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Marine Biotechnology

Advancing Innovation in Europe's Bioeconomy

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European Marine Board

The European Marine Board provides a pan-European platform for its member organizations to develop common priorities, to advance marine research, and to bridge the gap between science and policy in order to meet future marine science challenges and opportunities.

The European Marine Board was established in 1995 to facilitate enhanced cooperation between European marine science organizations towards the development of a common vision on the research priorities and strategies for marine science in Europe. Members are either major national marine or oceanographic institutes, research funding agencies, or national consortia of universities with a strong marine research focus. In 2017, the Marine Board represents 33 Member Organizations from 19 countries.

European Marine Board Member Organizations

This policy brief is a collaboration between EMB and ERA-MBT. It provides a summary of, and draws content directly from, the Marine Biotechnology Strategic Research and Innovation Roadmap, a key deliverable of the H2020 ERA-MBT project – see Hurst, D.; Børresen, T.; Almesjö, L.; De Raedemaecker, F.; Bergseth, S. (2016). Marine biotechnology strategic research and innovation roadmap: Insights to the future direction of European marine biotechnology. Marine Biotechnology ERA-NET: Oostende.
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Marine Biotechnology ERA-NET

The Marine Biotechnology ERA-NET vision is "to support Europe's marine biotechnology community to participate in a lasting, enterprise-driven network that adds value to marine biological resources in ways that nurture and sustain the lives of European citizens."

The Marine Biotechnology ERA-NET is a consortium of 19 national funding bodies from 14 countries seeking complementarities between national activities and resources to undertake joint funding of transnational projects in the area of Marine Biotechnology. It works with a wide range of stakeholders to enhance all elements of the marine biotechnology value chain; in doing so it directs attention to the exploration of the marine environment; biomass production and processing; product innovation and differentiation; enabling technologies and infrastructures; and the need for continued policy support and stimulation. Marine Biotechnology ERA-NET (ERA-MBT) is funded under the European Commission's Seventh Framework Programme, Grant Agreement Number 604814, December 2013 - November 2017.

Marine Biotechnology ERA-NET Partner Organizations

Marine biotechnology: Adding value to marine bioresources

Marine biotechnology is a fast growing, knowledge- and capital-intensive enabler of innovation in the use of marine bioresources and contributes to the wider bioeconomy by providing solutions to today's grand challenges of food and nutrition security, sustainable economic growth and population health.

Products from marine biotechnology research and innovation are already used in, and support developments in, global markets for food and feed, cosmetics, aquaculture, agriculture, chemistry and pharmacology. The range of products and services based on marine bioresources is rapidly diversifying with new applications in markets for industrial enzymes, functional foods, cosmeceuticals, pharmaceuticals, biomaterials, bioprocessing and medical devices.

The global market for marine biotechnology enabled products and processes is predicted to reach US$4.8 billion by 2020, rising to US$6.4 billion by 2025 (Smithers Rapra, 2015). In Europe, marine biotechnology was identified by the EU Blue Growth Strategy (2012) as an enabling activity of high potential for the bioeconomy. Revenue from marine biotechnology in Europe is predicted to reach €1 billion by 2020 if a market growth of 6-8% per annum is maintained, resulting in the creation of 10,000 new jobs (ECORYS and consortium partners, 2014).

