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Executive summary

Foresight serves to look into the future and investigate the actions needed to achieve it. This report captures the major foresight initiatives and documents relevant for European ocean observation and forecasting. The document starts with an introduction that defines foresight and the scope of the report (chapter 1). It highlights more than 120 initiatives, strategies and roadmaps that contribute to foresight in ocean observation internationally (chapter 2.1), at the scale of Europe (chapter 2.2), and regionally at the sea basin scale (chapter 2.3). The document ends with some final remarks and opportunities (chapter 3).

The report highlights the complexity of the ocean observing landscape and how that influences the clarity of the foresight that can be achieved. The ocean observing landscape is interconnected at all levels. This complex landscape has grown organically, as different stakeholders have understood the importance of ocean observing for understanding our climate, the provision on ecosystem services such as food and generally for understanding how the ocean functions. In this complex landscape many initiatives depend on partnerships with other communities and end-users. It is imperative that the current coordination and partnership efforts are supported, reinforced and possibly better organised. This support is needed in different communities such as the ocean research communities, the monitoring community for policy-driven objectives, as well as between these communities.

As most ocean observations are funded at a national level, national coordination and sustainability discussions, should be reinforced by EuroSea and the upcoming EU Ocean Data Collection Framework Directive. At the European level, the European Ocean Observing System (EOOS) framework, supported by EuroSea, will provide the discussion forum to promote the alignment and coordination of integrated observation systems in Europe. EOOS aims to bring together the national, regional and international ocean observing community to enhance ocean observing in Europe.

This report will inform the EuroSea project on the governance implications of its activities, by providing the baseline foresight initiatives and documents to consider duration the project in the preparation of its legacy. This publication is primarily aimed at readers interested in learning more about the international and European ocean observing and forecasting landscape. Interested readers also include stakeholders involved in ocean observing and forecasting, spanning diverse roles from commissioning, managing, funding and coordinating, to developing, implementing, or advising on programmes.

1. Introduction

The ocean is a fundamental part of the global life-support system and provider of a wealth of resources to humanity. Despite its paramount importance to society, there are fundamental gaps in ocean observing and forecasting systems, limiting our capacity to sustainably manage our activities in the ocean. Global Ocean Observing is "big science" and cannot be addressed by individual nations. The European Union Horizon 2020 Innovation Action **EuroSea** will support European integration for coordinated observations of the ocean that can be sustained in the long term. It brings together key European actors of ocean observation and forecasting with key end users of ocean observation, responding to the G7 Future of the Seas and Oceans Flagship Initiative. EuroSea's innovative demonstration activities are focused on operational services, ocean health and climate, where a dialogue between actors in the ocean observing systems will guide the development of the services.

EuroSea will also investigate the **governance and coordination of ocean observing and forecasting systems**, in a European and international context, while strengthening interactions between regional, national and international observing systems, through the European Ocean Observing System framework (EOOS).

Foresight is a systematic, participatory, future intelligence gathering and medium- to long-term vision-building process aimed at present-day decisions and mobilising joint actions (CSA Oceans Consortium, 2012). In short, foresight is an approach for studying the possible consequences of our actions (Woensel & Vrščaj, 2015). Foresight studies and horizon-scanning activities aim to identify emerging issues and to anticipate future policy needs (Reillon, 2015). Many organisations and networks use foresight to generate a shared strategic vision among their participants about what the future should look like and to understand the challenges and necessary steps that need to be taken to realise such a vision. For instance, the European Commission Directorate-General for Research & Innovation (DG RTD) is actively involved in foresight for scientific research and technological innovations. The fact that the foresight process is participative helps to develop both a sense of ownership and a sense of commitment to this vision, and with aim to encourage to work together towards an agreed goal (CSA Oceans Consortium, 2012).

In the marine and maritime fields, four types of foresight and foresight-related activities have been identified (CSA Oceans Consortium, 2012):

1. Analyses of the *status quo*: While not strictly foresight, examination of the current state of affairs is indispensable groundwork for any foresight exercise. *Status quo* reports are designed as benchmark studies, providing a baseline against which future developments can be evaluated. Some go further by giving indications of future trends as well as identifying priorities for future action. Example: OSPAR periodical Quality Status Reports (QSRs).
2. Elaborations of strategic research (and innovation) agendas (SRAs or SRIAs): Generally, SRAs identify gaps in current scientific knowledge or the technological base and conclude from these research priorities and needs. They tend to be forward-looking as they provide a list of future research topics that are of particular relevance. Example: JPI Oceans Strategic Research and Innovation Agenda (SRIA).
3. Development of visions for the future: Visions seek to generate future scenarios that are desirable to attain. On the one hand, visions can be developed in conjunction with an SRA and an implementation plan, thus outlining not only the desired end-goal, but also the necessary steps for its realisation. On the other hand, there are stand-alone visions which are developed detached from concrete implementation strategies. Example: European Marine Board & EuroGOOS vision on the European Marine Observation and Data Network (EMODnet).

4. Actual foresight: Combining all the above, actual foresight provide an analysis of the status quo of a specific topic, identify future challenges and needs as well as priorities, and make recommendations on emerging topics and societal challenges. Example: The European Marine Board Navigating the Future publication series.

Building on previous and ongoing work in Europe and worldwide, this report will inform EuroSea on current and upcoming initiatives, strategies and roadmaps that contribute to foresight in ocean observation. As EuroSea will run from November 2019 to December 2023, this report provides a baseline of the main international and European actors and activities related to ocean observation foresight. It will be revisited at the end of the project during the preparation of its legacy plan.

Foresight is **crucial to support decisions** to develop sustained fit-for-purpose ocean information products and services as it gives a forward look to the drivers and capabilities, the latest scientific knowledge and the technological feasibility in observing infrastructure. Identifying foresight initiatives will help EuroSea to analyse how the governance of the observing systems can best respond to the relevant international and European legal frameworks and mechanisms focusing on sustained ocean observing.

This report is not an exhaustive review of all initiatives, strategies and roadmaps related to ocean observation and forecasting. For instance, joint strategies for the Blue Economy of a specific sea basin may (and should) point out needs for ocean observation and forecasting, but is not their primary aim. In addition, as EuroSea is an EU Horizon 2020 project, this report captures the landscape of major initiatives relevant for Europe. Foresight conducted by national oceanographic, hydrographic and meteorological agencies and institutes, universities and national research managers and funding agencies was excluded from this analysis. Such national foresight initiatives are mostly aligned with other European, international or community-based foresight activities, and national organisation, responsibility, operability and competences for ocean observation and forecasting would add complexity to this report. Accessing and querying all national information was not possible, due to the lack of comprehensive national coordination of ocean observation and forecasting. Strengthening national contacts for ocean observation and forecasting, and partnership with key users to support the delivery of an integrated fit-for-purpose observing system will be supported by the dedicated task 1.1.1 of EuroSea. However, national strategies for the ocean such as Portugal's commitments the Ocean Dimension of the 2030 Agenda[1], with a strong ocean observation component, should be highlighted.

This report was not done in isolation. EuroSea gathers a very strong partnership of key European and international actors involved in ocean observing and forecasting in the European Seas, consisting of national research institutions as well as European and international organizations. Input was provided by EuroSea Work Package leaders, the EuroSea coordinator, Work Package 1 participants, and the EOOS Advisory Committee. In addition, this report is inspired by the European Union's Horizon 2020 AtlantOS project deliverable "Strategic foresight paper on AtlantOS in the European context" (Larkin et al., 2018).

[1] https://www.dgpm.mm.gov.pt/agenda-2030-en

2. Initiatives, strategies and roadmaps that contribute to foresight in ocean observation and forecasting

2.1. Foresight at international level

In general, broader international initiatives appreciate and welcome the valuable evidence provided by the scientific community, intrinsically highlighting the role of systematic observation and forecasting. Unfortunately, historically worldwide marine management has addressed each sector separately, producing a patchwork of international initiatives, legislation, policies and visions (see figure 1). This results in a piecemeal approach for national management of the marine environment (including ocean observation and forecasting) (Boyes & Elliott, 2014).

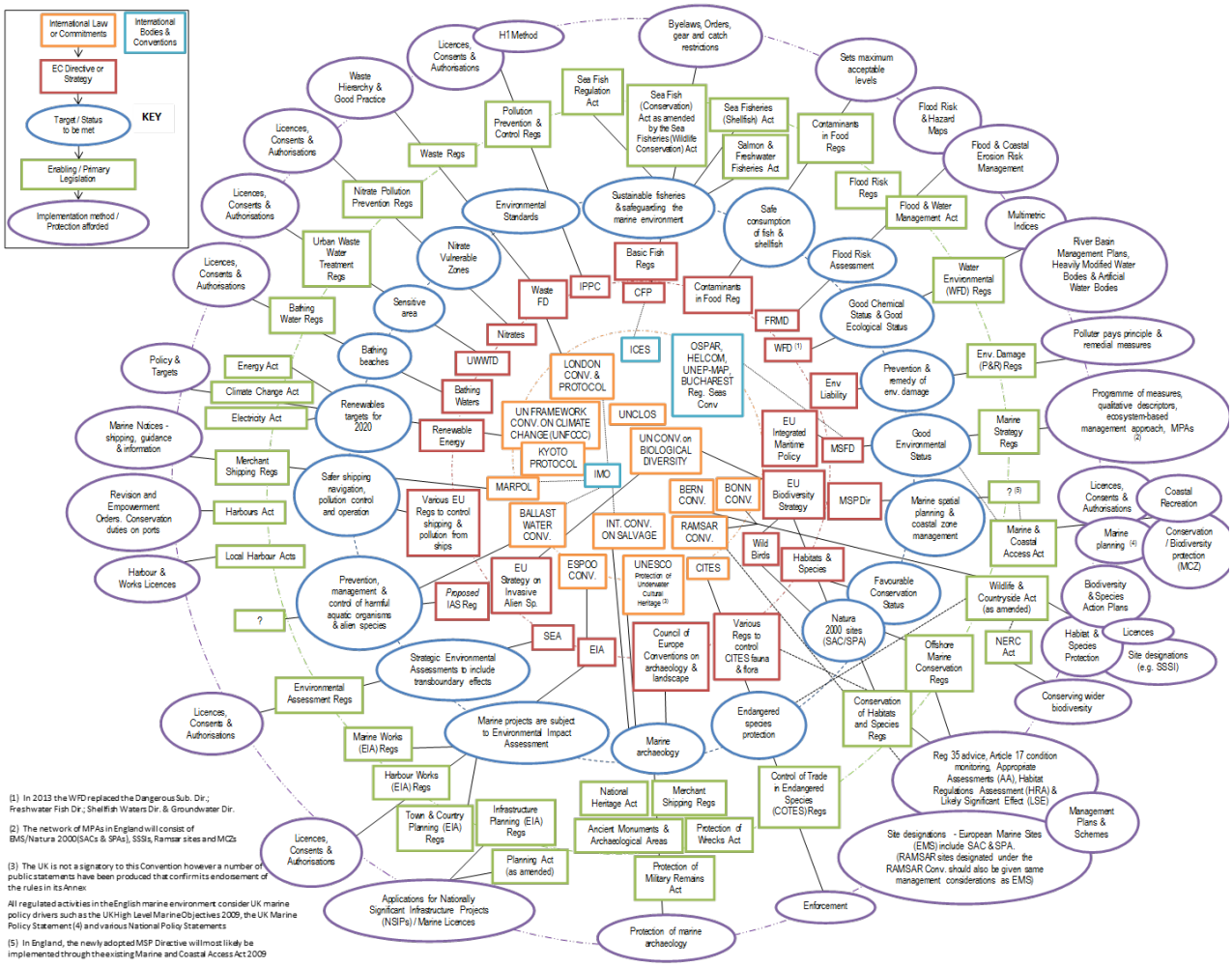

Fig. 1: It's a complicated landscape. Horrendogram showing the complexity of marine environmental policy and management across vertical governance. Source: (Boyes & Elliott, 2014)

International frameworks relevant to ocean observing and forecasting

The international legal framework for marine and maritime activities and regulations lies in the 1982 **United Nations Convention on the Law of the Sea[2] (UNCLOS)**. The Convention defines the limits of States' maritime zones, including the Exclusive Economic Zones (EEZs), and includes the requirement of States and competent international organizations to promote and facilitate marine scientific research, including through cooperation. It is noted that additional implementation agreements exist, relating to minerals on the seabed beyond the continental shelf (Part XI of UNCLOS) and to the conservation and management of straddling and highly migratory fish stocks (Fish Stocks Agreement), which underpin the role of marine scientific research (including ocean observation and forecasting). Currently, an additional process is being carried out for the development of an international legally binding instrument under UNCLOS on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (BBNJ). The fourth and final session of the Intergovernmental Conference developing this instrument was due to take place in March 2020, but was postponed in light of the COVID-19 pandemic. More information and analysis of the legal frameworks important for ocean observation and forecasting will be presented in EuroSea deliverable 1.7, in early 2023.

