taken as proxy for the dissolved plume and the returned water as there was no consensus on potential positive or negative effects of dissolved compounds (nutrients/toxic); and
- Direct site mining refers to removal of habitat.

22. In its discussion, the group agreed that this approach is useful to model vent site (local) impacts but had no consensus if such a food-web model could be applied on a regional scale, due to uniqueness of known vent-associated communities. For instance, depth and temperature are important abiotic factors controlling both biological communities and the hydrothermal system. Also, the nature of host rock is another relevant factor to take into account. It influences the chemistry of fluids, which determines the hydrothermal system that would be under pressure because different mining operations take place in different types of rocks. In addition, it is not clear whether it is possible to link food-web models to connectivity models to assess the cumulative impacts at regional scale.

**Table 1.** Pressures derived from deep-sea mining and components of active sulphide ecosystem being affected by these stressors.

Ecosystem components	Pressures				
	Mining Noise	Mining Light	Particle plume	Direct site mining	Cut off vent fluid
Symbiotic Bacteria				x	x
Particle Organic					
Attached Bacteria				x	x
Subsurface bacteria					
Symbiotic Hosts		x	x	x	
Suspension Filter Feeders			x	x	
Grazers		x	x	x	
Scavengers & Detritivores		x	x	x	
Predators	x	x	x		
Larvae	x	x	x		

23. The group agreed that models can be used to identify knowledge gaps. Such gaps could be addressed in the scope of an REMP. Key knowledge gaps identified by the group include, *inter alia*:

- Connectivity is a key driver, but knowledge is severely lacking. Recovery from impacts would depend on connectivity to other vent fields. There are no predictions possible at the north MAR since no such events have ever been studied to date.
- There is not enough information about larval biology, but disruption on one site may not affect the whole regional larval pool.
- No studies have been conducted to confirm plume effects.
- Responses to noise/vibration/light are inferred from shallow water studies but not studied for active vent systems.

### Inactive sulphide ecosystems and hard substrates

24. The group discussed the interactions between pressures derived from deep-sea mining and ecosystem components (Tables 2 and 3) and highlighted that:

- Ecosystem components are the same for inactive sulphide systems and hard substrata, but the relative abundance of autotrophic vs heterotrophic microbes will be different; in both these ecosystems; particulate organic carbon (POC) is an additional component as food source, comparatively to active sulphide ecosystems;
- Deep-sea mining pressures considered in inactive vent systems are the same as discussed by the active vent system group, but instead of vent fluid cut off, reactivation of fluid flow could potentially occur;
- For this preliminary analysis, particle plume includes both dissolved plume (nutrients/toxic compounds) and returned water, for inactive sulphide systems and hard substrata, but may be toxic in inactive sulphide ecosystems; plumes could induce a positive response to some components of the ecosystem (e.g. due to nutrient enrichment) but it does not mean that the environmental effect is necessarily positive; most of the animals at inactive sulphide systems are suspension feeders and would become clogged (i.e. damage the feeding apparatus);
- The larval input contributes to each ecosystem component, but reproduction of each of those components also contributes to the larval pool (source and sink populations);
- Endemicity is an important factor to consider and impacts would be more or less localized in where endemic species occur; and
- Mining of inactive sulphide ecosystems will likely mean that some of these other pressures (noise, light, plumes) would not occur simultaneously because fauna would be lost as a result of removal of the substrate (sulphide).

**Table 2.** Pressures derived from deep-sea mining and components of inactive sulphide ecosystem being affected by these stressors.

Ecosystem components	Pressures				
	Mining Noise	Mining Light	Particle plume	Direct site mining	Reactivation
Autotrophic microbes				x	x
Heterotrophic microbes				x	x
Deposit feeders				x	x
Suspension Filter Feeders			x	x	x



<b>Grazers</b>		x	x	x	x
<b>Benthic Predators/Scavengers</b>	x	x	x	x	x
<b>Larvae</b>	x	x	x	x	x

**Table 3.** Pressures derived from deep-sea mining and components of hard substrata ecosystem being affected by these stressors.

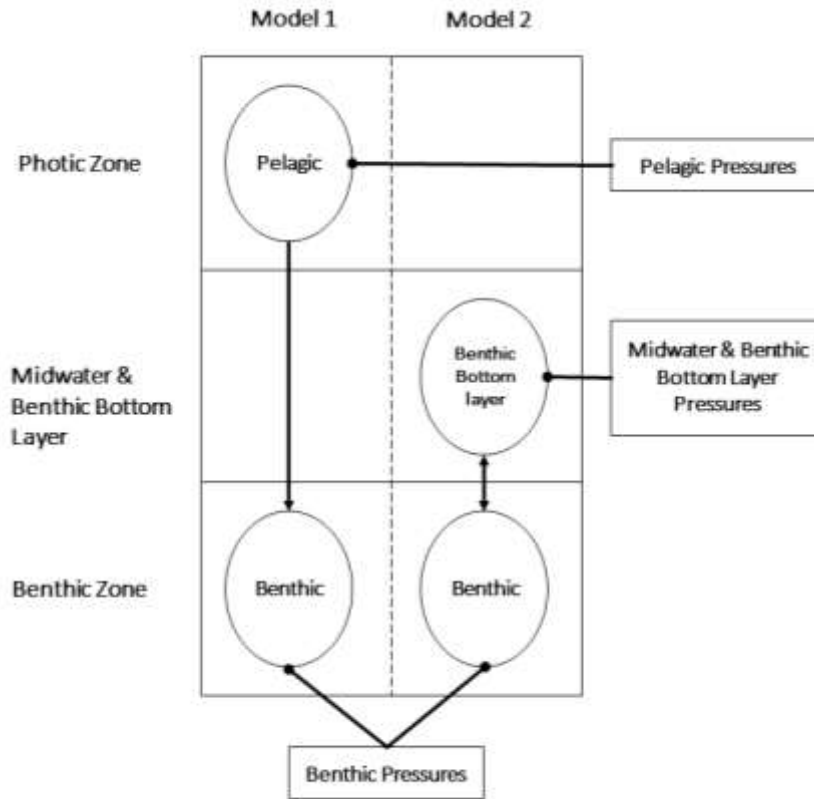
<b>Ecosystem components</b>	<b>Pressures</b>		
	<b>Mining Noise</b>	<b>Mining Light</b>	<b>Particle plume</b>
<b>Microbes</b>			
<b>Deposit feeders</b>			x
<b>Suspension Filter Feeders</b>	x	x	x
<b>Grazers</b>			x
<b>Benthic Predators/Scavengers</b>	x	x	x
<b>Larvae</b>	x	x	x

### **Pelagic and sediment ecosystems**

24. The group discussed different ecosystem models available in the literature and reviewed in the Draft Regional Environmental Assessment (e.g. Morato et al. 2016, Anderson et al. 2019). Some of these models incorporate chemosynthesis-based food webs in addition to surface POC-driven ecosystem. For the purpose of this preliminary analysis, experts agreed to focus on a simple model excluding chemosynthetic sources of organic matter.

25. Interactions between ecosystem components and pressures derived from deep-sea mining, as well as from other human activities (pelagic fishing and shipping) and ocean acidification, were discussed for sub-compartments of the pelagic and benthic ecosystems, corresponding to different depth zones along the water column, namely surface (0-200m), mid-water (including mesopelagic, 200-1000m, and bathypelagic, 1000-50m above the bottom), benthic boundary layer (BBL, 50 m above the bottom), and at the seafloor. Experts highlighted that there are cascade effects, bottom up and top down effects and horizontal effects, therefore water column and sediment habitats should be treated in combination for modelling cumulative impacts.

26. However, considering the complexity and computational demand of integrating all compartments of the pelagic and benthic (sediments) ecosystems, two simplified models were defined as shown in Figure 3. Model 1 includes the surface and benthic/seafloor ecosystem compartments, excluding mid-water and BBL zones, and Model 2 includes mid-water/BBL and benthic compartments (excluding the surface zone).



**Figure 3:** Conceptual diagram that represents the two models used to describe the effect of cumulative impacts on pelagic, midwater and benthic systems

27. For this preliminary analysis, the group considered that:
- Impacts on residents and migratory species were not discriminated;
  - Sedimentation derived from mining plume, discharge plume and overburden (displacement of natural sediments, more or less rich in metal) need to be distinguished from one another;
  - Particle plume causes shadow effects at the surface by inhibiting photosynthesis, and also interacts with other components of the ecosystems; particle plumes would impact the zooplankton, nekton and filter-feeders by clogging feeding apparatus and diluting organic carbon (increasing energy costs), and would also the deposit-feeders by smothering and diluting organic carbon; particle plumes may potentially reduce buoyancy and there are also energy costs of escape behavior;
  - Overburden can have positive effect in seafloor microbiome; overburden is similar to habitat removal and all functional groups would be impacted, except highly mobile predators and scavengers that may escape;
  - Dissolved plume (nutrients) could have increase productivity (positive impact on phytoplankton);
  - Dissolved plume also contains toxic materials, thus a separate toxic plume was added to the list of pressures; the toxicity may be acute for all faunal groups but large predators may avoid the contaminated waters; toxicity includes also pathogens that affect all the same ecosystem components;
  - Returned water (discharge plume) enhances mining plume effect;
  - Noise and light interact with same components, thus can be treated as a single pressure; light and noise mainly impact midwater predators/scavengers or interfere with bioluminescence;

other functional groups of the benthic ecosystem would not be affected as most species are blind; aggregation vs repulsion effects (Peña, 2019) were not distinguished in this preliminary analysis;

- The phytoplankton is recognized as the main source of primary production confined to the surface layers of the ocean, but with processes of consumption and export (Anderson et al. 2019) it is assumed to extend below 200 m, mediated in part by vertical migration;
- The zooplankton includes the larval pool, but only trophic interactions are considered for now in the model, not the population dynamics;
- Ocean acidification affects phytoplankton and zooplankton (e.g. calcified organisms); oxygen depletion would have same impacts as toxic compounds;
- Nekton is dominated by the large biomass of fishes, shrimps and cephalopods of the deep scattering layer that undergo daily vertical migration but also includes surface-living species
- Large predators refers to vertebrates, including whales, dolphins, porpoises, tunas, billfish, sharks and turtles that often migrate long distances, some diving to great depths.
- Regarding pelagic fishing activity, the group considered mostly longline fishing as there was not so much consensus on how much pressure exists from other types of fishing in MAR;
- Sea birds are recognized as a special case where individuals such as fulmars can rapidly migrate between breeding sites on land and feeding areas of the Mid-Atlantic Ridge (Edwards et al. 2013) where they capture mesopelagic (midwater) fishes (Danielsen, 2013); and
- Shipping was also considered as an important human activity in the region.

28. Key knowledge gaps highlighted by the group of experts include, *inter alia*:

- How dissolve plume interacts with POC (flocculation, increase weight –ballasting effect);
- Temperature changes from mining equipment and discharge plumes needs to be further studied; and
- Knowledge of virus and bacteria is currently a “black box”.

29. Tables 4 to 7 summarize the list of anthropogenic pressures considered in this preliminary analysis, and the ecosystem components that would be affected by these stressors at the surface, mid-water, BBL and benthic sediment ecosystem compartments.

30. For each model, two scenarios for the depth at which the discharge plume would be returned were considered: i) Return Pelagic Plume, at the surface in Model 1 and in mid-water/BBL in Model 2, and ii) Return Benthic Plume at the seafloor in both models. Figures 4 and 8 illustrate the interactions between pressures and ecosystem components for each model, as described above and summarized in Tables 4 to 7. In these figures both returned water scenarios (Return Pelagic Plume and Return Benthic Plume) are shown. To calculate the separate scenario outputs, each return water variable is excluded from the models i.e. one without return benthic plume (scenario i), and the other without return pelagic plume (scenario ii). The model outputs are presented in Figs. 5-7 for Model 1 and Figs. 9-11 for Model 2.

31. Under a scenario of returned water at the surface in the pelagic-benthic model (Model 1, Fig. 5), the effect of Benthic Mining Plume (BMP) and returned pelagic plume (RPP) are particularly negative (or unknown) for most ecosystem components. In comparison, if the returned water is discharged at the seafloor (Model 1, Fig. 6) the effect of the Returned Benthic Plume (RBP) is completely unknown. This could be interpreted as the RPP is of higher impact based on our current knowledge of the system. While the impact of RBP is unknown, so with some more monitoring/modelling we could learn how detrimental this pressure actually is and reduced the uncertainty (unknowns) for this impact.

32. Figures 7 and 11, show a proportion of the different ecosystem component responses (positive, negative, neutral and unknown) for each individual pressure. These figures indicate which pressure has the most negative responses and then could be the most damaging. For example, in Model 1 return the plume to the surface is much worse than returning to the benthos. However, there are more unknowns in the Returned Benthic Plume (RBP), which means there are many unknowns on how ecosystems components will respond to pressures. This could be seen as a greater risk (in terms of uncertainty). There are many unknowns in all models, which also suggest that a lot more knowledge of these systems is needed to reduce the uncertainty/ambiguity in the models.

33. It should be noted that for many of simulations, pressures are interacting and a sum of all possible combinations is shown in figures 7 and 11, so there will be situations where pelagic and benthic plume are present at the same time. In realistic scenarios not all the potential pressure combinations occur simultaneously, and cumulative impact assessment should be combined with analysis of pressure distribution at spatial and temporal scales. For instance, a coral patch destroyed by removal of substrate resulting from mining activity (direct impact) would not be simultaneously affected by toxic metals released in the mining plume (indirect impact).

**Table 4.** Pressures derived from anthropogenic activities and components of surface water ecosystem (0-200 m) being affected by these stressors.

Ecosystem components	Pressures						
	Shipping	Mining vessel sound/light	Pelagic fishing	Particle plume	Dissolved plume	Toxic plume	Ocean acidification
Phytoplankton				x	x	x	x
Zooplankton				x		x	x
Nekton		x		x		x	
Large Predator	x	x	x	x		x	
Sea Birds	x	x				x	

**Table 5.** Pressures derived from anthropogenic activities and components of midwater water ecosystem (200 – 50 m above the bottom) being affected by these stressors.

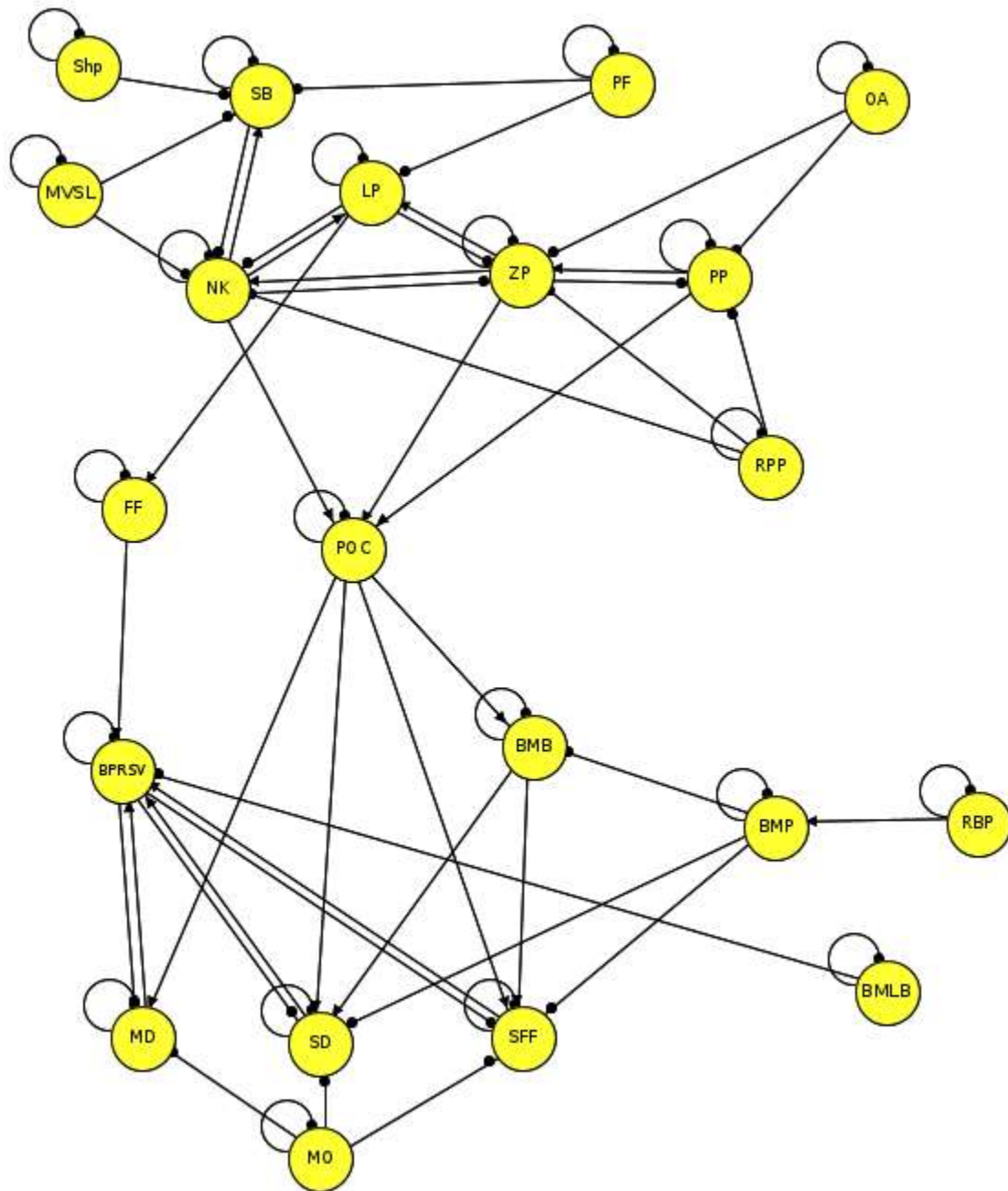
Ecosystem components	Pressures						
	Shipping	Mining vessel sound/light	Pelagic fishing	Particle plume	Dissolved plume	Toxic plume	Ocean acidification
Phytoplankton				x	x	x	x
Zooplankton				x		x	x
Nekton		x		x		x	
Large Predator	x	x	x	x		x	
Sea Birds	x	x				x	

**Table 6.** Pressures derived from anthropogenic activities and components of benthic boundary layer ecosystem (0-50 m above the bottom) being affected by these stressors.

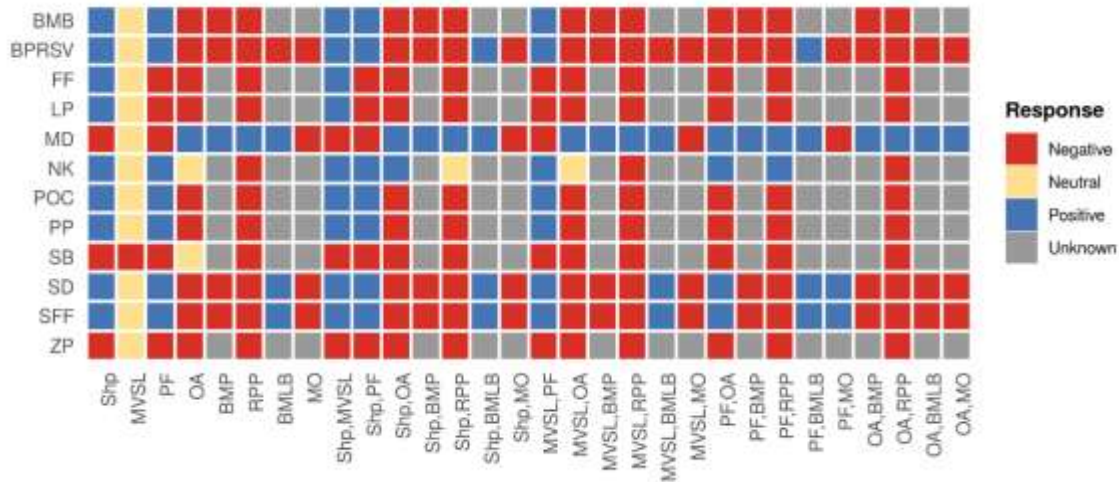
Ecosystem components	Pressures			
	Mining vessel sound/light	Particle plume	Toxic plume	Ocean acidification
Zooplankton	x	x	x	x
Nekton	x	x	x	x
Benthic Predators Scavengers	x		x	
Microbiome			x	x

**Table 7.** Pressures derived from anthropogenic activities and components of benthic sediment ecosystem being affected by these stressors.

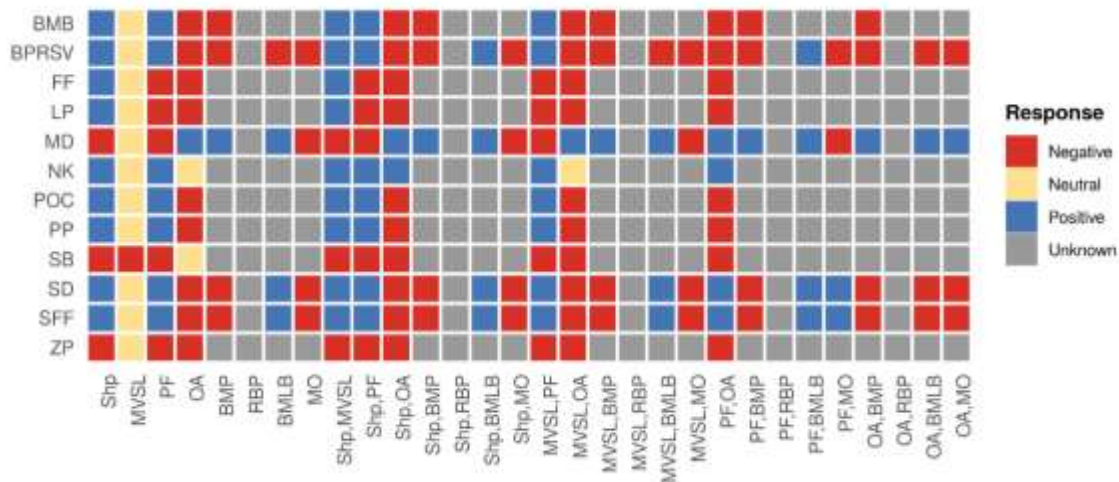
Ecosystem components	Pressures				
	Mining vessel sound/light	Overburden	Particle plume	Toxic plume	Ocean acidification
Mobile Detritivores		x		x	x
Sessile Detrivores		x	x	x	x
Suspension Filter Feeders		x	x	x	x
Benthic Predators Scavengers	x			x	
Microbiome		x		x	x



**Figure 4: Model 1. Pelagic-Benthic qualitative mathematical model to assess cumulative impacts.** *The Pelagic-Benthic qualitative mathematical model has the following ecosystem components: BMB, Benthic Microbes; BFRSV, Benthic Predators Scavengers; FF, Food Falls; LP, Large Predators; MD, Mobile Detritivores; NK, Nekton; POC, Particulate Organic Carbon; PP, Phytoplankton; SB, Sea Birds; SD, Sessile Detritivores; SFF, Suspension Filter Feeders; ZP, Zooplankton. And the following threatening pressures which will impact various ecosystem components: BMLB, Benthic Mining Light Noise; BMP, Benthic Mining Plume; MO, Mining Overburden; MVSL, Mining Vessel Light & Sound; OA, Ocean Acidification; PF, Pelagic Fishing; RBP, Return Benthic Plume; RPP, Return Pelagic Plume; Shp, Shipping.*

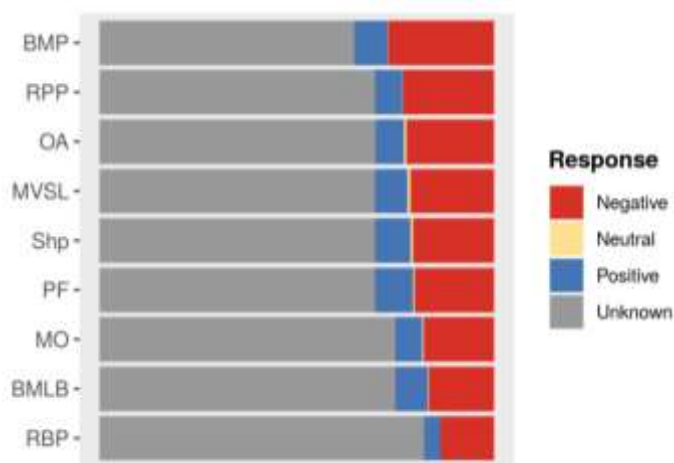


**Figure 5: Model 1. Scenario where (if present) the mining plume is returned to the pelagic water column above the photic zone.** Qualitative predictions on the direction in change for each ecosystem component to pressures in the model. The ecosystem components are the rows and the columns are the impact of the pressures. Responses of ecosystem components can be either negative (red), neutral (yellow), positive (red) or unknown (grey). Here we present the first 30 potential cumulative impacts out of a potential 511 combinations for eight threatening pressures. The Pelagic-Benthic qualitative mathematical model has the following ecosystem components: BMB, Benthic Microbes; BPRSV, Benthic Predators Scavengers; FF, Food Falls; LP, Large Predators; MD, Mobile Detritivores; NK, Nekton; POC, Particulate Organic Carbon; PP, Phytoplankton; SB, Sea Birds; SD, Sessile Detritivores; SFF, Suspension Filter Feeders; ZP, Zooplankton. And the following threatening pressures which will impact various ecosystem components: BMLB, Benthic Mining Light Noise; BMP, Benthic Mining Plume; MO, Mining Overburden; MVSL, Mining Vessel Light & Sound; OA, Ocean Acidification; PF, Pelagic Fishing; RPP, Return Pelagic Plume; Shp, Shipping.



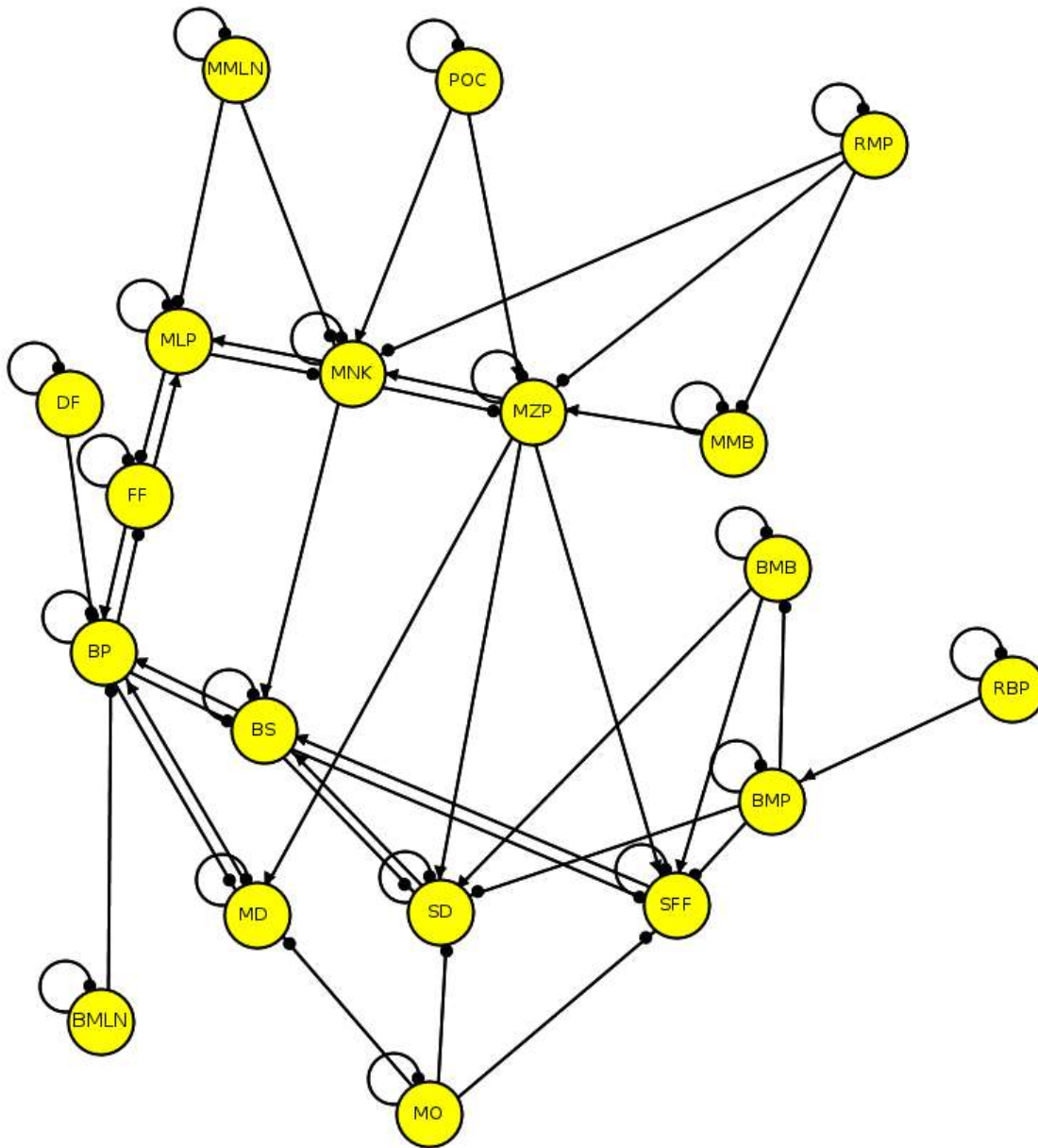
**Figure 6: Model 1. Scenario where (if present) the mining plume is returned to the benthos.** Qualitative predictions on the direction in change for each ecosystem component to pressures in the model. The ecosystem components are the rows and the columns are the impact of the pressures. Responses of ecosystem components can be either negative (red), neutral (yellow), positive (red) or unknown (grey). Here we present the first 30 potential cumulative impacts out of a potential 511 combinations for eight threatening pressures. The Pelagic-Benthic qualitative mathematical model has the following ecosystem components: BMB, Benthic Microbes; BPRSV, Benthic Predators Scavengers; FF, Food Falls; LP, Large Predators; MD, Mobile Detritivores; NK, Nekton; POC, Particulate Organic Carbon; PP, Phytoplankton; SB, Sea Birds; SD, Sessile Detritivores; SFF, Suspension Filter Feeders; ZP, Zooplankton. And the following threatening pressures which will impact various ecosystem

components: BMLB, Benthic Mining Light Noise; BMP, Benthic Mining Plume; MO, Mining Overburden; MVSL, Mining Vessel Light & Sound; OA, Ocean Acidification; PF, Pelagic Fishing; RBP, Return Benthic Plume; Shp, Shipping.

