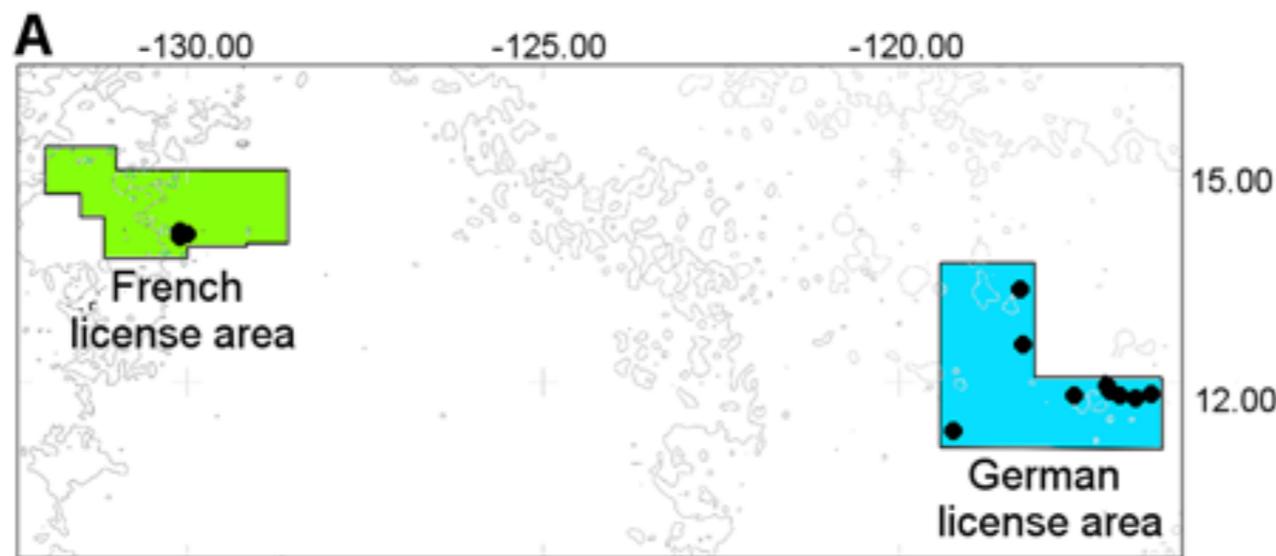
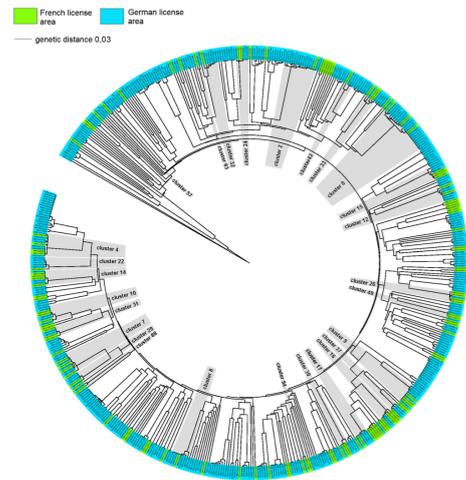
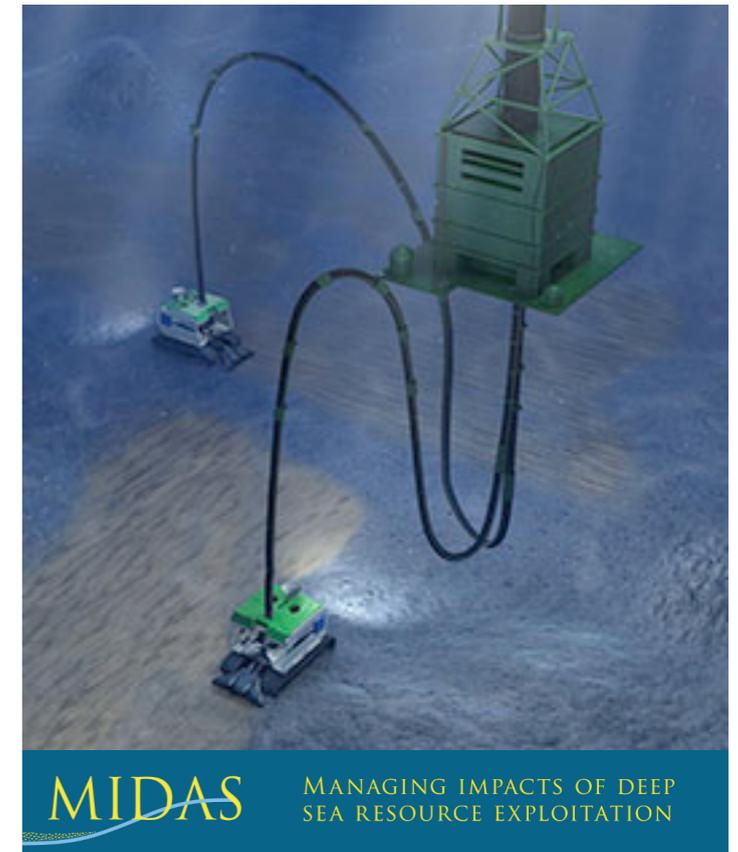


# Protection and preservation of the marine environment from activities in the Area

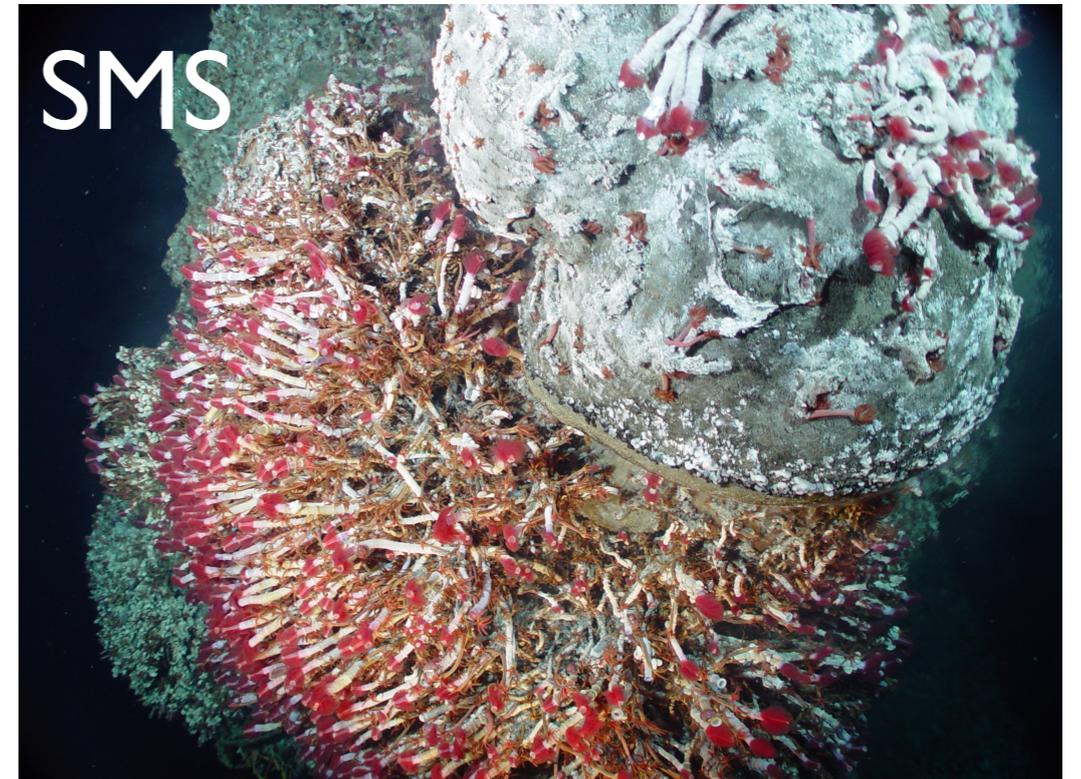
S. Kim Juniper  
Ocean Networks Canada  
University of Victoria



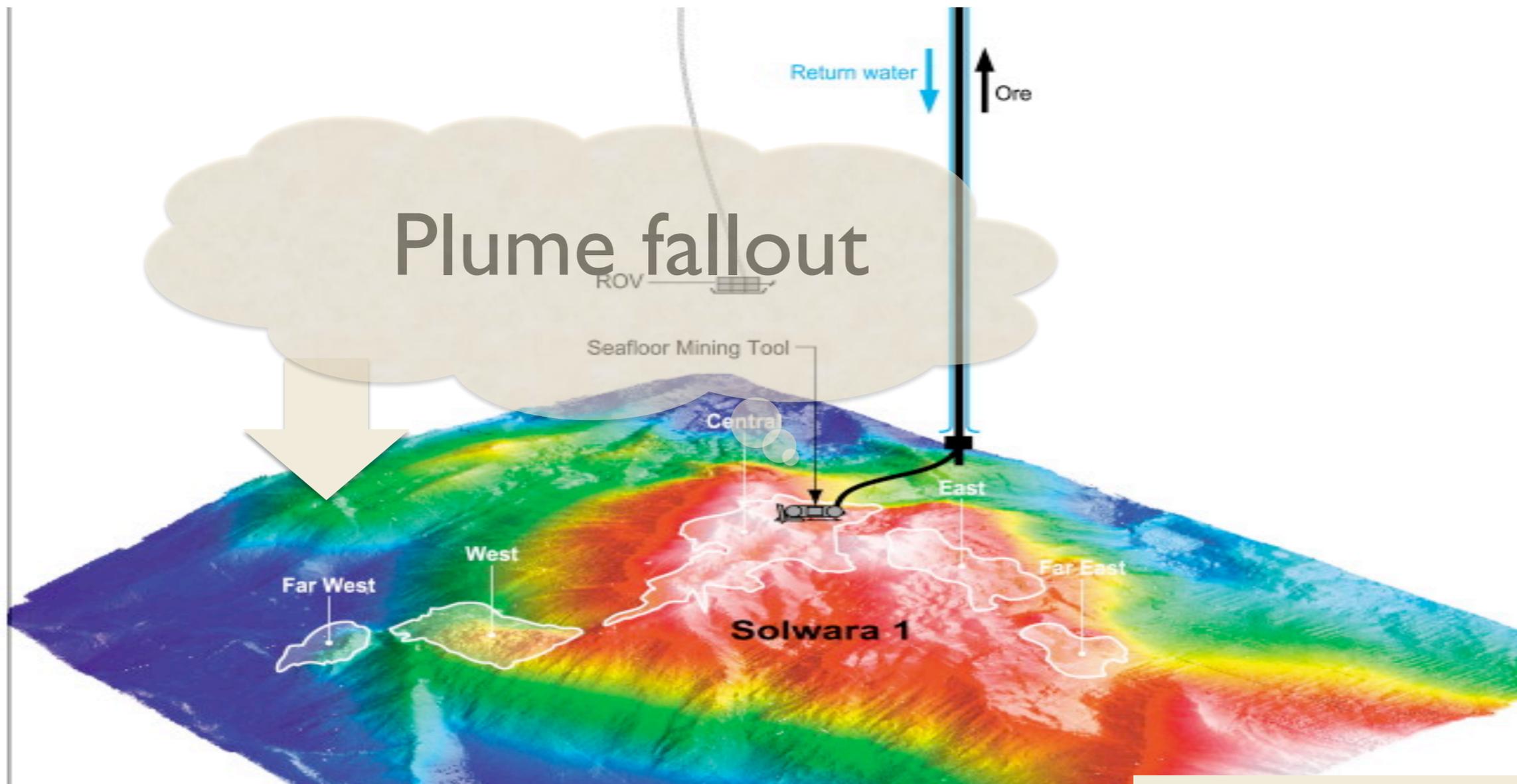
# Who are the players? What is the game?



# Background - mineral deposits are habitats for deep-sea species



# Effects of mining on deep-sea organisms



**Extinction of local populations**

**Direct physical damage to habitat**

# The game – use conflicts

## Key Players (stakeholders):

### *Mining interests*

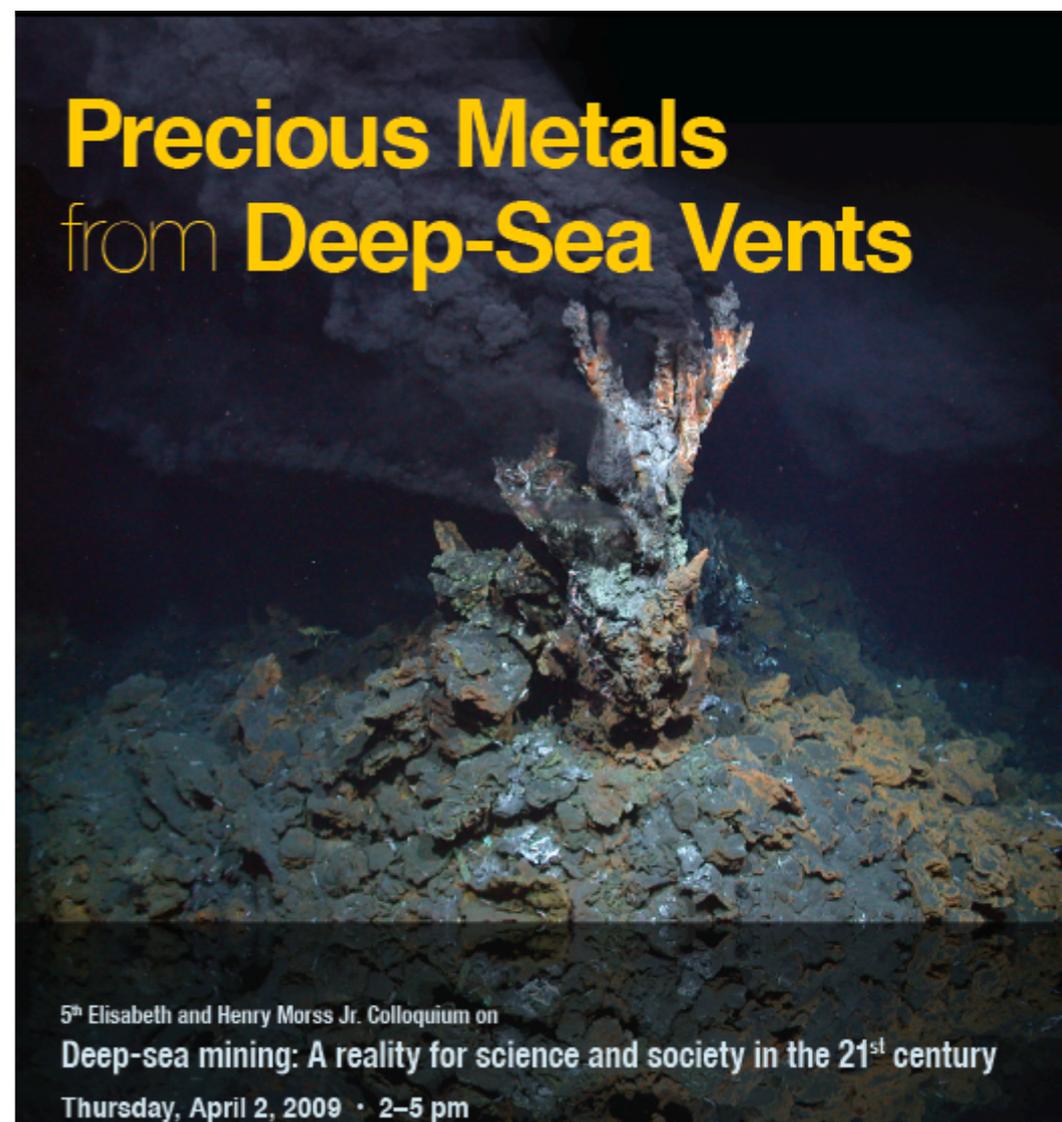
- Exploitation of crusts, nodules and SMS

### *Deep-sea biologists*

- Approx. 600 experts worldwide
- Primary source of knowledge about deep-sea biodiversity
- New interest in ecosystem services

### *Conservation NGO's*

- Recent interest in deep-sea conservation
- Genetic resource potential



# *...many conservation players*

**INDEEP**

Deep-sea ecology and  
biodiversity network



**DOSI**

Promoting deep-sea  
stewardship



**VentBase**

SMS stakeholder forum

Primer & best practices documents

**IUCN Commission**

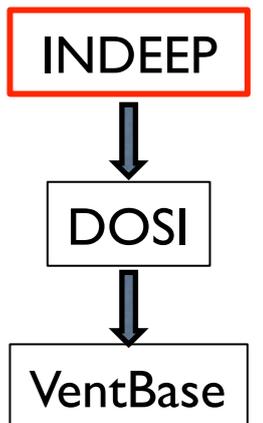
**International  
Seabed Authority**

**MIDAS**

MANAGING IMPACTS OF DEEP  
SEA RESOURCE EXPLOITATION

(EU project 2013-2016)

# ..... who are the players?



- Evolved from Census of Marine Life
- International network for deep-sea ecosystem **research**
- Aims:
  - Advance understanding of biodiversity and ecosystem function in global deep ocean.
  - Bridge gap between science and society to inform sustainable management.
- Funded by Total Foundation for 2011-2016
- 450 members in 36 countries

# Deep-Ocean Stewardship Initiative

Inaugural Meeting  
April 15-17, 2013  
Mexico City



## Mission Statement

*DOSI seeks to integrate science, technology, policy, law and economics to advise on ecosystem-based management of resource use in the deep ocean and strategies to maintain the integrity of deep-ocean ecosystems within and beyond national jurisdictions*

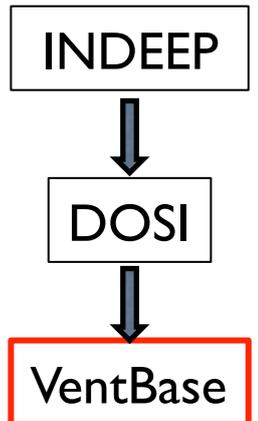
# Future DOSI Workshops

- *Strategic Environmental Assessment of mining along the mid-Atlantic ridge (SMS and crusts)*
- *Environmental Management Strategy for The Area.*
- *Deep-sea economic tools and cost-benefit analysis for fisheries and mining*

..... *who are the players?*



# VentBase



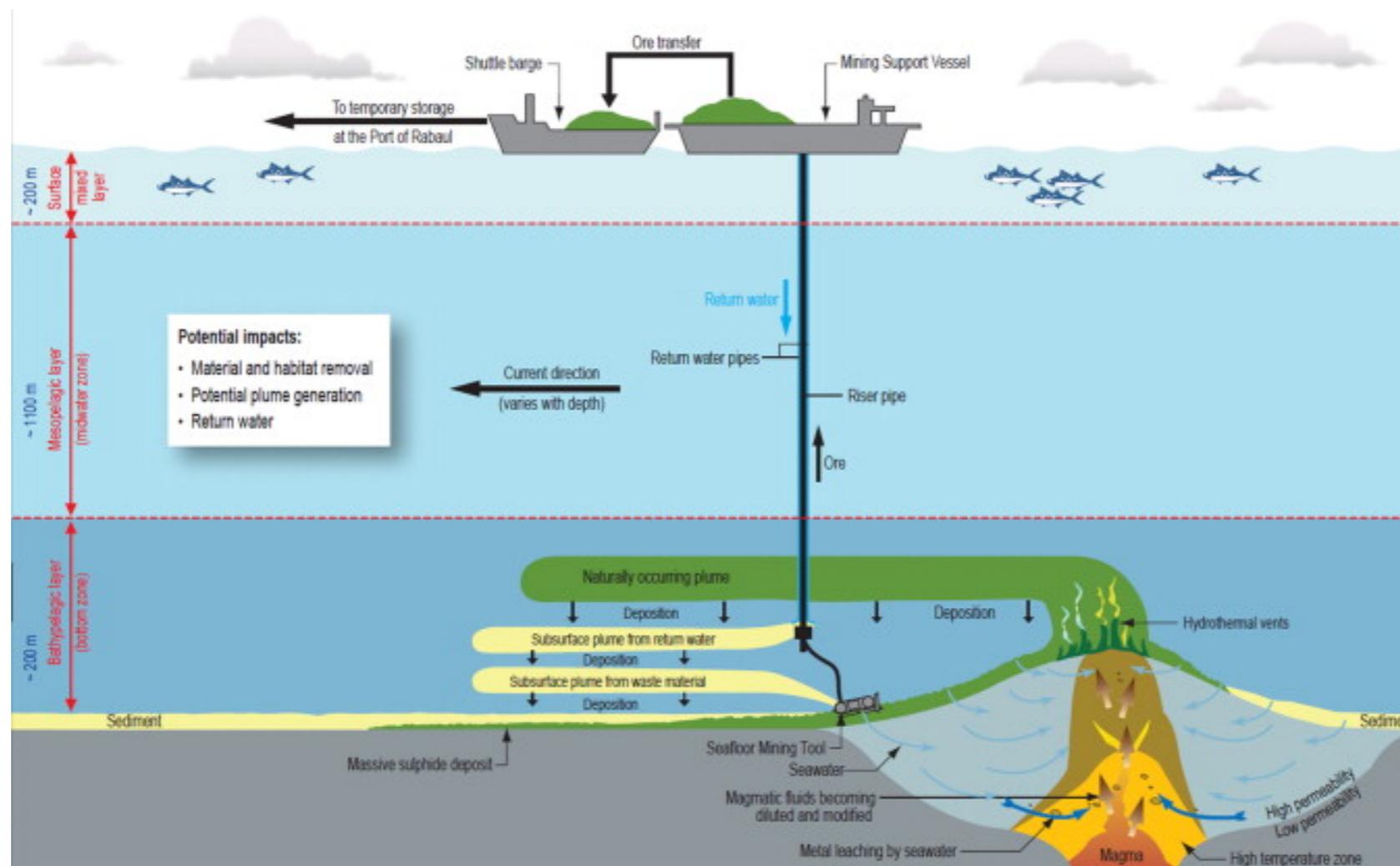
Forum for **all stakeholders** to develop a consensus on best way to manage the mining of SMS deposits.

