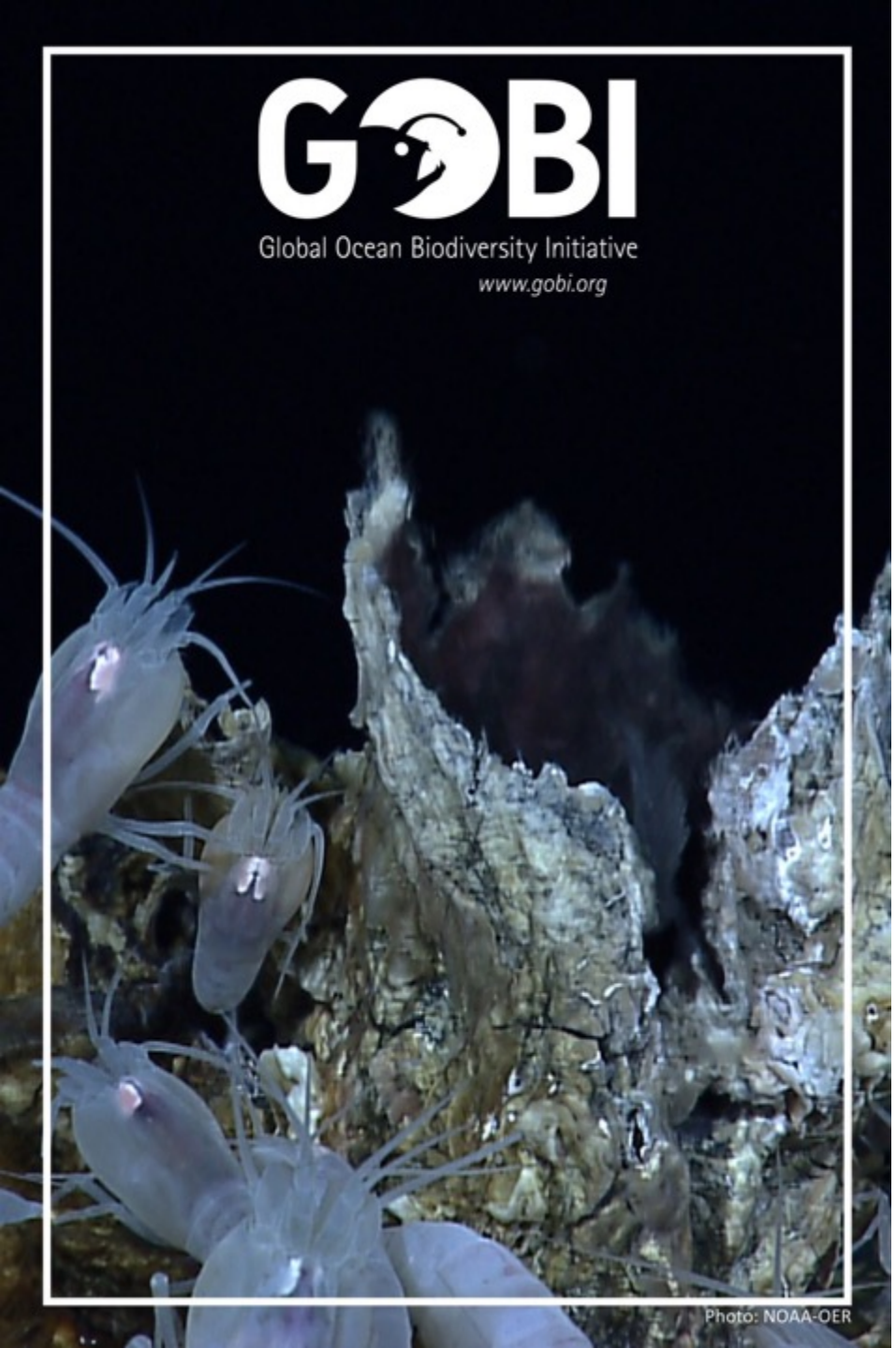

GOBI WEBINAR SERIES

6 Protecting biodiversity at deep-sea hydrothermal vents

TOPICS

1. Introduction to sulfide ecosystems and deep-sea mining interests
2. Scientific rationale for protection of vent ecosystems
3. Global status of protection of vent ecosystems
4. Area-Based Management Tools (ABMTs) and Regional Environmental Management Plans (REMPs) that might offer protection of vent ecosystems
5. Larval links to vent ecosystems and the mid-water highway
6. Inactive and extinct sulfide ecosystems as targets for mining

CREDITS

The presentations in this webinar result from the work of many international colleagues who share co-authorship on the papers at right, with partial support from GOBI.

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Marine Policy 90 (2018) 20-28

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Scientific rationale and international obligations for protection of active hydrothermal vent ecosystems from deep-sea mining

C.L. Van Dover[a,*], S. Arnaud-Haond[b], M. Gianni[c], S. Helmreich[d], J.A. Huber[e], A.L. Jaeckel[f], A. Metaxas[g], L.H. Pendleton[h], S. Petersen[i], E. Ramirez-Llodra[j], P.E. Steinberg[k], V. Tunnicliffe[l], H. Yamamoto[m]

Marine Policy 108 (2019) 103654

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journal homepage: www.elsevier.com/locate/marpol

An atlas of protected hydrothermal vents

Elisabetta Menini[a,*], Cindy Lee Van Dover[b]

SCIENCE ADVANCES | RESEARCH ARTICLE Dunn et al., Sci. Adv. 2018;4:eaar4313

OCEANOGRAPHY

A strategy for the conservation of biodiversity on mid-ocean ridges from deep-sea mining

Daniel C. Dunn[1*†], Cindy L. Van Dover[2*†], Ron J. Etter[3], Craig R. Smith[4], Lisa A. Levin[5,6], Telmo Morato[7], Ana Colaço[7], Andrew C. Dale[8], Andrey V. Gebruk[9], Kristina M. Gjerde[10,11], Patrick N. Halpin[1], Kerry L. Howell[12], David Johnson[13], José Angel A. Perez[14], Marta Chantal Ribeiro[15], Heiko Stuckas[16], Philip Weaver[17], SEMPIA Workshop Participants[‡]

Deep-Sea Research II 180 (2020) 104819

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Deep-Sea Research Part II

journal homepage: http://www.elsevier.com/locate/dsr2

Biophysical models of persistent connectivity and barriers on the northern Mid-Atlantic Ridge

J.M. Yearsley[a,b,*], D.M. Salmanidou[a,b,c], J. Carlsson[a,b], D. Burns[a], C.L. Van Dover[d]

Marine Policy 121 (2020) 104183

Contents lists available at ScienceDirect

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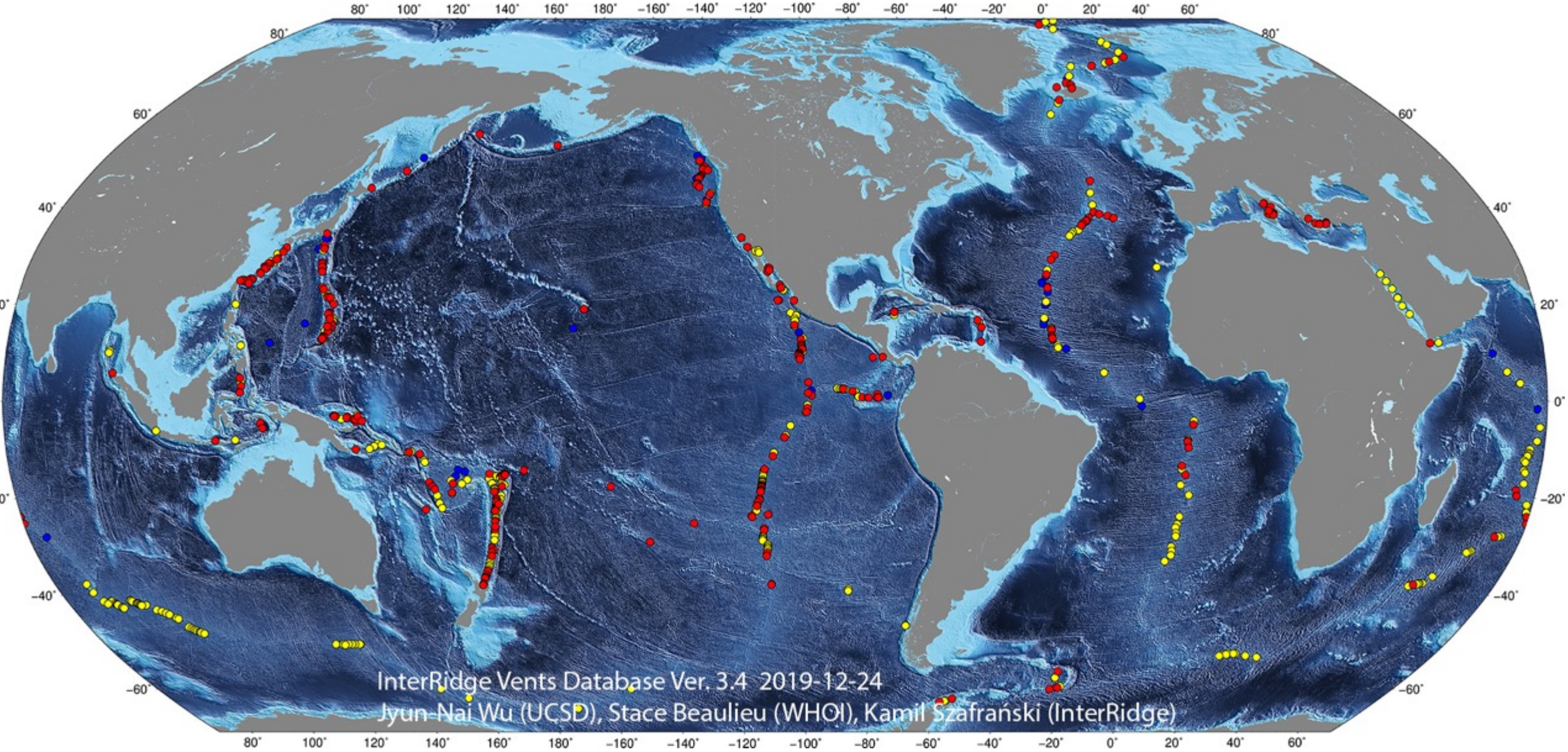
journal homepage: http://www.elsevier.com/locate/marpol

Research is needed to inform environmental management of hydrothermally inactive and extinct polymetallic sulfide (PMS) deposits

C.L. Van Dover[a,*], A. Colaço[b], P.C. Collins[c], P. Croot[d], A. Metaxas[e], B.J. Murton[f], A. Swaddling[g], R.E. Boschen-Rose[h], J. Carlsson[i], L. Cuyvers[j], T. Fukushima[k], A. Gartman[l], R. Kennedy[m], C. Kriete[n], N.C. Mestre[o], T. Molodtsova[p], A. Myhrvold[q], E. Pelleter[r], S. O. Popoola[s], P.-Y. Qian[t], J. Sarrazin[u], R. Sharma[v], Y.J. Suh[w], J.B. Sylvan[x], C. Tao[y,z], M. Tomczak[aa], J. Vermilye[l]

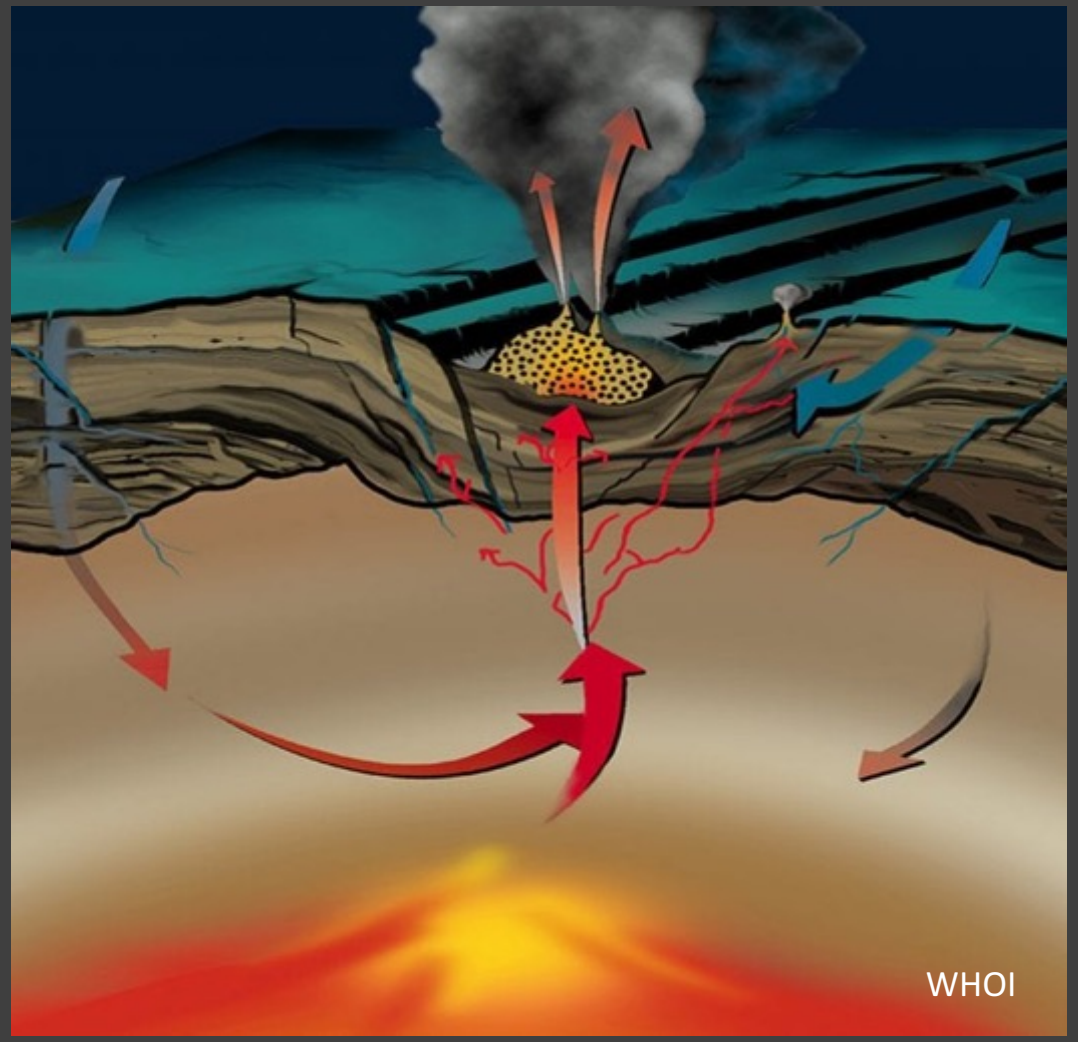


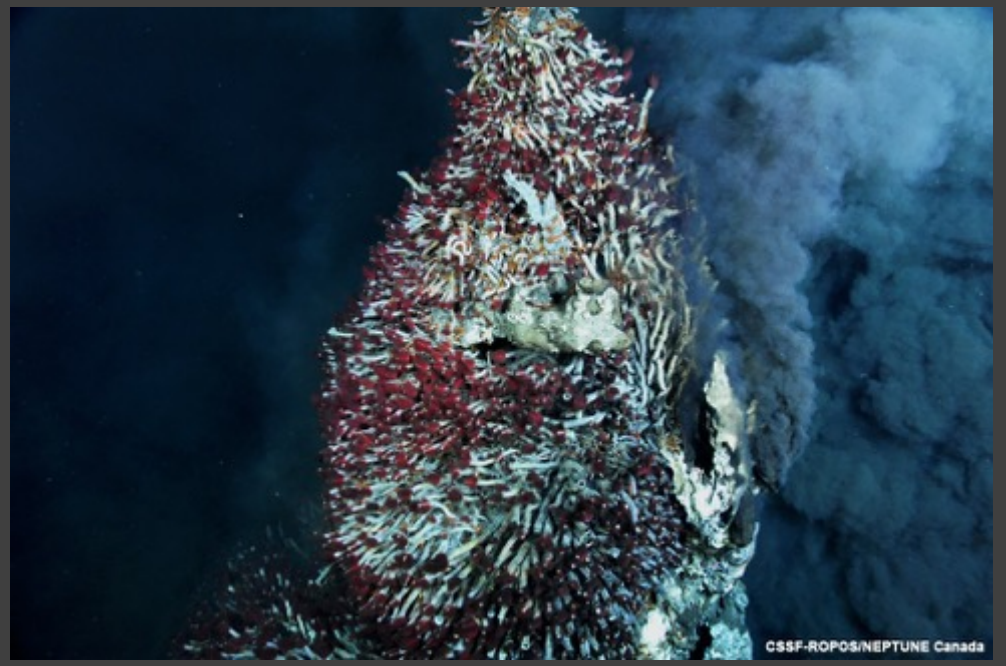
Global Active, Inferred Active, and Inactive Hydrothermal Vents

active hydrothermal vent ecosystems

areas of intense biological activity
fueled by chemosynthesis

biomass-dominant taxa are typically endemic,
i.e., only found at active hydrothermal vents

