Towards a global census of deep-sea biodiversity

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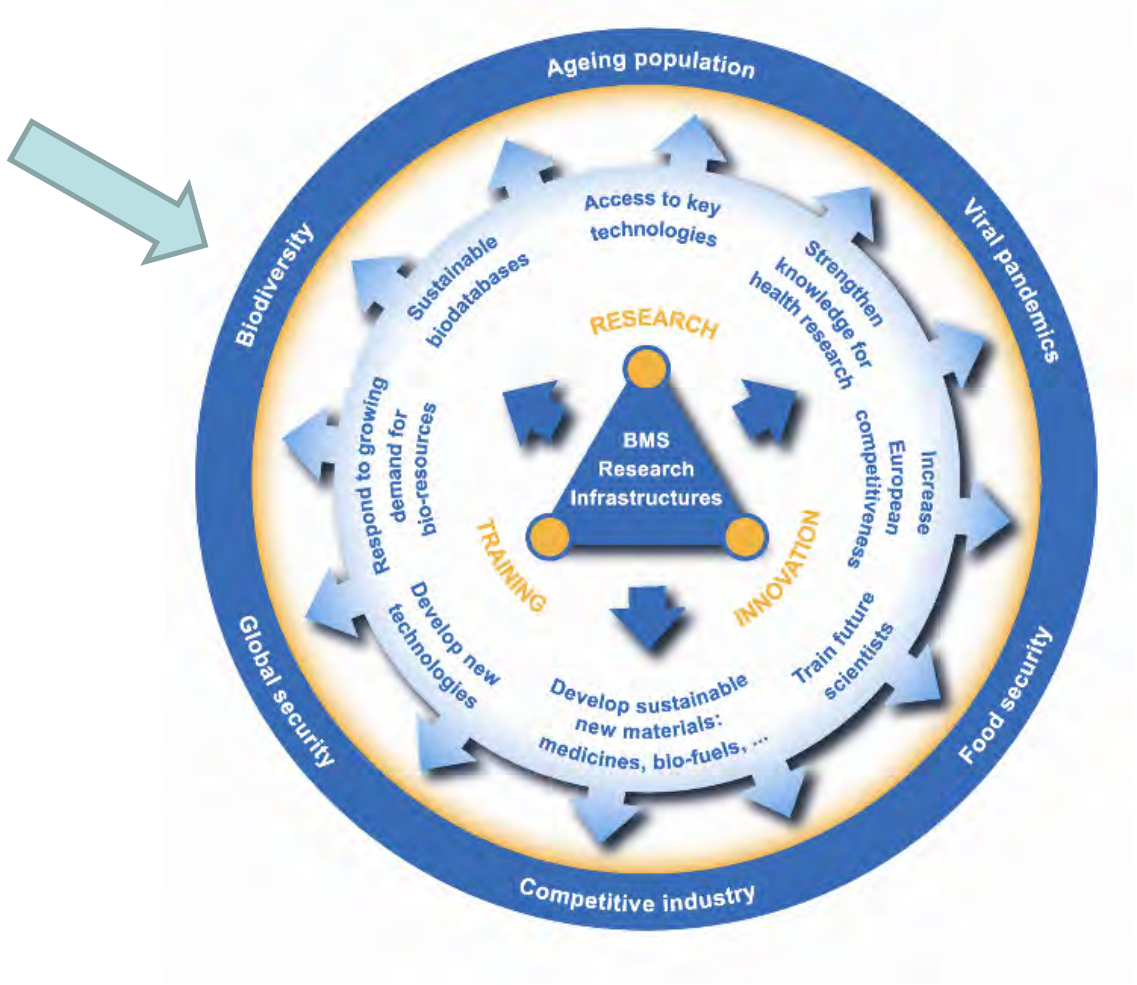
DEEP SEA

Huge Biodiversity – Big questions?

BIG QUESTIONS:Is the Deep ocean instrumental to Meet the Global European Grand Challenges?



Blue expectations

European dimension of the Blue Growth:
Jobs for 5,4 millions citizens
500 billions euros in 2010
600 billions euros in 2020
(and 7 millions jobs)

ECORYS Deltares OCEANIC DEVELOPPEMENT

Blue Growth

Scenarios and drivers for Sustainable Growth from the Oceans, Seas and Coasts

Third Interim Report

Call for tenders No. MARE/2010/01

Client: European Commission, DG MARE

Rotterdam/Brussels, 13 March 2012

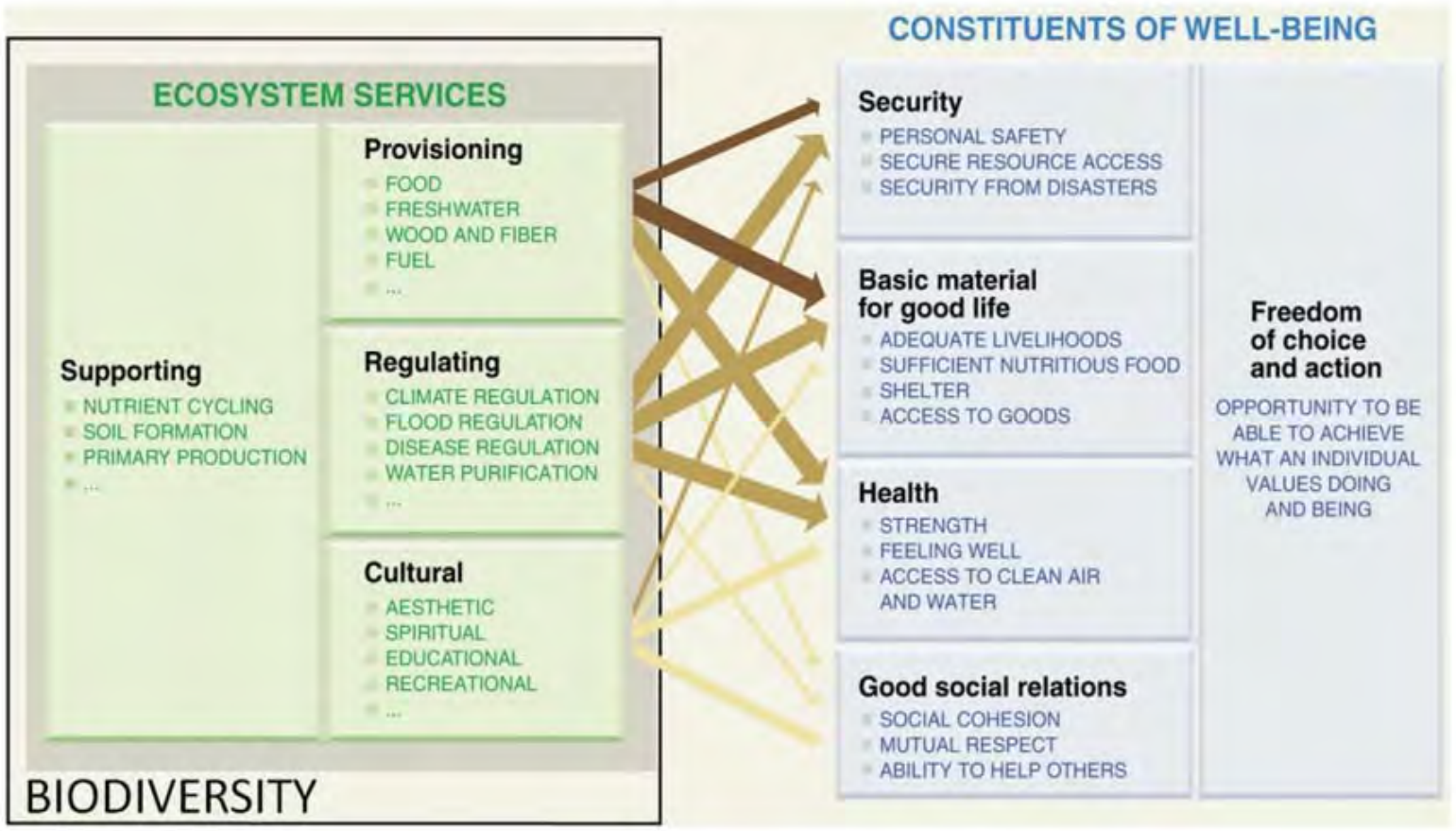
United Nations Decade of Ocean Science for Sustainable Development (2021-2030)

The challenges for the next decade

Marine Biotechnology	• To identify new molecules produced by marine organisms of interest in the pharmaceutical, nutraceutical or industrial companies
Global changes	• To develop a global network of observatory integrating biological components to the environmental variables
Conservation	• To develop a network of protection for species and marine habitats able to support the achievements of the objectives of the Aichi targets and UN - SDG14
Marine Resources	• To develop new approaches and solutions for the sustainable use of marine biotic and abiotic resources

Who cares about biodiversity ?

(we do but apparently Society does not)



Mulder et al , 2015 Advances in Ecological Research

The deep sea, a big player for essential ecosystem goods and services

Knowledge:
good (blue)
some (green)
little (yellow);
none (grey)
irrelevant (white)

Value:
present (+);
not present (0);
unknown (?);
monetarily known (€)

Armstrong et al., 2012

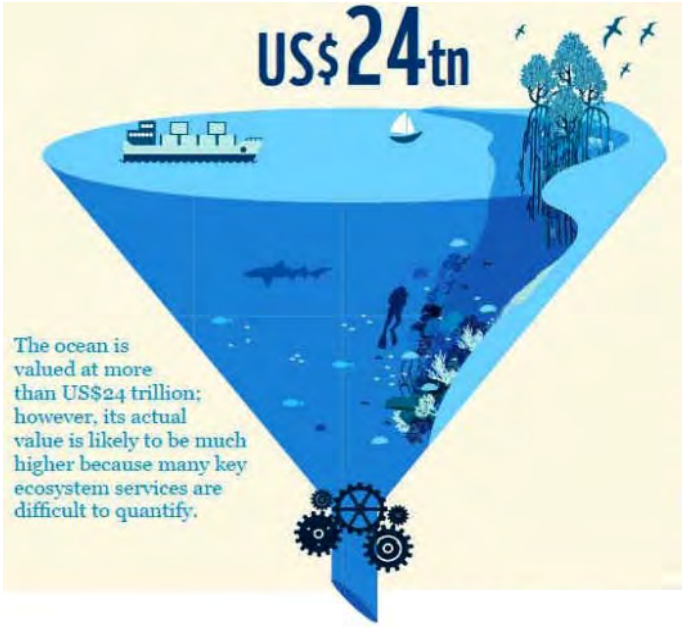
ECOSYSTEMS AND HABITATS	COLD-WATER CORALS	OPEN SLOPES AND BASINS	CANYONS	SEAMOUNTS	CHEMOSYNTHETIC ECOSYSTEMS	PELAGIC SYSTEMS	SUB-SEABED
Provisioning services							
Carbon capture and storage						+	€
Finfish, shellfish, mammals	+	+	+	+	+	€	
Oil, gas, minerals	?	?		?	?		€
Chemical compounds	+	?	?	?	+	?	?
Waste disposal sites		+	+				+
Regulating services							
Gas and climate regulation		+	+		+	+	+
Waste adsorption and detoxification zones		+	+			+	
Biological regulation	?	+	?	?	+	+	
Supporting services							
Nutrient cycling	?	+	?	?	+	+	
Habitat	+	+	+	+	+	+	
Resilience	?	?	?	?	?	?	?
Primary productivity	?	?	?	?	+	+	
Biodiversity	+	+	+	+	+	+	?
Water circulation and Exchange		+	+	?		+	
Cultural services							
Educational	+	+	+	+	+	+	+
Scientific	+	+	+	+	+	+	+
Aesthetic	+	?	?	?	+	+	
Existence / Bequest	+	?	?	?	?	+	

The (economic) value of marine ecosystems

- Coastal ecosystems produce ca. 60% of the Planet ecosystem services values for the humans.