The **United Nations (UN) 2030 Agenda for Sustainable Development[3]**, with its **17 Sustainable Development Goals** (SDGs), provides the main global and encompassing instrument to focus scientific effort on delivering the knowledge and expertise required to underpin sustainable development for society and the environment, including our ocean and seas. SDG 14 refers specifically to the need to conserve and sustainably use the ocean, seas and marine resources for sustainable development. However, the marine environment underpins about 60% of all SDGs (Larkin et al., 2018). The SDG target 14.A aims to increase scientific knowledge, develop research capacity and transfer marine technology, to improve ocean health and to enhance the contribution of marine biodiversity to the benefit of developing countries, in particular small island developing States and least developed countries.

Other international and wider sustainability agreements and policy developments relevant to ocean observation and forecasting include the **Sendai Framework for Disaster Risk Reduction 2015-2030[4]**, which is the roadmap for how to make communities safer and more resilient to disasters. This calls on countries to address challenges related to operational oceanography and early warning as they form the basis of preventing and reducing the risk of disasters. The 2015 **Paris Agreement[5]**, the outcome of the 21st Conference of the Parties (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC) delivered an ambitious legally binding and universal agreement on climate. The Paris Agreement mentioned ocean ecosystems for the first time in an UNFCCC agreement. The Conference of Parties (COP), its supreme decision-making body (UNFCCC, Art 7(2)), usually meets every year, but due to the COVID-19 pandemic, COP26 has been postponed to 2021, and has a standing agenda item on sustained observations under the topic "research and systematic observation".

The COP has repeatedly expressed appreciation for the work of the Intergovernmental Panel on Climate Change (IPCC), an independent body founded under the auspices of the World Meteorological Organization

[2] https://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm
[3] https://sustainabledevelopment.un.org/
[4] https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf
[5] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

(WMO) and the United Nations Environment Programme (UNEP). The IPCC provides assessments of the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change. In 2019, the IPCC published the **Special Report on the Ocean and Cryosphere in a Changing Climate**[6] **(SROCC)**, which compiled key findings on observed changes and impacts, projected changes and risks, and recommended implementation responses to ocean and cryosphere change. Throughout the report, statements have levels of confidence (low, medium, high, etc.), and it mentions that uncertainty and low confidence arises from limited observations, inadequate model representation and limited understanding of the complex interactions between the atmosphere, ocean and cryosphere.

The SROCC follows two other Special Reports: one on Global Warming of 1.5°C (SR1.5) and another on Climate Change and Land (SRCCL), as well as the **Global Assessment Report on Biodiversity and Ecosystem Services**[7] of the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES). This report highlights that thanks to observational evidence, we now understand that the effects of climate change are accelerating in marine, terrestrial and freshwater ecosystems and are already impacting agriculture, aquaculture, fisheries and nature's contributions to people (i.e. ecosystem services).

In addition, the UN Ocean is an inter-agency mechanism that seeks to enhance the coordination, coherence and effectiveness of the competent organizations of the UN system that holds triannual conferences. One of the interactive dialogues of the UN Ocean conferences is on increasing scientific knowledge, developing research capacity and improving transfer of marine technology. Unfortunately, the **2020 UN Ocean Conference**[8] has been postponed in light of the COVID-19 pandemic.

Foresight relevant to ocean observing and forecasting international coordination

The United Nations Environment Programme (UNEP) is the authoritative advocate for the global environment and provides UN secretariat support to the IPBES. **UNEP's Medium-Term Strategy**[9] **(2018-2021)** highlights the need for data and assessments to inform evidence-based policymaking to fully integrate the environmental dimension of sustainable development. In addition, UNEP and the UN Science-Policy-Business Forum working group on "Data, Analytics and AI" began in 2019 to build a strong case for **a digital ecosystem on the environment**[10], defined as 'a complex distributed network or interconnected socio-technological system'. The second edition of the **World Ocean Assessment**[11] **(WOA)**, a UN initiative to review the environmental, economic and social aspects of the world's ocean, is due to be published in early 2021. This second WOA gathers other assessments across local, regional and global scales, including economic, social and cultural aspects of the ocean, and expands opportunities for the exchange of information and input into the assessment by incorporating two rounds of regional workshops, and a stakeholder dialogue and capacity building event (Evans et al., 2019).

[6] https://www.ipcc.ch/report/srocc/
[7] https://ipbes.net/global-assessment
[8] https://www.un.org/en/conferences/ocean2020
[9] http://wedocs.unep.org/bitstream/handle/20.500.11822/7621/-UNEP_medium-term_strategy_2018-2021-2016MTS_2018-2021.pdf.pdf?sequence=3&isAllowed=y
[10] https://un-spbf.org/wp-content/uploads/2019/03/Digital-Ecosystem-final.pdf
[11] https://www.un.org/regularprocess/content/first-world-ocean-assessment

The United Nations Educational, Scientific and Cultural Organization (UNESCO) established the Intergovernmental Oceanographic Commission (IOC) as a body with functional autonomy, to promote international cooperation, coordinate programmes in marine research, services, observation systems, hazard mitigation, and develop capacity to understand and effectively manage the resources of the ocean and coastal areas. The **IOC's Medium-Term Strategy[12] (2014-2021)** envisions strong scientific understanding and systematic observations to underpin sustainable development and global governance for a healthy ocean. The IOC also delivers the **Global Ocean Science Report[13] (GOSR)** on the status and trends in ocean science capacity around the world. Ocean observation and marine data are cross-cutting categories to all ocean science. The second GOSR report was due to be launched at the now postponed 2020 UN Ocean Conference (postponed in light of the COVID-19 pandemic).

The IOC was mandated by the United Nations General Assembly to prepare and plan for the international Decade of Ocean Science for Sustainable Development for the period 2021-2030. This Decade is an important development and opportunity to increase our understanding of the ocean and to strengthen its management.

The UN Decade of Ocean Science for Sustainable Development

In 2017, the upcoming decade 2021-2030 was proclaimed as the Decade of Ocean Science for Sustainable Development (in short Ocean Science Decade or OSD) by the United Nations General Assembly, representing 193 States. The Ocean Science Decade represents the biggest opportunity for the ocean community to mobilise behind the ideas of sustainable development and serve to focus the research and technological development in ocean science on existentially important issues of protection and sustainable use of the ocean. This will be a decisive contribution by the ocean community to the implementation of the 2030 Agenda and its Sustainable Development Goals (SDGs) (Ryabinin et al., 2019).

The IOC is formulating and delivering the **Implementation Plan for the Ocean Science Decade[14]** to the UN General Assembly of 2020 under the motto "the ocean we need for the future we want" (see figure 2). From 2018 to 2020 the IOC has undertaken an extensive foresight exercise as part of the Preparatory Phase. This foresight exercise, organised around six holistic societal outcomes (a clean, healthy and resilient, predicted, safe, sustainably harvested and productive, "transparent and accessible" ocean), was supported through four interlinked mechanisms: the Executive Planning Group (EPG), the Stakeholder Forum (consultative body), several Regional Workshops and two Global Planning Meetings. Using these mechanisms and several rounds of consultations, a wide range of stakeholders were involved in providing input towards the Implementation Plan, including the IOC and UN Member States, UN bodies, institutional partners, the scientific community, the economic actors/private sector, civil society and foundations.

[12] http://www.ioc-unesco.org/index.php?option=com_content&view=article&id=29&Itemid=81
[13] https://en.unesco.org/gosr
[14] https://en.unesco.org/ocean-decade/preparatory-process

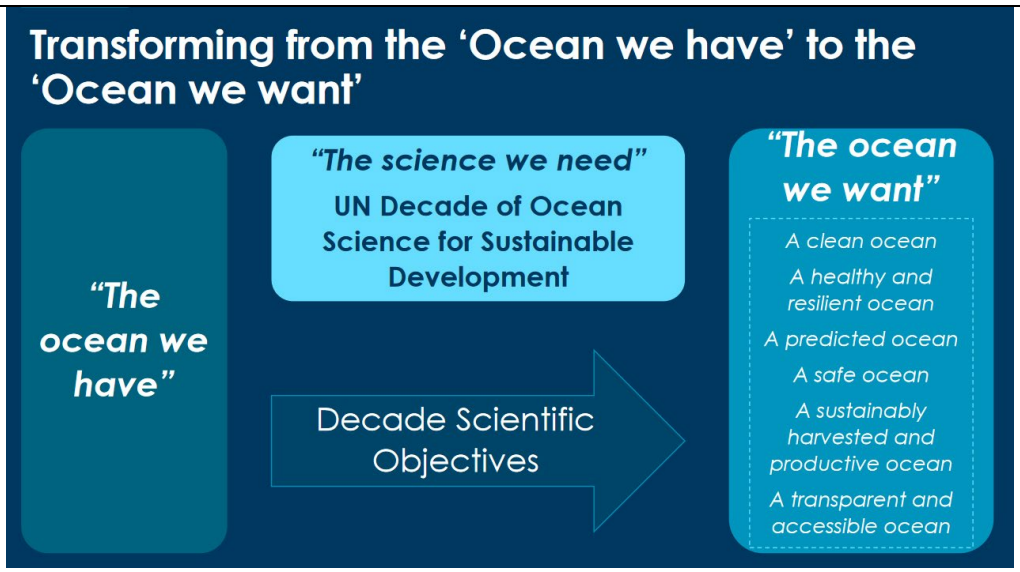

Fig. 2: The Ocean Science Decade scientific objectives to achieve "the ocean we want". Source: Presentation of the Draft Implementation Plan for the Ocean Decade, conducted by UNESCO's Intergovernmental Oceanographic Commission on March and April 2020.

The Implementation Plan is a living document and will be adjusted to accommodate new needs, activities and partners (Ryabinin et al., 2019). Objectives and orientations of the Implementation Plan target the entire value chain from knowledge generation, applications and services, to end users. The Implementation Plan will include four components: 1) a Capacity Development Plan; 2) a Resource Mobilisation Plan; 3) a Communications and Engagement Plan; and 4) a Science Plan, with ocean observation at the core (Ryabinin et al., 2019). Research priorities include the development of a comprehensive ocean observing system, and the integration of the ocean in Earth-system observation, research, and prediction.

Under the Implementation Plan for the Ocean Science Decade, long-term (multi-year), interdisciplinary and typically multi-national programmes at global or regional scale will be put in place to fulfil one or more of the Decade objectives. An example of possible activities is the current proposal for a UN Ocean Science Decade Programme called **"Predicting the Global Coastal Ocean"**[15], being developed as an open community initiative.

The IOC coordinates ocean observation and monitoring through the Global Ocean Observing System (GOOS), sponsored by WMO, UNEP and the International Council for Science (ICSU). GOOS was set up as a long-term international cooperation platform for sustained observations of the oceans, and aims to develop a unified network providing information and data exchange on the physical, chemical, and biological aspects of the ocean. GOOS responds to society's increasing needs of ocean data and knowledge for sustainable development, considers the evolving observing capabilities, and aligns with other international initiatives. GOOS is providing foresight to 2030 (see box below) to deliver an integrated global ocean observation

[15] https://www.coastspredict.org/

system. The **Global Climate Observing System (GCOS) Implementation Plan**[16] highlights that GOOS is vital to the strong and capable ocean climate component of GCOS. GCOS is a co-sponsored programme between IOC, WMO, UNEP and ICSU, which regularly assesses the status of global climate observations and produces guidance for its improvement, meeting the needs of the UNFCCC (see above).

