Food and Agriculture Organization of the United Nations

SponGES POLICY BRIEF

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The ecological value of deep-sea sponges

The ecological value of deep-sea sponges is determined by sponges' specific ecological features and the role that sponge grounds play in the deep sea. Research on sponges in the deep sea is technologically complex and deeply weaved into microbiology, ecology, evolution, taxonomy, genetics, molecular biology and biotechnology.

In December 2020, at the end of the four-year EU-funded SponGES project, the current ecological knowledge on deep-sea sponges was condensed into a list of main ecological features. These ecological features are simple statements describing, in qualitative terms, experts' knowledge on deep-sea sponges.

This approach has been already adopted by the scientific community as a way to support, in practical terms, ecosystem management and policy decision-making (Towsend *et al.*, 2011; Jobstvogt *et al.*, 2014).

The ecological features covered five different domains: distribution; biodiversity; genetic diversity; nutrient and element fluxes; response to threats and impacts.

SponGES

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Major ecological features of deep-sea sponges

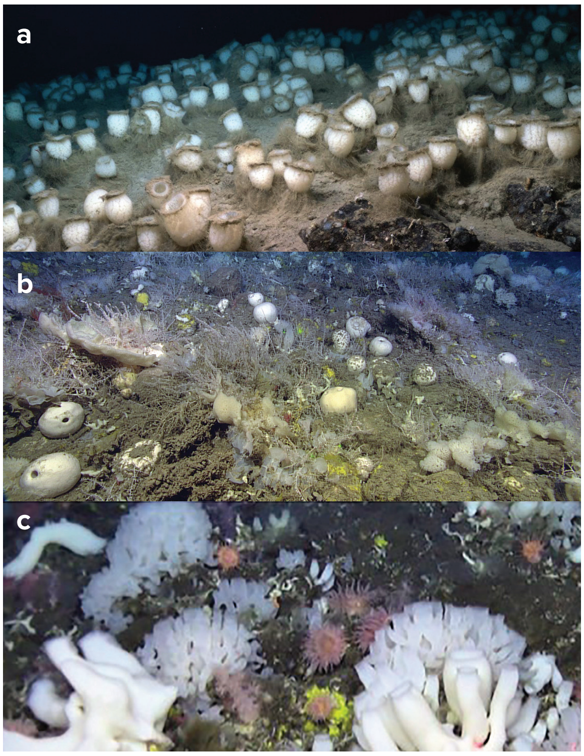
A first set of ecological features describes the occurrence of sponges and high-density sponge aggregations (i.e. deep-sea sponge grounds) in the deep sea:

- Deep-sea sponges occur between 200 and 3 000 m depth.
- Deep-sea sponges can form high-density communities known as sponge grounds.
- Deep-sea sponge aggregations are often found in high densities, on topographic features (e.g. seamounts, ridges, continental slopes and fjords).
- Deep-sea sponge grounds can be dominated by a single sponge species (monospecific), or by a mix of sponge species with a prevalence of few species (Figure 1).

A second set of ecological features expresses how deep-sea sponge grounds support an enhanced level of biodiversity:

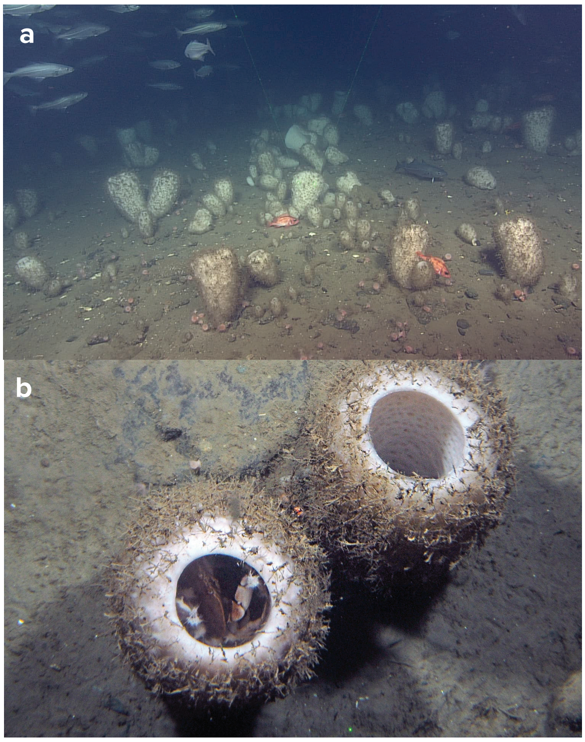
- Deep-sea sponges live attached to the seafloor and provide complex three-dimensional habitat for other marine organisms.
- Deep-sea sponge grounds host a high diversity and abundance of marine invertebrates, which are typically less frequent outside sponge grounds.
- Deep-sea sponge grounds can potentially be used by deep-sea fish and other marine organisms as feeding grounds, shelter, spawning grounds or nursery habitats.
- Deep-sea sponges support marine food webs by making dissolved and particulate nutrients (organic and inorganic) available to other marine organisms.