~21,000 billions $ per year (Costanza et al. 1997 Nature)

~ 49,700 billions $ per year, estimated in 2001 (Costanza et al. 2014 Glob Env Ch)



Not available yet for the deep sea but a conservative estimate could be an additional **~ 43,000 billions** $ per year

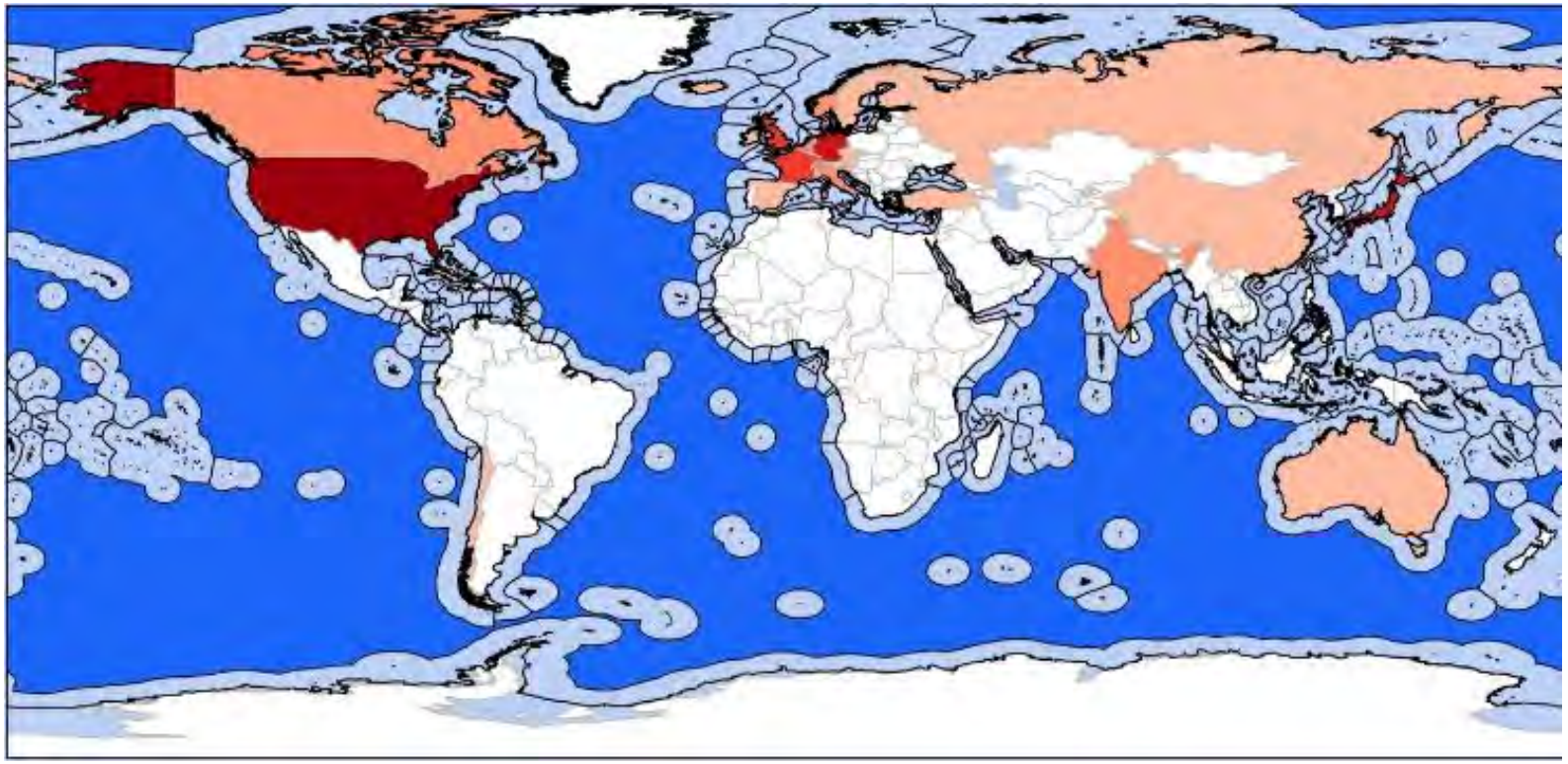
WHAT ABOUT THE INTANGIBLE VALUES?

DEEP SEA

How many Species?

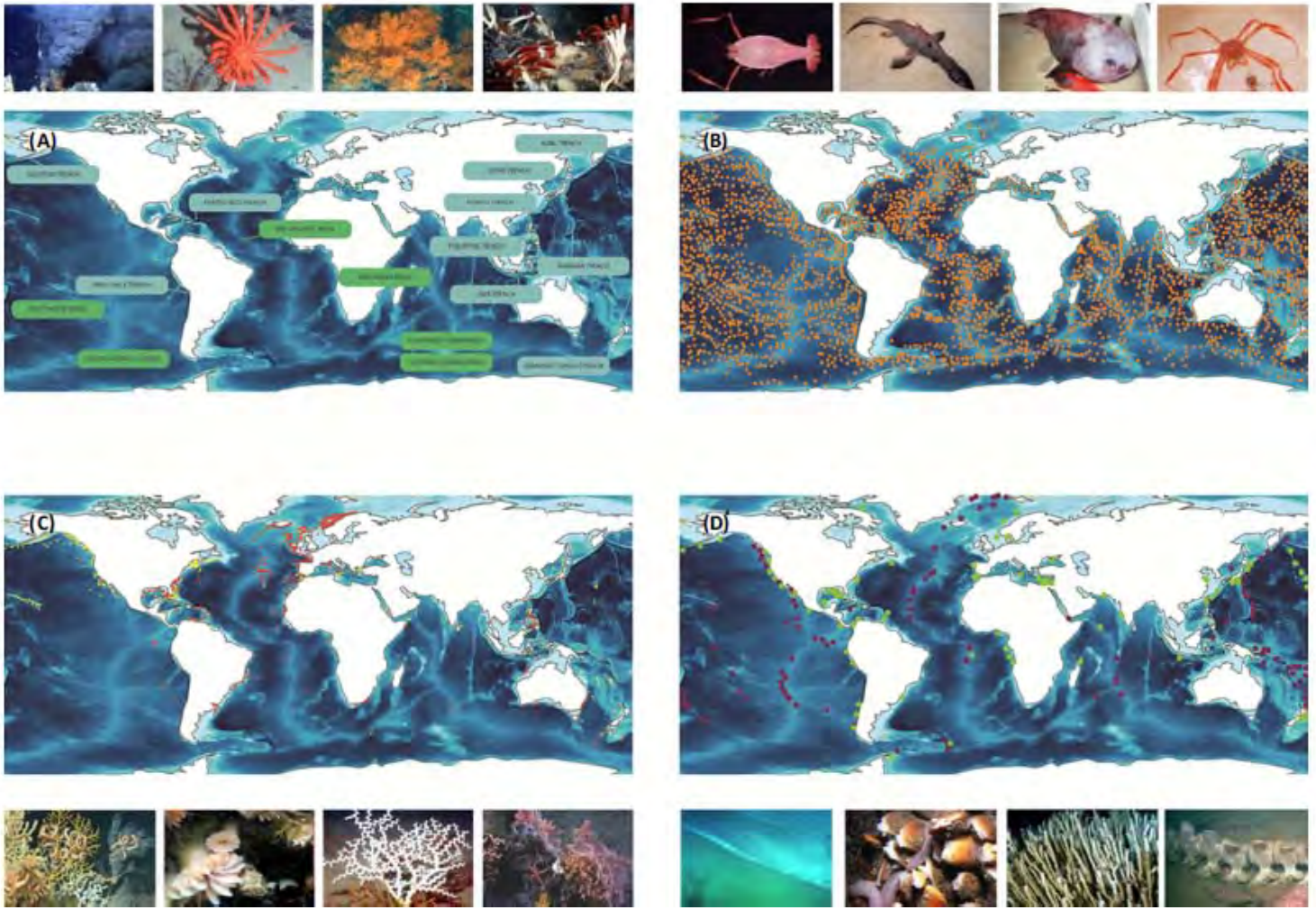
But even more complicated:
most of it is in Areas Beyond national jurisdiction

>50% of the surface of the Oceans



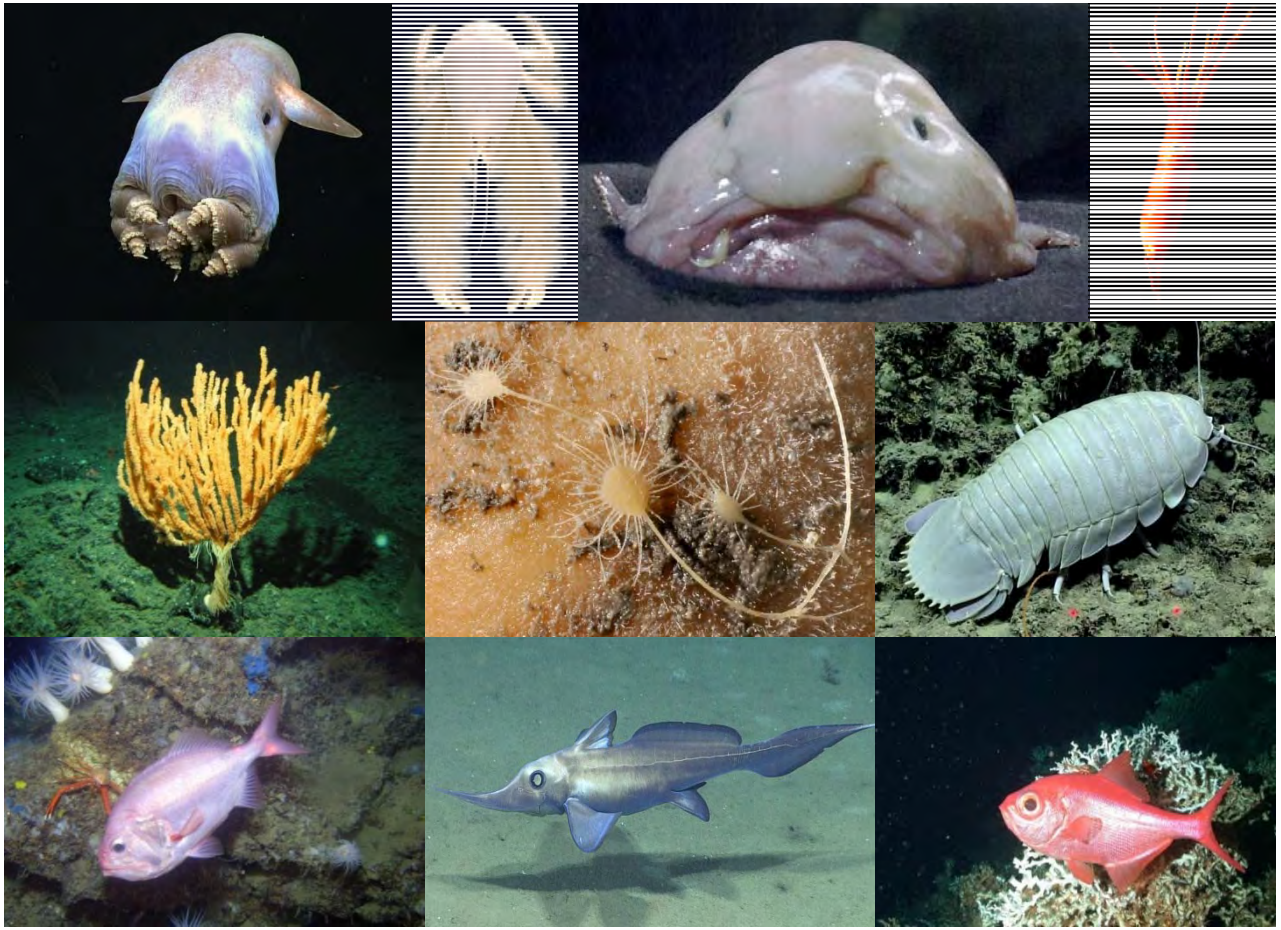
Oceans' future will be very conflictual for the "reclamation" of areas to exploitable deep-sea zones