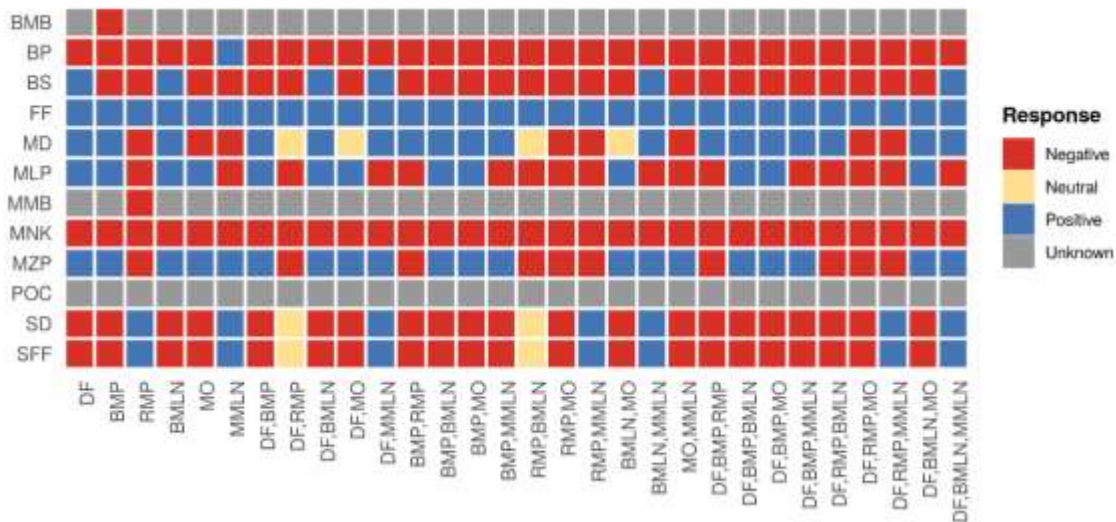


**Figure 7: Model 1. Proportion of responses of all ecosystem components to each pressure.** This figure helps identify which pressures have the highest amount of negative, neutral, positive or unknown responses. The following pressures are included in the pelagic-benthic model: BMLB, Benthic Mining Light Noise; BMP, Benthic Mining Plume; MO, Mining Overburden; MVSL, Mining Vessel Light & Sound; OA, Ocean Acidification; PF, Pelagic Fishing; RBP, Return Benthic Plume; RPP, Return Pelagic Plume; Shp, Shipping.

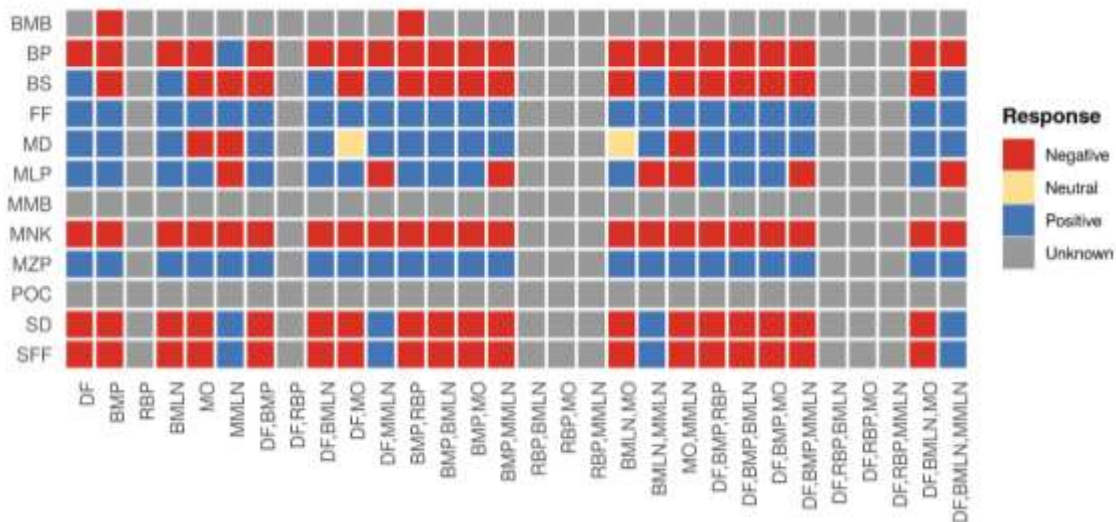




**Figure 8: Model 2. Midwater-Benthic qualitative mathematical model to assess cumulative impacts.** *The Midwater-Benthic qualitative mathematical model has the following ecosystem components: BMB, Benthic Microbes; BP, Benthic Predators; BS, Benthic Scavengers; FF, Food Falls; MLP, Midwater Large Predators; MMB, Midwater Microbes; MNK, Midwater Nekton; MZP, Midwater Zooplankton; MD, Mobile Detritovores; POC, Particulate Organic Carbon; SD, Sessile Detritivores & SFF, Suspension Filter Feeders. The model also has the following pressures which will impact the ecosystem components: BMLN, Benthic Mining Light Noise; BMP, Benthic Mining Plume; DF, Demersal Fishing; MMLN, Midwater Mining Light Noise; MO, Mining Overburden; RBP, Return Benthic Plume & RMP, Return Midwater Plume.*

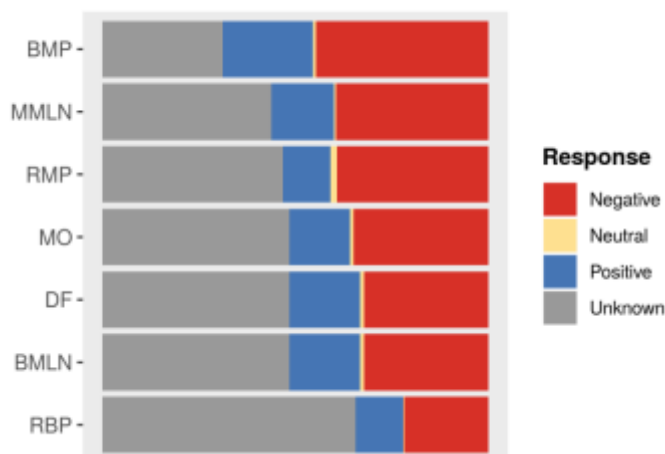


**Figure 9: Model 2. Scenario where (if present) the mining plume is returned to the midwater layers.** Qualitative predictions on the direction in change for each ecosystem component to pressures in the model. The ecosystem components are the rows and the columns are the impact of the pressures. Responses of ecosystem components can be either negative (red), neutral (yellow), positive (blue) or unknown (grey). Here we present the first 30 potential cumulative impacts out of a potential 127 combinations for seven threatening pressures. The ecosystem component responses are the rows and are as follows: BMB, Benthic Microbes; BP, Benthic Predators; BS, Benthic Scavengers; FF, Food Falls; MLP, Midwater Large Predators; MMB, Midwater Microbes; MNK, Midwater Nekton; MZP, Midwater Zooplankton; MD, Mobile Detritivores; POC, Particulate Organic Carbon; SD, Sessile Detritivores & SFF, Suspension Filter Feeders. The scenarios are combinations of the following pressures, which will impact the ecosystem components: BMLN, Benthic Mining Light Noise; BMP, Benthic Mining Plume; DF, Demersal Fishing; MMLN, Midwater Mining Light Noise; MO, Mining Overburden; RBP & RMP, Return Midwater Plume.



**Figure 10: Model 2. Scenario where (if present) the mining plume is returned to the benthos.** Qualitative predictions on the direction in change for each ecosystem component to pressures in the model. The ecosystem components are the rows and the columns are the impact of the pressures. Responses of ecosystem components can be either negative (red), neutral (yellow), positive (blue) or unknown (grey). Here we present the first 30 potential cumulative impacts out of a potential 127 combinations for seven threatening pressures. The ecosystem component responses are the rows and are as follows: BMB, Benthic Microbes; BP, Benthic Predators; BS,

Benthic Scavengers; FF, Food Falls; MLP, Midwater Large Predators; MMB, Midwater Microbes; MNK, Midwater Nekton; MZP, Midwater Zooplankton; MD, Mobile Detritivores; POC, Particulate Organic Carbon; SD, Sessile Detritivores & SFF, Suspension Filter Feeders. The scenarios are combinations of the following pressures, which will impact the ecosystem components: BMLN, Benthic Mining Light Noise; BMP, Benthic Mining Plume; DF, Demersal Fishing; MMLN, Midwater Mining Light Noise; MO, Mining Overburden & RBP, Return Benthic Plume.



**Figure 11: Model 2. Proportion of responses of all ecosystem components to each pressure.** This figure helps identify which pressures have the highest amount of negative, neutral, positive or unknown responses. The following pressures are included in the midwater-benthic model: BMLN, Benthic Mining Light Noise; BMP, Benthic Mining Plume; DF, Demersal Fishing; MMLN, Midwater Mining Light Noise; MO, Mining Overburden; RBP & RMP, Return Midwater Plume.

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## *Annex VIII*

### ***Results of workshop discussion on the scenario planning for adaptive management***

#### **Adaptive Management**

1. Under this agenda item, the workshop participants discussed an adaptive management approach which could form one component of the REMP. There is a need for adaptive management because of the large number of unknowns related to mining polymetallic sulphides on mid-ocean ridges. This approach allows for environmental information to accumulate with time and for controlled mining activities to proceed in the absence of some environmental information. As such, mining activities could be facilitated while ensuring that conservation objectives are met. This annex summarizes the results of breakout group discussions on this topic, as inputs to designing the draft REMP. This discussion focused on identifying sensitive ecosystems and dealing with these on a case by case basis. As information accumulates it may be possible to modify thresholds and other components of the adaptive management plan at a later stage.
2. This section summarizes the main points from the different habitat group discussions on adaptive management as described in Figures 1 – 7. It should be read in conjunction with appendix 1 to this annex, where more information is presented on the knowledge gaps/unknowns identified during the breakout group discussions.

#### **Summary of Discussions**

3. The scenarios presented in Figures 1 – 7 show a plan view of the mid-Atlantic ridge. The continuous brown vertical line represents the ridge axis. Active vents are known to occur at least 12 km away from the ridge axis (dashed line) but current exploration extends to 20-30 km each side of the axis. The blue area therefore represents the likely area where mining would be concentrated. To either side of this the sediment thickness may be too great to identify deposits and/or to mine them. Hydrothermal vents are indicated on the figures as red circles with representative spacing, as determined from the InterRidge vents database (version 3.4). Inactive vents are shown as black circles and may or may not be clustered near to active vent sites. Areas of potentially sensitive habitat, such as coral or sponge aggregations, are denoted by the larger blue symbols – the location of such areas is not known but they are predicted to occur along at least part of the ridge axis. Potential mine sites are indicated by green circles, and areas that may be affected by plumes are indicated by pale green ellipses. The aerial extent of such plumes is not known and will be dependent on the equipment used and site-specific water current regimes.

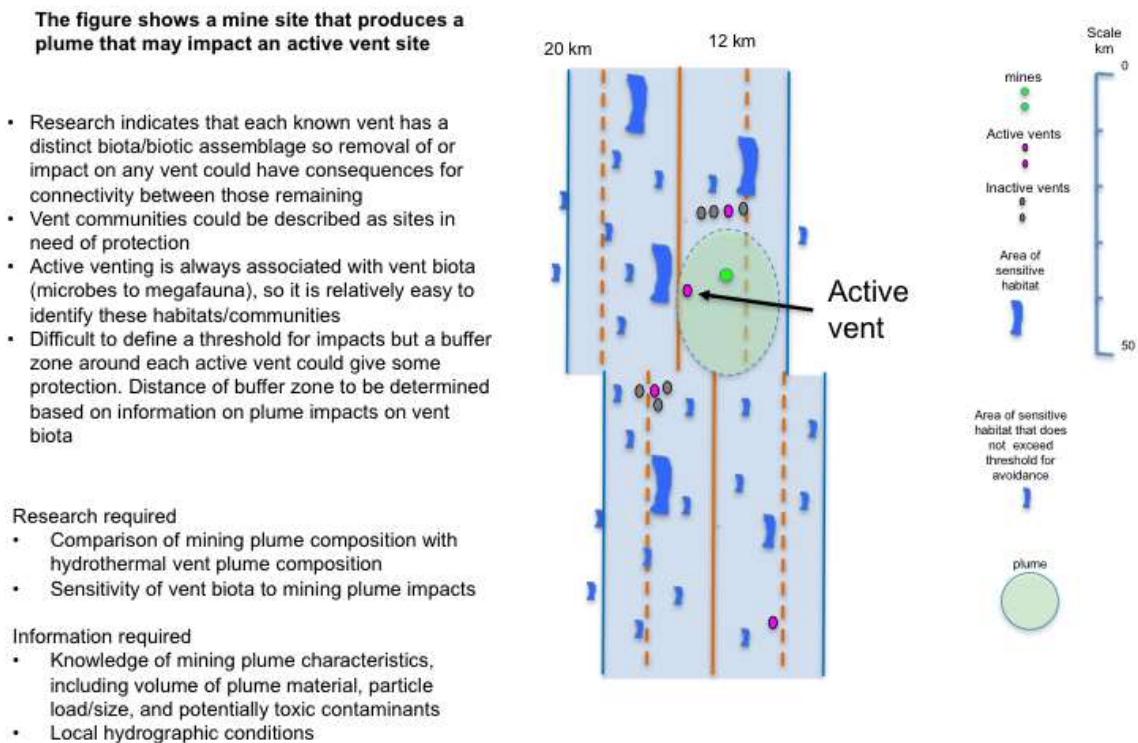
#### **Active vent fauna (Figures 1 – 2)**

4. An active hydrothermal vent is easy to recognise by the vent fluids emanating at the seabed. Even when new vents are formed at the seabed they are rapidly colonised by bacteria and higher organisms. All known active vents in the North Atlantic have colonies of higher organisms.
5. Each active vent that has been investigated has a different biotic composition, which may be controlled by a number of factors such as fluid composition and flow rate, water depth, latitude and water flow regimes. Other issues related to vent biota include different species traits related to different size classes of organisms and different larval dispersal strategies ranging from brooders to production of planktonic larvae. Much of this information is unknown. Thus, the mining of an active vent, or impact on an active vent biota by mining plumes, may have a significant and unknown impact on the connectivity of organisms between other active vents within the area. These characteristics of vent biota suggest that each active vent could be described as a site in need of protection.
6. Active vents could be subject to mining plume impacts especially if mine sites are located nearby. We do not know if plumes caused by mining will have different compositions to natural hydrothermal plumes and research is needed here. The toxic components of plumes may have a greater

impact than the particulate load but this is also unknown. It may be prudent to prevent plumes reaching hydrothermal vent locations. Various suggestions for measuring this impact are provided later in this section. One possibility could be to define a buffer zone around an active vent site. This could be based on a fixed distance but would need to take into consideration the local current regime, as this will influence the direction and distance of plume spread. Further research may be needed to define suitable distances for buffer zones. There is a need for measurements of advection and eddy diffusion to be able to model potential plume dispersal in different environmental settings. It will also be necessary to know the expected volumes and composition of mining plumes which may be dependent on the technology used.

7. Active hydrothermal vent sites often occur in association with inactive and extinct vent systems. In some cases, multiple vents can be fed by the same subsurface fluid source which has found different routes to the seabed. If an inactive vent is mined that has a linked subsurface pathway to an active vent, there is a possibility that the fluid flow to the active vent could be altered, potentially leading to reduced fitness or even death of the vent organisms. It was suggested that these potential fluid pathways are investigated at an early stage in mine planning and that local active vents are monitored during mining to verify continuation of hydrothermal flow to any active vents. It is possible that buffer zones around active vents may reduce the likelihood of hydrothermal flow alteration through mining activities.

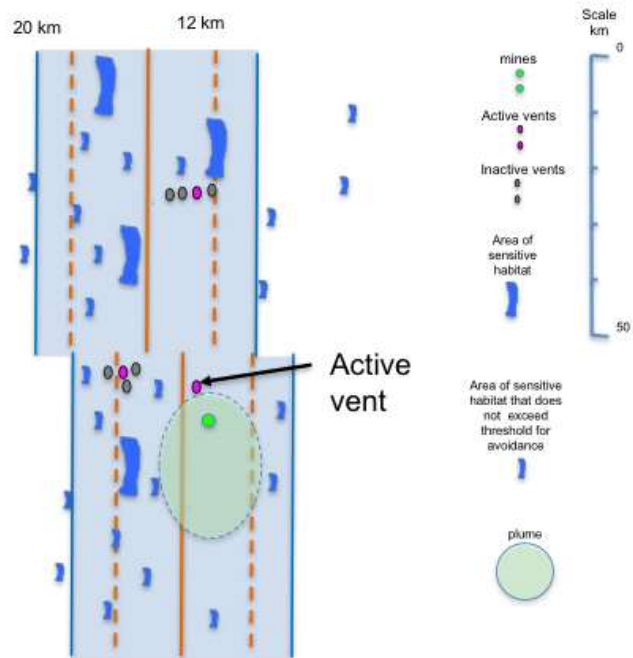
**Figure 1 Preservation of the network of active vent communities**



**Figure 2 Preservation of the network of active vent communities**

The figure shows a mine site that alters the subsurface fluid flow pattern and reduces or stops the fluid flow to an active vent site, which damages its biota

- Attention should be paid to the subsurface structure of vent fields with an attempt to understand the subsurface fluid flow regime, as part of Environmental Impact Assessment (EIA)
- If it can be demonstrated that an active vent site (defined as more than one chimney) is turned off due to nearby mining, consideration should be given as to whether this mine site should be reclassified as hydrothermally active, even though mining activity was initiated on an inactive vent



### Inactive vent biota and potential impacts (Figure 3)

8. Inactive habitat is composed of sulphide minerals that are exposed at the seafloor and which were formed by previous hydrothermal venting. It is possible that inactive vents will reactivate and again be colonised by vent biota. Alternatively, they may never reactivate and be termed extinct vents. Both are considered here under the term inactive vent. The composition of this substratum is different to the basaltic nature of other rocks on the mid-Atlantic Ridge and may therefore represent a distinct habitat with its own distinct microbial community and higher biota. Quantitative studies of megafaunal invertebrate taxa associated with inactive sulphide habitats of the Kermadec Arc (Boschen *et al.*, 2015; Boschen *et al.*, 2016) and the Central Indian Ridge (Gerdes *et al.*, 2019) suggest that these habitats may support characteristic *assemblages* of megafauna not found elsewhere in a given study area. Thin sediment layers associated with inactive vents may also provide distinct habitats as these sediments have high metal contents.

9. At present the distribution of inactive vents is unknown but they are expected to occur more widely than active vents. We do not know the metal content of many inactive vents but some inactive vents are expected to contain economically attractive accumulations of ores.

10. To preserve connectivity between inactive vent fauna it is important that not all inactive vents are mined in one area, so that a proportion can be protected to achieve conservation objectives. The size of this area is related to connectivity between populations of a given species and these distances are not known at present. Contractors could be asked to provide information on inactive vents in the vicinity of any area they wish to mine, and potentially to demonstrate that these are located outside of the area of expected impact by plumes.

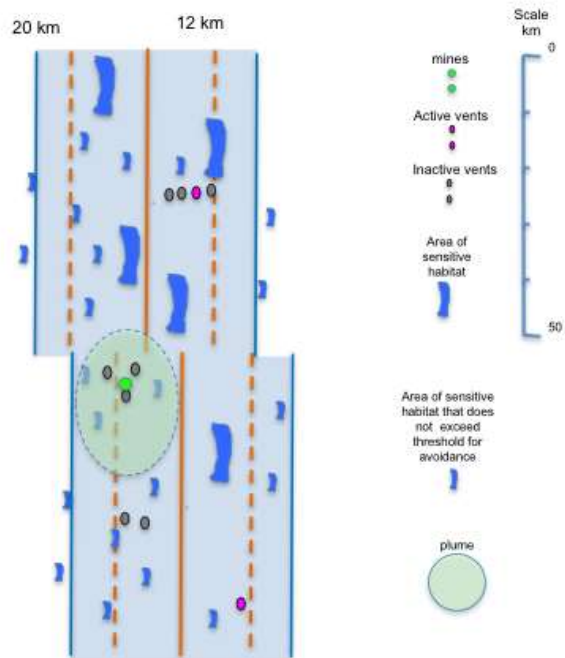
**Figure 3 Conserving a proportion of inactive vent sites**

The figure shows a mine site on an inactive vent with an associated plume. Other inactive vents are found at different locations on the figure

- Obligate inactive vent species are not known, but inactive vents are predicted to be a distinct habitat, considering the distinct chemical composition of the substrate (sulphide rich). Consequently a proportion of this habitat could be described as sites in need of protection
- Connectivity should be maintained between inactive vent sites when considering the location of mine sites

**Research required**

- Biological sampling of inactive vent fauna to verify if the inactive vent habitat is distinct from other habitats in the region



**Hard substrate biota and potential impacts (Figure 4)**

11. This section refers to the attached fauna on rocky outcrops, excluding the inactive vent fauna. A wide range of species fall into this category, such as corals, sponges, bryozoans, sea-pens, stalked crinoids and xenophyophore (giant protozoan) aggregations. Some of these species have been identified as Vulnerable Marine Ecosystem (VME) indicators by Regional Fisheries Management Organizations (RFMOs), using the Food and Agriculture Organization (FAO) criteria for VMEs, to determine communities or species most at risk from bottom trawling impacts. A similar process is suggested to identify sensitive habitat in the context of deep-sea mining. In all cases, it will be necessary to define a density threshold of the organisms at the seafloor for an occurrence to be considered a sensitive habitat. For example, the occurrence of one sponge, as an indicator species, would not reach this threshold, but an aggregation of sponges over a defined unit area may exceed this threshold. Consideration should be given as to whether thresholds should vary with depth, taking into account the decrease in abundance and biomass of organisms with increasing depth in many cases. Thresholds for determining whether occurrences should be considered VMEs were not determined during this meeting but could be established in future meetings.

12. Once sensitive species/habitats have been defined by the ISA these would need to be identified, assessed and mapped by contractors. Consideration should be given to maintaining local and regional connectivity especially for larval dispersal, the mechanisms of which may vary considerably between species. Mine sites should avoid areas particularly important for connectivity, and plumes should also not impact these areas. This may require a buffer zone around such areas. For the vast majority of organisms in this habitat, it is not known what level of plume impact can be tolerated by adults or their larvae, but it is anticipated that these organisms may be sensitive to both particulates and potentially toxic contaminants.



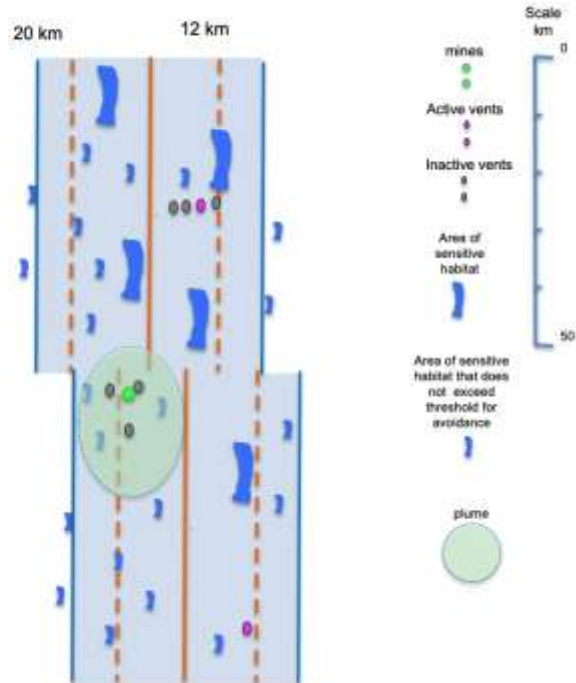
**Figure 4 Conserving sensitive fauna on non-hydrothermal hard substrates**

The figure shows a mine site on an inactive vent with an associated plume. The plume does not reach areas of sensitive non-hydrothermal hard substrate habitat.

- The FAO VME criteria could be adapted in the context of mining to describe sensitive species/habitats (for example, sponge and coral aggregations but also other species)
- Non-hydrothermal hard substrate biota could be seriously impacted by plumes, particularly sessile suspension and filter feeders, such as corals and sponges

**Research required**

- Assessment of which habitats/species could be considered vulnerable to mining, including appropriate seafloor density thresholds, based on the example FAO VME criteria
- Tolerance of each sensitive habitat/species to plume impact
- Spatial extent of plume impacts



**Soft sediment biota and potential impacts (Figure 5)**

13. Soft sediment biota is very different to hard substrate biota and includes animals that live in and on the sediment as well as swimming above the seabed. FAO VME criteria have been used by RFMOs to identify some soft sediment VME indicator species and these species could also be considered as species potentially sensitive to mining impacts. In addition, newly discovered animals such as Enteropneusts (acorn worms), that may occur in aggregations, could also be considered as species potentially sensitive to mining impacts. As with other sensitive habitats it will be necessary to define a density threshold to determine if an occurrence of a species or habitat exceeds this threshold.

14. Mine sites should avoid areas of sensitive sediment habitat and plumes should not impact these areas. At present, we do not know the susceptibility of sediment biota and their larvae to plumes, especially potentially toxic contaminants within such plumes. Determining the sensitivity of sediment biota to plume impacts requires further research.

15. Sediment can accumulate in ponds or larger “lakes” in some ridge areas from natural redeposition of sediments, for example through turbidity currents. These ponds are subject to relatively frequent sedimentation events and as such may be good locations for disposal of overburden from any shallowly buried ore bodies, providing that sensitive biota in adjacent locations are not impacted.

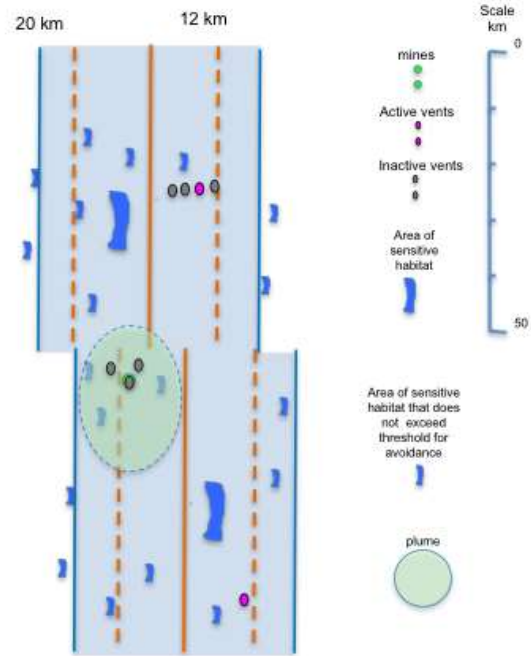
**Figure 5 Conserving sensitive fauna on sediment substrates**

The figure shows a mine site on an inactive vent with an associated plume. The plume does not reach areas of sensitive sediment substrate habitat.

- Some organisms in soft sediment habitats, such as pennatulid corals, have been identified as VME indicators by RFMOs in relation to bottom fishing
- Other organisms, such as fragile Enteropneusts (acorn worms), could be considered as potential VME indicators in the context of mining
- Plumes may have an impact over a wide area particularly along ridge axis.
- Large sediment ponds may be suitable areas for disposal of overburden as they are subject to repeated disturbance

**Research required**

- Assessment of which habitats/species could be described as VME indicators within the context of mining
- Tolerance of each sensitive habitat/species to plume impacts
- Spatial extent of plume impacts



**Pelagic environment biota and potential impacts (Figures 6 – 7)**

16. We do not know what the volume of return water will be nor its particulate content (in terms of particulate load and size), nor the potentially toxic properties of contaminants within this water. Treatment of the returned water on the vessel may remove some or all of the potentially toxic contaminants but this is not a requirement at present. Waste water may also be produced if transshipment is carried out, with ores being re-wetted for the purpose of transferring to transport barges.

17. Research shows that there is a layer near or below the thermocline where organisms are concentrated (known as the deep-scattering layer). Due to the elevated concentration of organisms here this layer was suggested to be avoided for the release of any returned water. Organisms in such layers may migrate towards the surface waters each night to feed, in response to light cues, and this behavior could be altered by increased turbidity and reduced light penetration as a result of mining plumes. If potentially toxic contaminants released through mining plumes enter the food web in the deeper parts of the water column, upward migration of these biota could introduce these contaminants into the surface waters and potentially into commercial fish species captured for human consumption.

18. Consideration could be given to returning the mining discharge water into the deeper parts of the water column to ensure that the returned water does not rise into the deep scattering layer due to its buoyancy. Consideration could be given to discharging all return water to near the seabed or possibly into the mining plume, to spatially constrain impacts to the mined area as much as possible. Concerns relating to potential toxicity of contaminants within the discharge water could be considerably reduced if the toxic components are removed from the return water at the ship through engineering solutions.

19. If mines are located at shallow water locations the operational mining plumes could be generated at the level of the deep scattering layer. This could have a greater impact on the high concentration of biomass found within the scattering layer, and on the marine environment more broadly through reducing the functionality of the biological pump. In this case mitigation strategies may be required to address these impacts.

20. The SOFAR (sound fixing and ranging) channel is a layer in the ocean, often at approximately 1000 m depth, where sound travels for very long distances. This channel is used for communication by some mammals and care should be taken to prevent generation of noise at these depths for example through mining or from pumps on the riser pipe.

21. It is possible that migratory birds or mammals may be affected by lights on a stationary ship, noise from the ship or by midwater plumes. Further research is required to understand the potential impacts on migratory birds and mammals.

### Figure 6 Conserving pelagic environment biota

**The figure shows a large plume in midwater formed from the returned water. This plume has a very poorly defined extent**

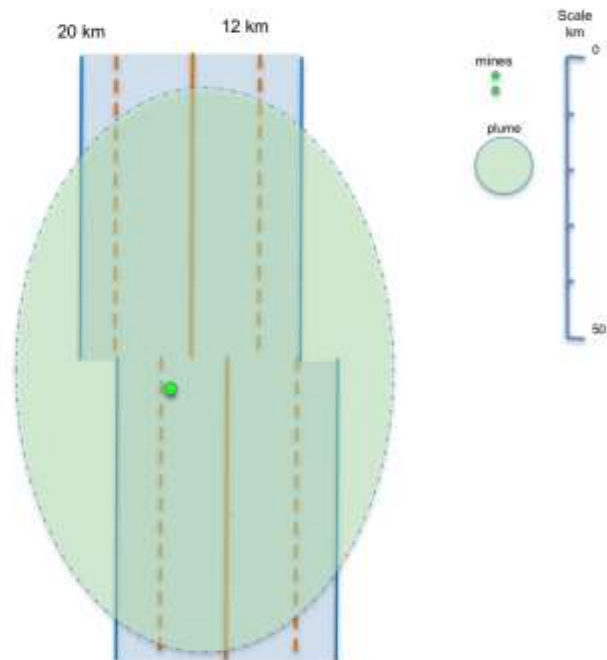
- Difficult to define sensitive assemblages as the properties of the mining plume are unknown and the tolerance thresholds are unknown
- Difficult to define tolerance thresholds for pelagic biota, which are often mobile or drift with currents
- Any returned water would be better injected below the deep-scattering layer
- Consideration could be given to discharging all return water close to the seabed or within the operational plume, to spatially constrain plume impacts
- Impacts could be greater if the mine site is within the depth of the deep-scattering layer
- Care should be taken to prevent noise in the sofar (sound-fixing-and-ranging) channel, which is used for long-distance communication by some marine mammals

#### Research required

- Possibility of treating returned water to remove potentially toxic contaminants
- Possible engineering solutions to reduce plume impacts

#### Information required

- Characteristics of the return water plume, including volume, particle concentration/size, and potentially toxic contaminants



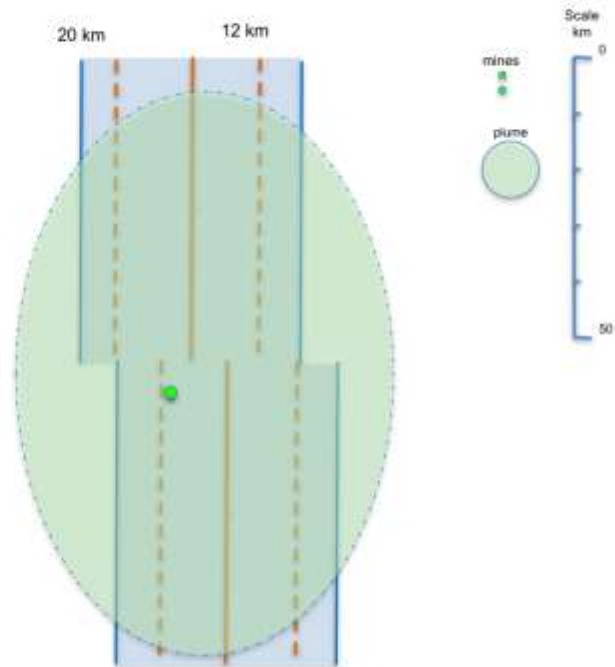
**Figure 7 Preventing impacts on air-breathing fauna, such as mammals, reptiles and birds**

The figure shows a large plume in the surface or mid-water formed from the returned water. This plume has a very poorly defined extent

- Care should be taken to ensure that the operations do not interfere with migrations of various species including marine mammals, sea turtles, and sea birds
- These issues require further investigation, as the respective expertise was not available within this meeting

**Research required**

- Possible impact of vessel and its lights on migratory birds
- Possible impact of static vessel, noise from vessel and riser pipe, and plume on migratory marine mammals and sea turtles



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*Appendix to Annex VIII.*

***Summary of individual habitat group discussions relating to knowledge gaps/unknowns relevant to scenario planning for adaptive management along the northern mid-Atlantic ridge***

*Background and scope of knowledge gap/unknowns discussions*

1. During habitat break-out group discussions on adaptive management, participants considered the knowledge gaps which may need to be addressed to support effective adaptive management of the northern mid-Atlantic Ridge (MAR). These discussions are briefly summarized in Annex VIII, with the additional details provided within this appendix.
2. The following information does not provide an exhaustive list of the knowledge gaps/unknowns which may need to be considered, nor the ways in which these gaps could be addressed. Instead, it summarizes the exchange of views by the workshop participants, within their respective discussion groups, which is structured by habitat type. Further consideration of these knowledge gaps/unknowns could include a more comprehensive and structured assessment, drawing on a wider group of experts.