FIGURE 1 **Examples of different types of deep-sea sponge grounds**



(a) monospecific aggregation of *Pheronema carpenteri* in the Azores, Northeast Atlantic (©IMAR), (b) multispecific sponge aggregation belonging to the genus *Geodia* in the Flemish Cap area, Northwest Atlantic (©Fisheries and Oceans Canada), (c) multispecific sponge aggregation on the Schulz Bank, Arctic Mid-Ocean Ridge (©The University of Bergen, UiB).

FIGURE 2 **Examples of different types of fauna recorded on deep-sea sponge aggregations of *Vazella pourtalesii* in the Emerald Basin, Nova Scotia, Canada.**



(a) Red fishes (*Sebastes* spp.) (©Beazley *et al.*, 2018), (b) crab (*Cancer borealis*) (©Hawkes *et al.*, 2019).

A third set of ecological features points out to the genetic diversity characterizing deep-sea sponges and their capacity to produce a great diversity of chemical compounds:

- Deep-sea sponges contain families of genes found in several animal species, including humans.
- Deep-sea sponges host a community of symbiontic micro-organisms (e.g. bacteria, viruses, fungi), known as microbiome, which is specific not only at the species level but also at the individual level.
- Deep-sea sponges and their microbiomes produce, in small amounts, compounds able to trigger a response, with therapeutic potential, in cells and tissues of several animals, including humans.

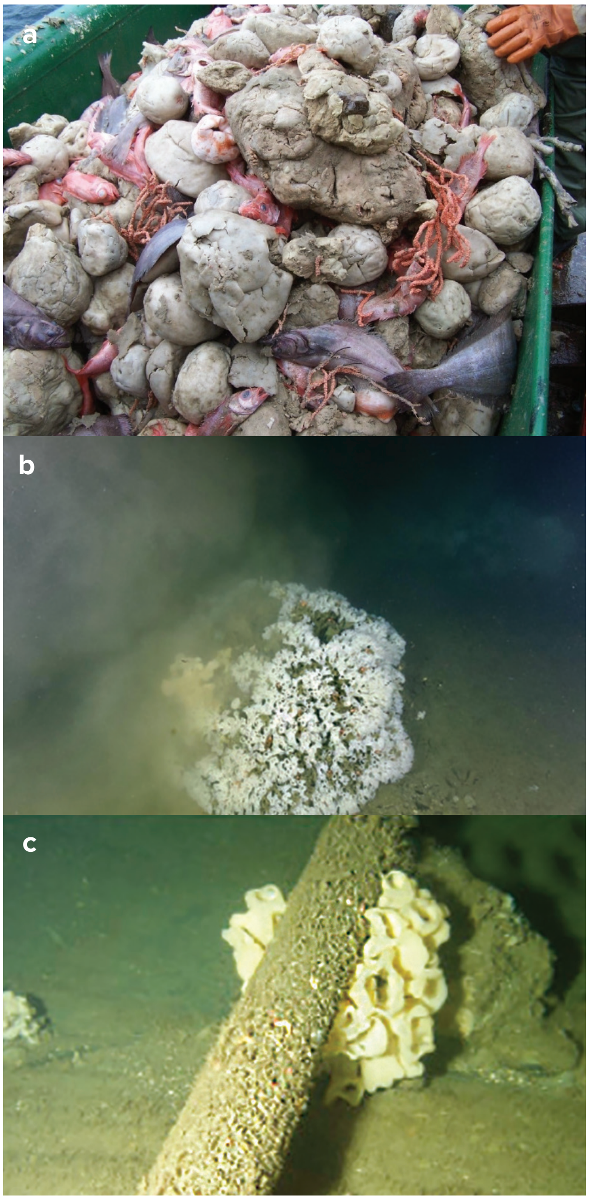
A fourth set of ecological features explains how sponge physiology concurs to the transport and cycling of several nutrients in the deep sea:

