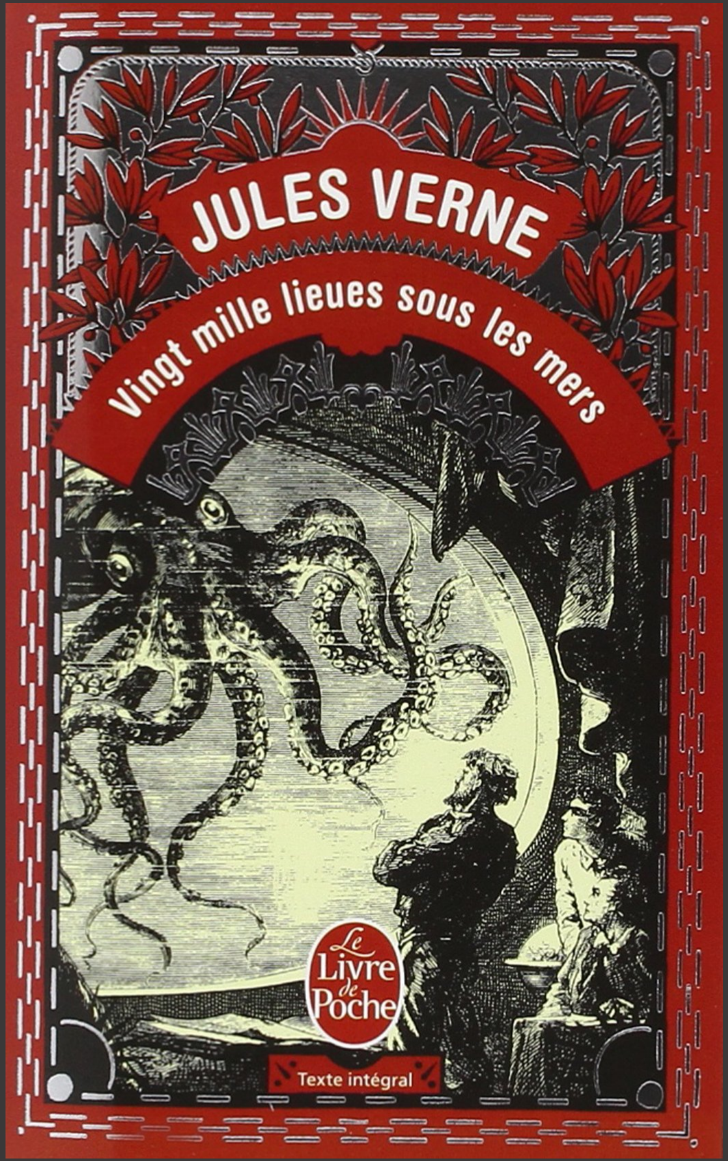


Deep-Sea Mineral Exploration and Exploitation

Professor Cindy Lee Van Dover

Division of Marine Science and Conservation

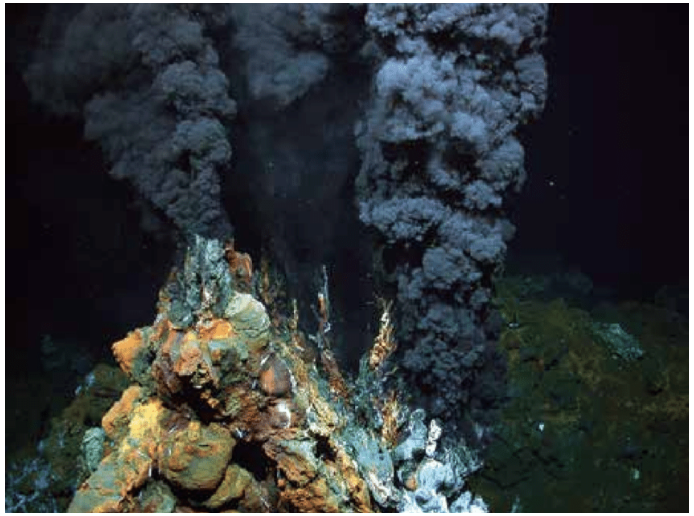
Nicholas School of the Environment

"In the ocean depths, there are mines of zinc, iron, silver and gold, which would be quite easy to exploit."

Jules Verne, 1870

Mineral Resources of the Deep Sea

polymetallic nodules



Rogers et al. 2015

polymetallic sulfides

Prof. Halbach, FU Berlin

polymetallic crusts

5000-6000 m
abyssal plain

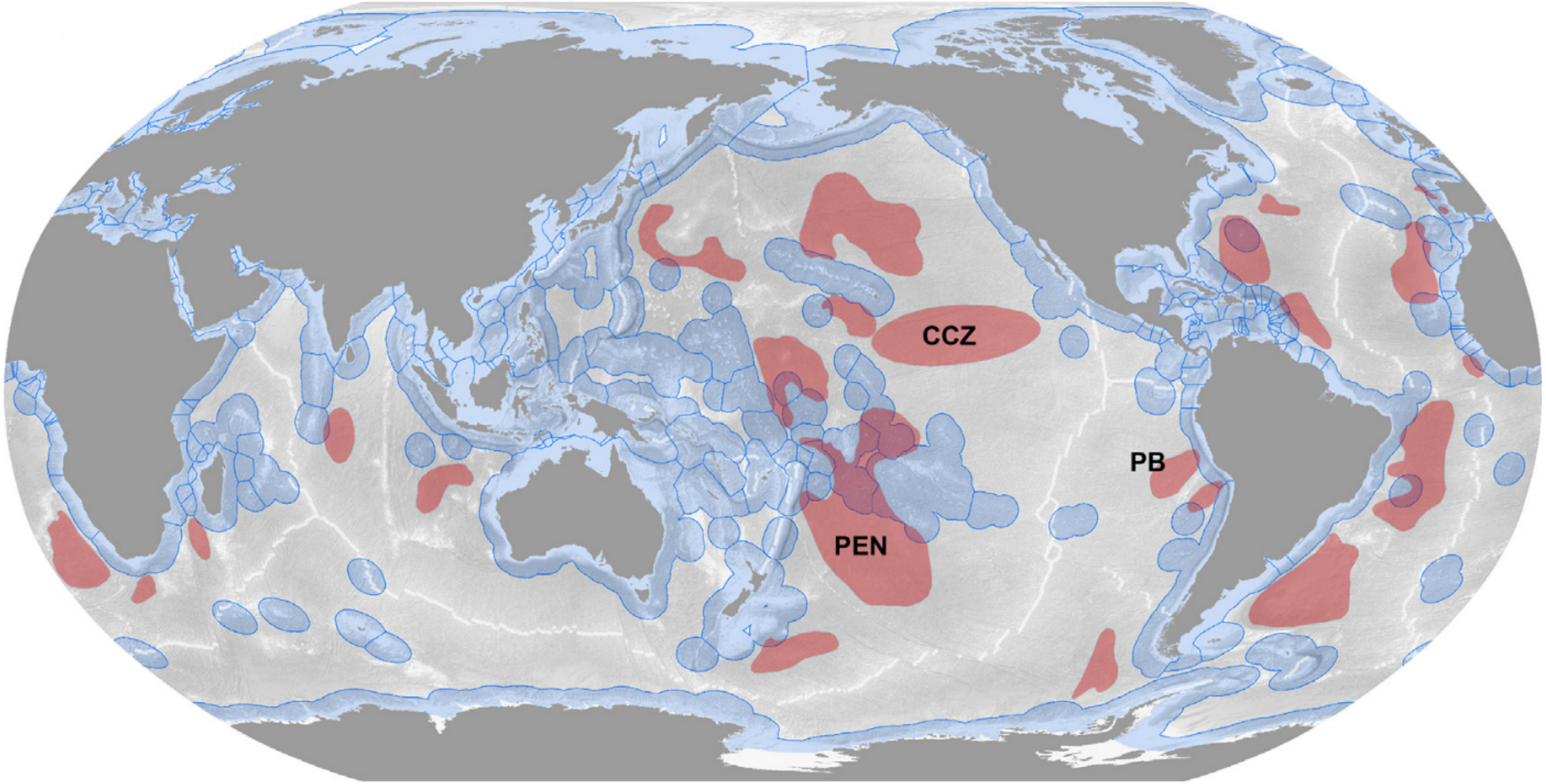
1500-3500 m
mid-ocean ridges
back-arc spreading centers
island arcs