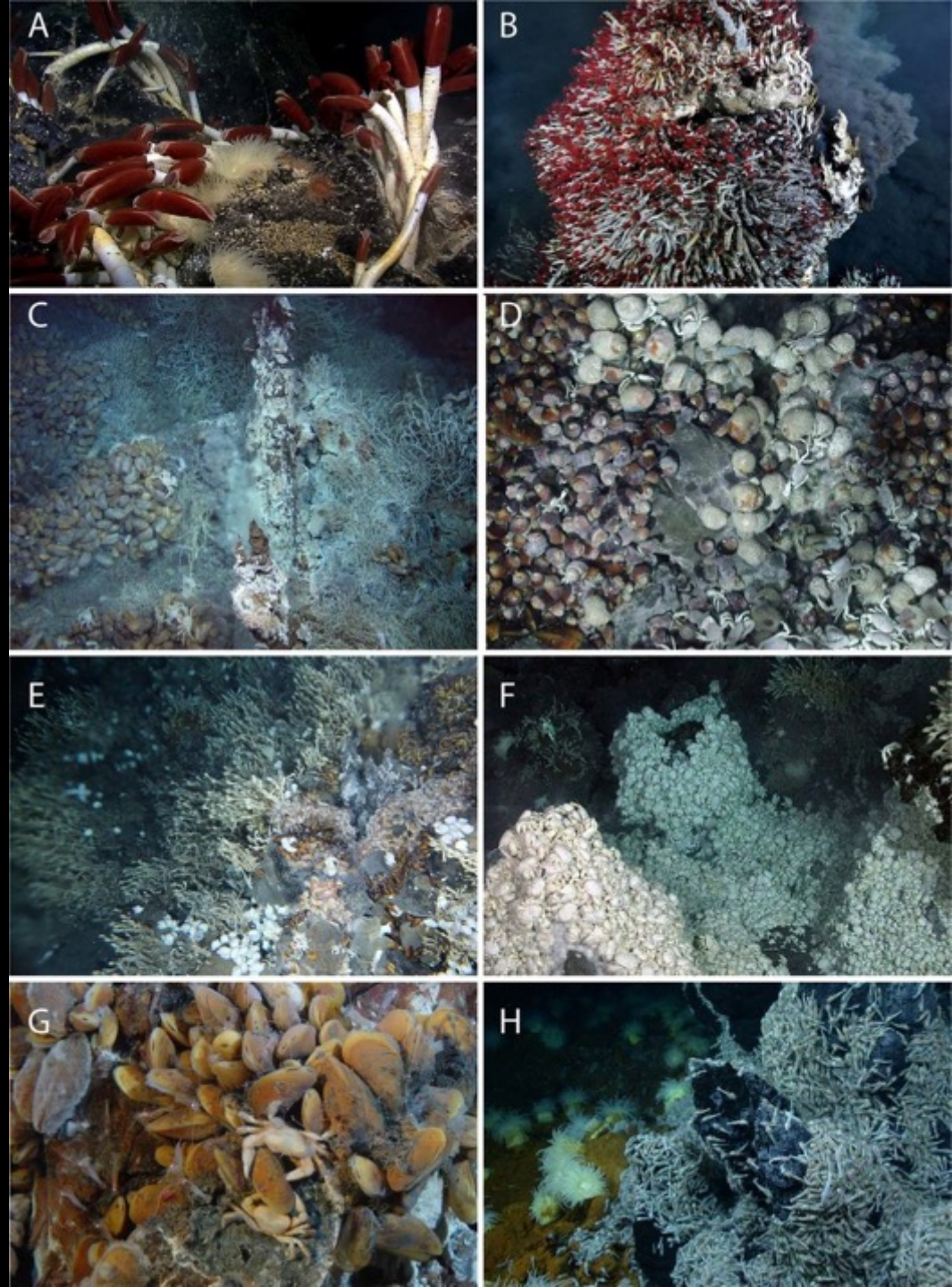




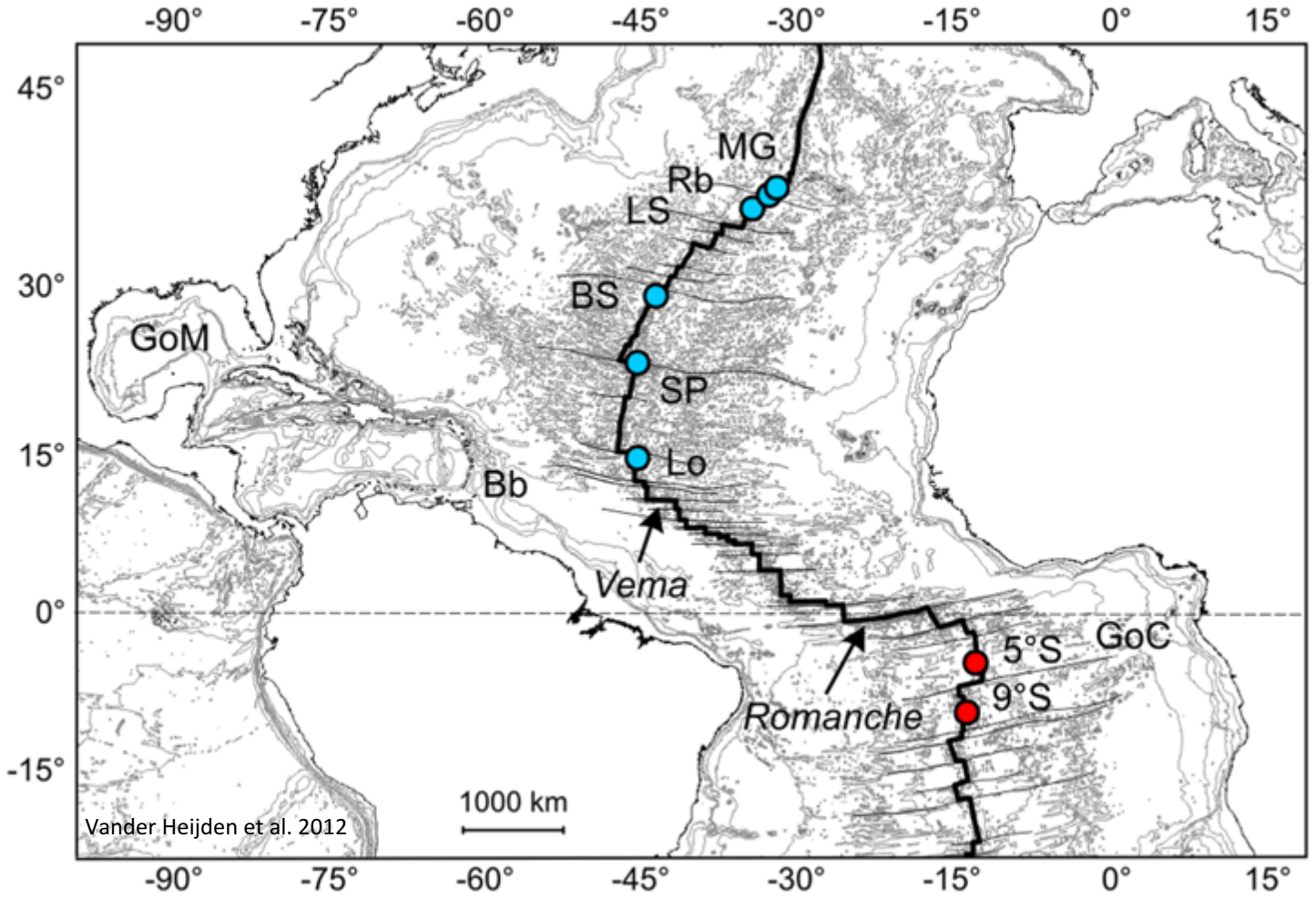
dominant role of microbial symbionts of invertebrates

these symbiotic associations thrive at the interface between sulfide-rich vent fluids and oxygen-rich seawater

different host species dominate
in different parts of the world's ocean

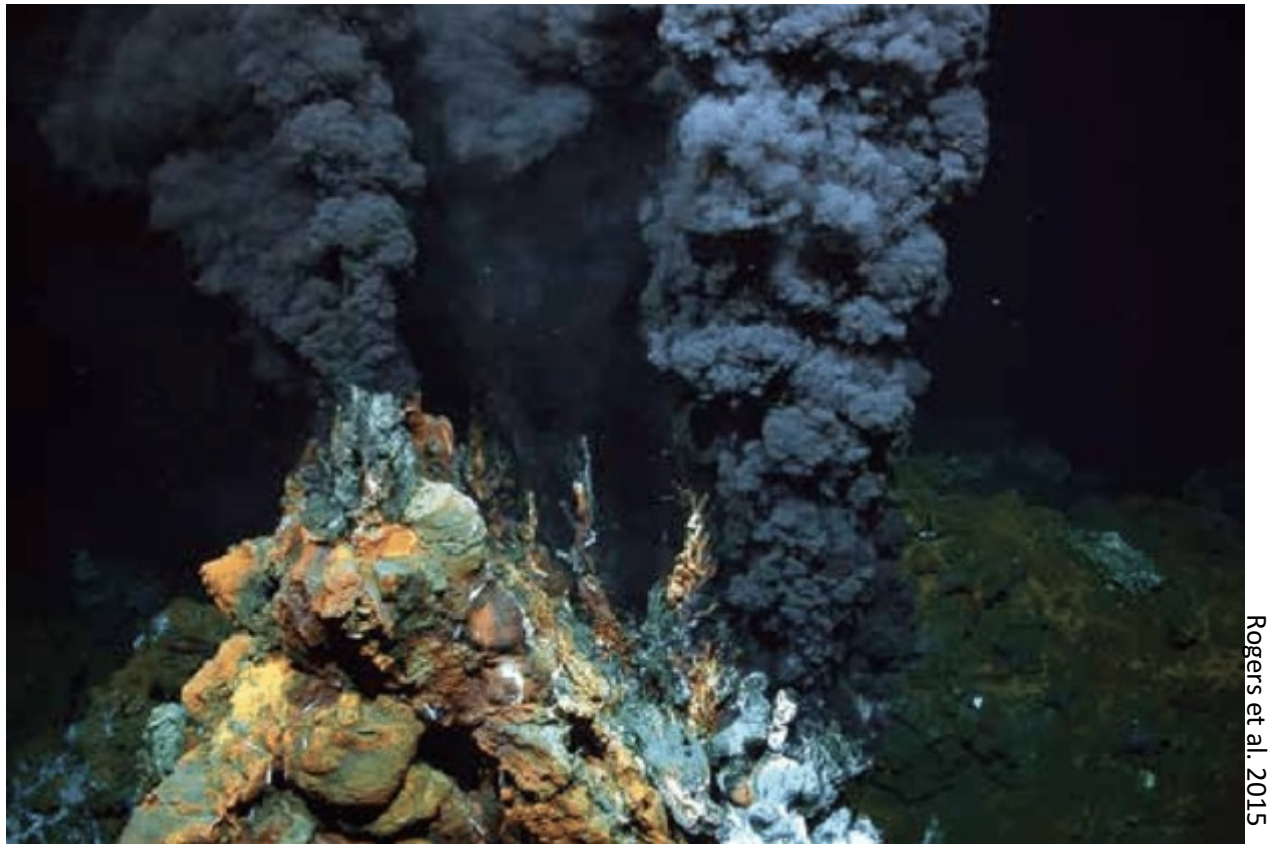


Active Vent Ecosystems: Linear Archipelagoes

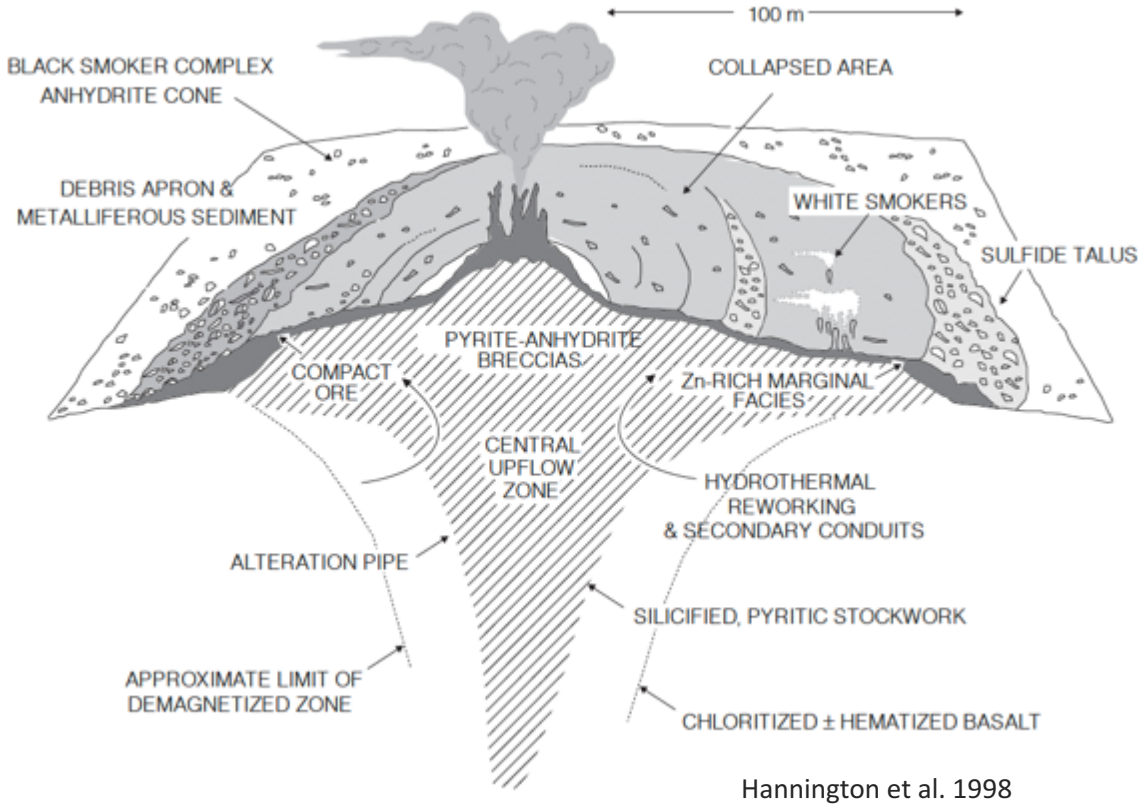


Larval Dispersal

Active hydrothermal vents: Metal foundries on the seabed



Rogers et al. 2015



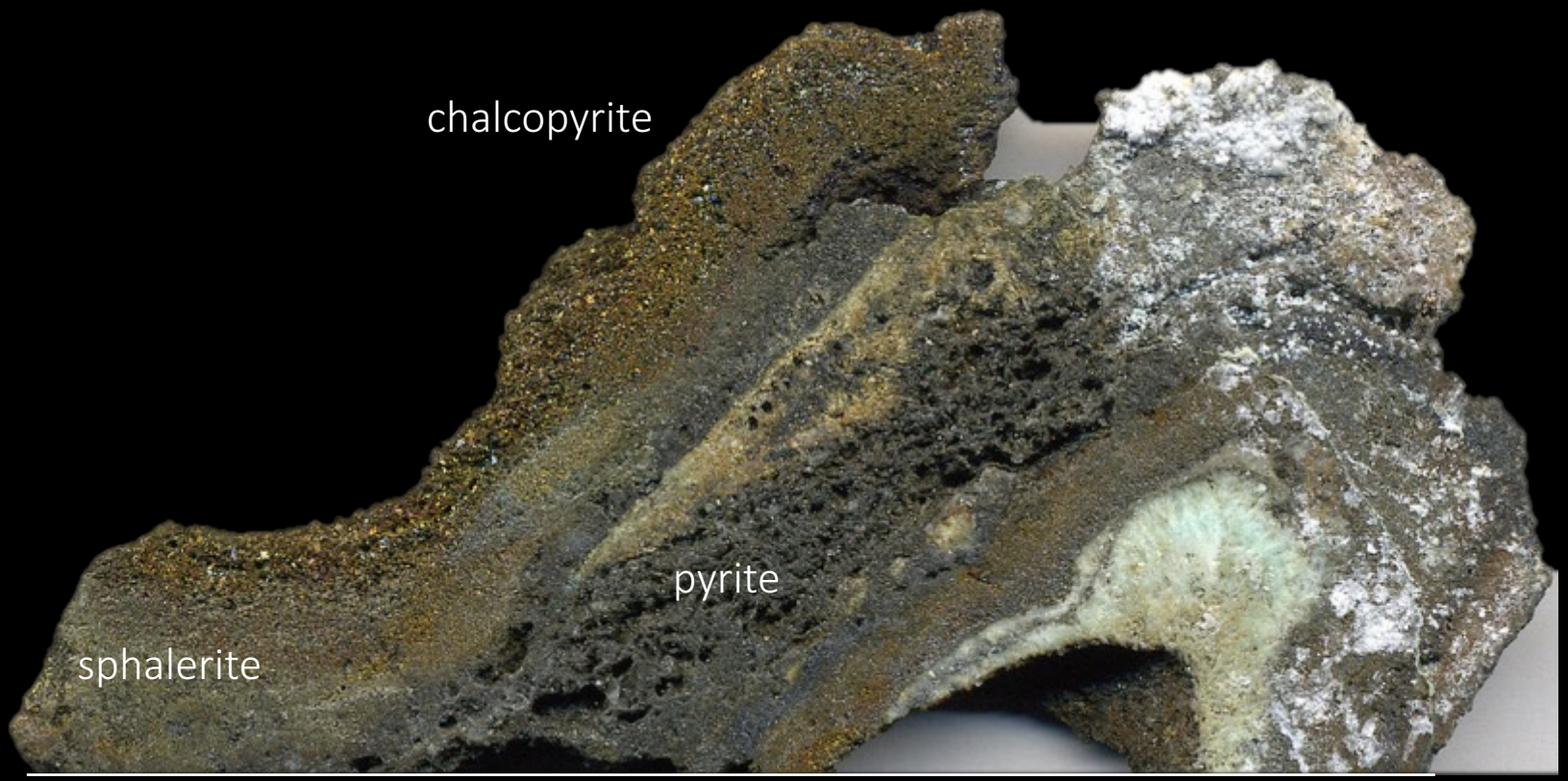
Hannington et al. 1998

Seafloor Massive Sulfides: Minerals of Economic Interest

- chalcopyrite (copper sulfide)
- sphalerite (zinc sulfide)

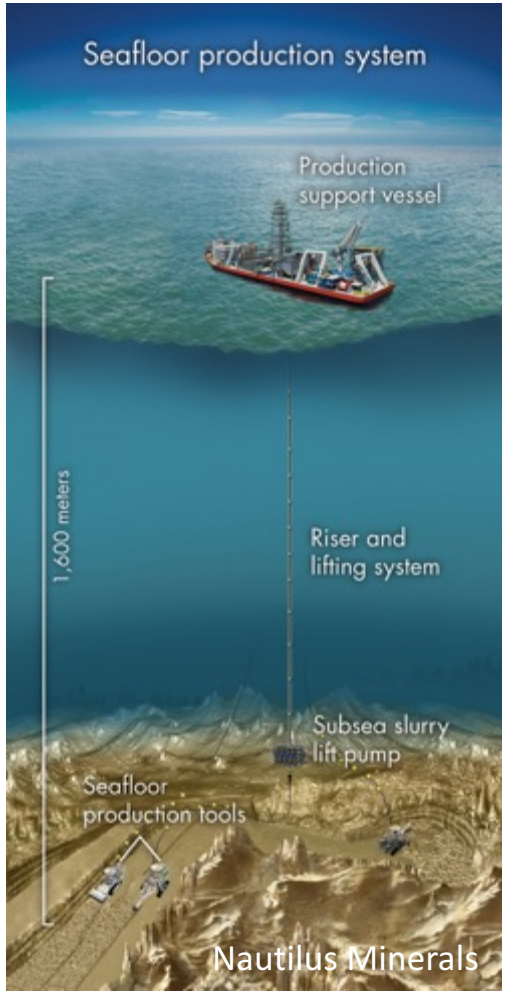
In some settings:

