Ecology and knowledge gaps relevant to deep seabed mining environmental impacts.

Renewable Natural Resources Foundation

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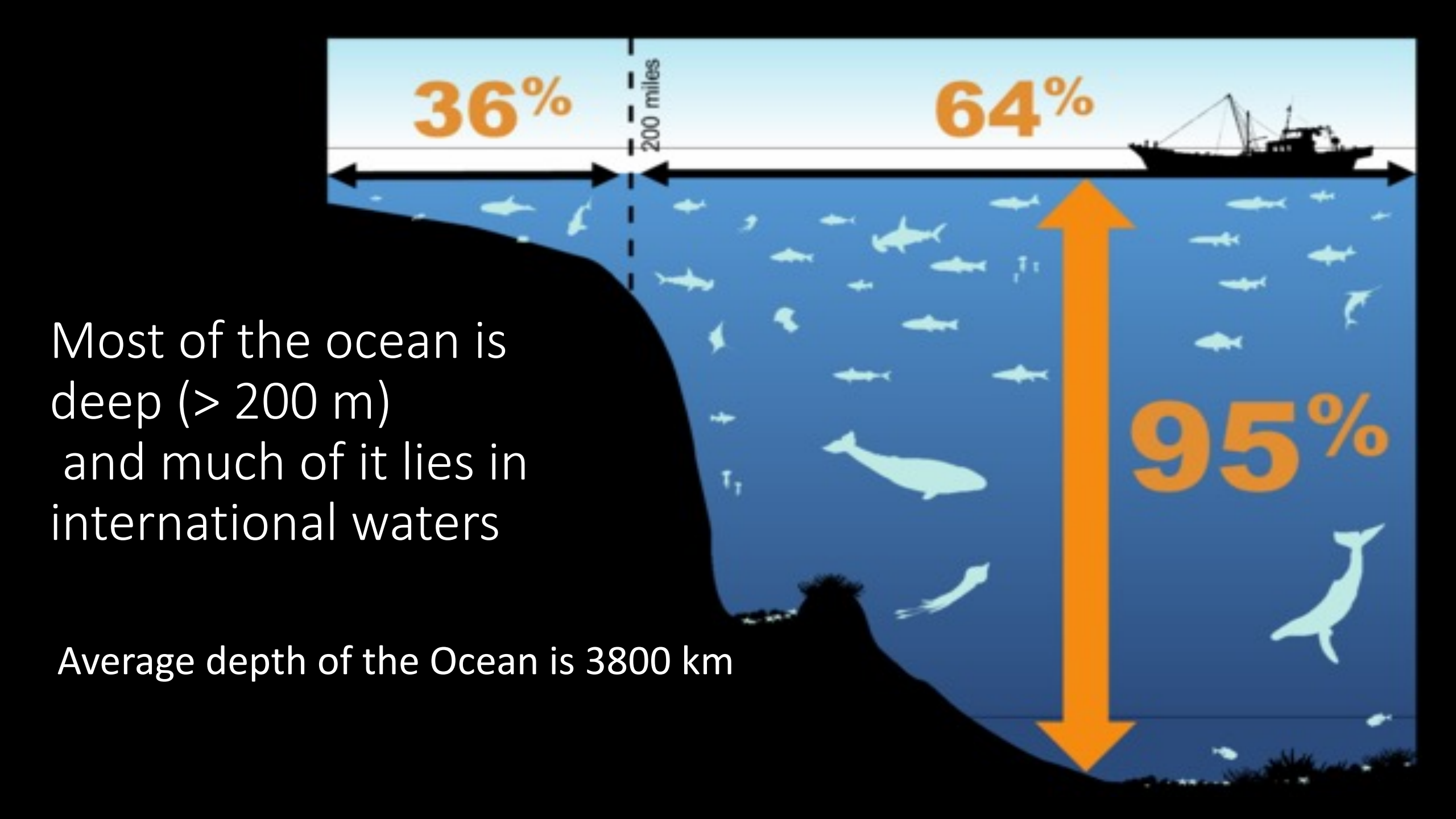
DEEP OCEAN OBSERVING STRATEGY

Schmidt Ocean Institute
Costa Rica Connections- 2019

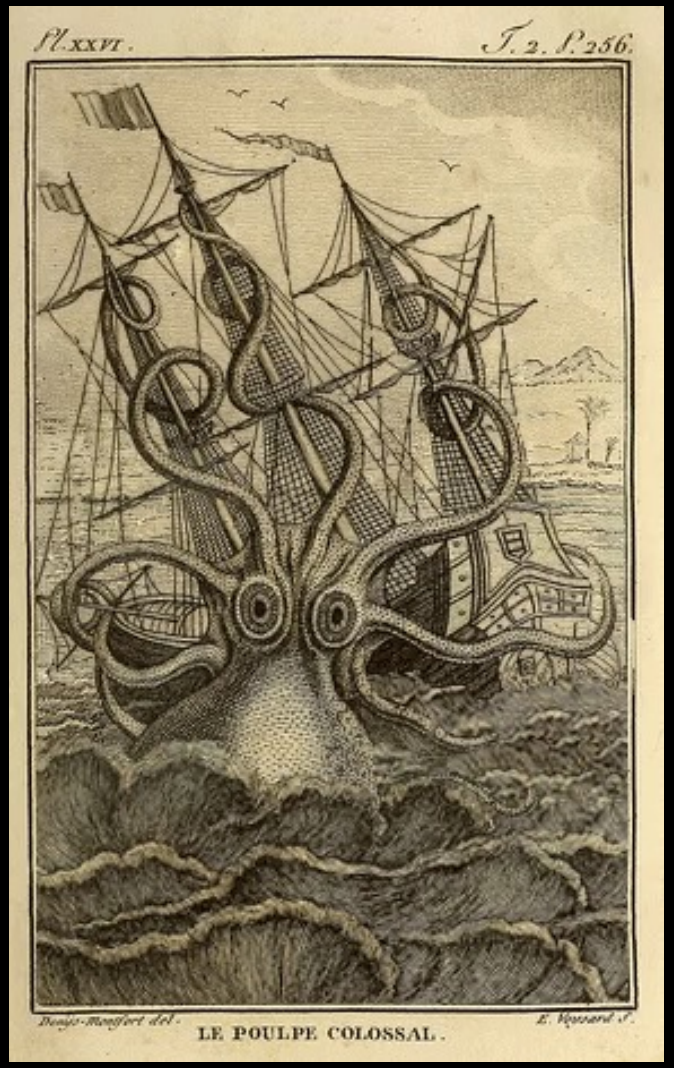
DOS
DEEP-OCEAN STEWARDSHIP INI



Most of the ocean is deep (> 200 m)
and much of it lies in international waters

Average depth of the Ocean is 3800 km

Our understanding of the deep ocean has evolved….

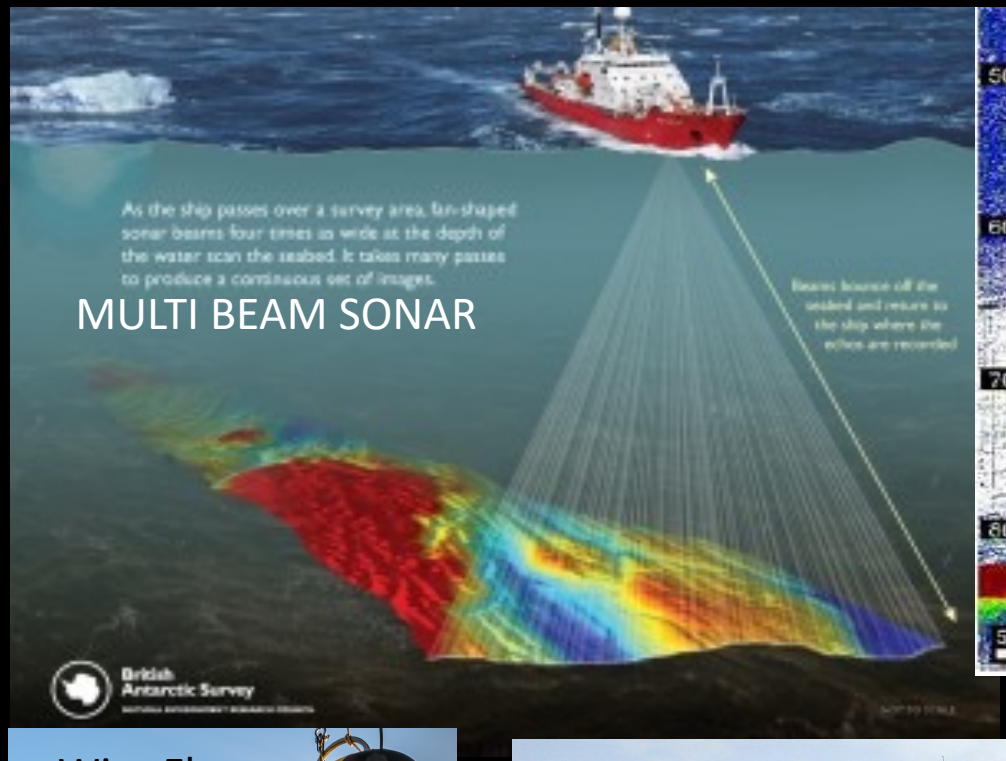


A hundred years ago…

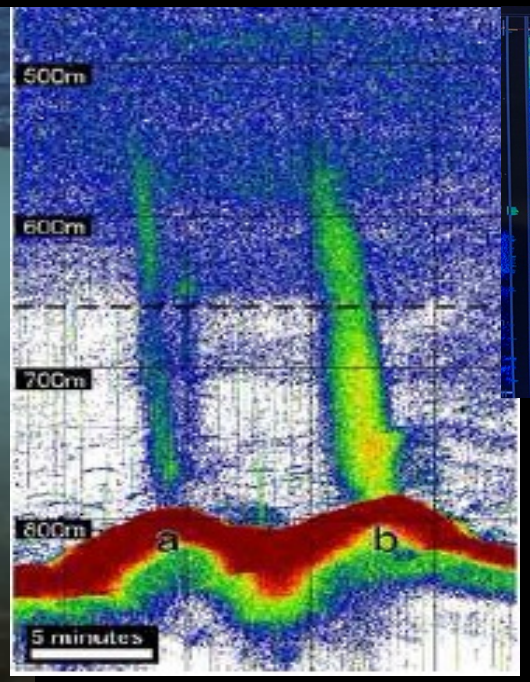
- Cold (2-4^{o} C)
- Dark (no sunlight)
- Salty (34.8)
- High Pressure (1 atm/10 m)

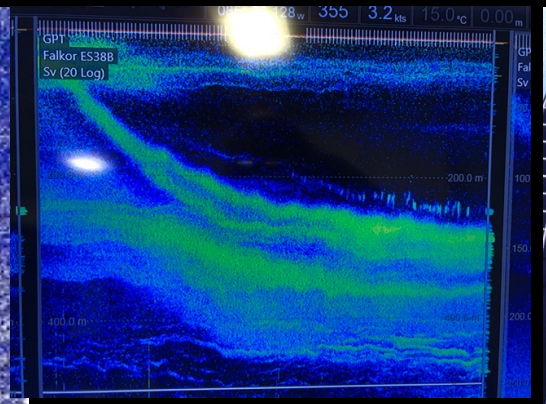
- Muddy
- Homogeneous
- Stable
- Quiescent
- Food Limited

New exploration tools reveal a wealth of environmental heterogeneity



MULTI BEAM SONAR

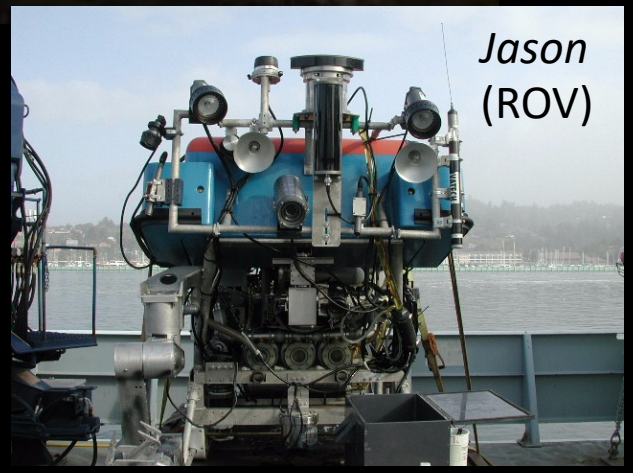


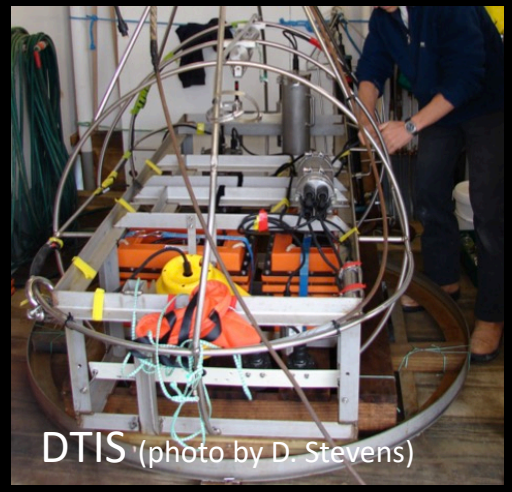


Acoustics

HOV

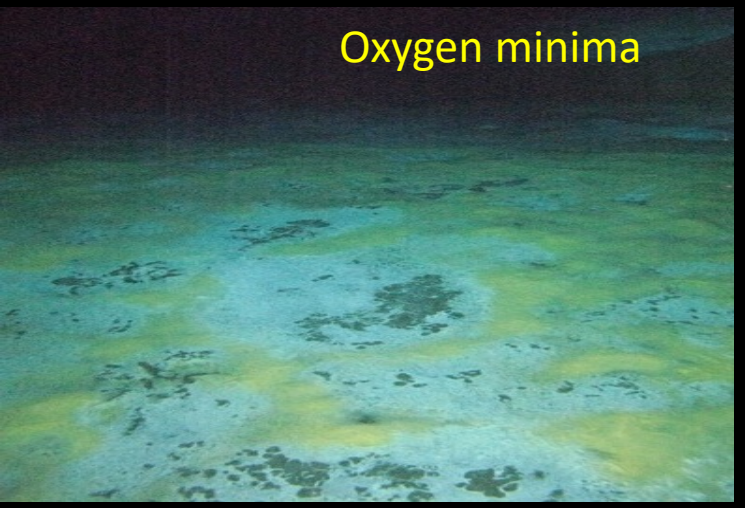

Wire Flyer

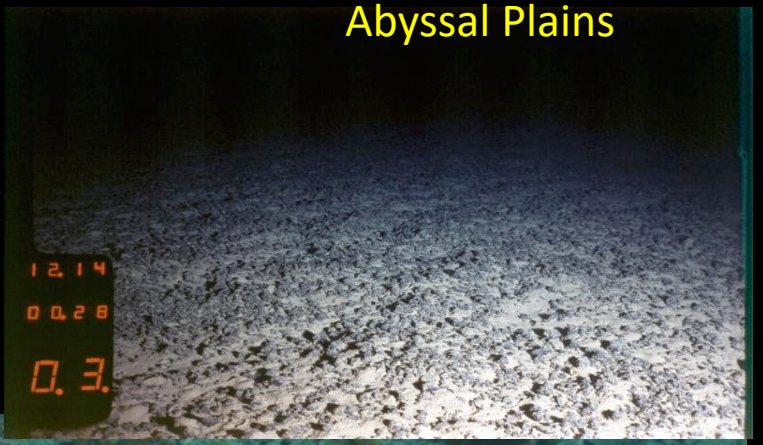

Jason (ROV)

