Ecological aspects of Deep-sea Mining: Impacts & risks



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Deep-Sea Ecosystems

- >200 m depth
- 96% of habitable space on earth
- Extraordinary variety of habitats & extremely high biodiversity (250K described, estimated >2M spp)
- Largely understudied in terms of biodiversity and ecosystem functions
- Extreme conditions:
 - Temperature
 - Pressure
 - Light
 - Chemistry
 - Nutrients
 - =>Adaptations
- What we know from land/coastal ecosystems (conservation, restoration) is not applicable to the deep sea.

Photo credit: NOAA



Stewardship and bequest value

Maintaining or preserving something to be available to current and future generations

Existence value

The value of knowledge that a species or habitat exists

Genetic resources

e.g., gene adaptations, pharmaceuticals, industrial agents, biomaterials

Food sources e.g., fish and shellfish

Habitat and trophic support

e.g., breeding grounds, spawning grounds, nursery habitat, feeding grounds, refugia

Ornamental value e.g., bamboo corals, glass sponges



Illustrated by Stacey McCormack.. In Le et al. (2020) DOSI policy brief

Non-living resources

e.g., oil, natural gas, minerals, wind and geothermal energy, and gas hydrates

Climate regulation

Through heat absorption, and carbon sequestration and storage

Biogeochemical cycling

Cycling of elements, nutrients, and chemicals, including pollutants and their retention

Cultural services

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

Historical archive

Soft sediments (and small fossils therein) archive past climate and biodiversity changes

Biomimicry

Nature-inspired innovation

KEY

- Provisioning services: result in tangible goods and/or products
- •- Regulating services: contribute to the natural production and resilience of habitats and ecosystem processes
- Supporting services: underlying ecosystem functions that are essential to produce other services
- Cultural services: non-material benefits deriving from nature
- Biodiversity values: biodiversity has intrinsic value, but is also the source of most ecosystem services

Mineral Resources in the Deep Sea



Polymetallic Nodules

Abyssal Plains (3000-6000 m) Ni, Co, Cu, Mn, Li, Mo, Ti, REE CCZ: 21,100 Mio t = US\$ 15-20 trillion

Ferromanganese Co-rich Crusts

Seamounts (800-2500 m) Co, Ni, REE, Pt, Au, Ag, Te, Mo PCZ: 7,533 Mio t = US\$ 7-10 trillion

Massive Sulfides

Hydrothermal Vents (1000-4000 m) Zn, Cu, Au, Ag, In, Ga, Ge, Te, Tl MOR neovolcanic zone: 600 Mio t = US\$ 0.3 trillion

Petersen et al. (2016) Marine Policy; Boetius & Haeckel (2018) Science



Benthic ecosystem in the deep Pacific Ocean

- Nodule ecosystems support a highly diverse fauna of sessile and mobile species
- Faunal communities & environmental parameters show high variability on local spatial scale



Impacts of polymetallic nodule mining



Boetius & Haeckel (2018) Science 359

Oebius et al. (2001) DSR II 48

Protection & management tools:

- Spatial planning: MPAs REMPs -
- EIA -

Monitoring

Knowledge gaps:

- **Parameters:** _
 - **Environmental conditions** _
 - **Biodiversity** -
 - Natural variability (space, time) -
- Processes: -
 - Connectivity
 - Life histories -
 - Trophic relationships
- Ecosystem functions & services -
- Resilience to: -
 - **Removal of resources**
 - Plumes -
 - Noise, light -
 - Long-term -
 - Cumulative impacts (e.g. climate change) -

Amon et al 2022, Marine Policy





Key Scientific Gaps			Habitat								
	Торіс	Sub-Topic	Nodules			Active Sulfides		Inactive Sulfides		Cobalt-rich Ferromanganese Crusts	
Theme			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									
	Biotic*	Species taxonomy									
		Trophic relationships									
		Life histories (e.g., age of maturity, longevity, reproduction, fecundity)									
		Spatial variability									
		Temporal variability									
		Connectivity (e.g., dispersal mechanisms, species ranges, source/sink populations)									
		Ecosystem functions and services									
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									



Mining Impact I & II https://miningimpact.geomar.de

DeepRest https://deep-rest.ifremer.fr/







Effects of disturbances on benthic ecosystem & functions

- Loss of seafloor integrity by nodule and seafloor removal reduces population densities and alters ecosystem functions (e.g., organic matter remineralization, productivity)
- The effects persist decades after the impact



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Bethic food web altered



Increasing seafloor disturbance level

Vonnahme et al. (2020) Science Advances 6

Biogeochemical activity

De Smet et al (2020) Progress in Oceanography

Independent scientific research on the impact of a nodule collector trial









pre- and post collector trial



SO295 (2022) Ref + trial sites 1.5 yr after trial

Collector tracks and sediment plume dispersal

Collector test areas:BEL 37,000 m²GER 22,000 m²Plume deposition area several times larger than test area





- Removal of 4-8 cm of surface sediment => redeposition of 2-3 cm inside+vicinity
- Sediment plume 5-10 m from seafloor
- Far-field transport (4 km in 24 h) in low concentrations with bottom currents



Immediate impact-related changes in environmental conditions



Increasing physical impact (sediment removal, redeposition)

(Bio)geochemical/environmental variables
clearly affected by the impact
(1) physical impact
(2) immediate effect on biogeochemistry

Pore water

Solid phase

EEA: extracellular enzymatic activities

Sediment plume dispersal and deposition

JUB-PFM-01 close to BEL-3



Release of metals in the sediment plume





Implications for conservation

Impact: immediate after - short term (1-10 yrs) - medium term (10 – 100 yrs) - long term (> 100 yrs- ???)



Protection & management tools:

- Spatial planning: MPAs REMPs
- EIA
- Monitoring

Thresholds

Robust Science



Thank you.

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