Food and Agriculture Organization of the United Nations

SponGES POLICY BRIEF

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Deep-sea sponges: Biotechnology and the blue economy

Source of novel chemicals and bioproducts

The ocean supports a great diversity of life and ecosystems. This biodiversity is the source of chemical and molecular diversity, which is the basis for exploration and discovery of novel, marine-derived chemicals and other bioproducts. Sponges are the source of thousands of chemicals with potential pharmaceutical and industrial applications (Jimenez, 2018), and some sponge-derived drugs are clinically available or in advanced clinical trials (Table 1).

TABLE 1. **Sponge-derived chemicals clinically available or in clinical trials, as of August 2020.**

DRUG OR COMPOUND NAME	STATUS	DISEASE AREA	COMPANY
Halaven®	Clinically available	Cancer	Eisai Inc.
Vira-A®	Clinically available	Antiviral	Mochida Pharmaceutical Co.
Cytosar-U®	Clinically available	Cancer	Pfizer
Plocabulin	Phase II	Cancer	PharmaMar
MORAb-202	Phase I	Cancer	Eisai Inc.

Source: A.M.S. Mayer, Midwestern University (marinepharmacology.midwestern.edu)

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SponGES has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 679849. This document reflects only the author's view – the Executive Agency for Small and Medium-sized Enterprises is not responsible for any use that may be made of the information it contains.

Although most marine-derived drugs are from shallow water organisms, many novel chemicals and bioproducts have been reported from deep sea organisms. One example is the aphrocallistins from the deep-sea glass sponge, *Aphrocallistes beatrix* (Fig. 1a), active against triple negative breast cancer (Wright *et al.*, 2009). A key sponge from North Atlantic sponge grounds, *Geodia barretti* (Fig. 1b) produces the barettins, which have anticancer, antiviral, and antifouling activities (Lind *et al.*, 2013).

Why sponges produce these chemicals is not well known, especially for deep water sponges. It is hypothesized that because sponges are sessile for their adult life, the chemicals are involved in communication and signaling for a variety of functions, including reproduction, deterring predation, and preventing settlement of other organisms.

The chemicals have pharmaceutical potential because they interact with molecules that have been conserved for hundreds of millions of years and are also involved in human disease processes, for example, cell division and cell death, immune and inflammatory responses, and calcium and sodium regulation.

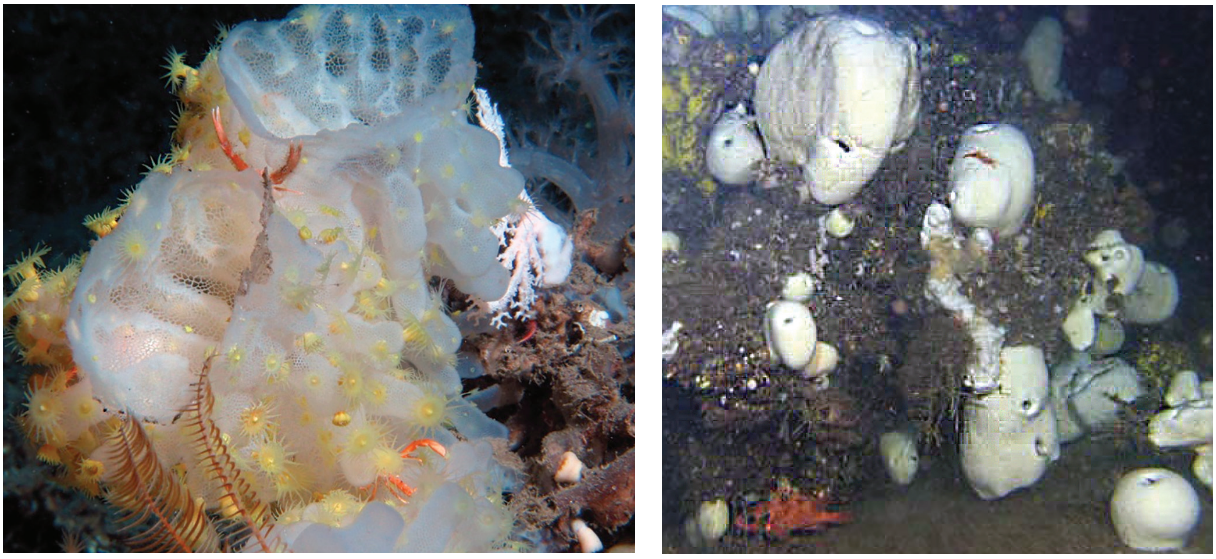
"Metabolic fingerprinting"