The GOOS 2030 Strategy and Roadmap for Implementation

The vision for a truly integrated global ocean observing system that delivers the essential information needed for sustainable development, safety, wellbeing and prosperity, is identified in the **GOOS 2030 Strategy**[17]. This integrated global ocean observing system will deliver ocean information across three key application areas: operational services, climate, and ocean health (IOC-UNESCO, 2019). It will capture the essential physical, chemical, biological, and ecological ocean properties, from global to local coastal scales. This fully integrated global observing system will range across the value chain from observations, through data management systems, scientific analysis and forecast, to end users via information, data and decision-making services. This system needs to integrate information on human pressures, and the data produced need to be freely available for use.

To achieve this vision, GOOS needs to develop strong partnerships to ensure the observing system delivers the information needed in a range of assessments, forecasts, data products and services. The strategy also supports developing observing capacity and build new advocates for sustainability.

The GOOS Strategy for 2030 is complemented by an Implementation Plan, entitled **A Roadmap for the Implementation of the GOOS 2030 Strategy**[18]. This Roadmap is designed to provide a framework for nations, partners and sponsors to guide priorities and actions for the global community towards achieving the 2030 Strategy and vision. The Implementation Plan strongly depends on co-design, it anticipates evolving the governance for an expanded observing system.

The now disbanded Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) was a coordination mechanism for the fit-for-purpose delivery of an end-to-end system, from ocean observation to meteorology-ocean operational services. A new advisory body under GOOS, the WMO-IOC Joint Collaborative Board (JBC) will offer strategic advice to IOC and WMO on co-design, co-develop and implementing joint scientific and technical work across oceanography and meteorology. The JBC incorporates JCOMM functions and activities, and ensures that vital JCOMM functional connections are maintained. One of the major tasks of the new JBC will be to develop the **JCOMM Centre for Oceanography and Marine Meteorology *in situ* Observations Programme Support (JCOMMOPS) strategic plan**[19] for the next 5–10 years to ensure the sustainability of the service (Pinardi et al., 2019).

The IOC and WMO facilitates the implementation of GOOS via the Observations Coordination Group (OCG), and satisfies their data and information needs through JCOMMOPS, the WMO Global Telecommunication

[16] https://gcos.wmo.int/en/gcos-implementation-plan
[17] https://www.goosocean.org/2030strategy
[18] https://goosocean.org/index.php?option=com_oe&task=viewDocumentRecord&docID=26687
[19] Pinardi *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00410/full

System (GTS), the IOC Ocean Data and Information System (ODIS), and the Intergovernmental Oceanographic Data and Information Exchange (IODE) programme.

IODE is a coordinated network of national oceanographic data centres (NODCs), associated data units and global data assembly centres. The **IOC Strategic Plan for Data and Information Management[20] (2017-2021)** directs the IODE and envisions the achievement of "a comprehensive and integrated ocean data and information system, serving the broad and diverse needs of IOC Member States, for both management and scientific use" and contributes to the outputs and activities of the **IOC Capacity Development Strategy[21] (2015–2021)**. The new initiative since 2020, the IOC Ocean InfoHub Project will streamline access to ocean science data and information for management and sustainable development. This project will establish and anchor a network of regional and thematic nodes that will improve online access to and synthesis of existing global, regional and national data, information and knowledge resources.

The Ocean Best Practices System (OBPS) is joint IODE/GOOS Project, that aims to provide a mechanism to disseminate ocean best practices as widely as possible (Pearlman et al., 2019). The core objectives of the **future vision for OBPS[22]** are to enable the ocean research, observing, and application communities to create methods for activities in ocean observing, from research to operations to applications that are discovered, reviewed, agreed upon, adopted, and supported across communities (Pearlman et al., 2019). Task 1.1.4 of EuroSea will ensure that best practices identified by EuroSea from European programs and infrastructures are accessible in the OBPS.

GOOS has three expert panels: 1) the Physics and Climate Panel (built on the existing Physics and Climate Panel on the Ocean Observations Panel for Climate - OOPC), 2) the Biogeochemistry Panel (built on the existing International Ocean Carbon Coordination Project - IOCCP) and 3) the Biology and Ecosystems (BioEco) Panel. These panels synthesize ocean observation requirements and provide guidance on observing system design. They have been tasked with identifying a number of environment and ecosystem focused **Essential Ocean Variables[23] (EOVs)** on which global monitoring efforts should be focused over sustained time-frames. This identification process has been based on the societal importance of each variable and on the feasibility of observation (Evans et al., 2019). All three panels have Action Plans and the Biology and Ecosystems Panel, for instance, draws on experience from the last decade and works with other global initiatives to develop **a work plan for marine biological observations[24]** in the next decade. EuroSea will strengthen and extend the biology and ecosystems networks throughout Europe with the dedicated task 1.1.2.

The GOOS Regional Alliances (GRAs) implement observing systems and ensure the flow of observations across the global networks and regional observing structures (IOC-UNESCO, 2019) (see chapter 2.3).

The GOOS Expert Team on Operational Ocean Forecast Systems (ETOOFS) manages and promotes the adoption of an international standard to support interoperability, the common formatting of ocean forecast products and services, and the quality assessment of the products. This is done in cooperation with OceanPredict, the former Global Ocean Data Assimilation Experiment (GODAE) Ocean View (GOV). OceanPredict is an international science programme that aims to accelerate, strengthen and increase the

[20] https://www.iode.org/index.php?option=com_content&view=article&id=423&Itemid=107
[21] https://unesdoc.unesco.org/ark:/48223/pf0000244047
[22] Pearlman *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00277/full
[23] https://www.goosocean.org/eov
[24] Bax *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00395/full

impact of oceanographic modelling and prediction, as part of the broader network of international operational oceanography initiatives. The **OceanPredict'19 Forum**[25] discussed recent developments in operational oceanography and brainstormed on future directions of ocean prediction services. This set the basis for the development of the **OceanPredict Strategy**, to be published in 2020, which will see closer engagement with international and intergovernmental groups, to reinforce the ocean modelling and prediction component of the operational oceanography value-chain (i.e. from ocean observation, data and information systems, predictions and scientific assessments, to end-users). The dedicated EuroSea task 1.1.5 will link with the international activities of OceanPredict on data assimilation and marine ecosystem predictions, as well as coastal modelling.

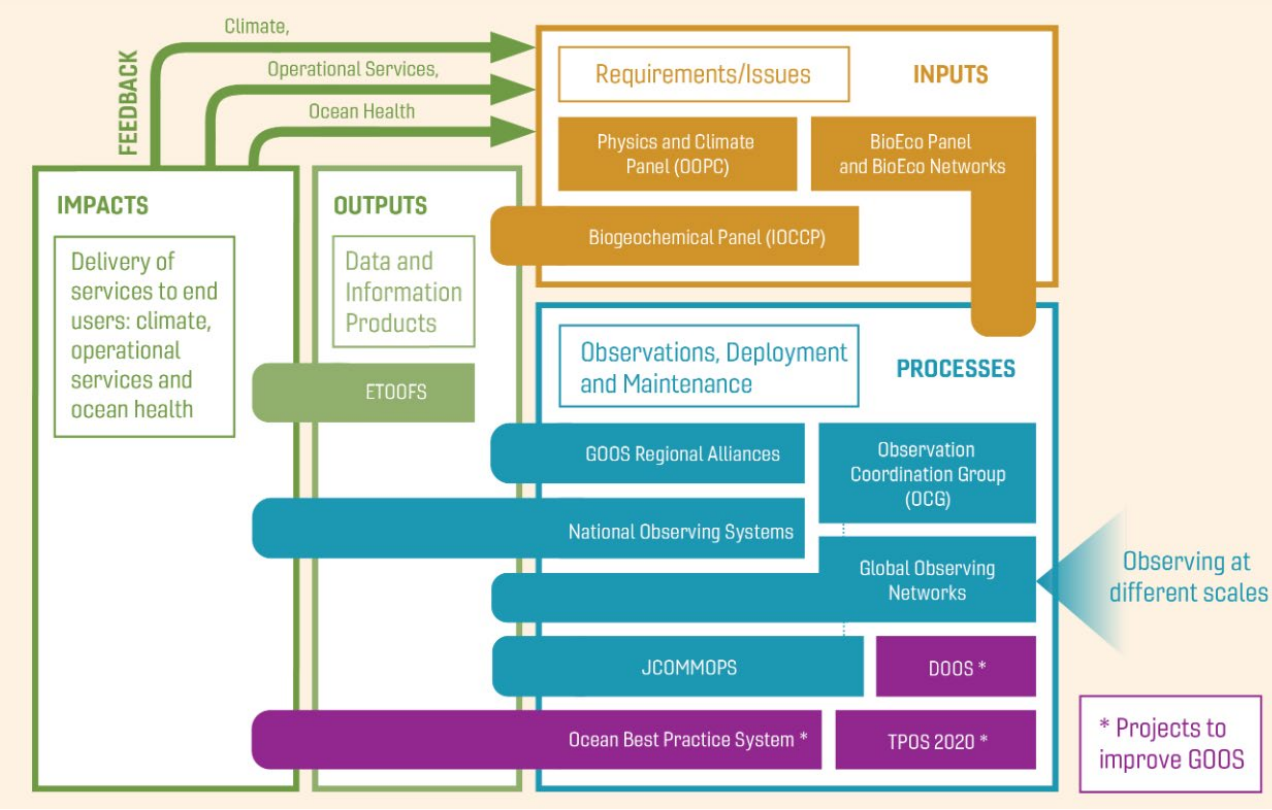

Fig. 3: Diagram of the GOOS components following the Framework for Ocean Observing. Source: A Roadmap for the Implementation of the Global Ocean Observing System 2030 Strategy (IOC-UNESCO, 2020)

GOOS conforms to the methodology of the **Framework for Ocean Observing**[26] **(FOO)** (see figure 3), which provides a system-level view of effective guidelines for setting requirements, coordinating observation networks, assessing technology readiness, and assessing the usefulness of data and products for users. The FOO was developed by an international working group based on the consensus of the OceanObs'09 Conference (see bow below) on the need for a common set of guidelines for the global ocean observing

[25] Vinayachandran *et al.* (2020) https://journals.ametsoc.org/bams/article/101/4/E485/345600/Toward-Joint-Assessments-Modern-Capabilities-and

[26] Lindstrom *et al.* (2012) http://www.oceanobs09.net/foo/FOO_Report.pdf

community. Since then, the FOO has been widely endorsed by the ocean observing community, and has been adopted formally by GOOS as a guiding document (Tanhua et al., 2019).

OceanObs conferences

OceanObs conferences are held once every 10 years for the scientific, technical, and operational communities involved in the planning, implementation, and use of ocean observing systems. They serve to communicate progress, promote plans, and to define advances in ocean observing in response to societal needs (Speich et al., 2019). This decadal conference series provides community-based foresight, joining efforts to review the state of the ocean observing science and operations, and to defining goals and plans to achieve in the next decade.

The First International Conference on the Ocean Observing System for Climate[27] (OceanObs'99), took place in Saint Raphaël (France) in October 1999. The conference addressed technical and scientific challenges of ocean observing systems, covered data analysis, modelling, and assimilation; and led to concrete actions, such as the creation of the Argo programme (Speich et al., 2019). OceanObs'09[28], organised in Venice (Italy) in September 2009, celebrated a decade of progress in implementing the initial ocean observing system. Its foremost outcomes were the Framework for Ocean Observing (see above), major advances in understanding and projecting climate change, and heightened awareness that improvements in the tracking of biological variables were required (Speich et al., 2019).

OceanObs'19[29], which took place in Hawaii (USA) in September 2019, was a community-driven conference that brought people from all over the planet together to communicate the decadal progress of ocean observing networks and to chart innovative solutions to society's growing needs for ocean information in the coming decade. OceanObs'19 strived to improve the governance of the global ocean observing system, including advocacy, funding, and alignment with best practices and to designate responsibility for product definition, including production and timely delivery at the appropriate scales (global, basin, regional, national) to serve user needs.