800-3000 m
seamounts, guyots,
ridges, plateaus

Petersen et al. 2016

Mineral Resources of the Deep Sea

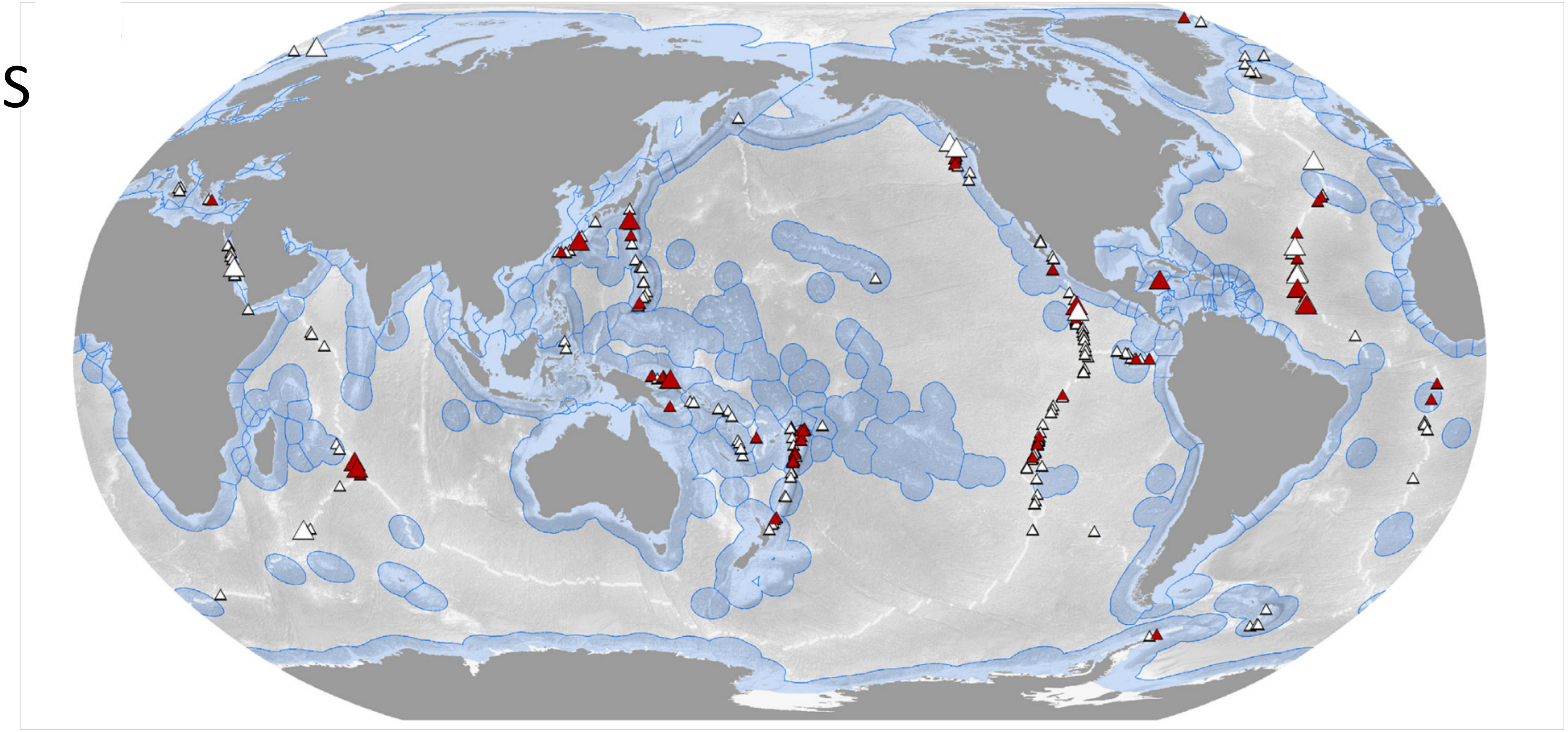
NODULES



Petersen et al. 2016

Mineral Resources of the Deep Sea

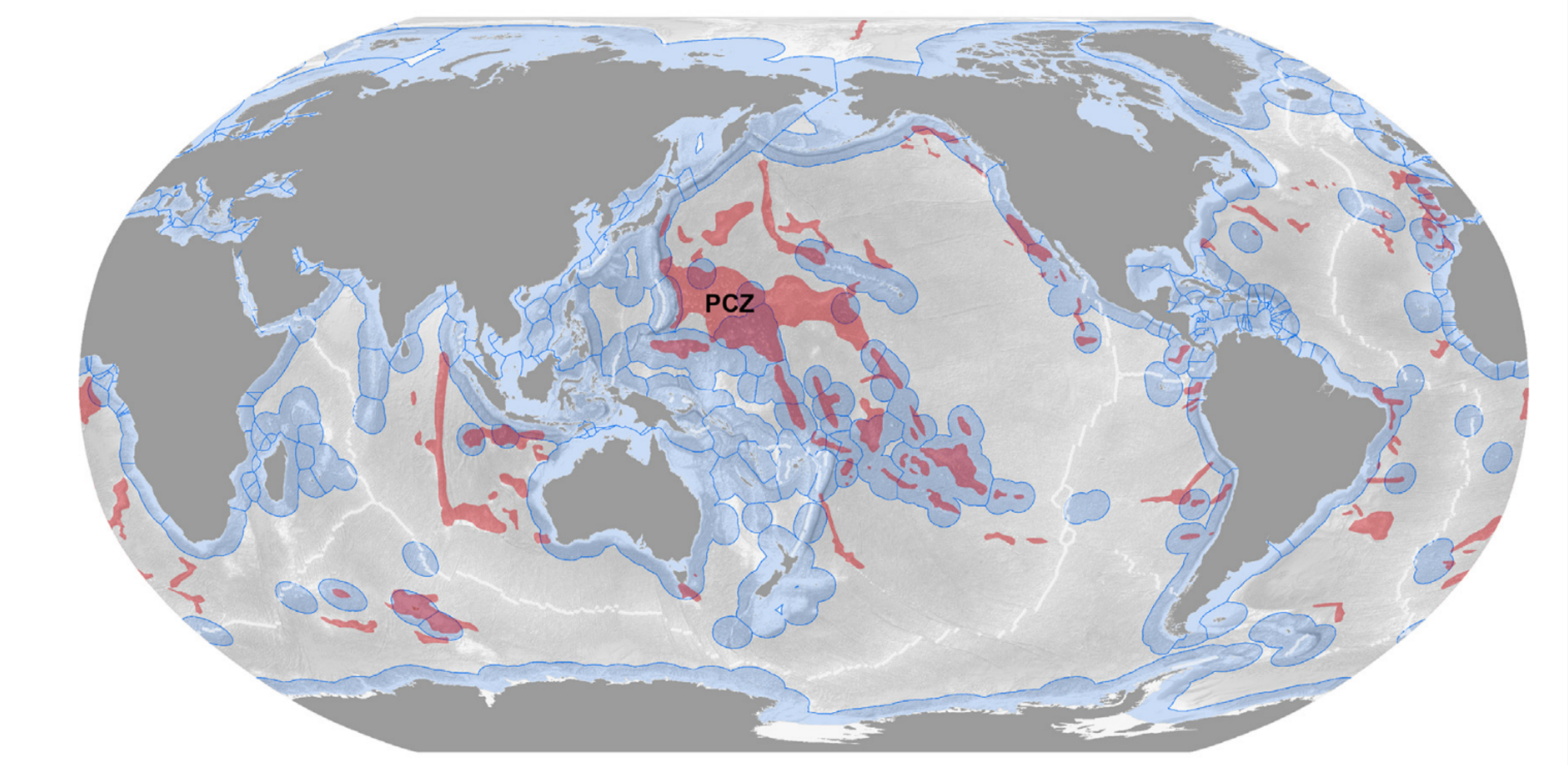
SULFIDES



Petersen et al. 2016

Mineral Resources of the Deep Sea

CRUSTS



Petersen et al. 2016

Mineral Resources of the Deep Sea

Metal Tonnages in Excess of Global Terrestrial Reserves

Nodules (Clarion Clipperton Zone), Crusts (Prime Crust Zone)

Manganese
Nickel
Molybdenum
Cobalt
Arsenic
Bismuth
Yttrium
Tellurium
Thallium

Hein et al. 2013

Primary Drivers for Deep-Sea Mining

- Ore grade
- Technology advances and access
- Growing demand for metals
  - Urbanization and development esp. in China, India
  - Green Economy with REEs
- Geopolitics (90% of REE currently from China)
- New income source (esp for Small Island Developing States)
- "*The Last Frontier*" – competition to be the first to succeed
- International Seabed Authority

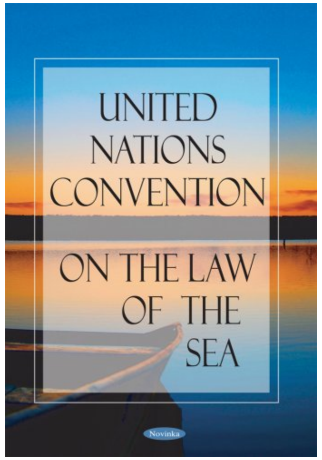
International Seabed Authority

ISA Environmental Obligation:

- To protect and preserve the marine environment from serious harm that could result from mining activities.

Precautionary Approach:

- Implementation of protective measures at an early stage in response to a risk of harm, even if scientific evidence as to the specific harm remains uncertain.



International Seabed Authority

Global Exploration Licenses

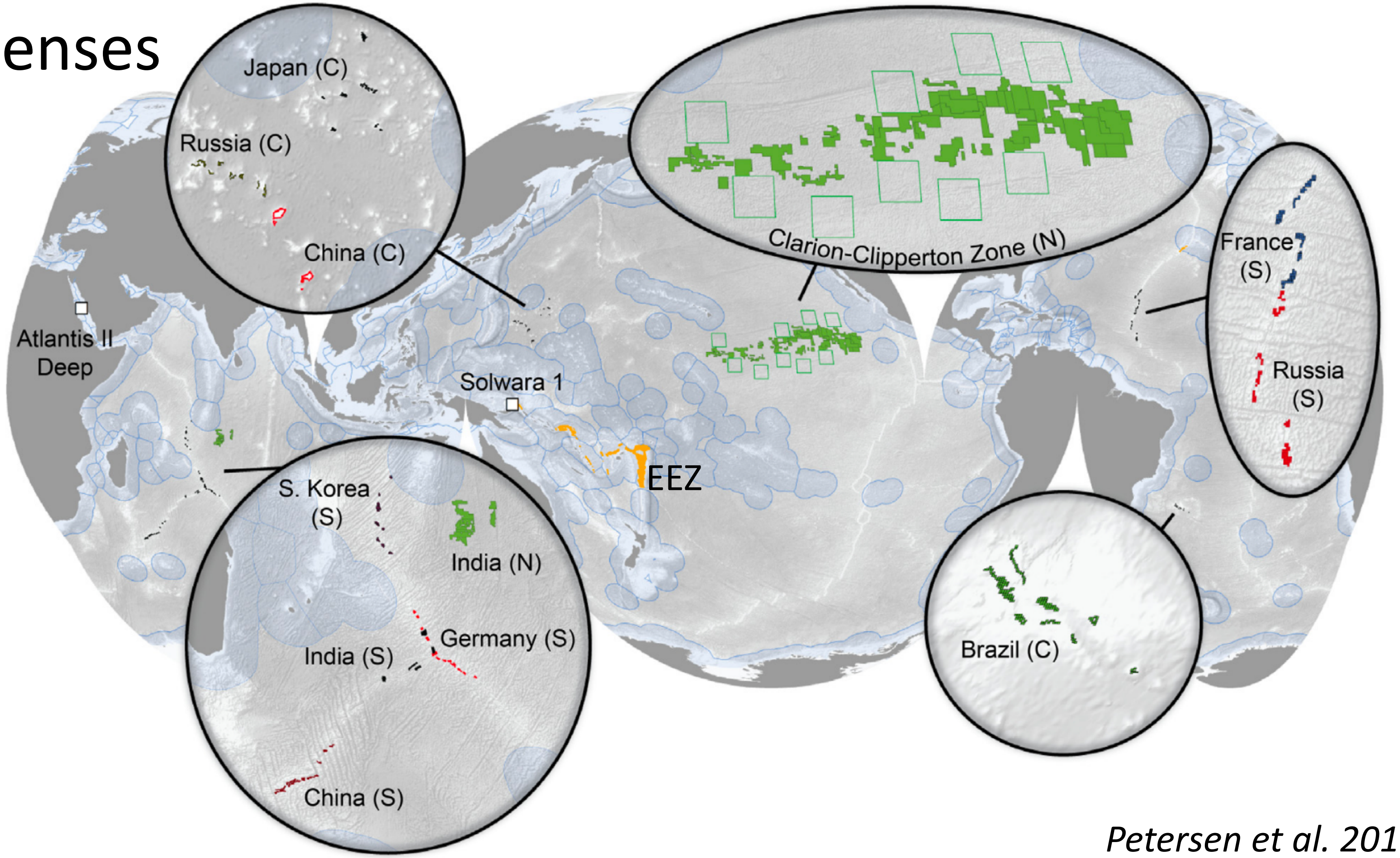
ISA: 29 Contractors

(as of 25 November 2018)