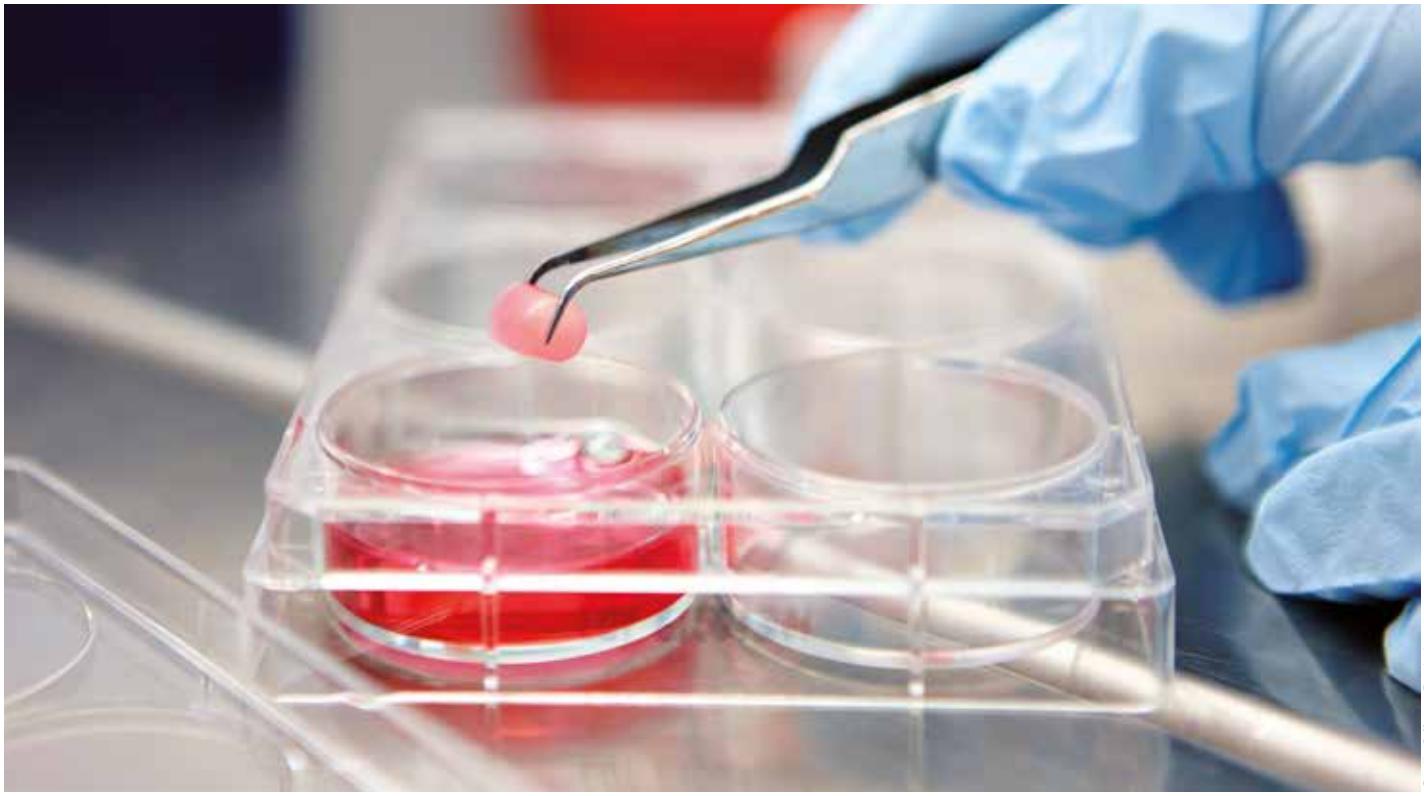
Definition

Marine biotechnology – also known as blue biotechnology - is defined as "the application of science and technology for the production of knowledge, goods and services from (marine) biological resources" (adapted from the OECD general definition of biotechnology, 2005).

A Roadmap for European marine biotechnology

In 2010 the European Marine Board Position Paper 15 set out a vision for European marine biotechnology (Querellou *et al.,* 2010). In September 2016 the European Marine Biotechnology (MBT) ERA-NET published a marine biotechnology strategic research and innovation roadmap (Hurst, *et al.* 2016), identifying five key thematic areas, namely exploration of the marine environment; biomass production and processing; product innovation and differentiation; enabling technologies and infrastructure, and policy support and stimulation.