Community White Papers are an integral part of the OceanObs conference series and the OceanObs'19 community white papers were published as part of a Research Topic in *Frontiers in Marine Science*[30]. A total of 135 open-access articles were published with input from 2,552 global ocean observation community authors. They provided a forum for community recommendations to inform the outcome of OceanObs'19 and to guide post-conference activities. These papers promote international collaboration, describe the status of a truly large-scale sustained ocean observing effort, and collectively help shape a vision for the next decade (Speich et al., 2019). These include needs and requirements for the next decade from ocean communities, such as sea surface temperature (O'Carroll et al., 2019), sea level (Cazenave et al., 2019), the deep ocean (Levin et al., 2019), marine biodiversity (Bax et al., 2019; Canonico et al., 2019) and marine ecosystem modelling and forecasting (Capotondi et al., 2019); reviews of current observation systems and technologies, such as for the air–sea interface (Centurioni et al., 2019), Southern Ocean observations (Newman et al., 2019), biogeochemical, biological and ecosystem *in situ* sensing technologies (Wang et al., 2019), the Argo Programme (Roemmich et al., 2019), and the International Long-Term Ecological Research Network (ILTER) (Muelbert et al., 2019); and visions for the future of ocean observations, such as on connecting climate, fisheries and marine ecosystem observations (Schmidt et al.,

[27] http://www.oceanobs09.net/work/oo99.php
[28] http://www.oceanobs09.net/
[29] http://www.oceanobs19.net/
[30] https://www.frontiersin.org/research-topics/8224/oceanobs19-an-ocean-of-opportunity#overview

2019), and on an Integrated Marine Debris Observing System (Maximenko et al., 2019), which EuroSea will support with the specialized task 1.1.3.

The Community White Papers and the recommendations from the conference sessions form the **Living Action Plan**[31] from OceanObs'19, a gathering of community strategies outlining a variety of actionable tasks for the next decade.

Another important actor in the field of ocean observation that calls for continuous support of GOOS by national governments, is the Partnership for Observation of the Global Ocean (POGO). POGO consists of directors of oceanographic institutions around the world, and act as a forum to promote and coordinate observation of the global ocean. **POGO's Strategy Document**[32] focuses attention on implementation issues such as technical compatibility among observing networks, shared use of infrastructure, public outreach and capacity building.

The Group on Earth Observation (GEO) is a partnership between national governments and participating organisations and coordinates international efforts to build a **Global Earth Observation System of Systems**[33] **(GEOSS)**. This 'system of systems' will proactively link together existing and planned observing systems around the world and support the development of new systems where gaps currently exist. GOOS helps to develop GEOSS through the Blue Planet initiative, the ocean and coastal arm of GEO. As indicated in the **GEO Blue Planet Initiative 2020 – 2022 Implementation Plan**[34]**,** work will focus on identifying and sharing best practices on stakeholder engagement and societal awareness; communications; data discovery, access and utilization; and capacity development (i.e. focused on applications and users of ocean observation). In addition, to address the pressing need for coordinated biodiversity observations around the globe, GEO is implementing a Biodiversity Observation Network (GEO BON), with a thematic focus on the Marine Biodiversity Observation Network (MBON). MBON is a global community of practice for sustained, operationalized measurements of marine biodiversity, who are developing marine **Essential Biodiversity Variables**[35] **(EBVs)** (Canonico et al., 2019). The **vision of MBON**[36] is to establish sustained biological ocean observing capability integrated with GOOS approaches and systems, which will enhance the understanding of life in the ocean, and support robust, resilient economies and communities, while increasing our ability to protect ocean resources (Canonico et al., 2019).

In an effort to coordinate a global marine biodiversity observing system, the GOOS BioEco Panel, GEO MBON, and the Ocean Biogeographic Information System (OBIS, a distributed global data system and a community of data contributors and users within the IODE programme) signed the **GOOS – MBON - OBIS collaboration agreement**[37] in 2016. This agreement acknowledges MBON's role to inform and assist the development of national and regional observing networks and EBVs, the role of GOOS in articulating the interdisciplinary observing requirements for EOVs, and the role of OBIS to serve local, regional, and international user needs

[31] http://www.oceanobs19.net/living-action-plan/
[32] http://ocean-partners.org/sites/ocean-partners.org/files/public/attachments/article/Products/POGO_strategy_document_Final.pdf
[33] https://www.geoportal.org//
[34] https://geoblueplanet.org/wp-content/uploads/2020/02/2020-2022-Implementation-Plan.pdf
[35] https://geobon.org/ebvs/what-are-ebvs/
[36] Canonico *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00367/full
[37] Benson *et al.* (2018) https://www.frontiersin.org/articles/10.3389/fmars.2018.00428/full

for harmonized biodiversity and biogeographic data (Canonico et al., 2019). The **vision for 2030 of OBIS**[38] is to mature as a critical component in accelerating data sharing of marine species observation in response to the urgent needs imposed by a changing planet.

OBIS supports several international processes such as those under the UN Regular Process (World Ocean Assessment), the IPBES and the Convention on Biological Diversity (CBD). The CBD, originated by UNEP, is a multilateral treaty for the conservation of biological diversity, the sustainable use of the components of biological diversity, and the fair and equitable sharing of the benefits arising from the utilization of genetic resources. The **CBD Strategic Plan for Biodiversity 2011-2020**[39] provides an overarching framework on biodiversity, not only for the biodiversity-related conventions, but also for the entire United Nations system and all other partners engaged in biodiversity management and policy development. This includes the Cartagena Protocol on Biosafety, the Nagoya Protocol on Access and Benefit-sharing, and 20 time-bound, measurable Aichi Biodiversity Targets that should be met by the year 2020. The Aichi Biodiversity Targets aim to better understand and predict how biological diversity underpins ecosystem function and how the provision of ecosystem services are essential for human well-being (Klein et al., 2019). The identification and monitoring of components of biological diversity that need to be conserved and used sustainably is mainly the responsibility of national governments who are required to develop national biodiversity strategies and action plans. National governments are also required to integrate these targets into broader national plans for environment and development. The **post-2020 global biodiversity framework**[40] was due to be adopted in October 2020 at the 15th meeting of the Conference of the Parties (COP 15) to the CBD, but in light of the COVID-19 pandemic, this meeting will be postponed.

The International Union for Conservation of Nature (IUCN) Species Programme provides advice to CBD Parties, governments and partners on the implementation of the Strategic Plan for Biodiversity and its Aichi Biodiversity Targets. The IUCN is also heavily involved in work towards the Targets themselves. Building on the Post-2020 Global Biodiversity Framework to address the 'nature emergency' and the action needed to secure the planet's life support systems, the **IUCN World Conservation Congress 2020**[41] will be an opportunity to shape the ambition and galvanize the necessary action on restoring ocean health and advancing knowledge, learning, innovation and technology (with dedicated sessions on monitoring and Earth observations, for instance). The congress was postponed from its original date in June 2020 to January 2021 in Marseille (France), in light of the COVID-19 pandemic. The IUCN World Conservation Congress, held once every four years, brings together several thousand leaders and decision-makers from government, civil society (including indigenous peoples), business, and academia, with the goal of conserving the environment and harnessing the solutions nature offers to global challenges.

The annual Our Ocean conferences are hosted by a different country each year. They aim to build partnerships between government, industry, science and civil society and generate commitments for ocean action that link scientific knowledge, technology and finance to meet the challenges facing the ocean. The seventh edition, **Our Ocean Conference 2020**[42] hosted by Palau, was postponed from its original date in August, and should be held in December 2020. It will convene partners from across the globe to enable protection and sustainable use to go hand in hand so that the ocean can continue to provide for the needs

[38] Klein *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00588/full
[39] https://www.cbd.int/sp/
[40] https://www.cbd.int/conferences/post2020
[41] https://www.iucncongress2020.org/
[42] https://www.ourocean2020.pw/

of future generations. At the core of the Our Ocean conferences are voluntary commitments for significant and meaningful actions towards a clean, healthy and productive ocean. Some of the commitments include monetary government support to national and international ocean observation systems.

In 2018, Norway, the host country of the Our Ocean 2019 Conference, established the High Level Panel for a Sustainable Ocean Economy, a unique group of world leaders from around the globe committed to developing, catalysing and supporting solutions for ocean health and wealth in policy, governance, technology and finance. The final report of this panel, entitled **A Sustainable Ocean Economy**[43], to be completed in 2020, will highlight that the protection and sustainable use of the ocean will generate higher value creation that will help meet some of humanity's most urgent needs. In advance of the final report, the World Resources Institute, which hosts the secretariat supporting the initiative, published a series of **Blue Papers**[44] exploring specific themes of the Sustainable Ocean Economy, including technology, data and new models for sustainably managing ocean resources.

The growing interest in expanding the blue economy, and the costs and benefits of ocean observation supporting these, has led the Organisation for Economic Co-operation and Development (OECD) to publish reports on the **Ocean Economy to 2030**[45] (Larkin et al., 2018) and **Rethinking Innovation for a Sustainable Ocean Economy**[46]. In recent years, the Group of Seven (G7) has increased political awareness in the seas and ocean domain by having priorities, discussions and actions on ocean observation (**Tsukuba communiqué**[47] **or G7 Future of the Seas and Oceans Flagship Initiative, and Turin communiqué**[48]), coastal communities (**Charlevoix blueprint**[49]) and biodiversity (**Biarritz summary**[50]).

As is evident from this section on international ocean observing foresight, the landscape is a crowded, interlinked network, with multiple initiatives and overlapping visions, implementation plans, and agendas. Multiple conference series, addressing everything from scientific knowledge to political will, addresses multiple levels of need and readiness to achieve society relevant and sustained ocean observations at a global level. Due to this historical approach to ocean management some redundancies are present in the landscape. However, the fact that different organisations and initiatives develop foresight activities relevant to ocean observation shows the great importance that these have placed in providing robust and scientifically based advice to international management. To achieve sustained ocean observations globally we need to capitalise on these redundancies as opportunities to work closer together.

[43] https://www.oceanpanel.org/the-report
[44] https://www.oceanpanel.org/blue-papers
[45] https://www.oecd.org/environment/the-ocean-economy-in-2030-9789264251724-en.htm
[46] http://www.oecd.org/publications/rethinking-innovation-for-a-sustainable-ocean-economy-9789264311053-en.htm
[47] https://www8.cao.go.jp/cstp/english/others/communique_en.html
[48] http://www.g7italy.it/en/science-ministerial-meeting/
[49] https://www.international.gc.ca/world-monde/international_relations-relations_internationales/g7/documents/2018-06-09-summit-communique-sommet.aspx?lang=eng
[50] https://www.elysee.fr/admin/upload/default/0001/05/622fadea9ed312f1f42c6e4e7cbb126086a30897.pdf

2.2. European level foresight

As it is globally, European ocean observation and forecasting capabilities remain the responsibility of individual countries and are the essential building blocks of the European observation and forecasting landscape. There are many strong regional ocean observing and forecasting systems and initiatives. Unfortunately, Europe's capability in ocean observing and monitoring remains largely uncoordinated. There has been increased momentum and investment towards a more coherent and coordinated ocean observing value chain both within Europe and connected to global initiatives (Larkin et al., 2018). However, a full and comprehensive European alignment on funding and programming priorities is difficult due to the diversity of priorities and interests at national and European level. The ocean observing community's priorities includes everything from operational oceanography to wider research, and from environmental assessments to blue economy activities (Mackenzie et al., 2019).

European Union's frameworks relevant to ocean observing and forecasting

The European Union (EU) has historically been one of the drivers for coordinating ocean observation, monitoring and forecasting in European seas. This includes initiatives to bring together different communities and to bridge the gap with end-users, and policies and directives that mandate European Member States to collect ocean observation data nationally and empower national coordination and collaboration between countries.

One of first ocean policy areas to be governed at EU level was the management of fisheries, with the **Common Fisheries Policy**[51] **(CFP)** introduced in the 1970s, and reformed several times including most recently in 2014. The CFP is a set of rules for managing European fishing fleets and for conserving fish stocks. The CFP relies on biological, environmental, technical and socio-economic data collected, managed and supplied by EU countries under the **Data Collection Framework**[52]. In addition, the best available scientific advice is a basis for defining management measures, is provided by the Scientific, Technical and Economic Committee for Fisheries (STECF), supported by the European Commission's Joint Research Centre (JRC), the International Council for the Exploration of the Sea (ICES, see below) for the North Atlantic, the General Fisheries Commission for the Mediterranean (GFCM), the Black Sea and connecting waters, and other regional fisheries management organisations (RFMOs).

