INTERNATIONAL SYMPOSIUM

Transformative Ocean Science

Strategic Reflection Document

“Priorities for European Ocean Sciences”

A science-based roadmap for the Transformative Ocean Science symposium 2026

LIST OF TOPICS

1. Introduction

This document serves as a working reference for the Transformative Ocean Science Symposium 2026. It is also intended to provide the foundation for the policy brief produced during the Symposium and to be delivered to the European Commission and national/international decision-makers.

Rapid geopolitical shifts, transformative technological advances, escalating environmental crises, the urgent need for sustainable development and food system security, the threat of future pandemics, and the demand for new materials and advanced technologies in strategic sectors are among the key challenges shaping an uncertain future. Addressing these challenges is imperative. The future of Europe will, in part, depend on prioritising marine scientific research, which underpins human health and well-being, social development, and sustainable and equitable economic growth and access to resources.

Addressing many of the above challenges hinges on the careful and ethical use of marine resources. This, in turn, requires a more thorough understanding of how ocean dynamics are shaped by both natural bio-geophysical forces and human activities.

Achieving this requires strong collaboration across different scientific disciplines and sectors, including inter- and transdisciplinarity approaches supported by advanced research capacities. Prioritising knowledge development must therefore become central to future European research and innovation strategies. In this context, concepts such as transdisciplinarity, research and innovation, research excellence and valorisation of knowledge must be at the core of future European research policies.
These guiding principles should inspire and be translated into coherent and integrated policy instruments.

Attracting global talent to value socio-environmental sciences with a diverse and inclusive view and fostering research excellence also in less research-intensive regions can facilitate this.

Bridging the traditional divide between fundamental and applied research is also essential, as this separation hinders the creation of a seamless knowledge value chain and limits the potential for innovation. Efficient pathways must be developed to bring research outcomes to market, supported by pre-competitive scale-up tools and synergistic collaboration among researchers, technology transfer experts, and capital holders. While these goals are embedded in existing EU strategies, their implementation remains uneven and requires stronger focus, particularly in marine technology development and validation schemes.

Advancing knowledge of the ocean as the largest and least explored ecosystem on the planet is also crucial. The ocean plays a fundamental role in sustaining life on Earth, providing critical ecosystem services such as nutrient cycling, CO_2 absorption, and—above all—regulating the global climate. Its extraordinary diversity of habitats supports unique organisms that have evolved remarkable adaptations to thrive under extreme and variable conditions. Yet, the extent to which cumulative impacts, directly and indirectly caused by human activities, are compromising the resilience of these ecosystems remains poorly understood. Persistent knowledge gaps limit our ability to model, predict, and manage marine system dynamics, underscoring the need for targeted and sustained research programmes.

Across Europe, numerous Institutions and bodies such as the European Marine Board (EMB), the Sustainable Blue Economy Partnership (SBEP), JPI Oceans with its recently launched "JPI Oceans Strategy 2026–2030" and others, are actively proposing visions for the future development of marine science, particularly in preparation of the strategic plan of the 10th Framework Programme (FP10), which will shape European research and innovation funding from 2028 onwards.

2. Priorities for European Ocean Sciences at the time of the European Ocean Pact

This document contributes to a collective ongoing effort to define the future of ocean research and innovation strategy in Europe. It reflects the outcomes of extensive discussions among Directors of European research centres, Heads of marine science departments, and experts from diverse disciplines within ocean sciences who recently met to share visions, concerns, and strategies for a coordinated action and collective impact. Rather than establishing a new institutional body, this initiative seeks to build a flexible mission-oriented research alliance focused on shared values and urgent priorities.

Current approaches to marine science need to place greater emphasis on anticipating emerging challenges and fostering bold forward-looking, innovative visions. Alongside rethinking traditional methods, it is crucial to strengthen collaboration, build trust, and create connections between marine institutions and fora. These efforts not only reinforce existing structures but also lay the foundation for a European alliance in marine science, capable of inspiring and supporting the next generation of researchers and extending its impact even beyond European borders.

Addressing the challenges of 21st-century ocean science demands new training models integrating deeper connections across diverse knowledge systems, and ongoing reflection on the ethical and social implications of research. Through this integrated approach, ocean science can more effectively advance sustainability, inclusive governance, and human and planetary well-being, reinforcing its role as a guiding force for society.