This Policy Brief assesses the latest advancements in marine biotechnology across five thematic areas identified by the ERA-NET roadmap, including long-term (2020-2030) opportunities where significant scientific, technological and other challenges remain. It also presents examples of commercial applications of marine biotechnology, the resulting high-value products and services and examples of other European projects and initiatives that are seeking to streamline the marine biotechnology pipeline.



Credit: Jellagen Pty Ltd

Next generation jellyfish collagen 3D scaffolds for cell culture applications.

Exploration of the marine environment

The world's seas and ocean contain some of the greatest biodiversity on the planet, present in a wide range of habitats from the coasts to the deep sea. Marine environments are incredibly varied and can display extreme physical characteristics, e.g. pressure, temperature, salinity, density, light. These conditions result in marine organisms undergoing physiological adaptations, activating genes and producing bioactive molecules that have a high potential for use in biotechnology enabled applications, generating novel sources of natural products used in an array of high value-added products and processes.

This wealth of opportunity has attracted the attention of researchers and the enterprise sector. For example, the Norwegian company ArcticZyme[1] focuses on bioprospecting activities in the marine Arctic, specifically novel cold-adapted enzymes from marine organisms for molecular research, diagnostics and manufacturing. An example is a thermolabile enzyme isolated from the northern shrimp *(Pandalus borealis)* which is specific for double-stranded DNA and is now used in a product removing DNA contamination in PCR amplifications.

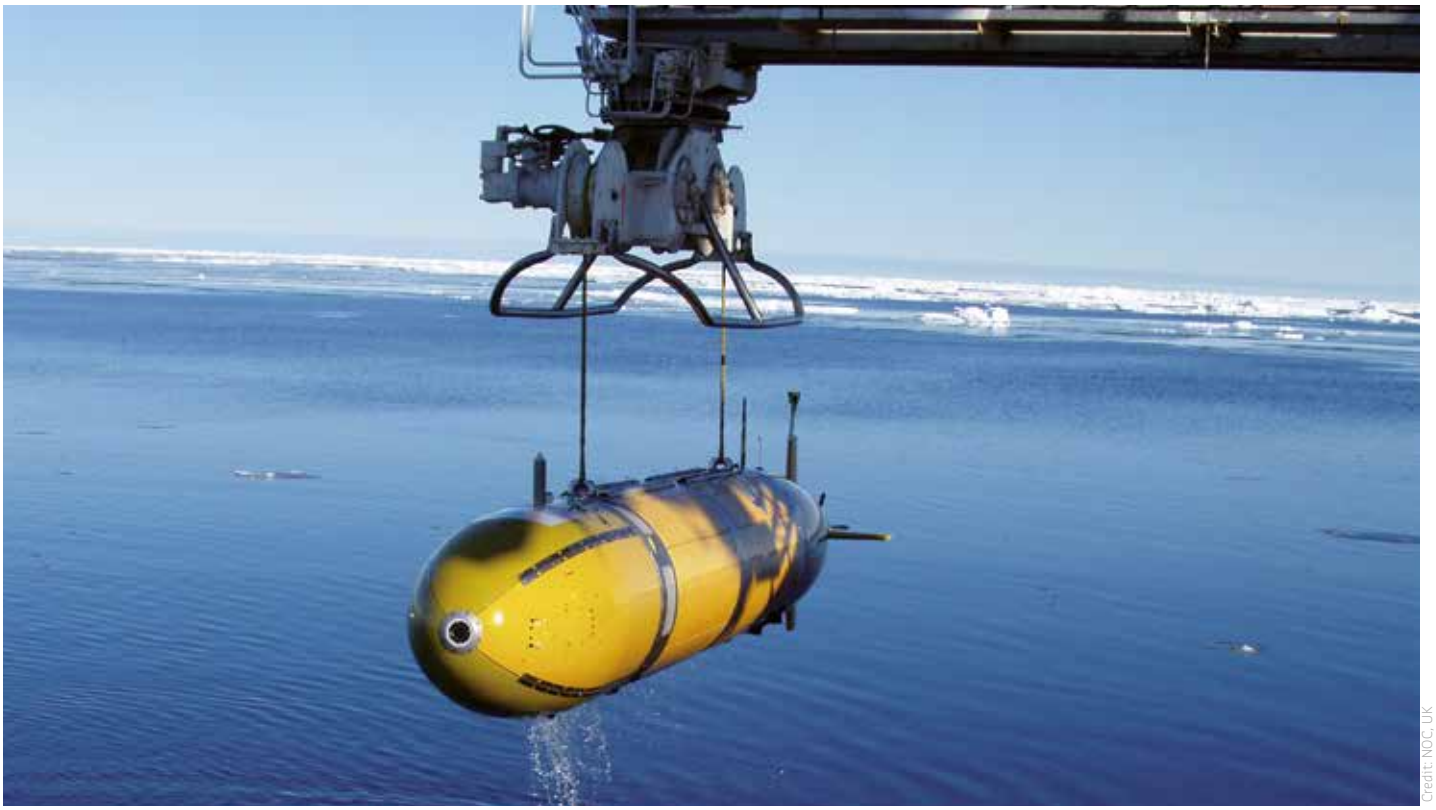
Despite ongoing efforts, many marine regions remain vastly under-explored compared to terrestrial environments. Further exploration and sampling is vital to expand the range and availability of novel marine origin materials. For instance, there are early signs that further successes in health applications, particularly new pharmaceuticals, will be derived from sponges and other marine invertebrates, algae, fungi and marine microorganisms.