The protection of the environment is also a policy area where historically the European Union coordinates and enforces action in its Member States, aligning with international agreements, such as the Convention on Biological Diversity Strategic Plan for Biodiversity 2011-2020 (see above), which was translated into the **EU Biodiversity Strategy to 2020**[53]. Under the new European Green Deal, the roadmap for making the EU's economy sustainable, the new **EU Biodiversity Strategy to 2030**[54] is a comprehensive, ambitious, long-term plan for protecting nature and reversing the degradation of ecosystems. This strategy includes commitments to manage and monitor protected areas (30% of the EU's sea area by 2030) and requirements the monitoring of pollution. A key element for the marine environment under this new strategy is the application of an

[51] https://ec.europa.eu/fisheries/cfp_en
[52] https://ec.europa.eu/fisheries/cfp/fishing_rules/data_collection
[53] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0244
[54] https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm

ecosystem-based management approach for national maritime spatial plans by 2021, including area-based conservation-management measures, under the **Maritime Spatial Planning (MSP) Directive**[55]. In addition, the **7th Environment Action Programme**[56], which entered into force in 2014, guided the European Union environment policy until 2020 and provides a long-term vision to 2050, and provided the EU with policy frameworks to ensure predictable and coordinated action for Europe's environment and climate change policies. Currently, and in line with the European Green Deal, the **8th Environment Action Programme** is being prepared.

EU nature legislation forms the backbone of biodiversity policy and the legal basis for the nature protection network in the EU. This legislation includes the **Birds Directive**[57], which designates Special Protection Areas (SPAs) and include many marine migratory species, and the **Habitats Directive**[58], which designates Special Areas of Conservation (SACs). SPAs and SACs constitute the Natura 2000 network of protected areas in Europe. More than 3000 marine Natura 2000 sites have been designated in Europe, which cover more than 5% of the total EU marine area and provide protection in a range of coastal habitats (mainly shallow coastal areas) and for a range of species covered by the Directives (Benedetti-Cecchi et al., 2018). Reinforcing these Directives, the **Marine Strategy Framework Directive**[59] **(MSFD)** has the goal of achieving Good Environmental Status (GES) in European waters by 2020. Member States have to update their marine strategies every six years, which include a reporting obligation on updated monitoring programmes. The next such reporting obligation is due at the end of 2020. The **Report on the First Implementation Cycle of the MSFD**[60] highlights some avenues to explore for improving monitoring and suggests to better harness ocean observation systems coordinated through research programmes to increase the resources devoted to implementing the MSFD. Supporting the implementation of the MSFD, the EU's Joint Research Centre (JRC) together with a modelling experts' group, has been working on building robust and reliable marine models (Marine Modelling Framework, MMF) to simulate the different compartments that influence the dynamics of marine ecosystems (Macias et al., 2019). These models have been used to test the impacts of diverse management options on the status and services of marine ecosystems at all EU basins and are used to forecast the future impact of pressures on the marine environment.

The **Water Framework Directive**[61] **(WFD)** is closely linked to the MSFD. It set a goal of achieving Good Status for all EU surface and groundwaters by 2015 (with the possibility to extend the maximum deadline until 2027), tying in with the goal of Good Environmental Status under the MSFD. WFD actions taken to achieve Good Status aim to reduce marine pollution from land-based sources and protect ecosystems in coastal and transitional waters, which are vital spawning grounds for many marine fish species. Other European Directives with monitoring requirements in the marine environment (see figure 4) include the **Bathing Water Directive**[62] **(BWD)** (for microbial pathogens), the **Urban Waste Water Treatment Directive**[63] **(UWWTD)**

[55] https://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning_en
[56] https://ec.europa.eu/environment/action-programme/
[57] https://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm
[58] https://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm
[59] https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/marine-strategy-framework-directive/index_en.htm
[60] https://ec.europa.eu/info/sites/info/files/com2020_259_final_en.pdf
[61] https://ec.europa.eu/environment/water/water-framework/index_en.html
[62] https://ec.europa.eu/environment/water/water-bathing/index_en.html
[63] https://ec.europa.eu/environment/water/water-urbanwaste/index_en.html

(estuaries and coastal waters considered as Sensitive Areas), and the **Nitrates Directive**[64] (monitoring in water bodies with regard to nitrate concentrations), which could lead to eutrophication.

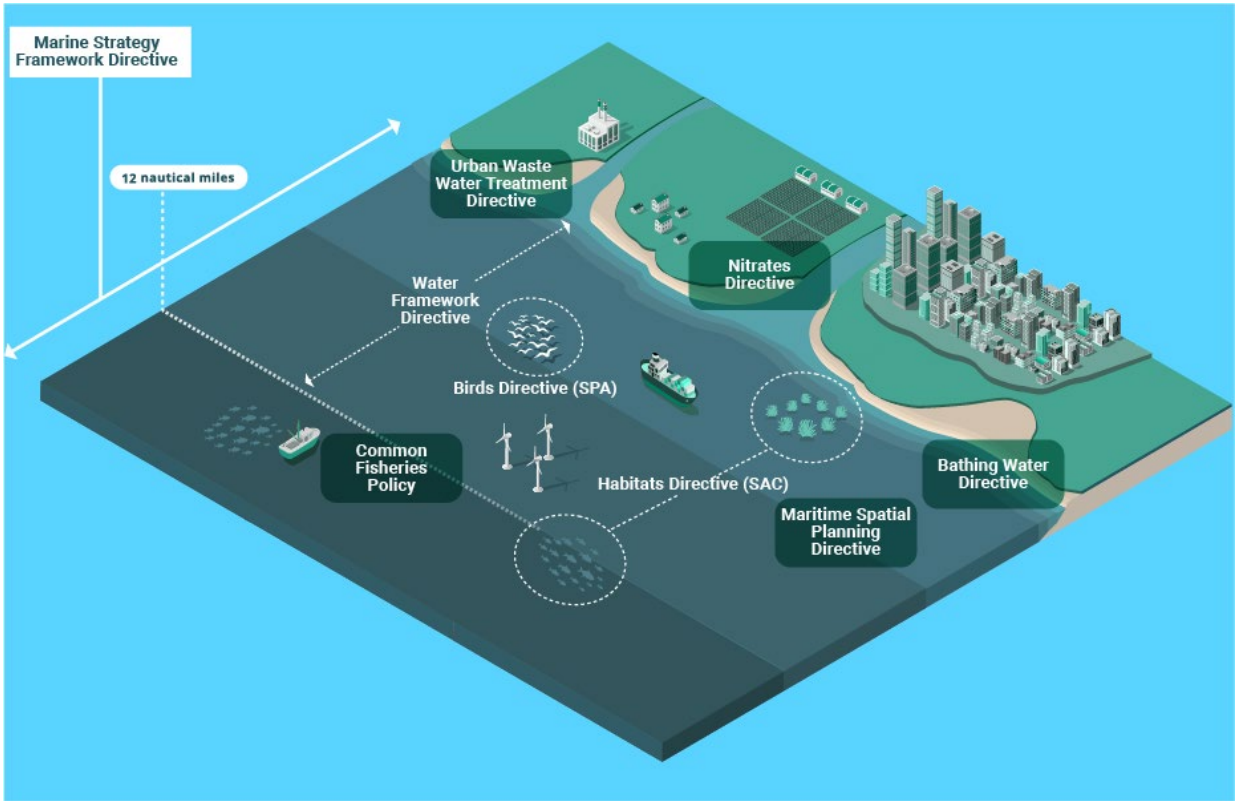

Fig. 4: European Directives regulating marine-related elements. Source: EEA-ETC/ICM, prepared for WISE Marine portal[65]*.*

Recognising the inter-connectedness of industries and human activities centred on the sea, and how a decision in one area can affect all the others, the EU **Integrated Maritime Policy**[66] **(IMP)** seeks to provide a more coherent approach to maritime issues, with increased coordination between different policy areas. The now defunct EU **Strategy for Marine and Maritime Research**[67] **(MMRS)** was adopted to provide a solid science base to the IMP and considered the coordinated development of marine research infrastructures at European level as an essential objective for the European Commission in cooperation with the Member States. The vision was supported by the establishment of the European Strategy Forum on Research Infrastructures (ESFRI) as a self-regulated body between the EU countries and the European Commission, playing a key role in policy-making on Research Infrastructures in Europe. Ocean observation is a key component of the **ESFRI Roadmap 2018**[68] which lays out a medium- to long-term vision (2020-2040) for environmental Research Infrastructures (including Marine Research Infrastructures - MRI). An **update of the ESFRI Roadmap is expected in 2021**[69]. Facilitating the establishment and operation of new or existing Research Infrastructures with European interest, European Research Infrastructure Consortia (ERICs) are

[64] https://ec.europa.eu/environment/water/water-nitrates/index_en.html
[65] https://water.europa.eu/marine
[66] https://ec.europa.eu/maritimeaffairs/policy_en
[67] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=LEGISSUM%3Ari0008
[68] https://ec.europa.eu/info/files/esfri-roadmap-2018_en
[69] https://www.esfri.eu/sites/default/files/ESFRI_Roadmap2021_Public_Guide_Public.pdf

specific legal entities recognised in all EU countries. The ESFRI Roadmaps combine ESFRI Projects, which are new Research Infrastructures in progress towards implementation, such as DANUBIUS-RI (International Centre for Advanced Studies on River-Sea Systems); and successfully implemented Research Infrastructures, called ESFRI Landmarks. Most of the Marine ESFRI Landmarks are ERICs, such as LifeWatch ERIC, Euro-Argo ERIC, ICOS ERIC (Integrated Carbon Observation System), EMBRC ERIC (European Marine Biological Resource Centre) and EMSO ERIC (European Multidisciplinary Seafloor and water column Observatory). These five ERICs are collaborating to develop a **Comprehensive and Integrated Strategy of the European Marine Research Infrastructures for Ocean Observations**[70]. The European coastal observing research infrastructure (JERICO-RI) has also developed a **Coastal Science Strategy**[71] and is currently applying to be included in the ESFRI Roadmap 2021.

EuroGOOS' Regional Operational Oceanographic Systems (ROOS, see below); other global ocean observing networks; and several research infrastructures under the umbrella of the ENVRIplus project, are feeding into the *in situ* components of the European Union's flagship satellite Earth Observation Programme, Copernicus. Copernicus focuses on operational monitoring and forecasting for the atmosphere, ocean and land services and its main users are policy-makers and public authorities. The Copernicus Programme and its services are implemented in partnership with several actors. Mercator Ocean International implements the Copernicus Marine Environment Monitoring Service (CMEMS), and provides regular and systematic reference information on the physical and biogeochemical ocean and sea-ice state for the global ocean and the European regional seas (Le Traon et al., 2019). Copernicus Climate Change Service is implemented by the European Centre for Medium-Range Weather Forecasts (ECMWF). One of the most important scientific goals of the **ECMWF Strategy 2016–2025**[72] is the incorporation of the interaction between atmosphere, ocean, sea-ice and land into its Earth system model to improve its medium range forecasting skills. The European Environment Agency (EEA) is leading work to catalogue the *in situ* requirements of the Copernicus services (including **the main CMEMS recommendations for the evolution of the ocean observing system**[73]), developing frameworks and pilot agreements to ensure access to all the relevant data in a timely and sustainable way. The EEA is the environment agency of the European Union, whose task is to provide sound, independent, timely, targeted, relevant and reliable information to policy-making and the public. The EEA also contributes to the Marine Water Information System for Europe (WISE-Marine), which shows the information and knowledge gathered or derived through the MSFD (see above) and other key marine EU policy drivers. With all this available information collected under EU and other regional and international initiatives, the EEA synthesizes **Marine Messages**[74], which gives an overview of the current state-of-affairs of European seas and their uses. The latest edition of Marine Messages proposes the establishment of a consistent, long-term, EU-supported and -coordinated monitoring programme, and the related infrastructure, for the environment, nature and living resources in each marine region.

