Thoughts on US NSF Science Priorities for "Critical Minerals" (Marine Minerals) research

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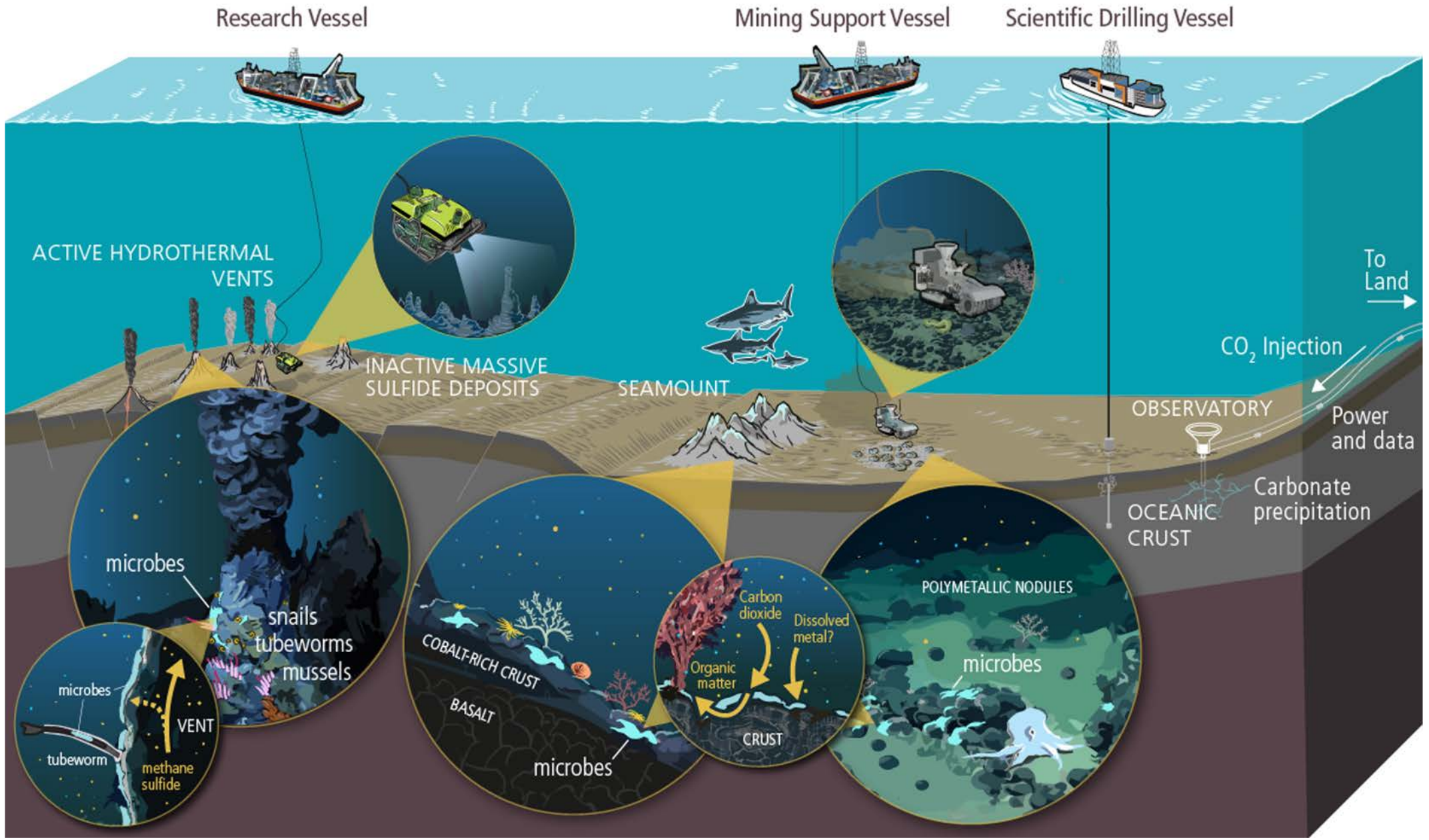
Bigelow | Laboratory for Ocean Sciences

Photo: Ocean Exploration Trust | NOAA

How might marine mineral exploitation impact the deep sea?



Credit: Orcutt et al. (2020) Open Science Foundation

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INFORMATION SHEET

July 2023

https://www.dosi-project.org/topics/minerals-deep-sea-mining/

Figure 1: Seamount Ecosystem Services

Food sources
Habitat and sites of abundant prey for >80 benthic and pelagic commercial species worldwide, e.g., tuna and billfish aggregate above seamounts and redfishes (*Sebastes* spp.) and Orange Roughy (*Hoplostethus atlanticus*) live on seamounts

Climate regulation
Increased productivity leads to more flux to the seafloor (i.e., more blue carbon transport, sequestration and storage), engineer of local and regional ocean conditions (upwelling and mixing of cold bottom water)

Habitat and trophic support
e.g., hotspots of biological diversity, occurrence of Vulnerable Marine Ecosystems indicator species, breeding grounds, spawning grounds, refugia (beyond the reach of many nearshore human stressors), migratory way-stations (for birds, marine mammals, sea turtles, and many fish species), stepping-stones for dispersal

Biogeochemical cycling
Cycling of elements, nutrients, and chemicals, including enhanced upwelling, flow, and productivity, eddy production and trapping, advection by rotational flow, trapping of biological material

Biomimicry
Nature-inspired innovations (adhesion, antifouling, armour, buoyancy, movement, sensory, stealth)

Historical archive
e.g., volcanic islands erode back into the sea becoming seamounts, archiving past conditions and biodiversity

Cultural services
e.g., spiritual significance, emotional and historical value, science and research, education and outreach, aesthetic value, entertainment

Genetic resources
e.g., microbial associates of sponges and corals with biopharmaceutical potential; potential genetic "rescue" reserve for impacted coastal populations