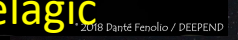

DTIS (photo by D. Stevens)

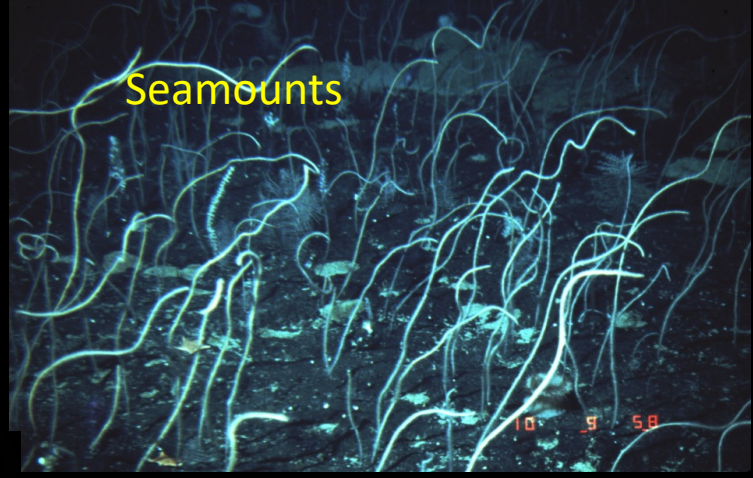

AUV

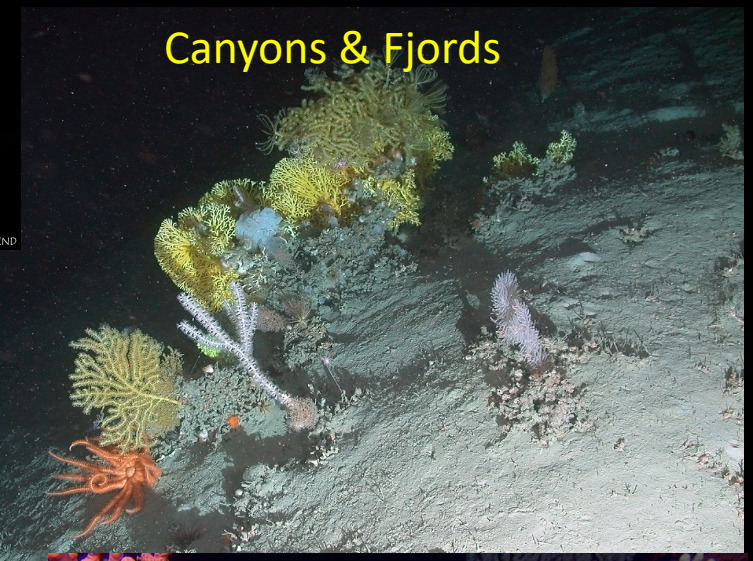
Habitat Heterogeneity abounds generating biodiversity

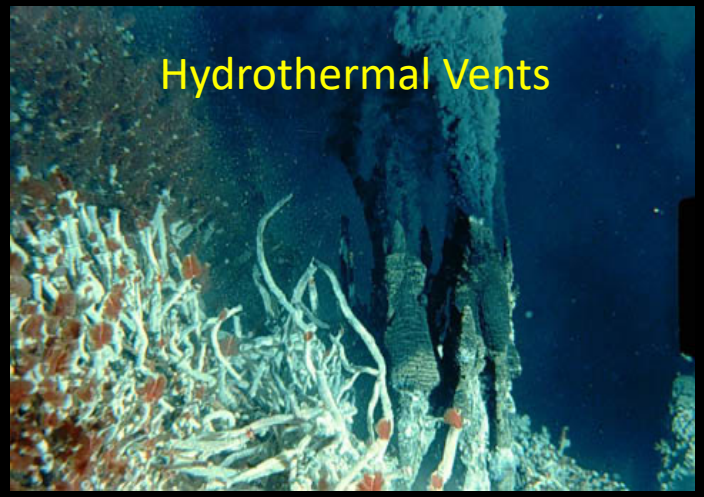




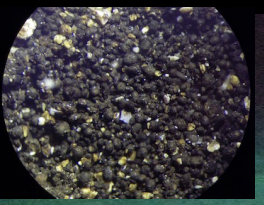








Habitat heterogeneity also generates RESOURCES!



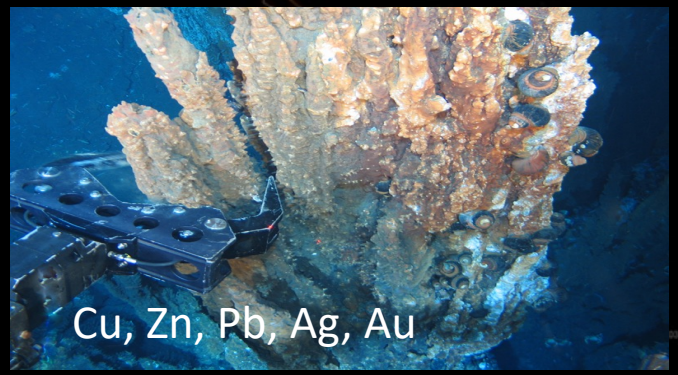
Oxygen minima

Phosphorites

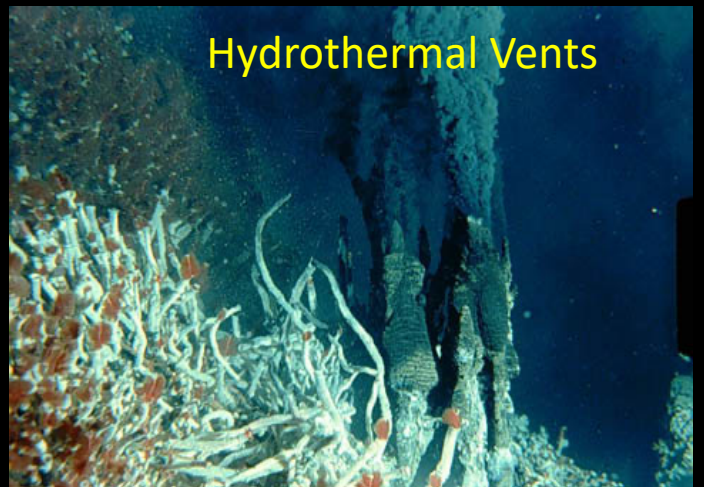
Abyssal Plains

Cu, Zinc, Co, Ni

Methane Seeps



Cu, Zn, Pb, Ag, Au

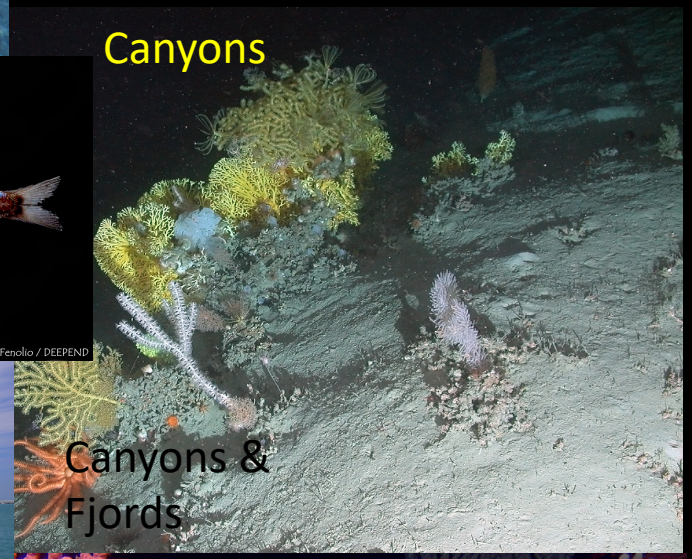


Hydrothermal Vents

Co, Ni, Mo, Ce

Seamounts

Mesopelagic



Canyons

Canyons & Fjords

Cold water coral & sponge reefs

Adaptation to extremes yields superpowers

- High Temperature
- Hydrogen Sulfide
- High Pressure
- Low Oxygen
- Low pH

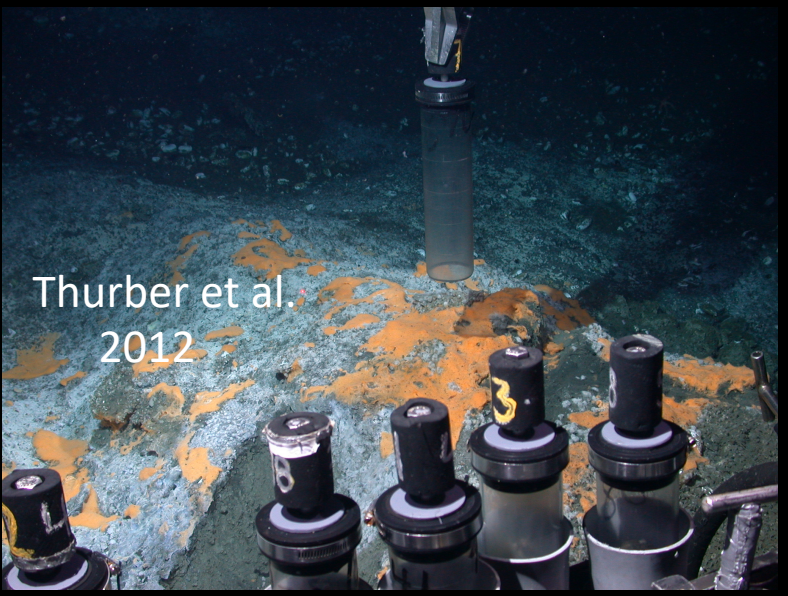
55°C (131°F)

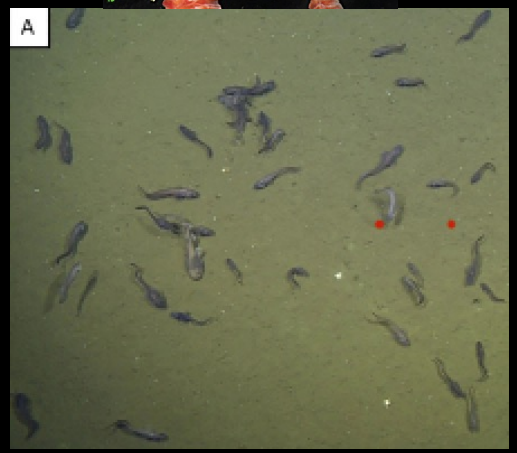
1% O_2 Saturation

800 atm pressure

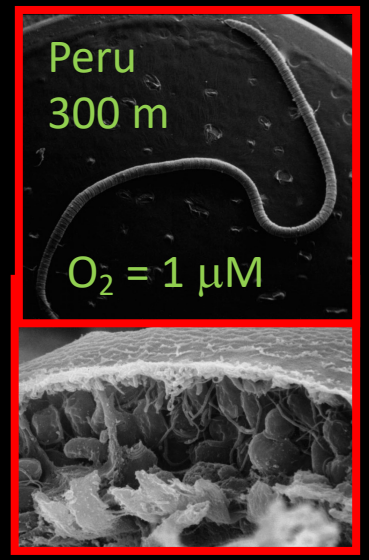
Olavius crassitunicatus

5 mM H_2S

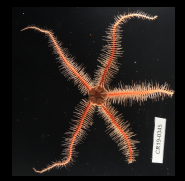




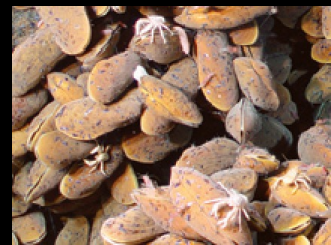
Gallo et al. 2018



Low pH: Calcification in undersaturated waters



Mussels at pH 5.3-7.3



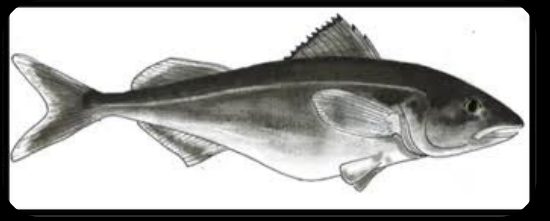
Extreme longevity:

Leiopathes sp. – **4,265 y old**

17,000 y old *Monorhaphis chuni*

Garrardia sp.