The European Marine Observation and Data Network (EMODnet) is central to the EU's **Blue Growth Strategy**[75], which contributes to the EU's Integrated Maritime Policy (IMP) as part of the EU's **Marine Knowledge 2020 Agenda**[76]. EMODnet is a network of marine organisations working together to process the

[70] Dañobeitia *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2020.00180/full
[71] Farcy *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00529/full
[72] https://www.ecmwf.int/sites/default/files/ECMWF_Strategy_2016-2025.pdf
[73] Le Traon *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00234/full
[74] https://www.eea.europa.eu/publications/marine-messages-2/
[75] https://ec.europa.eu/maritimeaffairs/policy/blue_growth_en
[76] https://ec.europa.eu/maritimeaffairs/policy/marine_knowledge_2020_en

ocean observation data according to international standards and make that information freely available as interoperable data layers and data products. Having achieved the **EMODnet Strategic Vision**[77] target for 2020, the 2nd EMODnet Open Conference in 2021 (postponed from its 2020 date due to the COVID-19 pandemic) will discuss the future of EMODnet. SeaDataNet, the Pan-European Infrastructure for Ocean & Marine Data Management, is the leading infrastructure for the EMODnet data management, providing standards to marine data centres, as well as high-quality archive for this data. The three main components of the European marine data management landscape (SeaDataNet, EMODnet and CMEMS, see figure 5) are working together to implement the establishment of the marine-thematic Blue-Cloud Pilot as an element of the **European Open Science Cloud (EOSC) Strategic Implementation Plan**[78].

Currently, the EU is preparing a legal framework for the collection of ocean data to be ready by mid-2021, and the "Towards a Digital Twin of the Ocean" initiative, which aims to integrate a wide range of data sources, infrastructures and communities in support to the EU Green Deal and to societal transitions.

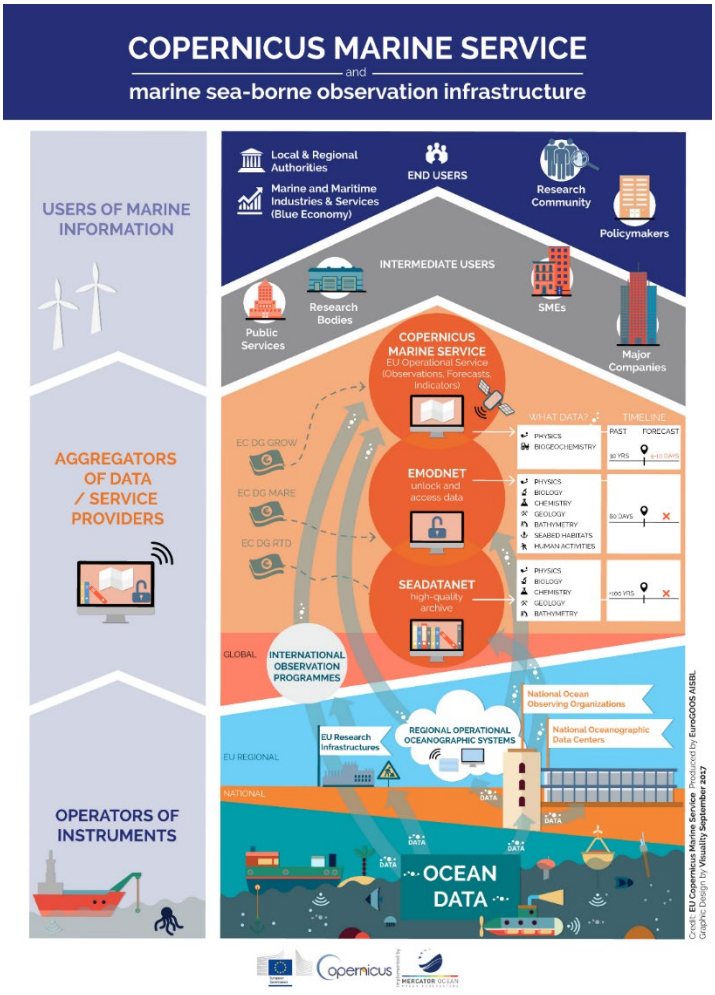

Fig. 5: Components of the pan-European marine data management landscape. Credit: EU Copernicus Marine Service and EuroGOOS AISBL.

[77] Martín Míguez *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00313/full

[78] https://ec.europa.eu/info/publications/european-open-science-cloud-eosc-strategic-implementation-plan_en

The European Union also leads the regional component of the Group on Earth Observations (GEO, see above), called EuroGEO. This European effort is helping to build the Global Earth Observation System of Systems (GEOSS) through networking and promoting further incubation and scaling-up of the most promising user-oriented Earth observation services conducted at national or EU levels, moving from a data-centric- to a user-driven approach. EuroGEO (former EuroGEOSS) brings together all of the Earth observation resources available in Europe, including Copernicus, the European Space Agency, the resources from the **INSPIRE Directive (Infrastructure for Spatial Information in Europe)**[79] and Horizon 2020 funded projects, to more effectively support governments in their decisions, boost innovation and improve lives in Europe. The **EuroGEO Implementation Plan (2020-2022)**[80] outlines five strategic actions to be conducted, including the development of application pilots by bottom-up Action Groups, one of which is on marine.

The EU is investigating how to provide leadership to further advance the role of science in international ocean governance. This includes a dedicated Thematic Expert Working Group[81] on strengthening international ocean research, data and knowledge. This working group will explore and suggest actions for the EU and its Member States to enable coordinated, sustainable and fit-for-purpose ocean observation to progress international ocean governance.

The European Commission also helps to fill short-term gaps in knowledge by funding calls for tenders and proposals, enabling studies to be conducted that result in scientific advice. Long-term research projects are supported under EU Framework Programmes such as Horizon 2020 (2014-2020), and the upcoming 9th EU Framework Programme for Research and Innovation, Horizon Europe (2021-2027). Several ocean observation systems and coordination efforts have been sustained using these European Commission instruments, including coordination and innovation actions such as EU Horizon 2020 projects EUROFLEETS+, AtlantOS, PERSEUS, ODYSSEA and EuroSea. Horizon Europe will support European Partnerships as a new instrument to link research and innovation closely to policy needs, develop close synergies with national and regional programmes, bring together a broad range of innovation actors to work towards a common goal, and turn research into socio-economic results. The **European Partnership for a climate neutral, sustainable and productive Blue Economy**[82] is being prepared for implementation in 2023. The vision for this partnership is to develop, among other activities, a fully integrated ocean, seas and inland waters monitoring system by 2030, which will provide a holistic systemic view of the environmental impact of human-induced activities. Interventions under this Partnership will build on already existing Strategic Research and Innovation Agendas (SRIAs) developed for dedicated EU sea basins (see below), and EU and national projects and initiatives, bringing all these initiatives under one umbrella.

Community coordination efforts relevant to ocean observing and forecasting

The European marine research community considers ocean observation essential to monitor and understand the marine environment and how it is changing, but agrees that some efforts are needed in the coordination of European ocean observation and forecasting (EOOS Steering Group, 2017). The ocean observing

[79] https://inspire.ec.europa.eu/
[80] https://www.earthobservations.org/documents/gwp20_22/EUROGEO.pdf
[81] https://webgate.ec.europa.eu/maritimeforum/en/node/4515
[82] https://www.era-learn.eu/partnerships-in-a-nutshell/r-i-partnerships/european-partnerships-under-horizon-europe/partnerships-under-preparation/candidates-for-european-partnerships/31_blueeconomy.pdf

community is already aligned with international (see chapter 2.1) and regional (see chapter 2.3) initiatives. However, *in situ* observing of the ocean is much less coordinated and integrated than remote sensed observations from satellites or than data infrastructures, as *in situ* observations are not funded centrally, among other reasons. Building on earlier initiatives, the European ocean observing community has made significant progress towards a sustained and fit-for-purpose European Ocean Observing System (EOOS) by coordinating the components of *in situ* ocean observation.

The European Ocean Observing System

The European Ocean Observing System (EOOS) is a coordinating framework designed to align and integrate Europe's long-term ocean observing capacity; to promote a systematic and collaborative approach to collecting information on the state and variability of our seas and ocean; and to underpin sustainable development, protection and conservation of the marine environment and its resources. EOOS is not a new observation network or system. It will not do what other networks do, but instead it acts as a framework to strengthen coordination and dialogue between systems, networks and stakeholders. As an inclusive, voluntary federation, EOOS will contribute to global efforts in ocean observing such as GOOS and GEOSS, and international policies including the UN 2030 Agenda for Sustainable Development and climate change agreements such as the COP21 Paris Agreement (see above).

As envisioned in the **EOOS Strategy 2018-2022**[83], the EOOS framework will help make ocean observation a public utility in Europe by 2030. It will do this by strengthening coordination, strategy and sustainability in ocean observation (Mackenzie et al., 2019). The **EOOS Implementation Plan 2018-2022**[84] focuses on six thematic areas: mapping and stakeholder engagement, policy context and foresight, implementation of system elements, funding, communications, and governance. The EuroSea dedicated task 1.1.1 will support the implementation of EOOS.

Since 2007, EuroGOOS and the European Marine Board (see below) have been working together to develop EOOS as a community supported-, and co-developed framework to achieve an end-to-end sustained European ocean observing system. The current EOOS governance includes a broad representation of the European and International ocean observation community, including JPI Oceans (see below) and GOOS (see above), and guides the development of the EOOS Strategy and Implementation Plan. The EOOS framework is co-designed with stakeholders through several rounds of review and consultation, led by the EOOS steering group, and widely open to all. To date, two stakeholder consultations and several events (a first brainstorming workshop, a European Parliament event, an EOOS Forum, and an EOOS Conference) have taken place, as a platform to connect disparate groups of stakeholders. The 2018 EOOS conference delivered a **Call to Action for Evolving European Ocean Observing**[85]. It calls on European countries and the EU, to establish roadmaps with specific actions and indicators to move towards a more integrated, transparent and coordinated approach. Since 2018, different communities have provided avenues to make EOOS a reality, such as the **integration of European coastal and biological observing systems**[86].

The following organisations have coordination and integration of ocean observation at the core of their strategies and activities and support the implementation of EOOS.

[83] http://www.eoos-ocean.eu/download/EOOS_Strategy_2018-2022_October2018.pdf
[84] http://www.eoos-ocean.eu/download/EOOS_ImplementaionPlan_2018-2022_October2018.pdf
[85] https://www.emodnet.eu/conference/eoos2018/call-action.html
[86] She *et al* (2019)https://www.frontiersin.org/articles/10.3389/fmars.2019.00314/full

EuroGOOS (the European GOOS Regional Alliance (GRAs), see above) contributes to the definition, support, promotion and implementation of operational oceanography, ocean health and climate services, fostering the scientific understanding of the European seas, as well as their preservation and sustainable exploitation. EuroGOOS working groups, and networks of observing platforms (task teams) provide fora for cooperation, unlock quality marine data and deliver common strategies, priorities and standards. These EuroGOOS networks work towards integrated, sustained and fit-for-purpose European ocean observing, underpinning the EOOS framework. The EuroGOOS Policy Brief **European operational oceanography: Delivering services for Blue Growth and ecosystem-based management**[87] puts forward four priority areas for the European operational oceanography, including developing operational ecology services for ecosystem-based management and improved modelling and forecasting. In addition, the **EuroGOOS perspective on Operational Modelling Capacity in European Seas**[88] provides recommendations and proposed actions, to foster the marine and coastal operational modelling capacity in Europe. The **EuroGOOS 2020-2030 strategy**, dovetailed with the GOOS 2030 Strategy, is currently under development and will be published in late 2020. EuroGOOS supports the Regional Operational Oceanographic Systems (ROOS) in European regional seas, mainly the Arctic (Arctic ROOS), the Baltic (BOOS), the North West Shelf (NOOS), the Ireland-Biscay-Iberian area (IBI-ROOS) and the Mediterranean (MONGOOS). EuroGOOS also facilitates cooperation in the Black Sea region, following the Black Sea GOOS Strategic Action and Implementation Plan (see below). The ROOSs coordinate and support development and joint service production in European maritime regions, feed marine data to pan-European portals, bringing tangible added value to European cooperation, and together with EuroGOOS and its networks enhance the European leadership in ocean observing, forecasting and services.