Such biodiscovery activity should be conducted sustainably and in parallel with maximizing the use of extensive collections of marine samples stored in repositories and biobanks, following best practices in identification and sample provenance.

Credit: Erling Svendsen

Nudibranch (sea slug) *Flabellina pedata*.

Long-term (2020-2030) challenges include continued access and exploration of biodiversity hotspot regions, e.g. deep sea and polar regions, and targeted sampling of under-represented organisms, e.g. marine microbes; developing next generation sampling methods. New generations of autonomous under-water vehicles (AUVs) to access and collect samples may be combined with remote systems for *in-situ* analysis, enabling more rapid screening of marine compounds; and developing novel methods for the taxonomic, chemical, and biochemical evaluation of marine species as sources of bioactive compounds and other materials.



Credit: NOC, UK

Autosub long-range Autonomous Underwater Vehicle (AUV) in the Arctic Ocean.

[1] http://arcticzymes.com

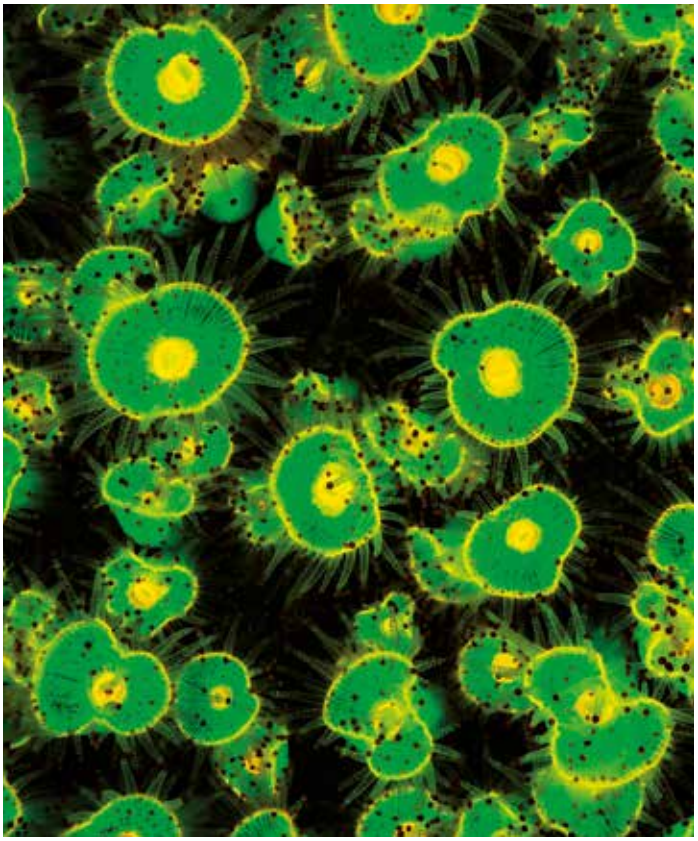
Biomass production and processing

Marine biotechnology has a prime role to play in offering solutions for sustainable food production, including the use of wild species and the culture of marine organisms. For example, the global demand for marine lipids for use in functional foods, ingredients and in nutraceutical products, is expanding and utilizes marine biotechnology to extract Omega-3 from microalgal, fish and macro-algal sources.

The production and use of algal and other marine biomass is important in developing the bioeconomy. New concepts of bioprocessing are emerging, utilizing close to 100% of the available biomass in sustainable multistream biorefineries. These processes deliver customized products, including the production of marine derived biomolecules, by the application of circular economy concepts to minimize waste and energy use.

Engaging industry and academia in collaborative research is crucial in furthering innovation. For example, the NEPTUNA and SeaRefinery projects, funded by ERA-MBT[2], are stimulating academic-industry partnerships to identify novel bioactives from macroalgae (seaweeds), microalgae and cyanobacteria. Not only do these projects target high-value compounds, they are also developing novel processing technologies to extract and purify them for use in food, cosmetics, animal health (aquaculture) and personal home care products.