A plethora of habitats

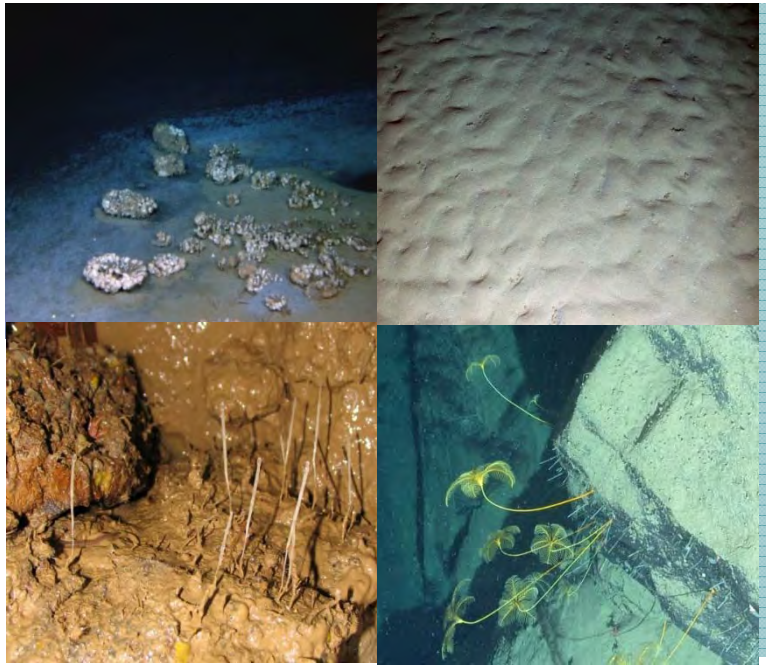


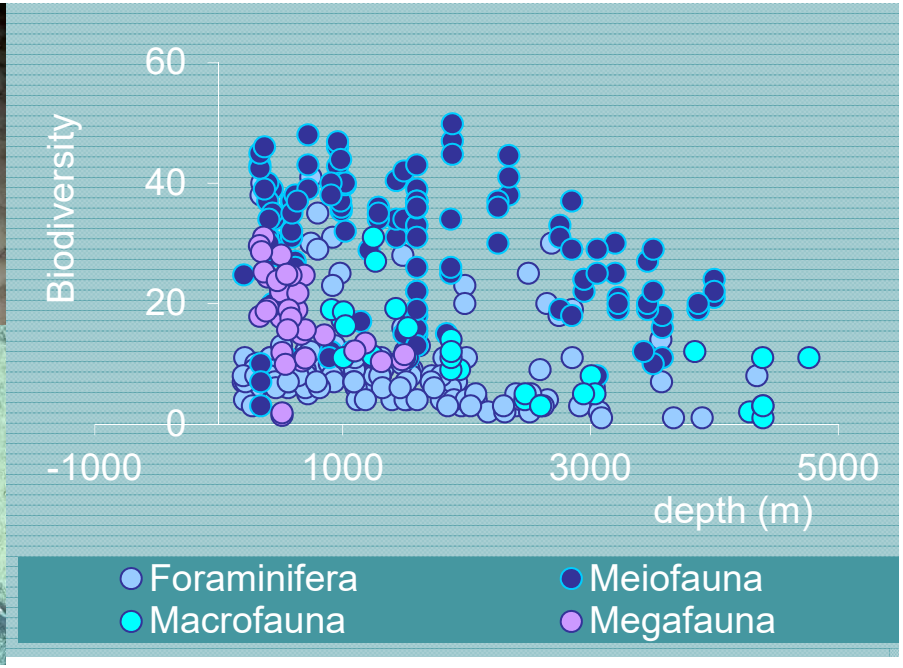
Danovaro et al. TREE 2014

And full of iconic species….



Deep sea: rich in biodiversity, highly heterogeneous and dynamic

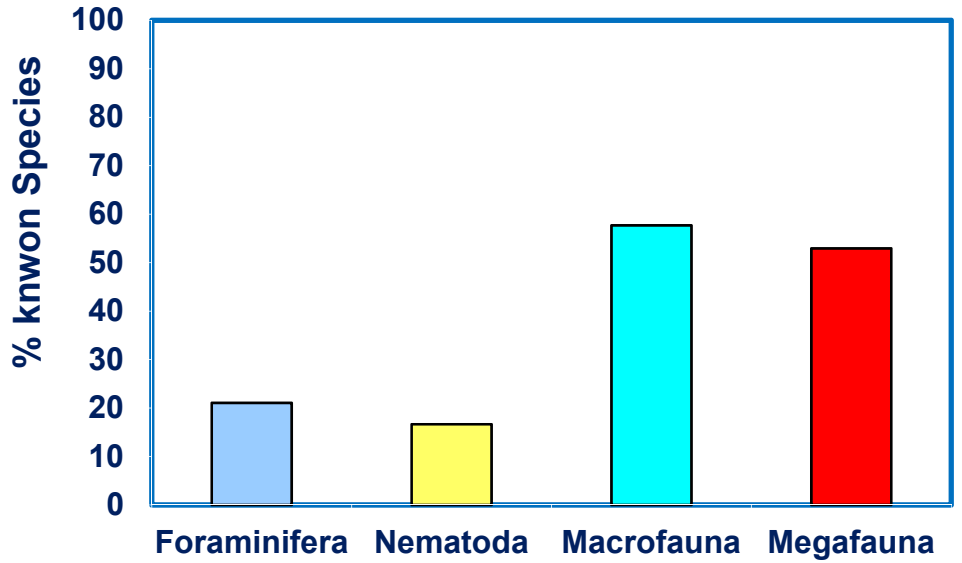




Danovaro, Company, Corinaldesi, D'Onghia, Galil, Gambi, Gooday, Lampadariou, Luna et al. 2010. Plos One

Largely undiscovered deep-sea biodiversity

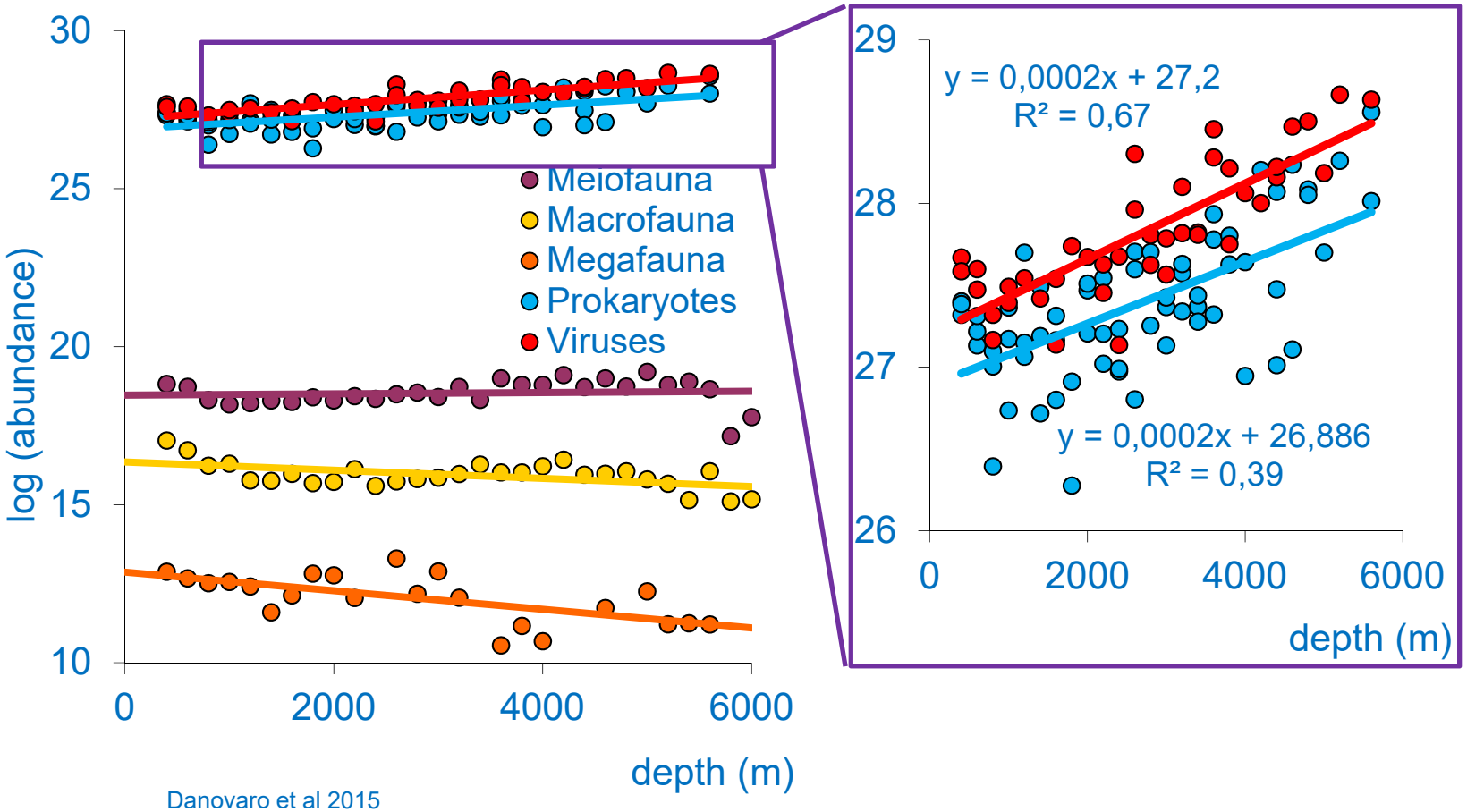
50-90% undiscovered yet



Macro and megafauna are known better (50-60%)
60-70% of the marine biodiversity is undiscovered
For some groups >90% of species is unknown

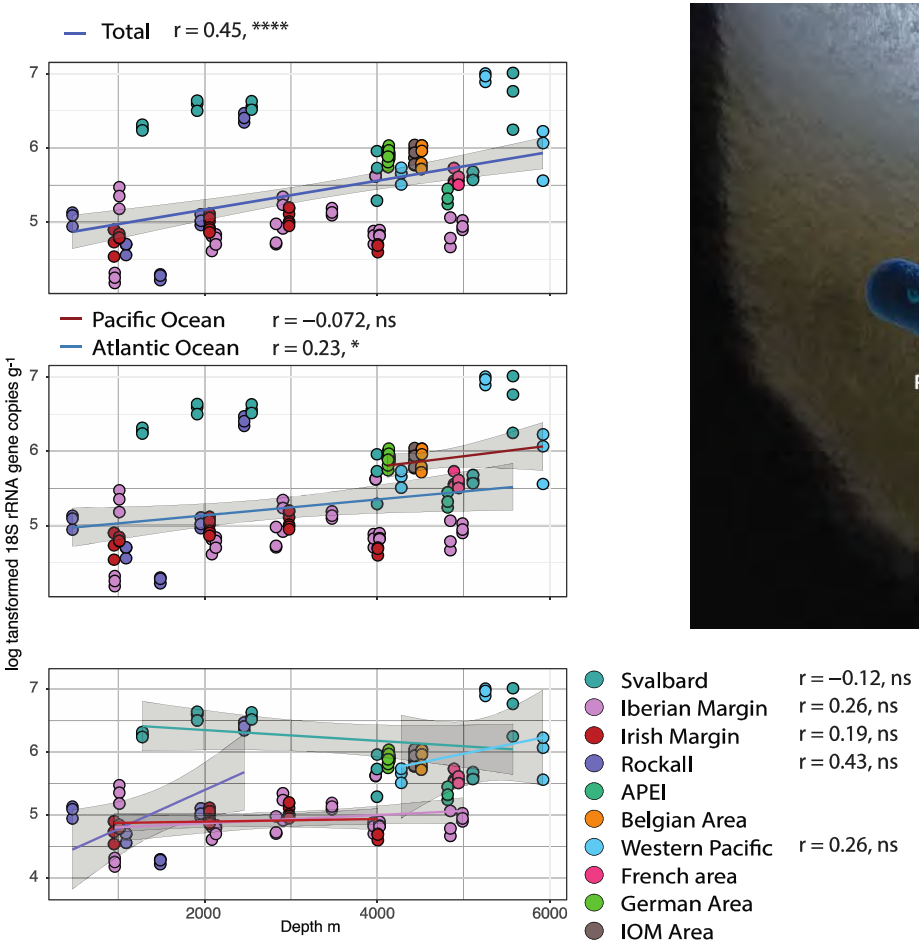
What is really big in the oceans?