This document presents a forward-looking vision for European ocean sciences, developed through European and transatlantic collaboration, and relevant to the broader international community. Anchored in the evolving framework of *The European Ocean Pact* and the EU's *Research and Innovation* priorities, it reflects two central pillars of a policy cycle: shaping scientific and technological innovation and securing long-term financial support.

This strategic vision, also aligned with the outcomes and recommendations of the *2025 One Ocean Science Congress in Nice*, builds on the foundational values of the *Treaty on European Union (TEU*), which recognises healthy ecosystems as central to human well-being, and is further supported by the ambitions of the *European Green Deal*. While rooted in European strategic priorities reported in the recent document[1], the vision was developed in close collaboration with European and U.S. scientific leaders and aims to inform and inspire broader international dialogue on the future of ocean science.

[1] *On establishing the Specific Programme implementing Horizon Europe - the Framework Programme for Research and Innovation for the period 2028-2034, laying down their rules for participation and dissemination under that Programme, and repealing Decision (EU) 2021/764*

3. A Perspective on the European Ocean Pact

The *European Ocean Pact*[2] marks a significant effort to strengthen governance at the EU level. The Pact recognises the ocean as a strategic, ecological, and economic pillar of Europe's future and lays the groundwork for a potential European Ocean Union.

The Pact makes an important attempt to integrate environmental sustainability, economic competitiveness, and social equity. The Ocean Pact adopts a holistic, cross-cutting approach to ocean governance, recognising the ocean as an interconnected system rather than a collection of sectoral competences. By prioritising the protection and restoration of marine ecosystems as its first pillar, it places ecological sustainability at the core of the EU's oceans and seas agenda and reflects the growing recognition that environmental health underpins human health and well-being and socio-economic prosperity.

The future Ocean Act, scheduled for 2027 should serve as a foundation, offering a coherent legal and policy framework that consolidates Europe's ocean commitments into a single strategic instrument. By harmonising objectives across key EU instruments and embedding cross-cutting principles—such as the ecosystem-based approach and the use of best available science—the Act would strengthen coherence, accountability, and effectiveness in ocean governance. This alignment is essential to better reconcile the environmental ambitions of the MSFD[3] with the spatial and economic objectives of the MSPD[4].

4. Challenges and Opportunities

Over the past two decades, the EU has made major contributions to ocean sciences through large-scale research investments and collaborative frameworks. Successive Framework Programmes including Horizon 2020, Horizon Europe, and related funding streams have enabled the development of cutting-edge marine research infrastructures as well as the *Mission: Restore our Ocean and Waters by 2030*. These efforts have generated and advanced knowledge of ocean-climate interactions, supported innovation in observation technologies, and strengthened European scientific leadership. However, the pace and scale of global ocean change, driven by climate change, habitat disruption, biodiversity loss, and intensifying geopolitical competition, continue to outstrip our ability to respond. As underscored by The Copernicus State of the Ocean Report[5], no ocean is spared from the triple planetary crisis of climate change, biodiversity loss, and pollution.

Despite progress, European ocean science still faces key structural and strategic limitations, including:

- Fragmentation across disciplines, sectors, institutions, funding mechanisms, and governance levels (from local to global) and national agendas, remains a key challenge. For

[2] COM/2025/281 Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the committee of the regions. The European ocean pact (2025)
[3] EC (2008) Directive 2008/56/EC of the European Parliament and of the Council establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive), Off. J. Eur. Union L164 (2008), 19–40.
[4] EU (2014) Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, Off. J. Eur. Union L257 (2014) 135–145.
[5] Copernicus (2025), Ocean State Report 2025.

example, limited interoperability between national and EU-level marine data platforms often results in duplication and underutilisation of valuable resources.
- Gaps in long-term observation and data continuity and data organization (existence of multiple different data portals, such as EMODnet, Copernicus, national databases).
- Weak integration between science, research, technology development, and policy implementation.
- Insufficient ethical reflection on marine resource management and stakeholder inclusion.
- Fragile connections with private sectors, and limited use of financial instruments to support research, innovation and technology transfer. As a consequence, promising blue technologies often fail to reach the market, also due to regulatory bottlenecks and lack of coherent regulatory frameworks (especially for emerging, discouraging private investment).