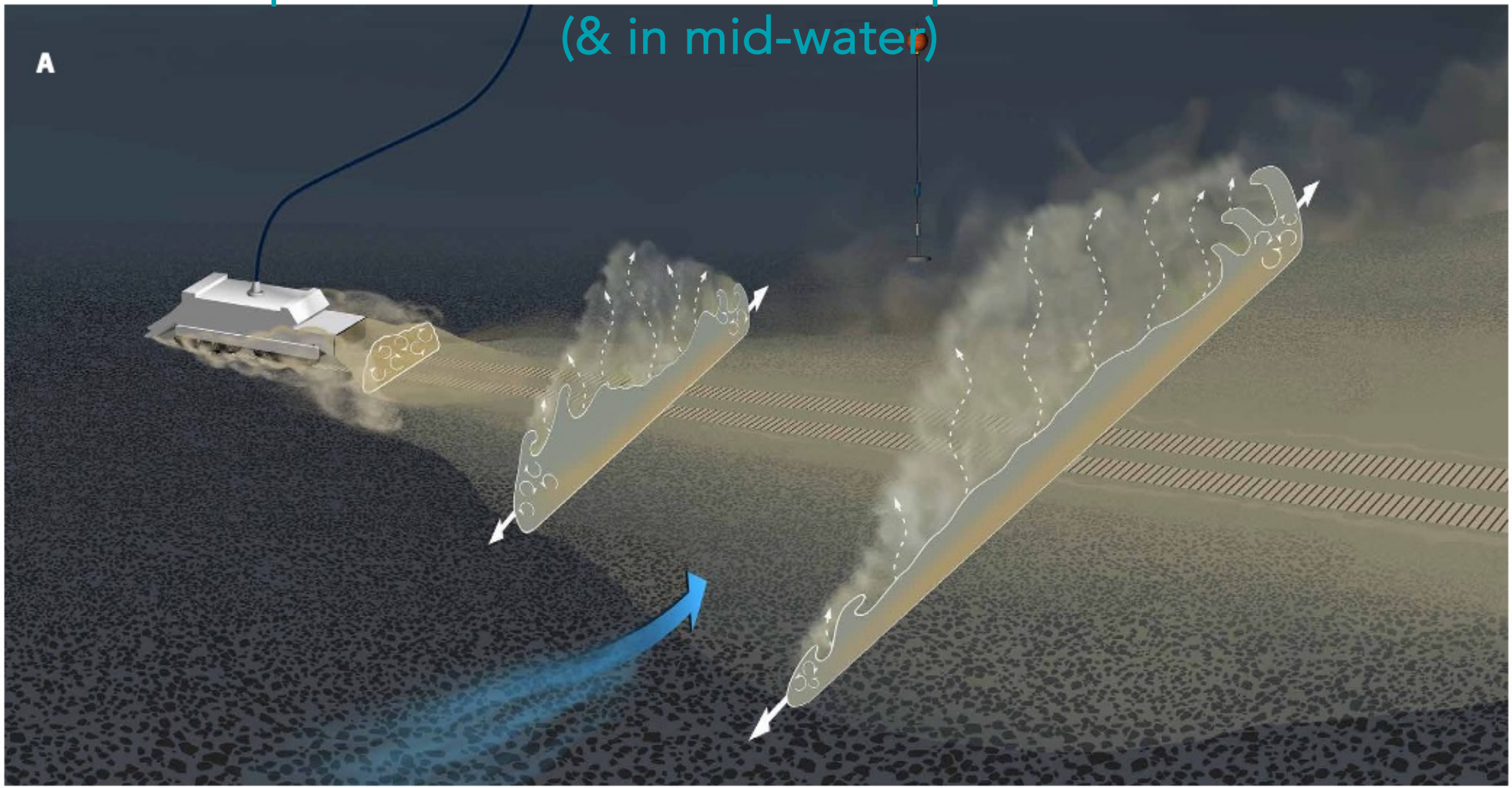
Ornamental value
Nature-themed and/or -inspired art (e.g., movies, books, paintings, carvings

Non-living resources
e.g., mineral resources (primarily ferromanganese crusts but also polymetallic nodules), phosphorites

Stewardship and bequest value
Maintained or preserving something available to current and future generations

Existence value
The value of knowledge that a species or habitat exists

Example disturbance – sediment plume on seafloor (& in mid-water)



Credit: Muñoz-Royo et al. 2022 Science Advances

Note: not shown - animals

Knowledge Gaps

Key Scientific Gaps			Habitat								
			Nodules			Active Sulfides		Inactive Sulfides		Cobalt-rich Ferromanganese Crusts	
Theme	**Topic**	**Sub-Topic**	**1**	**2**	**3**	**4**	**5**	**4**	**5**	**6**	**7**
Environmental Baselines	Abiotic	High-resolution bathymetry									
		Oceanographic setting (e.g., currents, oxygen minimum zones, temperature, turbulence levels, sound, suspended particles)									
		Seabed properties (e.g., sediment characteristics, oxygen penetration, redox zonation, metal reactivity)									
		Natural disturbance regimes									
		Species taxonomy									
		Trophic relationships									
		Life histories (e.g., age of maturity, longevity, reproduction, fecundity)									

Amon et al. (2022) Marine Policy

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Deep-Seabed Mining	Impacts	Removal of resources									
		Plumes									
		Contaminant release and toxicity									
		Noise, vibration and light									
		Cumulative impacts									
	Resilience										
	Management	Environmental goals and objectives									
		Survey and monitoring criteria									
		Effectiveness of mitigation strategies									

