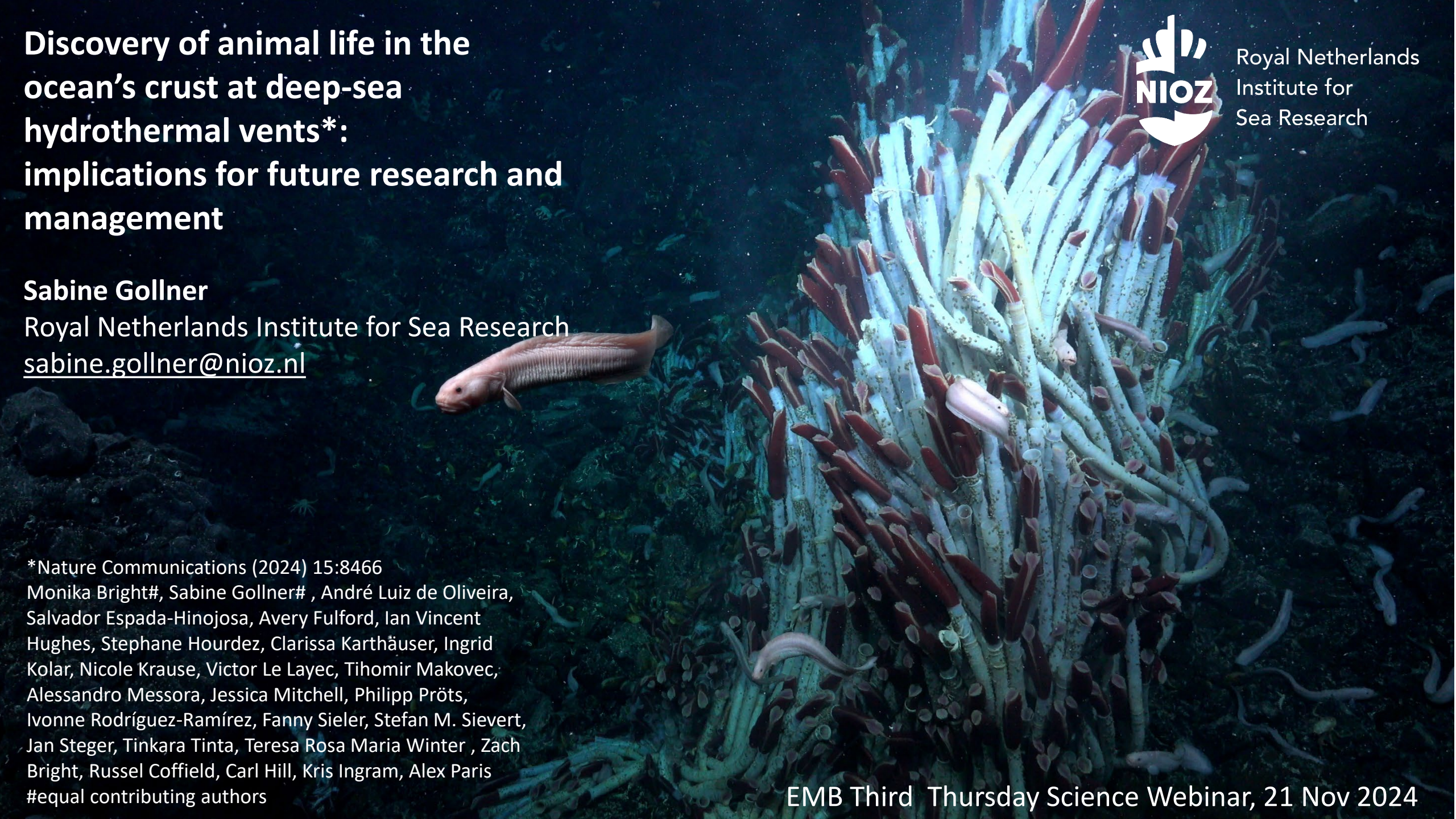
Discovery of animal life in the ocean's crust at deep-sea hydrothermal vents*: implications for future research and management

Sabine Gollner
Royal Netherlands Institute for Sea Research
sabine.gollner@nioz.nl



Royal Netherlands Institute for Sea Research

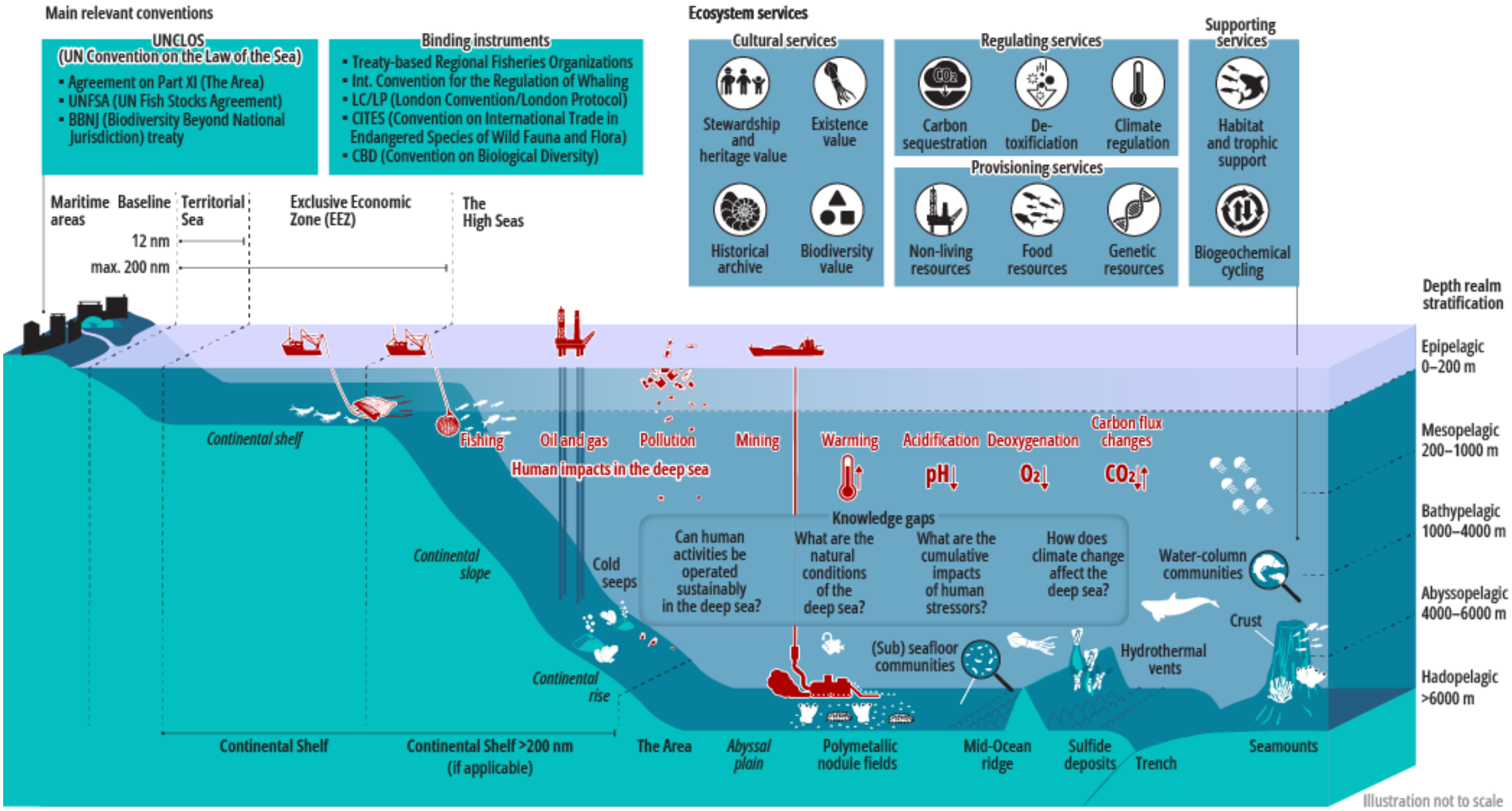
*Nature Communications (2024) 15:8466
Monika Bright#, Sabine Gollner# , André Luiz de Oliveira, Salvador Espada-Hinojosa, Avery Fulford, Ian Vincent Hughes, Stephane Hourdez, Clarissa Karthäuser, Ingrid Kolar, Nicole Krause, Victor Le Layec, Tihomir Makovec, Alessandro Messora, Jessica Mitchell, Philipp Pröts, Ivonne Rodríguez-Ramírez, Fanny Sieler, Stefan M. Sievert, Jan Steger, Tinkara Tinta, Teresa Rosa Maria Winter , Zach Bright, Russel Coffield, Carl Hill, Kris Ingram, Alex Paris
#equal contributing authors

EMB Third Thursday Science Webinar, 21 Nov 2024

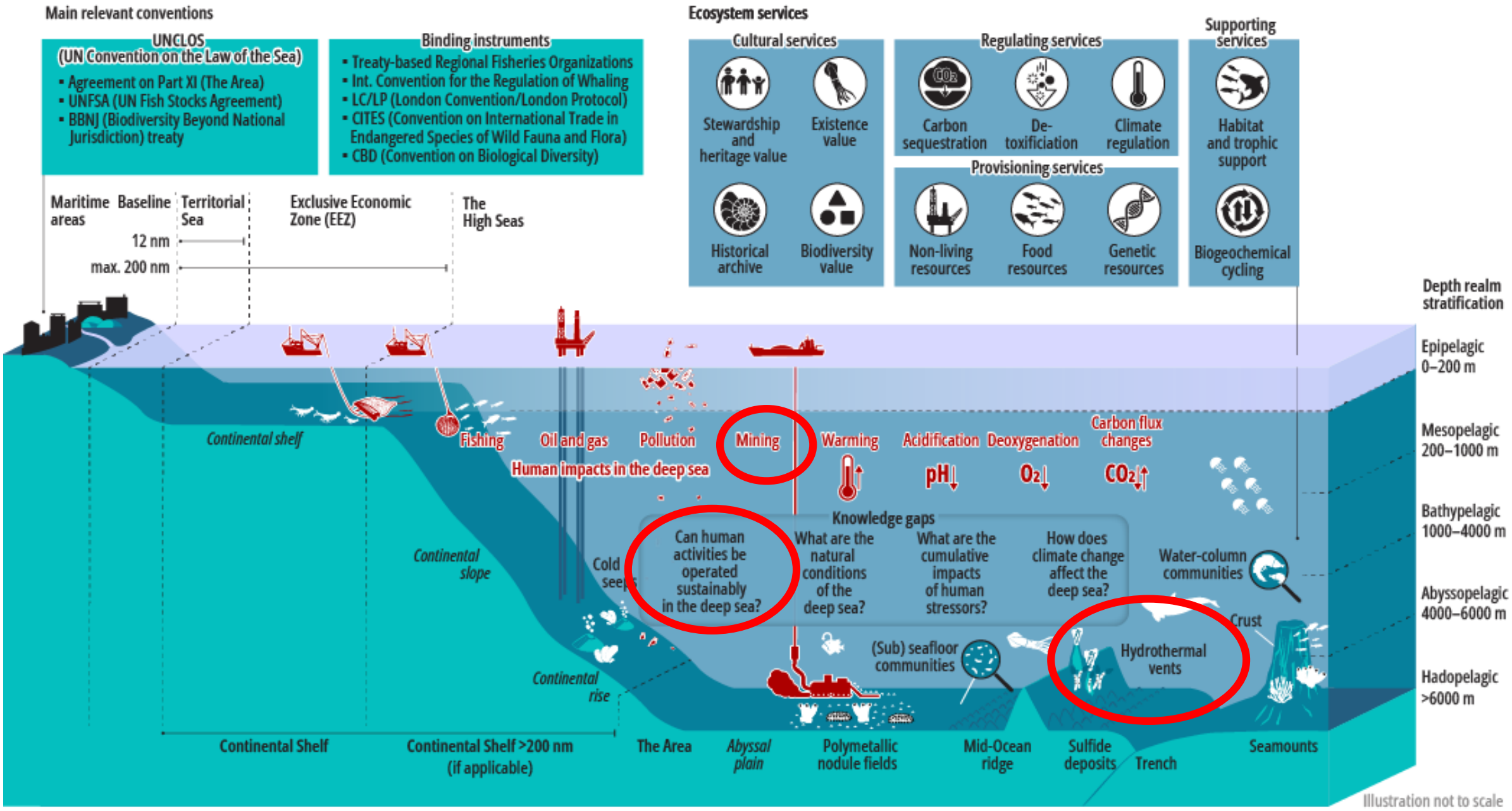
Our blue planet

Our black planet

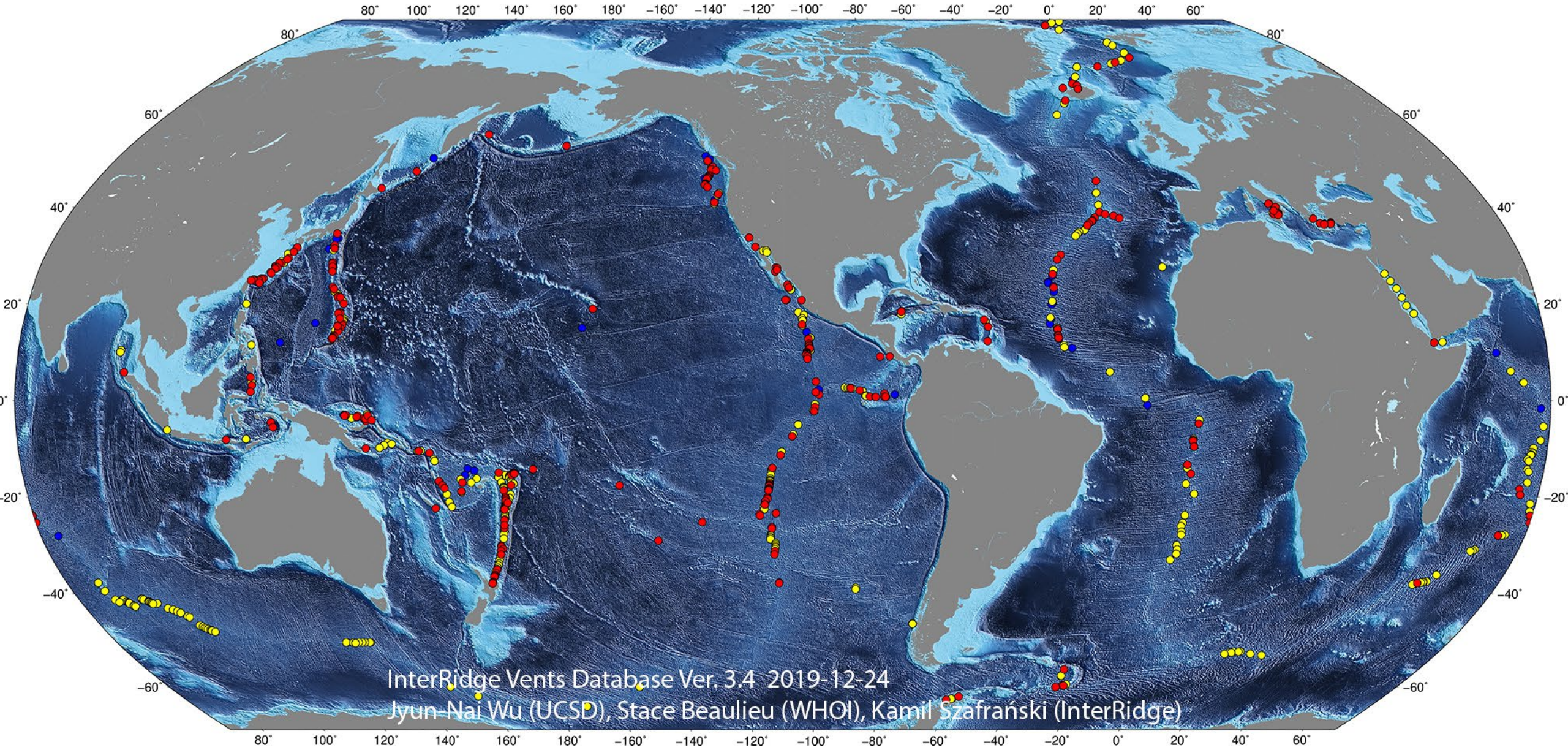
European Marine Board: Future Science Brief #12 -Deep Sea Research and Management Needs