New technologies are accelerating the pace of discovery of novel chemicals and bioproducts. Metabolic diversity of key sponge ground species is being assessed by "metabolic fingerprinting" to identify new chemicals with applications to human health and industrial use. An integrated "-omics" approach (metagenomics, metatranscriptomics, and metabolomics) is being used to search for pharmaceutically relevant genes.

Bone tissue engineering

In addition, deep sea sponges produce intricate silica skeletons (Fig. 2) that inspire research on bone tissue engineering and regenerative medicine (Dudik *et al.*, 2018). Bioorganic silica produced by sponges attracts and stimulates human stem cells to differentiate into bone forming cells. Silica-based composites, inspired by the composition of bioorganic silica and the unique 3-dimensional architecture of sponge skeletons, are being developed as implants for bone tissue regeneration (Dudik *et al.*, 2018).

FIGURE 1. **LEFT: the deep-sea hexactinellid sponge, *Aphrocallistes beatrix*, source of the aphrocallistins. RIGHT: deep-sea demosponges *Geodia barretti*, source of the barettins.**



Sources: Left, ©S. Pomponi, Harbor Branch Oceanographic Institute, Florida Atlantic University; Right, ©Fisheries and Oceans Canada.

FIGURE 2. **Scanning electron microscopic image of silica spicule skeleton of *Geodia barretti*.**

Source: @Dudik *et al.*, 2018.

Key messages

- Sponges are an important source of chemicals with potential pharmaceutical and industrial applications.
- New technologies are accelerating the discovery of new chemicals and bioproducts.
- Silica skeletons of sponges inspire research on bone tissue engineering and regenerative medicine.
- Bioorganic silica produced by sponges attracts and stimulates human stem cells to differentiate into bone forming cells.

Knowledge gaps and challenges

There are key knowledge gaps and challenges in unlocking the biotechnological potential of deep-sea sponges. Sponge grounds are poorly explored and access to deep sea sponge grounds requires expensive ships and technologies to explore and sample the benthos.

Threats from industrial uses of the deep sea (e.g. fishing and mining activities) as well as changes in ocean chemistry and temperature as a result of global climate change will have adverse effects on deep sea sponge ground biodiversity, and as a result, on our ability to discover new chemical and molecular diversity.

There are additional challenges. Ensuring an adequate supply of the bioproducts requires the development of sustainable production methods; wild harvest of the source sponges is neither economically nor ecologically sustainable.