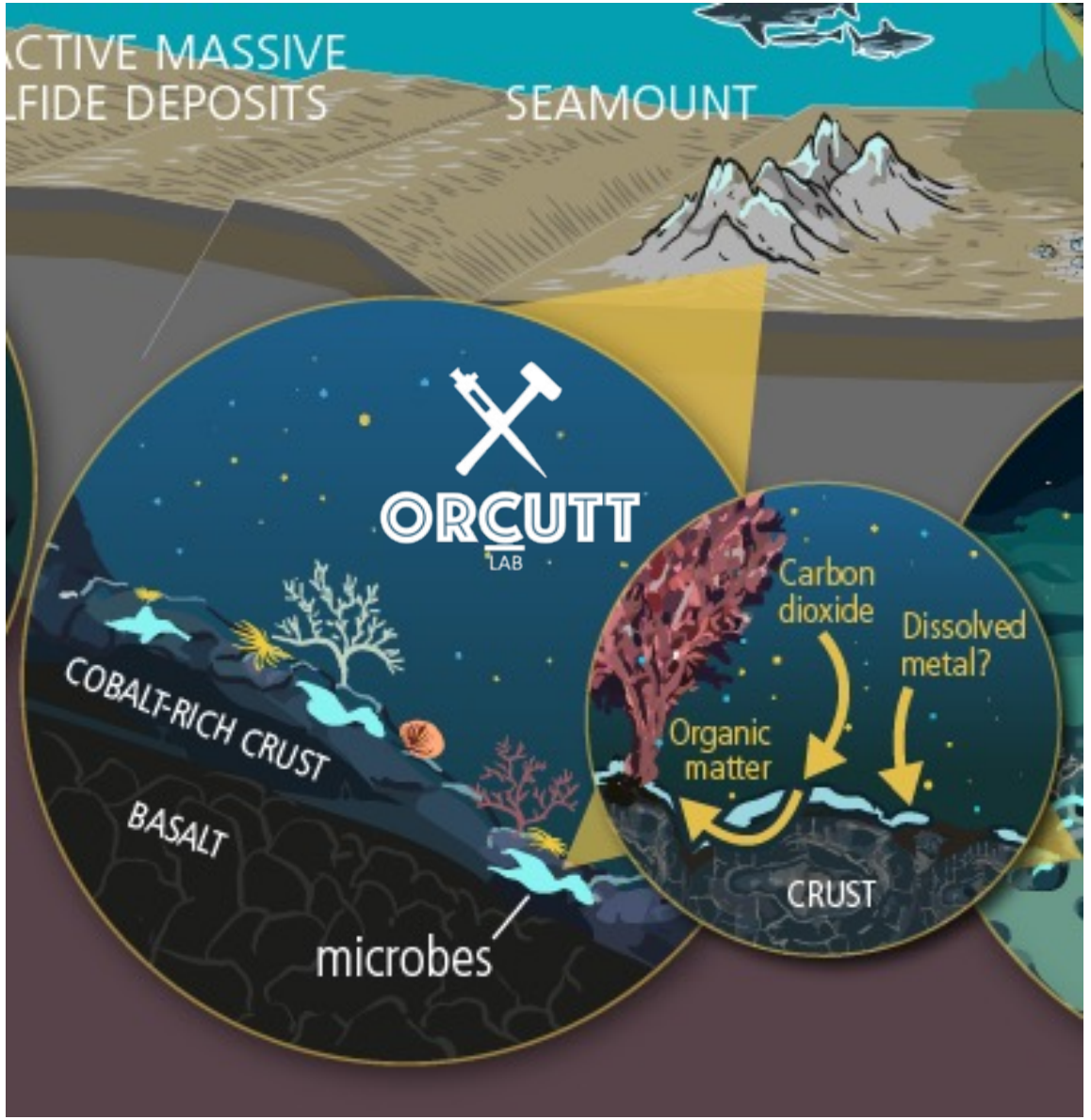
Amon et al. (2022) Marine Policy

Microbial ecosystem services

PROVISIONING
Primary Production
Organic Transformation
Genetic Resources

SUPPORTING
Nutrient & Metal Cycling
Animal Habitat Formation
Animal Habitat Signaling
Animal Symbioses

REGULATING
Waste remediation
Carbon sequestration
Mineral precipitation?



Credit: modified from Orcutt et al. (2020) *Limnology & Oceanography*

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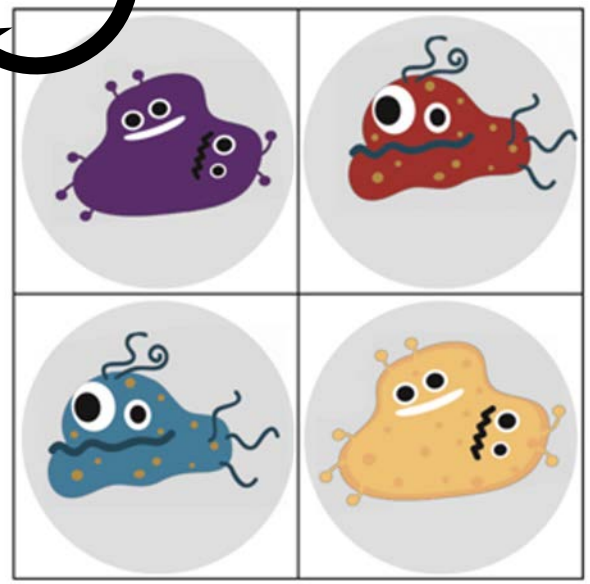
CARBON DIOXIDE

ORGANIC CARBON



This is fueled by chemosynthesis!