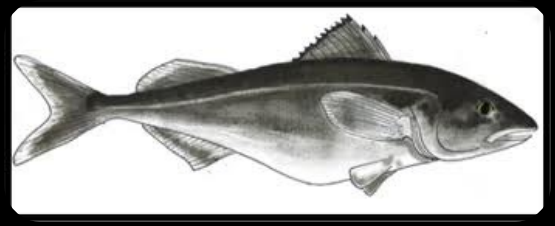
2,320 years old



Sablefish – 114 y

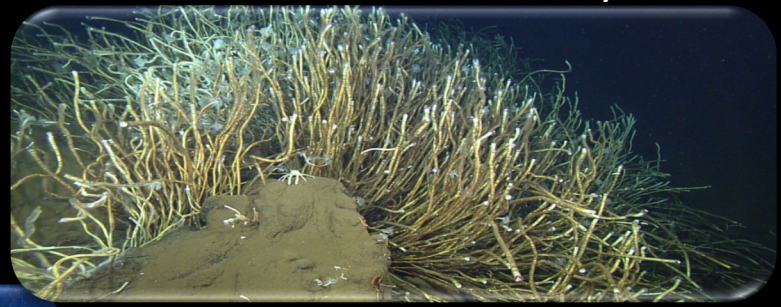
Orange Roughy - - 149 y

Smooth oreo dory – 100 y



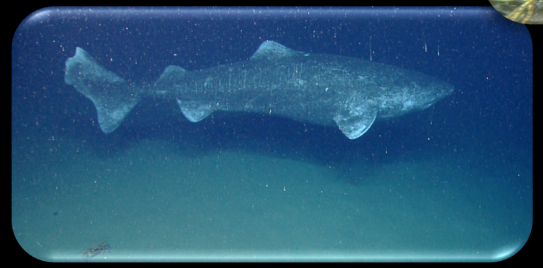
Sablefish – 114 y

Black Oreo- 153 y



Seep tubeworms at least 300 yrs old

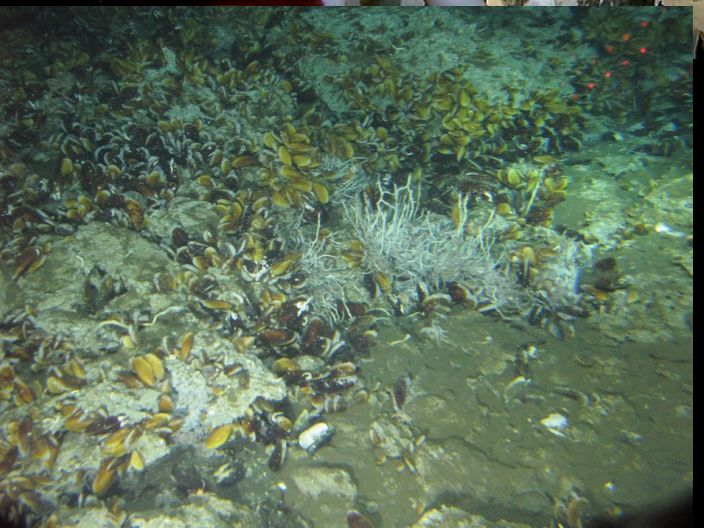
Greenland shark - 400 yrs old



Images NOAA and MBARI

Novel Feeding Modes

- **Oxidation of sulfide, methane hydrogen**

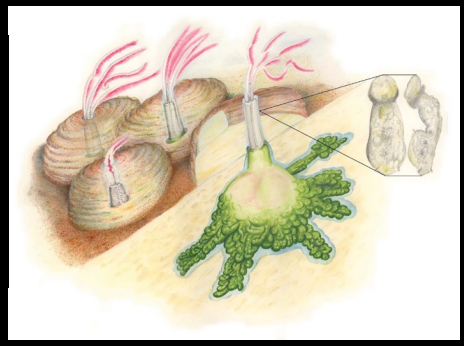


- **Digesting wood**

Xylophaga has cellulose-digesting symbionts

- **Digesting whale bone**

Osedax has collagin-digesting symbionts



Biodiversity as a service

Species – novel symbioses, behaviors, tolerances

Genes – GENETIC POTENTIAL TO ADAPT TO CHANGE!

Enzymes - e.g. cold water detergents, UV resistance

Metabolites/Drugs – antibiotics, anticancer, anti – inflamatory

Scylloinositol - Alzheimers

Biomaterials – sponge fiber optics

- coral bone grafts

-scaly foot snail - armor

Anti fouling – for marine or medical

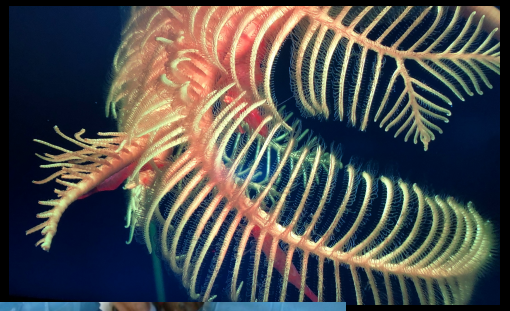
Detoxification – Methyl mercury

Cellulases – fermentation

Pyrolase – used in fracking

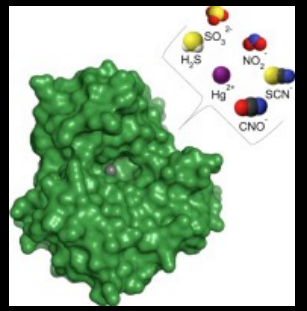
Artificial blood – from vent tubeworms

UV Resistant Skin Products

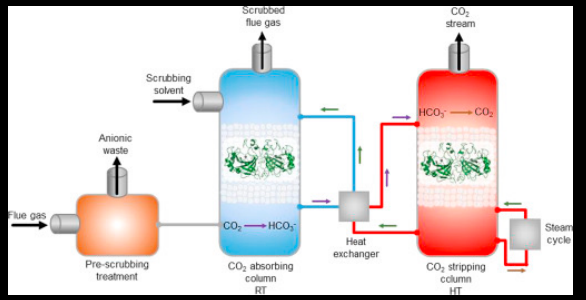


Diaz-Torres et al. 2015

Photograph by Peter Batson



Industrial CO_2 Scrubbing

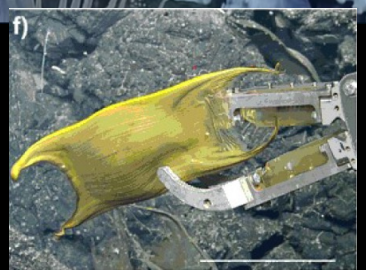


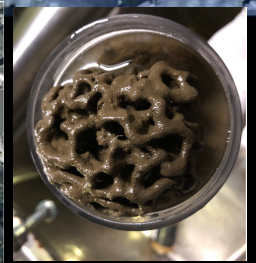
Mahon et al. 2015

Ecosystem services are still being revealed

Supporting Services

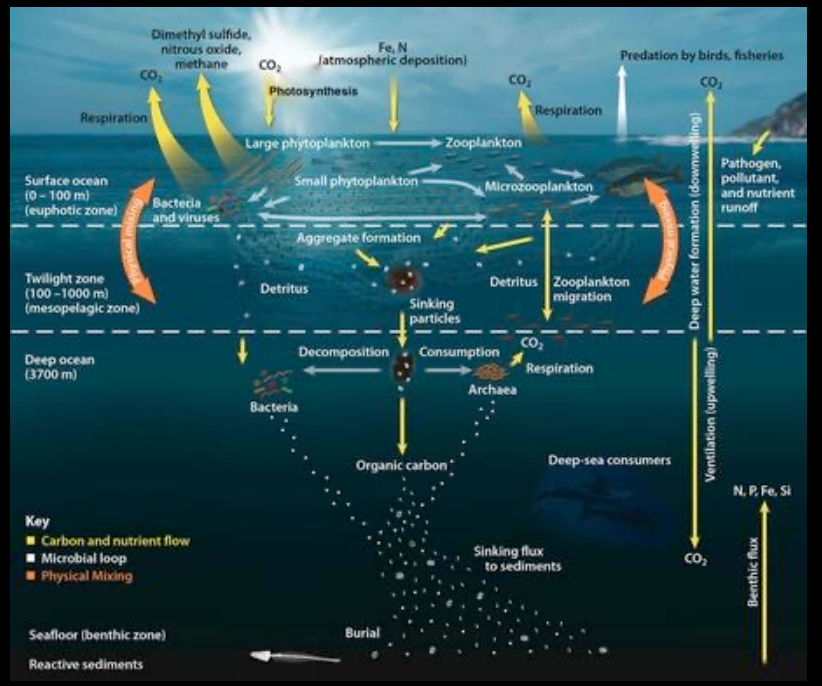
-Substrate
-Nursery
-Refugia
-Trophic Support



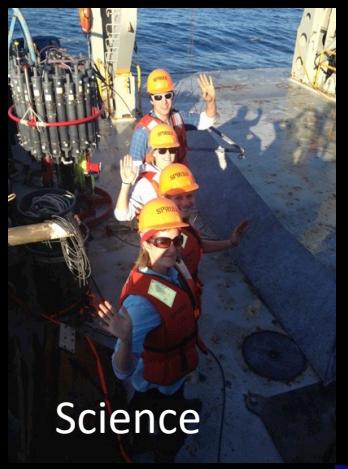


Regulating Services

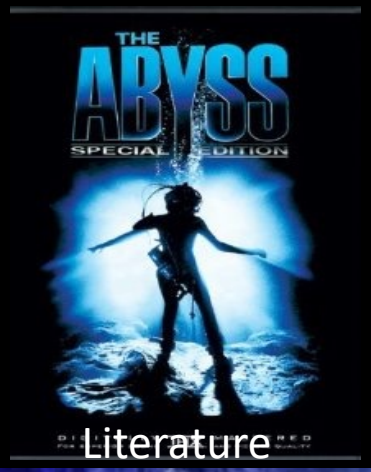
-Remineralization
-Carbon transport
-Carbon storage
-Carbon burial



Cultural Services



Science



Literature

Art

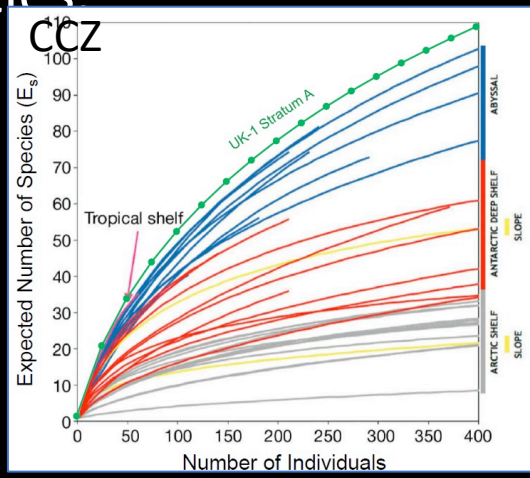
Film

Traditional Knowledge

Communications

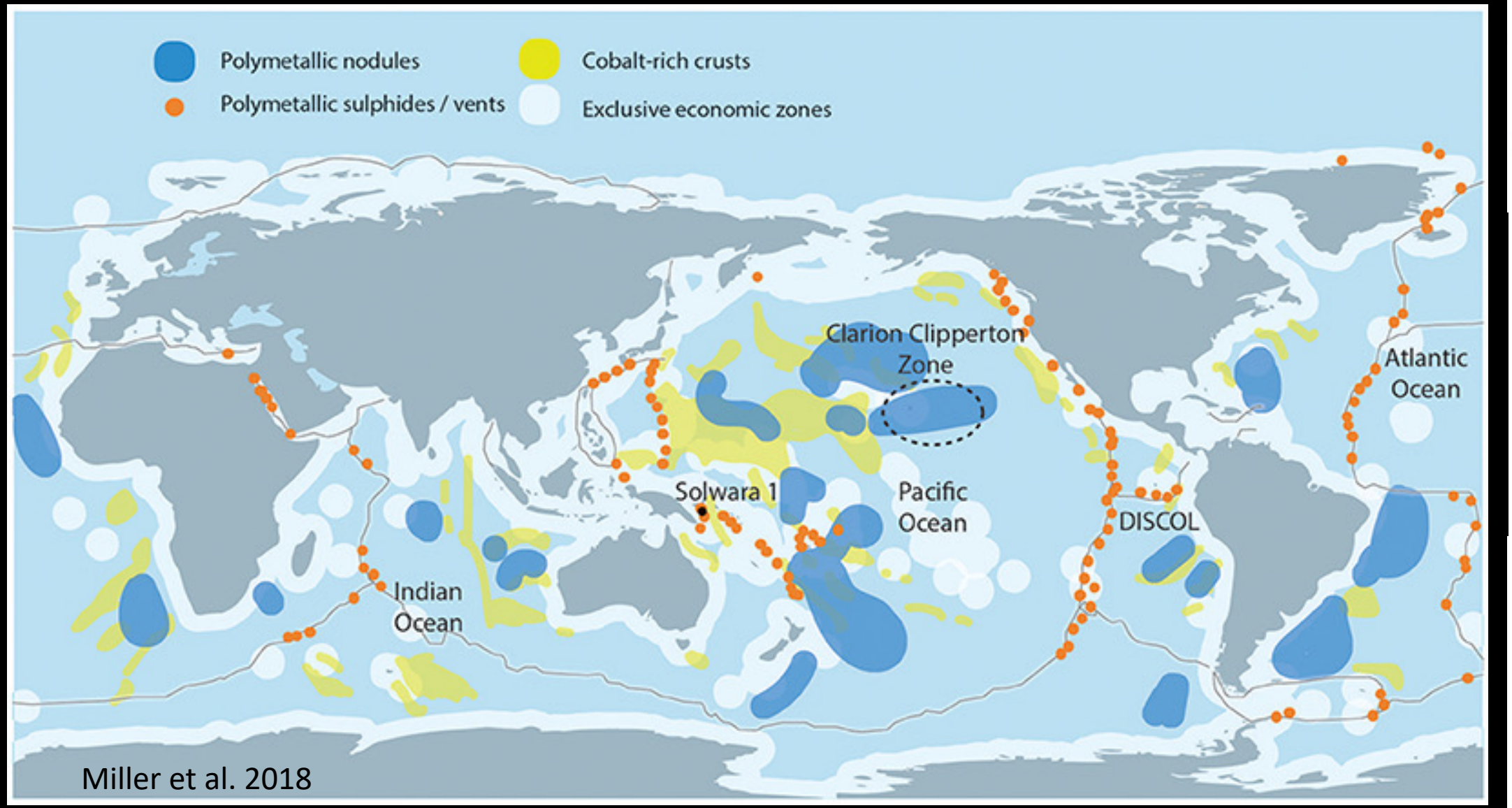
CRITICAL KNOWLEDGE

- The deep sea is heterogeneous. Even the CCZ consists of different habitats, productivity regimes, bathymetric features, substrates and vulnerabilities to climate change.
- Substrate, food supply, water geochemistry & flow regime shape communities
- Biodiversity is high (thousands of species in the CCZ)
  but most deep-sea species remained undescribed
- Animals have different lifestyles, feeding modes,
  life histories that determine vulnerability
- Animals can be long lived, grow slowly, mature late
- Endemicity is common – by habitat and location
  (everything is not everywhere)
- Rarity is common
- Seafloor and water columns are highly connected
- Biodiversity underpins ecosystem services

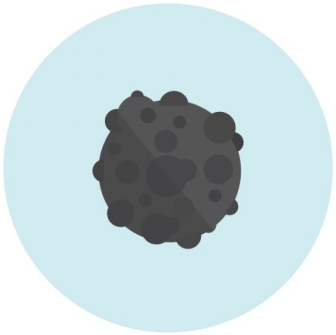


Vent Molluscs
PA/DrChongChen)

What does this have to do with seabed mining?