Production of best-practice and primer documents to inform stakeholders and highlight up-to-date science to underpin effective management.

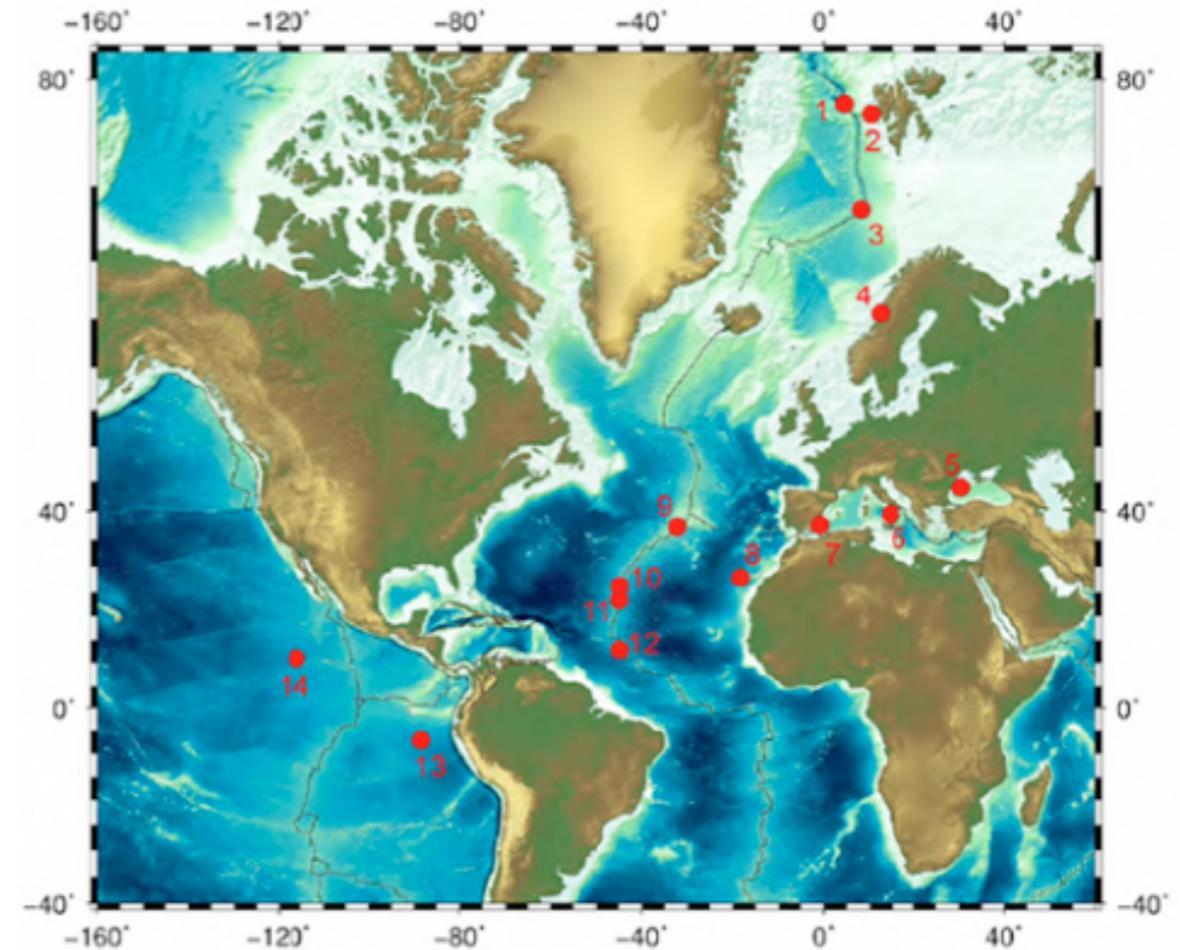
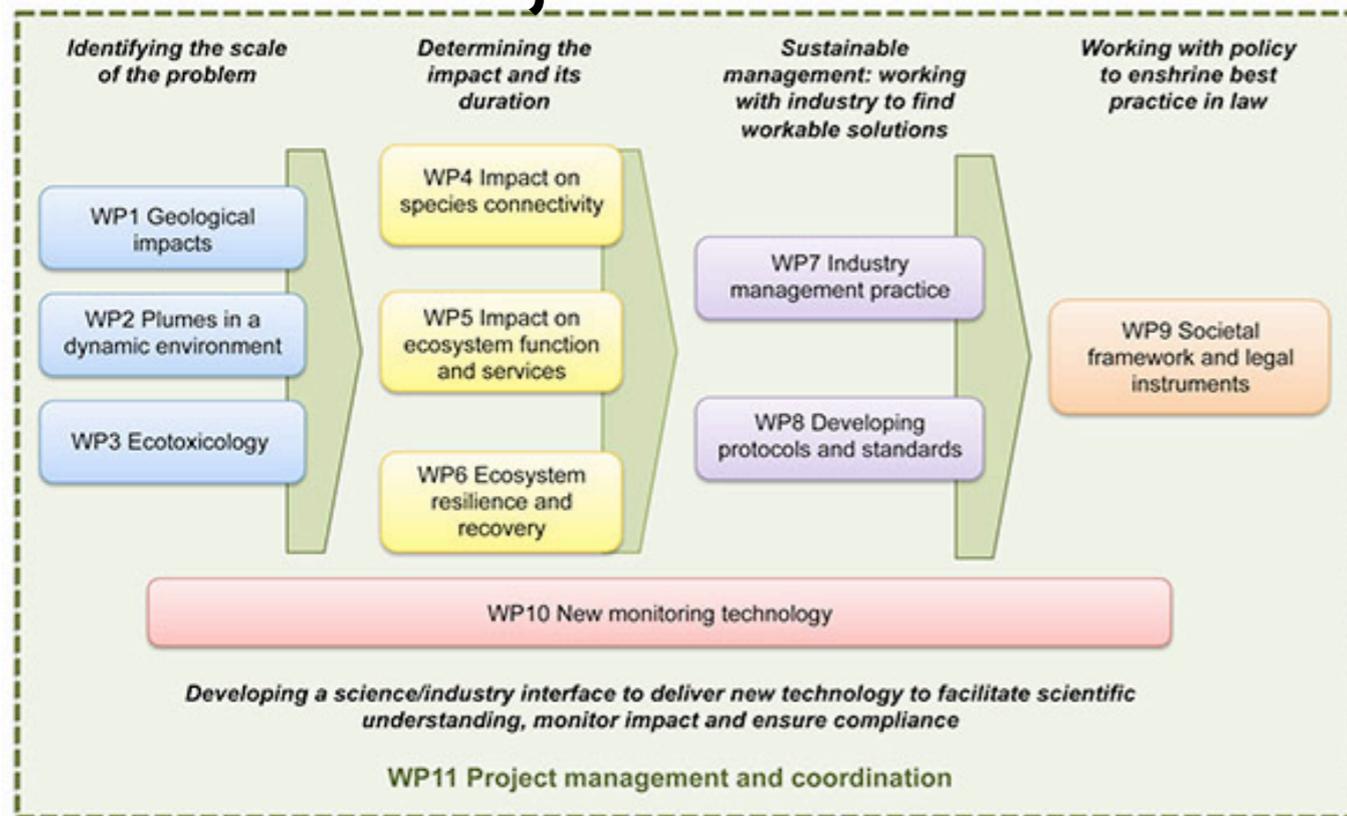
## A primer for the Environmental Impact Assessment of mining at seafloor massive sulfide deposits



Patrick Colman Collins<sup>a,\*</sup>, Peter Croot<sup>a</sup>, Jens Carlsson<sup>b</sup>, Ana Colaço<sup>c</sup>, Anthony Grehan<sup>a</sup>, Kiseong Hyeong<sup>d</sup>, Robert Kennedy<sup>a</sup>, Christian Mohn<sup>e</sup>, Samantha Smith<sup>f</sup>, Hiroyuki Yamamoto<sup>g</sup>, Ashley Rowden<sup>h</sup>

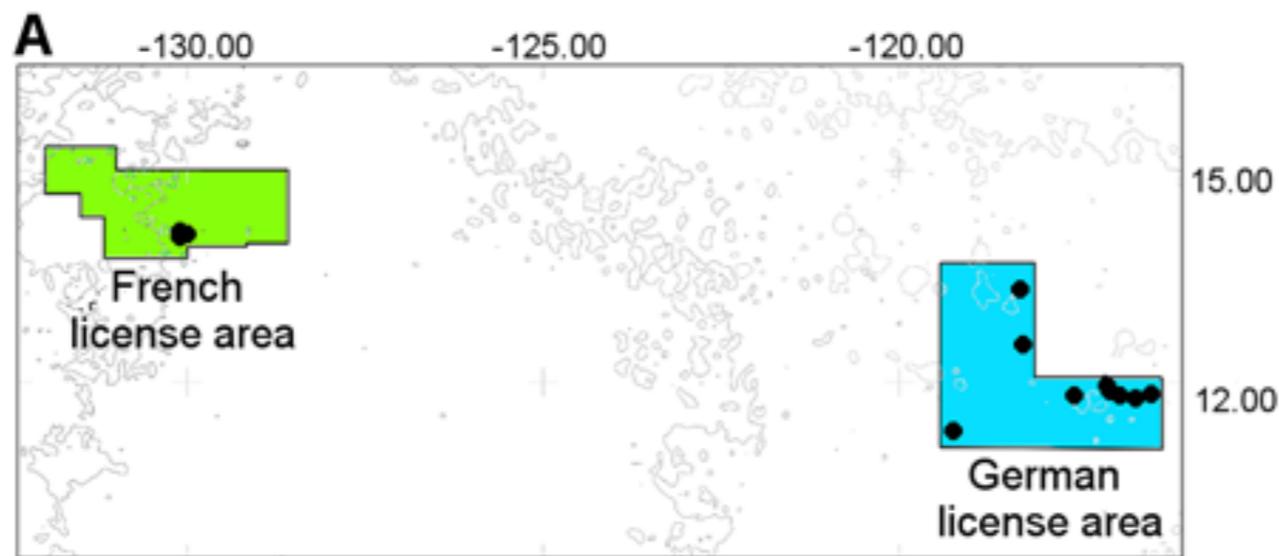
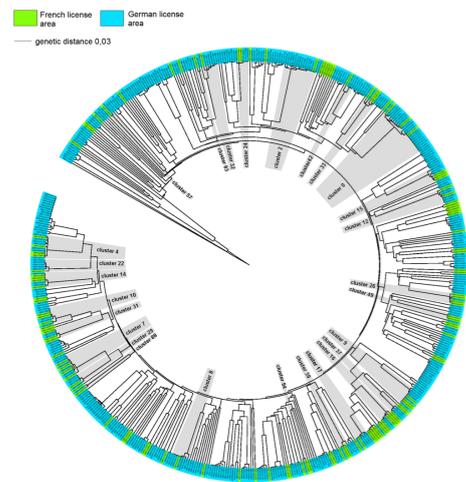
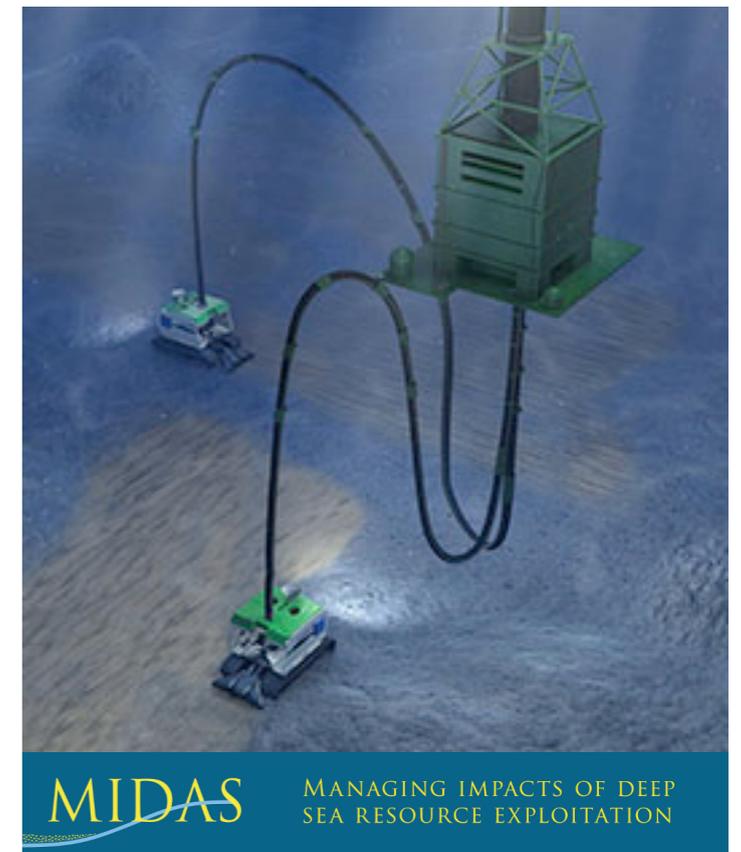
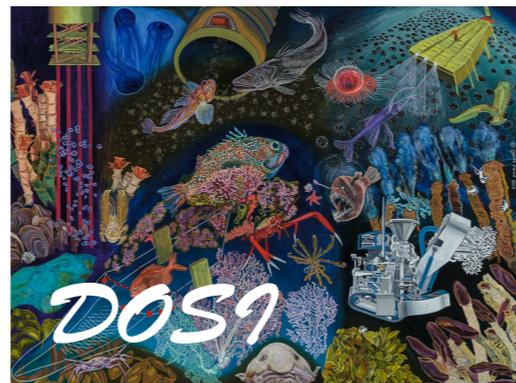


## EU Project 2013-2016



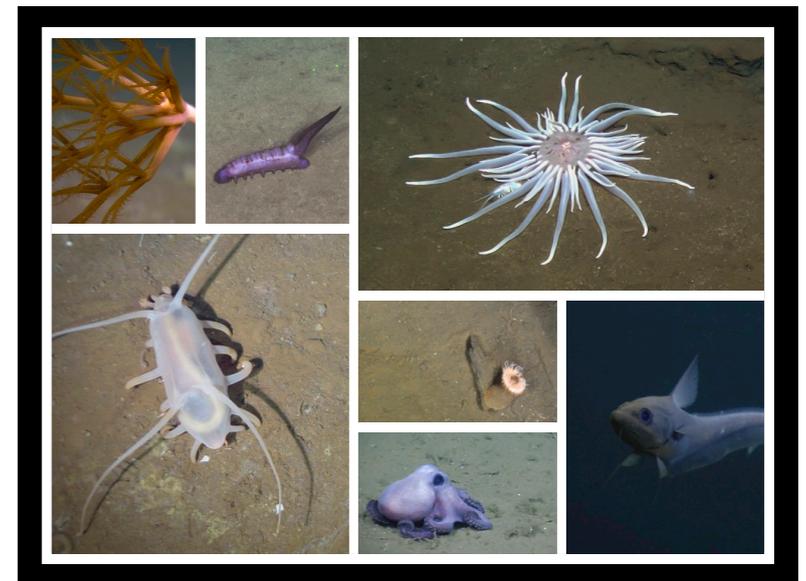
# *Multiple players*

## *Multiple approaches to the game*

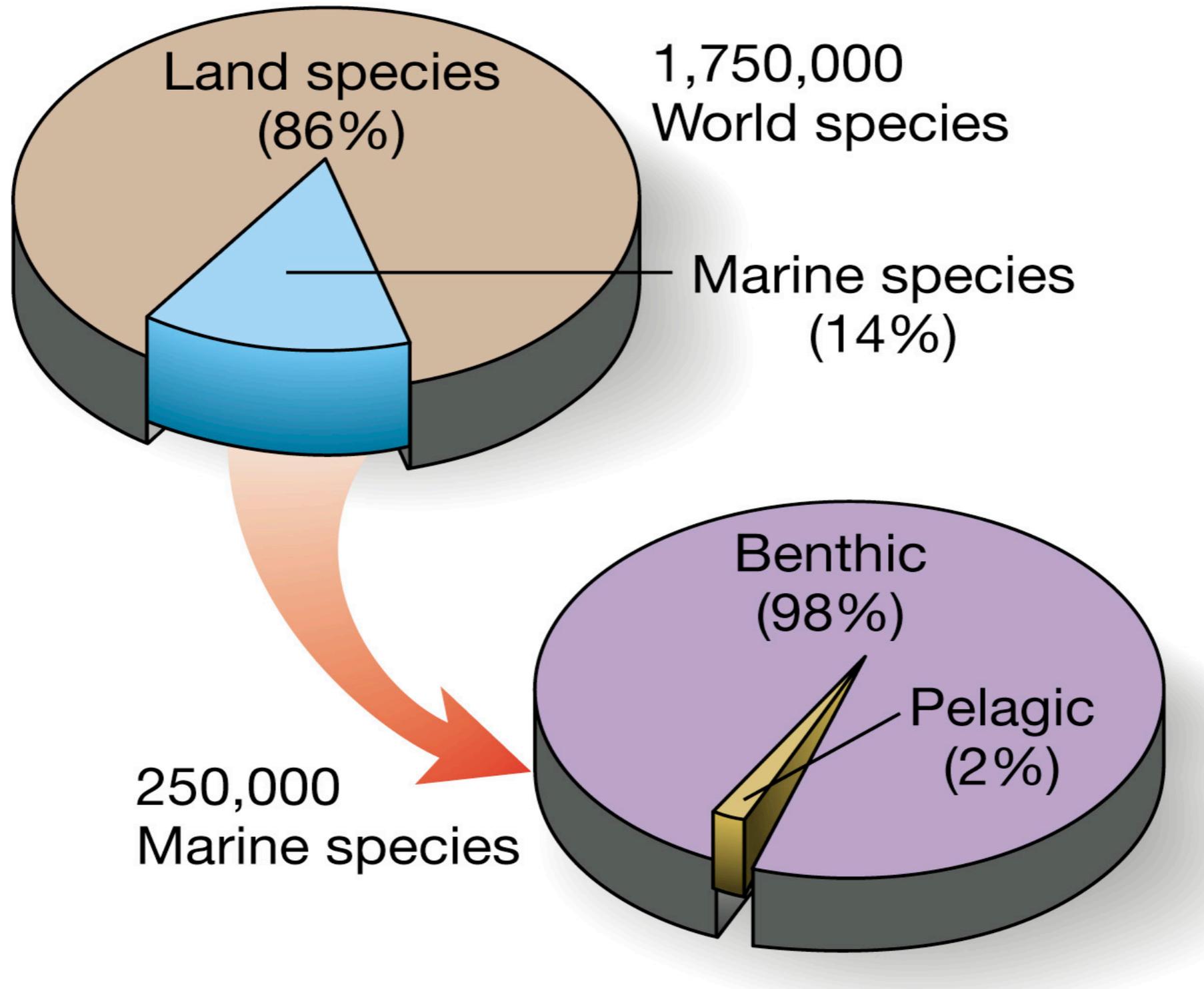


# Simplified framework for considering impacts of seabed mining on deep-sea organisms

- Valuation
  - What's there? (rarity, uniqueness)
  - Value to marine ecosystem? (ecosystem function)
  - Value to society? (ecosystem goods and services)
- Recovery Trajectory
  - How long?
- Spatial Planning Considerations