To consolidate and extend Europe's leadership in ocean science, and to enhance its capacity for meaningful impact, the following strategic priorities are proposed.

4.1 Ethical and Interdisciplinary/Transdisciplinary Marine Research

Strengthening the ethical foundations of ocean science is essential to ensure that research serves the public good and responds to complex social-ecological systems.

This includes embedding ethics into the design, funding, and implementation of research projects by incorporating ethics reviews, early community engagement, transparency, risk monitoring, fair resource use, and the protection of shared knowledge, all the while actively including underrepresented voices and fostering inclusive stakeholder and public engagement.

To close the gap between ethical principles and research practice, we propose that future programmes explicitly promote ethical and sustainable behaviours in ocean use. Two critical areas of focus are:

- Fair governance of marine common goods, ensuring long-term access and stewardship for all, rather than exploitation by a privileged few; and
- Sustainable blue economy pathways, combining responsible use of resources (renewable and non-renewable) with socio-economic development that respects ecosystem boundaries and health.

While stakeholder engagement is a formal requirement in many projects, we argue that it must go further by embedding it into the ethical foundations of research, emphasizing co-design, co-accountability, and long-term commitment to inclusive and just ocean science.

A more integrated approach is also needed to bridge the natural and social sciences; although steps have been taken, these domains remain largely disconnected. Ethical frameworks and participatory processes are increasingly crucial in areas such as deep-sea exploration, where scientific uncertainty and global governance gaps raise major societal questions. By promoting transdisciplinary research, Europe can better address challenges at the intersection of science, society, the private sector and the marine environment. To overcome fragmentation, marine research must integrate natural and human sciences, recognizing the interplay between scientific, political, economic, and moral dimensions. To this end, we propose targeted strategies, such as joint funding calls, cross-sectoral research hubs, and participatory foresight exercises, to support inter- and transdisciplinary approaches that drive concrete actions and foster meaningful collaboration

between research and innovation communities at both global and local levels. Finally, the human sciences and ethics are critical in shaping, now more than ever, the responsible development and use of emerging technologies also in ocean science, such as invasive observation tools and Artificial Intelligence, by addressing their societal implications, promoting transparency, and guiding inclusive governance.

4.2 Science Diplomacy

Europe's model of ocean governance, grounded in scientific excellence and coupled with legal instruments such as the *Marine Strategy Framework Directive (MSFD), the Maritime Spatial Planning Directive (MSPD)*, the EU Data Collection Framework (DCF) collecting fisheries data to support the Common Fisheries Policy, as well as the recently adopted *Nature Restoration Law,* sets a global benchmark. In a world facing growing climate and geopolitical tensions, ocean science must be promoted as a strategic asset for international cooperation and conflict prevention. As climate change, biodiversity loss, and competition over ocean resources intensify, the ocean is becoming an increasingly contested geopolitical space. The annual market value of marine and coastal resources and industries is estimated at USD 2.5–3 trillion globally, and is expected to double by 2030 (OECD, 2016; UNCTAD, 2023; WWF, 2015).

The EU has a vital role to play in promoting ocean science as a diplomatic tool, fostering long-term strategic partnerships with key global actors, including the United States, Canada, China, Japan, Australia, South America and Africa. Collaborative research on transboundary ecosystems, polar region access, and high seas governance, particularly through long-term joint global programmes such as *Future Earth* (a global sustainability science initiative building on the IGBP - International Geosphere-Biosphere Programme) and the *UN Decade of Ocean Science* 2021–2030 (a UN-led effort to support ocean science for sustainable development), or the All Atlantic Ocean Research and Innovation Alliance offers opportunities to advance science-informed diplomacy and reinforce EU leadership in global ocean affairs. To fully realise this potential, enduring mechanisms are needed to ensure that scientific expertise and place-based knowledge systematically inform ocean-related policy making at all levels.