Nodules: 17

Sulfides: 7

Crusts: 5

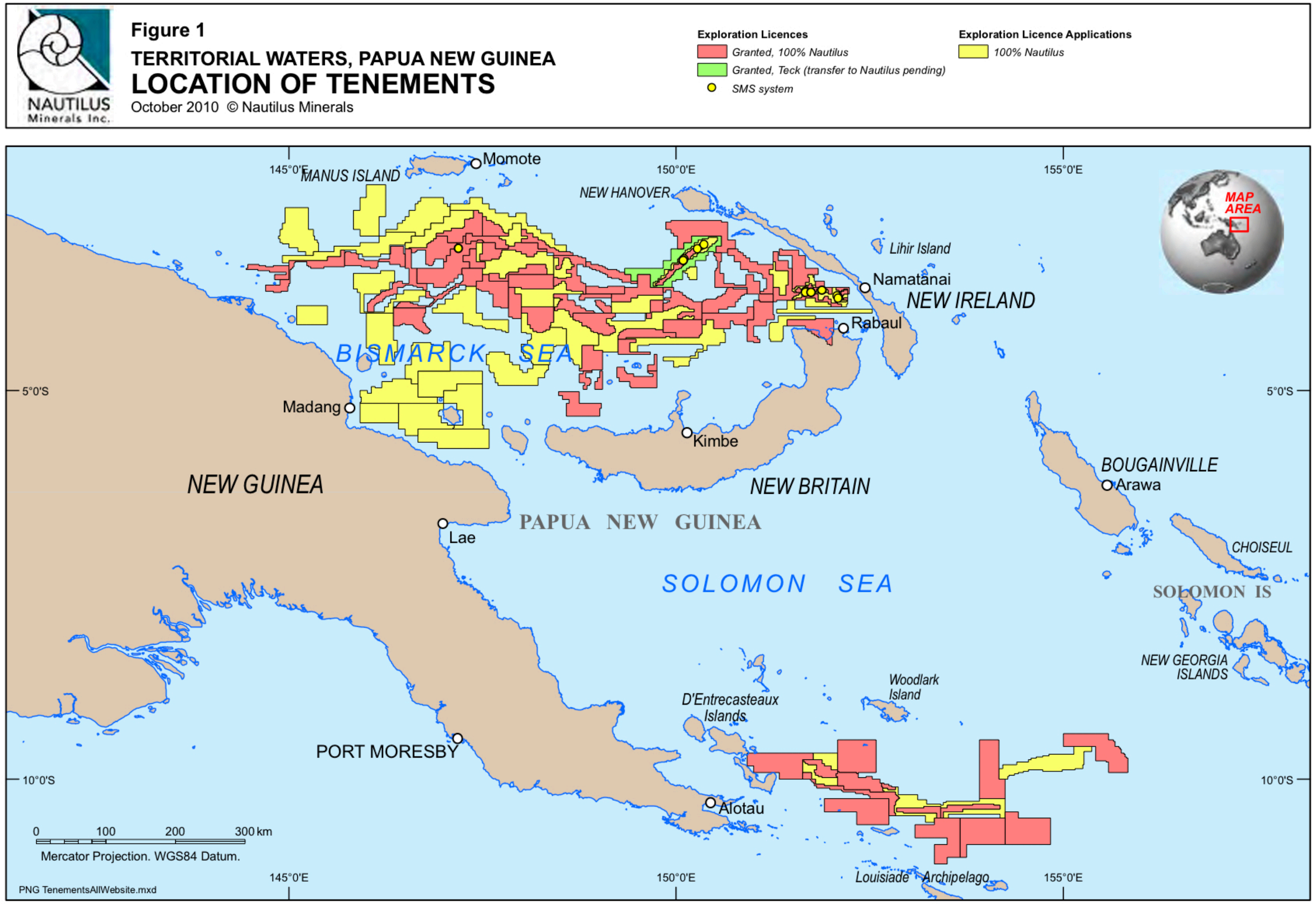


Petersen et al. 2016

EEZ Exploitation Licenses

Nautilus Minerals

NAUTILUS
Minerals

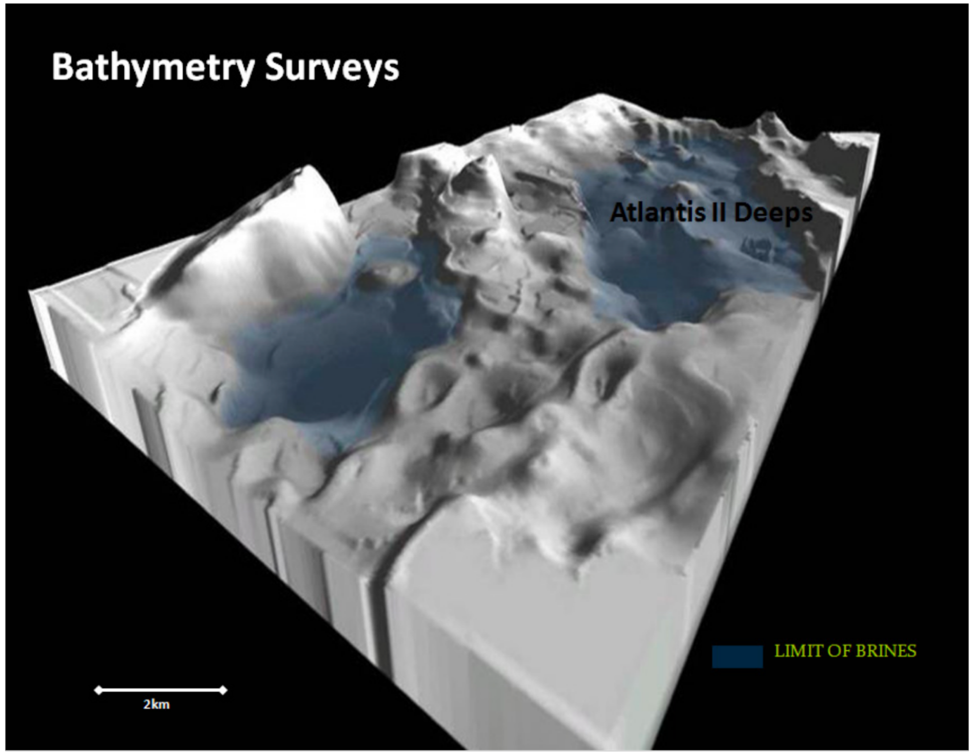


EEZ Exploitation Licenses

Diamond Fields Resources
Red Sea Project

- largest known hydrothermal metal deposit in modern ocean
- unconsolidated metal-bearing muds