# Valuation - What's there?

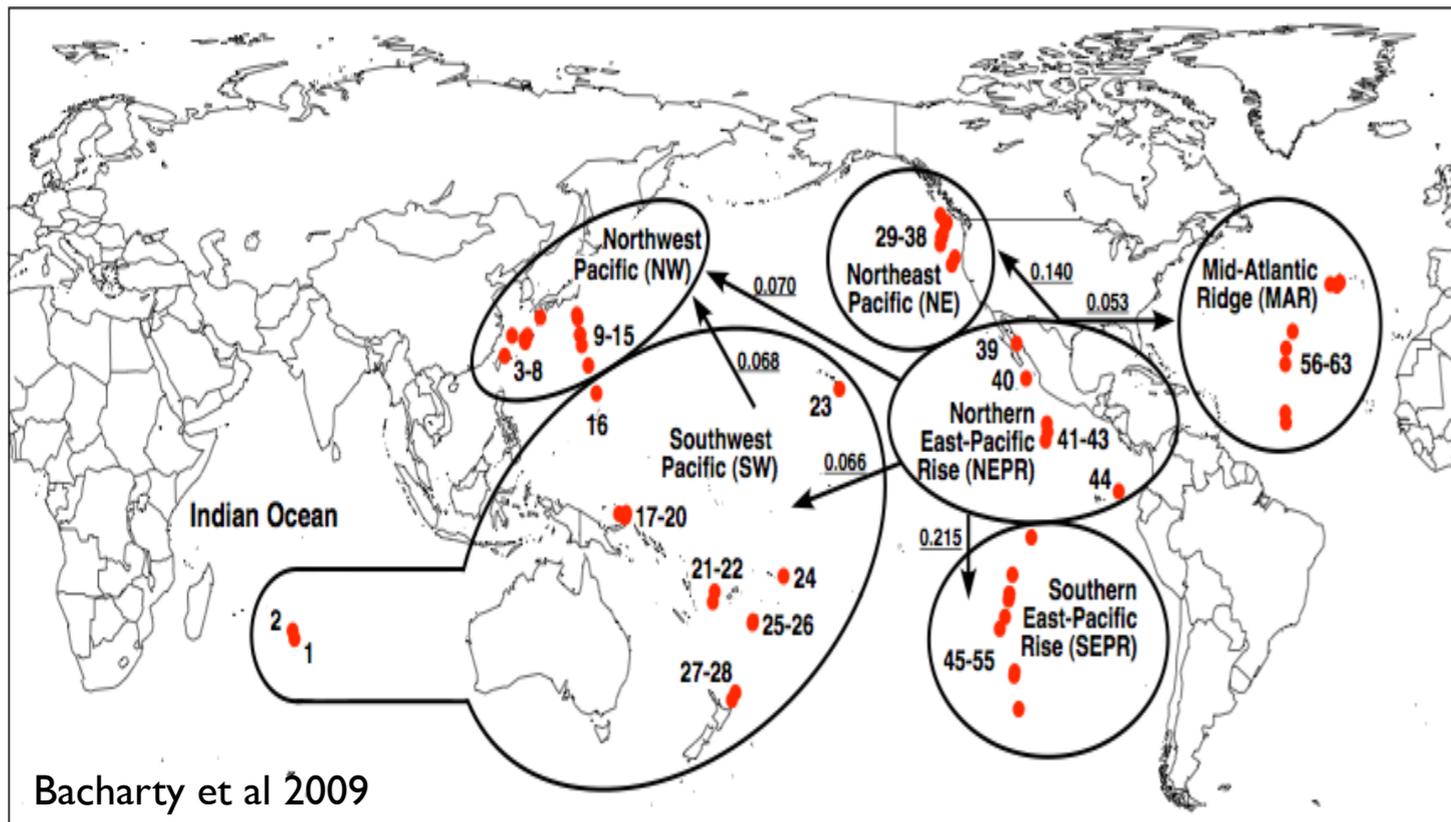


# Valuation – Rarity or Uniqueness

(everything is not everywhere)

Geographic range of affected species

Uniqueness of local gene pool



# Valuation – Ecosystem function

(“benefits that ecosystems derive from different components”)

<b>Ecosystem Function Category</b>	<b>Examples</b>
Food	Photosynthesis by plankton supports fisheries
Regeneration processes	Recycling and filtration of natural and human waste
Physical habitat	Corals and sponges create habitat for fish and other organisms
Unknown	Ecosystem functions yet to be discovered

# Valuation – Ecosystem services

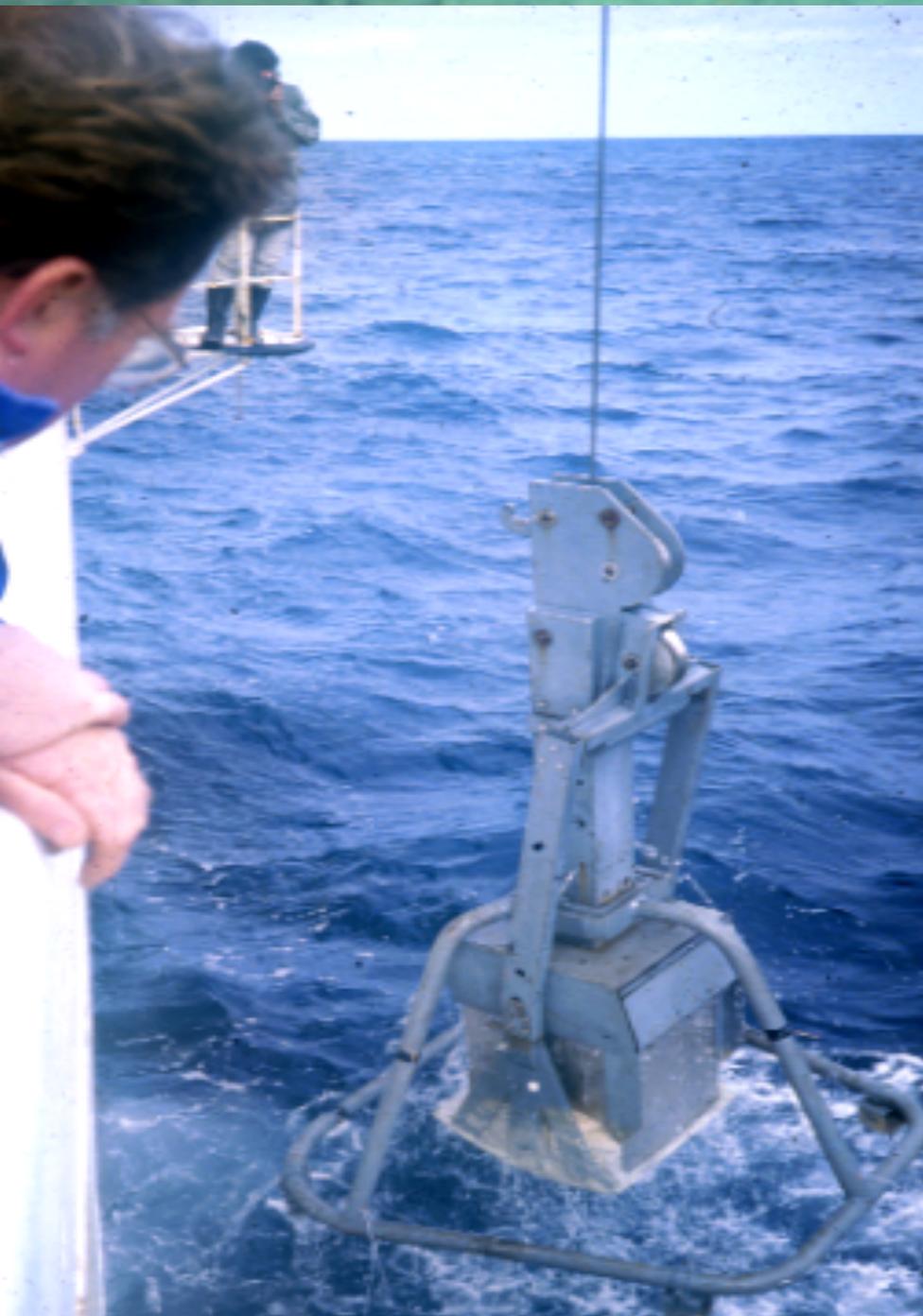
(“the benefits that people derive from ecosystems”)

Ecosystem Service Category	Examples
Production of goods	Food, <b>Pharmaceuticals</b> Durable materials Energy
Stabilization processes	Seabed and seashore stabilization Weather and climate modulation
Scientific and Cultural value	<b>Scientific discovery</b> <b>Educational value</b>
Preservation of options	Goods and services yet to be discovered

# Valuation – Scientific Value

Marine Scientific Research is major stakeholder in deep-sea

- > 600 researchers globally, approx. 30 laboratories
- > \$250M annually in research funding



# Valuation - Cultural Value

- Entertainment
- Public education



# Valuation – Potential Economic Value

## Genetic Resources in the Deep Sea – The Promise



*“... a source of new and viable wealth creation”\**

\* National strategy on marine bioprospecting, Norway, 2009

# Yondelis® (trabectedin)

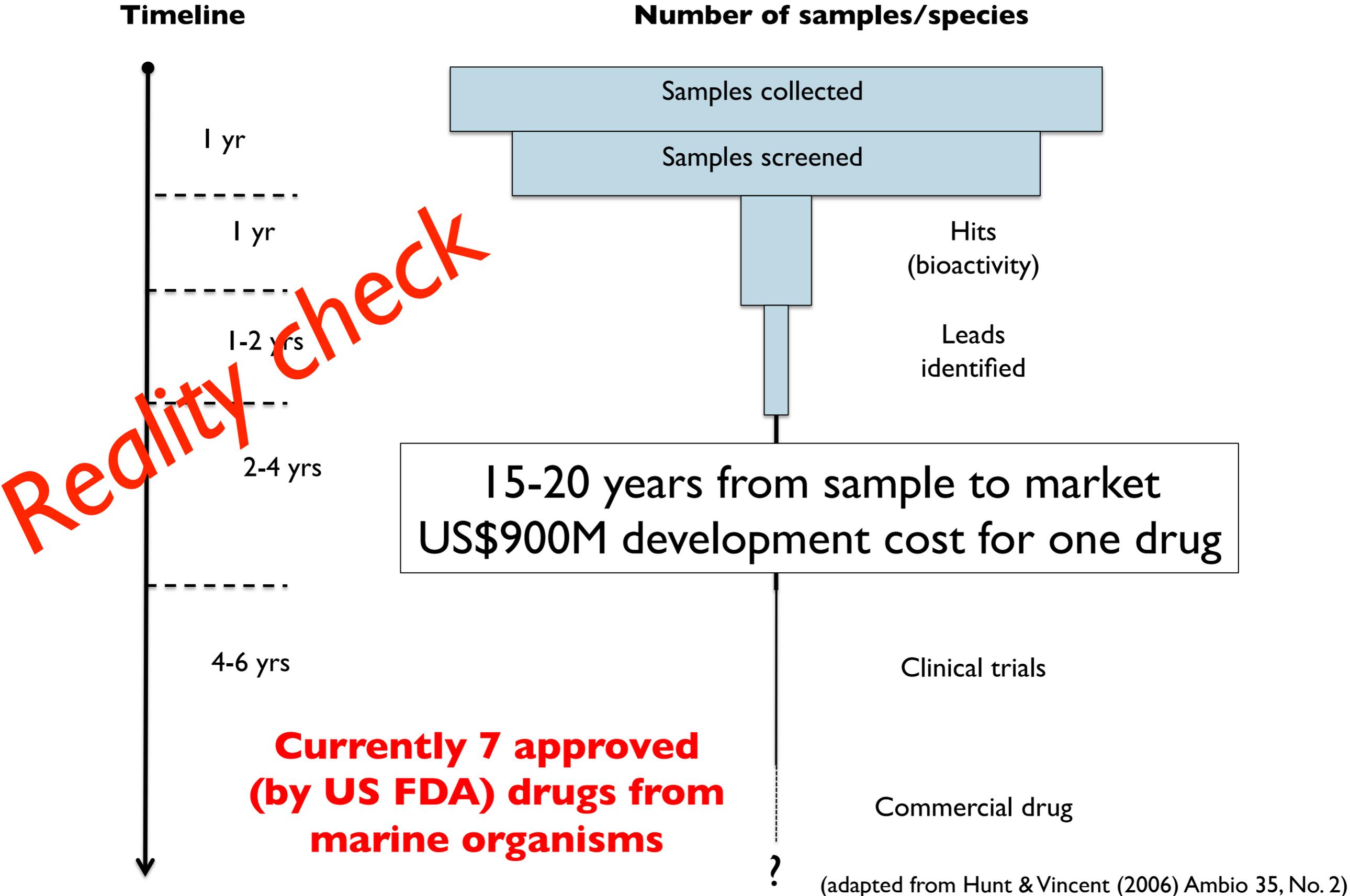
- Marine derived anti-tumoral agent discovered in the colonial tunicate *Ecteinascidia turbinata* and now produced synthetically by PharmaMar.
- Currently approved for treatment of ovaria cancer in 57 countries



*Ecteinascidia turbinata*

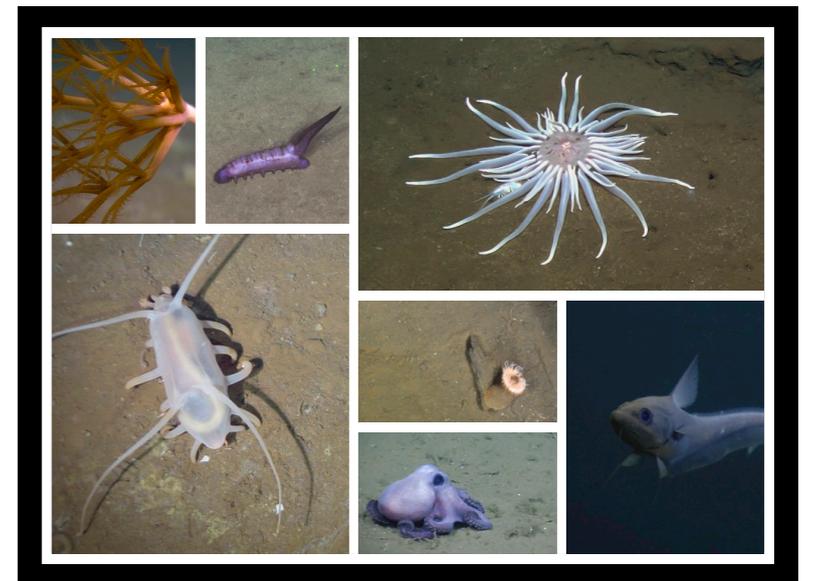


# Drug discovery and development from natural products

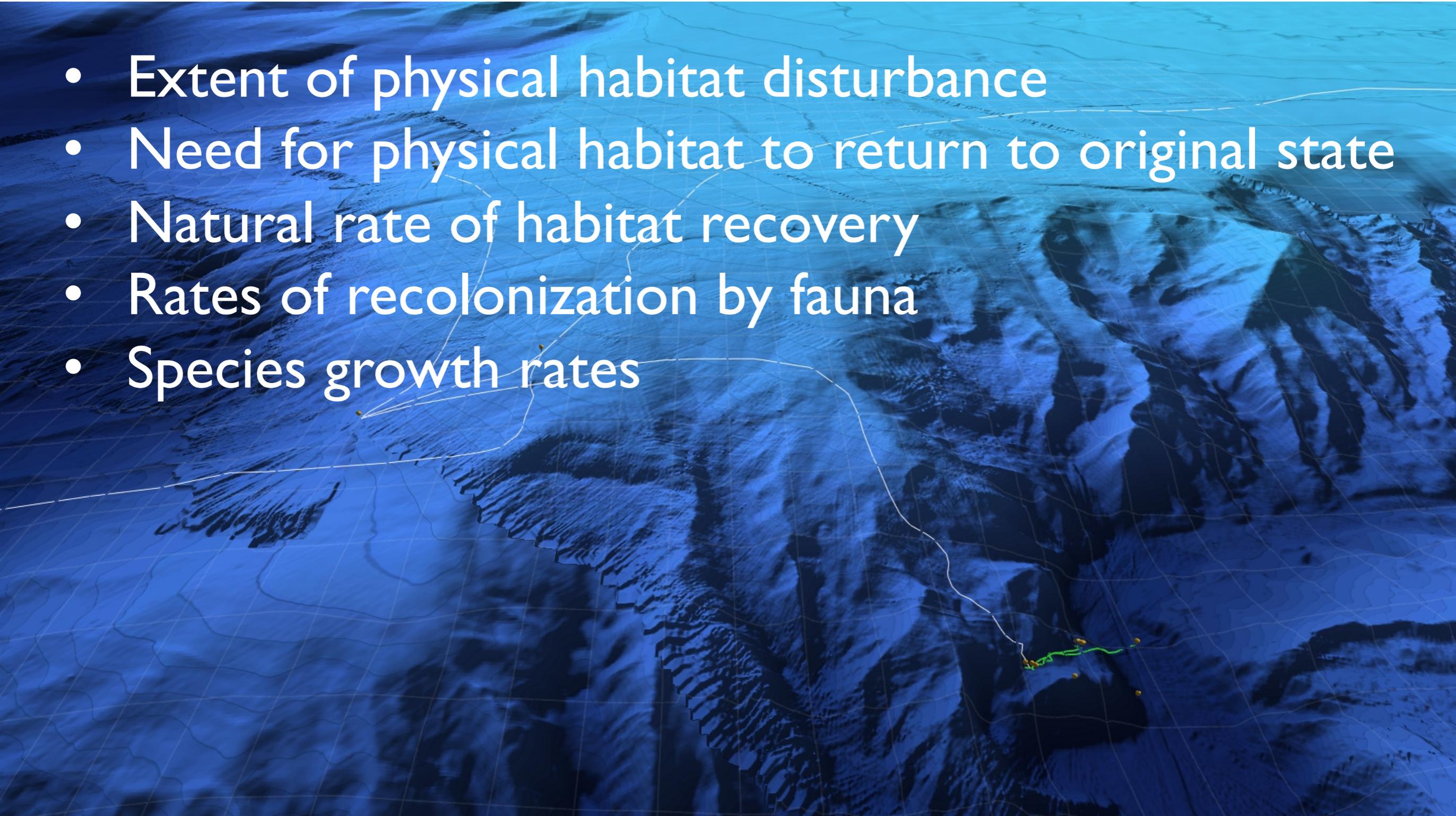


# Framework – evaluating seabed mining impacts

- Valuation
  - What's there? (rarity, uniqueness)
  - Value to marine ecosystem? (ecosystem function)
  - Value to society? (ecosystem goods and services)
- Recovery Trajectory
  - How long?
- Spatial Planning Considerations

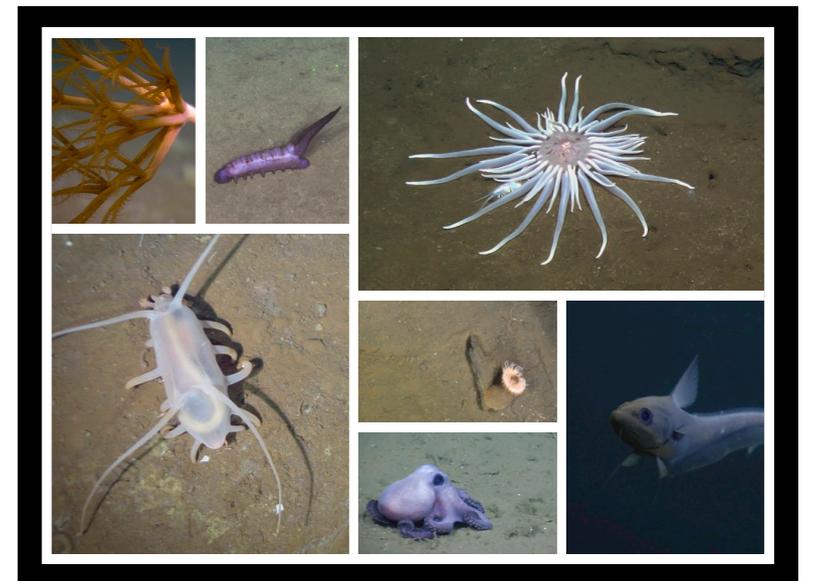


# Recovery Trajectory

- Extent of physical habitat disturbance
  - Need for physical habitat to return to original state
  - Natural rate of habitat recovery
  - Rates of recolonization by fauna
  - Species growth rates
- 