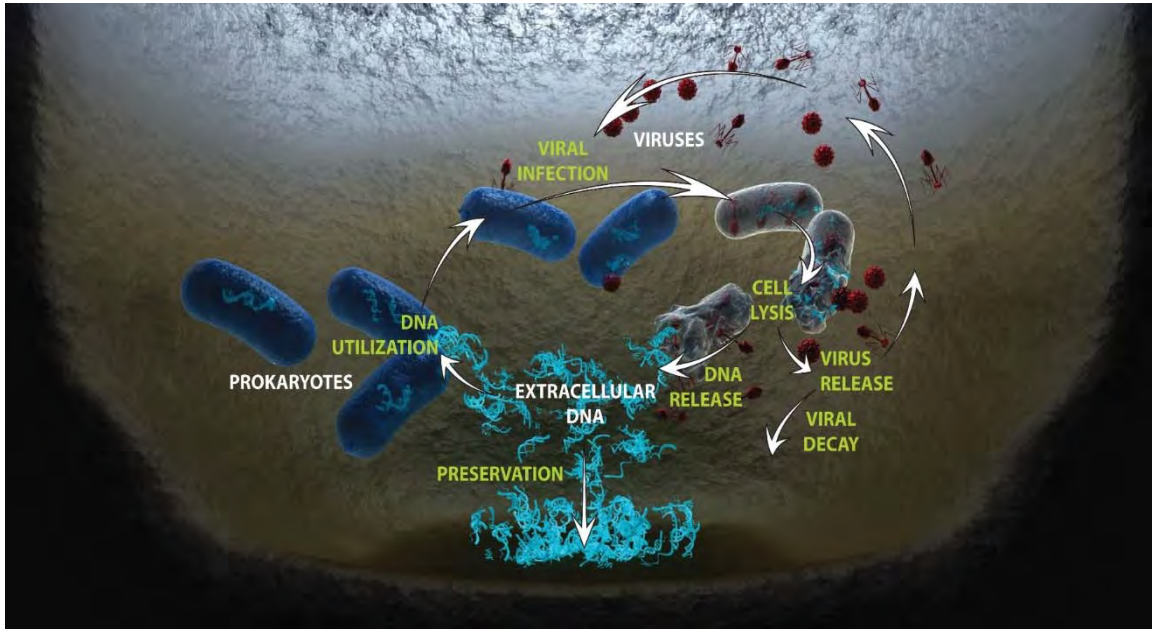
The relative importance of the different “life forms” in oceanic sediments



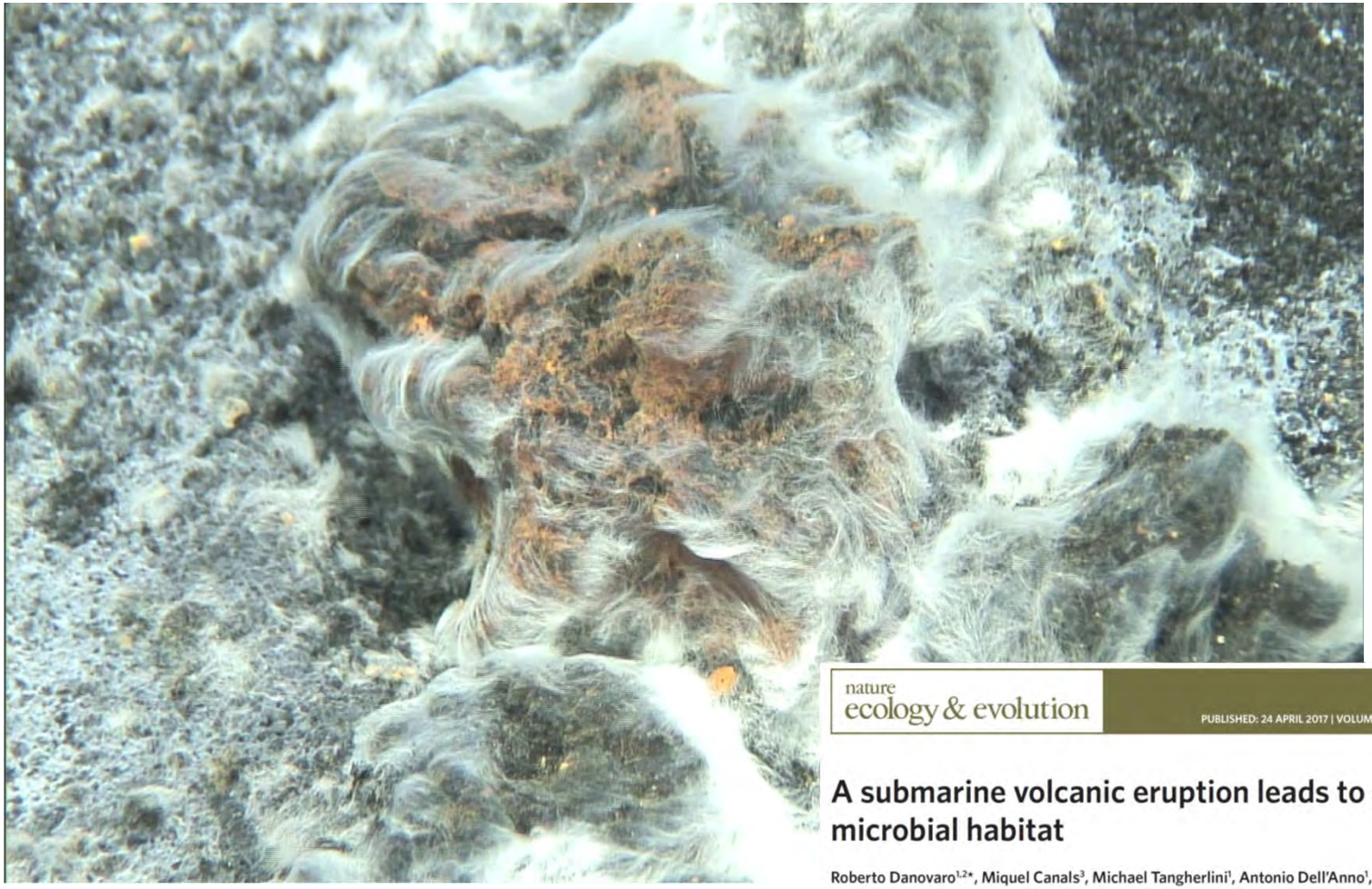
Danovaro et al 2015

Microbes, microbes everywhere





Volcanic eruptions and novel habitats



nature ecology & evolution

ARTICLES

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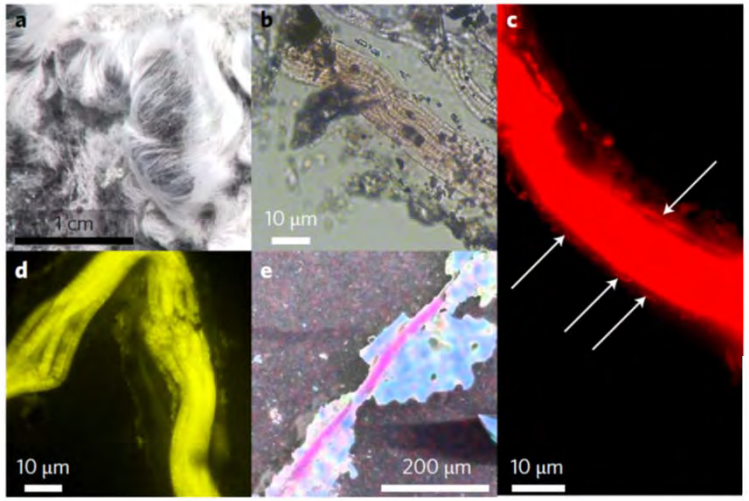
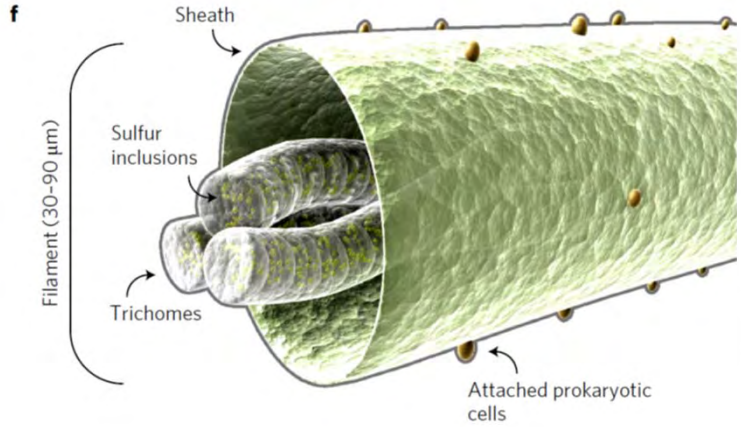
A submarine volcanic eruption leads to a novel microbial habitat

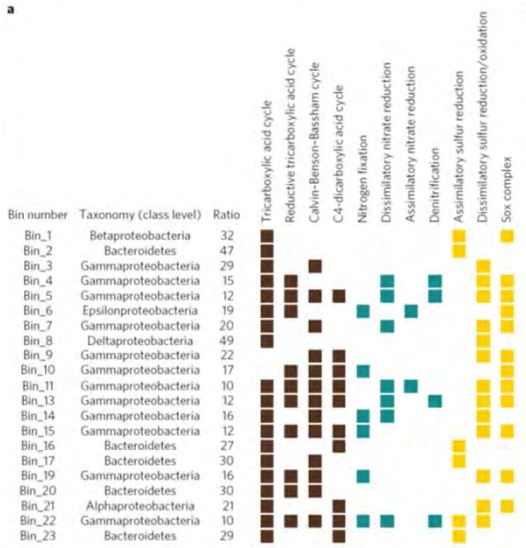
Roberto Danovaro[1,2*], Miquel Canals[3], Michael Tangherlini[1], Antonio Dell'Anno[1], Cristina Gambi[1], Galderic Lastras[3], David Amblas[3,4], Anna Sanchez-Vidal[3], Jaime Frigola[3], Antoni M. Calafat[3], Rut Pedrosa-Pàmies[3], Jesus Rivera[5], Xavier Rayo[3] and Cinzia Corinaldesi[6]

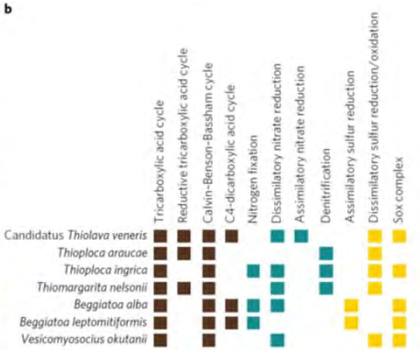
Volcanic eruptions and novel habitats



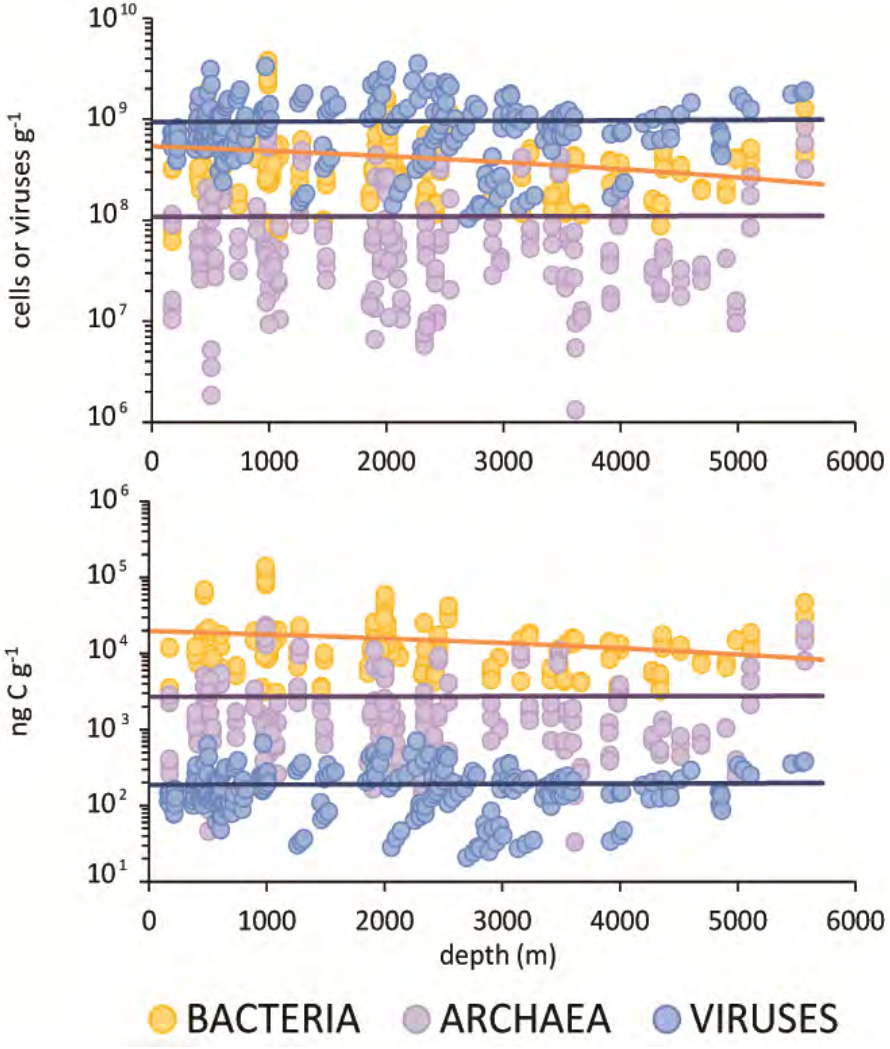
Venus's hair: after volcanic eruptions new genus and species of the order Thiotrichales, *Thiolava veneris*.