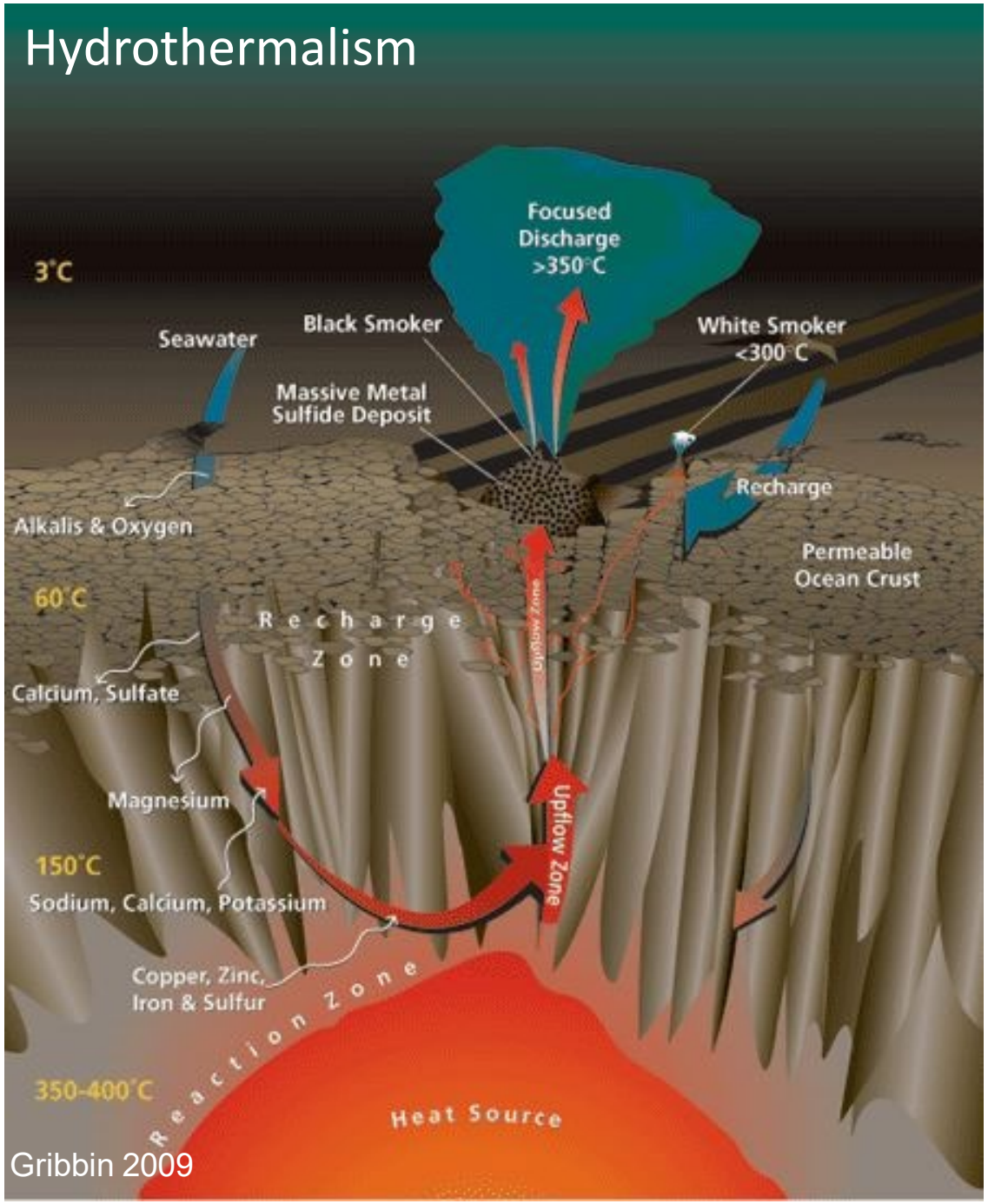
European Marine Board: Future Science Brief #12 -Deep Sea Research and Management Needs



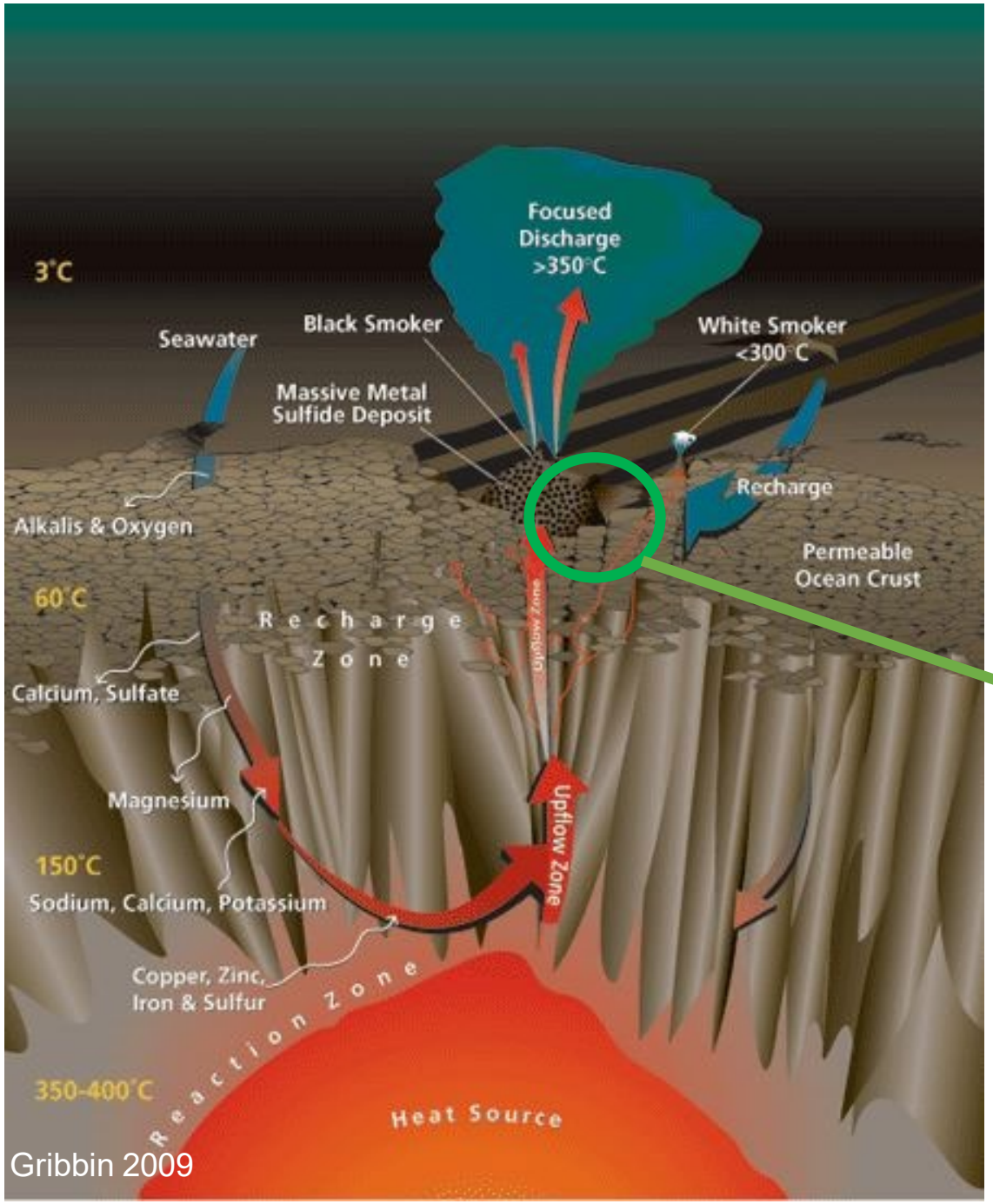
Global distribution of hydrothermal vents