Credit: modified from Orcutt et al. (2020) *Limnology & Oceanography*

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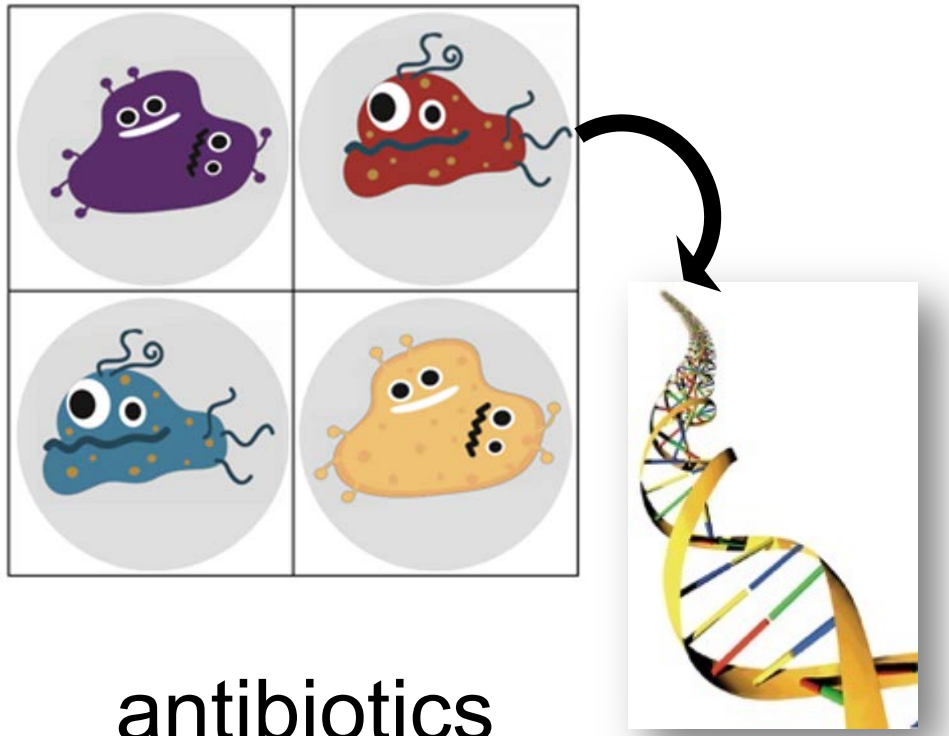

antibiotics
anti-cancer compounds

Credit: modified from Orcutt et al. (2020) *Limnology & Oceanography*

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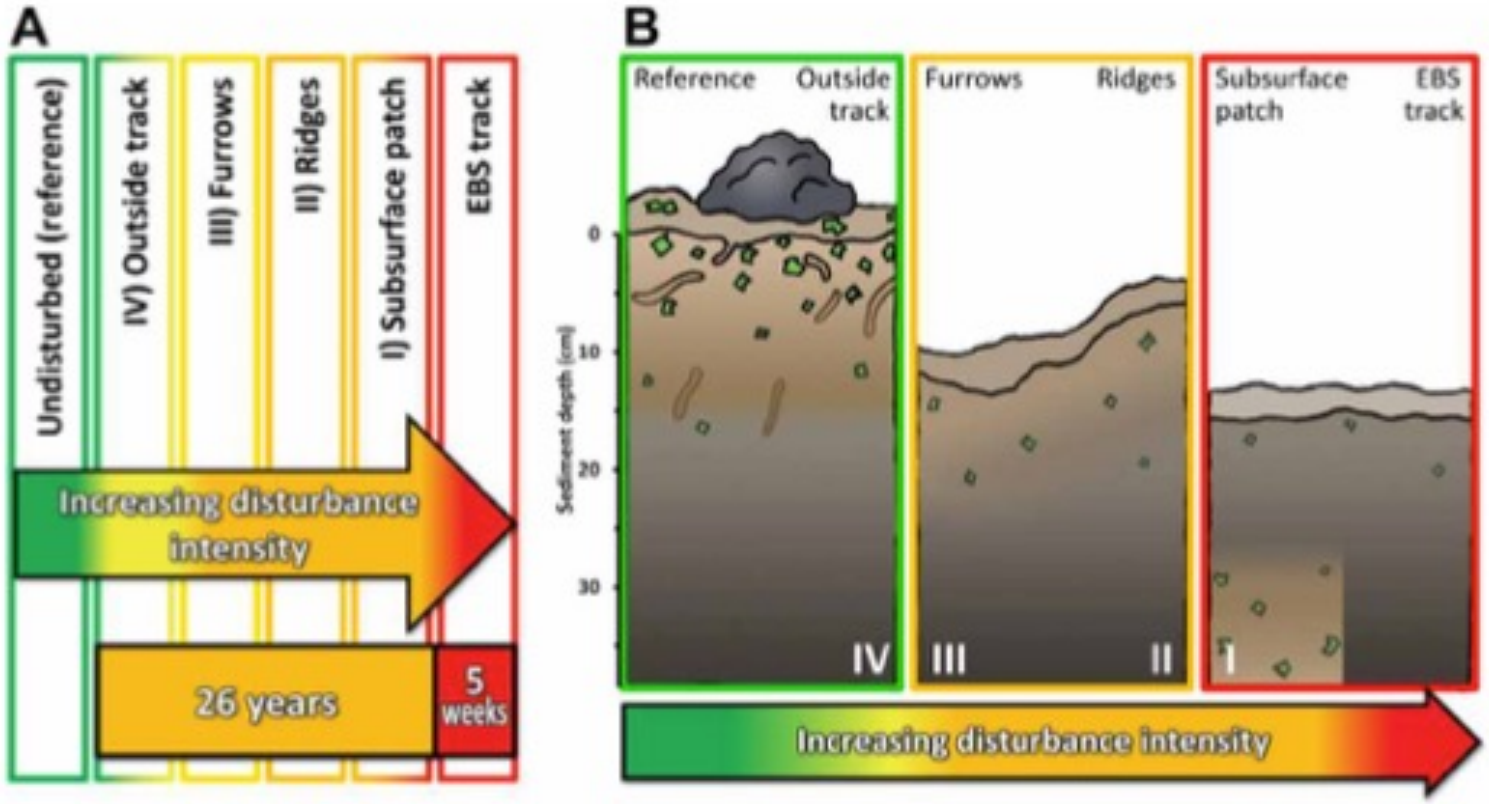
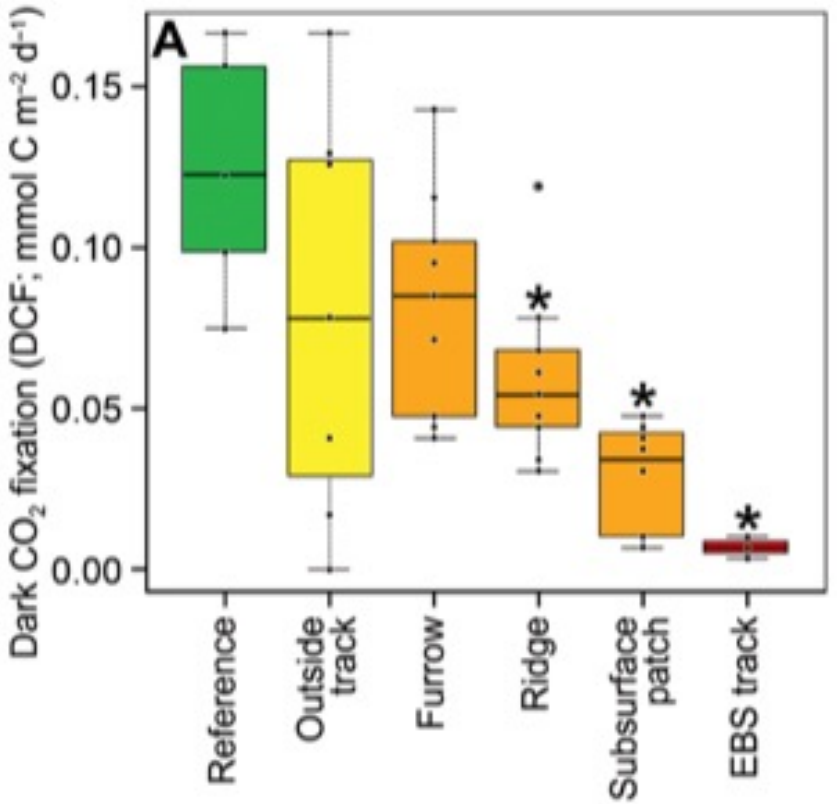
Example: Decreased microbial biomass and ecosystem services *even after decades of recovery*