- gold
- silver



seabed mining concept

Nautilus Minerals



terrestrial copper mine

Bingham Canyon (Kennecott)

Potential Environmental Impacts
(simplified examples)

Physico-Chemical Impacts (Cause)
Loss of habitat
Degradation of habitat quality
Modification of fluid flux regimes
Sediment plume and sedimentation
Plumes from return water

Biological Impacts (Response)
Elimination or reduction of local populations
Decreased diversity (genetic, species, habitat)
Decreased seafloor primary production
Decreased connectivity between populations
Loss of ecosystem function and services

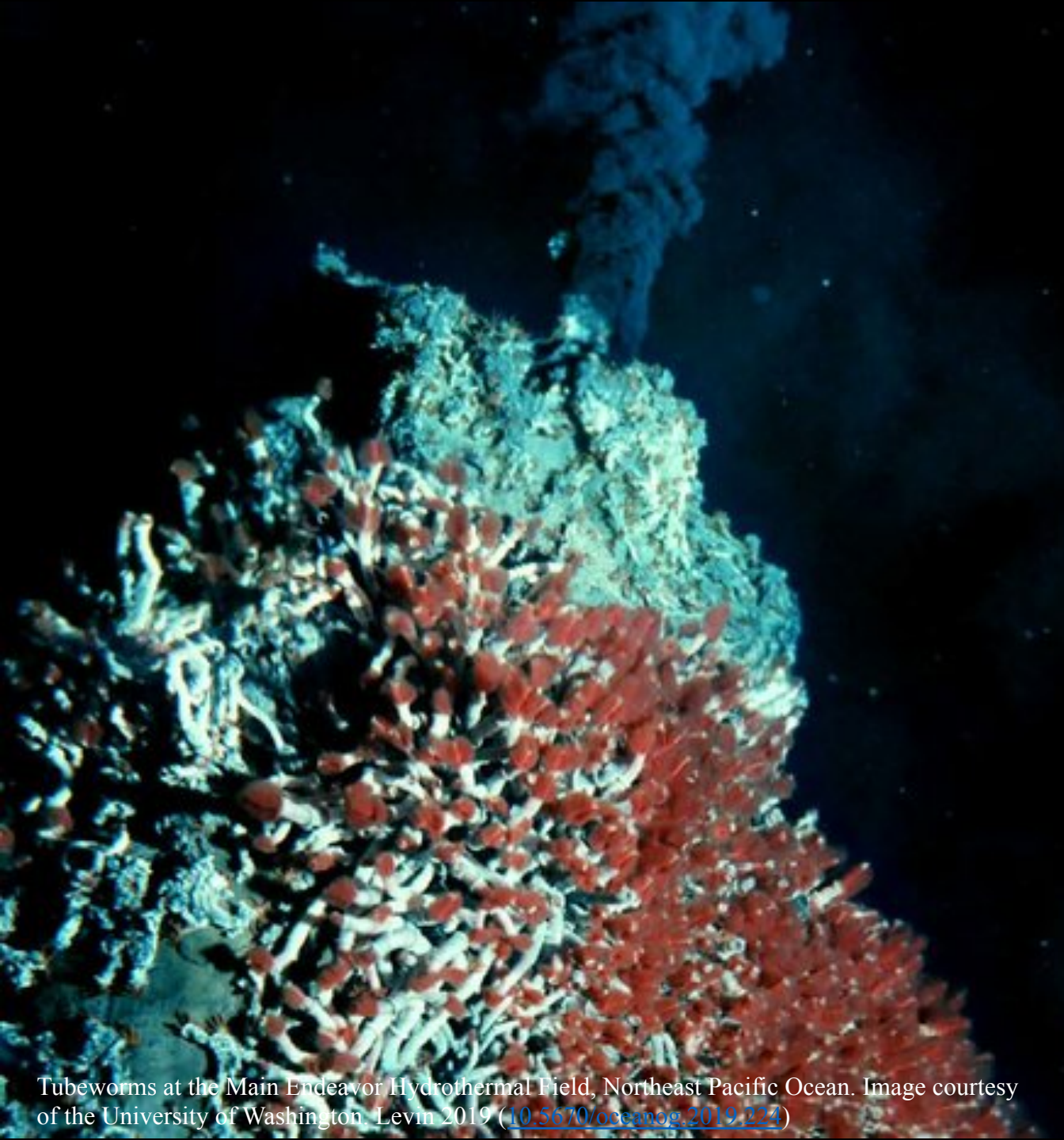
next up…..

Why Protect Active Hydrothermal Vent Ecosystems?

Dr. Eva Ramirez-Llodra

Senior Researcher

Norwegian Institute of Water Research



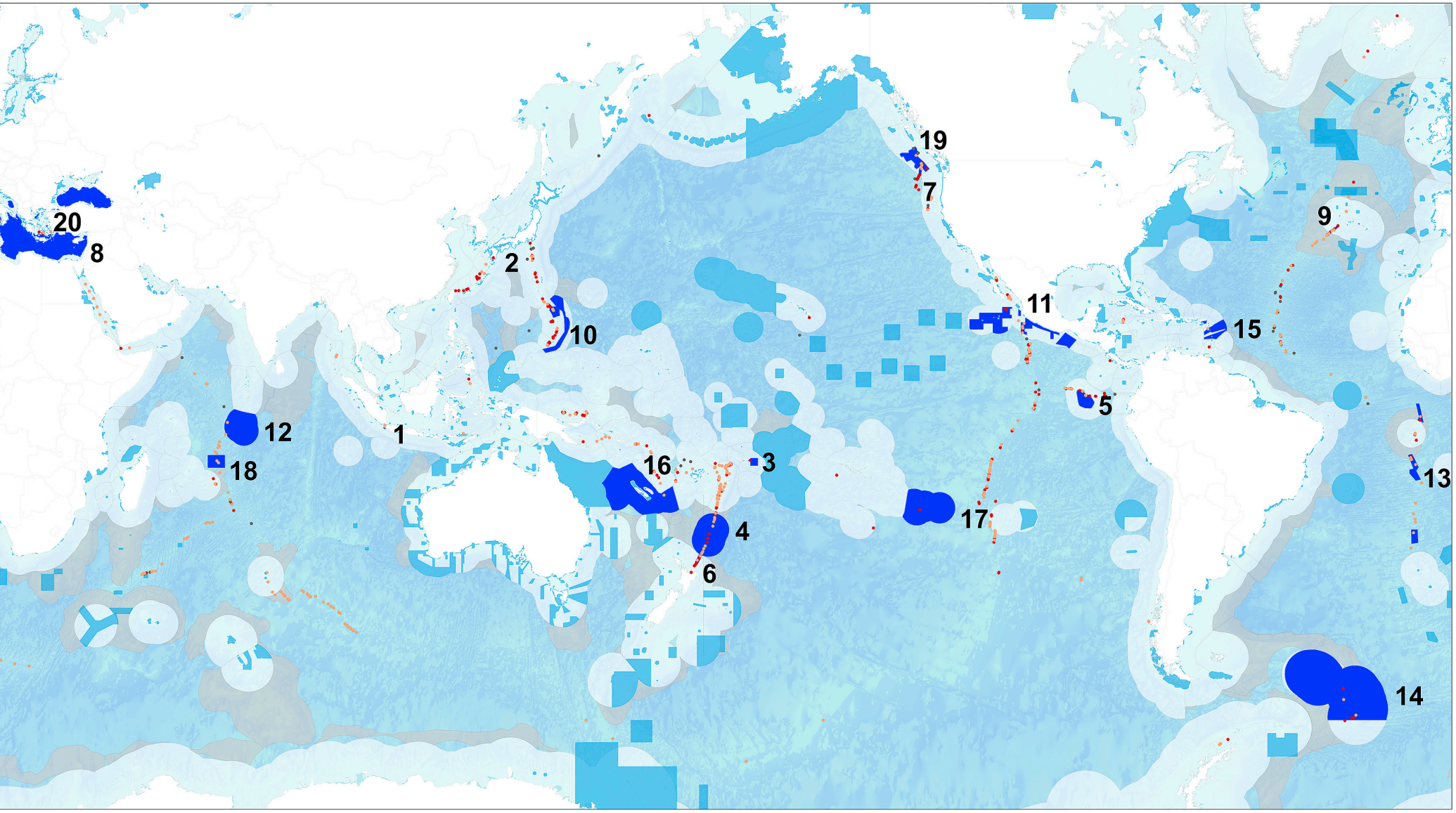
Tubeworms at the Main Endeavor Hydrothermal Field, Northeast Pacific Ocean. Image courtesy of the University of Washington. Levin 2019 (10.5670/oceanog.2019.224)

Where are the protected hydrothermal vents?

Elisabetta Menini

Duke University, USA

Area Based Management Tools with Deep-sea Hydrothermal Vents



20 ABMT:
16 in EEZ
1 in ECS
3 in high seas

7 designated MPAs or MPA network

VMEs closure by:
SEAFO
GFCM
SIODFA

0 2.500 5.000 10.000 Kilometers

N

Coordinate System: WGS 1984 World Mercator 180 | Projection: Mercator | Datum: WGS 1984

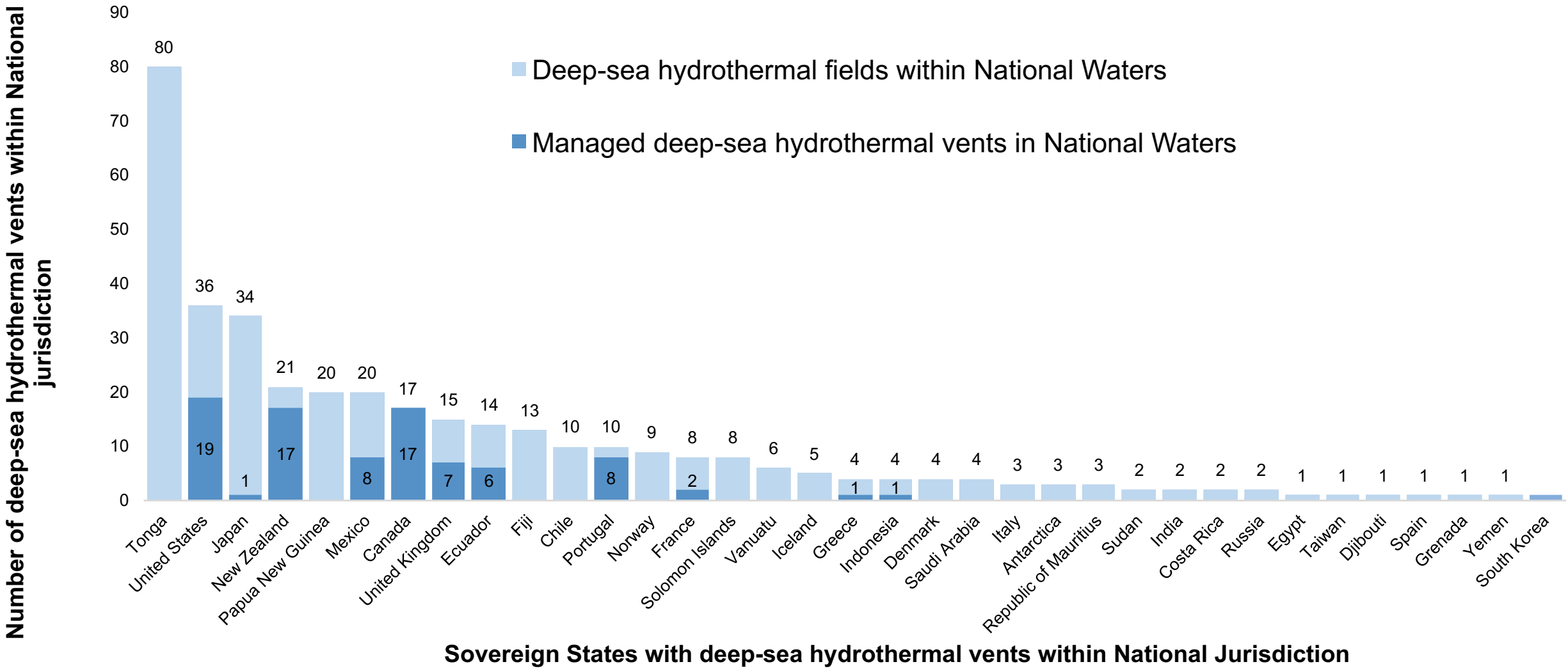
Service Layer Credits: GEBCO, 2014; InterRidge, 2015; Marineregion; MarinePlan; GEOMAR; MPAtlas, Seattle, WA (2018);Marine Minerals Group at GEOMAR, Helmholtz Centre for Ocean Research; DFO, Canada 2018; FAO, 2019.

Hydrothermal Vents Below 200 m depth
- Active, Confirmed
- Active, Inferred
- Inactive

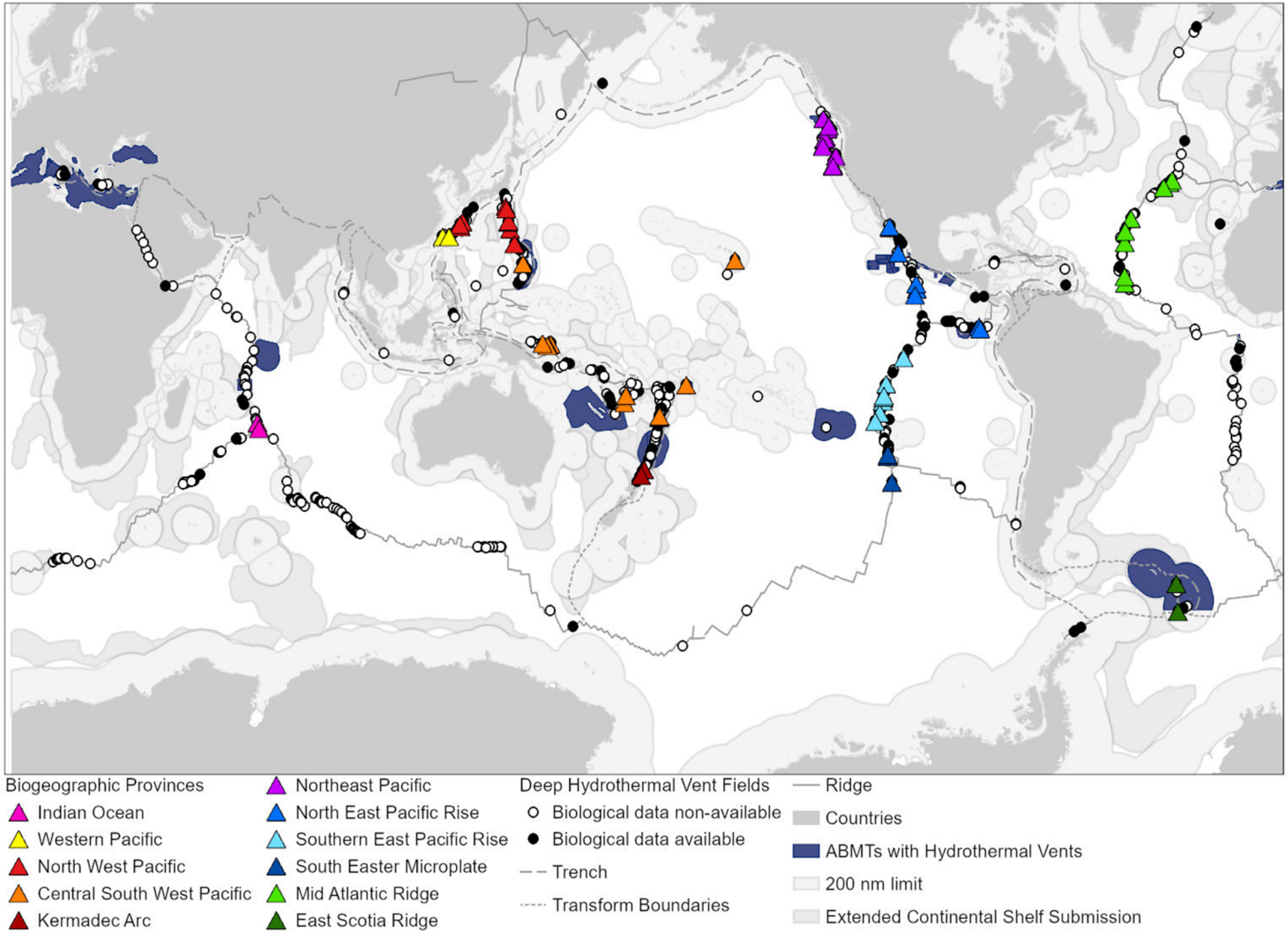
ABMTs with Hydrothermal Vents
Other ABMTs
Extended Continental Shelf Claim
Exclusive Economic Zone

Menini & Van Dover 2019 (10.1016/j.marpol.2019.103654)

~15% of deep sea hydrothermal vents are managed



Menini et al., IN PROCESS



ABMTs cover 9/11 Bio-provinces

Is it enough?

…

Rogers et al., 2012
Menini et al., IN PROCESS

next up…..

