Applied Microbiology International

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EU Ocean Act collaborative response

This document outlines AMI's response to the EU Ocean Act consultation. This document provides extra context to our submission including 1) information on the relevance of marine microbes to this new policy and 2) a more detailed overview of AMI's survey response, as our official survey submission represents the majority view of several individuals. The full range of responses we received can be found below and expand on this.

AMI supporting document

Marine microorganisms are a fundamental component of the ocean, and therefore to ocean-related policy. This document underpins marine microbial relevance to several key areas that will be covered in the EU Ocean Pact, illustrating why it must be considered and incorporated into this new legislation, and additionally provides some specific recommendations on how to do so.

This document also expands on AMI's survey responses and the full range of views it represents, as several AMI members contributed to this coordinated response.

1. **The relevance of marine microbes to the policy and its cross-cutting themes**
   This section highlights how microbes underpin ocean health and therefore are integral to this new policy, requiring explicit recognition.

Climate change

Marine microorganisms are fundamental to the ocean's role in regulating the Earth's climate. They drive many of the biological and chemical processes that determine how carbon moves through marine ecosystems as well as between the ocean and the atmosphere. Marine microorganisms, including but not limited to phytoplankton, bacteria, and archaea, are responsible for recycling approximately half of global primary production. As part of the biological carbon pump (BCP), phytoplankton remove carbon dioxide from the atmosphere through photosynthesis, and convert it into organic matter, with a fraction of this carbon exported to deeper waters and less than 1% of it stored through sedimentation. Complementary to this, microorganisms, including viruses, drive the microbial carbon pump (MCP), a process through which microbial metabolism transforms degradable organic matter into refractory dissolved organic matter that can persist in the water column for centuries to millennia.

Microorganisms also regulate the cycling of key climate-relevant elements other than carbon, including nitrogen, phosphorous and iron. Through these processes, marine

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microbes can influence greenhouse gas production and consumption, nutrient availability, and the overall capacity of the ocean to act as a climate regulator. As ocean conditions change in response to warming, acidification, deoxygenation, and other anthropogenic drivers, microbial communities are expected to respond rapidly due to their high turnover rates, with potential consequences for carbon sequestration and ecosystem functioning.

Bressac, M., *et al.* Decoding drivers of carbon flux attenuation in the oceanic biological pump. *Nature* 633, 587–593 (2024). https://doi.org/10.1038/s41586-024-07850-x

Jiao, N., *et al.* The microbial carbon pump and climate change. *Nat Rev Microbiol* 22, 408–419 (2024). https://doi.org/10.1038/s41579-024-01018-0

Moran, M.A., *et al.* Microbial metabolites in the marine carbon cycle. Nat Microbiol 7, 508–523 (2022). https://doi.org/10.1038/s41564-022-01090-3

Sunagawa, S., *et al.*, Structure and function of the global ocean microbiome. *Science* 348,1261359 (2015). https://doi.org/10.1126/science.1261359

Ecosystem functioning and restoration

Microbes also play an essential role in ecosystem functioning and restoration. Coral reefs provide a particularly relevant example as they are under imminent threat from ocean warming, with more and more global mass bleaching events driving them to extinction. Corals do not live in isolation but as so-called ‘holobionts’, living in close association with diverse communities of bacteria, archaea, fungi, protists, and symbiotic algae (all microorganisms). These microbial partners contribute to nutrient acquisition, pathogen defence, and host resilience, helping corals cope with environmental change and rising temperatures.

As coral reefs face increasing pressures from climate change, pollution, and diseases, there is growing interest in leveraging microbes for coral restoration. The Beneficial Microorganisms for Corals (BMC) concept proposes the use of naturally occurring microbial partners to enhance coral health, resilience, and recovery. Experimental studies have demonstrated that selected microbial consortia can improve coral response to thermal stress and disease, highlighting the potential of microbiome-based interventions for ecosystem restoration. Recognising microbes as integral components of ecosystem function can improve restoration outcomes and help ensure that conservation efforts support not only the recovery of species and habitats but also the ecological and microbial processes upon which they depend.

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Peixoto, RS, *et al.,* Beneficial Microorganisms for Corals (BMC): Proposed Mechanisms for Coral Health and Resilience. *Front. Microbiol.* 8:341 (2017). https://doi.org/10.3389/fmicb.2017.00341

Blue economy, biotechnology and bioeconomy

Marine microbes represent an underexplored source of biological innovation in the ocean. Microbial communities associated with marine hosts and habitats contain an enormous reservoir of genetic and biochemical diversity with significant potential for biotechnology, medicine, and industry. Marine host-associated microbiomes, including those associated with corals, sponges, and other invertebrates, are particularly promising sources of novel enzymes, bioactive compounds, and biosynthetic pathways. Many of these may have pharmaceutical applications. One notable example is ecteinascidin 743 (trabectedin), an anticancer compound produced by a bacterial symbiont of a marine tunicate that became the first marine derived anticancer drug approved in Europe.