Atlantis II Deep

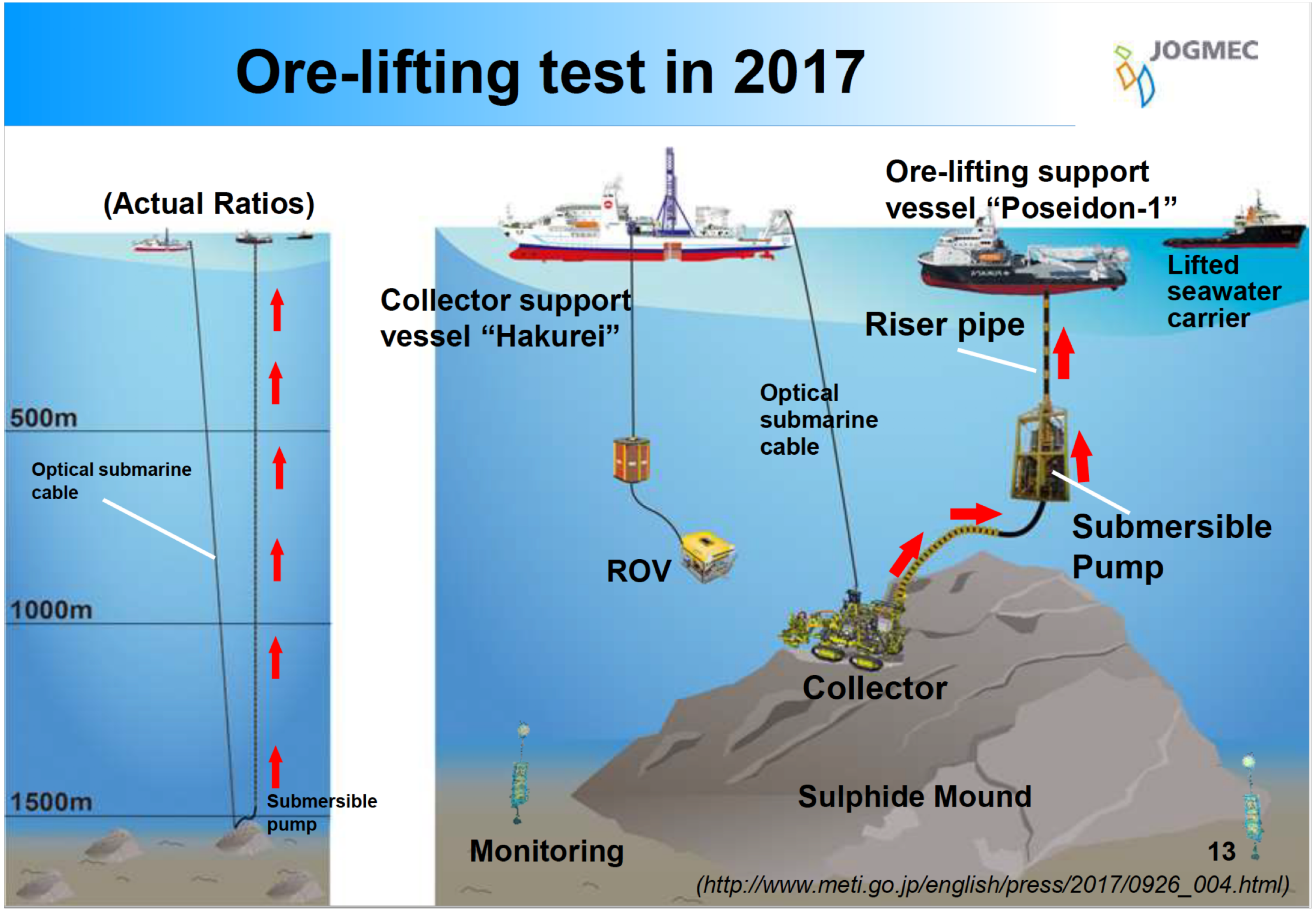


http://www.diamondfields.com/operations-and-projects/atlantis-ii-red-sea-deeps/

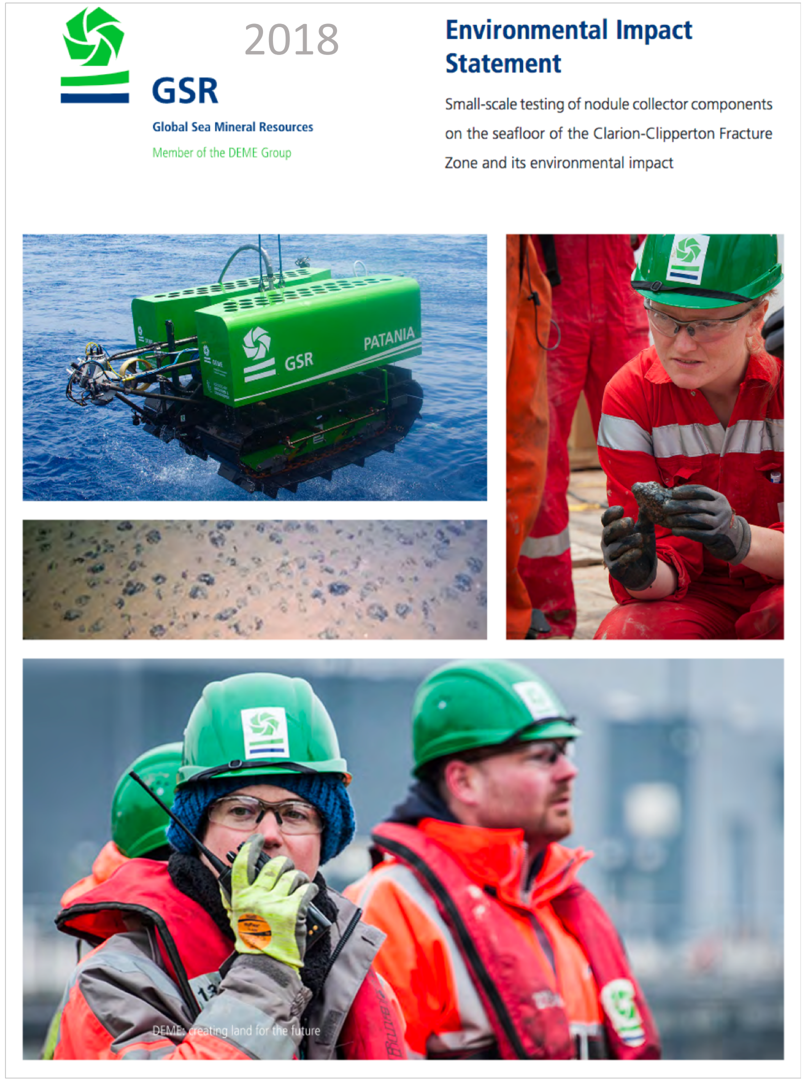
EEZ Test Mining

JOGMEC
Japan

Japan Oil, Gas and Metals National Corporation



ABNJ Mining Preparation (nodules)



Patania II Field Tests

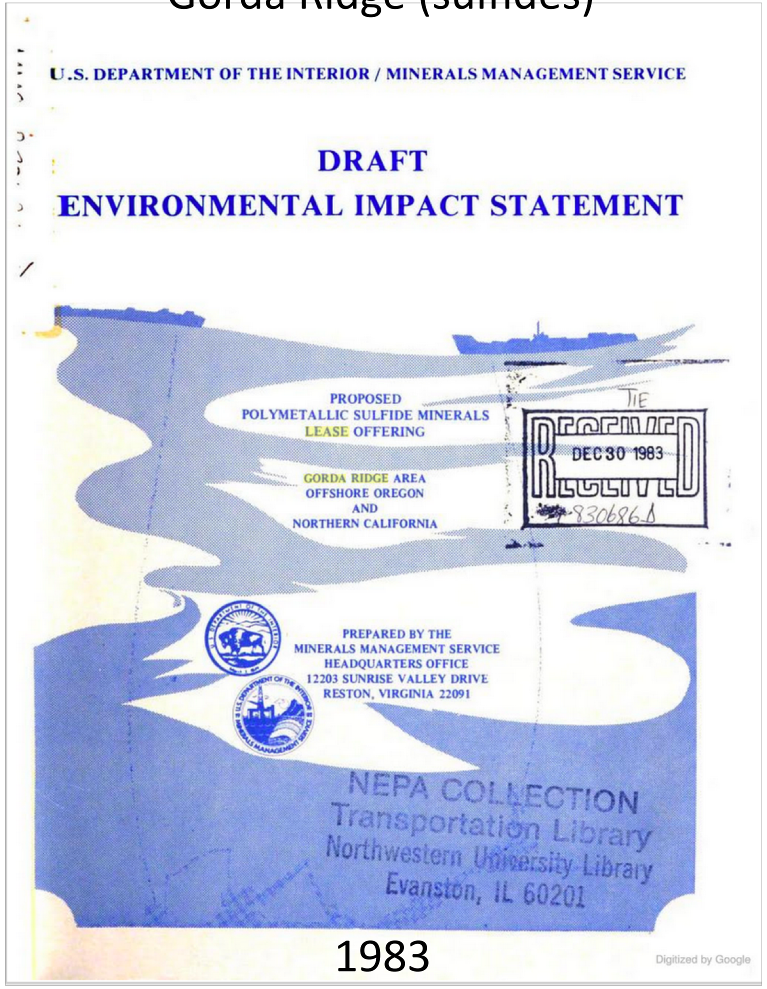
EIS calls for:

- strong collaboration and transparency among all stakeholders
- collaboration between industry and an independent team of scientists
- sharing of environmental knowledge generated
- setting a high bar for environmental baselines and monitoring

"academic-industrial complex"

US Activities

Gorda Ridge (sulfides)