ABMTs and Regional Environmental Management Plans that might offer protection to vents ecosystems

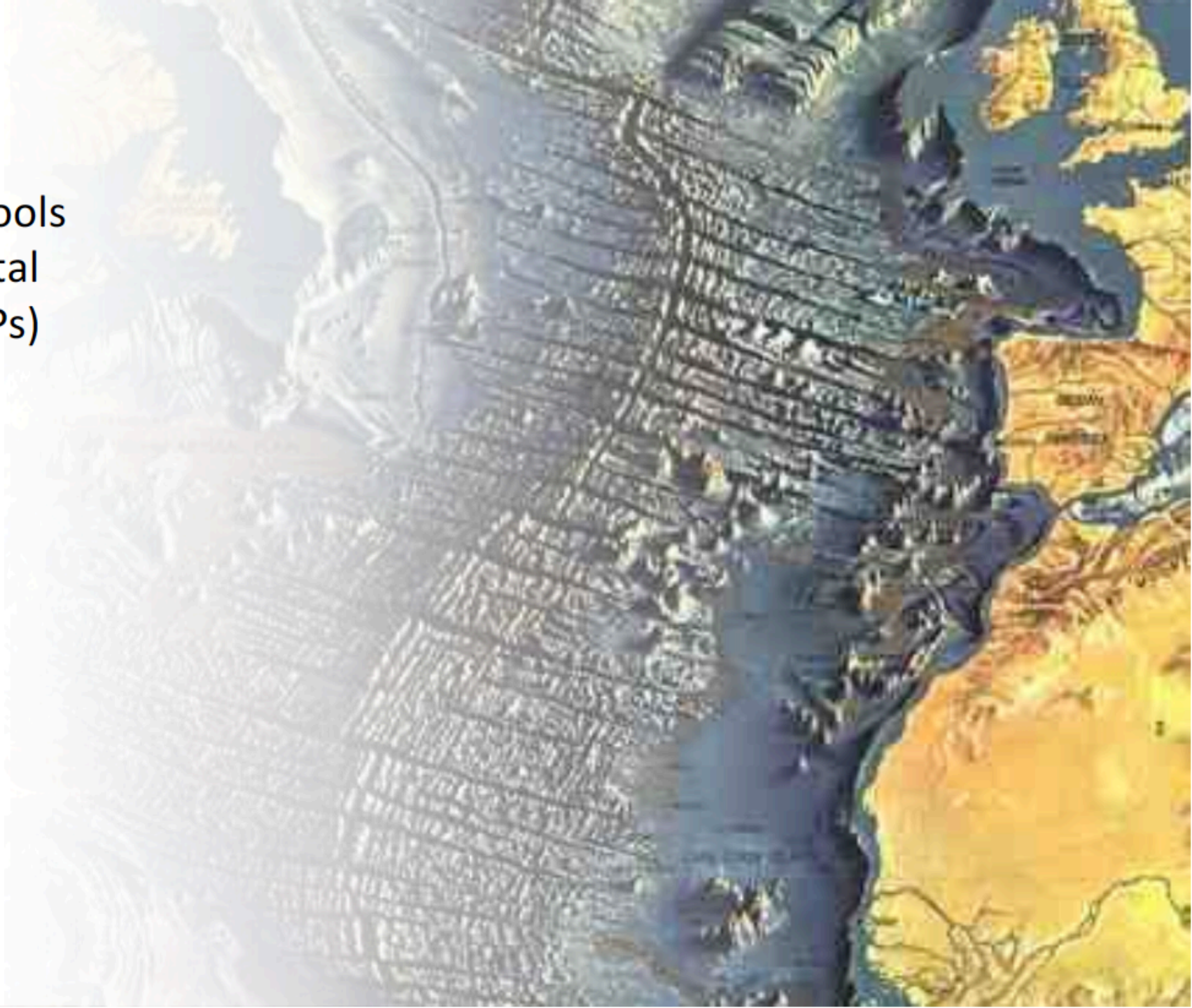
Dr. Pat Halpin

Marine Geospatial Ecology Lab

Duke University

Area Based Management Tools and Regional Environmental Management Plans (REMPs)

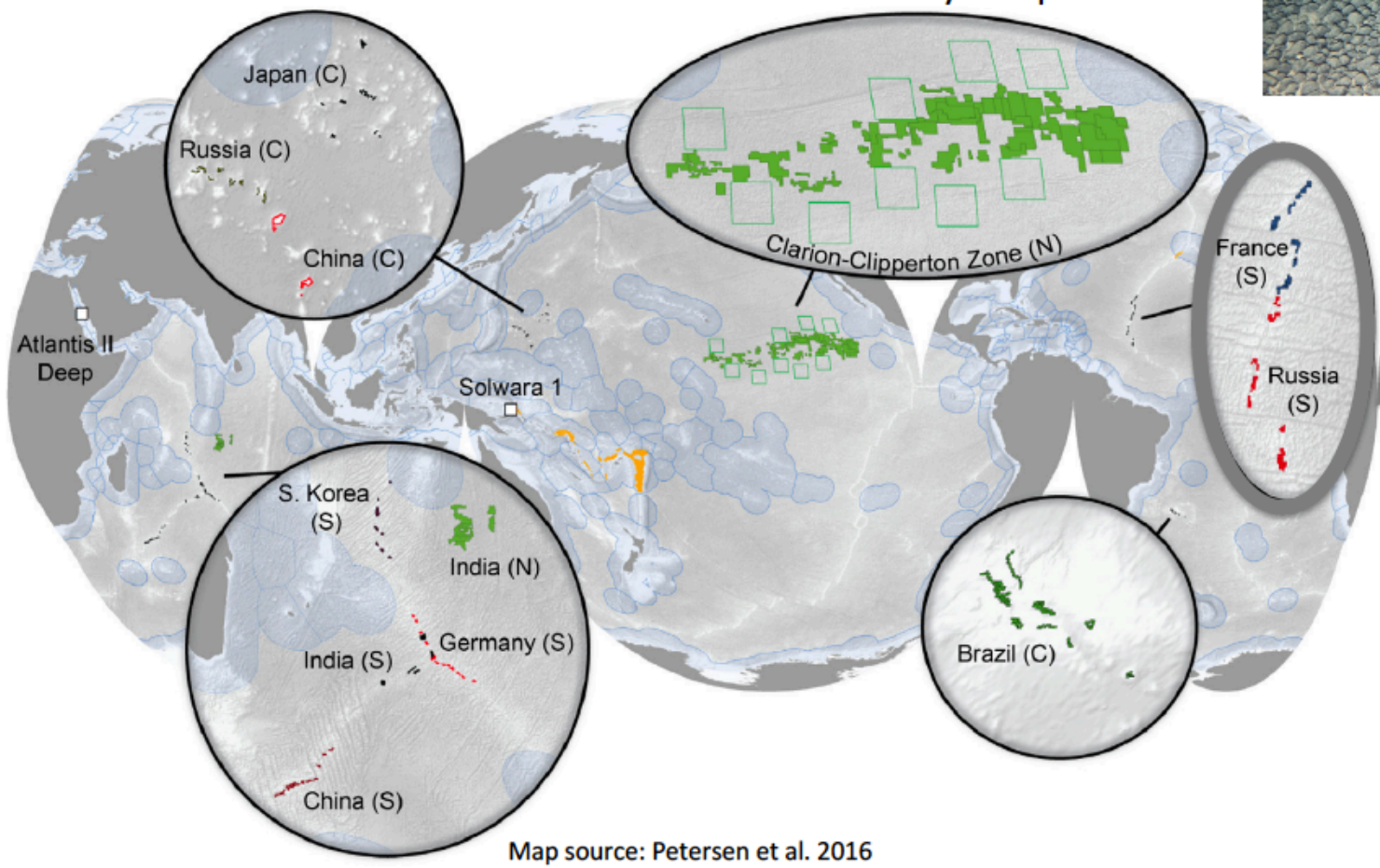
Patrick N. Halpin
Marine Geospatial Ecology Lab
Duke University



The Area Based Management Tools (**ABMT**s) considered for Regional Environmental Management Plans (**REMPs**) will vary between regions and mineral types and may require different approaches and thresholds to ensure effective management.

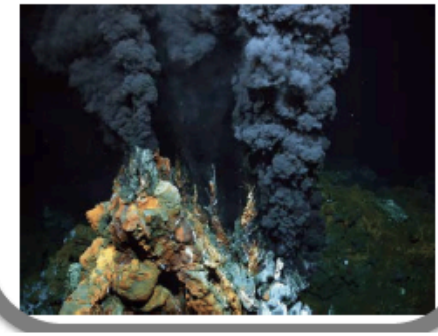
Polymetalic nodules
5000-6000 m
abyssal plain

Polymetalic crusts
800-3000 m
seamounts,
guyots,
ridges, plateaus



Map source: Petersen et al. 2016

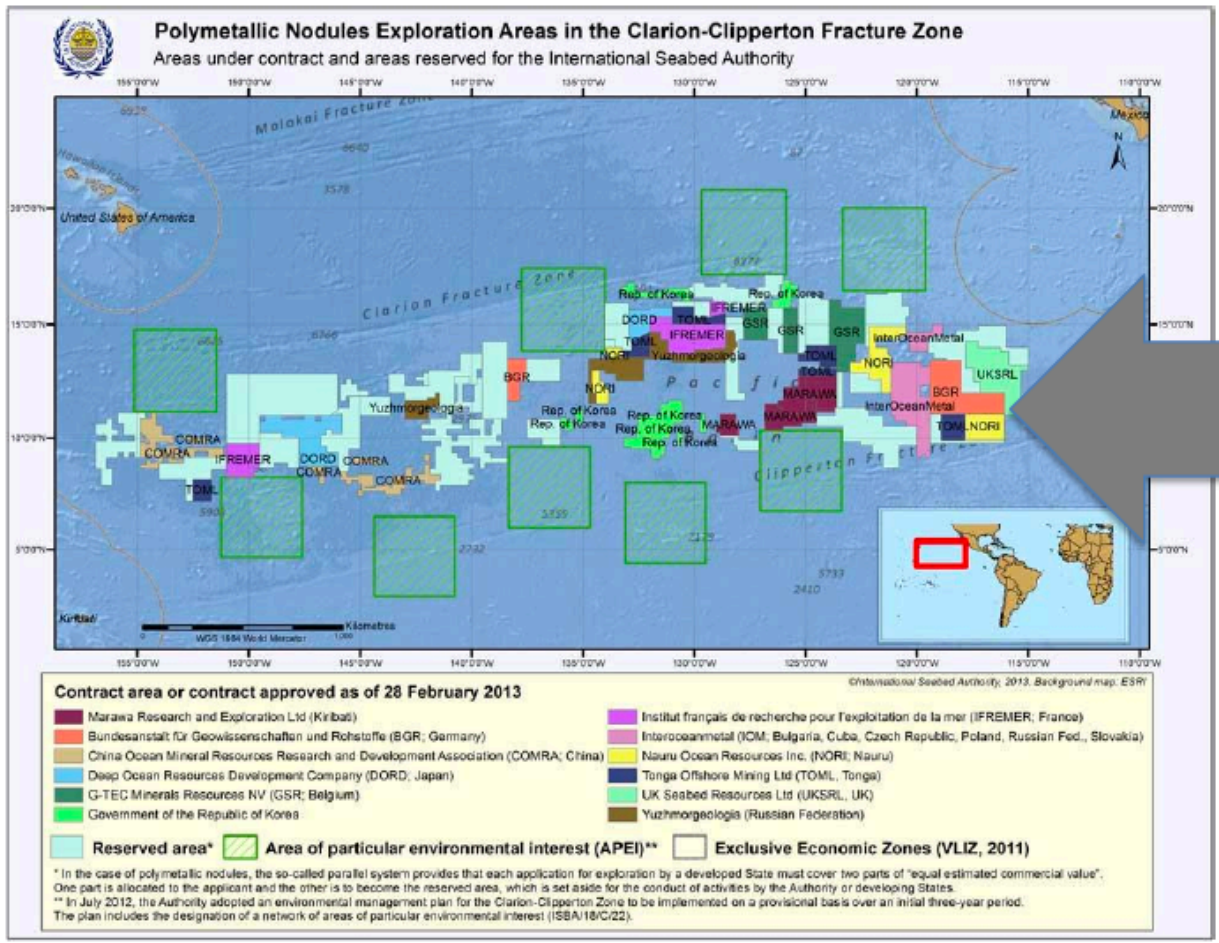
Polymetalic sulphides
1500-3500 m
mid-ocean ridges
back-arc spreading centers
island arcs

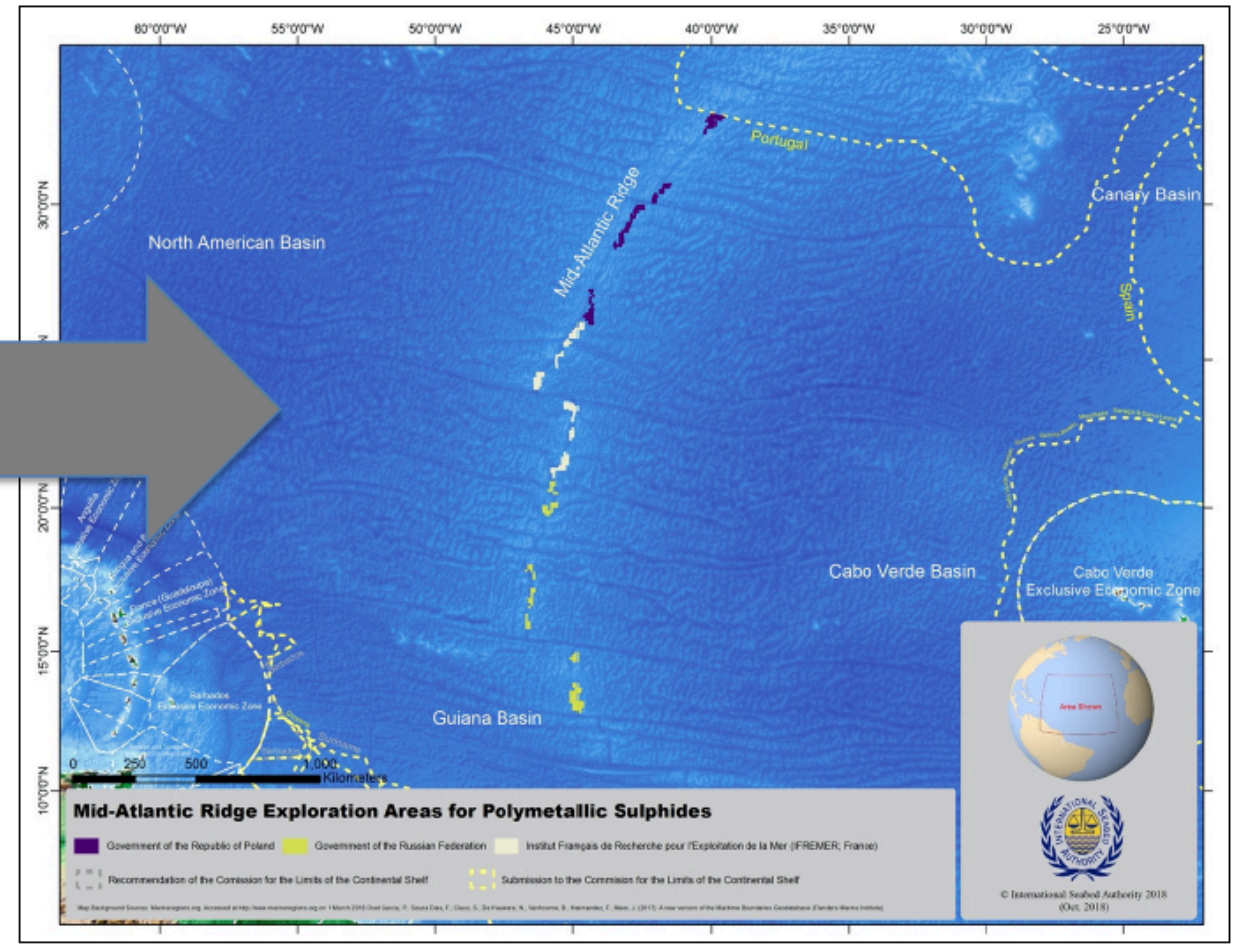


Previous ABMT planning example: CCZ

The CCZ example relied on large APEI areas (400x400km) intended to protect large, generalized gradients of habitats and ecosystems

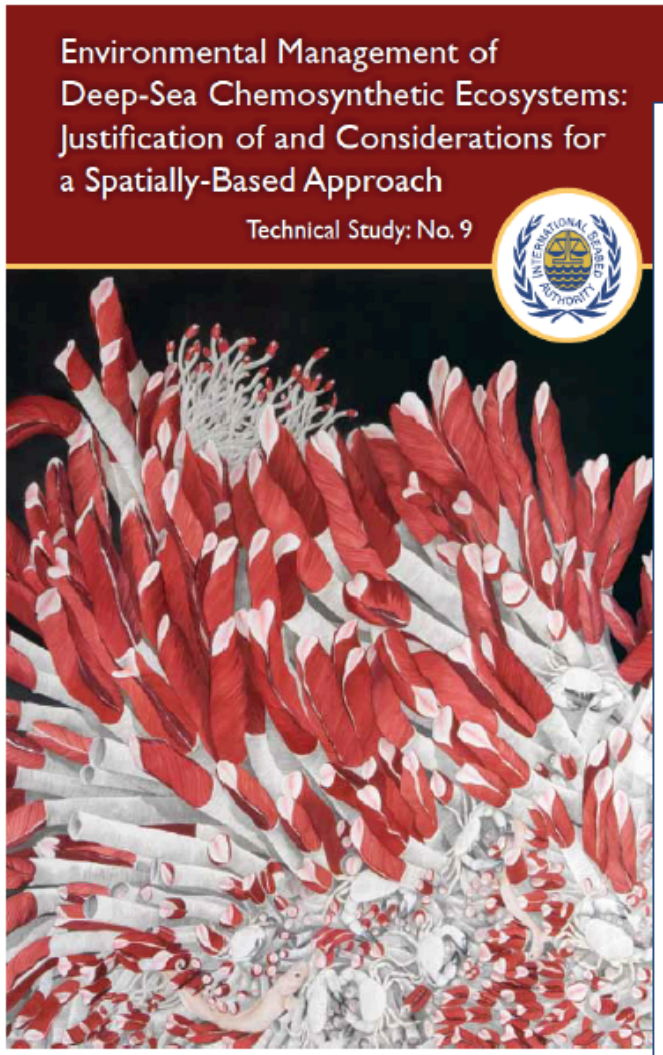
The nMAR region presents a very different case in terms of both the **geophysical and ecological features**, but also **available knowledge about specific important sites & areas**





ABMT & REMP preliminary workshops:

ABMT
- Criteria
- Approaches
- Metrics



Dinard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Designating networks of chemosynthetic ecosystem reserves in the deep sea

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ABSTRACT

From the moment of their discovery, chemosynthetic ecosystems in the deep sea have h
scientific value. At the same time that the scientific community is studying chemosynthetic
other sectors are either engaged in, or planning for, activities that may adversely i
ecosystems. There is a need and opportunity now to develop conservation strategies for
chemosynthetic ecosystem reserves in national and international waters through collabora
concerned stakeholders.