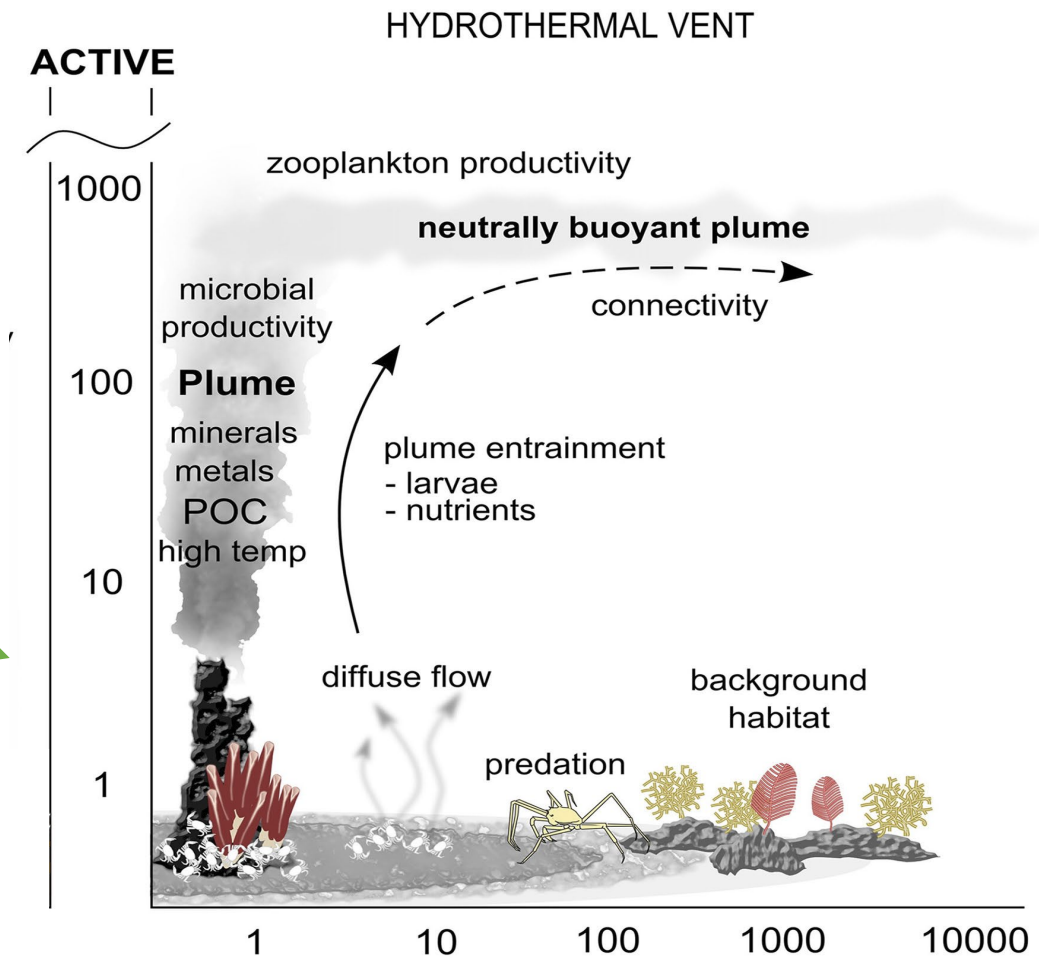
Hydrothermalism



Gribbin 2009

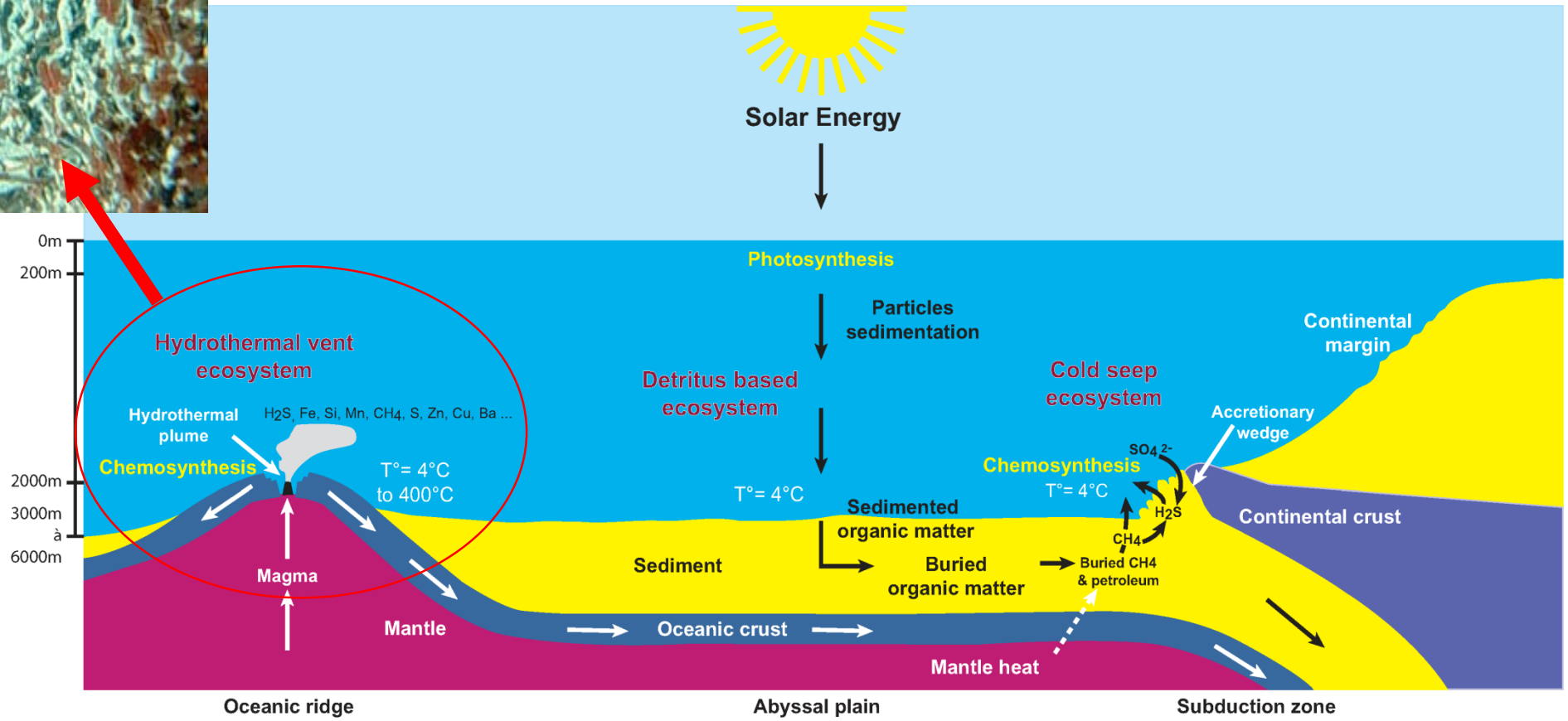


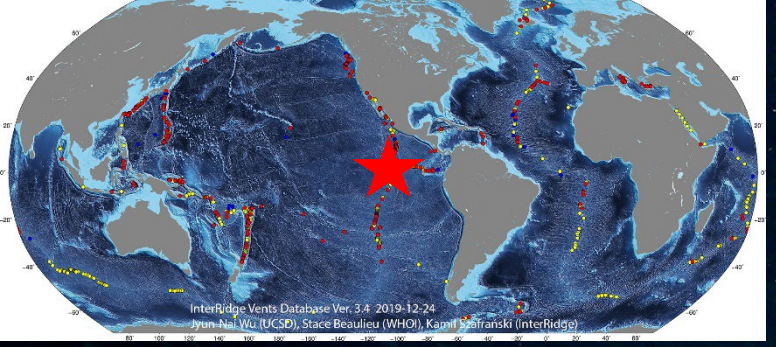
Gribbin 2009



Levin et al. 2016

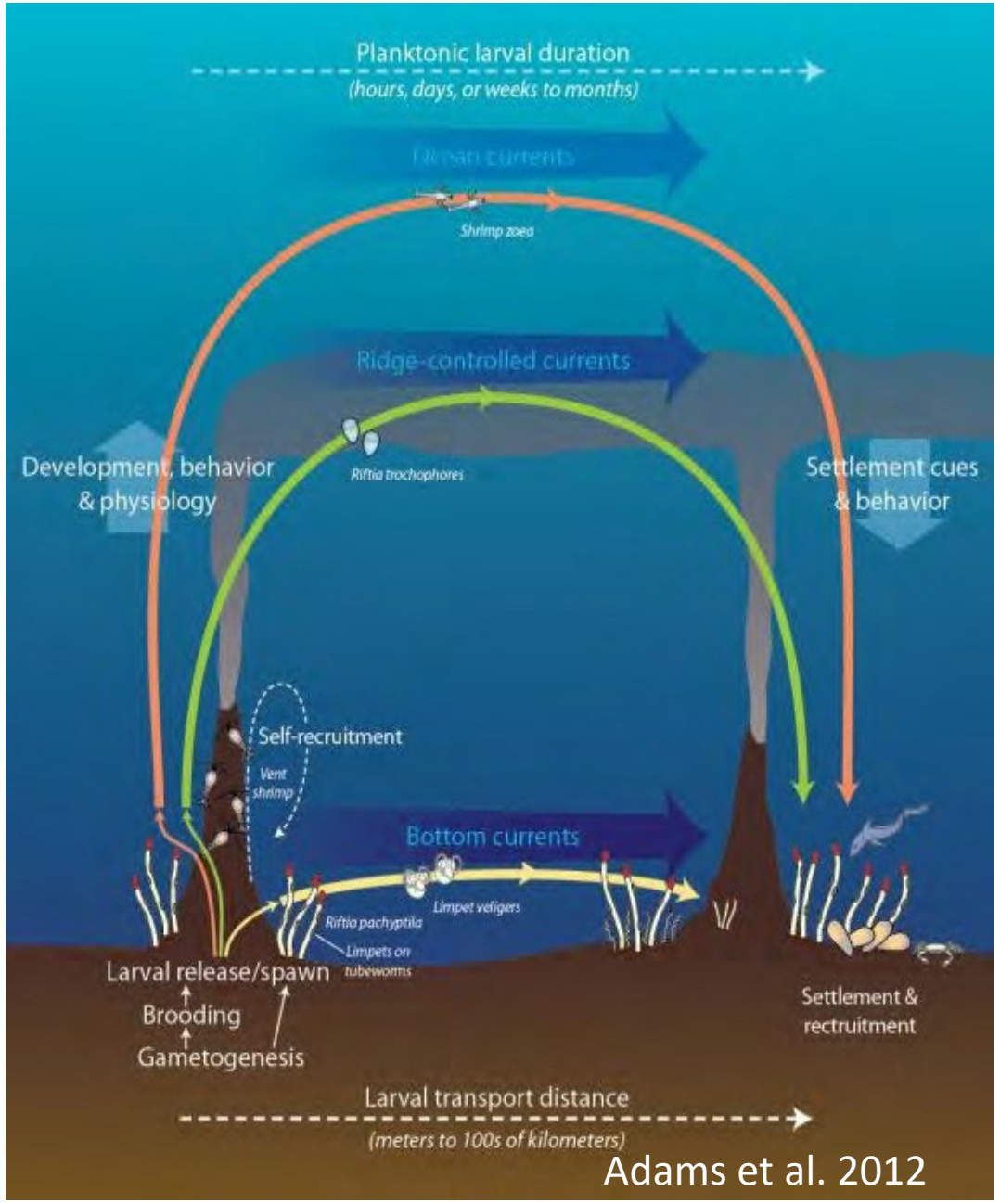
- Energy rich, reduced and hot fluids are venting out of the deep-sea floor.
- In situ primary production
- High biomass, low diversity, but unique species





Prime study site:
9°50’ North on the East Pacific Rise

- Unique species
- Well known biodiversity
- Succession studies after volcanic eruptions



Adams et al. 2012

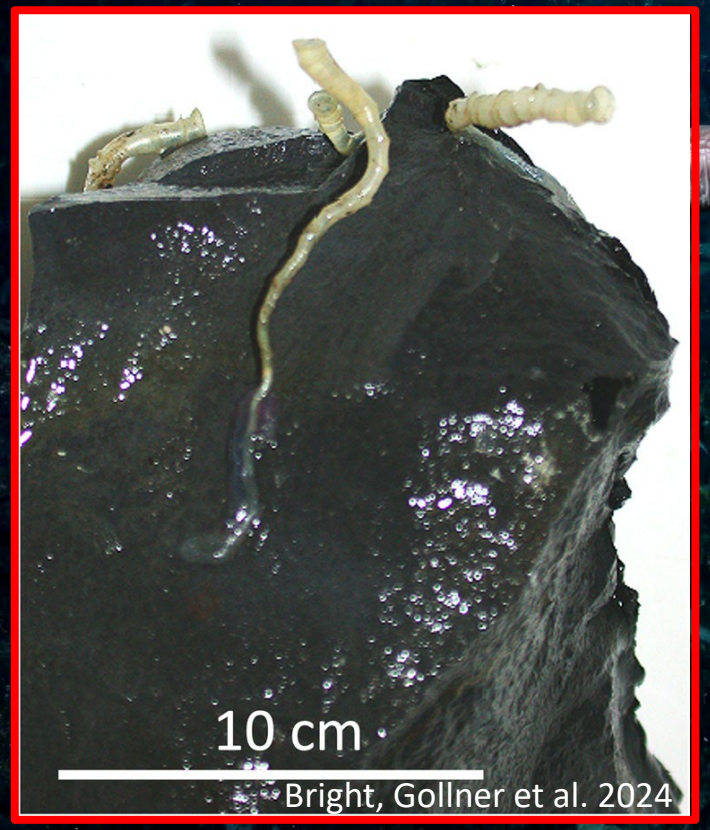
Knowing larval dispersal pathways is crucial to understand population connectivity at patchy distributed vents.

Vent larvae have been found in:

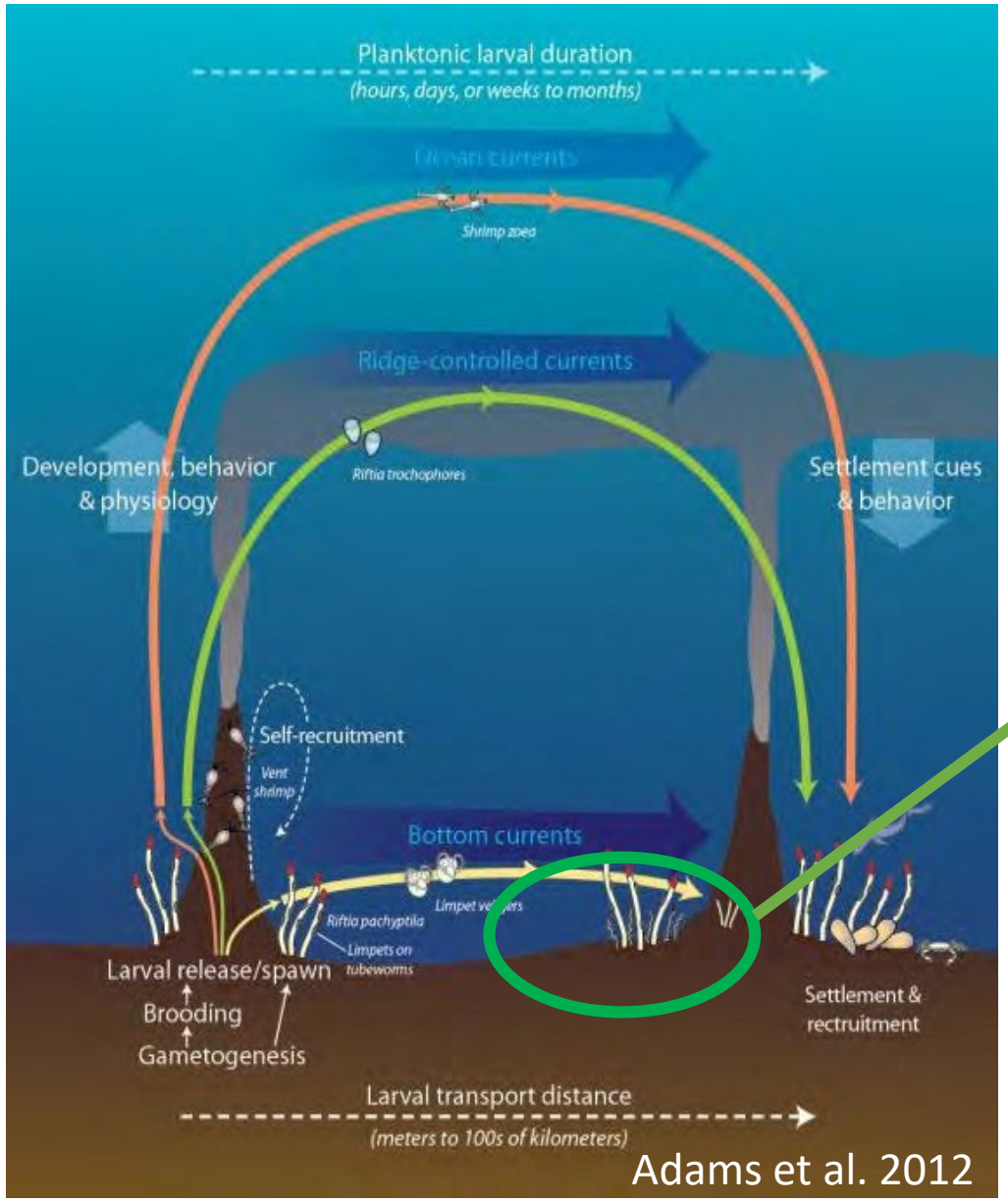
- Bottom currents
- Ridge-controlled currents
- Ocean currents

Tubeworms:

- Important foundation at hydrothermal vents
- Larvae have not been detected in the water sofar
- Tubeworms love to sit in cracks of the basalt

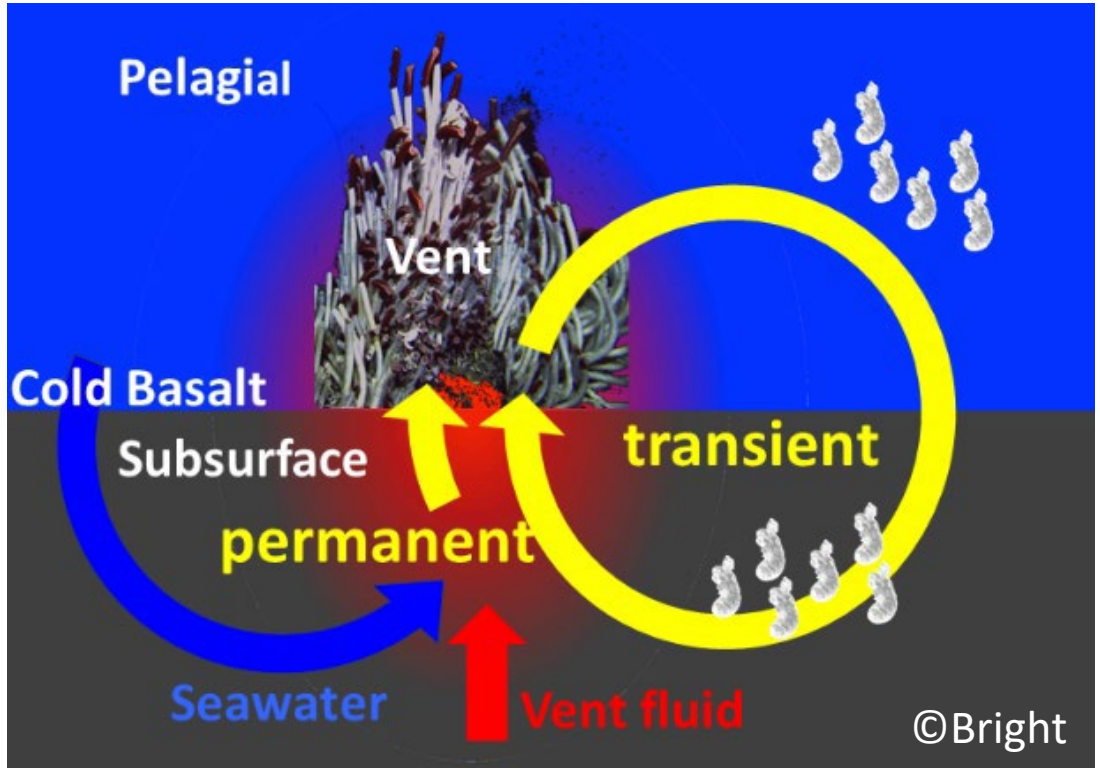


Knowledge as of 2023



Adams et al. 2012

Hypothesis:
Larvae can colonize vents via the subsurface vent channels



SOI proposal: Subsurface life – from viruses to animals – at deep-sea hydrothermal vents (PI: Bright, CO-PIs Gollner, Beinart, Gurguis, Pasulka, Sievert, Winter); funding of ship-time