Miller et al. 2018

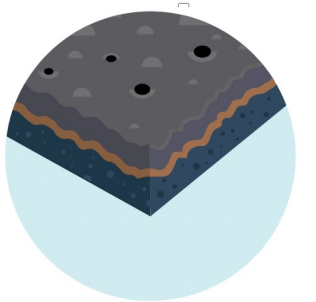


Polymetallic nodules

Source of nickel, cobalt, copper and manganese

Polymetallic sulfides

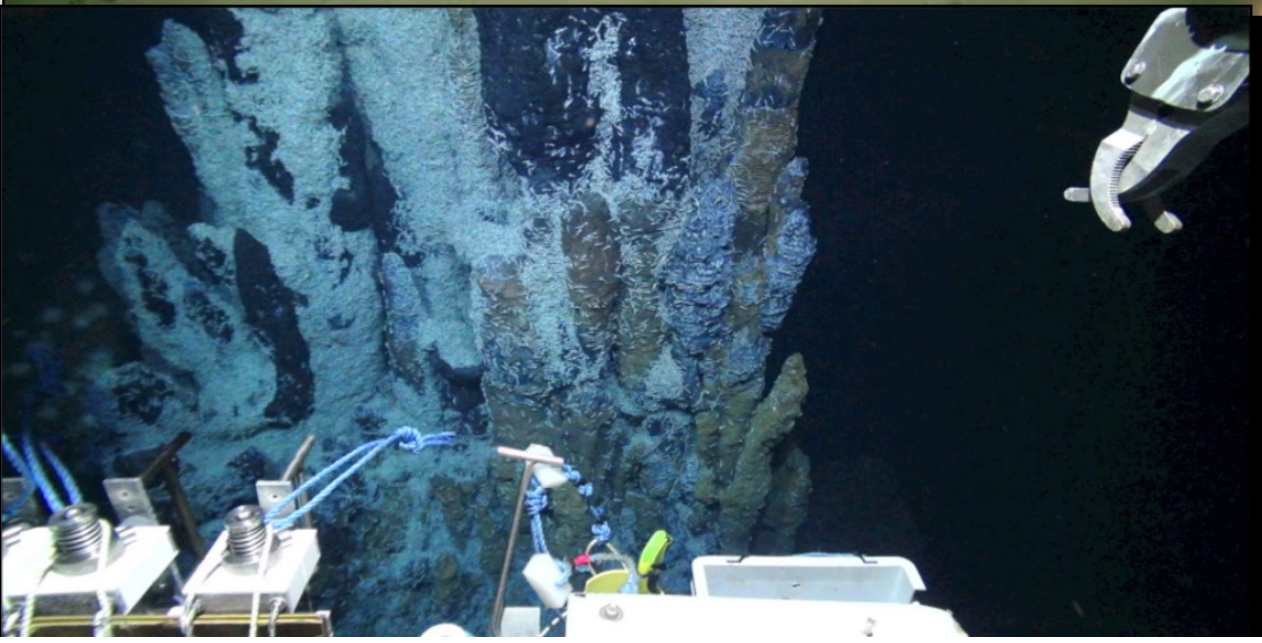
Copper, lead, zinc, gold and silver

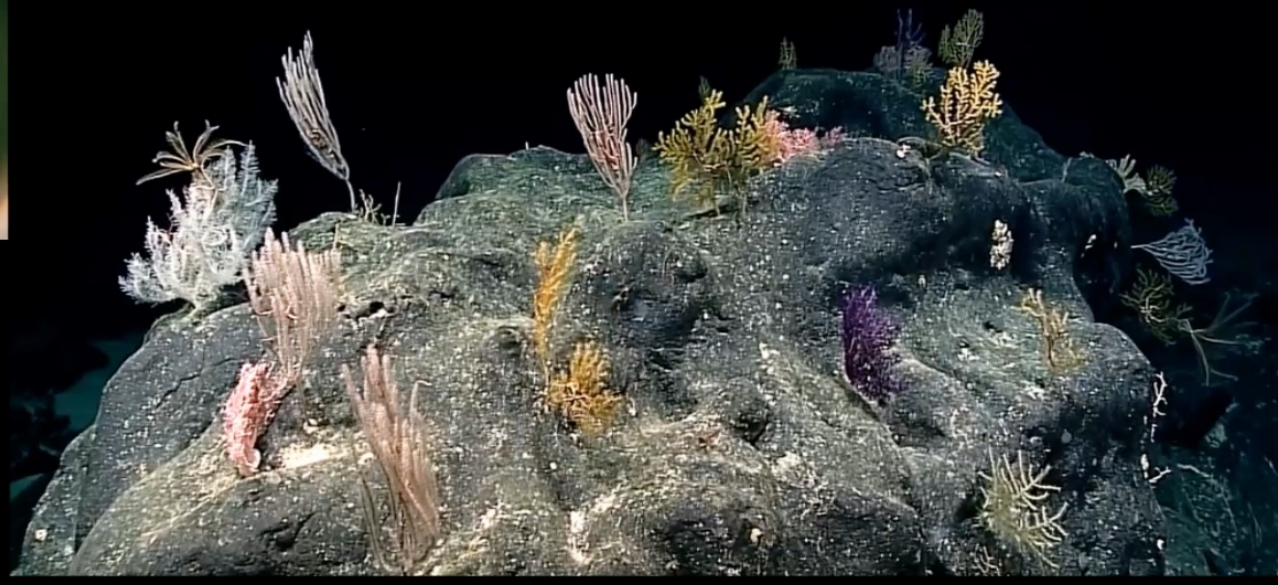


Cobalt-rich crust

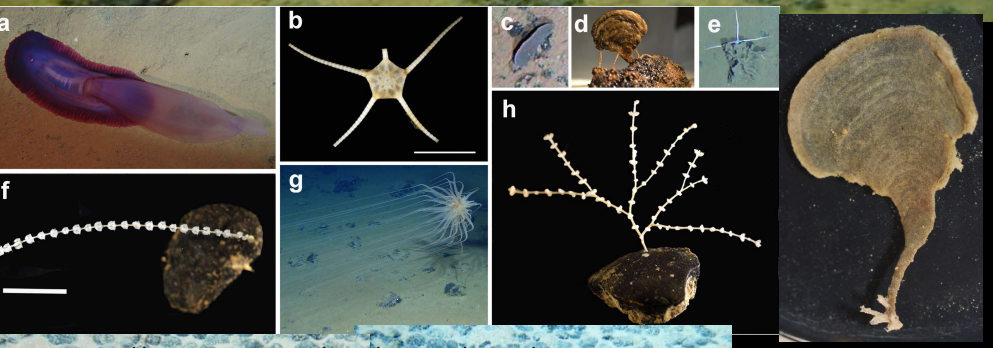
Cobalt, vanadium, molybdenum platinum and tellurium