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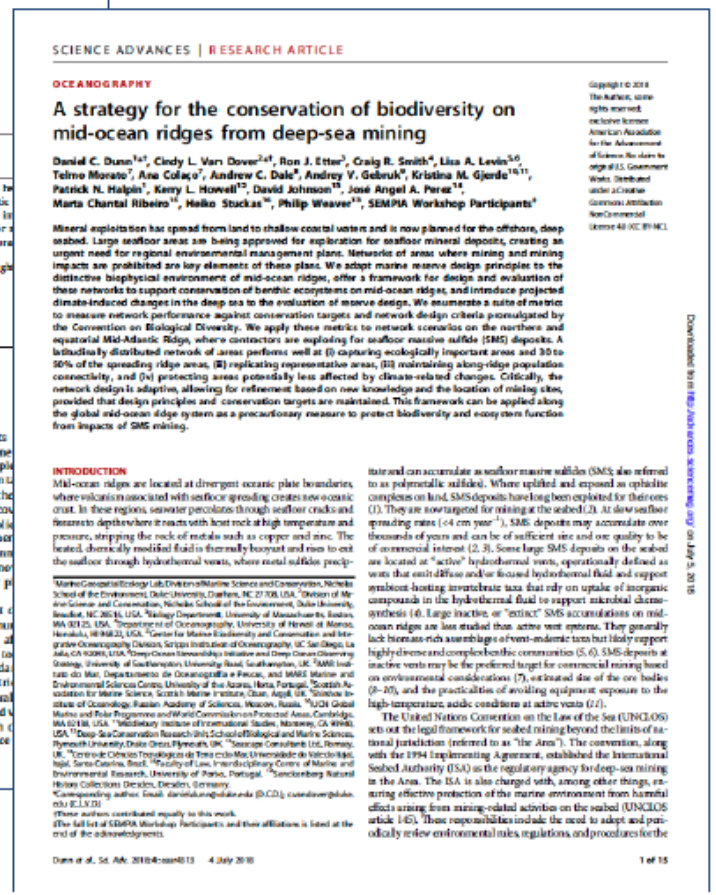
1. Introduction

Chemosynthetic ecosystems are patchy habitats
microbial primary production that uses chemical ene
than photosynthesis to create organic matter. Exampl
ecosystems on Earth include cold seeps of continen
and hot-vent ecosystems of mid-ocean ridges and othe
ine volcanic systems. From the moment of their disco
and vents captured the curiosity of the general public
have since advanced our understanding of ocean che
formation, biological adaptations to extreme environm
bal biodiversity and biogeography, evolutionary ne
cradles for the origin of life on Earth and on other p
moons [1].

Scientific exploration and discovery continues at
thetic ecosystems, e.g., [2–4]. Simultaneously, other hu
ities are underway or planned that may adversely a
ecosystems. These include, but are not limited to
activities such as trawling that have been known to da
habitats, and seeking or up-coming extractive industri
those that target energy resources at seeps or mineral
(Cu, Zn, Au, Ag) of seafloor massive sulfides associated
A disconnect exists between multiple activities with
impacts at chemosynthetic ecosystems and governance

SEMPIA (Azores, Lisbon, Sintra)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OCEANOGRAPHY

A strategy for the conservation of biodiversity on mid-ocean ridges from deep-sea mining

Daniel C. Dunn[1*†], Cindy L. Van Dover[2*†], Ron J. Etter[3], Craig R. Smith[4], Lisa A. Levin[5,6], Telmo Morato[7], Ana Colaço[7], Andrew C. Dale[8], Andrey V. Gebruk[9], Kristina M. Gjerde[10,11], Patrick N. Halpin[1], Kerry L. Howell[12], David Johnson[13], José Angel A. Perez[14], Marta Chantal Ribeiro[15], Heiko Stuckas[16], Philip Weaver[17], SEMPIA Workshop Participants[‡]

Mineral exploitation has spread from land to shallow coastal waters and is now planned for the offshore, deep seabed. Large seafloor areas are being approved for exploration for seafloor mineral deposits, creating an urgent need for regional environmental management plans. Networks of areas where mining and mining impacts are prohibited are key elements of these plans. We adopt marine reserve design principles to the distinctive biophysical environment of mid-ocean ridges, offer a framework for design and evaluation of these networks to support conservation of benthic ecosystems on mid-ocean ridges, and introduce projected climate-induced changes in the deep sea to the evaluation of reserve design. We enumerate a suite of metrics to measure network performance against conservation targets and network design criteria promulgated by the Convention on Biological Diversity. We apply these metrics to network scenarios on the northern and equatorial Mid-Atlantic Ridge, where contractors are exploring for seafloor massive sulfide (SMS) deposits. A latitudinally distributed network of areas performs well at (i) capturing ecologically important areas and 30 to 50% of the spreading ridge areas, (ii) replicating representative areas, (iii) maintaining along-ridge population connectivity, and (iv) protecting areas potentially less affected by climate-related changes. Critically, the network design is adaptive, allowing for refinement based on new knowledge and the location of mining sites, provided that design principles and conservation targets are maintained. This framework can be applied along the global mid-ocean ridge system as a precautionary measure to protect biodiversity and ecosystem function from impacts of SMS mining.

INTRODUCTION

Mid-ocean ridges are located at divergent oceanic plate boundaries, where volcanism is associated with seafloor spreading creates new oceanic crust. In these regions, seawater percolates through seafloor cracks and fissures to depths where it reacts with host rock at high temperature and pressure, stripping the rock of metals such as copper and zinc. The heated, chemically modified fluid is then buoyant and rises to exit the seafloor through hydrothermal vents, where metal sulfides precipitate and can accumulate as seafloor massive sulfides (SMS; also referred to as polymetallic sulfides). Where uplifted and exposed as ophiolite complexes on land, SMS deposits have long been exploited for their ores (1). They are now targeted for mining at the seabed (2). At slow seafloor spreading rates (<4 cm year^{-1}), SMS deposits may accumulate over thousands of years and can be of sufficient size and ore quality to be of commercial interest (2, 3). Some large SMS deposits on the seabed are located at "active" hydrothermal vents, operationally defined as vents that emit diffuse and/or focused hydrothermal fluid and support symbiont-hosting invertebrate taxa that rely on uptake of inorganic compounds in the hydrothermal fluid to support microbial chemosynthesis (4). Large inactive, or "extinct" SMS accumulations on mid-ocean ridges are less studied than active vent systems. They generally lack biomass-rich assemblages of vent-endemic taxa but likely support highly diverse and complex benthic communities (5, 6). SMS deposits at inactive vents may be the preferred target for commercial mining based on environmental considerations (7), estimated size of the ore bodies (8–10), and the practicalities of avoiding equipment exposure to the high-temperature, acidic conditions at active vents (11).

The United Nations Convention on the Law of the Sea (UNCLOS) sets out the legal framework for seabed mining beyond the limits of national jurisdiction (referred to as "the Area"). The convention, along with the 1994 Implementing Agreement, established the International Seabed Authority (ISA) as the regulatory agency for deep-sea mining in the Area. The ISA is also charged with, among other things, ensuring effective protection of the marine environment from harmful effects arising from mining-related activities on the seabed (UNCLOS article 145). These responsibilities include the need to adopt and periodically review environmental rules, regulations, and procedures for the

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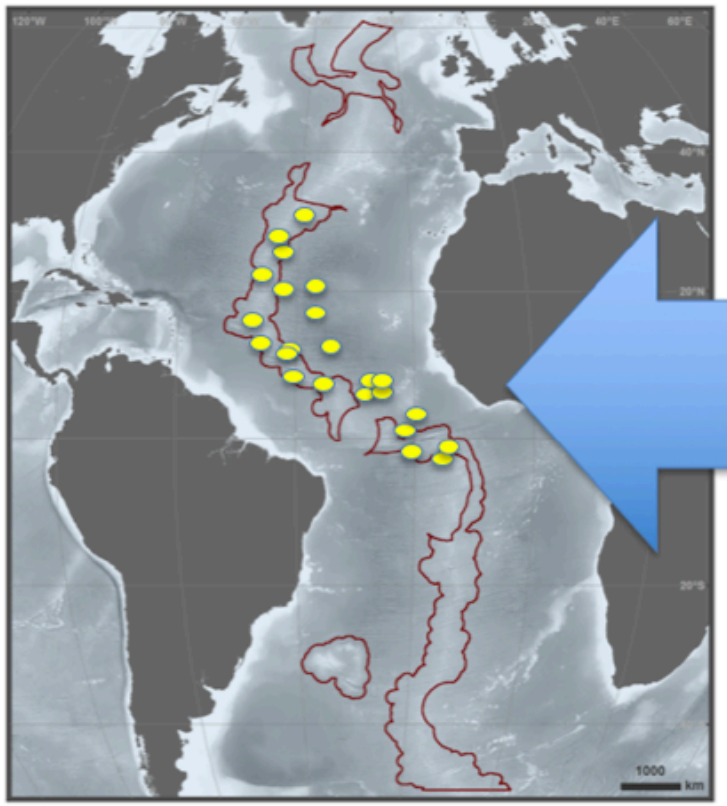
†These authors contributed equally to this work.
‡The full list of SEMPIA Workshop Participants and their affiliations is listed at the end of the acknowledgments.

General ABMT approaches

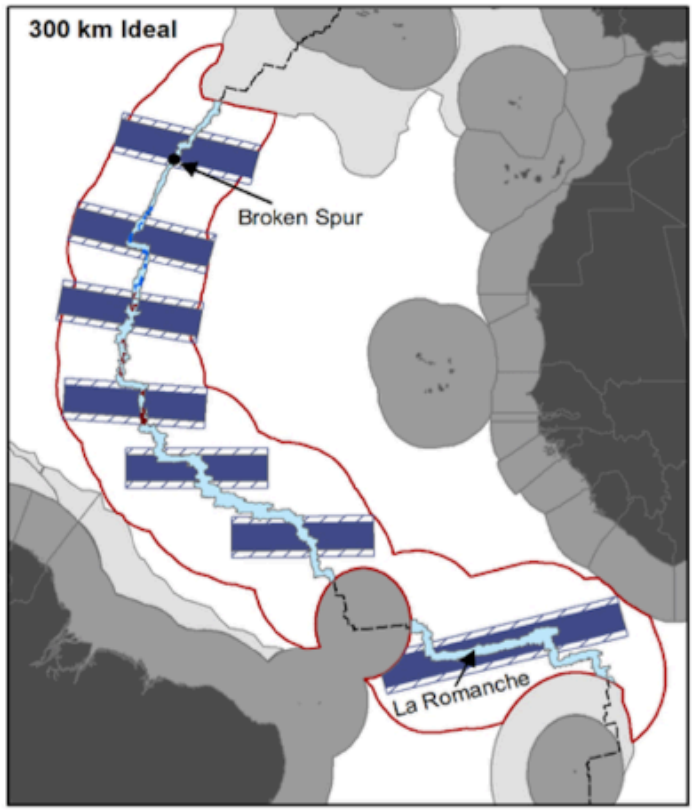
Bottom-up
Start with
“fine-filter”
features

Systematic planning approach



Spatially precise, optimization approach

Banded APEI approach

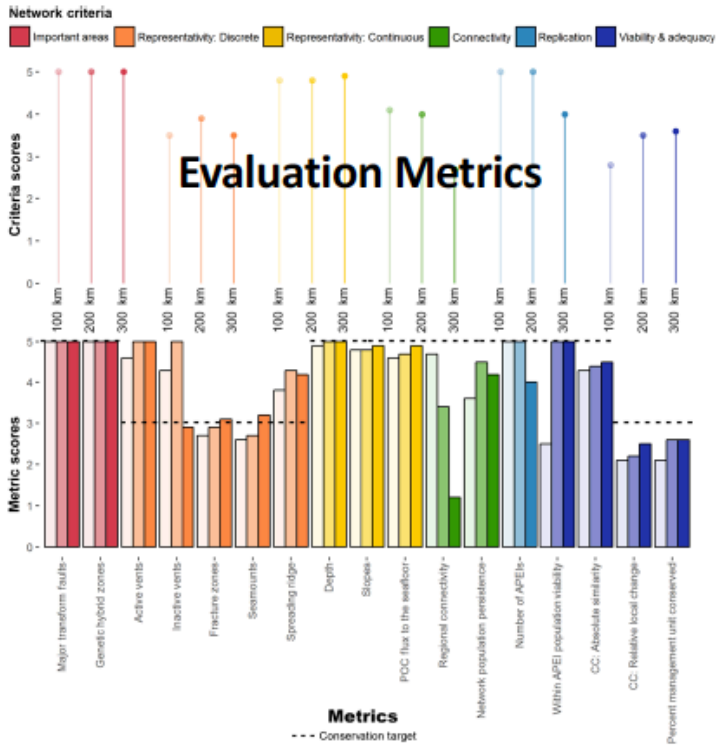


Spatially coarse, rule-based approach

Start with
“coarse-filter”
features
Top-down

ABMT network evaluation strategy & metrics

Dunn *et al*. 2018



SCIENCE ADVANCES | RESEARCH ARTICLE Dunn et al., Sci. Adv. 2018;4:eaar4313

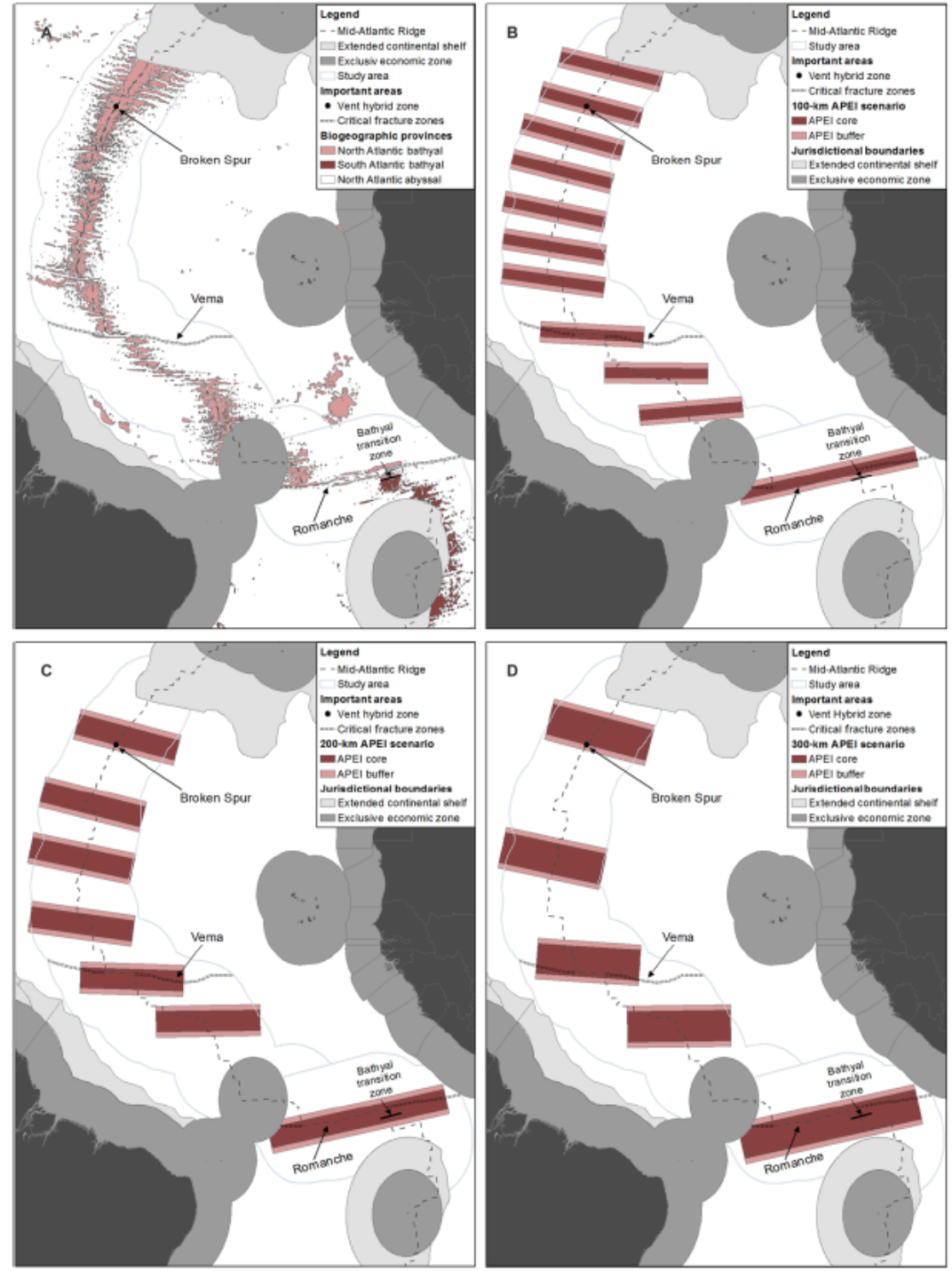
OCEANOGRAPHY

A strategy for the conservation of biodiversity on mid-ocean ridges from deep-sea mining

Daniel C. Dunn[1*†], Cindy L. Van Dover[2*†], Ron J. Etter[3], Craig R. Smith[4], Lisa A. Levin[5,6], Telmo Morato[7], Ana Colaço[7], Andrew C. Dale[8], Andrey V. Gebruk[9], Kristina M. Gjerde[10,11], Patrick N. Halpin[1], Kerry L. Howell[12], David Johnson[13], José Angel A. Perez[14], Marta Chantal Ribeiro[15], Heiko Stuckas[16], Philip Weaver[13], SEMPIA Workshop Participants[‡]

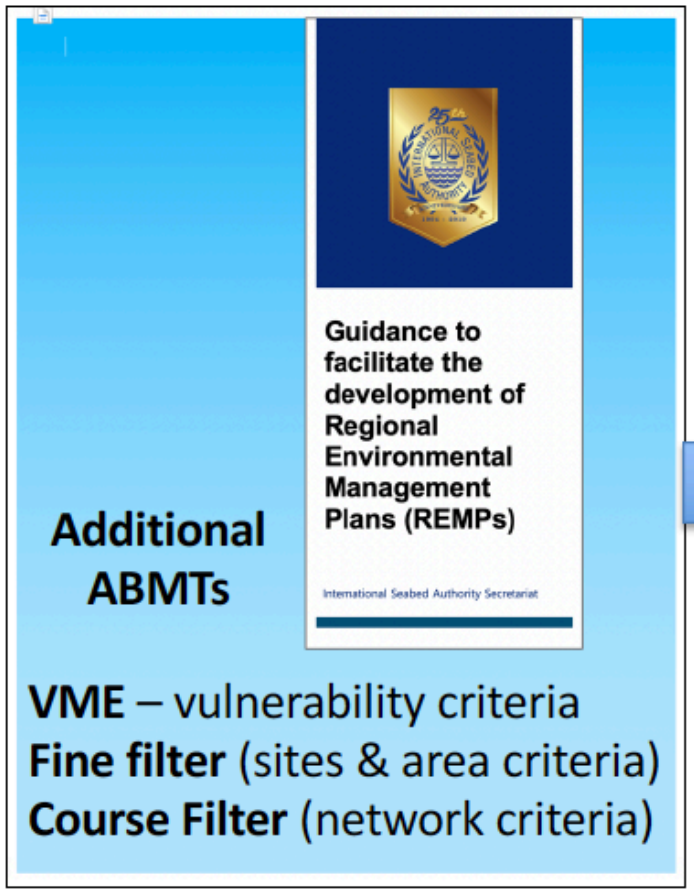
Network Criteria

- Important areas
- Representativity
- Connectivity
- Replication
- Viability & Adequacy



ISA nMAR REMP process

June 2019
REMP Guidance



November 2019
REMP workshop #1


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.[1]

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).[2] 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.[3] 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

[1] United Nations Convention on the Law of the Sea, art. 145.
[2] See ISBA/17/LTC/7; ISBA/17/C/19 and ISBA/18/C/22.
[3] See ISBA/24/C/3.