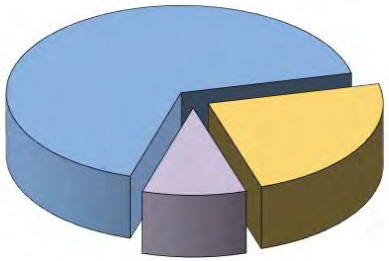


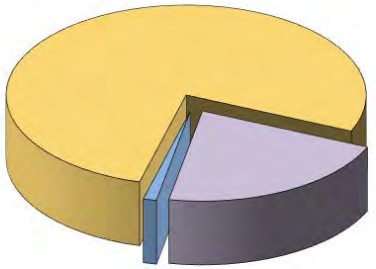




Benthic deep-sea bacteria, archaea, and viruses

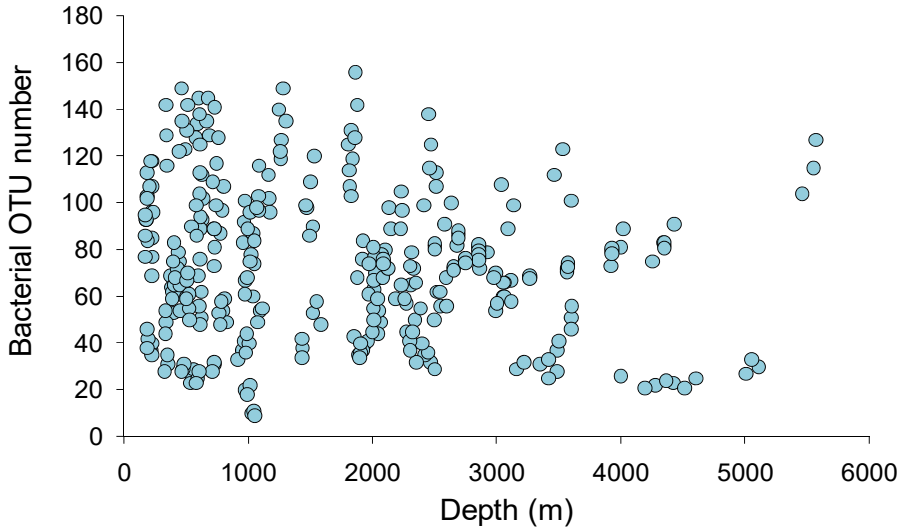




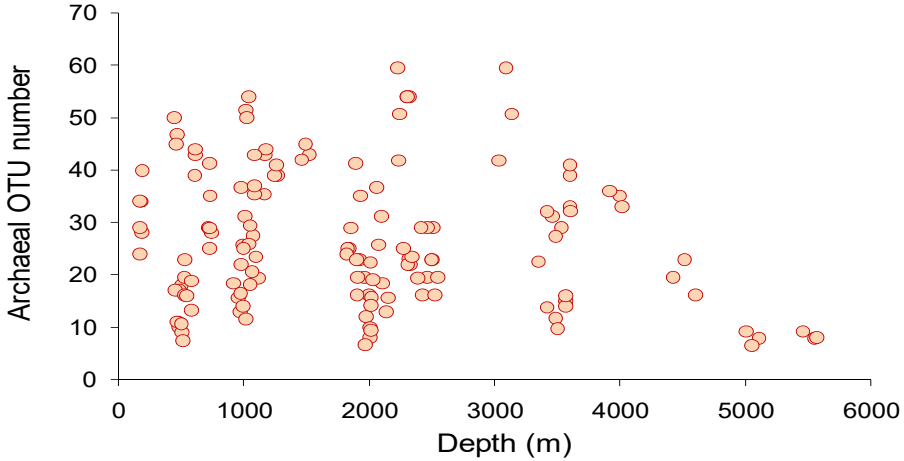


Danovaro et al. 2015 AME

Bacterial *vs* Archaeal diversity

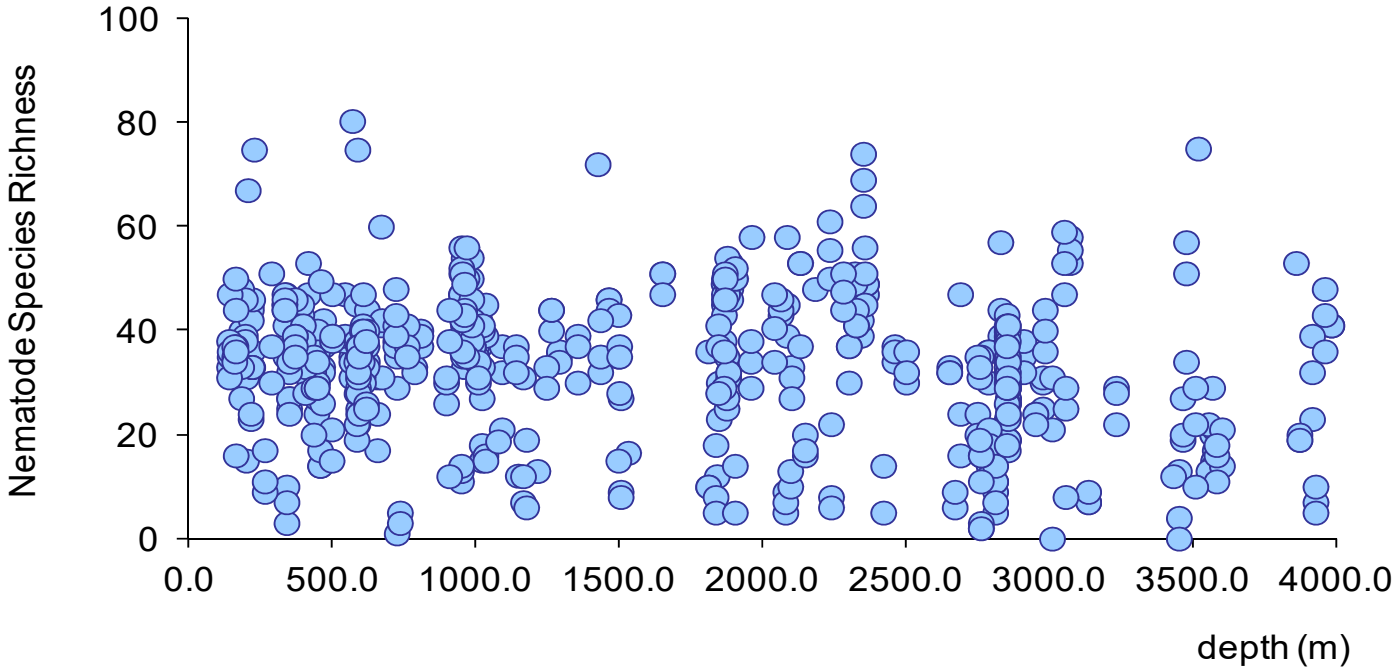


Bacteria are more diversified than Archaea



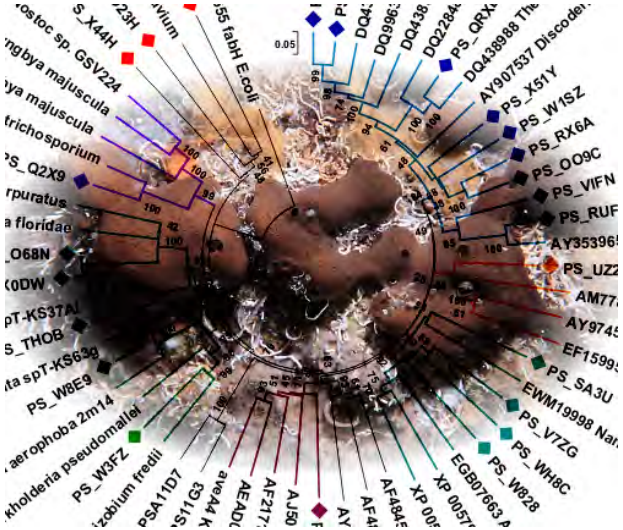
Lack of clear bathymetric patterns

High deep-sea nematode biodiversity at all depths



Metazoans (i.e., nematodes) display high diversity from the upper slopes to the deep basins

Microbiomes associated with deep-sea species



Associations between marine metazoans and microbes play fundamental roles in driving host functions, nutrition and health.

Studies conducted on the microbiomes of marine invertebrates (e.g., sponges and corals) for discovering bioactive compounds and understanding causative agents of disease.

Very limited information for the deep-sea species, which can represent a laboratory to study the relationships between microbiome and marine metazoans, and their adaptation to extreme conditions.