4.3 Enhanced Research Infrastructures (RIs)

European marine research infrastructures, such as *EMSO, Euro-Argo*, and *Danubius* have significantly advanced the continent's capacity for ocean observation, data collection and management. However, barriers to access, fragmented data systems, lack of cross-domain interoperability, presence of overlaps, insufficient synergy with public policies and industry sectors, and misaligned funding streams continue to limit their full potential. A strategic reassessment is needed to better integrate existing marine ESFRI and design new ones where appropriate.

This includes promoting transnational access to state-of-the-art equipment, unifying data management across platforms, and, most importantly, ensuring sustained cooperation and structured interfaces with ongoing marine research initiatives. This goes beyond simply increasing observational capacity: it calls for more coordinated, accessible, and mission-driven research infrastructure systems. Aligning EU and national investments will help enhance impact, coordination, and the long-term sustainability of Europe's marine RI landscape.

As other global actors retreat from long-term observational efforts, Europe has both the opportunity and responsibility to maintain and expand its marine RIs as a global public good. Optimizing these

assets is not only a regional priority and a pathway for reinforcing Europe's leadership in international marine cooperation, but also a contribution to global ocean stewardship.

4.4 Next-Generation Training

Europe's ability to lead in ocean sciences and ocean-facing sectors depends on empowering a new generation of researchers with strong inter- and transdisciplinary skills, international cooperation experience, and the capacity to navigate complex science-policy-society interfaces. In addition, they must be prepared to engage with emerging technologies such as nanotechnology, nanorobotics and artificial intelligence.

New paradigms for 21st-century ocean science demand innovative training approaches, deeper connections across diverse knowledge areas, and critical reflection on the ethical and social implications of research. Only through this integrated perspective can ocean science meaningfully contribute to sustainability, inclusive governance, and, more broadly, to human and planetary well-being, reaffirming its role of science as a beacon for society.

We propose launching co-supervised, international training programmes, such as joint PhDs or structured exchange schemes, alongside existing MSCA actions. These should be supported by co-funding mechanisms that strengthen collaboration across institutions, disciplines, and ocean basins.

Adaptation skills to rapidly evolving scientific methods should be a key competency for the next generation of marine scientists. Establishing institutional links between leading marine research centres in Europe, the United States and Asia should be a priority. These links will help create effective transatlantic knowledge bridges and improve ocean science training opportunities for students and early-career researchers. Finally, intergenerational dialogue between experienced professionals and early-career researchers, paired with innovative mentoring and coaching models, will be essential in shaping next generation training programmes.

4.5 Artificial Intelligence in Ocean Sciences

There is an urgent need for a coordinated European alliance on artificial intelligence in ocean science, potentially leading to the establishment of a European Centre for AI in Ocean Science. Such an initiative would consolidate expertise, build strategic capacity, and address societal challenges where AI can deliver transformative impact.

AI is critical for unlocking the value of vast, high-resolution ocean and satellite datasets, enabling new scientific insights, products, and services. Priority applications include:

- assisting automated ecosystem and biodiversity monitoring using satellite imagery, acoustics, omics, and underwater video;
- predictive modelling of oceanographic and climate-driven processes;
- optimisation of observing systems through adaptive autonomy;
- integration of physical, chemical, biological and social datasets to support ecosystem-based management and marine spatial planning;
- sustainable fisheries management, to improve stock predictions, fishing gears design, bycatch reduction and fishing vessel behaviour monitoring (for illegal fishing detection);
- sustainable and restorative aquaculture, to improve precision feeding, resource efficiency, early warning systems for farmed organisms' health and welfare, scenario modelling and water quality forecasting:
- accelerated discovery in marine biotechnology through AI-assisted omics analysis.

AI also offers opportunities to strengthen citizen science by validating and integrating community-generated data, broadening engagement and spatial coverage.

5. Priority Knowledge Areas

5.1 Ocean Health

Ocean ecosystems face escalating pressure from habitat degradation, pollution, biodiversity loss, climate stressors, and resources overexploitation. Addressing these challenges requires coordinated action across maritime spatial planning, protected area management, and blue carbon strategies.

Priority actions include:

- implementing a source-to-sea pollution approach;
- improving understanding of contaminant dynamics, including emerging ones, across trophic webs;
- enhancing coupled physical-biogeochemical modelling;
- applying the precautionary principle;
- strengthening the science-policy interface;
- adopting ecosystem-based management across all ocean uses;
- addressing hidden degradation in poorly observed habitats;
- supporting ecosystem restoration and regeneration.