NWO Project: SUBLIFE (PI Gollner, co-PIs as above); Funding of material costs and post-doc

SOI movie 06 (3 min)

Whole series of videos from expedition open accessible:

Traveling through Vents | The Underworld of Hydrothermal Vents - Week 1
https://youtu.be/lLo09UflWaQ

Curiosity-Driven Science | The Underworld of Hydrothermal Vents - Week 2
https://youtu.be/M7oqvMZriEc

A New World Beneath Vents | The Underworld of Hydrothermal Vents - Week 3
https://youtu.be/E4_CCzfwKmw

The Underworld of Hydrothermal Vents | 4K ROV Highlights
https://youtu.be/0UHB2dy1lr4

nature communications

Article

https://doi.org/10.1038/s41467-024-52631-9

Animal life in the shallow subseafloor crust at deep-sea hydrothermal vents

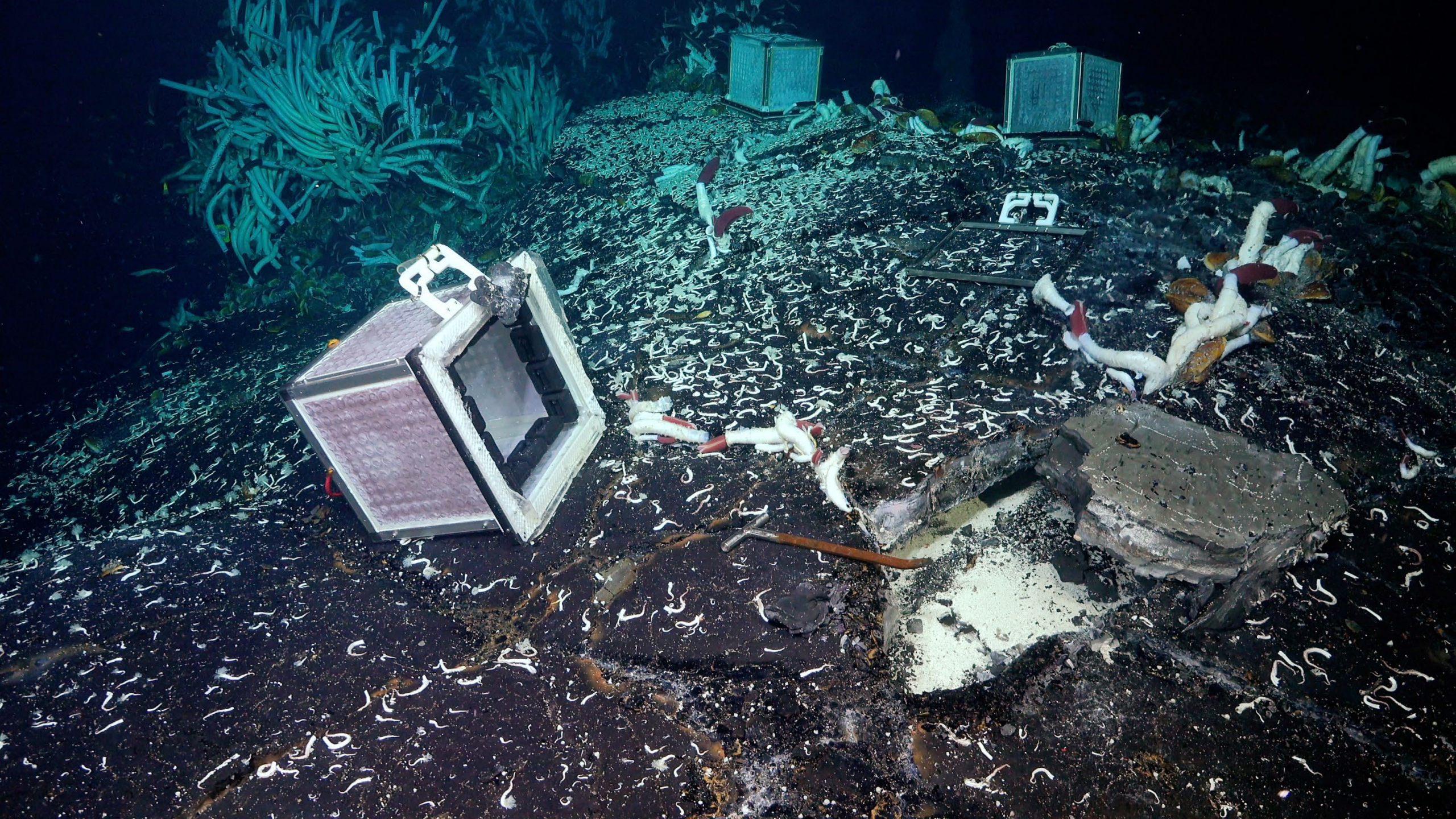
Received: 24 May 2024

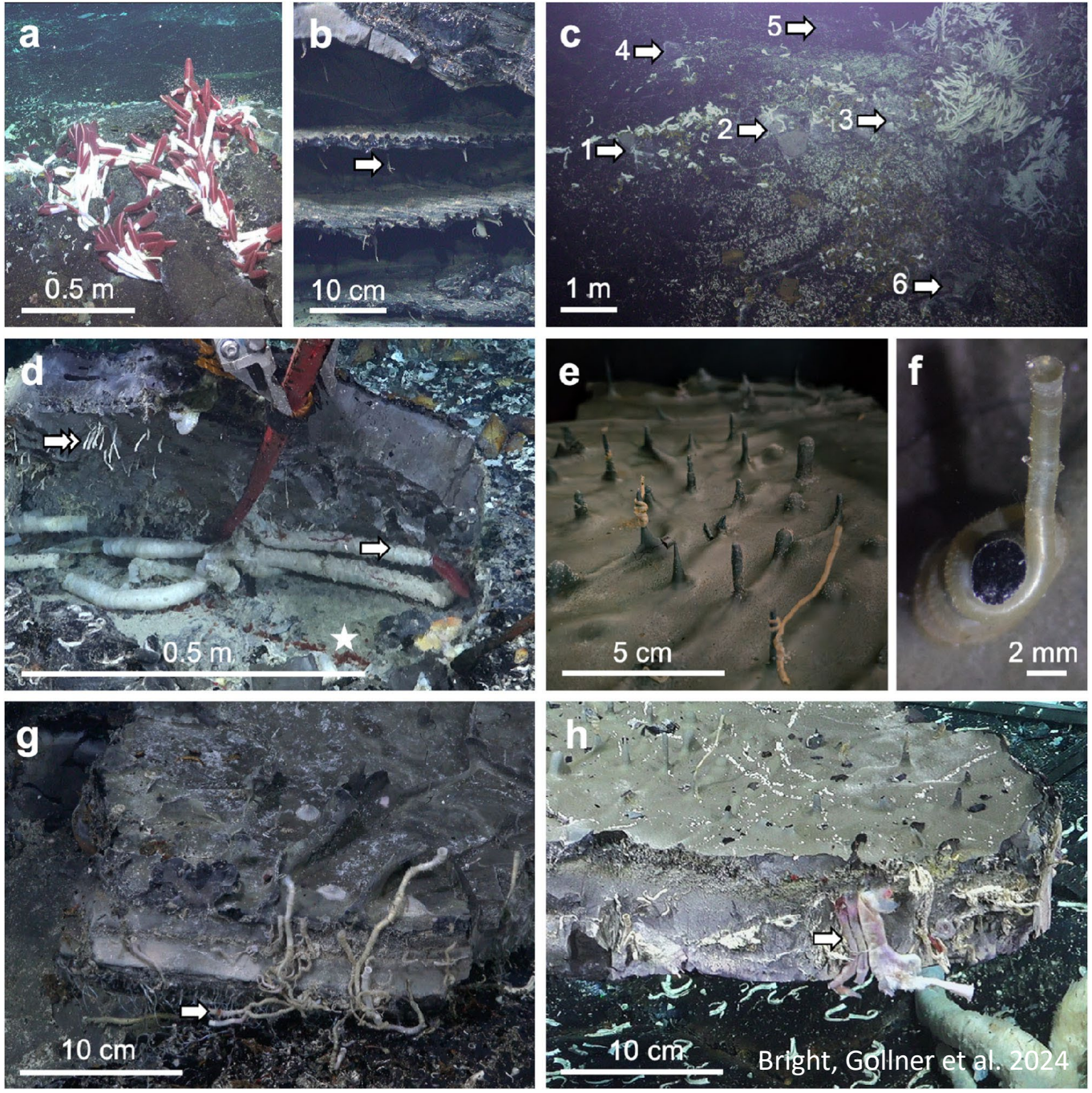
Accepted: 16 September 2024

Published online: 15 October 2024

Check for updates

Monika Bright[1,12], Sabine Gollner[2,12], André Luiz de Oliveira[3], Salvador Espada-Hinojosa[1], Avery Fulford[4,5], Ian Vincent Hughes[6], Stephane Hourdez[7], Clarissa Karthäuser[4], Ingrid Kolar[1], Nicole Krause[1], Victor Le Layec[7], Tihomir Makovec[8], Alessandro Messora[2], Jessica Mitchell[6], Philipp Pröts[1], Ivonne Rodríguez-Ramírez[9], Fanny Sieler[2], Stefan M. Sievert[4], Jan Steger[10], Tinkara Tinta[8], Teresa Rosa Maria Winter[1], Zach Bright[11], Russel Coffield[11], Carl Hill[11], Kris Ingram[11] & Alex Paris[11]



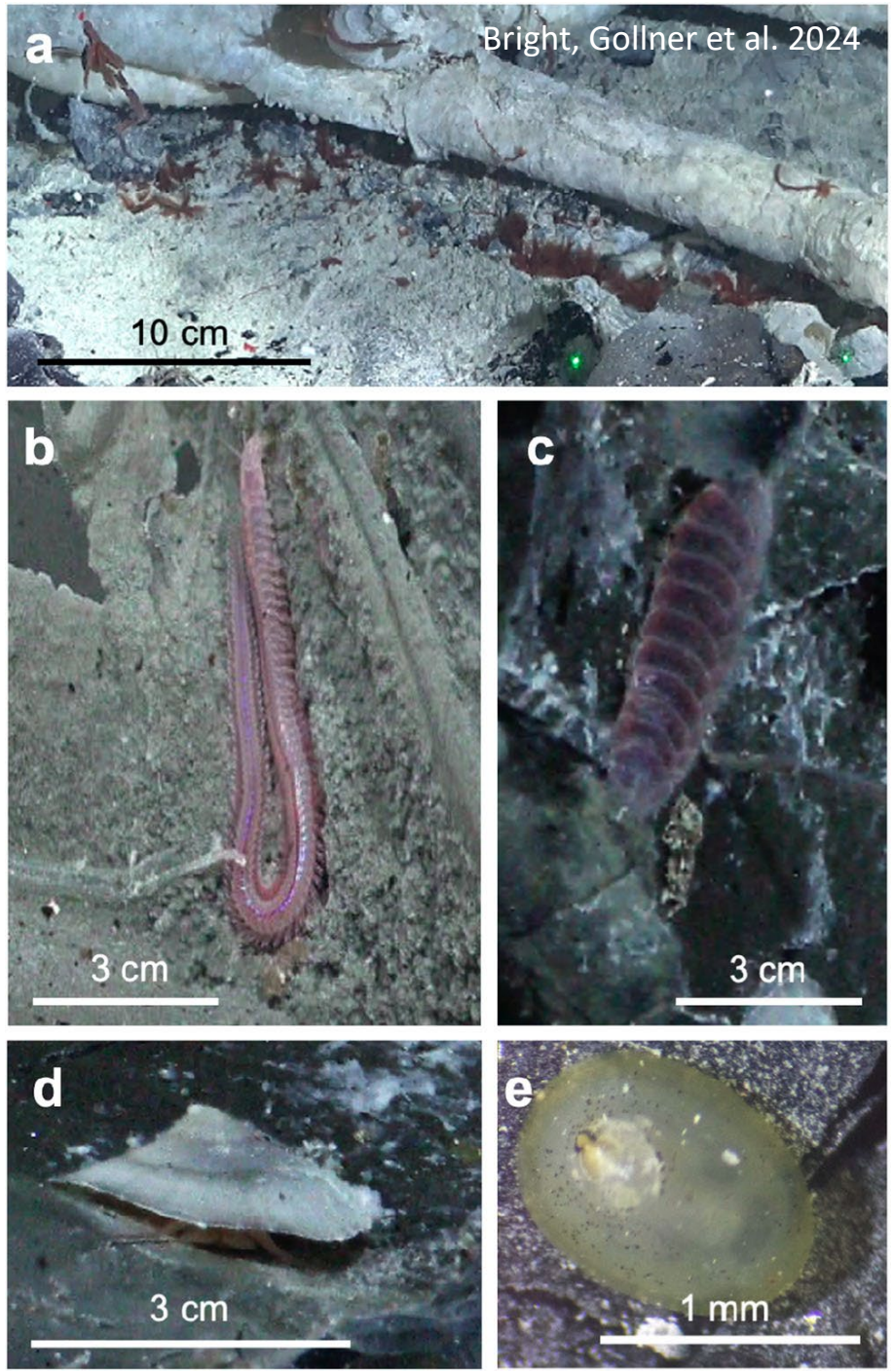


- Opened up 6 shallow vent fluid filled cavities:
  in 10 cm depth, ~10 cm in height