1

Evora, Portugal

November / December 2020
REMP workshop #2


Workshop on the Development of a REMP for the Area of the Northern Mid-Atlantic Ridge with a Focus on Polymetallic Sulphides Deposits

23 November 2020 - 04 December 2020
Virtual Meeting

Co-funded by the European Maritime and Fisheries Fund

ALL SESSIONS
26th Session 2020
25th Session 2019
24th Session 2018
23rd Session 2017
22nd Session 2016

Terms of Reference | Call for Nominations and Information | Provisional Agenda | Annotations to Provisional Agenda | Background Documents | Participants | Information Note | Videos

The International Seabed Authority (ISA) will convene a workshop on the development of a Regional Environmental Management Plan (REMP) for the Area of the Northern Mid-Atlantic Ridge (MAR) with a focus on polymetallic sulphides (PMS) deposits, from 23 November to 4 December 2020 (week days only), via an online meeting platform.

The workshop was originally scheduled to take place in St. Petersburg, Russian Federation, in June 2020. However, due to the implications associated with the pandemic of COVID-19, the decision has been made to postpone it. The workshop will be held in collaboration with the Atlantic REMP Project co-funded by the European Maritime and Fisheries Fund, the Ministry of Natural Resources and Environment of the Russian Federation and the All-Russia Scientific Research Institute for Geology and Mineral Resources of the Ocean (VNIIOkeangeologia).

The workshop aims to:

- Describe the geographical scope and environmental goals and objectives for the draft REMP,
- Identify possible elements to be included in the draft REMP for the Area of the northern MAR with a focus on PMS deposits,
- Identify potential management approaches and measures, with a focus on PMS deposits, that can be considered in the development of a REMP, including spatial and non-spatial measures as well as approaches for addressing cumulative impacts at the regional level, and
- Discuss the framework for implementation, including priority actions for addressing the knowledge gaps, monitoring and review of the implementation of the REMP, collaboration and capacity development.

The report of this workshop will be presented to the Legal and Technical Commission (LTC) in its future meeting for their consideration in developing the REMP for the Area of the Northern MAR. This workshop builds on the results of previous REMP workshops, in particular the Évora Workshop, which reviewed and synthesized scientific data and information,

online

nMAR ABMT approach matrix

Implementation: **Protection** **Precaution**

Type of Site or Area

	Observed & described features or ecosystems	Inferred or predicted features or ecosystems	criteria used
Observation of vulnerable species/ecosystem occurrences	Sites in Need of Protection (SINP)	Sites in need of Precaution (SINPr)	VME criteria / template
Description of specific important areas	Areas in Need of Protection (AINP)	Areas in need of Precaution (AINPr)	Important area criteria / template
Selection of Representative / connectivity features or gradients	Representative / connectivity areas	Representative / connectivity areas	Network criteria / regional analysis

Application of network criteria and evaluation metrics has not been addressed

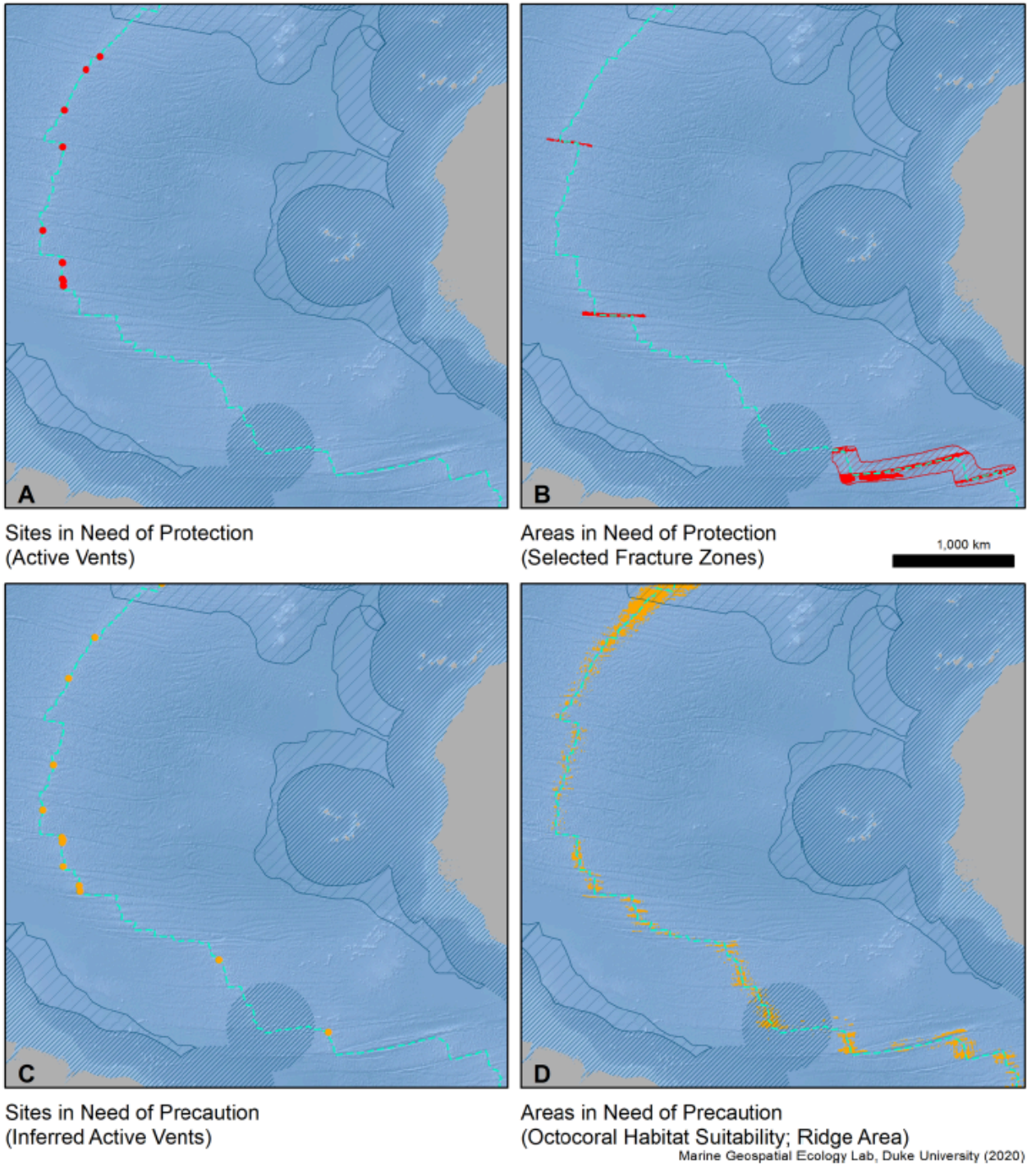
ABMT Summary

Sites & Areas in need of **protection**

A. **11 sites in need of protection SINP** (active hydrothermal vents areas)
B. **3 Areas in Need of Protection AINPs** (fracture zone systems)

Sites & Areas in need of **precaution**

C. **12 sites in need of precaution** (inferred active vent sites)
D. **Suitability modeled Areas in Need of Precaution** (octocoral suitability areas within the ridge area)



Sites in Need of Protection (Active Vents)

Areas in Need of Protection (Selected Fracture Zones)

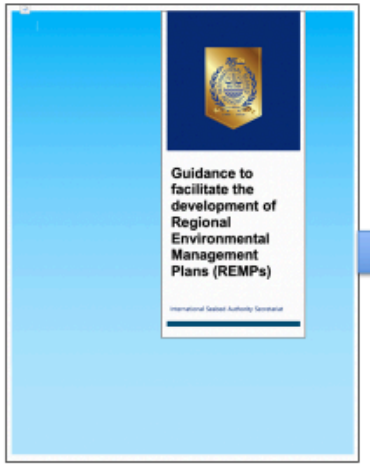
Sites in Need of Precaution (Inferred Active Vents)

Areas in Need of Precaution (Octocoral Habitat Suitability; Ridge Area)

Marine Geospatial Ecology Lab, Duke University (2020)

Necessary next steps

June 2019
REMP Guidance

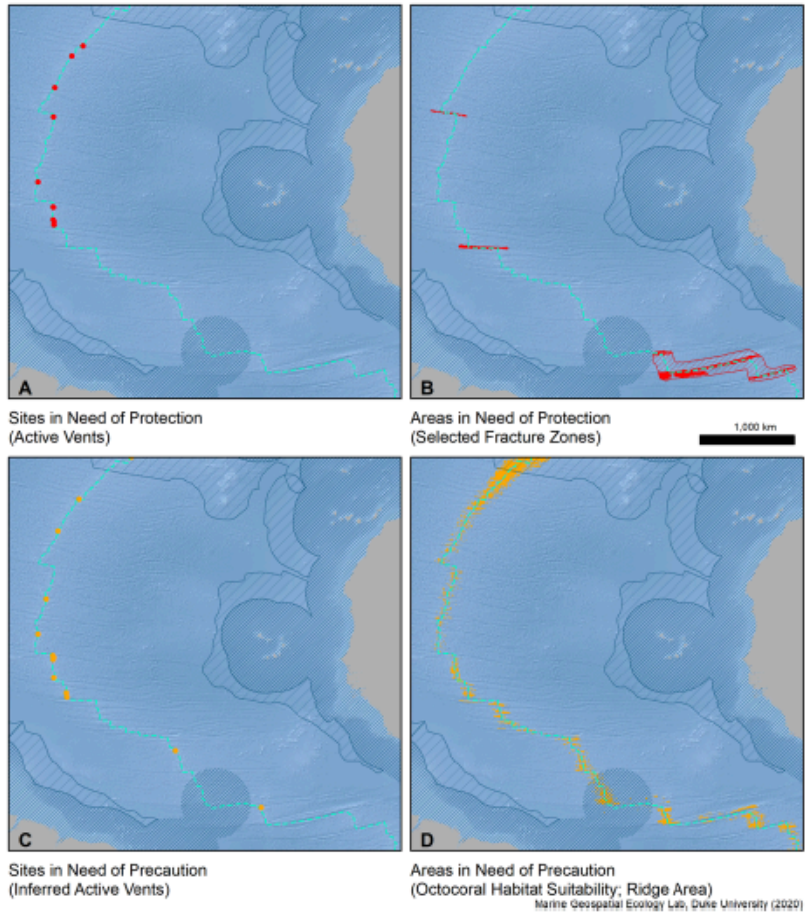


November 2019
REMP workshop #1

November 2020
REMP workshop #2

*"...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." (Evora workshop report p79)*

Additional scientific workshop(s) to implement network criteria and evaluate ABMT planning metrics



Sites in Need of Protection
(Active Vents)

Areas in Need of Protection
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Sites in Need of Precaution
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Areas in Need of Precaution
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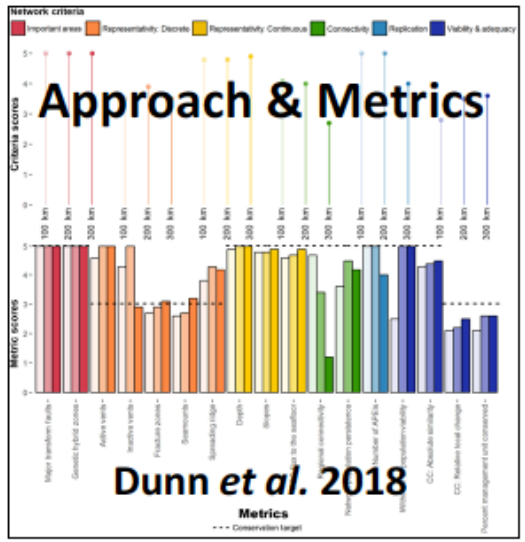
Marine Geospatial Ecology Lab, Duke University (2020)

Necessary next steps

GOBI inputs



SCIENCE ADVANCES | RESEARCH ARTICLE

Dunn et al., Sci. Adv. 2018;4:eaar4313

OCEANOGRAPHY

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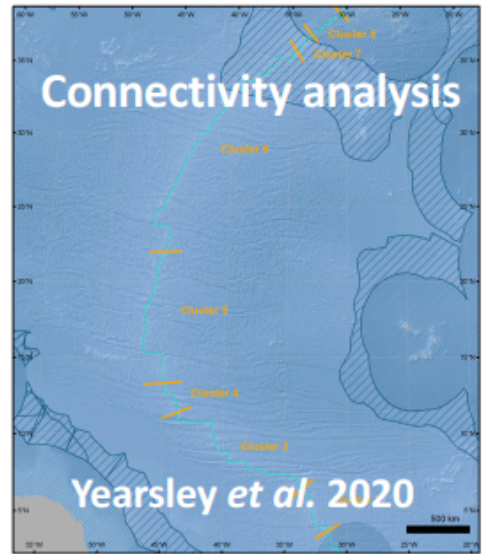
Next up...



Contents lists available at ScienceDirect

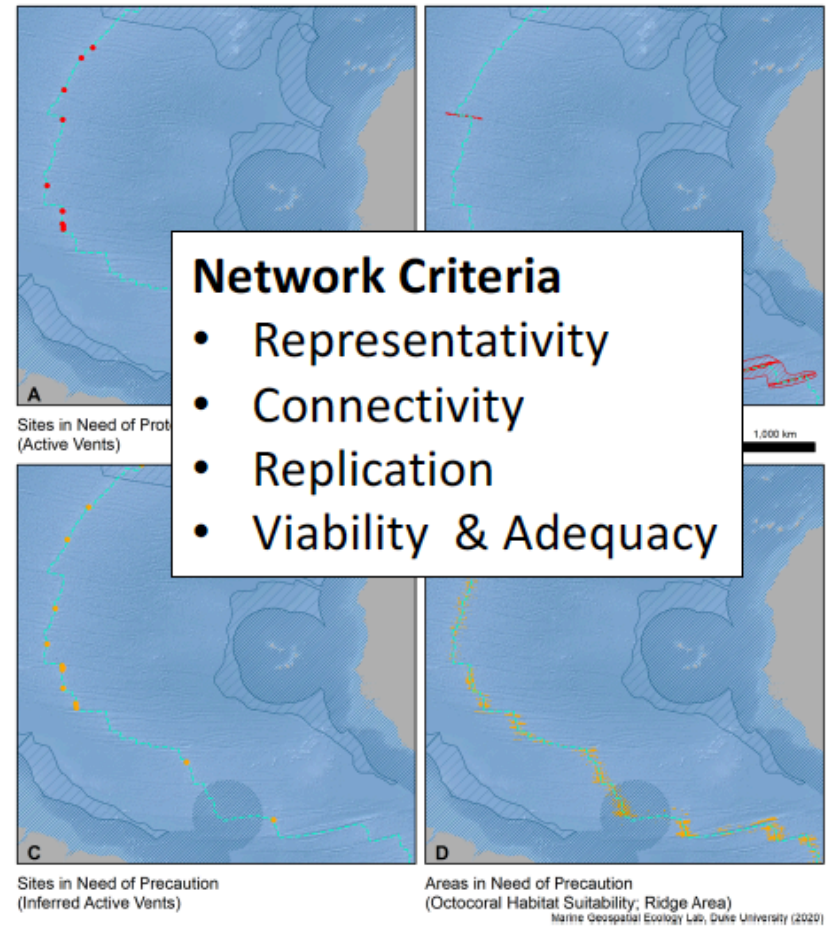
Deep-Sea Research Part II

journal homepage: http://www.elsevier.com/locate/dsr2

Biophysical models of persistent connectivity and barriers on the northern Mid-Atlantic Ridge

J.M. Yearsley[a,b,*], D.M. Salmanidou[a,b,c], J. Carlsson[a,b], D. Burns[a], C.L. Van Dover[d]

Additional scientific workshop(s) to implement **network criteria** and evaluate ABMT **planning metrics**