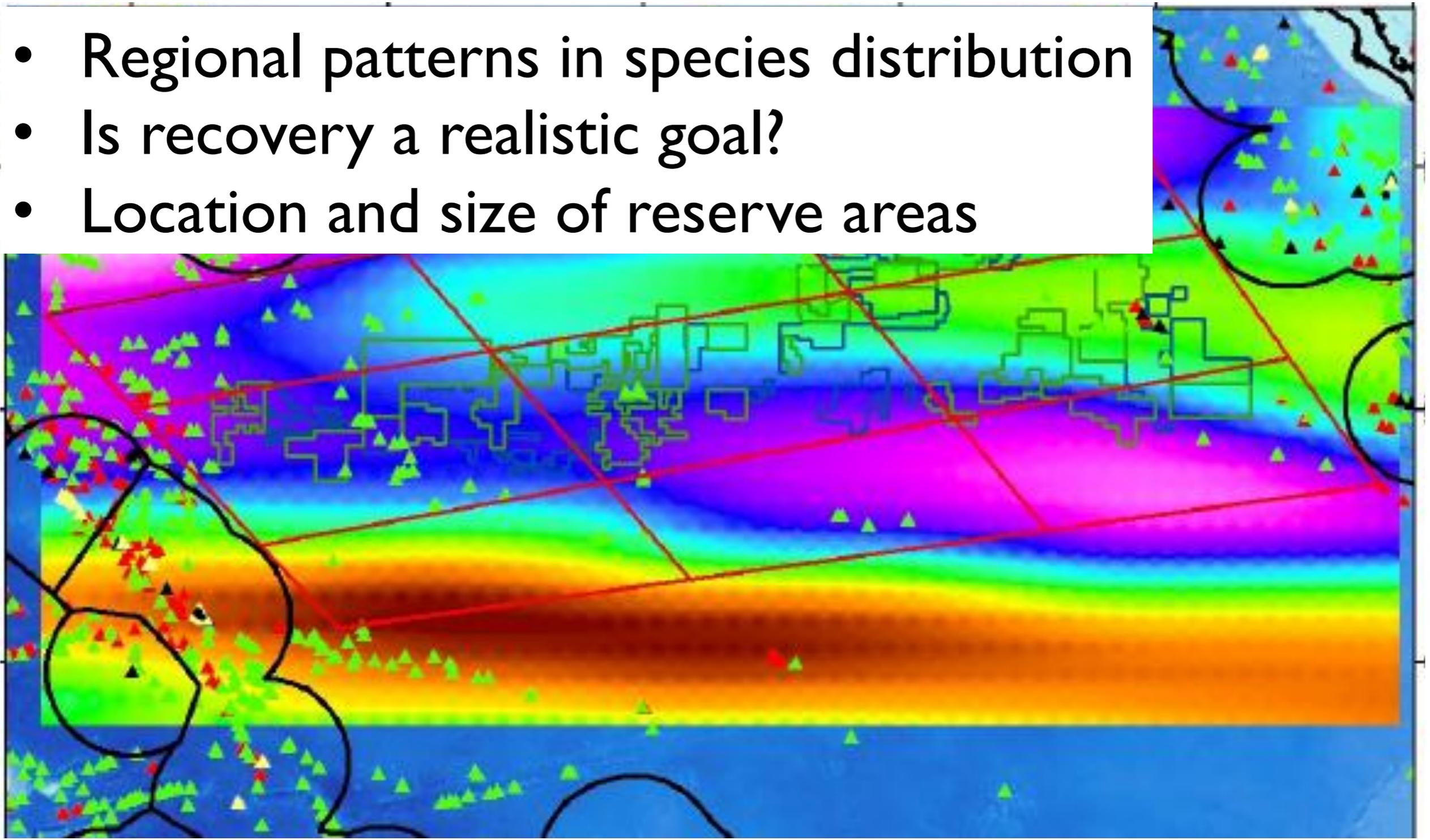
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- Recovery Trajectory
  - How long?
- Spatial planning considerations



# Spatial Planning Considerations

- Regional patterns in species distribution
- Is recovery a realistic goal?
- Location and size of reserve areas



## Fauna of Cobalt-Rich Ferromanganese Crust Seamounts

Technical Study: No. 8

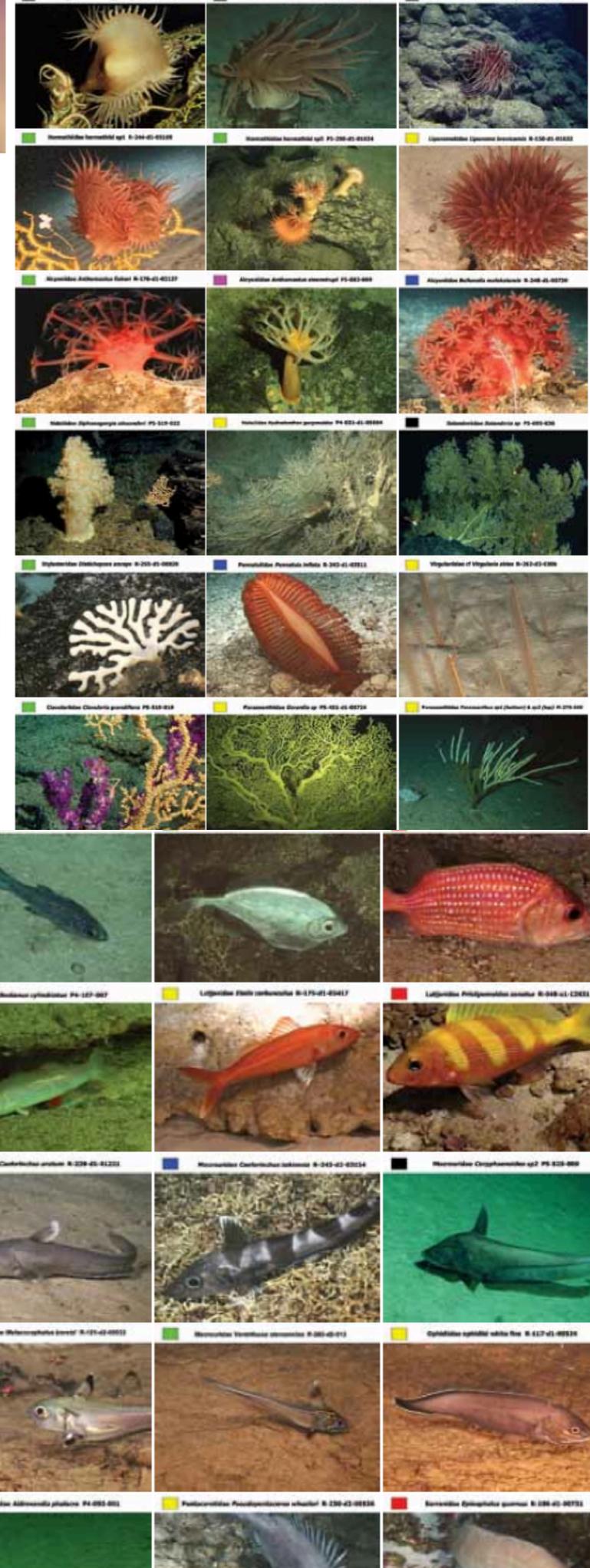


## Crusts (Co-rich, Fe-Mn)

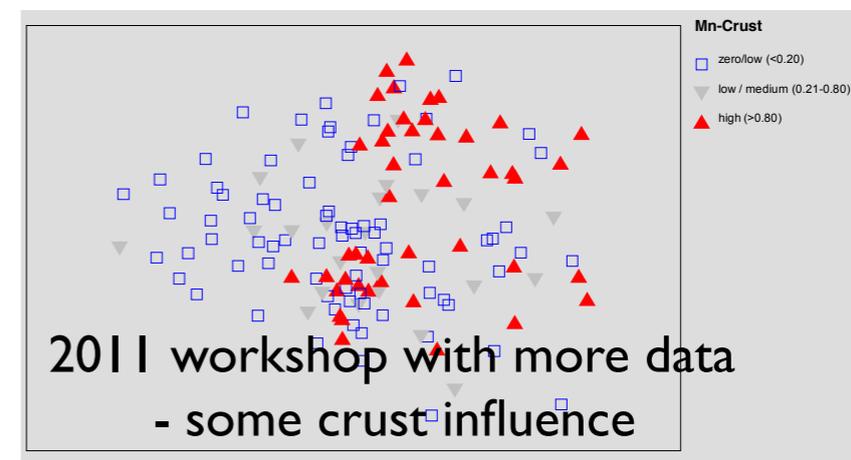
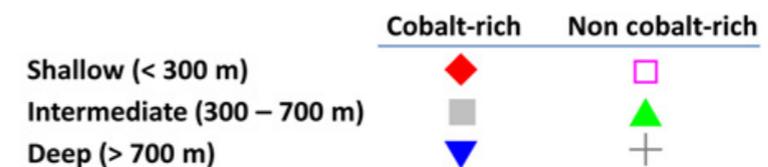
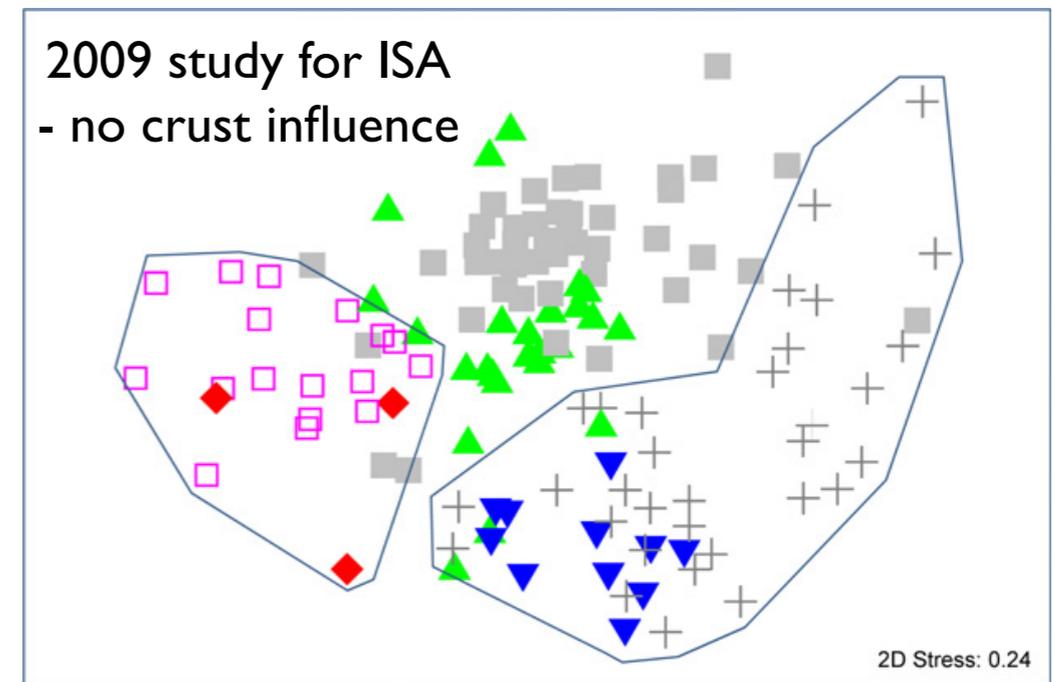
- Fauna data from studies in Hawaiian seamount chain
- Video from submersible & ROV dives



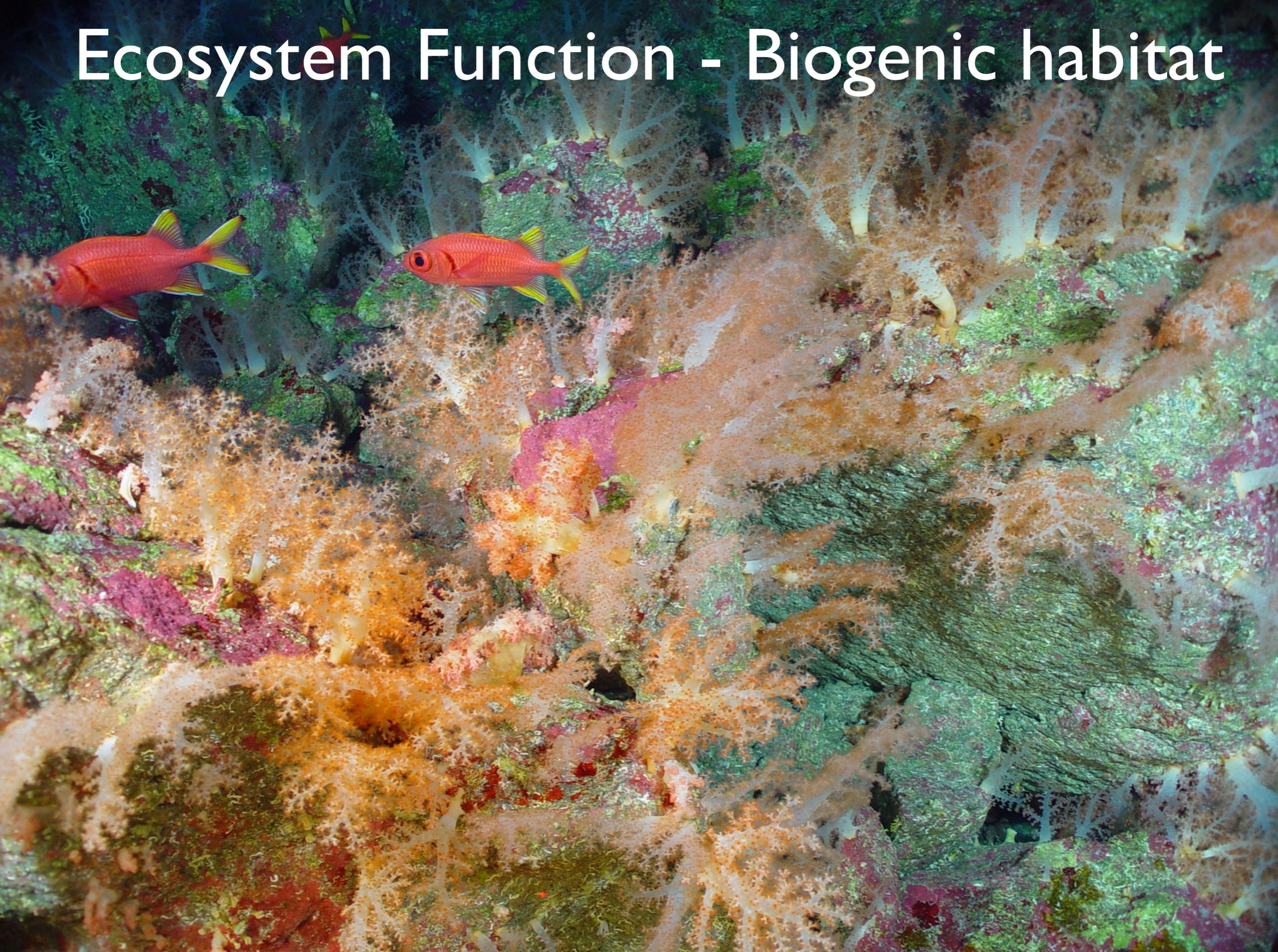
- 967 'species'
- What lives where?



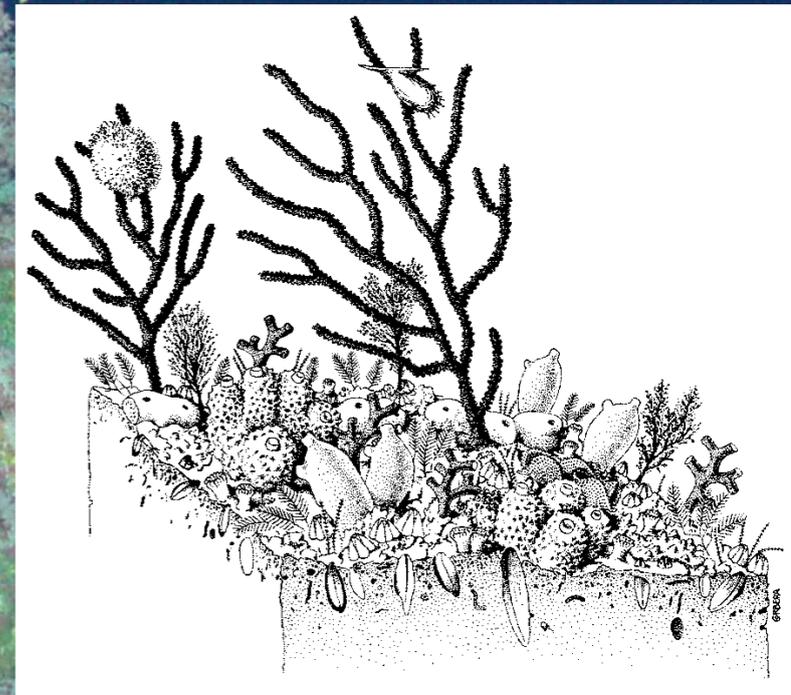
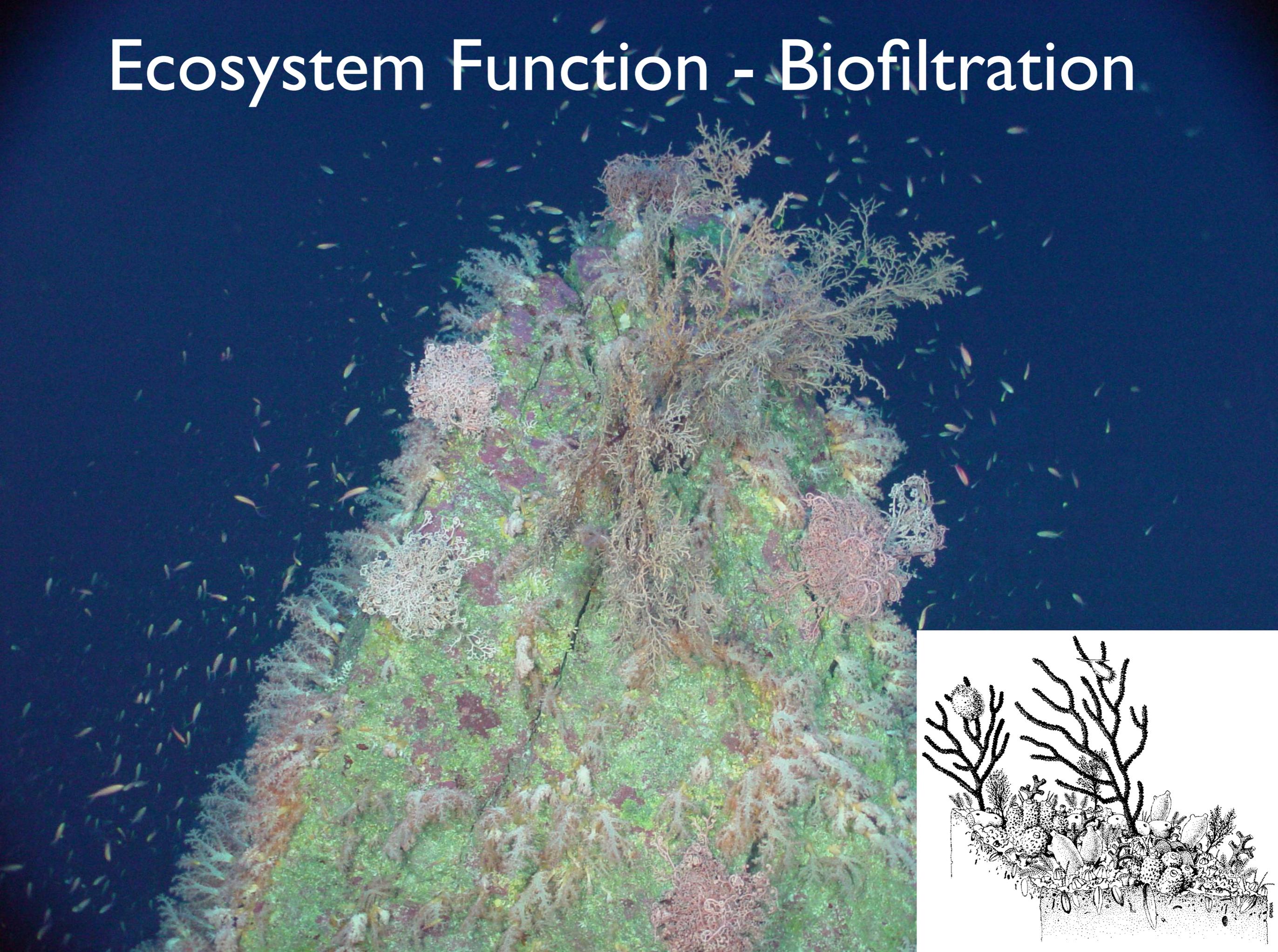
# Seamounts with Co-crusts *may* have different fauna from non-crust seamounts