- Deep-sea sponges are highly efficient filtering organisms, pumping large volumes of water.
- Deep-sea sponges feed mainly on bacteria and dissolved organic matter in the ocean water. They consume organic carbon and release CO_2 through respiration, thus they do not concur to ocean carbon sequestration.
- Deep-sea sponges, depending on nutrient availability as well as on the abundance and composition of their microbiome, can consume a variety of inorganic nitrogen compounds or release them.
- Deep-sea sponges, particularly glass sponges, use large quantity of dissolved silicon to build their skeleton.

A fifth set of ecological features describes the response and vulnerability of deep-sea sponges to threats and impacts in the deep sea:

- Deep-sea sponges are severely damaged by human activities impacting the seafloor (Figure 3).
- Deep-sea sponges show a species-specific response to climate-change related variation of ocean conditions (increased water temperature and decreased pH).
- Deep-sea sponges can cope, for a short period of time, with increased sediment suspended in the water column and/or accumulated sediment on the seafloor.
- Deep-sea sponges and their associated invertebrate fauna are very sensitive to crushed seafloor massive sulphides and die when exposed to such suspended, crushed sediments.
- Deep-sea sponges have some regeneration capacity but, as slow-growing organisms, show little recovery over time.

FIGURE 3 **Examples of different types of impacts on deep-sea sponges**



(a) Sponge bycatch from bottom trawling (©Fisheries and Oceans Canada), (b) a plume of suspended sediment over *Farrea occa* and *Heterochone calyx* (©Sally Leys, University of Alberta), (c) impact of submarine power transmission cables on a glass sponge reef (*Aphrocallistes vastus*) (©Dunham *et al.*, 2015).

Scientists explain the consequences of deep-sea sponge grounds damage/destruction

FAO administered a questionnaire to 20 sponge experts, within the SponGES project, to gain further knowledge and understanding on the overall ecological value of deep-sea sponges and possible consequences of their damage/destruction.

The scientists were asked to express their opinion on four different scenarios on the basis of four indices: plausibility, evidence, species generality, and geographic generality (Box 1).

> BOX 1 **Indices used to evaluate the scenarios**
>
> **Plausibility:** Expresses the degree to which experts believe that the scenario is plausible, even if data to demonstrate the scenario might not be currently available.
>
> **Evidence**: Expresses the degree to which experts believe/know that the scenario is based on existing datasets and analyses undertaken.
>
> **Species generality:** Expresses the degree to which experts believe/know that the scenario is applicable to different sponge aggregations.
>
> **Geographic generality:** Expresses the degree to which experts believe/know that the scenario occurs in sponge grounds located in different geographic areas.

SCENARIO A: DECREASE OF NUTRIENT AVAILABILITY MEDIATED BY DEEP-SEA SPONGES

NARRATIVE

Deep-sea sponges and their associated microbiomes are able to feed on dissolved organic matter (DOM). DOM constitutes the largest reservoir of organic carbon of the ocean, but is largely unavailable to other marine multicellular organisms. Deep-sea sponges, by feeding on both DOM and plankton filtered from the water column, make organic matter available to invertebrates and microorganisms in the form of detritus, and/or to other species directly predating them. Therefore, deep-sea sponges concur to sustain benthic food webs.

The destruction/damage of deep-sea sponge grounds is likely to have a major impact on the transfer of sponge-derived organic matter to other marine organisms, who could suffer from reduced food availability.