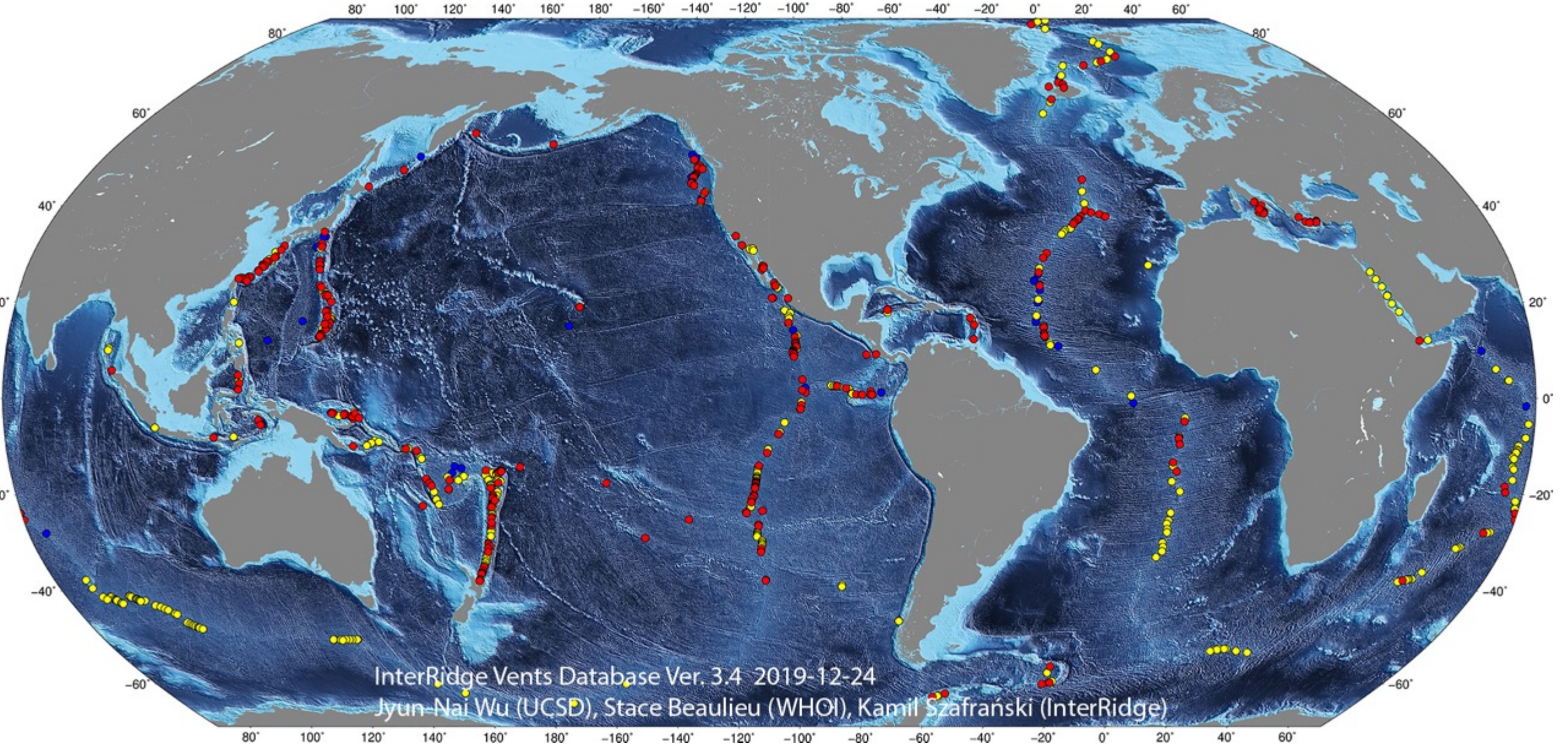
Network Criteria

- Representativity
- Connectivity
- Replication
- Viability & Adequacy

Larval links to vent ecosystems and the mid-water highway

Jon Yearsley
University College Dublin

GOBI
Global Ocean Biodiversity Initiative

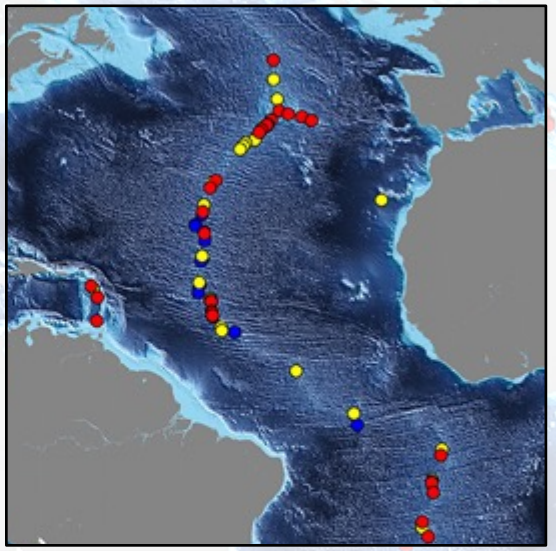


Global Active (red), Inferred Active (yellow), and Inactive Hydrothermal Vents (blue)

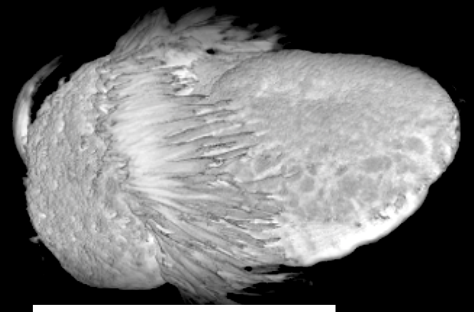
Photo: Julia Sigwart

Adults are usually poor at dispersing…

larvae are more likely to disperse in the ocean currents



Chiton larvae

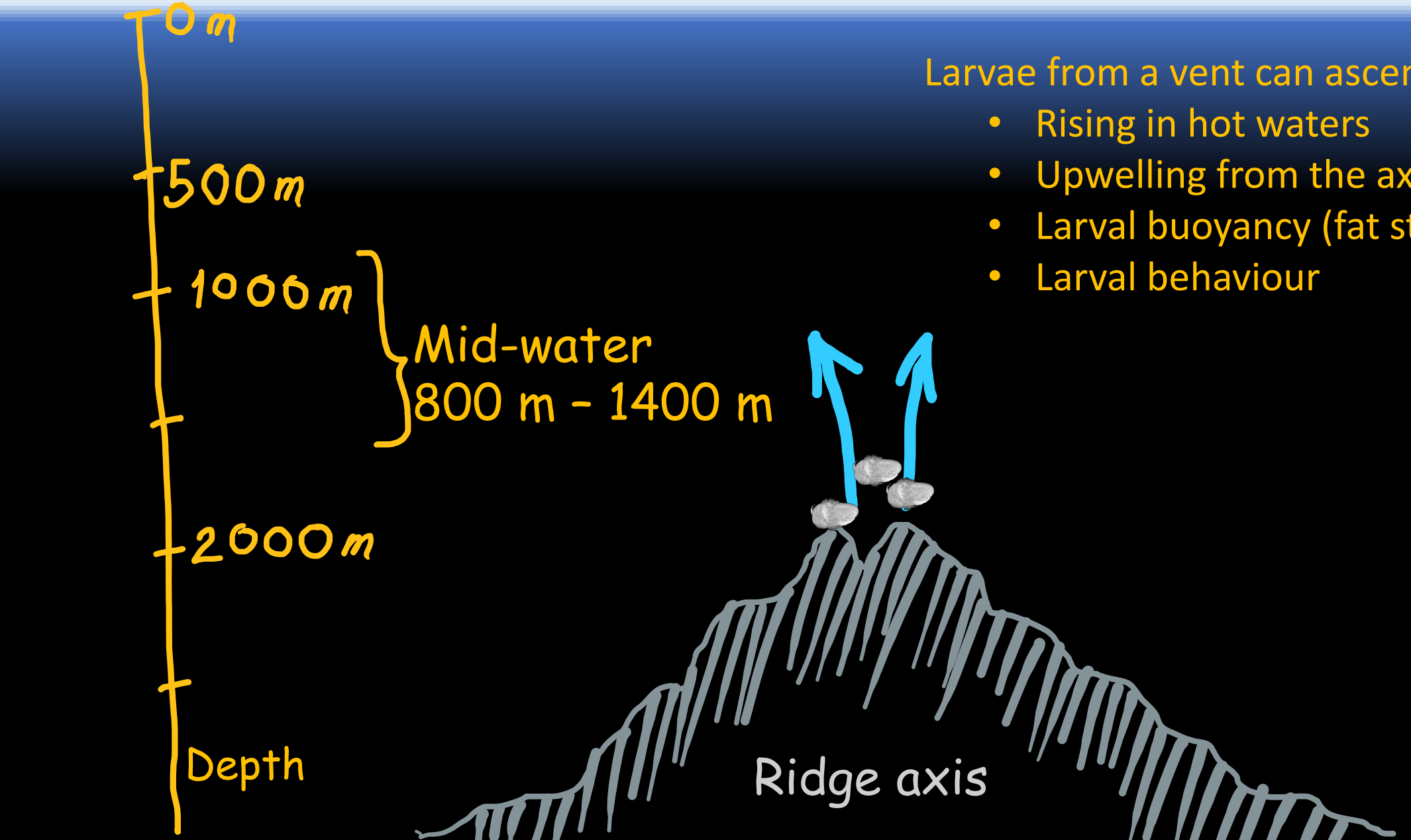


0.1mm

Photo: *Acanthopleura hirtosa*
Jeremy Shaw & Derek Gerstmann, Univ. Western Australia

Global Active (red), Inferred Active (yellow), and Inactive Hydrothermal Vents (blue)

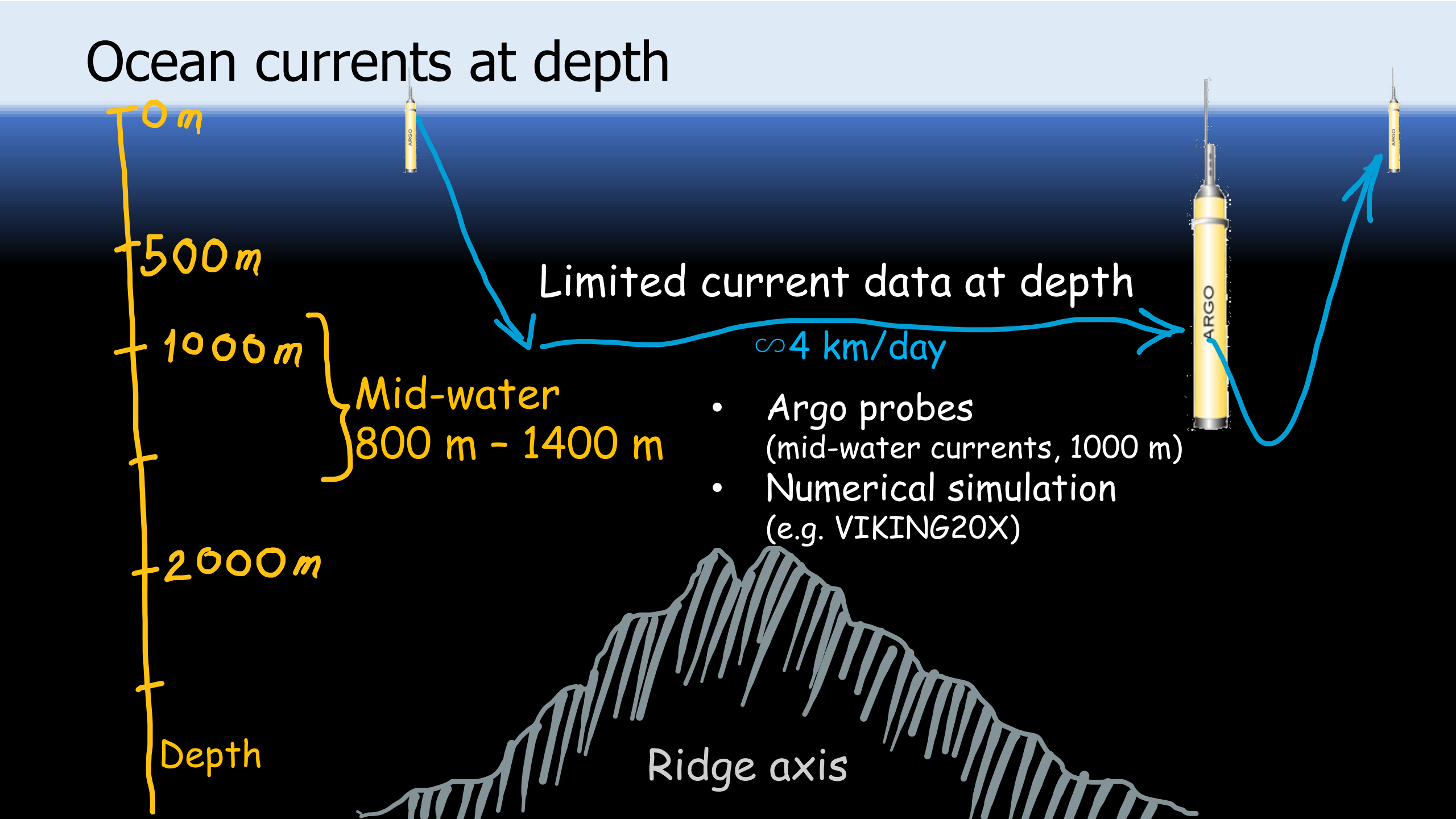
Where can larvae go in the water column?



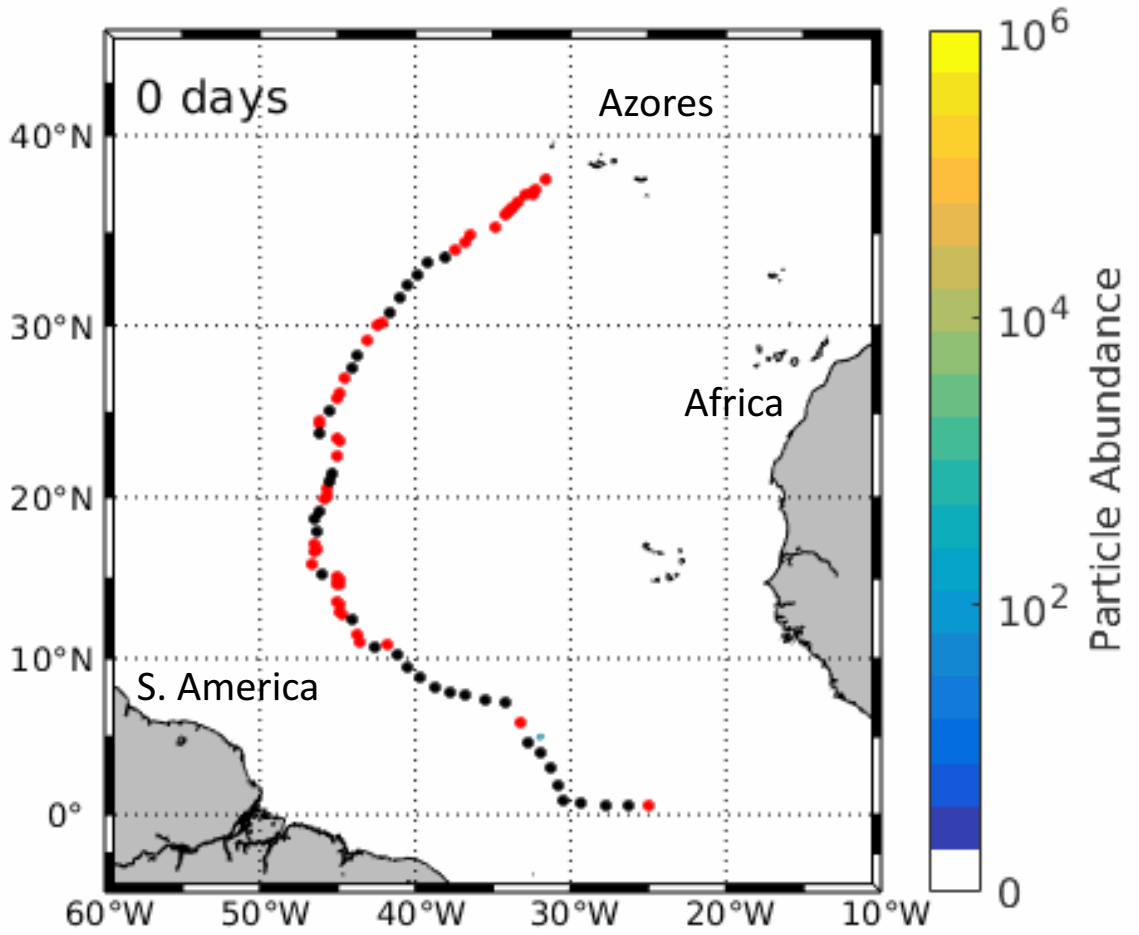
Larvae from a vent can ascend by:

- Rising in hot waters
- Upwelling from the axial valley
- Larval buoyancy (fat stores)
- Larval behaviour

Ocean currents at depth

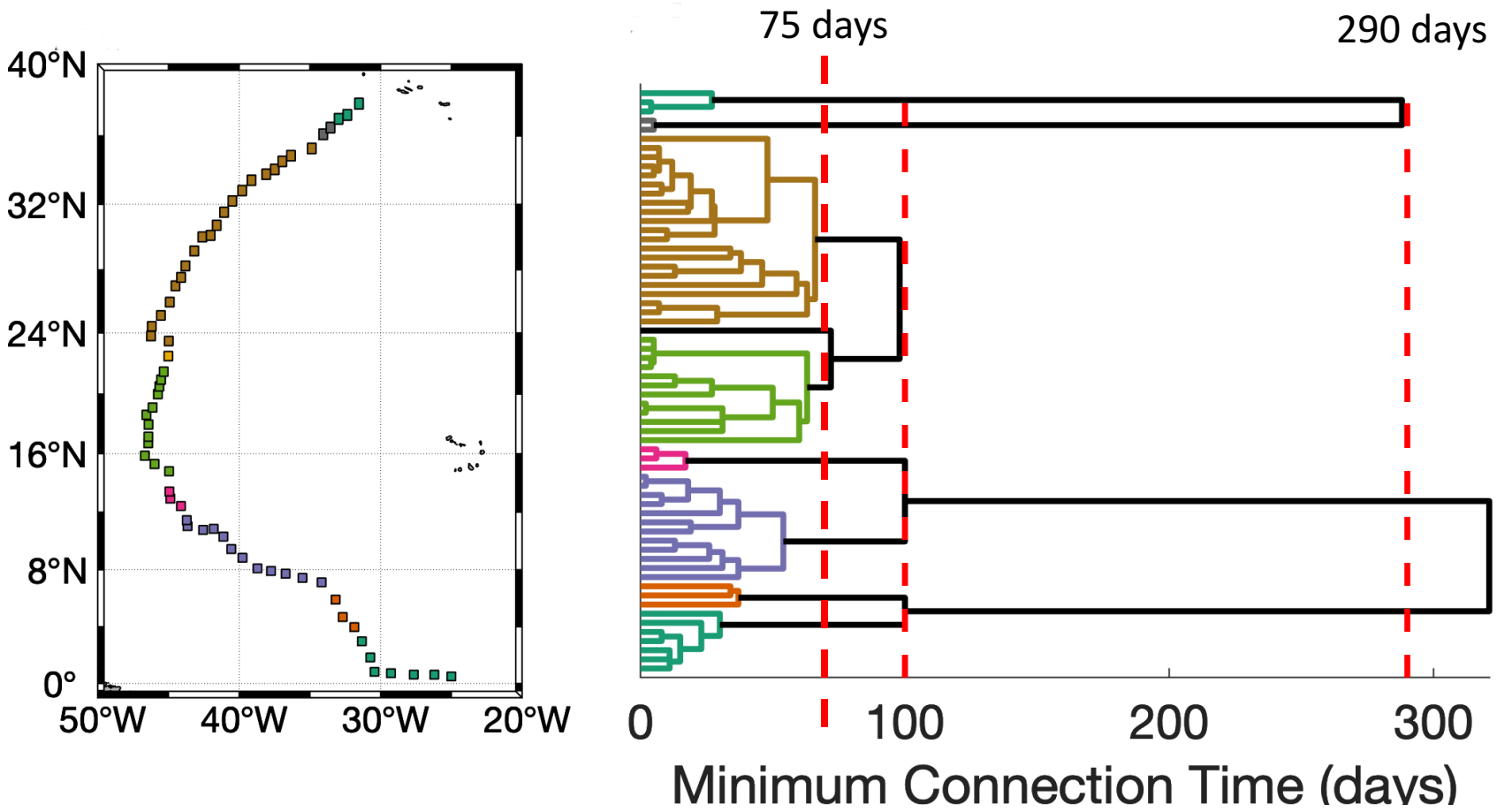


Millions of neutrally buoyant particles drifting in currents inferred from Argo probes