*Knowledge gaps/unknowns relating to the mining process*

3. Mining will generate different plumes: the operational plume is associated with mining on the seafloor; and the discharge (or return water) plume associated with the dewatering of the ores on the surface vessels. These plumes will have different properties and as a result their impacts may affect different elements of the biota.
4. With the discharge plume, there are several different scenarios as to where the impact may occur. Discharge plumes could be released in the surface ocean; in the mid-water: above, within, below deep-scattering layer (DSL); within the bathypelagic; within any local hydrothermal plumes; and at the seabed, potentially in combination with the operational plume. In each of these areas there may be different impacts. There are many unknowns relating to the properties of the discharge water, such as temperature, buoyancy, particulate content and toxic components. If the return water has different physical characteristics to the surrounding environment, then it may rise/sink out of the discharge depth.
5. The depth of the mine location will determine the depth where the operational plume is generated. Shallow mine sites may generate operational plumes with impacts in the DSL of the pelagic environment, potentially creating a more widespread impact than a deeper mine where the plume may be more constrained. In general, there is a need to model the discharge plume, in terms of particles and chemical properties. Once there is a better understanding of plume dynamics and properties it will be possible to consider thresholds for impacts. Shipboard treatment especially for toxic components could also be considered. Test mining would provide much-needed information on plume characteristics.

**Table 1.** Mining process knowledge gaps/unknowns, their importance and suggestions for addressing these gaps/unknowns.

Knowledge gap/unknowns	Why is it important?	Suggestions for addressing gap
Depth and location of mine site	Depending on the location of the mine site, there is the potential for the plume to impact the deep-scattering layer. The location of the mine with respect to currents and topography will also impact the dispersal of the plume.	Better seabed mapping to determine mine site locations and potential impacts

Location of any inactive deposits beyond the axial valley	If hydrothermally inactive deposits are located outside of the axial valley, these may be covered with more sediment overburden. Mining these deposits may have a greater impact on sediment fauna.	Increased survey spatial coverage and resolution
What will be mined: active or inactive vents?	The type of mineral being targeted (whether hydrothermally active or inactive) will influence the properties of the return water, including chemical composition, potential toxic contaminants and plume behaviour.	Discussion with industry to determine the probable mining targets
Mining technology to be employed	The mining technology will determine the particle size, plume density, temperature of return water, whether there is an increased nutrients content, and if dissolved or particulate contaminants will occur.	- Discussion with industry to determine probable mining technology - Engineering solutions to minimise plume and other mining impacts
Whether material will be re-wetted for transshipment	If transshipment occurs, there is the potential for an additional plume to be discharged and also the potential for accidental spillage at the surface.	- Discussion with industry to determine whether transshipment will occur - Engineering solutions to minimise transshipment plume
Volume of sediment overburden to be removed	The volume of sediment overburden to be removed will determine the degree of smothering of benthic fauna and clogging of filter feeding mechanisms, with wider ecosystem impacts.	- Detailed mapping of area and site selection for overburden disposal - <i>In situ</i> or <i>ex situ</i> experimental tests of sediments from MAR sites and impacts on sediment biota to establish thresholds for particle density
The properties of the overburden	Overburden may contain potentially toxic contaminants, and particle size of the overburden will influence the extent of plume spread and associated impacts.	<i>In situ</i> or <i>ex situ</i> experimental tests of sediments from MAR sites
Potential for particle aggregation	The potential for particle aggregation will influence particle settling dynamics and so the extent of plume spread and associated impacts.	<i>In situ</i> or <i>ex situ</i> experimental tests of sediments from MAR sites
The physical properties of the return water plume, including volume of water, concentration of particulate, and particle size	High dilution may lead to fine particles being entrained within the water column for longer, and so dispersing further. High turbidity from plumes may have long-term impacts on fragile pelagic fauna, and depending on the physical properties of the plume, there could be a large impact area for benthic fauna.	Modelling and <i>in situ</i> experiments, test mining
Concentration of potentially toxic contaminants in the plume	Contaminants within the plume may be toxic to the biota, depending on their chemical	- <i>In situ</i> or <i>ex situ</i> experimental tests of

	properties and concentrations. This could have widespread impacts on the marine environment. Knowledge of potentially toxic contaminants within the plume is needed to understand whether engineering solutions are needed to ensure the tolerance thresholds of biota are not exceeded	contaminants in the plume - Engineering solutions to minimise toxicity
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*Knowledge gaps/unknowns relating to the pelagic environment as a whole*

6. The release of plumes into the pelagic environment would have largely unknown impacts. It is not currently possible to establish thresholds for impacts for the vast majority of organisms, as plume characteristics and inherent sensitivity are unknown. Given the general absence of quantitative information, a precautionary approach may be to limit the material released to the environment (both particulate and chemical) as much as possible, taking into account that finer particles and dissolved contaminants are generally more toxic and can affect larger areas. When more information is available, it may be possible to establish specific thresholds.

7. Whilst some pelagic organisms may be abundant, on an individual level they can be very fragile in relation to physical disturbance, for example gelatinous zooplankton. Some fauna may not have adaptations to cope with increased suspended sediment concentrations, for example no coughing mechanism in mid-water fishes and clogging of gelatinous zooplankton feeding nets. The sensitivity of pelagic organisms to contaminants is unknown. Within the pelagic environment there are also many of the early life stages and dispersal stages of benthic organisms, whose tolerance to particulates and contaminants are unknown.

8. The characteristics of the plume from return water following dewatering are not known. However, if the return water has higher nutrient concentrations than the surface water into which is released, this could stimulate primary production by phytoplankton. This may have subsequent effects on trophic relationships and ecosystem function, for example through enhanced carbon sequestration. Conversely, if the return water has high suspended sediment concentrations, the increased turbidity could shade the phytoplankton and lead to a decrease in primary productivity. Primary productivity could also decrease if there are toxic contaminants in the return water, which are at concentrations high enough to have negative impacts on the phytoplankton. Contaminants could also have direct negative impacts on zooplankton, with consequences for trophic linkages, potential bioaccumulation, and ecosystem function. The thresholds for suspended sediment and contaminants to have a significant negative impact on the phytoplankton and zooplankton are unknown. The potential for bioaccumulation of contaminants to higher trophic levels is also unknown.

9. The microbial community in the surface environment is very poorly characterised, although the microbial loop plays an important role in nutrient cycling, trophic linkages, and ecosystem function, such as carbon sequestration.

10. Seabirds have been observed to respond to the working lights on installations at sea used by other industries. Lights on vessels involved in deep-sea mining have the potential to disrupt seabirds feeding at or migrating across/along the MAR. This has not yet been quantitatively addressed, and the feeding grounds and migratory patterns of many seabirds are unknown.

11. Cetaceans, such as whales and dolphins, can use the SOFAR (sound-fixing-and-ranging) channel to communicate, which occurs at approximately 1000 m depth. Cetacean communication in this channel can travel for thousands of kilometres, extending far beyond exploration contract areas. Cetaceans are known to react to noise in the marine environment, and if mining activities (such as riser pipe pumps) create noise within the SOFAR channel, this noise could propagate for considerable

distances, disturbing communication and potentially feeding and migratory behaviours well beyond the mine site. Depending on migratory patterns, cetaceans may be more susceptible to disturbance from noise or plumes in certain locations or at certain times of the year. The feeding and breeding grounds and migratory behaviours of many cetaceans are unknown.

12. The bathy-pelagic environment and benthic boundary layer is dark, and the only natural light is from bioluminescence, which is used to communicate and detect prey. Due to the extremely low natural turbidity, organisms are likely to be highly sensitive to increased turbidity from sediment plumes released in this environment, which may inhibit population development. Turbidity is slightly increased in the benthic boundary layer, the zone immediately above the seafloor in which some mixing occurs.

13. Very little known about the bathy-pelagic environment and benthic boundary layer. There are many unknown species, which can be fragile and difficult to sample via nets. *In situ* observations, such as with advanced visual tools, are required to characterise this fauna, especially gelatinous macrozooplankton. Quantitative sampling is a challenge due to the proximity to the seafloor and the low concentration of organisms. It is difficult to collect and experiment on these fragile organisms to determine sensitivity to contaminants, and shallow-water proxy species may not respond in the same way.

14. Population size, abundances and life cycles of all benthopelagic organisms, including jellyfish, are unknown. Also, the food web is insufficiently described (but see Christiansen *et al.*, 2001; Christiansen *et al.*, 1999). Siphonophores are important predators in the water column. Meroplankton (larvae from benthic species) can be a significant constituent of the overall community. Compared to the very low biomass per volume in the bathypelagic, the organism biomass in the benthic boundary layer is elevated reflecting the higher content of organic material in the water column and the interaction with the sediments.

15. Very little is known about the biology of hydrothermal plumes, but it is suggested that they may act as larval transport vector for vent fauna. This has been described for microbial communities, which are restricted to the plume and propagate using the plume. Therefore, the impacts of releasing a mining plume into the natural plume may be significant. There is some evidence of enhanced biomass in the plume.

**Table 2.** Knowledge gaps for the pelagic environment as a whole, their importance and suggestions for addressing these gaps

Knowledge gap	Why is it important?	Suggestions for addressing gap
Response of marine mammals and sea turtles to mining plumes	Mining plumes could disrupt migration, feeding, and breeding behaviours.	<ul style="list-style-type: none"> <li>- Detailed observations of behaviour during test mining</li> <li>- Literature on response to analogous plumes from other industries</li> </ul>
Response of seabirds to lights on the mining vessel	Light from the mining vessel could disrupt migration, feeding, and breeding behaviours.	<ul style="list-style-type: none"> <li>- <i>In situ</i> observations whilst collecting environmental baseline information</li> <li>- Detailed observations of behaviour during test mining</li> <li>- Literature on response to light on installations from other industries</li> </ul>



Response of marine mammals to noise from mining activities, including pumps on the riser pipe	Sound emitted in the SOFAR (sound-fixing-and-ranging) channel could travel for considerable distances, potentially disrupting migration, feeding, and breeding behaviours.	<ul style="list-style-type: none"> <li>- Detailed observations of behaviour during test mining</li> <li>- Literature on response to analogous sounds from other industries</li> </ul>
Migratory patterns of marine mammals and turtles	Migratory patterns may overlap spatially with the mining plume, increasing the likelihood of impacts.	<ul style="list-style-type: none"> <li>- Supplementing existing tagging data with additional tagging data</li> <li>- Modelling of migratory behaviours to project beyond tag data and generate regional models</li> </ul>
Migratory patterns of seabirds	Migratory patterns may overlap spatially with mining vessel location, increasing the likelihood of impacts.	<ul style="list-style-type: none"> <li>- Supplementing existing tagging data with additional tagging data</li> <li>- Modelling of migratory behaviours to project beyond tag data and generate regional models</li> </ul>
Sediment and contaminant plume impacts on microbial communities	Plumes may disrupt the microbial loop, with subsequent impacts on ecosystem functions, such as nutrient cycling, carbon sequestration and trophic linkages.	<ul style="list-style-type: none"> <li>- <i>In situ</i> or <i>ex situ</i> experimentation</li> <li>- Literature on response of microbial communities to analogous plumes from other sources</li> </ul>
Sediment plume impacts on primary productivity	Sediment plumes may increase turbidity in the water column, shading phytoplankton and reducing primary productivity. Linkages to trophic relationships and carbon sequestration.	<ul style="list-style-type: none"> <li>- <i>In situ</i> or <i>ex situ</i> experimentation</li> <li>- Literature on response of microbial communities to analogous plumes from other sources</li> </ul>
Contaminant plume impacts on primary productivity	Contaminants may have toxic effects on plankton, reducing primary productivity. Some metal contaminants may act as fertilisers enhancing primary productivity. Linkages to trophic relationships and carbon sequestration.	<ul style="list-style-type: none"> <li>- <i>In situ</i> or <i>ex situ</i> experimentation</li> <li>- Literature on response of microbial communities to analogous plumes from other sources</li> </ul>
Potential for contaminants to bioaccumulate and biomagnify	Bioaccumulation of contaminants could propagate to higher trophic levels with impacts on trophic relationships and carbon sequestration.	<ul style="list-style-type: none"> <li>- <i>In situ</i> or <i>ex situ</i> experimentation</li> <li>- Literature on bioaccumulation from other analogous sources</li> </ul>
Localised spatial and temporal variation in the location of the deep-scattering layer	The deep-scattering layer is the centre of pelagic biomass over the MAR, acting as biological pump linking the water column environment in the vertical dimension. Temporal variation in the position of the deep-scattering layer could make it periodically more vulnerable to mining impacts. Impacts to the deep-scattering layer would have strong linkages to with trophic interactions and ecosystem functions, such as carbon sequestration	<ul style="list-style-type: none"> <li>- Local <i>in-situ</i> observations over suitable time period to capture diurnal migration, using acoustic surveys</li> </ul>
Currents at different depths	Currents have a strong influence on	<ul style="list-style-type: none"> <li>- Obtain more detailed current</li> </ul>

unknown	connectivity, if different current regimes occur at different depths, plumes could have different impacts on connectivity at different depths. The relationships between biota of different depth layers are unknown.	measurements at different depths
Small scale horizontal and vertical seabed currents poorly known	Knowledge on seabed currents are necessary to enable accurate plume modelling. Physical measurements are required to quantify dispersal potential at depths where mining plumes may occur.	<ul style="list-style-type: none"> <li>- Obtaining fine scale bathymetric data</li> <li>- Velocity measurements from current meters and Acoustic Doppler Current Profiles (ADCPs)</li> <li>- Measurements of eddy diffusive dispersal, for example using Lagrangian experiments</li> </ul>
Circulation patterns within the axial valley unknown	Axial valley circulation patterns will influence the dispersal of plumes if they occur within the axial valley.	- Detailed bathymetry and local current circulation observations
Vertical transport vectors within axial valley and beyond	Vertical transport vectors are needed to assess the potential for vertical dispersal and spatial spreading.	- Water properties measurement and physical oceanographic modelling
Lack of detailed bathymetry	Topography affects the dispersion of plumes, and detailed bathymetry is necessary to enable accurate plume modelling.	<ul style="list-style-type: none"> <li>- Existing contractor data</li> <li>- Obtaining higher resolution of bathymetric data</li> </ul>
Unknown impacts of elevated suspended sediment concentrations from plume on pelagic fauna	Suspended sediment may affect feeding, behaviour and breeding of pelagic fauna.	<ul style="list-style-type: none"> <li>- Measuring background suspended sediment levels</li> <li>- <i>In situ</i> or <i>ex situ</i> experiments to determine tolerance and develop thresholds for suspended sediment concentrations from the plume</li> </ul>
Unknown impacts of elevated contaminant concentrations from plume on pelagic fauna	Contaminants from the plume may affect feeding, behaviour, breeding, or connectivity. Bioaccumulation of contaminants may occur, with subsequent negative consequences to the organisms and ecosystem.	<ul style="list-style-type: none"> <li>- Measure background contaminant levels</li> <li>- <i>In situ</i> or <i>ex situ</i> experiments to determine tolerance and develop thresholds for contaminants from plume</li> </ul>
Pelagic population composition, size and connectivity unknown	Need information on the pelagic biota to determine environmental baselines and to understand potential mining impacts at population to ecosystem level.	<ul style="list-style-type: none"> <li>- Comprehensive baseline surveys</li> <li>- Dedicated scientific studies</li> </ul>
Life-history traits of different taxonomic groups	Need information on life history traits to understand potential mining impacts on connectivity, with implications for resilience and recovery.	<ul style="list-style-type: none"> <li>- Further life-history studies</li> <li>- Potential to use proxies from closely related species</li> </ul>
Basic information on the bathypelagic biota and	Need basic biological information to determine environmental baselines and	<ul style="list-style-type: none"> <li>- Dedicated food web studies</li> <li>- Targeted research, including</li> </ul>

associated food web, particularly gelatinous organisms	to assess changes due to mining impacts.	modern visual <i>in situ</i> observations
Basic information on the benthic boundary layer biota and associated food web, including meroplankton larvae	Need basic biological information to determine environmental baselines and to assess changes due to mining impacts.	- Comprehensive baseline surveys - Targeted research, including modern visual <i>in situ</i> observations
Importance of hydrothermal plume composition and propagation for larval transport	Need information on hydrothermal plume habitat to determine environmental baselines and to assess potential inhibition of larval propagation if any mining plumes are released within the hydrothermal plume.	- <i>In situ</i> studies to characterise the biological environment of the natural hydrothermal plume
Spatial and temporal variability of all components in the bathypelagic and benthic boundary layer	Need information on spatial and temporal variability to determine environmental baselines and to assess changes due to mining impacts, such as the significance of local or regional loss of biodiversity.	- Time-series observations to capture natural variability and changes due to climate change
Bathypelagic and benthic boundary layer biota sensitivity to increased turbidity	Sensitivity to turbidity needs to be established to predict plume impacts and to establish suspended sediment thresholds	- <i>In situ</i> experiments
Bathypelagic and benthic boundary layer biota sensitivity to contaminants	Sensitivity to contaminants needs to be established to predict plume impacts and to establish contaminant thresholds.	- <i>In situ</i> experiments
Potential bioaccumulation and biomagnification effect in the bathypelagic and benthic boundary layer food web	Potential for bioaccumulation and biomagnification needs to be determined to predict impacts and to establish thresholds.	- Measurements of contaminants in food web components - Food web modelling
Potential bioaccumulation effect on population connectivity for bathypelagic and benthic boundary layer biota	Potential for disproportionate bioaccumulation in different life history stages needs to be determined to predict impacts on connectivity and establish thresholds.	- Measurements of contaminants in larval dispersal stages

#### *Knowledge gaps relating to soft sediment habitat*

16. The properties of soft sediment communities are not homogenous and may vary due to:

- Latitudinal change driven by biogeography, overlying productivity, water temperature, water masses, among others;
- Depth zones on either side of the ridge with differences in assemblages from the summit of the ridge down to the abyssal plains;
- Spatial heterogeneity driven by local changes in slope, sediment thickness and slope stability; and
- Patchy distribution of fauna, with aggregations of particular species, driven by intrinsic properties (for example, reproduction and growth) of each species.

17. Soft-sediment organisms immediately in the way of the mining vehicle will be removed/destroyed by mining at the seabed. Soft-sediment organisms nearby may also be impacted by the operational plume. If the return water from dewatering is released at the seafloor near the mine site, it could compound impacts from the operational plume, reducing the ability of these fauna to recover. Particles settling out from the return water plume could mix with organic matter, altering food quality on the seafloor. Surface deposit feeders, such as acorn worms, may have their food source buried or be buried themselves; these organisms have an important role in bioturbation of the sediments with implications for ecosystem function such as carbon sequestration. The sensitivity of these surface deposit-feeders to burial by sediment or tolerance of contaminants is unknown.

18. Some of the benthic organisms in sediment habitats on the MAR appear to be rare and may be disproportionately impacted by mining disturbance. Further information is needed on the distribution of different species, to establish whether apparent rarity is not just the result of sparse sampling. In general, most data are from the north of the MAR where it is shallower; patterns observed here for the benthic fauna may not be analogous to those in the southern portion of the MAR where it is deeper.

**Table 3.** Knowledge gaps relating to soft sediment habitats, their importance and suggestions for addressing these gaps

<b>Knowledge gap</b>	<b>Why is it important?</b>	<b>Suggestions for addressing gap</b>
Need more detailed information on habitat distribution and biota distribution. Most data are from the north of the MAR where it is shallower and may not be analogous to the southern portion of the MAR where it is deeper.	Detailed information on habitat and biota distribution is needed to understand levels of biodiversity/complexity of assemblages, or presence of functionally important species/groups. If not all species are known, functionally important groups can be used as a proxy to help manage impacts.	- Baseline studies are needed to identify and map those species or habitats in need of protection, which fit the adopted criteria <sup>1</sup>
Need to know the potential for mining activities to impact the whole food web and ecosystem functioning	Sediment particles may mix with organic matter, altering food quality. Surface deposit feeders, such as acorn worms, or their food source, may become buried, with wider implications for trophic linkages and ecosystem function.	- <i>In situ</i> impact and recovery experiments following test mining and multiple disturbances.  - <i>In situ</i> experiments will help to determine thresholds for tolerance to sediment and contaminants, food web impact and response, larval settlement, recovery rates, and tipping points
Sensitivity to mining plumes, including potentially toxic contaminants, settling particles and changes to temperature and salinity	It is important to determine the sensitivity to mining plumes, particularly as the thresholds for tolerance to sediment or contaminants may vary according to location and life history stage.	
Larval settlement cues are unknown	The settling potential for benthic fauna larvae needs to be determined, as this influences population connectivity, which is an important aspect of resilience and recovery.	

The threshold for when impacts from multiple plume sources would exceed the soft sediment fauna's ability to recover	Seafloor organisms immediately in way of the mining vehicle will be removed/destroyed. If the dewatering plume is released in this environment, and extends to areas impacted by the operational plume, cumulative impacts may occur for fauna not killed by the operational plume.	
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<sup>1</sup>Soft-sediment VME indicator taxa have been listed by ICES Working Group on Deep Water Ecology. These are: pennatulid corals, some sponges and xenophyophores.

19. Additional potential species or habitats in need of protection in the context of mining activities have been identified by the group, including Enteropneusts (acorn worms). Two species of acorn worms are only known from the MAR and could be endemic (Priede *et al.*, 2012). Enteropneusts are rare and fragile and they provide important functions such as bioturbation.

#### *Knowledge gaps relating to active vent habitat*

20. There are many knowledge gaps regarding the biology of active vent habitats, and their vulnerability to potential mining impacts

**Table 4.** Knowledge gaps relating to active vent habitat, their importance and suggestions for addressing these gaps

<b>Knowledge gap</b>	<b>Why is it important?</b>	<b>Suggestions for addressing gap</b>
Bottom current patterns	Modelling dispersal of plumes and determining the plume impact area needs detailed bottom current information.	- Advection and eddy diffusion measurements needed to be obtained to include in the model
Low level of knowledge on the distribution, biology and ecology of active vent habitat	Vent habitats are highly heterogeneous, complicating environmental management. It is important to understand the drivers of this heterogeneity, such as depth gradient, slope, and cross-axis variations in geomorphological features. Basic knowledge of active vent habitat is also needed to identify biogeographic units for potential future management.	- Identify sites with poor knowledge level and determine potential drivers of heterogeneity at each site. Initiate studies on biodiversity and ecology with a systematic, regional-scale approach along the MAR.
Population connectivity and source-sink dynamics between populations	Understanding population connectivity is essential, as maintenance of active vent communities is only possible if source population is large enough. Mining sites with source-populations could affect other sites through impacting connectivity amongst sites.	- Studies on connectivity, addressing source-sink dynamics of meta-populations
Fauna life history characteristics, such as levels of larval dispersal and recruitment	Mining may affect larval dispersal and recruitment. Understanding dispersal and recruitment is necessary if environmental management	- Studies on fauna life history and larval dispersal, taking into account different dispersal strategies, such as planktotrophic and

	measures are to maintain biodiversity	lecithotrophic larvae, and brooding behaviours
Whether hydrothermal vent fauna larvae are constrained by the topography of the axial valley	Mining plumes may be retained in the axial valley and affect larval dispersal, recruitment and connectivity.	- Conduct studies on fauna larval dispersal and connectivity in the axial valley
Biota succession and recolonization following disturbance is not well characterized for the MAR	There is less natural disturbance at vents on the MAR compared to fast-spreading ridges such as the East Pacific Rise, so it is very difficult to predict effects on faunal succession and recolonization following disturbance.	- Ocean observatories to study natural stability of active vent habitat and vent fields more widely
Unknown impacts of elevated suspended sediment concentrations from plume on fauna	Suspended sediment may affect feeding, behaviour, and breeding. Suspended sediment could also lead to individual mortality and negatively affect meta-population size, influencing connectivity. Information on suspended sediment impacts is needed to develop thresholds for suspended sediment concentrations from the plume.	- Measuring background suspended sediment levels to establish environmental baselines - <i>In situ</i> experiments to determine tolerance
Unknown impacts of elevated contaminant concentrations from plume on fauna	Contaminants may affect feeding, behaviour, breeding, and result in bioaccumulation with subsequent negative consequences to the organisms/ecosystem. Contaminants may lead to individual mortality and negatively affect meta-population size, influencing connectivity. Information on contaminant impacts is needed to develop thresholds for contaminant concentrations from the plume.	- Measure background contaminant levels to establish environmental baselines - <i>In situ</i> experiments to determine tolerance
Potential for contaminants to bioaccumulate and biomagnify	Bioaccumulation of contaminants could propagate to higher trophic levels with impacts on trophic relationships and carbon sequestration. Bioaccumulation could occur disproportionately for different life history stages, impacting connectivity	- <i>In situ</i> and/or <i>ex situ</i> experimentation - Literature on bioaccumulation and biomagnification from other analogous sources - Measurements of contaminants in dispersal stages
Potential indicator species for mining impacts unknown	Indicator species are needed as they can be monitored to detect change. Typically, indicator species are identified based on species sensitivity and specificity to detect the specific environmental change being introduced, and should consider aspects of food web and connectivity.	- <i>In situ</i> and/or <i>ex situ</i> experimentation on different species to assess sensitivity and specificity to environmental change incurred by mining

*Knowledge gaps relating to inactive sulphide habitat*

21. While there is a scientific basis for recognizing inactive sulphide substrata as habitats that may benefit from additional environmental management measures at a regional scale, there are many knowledge gaps that need to be addressed.
22. Operational definitions of active, inactive, and extinct sulphide habitats are needed to help characterize and identify these habitats. Operational definitions would also help to facilitate the development of tailored environmental management measures for active, inactive, and extinct sulphide habitats, where appropriate.
23. Buried sulphide habitats may host distinctive microbial populations (Kato & Yamagishi 2015), with the additional possibility that the overlying sediment habitat is geochemically modified and supports a distinctive faunal assemblage.
24. The size and distribution of inactive, extinct, and buried sulphide habitats are unknown at a regional scale, particularly occurrences of these habitats which may occur outside of existing contractor blocks for exploration.
25. The geological and biological characteristics of inactive and extinct sulphide habitats, and how these compare to non-hydrothermal hard substrata habitats distributed along the northern Mid-Atlantic Ridge, are not known. The geological and biological characteristics of these habitats which need to be better understood include mineralogy and chemistry, age of sulphides, species diversity, functional characteristics, and trophic interactions. Biological data may be correlated with geochemical data to explore drivers of patterns in distributions of species and assemblages.
26. Geological and biological information on inactive and extinct sulphide habitats is needed to determine the extent to which there are faunal assemblages (or species) at this habitat which exhibit specialized adaptations to the inactive sulphide habitat, serve as an important source population for connectivity, may be vulnerable to mining impacts, or are in other ways potentially in need of protection.
27. The extent to which active and inactive sulphide habitats may (or may not) share a subsurface hydrothermal system within a vent field is site-specific and poorly known. There is some evidence that inactive sulphide habitat may become reactivated by drilling (Kawagucci *et al.*, 2013; Von Damm *et al.*, 2005; Zierenberg *et al.*, 1998). It may not be possible to obtain this information in advance of drilling or mining activities. However, where there are active and inactive sulphide habitats in the same hydrothermal field, monitoring of hydrothermally active sites during drilling may be required to determine if there are any impacts on hydrothermal activity, such as a reduction or cessation of flow, as a result of drilling.

**Table 5.** Knowledge gaps relating to inactive sulphide habitat, their importance and suggestions for addressing these gaps

<b>Knowledge gap</b>	<b>Why is it important?</b>	<b>Suggestions for addressing gaps</b>
Operational definitions of active, inactive and extinct sulphide habitats	Each of these sulphide habitats host different communities and may require different environmental management measures.	- Development of standard definitions for active, inactive and extinct sulphide habitats
Whether sediment-covered sulphide habitats host distinctive microbial populations	Distinctive microbial populations which are restricted to sediment-covered sulphide habitat may require additional management considerations.	- Studies conducted whilst collecting environmental baseline information
Whether the sediment overlying buried sulphide	Distinctive faunal assemblages which are restricted to the sediment overlying	- Studies conducted whilst collecting environmental baseline information

minerals hosts a distinctive faunal assemblage	buried sulphide minerals may require additional management considerations.	
Regional distribution of inactive, extinct and sediment-covered sulphide habitat	The regional distribution of sulphide habitats would need to be known if a proportion of these are to be protected through a network of protected sites.	<ul style="list-style-type: none"> <li>- Habitat mapping using environmental baseline information collected by contractors within exploration contract areas</li> <li>- Collaboration between contractors and the scientific community to identify and map sulphide habitats in the Area beyond contractor blocks</li> </ul>
Whether inactive sulphide habitat support an assemblage or species which only occur in this habitat	The existence of an assemblage or species which only occur at inactive sulphide habitat needs to be investigated, to determine the vulnerability of biota at inactive sulphide habitat to potential mining impacts.	<ul style="list-style-type: none"> <li>- Detailed environmental baseline information on the geological and biological characteristics of inactive and extinct sulphide habitats, and of non-hydrothermal hard substrata in the region</li> <li>- Dedicated studies addressing the potential relationships between the geological or geochemical environment and the biological assemblages present</li> </ul>
Whether inactive sulphide habitat hosts source populations of species occurring in other habitats within the region	The existence of source populations at inactive sulphide habitat needs to be ascertained to determine the contribution of inactive sulphide habitat to regional connectivity of populations.	<ul style="list-style-type: none"> <li>- Detailed environmental baseline information on the geological and biological characteristics of inactive and extinct sulphide habitats, and of non-hydrothermal hard substrata in the region</li> <li>- Dedicated studies addressing the potential relationships between the geological or geochemical environment and the biological assemblages present</li> <li>- Dedicated studies addressing the population connectivity of species shared amongst inactive and extinct sulphide habitats, and non-hydrothermal hard substrata</li> </ul>
Ecosystem services provided by inactive sulphide habitat	Ecosystems services provided by inactive sulphides need to be determined to assess whether potential mining impacts on inactive sulphide habitat could impact wider ecosystem function and services.	<ul style="list-style-type: none"> <li>- Dedicated studies addressing the ecosystem services provided by inactive sulphide habitat</li> </ul>
The extent to which inactive and active sulphide habitat may share a subsurface hydrothermal system within a vent field	Subsurface connections need to be determined to assess if drilling of inactive sulphide habitat could lead to reactivation of hydrothermal flow at that site, and whether this could divert hydrothermal flow from an existing active vent site.	<ul style="list-style-type: none"> <li>- Dedicated studies addressing the subsurface connections between hydrothermally inactive and active portions of vent fields</li> </ul>

*Knowledge gaps relating to non-hydrothermal hard substrata habitat*

28. There are many knowledge gaps regarding the biology of non-hydrothermal hard substrata habitats, and their vulnerability to potential mining impacts.