5.2 Long-Term Monitoring conceptual 'redesign'

The ocean observing system represents a "planetary health monitor" and, as such, must be fully integrated into both scientific frameworks and political agendas. Long-term monitoring must be embedded into strategic planning at both institutional and continental levels, recognizing its foundational role in sustainable ocean governance. To be effective, monitoring systems must employ all available techniques and instruments to meet obligations under key EU marine directives, including the Water Framework Directive (WFD), Marine Strategy Framework Directive (MSFD), the Marine Spatial Planning Directive (MSPD) and the Common Fisheries Policy (CFP). As stated: "Monitoring is not glamorous but it is vital" for regional and national well-being. Despite its importance, current evaluation systems often disincentivise sustained data collection in favour of short-term scientific outputs. This calls for a fundamental shift in how monitoring is valued, funded, and integrated into scientific excellence criteria. At the same time, innovative governance frameworks are needed to demonstrate the societal value of ocean observation, remove regulatory barriers, and promote the long-term continuity, interoperability, and accessibility of data across Member States and research communities.

5.3 Digital Twins of the Ocean (DTO) for resilient marine futures

In terms of technologies, collaborative models and informing policy the Digital Twins of the Ocean (DTO) concept is promising. Our vision is for DTOs to serve as dynamic decision-support tools that integrate continuous stakeholder input with real-time observational data, AI-powered analytics, and high-resolution modelling into a virtual representation of the ocean. When DTOs function as a decision support tool, they can enhance scientific understanding of marine ecosystems and provide dynamic, interactive platforms and applications that support evidence-based decision making. DTOs have the potential to empower regional, local, and managing authorities to effectively implement ocean and water policies, including the ecosystem-based objectives of the MSFD, MSPD, CFP.

Scientists must increasingly co-create and co-develop these tools with stakeholders to ensure that they are usable across governance levels and responsive to evolving policy needs in the context of climate change. The next generation of DTOs should include scenario-building and interactive planning capabilities. This involves coupling physical, ecological, and economic models with resilience assessments and decision-support features. Stakeholder-driven scenarios should be visualised through accessible, GIS-based platforms capable of comparing "what-if" alternatives over time and space.

Risk-based cumulative effects assessments (CEAs) should be embedded within these systems. These assessments must identify policy goals for specific areas, map relevant ecosystem services and model future scenarios, based on land-sea use and climate-related variables. Integrated resilience analysis should show how Ecosystem Service indicators evolve, across different scenarios, supporting planning aligned with environmental thresholds and long-term sustainability. The ultimate goal is to establish a system where planetary boundaries are understood and respected while valuable services of the European Seas are enhanced by creating a safe operating space.

5.4 Deep-Sea Knowledge and Exploration

The deep-sea is the largest and least explored ecosystem on the planet. Scientific exploration of this vast realm involves investigating the physical, chemical and biological conditions beyond the continental shelf. An urgent effort to improve responsible exploration technologies for the deep ocean realm is required to unravel the main features of the deep sea and consider protection and sustainable use of its abiotic and biological resources.
Interconnected processes such as surface stratification, reduced ventilation, deoxygenation, and acidification combine in the so-called "triple threat". Together, they risk altering physical, biological, and biogeochemical processes with profound consequences for biodiversity.

Due to growing demands for resources, many deep-sea environments have become frontiers for exploitation (fishing, rare metal and hydrocarbon extraction, renewable energy, bioprospecting, etc). Fish stocks on continental shelves have declined significantly, and fishing pressure is shifting to mesopelagic depths characterized by particularly vulnerable species. The exploitation of mesopelagic fishes, believed to host 90 % of the fish biomass of the planet, can carry substantial environmental risks related to these populations' role in the oceanic carbon pump. Impacts from human activities at the surface (pollution, litter, noise, etc.) have been increasingly documented, together with mounting evidence of climate change effects. The Mediterranean is also especially exposed to non-indigenous species, some of which become invasive, altering native communities and ecosystem functions.