CONSEQUENCES

The damage/destruction of deep-sea sponge grounds is expected to:

- **affect the carbon and nitrogen cycling with a decrease in food availability for different marine species.**

EXPERTS' OPINION

A good share (90 percent) of respondents considered plausible this scenario. However, almost all respondents found the evidence in support of this scenario to be limited as data have only been collected on a few North Atlantic sponge species. Only 45 percent of the scientists felt confident in extrapolating this possible scenario to other geographic areas beyond the North Atlantic. One source of uncertainty relates to the spatial scale (local vs regional) at which the effects of the decreased nutrient availability due to destruction of deep-sea sponges would be felt.

SCENARIO B: DECREASE IN BIODIVERSITY ASSOCIATED TO DEEP-SEA SPONGES

NARRATIVE

Deep-sea sponges are ecosystem engineers and therefore constitute an incredibly diverse habitat on the deep-sea seafloor. Deep-sea sponge grounds host an increased abundance and diversity of marine invertebrate species such as shrimps, crabs and squids. In addition, deep-sea

sponges could represent an essential fish habitat for several deep-sea fish. Some deep-sea fish species could feed on deep-sea sponge grounds due to an increased abundance of marine invertebrate species or use sponge grounds as shelter, as sites to lay eggs, or as nurseries. Deep-sea sponge grounds can therefore be considered benthic hotspots of biodiversity.

CONSEQUENCES

The damage/destruction of deep-sea sponge grounds is expected to:

- **cause a decrease in the diversity and abundance of species (invertebrates and vertebrates) associated to deep-sea sponge aggregations.**

EXPERTS' OPINION

All respondents considered plausible this scenario. The fact that sponge grounds create additional habitat diversity is undeniable, and an increased habitat diversity inevitably leads to an increased diversity of species. This explains why scientists overall believe that this scenario could well apply to different sponge aggregations (89 percent) and geographical areas (63 percent). However, gaining statistical evidence of species-habitat association occurring in deep-sea sponges is hampered by logistic and sampling difficulties (FAO, 2020a) and this explains why not all scientists (58 percent) believed that a robust set of evidence is currently available.

SCENARIO C: DECREASE IN DEEP-SEA SPONGE GENETIC DIVERSITY

NARRATIVE

Deep-sea sponges are characterized by a genetic pool which includes the genes of the sponge organism as well as the genes of their associated microbiome. This variety of genes enables sponges to produce a large number of chemical compounds. Some of these compounds are used by sponges as a chemical defense against predation or for internal repairing processes. These compounds are known to have a degree of bioactivity inducing specific responses/reactions, with therapeutic potential, in the cells and tissues of several animal species, including humans.

The genetic diversity of sponges varies among sponge species, among different sponge grounds and among different individuals found at different water depths.

Deep-sea sponges, as any population, need high genetic diversity to be able to tolerate stress related to changes in environmental conditions due to natural or antrophic causes.

In fact, high genetic diversity provides a high number of gene variants in a population. Among these variants one or more gene combinations might result suitable to face new environmental conditions. Thus, the persistence of the sponge population over time is enabled by the survival and reproduction of these better-adapted individuals having these genes variants.

CONSEQUENCES

The damage/destruction of deep-sea sponge grounds is expected to:

- **cause a decrease in sponge genetic diversity and consequently chemical diversity of compounds produced by deep-sea sponges.**

EXPERTS' OPINION

The majority (74 percent) of respondents assessed this scenario as plausible. Genetic characterization of sponges is complex and just at its start, but there is some preliminary evidence showing genes diversity recorded at the species, at the population and at the individual level. However, it is currently difficult to forecast how these sources of genetic variability (individual/population/species) will vary on a spatial/regional scale. This explains why not all scientists, but respectively 53 percent and 42 percent, were comfortable with making generalizations about the geographical realm and diversity of sponge-aggregations affected by this scenario.

SCENARIO D: INCREASE OF IMPACTS ON DEEP-SEA SPONGES

NARRATIVE

Deep-sea sponges are ancient organisms that succeeded in inhabiting one of most inhospitable areas of the planet. Deep-sea sponges have the capacity to respond to changes in their environment, but may not cope efficiently with multiple environmental stressors due to synergistic effects. Moreover, deep-sea sponges are usually considered slow growing organisms and sponge grounds, when damaged or destroyed, show little recovery over time.