Long-term (2020-2030) challenges include the sustainable harvesting of marine bioresources, including algae; developing offshore and land based aquaculture and next generation refining of marine biomass, including multi-stream refining and integrated processing of mixed feed-stock.



Credit: Alex Mustard

A blue light fluorescence photo of Jewel anemones *Corynactis viridis*, English Channel, UK.

[2] www.marinebiotech.eu/first-transnational-call

Product innovation and differentiation

A range of bioactive compounds extracted from marine organisms are already of great interest to the medical sector, displaying anti-tumor, anti-inflammatory, analgesic, immunomodulation, anti-allergy, and anti-viral properties. Some have already been commercialized and are widely used to treat various cancers and in pain relief. Next generation marine biotechnology is set to broaden derived products and end-use areas. On-going novel research and innovation includes the commercial farming of coral for bone grafting and the production of biodegradable plastic from dried shrimp shells.

The continued generation of fundamental knowledge of marine organisms' chemical composition, life cycle and biogeography can drive new product innovation. For example, Jellagen Pty Ltd[3], a commercial Med-Tech business, manufactures next generation collagen products sourced from Jellyfish for medical applications. Products include 2D and 3D cell culture and medical devices for clinical settings, offering new approaches to wound management and tissue engineering.

Long-term (2020-2030) challenges include developing customized diets, integrated food production also from new species; and developing biological indicators and sensors by maximizing the potential of synthetic biology to develop novel biological systems and processes.

Credit: Jellagen Pty Ltd

Jellyfish *Rhizostoma pulmo* in UK waters, a source of collagen for next generation medical applications.

[3] www.jellagen.co.uk

Enabling technologies and infrastructures

Marine biotechnology relies upon a wide range of scientific disciplines, distributed infrastructures and analytical tools. Integrating expertise and enhancing access to enabling facilities is crucial in furthering its development. Rapid and extensive innovation in the biosciences is enhancing the marine biotechnology toolbox. The widespread adoption of high throughput screening and "-omics" technologies is accelerating the search for novel biomaterials. The analytical tool-kit includes an integration of the -omics technologies and infrastructures making full use of the latest developments in bioinformatics.