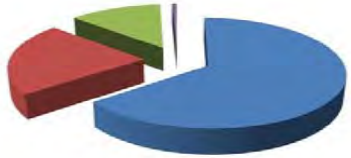
DEEP SEA

The linkage between Biodiversity and Ecosystem Functions

Global biomass: shallow vs deep

Slopes: 200-2000 m depth

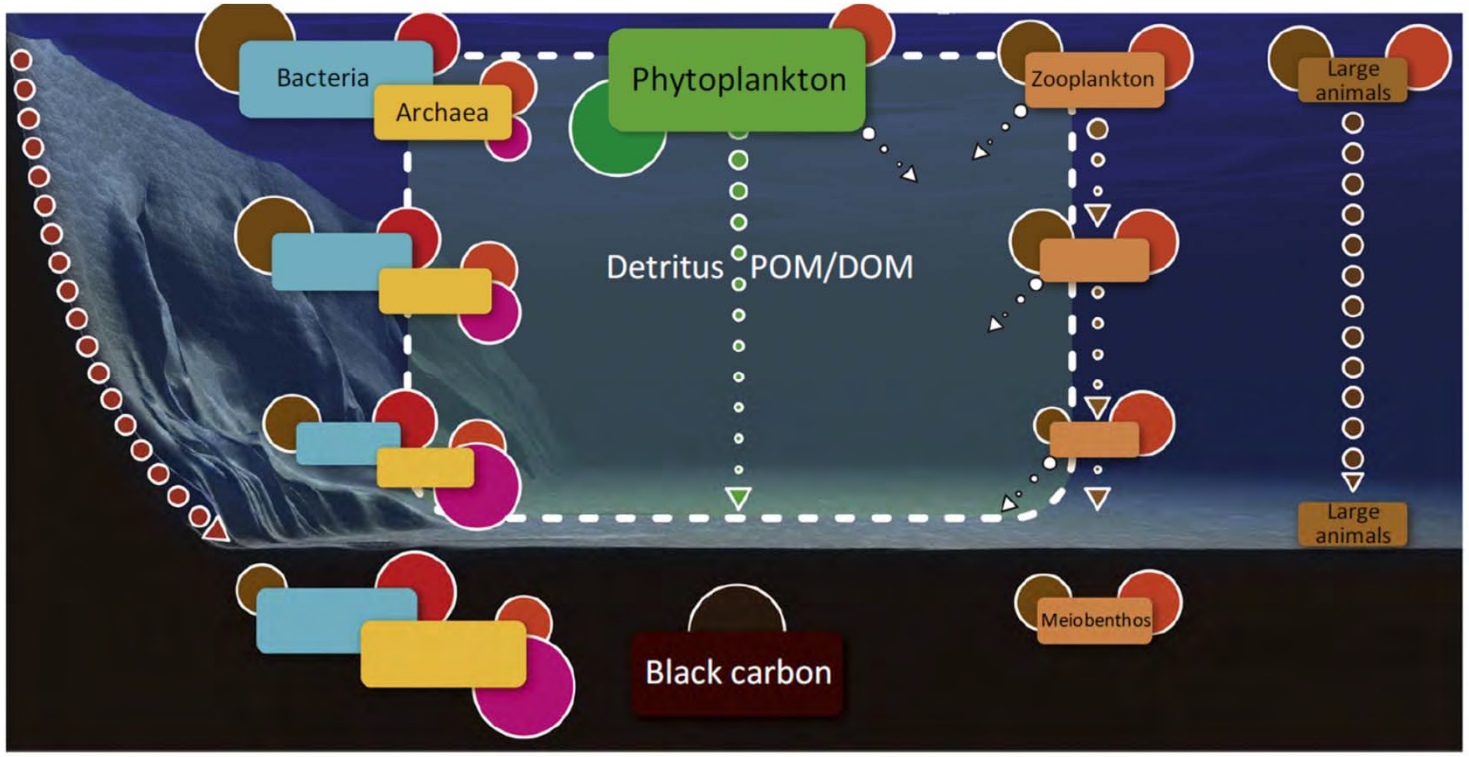
Bathyal sediments: 2000-4000 m depth



Abyssal sediments: 4000-6000 m depth

Global biomass
ca. 0.3 Pg C

Critical Supporting Functions



Stocks/biomasses

Bacteria
Phytoplankton
Archaea
Zooplankton
Large animals
Black carbon
Detritus POM/DOM
Detritus

Processes

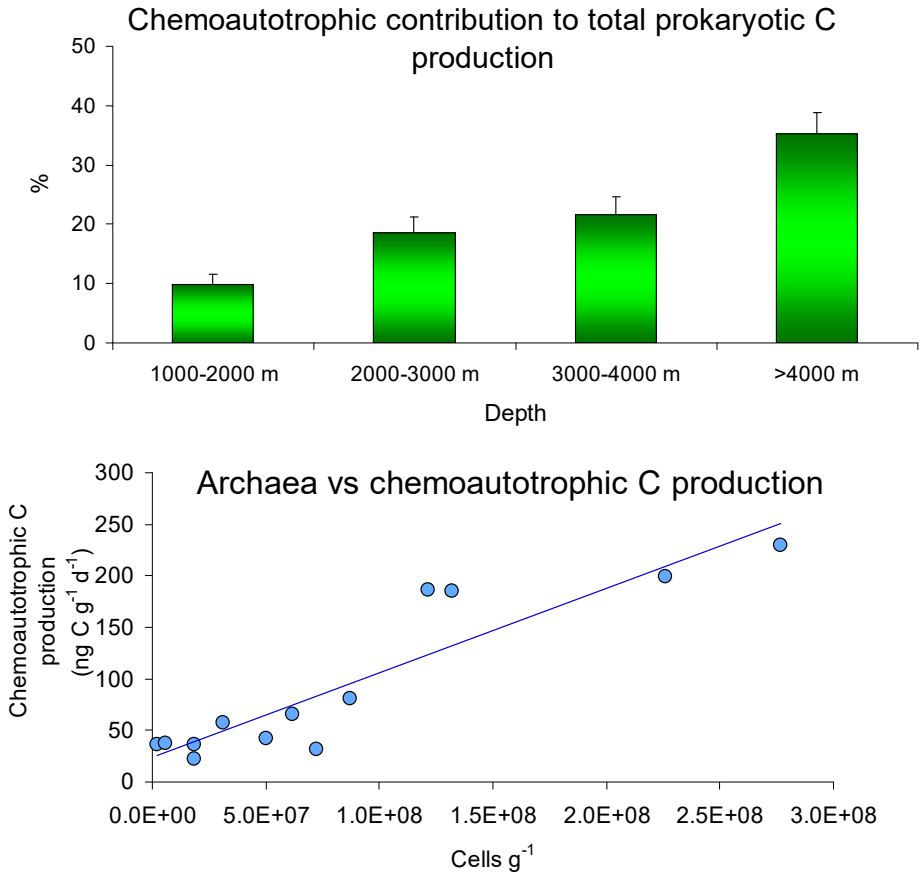
Chemiotrophy
Photosynthesis
Heterotrophy
Viral shunt
Viral shunt (not yet quantified)
Burial

Fluxes

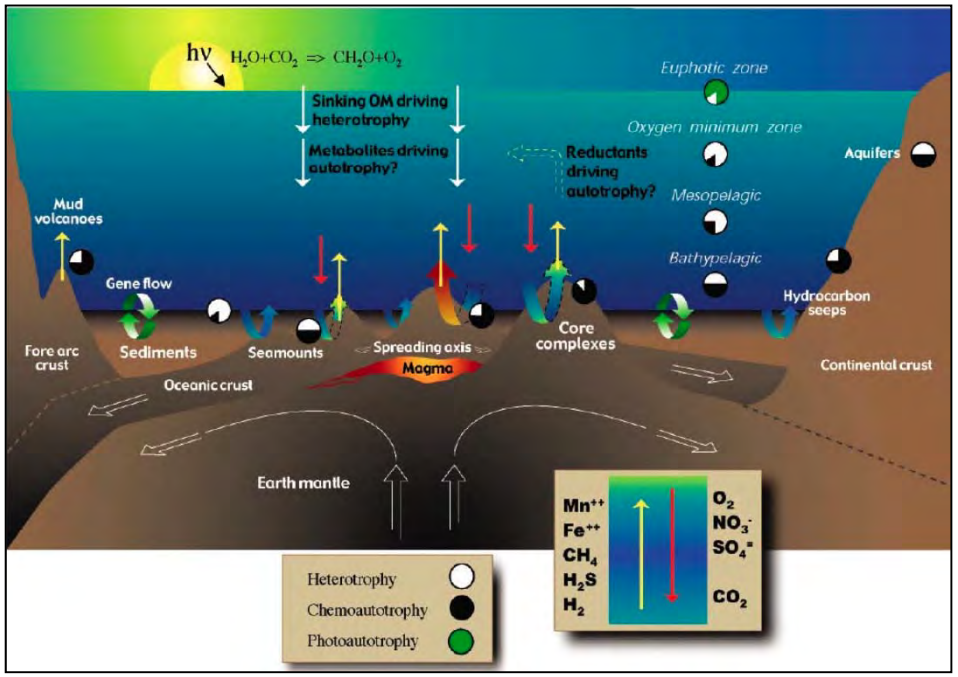
Loss to POM/DOM
Export

Danovaro, Snelgrove & Tyler TREE (2014)

“Dark energy” in the deep ocean



Molari, Manini, Dell’Anno 2013 Global Biogeoc. Cycles

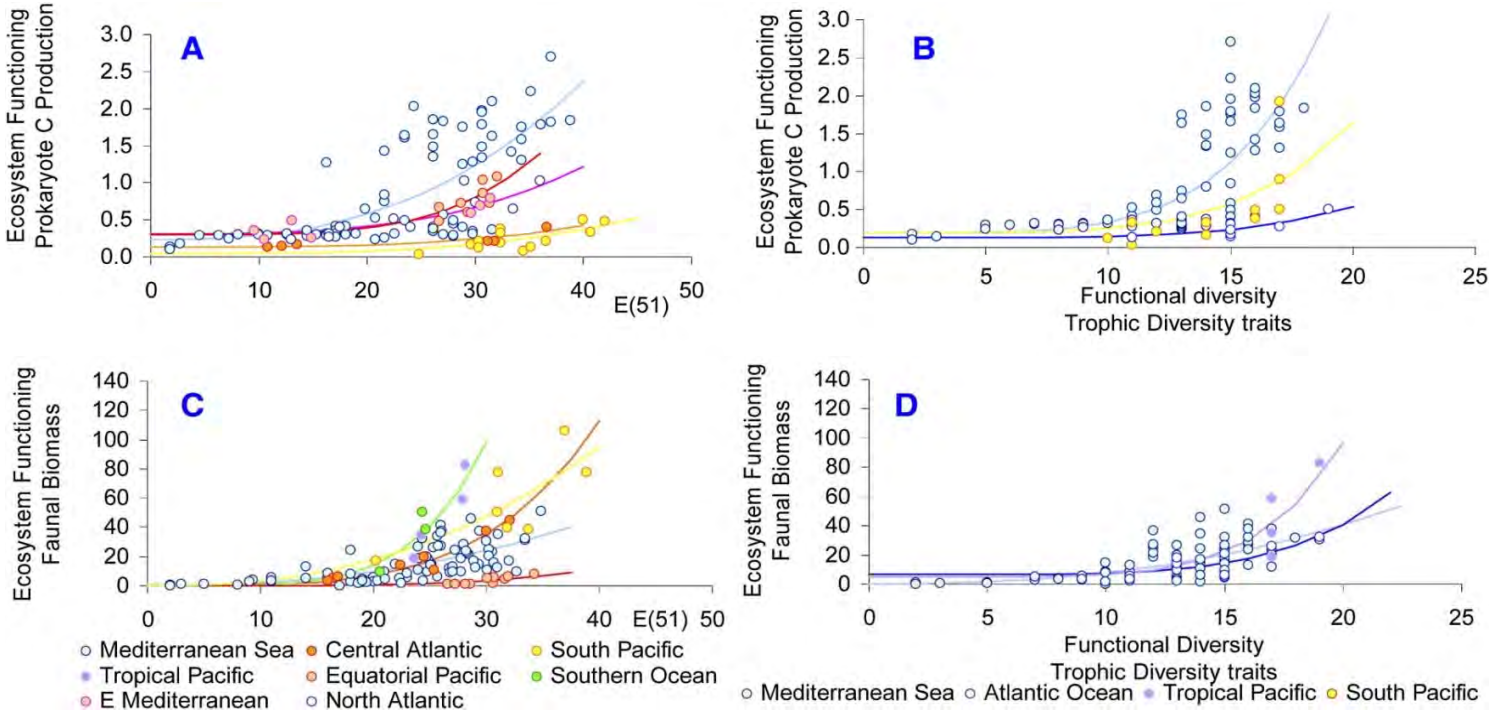


The amount of C produced by chemosynthetic processes is relevant also at abyssal depths

Chemoautotrophic production can account for up to 20-30% or more of total heterotrophic biomass production

Archaea are the key actors involved in inorganic C fixation in surface deep-sea sediments

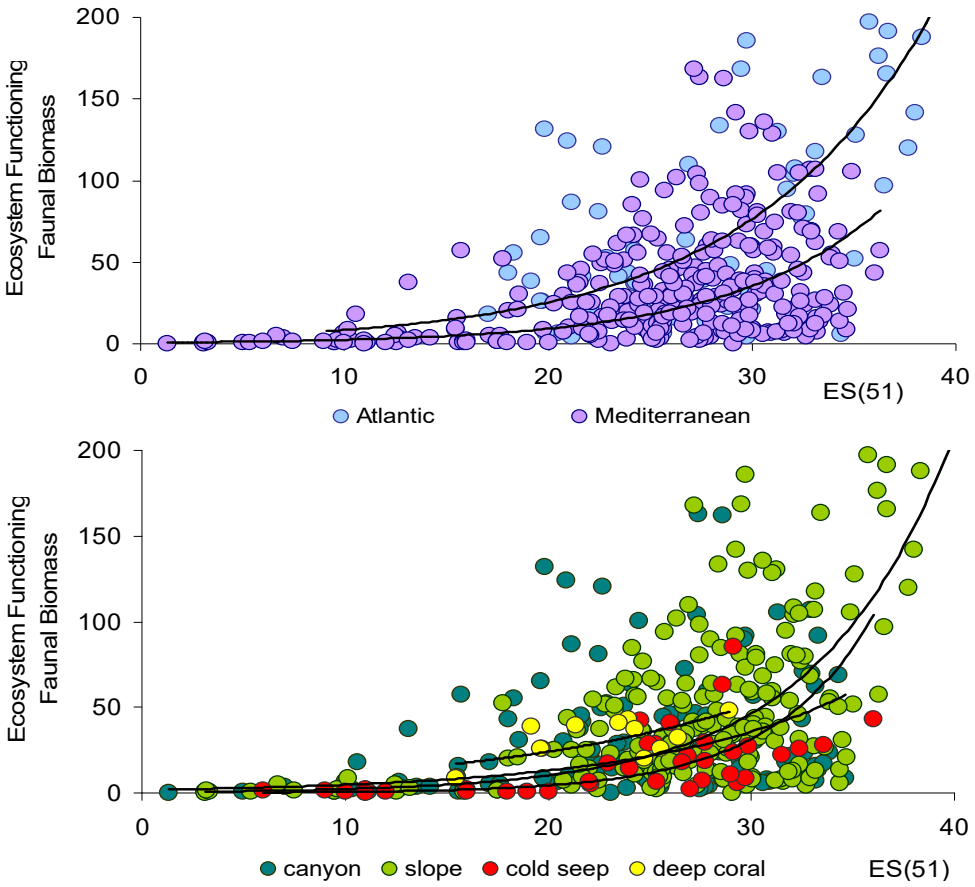
Is biodiversity relevant to ecosystem functioning (and thus to ecosystem services)?