Extractive activities targeting deep sea minerals such as copper, nickel, manganese, gold, lithium, platinum, and rare earth elements represent a potentially enormous threat to fragile ecosystems. Resources occur in polymetallic nodules, polymetallic sulphides, and cobalt-rich ferromanganese crusts, critical for high-tech and renewable-energy industries. Although still experimental, deep-sea mining is expected to become one of the largest mining operation on the planet. While impacts are uncertain, available evidence points to highly significant risks for deep ecosystems.

Digital Twins of the Ocean must fully integrate the deep-sea domain by combining real-time observational data, AI-powered analytics, and improved high-resolution modelling. This can enhance scientific understanding of deep-sea ecosystems creating dynamic, interactive platforms to support evidence-based decision-making

5.5 Coastal Adaptation and Resilience

Our oceans will be very different by the end of the century. Ensuring resilience in islands, coastal and outermost regions, requires targeted strategies that affect their critical roles in food security and renewable energy provision.

The following should be considered:

- Adaptation: it is not optional as it is the defining challenge of our century.
- Rapid expansion of coastal mega-cities: it requires urgent advances in knowledge and technology to limit the anthropogenic impacts on marine environments.
- Systemic approaches: to be developed to design and implement infrastructure capable of sustainably responding to sea level rise projections over the coming decades.
- Ethical implications of adaptive planning: will necessarily drive diverse national strategies linking physical infrastructure to cultural and ecological resilience.
- Finding existing examples of adaptive management in regional seas: in certain regional seas examples can be leveraged over the next decade to inform strategies in coastal cities.

5.6 Science-based support to MSFD

The EU Marine Strategy Framework Directive (MSFD) promotes a holistic, ecosystem-based approach that views marine environments as complex systems where organisms interact with abiotic conditions and are closely connected to socio-economic systems. The Directive's core consists of 11 descriptors and 57 criteria, guiding the assessment of Good Environmental Status (GES) through specific indicators. Some descriptors focus on anthropogenic pressures, while others address the persistence of ecosystem structure or functioning.

Limited knowledge of marine ecosystem functioning remains a major barrier to the sustainable use of the seas and the protection of marine ecosystem services. The MSFD is one of the initiatives designed to establish criteria for the precautionary exploitation of marine environments, aiming to prevent irreversible changes and, where possible, mitigate or reverse impacts caused by human activities.

Even within the marine environment alone, the interaction of numerous species with each other and their abiotic context creates a complex system with nonlinear dynamics that are difficult to assess. The survival of an organism depends not only on abiotic factors (nutrients, temperature, resources, pollutants, hydrodynamic forces, etc.) or biotic traits (metabolic capacity, tolerance ranges, plasticity, etc.) but also on interactions with other species. Therefore, pressures on a single species cannot be fully understood through univariate analyses of abiotic-biotic relationships alone. Similarly, the local extinction or migration of a species can affect the entire community, requiring an approach that goes beyond simple target-species censuses.

Despite the innovative ecosystem-based vision, MSFD implementation continues to face several challenges. These include regional and national discrepancies in assessment procedures, reliance on semi-quantitative expert-based evaluations, lack of standardized metrics for indicators, unclear terminology and persistent governance and geopolitical barriers and sampling strategies.

Science could and should contribute to revising criteria, developing risk-based approaches where needed, providing rigorous definitions, and clarifying thresholds and GES. Additionally, it is essential to promote data harmonization and interoperability, as well as integration across the different MSFD descriptors.

5.7 Marine Biodiversity and Genetic Resources: from Exploration to Biotech

The ocean hosts the highest phylogenetic diversity on the planet. Its biota exhibit a vast suite of adaptive solutions, likely driven by the unique constraints of inhabiting a fluid, continuously moving medium. Even though molecular data are available for only a fraction of marine organisms, the proportion of "unknown" genes and proteins in the marine realm appears to exceed that of terrestrial systems, with the possible exception of soil microbiota. This represents both a significant challenge and an immense resource for advancing our understanding of basic biological mechanisms, evolution, and potential biotechnological applications.

Traditionally, marine biochemical applications have relied on bioprospecting followed by empirical testing. However, by merging increasing knowledge of in situ processes—derived from direct and indirect observations—with our growing understanding of complex molecular mechanisms, it is now possible to reverse this approach. We can now select target organisms by hypothesizing specific adaptive solutions, integrating in situ omics data with targeted laboratory validation.