**Table 6.** Knowledge gaps relating to non-hydrothermal hard substrata habitat, their importance and suggestions for addressing these gaps

<b>Knowledge gap</b>	<b>Why is it important?</b>	<b>Suggestions for addressing gap</b>
Lack of detailed bathymetry	Bathymetry data is needed to identify and spatially define hard substrata habitats and quantify the distance between suitable habitats. Topography affects the dispersion of plumes Necessary to enable accurate plume modelling	<ul style="list-style-type: none"> <li>- Contractor data</li> <li>- Increased resolution of bathymetric data</li> </ul>
Currents at different depths	The relationships/connectivity between fauna at different depth layers are unknown. Mining impacts at one depth could have unforeseen impacts at depths above/below the immediate impact area.	<ul style="list-style-type: none"> <li>- Obtain further current measurements at different depths</li> </ul>
Bottom current patterns	Modelling dispersal of plumes and determining the plume impact area needs detailed seabed current information.	<ul style="list-style-type: none"> <li>- Increased resolution of bathymetric data</li> <li>- Lagrangian-type studies and models, especially in the axial valley and on the slopes of the ridge</li> </ul>
Whether the axial valley has similar biological communities to those occurring in other ridge habitats, such as the crest and flanks.	Need to know if the axial valley has the same biological communities as other ridge habitats to help predict suitable habitats for vulnerable hard substrate communities	<ul style="list-style-type: none"> <li>- Contractor data to validate suitability models</li> <li>- Increased resolution of bathymetric data</li> <li>- Comparative analyses of biological communities from the axial valley to those occurring in other ridge habitats</li> </ul>
Data on species distribution, including local variation in abundances, centers of distribution, and whether species are truly endemic or just under-sampled	It is crucial to understand levels of biodiversity/complexity of assemblages, or presence of functionally important species/groups, to predict and manage mining impacts. If not all species are known, functionally important groups could be used as proxies.	<ul style="list-style-type: none"> <li>- Baseline studies on hard substrata habitat are needed to identify and map those species or habitats in need of protection, which fit the adopted criteria</li> </ul>
Life history characteristics of hard substrata biota, including larval dispersal distances and development mode	Life history characteristics are a key contributor to population connectivity, which is an important aspect of resilience and recovery.	<ul style="list-style-type: none"> <li>- Genetic and biological studies focused on the intrinsic biological characteristics of the species (growth rate, age at first maturation, fecundity, periodicity/seasonality in reproduction)</li> <li>- Biophysical modelling to predict patterns of connectivity</li> </ul>
Larval settlement cues are unknown	The settling potential for benthic fauna larvae is a contributor to population connectivity, which is an important aspect of resilience and recovery.	<ul style="list-style-type: none"> <li>- <i>In situ</i> impact experiments</li> <li>- Recovery studies following test mining to identify thresholds for tolerance to suspended sediment and contaminants, including: food web impact and response, larval</li> </ul>

		settlement, recovery rates and tipping points
Population connectivity unknown	Connectivity of populations is a key aspect of resilience and recovery. Could have complex patterns of connectivity including source/sink dynamics.	- Undertake comprehensive baseline surveys and connectivity studies
Densities thresholds of Vulnerable Marine Ecosystem indicator species comprising a 'VME' on hard substrata	Understanding what constitutes a VME at the seafloor is required to ensure that the impacts on VMES from mining are appropriately managed.	- Development of thresholds for defining VMEs using imagery data, based on existing and ongoing work (Kenchington <i>et al.</i> , 2014; Morato <i>et al.</i> , 2018; Rowden <i>et al.</i> , 2017)
Effects of plumes on VME indicator species (and other species)	Plumes from mining activities could clog/damage feeding apparatus of suspension feeders, with implications for trophic linkages and ecosystem function. Need to determine the effects of plumes to establish thresholds for suspended sediment concentrations	- Determining plume dispersal distances through test mining - Detailed observations of the behavior of VME indicator species (and other species) during test mining - Measuring background suspended sediment levels to compare with plume characteristics - <i>In situ</i> or <i>ex situ</i> experiments to determine tolerance of VME indicator species to plume impacts
Unknown impacts of elevated trace metal concentrations from plume on fauna	Elevated trace metal concentrations may affect feeding, behaviour, breeding, connectivity and result in bioaccumulation, and subsequent negative consequences to the organisms/ecosystem. These impacts need to be understood to develop thresholds for potentially toxic contaminants from plumes.	- Measure background trace metal levels - <i>In situ</i> or <i>ex situ</i> experiments to determine tolerance
Detailed information on the food web at hard substrata habitats. This includes different life stages, such as eggs, larvae, juveniles and adults.	Food web information is needed to be able to assess changes due to mining impacts. Need to understand impacts on the whole food web.	- Contractor environmental baseline surveys - Dedicated food web studies, including <i>in situ</i> visual observations
Potential bioaccumulation and biomagnification effect in the food web	Bioaccumulation and biomagnification effects have the potential to considerably alter the food web, with implications for ecosystem function.	- Measurements of contaminants in food web components - Food web studies and modelling
Spatial and temporal variability of all biological components	Spatial and temporal variability need to be characterized to be able to assess the significance of local or regional loss of biodiversity, and to have a baseline to measure impacts against.	- Time series observations to capture natural variability and changes due to climate change

29. Hard substrata habitats may be inhabited by Vulnerable Marine Ecosystem (VME) indicator species. The criteria to define VMEs have been described by the International Guidelines for the Management of Deep-sea Fisheries in the High Seas (FAO, 2009) and include uniqueness or rarity, fragility, functional significance, structural complexity and life history traits. However, VMEs are a

concept which has developed in the context of deep-sea bottom fishing, specifically vulnerability to benthic trawling impacts. It may be useful to adapt the VME concept and apply this within the context of deep-seabed mining, in order to identify occurrences of non-hydrothermal hard substrata habitat within a region which may require additional environmental management measures.

30. VMEs are composed of aggregations of VME indicator species, and examples of VME indicators from the North Atlantic region, in the context of deep-sea bottom fishing, are described in Table 7. To date, the establishment of VMEs has been based on move-on thresholds for bottom fishing, for example within Article 9, Recommendation 19 2014: Protection of VMEs in NEAFC Regulatory Areas, as Amended by Recommendation 09:2015 and Recommendation 10:2018 - “An encounter with a possible VME is defined as: (a) for a trawl tow, and other fishing gear than longlines: the presence of more than 30 kg of live coral and/or 400 kg of live sponge of VME indicators”.

31. In the context of deep-seabed mining, threshold densities of VME indicators comprising VME habitats could be established from seabed imagery data, and existing methods could be used to support this (Kenchington *et al.*, 2014; Morato *et al.*, 2018; Rowden *et al.*, 2017). Seabed density thresholds for VME definitions are a key evidence gap for non-hydrothermal hard substrata habitats and should be reviewed.

32. Many VME indicator species have larval dispersal through the water column, whilst others are brooders or have crawling larvae (Tyler, 2003). In general, life history characteristics and connectivity are poorly known for VME indicator species. More information will be required on the life history and connectivity of these organisms if local and regional connectivity is to be maintained through any future environmental management measures for this habitat.

**Table 7.** VMEs from the North Atlantic that occur on hard substrata with associated representative taxa (source: ICES, 2019)

VME Habitat	Representative taxa	VME criteria (FAO 2009)
Cold-water coral reef	<i>Lophelia pertusa</i> <i>Madrepora oculata</i> <i>Solenosmilia variabilis</i>	<b>Uniqueness or rarity</b> An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include:
Coral garden (mono-specific or multi-specific)	Acanthogorgiidae Alcyoniidae Anthothelidae Antipathidae Caryophylliidae Chrysogorgiidae Coralliidae Dendrophylliidae Isididae Leiopathidae Nephtheidae Paragorgiidae Plexauridae Primnoidae Schizopathidae Stylasteridae	- Habitats that contain endemic species; - Habitats of rare, threatened or endangered species that occur only in discrete areas; or - Nurseries or discrete feeding, breeding, or spawning areas.  <b>Functional significance of the habitat</b> Discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species.
Deep-sea sponge aggregations	Geodiidae Ancorinidae Azoricidae Corallistidae	<b>Fragility</b> An ecosystem that is highly susceptible to degradation by anthropogenic activities.  <b>Life-history traits of component species that make recovery difficult</b> Ecosystems that are characterized by populations

	Pachastrellidae Rossellidae Pheronematidae Hyalonematidae Macandrewiidae Axinellidae Mycalidae Polymastiidae Tetillidae Petrosiidae Lithistidae	or assemblages of species with one or more of the following characteristics: - Slow growth rates; - Late age of maturity; - Low or unpredictable recruitment; or - Long-lived.
Sea-pen fields (hard substrata)	Anthoptilidae	<b>Structural complexity</b> An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.
Stalked crinoid aggregations	Rhizocrinidae Bathycrinidae Septocrinidae Phrynocrinidae Isocrinidae Hyocrinidae	
Xenophyophore aggregations	Syringamminidae Psamminidae	
Bryozoan patches		

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*Results of workshop discussion on the application of area-based management tools*

**I. Background**

1. The objectives outlined in the REMP guidance document<sup>16</sup> (ISA 2019) state that an initial workshop should “describe potential areas that could be protected from exploitation in order to achieve effective protection of the marine environment, through the designation of areas of particular environmental interests (APEIs) and/or potential sites in need for protection to maintain ecological balance of the marine environment from harmful effects of mining activities, as a means to ensure effective protection for the marine environment under Article 145 of the Convention, which is further informed by Article 194 (5)”.

2. In order to describe potential areas that are in need of protection, the workshop considered several types of approaches for applying area-based management tools (ABMTs). The workshop identified three general categories of approaches that could be useful for spatial management to support the Northern Mid-Atlantic Ridge REMP process. These tools include fine-scale sites in need of protection and areas of coarse-scale planning (e.g. APEIs) relating to Article 145 of the Convention as described in the ISA REMP guidance document (ISA 2019). This workshop suggested that these two approaches for area-based tools could be augmented with a third approach: sites in need of increased precaution. This third category could provide additional information to help highlight areas of potential sensitivity that may or may not contain sites or areas in need of protection, but may require increased precaution and potentially increased survey/data collection needs.

3. This section provides a review of possible spatial planning approaches, not in an exhaustive manner, which can be applied to describe potential areas through workshop discussion, for designation of APEIs or sites requiring enhanced protection measures as part of regional environmental management planning process. This section compiles potentially relevant scientific criteria for applying area-based management tools, including their relevance to the activities in the Area. This section draws on document ISBA/17/LTC/7 (Environmental Management Plan for the Clarion-Clipperton Zone) as well as reports of ISA workshops held on REMPs in Qingdao (China) in May 2018, and Szczecin (Poland) in June 2018.

4. In general, spatial planning requires two types of criteria and scales of analysis: (1) individual site criteria that provide guidance on the priority, size, shape, and orientation of individual sites; and (2) network or regional criteria that provide guidance on the representativity, adequacy, spatial configuration, connectivity and other broader criteria guiding the development of the entire collection of sites.

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<sup>16</sup> [https://ran-s3.s3.amazonaws.com/isa.org/jm/s3fs-public/files/documents/rem\\_p\\_guidance\\_.pdf](https://ran-s3.s3.amazonaws.com/isa.org/jm/s3fs-public/files/documents/rem_p_guidance_.pdf)

**Table 1. Comparison of approaches for applying area-based management tools**

Approaches for ABMT	Spatial precision	Potential management
Site in need of protection to maintain ecological balance of the marine environment from harmful effects of mining activities	fine scale sites	avoidance, enhanced management or closure
Areas of Particular Environmental Interest	coarse scale areas	Avoidance, enhanced management or closure
Areas/sites of increased precaution	defined areas	Elevated precaution, increased data collection or monitoring

5. This workshop focused exclusively on the application of individual site and area criteria describing potential sites in need of protection (e.g. specific active vent systems) and areas potentially considered for area of particular environmental interest (e.g. specific fracture zones). The workshop discussed but did not attempt to apply broader scale network or regional criteria (i.e. representativity, connectivity, replication or adequacy) in our current work. It is the consensus of this workshop that these network criteria for the region as a whole, as outlined in the ISA REMP guidance document (2019), be applied in the future for this region and be incorporated into future REMP updates.

**Sites in Need of Protection criteria**

6. The following fine-scale, site-based criteria were applied within the context of activities in the Area following FAO’s Vulnerable Marine Ecosystem criteria as summarized in the REMP guidance document (ISA 2019). These criteria are intended to be used to describe specific fine-scale sites on an individual site basis. Sites meeting these criteria are described in the Appendices to this annex.

*Compilation of scientific information to describe sites in need of protection relating to Article 145 of the Convention*

**Uniqueness or rarity** An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.

**Functional significance of the habitat** Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.

**Fragility** An ecosystem that is highly susceptible to degradation by anthropogenic activities.

**Life-history traits of component species that make recovery difficult** Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.

**Structural complexity** An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.

**Information relating to any other relevant scientific criteria (Optional):** including for example ecosystem services

#### *Scientific Reference Site*

7. In addition to ecological criteria, an additional criterion was used that places value on the site as an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems. The use of “scientific significance” has long been used as a criterion for assessing the value of natural areas (Smith and Theberge, 1986). A notable precedent for using this criterion exists in the Antarctic Treaty that designated particular ‘*Sites of Special Scientific Interest*’, which “were designated to protect areas where scientific investigations were undertaken (or planned to be undertaken in the future) from willful or accidental damage or interference” (Hughes et al., 2013). Within the context of the United Nations Convention on the Law of the Sea, article 143 provides that “the Authority shall promote and encourage the conduct of marine scientific research in the Area”, which could include ongoing scientific investigations of active vent sites on the MAR that provide one of the few long-term time series of data in the deep sea (Glover et al., 2010).

#### **Areas of Coarse-scale Planning (e.g. Areas of Particular Environmental Interest) relating to Art.145 of the Convention**

8. The description of fine scale sites in need of protection are meant to preserve specific examples of ecosystems and habitats that are vulnerable to disruption or impact from human activities, while coarse scale APEIs in a region is meant to preserve large, representative and self-sustaining areas of the ecosystem. There is a range of coarse area criteria used in spatial planning applications. These criteria are often implemented using multiple scales of application with an individual area scale of application as well as a broader, regional network scale of application. The CBD scientific criteria on ecologically or biologically significant area (EBSA) as well as network criteria provide an example of this type of two-scale application.

#### *EBSA criteria for individual area (annex I to CBD decision IX/20)*

- Uniqueness or rarity
- Special importance for life history
- Importance for threatened, endangered or declining species or habitats
- Vulnerability, fragility or slow recovery
- Biological productivity
- Biological diversity
- Naturalness

#### *Network criteria for representative network of MPAs (annex II to CBD decision IX/20)*

- representativity
- connectivity
- replication
- adequacy



9. In the case of the CCZ region, the size, shape and configuration of individual APEIs were based on simple criteria stating that each APEI:

- should take into account biophysical gradients which affect the biogeography of marine biodiversity in the planning region;
- should protect a full range of habitat types found within each subregion;
- should be large enough to maintain minimum viable population sizes for species potentially restricted to a subregion;
- should be surrounded by a buffer zone to ensure that biota and habitats in the protected area are not affected by anthropogenic threats occurring outside the APEIs; and
- the boundaries should be straight lines to facilitate rapid recognition and compliance.

**Table 2. General APEI criteria and assessment approach**

<b>APEI criteria</b>	<b>Assessment approach</b>
Large areas	Spatial analysis of ecosystem extent vs. relative areas
Self-sustaining populations	Metapopulation, dispersal distance and connectivity analysis
Broad range of habitat variability	Habitat models and representative analysis
No direct mining effects	Disturbance and recovery models
No indirect mining effects	Physical models (plumes)
Unknown impacts	Precautionary approach

**Areas/sites of increased precaution**

10. Areas/sites of increased precaution were considered as sites that contain: (i) proxies or indicators of species and habitat that would, if their presence was confirmed by direct observation, likely to enhance protection through area or adaptive management measures; and (ii) conditions that contribute to the vulnerability of species and habitats of conservation importance.

11. Examples of accepted proxies or indicators of species and habitats of conservation importance include:

- Geophysical features typically associated with the presence of species and habitat of conservation importance, such as benthic topographic complexity and/or substrate.
- Presence or predicted presence of suitable habitat for sites in need of protection or VMEs, as provided by habitat suitability modelling for indicator species of sites in need of protection or VMEs.
- Environmental conditions known to increase the vulnerability of species and habitat of conservation importance, including barriers or filters to dispersal and habitat conditions that can be associated with species and habitats of conservation importance.

12. Exploration or exploitation activities within areas of increased precaution should proceed with: (i) enhanced studies to confirm whether or not vulnerable marine ecosystems are present; (ii) heightened awareness that sites in need of protection or VMEs may be in the area; and (iii) greater efforts to reduce the environmental impact of seabed activities.

13. This workshop agreed that information indicating the potential occurrence of sensitive features or habitats such as habitat suitability models could be used to help identify areas of increased precaution. An example of this type of information included models of suitability for cold water corals (e.g. Yesson et al. 2012, Davies and Guinotte 2011, Yesson et al. 2017). Areas identified as potentially suitable for sensitive species could be used to help guide future management actions such as increased needs for data collection and/or elevated levels of precaution. Example regional maps of potential areas of increased precaution based on suitability for cold water octocorals are included in Figure 5.

## **II. Results of break-out session**

### **General characteristics of the Northern Mid-Atlantic Ridge sub-regions:**

#### *North of the Azores*

14. There is a relatively short segment of the MAR (300 km) between the proposed areas of the extended continental shelf (ECS) claim areas of Portugal (Azores) and Iceland. This area includes part of the North Atlantic Drift Ecoregion, the sub-polar front and the Charlie-Gibbs Fracture Zone.

- Very high seasonal productivity
- Summits of the ridge and associated seamounts are relatively shallow
- High biomass of deep-scattering layer fauna attracted to the summit
- Well documented presence of rare and vulnerable species (ECOMAR/MARECO)
- Globally unique oceanographic setting of North Atlantic current eddy field
- CGFZ important pathway for water and fauna between East and West Atlantic

#### *South of Azores*

- Deeper ridge features
- Multiple active vent fields
- Five transverse sections
- Three primary fracture zones

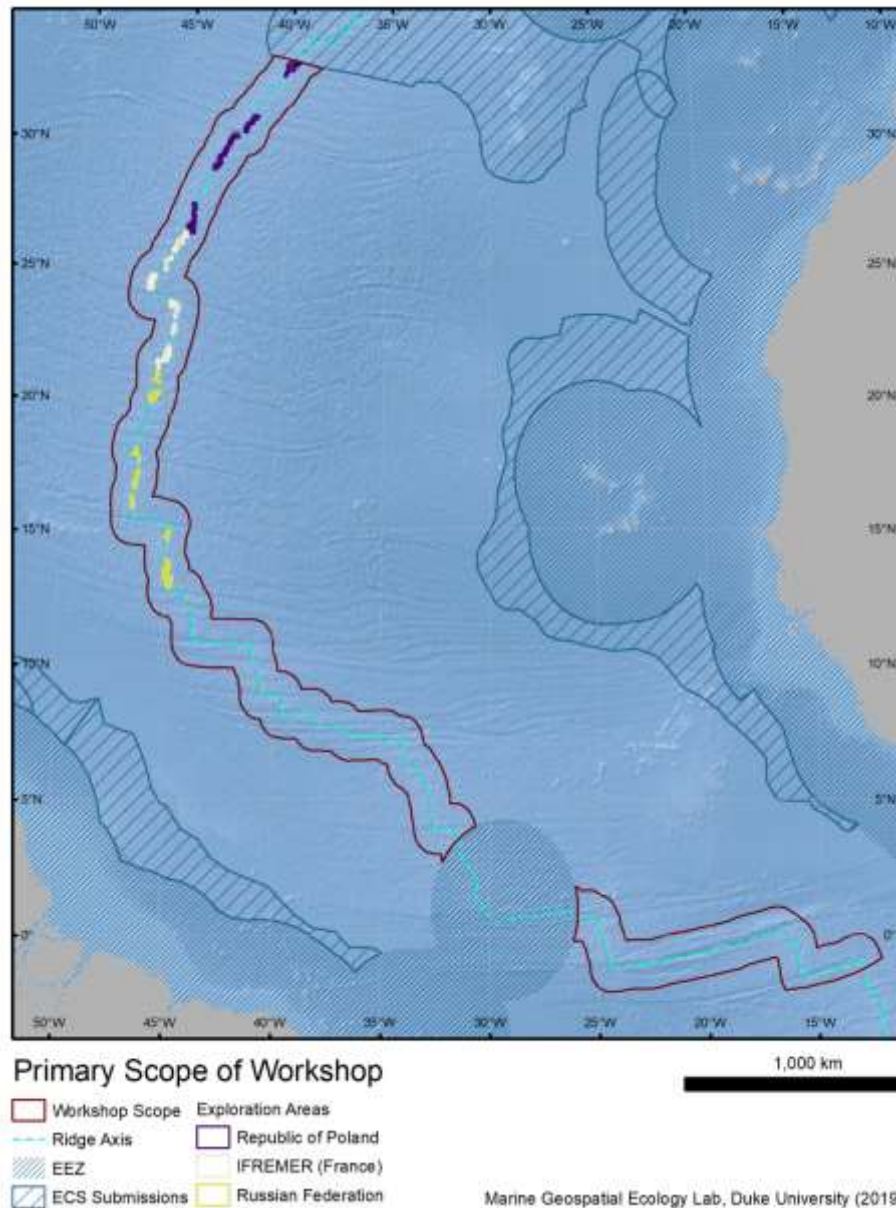


Figure 1. Primary scope of workshop deliberation on area-based management tools

### Fine-scale sites in need of protection

15. Active hydrothermal vents were identified as regionally important ecosystem features in potential need for fine-scale site protection. Hydrothermal vents can be defined as active or senescent and the identification of active vents can be confirmed or inferred.

*Definition of active vents and senescent vents:*

- Active vent sites are characterized by active venting of hydrothermal fluids. Each site exhibits temporal variability in vent fluid chemistry, temperature and style of venting (German & Seyfried 2013).

- Senescent vents are characterized by (1) absence of vent fluid emissions, i.e. no visible shimmering water and a temperature anomaly above the ambient (Van Dover, 2002) and (2) presence of (mostly) dead large symbiotic fauna, i.e. vestimentiferan tubes with no visible branchial plumes (Tsurumi and Tunnicliffe, 2003). ~50% of fauna at senescent vents are known from active sites.

*Definition of confirmed vents and inferred vents:*

16. Confirmed active vent systems have been directly observed and possibly sampled. These are often classified into two possible categories: known or discovered. Inferred active vents may be inferred by temperature or other proxy indicator measurements.

- **Known** – in situ observation >1 scientific publication
- **Discovered** – in situ observation but no scientific publication yet (captured in template)
- **Inferred** – measures that a vent field may be present. Typically based upon CTD measurements

13. Confirmed active hydrothermal vent systems were identified as potential fine scale sites in need of protection. There are 11 Confirmed Active Vents included in the study area that have been identified (from South of the Portuguese Extended Continental Shelf in the Azores region to the Romanche Fracture Zone).

14. The Confirmed Active Vents are listed first from 1 to 11 with the name and the correspondent Node ID number. The sites Irinovskoe and Pobeda have been recently discovered (Cherkashov et al, 2017; Escartin et al. 2017) and are going to be added to the InteRidge Dataset.

15. Additional information requirements for the location and representation of vent areas for spatial management include:

- What is the surface area of the vent field?
- Is the site described with point data versus area data?
- How many sites are located within a field?

16. General (not exhaustive) characteristics of vent fauna/communities and how they relate to the given criteria:

- **uniqueness or rarity**
  - endemic species: to vent environment
  - endemic species: in a region e.g. like the MAR
  - small global size of vent fields (within the primary scope considered at MAR: 11 known & 12 inferred active vent sites)
  - “rare” species (e.g. high number of singletons)
  - community composition differs with vent fluid
- **functional significance of the habitat** (e.g. patchy distribution of vent fields, high productivity & reproduction)
- **fragility** (dependent to hydrothermal fluids, small areas)
- **life-history traits** (reproductive strategy; larval dispersal; unknown settlement-cues; unpredictable recruitment)
- **structural complexity** (3d structure, abiotic and biotic; ecosystem engineers)
- **optional information:**
  - Baseline/scientific values
  - natural laboratory to study evolution & adaptation to extremes

- ecosystem service (e.g. novel adaptations like armor, marine genetic resources...)

17. Total of 11 confirmed active hydrothermal vent systems that were currently identified are listed below and are described in detail with the criteria in Appendix 1-1 to this annex: Lost City; Broken Spur; TAG; Snake Pit; Pobeda; Logatchev 1; Logatchev 2; Semyenov 2; Irinovskoe; Ashadze 2; Ashadze 1.

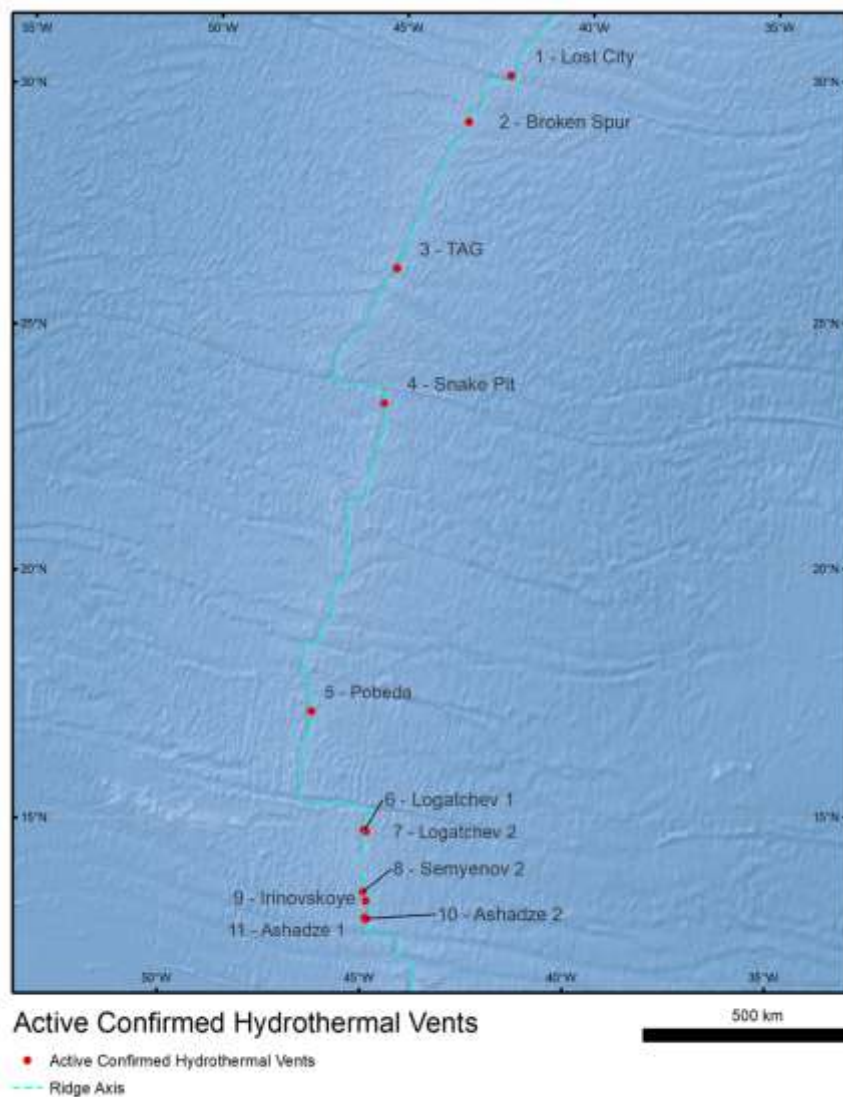


Figure 2. Confirmed active hydrothermal vent fields identified as potential sites in need of protection

### Fine-scale sites of increased precaution

18. Inferred active hydrothermal vent systems were described as potential fine scale sites in need of precaution. There are 12 Inferred Active Vents included in the study area (from South of the Portuguese Extended Continental Shelf in the Azores region to the Romanche Fracture Zone).

19. The Inferred Active Vents are listed from 1 to 12 with the name and the correspondent Node ID number. Scientific information of inferred vents is compiled in the Appendix 1-2 to this annex: MAR,

30°N; MAR, 27°N; Puy des Folles; MAR, 17°09'N; MAR, south of 15°20'N fracture zone; MAR, 14°54'N; Logatchev 3; Neptune's Beard; MAR, 11°26'N; MAR, 11°N; Markov Deep; MAR, segment south of St. Paul system.