Functioning of the largest ecosystem on Earth is **positively** and **exponentially** related to biodiversity (Danovaro et al. 2008)

These exponential relationships have been before only hypothesized to occur through a keystone mechanism (Naeem et al. 2002)

Exponential relationship between faunal diversity and ecosystem functioning



Exponential relationships are consistent in across regions and oceans **BUT** the Atlantic is more vulnerable to species loss than the Mediterranean

Exponential relationships are consistent in different habitats BUT the regression coefficients of BEF are different in canyons, open slopes, cold seeps and corals

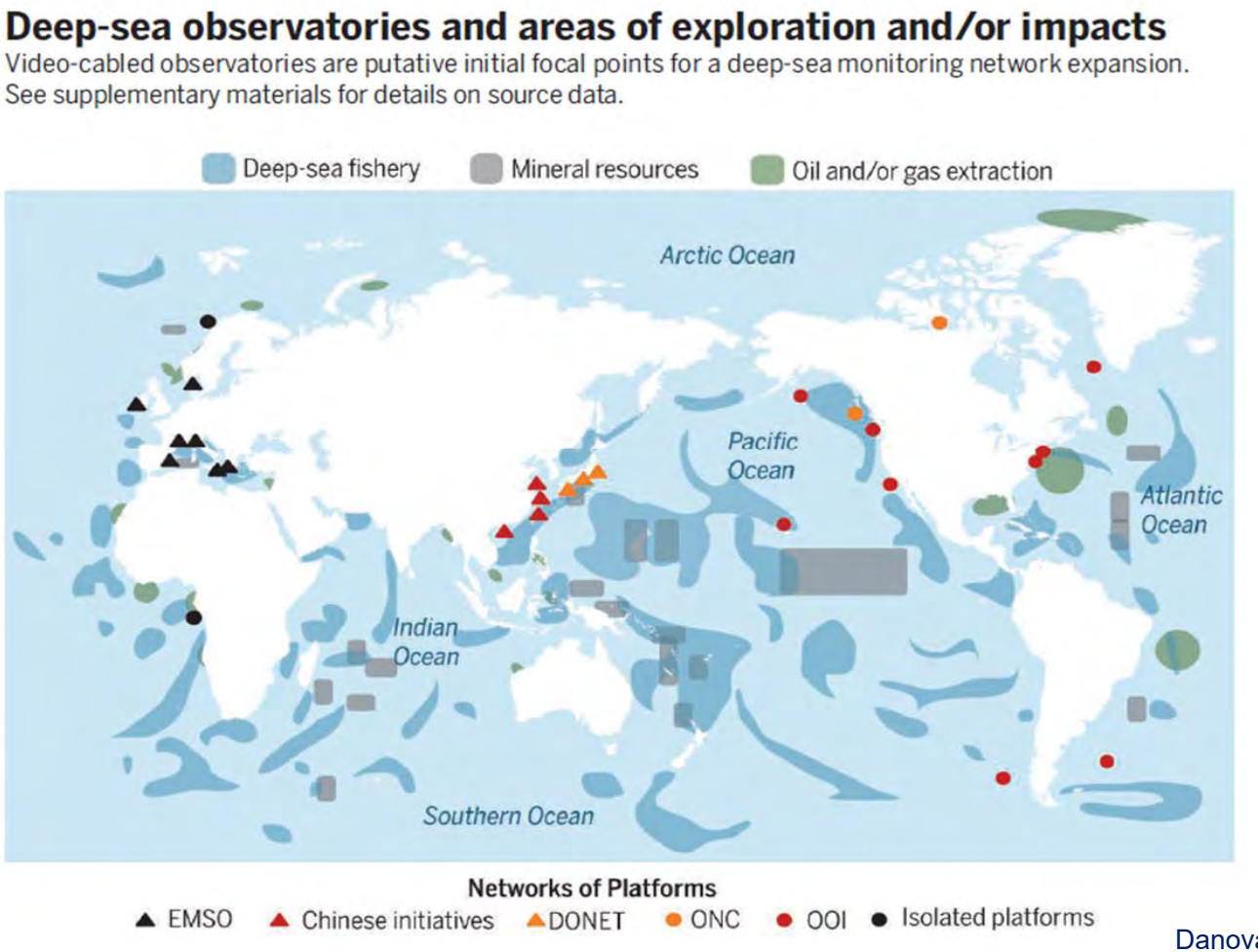
Deep corals are apparently the most vulnerable habitats to species loss

Danovaro et al., 2008 Curr Biol

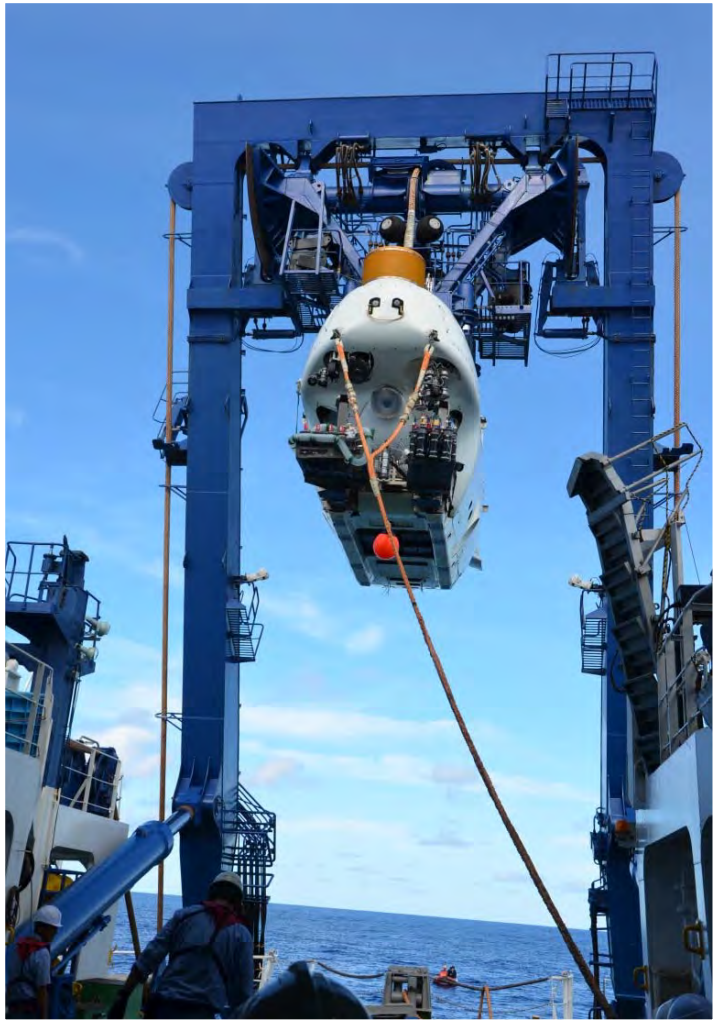
DEEP SEA

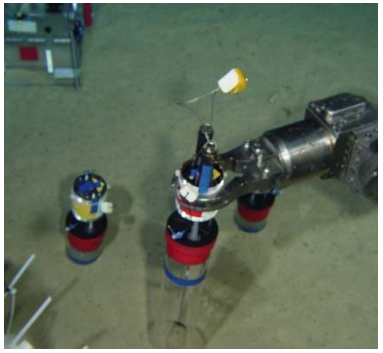
The Technological Bottleneck

Too wide, too extreme, we need better technologies BUT

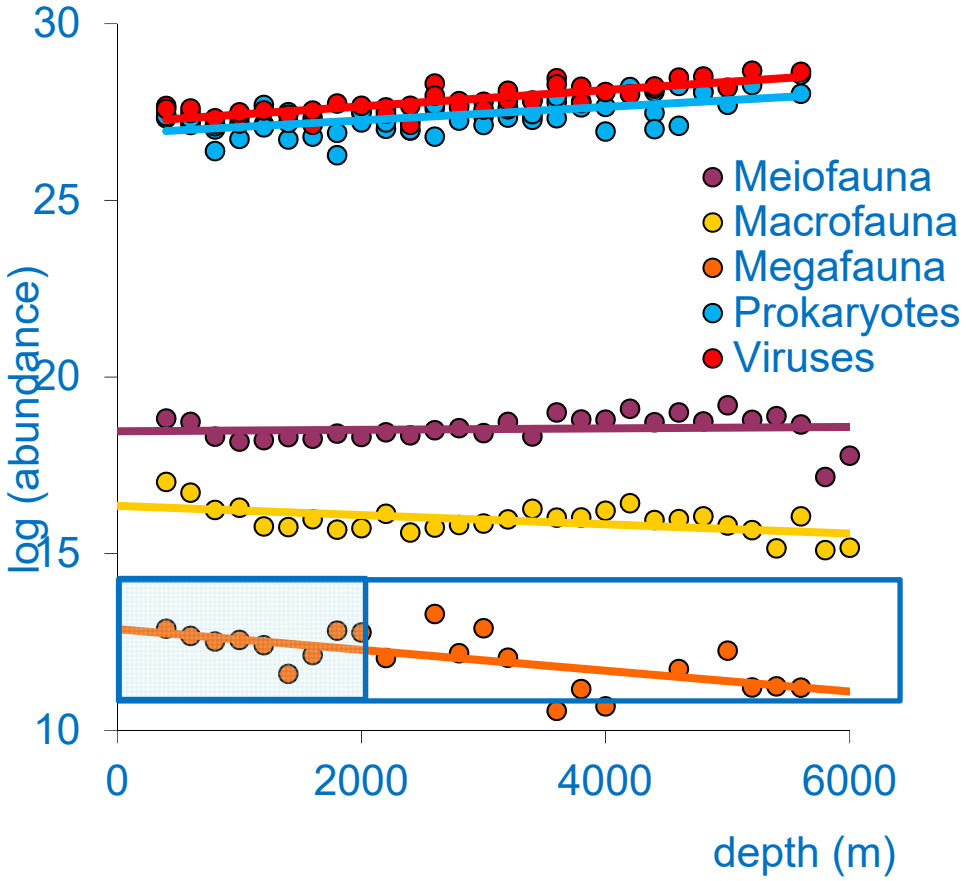


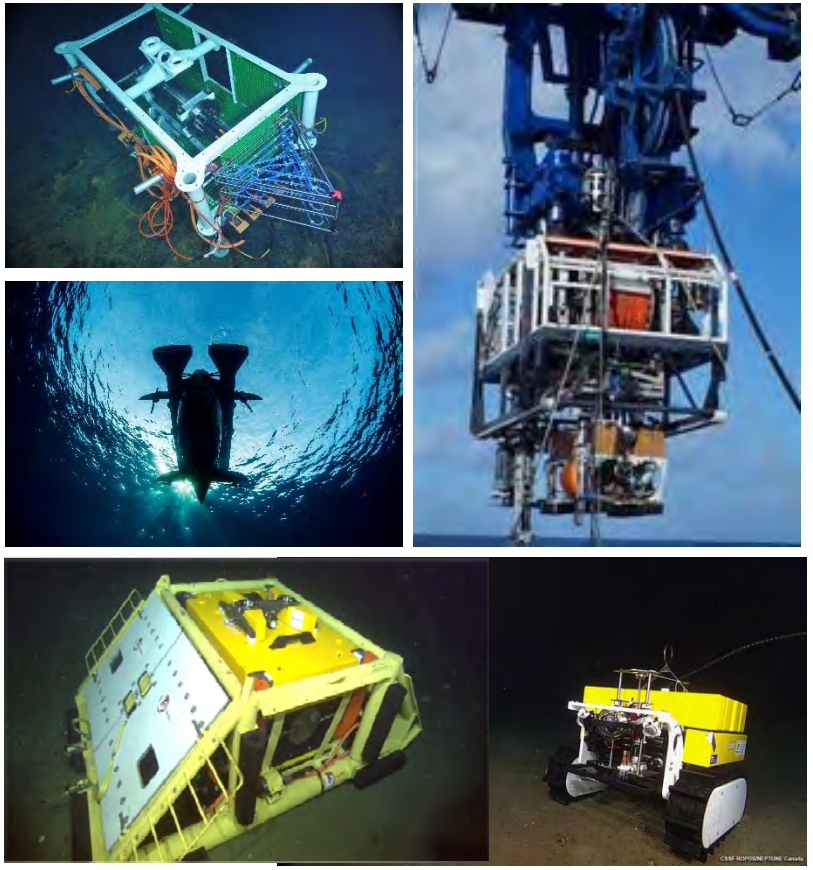
Danovaro et al 2017 Science





Which are the targets of current technologies?