This approach is minimally invasive, particularly for marine microbiota, and facilitates progress in exploiting biological "solutions" via synthetic biology rather than the organisms themselves. Recent global expeditions have generated a massive repository of samples and data; analyzing these will pave the way for more focused observations and sophisticated experiments, both in situ and in the laboratory. Sustaining and coordinating these efforts through international networking initiatives should be a high priority for the European research community.

5.8 Fisheries science and resource management

Marine fisheries play a vital role in ensuring food security and nutrition, while supporting the economy and the overall well-being of coastal populations. Fisheries research and marine resource management face multiple, interconnected challenges that are critical for ensuring sustainable use of ocean resources. The long-term sustainability of marine fisheries is thus a multi-dimensional challenge, carrying profound ecological, social, economic, and political weight. Overexploitation of fish stocks, IUU (illegal, unreported, and unregulated) fishing, coupled with limited understanding of fish biology and ecosystem dynamics and the increasing consequences of climate change on marine biota, threatens both biodiversity and the long-term provision of ecosystem services. Contemporary fisheries science increasingly emphasizes an ecosystem-based approach, recognizing that species interactions, habitat health, and environmental variability all influence the outcomes of management decisions.

Key challenges include:

- sustainable stock assessment and harvesting, technology development for advanced, biodiversity-friendly gears and fish-finding technologies
- minimising bycatch and reduce the impact of fishing gear on non-target species and habitats (e.g. seafloor),
- addressing climate change impacts on species distribution and abundance, also capable to alter the sharing of fish stocks across jurisdictional and management boundaries,
- integrating advanced monitoring technologies into decision support systems,
- developing predictive models to support adaptive management strategies.
- governance and policy complexity, including regional discrepancies, stakeholder conflicts, and international coordination, further complicate effective management.

To address these challenges, research must combine robust scientific data with innovative tools and risk-based frameworks, fostering collaboration between scientists, policymakers, and fisheries stakeholders. Promoting data harmonization, integration across ecosystem indicators, and evidence-based decision-making will support the transition to a sustainable and resilient future for marine fisheries.

5.9 Forging the Way Forward – Transformative Ocean Science Symposium

The Transformative Ocean Science Symposium is conceived as a biennial flagship initiative.
It is envisioned as a premier gathering of the global oceanographic community, bringing together leading scientists, policymakers, and stakeholders to foster innovation, collaboration, and strategic advancements in ocean sciences.
The overarching goal of the symposium series is to shape the future directions of ocean science towards unleashing the ocean's potential to address societal challenges.

The symposium is an inclusive event, bringing together scientists from across disciplines and regions to explore innovative directions for ocean research, policy stakeholders and innovators.
The goal of the symposium is to be a platform for provocative and visionary discussions, interdisciplinary exchange, and the co-creation of transformative and disruptive scientific insights. It is not conceived as a "mainstream" scientific meeting focused on presenting ongoing research. Shared learning and collaboration will be fostered to define new pathways to connect ocean science more directly with the needs of society. It aims to define a long-term vision for the role of ocean sciences in addressing the grand environmental, social, and economic challenges of the 21st century.
The symposium will serve as a cornerstone for sustained global efforts to advance ocean knowledge, policy, and innovation.

Executive Synthesis

A science-based roadmap for the Transformative Ocean Science Symposium 2026

The ocean is a strategic pillar of Europe's environmental security, economic resilience, and global leadership. It regulates the climate, sustains biodiversity, supports food systems, enables renewable energy, and underpins a growing blue economy. Yet Europe's seas are increasingly exposed to climate change, biodiversity loss, pollution, and intensifying competition for marine space and resources. Addressing these interconnected challenges requires a step change in how ocean science is prioritised, organised, and mobilised across Europe.

This Executive Synthesis presents a forward-looking vision for European ocean sciences, aligned with the European Ocean Pact, the European Green Deal, and the EU's Research and Innovation ambitions for the post-2027 period. It reflects the collective perspectives of European marine research leaders and international partners and provides strategic guidance for policymakers, funders, and research institutions.