Recent large-scale genomic surveys have demonstrated that marine microbiomes contain extensive unexplored biosynthetic diversity, highlighting the ocean as a major reservoir of future innovation and revealing that the vast majority of marine microbial diversity remains undescribed. More than 99% of the microbial genomes identified in coral reefs across the Pacific Ocean lacked prior genomic representation, illustrating how much of the ocean's biotechnological potential remains unexplored. Marine host-microbe associations remain the single most productive frontier in natural product drug discovery to date. As the EU seeks to strengthen its blue bioeconomy, marine microorganisms should be recognised as strategic biological resources. Protecting marine biodiversity is not only a conservation objective but also an investment in future innovation, helping to preserve genetic resources that may contribute to new medicines, industrial enzymes, biomaterials, and other biotechnology applications.

Chen, J., *et al.* Global marine microbial diversity and its potential in bioprospecting. *Nature* 633, 371–379 (2024). https://doi.org/10.1038/s41586-024-07891-2

Rinehart, K. L., *et al*. Ecteinascidins 729, 743, 745, 759A, 759B, and 770: Potent Antitumor Agents from the Caribbean Tunicate Ecteinascidia Turbinata. *The Journal of Organic Chemistry* 55 (15): 4512–15 (1990). https://doi.org/10.1021/jo00302a007

Wiederkehr, F., *et al.* Coral microbiomes as reservoirs of unknown genomic and biosynthetic diversity. *Nature* 652, 686–693 (2026). https://doi.org/10.1038/s41586-026-10159-6

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2. **How the current policy could be strengthened to better recognise the relevance of marine microbes**

   This section analyses some of the key definitions/terminology currently used in EU ocean policy and highlights how it can be strengthened to ensure marine microbes are sufficiently included.

Definition of 'Good Environmental Status'

The qualitative descriptors EU countries are asked to choose from and use to determine "good environmental status" in their respective waters already encompass microorganisms, e.g., as part of the marine food-web; however, explicit consideration and mention of microbial diversity (both taxonomic and functional diversity), community composition, and microbial ecosystem services within the existing descriptors would improve assessments of GES.

Regarding the characteristics currently listed as being indicative of GES, the existing characteristics are broadly sufficient to encompass free-living microbial communities in seabed and water-column habitats. However, they do not explicitly recognise host-associated microbiomes, despite growing evidence that these communities are integral components of the health, functioning, and resilience of corals, sponges, seagrasses, shellfish, fish, and other marine organisms. Adding these to the "Biological features" section could look like this: "information on host-associated microbial communities where relevant to the functioning, health, and resilience of protected species, habitats, or ecosystems".

On the other hand, regarding the 'pressures & impacts' currently listed as potentially affecting GES, the present list of pressures already encompasses a variety of factors that have been demonstrated to alter microbial communities, including nutrient enrichments, contaminants, physical disturbance, and changes in environmental conditions, which is encouraging to see.

Definition of 'ecosystem-based approach'

Microorganisms are not yet sufficiently recognised in current interpretations of ecosystem-based management. While they are implicitly included through concepts such as biodiversity, food webs, and ecosystem functioning, management and monitoring frameworks remain largely focused on visible organisms, habitats, and ecological interactions. This overlooks the fact that microorganisms drive many of the processes that ecosystem-based approaches seek to protect, including nutrient cycling, carbon sequestration, primary productivity, decomposition, and the maintenance of healthy host-associated communities. Microbial communities also respond rapidly to environmental change and can provide valuable information on ecosystem condition, resilience, and recovery.

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Current ecosystem-based management largely treats organisms as independent entities; however, many marine organisms such as sponges, corals, seagrasses, and fish, function as holobionts whose health, nutrition, disease resistance, and resilience depend on associated microbial communities. Recognising these host-associations would help improve ecosystem-based management and the protection of ecosystem processes that are the base for marine biodiversity and ecosystem services.

Explicit consideration of microorganisms would strengthen ecosystem-based management by providing a more complete representation of ecosystem structure and function. This does not require the creation of separate management frameworks for microbes. Rather, microbial communities should be recognised as integral components of marine ecosystems and incorporated into ecosystem assessments, monitoring programmes, and evaluations of ecosystem functioning.

Definition of 'biodiversity'

The definitions of biodiversity used by the EU and the Convention on Biological Diversity are broad enough to include microorganisms. However, in practice, biodiversity assessments, monitoring programmes, conservation targets, and policy discussions tend to focus on plants and animals. As a result, microbial diversity is often underrepresented.