# Ecosystem Function - Biogenic habitat

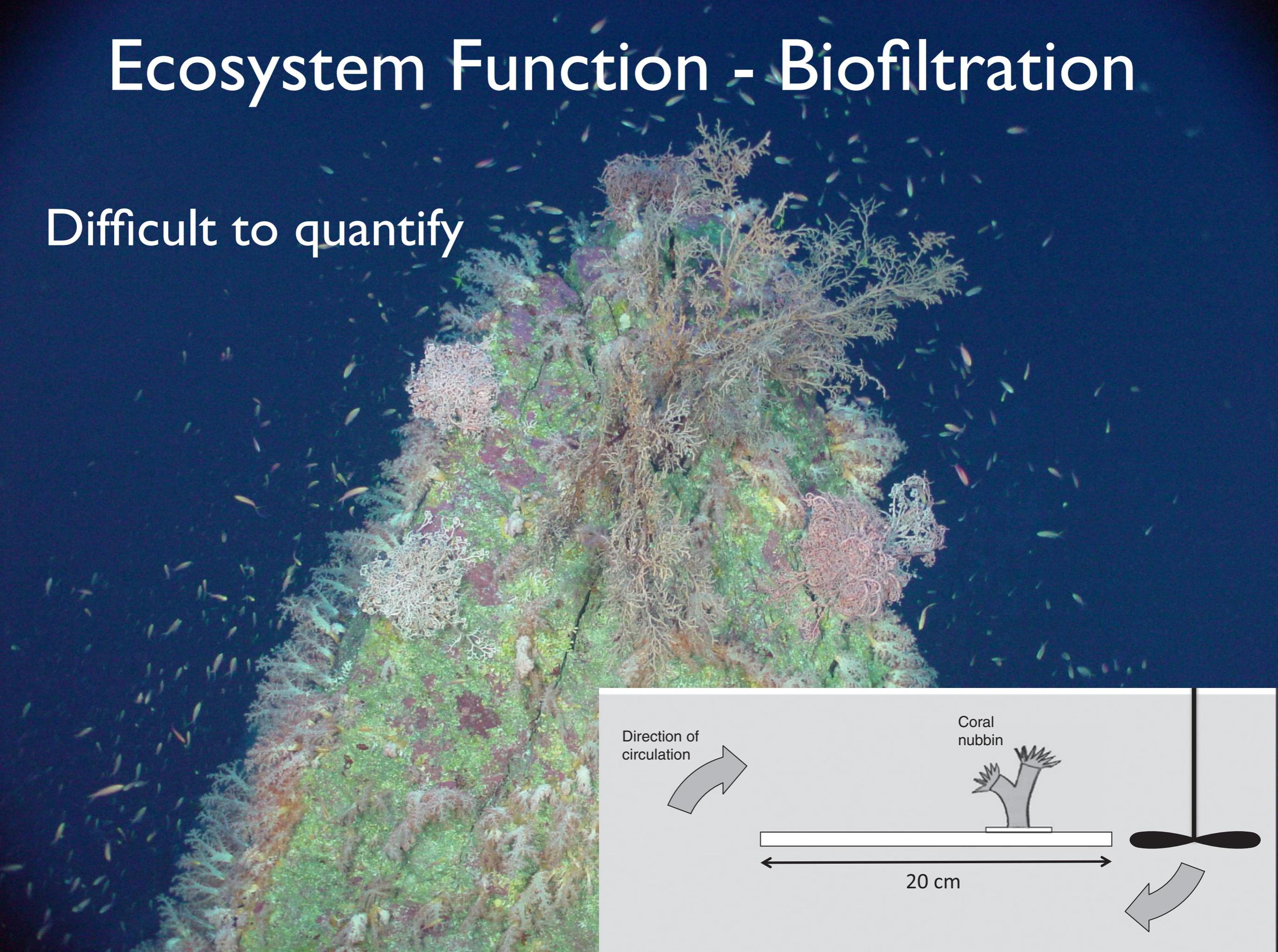


# Ecosystem Function - Biofiltration



# Ecosystem Function - Biofiltration

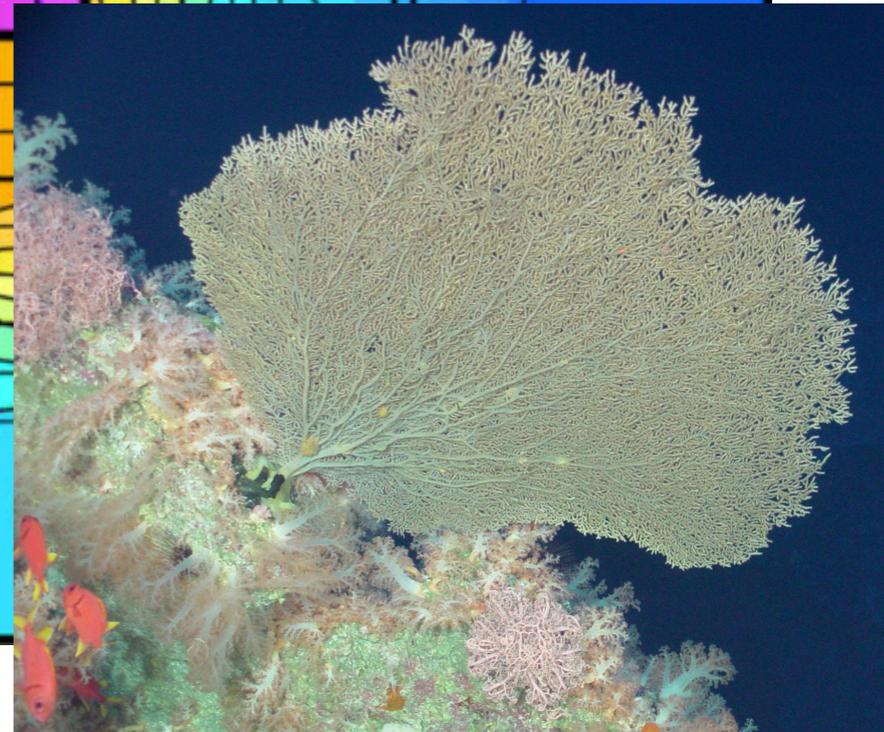
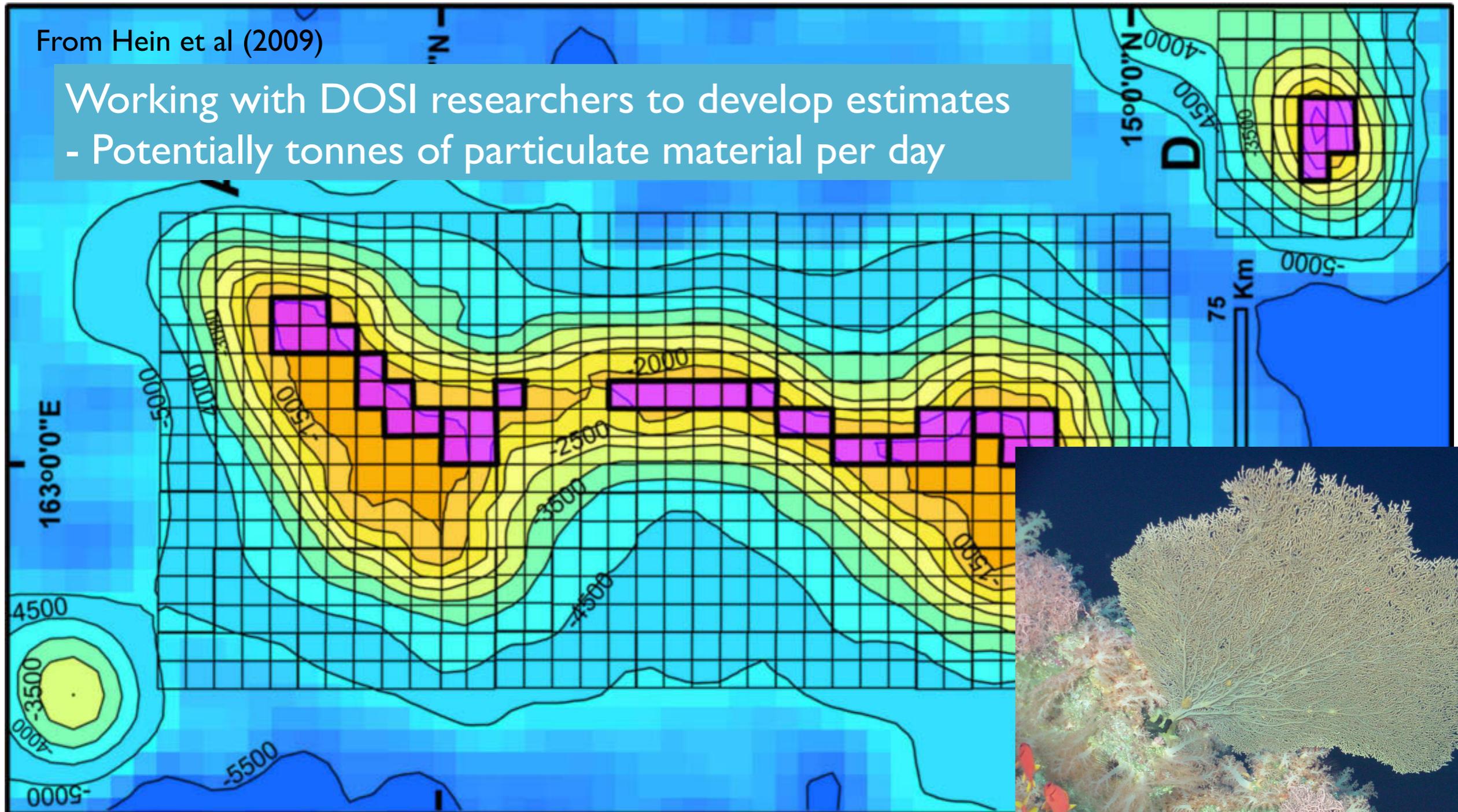
Difficult to quantify



# Potential loss of biofiltration capacity for 20 km<sup>2</sup> mine sub-block on seamounts

From Hein et al (2009)

Working with DOSI researchers to develop estimates  
- Potentially tonnes of particulate material per day

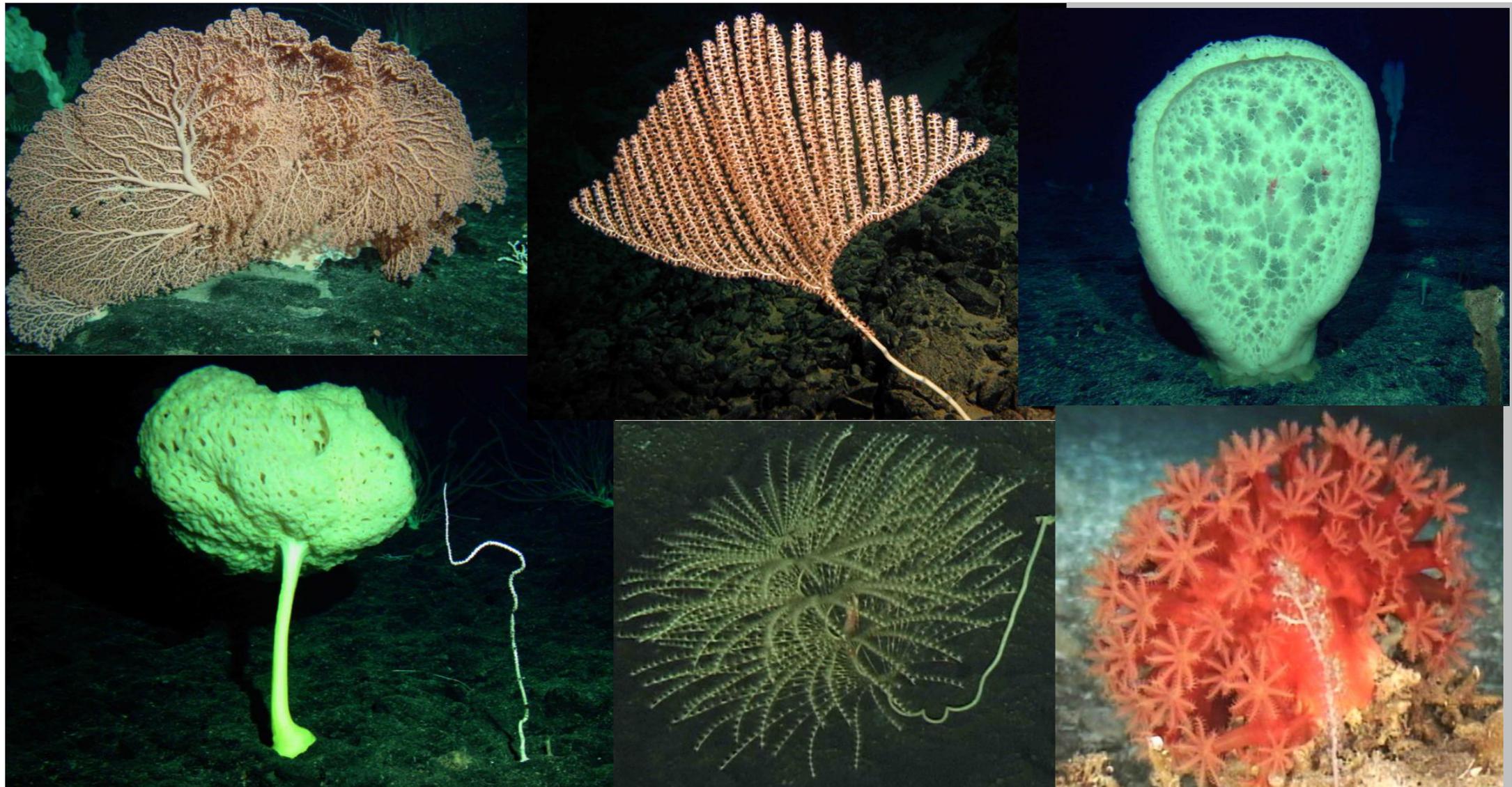


# Impact evaluation framework - crusts

Valuation Criterion	Value
What's there?	967 'species' on Hawaiian seamount chain
Rare or unique	Possibly ...
Ecosystem function	Corals create physical habitat Corals and sponges filter seawater
Scientific and Cultural value	Seamounts are biodiversity hotspots
Potential economic value	Seamount fisheries

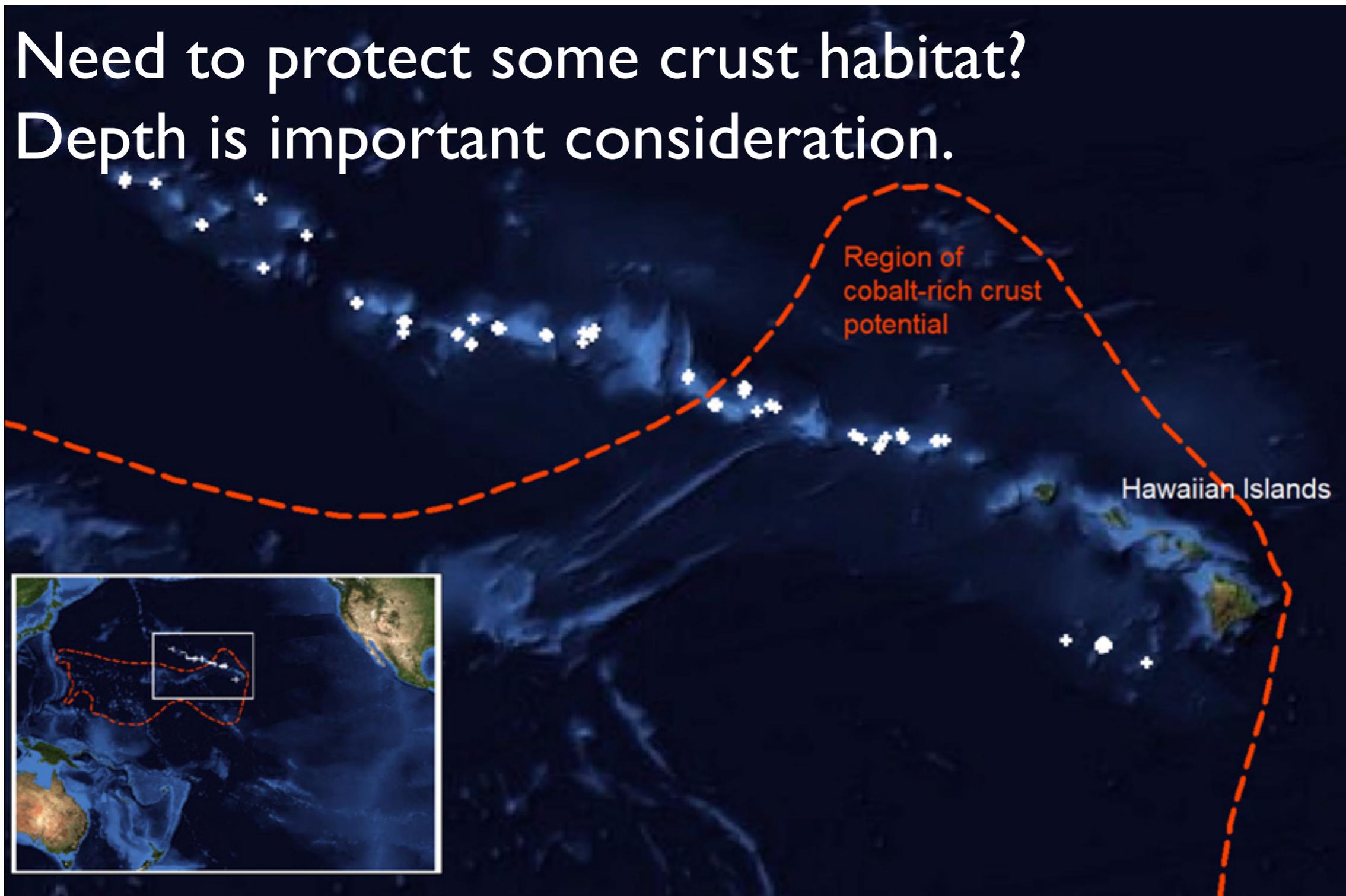
# Recovery Trajectory

- crusts take millions of year to form
- large organisms on crusts grow very slowly (10's to 100's of years)



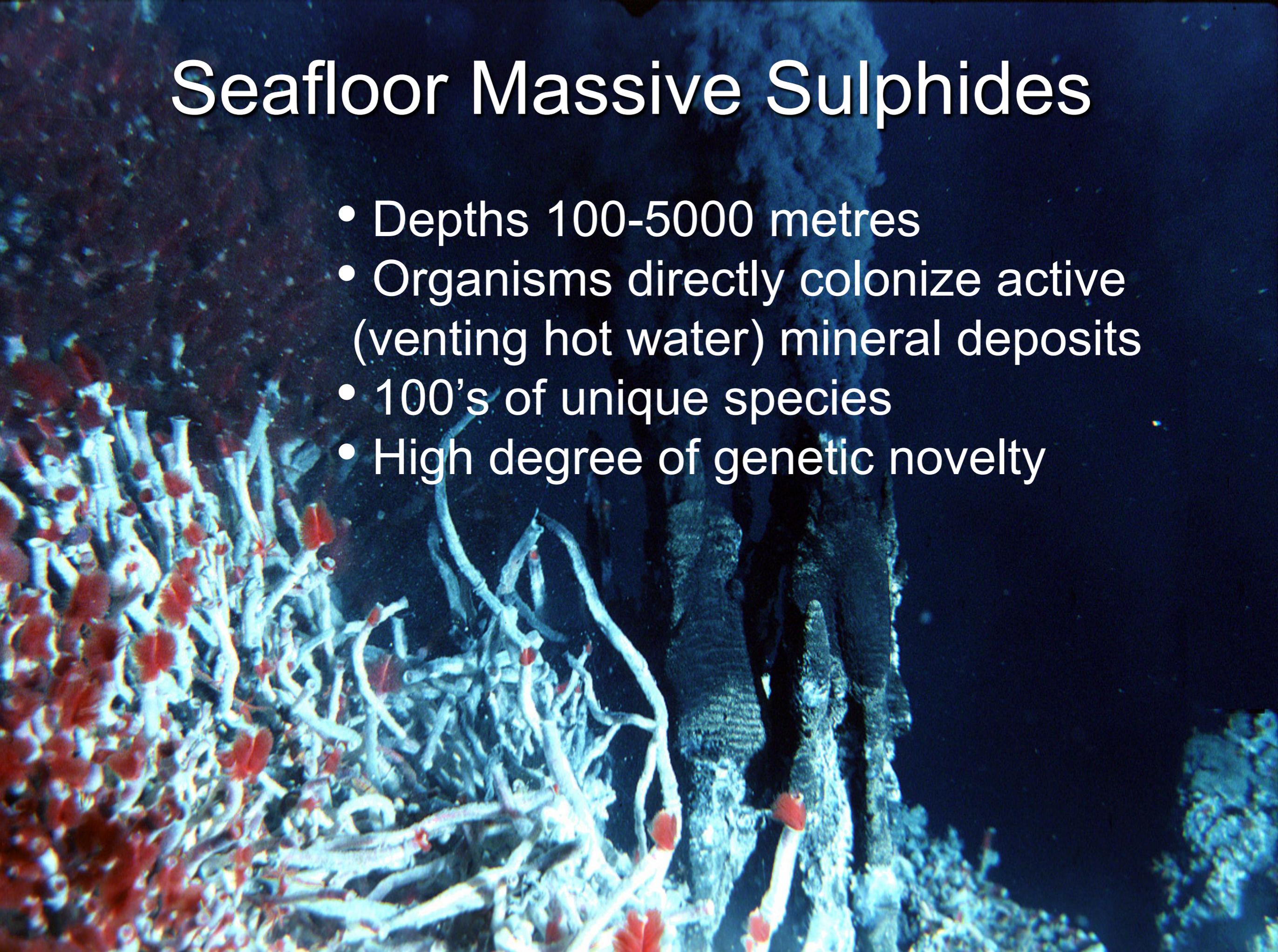
# Spatial Planning Considerations - Crusts

Need to protect some crust habitat?  
Depth is important consideration.