Projects such as the ESFRI European Marine Biological Research Centre (EMBRC)[4], H2020 European Marine Biological Research Infrastructure Cluster (EMBRIC)[5] and parts of the ELIXIR[6] distributed infrastructure for life science information in Europe are starting to enhance trans-national access to key infrastructures and facilities across scientific disciplines. Several European initiatives exist to advance graduate training in marine biotechnology such as the Erasmus Mundus postgraduate programmes and the European Commission funded Blue Career projects[7]. However, a more coordinated approach to developing and communicating career pathways in blue biotechnology is required to attract graduates with the required knowledge, skills and competencies.

Long-term (2020-2030) challenges include the development of next generation sampling, anlaysis and screening; the creation of trans-disciplinary self-sustained marine biotechnology research and innovation networks; developing the marine biotechnology tool box, offering industrial access to enabling technologies and facilitating the integration of expertise; and the dissemination of knowledge about marine bioresources, research capabilities, equipment and facilities through enhancing marine knowledge portals; enhancing marine graduate training to ensure a suitably skilled workforce to meet the expected growth of marine biotechnology related jobs.

Policy support and stimulation

Marine biotechnology depends upon access to marine organisms, collectively termed marine genetic resources (MGR). Strong supportive policies relating to governance, regulation and stimulation of sustainable utilization of marine bioresources establish the environment for societal value creation. Engagement of marine scientists, conservationnists and biotechnologists when developing marine governance is crucial, particularly for a broad dialogue to achieve input concerning access to and ownership of biological resources from marine areas.

Marine biotechnology is a knowledge intensive activity and multidisciplinary exchanges and collaborations are vital to stimulate investment and innovation. The ERA-MBT project engages with stakeholders from industry (including SMEs), academia, the European Commission and policy makers to stimulate technology and knowledge transfer on state-of-the-art developments and strategy. The European Commission Blue Economy Business and Science Forum also offers a forum for interconnecting academia with industry. The recently launched Bioeconomy Knowledge Centre of the European Commission will also enable greater sharing of information about biotechnologies, making knowledge available for policy makers and stakeholders. There remains a need to further improve policy awareness and literacy on marine biotechnology enabled opportunities and to move towards dedicated funding schemes led by industry.

Long-term (2020-2030) challenges include the development of EU agreements on access to marine bioresources; implementing Access Benefit Sharing; and common licensing and use of marine bioresources. Funding challenges to develop the bioeconomy include the creation of dedicated public-private partnerships (PPPs) where marine biotechnology is recognized as an enabler of enterprise activity.

Credit: Biological Station, Roscoff, France

Crystallography Platform for crystallization of biological macromolecules and molecular modelling.

Credit: Vivian Hertz

Investment in marine graduate training and engaging with diverse stakeholders is crucial for innovation in marine biotechnology.

[4] http://www.embrc.eu/
[5] http://www.embric.eu/
[6] https://www.elixir-europe.org/
[7] e.g. A Blue Biotechnology Master for a Blue Career https://ec.europa.eu/easme/en/blue-biotechnology-master-blue-career

The way forward – key action areas

Globally, marine biotechnology is rapidly developing as a powerful enabler contributing to the broader bioeconomy and contributes to multiple United Nations Sustainable Development Goals (SDGs) including aspects of sustainable food production systems, regulating the harvesting of marine bioresources and ending overfishing. In Europe, marine biotechnology remains a key enabler advancing Blue Growth (EC 2014, 2017). The ERA-MBT roadmap (Hurst *et al.*, 2016) provides a framework for this to be achieved through marine biotechnology related research and innovation activities up to 2030 that supports Europe's long-term commitment to addressing economic, environmental and societal challenges.