Clearer recognition of microbial biodiversity would provide a more complete understanding of ecosystem condition, resilience, and responses to environmental change. Advances in environmental genomics and DNA sequencing now make microbial biodiversity measurable at scales relevant for environmental assessment and monitoring.

Microbial biodiversity should not be characterised solely through taxonomic diversity, simply counting how many species are there. As microorganisms are relevant to many ecosystem processes, consideration should also be given to functional diversity and the ecological roles performed by microbial communities, as taxonomic and functional diversity are not necessarily coupled. Incorporating these aspects would provide a more comprehensive and ecologically meaningful representation of marine biodiversity.

Full range of survey responses:

This section expands on AMI's survey response, showing the full range of answers from the group of microbiological experts who contributed to AMI's coordinated response.

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How familiar are you with maritime spatial planning? **Answers ranged from 'somewhat familiar' (x3 respondents) to 'slightly familiar' (x3 respondents).**

Were you aware that the EU has a law to plan maritime space called the Maritime Spatial Planning Directive (MSPD)? **Answers varied from 'No, I was not aware of it' (x1 respondent) to 'I have heard of it, but don't know what it does (x1) to 'Yes, but I only have a general understanding of it' (x2) to 'Yes, and I am familiar with its objectives and requirements' (x1).**

The Maritime Spatial Planning Directive, adopted by the EU in 2014, requires Member States to develop and implement maritime spatial plans for their marine waters by 2021. In your opinion, what impact have these plans had on:

- The contribution to the growth of maritime economies **– answers ranged from neutral (x1) to positive (x4) to very positive (x1).**

- The sustainable use of marine resources **– answers ranged from negative (x1) to neutral (x2) to positive (x2) and very positive (x1).**

- The planning of existing and future uses of the marine waters **– answers ranged from neutral (x1) to positive (x3) to very positive (x2).**

- The protection of the marine environment **– answers ranged from neutral (x2) to positive (x1) to very positive (x3).**

- The contribution to increasing knowledge in maritime areas **– answers ranged from positive (x5) to very positive (x1).**

- Contribution to achieving Good Environmental Status under the MSFD **– answers ranged from neutral (x3) to positive (x2) to very positive (x1).**

- Other **– answers ranged from don't know (x2) to positive (x1) to negative (x1) with the remaining respondents opting out of the question. In the comments section for those who selected 'Other' one respondent put 'negative impact on socio-cultural communities'.**

13**.** To what extent do you agree with this statement: Stronger EU rules are necessary to help use the space more efficiently **– answers ranged from neutral (x1) to agree (x3) to strongly agree (x2)**

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14. To what extent do you agree with this statement: The protection of marine ecosystem should be a priority in maritime planning decisions **– answers ranged from agree (x2) to strongly agree (x4)**

15. To what extent do you agree with this statement: Governments should be required to trace and share ocean data used to improve decision-making on EU national, regional and local levels **– answers ranged from agree (x3) to strongly agree (x3)**

16. To what extent do you agree with this statement: The EU should ensure that ocean policies support both environmental protection and economic competitiveness **– answers ranged from agree (x2) to strongly agree (x4)**

17.To what extent do you agree with this statement: A new EU Ocean governance framework should be created to better plan and utilize maritime space **– answers ranged from neutral (x1) to agree (x2) to strongly agree (x3)**

18. To what extent do you agree with this statement: Ocean planning should systematically address climate change impacts on coasts, seas and oceans **– answers ranged from agree (x4) to strongly agree (x2)**

19. How important is cooperation between neighbouring countries for managing shared sea areas? **All respondents put very important as their answer (x6).**

20. The MSPD, as currently implemented, is effective in achieving its objectives **– answers ranged from disagree (x1) to neutral (x3) to agree (x2).**

21.Which objectives should the revision of the MSPD prioritise? **Respondents chose the following objectives:**

- Making maritime spatial planning ecosystem based meaning that maritime activities need to operate within the ecological boundaries of marine ecosystems **(x5 respondents)**
- Making climate smart, meaning that climate mitigation and adaptation are integrated into planning **(x5 respondents)**
- Integration of EU's Biodiversity objectives and Marine Protected Areas (MPAs) **(x4 respondents)**
- Better co-existence/multi-use **(x1 respondent)**
- Better monitoring of how maritime spatial planning contributes to achieving environmental, social and economic objectives **(x3 respondents)**
- Advancing ocean research, knowledge, skills and innovation **(x2 respondents)**
- Boosting sustainable competitiveness **(x1 respondent)**
- Improved stakeholder cooperation and engagement **(x1 respondent)**
- Increase cross-sectoral coordination at national administration level **(x1 respondent)**