- Temperature & chemistry in cavities was similar to surface vents:
  ~7-25°C
  pH 5.5-6.5
  min. H2S (Σmol·L−1) 14 – 401

- Microbial communties were present in 6 cavities

- Animal communities were present in 5 cavities
  -alive & fertile sessile tubeworms
  (*Riftia* up to 0.5 in lenght)
  -*Oasisia* tubeworm more abundant in subseafloor than on surface
  -mobile vent species



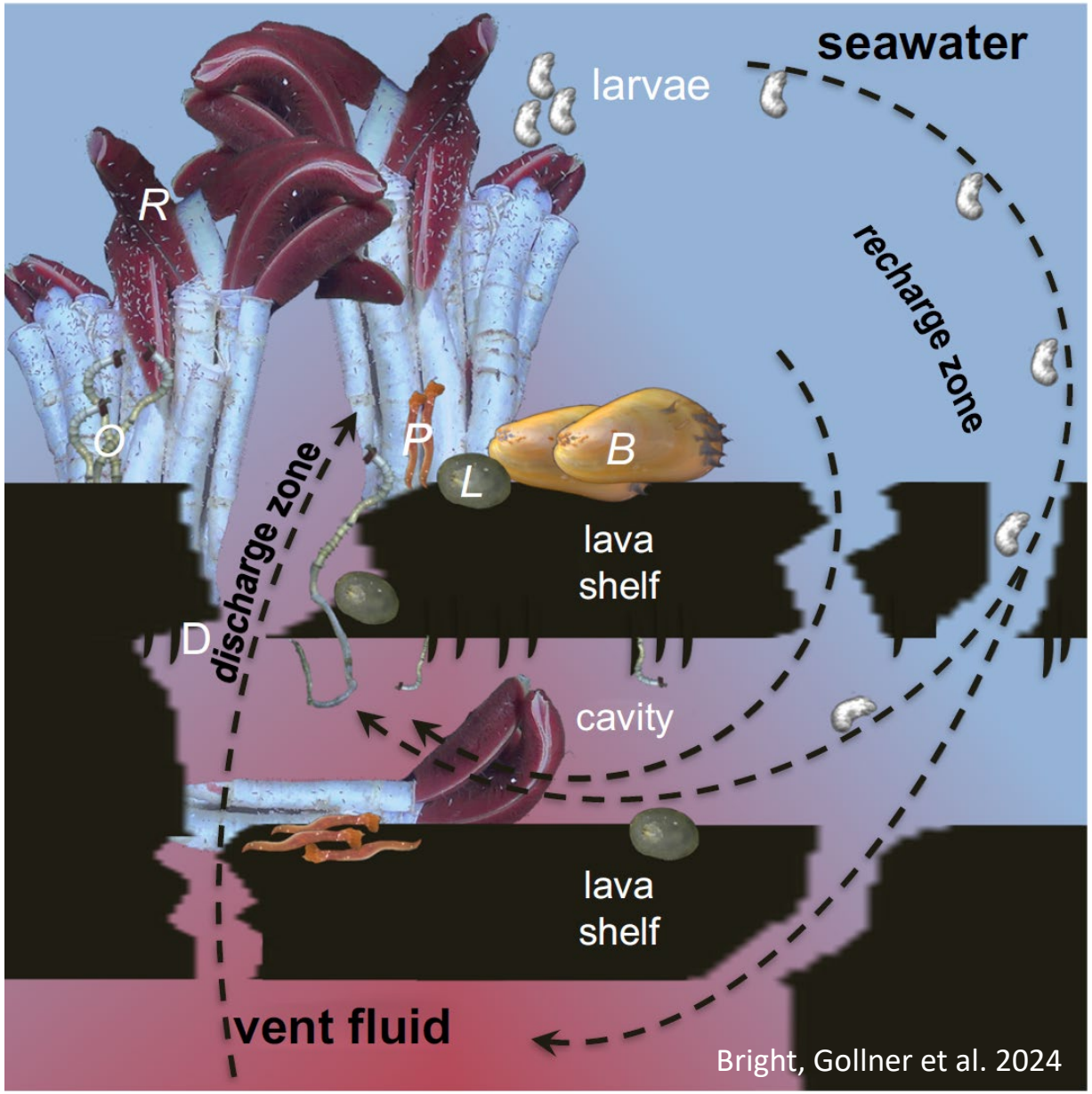
Visual mobile animals in crustal subseafloor cavities:

- Many *Paralvinella* spp. specimens on top of *Riftia pachyptila* tubes and below at the cavity bottom.
- *Nereis sandersi* on roof of cavity
- *Branchinotogluma* spp.
- Semi-sessile *Neomphalus fretterae*
- *Lepetodrilus* spp. from roof of cavity

Ongoing analyses by Lara Baptista on macro- and meiofaunal communities:

macrofauna surface vent: ~50 species
macrofauna subseafloor vent: ~30 species

-> The vent communities on the surface and in the subseafloor are connected!



Proposed connectivity model between seafloor surface and crustal subseafloor hydrothermal vents.

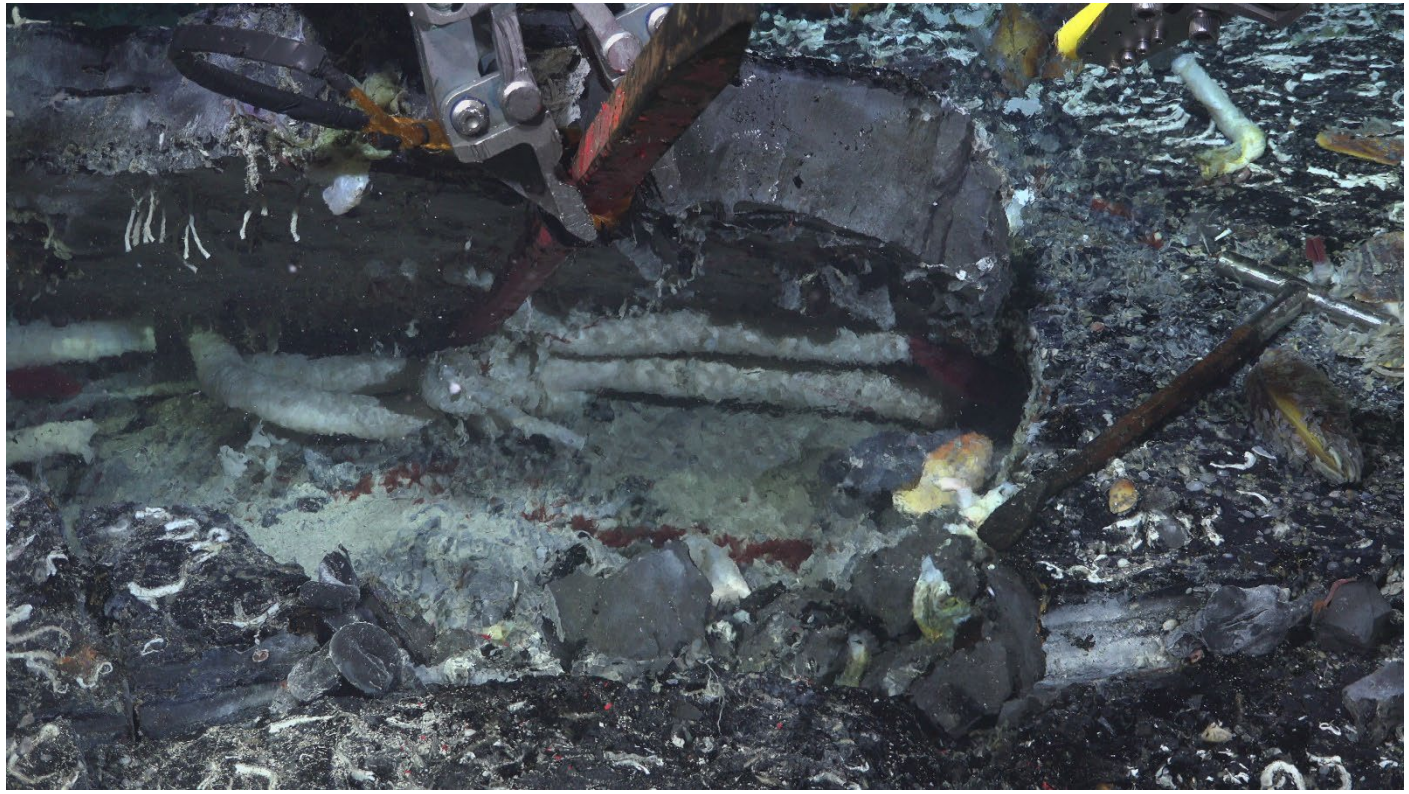
Implications of subseafloor animal life on the ecology at deep-sea hydrothermal vent:

- **Connectivity** of vent subseafloor and seafloor surface habitats **may be essential** to persist and **maintain local and regional biodiversity** where the habitat is patchy and transient.

- The proposed vent subseafloor connectivity model adds **a new dimension to the known larval dispersal**

- Potential **migration routes of mobile vent fauna** extend into the crustal subseafloor.

- Many of the observed subseafloor animals are host to dense bacterial communities that oxidize reduced chemicals and fix carbon, which has **implications for local and regional geochemical flux measurements**



The unknown extent of subseafloor cavities

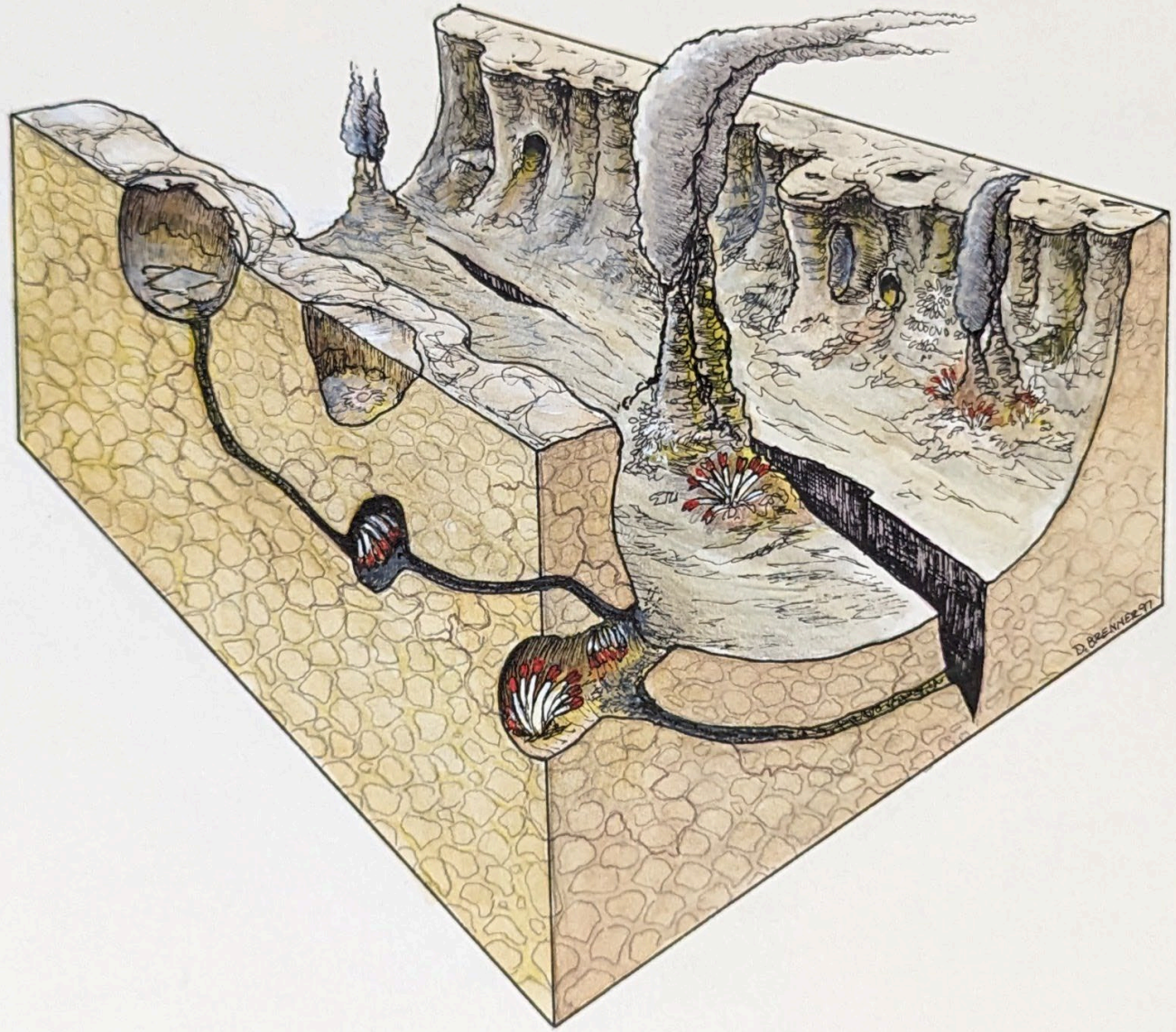
Extent of the subseafloor cavities at 9°North East Pacific Rise

- Likely reaches several lava shelfs down (up to max. a few meters)
- No knowledge on how distant to active vent sites on the seafloor

Global occurrence of subseafloor cavities

- Likely at intermediate and fast-spreading ridges (geological formation of lava shelfs with lava drips known from Juan de Fuca and EPR)
- Unknown if at slow-spreading ridges?

TECHNOLOGICAL ADVANCEMENT and **INTERDISCIPLINARY RESEARCH** needed to unravel the extend of subseafloor habitat!