Yearsley et al, Deep Sea Research II (2020)

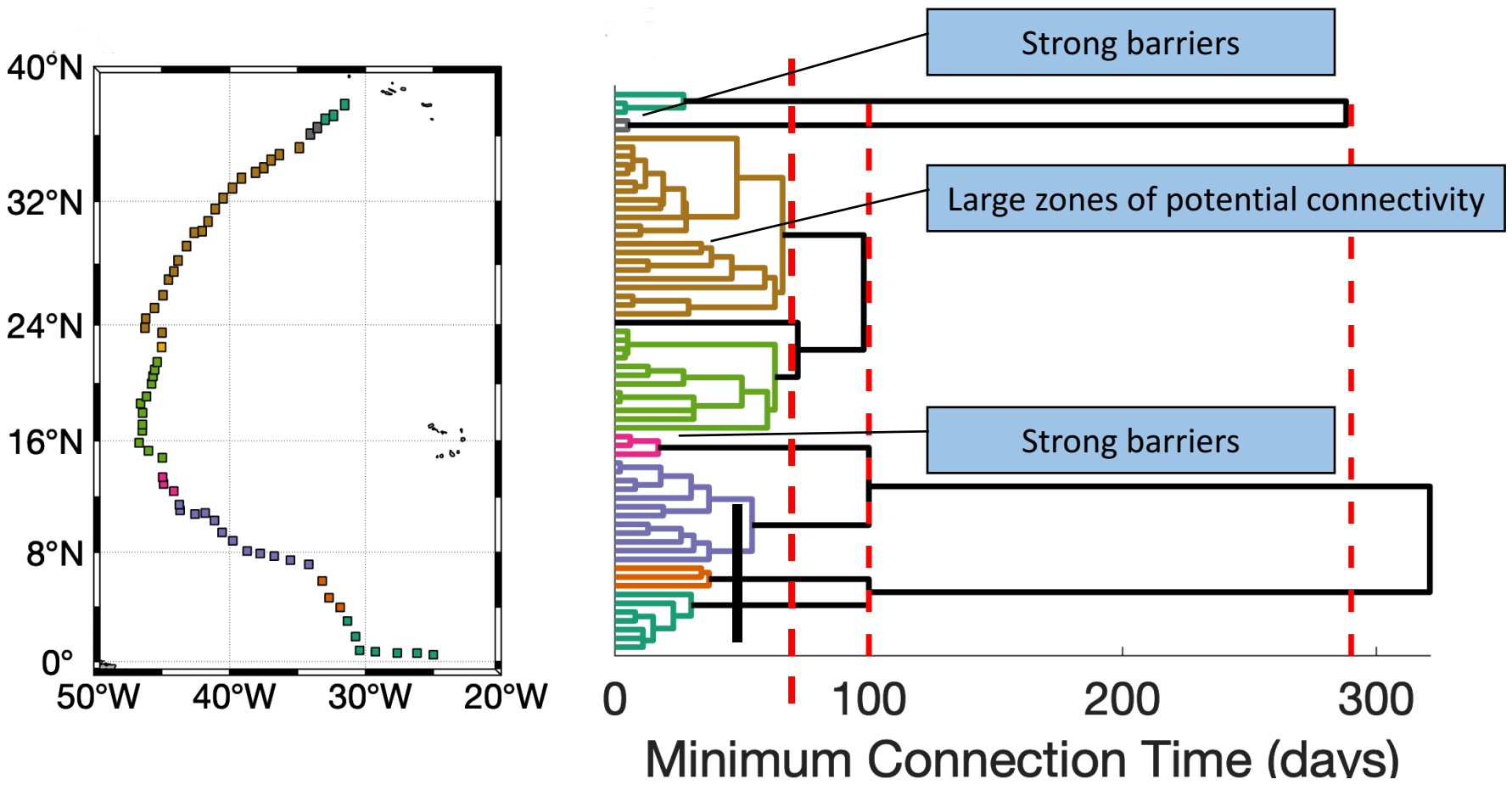
Connectivity and barriers



Connection time = Time to reach a connectivity probability of 1 in 10,000 larvae

Yearsley et al, Deep Sea Research II (2020)

Connectivity and barriers



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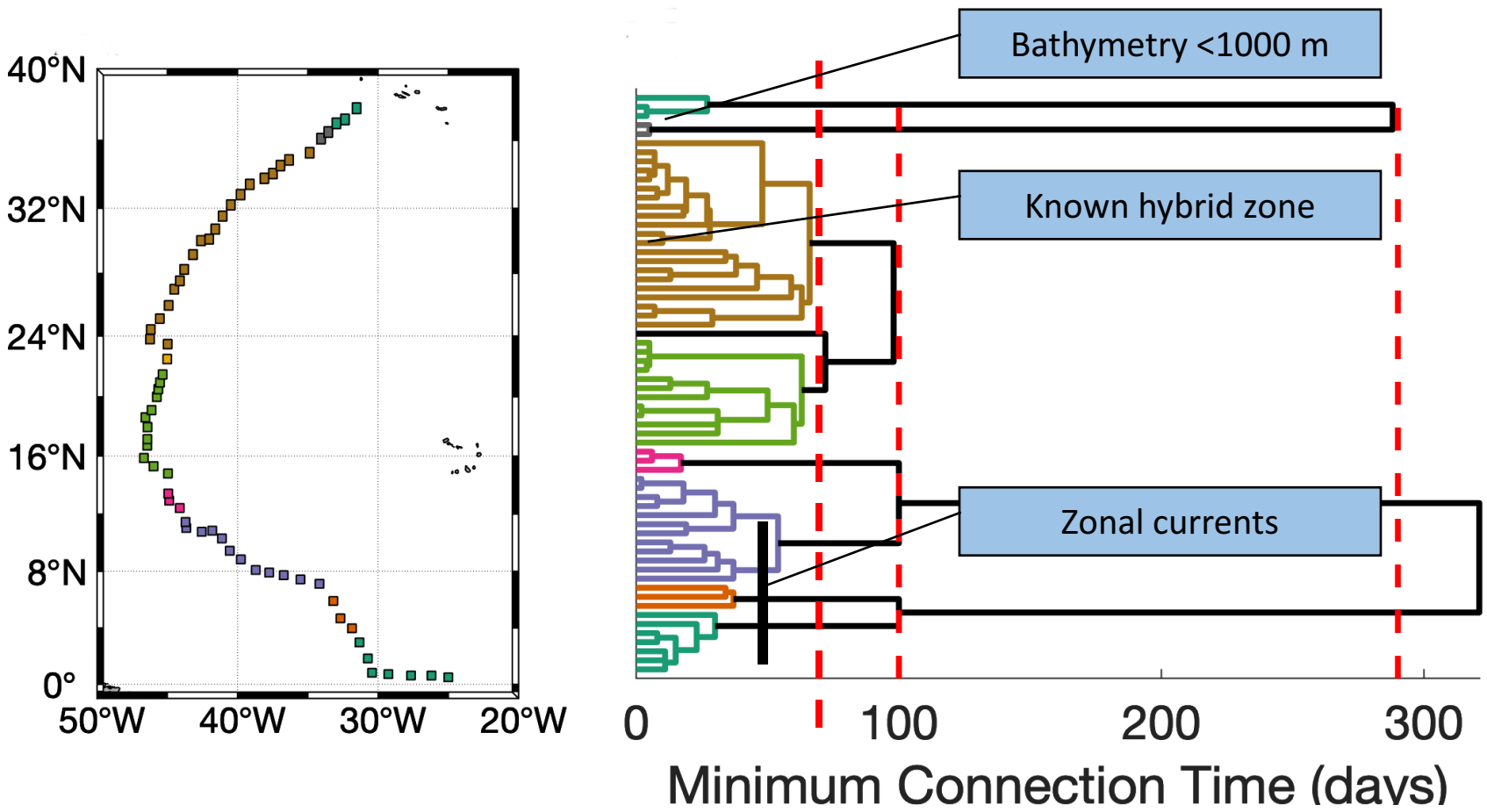
Connectivity and barriers



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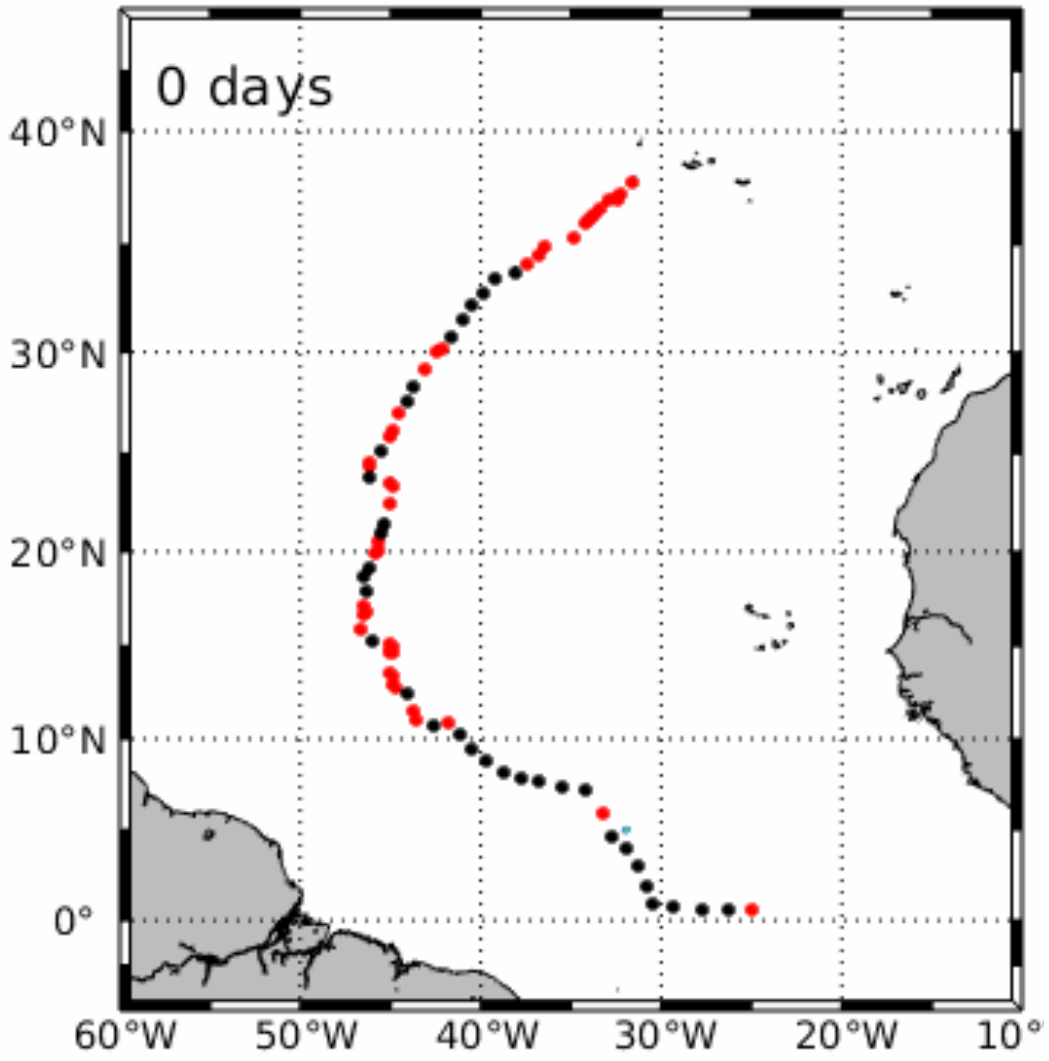


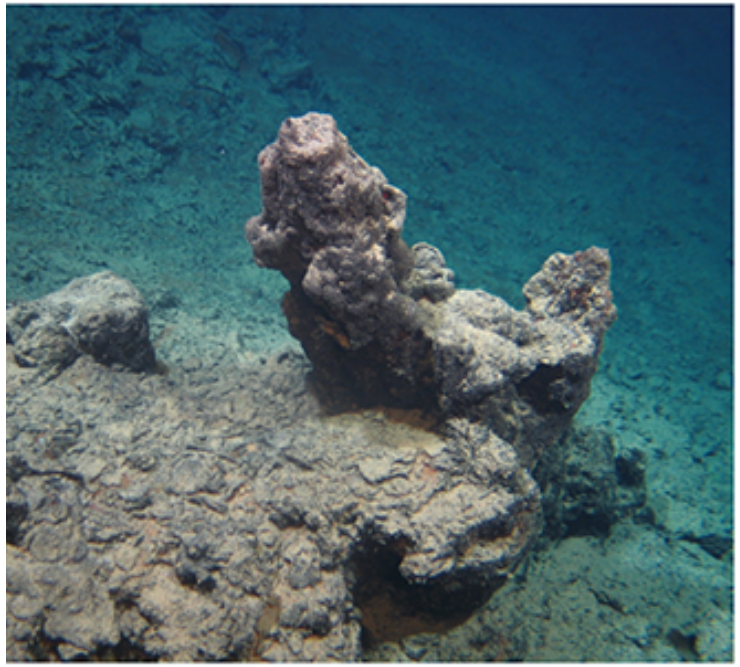
next up…..

Inactive and extinct sulfide ecosystems as targets for mining

Dr Cindy van Dover

Duke University, USA

hydrothermally inactive and extinct sulfide ecosystems as targets for mining



BGR Federal Institute for Geosciences and Natural Resources Germany

The Hydrothermal Cycle

- Initiation of hydrothermal activity
- Hydrothermal vent communities become established
  - Venting duration depends on the geological setting
    - For commercial deposits: 1000’s to >100,000 yrs
- Waning of hydrothermal activity caused by, for example
  - Earthquakes
  - Volcanic eruptions
  - Clogging (mineralization)
  - Movement of tectonic plates
- Cessation of hydrothermal flow and demise of the vent-obligate taxa
- Ultimately, burial beneath pelagic sediment

International Seabed Authority Definitions (2019)

[Hydrothermally] Active Sulfides *(aka hydrothermal vents)*

- polymetallic sulfides through which warm or hot water is flowing

[Hydrothermally] Inactive (or Dormant) Sulfides

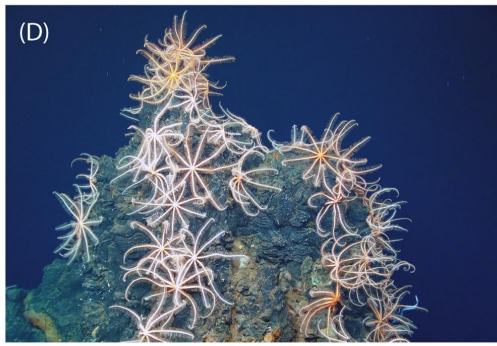
- polymetallic sulfides through which warm water is no longer flowing (i.e., they are “cold”)
  - Disturbance of these sulfides may result in renewal of hydrothermal fluxes into the water column, turning inactive sulfides into active sulfides

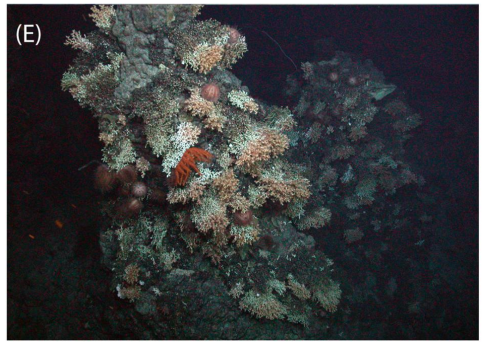
[Extinct Sulfides]

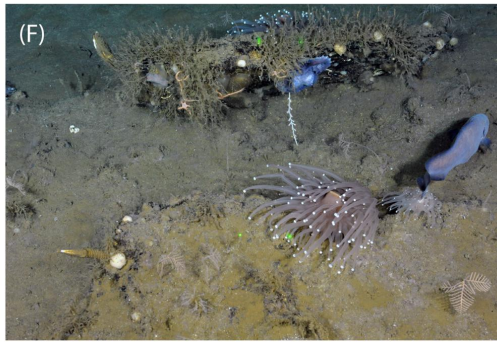
- Polymetallic sulfides that remain hydrothermally inactive even when disturbed

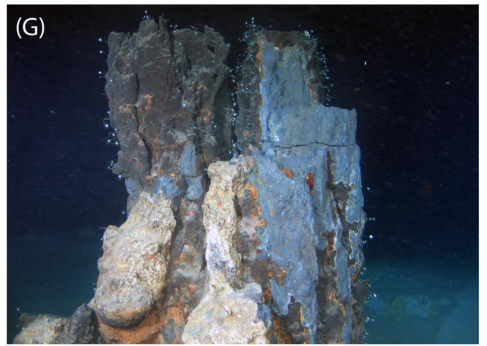
Biota on hydrothermally Inactive/extinct sulfides

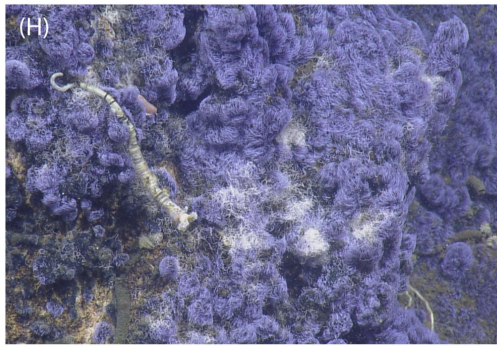
- Invertebrate populations may be apparently absent or abundant
  - so far, invertebrate species occurring on hydrothermally inactive/extinct sulfides are not known to be endemic/obligately linked to the sulfide substratum, i.e., they occur elsewhere on other hard substrata
  - no evidence to date of any invertebrate-microbe symbioses at inactive/extinct sulfides
- megafaunal succession during transition from hydrothermally active to inactive is not yet well documented but probably includes a transient scavenger phase as fluids cease flowing and vent-obligate taxa die off
- microbial succession from active to inactive sulfides has been documented
- sulfide minerals can be mobilized by microorganisms for chemosynthesis











RESEARCH GAPS
the ecology of hydrothermally inactive and extinct sulfides has historically been poorly studied

- Basic ecological studies (environmental baselines) are needed, including
  - Quantitative characterization of microbial and invertebrate community structure
    - Who's there? Are there any endemic taxa?
  - Trophic interactions and the role (if any) of microorganisms in supporting invertebrate populations on the sulfides
- How would local and regional biodiversity be impacted by mining activities?

If an inactive sulfide deposit shares a subsurface reservoir with an active vent ecosystem, how would reactivation of the inactive site impact the ecosystem at the active site?

k jacobsen

next up.....

Discussion