Three ecosystems targeted in international waters

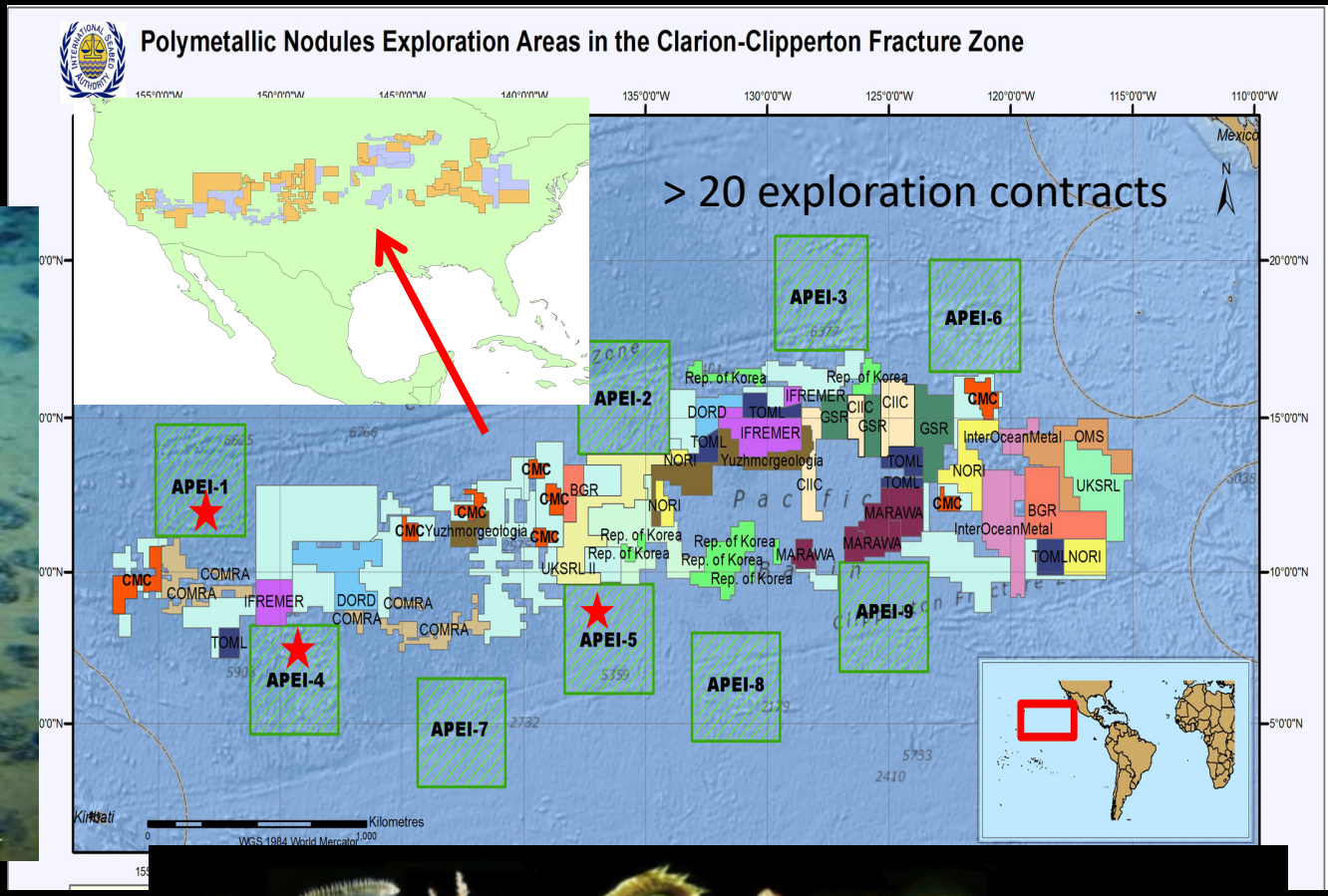




Clarion Clipperton Fracture Zone: Largest, best studied



http://www.isa.org.jm/files/images/maps/CCZ-Sep2012-Official.jpg

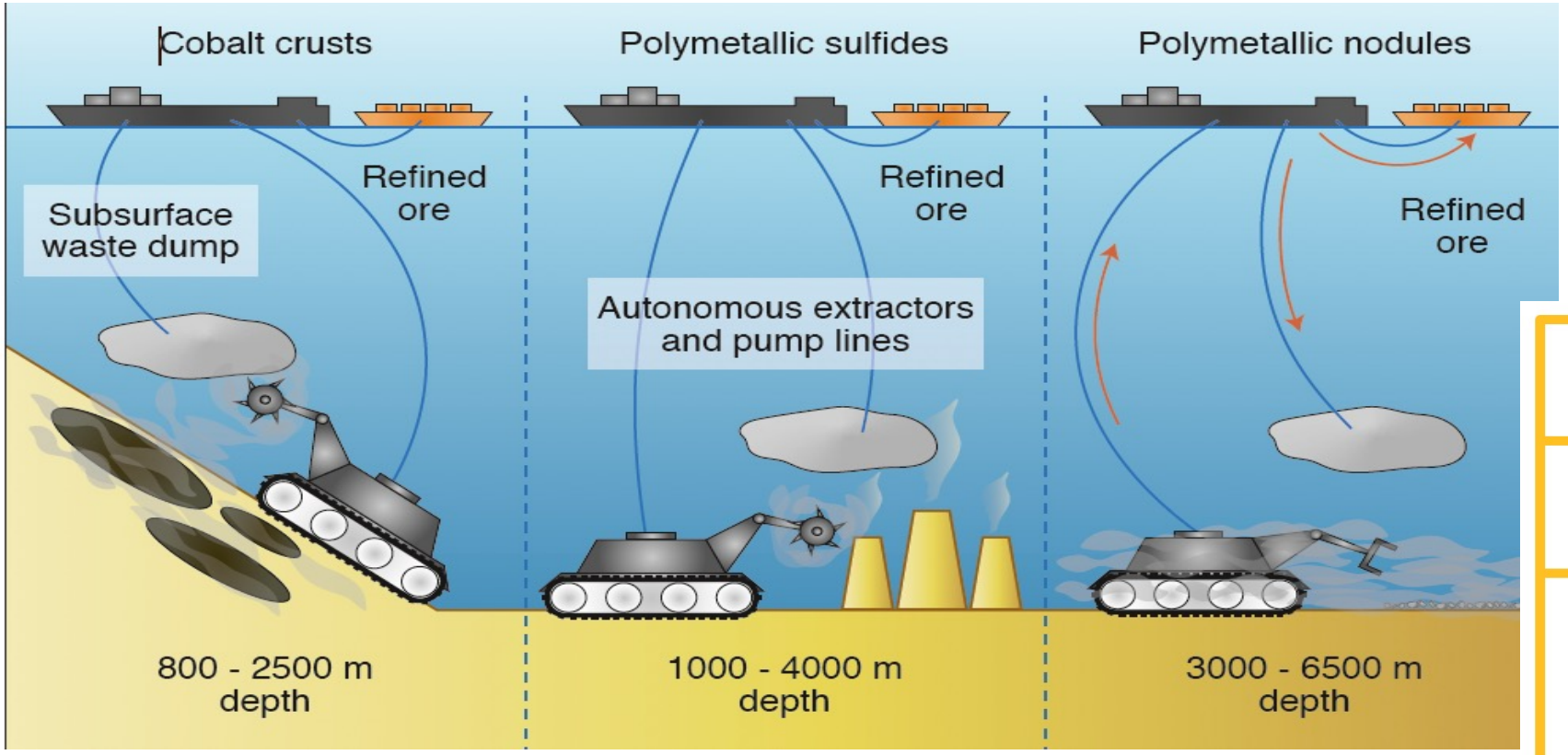


Diversity is high
Animals are small!

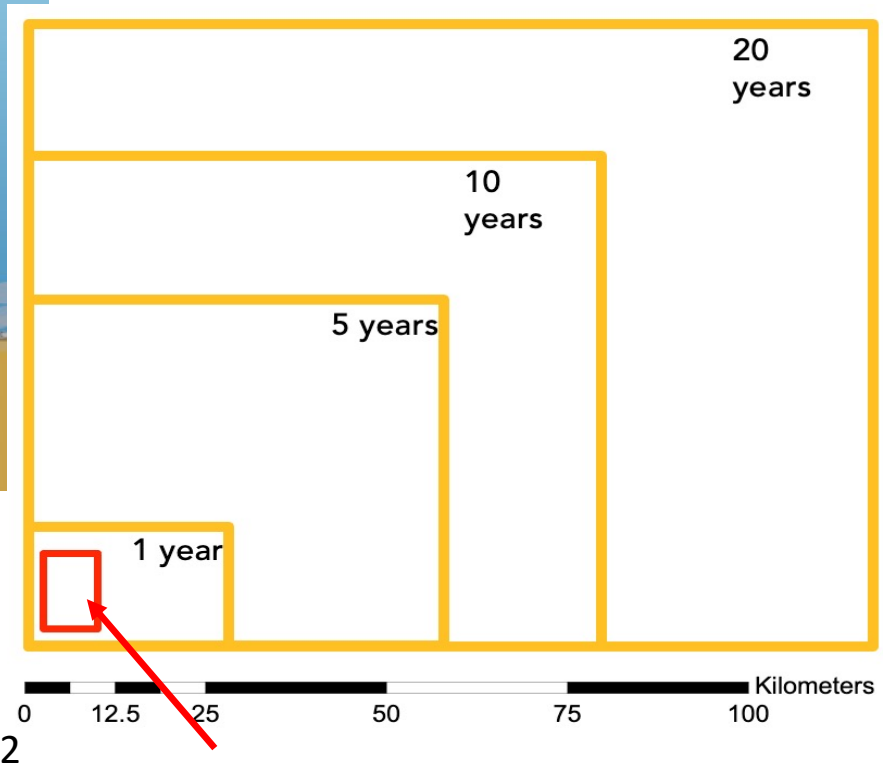
High Density & Diversity are associated with nodules

Credit: Craig McClain

Mining comes with environmental impacts over large areas for long periods



Levin et al. 2020



Largest coal mine in Germany

Exploration contracts in for polymetallic nodules are 75,000 km^2.

Exploitation activities are expected to last for 20-30 y per contract

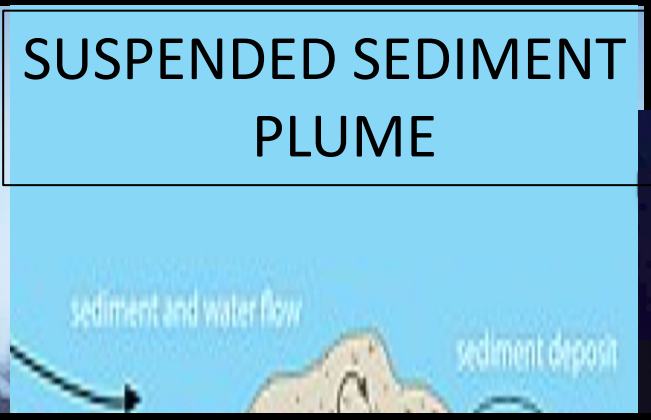
Mining disturbance

LIGHT, SOUND, VIBRATION

ALTERED GEOCHEMISTRY

PHYSICAL DISRUPTION/ANIMAL REMOVAL

SUSPENDED SEDIMENT PLUME



ALTERED SUBSTRATE

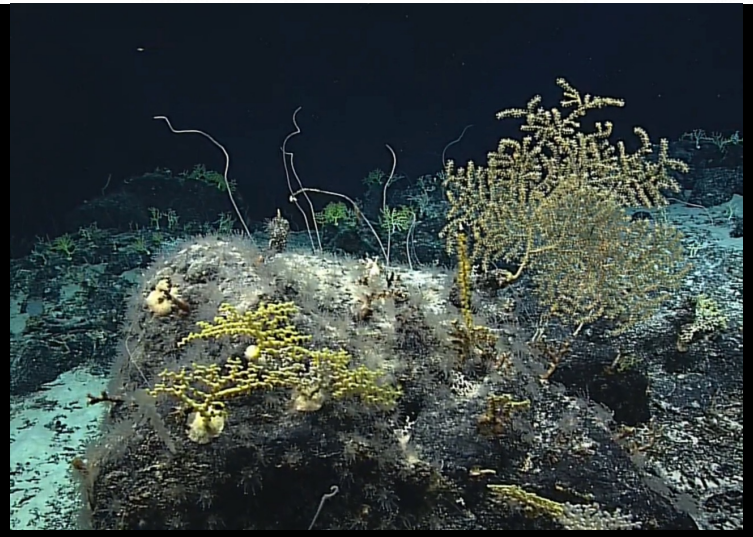
Effective protection of the marine environment from harmful effects (UNCLOS Art. 145)

CONTA

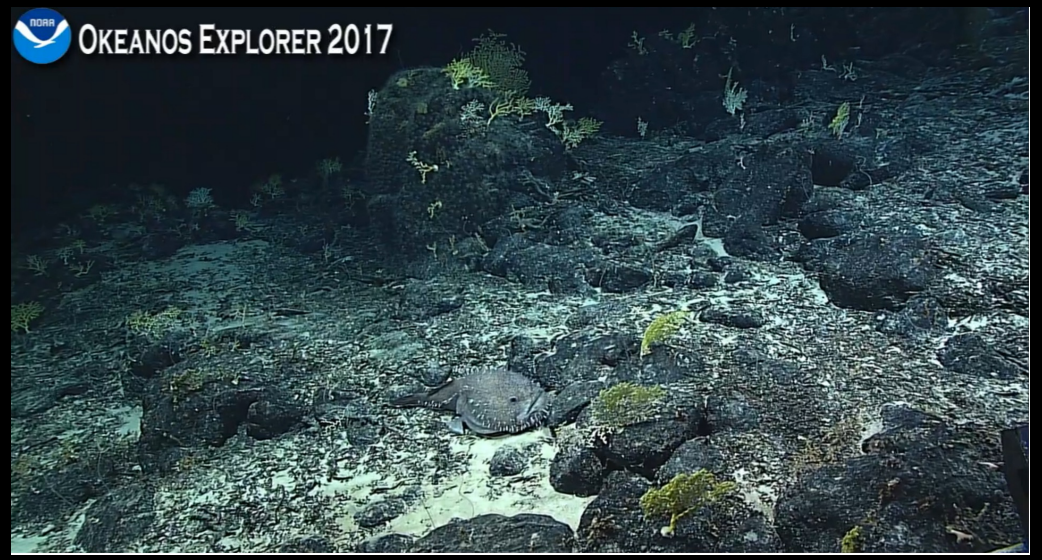
Harmful Effects

Altered Substrate: Removal, loss of vertical topography and heterogeneity, & altered texture may cause loss of genetic, species, functional and habitat diversity.

Vents



Polymetalic Nodules



Harmful Effects

Loss of Biogenic Habitat: Complex, often fragile.
Loss will reduce diversity of associated organisms

Harmful Effects

Mining Can alter **Geochemical Underpinnings**

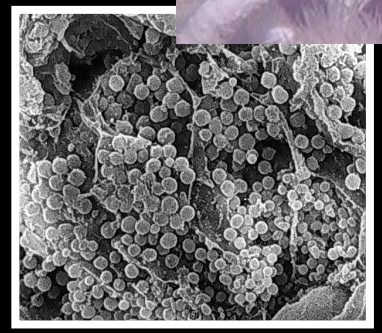
Diverse bacteria as the foundation of food webs

Reduced Compounds (electron donors) H_2S, CH_4, H_2 , Fe

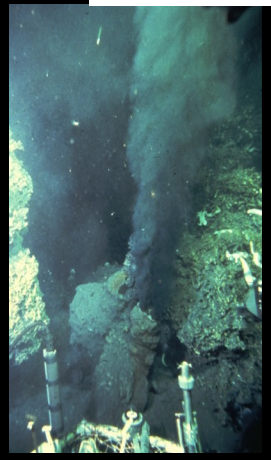
Availability of Oxygen and H_2S in sediments

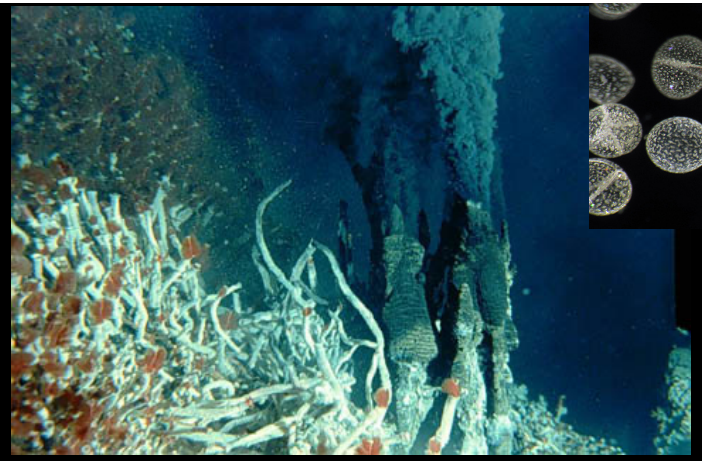
y

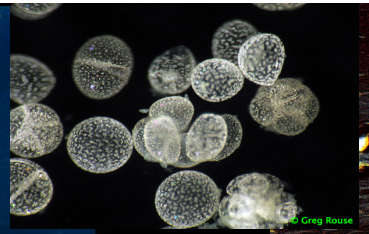
Scaly foot snail



Stewardship of geochemical source diversity required to support free-living microbes, symbionts, and animals that feed on them.