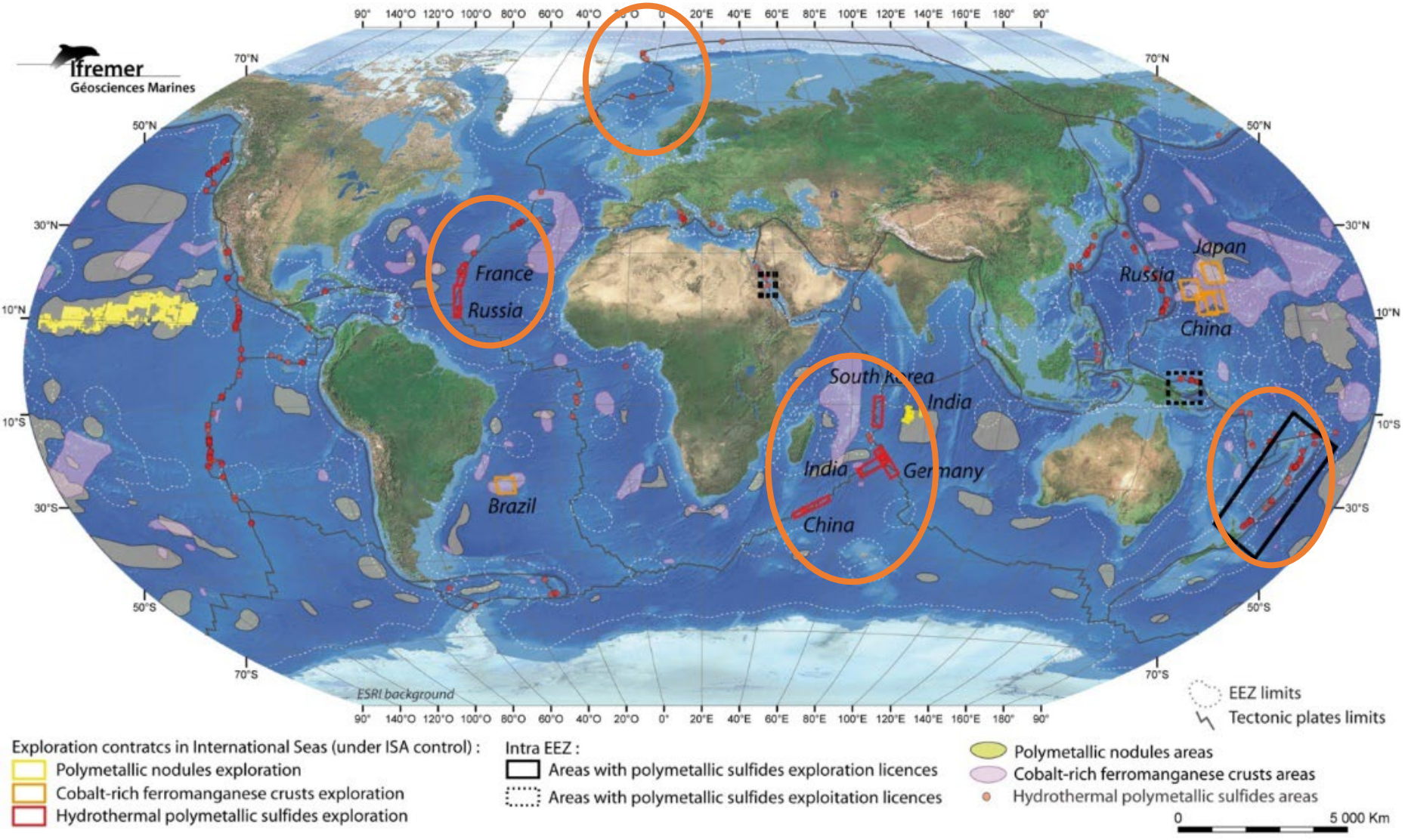


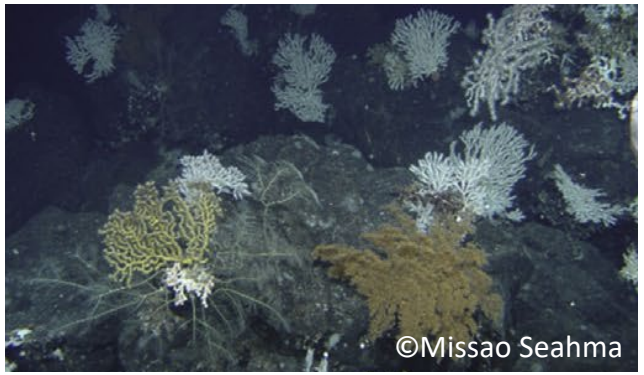
Art work commissioned by Cindy van Dover in 1997

Animal life in subseafloor cavities below hydrothermal vents: implications for management

Deep-sea mineral resources

polymetallic nodules/abyssal plains, **polymetallic sulfides/hydrothermal vents**, cobalt-rich crusts/seamounts

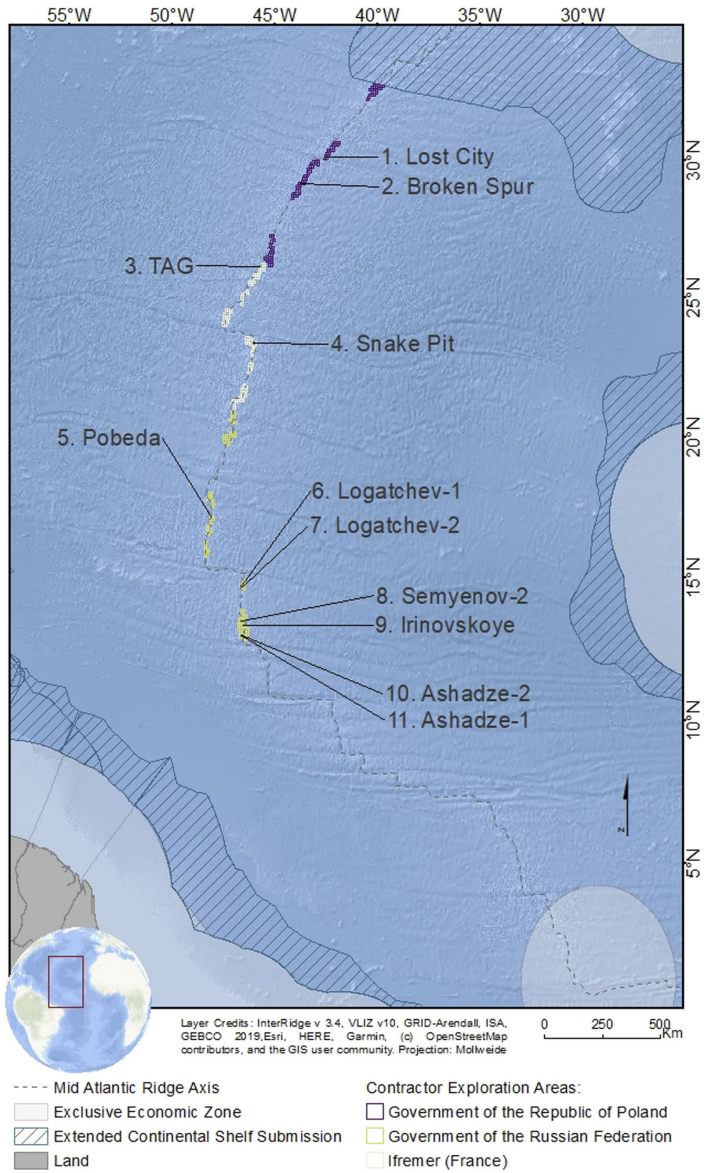


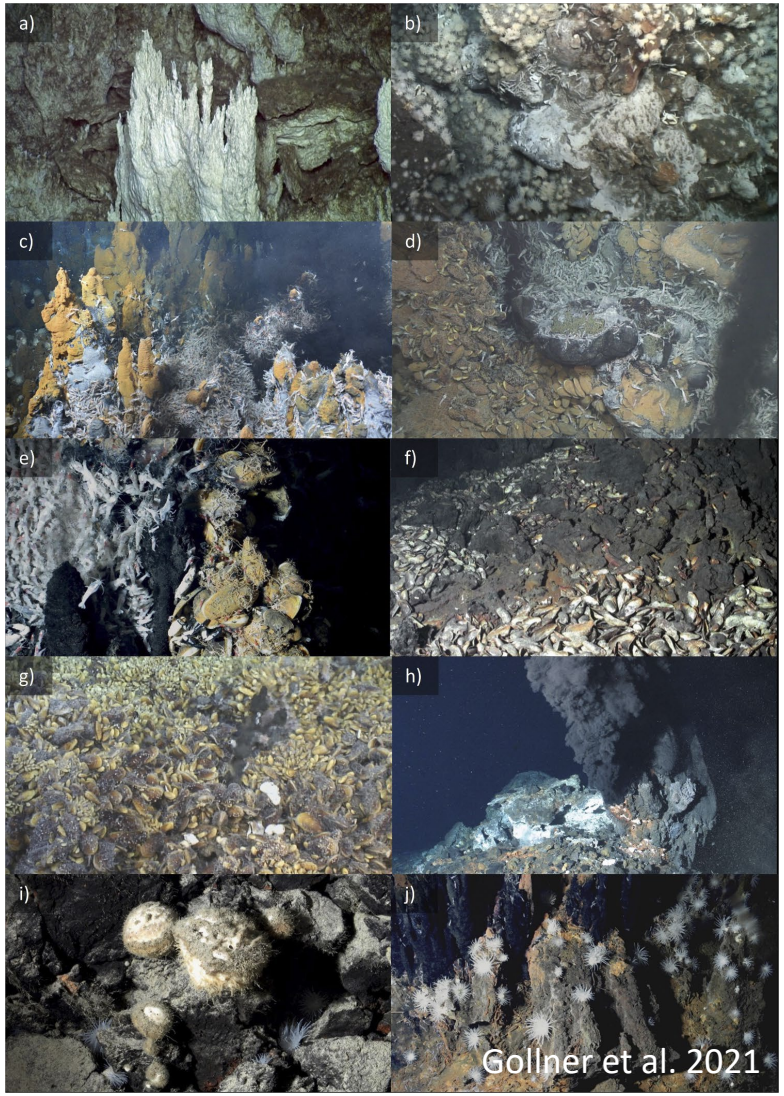


Known active vent fields under mineral exploration at nMAR (ABNJ)

Locations of the 11 hydrothermal vent fields within the *Area* on the nMAR and of the exploration contract blocks (≤ 10 km x 10 km; not to scale) awarded by the International Seabed Authority to date.

From the InterRidge Global Database of Active Submarine Hydrothermal Vent Fields Version 3.4. PANGAEA.





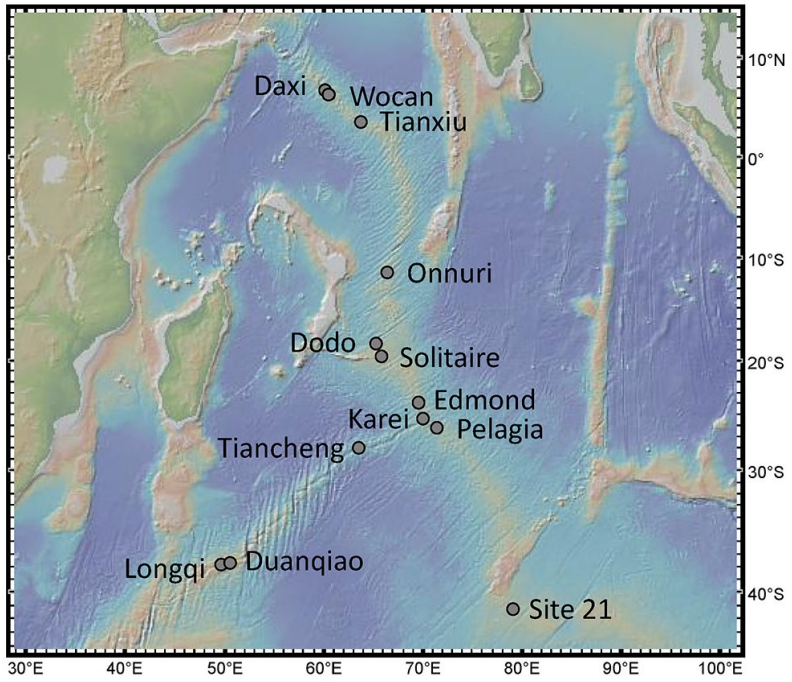
Vent fields on the nMAR.
a)Lost City
b) Broken Spur
c) TAG
d) Snake Pit
e) Logatchev-1
f) Logatchev-2
g) Semyenov-2
h) Irinovskoe
i) Ashadze-2
j) Ashadze-1
Images copyright Ifremer

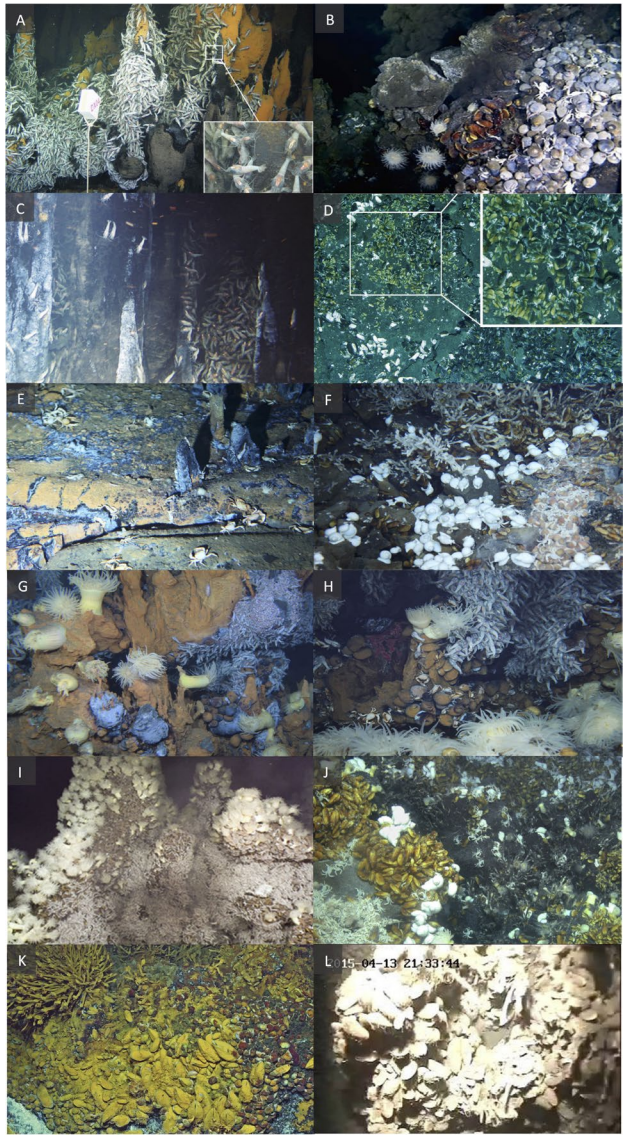
Known active vent fields under mineral exploration in the Indian Ocean (ABNJ)

Active hydrothermal vent ecosystems in the Indian Ocean are in need of protection

Naomi van der Most[1*], Pei-Yuan Qian[2,3*], Yan Gao[4] and Sabine Gollner[1]