U.S. DEPARTMENT OF THE INTERIOR / MINERALS MANAGEMENT SERVICE

DRAFT
ENVIRONMENTAL IMPACT STATEMENT

PROPOSED
POLYMETALLIC SULFIDE MINERALS
LEASE OFFERING

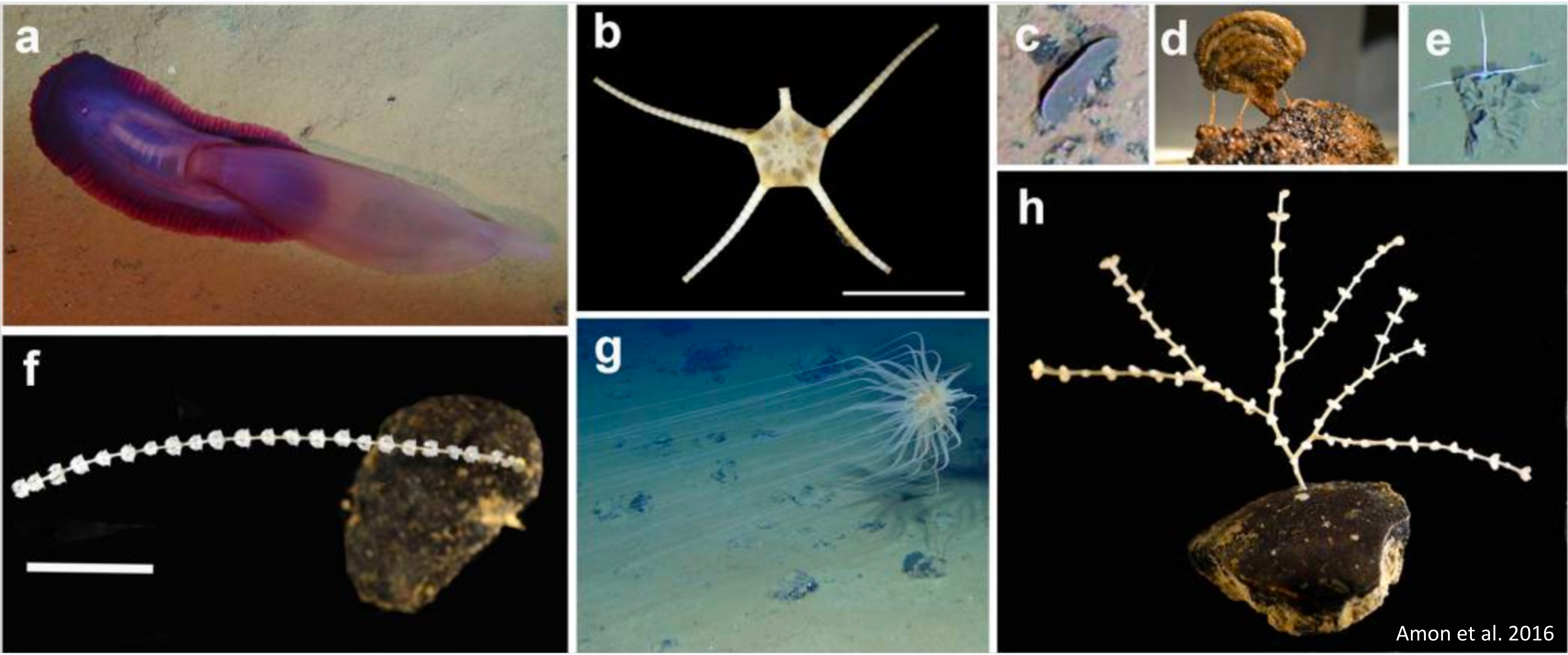
GORDA RIDGE AREA
OFFSHORE OREGON
AND
NORTHERN CALIFORNIA

PREPARED BY THE
MINERALS MANAGEMENT SERVICE
HEADQUARTERS OFFICE
12203 SUNRISE VALLEY DRIVE
RESTON, VIRGINIA 22091

1983

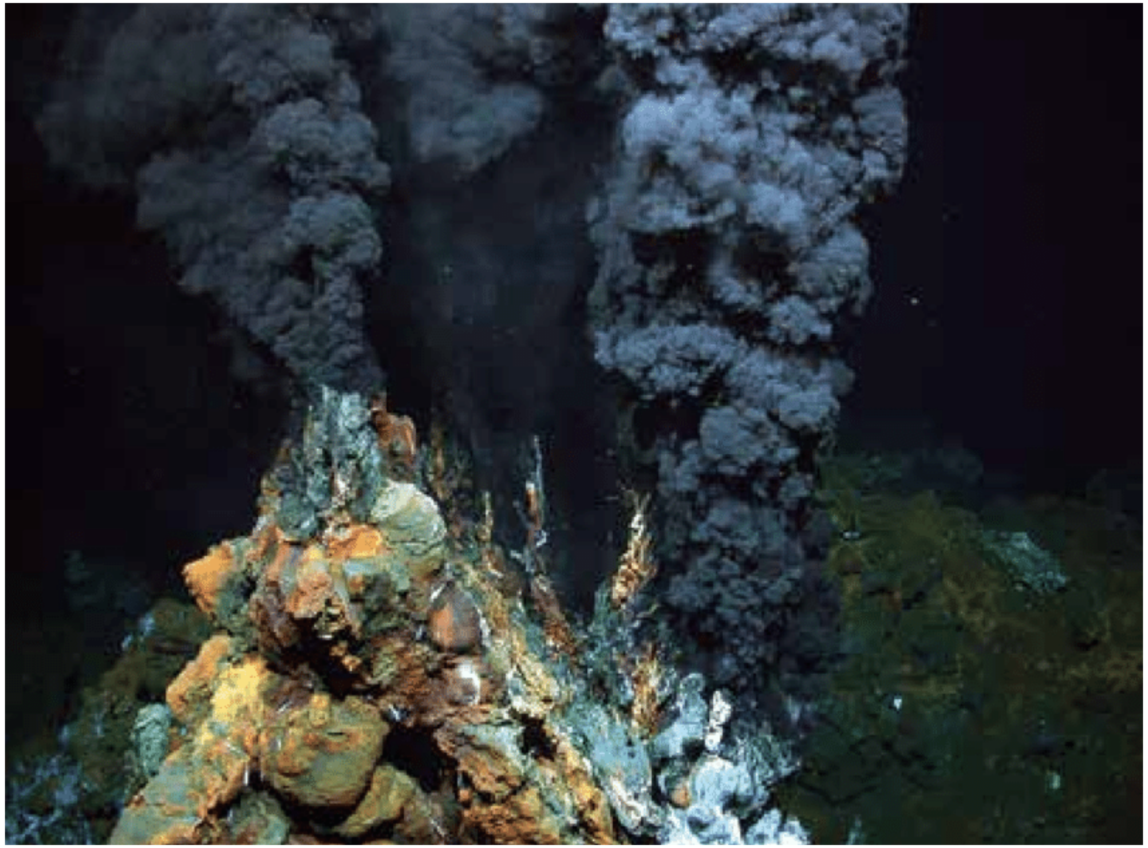
Glomar Explorer 1974 (nodules)
(cover for CIA recovery of Soviet K-129 nuclear submarine, 5000 m)

Ecosystems at Risk: Nodules



Ecosystems at Risk: Nodules

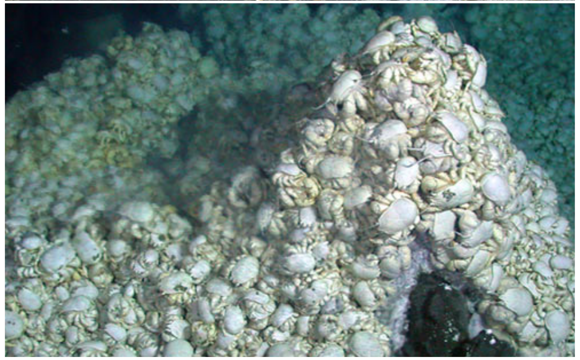
Ecosystems at Risk: Sulfides



Rogers et al. 2015

NOAA OER, Schmidt Oceanographic Institute, Thatje et al. 2015

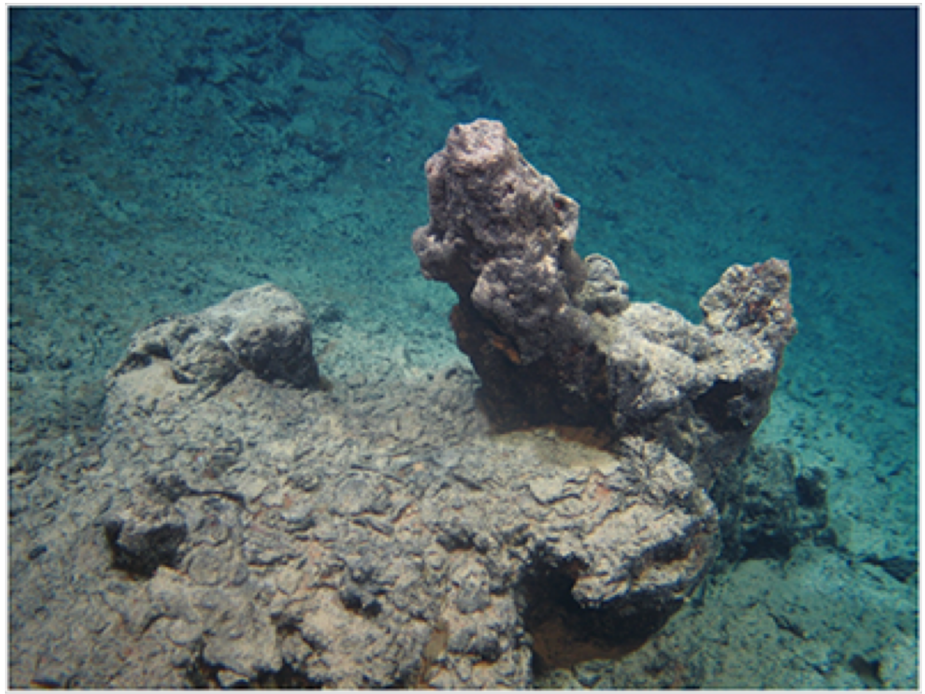
Ecosystems at Risk: Sulfides



Active hydrothermal vents:

- oases of vibrant & exotic life dependent on microbes that produce food using chemical energy (chemosynthesis)
- tiny islands; globally ~1% of the area of Yellowstone National Park
- limited mineral resource opportunity
  - REEs low compared to terrestrial systems
- dominated by species that can live nowhere else – dependent on flux of fluids from the ocean crust
- “vulnerable marine ecosystems” protected from bottom fishing by RFMOs
- living libraries, where sciences, arts, and humanities gain new knowledge and understanding at the intersection of Life and Earth processes
- catalyze research into the possibilities for, and limits of, Life itself
- storehouses of endemic marine genetic diversity
- appealing to segments of society, generating important non-extractive use values (TV documentaries, films, books, art, etc)