The European Marine Board (EMB) is the leading European think tank in marine science policy. EMB conducts foresight activities on topics of strategic importance for marine sciences in Europe and on topics that are yet to be addressed properly, or lack visibility. Ocean observation, monitoring, data, modelling and forecasting are essential to understand the marine environment and how it is changing, and to take informed decisions to ensure the sustainable use of resources from the ocean. For this reason, EMB has conducted foresight documents on specific marine research infrastructures, such as the **Next Generation European Research Vessels**[89]; and recommendations to **Strengthening Europe's Capability in Biological Ocean Observation**[90], and to **Enhancing Europe's Capability in Marine Ecosystem Modelling for Societal Benefit**[91], among many others. In addition, the EMB's flagship series, Navigating the Future, provides regular pan-European summaries of the current status of marine research, priority recommendations and future scientific challenges in the context of European societal needs. A dedicated **Navigating the Future IV**[92] chapter addressed research frontiers for next-generation ocean observation and current and future infrastructure developments, and placed these in the context of European needs and policy frameworks. Most recently, **Navigating the Future V**[93] gives a holistic view of marine science and highlights the need of integrated, augmented and sustained ocean observation to address the current knowledge gaps of the ocean.

The EMB co-organises the EurOCEAN conferences with the European Commission and others, such as the Presidency of the Council of the European Union or the Intergovernmental Oceanographic Commission of

[87] http://eurogoos.eu/download/publications/EuroGOOS-Policy-Brief-2016.pdf
[88] Capet *et al.* (2020) https://www.frontiersin.org/articles/10.3389/fmars.2020.00129/full
[89] https://www.marineboard.eu/european-research-vessels
[90] https://www.marineboard.eu/biological-ocean-observation
[91] https://www.marineboard.eu/marine-ecosystem-modelling
[92] https://www.marineboard.eu/publication/navigating-future-iv
[93] https://marineboard.eu/sites/marineboard.eu/files/public/publication/EMB_NFV_Webv12%20%28002%29.pdf

UNESCO. EurOCEAN conferences are major European marine science policy conferences, which bring stakeholders together to speak with one voice towards policy. Since EurOCEAN 2004, conference delegates have delivered EurOCEAN Declarations, joint policy statements to raise decision-makers' awareness of the marine research priorities and propose concrete actions. These statements have been critical drivers of research and policy developments in Europe. The **Ostend Declaration**[94] adopted by the EurOCEAN 2010 conference put EOOS as one of three top priorities to 2020. The **Rome Declaration**[95] (EurOCEAN 2014) called for further development of EOOS. The EurOCEAN 2019 conference broke this tradition of delivering conference Declarations, as Navigating the Future V (see above), developed by a wide range of experts and peer-reviewed, was a more comprehensive declaration of what marine science should look like in the next decade and how can it contribute to achieve the Sustainable Development Goals. The requirement for observations to support this science was highlighted in Navigating the Future V.

The EurOCEAN 2010 Ostend Declaration also supported the Joint Programming Initiative on "Healthy and Productive Seas and Oceans (JPI Oceans). Joint Programming Initiatives were introduced by the European Commission in 2008 to tackle Grand Societal Challenges that cannot be solved by one nation alone. Joint Programming Initiatives were created to allow EU Member States and Associated Countries to participate in joint initiatives most relevant to their national priorities (JPI Oceans, 2015). Due to the interconnected nature of the marine environment, climate change and the maritime economy, the seas and ocean were recognised as a Grand Societal Challenge, which led to the implementation of JPI Oceans. The strategy, **JPI Oceans Strategic Research and Innovation Agenda 2015-2020**[96] **(JPI Oceans SRIA)**, was developed and agreed by the participating countries after a forward-looking exercise and consultation process. Observing, Modelling and Predicting Oceans State and Processes, was highlighted in the strategy and the shared use of research infrastructures and sustained cost-effective observing systems is a cross-cutting issue. At the end of 2020, an updated version of the JPI Oceans SRIA will be made public focusing on strategic research areas to achieve a healthy and productive ocean, with cross-cutting tools including governance and ocean observation.

Similar to the international ocean observing foresight section, it is clear that the European ocean observing landscape is also quite crowded and interlinked, with multiple initiatives, visions, research agendas, and plans. However, at the European level these are very well interlinked and networked and unlike the international landscape there are not as many perceived redundancies in the system. If one of these networks are discontinued the hope for sustained ocean observations in Europe will be minimized. However, this does not necessarily make the system more efficient, as the multiple levels of interaction, can also be a drawback. To achieve sustained ocean observations at European level we need to support the EOOS framework, where all these systems can work together, creating the efficiency but with built in redundancy where needed.

94 http://www.euroceanconferences.eu/sites/euroceanconferences.eu/files/public/attachments/EurOCEAN2010_Ostend_Declaration_Oct2010.pdf

95 https://marineboard.eu/sites/marineboard.eu/files/public/publication/Rome%20Declaration-249_0.pdf

96 http://www.jpi-oceans.eu/library?refid=246303

2.3. Ocean- and sea basin-based foresight

The sea basins connect regions and countries, implying that their challenges are also shared, such as environmental problems or specific Blue Economy challenges. Under the premise that countries shouldn't tackle transnational challenges alone, many countries and marine research organisations collaborate at sea-basin scale. In addition, the sea-basin approach for transnational and transboundary cooperation is of great importance for leading international and European processes in terms of practical implementation (COLUMBUS consortium 2016).

The Integrated Maritime Policy (IMP, see above) have as one cross-cutting priority the development of sea basin strategies as specific agreements and research activities for the Atlantic Ocean, Mediterranean, Baltic and the Black Sea basins (see below). These sea-basin strategies play a key role in the economic development of the respective sea basins and at country level. The imporance of coastal regions and their economic development is of special concern unifying all sea basins. In addition, the Marine Strategy Framework Directive (MSFD, see above) requires that EU Member States develop marine strategies for monitoring by using existing regional cooperation structures such as the Regional Sea Conventions. The aim is to coordinate their actions with those of third countries outside the EU in the same sea basin. Regional Sea Conventions can support the implementation of the MSFD in at least three ways: 1) by improving regional and cross-regional coherence of national implementation; 2) by making their long-standing experience and established cooperation structures available to increase the efficiency and effectiveness of national implementation; and 3) by offering practical opportunities for the mobilisation and coordination of relevant third countries' activities.

The **Convention for the Protection of the Black Sea**[97], known as the Bucharest Convention and implemented by the Black Sea Commission, is the basic legal framework for regional cooperation to protect the coastal and marine environment in the Black Sea. It provides a framework for scientific and technical cooperation, and monitoring and assessment programs, laid down in the **Black Sea Integrated Monitoring and Assessment Program**[98] **(BSIMAP)** and based on national monitoring programs financed by the Black Sea States. Another political agreement in this region, the **Ministerial Declaration Towards a Common Maritime Agenda for the Black Sea**[99] **(Burgas Declaration)**, encourages the countries around the Black Sea to work together in areas such as environmental observation and monitoring, and marine research and innovation. This triggered the adoption of the **European Black Sea Strategic Research and Innovation Agenda**[100] **(Black Sea SRIA)**, which provides a shared vision to 2030 including smart and integrated observing systems, and alignment of working methodologies and national policies for research and innovation. Currently, the majority of *in situ* observations in the Black Sea are commonly used for monitoring, and are generally based on near-shore monitoring programs or irregular oceanographic cruises that provide either coarse resolution of large-scale processes, or detailed but time- and site-specific snapshots of local features (Palazov et al., 2019). Several frameworks and projects, including EuroGOOS, have facilitated the cooperation between the Black Sea ocean observing, modelling and forecasting communities, following the **Black Sea GOOS Strategic Action and Implementation Plan**[101], and EU projects and initiatives such as FP7 PERSEUS and CMEMS (see above). As

[97] http://www.blacksea-commission.org/_convention.asp
[98] https://ec.europa.eu/environment/marine/international-cooperation/regional-sea-conventions/bucharest/pdf/BSIMAP_2017_to_2022_en.pdf
[99] https://ec.europa.eu/maritimeaffairs/maritimeday/sites/mare-emd/files/burgas-ministerial-declaration_en.pdf
[100] http://www.sust-black.ro/Black%20Sea%20Strategic%20Research%20and%20Innovation%20Agenda.pdf
[101] https://unesdoc.unesco.org/ark:/48223/pf0000132641

such, there is a community agreement to build a sustained **Black Sea Observing and Forecasting System[102] (BSOS)**.

The **Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean[103]**, or the Barcelona Convention, implemented by the United Nations Environment Programme Mediterranean Action Plan (UNEP-MAP), provides a platform for regional cooperation in protecting and enhancing the marine and coastal environment and promoting sustainable development in the Mediterranean region. The signing parties are required to establish national monitoring systems to regularly assess the impact of human activities on the environment. The current **UNEP-MAP Mid-Term Strategy 2016-2021[104]** includes the objective of delivering knowledge-based assessments of the Mediterranean environment and scenario development for informed decision-making and stakeholder participation, under the overarching theme of governance.

As a shared vision between the European countries bordering the Mediterranean Sea, and now adopted by all the member countries of the Union for the Mediterranean (UfM), the **BlueMed Strategic Research and Innovation Agenda[105] (BlueMed SRIA)**, requires the creation of an interoperable, fully integrated observing and forecasting system to foster blue growth in the Mediterranean area without challenging the sustainability of the marine environment. This SRIA also provides priorities to other initiatives, such as the Initiative for the Sustainable Development of the Blue Economy in the Western Mediterranean (WestMED Initiative).

Historically, coordination in the Mediterranean Sea between the research and environmental institutions conducting ocean observation has been limited (Tintoré et al., 2019). The Mediterranean Oceanography Network for the Global Ocean Observing System (MONGOOS) is a EuroGOOS (see above) partnership to develop operational oceanography and implement GOOS in the Mediterranean Sea. MONGOOS is at the core of promoting partnerships and capacity building in the Mediterranean Sea, to improve fit-for-purpose ocean observation and enhance the usability of their services, as indicated at the **MONGOOS Science and Strategy Plan[106]**. The community-based **Prospects for the Next Decade for Sustained Observing and Forecasting Systems in the Mediterranean Sea[107]** include a large and intensive international and national collaboration framework. Bringing the end-users of ocean observation closer and in collaboration with MONGOOS, EMODnet, CMEMS and other partners, the EU Horizon 2020 project ODYSSEA will develop an interoperable and cost-effective platform that fully integrates networks of observing and forecasting systems across the Mediterranean basin. It is the ambition of the ODYSSEA partners to become shareholders of a company continuing to operate the platform, ensuring its legacy and sustainability beyond public funding.

The **Convention on the Protection of the Marine Environment in the Baltic Sea Area[108]**, the Helsinki Convention, commits the signatory countries to take measures on conserving habitats and biological diversity, preventing all sources of pollution from land, air and sea, and for the sustainable use of marine

[102] Palazov *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00315/full
[103] https://wedocs.unep.org/handle/20.500.11822/31970
[104] https://wedocs.unep.org/bitstream/handle/20.500.11822/6071/16ig22_28_22_01_eng.pdf
[105] http://www.bluemed-initiative.eu/wp-content/uploads/2018/12/BLUEMED-SRIA_Update_2018.pdf
[106] http://www.mongoos.eu/documents/11176/135008/MonGOOS+Science+and+Strategy+Plan+Document+(Lower+Resolution)
[107] Tintoré *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00568/full
[108] https://helcom.fi/media/publishingimages/Helsinki-Convention_July-2014.pdf

resources of the Baltic Sea. The Helsinki Convention, facilitated by the Baltic Marine Environment Protection Commission, also known as the Helsinki Commission (HELCOM), includes a specific article on scientific and technological cooperation, where the countries need to cooperate in the areas of science, technology, research and monitoring, exchange data and scientific information, and cooperate in developing inter-comparable observation methods. In addition, the **Baltic Sea Action Plan[109] (BSAP)**, currently updating its objectives post-2021, aims to achieve Good Environmental Status (MSFD, see above) for the Baltic Sea and lays out the monitoring and assessment requirements. After providing the scientific basis for developing and implementing regulations, policies and management practices of relevance to HELCOM, the Baltic Sea marine research and development programme (BONUS) is now expanding to the North Sea. The **joint Baltic Sea and North Sea Strategic Research and Innovation Agenda (BANOS SRIA)** will be published in 2021 and will launch the BANOS programme from 2021 onwards.