TYPE Review
PUBLISHED 25 January 2023
DOI 10.3389/fmars.2022.1067912

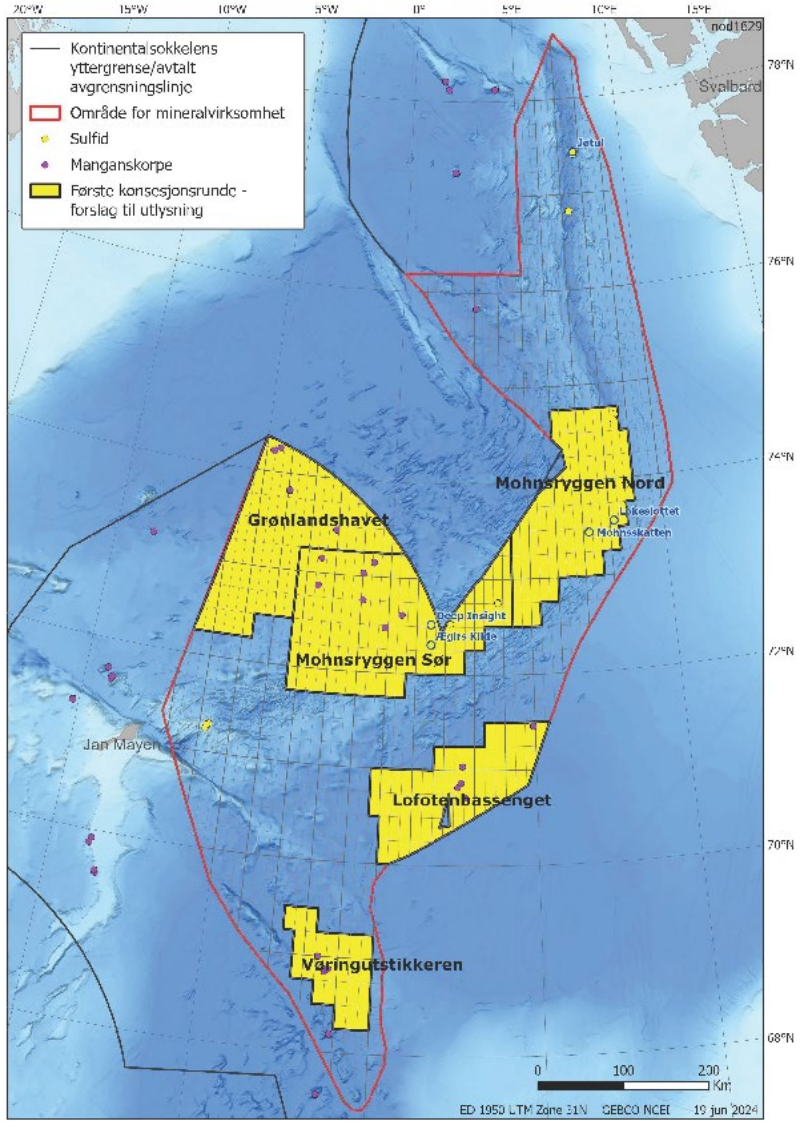




Vent fields at IOR

(A) Daxi
(B) Wocan
(C) Tianxiu
(D) Onnuri
(E) Dodo
(F) Solitaire
(G) Edmond
(H) Kairei
(I) Pelagia
(J) Tiancheng
(K) Longqi
(L) Duanqiao

Mineral exploration in areas within national jurisdiction: example Norway



The Norwegian government has started a process suggesting to open areas in the Arctic for mineral exploration.

Application of scientific criteria for identifying hydrothermal ecosystems in need of protection

S. Gollner, A. Colaço,A. Gebruk, P.N. Halpin, N. Higgs, E. Menini, N.C. Mestre, P.-Y. Qian, J. Sarrazin, K. Szafranski, C.L. Van Dover

Criteria (e.g. uniqueness, functional significance, fragility,…) adapted from

FISHING

Food and Agricultural Organization (FAO)

Vulnerable Marine Ecosystems (VMEs)

MARITIME ACTIVITIES

International Maritime Organization (IMO)

Particularly Sensitive Sea Areas (PSSAs)

BIOLOGICAL DIVERSITY

Convention on Biological Diversity (CBD)

Ecologically or Biologically Significant Areas (EBSAs)

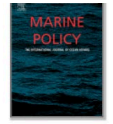
Highlights

- Criteria exist to assess vulnerability and importance of marine ecosystems.
- Nine criteria were applied to 11 hydrothermal vents on the Northern Mid-Atlantic Ridge, and to 12 in the Indian Ocean
- Suites of physico-chemical and biological attributes are unique at each vent field.
- **All vent fields meet multiple or all criteria for vulnerability and importance**.
- While further research always adds insight, **enough is known** about active hydrothermal vents now **to proceed with their protection (worldwide).**

ELSEVIER

Marine Policy

Volume 132, October 2021, 104641



Application of scientific criteria for identifying hydrothermal ecosystems in need of protection

S. Gollner [a] ✉, A. Colaço [b], A. Gebruk [c], P.N. Halpin [d], N. Higgs [e], E. Menini [d], N.C. Mestre [f], P.-Y. Qian [g], J. Sarrazin [h], K. Szafranski [i,j], C.L. Van Dover [d]

CRITERION	SUBCRITERIA	nMAR Vent Fields in the *Area* (North to South)										
		Lost City	Broken Spur	TAG	Snake Pit	Pobeda	Logatchev 1	Logatchev 2	Semyenov	Irinovskoe	Ashadze 2	Ashadze 1
1. 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:	1.1 habitats that contain endemic species											
	1.2 habitats of rare, threatened, or endangered species; only in discrete areas											
	1.3 nurseries or discrete feeding, breeding, or spawning areas	?										
	1.4 unique or unusual biotic or abiotic features (chemical, physical, geological)											
2. Functional significance. A discrete area or habitats that are necessary:	2.1 for survival, function (e.g., feeding), spawning/reproduction, or recovery of species							?				
	2.2 for specific life history stages (e.g., nursery grounds or rearing areas, migratory routes for fish, reptiles, birds, mammals, invertebrates)	?						?				
	2.3 for rare, threatened, or endangered marine species							?				
3. Fragility.	3.1 An area that contains 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)											
4. Life-history traits that make recovery difficult. Ecosystems that are characterized by populations or assemblages of species with one or more of the following characteristics	4.1 slow growth rates							?				
	4.2 late age of maturity							?				
	4.3 low or unpredictable recruitment							?				
	4.4 long-lived species							?				
5. Structural complexity. An area or ecosystem that is characterized by:	5.1 complex physical structures created by biotic and abiotic features											
	5.2 ecological processes are dependent on these structured physical systems							?				
6. Biological diversity.	6.1 An area that contains comparatively higher diversity of ecosystems (including high diversity associated to complex structures), habitats, communities, or species, or has higher genetic diversity											
7. Biological productivity.	7.1 An area that has a particularly high rate of natural biological production. Such productivity is the net result of biological and physical processes which result in an increase in biomass							?				
8. Naturalness.	8.1 An area with a comparatively higher degree of naturalness due to lack of or low level of human-induced disturbance or degradation							?				
9. Ecosystem services. An area or ecosystem that provides or has high potential to provide:	9.1 provisioning services, such as food and energy, which are directly used by people (including marine genetic resources and bioprospecting, bioinspired materials, bioinspired processes)							?				
	9.2 regulating services, that cover the way ecosystems regulate other environmental media or processes (including climate regulation, biological pump, and carbon sequestration)							?				
	9.3 cultural services that are related to the cultural or spiritual needs of people. These include spiritual services, aesthetic services, recreation, education (e.g., an area that offers an exceptional opportunity to demonstrate natural phenomena), and science (e.g., a research area that has high scientific interest, increasing scientific knowledge; or e.g., an area that suitable for baseline monitoring conditions because it is in near natural condition)											
	9.4 supporting services, such as ecosystem processes and functions that underpin other three types of services (including primary production, nutrient cycling)											

Transdisciplinary research to protect vents: law & science & policy

- In draft Regional Environmental Management Plans (REMP) for the nMR, the International Seabed Authority (ISA) lists active vents as “sites in need of protection” in a “point-coordinate format”.
- Currently, Norway does not favor mining exploration at active vents.

-> It is thus acknowledged that active vents need protection.
-> **but**….

Area-based management at vents:
from currently insufficient protection to effective future protection

From a science perspective we know enough to proceed with the protection of the vent ecosystem.

Current protection in ABNJ includes a point-coordinate for active vents (SINP) and a not further spatially defined zoning scheme for protection.

Science: There is a need to consider the sphere of vent influence and **to define the 3-D space that protects the unique and fragile active vent** to safeguard the high ecosystem services.

Goal: A standardized approach to define this 3-D space that may be applied by different bodies.

The vent ecosystem: hot fluids, enriched in sulfide and minerals

<u>The vent ecosystem:</u>
Fluids derive from ocean water which
(1) sinks through cracks into crust
(2) gets heated by magma and enriched in minerals
(3) exits through channels & precipitates the metals (= black smokers)

OR (=INACTIVE VENTS)
(4) Fluids can't exit anymore (channels naturally blocked thus stopping temporally vent fluid emissions).

ACTIVE and INACTIVE vents within the same active vent field are spatially very close to each other!