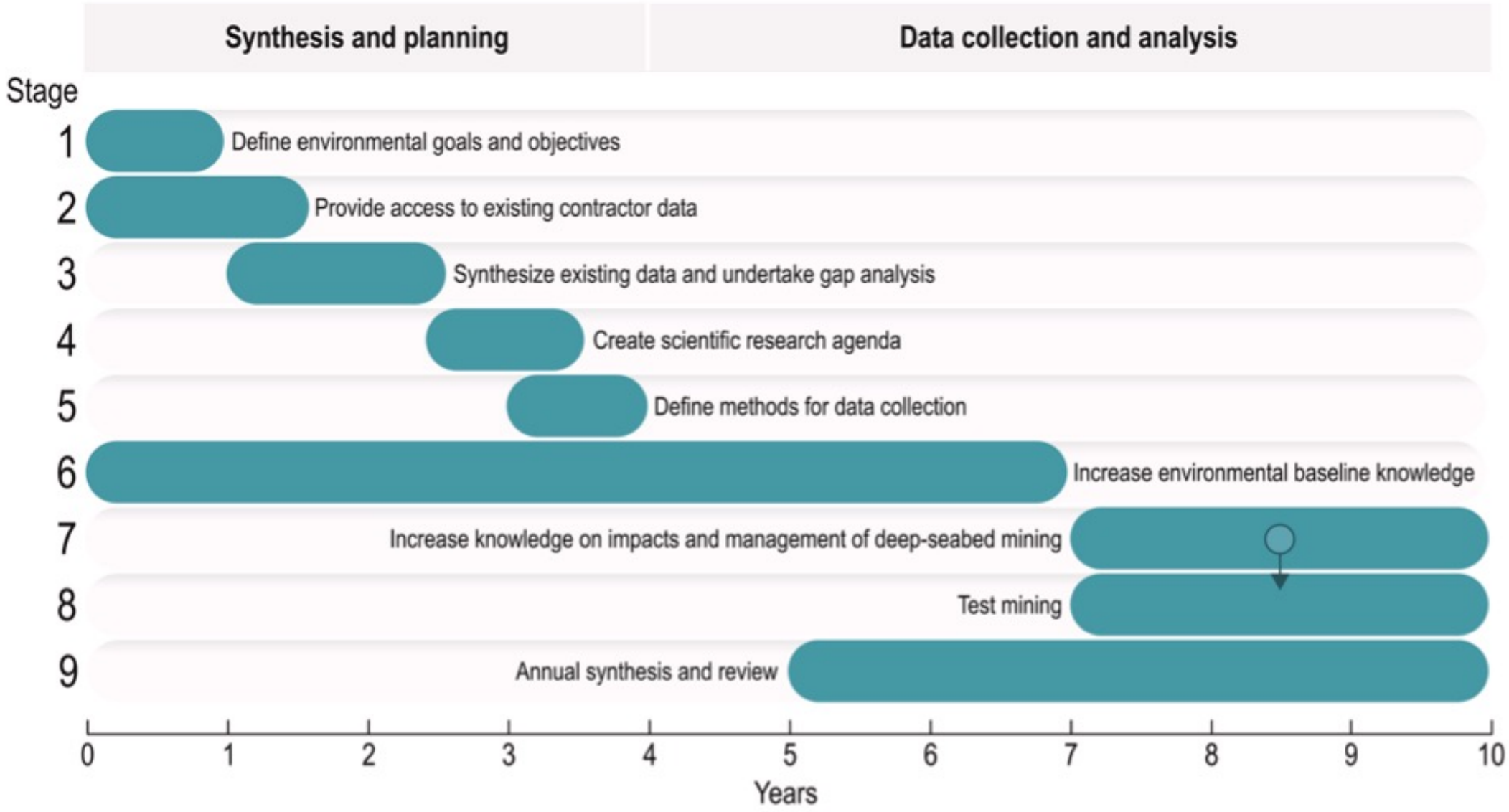


Credit: Vonnamhe et al. (2020) *Science Advances*

Critical knowledge gaps

- What are the marine mineral contents of seafloor materials?
- What are the biodiversity and ecosystem services that could be impacted by critical mineral exploitation (on the seafloor and in the mid-water)?
- What is the resilience of ecosystem services to perturbation (on the seafloor and in the mid-water)?
- What are cost-effective strategies to provide early warning to prevent serious harm (on the seafloor and in the mid-water)?
- How might impacts be cumulative with other stressors (like climate change)?
- Need: Expand the field of deep-sea scientists
- Need: Train scientists to communicate findings to other stakeholders