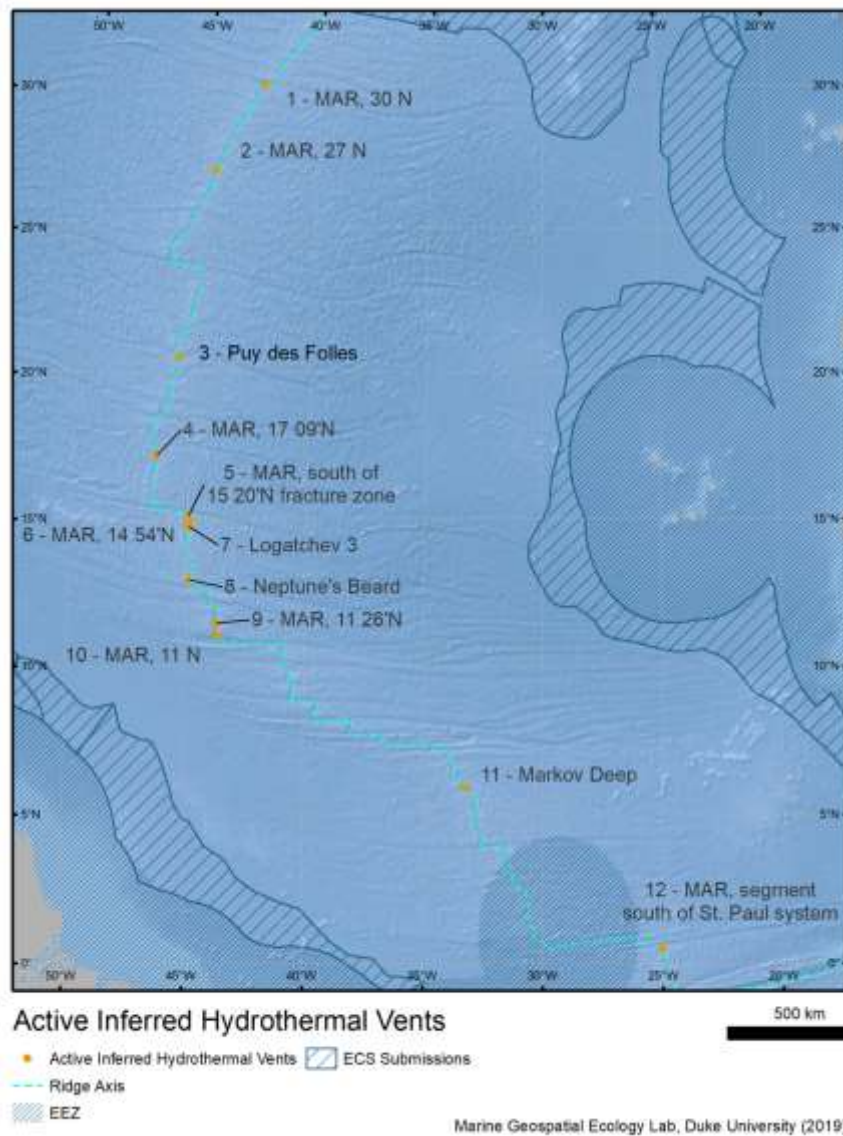
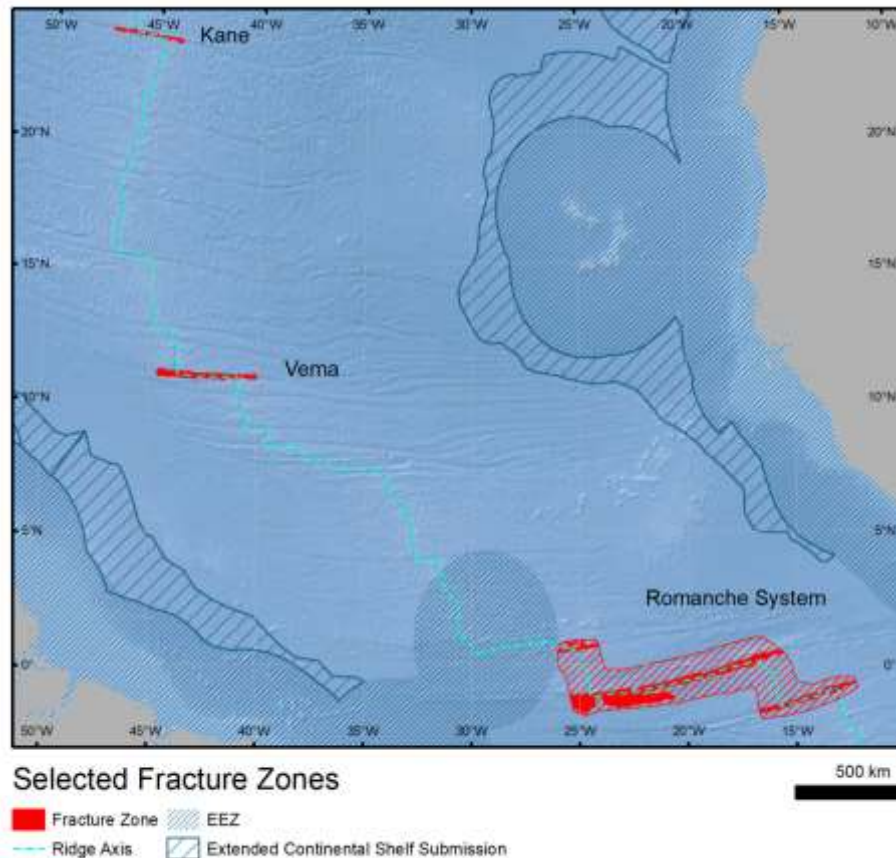


Figure 3. Inferred active hydrothermal vent fields identified as potential sites in need of precaution

### Coarse-scale areas of particular environmental interest

20. A set of fracture zones were identified as areas that potentially meet the criteria of coarse scale APEIs. These areas are described in Appendix 2 to this annex.



Marine Geospatial Ecology Lab, Duke University (2019)

Figure 4: Fractures zones proposed as areas that potentially meet the criteria of coarse scale areas of particular environmental interest

Fracture Zones: Scientific information is compiled in Appendix 2 to this annex.

1. Kane Fracture Zone
2. Vema Fracture Zone
3. Romanche Fracture Zone System

### Coarse-scale areas of increased precaution

21. Areas of potential cold water octocoral habitat suitability were proposed as areas that may require increased precaution. These areas were drawn from habitat suitability models from Yesson (2012).

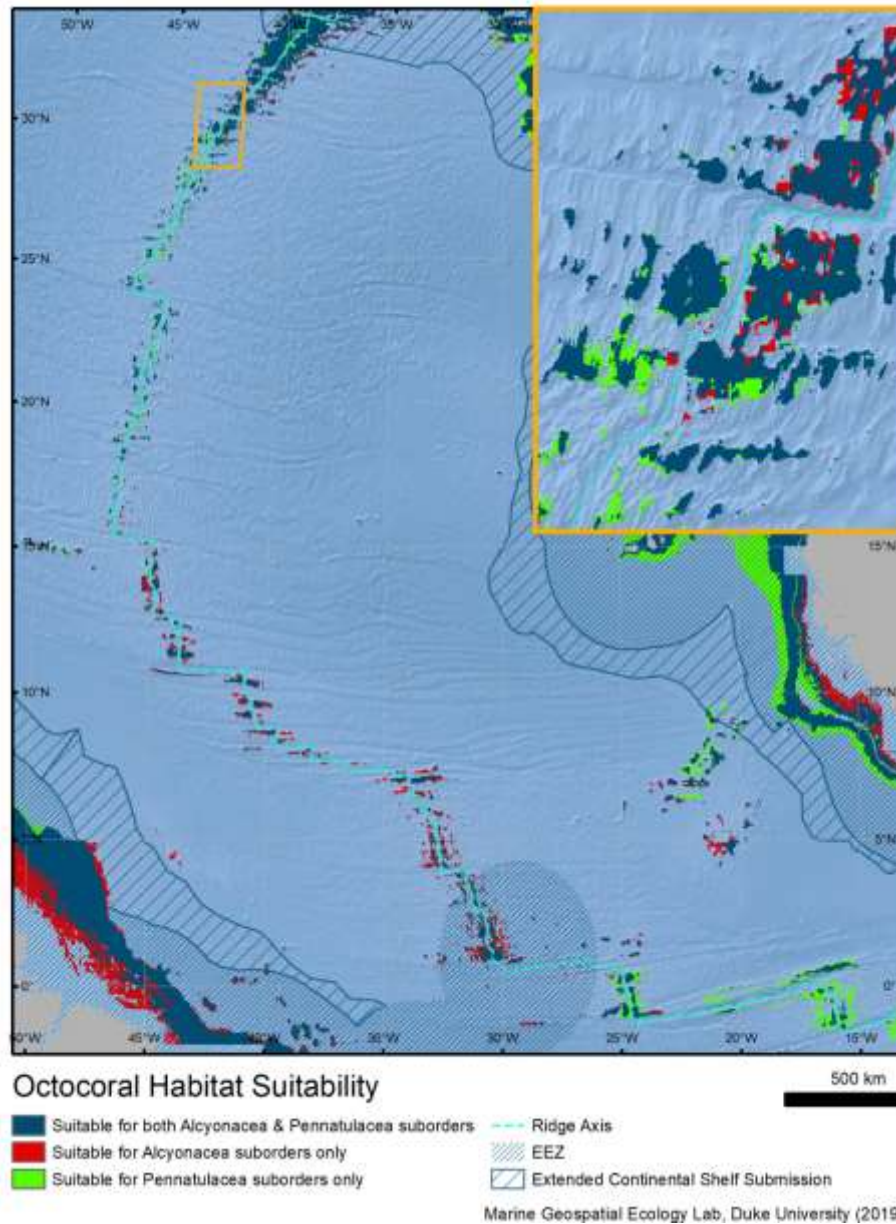


Figure 5. Cold water coral suitability areas proposed as areas that may require increased precaution.

22. Suggested considerations concerning areas of increased sensitivity/precaution include:
- Inferred sites should be treated as sites of increased sensitivity/precaution and/or APEIs as long as there is limited knowledge;
  - Inferred sites that are confirmed as known active sites should be considered as potential sites in need for protection;
  - When new sites are discovered adaptive management could be applied;
  - A REMP could be updated when a new active site is discovered.



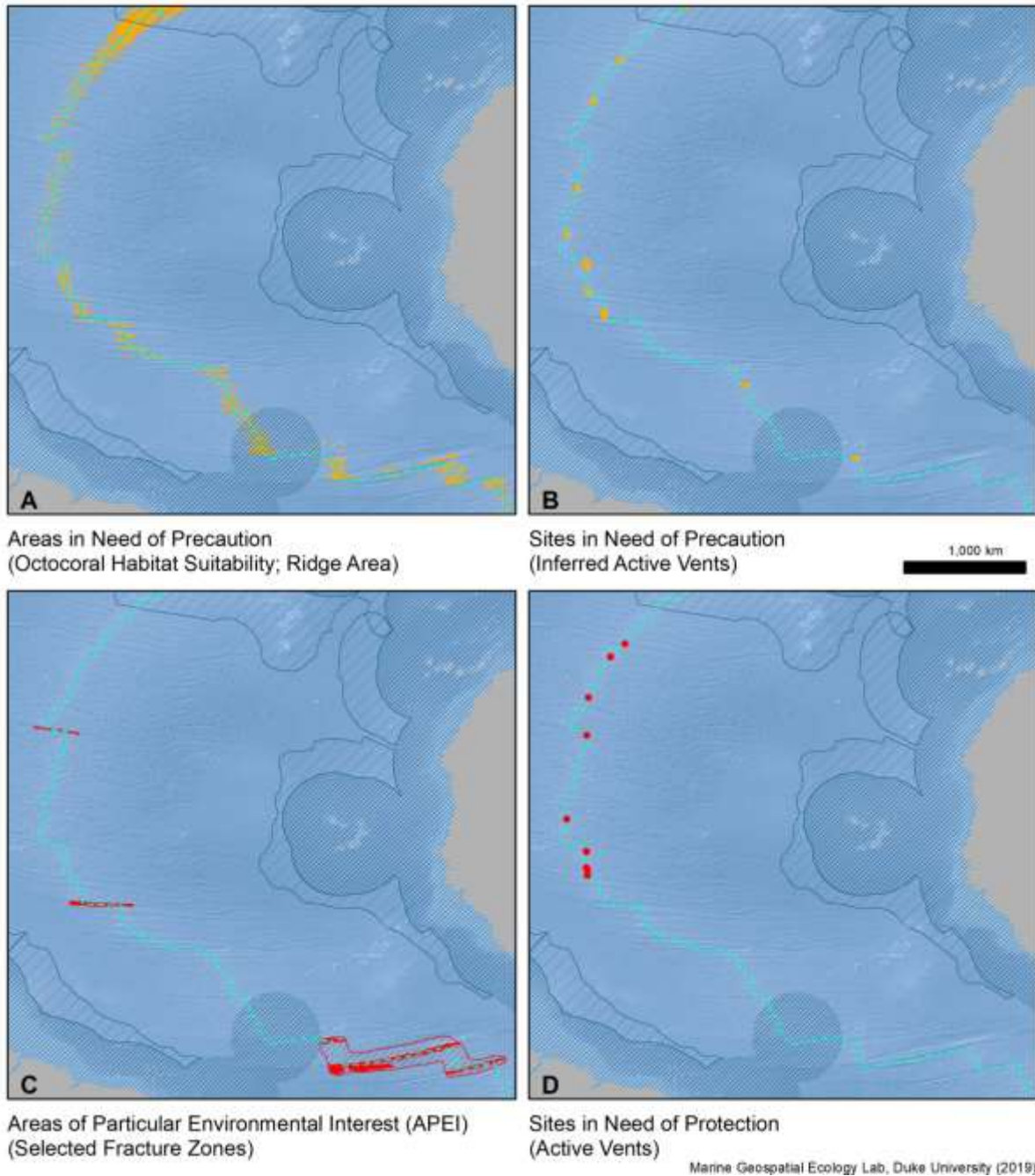


Figure 6. Comparison of areas in need of increased precaution (A), sites in need of increased precaution (B), areas of particular environmental interest (APEI) (C), and sites in need of protection (D)

### Regional sub-units

23. The definition of functional regional sub-units based on biogeographical, physiographic or connectivity function can be help in the evaluation of network criteria such as regional representativity, connectivity, viability and adequacy. An example of regional sub-units based on simulations of expected midwater connectivity is presented in Figure 7.

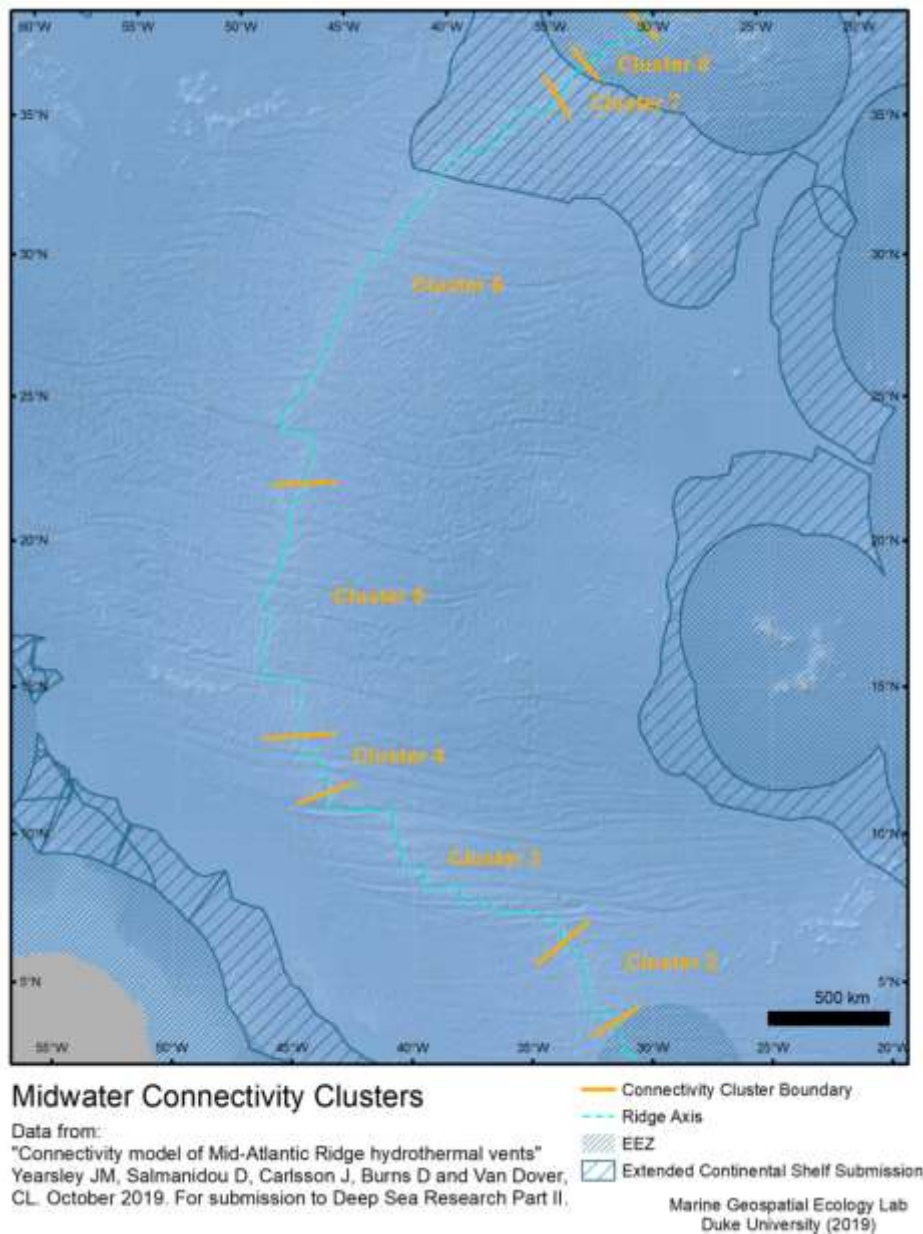


Figure 7: Midwater connectivity sub-regions. These clusters are based on a maximum planktonic larval duration of 70 days. Lower planktonic larval durations yield more clusters. The breaks between clusters are not hard boundaries, but are indicative of the varying strength of dispersal barriers along the ridge.

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## Appendix 1 to Annex IX<sup>17</sup>

### *Editorial note for the templates used for Appendix 1*

The workshop participants, with the help of the ISA secretariat and technical support team, prepared the templates “Compilation of Scientific Information to Describe Sites in Need of Protection/Precaution relating to Article 145 of the Convention”, modifying from the example of CBD template for describing areas meeting the scientific criteria for ecologically or biologically significant marine areas. The distinctive ecological characteristics of active vents qualify them as sites in need for protection, applying the following criteria: (1) Uniqueness or rarity, (2) Functional significance of the habitat, (3) Fragility, (4) Life-history traits of component species that make recovery difficult, (5) Structural complexity, and (6) Information relating to any other relevant scientific criteria.

The following ranking was used for describing the relevance in terms of respective scientific criteria.

- High: Well documented evidence supporting criteria: multiple publications, including peer-reviewed articles, scientific papers, reports; expert knowledge based on direct observations and scientific rationale.
- Medium: Less well documented evidence: few publications; expert knowledge based on models, indirect observations.
- Low: Very limited evidence from publications or expert knowledge.
- No information: No data/information is available.

### *General information relating to Appendix 1*

Globally hydrothermal vents are extremely localized, rare in area occupancy, and unique due to geophysical, geological, geochemical and biota combinations (Desbruyeres et al., 2001; VanDover et al., 2018). Deep-sea vents represent one of the most physically and chemically unusual biomes on Earth (Takai & Nakamura 2011). The uniqueness of each vent, due to the diversity of hydrothermal settings, the depth range and water mass distribution over oceanic ridge crests, significantly influence biodiversity and species composition (VanDover et al. 2018). The hydrothermal vent biota is characterized by a high level of endemism as well as the prevalence of symbioses between invertebrates and bacteria (Dubilier et al. 2008; Kiel 2010). The species living in the vent communities are unique and have specialized adaptations. Particular features allow the organisms to exploit vent habitats, endowed with major reorganization of internal tissues and physiologies to house microbial symbionts, biochemical adaptations to cope with sulphide poisoning, behavioral and molecular responses to high temperature, presence of metal-binding proteins and development of specialized sensory organs to locate hot chimneys (Tunnicliffe et al. 1998). Deep-sea hydrothermal vents are areas of high *in situ* primary production, with high faunal densities and biomass compared to the surrounding deep sea.

Studies of hydrothermal vents on the northern Mid-Atlantic Ridge (MAR) initially focused on the TAG (TransAtlantic Geotraverse) site (Rona et al. 1984). The first hot springs were discovered in 1985, at TAG (Rona et al. 1986) and Snake Pit (Ocean Drilling Program Leg 106 Scientific Party, 1986). For biologists, there was immediate interest in the biota colonizing these sites, as they were distinct from the animals dominating vent sites on the East Pacific Rise (see Karson et al. 2015) for an overview of global hydrothermal settings). Instead of giant tubeworms, clams, and mussels, TAG vents are colonized by dense aggregations of ‘blind’ shrimp and peripheral carnivorous (shrimp-eating)

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<sup>17</sup> The list of scientific references in this appendix was prepared without intending to be exhaustive or complete in terms of editorial requirements in view of limited time available during the workshop and post-workshop editorial process.

anemones. While mussels are so far unrecorded at TAG, they are abundant at Snake Pit, but belong to a different species from those found on the East Pacific Rise. Lucky Strike was the next vent site to be discovered on the MAR, with yet a different assemblage of species adapted to the vent environment (Van Dover et al. 1996). In the 1990s, Van Dover (1995) and Gebruk et al. (1997) reviewed the ecology of MAR vent ecosystems, including insights into the distribution of species and their biogeography. As new sites were discovered and characterized, Desbruyères et al. (2000) described the heterogeneity of vent environments and biota on the Mid-Atlantic Ridge. Desbruyères et al. (2000) documents the dissimilarity among sites - of the known active vent sites on the northern MAR, no two are alike. These dissimilarities are likely driven by a combination of factors including depth (e.g., Gebruk & Mironov 2006, Rybakova and Galkin 2015), abiotic factors (Desbruyères et al. 2000) and by environmental factors (e.g., Fabri et al. 2001). Scientific studies of MAR vent ecosystems continue to this day, including studies of species connectivity, biogeography, adaptations to extreme chemical and physical conditions at vents, biogeochemical cycling, etc. They are “living libraries” for scientists (Godet et al. 2011, Van Dover et al. 2018), who study them following the InterRidge Code of Conduct (<https://www.interridge.org/irstatement>; accessed 2 December 2019). The Code of Conduct includes the guideline that scientists “Avoid, in the conduct of scientific research, activities that will have deleterious impacts on the sustainability of populations of hydrothermal vent organisms.”

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## **Appendix 1-1 CONFIRMED ACTIVE VENTS<sup>18</sup>**

### **Compilation of Scientific Information**

#### **to Describe Sites in Need of Protection relating to Article 145 of the Convention**

##### **1. Lost City – Node ID 967**

###### **Introduction**

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

The Lost City hydrothermal site was discovered in 2000 (Kelley et al. 2001, 2005; see also Blackman et al. 2001) on the Atlantis Massif (an Oceanic Core Complex), 30°N, MAR, bounded to the south by the Atlantis Fracture Zone. It remains to date a singular site among hydrothermal systems, characterized by diffusely venting, low- temperature (90°C max) carbonate monoliths (30 to 60 m height) on a relatively shallow (720-800 m) region of the Mid-Atlantic Ridge. The site is located on 1.5-Myr-old crust, nearly 15 km from the spreading axis. Fluids emanating from the seabed are dominated by heat and products of exothermic serpentinization of peridotite (ultramafic rock) rather than seawater-basalt reactions. Fluids emanating from Lost City are alkaline (pH 9 to 11), hydrogen- and methane-rich, and devoid of dissolved metals. The fauna of Lost City vents is visually dominated by wreckfish (*Polyprion americanus*), cut-throat eels (*Synaphobranchus kaupii*), and large geryonid crabs (Kelley et al. 2005). Lost City hydrothermal vents are posited as a contemporary analogue for conditions where life on early Earth may have originated (Sojo et al. 2016), where there is abiogenic production of organic carbon (Proskurowski et al. 2008), and where there are conditions similar to those that might support life within oceans of extra-terrestrial planetary bodies (Judge 2017). Lost City is recognized as an Ecologically and Biologically Significant Area EBSA by the Convention on Biological Diversity (<https://chm.cbd.int/pdf/documents/marineEbsa/204107/1>). Lost City was also recognized as a potential site of outstanding universal value in the high seas (Freestone et al. 2016).

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<sup>18</sup> For each of the currently confirmed active hydrothermal vent fields located in the Area along the Northern Mid Atlantic Ridge (from South of the Azores' Extended Continental Shelf to the Romanche fracture Zone), scientific results based on peer-reviewed literature are provided in relation to assessing the sites against the above listed criteria – each of these active sites meeting one or more criteria. It should be stressed, however, that the information provided here and references in the templates are not exhaustive. The Appendix reflects input from the participants during the workshop held in Evora from 25-29 November 2019. The participants aim to further work on this description by engaging a broader science community in this process. It is envisaged that the result of this process would include updated description and be submitted to the ISA Secretariat as a separate document before the second workshop on Regional Environmental Management Plan for the Area of the Northern Mid Atlantic Ridge that will be held in Russia in June 2020.

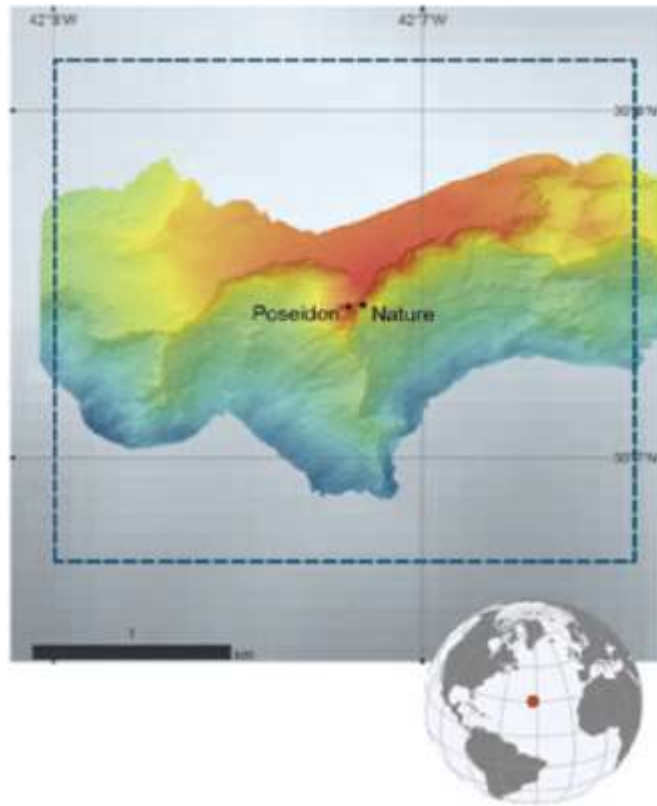


Fig1. The Lost City Hydrothermal Field. Copied from Freestone et al. 2016.

**Location**

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 30.1250

Longitude: -42.1183

Number of vent sites within vent field: 4

See: <https://vents-data.interridge.org/ventfield/lost-city>

**Feature description of the area**

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

See introduction above.

**Assessment of the area against relevant scientific criteria**

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)*



Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Lost City is the only known example of carbonate monoliths with low temperature, diffuse, alkaline, methane- and hydrogen-rich fluids with characteristics derived primarily from serpentinization reactions. It is thus a unique as well as a discrete habitat. It is the only known site that is off-axis, outside the axial valley, and it is the shallowest active vent field in the study area, located on an ocean core complex. Lost City hosts an isolated population of mussels (<i>Bathymodiolus azoricus</i>) with symbiont characteristics that may be important in microbial source-sink population dynamics (DeChaine et al. 2006). Lost City has low biomass and abundance of metazoans compared to other active vent sites, but it does host microbial taxa considered to be endemic (Boetius 2005).</p>					
<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Lost City is a discrete, diffuse-flow, hydrothermal habitat that supports unusual CH<sub>4</sub>- and H<sub>2</sub>-oxidizing autotrophic production by microorganisms under alkaline venting conditions (Kelley et al. 2001, Schrenk et al. 2004). Lost City vents host rare species (Gebruk et al. 2002), and may be critical in source-sink dynamics of vent species. It also supports increased fish biomass compared to the background environment (Kelley et al. 2005) due to its shallow depth, being one of the shallowest active vent sites at the Mid Atlantic Ridge.</p>					

<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Lost City is a unique carbonate-hosted hydrothermal system lacking in metals and may not be of interest to miners. But as a site meeting the criteria above, Lost City qualifies for protection from mining impacts. It is associated with the Mid-Atlantic Ridge; the location of any mining prospect on this ridge axis has yet to be determined, but close proximity to the Lost City Vent Field would place it in danger of degradation.</p> <p>Lost City hosts an isolated population of mussels (<i>Bathymodiolus azoricus</i>) with symbiont characteristics that may be important in microbial source-sink population dynamics (DeChaine et al. 2006). The isolation and uniqueness of this system make it very fragile.</p> <p>Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018).</p>					
<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.		x		
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Life histories of the fish and invertebrates found at Lost City are unknown at this time. Larval recruitment at deep-sea hydrothermal vents is typically unpredictable (Laming et al. 2018, Mullineaux et al. 2018).</p>					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.				x

*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Complex of large carbonate structures and diffuse-flow habitats present (Kelley et al. 2001).

Engineering species present (*B. azoricus*) alive and in form of shells only (Gebruk et al. 2002, Sagalevich et al. 2005).

At Lost City, like at other active hydrothermal systems in the deep sea, the vent habitat is discrete, small patch, with complex geological, geochemical, and biological features and microhabitats. The vent ecosystem is reliant on microbial autotrophic production driven by the chemistry of the hydrothermal fluids (Van Dover 2000). The diversity of active vent ecosystems is relatively low in terms of species richness, compared to the surrounding deep-sea habitats, but the diversity of adaptations to the vent environment is exceedingly rich (Van Dover 2000).

**Information relating to any other relevant scientific criteria (Optional)**

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<b>Scientific Reference Site</b>	Site is an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems				X

*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Lost City represents a different environment for microbial communities, with its carbonate chimneys forming through highly alkaline vent fluid, in contrast to the acidic vent fluids occurring at all other known vent fields along the MAR. Studies at Lost City hydrothermal vents discovered shifts in archaeal and bacterial communities over 1000-year time scales (Brazelton et al., 2010). Correlations between carbonate chimney ages and RNA sequences from the associated archaeal and bacterial communities suggest that ‘rare’ members of the microbial community can become dominant when environmental conditions change, on 1000-year timescales (Brazelton et al., 2010). The long history of chimney growth cycles at Lost City has resulted in numerous closely related microbial ‘species’, each preadapted to a particular set of recurring environmental conditions (Brazelton et al., 2010). Lost City also represents an important analog site for the origin of life on Earth and elsewhere in the Universe (Martin et al. 2008, McCollom et al. 2013, Sojo et al. 2016), as well a site where organic carbon is produced abiotically (Konn et al. 2015, Proskurowski et al. 2008).

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**Maps and Figures**

See: <https://vents-data.interridge.org/ventfield/lost-city>

## 2. Broken Spur – Node ID 663

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Host rock: MORB

Deposit type: PMS

Depth: 3100m

Depthrange: n.a. (3100m)

Oceanography: 1 station (data on temperature, salinity) – WOD (World Ocean Database) [<http://www.nodc.noaa.gov/OC5/WOD13>]

Number of vent sites within vent field: 5

Maximum temp: 365°C

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 29.1700

Longitude: -43.1717

See: <https://vents-data.interridge.org/ventfield/broken-spur>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Broken Spur comprises at least 3 hydrothermally active (365 °C) mounds (up to 40 m high) and two weathered sulphide mounds on the neovolcanic ridge of the rift valley (3100 m). Venting fluids are clear, with diffuse (50C) venting at the base of chimneys (Murton et al. 1994, 1995, Vereschaka et al. 2002). Quantitative studies of vent communities at Broken Spur are reported in Rybakova et al. (2015) and Copley et al. (1997). No change in shrimp density was detected at an interval of 15 months (Copley et al. 1997). Broken Spur is described as an Ecologically and Biologically Sensitive Area (EBSA) by the CBD (<https://chm.cbd.int/pdf/documents/marineEbsa/204107/1>).

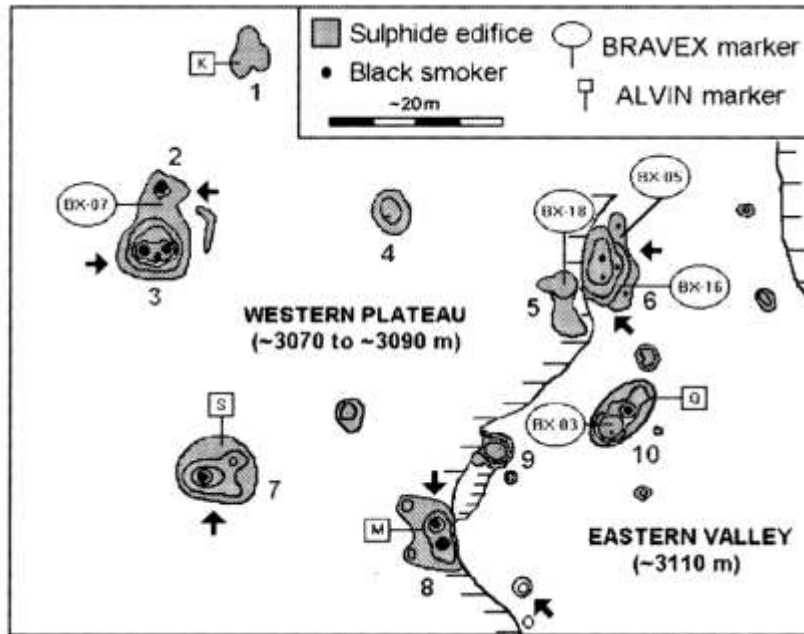


Fig 2. The Broken Spur Active Vent Site. Copied from Copley et al. (1997).