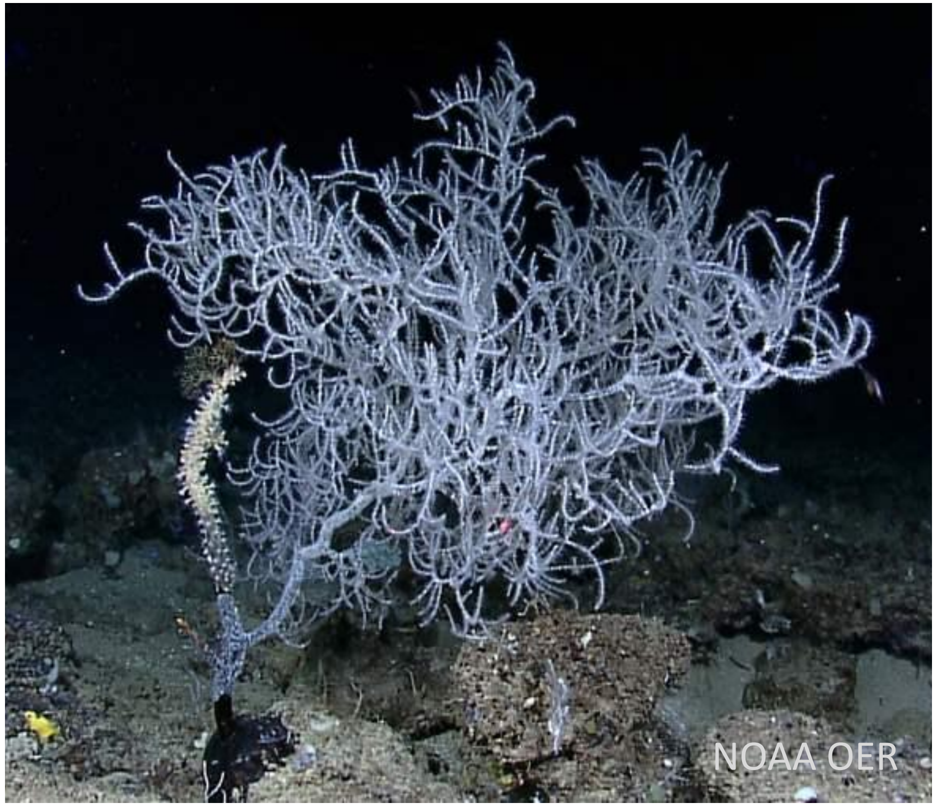
Ecosystems at Risk: Sulfides



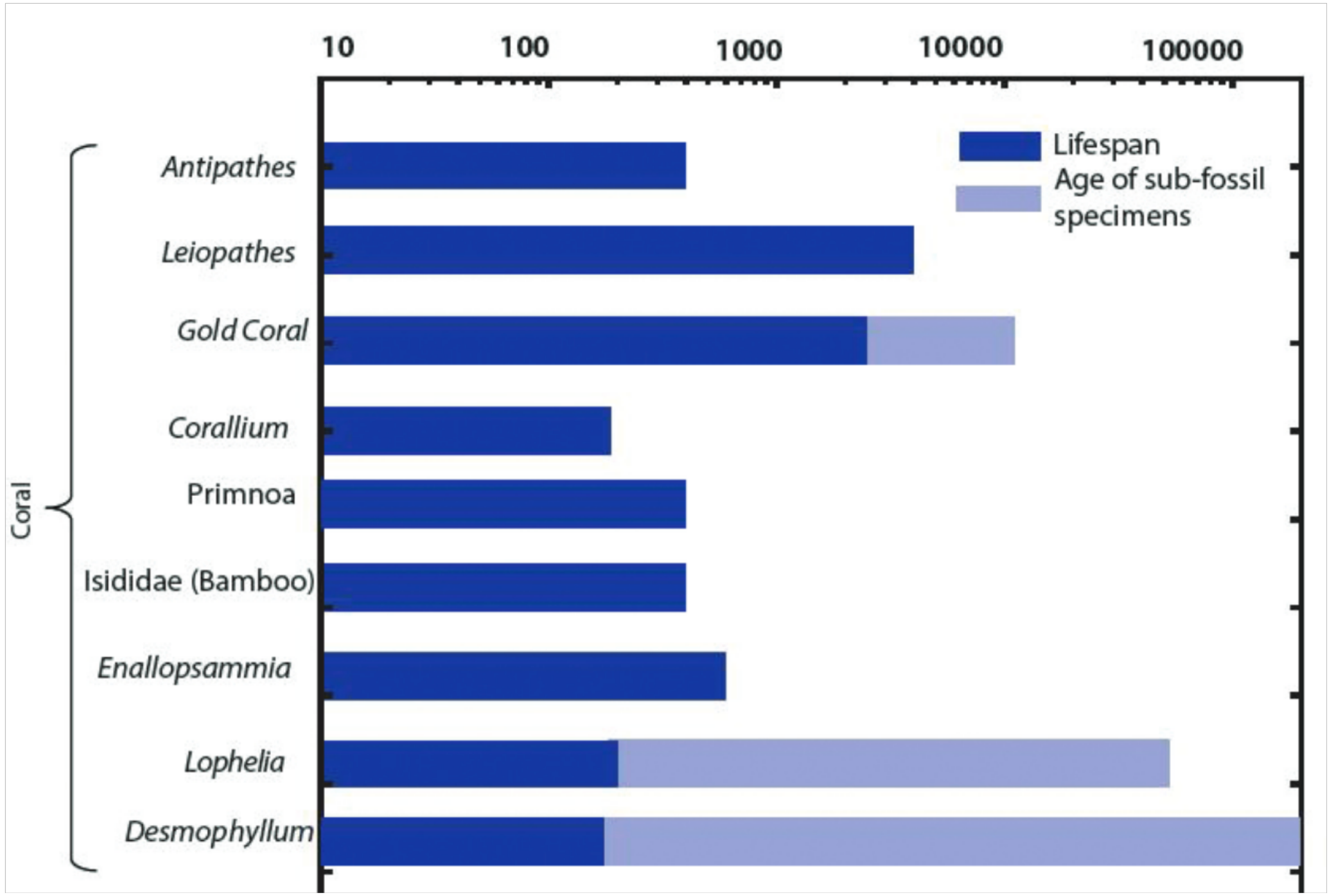
https://www.bgr.bund.de/EN/Themen/Min_rohstoffe/Bilder/proj_lagerst_INDEX_schlot_k_en.png?__blob=normal&v=4

Ecosystems at Risk: Crusts

Ecosystems at Risk: Crusts



Leiopathes black coral colony
400 to 1000 years old



Maximum lifespan of key deep-sea corals. Prouty et al. 2017

Ecosystems at Risk: Crusts

CenSeam-NIWA

Ecosystems at Risk

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

Biological Impacts (Response)
Elimination or reduction of local populations
Decreased reproductive output
Local, regional, or global extinction of rare species
Decreased seafloor primary production
Decreased diversity (genetic, species, habitat)
Mortality or impairment due to toxic sediments
Altered behaviors

Ecosystems at Risk

Cumulative Effects of Multiple Mining Events on Ecosystems
chronic regional losses of: brood stock genetic diversity species trophic interactions and complexity resilience
genetic isolation
species invasions

Ecosystems at Risk: Nodules

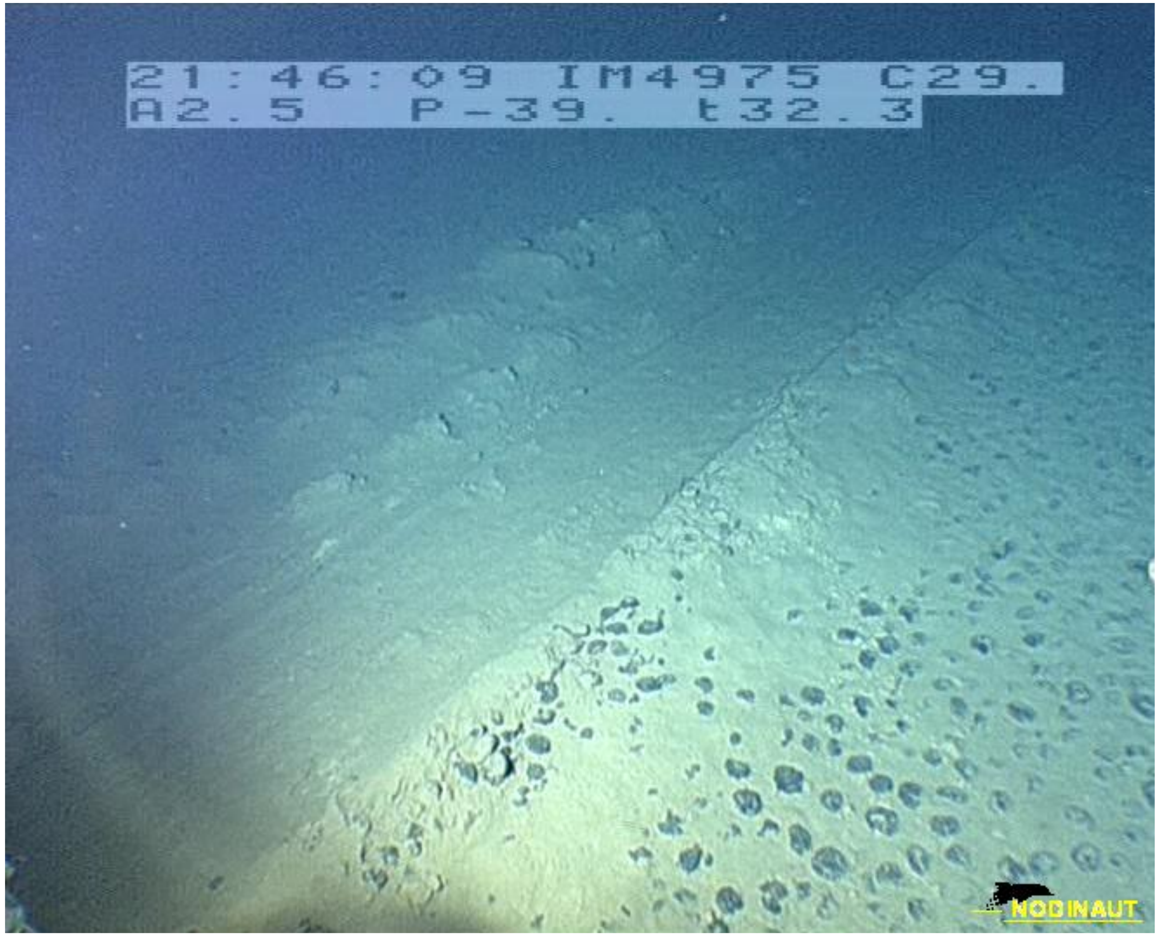
PLOS | ONE 2017

RESEARCH ARTICLE

Biological responses to disturbance from simulated deep-sea polymetallic nodule mining

Daniel O. B. Jones[1]*, Stefanie Kaiser[2], Andrew K. Sweetman[3], Craig R. Smith[4], Lenaick Menot[5], Annemiek Vink[6], Dwight Trueblood[7], Jens Greinert[8,9], David S. M. Billett[1], Pedro Martinez Arbizu[2], Teresa Radziejewska[10], Ravail Singh[2], Baban Ingole[11], Tanja Stratmann[12], Erik Simon-Lledó[1,13], Jennifer M. Durden[1,13], Malcolm R. Clark[14]