10+ years to fill gaps, *for each resource type*



Amon et al. (2022) Marine Policy

More info about knowledge gaps and status of Deep-Sea Mining

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COBRA Webinar – January 2023

Impacts of Deep Seabed Mining – Results from Independent Scientific Monitoring

Dr. Matthias Haeckel (GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany)

Interest of various states and companies in the mining of metal ores (polymetallic nodules, massive sulphides, and cobalt-rich crusts) from the abyssal seabed has been sparked by the projected future demands of metals for the transition to a low-carbon energy system and the increasing consumption of high-tech products in conjunction with global population growth. While extracting metals from deep-sea ores may contribute to the desired overall reduction of our CO_2 emissions, it will certainly introduce a new environmental threat to our oceans. This talk will present results of the European JPI-Oceans project 'MiningImpact' with a particular focus on the design and initial results of the independent scientific monitoring of the first industrial trial of a pre-prototype nodule collector vehicle. Two trial areas have been investigated before, during and immediately after the trials of Patania II in the Clarion Clipperton Zone (CCZ). The different contract areas offer the ability to study two regions of the CCZ with different environmental conditions. The talk will summarize the challenges and consequences arising from the observed high spatial variability of environmental variables, the immediate impact-related changes in environmental conditions, such as biogeochemical fluxes, benthic macrofauna and meiofauna densities, endofauna, and it will discuss the strategy and methodologies applied to monitor sediment plume dispersal and environmental impacts. Initial results indicate that impacts will be at least locally severe and last for centuries to millennia. Larger-scale consequences are still uncertain due to the largely unknown species connectivity and our limited understanding of ecosystem structure and functions.

> Learn more about the recent MiningImpact SO295 expedition

https://youtu.be/RhPg30AZrTU

COBRA Webinar – March 2023

The Status of Deep-Sea Mining

Dr. Diva Amon (SpeSeas)
Hannah Lily (Independent Consultant – Ocean, Natural Resources, and Regulatory Law)

There is growing interest of various states and companies in the mining of metal ores (polymetallic nodules, massive sulphides, and cobalt-rich crusts) from the deep seabed, with this year being critical for this nascent industry. This talk will summarise the state of play in deep-sea mining from four perspectives: industry, science, governance and politics.

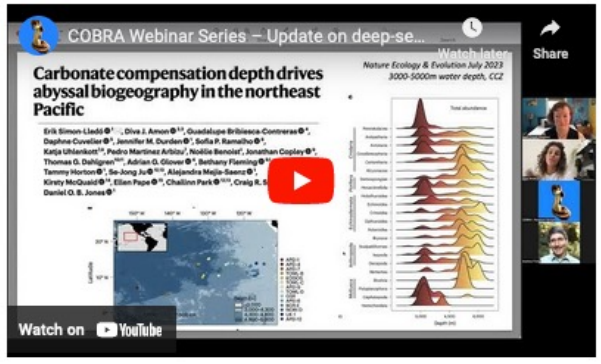
https://youtu.be/lk16IPABhW8

COBRA Webinar – August 2023

Update on deep-sea mining negotiations and addressing knowledge gaps for developing robust baselines, thresholds, and monitoring for protection of the marine environment

Dr. Beth Orcutt (Bigelow Laboratory for Ocean Sciences and Associate Director of COBRA)
Dr. Diva Amon (Director of SpeSeas)

Building on the COBRA webinar from March 2023, this webinar will provide an update on the state-of-play of negotiations for deep-sea mining following Parts I and II of the 28th session of the International Seabed Authority Council meetings that have occurred this year. Drs. Amon and Orcutt will provide their perspectives as deep-sea scientists who have been involved in providing scientific guidance to policy makers during these proceedings. They will also provide an overview of some of the major scientific findings that have come out in the past year to address key knowledge gaps related to ecosystem baselines, thresholds for harm, and monitoring for protection of the marine environment.



https://youtu.be/W7WnATpPxOg

Funding provided by the U.S. National Science Foundation's AccelNet program award OISE-2114593

What is COBRA ?

COBRA
CRUSTAL OCEAN BIOSPHERE RESEARCH ACCELERATOR

ACTIVITIES

CO-ORDINATION
Catalyze collaborations

ACCELERATION
Fill knowledge gaps

TRANSLATION
Bringing findings to policy makers, industry, and the public

EDUCATION
Training next generation in deep-sea expedition leadership

OUTCOMES

A larger network of diverse individuals leading deep-sea science and engaged in crustal ocean biosphere research and policy translation

Distillation and sharing of new knowledge for policy makers, resource managers, industry, and the public

Funding provided by the U.S. National Science Foundation's AccelNet program award OISE-2114593

IMPACTS

Equitable research priority roadmaps to address knowledge gaps

Evidence-based policy, management, and solutions for sustainable crustal ocean biosphere conservation and use

cobra.bigelow.org

Example: Science to inform policy making

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Example: recent workshop

Develop a white paper for policy makers* summarizing what is known and unknown about value, thresholds, monitoring and observing capacities