**Assessment of the area against relevant scientific criteria**

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)*

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.				X

*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Broken Spur differs from other vent sites on the Mid-Atlantic Ridge in that the hydrothermal fluids have elevated sulphide concentrations and low methane concentrations (Desbruyères et al. 2000). The shrimp *Rimicaris exoculata* is endemic to active hydrothermal vents on the Mid-Atlantic Ridge, where it typically occurs in dense aggregations (Copley et al. 1997, Schmidt et al. 2008, Rybakova & Galkin 2015). At Broken Spur, this species occurs in low densities, with the exception of larger populations at one structure (Copley et al. 1997). Other dominant taxa endemic to discrete active hydrothermal vents on the MAR include crabs (*Segonzacia mesatlantica*) nematodes, limpets, and anemones (*Parasicyonis ingolfi*) (Galkin et al. 1997).

Perhaps the most unique feature of the Broken Spur hydrothermal field is that it is a zone where two species of mussels (the northern species *Bathymodiolus azoricus* and the southern species *B. puteoserpentis* overlap and where they hybridize (O'Mullan et al. 2001, Breusing et al. 2016).

<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.				X
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*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Broken Spur comprises a complex of large sulphide structures, some active, some not, with high-temperature and diffuse flow zones (Murton et al, 1995). Species occurring at Broken Spur are dependent on hydrothermal fluid flux (endemic) either directly (through symbiotic microbes) or indirectly, through the food web (Copley et al. 1997, Rybakova & Galkin 2015). As noted above, Broken Spur is a hybrid zone for two species of mussels, making it of importance to reproduction and evolution (O'Mullan et al. 2001, Breusing et al. 2017).

<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				x
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*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Taxa at Broken Spur depend on the active vent habitats (including fluid flow characteristics, microbial autotrophic productivity, the nature of the sulphide substrata and structures (Copley et al. 1997, Rybakova & Galkin 2015). Like all known active vent sites, Broken Spur is likely important in source-sink dynamics of its endemic species (Breusing et al. 2017). Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018).



<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Life-history traits of most species at Broken Spur are unknown and may have unpredictable larval dispersal/recruitment (Copley et al. 1997). An exception is the shrimp, for which there is some knowledge of their dispersal (Herring &amp; Dixon 1998), but for which there is unpredictable larval dispersal/recruitment.</p>					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>At Broken Spur, like at other active hydrothermal systems in the deep sea, the vent habitat is discrete, small patch, with complex geological, geochemical, and biological features and microhabitats. The vent ecosystem is reliant on microbial autotrophic production driven by the chemistry of the hydrothermal fluids (Van Dover 2000). The diversity of active vent ecosystems is relatively low in terms of species richness, compared to the surrounding deep-sea habitats, but the diversity of adaptations to the vent environment is exceedingly rich (Van Dover 2000).</p> <p>Broken Spur is characterized by a high diversity of microhabitats with diverse gradients of temperature, fluid flux, and mineral substrata (Murton et al. 1994, 1995, Copley 1997). The mussel species at Broken Spur are bioengineers that host associated invertebrate assemblages (Rybakova &amp; Galkin 2015).</p>					

**Information relating to any other relevant scientific criteria (Optional)**

<b>Other Criteria</b>	<b>Description</b>	<b>Ranking of criterion relevance</b> (please mark one column with an X)			
		<b>No Information</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>

<i>Scientific Reference Site</i>	Site is an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>As noted above, Broken Spur represents a hybridization zone between the mussels <i>B. azoricus</i> and <i>B. puteoserpentis</i>, with both species present and apparently able to interbreed (O’Mullan et al., 2001; Breusing et al., 2016). Rybakova &amp; Galkin (2015) provide benchmark information on the community composition, and Copley et al. (1997) provide baseline data for continuing time-series study of the fauna, including recruitment, stability, and resilience.</p>					

## References

(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)

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Duperron S, Bergin C, Zielinski F, Blazejak A, Pernthaler A, McKiness ZP, DeChaine E, Cavanaugh CM & Dubilier N (2006) A dual symbiosis shared by two mussel species, *Bathymodiolus azoricus* and *Bathymodiolus puteoserpentis* (Bivalvia: Mytilidae), from hydrothermal vents along the northern Mid-Atlantic Ridge. *Environmental Microbiology*, 8 (8): 1441 – 1447.

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### **Maps and Figures**

See: <https://vents-data.interridge.org/ventfield/broken-spur>

### 3. TAG – Node ID 1181

#### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Host rock: MORB

Deposit type: PMS

Depth: 3670m

Depthrange: 3436 - 3670.

Oceanography: 1 station (data on temperature, salinity) – WOD (World Ocean Database) [<http://www.nodc.noaa.gov/OC5/WOD13>]

Number of vent sites within vent field: 7

Maximum temp: 369°C

#### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 26.1367

Longitude: -44.8267

See: <https://vents-data.interridge.org/ventfield/tag>

#### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

The basalt-hosted TAG active hydrothermal vent site is to date the largest known sulphide occurrence on the mid-ocean ridge system at a nominal depth of 3500 m (Karson et al. 2015). It is a complex environment, with high-temperature black smoker complexes and a large apron with lower temperature, diffuse flow. The site has been supported hydrothermal activity for at least 150,000 years, with episodic high-temperature activity lasting 10s to 100s of years (Lalou et al. 1990, 1995). In addition to the hydrothermally active TAG mound, there are numerous inactive or extinct sulphide mounds, recently mapped by Murton et al. (2019). The TAG active mound has been classified as an Ecologically and Biologically Significant Area (EBSA) by the CBD (<https://chm.cbd.int/pdf/documents/marineEbsa/204107/1>). Biomass at the active TAG site is dominated by dense aggregations of ‘blind’ shrimp (*Rimicaris exoculata*) on black smoker chimneys. There is a large literature on the feeding strategies of these shrimp, their derived eyes modified for detecting dim sources of light, and their reproductive biology and connectivity. On the lower temperature, sulphide apron, there are abundant shrimp-eating anemones (*Maractis rimicarivora*). Mussels are so far absent at the active TAG mound (Galkin & Moskalev 1990), though they are found at every other known active vent on the northern Mid-Atlantic Ridge. The biological attributes of TAG are discussed in the template that follows.

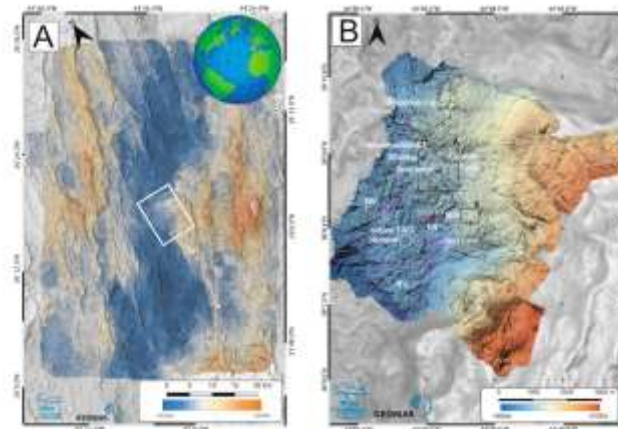


Figure 3. The TAG Hydrothermal Field showing the active TAG mound and a number of inactive or extinct sulphide mounds. Copied from Murton et al. 2019.



Figure 4. Left: multiple species of shrimp that co-occur at TAG. Right: *Rimicaris exoculata* aggregations on the surface of a black smoker chimney at TAG. Karen Jacobsen, artist; with permission.

#### **Assessment of the area against relevant scientific criteria**

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used*

for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>The active TAG hydrothermal mound hosts taxa endemic to discrete hydrothermal vents on the Mid-Atlantic Ridge, including the alvinocarid shrimp <i>Rimicaris exoculata</i> and shrimp-eating anemones <i>Maractis rimicarivora</i> (Van Dover et al. 1997, cited in Fautin &amp; Barber 1999). The TAG active mound is a discrete feeding and spawning area for its endemic taxa. Because the active TAG mound hosts large (Van Dover et al. 1988, Gebruk et al. 1993, Copley et al. 2007) and stable (Copley et al. 1999, 2007) populations of <i>Rimicaris exoculata</i> and <i>Maractis rimicarivora</i> (Copley et al. 1997), these populations are considered to be important source populations for their respective metapopulations, i.e., the site is important as a reproductive area.</p>					
<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.				X

*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

As at all active hydrothermal vent sites known to date, the active vent habitat is essential for the survival, reproduction, and recovery of endemic species, including *Rimicaris exoculata* and *Maractis rimicarivora*, and is necessary for juvenile and adult life history stages. The dominant shrimp species is dependent on proximity to diffuse vent fluid, with autotrophic microbial epibionts and special stomach microbial assemblages that do not survive elsewhere (Van Dover et al, 1988; Gebruk et al. 2000). Adult *R. exoculata* have a hypertrophied cephalothorax that hosts a dense epibiotic bacterial community. These bacteria colonize the mouthparts and inner surfaces of the shrimp carapace (Zbinden et al. 2004; Zbinden et al. 2008). From a metabolic perspective, *R. exoculata*, which ingests mostly minerals, relies on its symbionts for nutrition (Ponsard et al. 2013).

At TAG and other hydrothermal vents on the Mid-Atlantic Ridge, populations of the shrimp *Rimicaris exoculata* are often segregated by size, with adults adjacent to (Gebruk et al. 2000) or above (Copley et al. 2007) juveniles. The adult and juvenile shrimp were initially described as different species, but molecular approaches soon revealed they were life-history stages (Creasey et al. 1996, Shank et al. 1998), indicating that TAG provides critical habitat for both juvenile and adult shrimp.

<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				x
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*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Dominant invertebrate taxa at the TAG active mound, are restricted to hydrothermally active systems and, as at all other active hydrothermal vents, represent isolated populations that, together with populations at other active vents in the region, comprise a metapopulation. In metapopulations (and metacommunities), source-sink dynamics are critical to resilience and persistence of the metapopulation/metacommunity (Vrijenhoek 2010, Mullineaux et al. 2018). Given the large population densities of shrimp, anemones, and other species at the active TAG site, reduction or loss of TAG populations through human activities is likely to eliminate source populations that were both self-recruiting and served as an important supply of offsprings to other sites on the MAR.

*Rimicaris exoculata* shrimp have modified eyes that are poorly designed at the cellular level to recover from intense illumination (Van Dover et al. 1989, Herring et al. 1999, Jinks et al. 1998, Chamberlain 2000). While there is no evidence that brief exposure to high intensity light from submersible assets has not led to an apparent decline in the population density (Copley et al. 2007), long-term exposure to light and loss of visual sensitivity have the potential to alter the behavior and resilience of the shrimp populations.

Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018).

<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>While life-history traits of most species at TAG are unknown, vent taxa ‘historically’ have been considered to have rapid growth rates, have high fecundity, undergo early maturity, and to be relatively short-lived, compared to, for example, slow-growth deep-sea corals (Van Dover 2000). Reproductive biology of three shrimp species were studied (Llodra et al. 2000). The shrimp populations are stable on a decadal time scale (Copley et al. 2007, and there is time-series evidence that there is a scarcity of ovigerous shrimp at TAG during at least some parts of the year and that reproductive events and recruitment of shrimp may be unpredictable (Copley et al. 2007).</p>					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>At the active TAG mound, as at other active hydrothermal systems in the deep sea, the vent habitat is discrete, small patch, with complex geological, geochemical, and biological features and microhabitats. The vent ecosystem is reliant on microbial autotrophic production driven by the chemistry of the hydrothermal fluids (Van Dover 2000). The diversity of active vent ecosystems is relatively low in terms of species richness, compared to the surrounding deep-sea habitats, but the diversity of adaptations to the vent environment is exceedingly rich (Van Dover 2000).</p>					

**Information relating to any other relevant scientific criteria (Optional)**

<b>Other Criteria</b>	<b>Description</b>	<b>Ranking of criterion relevance</b> (please mark one column with an X)			
		<b>No information</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>



<i>Scientific Reference Site</i>	Site is an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Since its discovery, the active TAG mound has been one of the most studied and visited sites by scientists on the Mid-Atlantic Ridge (Murton et al., 2019), including but not limited to geological and geophysical, ecological, and geochemical studies. It is also the locale of the only successful ODP drilling program on the Mid-Atlantic Ridge, with time-series studies of fluid chemistry (Edmonds et al. 1996). There are two time-series studies of shrimp distribution and abundance (Copley et al 1999, 2007).</p>					

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- (e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc)
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### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/tag>

#### 4. Snake Pit– Node ID 1128

##### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Host rock: MORB

Deposit type: PMS

Depth: 3500m

Depth range: 3350 - 3500.

Oceanography: A few stations in the adjusted area (data on temperature, salinity) – WOD (World Ocean Database) [<http://www.nodc.noaa.gov/OC5/WOD13>]

Number of vent sites within vent field: 4

Maximum temp: 366°C

##### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 23.3683

Longitude: -44.9500

See: <https://vents-data.interridge.org/ventfield/snake-pit>

##### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

The Snake Pit (SP) hydrothermal field, located at the summit of Snake Pit Ridge, was so-named because of the abundance of synphobranchid cutthroat eels (*Ilyophis saldanhai*) observed during an *Alvin* dive in 1986 (Thompson et al. 1988). The high-temperature field was first discovered during an ODP site-survey cruise in 1985 (Karson et al. 1987) and was further explored by geologists during a French submersible dive series in 1988 (Gente et al. 1991). Snake Pit is located 25 km south of the Kane fracture. The valley has a depth of 3800m and width of 15 km and the seafloor is composed of tectonized basaltic lava (Karson et al. 1987). The graben formation occurred 2850 to 2500 years ago, the most ancient sulphides being approximately 4000 years old (Lalou et al. 1993). Thus SP is much younger than the TAG vent field. The vent field is located on the southern flank of the highest volcanic cone. It is composed of three mounds. Covering an area of 45,000m<sup>2</sup>, the field is divided in distinct zones all characterized by the presence of a large talus mound of several meters on top of which active and extinct vents are perched (Fouquet et al. 1993, Honnorez et al. 1990). The most active mound and the larger sulphide deposits is the most eastern one; it was drilled during ODP leg 106 (Fouquet et al. 1993). SP is particularly remarkable for its high geochemical and mineralogical diversity (Fouquet et al. 1993, 2010, Honnorez et al. 1990, Kase et al. 1990, Charlou et al. 2010).

The active zone had at least 12 active structures separated by talus of intact inactive chimneys, massive sulphide blocks and deposit of hydrothermal sediments (Karson et al. 1987, Karson and Brown, 1989). High-temperature (366°C) fluids are vented from black-smoker chimneys and low-temperature (226 °C) fluids seep from sulphide domes (Karson and Brown, 1989).

Located ~300 km south of TAG, SP has four known active sites: Moose (Elan), Beehive (les Ruches), Fir Tree (le Sapin), and Nail (le Clou), an active not well characterizes site (La Falaise) as well as several low-temperature sites. The major venting activity of the field is found at Les Ruches (100m<sup>2</sup>). This mound harbors a complex of several active sulphide structures (~>10m high) as well as inactive

chimneys. Elan (3500m, 80m<sup>2</sup>) is particularly distinctive with the presence of chimneys with vertical conduits as well as large beehives and flanges that makes it resemble to moose antlers (Figure X); this type of structure is not reported anywhere else. On the center of the vent field, Le Sapin (few m<sup>2</sup>) is a 22m high mound characterized by low temperature diffuse flow areas. On the western part, le Clou (40m<sup>2</sup>) et La Falaise constitute a large north-south area of ~130m to 160m, with an elevation of 65m.

Relative to TAG, the Snake Pit sulphide mounds are small but the surfaces of high-temperature chimneys are occupied by dense populations of *Rimicaris exoculata* shrimp (Segonzac et al. 1992). Three other species of shrimp are also observed (*Rimicaris chacei*, *Mirocaris fortunata*, *Alvinocaris markensis*). Shrimp nurseries as well as areas of gastropod egg layouts have been observed (Sarrazin pers. obs.). Unlike TAG, Snake Pit hosts mussels (*Bathymodiolus puteoserpentis*) whose distribution is restricted to Elan and Le Clou (Vereschaka et al. 2002). Dense assemblages of peltospirid gastropods can be found in high-temperature habitats (Sarrazin et al. in prep). *Phymorhyncus* gastropods, anemones and ophiurids colonize the less active zones, at the base of the active sites. Zoarcid fish (*Pachycara thermophilum*) are particularly abundant (Sarrazin pers obs). A description of the Snake Pit biological community was first provided by Segonzac (1992) and a quantitative study of biodiversity associated with Snake Pit mussel beds was reported by Turnipseed et al. (2003). Like other active vent sites on the Mid-Atlantic Ridge, Snake Pit has been repeatedly visited by scientists, especially during the last 5 years partly due to its localization within the French permit area (Bicose cruises in 2014 & 2018, Hermine cruise in 2017). Recent biological studies are focused on connectivity (Breusing et al. 2016), physiological tolerances (Ravaux et al. 2019), microbial symbionts (Zbinden et al. 2017, Apremont et al. 2018) and trace metals (Dermina & Galkin 2016). Snake Pit was classified as an Ecologically and Biologically Significant Area by the Convention on Biodiversity (<https://chm.cbd.int/pdf/documents/marineEbsa/204107/1>).



Figure 5. The Moose hydrothermal site. Karen Jacobsen, artist; with permission

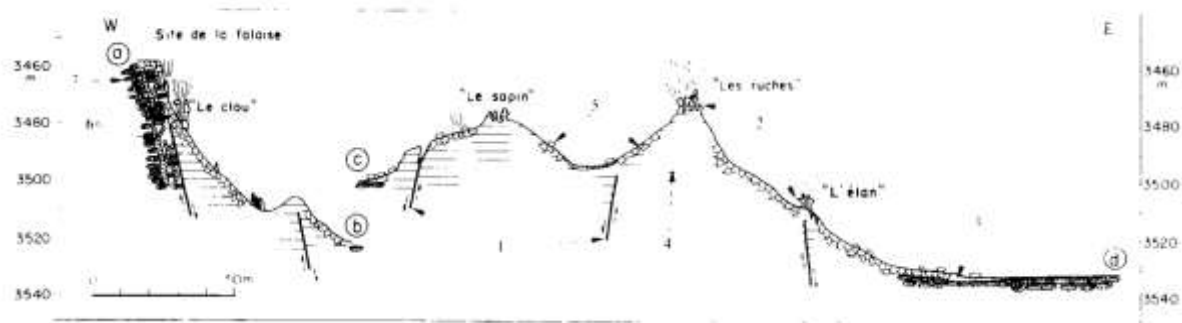


Figure 6. The Snake Pit hydrothermal field. Copied from Gente et al. 1991.

### Assessment of the area against relevant scientific criteria

(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Like other active hydrothermal vents, Snake Pit is a discrete site colonized by numerous <b>endemic</b> taxa dependent on chemoautotrophically based food webs (e.g., Turnipseed et al. 2004). Dominant taxa are the shrimp <i>Rimicaris exoculata</i> and the mussel <i>Bathymodiolus puteoserpentis</i>. The cutthroat eel (<i>Ilyophis saldanhai</i>), a deep-sea fish found in the Atlantic and Pacific) is notably abundant at Snake Pit. The eels are inferred to use Snake Pit as a feeding ground and possibly a breeding ground. Snake Pit supports a distinctive meiobenthos community relative to the surrounding seabed (Zekely et al. 2006).</p>					
<b>Functional significance</b>	Discrete areas or habitats that are necessary for (i) the survival,				X

<b>of the habitat</b>	function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.				
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>As at all discrete active hydrothermal vents, hydrothermal fluid at Snake Pit is necessary for the survival and reproduction of vent endemic taxa (Van Dover 2000, Van Dover et al. 2018).</p>					
<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>The Snake Pit site hosts taxa endemic taxa (Zekely et al. 2006). Degradation of the habitat and loss of the endemic taxa is likely to disrupt connectivity among populations . Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018).</p>					
<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.	x			
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>As at other active hydrothermal vents, recruitment dynamics are unknown and likely to be unpredictable given that the larvae are dispersed in the water column.</p>					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.				x



*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

At Snake Pit, as at other active hydrothermal systems in the deep sea, the vent habitat is discrete, with complex geological, geochemical, and biological features and microhabitats. The vent ecosystem is reliant on microbial autotrophic production driven by the chemistry of the hydrothermal fluids (Van Dover 2000). The diversity of active vent ecosystems is relatively low in terms of species richness, compared to the surrounding deep-sea habitats, but the diversity of adaptations to the vent environment is exceedingly rich (Van Dover 2000).

The shrimp *R. exoculata* and the vent mussel *B. puteoserpentis* are foundation species at Snake Pit. The physical structure of foundation species creates additional area for colonization, increases environmental heterogeneity and serves as a refuge from predation, and can modify the physical or chemical environment by altering fluid flow and composition (Rybakova and Galkin 2015).

**Information relating to any other relevant scientific criteria (Optional)**

Other Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<i>Scientific Reference Site</i>	Site is an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems				X

*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

A very well studied site of the MAR. Best site for knowledge of meiofauna: Zekely et al., (2006) determined the feeding guild of meiofauna collected from Snake Pit vent field on the MAR, and discovered that primary consumers, mostly deposit feeders, comprised more than 95 % of the total meiobenthos at the site, followed by parasitic copepods and mites. All the nematodes and the majority of copepod individuals were primary consumers, with parasites only making up 20% of the copepod community. Predators were absent in all samples.

Ambient light emissions where observed at Snake Pit (White et al. 2002).

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*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

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#### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/snake-pit>

## 5. Pobeda

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

During video profiling in this area indications of modern hydrothermal activity were recorded. Extensive fields of shells of *Bathymodiolus puteoserpentis* and *Thyasira* sp. were discovered and samples of bivalves were taken using the TV-grab and geological square corer.

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Pobeda 1  
Depth: 1950-2400  
Latitude: 17,145  
Longitude: -46,408

Pobeda 2  
Depth: 2800-3100  
Latitude: 17,138  
Longitude: -46,403

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Information on oceanographic data: <https://data.isa.org.jm/> (data on temperature, salinity, turbidity)

### Assessment of the area against relevant scientific criteria

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)*

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High

<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.				<b>x</b>
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Presence of endemic vent fauna. “ During video profiling in this area indications of modern hydrothermal activity were recorded. Extensive fields of shells of <i>Bathymodiolus puteoserpentis</i> and <i>Thyasira</i> sp. were discovered and samples of bivalves were taken using the TV-grab and geological square corer” (Molodtsova et al. 2017).</p>					
<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.		<b>x</b>		
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Presence of <i>Bathymodiolus puteoserpentis</i> that is dependent on hydrothermal fluid flux (endemic) either directly (through symbiotic microbes) (Dubelier et al. 2008, Moladtssova et al. 2017)</p>					
<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				<b>x</b>
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018).</p>					
<b>Life-history traits of component species that make recovery</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-	<b>x</b>			

<b>difficult</b>	lived.				
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
not known					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.	<b>x</b>			
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
not known					

## References

*(e.g. relevant documents and publications, including URL where available; relevant data sets,*

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## 6. Logatchev 1– Node ID 960

### Introduction

(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)

Host rock: MORB, serpentinite, gabbro

Deposit type: n.a.

Depth: 3050m

Depthrange: 2925 - 3050.

Oceanography: <https://data.isa.org.jm/> (data on temperature, salinity, turbidity)

Number of vent sites within vent field: 10

Maximum temp: 370

### Location

(Indicate the geographic location of the area/feature, preferably with a map.)

Latitude: 14.7520

Longitude: -44.9785

See: <https://vents-data.interridge.org/ventfield/logatchev>

### Feature description of the area

(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)

#### Notes on Vent Field Description:

The Logatchev-1, depth 2900-3050 m, formerly known as “14-45”, was discovered in 1993-1994 during the 7<sup>th</sup> Cruise of the RV *Professor Logatchev* (Batuyev et al., 1994). The Logatchev-1 area extends over approximately 600 m in the north-west south-east direction and comprises at least nine hydrothermal sites of various size and type (listed from NW to SE): Quest, Anya’s Garden, Irin-2, Site F, Site B, Irina-1, Candelabra, Anna-Louise and Site A (Borowski et al., 2008; Fouquet et al., 2008). The major geological peculiarities of the Logatchev-1 hydrothermal system include its association with gabbro-peridotites, location close to the top of the rift wall and development of “smoking craters” (Bodganov et al., 1997). Variety of habitats include active chimney complex (Irina II), “smoking crater” (Anna-Louise), large sulphide body (Irina I) and diffuse flow sites (Anya’s Garden and Site F).

#### Notes Relevant to Biology (Fauna/community description):

The Logatchev vent community was described by Gebruk et al. (2000). Van Dover and Doerries (2005) published a quantitative study of the mussel beds. The analysis of the symbioses between bivalves (*Bathymodiolus*, *Thyasira*, and *Abyssogena*) and bacteria, based on histological observations (TEM), and nitrogen and carbon stable isotopes, was published by Southward et al. (2001). The most striking biological feature of this hydrothermal field is the existence of a large population of vesicomid clams at the site “Anya’s Garden” together with small population of thyasirids *Thyasira* (*Parathyasira*) and mussels *Bathymodiolus puteoserpentis*. This is the only known live population of vesicomids north of the equator on the Mid-Atlantic Ridge. The clams were referred to *Ectenagena* aff. *kaikoi* in Gebruk et al. (2000), but appeared to belong to the new genus and species *Abyssogena southwardae* (Krylova et al., 2010). The biomass on the mussel bed at Irina-2 exceeded 70 kg m<sup>-2</sup> (wet weight with shells), it was the highest known for the MAR vent fields (Gebruk et al., 2000). Overall the Logatchev area is dominated by mussels which may be attributed to the presence in their gills of two types of symbionts: methane-oxidizing (dominant type) and sulphur-oxidizing (Southward et al., 2001). The large swarm of

*Rimicaris exoculata* is a characteristic of the Irina-2 chimney complex. Prominent features of the Logatchev field include the quantitative abundance of brittle stars *Ophioctenella acies*: at the Irina-2 site their contribution to the abundance exceeds 80% (Van Dover and Doerries, 2005), and a high biomass and density of the species of *Phymorhynchus* (*P. moskalevi*, *P. ovatus* and *P. carinatus*) (Gebruk et al., 2010).

Community dynamics over a decadal scale at Logatchev was studied by Gebruk et al. (2010). The most significant change in the community was at Irina-2 based on comparison of data from March 2007 and July 1997. The population density of predatory gastropods *Phymorhynchus* spp. increased dramatically- more than four times. Some increase in the abundance of the brittle star *Ophioctenella acies* also was noted. Over the same ten-year period, the population of vesicomysids at Anya's Garden has disappeared with no signs of recovery in the whole area of Logatchev-1 (Gebruk et al., 2010).

**Assessment of the area against relevant scientific criteria**

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)*

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.				x



*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

The most striking biological feature of Logatchev-1 is the presence of a large population of vesicomylid clams *Abyssogena southwardae* at the site “Anya’s Garden” together with small population of thyasirids *Thyasira (Parathyasira)* and mussels *Bathymodiolus puteoserpentis*. This is the only known live population of vesicomylids north of the equator on the Mid-Atlantic Ridge( Gebruk et al., 2000). The site is dominated by vent endemic mussels *B.puteoserpentis*, brittle stars *Ophiectenella acies*, gastropods *Phymorhynchus* (three species) and shrimps *R.exoculata* (Gebruk et al. 2000, 2010). The benthic macrofauna at Logatchev mussel bed was dominated by the ophiuroid *Ophiectenella acies*, whilst Lucky Strike was dominated by the amphipod *Bouvierella curtirama* (Van Dover & Doerries 2005). Logatchev and Snake Pit mussel beds shared 55% of associated macrofaunal benthic invertebrate species, whereas Logatchev and Snakepit only shared 20 – 25% of species with Lucky Strike.

<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.				x
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*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

The only known live population of vesicomylids north of the equator on the Mid-Atlantic Ridge is present at this site (Gebruk et al. 2010)). As at other active hydrothermal vents, species occurring at this site are dependent on hydrothermal fluid flux (endemic) either directly (through symbiotic microbes) or indirectly, through the food web (Van Dover 2000).

<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				x
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*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Ecosystem highly dependant on hydrothermal activity (Gebruk et al., 2000). Presence of species endemic/unique to hydrothermal vents (Gebruk et al., 2000). Clam field - *Abyssogena southwardae* - the only known life population north of Equator (Gebruk et al., 2000; La Bella et al. 2017). Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018).

<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.	x			
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>As at other active hydrothermal vents, recruitment dynamics are unknown and likely to be unpredictable given that the larvae are dispersed in the water column.</p>					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>At Logatchev-1, like at other active hydrothermal systems in the deep sea, the vent habitat is discrete, small patch, with complex geological, geochemical, and biological features and microhabitats. The vent ecosystem is reliant on microbial autotrophic production driven by the chemistry of the hydrothermal fluids (Van Dover 2000). The diversity of active vent ecosystems is relatively low in terms of species richness, compared to the surrounding deep-sea habitats, but the diversity of adaptations to the vent environment is exceedingly rich (Van Dover 2000).</p> <p>The engineering species present at this site is <i>B. puteoserpentis</i>, and extreme high density of <i>Ophioctenella acies</i> and species of <i>Phymorhynchus</i> was observed. Shrimp nurseries were also observed at this site (Gebruk et al. 2010).</p>					

**Information relating to any other relevant scientific criteria (Optional)**

<b>Other Criteria</b>	<b>Description</b>	<b>Ranking of criterion relevance</b> (please mark one column with an X)			
		<b>No information</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>

<i>Scientific Reference Site</i>	Site is an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>The area was revisited repeatedly by Russian, French, US and Germany expeditions. Numerous published data exist. Studies of community changes over a decadal scale - very limited on the MAR (Gebruk et al., 2010). The only known live population of clams north of Equator (Gebruk et al., 2010; LaBella et al. 2017).</p>					

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*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

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## Maps and Figures

See: <https://vents-data.interridge.org/ventfield/logatchev>

## 7. Logatchev 2– Node ID 961

### Introduction

(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)

Host rock: ultramafic-hosted

Deposit type: PMS; chalcopyrite, sphalerite, chalcocite

Depth: 2760m

Depthrange: 2640 - 2760

Oceanography: <https://data.isa.org.jm/> (data on temperature, salinity, turbidity)

Number of vent sites within vent field: 1

Maximum temp: 320°C

### Location

(Indicate the geographic location of the area/feature, preferably with a map.)

Latitude: 14.7200

Longitude: -44.9380

See: <https://vents-data.interridge.org/ventfield/logatchev-2>

### Feature description of the area

(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)

Notes on Vent Field Description:

Logatchev-2 lies 5.5 km south-east of Logatchev-1 at the depth of 2640-2760 m. This area was also discovered in 1993-1994 concurrent with Logatchev-1 (Batuyev et al., 1994).

Notes Relevant to Biology:

An extensive field (several tens of m across) of dead mussel shells (*B. puteoserpensis*) was found on the slope of the mound that had a weakly active chimney on top expelling shimmering water. The mussel shells still had their periostracum, indicating a recent catastrophic collapse of a large population, apparently as a result of a rapid slowing down of the hydrothermal activity. Only a few live mussels, as well as shrimps *Chorocaris chacei* and *Mirocaris fortunata* were recorded on the single active chimney (Gebruk et al. 2010).