Due to their ecological features, deep-sea sponge grounds are very vulnerable to impacts generated by economic activities in the deep sea. Bottom fisheries, deep-water oil and gas extraction, mineral mining, cable laying can physically damage or remove deep-sea sponge grounds or can negatively affect deep-sea sponge grounds by causing increased siltation and chemical pollution.

These human-induced impacts could be further worsened by the effect of climate change causing rising ocean temperatures coupled with ocean acidification.

CONSEQUENCES

Current/future multiple threats on deep-sea sponge grounds are expected to:

- **cause long-lasting impacts on deep-sea sponge grounds.**

EXPERTS' OPINION

The respondents unanimously agreed that impacts and threats on deep-sea sponges are very likely to increase in the near future causing long-lasting impacts on these vulnerable organisms.

The response to different stressors such as increased water temperature, siltation, chemical pollution is likely to affect sponge species differently. This explains why numerous scientists (53 percent) believed that more robust evidence should be gathered. At the same time, the impacts physically destructing sponge grounds will invariantly affect existing sponge aggregations occurring in different geographic areas ad this explains the large accordance found in the species (79 percent) and geographical (84 percent) generality scores. Currently, the major source of uncertainty concerns the full understanding of the cumulative effects of the stressors affecting different deep-sea sponge aggregations.

FIGURE 4 **Percentage of agreement among interviewed scientists on the outcomes and features of the four proposed scenarios.**

	Plausible scenario	Scenario confirmed by robust evidence	Scenario potentially affecting several sponge aggregations	Scenario plausible in the North Atlantic and other areas
SCENARIO A Decrease of nutrients mediated by deep-sea sponges	90%	5%	60%	45%
SCENARIO B Decrease of biodiversity associated to deep-sea sponge grounds	100%	58%	89%	63%
SCENARIO C Decrease of deep-sea sponge genetic diversity	74%	11%	53%	42%
SCENARIO D Increase of impacts on deep-sea sponge grounds	100%	47%	79%	84%

Agreement percentage varies between null (0%) and full agreement (100% = 20 experts). Source: Author's elaboration

Policy and management implications

The major point to consider is that these four scenarios are highly interdependent. Not only they can occur at the same time, but are likely to reinforce each other.