iDOOS

Workshop held in collaboration with NSF-funded AccelNet "iDOOS" project

Example: Science to inform policy making

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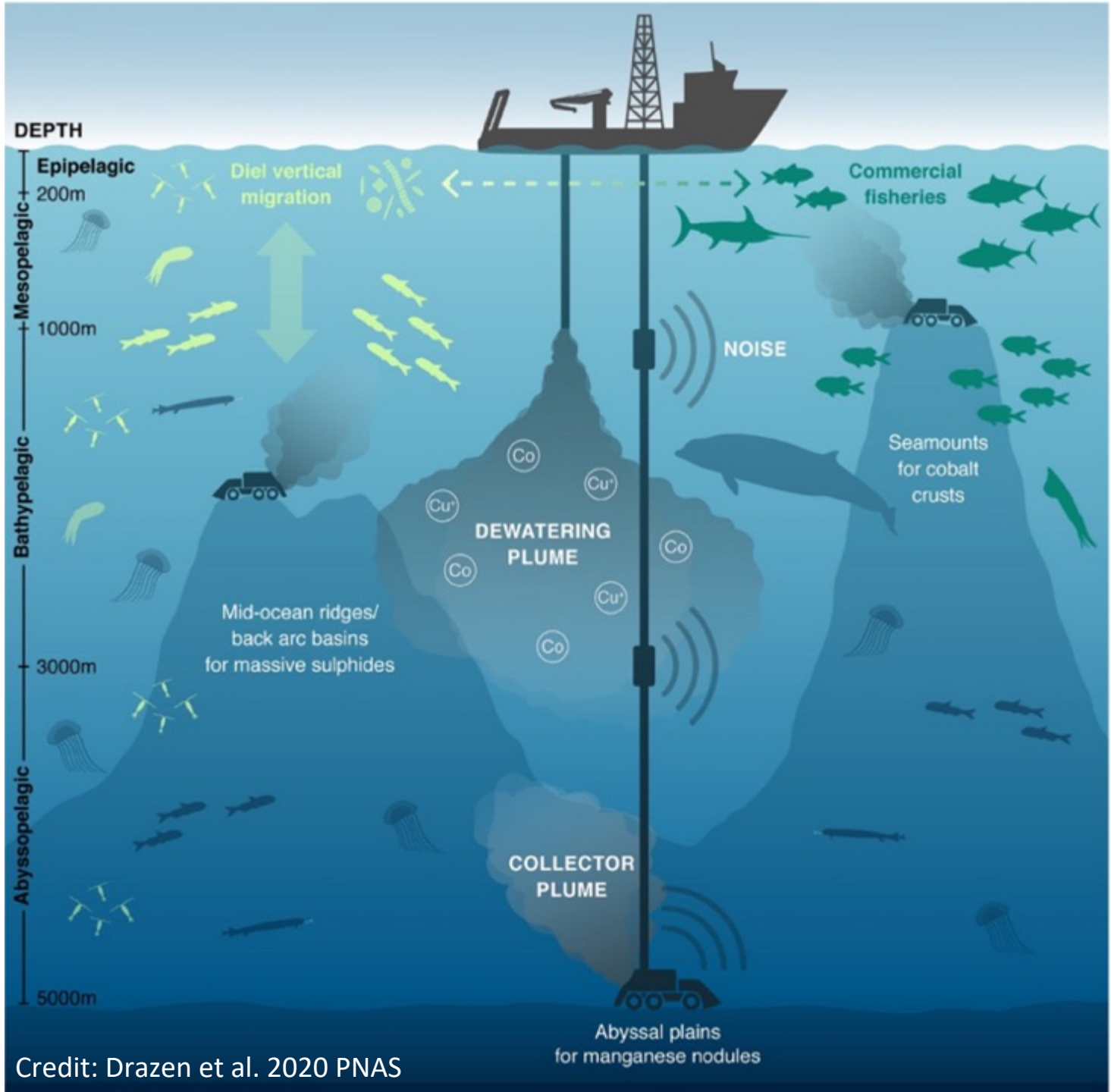
DEEP-OCEAN STEWARDSHIP INITIATIVE

Disclaimer:
I am an ambassador for DOSI, but views expressed here are my own

Photos by International Institute for Sustainable Development (IISD) / Earth News Bulletin and Diego Noguera.

We need *shipboard and in-situ methods* to assess changes in ecosystem services in real-time to indicate potential "harm" from human perturbation



Credit: Drazen et al. 2020 PNAS

We need more ocean observing technology in areas being targeted for critical mineral exploitation