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- Digital data-sharing and centralised monitoring data **(x1 respondent)**

Maritime spatial plans support the achievement of good environmental status, of EU seas and ocean, as defined under the Marine Strategy Framework Directive – **answers ranged from disagree (x1) to neutral (x1) to agree (x4).**

To what extent do you believe that referencing the relevant EU Ocean-related targets (for example in the European Ocean Pact Communication Annex) in the Ocean Act will facilitate their coherent and effective implementation? **Answers ranged from effective (x5) to extremely effective (x1). Comments on this were included in the submission and were from 2 different respondents:**

> **Based on current European Union policy priorities, particularly the European Green Deal, the Biodiversity Strategy for 2030, and the push for offshore renewable energy. The revision of the Maritime Spatial Planning Directive (MSPD) should prioritize objectives that balance rapid economic development with ecological limits in my opinion.**
>
> **Referencing existing EU ocean-related targets in the Ocean Act would likely improve coherence and policy integration by providing a common framework for implementation across sectors and Member States. However, references to existing targets alone are unlikely to be sufficient; the Act should also establish clear mechanisms for monitoring, coordination, and accountability to ensure that existing targets translate into measurable outcomes for marine ecosystems and sustainable ocean use.**

To what extent do you think that multi-use of maritime space (for example combining energy, transport and nature protection) should be encouraged where possible? **Answers ranged from neutral (x1) to in favour (x4) to strongly in favour (x1).**

To what extent do you agree with the following statement: For planning maritime activities, cumulative environmental impacts of human activities should be considered. **Answers ranged from often (x1) to always (x5).**

To what extent do you agree that the revised MSP Directive should require security considerations to be included in maritime spatial planning? **Answers ranged from don't know (x1) to agree (x2) to strongly agree (x3).**

To what extent do you agree with the following statement: Minimum stakeholder engagement requirements should be established **– answers ranged from neutral (x2) to agree (x3) to strongly agree (x1).**

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To what extent do you agree with the following statement: Clear guidance on stakeholder engagement should be established **– answers ranged from agree (x2) to strongly agree (x4).**

To what extent do you agree with the following statement: Public access to ocean information should be improved to increase transparency. **Answers ranged from neutral (x1) to strongly agree (x5).**

To what extent do you agree with the following statement: The competent authority should document public consultations and provide feedback on how comments were addressed **– answers ranged from agree (x2) to strongly agree (x4).**

To what extent do you agree with the following statement: Stronger participation in ocean planning decisions from local communities and authorities should be encouraged **– answers ranged from agree (x2) to strongly agree (x4).**

To what extent do you agree with the following statement: Member States should be required to share the data used for maritime spatial planning to improve decision-making **– answers ranged from agree (x2) to strongly agree (x4).**

To what extent do you agree with the following statement: Centralised data across EU Member States would help improve national and regional maritime spatial planning **– answers ranged from agree (x4) to strongly agree (x2).**

To what extent do you agree with the following statement: The introduction of ocean observation governance system should help to avoid fragmented ocean observation across and within Member States **– answers ranged from agree (x3) to strongly agree (x3).**

What is your assessment of the current European ocean observation system? **Respondents selected the following answers:**

- Would significantly benefit from improved governance at national level **(x4 respondents)**
- Would significantly benefit from improved governance at regional level (sea basin) **(x4 respondents)**
- Would significantly benefit from improved governance at EU level **(x3 respondents)**
- Would significantly benefit from improved governance at EU level to contribute to the international level **(x4 respondents)**
- Would significantly benefit from the development of efficient IT tools and mechanisms for better coordinating in-situ ocean campaign plans **(x5 respondents)**

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Should a European Forum on Ocean Observation be established to enhance governance (presumably composed of Member States and the European Commission), it should - **respondents selected the following answers:**

- Provide advice to the European Commission **(x5 respondents)**
- Provide advice to Member States **(x6 respondents)**
- Be able to take decision with an impact at EU level (e.g. using common standards, tools for collaboration) **(x4 respondents)**
- Be able to take decision with an impact on Member Sates (e.g. adapting national strategies following Forum recommendations) **(x3 respondents)**

Contributors

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About Applied Microbiology International

Applied Microbiology International is a charitable, membership-based organisation for those interested in or working in microbiology.

We aim to demonstrate how microbiology can help address global challenges, and our policy work focuses on bringing microbiological evidence and expertise into policy conversations. AMI is solving some of the world's greatest challenges by bringing the applied microbiology community together, across borders and disciplines, to enable meaningful collaboration that delivers scientific impact. With a strong focus on influencing international policy, we are organised around six core UN Sustainable Development Goals and encourage partnership between academia and industry to increase our impact.