# Seafloor Massive Sulphides

- Depths 100-5000 metres
- Organisms directly colonize active (venting hot water) mineral deposits
- 100's of unique species
- High degree of genetic novelty





# Hydrothermal vents - energy oases for specialized ecosystems

Specialised animals and  
microbes colonise seafloor  
vents

H<sub>2</sub>S in hydrothermal fluids  
provides energy for  
*chemosynthesis* of new  
organic matter

- High biomass
- Rapid growth
- Low animal biodiversity
- High microbial diversity

# Genetic resources at hydrothermal vents

- Small number of animal species
- High, unquantified diversity of microbes
- Genetic novelty
  - Growth at high temperatures
  - Resistance to heavy metals
  - Unusual symbioses



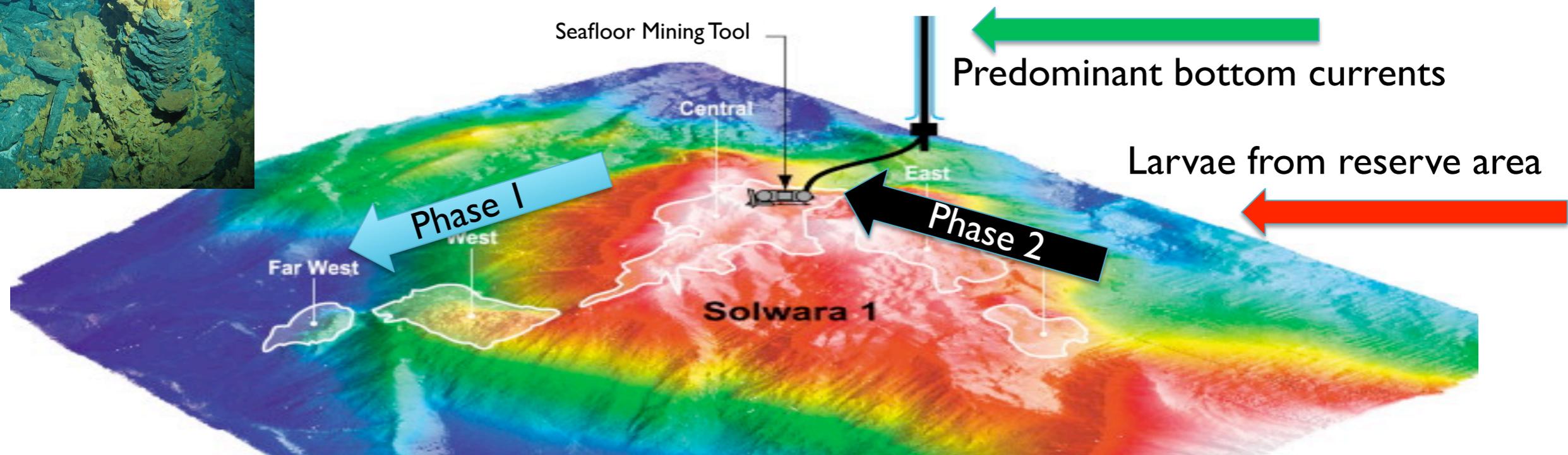
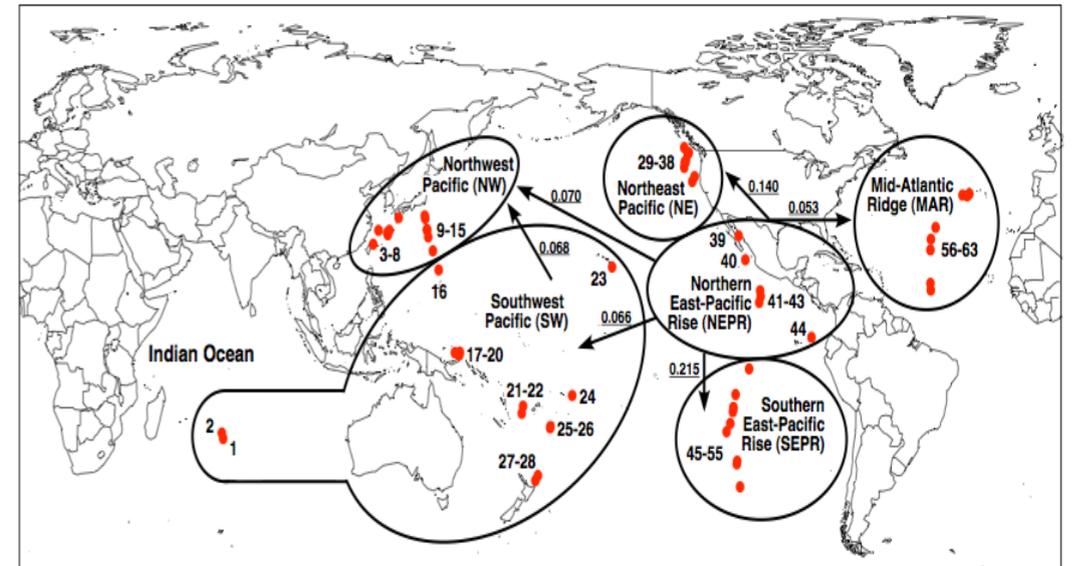
# Impact Evaluation Framework – SMS deposits

Valuation Criterion	Value
What's there?	Specialized animals and microbes at hydrothermal vents
Rare or unique	>80% unique to hydrothermal events Regional endemism
Scientific value	High
Cultural value	High
Potential economic value	High potential

**Recovery Trajectory = high capacity for rapid recolonisation – requires nearby mother populations**

# Spatial Planning Considerations – SMS

- Larvae can recolonize disturbed sites from nearby populations
- Some species known from single sites only – need more info
- Identify nearby reserve areas



# Manganese Nodules

Depth:  
4 000 - 6 500 metres

Very weak bottom currents (less than 5 cm/s)

Very low flux of  
particulate organic  
carbon

Very low bottom  
water temperature

1-2 °C

Sediments

Living in the sediments

Macrofauna

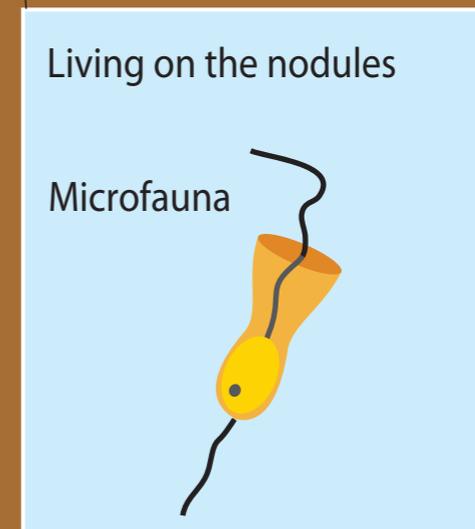
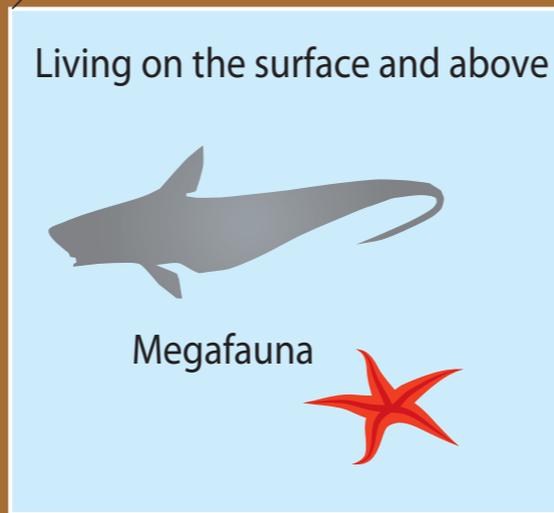
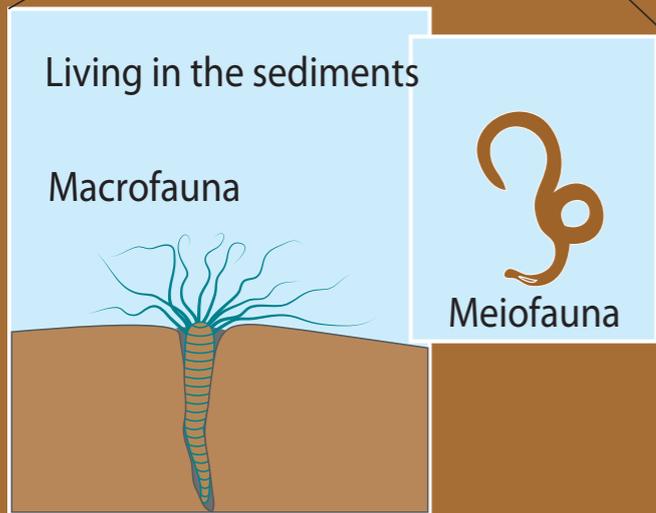
Meiofauna

Living on the surface and above

Megafauna

Living on the nodules

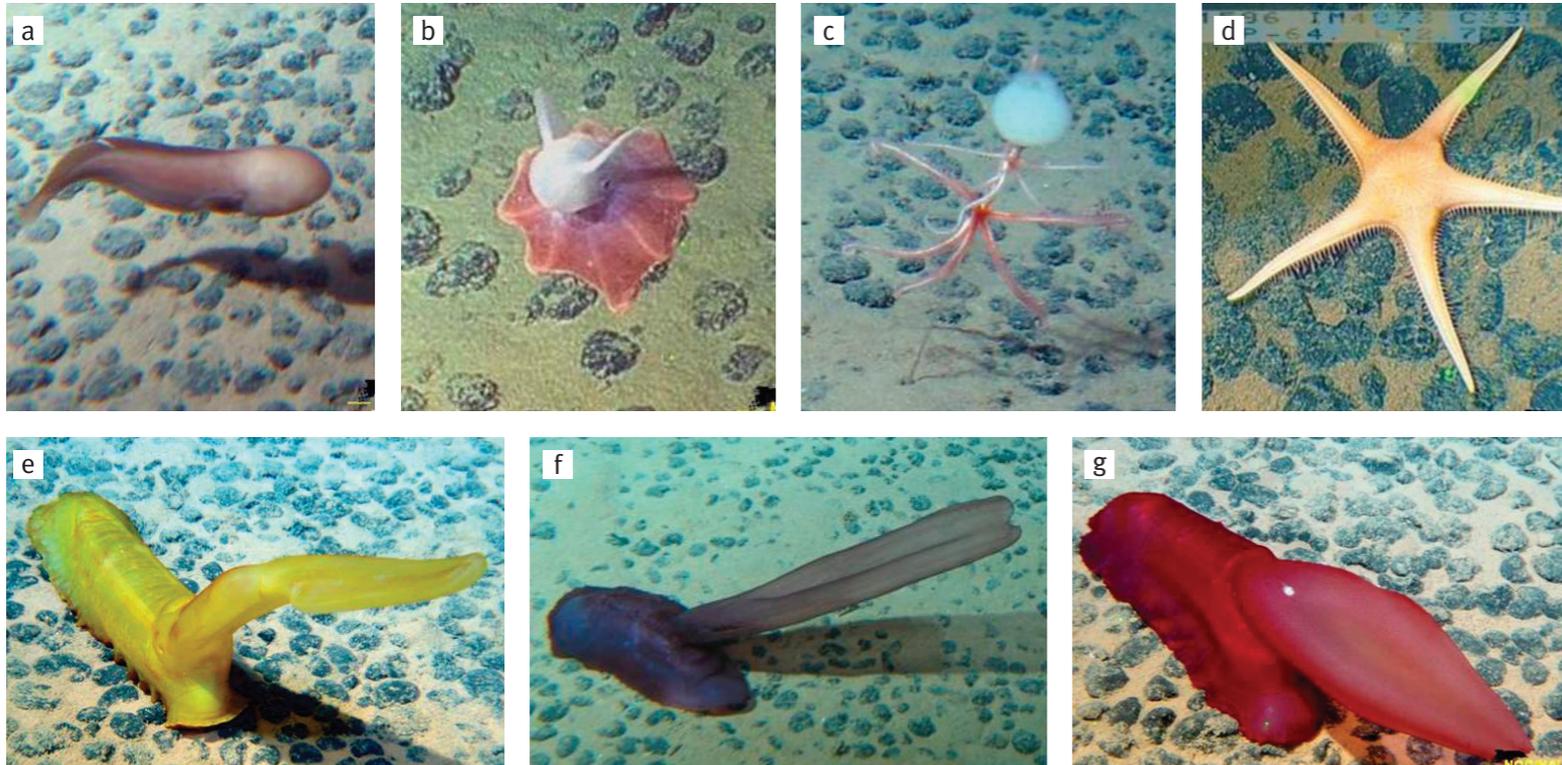
Microfauna



Note: nodules not on scale

# Manganese Nodule Fauna

## Mobile megafauna



## Attached to nodules



## Sediment infauna



# Impact evaluation framework – Mn nodules

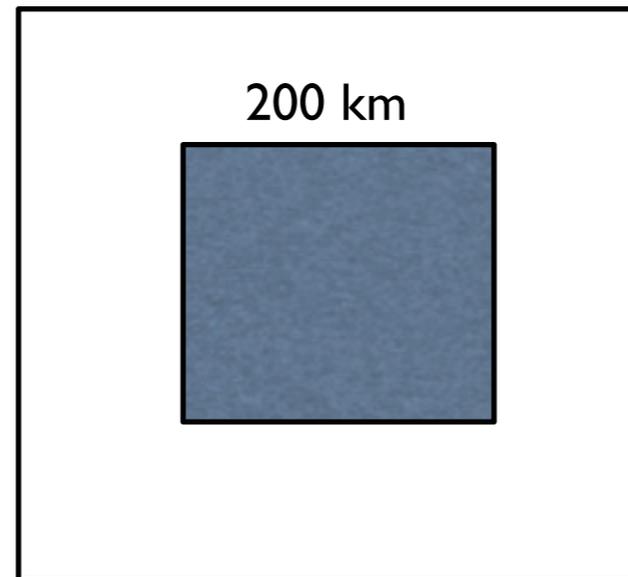
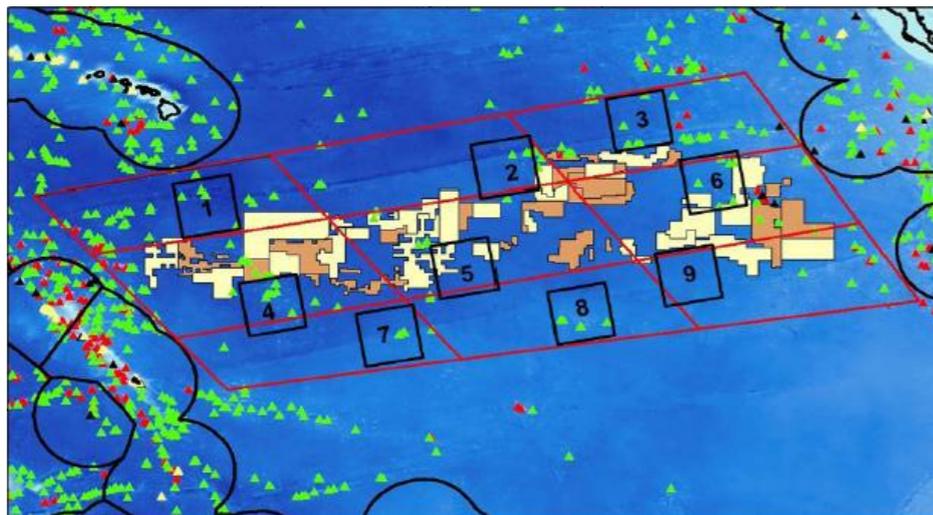
Valuation Criterion	Value
What's there?	High diversity, still counting
Rare or unique	Possibly, especially fauna on nodules 
Scientific value	Huge reservoir of species Key to understanding ecology of the abyss
Cultural value	Undeveloped
Potential economic value	Unknown

# Recovery trajectory = slow, very slow

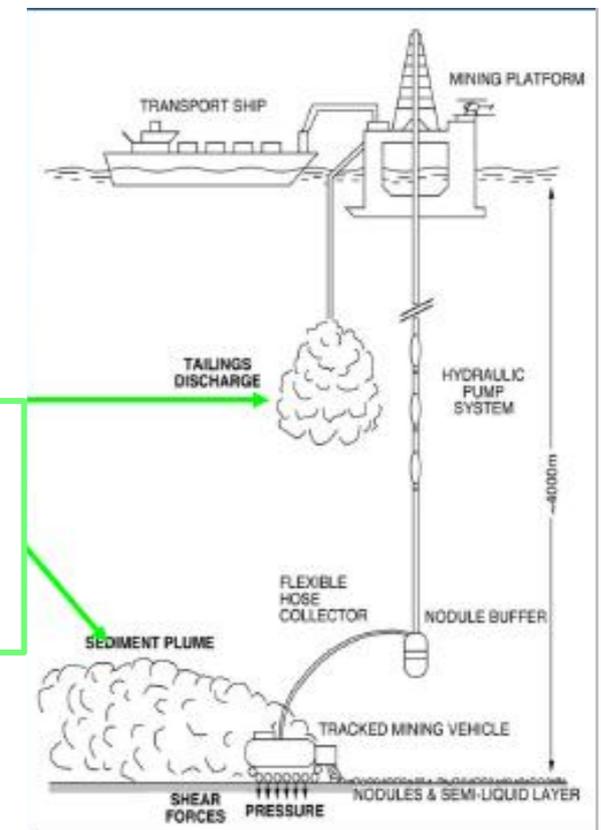


# Spatial Planning – Nodules

- Large scale mining operations
- Similar scales for buffer zones, protected areas
- Consider E-W and N-S gradients



*Sediment plumes travel at 100 km distance from mining operation*

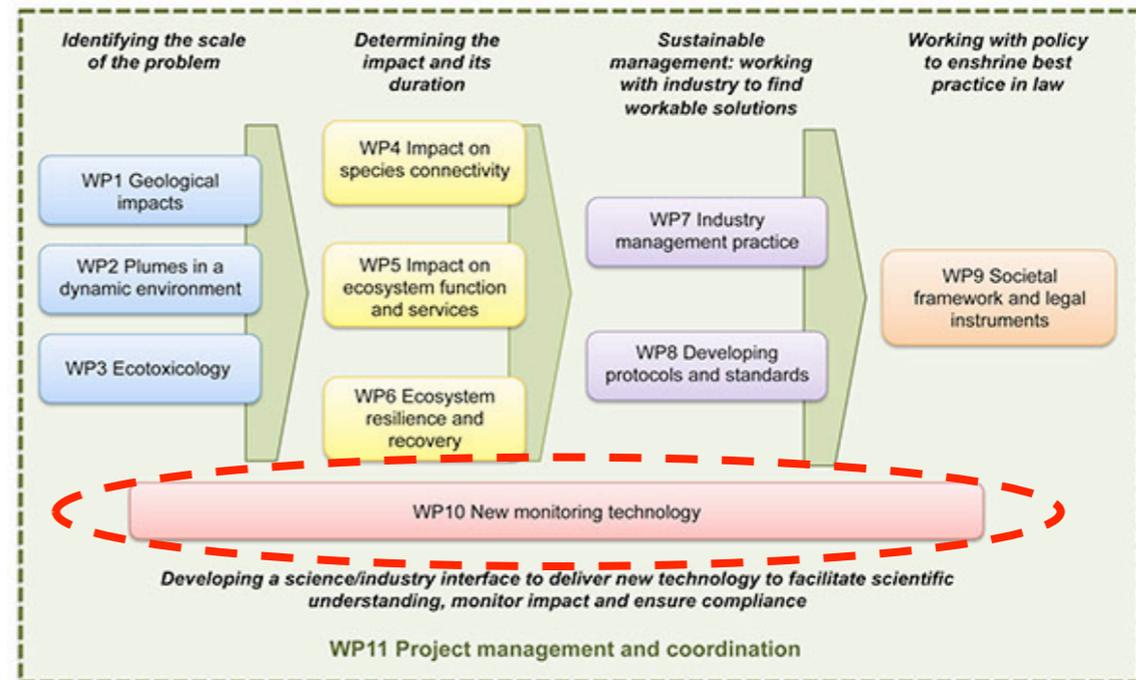
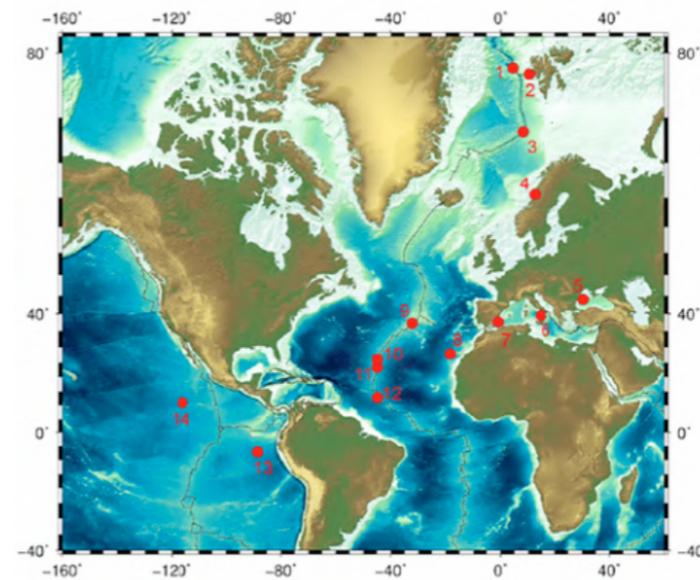
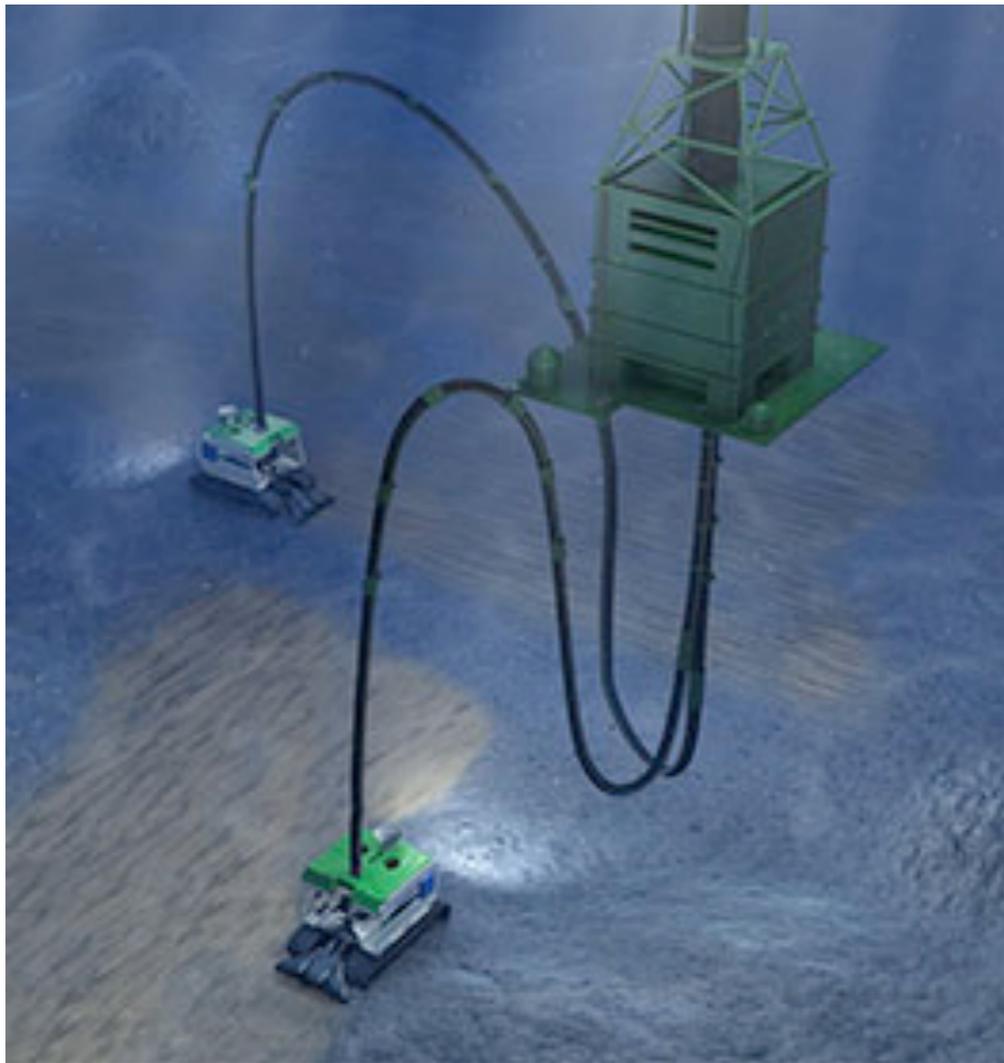