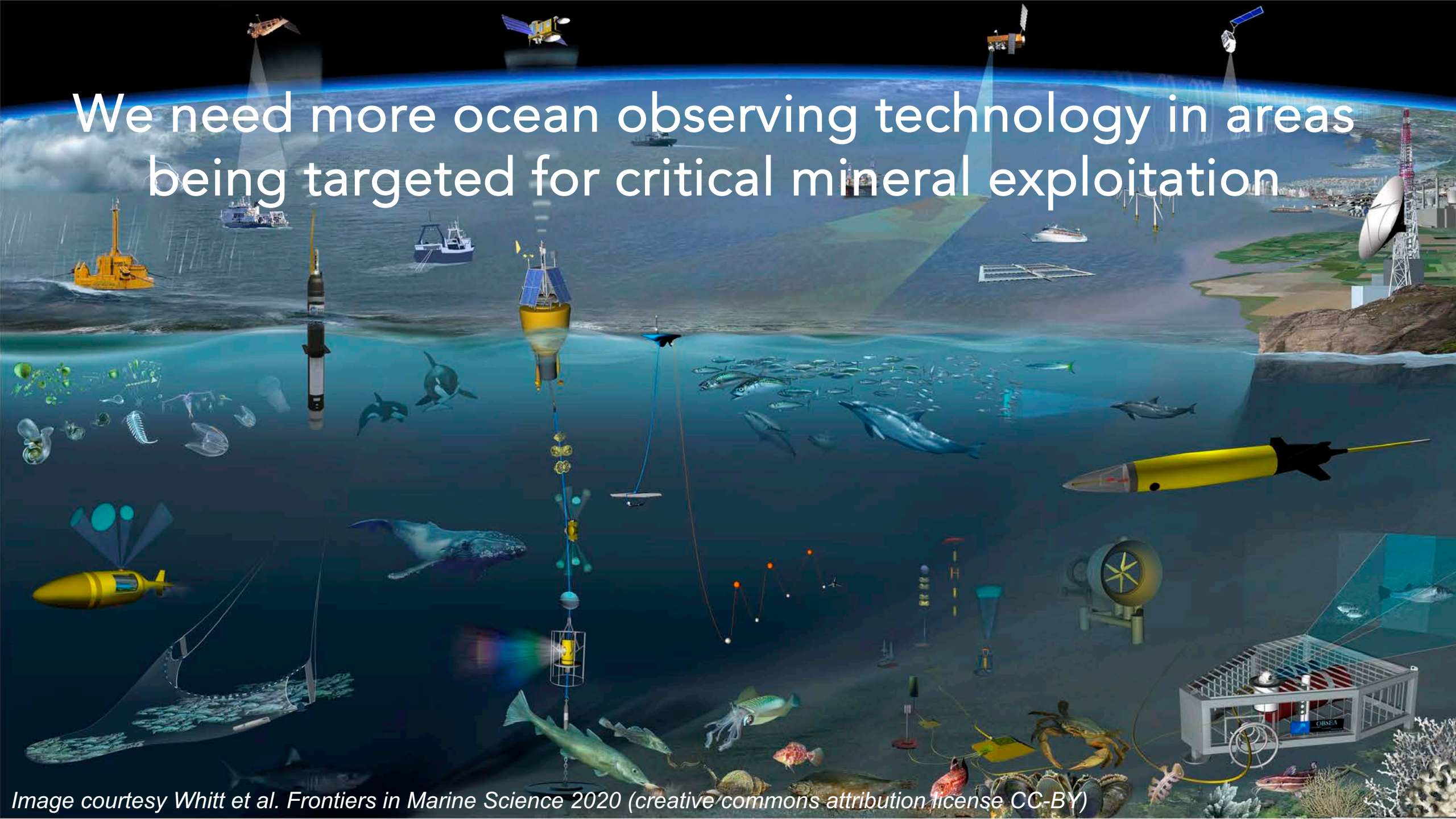


Image courtesy Whitt et al. Frontiers in Marine Science 2020 (creative commons attribution license CC-BY)

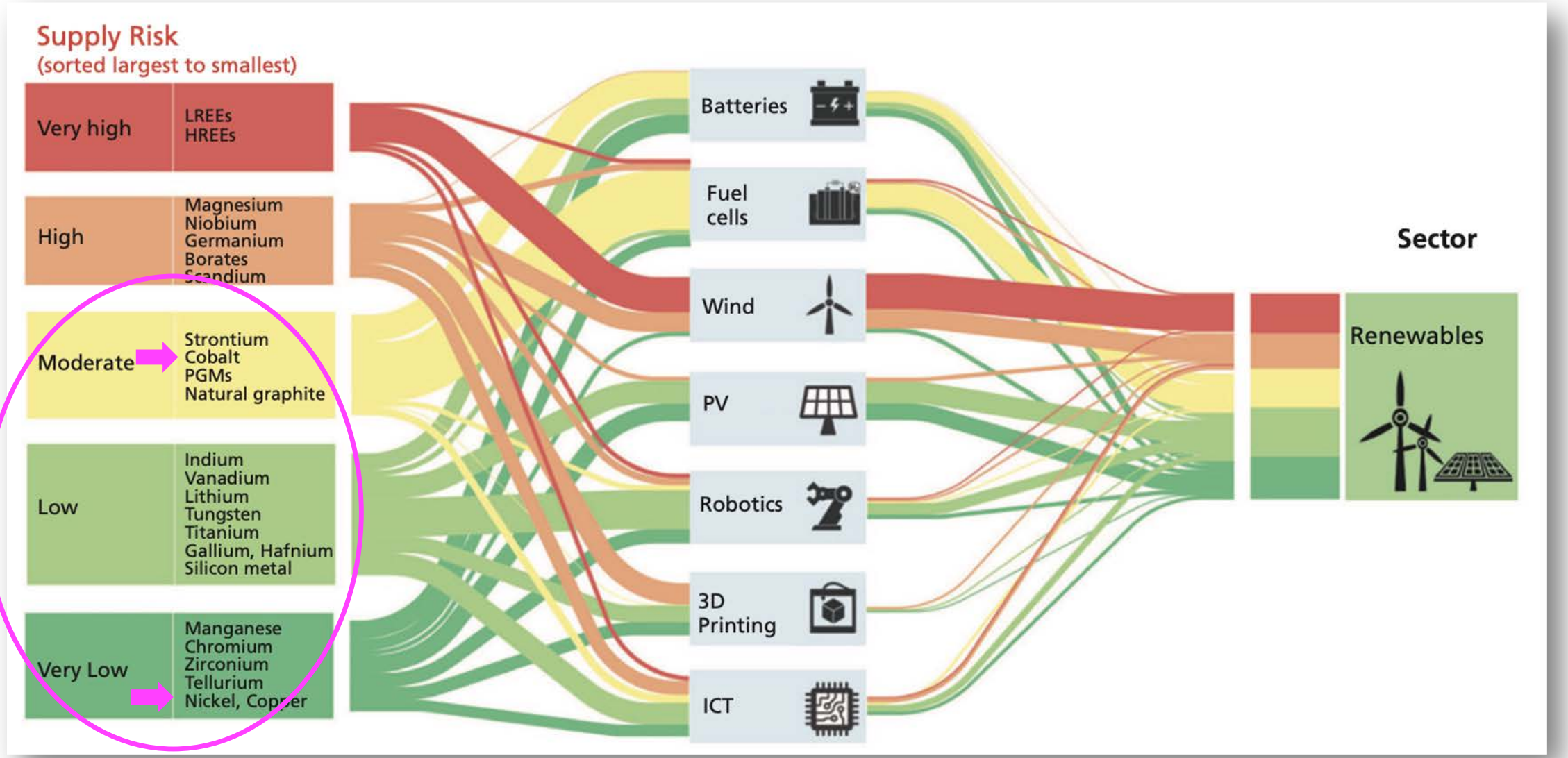
We need more global deep sea research assets
(ships, ROVs, AUVs, HOVs, moorings, profilers, coring, etc.)

Photo: Ocean Exploration Trust | NOAA

European Academies
easac
Science Advisory Council

June 2023

Deep-Sea Mining: assessing evidence on future needs and environmental impacts



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Deep-Sea Mining: assessing evidence on future needs and environmental impacts

June 2023

"The lack of a consensus on what constitutes 'serious harm' and the current lack of quantitative thresholds limits the ability of [the International Seabed Authority] to effectively protect the marine environment… until ecological consequences can be properly understood, measured and controlled."

These critical knowledge gaps need to be addressed