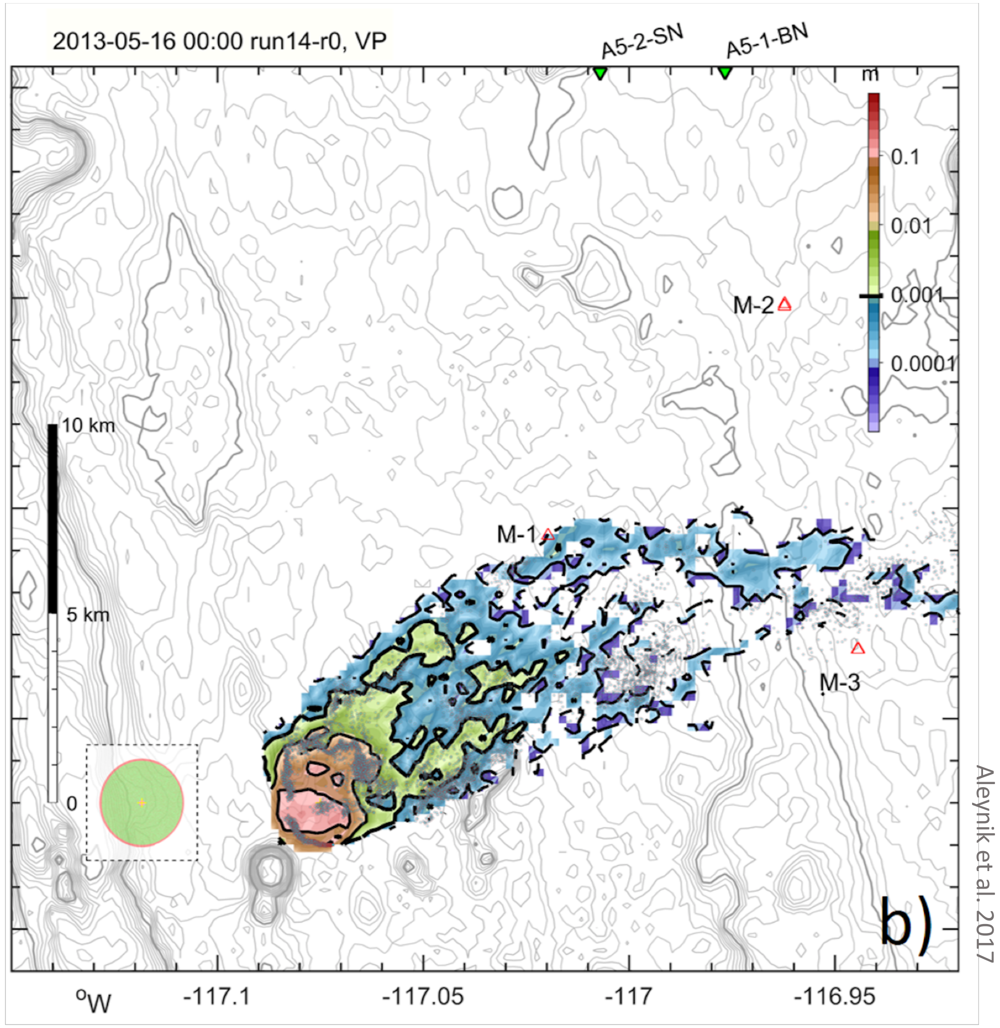
- very few faunal groups return to baseline or control conditions after two decades
- considerable negative biological effects of nodule mining, even at the small scale of test mining experiments
- variation in sensitivity amongst organisms of different sizes and functional groups
- effects of nodule mining are likely to be long term



‘test-mining’ track: 25 yrs since event

Jones et al. 2017

Ecosystems at Risk: Plumes



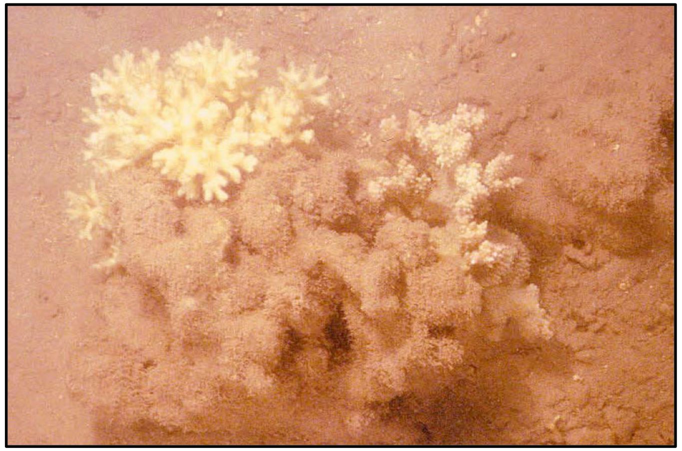
Images from NOA OER

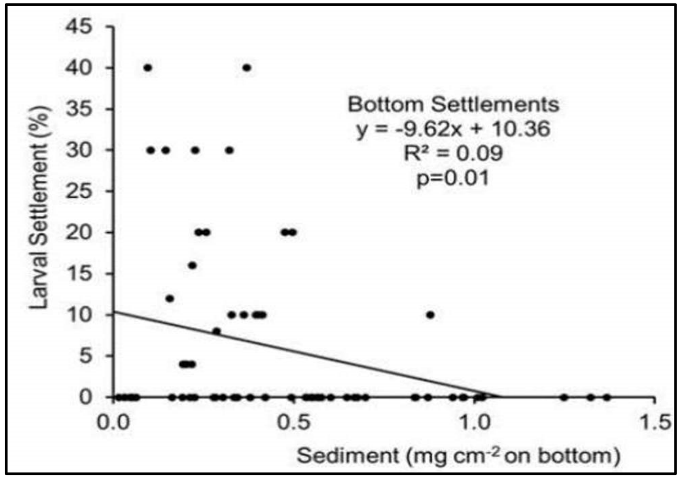
Ecosystems at Risk: Sedimentation, Toxicity

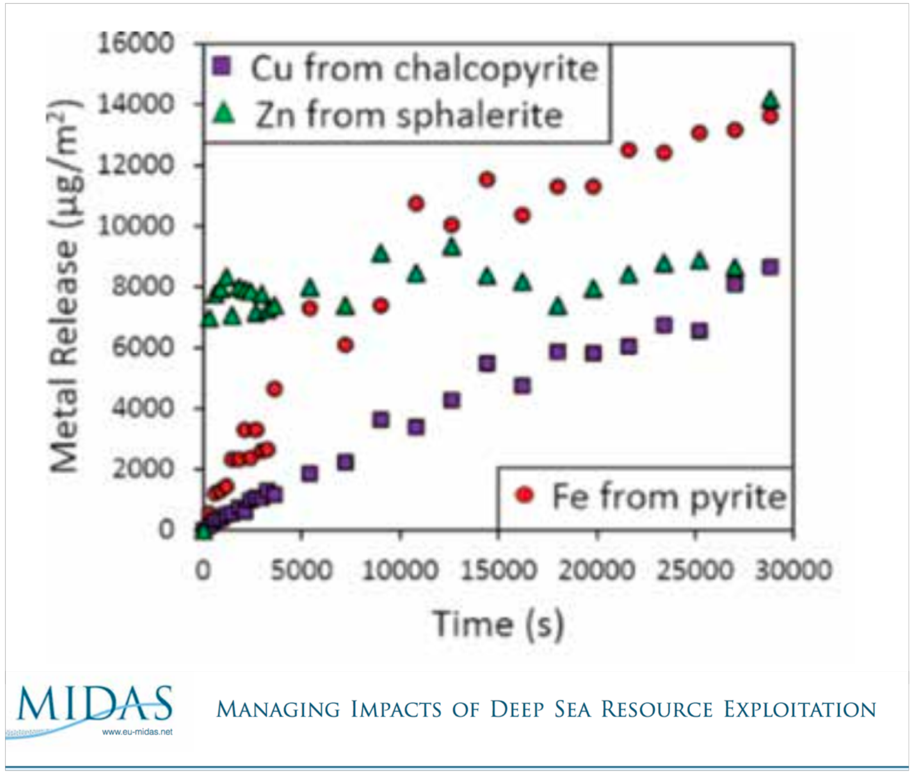
Sedimentation Effects

e.g., reduced recruitment?

Perez et al. 2014



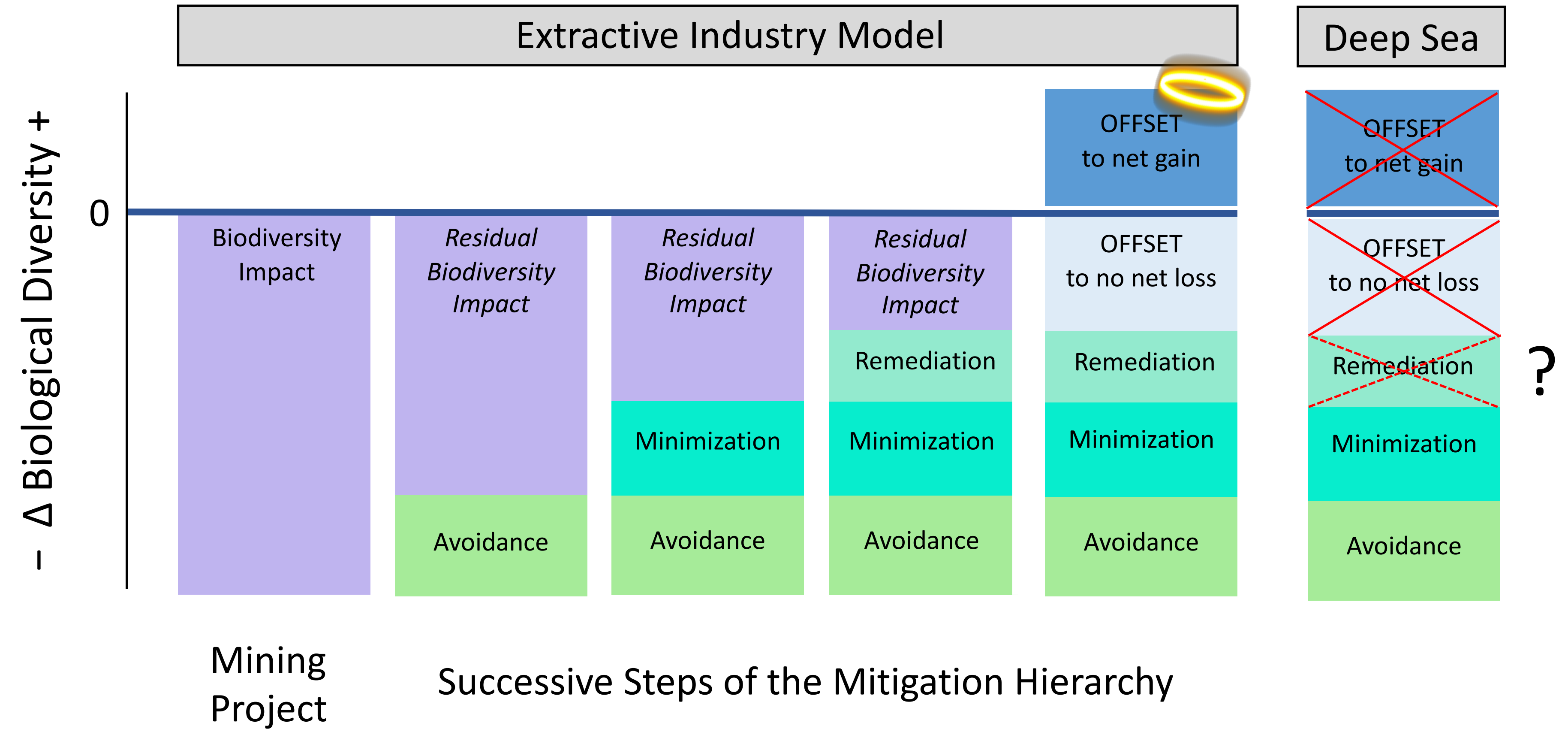




oxidation of sulfides ⇒ increased [dissolved metals]