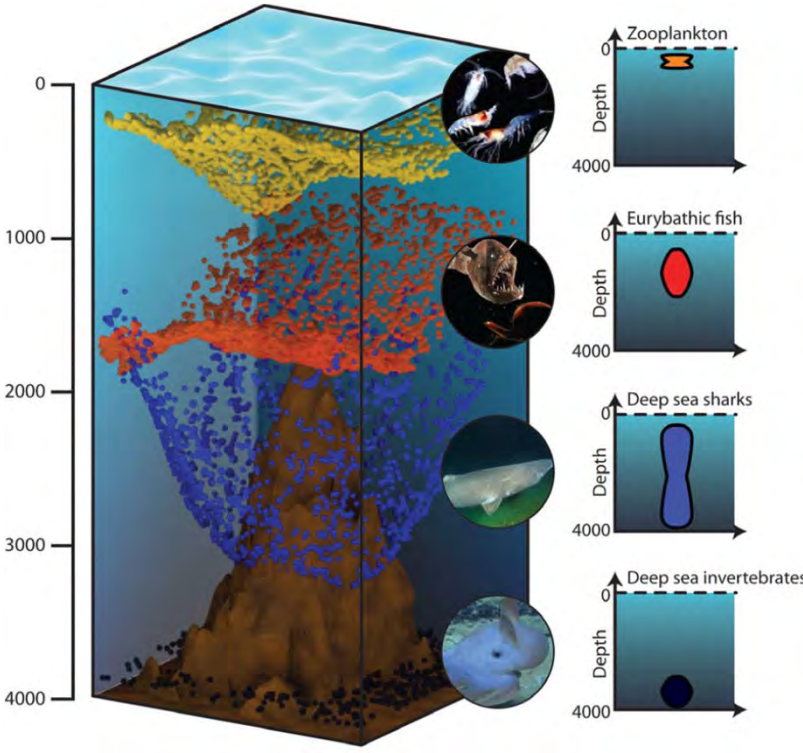
Modified from Rex et al 2005 MEPS

DEEP SEA
Biodiversity Conservation

3D structure of deep-sea ecosystems

Connections between shallow and deep environment

- Meroplanktonic **larvae** (Lee *et al.* 1992)
- **Commercially important species**
- **Refuge** habitat: daily vertical migrations to escape predation
- **Recruitment**
- **Hunting area** for large pelagic species and marine mammals



Conservation Letters
Open Access
A journal of the Society for Conservation Biology

REVIEW

Adding the Third Dimension to Marine Conservation

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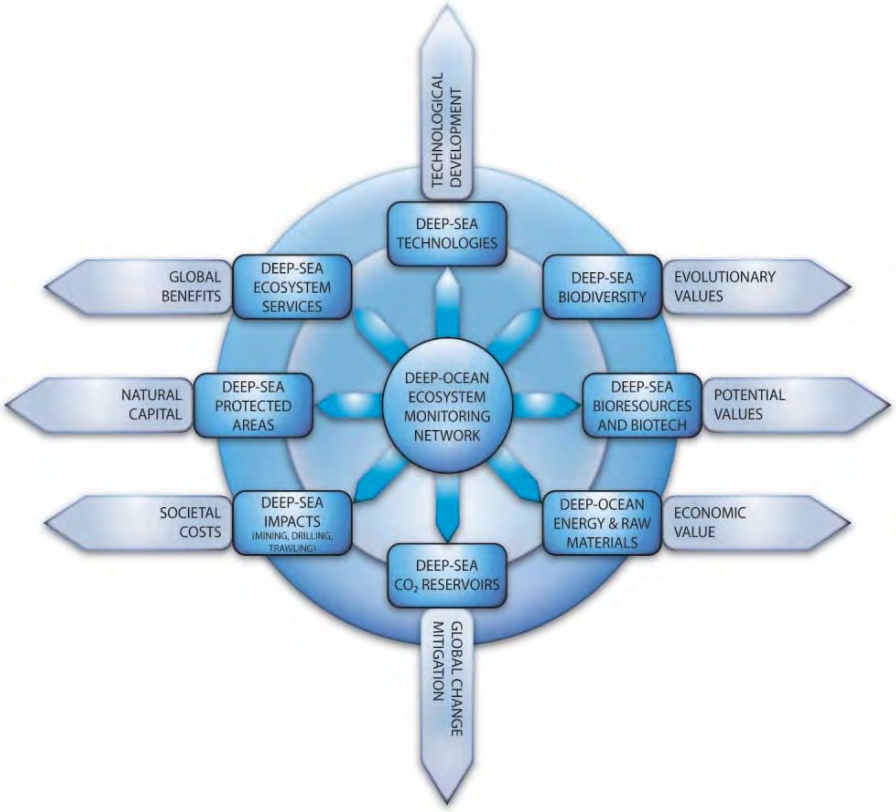
[5] Stazione Zoologica Anton Dohrn, Naples, Italy

An ecosystem-based deep-sea strategy

Implementing the knowledge of the deep-sea biology to protect and restore damaged habitats … using the best available approaches and technologies …. Improving our comprehension of the adaptation of marine life and ecosystems to extreme conditions



UN DECADE OF ECOSYSTEM RESTORATION

OCSE: Building the industry of Marine Ecosystems restoration

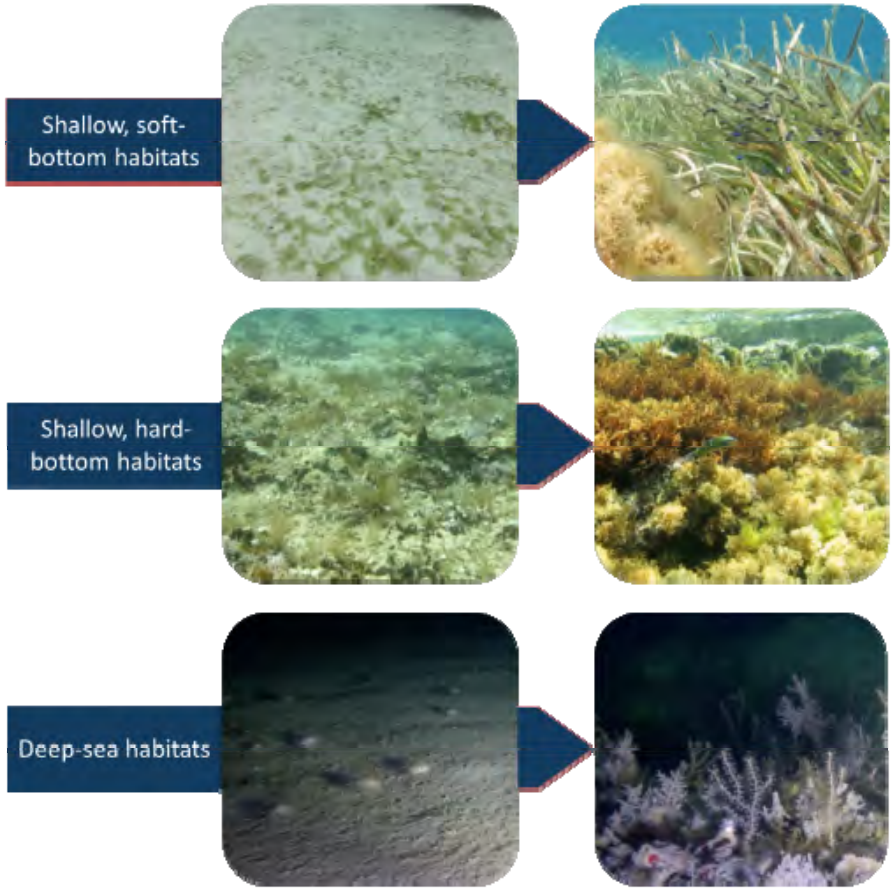
Ecological restoration expanding in the deep

is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.

Natural resilience is too slow to recover natural goods and services

Implication for marine economy and human health

EU launched a Restoration action in the Biodiversity Agenda

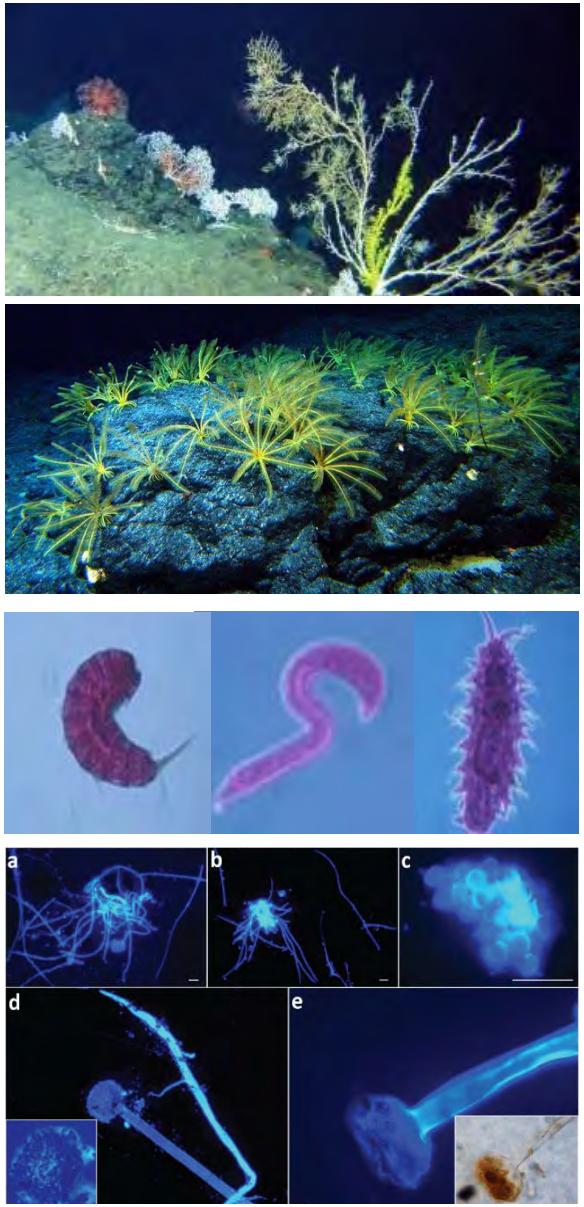


Life Watch moving DEEP

- Deep-sea habitat and biodiversity protection is a priority
- Need to increase our effort for censusing deep-sea biodiversity

  BUT

  Focusing Ecosystem services is instrumental to convince the Society that deep-sea biodiversity conservation is a priority.
- Need to implement technology enabling the study of deep-sea ecosystems and their biodiversity



Marine Ecosystem Restoration in Changing European Seas (MERCES)
Grant agreement n. 689518

www.merces-project.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689518.