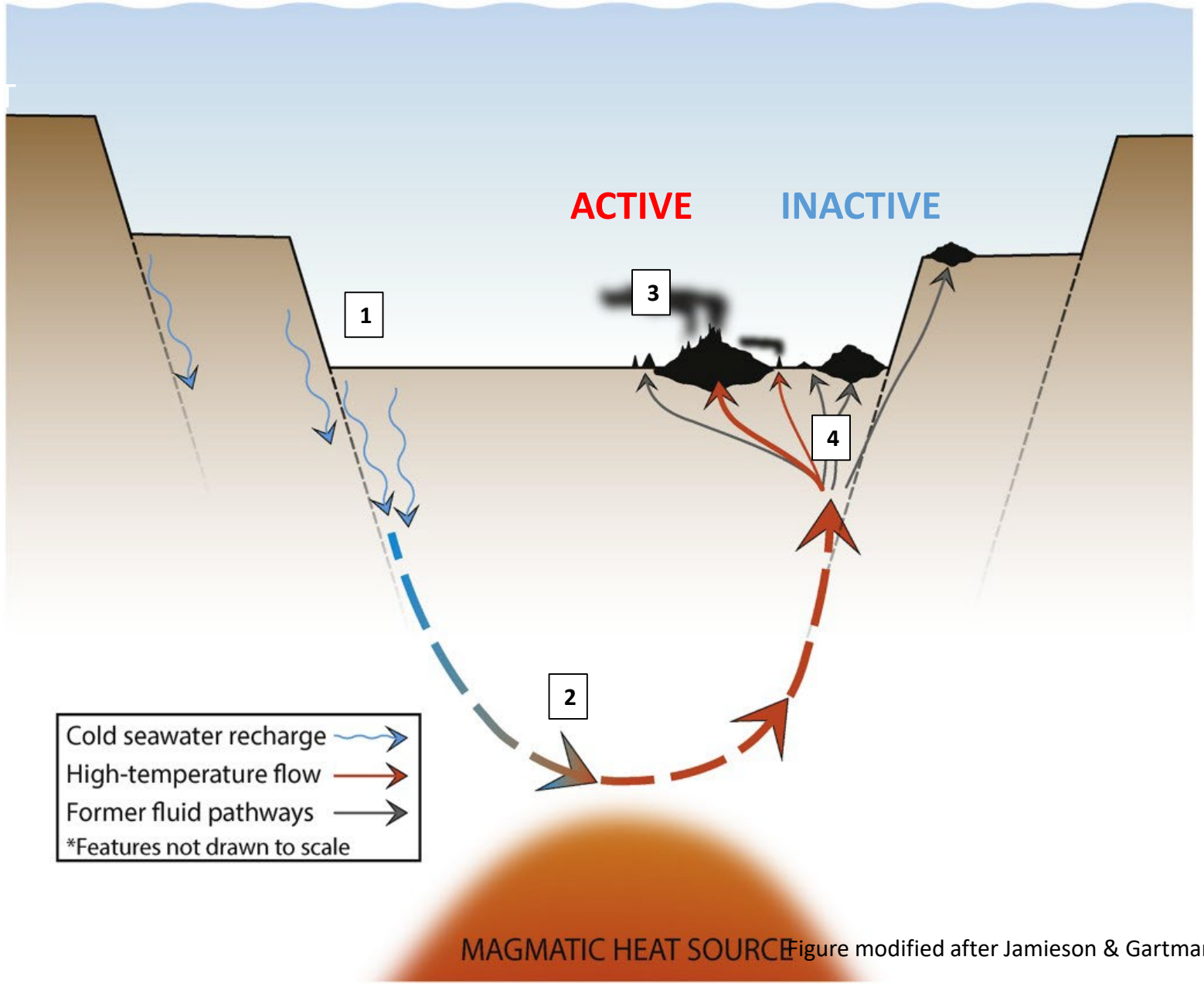


Figure modified after Jamieson & Gartman 2020

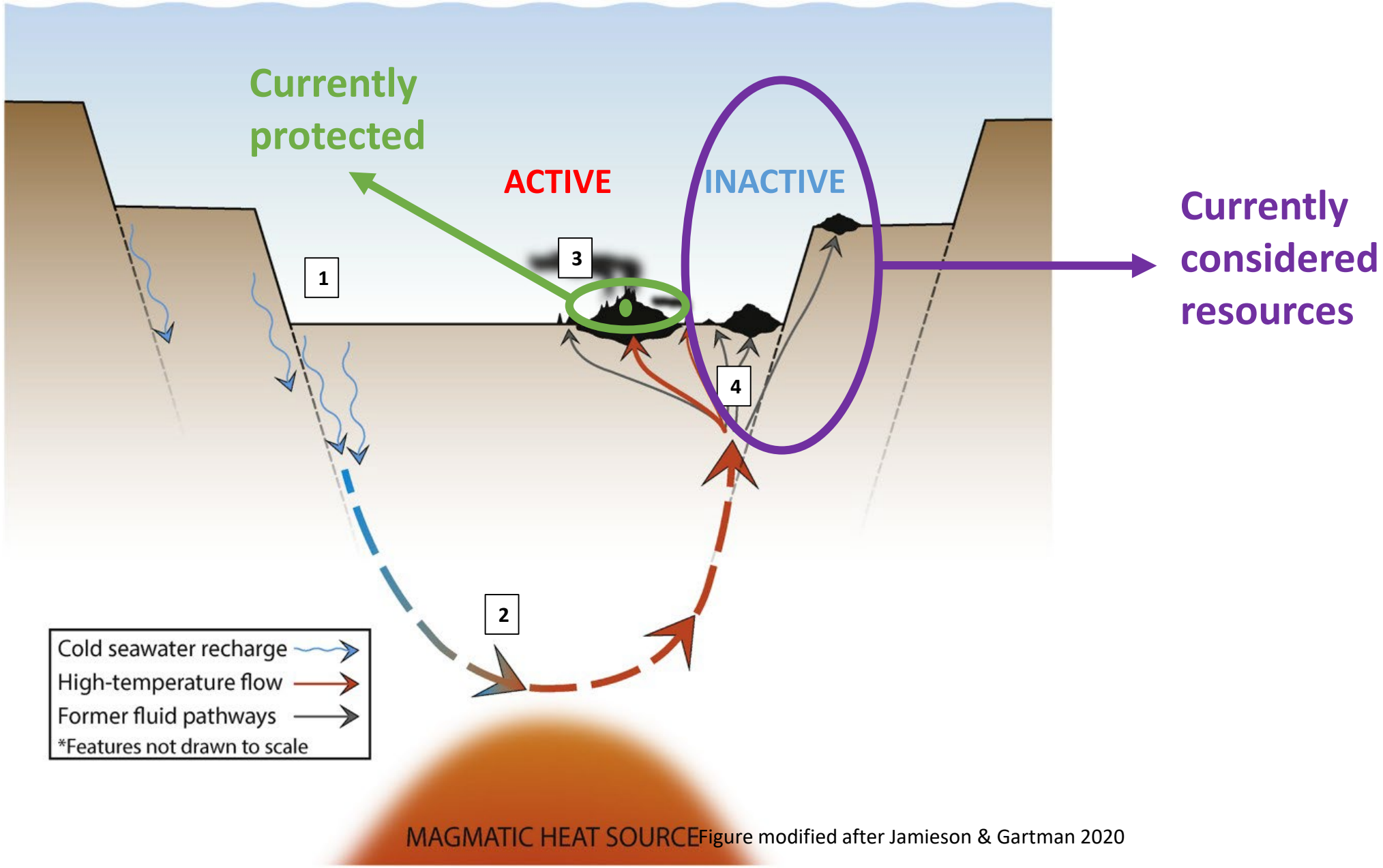
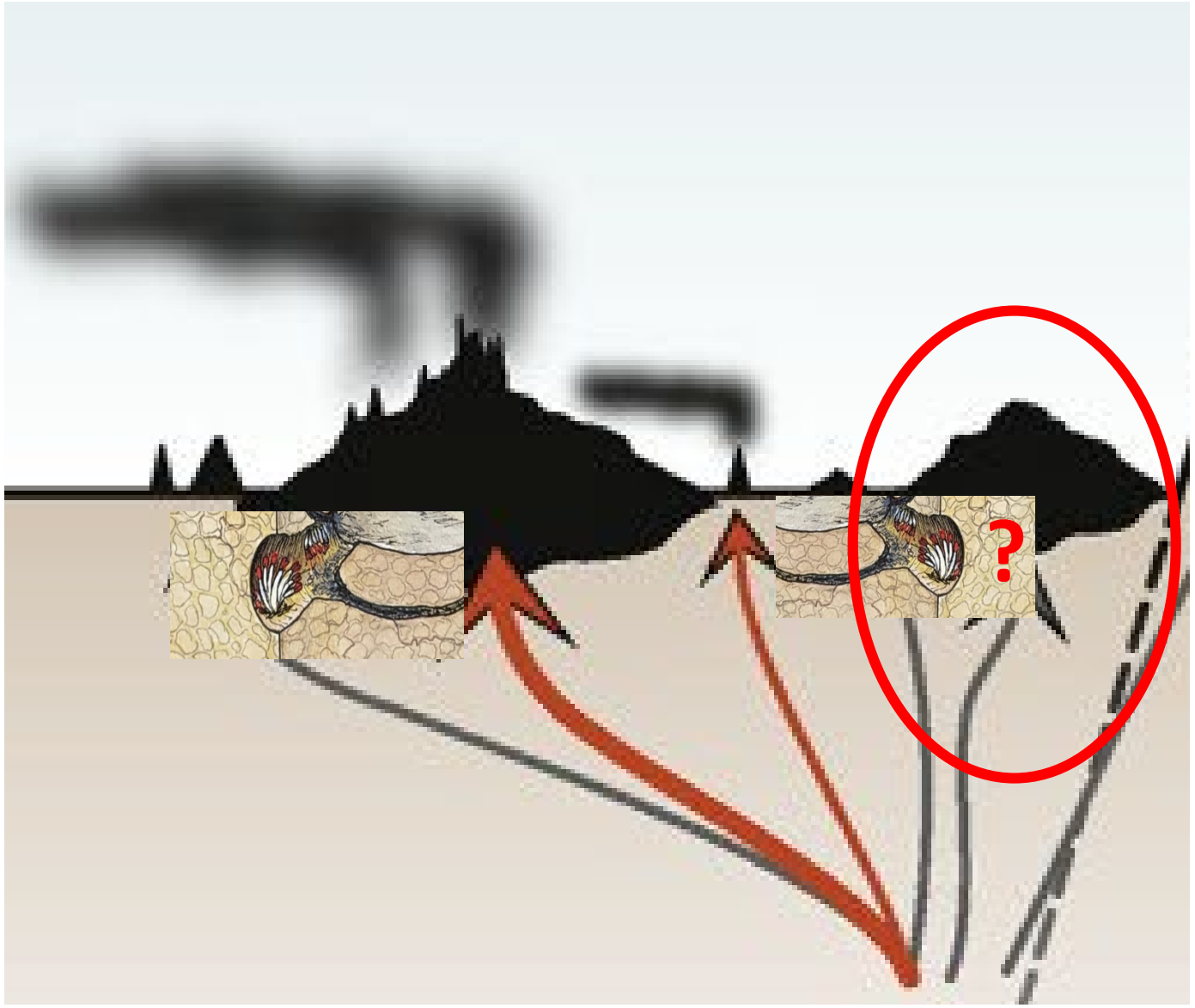
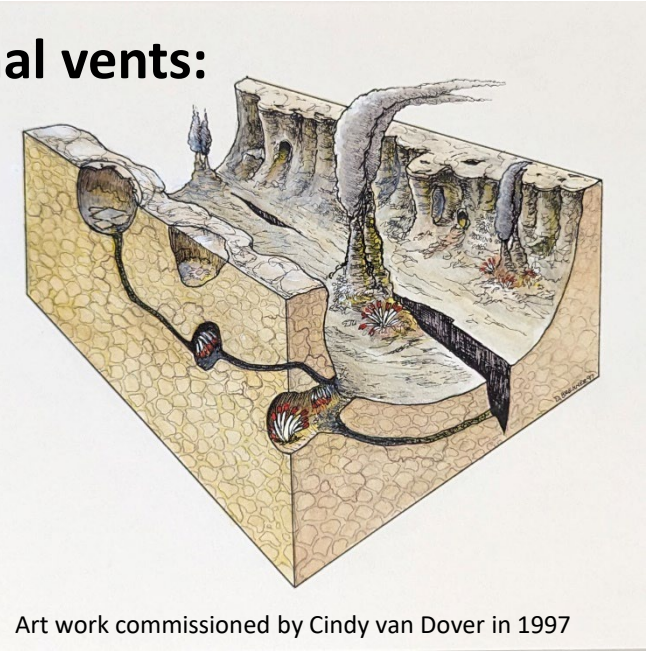


Figure modified after Jamieson & Gartman 2020

Insufficient scientific knowledge on extent of subseafloor life at hydrothermal vents:





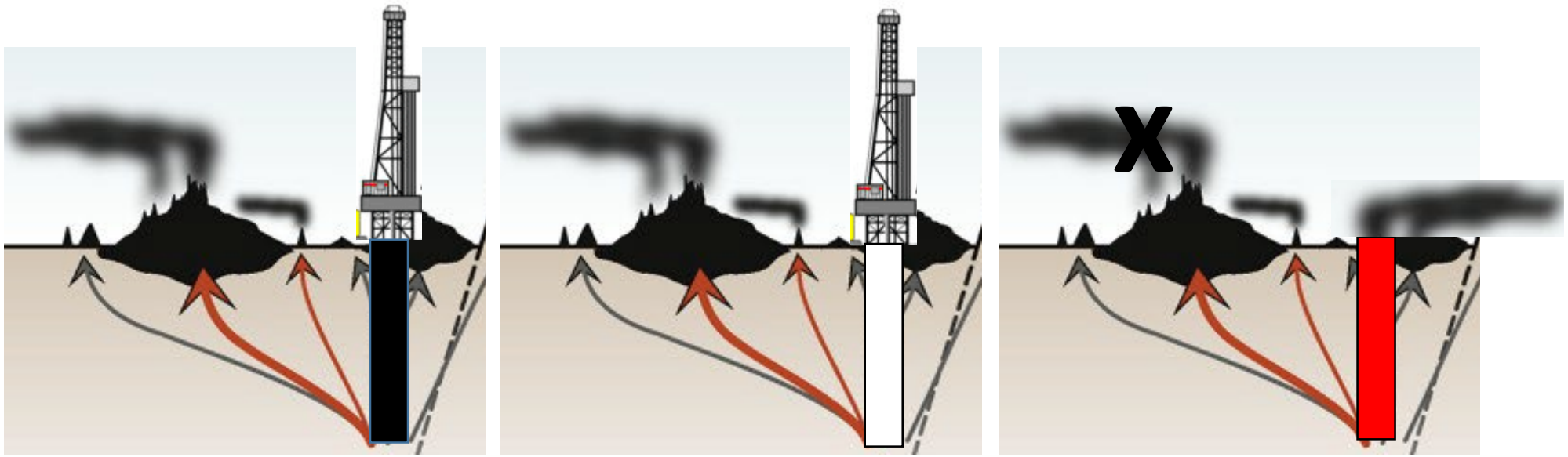
Art work commissioned by Cindy van Dover in 1997

What if subseafloor vent life extends to inactive areas?

->Resource extraction could harm unique active vent communities.

->Knowledge on extent of shallow subseafloor communities needed.

Insufficient scientific knowledge on pathways of vent fluids through the crust



What if resource extraction reactivates inactive vents and draws away energy from nearby active vents?

->Resource extraction at inactive vents could harm unique active vent communities.

->Knowledge on extent of subseafloor circulation system needed.

Potentially needed 3-D protected area to safeguard unique life and ecosystem function of active vents, recognizing the sphere of vent influence & acknowledging the knowledge gaps

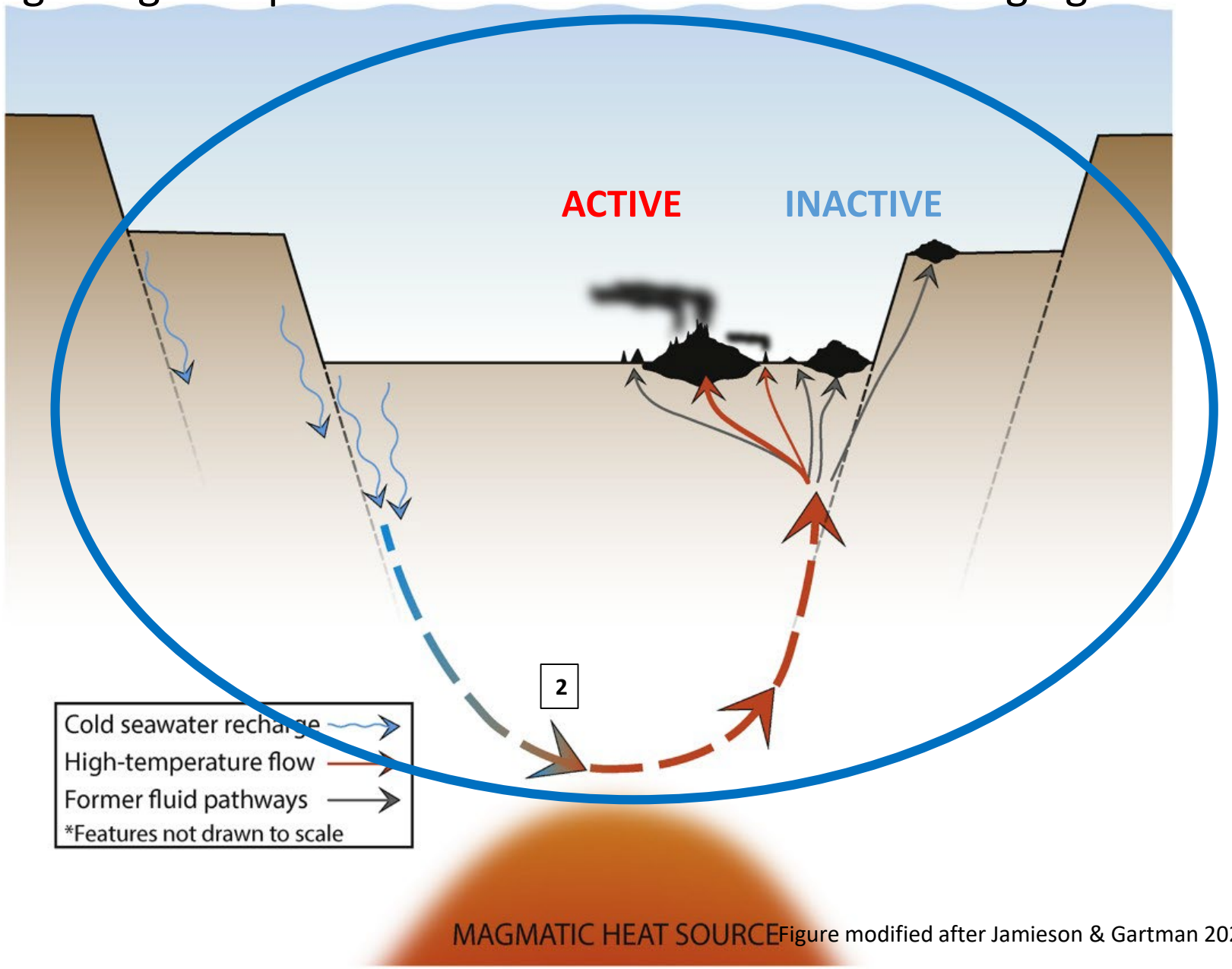


Figure modified after Jamieson & Gartman 2020

Take home messages:

- The deep sea is full of surprises.
- Vent animal life exists in the earths crust.
- Precaution is needed with regards to deep-sea mining at polymetallic sulfides. 3-D protecting zones are required.

Royal Netherlands Institute for Sea Research

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