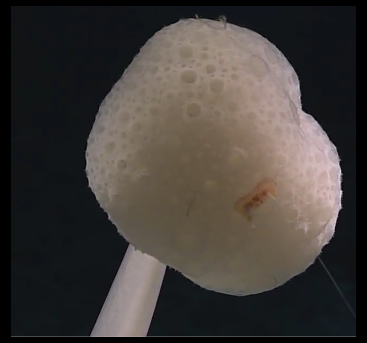


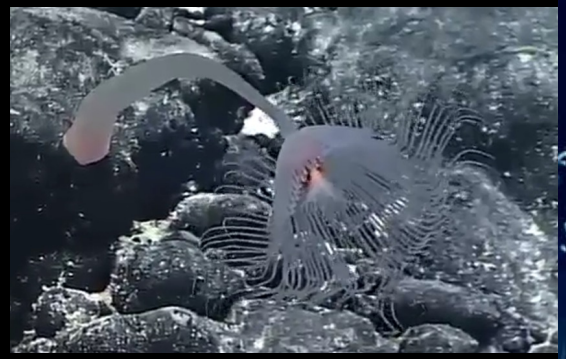
Harmful Effects

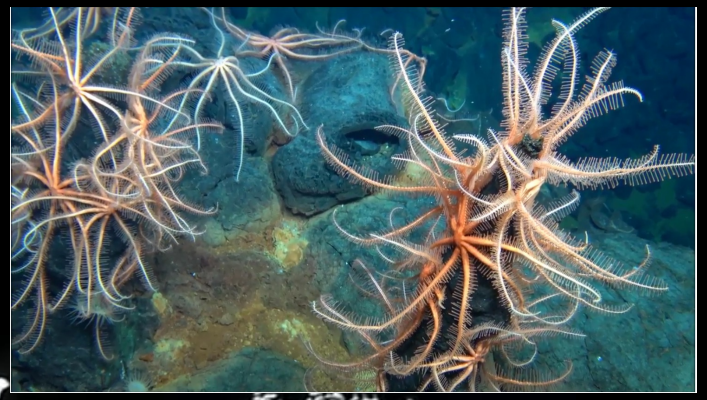
Plume Interference:

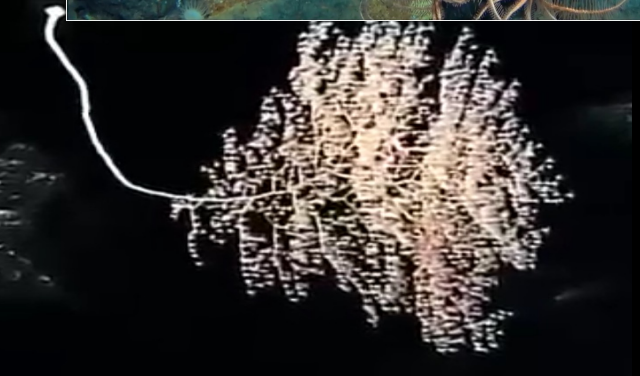
turbidity (suspended sediment) with effects on feeding, vision, metal contaminants , affecting development & bioaccumulation

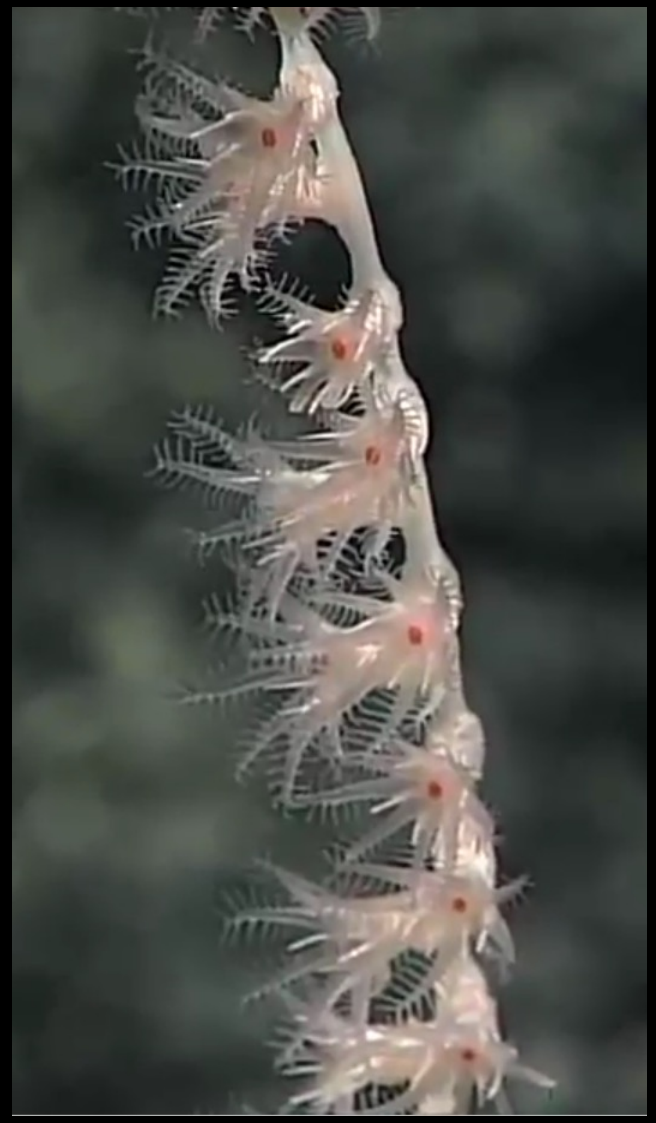
Filter Feeding Apparatus is easily clogged by suspended sediment





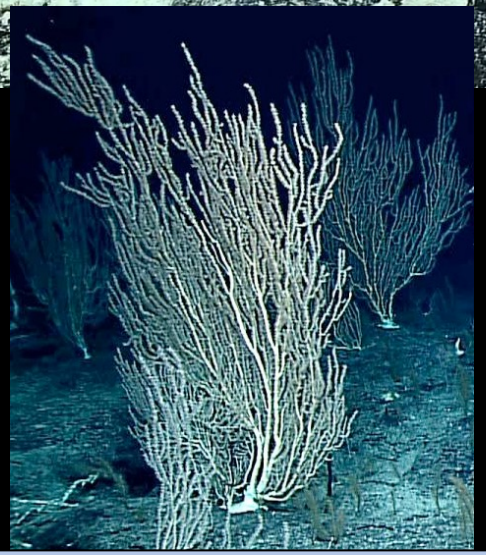






Harmful Effects

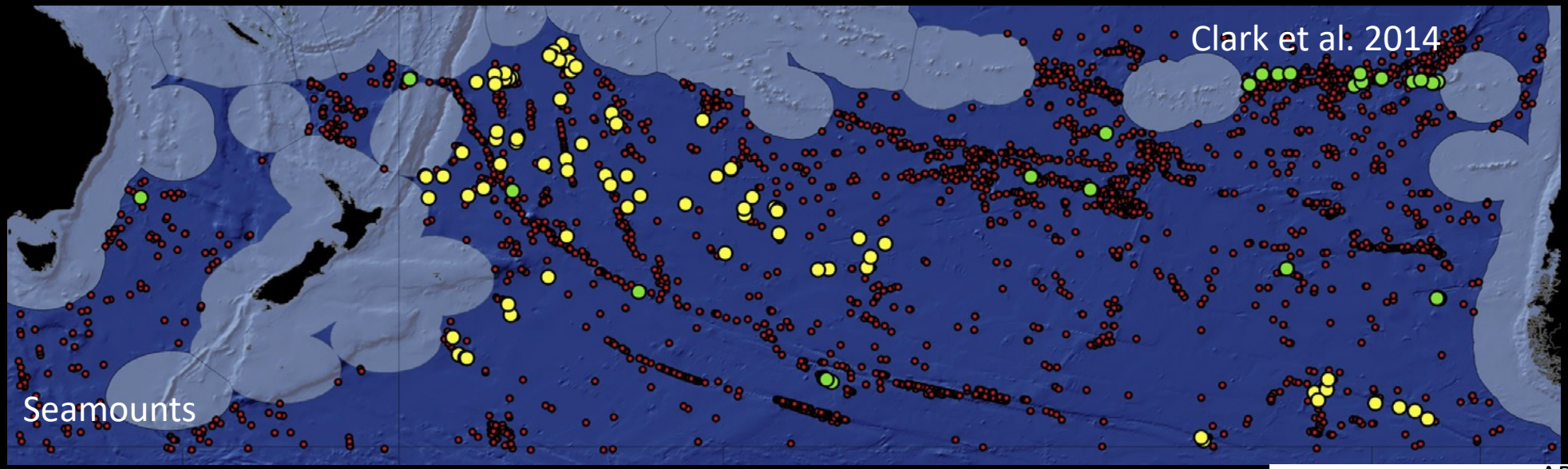
Great Longevity, Slow Growth, Late Maturity
reduce resilience and recovery from disturbance.
Disturbance may persist for centuries or indefinitely.

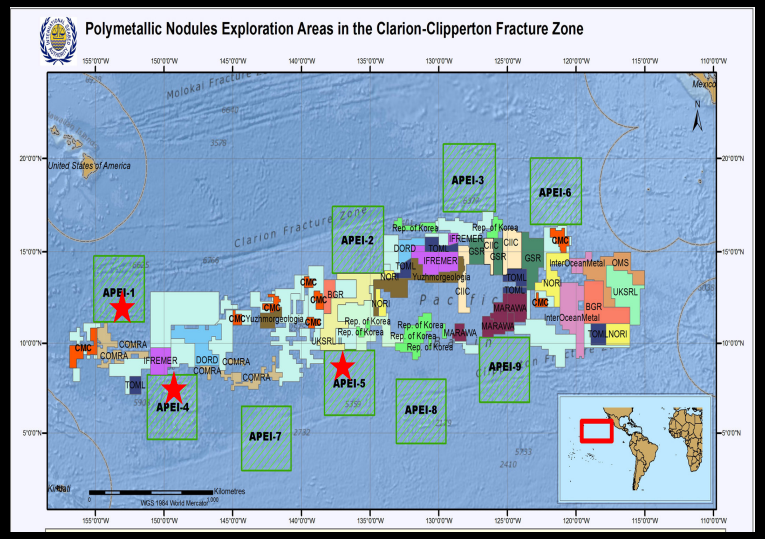


These attributes engender Vulnerable Marine Ecosystems

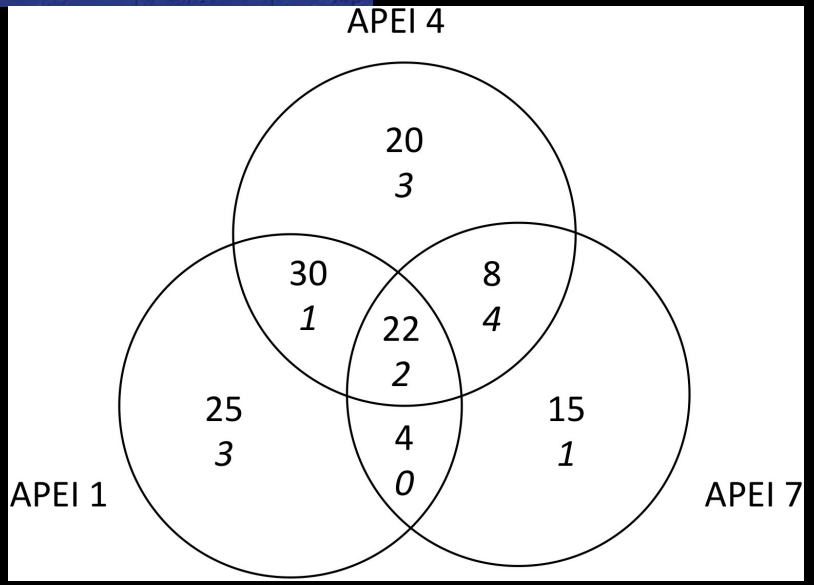
Harmful Effects

Limited Spatial Extent and patchy, isolated habitat yield high endemism. Mining may cause **breaks in connectivity and risk of local extinction,** especially from cumulative impacts