Commercialized products and benefit sharing

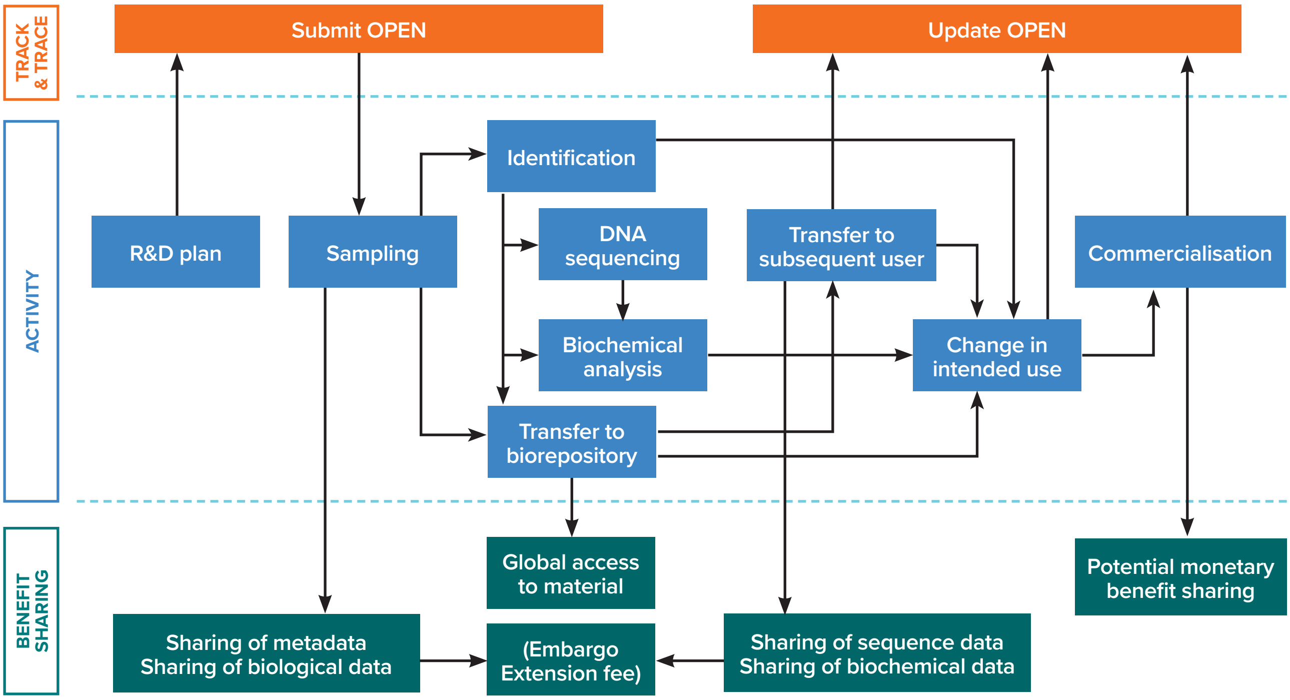
The timeline from identification of a bioproduct until it is clinically available can take as much as two decades. Discoveries must be patented and licensed for development. Pharmaceutical and biotech companies will spend millions to develop a drug, and royalties may be less than 5 percent of the net revenues from commercialization hence expectations regarding benefit sharing of commercialized products need to be realistic.

Frameworks are needed to manage genetic resources from deep-sea areas to ensure benefit sharing and capacity building, but there are still many details to resolve. Who administers, maintains, and ensures compliance with agreed upon procedures? Who is required to share and what is required to be shared? When are benefits shared, who are the beneficiaries, and how is capacity building implemented? Whether it will be simpler or more complex to resolve these issues in territorial waters than in areas beyond national jurisdiction (ABNJ's) is not known. They could be simpler because the areas are not under the jurisdiction of any state, but they may be more complex if benefit sharing with a variety of governing bodies is mandated.

An "Obligatory Prior Electronic Notification" (OPEN) procedure or framework has been proposed (Broggiato *et al.*, 2018) (Fig. 3). This is a good start, but there are still many details to resolve like the questions above (University of Aberdeen, 2018).

Regardless, mechanisms to identify and implement protection of biodiversity beyond national jurisdiction should include valuation of deep-sea sponge grounds for discovery of bioproducts with pharmaceutical and industrial applications. Exploration and discovery of ABNJ's and the services they provide must continue.

FIGURE 3. **Proposed framework for Obligatory Prior Electronic Notification (OPEN) for biodiscovery of marine-derived drugs from areas beyond national jurisdiction.**



Source: Broggiato *et al.* 2018.

Key messages

- Key knowledge gaps and challenges remain in unlocking the biotechnological potential of deep-sea sponges.
- Threats from industrial uses of the deep sea (e.g. fishing and mining activities) as well as changes in ocean chemistry and temperature due to global climate change will affects deep sea sponge ground biodiversity and our ability to discover new chemical and molecular diversity.
- An adequate supply of bioproducts requires the development of sustainable production methods.
- Wild harvest of the source sponges is neither economically nor ecologically sustainable.
- Frameworks are needed to manage genetic resources from deep-sea areas to ensure benefit sharing and capacity building, but there are still many details to resolve.

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