Key action areas to expand the role of marine biotechnology in the broader bioeconomy in a sustainable and ethical manner are outlined below:

- **Integrate expertise and access to infrastructures and e-infrastructures** across marine and life sciences to facilitate access to pilot plants, and transdisciplinary approaches to marine biotechnology;
- **Increase policy awareness and public literacy** of marine biotechnology and the potential of marine biomass as a crucial source of bioactive materials and biotechnology applications that offer solutions to improve human wellbeing;
- **Tailor marine graduate training**, including upskilling pathways and building technician capacity, to meet the trans-disciplinary skill sets required for an attractive career in blue biotechnology;
- **Enhance industry interaction and investment**, including the creation of dedicated public-private partnerships (PPPs) where marine biotechnology is recognized as an enabler of enterprise activity;
- **Expand the exploration of our seas and ocean** as a source of novel organisms and bioactive compounds underpinning marine biotechnology;
- **Strengthen the use and development of new, advanced methods** in the -omics toolbox integrated with metagenomics and bioinformatics;
- **Further engage marine scientists and biotechnologists in ocean governance** development and implementation to ensure awareness and co-design of regulations and legislation for equitable sharing whilst promoting the sustainable use and conservation of marine resources in dialogue with wider stakeholders.

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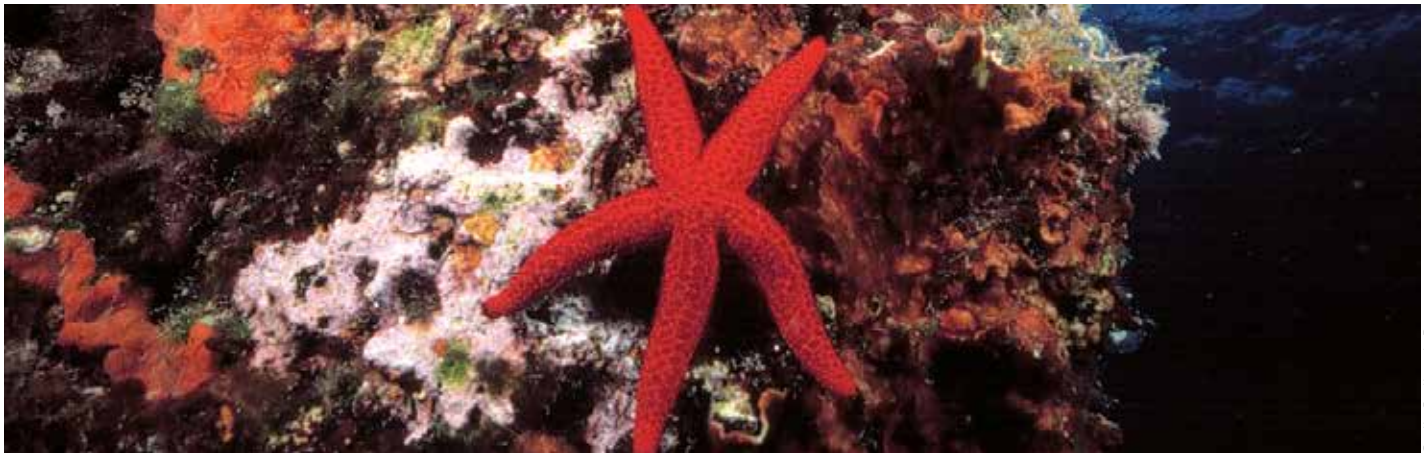

Credit: Ferdinando Boero

Coralligenous formation, a biogenic construction made of bryozoans, sponges, and coralline algae, with the sea star *Echinaster sepositus*, Mediterranean Sea.

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EMB policy briefs provide a high-level summary of the key research needs and priorities on topics of strategic and emerging importance in seas and ocean science from a European perspective. Policy briefs are normally (but not always) summary versions of full EMB position papers, produced by EMB expert working groups.

Cover image: Forest of brown algae (multiple species) present on the rocky coasts of the Atlantic, Channel and North Sea.

Credit: Ifremer /Olivier Dugornay

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