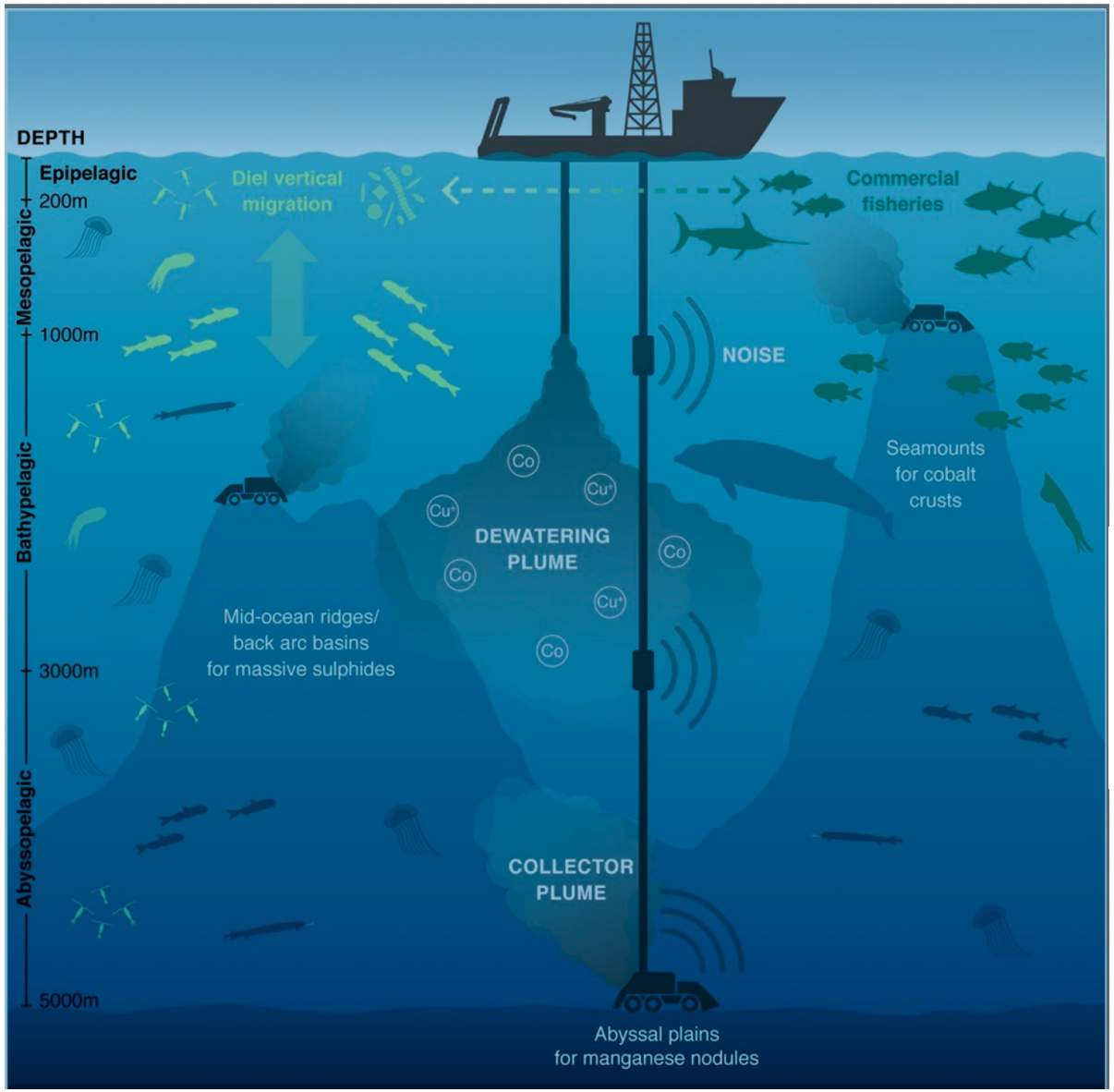


APEIs differ in density, diversity, composition



Durden et al. 2021

Bentho-pelagic coupling and pelagic impacts

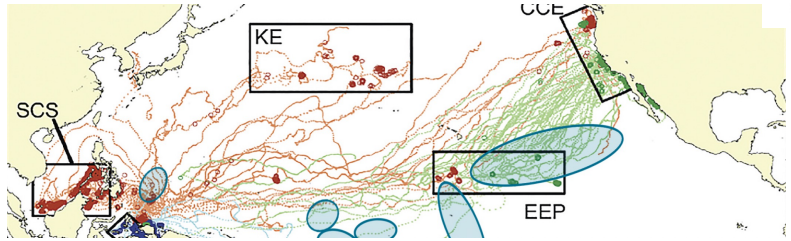


Drazen et al. 2020, PNAS

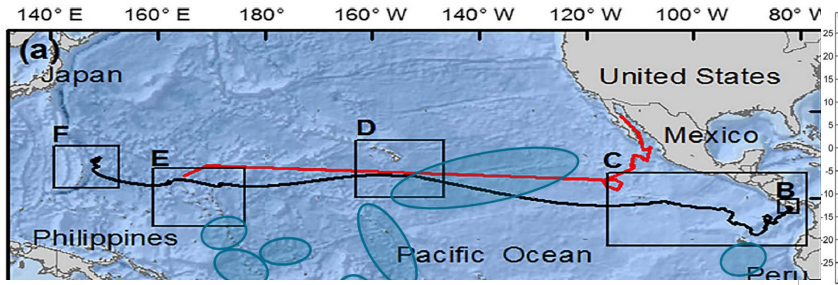
Mesopelagic migrations

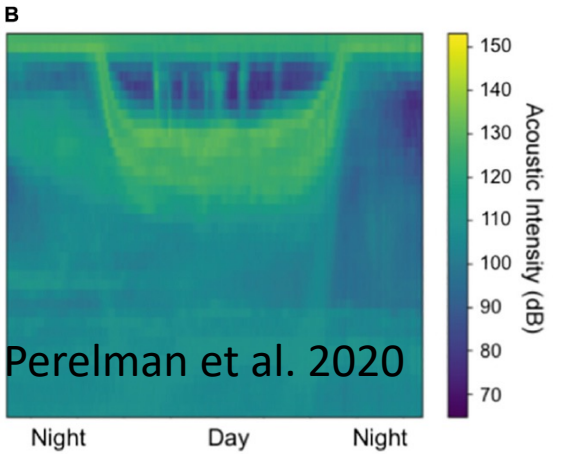
Chin and Hari, 2020

Leatherback Turtle Migrations

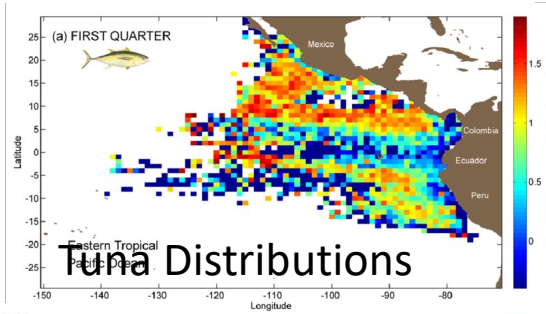


Whale Shark Migrations

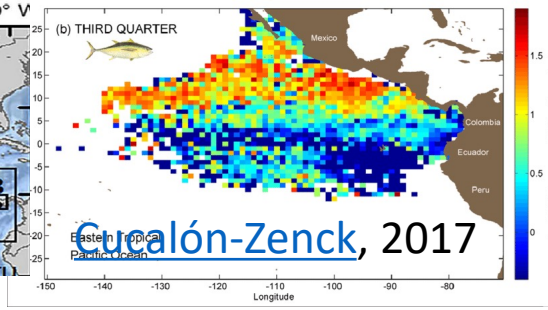




Perelman et al. 2020



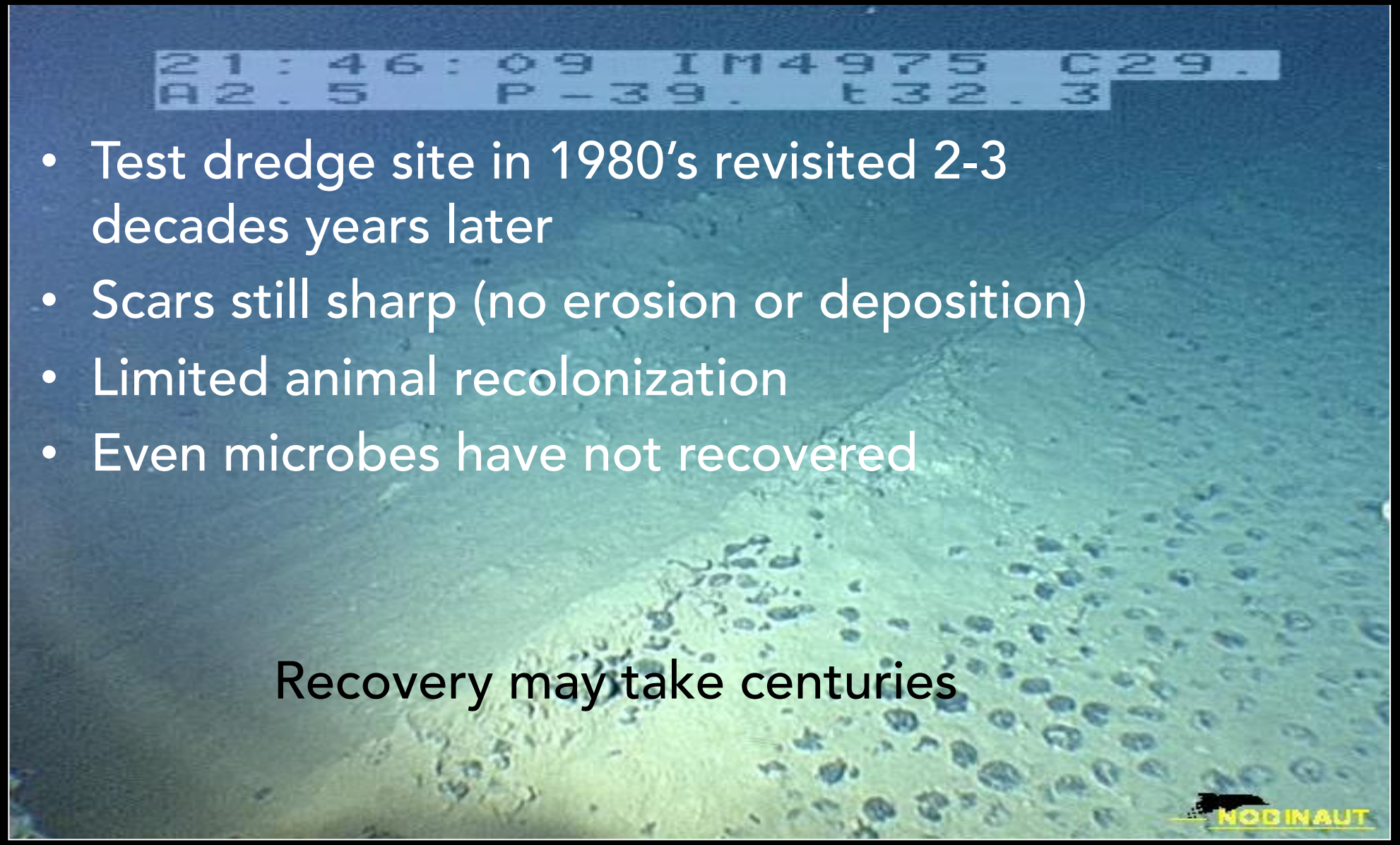
Tuna Distributions



Cucalón-Zenck, 2017

Individuals	Populations	Ecosystem Services
• Respiratory distress	• Changes in community composition	• Fisheries
• Auditory distress	• Emigration	• Seafood contamination
• Reduced feeding	• Mortality	• Carbon transport
• Reduced visual communication	• Decreased fitness/reproduction	• Biodiversity
• Buoyancy issues		
• Toxicity		

Science tells us mined areas may not recover in the nodule provinces



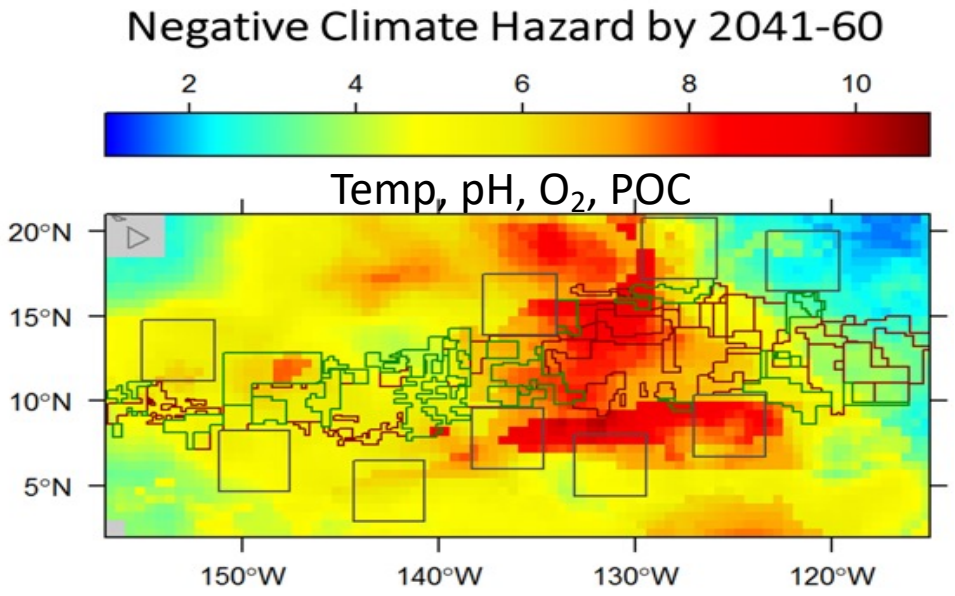
- Test dredge site in 1980's revisited 2-3 decades years later
- Scars still sharp (no erosion or deposition)
- Limited animal recolonization
- Even microbes have not recovered

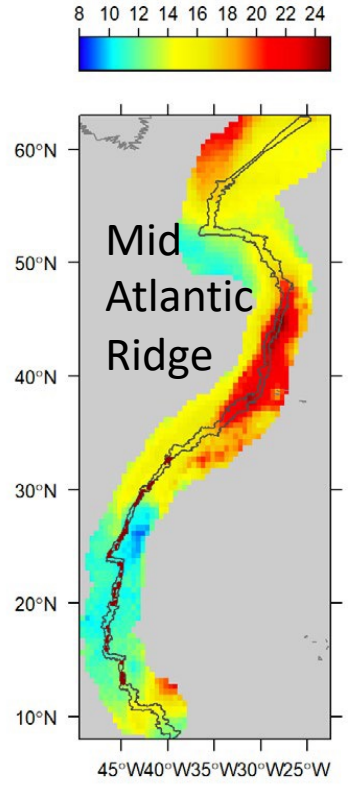
Recovery may take centuries

Climate change will alter environment and generate cumulative stress

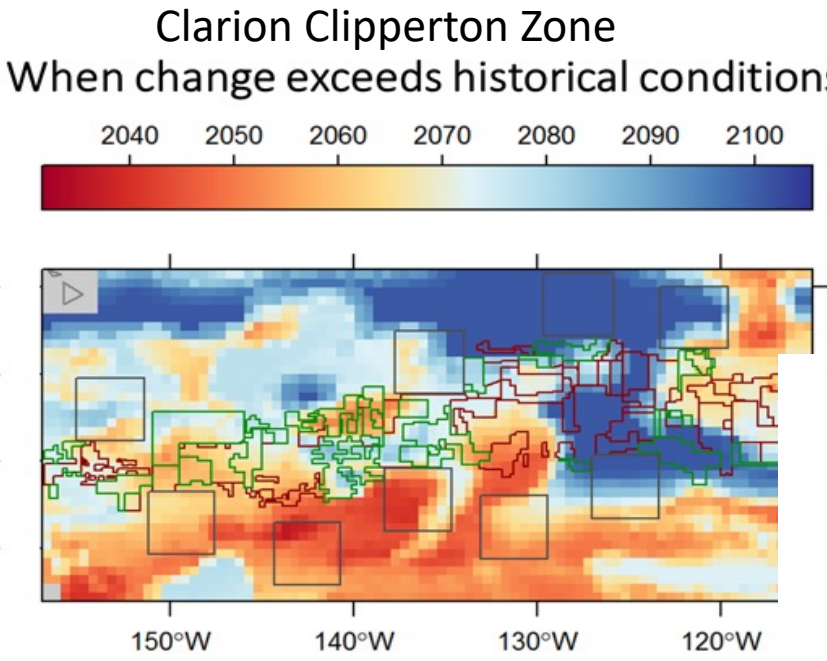
Projected climate change in varies spatially in areas targeted for mining