### Assessment of the area against relevant scientific criteria

(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High

<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>A unique example of a vanishing hydrothermal vent community on the MAR (Gebruk et al., 2010). Presence of vent endemic species <i>Bathymodiolus</i>, as well as shrimps <i>Chorocaris chacei</i> and <i>Mirocaris fortunata</i> were recorded on the single active chimney (Gebruk et al. 2010).</p>					
<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Presence of vent endemic species <i>Bathymodiolus</i>, as well as shrimps <i>Chorocaris chacei</i> and <i>Mirocaris fortunata</i> were recorded on the single active chimney (Gebruk et al. 2010). As at other active hydrothermal vents, most species occurring at this sites are dependent on hydrothermal fluid flux (endemic) either directly (through symbiotic microbes) or indirectly, through the food web (Van Dover 2000).</p>					
<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>A unique example of how fragile communities at hydrothermal vents are - example of a vanishing hydrothermal ot vent community on the MAR (Gebruk et al., 2010). Presence of vent endemic species <i>Bathymodiolus</i>, as well as shrimps <i>Chorocaris chacei</i> and <i>Mirocaris fortunata</i> were recorded on the single active chimney (Gebruk et al. 2010). Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018).</p>					

<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.	x			
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>As at other active hydrothermal vents, recruitment dynamics are unknown and likely to be unpredictable given that the larvae are dispersed in the water column.</p>					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>At Logatchev, an unusual habitat formed by large field of mussel shells was observed (Gebruk et al. 2010).</p>					

**Information relating to any other relevant scientific criteria (Optional)**

<b>Other Criteria</b>	<b>Description</b>	<b>Ranking of criterion relevance</b> (please mark one column with an X)			
		<b>No information</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>
<i>Scientific Reference Site</i>	Site is an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems				x



*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Valuable for understanding vent dynamics. Detachment faults displace the vents away from the ridge axis by as much as 12 km for the Logatchev 2 vent. Important for understanding vent community dynamics/ temporal variations (Gebruk et al. 2010).

## References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

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## Maps and Figures

See: <https://vents-data.interridge.org/ventfield/logatchev-2>

## 8. Semyenov-2 – Node ID 1122

### Introduction

(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)

Host rock: basalt-hosted

Deposit type: PMS

Depth: 2360-2580 m

Depthrange: n.a. (2440m)

Oceanography: <https://data.isa.org/jm/> (data on temperature, salinity, turbidity)

For few stations: data on dissolved Cu, Mn, Fe (unpublished)

WOD (World Ocean Database) [<http://www.nodc.noaa.gov/OC5/WOD13>] – 1 station (data on temperature, salinity)

Number of vent sites within vent field: 5

Maximum temp: n.a.

### Location

(Indicate the geographic location of the area/feature, preferably with a map.)

Latitude: 13.5137

Longitude: -44.9630

See: <https://vents-data.interridge.org/ventfield/semyenov>

### Feature description of the area

(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)

#### Notes on Vent Field Description:

Discovered on the 30<sup>th</sup> Cruise of RV Professor Logatchev in 2007 (Bel'tenev et al., 2007). Includes five vent sites, one of them, Semenov-2, active (Bel'tenev et al., 2009). Distance from the ridge axis varies from 0.5 km (Semenov-4) to 10.5 km (Semenov-1) (Cherkashev et al., 2017). The active site Semenov-2 is located 3.5 km from the axis at the depth 2360-2580 m and is related to basalts. This site consists of two deposits (sulphide mounds and products of their disintegration). The dimensions of the deposits are 600x400 m and 200x175 m respectively. Age estimations of this site vary from 3.1 to 76 ka years (Cherkashev et al., 2017).

#### Notes Relevant to Biology:

Information on biota comes from the only one TV-grab station (St. 275) taken at 13°30.82'N, 44°57.78'W, depth 2441 m. At least 12 taxa were preliminary identified in this sample, including the mussel *Bathymodiolus puteoserpentis*, the gastropod *Phymorhynchus ovatus*, polychaetes *Amathys lutzi* and *Levensteiniella* sp., the pycnogonid *Sericosura heteroscela*, shrimps *Alvinocaris markensis* and *Opaepele susannae*, the crab *Segonzacia mesatlantica*, and the brittle-star *Ophioctenella acies* (Bel'tenev et al., 2009).

Of special interest is the record of the shrimp *O. susannae* (six specimens in the sample). This species has been described on the MAR from two locations south of Equator: Lilliput (9°32'S, 1500 m) and Sisters Peak (4°48'S, 2986 m) (Komai et al., 2007). The new record of *O. susannae* north of Equator is important for understanding relationships of hydrothermal vent fauna north and south of Equator on the MAR.

**Assessment of the area against relevant scientific criteria**

(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Even based on just one sample, the site Semenov-2 has great scientific importance owing to the record of the vent endemic shrimp <i>Opaepele susannae</i>. This species has been described on the MAR from two locations south of Equator: Lilliput (9°32'S, 1500 m) and Sisters Peak (4°48'S, 2986 m) (Komai et al., 2007). The new record of <i>O. susannae</i> north of Equator is critical for understanding relationships of hydrothermal vent fauna north and south of Equator on the MAR (Bel'tenev et al., 2009).</p>					
<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.		X		
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Data is very limited. As at other active hydrothermal vents, most species occurring at this site are very likely dependent on hydrothermal fluid flux (endemic) either directly (through symbiotic microbes) or indirectly, through the food web (Van Dover 2000).</p>					

<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.					x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Communities are highly dependent on hydrothermal activity. Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018).</p>						
<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.	x				
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>As at other active hydrothermal vents, recruitment dynamics are unknown and likely to be unpredictable given that the larvae are dispersed in the water column.</p>						
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.	x				
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Data is very limited.</p>						

**Information relating to any other relevant scientific criteria (Optional)**

<b>Other Criteria</b>	<b>Description</b>	<b>Ranking of criterion relevance</b> (please mark one column with an X)			
		<b>No information</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>

<i>Scientific Reference Site</i>	Site is an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems			x	
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Even based on just one sample, the site Semenov-2 has great scientific importance owing to the record of the shrimp <i>Opaepele susannae</i>. This species has been described on the MAR from two locations south of Equator: Lilliput (9°32'S, 1500 m) and Sisters Peak (4°48'S, 2986 m) (Komai et al., 2007). The new record of <i>O. susannae</i> north of Equator is critical for understanding relationships of hydrothermal vent fauna north and south of Equator on the MAR (Bel'tenev et al., 2009).</p>					

### References

(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)

Bel'tenev V., V. Ivanov, A. Shagin, M. Segeyev, I. Rozhdestvenskaya, V. Shilov, I. Debretzova, G. Cherkashev, M. Samovarov, and I. Poroshina, 2005, New hydrothermal sites at 13°N, Mid-Atlantic Ridge. *InterRidge News*, 14, 14-16.

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Discovery References:

Beltenev et al. (2009) New data about hydrothermal fields on the Mid-Atlantic Ridge between 11- 14 N: 32nd Cruise R/V Professor Logatchev. *InterRidge News* 18: 13-17.

(deposits only) Beltenev et al. (2007) A NEW HYDROTHERMAL FIELD AT 13 30'N ON THE MID-ATLANTIC RIDGE. *InterRidge News* 16: 9-10.

(deposits only) Cherkashov et al. (2008) New important discoveries of hydrothermal deposits at the Mid-Atlantic Ridge (geological setting, composition and resources). IGC Oslo abstracts, session MRD-03 Recent developments on marine mineral deposits.

Other References:

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**Maps and Figures**

See: <https://vents-data.interridge.org/ventfield/semyenov>

**9. Irinovskoe -Node ID 982 (former MAR, 13 19’N OCC)**

**Introduction**

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

National Jurisdiction: high seas

Maximum or Single Reported Depth (mbsl): 3000

Oceanography: WOD (World Ocean Data Base) [<http://www.nodc.noaa.gov/OC5/WOD13>] – data on temperature, salinity

Data on turbidity – unpublished

**Location**

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 13.3333

Longitude: -44.9000

See: <https://vents-data.interridge.org/ventfield/mar-13-19n-occ>

**Feature description of the area**

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

The Irinovskoe hydrothermal field, explored during ROV dives 553 and 557, is located on the northern region of the 13820<sup>0</sup>N corrugated surface, 1.8 km from the footwall cutoff in the direction of extension. Coalescing mounds rise up to 10–20 m above surrounding seafloor, masking corrugations of the detachment surface over an area 300 - 200 m in the across- and along-extension directions, respectively. During two ROV dives two active vents at the summit of hydrothermal mounds, Active Pot and Pinnacle Ridge, were identified. Both show black smoker fluids venting at 365C from 1 to 2 m high cauldron-shaped structures with large exit orifices (several decimeters in diameter), clearly associated with very elevated heat and mass fluxes. We did not observe any associated macrofauna, while bacterial mats and diffuse lower-temperature outflow were limited to the immediate vicinity of these two active vents. The nearby hydrothermal mounds show both fallen and standing hydrothermal chimneys, up to 10 m in height (Escartin et al. 2017).

**Assessment of the area against relevant scientific criteria**

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)*

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High

<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.		x		
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Very few data. Observed presence of microbial mats associated with hydrothermal vent fluid emissions (Escartin et al. 2017).</p>					
<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.	x			
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Very few data. Observation of bacterial mats associated with hydrothermal vent fluid emissions (Escartin et al. 2017).</p>					
<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Data on presence of bacterial mats (Escartin et al. 2017). Communities are highly dependent on hydrothermal activity; Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018).</p>					



<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.	x			
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Very few data; no macrofauna observed (studied focus on geology).</p>					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>1 to 2 m high cauldron-shaped structures with large exit orifices (several decimeters in diameter), clearly associated with very elevated heat and mass fluxes. The nearby hydrothermal mounds show both fallen and standing hydrothermal chimneys, up to 10 m in height (Escartin et al. 2017).</p>					

**Information relating to any other relevant scientific criteria (Optional)**

<b>Other Criteria</b>	<b>Description</b>	<b>Ranking of criterion relevance</b> (please mark one column with an X)			
		<b>No information</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>
<i>Scientific Reference Site</i>	Site is an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems	x			

*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Limited data

### **References**

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Escartín, J., Mével, C., Petersen, S., Bonnemains, D., Cannat, M., Andreani, M., Augustin, N., Bezos, A., Chavagnac, V., Choi, Y., Godard, M., Haaga, K., Hamelin, C., Ildefonse, B., Jamieson, J., John, B., Leleu, T., MacLeod, C.J., Massot-Campos, M., Nomikou, P., Olive, J.A., Paquet, M., Rommevaux, C., Rothenbeck, M., Steinfuhrer, A., Tominaga, M., Triebe, L., Campos, R., Gracias, N., Garcia, R., 2017. Tectonic structure, evolution, and the nature of oceanic core complexes and their detachment fault zones (13°20'N and 13°30'N, Mid-Atlantic Ridge). *Geochemistry Geophysics Geosystems*, 18(4), 1451-1482.

Van Dover, C.L., Arnaud-Haond, S., Gianni, M., Helmreich, S., Huber, J.A., Jaekel, A.L., Metaxas, A., Pendleton, L.H., Petersen, S., Ramirez-Llodra, E., Steinberg, P.E., Tunnicliffe, V., Yamamoto, H., 2018. Scientific rationale and international obligations for protection of active hydrothermal vent ecosystems from deep-sea mining. *Marine Policy* 90, 20-28.

### **Maps and Figures**

See: <https://vents-data.interridge.org/ventfield/mar-13-19n-occ>

## 10. Ashadze 2– Node ID 647

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Host rock: ultramafic-hosted

Deposit type: n.a.

Depth: 3300m

Depthrange: 3200-3300m

Oceanography: <https://data.isa.org.jm/> (data on temperature, salinity, turbidity)

For 1 stations: data on dissolved and suspended Cu, Mn, Fe, Zn (unpublished)

For adjusted area (ore cluster Ashadze): data on dissolved and suspended Cu, Mn, Fe, Zn (unpublished)

Number of vent sites within vent field: n.a.

Maximum temp: “high”

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 12.9917

Longitude: -44.9067

See: <https://vents-data.interridge.org/ventfield/ashadze-2>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

The Ashadze 2 site was discovered by monitoring anomalies in the electric potential (EP) recorded by the deep-towed RIFT system during a 2003 cruise (Fouquet et al., 2008). There is a black smoker field on serpentinized peridotites; 2.5 miles NW of Ashadze 1; northern part of a wide terrace; small active crater with mixture of carbonates and copper-rich sulphides; Fouquet et al. (2008) state: "On the Ashadze 2 site a large group of smokers occurs, in a crater-shaped depression, about 25 m in diameter at the bottom of the graben structure. This constructional structure may indicate the sometimes-explosive nature of the hydrothermal fluid emissions". Two types of hydrothermal deposits are observed: massive copper-rich sulphides associated with the black smokers and carbonate/sulphides chimneys (Fouquet et al. 2007).

No biological data available.

### Assessment of the area against relevant scientific criteria

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)*

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)
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		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.		x		
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>No information on the biota from this site is available. Active venting of high temperature reducing fluids is confirmed at this site, which may provide suitable habitat for endemic hydrothermal vent animals but there is no published evidence of fauna at this site.</p>					
<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.		X		
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Active venting of high temperature reducing fluids is confirmed at this site, which may provide suitable habitat for endemic hydrothermal vent animals but there is no published evidence of fauna at this site. Many species at deep-sea hydrothermal vents are dependent on hydrothermal fluid flux (endemic) either directly (through symbiotic microbes) or indirectly, through the food web (Van Dover 2000).</p>					
<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018). On the Ashadze 2 site a large group of smokers occurs, in a crater-shaped depression, about 25 m in diameter at the bottom of the graben structure (Forquet et al, 2008).</p>					

<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.	X			
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
No information on the biota from this site is available.					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.		X		
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
“On the Ashadze 2 site a large group of smokers occurs, in a crater-shaped depression, about 25 m in diameter at the bottom of the graben structure” (Forquet et al, 2008), which are highly dependant on hydrothermal activity. The “small active crater can be interpreted as a hydrothermal volcano built up with a mixture of carbonates and secondary copper sulphides and chlorides. Massive sulphide chimneys are associated with the active smokers at the center of the crater. Many inactive carbonates/sulphides mounds are also aligned along an N-S depression” (Forquet et al, 2007).					

**Information relating to any other relevant scientific criteria (Optional)**

<b>Other Criteria</b>	<b>Description</b>	<b>Ranking of criterion relevance</b> (please mark one column with an X)			
		<b>No information</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>
<i>Scientific Reference</i>	Site is a scientific reference point that has provided historic data and progressed scientific knowledge on chemosynthesis-based ecosystems		X		

*Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)*

Data from scientific surveys shows that “the Ashadze 2 field is unusual; the small active crater can be interpreted as a hydrothermal volcano built up with a mixture of carbonates and secondary copper sulphides and copper chlorides. Massive sulphide chimneys are associated with the active smokers at the center of the crater” Fourquet et al., (2008). This unusual system may provide valuable insights into the functional dynamics of hydrothermal vent systems.

## References

Fouquet, Y et al. (2007) Diversity of Ultramafic Hosted Hydrothermal Deposits on the Mid Atlantic Ridge: First Submersible Studies on Ashadze, Logatchev 2 and Krasnov Vent Fields During the Serpentine Cruise. American Geophysical Union, Fall Meeting 2007, abstract #T51F-03.

Fouquet, Y et al. (2008) Serpentine cruise - ultramafic hosted hydrothermal deposits on the Mid-Atlantic Ridge: First submersible studies on Ashadze 1 and 2, Logatchev 2 and Krasnov vent fields. *InterRidge News* 17: 15-19.

Van Dover, Cindy. *The ecology of deep-sea hydrothermal vents*. Princeton University Press, 2000.

Van Dover, C.L., Arnaud-Haond, S., Gianni, M., Helmreich, S., Huber, J.A., Jaeckel, A.L., Metaxas, A., Pendleton, L.H., Petersen, S., Ramirez-Llodra, E., Steinberg, P.E., Tunnicliffe, V., Yamamoto, H., 2018. Scientific rationale and international obligations for protection of active hydrothermal vent ecosystems from deep-sea mining. *Marine Policy* 90, 20-28.

Discovery References:

\*Beltenev, V et al (2005) New hydrothermal sites at 13 N, Mid Atlantic Ridge. *InterRidge News* 14: 14-16. (\*did not confirm activity)

Fouquet, Y et al. (2007) Diversity of Ultramafic Hosted Hydrothermal Deposits on the Mid Atlantic Ridge: First Submersible Studies on Ashadze, Logatchev 2 and Krasnov Vent Fields During the Serpentine Cruise. American Geophysical Union, Fall Meeting 2007, [abstract #T51F-03](#).

Fouquet, Y et al. (2008) Serpentine cruise - ultramafic hosted hydrothermal deposits on the Mid-Atlantic Ridge: First submersible studies on Ashadze 1 and 2, Logatchev 2 and Krasnov vent fields. [InterRidge News 17: 15-19](#).

Other References:

G. Cherkashov , I. Poroshina , T. Stepanova , V. Ivanov , V. Bel'tenev , L. Lazareva , I. Rozhdestvenskaya , M. Samovarov , V. Shilov , G. P. Glasby , Y. Fouquet & V. Kuznetsov (2010) Seafloor Massive Sulfides from the Northern Equatorial Mid-Atlantic Ridge: New Discoveries and Perspectives, *Marine Georesources and Geotechnology*, 28:3, 222-239, [DOI: 10.1080/1064119X.2010.483308](#)

N.R. Ayupova, I.Yu. Melekestseva, V.V. Maslennikov, A.S. Tseluyko, I.A. Blinov, V.E. Beltenev (2018) Uranium accumulation in modern and ancient Fe-oxide sediments: Examples from the Ashadze-2 hydrothermal sulfide field (Mid-Atlantic Ridge) and Yubileynoe massive sulfide deposit (South Urals, Russia). [Sedimentary Geology, 367:164-174](#).

## Maps and Figures

See: <https://vents-data.interridge.org/ventfield/ashadze-2>  
[Site diagram](#) © from Ayupova et al (2018)

## 11. Ashadze 1 – Node ID 646

### Introduction

(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)

Host rock: ultramafic-hosted

Deposit type: n.a.

Depth: 4200m

Depthrange: 4080-4200m

Oceanography: <https://data.isa.org/jm/> (data on temperature, salinity, turbidity)

For adjusted area (ore cluster Ashadze): data on dissolved and suspended Cu, Mn, Fe, Zn (unpublished)

Number of vent sites within vent field: n.a.

Maximum temp: 355

### Location

(Indicate the geographic location of the area/feature, preferably with a map.)

Latitude: 12.9733

Longitude: -44.8633

See: <https://vents-data.interridge.org/ventfield/ashadze>

### Feature description of the area

(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)

Notes on Vent Field Description:

Black smoker field on serpentinized peridotites; at the foot of the western slope of the MAR rift valley; deepest active black smoker field known as of 2009 (<https://vents-data.interridge.org/ventfield/ashadze>).

Notes Relevant to Biology:

“Ashadze-1 (12° 58'N 44° 51'W, 4080 m) is the deepest known active hydrothermal vent field on the Mid-Atlantic Ridge (MAR). The first observations on this site were numerous clear and black smokers and surprisingly few known symbiotic species dominant in other vent areas on the MAR. The species most abundant at Ashadze-1 are those usually found at the periphery of hydrothermal communities: sea-anemones *Maractis rimicarivora* and chaetopterid polychaetes *Phyllochaetopterus* sp. Nov.” (Fabri et al. 2011).

### Assessment of the area against relevant scientific criteria

(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area may be provided on the basis of one or more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can be also used for description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)
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		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	An area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include (i) habitats that contain endemic species; (ii) habitats of rare, threatened, or endangered species that occur only in discrete areas; (iii) nurseries or discrete feeding, breeding, or spawning areas.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Ashadze-1 vent ecosystem is fundamentally different from all known MAR vent fields (Fabri et al., 2011). The benthic-megafauna community is dominated by two species, namely the sea-anemone <i>Maractis rimicarivora</i> and a new species of chaetopterid polychaete, <i>Phyllochaetopterus</i> sp. nov. Typical symbiotic mussels are absent and the molluscan fauna is represented by gastropods, including 2 new species. The vent endemic-shrimp <i>Rimicaris exoculata</i> is present in small numbers.</p>					
<b>Functional significance of the habitat</b>	Discrete areas or habitats that are necessary for (i) the survival, function, spawning/reproduction, or recovery of species; (ii) particular life history stages (e.g. nursery grounds or rearing areas); (iii) or of rare, threatened, or endangered marine species.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>As the deepest vent field on the MAR vent field, this site hosts a significant source population of hydrothermal vent fauna at depth (Fabri et al., 2011), maintaining connectivity along deeper sections of the MAR. Hydrothermal fluids are essential to support vent specialist animals. For example, this site hosts abundant populations of the amphinomid polychaete <i>Archinome</i> sp., scaleworms (Polynoidae) such as <i>Iphionella</i> sp. and <i>Levensteiniella iris</i>. Two species of <i>Phymorhynchus</i> (gastropod) are also present and are considered as predators of other mollusks or necrophagous. Pycnogonids were also collected at the base of the chimneys. The carnivorous/necrophagous level is also represented by the crab <i>Segonzacia mesatlantica</i> and by the zoarcid fish <i>Pachycara thermophilum</i>. Some galatheids are also present. (Fouquet et al. 2008).</p> <p>Ashadze - 1 could be the stepping stone in species dispersal along the MAR between Logatchev and areas south of the equator (Fabri et al. 2011).</p>					



<b>Fragility</b>	An ecosystem that is highly susceptible to degradation by anthropogenic activities.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Active vent ecosystems are “Small Natural Features” with ecological importance disproportionate to their size (Van Dover et al., 2018). The fine scale structures and faunal communities that are tightly linked to these structures are highly susceptible to disturbance.</p>					
<b>Life-history traits of component species that make recovery difficult</b>	Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics: (i) slow growth rates; (ii) late age of maturity; (iii) low or unpredictable recruitment; (iv) long-lived.	x			
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Although the faunal communities present at this site are well documented, the life-history traits of most species are not well characterized.</p>					
<b>Structural complexity</b>	An ecosystem that is characterized by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.				x
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>The Ashadze-1 hydrothermal vent site is organized around a group of three very active black vents. The 2-m high ‘Long chimney’ is located at the top of a small mound (Fabri et al., 2011). There are a high diversity of micro-habitats, with a complex of sulphide structures, high fluid flow/diffuse-flow habitats that provide essential temperature/fluid/substrata gradients for hydrothermal vent faunal communities (Fabri et al., 2011).</p>					

**Information relating to any other relevant scientific criteria (Optional)**

Other Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<i>Scientific Reference Site</i>	Site is an exemplary scientific reference-site that has provided baseline historic data and progressed scientific knowledge on chemosynthesis-based ecosystems.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Ashadze-1 is the deepest active vent site studied within the N-MAR area at 4200 m and fundamentally different from all known MAR vent fields: biomass dominated by non-symbiotrophic species (Fabri et al., 2011). Ashadze-1 seems to display the characteristics of a ‘waning stage’ ecosystem, i.e. gathering of scavengers and invasion by non-vent deep-sea taxa. High faunal diversity at the Ashadze-1 vent field emphasizes the fact that diversity is similar at both types of vent fields, and is maintained by non-chemosynthetic taxa invading the field owing to the low level of toxic sulphides.</p>					

**References**

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Fabri M-C, Bargain A, Briand P, Gebruk A, Fouquet Y, Morineaux M & Desbruyeres D (2011) The hydrothermal vent community of a new deep-sea field, Ashadze-1, 12°58’N on the Mid-Atlantic Ridge. *Journal of the Marine Biological Association of the United Kingdom*, 91 (1):1-13.  
<https://doi.org/10.1017/S0025315410000731>

Fouquet et al. (2008) Serpentine cruise - ultramafic hosted hydrothermal deposits on the Mid-Atlantic Ridge: First submersible studies on Ashadze 1 and 2, Logatchev 2 and Krasnov vent fields. *InterRidge News* 17: 15-19.

Van Dover, C.L., Arnaud-Haond, S., Gianni, M., Helmreich, S., Huber, J.A., Jaeckel, A.L., Metaxas, A., Pendleton, L.H., Petersen, S., Ramirez-Llodra, E., Steinberg, P.E., Tunnicliffe, V., Yamamoto, H., 2018. Scientific rationale and international obligations for protection of active hydrothermal vent ecosystems from deep-sea mining. *Marine Policy* 90, 20-28.

Discovery References:

Beltenev, V., et al. (2003) New discoveries at 12°58’N, 44°52’W, MAR: Professor Logatchev-22 cruise, initial results. *InterRidge News* 12, 13-14.

Fouquet et al. (2008) Serpentine cruise - ultramafic hosted hydrothermal deposits on the Mid-Atlantic Ridge: First submersible studies on Ashadze 1 and 2, Logatchev 2 and Krasnov vent fields. [InterRidge News 17: 15-19](#)

**Other References:**

Beltenev, V et al (2005) New hydrothermal sites at 13 N, Mid Atlantic Ridge. *InterRidge News* 14: 14-16.

Cherkashov et al. (2008) New important discoveries of hydrothermal deposits at the Mid-Atlantic Ridge (geological setting, composition and resources). IGC Oslo abstracts, session MRD-03 Recent developments on marine mineral deposits.

Cherkashov, G., Poroshina, I., Stepanova, T., Ivanov, V., Bel'tenev, V., Lazareva, L., Rozhdestvenskaya, I., Samovarov, M., Shilov, V., Glasby, G.P., Fouquet, Y., and Kuznetsov, V. (2010) Seafloor massive sulphides from the northern equatorial Mid-Atlantic ridge: New discoveries and perspectives. *Marine Georesources and Geotechnology*, 28: 3, 222–239.  
<http://doi.org/10.1080/1064119X.2010.483308>

Cherkashov, G.A., Ivanov, V.N., Bel'tenev, V.I., Lazareva, L.I., Rozhdestvenskaya, I.I., Samovarov, M.L., Poroshina, I.M., Sergeev, M.B., Stepanova, T.V., Dobretsova, I.G., and Kuznetsov, V. Yu. (2013) Massive sulphide ores of the northern equatorial Mid-Atlantic Ridge. *Oceanology*, 53: 5, 607–619.

Fabri et al. abstract 4th CBE Symposium (2009) Hydrothermal vent community of the new deep-sea field Ashadze-1, 12 58'N (MAR) and a comparison with all known northern Atlantic deep-sea hydrothermal communities.

\*Klinkhammer et al. (1985) Hydrothermal manganese plumes in the Mid-Atlantic Ridge rift valley. *Nature* 314: 727-731. (\*plume only)

Morineaux M, Nishi E, Ormos A & Mouchel O (2010) A new species of *Phyllochaetopterus* (Annelida: Chaetopteridae) from deep-sea hydrothermal Ashadze-1 vent field, Mid-Atlantic Ridge: taxonomical description and partial COI DNA sequence. *Cahiers de Biologie Marine*, 51: 239 – 248.

Roussel EG, Konn C, Charlou J-L, Donval J-P, Fouquet Y, Querellou J, Prieur D & Cambon Bonavita M-A (2011) Comparison of microbial communities associated with three Atlantic ultramafic hydrothermal systems. *FEMS Microbial Ecology*, 77: 647 – 665.

Yahagi T, Fukumori H, Warén A & Kano Y (2019) Population connectivity of hydrothermal-vent limpets along the northern Mid-Atlantic Ridge (Gastropoda: Neritimorpha: Phenacolepadidae). *Journal of the Marine Biological Association of the United Kingdom* 99 (1): 179-185.

### **Maps and Figures**

See: <https://vents-data.interridge.org/ventfield/ashadze>

## **Appendix 1-2 INFERRED ACTIVE VENTS**

### **Compilation of Scientific Information**

#### **to Describe Sites of Increased Precaution relating to Article 145 of the Convention**

##### **1. MAR, 30 N – Node ID 992**

###### **Introduction**

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 3400

###### **Location**

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 30.0333

Longitude: -42.5000

See: <https://vents-data.interridge.org/ventfield/mar-30-n>

###### **Feature description of the area**

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

longitude and depth approximate; Murton et al. (1994): "The anomalies at 30 02'N occurred in the lowermost 1500 m of the water column, in the nodal deep basin at the western ridge-transform intersection of the Atlantis Fracture Zone. These were limited to manganese enrichments, but without corresponding particulates;"

###### **References**

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

(plume only) B.J. Murton et al., (1994) Direct evidence for the Distribution and Occurrence of Hydrothermal Activity Between 27 and 30 degrees north on the Mid-Atlantic Ridge, Earth Planet. Sci. Lett. 125, pp. 119–128.

###### **Maps and Figures**

See: <https://vents-data.interridge.org/ventfield/mar-30-n>

## 2. MAR, 27 N – Node ID 991

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 2900

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 27.0000

Longitude: -44.5000

See: <https://vents-data.interridge.org/ventfield/mar-27-n>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

longitude approximate; Murton et al. (1994): "A particulate-rich water mass was observed 250 m above the axial valley floor of the MAR at 27 00'N... No corresponding manganese anomaly was observed."

### References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

(plume only) B.J. Murton et al., (1994) Direct evidence for the Distribution and Occurrence of Hydrothermal Activity Between 27 and 30 degrees north on the Mid-Atlantic Ridge, Earth Planet. Sci. Lett. 125, pp. 119–128.

### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/mar-27-n>

### 3. Puy des Folles– Node ID 1084

#### **Introduction**

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 2000

Oceanography: <https://data.isa.org/jm/> (data on temperature, salinity, turbidity)

WOD (World Ocean Database) [<http://www.nodc.noaa.gov/OC5/WOD13>] - data on temperature, salinity for adjusted areas

#### **Location**

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 20.5083

Longitude: -45.6417

See: <https://vents-data.interridge.org/ventfield/puy-des-folles>

#### **Feature description of the area**

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

seamount in axial valley; Georgy Cherkashov talk Apr 2009 used "active(?)"

#### **References**

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

(inactive vents only) Gente et al. (1996) On- and off-axis submersible investigations on an highly magmatic segment of the Mid-Atlantic Ridge (21 40'N): the TAMMAR cruise. InterRidge News 5(2): 27-31.

Other References:

31st cruise Professor Logatchev, in Russia national update InterRidge News 2008.

#### **Maps and Figures**

See: <https://vents-data.interridge.org/ventfield/puy-des-folles>

#### 4. MAR, 17 09' N – Node ID 1300

##### **Introduction**

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 3100

##### **Location**

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 17.1500

Longitude: -46.4200

See: <https://vents-data.interridge.org/ventfield/mar-17-09n>

##### **Feature description of the area**

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

position and depth approximate from GeoMapApp 3.4.1; Beltenev (2015): "Between November 2014 and April 2015, 15 blocks have been examined on the MAR between 17 51'N and 16 41'N... two new ore fields were discovered on the south-western slope of the seamount at the eastern flank of the rift valley of MAR, one at 17 09'N and second at 17 07'N. During video profiling in this area indications of modern hydrothermal activity were discovered."

##### **References**

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

Beltenev, V., et al. (2015) The cruise of the RV Professor Logachev to the Russian Claim Area on the Mid-Atlantic Ridge. INDEEP Deep-Sea Life, Issue 5, June 2015, p. 17.

##### **Maps and Figures**

See: <https://vents-data.interridge.org/ventfield/mar-17-09n>

## 5. MAR, south of 15 20' – Node ID 997

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 3000

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 15.0833

Longitude: -45.0000

See: <https://vents-data.interridge.org/ventfield/mar-south-15-20n-fracture-zone>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

The low TDM/CH<sub>4</sub> ratio contrasted with the higher TDM/CH<sub>4</sub> ratios found in plumes emitted by high-temperature venting ... and was interpreted as an indicator of ongoing hydrothermal venting associated with seafloor exposures of serpentinized peridotite.