⇒ Larval Toxicity

Potential for Biodiversity Loss



Avoidance (ABNJ)

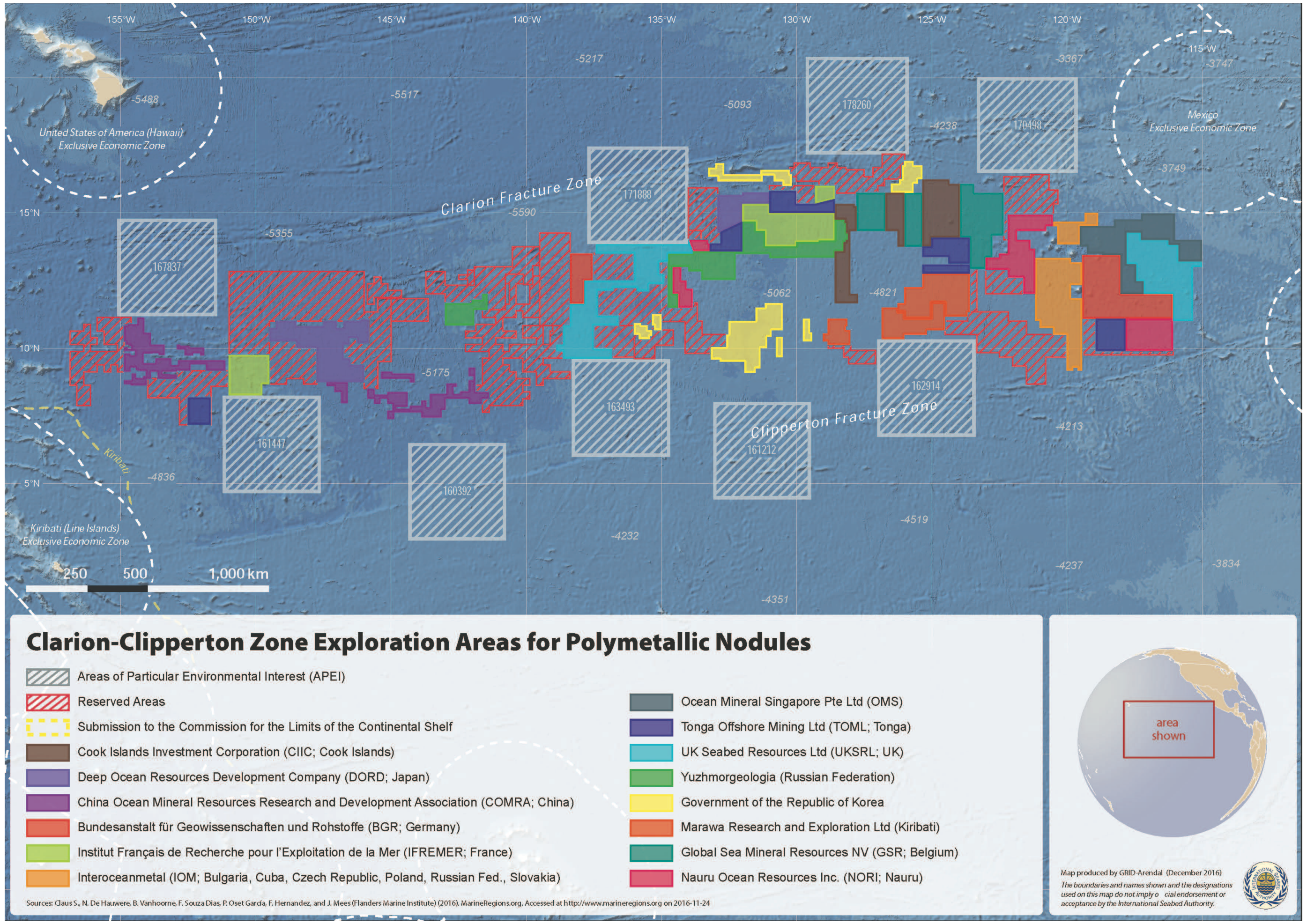
Regional Environmental Management Plans (REMPs)

Precautionary Approach

Areas of Particular Environmental Interest (APEIs)

network of large ‘no-mine’ areas

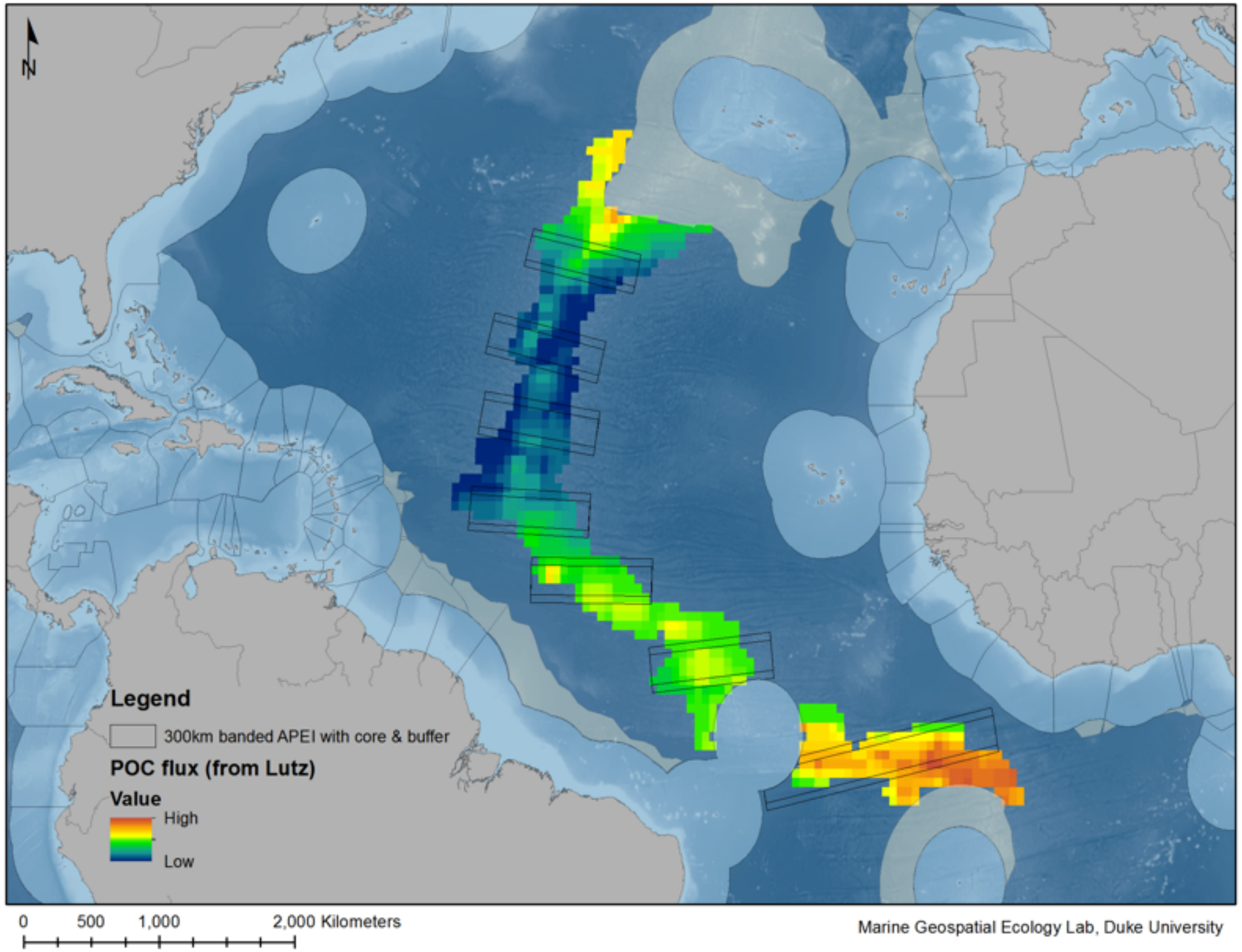
30 to 50 % of a region



Clarion-Clipperton Zone REMP

Avoidance (ABNJ)

Proposal for Sulfide REMP-APEIs on the Mid-Atlantic Ridge



Dunn, Van Dover et al. 2018

Environmental Regulations of the ISA Mining Code (in development)

INTERNATIONAL SEABED AUTHORITY

English Français Español

HOME THE AUTHORITY MINERALS LEGAL INSTRUMENTS CONTRACTORS ACTIVITIES TRAINING NEWS SESSIONS DOCUMENTS BBNJ

ONGOING DEVELOPMENT OF REGULATIONS ON EXPLOITATION OF MINERAL RESOURCES IN THE AREA

The ISA is in the process of developing Regulations for Exploitation of mineral resources in the Area which is the ultimate regulatory phase in developing the common heritage of mankind. In the course of its work, it has undertaken several activities and issued the following documents below. *During its 24th Session Council meetings in July 2018, all stakeholders were invited to comment on the revised draft regulations by the 30 September 2018 to* consultation@isa.org.jm .

NEW Stakeholder Submissions to the revised draft Regulations
NEW Briefing note on the submissions to the draft regulations on the exploitation of mineral resources in the Area

Mining Code

- Regulations
- Recommendations
- Draft Exploitation Code

Safe-Guarding Deep-Sea Ecosystems

- Protect all active deep-sea hydrothermal vents and other vulnerable marine ecosystems from impacts of mineral extraction.
- REMPs must be assessed for their ability to achieve environmental management objectives and be approved *before* exploitation is allowed to take place.
- Exploitation regulations must include best practices for Environmental Impact Assessment and Environmental Management and Monitoring Plans, with clear paths for Stop Work orders.
- Independent oversight of environmental monitoring and assessment of potential for serious harm by competent experts is essential.
- Remediation/restoration actions must not do more harm than good.
- Investment in scientific research and technology, including
    - biodiversity and ecosystem process studies
    - improvements in modeling and predictive capability for critical biogeochemical parameters and ecosystem services
    - automated, spatially and temporally relevant monitoring systems with real-time data telemetry
    - effective restoration/rehabilitation actions
    - building capacity.

Thank You

My sincere thanks to the **Renewable Natural Resources Foundation** for this opportunity to speak about the emergent field of Deep-Sea Environmental Management.