Clarion Clipperton Zone

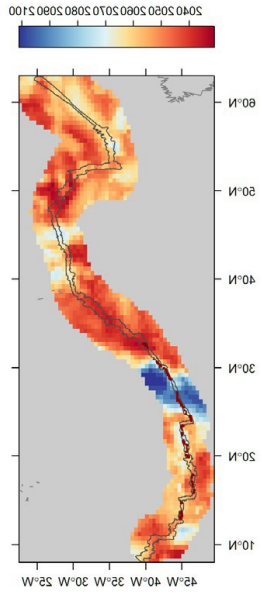




Clarion Clipperton Zone



Mid Atlantic Ridge



Some contract area will change a lot during the period of mining operations

Some APEIs will change a lot, others less

Levin, Wei et al. 2020 GCB

Many of these changes will occur over the next 20-40 y

Slow mineral growth of nodules and crusts (million years) = slow recovery

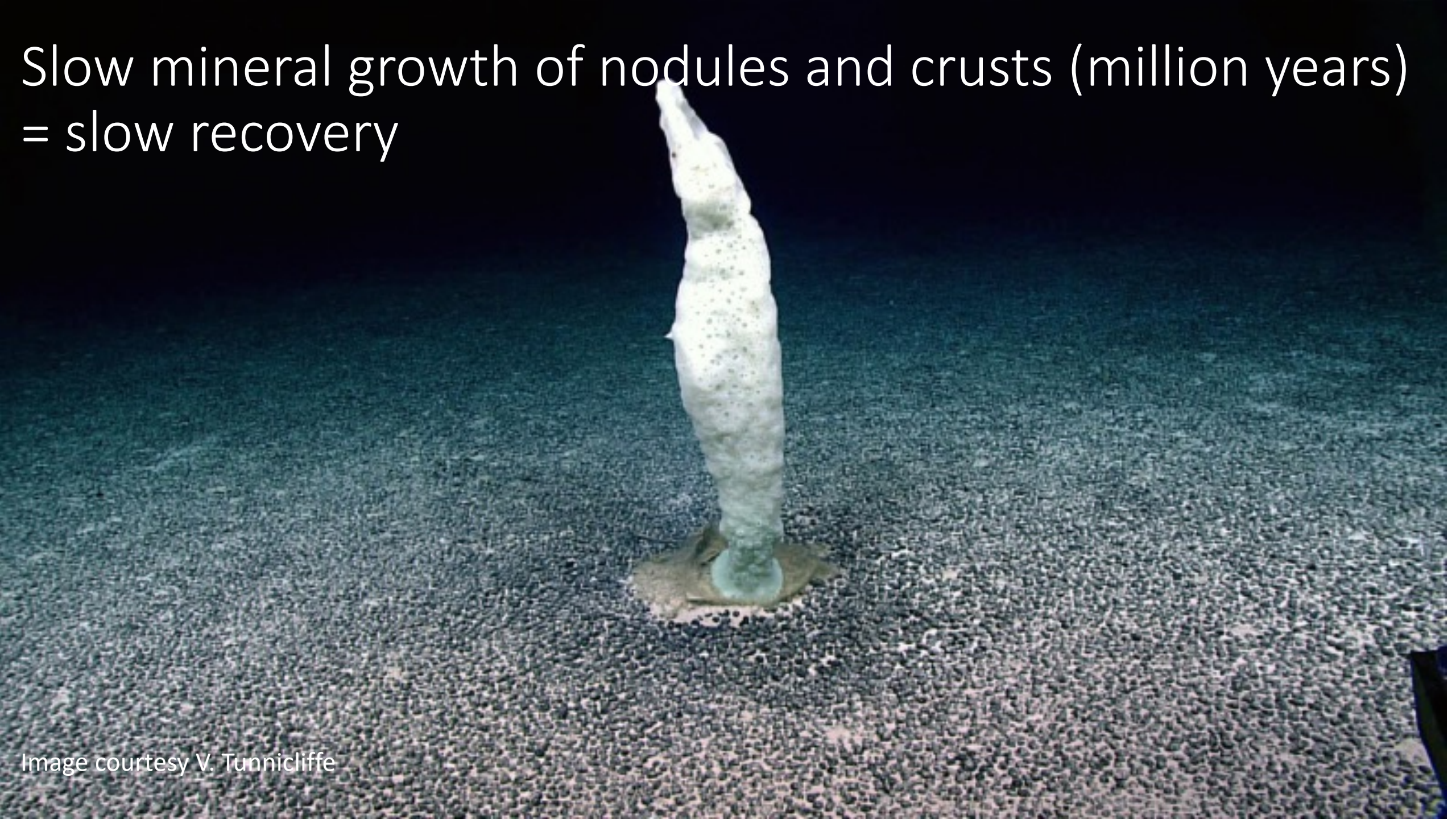


Image courtesy V. Tunnicliffe

Mitigation and Restoration will take decades to study and affirm.

A/B – set aside areas

C – return compacted waste sediments to seafloor

D. Transplant fauna

E – artificial substrates (nodules & sponge stalks)

F – Engineering to limit plumes

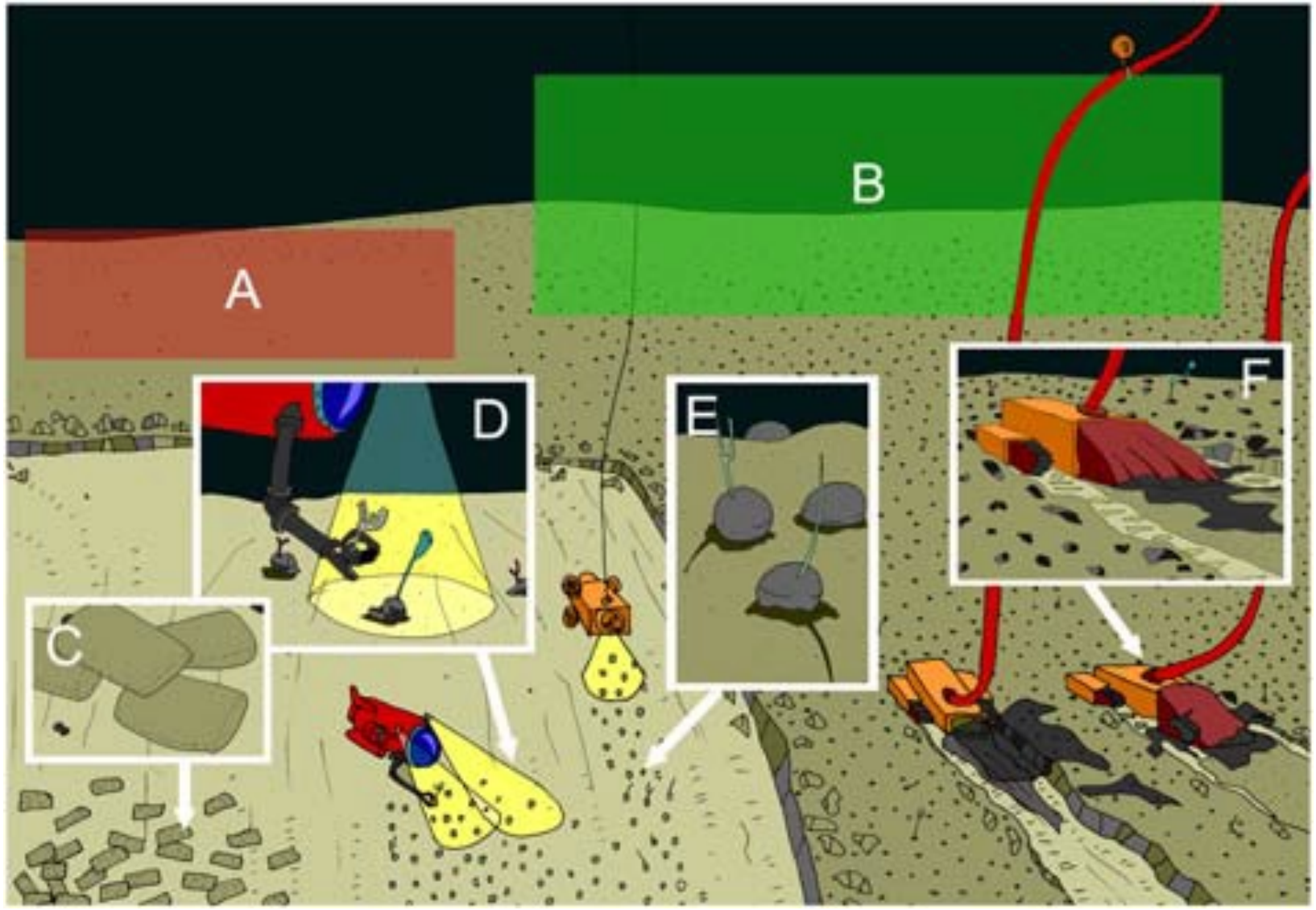
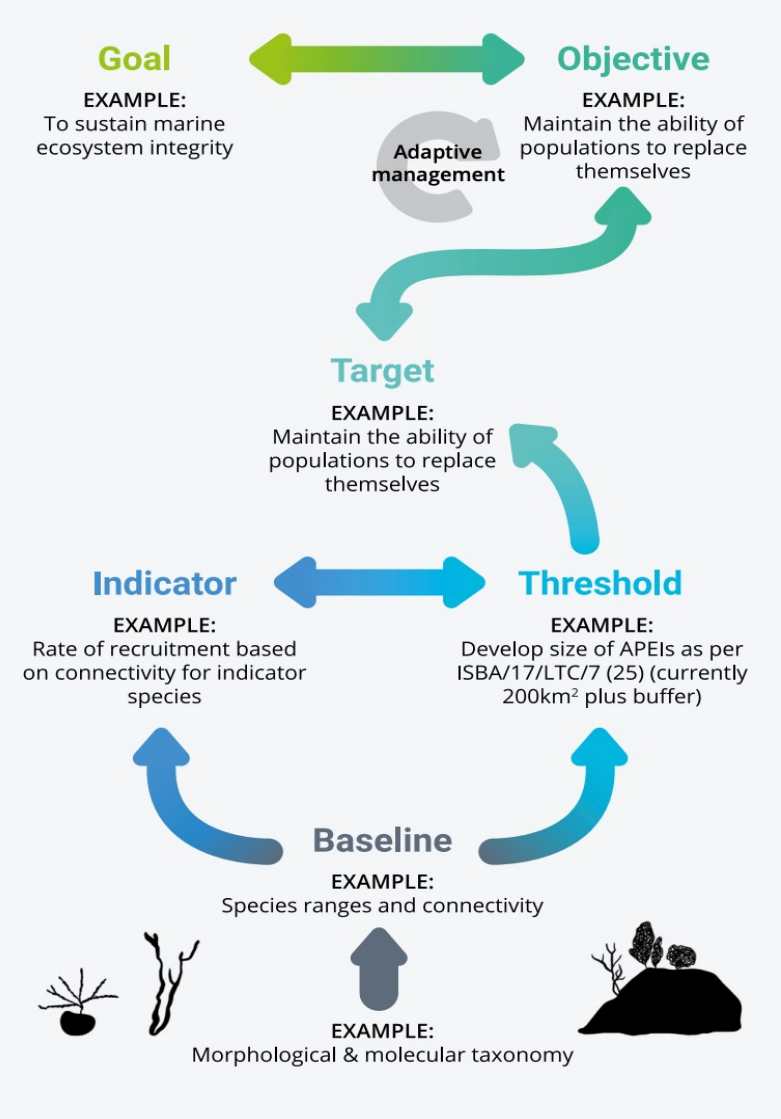


FIGURE 2 from Cuvelier et al. 2018

What don't we know that we need to ?

- Who lives there, what species live there, how long they live, when, how often and how much they reproduce, what they eat and what eats them, functional attributes?
- Natural temporal variability?
  (seasonal, interannual, interdecadal)
- Connections among populations?
- Appropriate indicators of ecosystem health?
- Tolerances & threshold values?
  (e.g. plume sediment concentrations)



This information will allow us to assess:

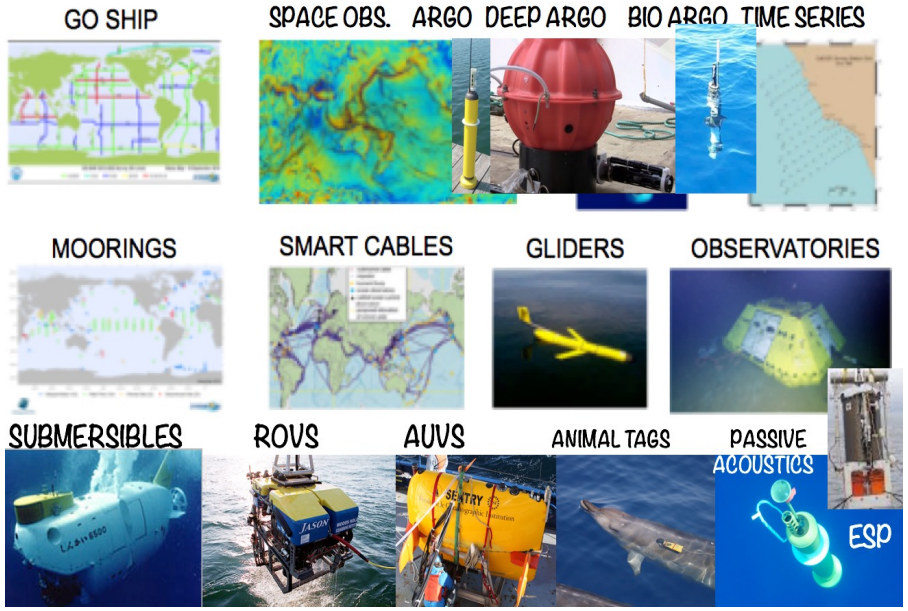
- The spatial extent and duration of impacts.
- The risk of species loss/extinction.
- The potential for recovery and how long it will take.
- Effectiveness of remediation or restoration methods.
- Impacts on adjacent ecosystems & fisheries
- How ecosystem services (and thus people) will be affected?
- The cumulative impacts associated with multiple mining operations, climate change or other ocean disturbance.

To operationalize
the precautionary principle & ecosystem-based management

Opportunities for science

The Global Ocean Observing System

2021 2030 United Nations Decade of Ocean Science for Sustainable Development



CHALLENGER 150 A DECADE TO STUDY DEEP-SEA LIFE

DEEP OCEAN OBSERVING STRATEGY

Thank you for listening

Acknowledgements:

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Artwork by Lily Simonson

DOSI
DEEP-OCEAN STEWARDSHIP INITIATIVE

DEEP OCEAN OBSERVING STRATEGY