### References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

(plume only) Charlou et al, *Geochim. Cosmochim. Acta*, 55, 3209-3222, 1991, Different TDM/CH<sub>4</sub> hydrothermal plume signatures: TAG site at 26°N and serpentinized ultrabasic diapir at 15°05'N on the Mid-Atlantic Ridge.

Other References:

Charlou et al., (1998). Intense CH<sub>4</sub> plumes generated by serpentinization of ultramafic rocks at the intersection of the 15°20'N fracture zone and the Mid-Atlantic Ridge, *Geochim. Cosmochim. Acta*, 62, 2323-2333.

### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/mar-south-15-20n-fracture-zone>



## 6. MAR, 14 54'N– Node ID 983

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 3500

Minimum Depth (mbsl): 3000

Host Rock: MORB

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 14.9200

Longitude: -44.9000

See: <https://vents-data.interridge.org/ventfield/mar-14-54n>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

Eberhardt et al. (1988): "The rift valley at site 3 (14°54' N), with postulated extrusive volcanic activity and a stage in valley evolution tending toward a U-shape, shows evidence of hydrothermal activity within the slightly faster spreading eastern inner wall."; Fouquet et al. (2008 InterRidge News) cite Eberhardt et al. (1988): "Sulphide-like deposits were found and photographed at 14°54'N near the foot of the eastern wall of the rift valley"; this field was not observed on 2004 cruise (Kuhn et al. 2004).

### References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

Eberhardt et al., Geologic controls of hydrothermal activity in the Mid-Atlantic Ridge rift valley: Tectonics and volcanics. *Mar. Geophys. Res.*, 10, 233-239, 1988

(plume only) Charlou et al, *Geochim. Cosmochim. Acta*, 55, 3209-3222, 1991, Different TDM/CH<sub>4</sub> hydrothermal plume signatures: TAG site at 26°N and serpentinized ultrabasic diapir at 15°05'N on the Mid-Atlantic Ridge.

Other References:

Charlou et al., Intense CH<sub>4</sub> plumes generated by serpentinization of ultramafic rocks at the intersection of the 15°20'N fracture zone and the Mid-Atlantic Ridge, *Geochim. Cosmochim. Acta*, 62, 2323-2333, 1998.

Kuhn et al. (2004) The Logatchev hydrothermal field - revisited: Preliminary results of the R/V Meteor cruise HYDROMAR I (M60/3). *InterRidge News* 13: 1-4.

### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/mar-14-54n>

## 7. Logatchev 3 – Node ID 962

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 3100

Oceanography: <https://data.isa.org.jm/> (data on temperature, salinity, turbidity)

### Location

(Indicate the geographic location of the area/feature, preferably with a map.)

Latitude: 14.7083

Longitude: -44.9667

See: <https://vents-data.interridge.org/ventfield/logatchev-3>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

depth approximate GeoMapApp; not observed in 2007 Serpentine cruise

### References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Cherkashov, G., et al. (2010) Seafloor Massive Sulfides from the Northern Equatorial Mid-Atlantic Ridge: New Discoveries and Perspectives. *Marine Georesources & Geotechnology* 28: 222 - 239, <http://dx.doi.org/10.1080/1064119X.2010.483308>.

### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/logatchev-3>

## 8. Neptune's Beard– Node ID 1043

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 4100

Oceanography: 2 stations (data on temperature, salinity, turbidity) – unpublished

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 12.9100

Longitude: -44.9000

See: <https://vents-data.interridge.org/ventfield/neptunes-beard>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

anomalies of temperature, salinity, transmissometer, Fe-oxides in sediment layer; west wall of MOR rift valley, in intensively faulted area; Sudarikov et al. (2001): "During the TV survey we observed, in real time, some shrimp and clouds resembling hydrothermal smoke."; MENTIONED AS VENT ON SEAFLOOR: July 2001: Mid-Atlantic Ridge Expedition

(<http://www.nrel.colostate.edu/projects/iboy/whatandwhere.html>)

### References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

(plume only) Klinkhammer et al. (1985) Hydrothermal manganese plumes in the Mid-Atlantic Ridge rift valley. *Nature* 314: 727-731.

Sудариков et al. (2001) A New Hydrothermal Plume at 12 54.6' N Mid-Atlantic Ridge: Initial Results of the R/V Yuzhmorgeologiya Cruise. *InterRidge News* 10(1): 37-40.

### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/neptunes-beard>

## 9. MAR, 11 26'N– Node ID 979

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 3835

Oceanography: 1 station (data on temperature, salinity, turbidity) – unpublished

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 11.4482

Longitude: -43.7035

See: <https://vents-data.interridge.org/ventfield/mar-11-26n>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Year and How Discovered: 2009 plume only

### References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

(plume only) Beltenev et al. (2009) New data about hydrothermal fields on the Mid-Atlantic Ridge between 11- 14 N: 32nd Cruise R/V Professor Logatchev. InterRidge News 18: 13-17.

### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/mar-11-26n>

## 10. MAR, 11 N– Node ID 980

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 4010

Oceanography: WOD (World Ocean Database) [<http://www.nodc.noaa.gov/OC5/WOD13>] – 1 station and a few stations in adjacent areas (data on temperature, salinity)

Data on turbidity – unpublished

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 11.0380

Longitude: -43.6483

See: <https://vents-data.interridge.org/ventfield/mar-11-n>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Year and How Discovered: 1984 plume only; 2009 plume only

### References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

(plume only) Klinkhammer et al. (1985) Hydrothermal manganese plumes in the Mid-Atlantic Ridge rift valley. *Nature* 314: 727-731

(plume only) Beltenev et al. (2009) New data about hydrothermal fields on the Mid-Atlantic Ridge between 11- 14 N: 32nd Cruise R/V Professor Logatchev. *InterRidge News* 18: 13-17.

### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/mar-11-n>

## 11. Markov Deep – Node ID 1002

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 3500

Oceanography: WOD (World Ocean Database) [<http://www.nodc.noaa.gov/OC5/WOD13>] – 1 station and a few stations in adjusted areas (data on temperature, salinity)

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 5.9100

Longitude: -33.1800

See: <https://vents-data.interridge.org/ventfield/markov-deep>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

depth approximate (GEBCO); dredge with massive sulphides and some water column indicators in Sierra Leone fracture zone area; Sharkov et al. (2007): "indirectly indicate that hydrothermal systems, discharging on the seafloor, may have existed and might exist in the Markov Deep"; note Tao et al. (2013) mentioned that "we found a new hydrothermal anomaly field located in the NAR at 4°-7°N."

Year and How Discovered: 2001-2002 and 2003 dredge only

### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/markov-deep>

### References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

S. G. Skolotnev, A. A. Peive, N. S. Bortnikov, et al., (2003) "Geology of Ore-Hosting Rift Deeps near Sierra Fracture Zone, Equatorial Atlantic," Dokl. Akad. Nauk 391 (2), 232–238 [Dokl. Earth Sci. 391 (5), 679–684.

Pushcharovsky (2004) Tectonic structures of the Atlantic Ocean and their connection with magmatism and ore formation - summary of successfully completed studies of the Russian Academy of Sciences. InterRidge News 13: 15-17.

Tao et al. (2013) New discovery of seafloor hydrothermal activity on the Indian Ocean Carlsberg Ridge and Southern North Atlantic Ridge - progress during the 26th Chinese COMRA cruise. Acta Oceanologica Sinica, 32, 85-88.

Other References:

Sharkov, E.V., Abramov, S.S., Simonov, V.A., Krinov, D.I., Skolotnev, S.G., Bel'tenev, V.E., and Bortnikov, N.S. (2007): Hydrothermal Alteration and Sulfide Mineralization in Gabbroids of the Markov Deep (Mid-Atlantic Ridge, 6°N). *Geology of Ore Deposits* 49(6), 467-486.

## 12. MAR, segment south of St. Paul system – Node ID 1290

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models.)*

Maximum or Single Reported Depth (mbsl): 3500

Oceanography: WOD (World Ocean Database) [<http://www.nodc.noaa.gov/OC5/WOD13>] - data on temperature, salinity

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

Latitude: 0.5000

Longitude: -25.0000

See: <https://vents-data.interridge.org/ventfield/mar-segment-south-st-paul-system>

### Feature description of the area

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

Notes on Vent Field Description:

position very approximate; depth rounded from Bird (2003) model step; Maia et al. (2013): "15 CTD stations with nephelometric profiles casted in the transform region returned a single hydrothermal plume signal, probably sourced in the MAR segment south of the St. Paul system, while no hydrothermal activity was directly detected inside the transform system" \

### References

*(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)*

Discovery References:

Maia, M., et al. (2013) Complex ridge-transform evolution and mantle exhumation at the St. Paul fracture zone system, Equatorial Atlantic. Preliminary results from the COLMEIA cruise. American Geophysical Union, Fall Meeting 2013, abstract #OS42A-01.

### Maps and Figures

See: <https://vents-data.interridge.org/ventfield/mar-segment-south-st-paul-system>



**Appendix 2 to Annex IX.**  
**Compilation of Scientific Information**  
**to Describe Areas of Coarse-scale Planning (e.g. Areas of Particular Environmental Interest)**  
**relating to Art.145 of the Convention**

**1. The Kane Fracture Zone**

**Introduction**

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models)*

Fracture zones are common topographic features of the global oceans that arise through plate tectonics. They are characterized by two strongly contrasting types of topography. Seismically active transform faults form near mid-ocean ridges where the continental plates move in opposing directions at their junction. Seismically inactive fracture zones, where the plate segments move in the same direction, extend beyond the transform faults often for 100s of kilometres. Their atypical crust thickness that can be as little as 2 km (Cormier *et al.*, 1984; Calvert and Whitmarsh 1986; Mutter *et al.*, 1984) allowing direct seismic investigations of the internal structure and composition of oceanic crusts used to model processes of seafloor spreading. In the Atlantic Ocean most fracture zones originate from the Mid-Atlantic Ridge (MAR) and are nearly perfectly west - east oriented. There are about 300 fracture zones occurring on average every 55 km along the ridge, with the offsets created by transform faults ranging from 9 to 400 km in length (Müller and Roest 1992).

Shallower portions of the MAR (e.g. Reykjanes Ridge) act like a barrier to water movements, while deep west-to-east fracture zones (e.g., Charlie-Gibbs or Vema Fracture Zone) seemed to guide the spatial and temporal distribution of thermal fronts and water masses (Belkin *et al.*, 2009).

The MAR holds 10 major fracture zones (from South to North, Romanche, Vema, Fifteen-Twenty, Kane, Atlantic, Hayes, Oceanographer, Pico, Kurchatov, Faraday, Charlie-Gibbs, and Bight). The longitudinally of MAR will present different geographic zones with different productivity regimes, and consequently different POC flux (a proxy for food supply), with effects on species diversity, trophic interactions, and other ecosystem attributes (Dunn *et al.*, 2018).

The North MAR plays an important role in the connectivity of deep-sea populations. It has been described both as an ecological barrier for megafaunal species (Alt *et al.*, 2019; Gebruk *et al.*, 2010) or an East-West Atlantic conduit for larval dispersal at fracture zones (German *et al.*, 2011).

**Location**

*(Indicate the geographic location of the area/feature, preferably with a map.)*

The Kane Fracture Zone (KFZ) and the surrounding oceanic domain is probably the most intensively surveyed area of the North Atlantic Ocean. It is located around 23°40' N (Fig. 1) and offsets the MAR by about 150 km.

The rift valley in the KFZ area is 10-17 km wide and 3500-4000 m deep, reaching 6100 m depth in the nodal basin at the Ridge-Transform Intersection (RTI). The motion along the transform segment is dextral and the measured full spreading rate in the area is close to 3 cm yr<sup>-1</sup> (Schuh *et al.*, 1988).

**Feature description**

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

The KFZ has been traced as a distinct topographic trough from the Mid-Atlantic Ridge near 24°N to the 80-m.y. B.P. isochron (magnetic anomaly 34) on either side of the ridge axis for a total of approximately 2800 km. Major changes in trend of the fracture zone occur at approximately 72 m.y. B.P. (anomaly 31 time) and approximately 53–63 m.y. B.P. (anomaly 21–25 time) which are the result of major reorientations in spreading directions in the central Atlantic Ocean (Purdy *et al.*, 1979). KFZ offsets the ridge axis over 150km in a left-lateral sense (Ballu *et al.*, 1997). The rift valley in the KFZ area is 10-17km wide and 3500-4000m deep, reaching 6100 m depth in the nodal basin at the RTI. The motion along the transform segment is dextral and the measured full spreading rate in the area is close to 3 cm yr<sup>-1</sup> (Schuh *et al.*, 1988). The eastern intersection between the KFZ and the MAR constitutes the Mid-Atlantic Ridge Kane (MARK) area and has been intensively surveyed by SeaBeam and Simrad (Gente *et al.*, 1991; Detrick *et al.*, 1984; Pockalny *et al.*, 1988).

The transform valley varies from 6 to 8 km in width. It is composed of a series of 4500 m deep basins separated by shallower saddles. The main trend of the transform valley floor varies from E-W to N 110-120. The relatively disturbed topography of the valley floor suggests that the sedimentary cover is probably thin. The northern wall of the KFZ shows an irregular pattern with a succession of 4500 m deep lows separated by N-S trending highs representative of the oceanic crust created along an N-S ridge axis. Toward the east the sedimentary cover attenuates the sharpness of the relief (Auzende *et al.*, 1994).

The southern wall of the KFZ consists of four successive massifs. They show different stages of vertical evolution from the RTI (zero age) to about the middle part of the FZ (4-5 Ma). The easternmost inside corner massif located (Auzende *et al.*, 1994) at the RTI reaches to less than 1200m depth, while the top of the westernmost massif is at about 2500m depth. Each massif shows a convex shape with a steep wall toward the transform valley. Their width is remarkably constant, at about 20km and they are separated by deep, N-S depressions several kilometres wide (Auzende *et al.*, 1994).

The cirriped species (Young, 1998), ascidians (Monniot and Monniot 2003) and carnivore sponges (Hestetun *et al.*, 2015) are found at different depths.

#### **Assessment of the area against relevant scientific criteria**

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area can be provided on the basis of one of more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can also be used for the description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)*

<b>Relevant Criteria</b>	<b>Description</b>	<b>Ranking of criterion relevance</b> (please mark one column with an X)			
		<b>No information</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>
<b>Uniqueness or rarity</b>	Area contains either (i) unique (“the only one of its kind”), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features.				X

<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
An important component of the deep-sea habitat. The KFZ plays a role in the movement of water masses and their movements above the seafloor and as such has relevance both for nutrient supply (trace metals, oxygen) as well as larval dispersal (near-bottom currents) (Fisher <i>et al.</i> , 1996).					
<b>Special importance for connectivity</b>	Areas that are required for a population to survive and thrive.	X			
<b>Importance for threatened, endangered or declining species and/or habitats</b>	Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.	X			
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
<b>Vulnerability, fragility, sensitivity, or slow recovery</b>	Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.	X			
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
<b>Biological productivity</b>	Area containing species, populations or communities with comparatively higher natural biological productivity.	X			
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
<b>Biological diversity</b>	Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.	X			
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
The area holds potential variety of habitats, including hard and soft sediments (Tucholke & Schouten, 1988). Biological information is very limited (Young, 1998, Hestetun <i>et al.</i> , 2015).					
<b>Naturalness</b>	Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or	X			

	degradation.				
Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)					

## References

- Alt, C. H., Kremenetskaia, A., Gebruk, A. V., Gooday, A. J., & Jones, D. O. (2019). Bathyal benthic megafauna from the Mid-Atlantic Ridge in the region of the Charlie-Gibbs fracture zone based on remotely operated vehicle observations. *Deep Sea Research Part I: Oceanographic Research Papers*, 145, 1-12.
- Auzende, J.M., Cannat, M., Gente, P., Henriot, J.P., Juteau, T., Karson, J., Lagabrielle, Y., Mével, C. and Tivey, M., (1994). Observation of sections of oceanic crust and mantle cropping out on the southern wall of Kane FZ (N. Atlantic). *Terra Nova*, 6(2), pp.143-148.
- Ballu, V., Dubois, J., Deplus, C., Diament, M., Bonvalot, S. (1997). Crustal structure of the Mid-Atlantic Ridge south of the Kane Fracture Zone from seafloor and sea surface gravity data. *Journal of Geophysical Research: Solid Earth*, American Geophysical Union, 103 (B2),10.1029/97JB02542. i
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## 2. The Vema Fracture Zone

### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models)*

Fracture zones are common topographic features of the global oceans that arise through plate tectonics. They are characterized by two strongly contrasting types of topography. Seismically active transform faults form near mid-ocean ridges where the continental plates move in opposing directions at their junction. Seismically inactive fracture zones, where the plate segments move in the same direction, extend beyond the transform faults often for 100s of kilometres. Their atypical crust thickness that can be as little as 2 km (Mutter *et al.* 1984, Cormier *et al.* 1984, Calvert and Whitmarsh 1986) allowing direct seismic investigations of the internal structure and composition of oceanic crusts used to model processes of seafloor spreading. In the Atlantic Ocean most fracture zones originate from the Mid-Atlantic Ridge (MAR) and are nearly perfectly west - east oriented. There are about 300 fracture zones occurring on average every 55 km along the ridge, with the offsets created by transform faults ranging from 9 to 400 km in length (Müller and Roest 1992).

Shallower portions of the MAR (e.g. Reykjanes Ridge) act like a barrier to water movements, while deep west-to-east fracture zones (e.g., Charlie-Gibbs or Vema Fracture Zone) seemed to guide the spatial and temporal distribution of thermal fronts and water masses (Belkin *et al.*, 2009).

The MAR holds 10 major fracture zones (from South to North, Romanche, Vema, Fifteen-Twenty, Kane, Atlantic, Hayes, Oceanographer, Pico, Kurchatov, Faraday, Charlie-Gibbs, and Bight). The longitudinally of MAR will present different geographic zones with different productivity regimes, and consequently different POC flux (a proxy for food supply), with effects on species diversity, trophic interactions, and other ecosystem attributes (Dunn *et al.*, 2018).

The North MAR plays an important role in deep-sea populations' connectivity. It has been described both as an ecological barrier for megafaunal species (Gebruk *et al.*, 2010; Alt *et al.*, 2019) or an East-West Atlantic conduit for larval dispersal at fracture zones (German *et al.*, 2011).

### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

The Vema Fracture Zone (VFZ) located at 10° 46' N is a narrow ~5000 m deep valley that offsets the MAR by 320 km (Kastens *et al.*, 1999).

### Feature description

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

The VFZ is one of the longest fracture zone traces in the Atlantic and covers crustal ages up to >100Ma. Along the walls of the Fracture Zone, crust is exposed representing seafloor ages covering this range.

The Atlantic Ocean contains several large fracture zones, one of the most prominent being the VFZ. Several studies have been carried out on an uplifted ridge to the south of the younger regions of the Vema Fracture Zone (e.g., Bonatti *et al.*, 2005; Cipriani *et al.*, 2009) and the active plate boundary (the Vema Transform Fault) has also been extensively studied in terms of its deeper crustal structure (Detrick *et al.*, 1982; Devey *et al.*, 2018; Lagabrielle *et al.*, 1992; Mamaloukasfrangoulis *et al.*, 1991; Potts *et al.*, 1986; Prince and Forsyth, 1988; van Andel *et al.*, 1971) and lithologies (Cannat *et al.*, 1991; Cannat and Seyler, 1995).

**Assessment of the area against relevant scientific criteria**

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area can be provided on the basis of one of more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can also be used for the description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)*

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	Area contains either (i) unique (“the only one of its kind”), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>An important component of the deep-sea habitat are the water masses and their movements above the seafloor. They have relevance both for nutrient supply (trace metals, oxygen) as well as larval dispersal (near-bottom currents). The VFM is an important conduit through the Mid-Atlantic Ridge for cold and dense bottom water flowing from the western to the eastern Atlantic basin (Fisher et al, 1996).</p> <p>Published records of vesicomyid clams <i>A. southwardae</i> in the VFZ suggest the presence of reducing habitats in this area (Krylova et al, 2010). Indications for chemoautotrophic life have also been reported for the active Vema transform fault (Cannat et al., 1991; Krylova et al., 2010). Recently, this evidence was confirmed by pore water anomalies along an E-W transect, indicating the advection of methane-rich fluids in this area (Devey et al., 2018).</p>					
<b>Special importance for connectivitty</b>	Areas that are required for a population to survive and thrive.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Patterns of faunal connectivity and abundance at the region demonstrated that the VFZ may act as a conduit for dispersal for the western and eastern basins. Along the VFZ, macrofauna abundances were generally higher on the eastern side than in the west (Brandt et al., 2018).</p>					
<b>Importance for threatened, endangered or declining species and/or habitats</b>	Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.	X			

<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
<b>Vulnerability, fragility, sensitivity, or slow recovery</b>	Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.				X
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
Alive habitat-forming scleractinian corals ( <i>Enallopsammia</i> ) and octocorals (Isididae, Corallidae) were reported from 094 James Cook cruise (Robinson, 2013).					
<b>Biological productivity</b>	Area containing species, populations or communities with comparatively higher natural biological productivity.			X	
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
The longitudinal extent of MAR will present different geographic zones with different productivity regimes, and consequently different POC flux (a proxy for food supply), with effects on species diversity, trophic interactions, and other ecosystem attributes (Dunn et al., 2018).					
<b>Biological diversity</b>	Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.				X
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
The area consists of a wide range of habitats such as crests, trenches, seamounts, vertical walls as well as soft and hard sediment. Such habitats will ensure the presence of diverse range of fauna (Devey et al., 2018; Robinson, 2013). VFZ suggest the presence of reducing habitats in this area (Krylova et al, 2010). Indications for chemoautotrophic habitats have also been reported (Krylova et al., 2010).					
<b>Naturalness</b>	Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.				X
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
A high level of naturalness can be attributed to the benthic habitats of the proposed habitats, since there are no records of significant human activities in these deep areas of the Atlantic Ocean (e.g. demersal fishing, mining) ( <a href="http://www.seafo.org">http://www.seafo.org</a> )					

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### 3. Romanche Fracture Zone System

#### Introduction

*(To include: feature type(s) presented, geographic description, depth range, oceanography, general information data reported, availability of models)*

Fracture zones are common topographic features of the global oceans that arise through plate tectonics. They are characterized by two strongly contrasting types of topography. Seismically active transform faults form near mid-ocean ridges where the continental plates move in opposing directions at their junction. Seismically inactive fracture zones, where the plate segments move in the same direction, extend beyond the transform faults often for 100s of kilometres. Their atypical crust thickness that can be as little as 2 km (Mutter *et al.* 1984, Cormier *et al.* 1984, Calvert and Whitmarsh 1986) allowing direct seismic investigations of the internal structure and composition of oceanic crusts used to model processes of seafloor spreading. In the Atlantic Ocean most fracture zones originate from the Mid-Atlantic Ridge (MAR) and are nearly perfectly west - east oriented. There are about 300 fracture zones occurring on average every 55 km along the ridge, with the offsets created by transform faults ranging from 9 to 400 km in length (Müller and Roest 1992).

Shallower portions of the MAR (e.g. Reykjanes Ridge) act like a barrier to water movements, while deep west-to-east fracture zones (e.g., Charlie-Gibbs or Vema Fracture Zone) seemed to guide the spatial and temporal distribution of thermal fronts and water masses (Belkin *et al.*, 2009).

The MAR holds 10 major fracture zones (from South to North, Romanche, Vema, Fifteen-Twenty, Kane, Atlantic, Hayes, Oceanographer, Pico, Kurchatov, Faraday, Charlie-Gibbs, and Bight). The longitudinally of MAR will present different geographic zones with different productivity regimes, and consequently different POC flux (a proxy for food supply), with effects on species diversity, trophic interactions, and other ecosystem attributes (Dunn *et al.*, 2018).

The North MAR plays an important role in deep-sea populations' connectivity. It has been described both as an ecological barrier for megafaunal species (Gebruk *et al.*, 2010; Alt *et al.*, 2019) or a East-West Atlantic conduit for larval dispersal at fracture zones (German *et al.*, 2011).

#### Location

*(Indicate the geographic location of the area/feature, preferably with a map.)*

The proposed area extends approximately 1.9 m km<sup>2</sup> across the Equatorial Atlantic Ocean from the western border of the Guinea Basin (10°W) in the east to the north-east limit of the Brazilian continental margin (32°W) in the west and enclose three major fracture zones: St Paul's, Romanche and Chain.

#### Feature description

*(This should include information about the characteristics of the area/ecosystem features, e.g. in terms of physical description (water column feature, benthic feature, or both), biological communities, role in ecosystem function, including data/information sources.)*

This feature is characterized by parallel ridge crests and trenches that extend in the east-west direction approaching north-east Brazilian and West African continental margins. This feature is characterized by parallel ridge crests (1000-2000m) and trenches that extend in the east-west direction approaching north-east Brazilian and West African continental margins. Crests are generally characterized by a roughed topography but may also include sediment-covered relatively flat areas and gentle slopes. Trenches may reach 4000 – 6000 m abyssal depths.

The Romanche Fracture Zone (RFZ) system affects dramatically the Atlantic deep-water circulation, chiefly determined by the northward flow of the Antarctic Bottom Water (ABW, >4000 m) and the southward flow of the North Atlantic Deep Water (NADP, 1500 – 4000 m). In the western side these

water masses flow through conduits created by the RFZ system communicating the North and South Atlantic deep environments. (Bickert and Mackensen, 2003; Dunn et al., 2018; Huang and Jin, 2002;). The influence of the RFZ system on the circulation patterns of NADP and ABW have been regarded as a key element to test the deep-water fauna dispersal hypothesis (German et al., 2011).

The Equatorial Atlantic has been characterized by an elevated diversity and abundance of pelagic organisms, when compared to the adjacent northern and southern subtropical gyres of the Atlantic. In essence that has been explained by the effect of complex surface circulation patterns, elevated temperature and productivity regimes. Data in support of these patterns are found in specific plankton and micronekton studies focusing on euphysiids (Gibbons, 1997), myctophids and other mesopelagic fish (Bakus et al., 1970; Bakus et al., 1977; Kobiliansky et al., 2010) and cephalopods (Perez and Bolstad, 2011; Rosa et al., 2008;). The area also concentrates important catches of large pelagic fishes, including the yellowfin tuna (*Thunnus albacares*), bigeye tuna (*Thunnus obesus*) and swordfish (*Xiphias gladius*) ([www.iccat.org](http://www.iccat.org)) (Fonteneau and Sobrier, 1995). Area is a feeding ground of west African population of leatherback turtle (*Demochelis coriacea*) and olive ridley turtles (*Lepidochelys olivacea*), (both critically endangered according to IUCN criteria) (Billes et al., 2006; Da Silva et al. 2011; Fretey et al., 2007; Georges et al., 2007; Witt et al., 2011).

Limited data available on benthic and benthic-pelagic fauna, but models tend to predict a relatively high seafloor biomass, particularly in the western Equatorial area (Wei et al., 2010). The data derived from surveys conducted in the southern Mid-Atlantic ridge have also revealed a high benthic diversity (Perez et al., 2010).

**Assessment of the area against relevant scientific criteria**

*(Discuss the area in relation to each of the relevant scientific criteria and relate the best available science. The description of the area can be provided on the basis of one of more of the criteria, and the polygons of the area can be defined without exact precision. Information on modeling can also be used for the description of the area, including the presence of relevant ecological attributes. Please note where there are significant information gaps.)*

Relevant Criteria	Description	Ranking of criterion relevance (please mark one column with an X)			
		No information	Low	Medium	High
<b>Uniqueness or rarity</b>	Area contains either (i) unique (“the only one of its kind”), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanographic features.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>The area is ranked as “highly unique” chiefly (but not only) because it contains the Equatorial Fracture Zone (Figure 1), a prominent geological feature ~60 M years-old that offsets the mid-Atlantic ridge central axis and connects the deep habitats of North and South Atlantic, and the South American and West African continental margins (Fairhead and Wilson, 2004). Because it is massive, elevating 4000 km from the seafloor, it affects the circulation patterns of the main deep-water masses of the Atlantic, the North Atlantic Deepwater (NADW, 1500 – 4000 m) and the Antarctic Bottom Water (ABW, &lt;4000</p>					

<p>m), being regarded as highly significant for dispersal processes of deep fauna (Stephens and Marshall, 2000; German et al., 2011). The Equatorial fracture zone includes an array of benthic habitats 1000 – 6000 m deep, mostly formed by ridge crests and trenches.</p> <p>Influenced by the oscillations of the Inter-tropical Convergence Zone and trade winds regime, this system includes, on the eastern extreme, a seasonal upwelling process that promotes an important equatorial phytoplankton bloom (Longhurst, 1993). This highly productive area in the middle of the vast oligotrophic zones of the northern and southern subtropical gyres has an “oasis” effect on both pelagic and deep biota, as associated with the high diversity and abundance levels of plankton and nekton communities, including large pelagic predators.</p>					
<b>Special importance for connectivity</b>	Areas that are required for a population to survive and thrive.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Unique circulation pattern of RFZ system supports circulation of the main deep-water masses of the Atlantic, the North Atlantic Deepwater (NADW, 1500 – 4000 m) and the Antarctic Bottom Water (ABW, &lt;4000 m), being regarded as highly significant for dispersal processes of deep fauna (Stephens and Marshall, 2000; German et al., 2011) so play a major role in inter-basin genetic exchange, however, there is no sufficient data on larval dispersal in the area.</p>					
<b>Importance for threatened, endangered or declining species and/or habitats</b>	Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>Area is a feeding ground of west African population of leatherback turtle (<i>Dermochelys coriacea</i>) and olive ridley turtles (<i>Lepidochelys olivacea</i>), (both critically endangered according to IUCN criteria) (Billes et al., 2006; Fretey et al., 2007; Georges et al., 2007; Witt et al., 2011; Da Silva et al. 2011).</p>					
<b>Vulnerability, fragility, sensitivity, or slow recovery</b>	Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.				X
<p><i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i></p> <p>The area presents deep sea coral species which are indicator species of Vulnerable Marine Ecosystems (VMEs), such as <i>Enallopsammia rostrate</i>, <i>Corrallium cf. bayeri</i> and <i>Narella alvinae</i> (Perez et al., 2012).</p>					
<b>Biological productivity</b>	Area containing species, populations or communities with comparatively higher				X

	natural biological productivity.				
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
Influenced by the oscillations of the Inter-tropical Convergence Zone and trade winds regime, this system includes, on the eastern extreme, a seasonal upwelling process that promotes an important equatorial phytoplankton bloom (Longhurst, 1993). This highly productive area in the middle of the vast oligotrophic zones of the northern and southern subtropical gyres has an “oasis” effect on both pelagic and deep biota, as associated with the high diversity and abundance levels of plankton and nekton communities, including large pelagic predators.					
<b>Biological diversity</b>	Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.				X
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
The area consists of a wide range of habitats such as crests, trenches, seamounts, vertical walls as well as soft and hard sediment. Such habitats will ensure the presence of diverse range of fauna (Perez et al., 2012).					
<b>Naturalness</b>	Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.				X
<i>Explanation for ranking (must be accompanied by relevant sources of scientific articles, reports or documents)</i>					
A high level of naturalness can be attributed to the benthic habitats of the proposed habitats, since there are no records of significant human activities in these deep areas of the Atlantic Ocean (e.g. demersal fishing, mining) ( <a href="http://www.seafo.org">http://www.seafo.org</a> )					

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(e.g. relevant documents and publications, including URL where available; relevant data sets, including where these are located; information pertaining to other relevant material, models, etc.)

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