# Summary – Crust, SMS and Nodules

Valuation Criterion	Crusts	SMS	Nodules
What's there?	High diversity seamount fauna	Low diversity vent fauna	High diversity, still counting
Rare or unique	Possibly	80% of species found nowhere else	Possibly, especially fauna on nodules
Scientific value	Larger reservoir of species	High, unusual adaptations	Huge reservoir of species
Cultural value	Undeveloped	High	Undeveloped
Potential economic value	Unknown	High biotech potential	Some fisheries, Otherwise unknown

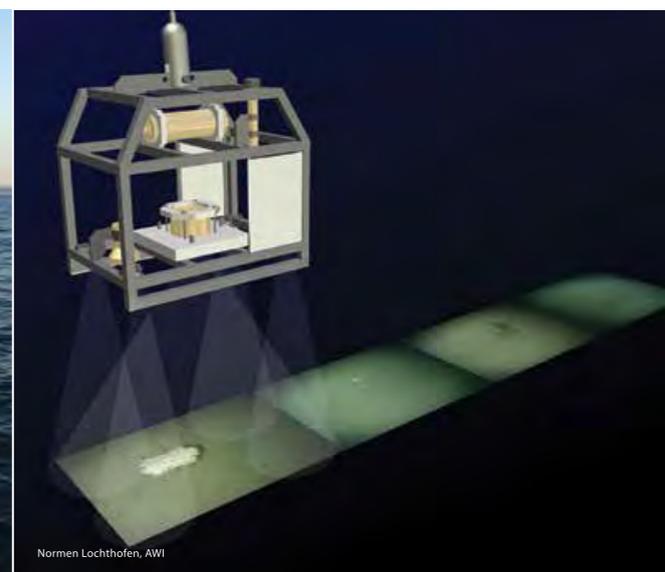
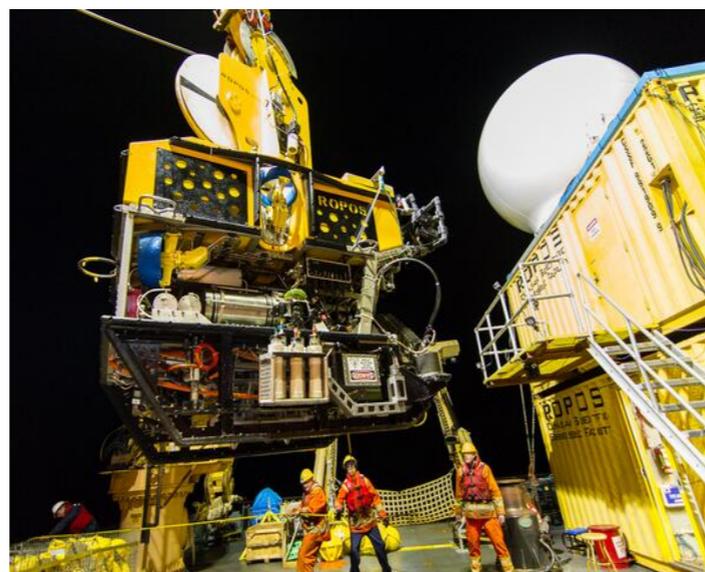
# Monitoring Technologies

- How do we monitor environmental effects of mining operations in remote, deep ocean?



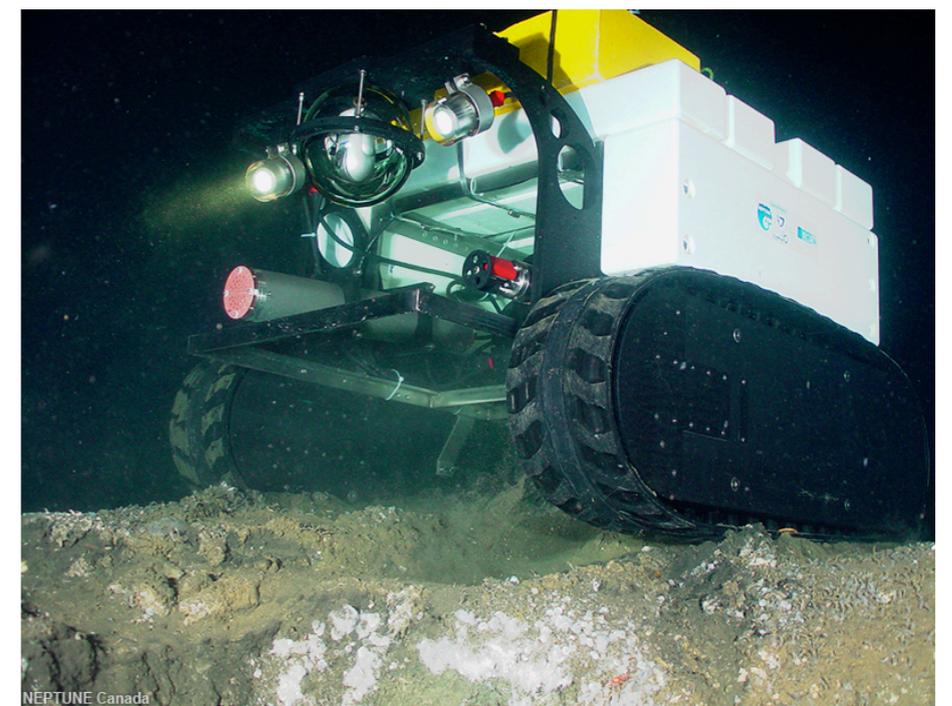
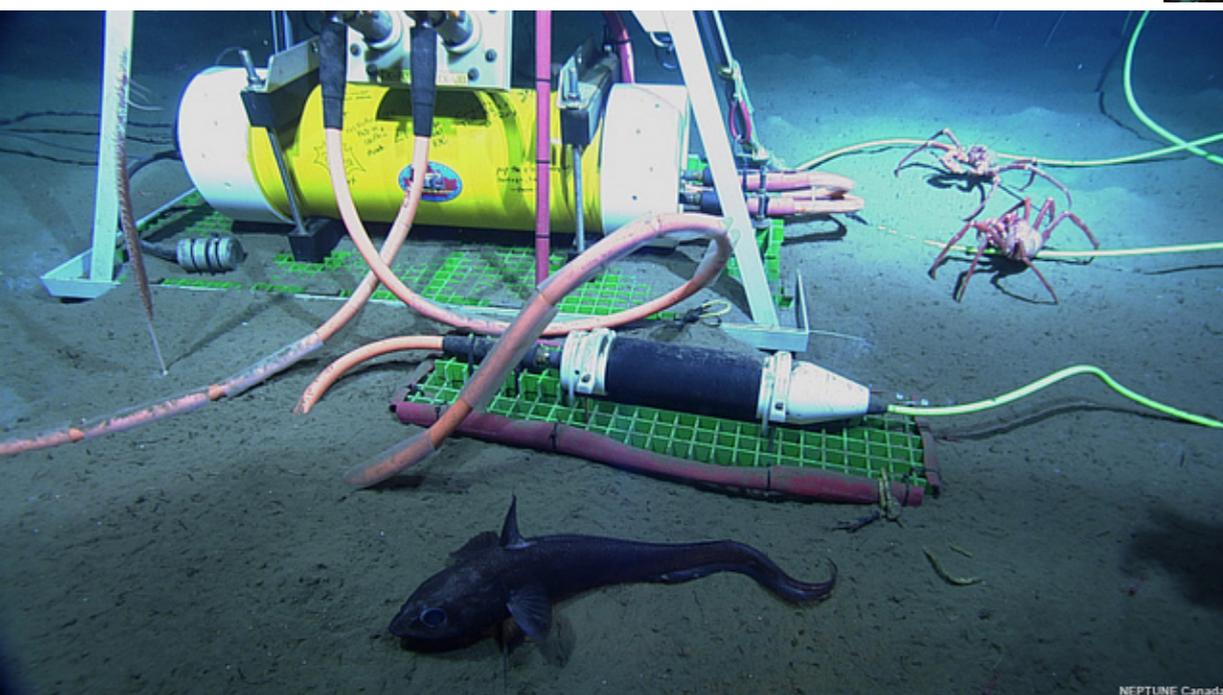
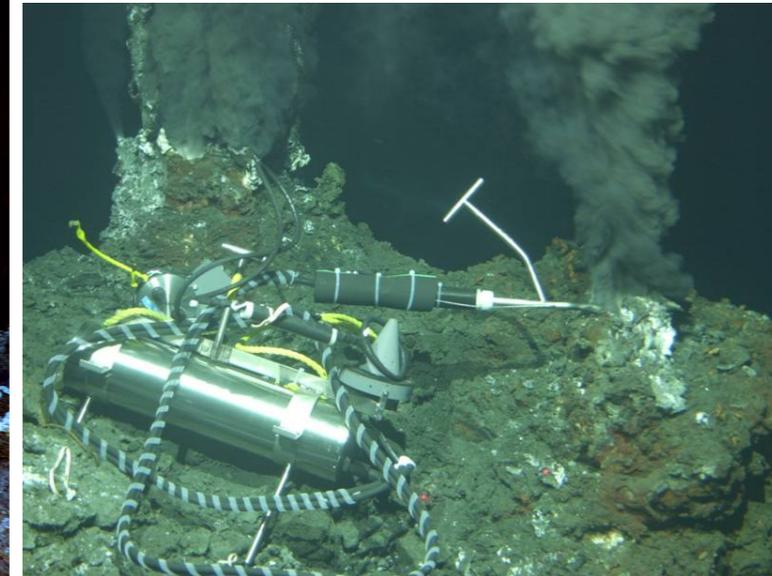
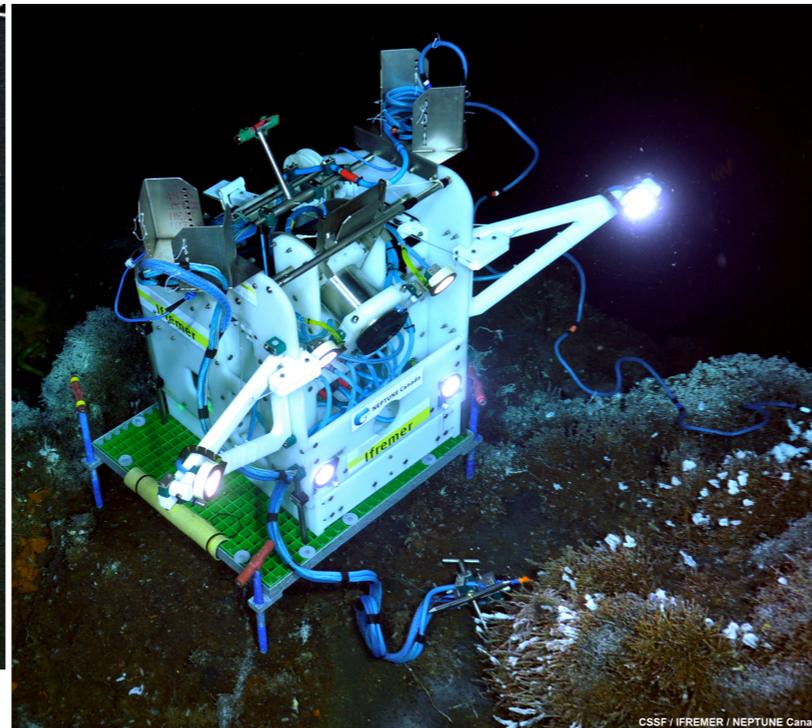
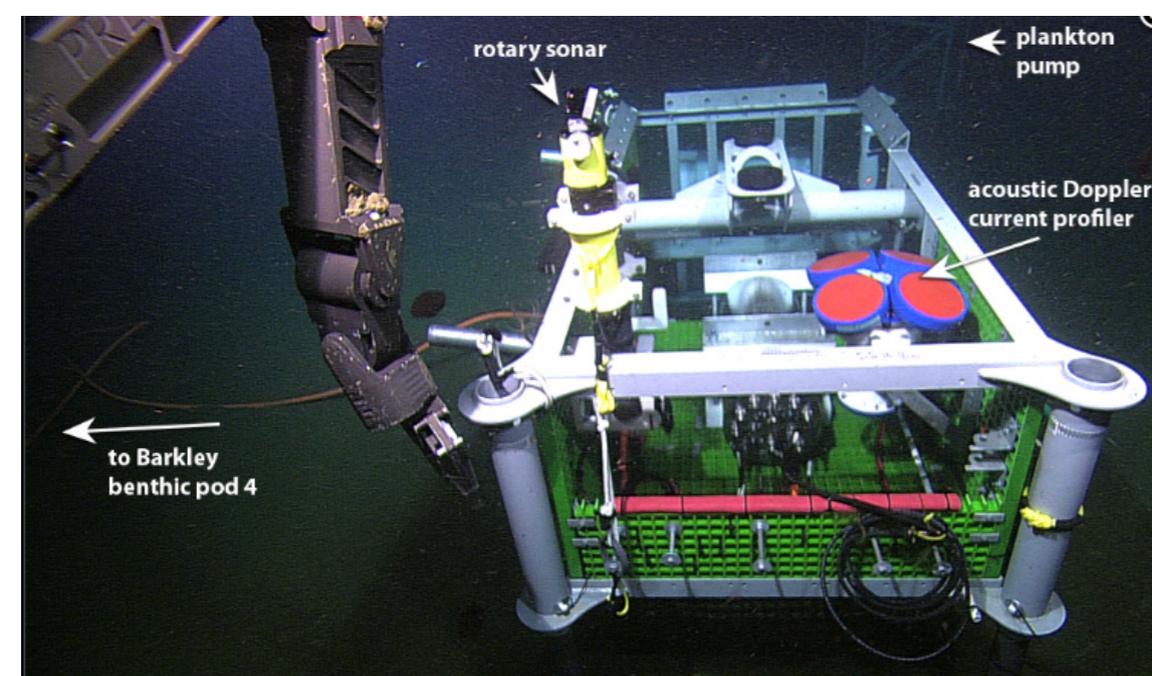
# Environmental monitoring of seabed mining operations

## *Ship-based monitoring programs*



# Environmental monitoring of seabed mining operations

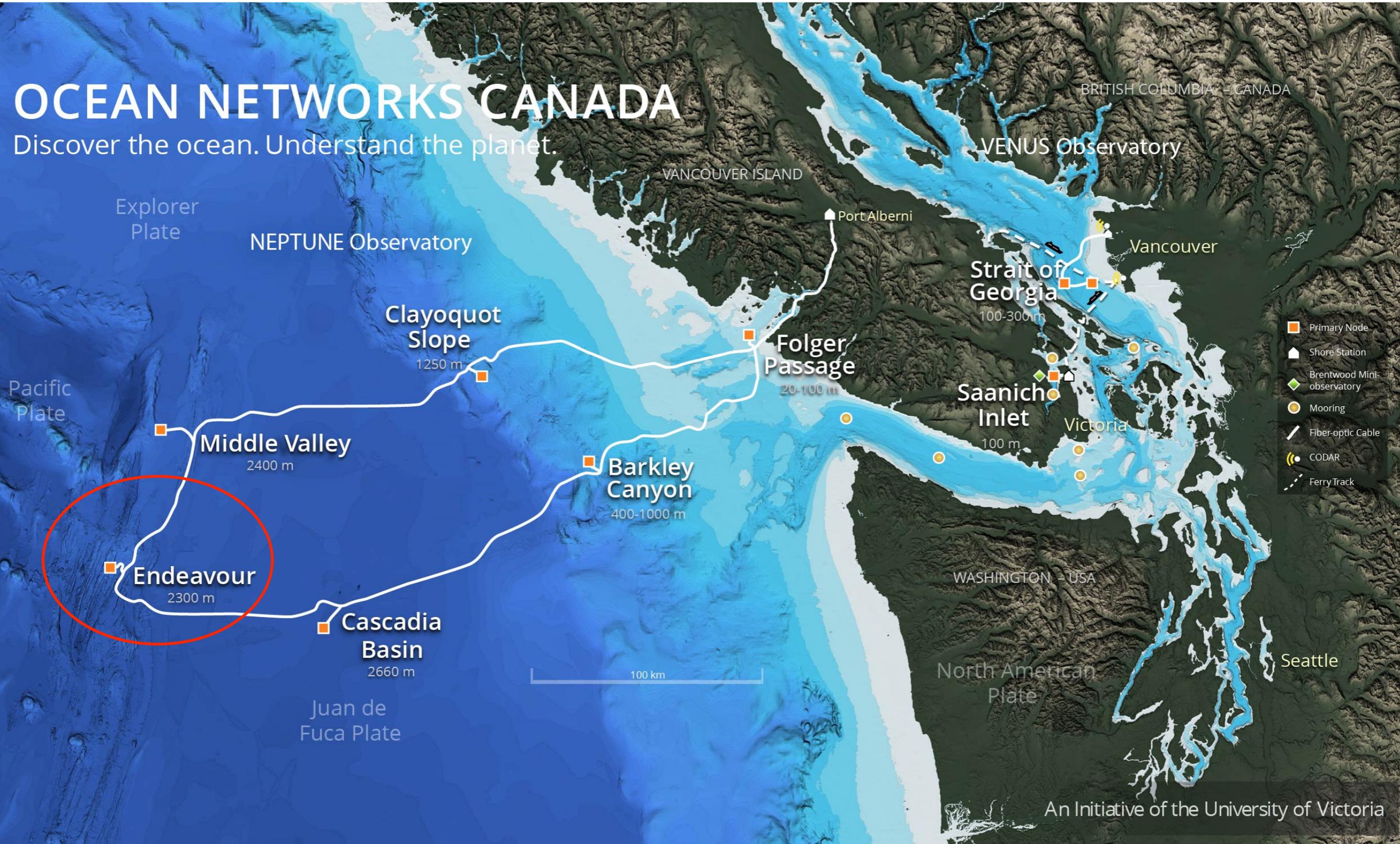
## *Underwater observatory technologies*



# Real-time cabled observatory technologies

## OCEAN NETWORKS CANADA

Discover the ocean. Understand the planet.