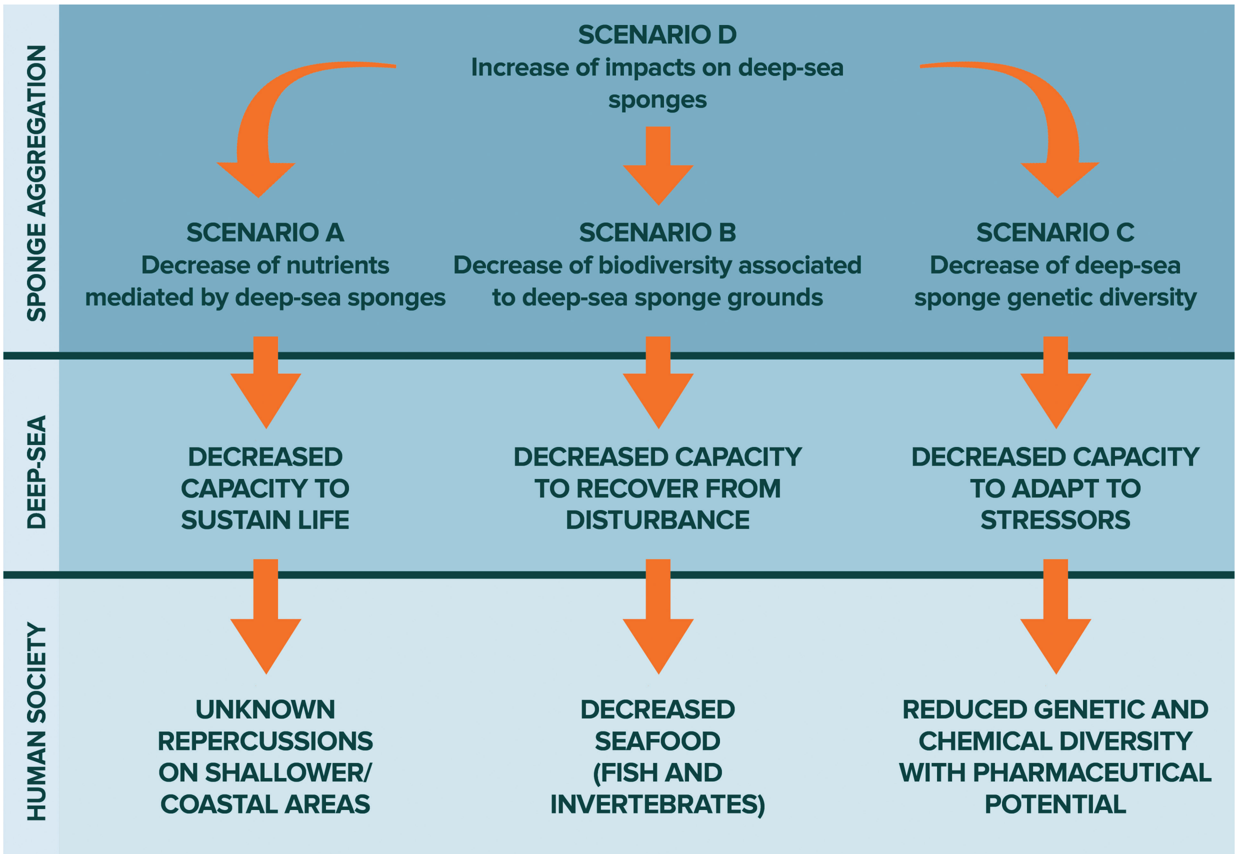
For example, an increased destruction/removal of deep-sea sponges (Scenario D) will cause a decrease in availability of nutrients mediated by sponges (Scenario A), a decrease in biodiversity associated to deep-sea sponge grounds (Scenario B) and a decrease in sponge genetic diversity (Scenario C) (Figure 5).

The repercussions on the deep-sea ecosystem are difficult to assess in quantitative terms on both a temporal and a spatial scale. Deep-sea sponge grounds represent biodiversity hotspots, sites of intense metabolic activity of the benthic community and reservoirs of genetic and chemical diversity. Consequently, the loss of deep-sea sponge grounds can translate into a decreased ecological capacity to: sustain life, recover from disturbance and adapt to stressors in the deep-sea environment.

The long-term consequences of the destruction/damage of deep-sea sponges on human society are likely to be multi-faceted. However, since knowledge of deep-sea functioning is still advancing, impacts are comprehensively difficult to foresee (Armstrong *et al.*, 2010)

This level of uncertainty calls for a precautionary approach towards deep-sea sponge conservation. Closure areas established on sites of high sponge density have proved to be (the only) effective management measures for deep-sea sponge conservation (FAO, 2020b).

FIGURE 5 **Examples of possible effects of damage/removal of deep-sea sponges on sponge aggregations, deep-sea ecosystems and human society.**



Source: Author's elaboration

However, **sponge-area closures need to be integrated into a wider spatial management plan**.

Threats to deep-sea sponge grounds can be generated outside the sponge-area closures but still affect deep-sea grounds inside the area-closures due to the connectivity of the deep sea and deep-sea processes.

The conservation of deep-sea sponge grounds, as vulnerable marine ecosystems (FAO, 2009)**, calls for a cross-sectorial and transboundary management plan.** This plan should seek to effectively reduce both direct and indirect impacts on deep-sea sponge grounds that occur both in individual countries exclusive economic zones (EEZs) and deep-sea areas found in areas beyond national jurisdiction (ABNJs).

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THIS POLICY BRIEF WAS PREPARED BY: **Daniela Ottaviani, FAO consultant**

CONTACT FOR FURTHER INFORMATION:

Merete Tandstad
Fisheries - Marine and Inland Fisheries Branch (NFIF)
Fi-inquiries@fao.org
fao.org/fisheries
Food and Agriculture Organization of the United Nations
Rome, Italy

info@deepseasponges.org
deepseasponges.org
@DeepSeaSponges
@DeepSea_Sponges

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