Ocean Science as a Strategic Enabler

Ocean science is essential for evidence-based policymaking, sustainable resource management, and Europe's competitiveness in strategic sectors. Long-term observation, cutting-edge research, and innovation are foundational to achieving the objectives of key EU instruments, including the Marine Strategy Framework Directive (MSFD), the Maritime Spatial Planning Directive (MSPD), Common Fisheries Policy (CFP), and the Nature Restoration Law. Science must therefore be recognised not only as a source of knowledge but as a strategic enabler of governance, resilience, and societal well-being.

Key Structural Priorities

To respond effectively to emerging challenges, European ocean science must overcome persistent fragmentation across disciplines, institutions, data systems, and governance levels. Priority actions include:

- Embedding ethics and transdisciplinarity at the core of marine research, ensuring inclusive stakeholder engagement, fair governance of marine common goods, and responsible innovation.
- Strengthening science diplomacy, positioning ocean science as a tool for international cooperation, conflict prevention, and leadership in global ocean governance.
- Consolidating and sustaining research infrastructures, ensuring long-term observation, open and interoperable data, and alignment between EU and national investments.
- Empowering the next generation of ocean scientists through interdisciplinary training, international mobility, and skills at the science–policy–society interface.
- Harnessing artificial intelligence responsibly, to unlock the value of ocean data, improve forecasting, optimise observing systems, and accelerate discovery while addressing ethical and societal implications.

Priority Knowledge Areas

Achieving healthy, resilient, and productive seas requires targeted investment in critical knowledge domains:

- Ocean health, integrating source-to-sea pollution approaches, biodiversity conservation, ecosystem-based management, restoration, and precautionary decision-making.

- Long-term monitoring, recognised as a pillar of scientific excellence and a planetary health indicator, essential for policy implementation and early warning.
- Digital Twin Ocean (DTO) systems, co-developed with stakeholders as dynamic decision-support tools for scenario analysis, cumulative impacts assessment, and resilience planning.
- Deep-sea knowledge and exploration, addressing major knowledge gaps and supporting precautionary governance of emerging activities, including deep-sea mining.
- Coastal adaptation and resilience, responding to sea-level rise, urbanisation, and socio-economic vulnerability through systemic, ethically informed solutions.
- Marine biodiversity and genetic resources, linking exploration, omics, conservation, and fair access to sustainable innovation in line with international agreements.
- Fisheries science and bioresource management, advancing ecosystem-based, adaptive approaches that integrate climate change, biodiversity, and socio-economic dimensions.
- Sustainable and restorative aquaculture capable to provide ecological benefits to the environment and support biodiversity conservation.

From Knowledge to Action

Bridging the divide between fundamental research, applied science, and policy implementation remains a critical challenge. Europe must strengthen pathways from knowledge generation to decision-making and innovation, supported by robust science–policy interfaces, pre-competitive research, and responsible technology transfer. Digitalisation, open data, and interoperability are essential enablers of this transition.

A Platform for Transformation

The Transformative Ocean Science Symposium is proposed as a biennial flagship initiative to catalyse this agenda. Designed as a platform for visionary, interdisciplinary, and policy-relevant dialogue, the symposium will connect scientists, policymakers, and stakeholders to co-create transformative pathways for ocean science and governance.

Conclusion

Europe stands at a pivotal moment. By investing strategically in ocean science, grounded in ethics, excellence, and inclusivity, the EU can strengthen its leadership in global ocean governance, support sustainable development, and safeguard the ocean as a common good for present and future generations. The priorities outlined here provide a science-based roadmap to realise the ambitions of the European Ocean Pact and to ensure that ocean science remains a cornerstone of Europe's resilience, prosperity, and global responsibility.

Ocean Pact Pillar	Relevant Strategic Science Focus of the symposium
Ocean Health	Ocean health, pollution, ecosystem restoration, MSFD support
Blue Economy	Sustainable blue economy, fisheries science, economic resilience
Coastal Communities	Coastal adaptation, resilience, socio-economic research
Research & Innovation	Long-term monitoring, DTO, AI, enhanced infrastructures
Maritime Security	Science supporting surveillance, risk modelling, resilient systems
Ocean Diplomacy & Governance	Science diplomacy, global collaboration, governance research