# Seafloor nodes provide power and communications to instrument platforms

←  
to instrument platforms



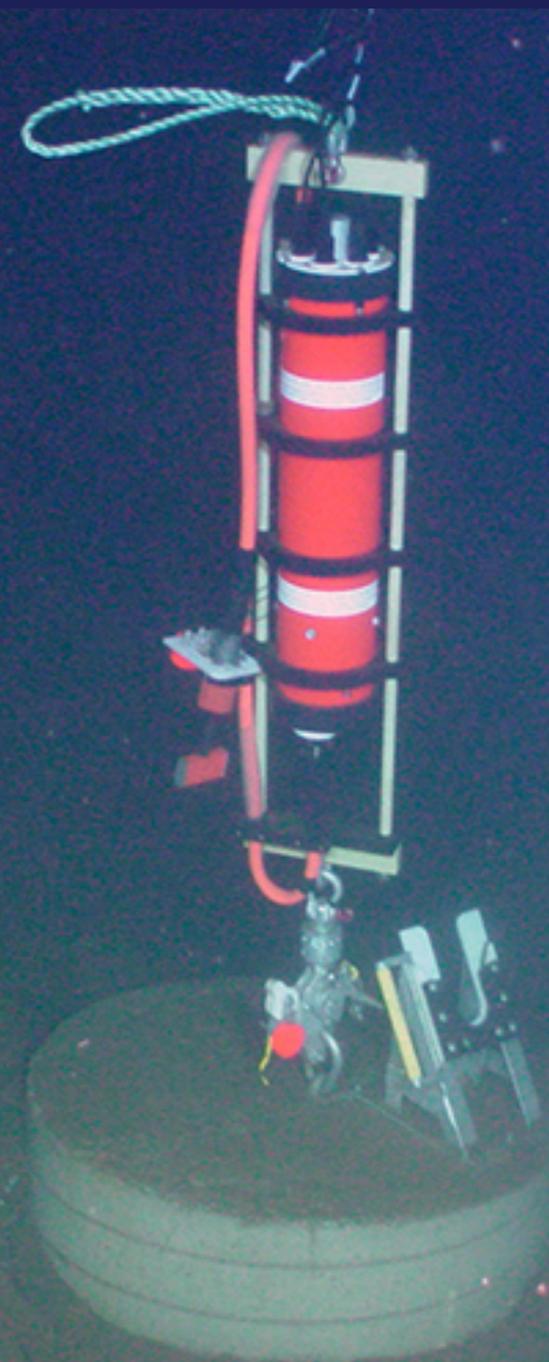
# Real-time plume monitoring



**75 kHz Acoustic Doppler Current Profiler (ADCP):**  
1903m below sea level;  
251m above the seafloor

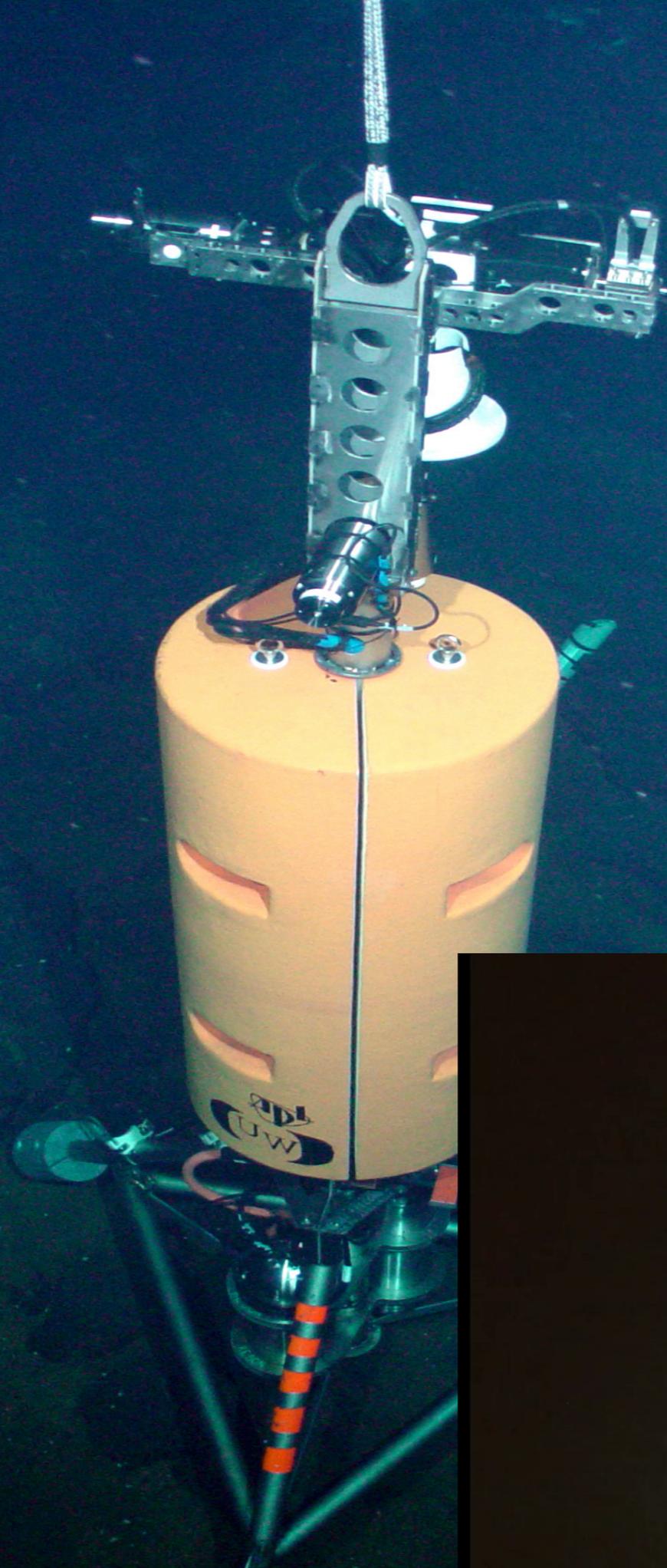


**Co-located CTDs and ACMs:**  
1953, 2028, 2103 & 2148m below  
sea level;  
201, 126, 51 & 4m above the seafloor

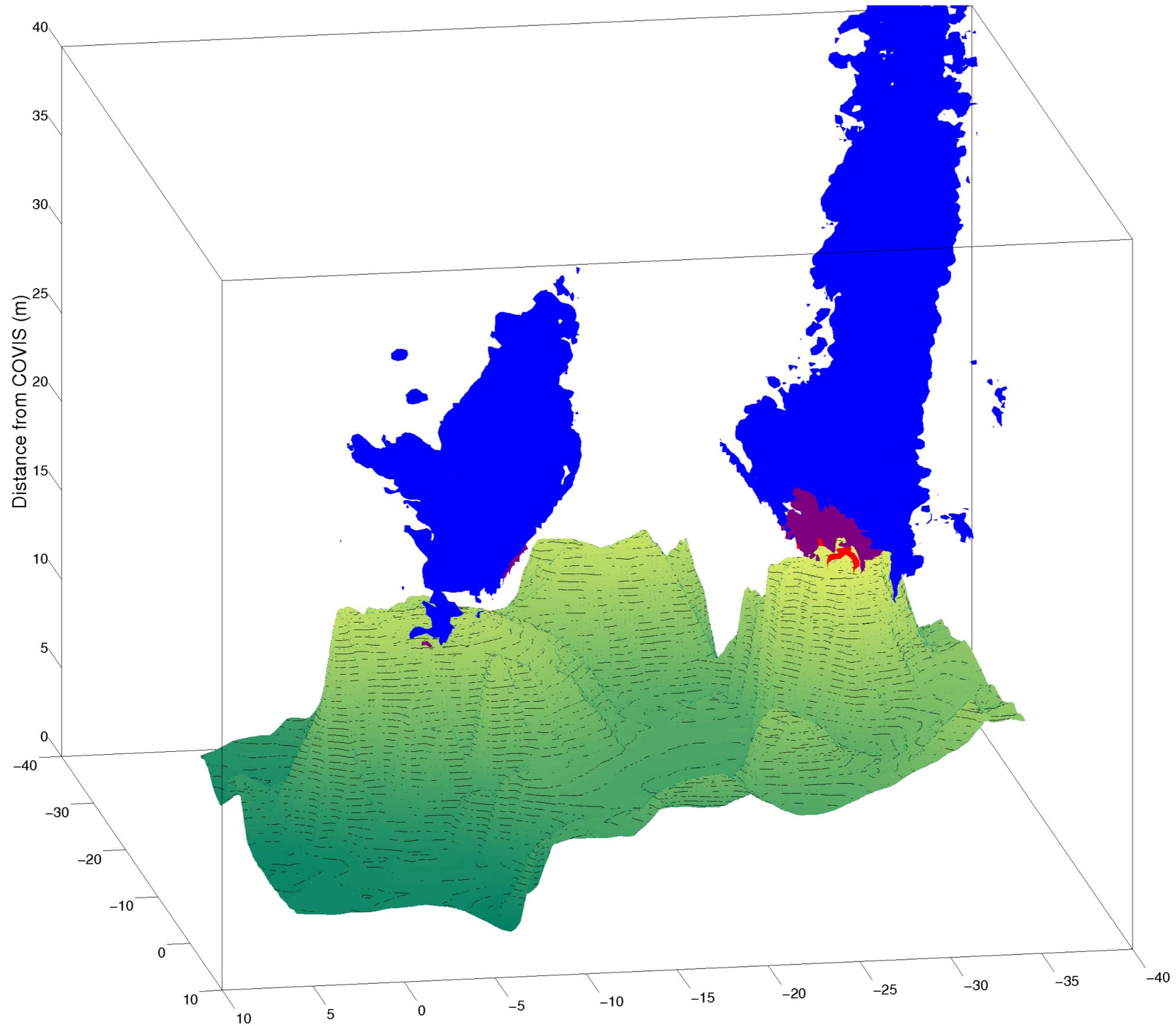


**Mooring base and 650kg anchor  
weight on seafloor (2154m)**

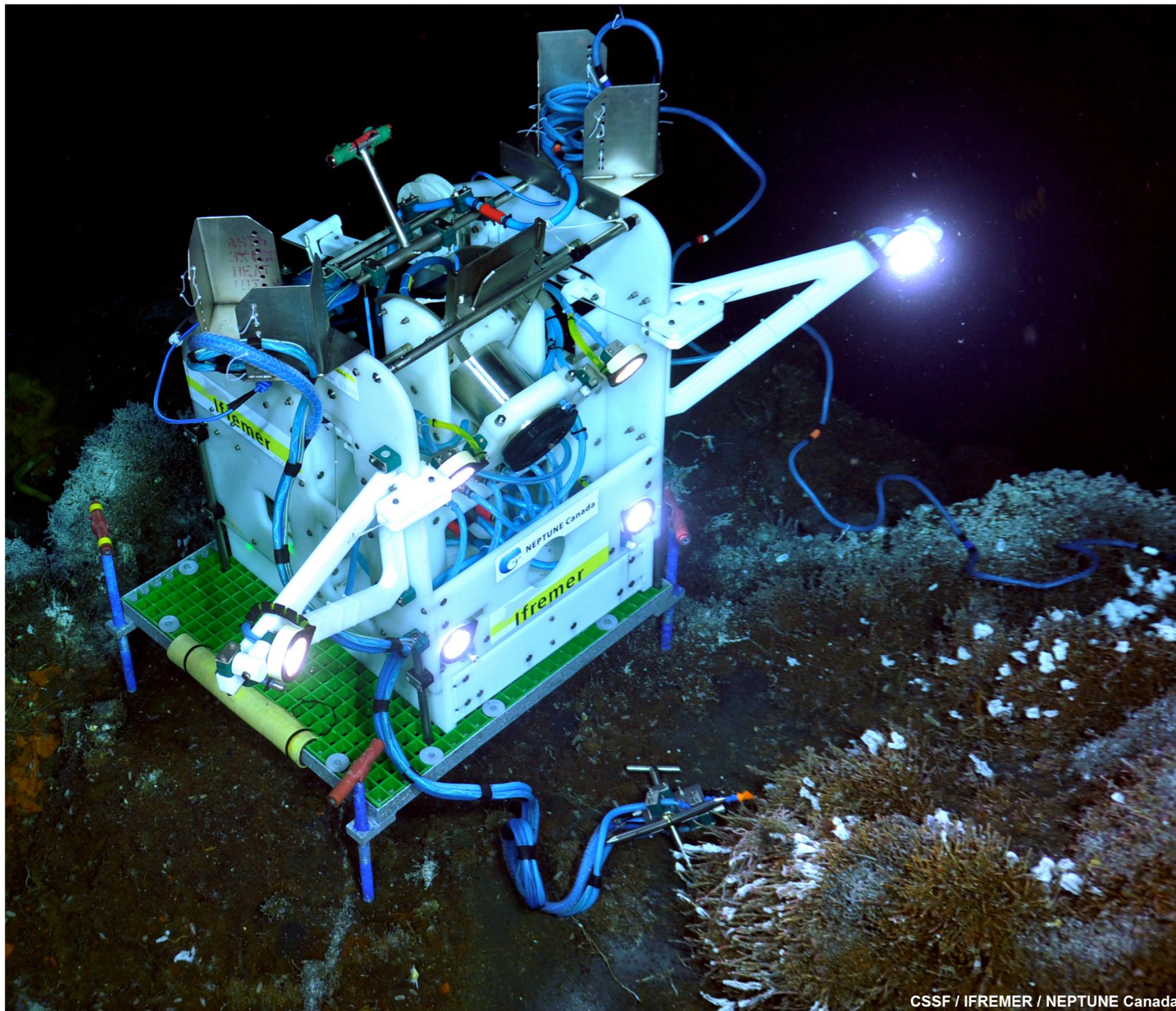
# Plume imaging sonar



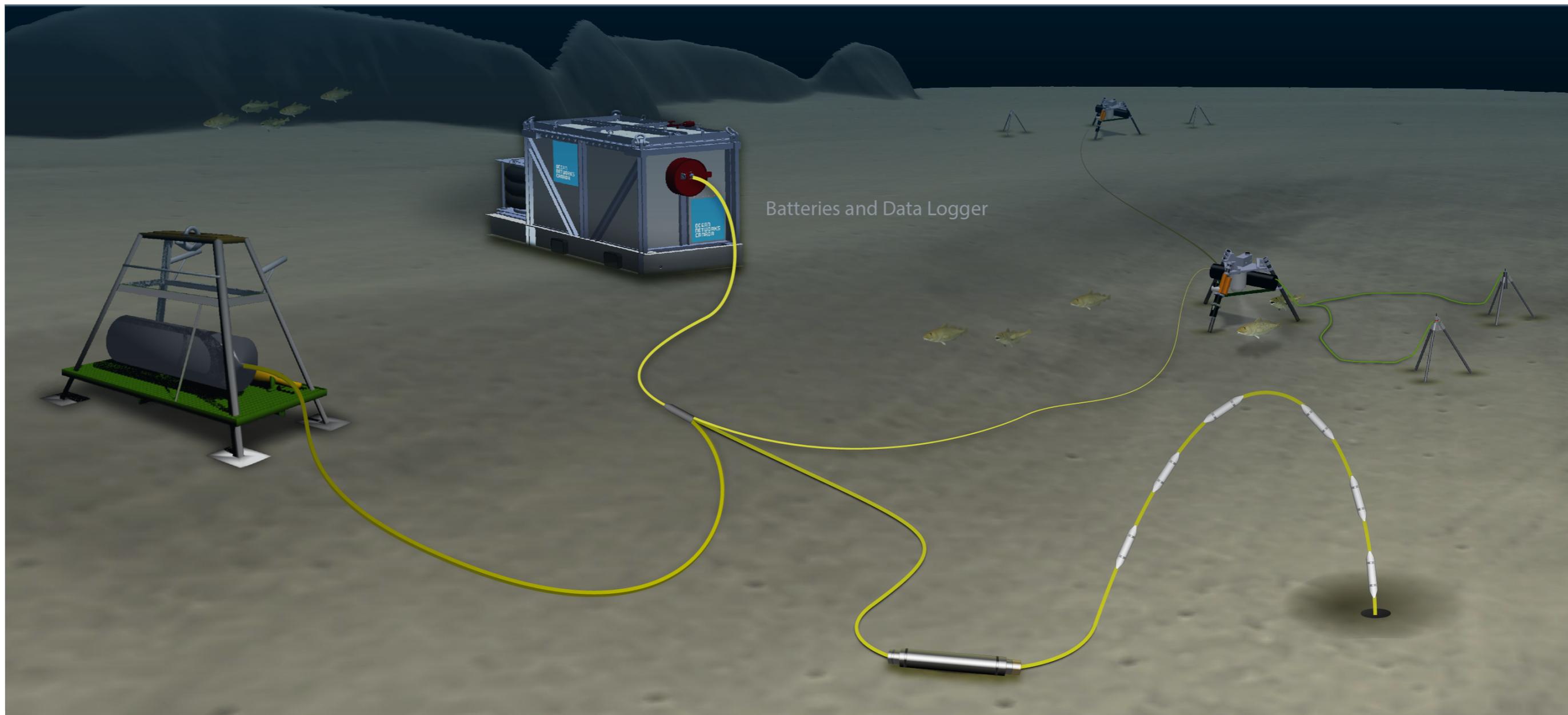
# Plume sonar - hourly images



# Cameras for monitoring recolonization



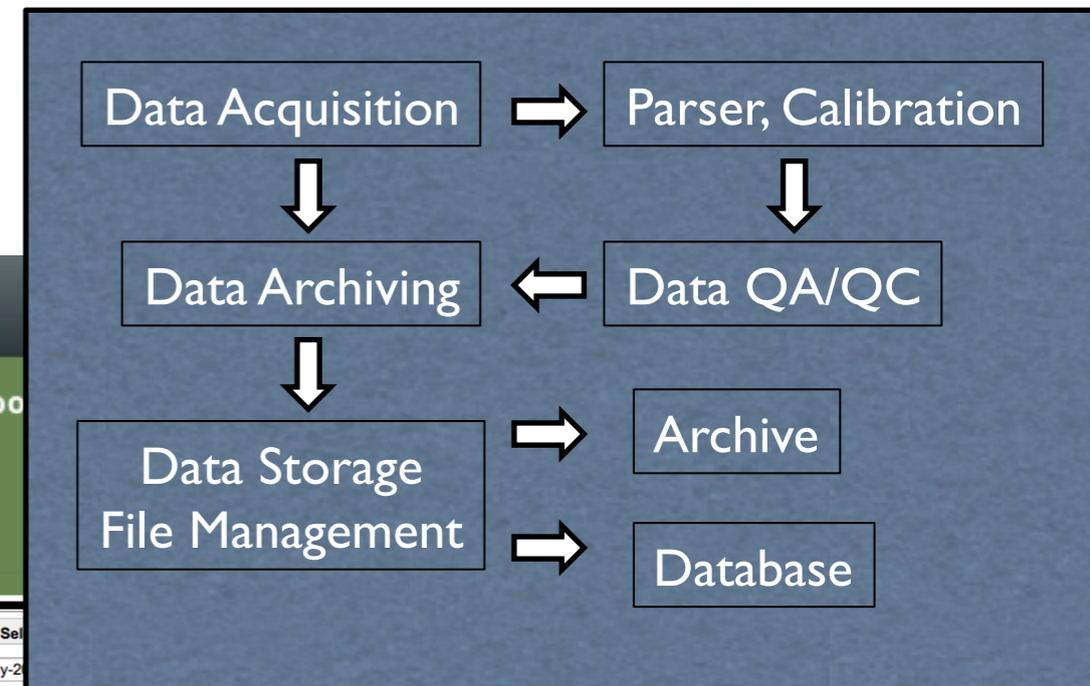
# Autonomous cabled observatory



Portable system for continuous monitoring  
ROV recharges battery pack and downloads data

# Data Access from Real-Time Observatories

- all sensor data and imagery archived
- online graphical previews of scalar data
- online viewing of video
- downloads of all data



The screenshot shows the 'Seatube' video player interface. It features a video player window displaying underwater footage of a vertical tube structure. To the left is a list of video entries with their respective dates and times. Below the video player is a table with columns for Start Date (UTC), End Date (UTC), Comment, Img, Latitude, Longitude, Depth, and Origin. The table contains several rows of data, including entries for 'VPS in sight' and 'DSC: Please add comment'.

The screenshot shows the 'Plotting utility' interface. It includes a 'Time Period Selection' section with 'Date From (UTC): 09-May-2013 21:00:00' and 'Date To (UTC): 13-Feb-2014 21:00:00'. Below this is a 'Location' tree view showing a hierarchy of locations and sensors, such as 'Barkley Canyon', 'BC Axis POD1', 'BC Hydrates', 'BC MidEast POD4', 'BC MidWest POD3', 'BC Upper Slope', 'ADCP 75 kHz', 'BPR', and 'CTD'. The 'CTD' sensor is expanded to show 'Conductivity', 'Density', 'Practical Salinity', 'Pressure', 'SigmaT', and 'Temperature'. Two plots are displayed: 'Plot 1' shows 'Oxygen Concentration Corrected' in ml/l over time, and 'Plot 2' shows 'Temperature' in degrees Celsius over time. Both plots have x-axis labels for 1 Jul 2013, 1 Oct 2013, and 1 Jan 2014. The plots include interactive elements like 'Hints', 'Options', and 'Download Data' links.

Plotting utility

# Observatory monitoring versus shipboard surveys and sampling

Issue	Approach	
	Observatory Experimentation	Surveys and Sampling
% Habitat destruction		X
Plume dispersal	X	
Uniqueness of gene pool		X
Resilience/ recolonization	X	X
Geographic range		X

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