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 million citizens
500 billions euros in 2010
600 billions euros in 2020
(and 7 millions jobs)

United Nations Decade of Ocean Science for Sustainable Development (2021-2030)
The challenges for the next decade

<table>
<thead>
<tr>
<th>Marine Biotechnology</th>
<th>To identify new molecules produced by marine organisms of interest in the pharmaceutical, nutraceutical or industrial companies</th>
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<tbody>
<tr>
<td>Global changes</td>
<td>To develop a global network of observatory integrating biological components to the environmental variables</td>
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<td>Conservation</td>
<td>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</td>
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<tr>
<td>Marine Resources</td>
<td>To develop new approaches and solutions for the sustainable use of marine biotic and abiotic resources</td>
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</table>
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 (€)

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Armstrong et al., 2012

<table>
<thead>
<tr>
<th>ECOSYSTEMS AND HABITATS</th>
<th>COLD-WATER CORALS</th>
<th>OCEAN GLOPS AND BLOBS</th>
<th>CANYONS</th>
<th>SEAMOUNTS</th>
<th>CHEMOSYNTHETIC ECOSYSTEMS</th>
<th>PLAGIC SYSTEMS</th>
<th>SUB-SEABED</th>
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<td>Provisioning services</td>
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<td>Fish, shellfish, mammals</td>
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<td>Oil, gas, minerals</td>
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<td>Chemical compounds</td>
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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

A submarine volcanic eruption leads to a novel microbial habitat

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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
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

- Nutrient cycling (N, C, P)
- Trophic support

Danovaro, Snelgrove & Tyler TREE (2014)
“Dark energy” in the deep ocean

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.

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