The Baltic Operational Oceanographic System (BOOS), supported by EuroGOOS, aims to provide integrated marine services to the marine users and policy-makers for the Baltic Sea. The main goal of the **BOOS Strategy 2016-2020[110]** is to develop the multi-platform interdisciplinary network of real-time observations further to meet the requirements of Copernicus marine service (see above), marine environment monitoring, climate change studies, maritime affairs and marine research and innovation.

The **Convention for the Protection of the Marine Environment in the North-East Atlantic[111]**, the Oslo-Paris Convention (OSPAR), includes all the countries surrounding the North Sea, and has a dedicated annex on the assessment of the quality of the marine environment where the signing countries (the OSPAR Commission) are expected to conduct research and monitoring programmes to identify patterns and trends of the marine environment. The current **Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2010–2020[112] (North-East Atlantic Environment Strategy)** guides the implementation of the Ecosystem Approach in the North-East Atlantic and facilitates the coordinated implementation of the MSFD (see above) between the signing countries.

The International Council for the Exploration of the Sea (ICES), an intergovernmental marine science organization with member countries covering the North Atlantic, North and Baltic Seas. The **ICES Strategic Plan[113]** have observation and exploration as one of the scientific priorities (expanded at the **ICES Science Plan[114]**).

In the Arctic Ocean, the Arctic Council acts as an intergovernmental forum that promotes cooperation, coordination and interaction among the Arctic States, Arctic indigenous communities and other Arctic inhabitants on common Arctic issues, in particular on sustainable development and environmental protection in the Arctic. The implementation or enforcement of guidelines, assessments or recommendations, and research and coordination projects and initiatives, is responsibility of the individual Arctic States. The **Arctic Council's Arctic Marine Strategic Plan 2015-2025[115] (AMSP)** guides actions to protect Arctic marine and coastal ecosystems, including the goal to strengthen the collection, observation, monitoring and dissemination of relevant data on the Arctic marine environment. In addition, the Arctic Council and the

[109] https://helcom.fi/baltic-sea-action-plan/
[110] http://www.boos.org/download/annual_meeting_documents/2016_sopot/BOOS%20Strategy%202016.pdf
[111] https://www.ospar.org/site/assets/files/1290/ospar_convention_e_updated_text_in_2007_no_revs.pdf
[112] https://www.ospar.org/site/assets/files/1200/ospar_strategy.pdf
[113] https://issuu.com/icesdk/docs/ices_stategic_plan_2019_web
[114] https://issuu.com/icesdk/docs/ices_science_plan_2019_web
[115] https://oaarchive.arctic-council.org/handle/11374/413

International Arctic Science Committee (IASC), a non-governmental organisation encouraging and facilitating cooperation in Arctic research, established the joint initiative Sustaining Arctic Observing Networks (SAON), which aims to strengthen multi-national engagement in pan-Arctic observing. The **SAON Strategy 2018-2028**[116] aims to create a roadmap to a well-integrated Arctic Observing System, and ensure sustainability of Arctic observing. The **SAON Roadmap for the Arctic Observing and Data Systems**[117] **(ROADS)** is expected to be published in 2022.

The EU Polar Cluster is a collaboration of Arctic and Antarctic projects funded by the European Commission. Projects strengthening, integrating and sustaining Arctic observations and forecasting, and contributing to the implementation of the **EU Arctic Strategy**[118], include the EU Horizon 2020 project BLUE-ACTION, which will boost the ability to describe, model and predict Arctic climate change and its impact on the Northern Hemisphere; and the EU Horizon 2020 project INTAROS, which will develop an integrated Arctic Observation System (iAOS) by extending, improving and unifying existing systems.

The Arctic Regional Ocean Observing System (Arctic ROOS) is a EuroGOOS supported network of European marine institutions conducting and maintaining operational monitoring and forecasting in the Arctic Sea. Linking with the SAON process, and building INTAROS and Arctic ROOS, the **Roadmap for establishing the Arctic Region Component of the Global Ocean Observing System**[119] **(ARCGOOS)** provides the steps and requirements to develop and sustained operation of a broadly supported framework for an Arctic Ocean Observing System.

The EU has invested in ocean observation and wider marine science initiatives in the Atlantic Ocean in the past (Larkin et al., 2018). Following the **EU Atlantic Strategy**[120], which promotes international cooperation on observation (among others), the Atlantic Ocean Cooperation Agreements (including the **Galway**[121] **and Belém**[122] **Statements** and other administrative agreements in marine research and innovation cooperation) were signed to implement the All Atlantic Ocean Research Alliance and Community. Sustained long-term ocean observation is a key area of cooperation in the Atlantic Ocean, reinforced in the **EU Atlantic Action Plan 2013-2020**[123], which prioritizes developing a European Atlantic Ocean observing and predictive capability. In addition, dovetailing from an EU Horizon 2020 project with the same name, the **Vision for an All-Atlantic Ocean Observing System (AtlantOS) in 2030**[124] explains the framework for collaboration in ocean observation in the Atlantic Ocean to achieve an integrated, coordinated, user-driven and sustained All-Atlantic Ocean Observing System (deYoung et al., 2019).

In addition, several European and international networks and initiatives, such as the North-West European Shelf Operational Oceanographic System (NOOS) and the Ireland-Biscay-Iberia Regional Operational

[116] https://www.arcticobserving.org/images/pdf/Strategy_and_Implementation/SAON_Strategy_2018-2028_version_16MAY2018.pdf
[117] https://arctic-council.org/en/news/a-roadmap-towards-sustained-observing-in-the-arctic/
[118] http://eeas.europa.eu/archives/docs/arctic_region/docs/160427_joint-communication-an-integrated-european-union-policy-for-the-arctic_en.pdf
[119] Lee *et al. (2019)* https://www.frontiersin.org/articles/10.3389/fmars.2019.00451/full
[120] https://ec.europa.eu/maritimeaffairs/policy/sea_basins/atlantic_ocean_en
[121] http://ec.europa.eu/research/iscp/pdf/galway_statement_atlantic_ocean_cooperation.pdf#view=fit&pagemode=none
[122] https://ec.europa.eu/research/iscp/pdf/belem_statement_2017_en.pdf
[123] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0279&from=EN
[124] deYoung *et al.* (2019) https://www.frontiersin.org/articles/10.3389/fmars.2019.00428/full

Oceanographic System (IBI-ROOS), both EuroGOOS supported networks for collaboration to develop and implement operational oceanography and forecasting systems, focus on ocean observation, forecasts, and model-based products describing the marine conditions. Another initiative, the multi-stakeholder network, Atlantic International Research Centre (AIR Centre), implement its policy initiatives through the five **Thematic Missions of the AIR Centre**[125], including bringing Earth Observation services closer to Atlantic stakeholders.

The regional observing landscape is more efficient, and spans all the important regions of Europe. It is important that the regional organisations work together, to create an efficient link between the seas of Europe and beyond with the international community.

[125] https://www.aircentre.org/#missoes

3. Conclusions

The ocean is a complex system that is more than the sum its different components (physical, chemical, biological, ecological), where every component is intrinsically connected to the others. It affects human lives and is influenced by human action. The importance of the ocean has created the complex ocean observing and forecasting landscape that we currently have. Historically, different components of the ocean have different stakeholders, different observation systems, sectors and different management structures. To improve the accuracy of forecasting, demonstrate the added value of ocean observations to society, and to ensure its sustainability, the ocean observation communities are now working closer together. The larger ocean observing community share the will to develop an improved, sustained global ocean observing system, that will provide scientifically sound policy advice and deliver services useful to society. In this, the ocean observing community wants to emulate a well-coordinated climate observing system.

Throughout the duration of the project, EuroSea will investigate governance and support coordination of ocean observing and forecasting systems, and strengthen interactions between regional, national and international observing systems. Foresight is a useful tool to look into the future and to analyse how the system can best respond to the challenges and needs ahead. The complex ocean observing landscape shows how important ocean observing is to these international, European and regional institutions. As shown in this report, many of these international and European communities have similar and complimentary ambitions and envision working together with other communities and end-users to make ocean observation responsive to societal needs. The list of ocean observing institutions and foresight documents could be revisited at the end of the project when preparing its legacy report. It is hoped that the EuroSea project will have a profound impact on this complex governance landscape.

It is important to remember that ocean observing is mainly financially supported at national level. Therefore, the sustainability of the system depends on continued national support. As a consequence of the historic approach to understanding the ocean, many countries do not have a clear overview on what variables are measured by their competent institutions and programmes. In Europe, several EU directives and policies have different reporting obligations, which are often allocated to different national competent authorities. This increases the complexity of the system. In light of the galvanizing effect of the European Green Deal, the planned EU Ocean Data Collection Framework Directive, which is proposed to be ready by 2021, should provide an excellent opportunity to centralise the information on what ocean variables are measured where and by whom. In addition, the integration of different legislation and policies could simplify overarching the conflicting objectives of these policies, connect the competent governing bodies with interest in the ocean, and investigate the reasons why the current efforts to improve the health of the ocean don't translate into achieving the objectives.

Many forecasting tools and services derived from ocean observations depend on international collaboration. In recent years, different communities are building partnerships and engaging in dialogues with peers, across disciplines, sea basins and internationally, to simplify the complexity of the current system. Thanks to community efforts many end-users are benefiting from ocean observation services. The ocean observing communities are willing to continue to find complementarities (translated in the success of the OceanObs'19 conference and its community white papers) and building partnerships (as highlighted in the GOOS 2030 strategy). The UN Decade of Ocean Science for Sustainable Development (2021-2030) will be an excellent opportunity to galvanize these efforts and connect them to society. Work remains on defining roles and responsibilities at the European level, and continuing to link these to regional and international organizations

and programmes. The EOOS framework, supported by the EuroSea project, has the opportunity to strenghten coordination in short-term projects, provide a forum to harmonize long-term European activities and make sure these are aligned with global efforts.

In conclusion, this report describes the more than 120 initiatives, strategies and roadmaps that contribute to foresight in Ocean observation at the International, European, and regional- sea basin scales. It highlights the complexity of the Ocean observing landscape where many initiatives depend on partnerships with other communities and end-users. It also highlights the support needed in, and between, the Ocean research and monitoring communities. This report formed the basis of Deliverable 1.7, the Report on the use of legal frameworks for Ocean Observations. The insights gained through this foresight exercise, the continued work of the EuroSea project in EOOS (i.e. EOOS Operations and Advisory committees), the Workshop on New Technologies (Task 1.3.2), and the Legal Frameworks (Deliverable 1.7), will feed into the Task 1.3.3: Workshop on sustainability of the ocean observations that is due to take place in 2022. Finally, this report informs the EuroSea project on the governance implications of its activities, by providing the baseline foresight initiatives and documents to consider during the project and in the preparation of its legacy.

4. Index of initiatives, strategies and roadmaps

Arctic Council's Arctic Marine Strategic Plan 2015-2025 (AMSP)	European Union (EU) Arctic Strategy	International Union for Conservation of Nature (IUCN) World Conservation Congress 2020
Atlantic International Research Centre (AIR Centre) Thematic Missions	European Union (EU) Atlantic Action Plan 2013-2020	International Council for the Exploration of the Sea (ICES) Strategic Plan
Baltic Operational Oceanographic System (BOOS) Strategy 2016-2020	European Union (EU) Atlantic Strategy	International Council for the Exploration of the Sea (ICES) Science Plan
Baltic Sea Action Plan (BSAP)	European Union (EU) Bathing Water Directive (BWD)	JERICO - Research Infrastructure Coastal Science Strategy
Belém Statement	European Union (EU) Birds Directive	Joint Baltic Sea and North Sea Strategic Research and Innovation Agenda (BANOS SRIA)
Black Sea Integrated Monitoring and Assessment Program (BSIMAP)	European Union (EU) Biodiversity Strategy to 2020	Joint Programming Initiative on "Healthy and Productive Seas and Oceans (JPI Oceans) Strategic Research and Innovation Agenda 2015-2020 (JPI Oceans SRIA)
Black Sea GOOS Strategic Action and Implementation Plan	European Union (EU) Biodiversity Strategy to 2030	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) Centre for Oceanography and Marine Meteorology *in situ* Observations Programme Support (JCOMMOPS) strategy plan

Black Sea Observing and Forecasting System (BSOS)	European Union (EU) Blue Growth Strategy	Marine Biodiversity Observation Network (MBON) vision
BlueMed Strategic Research and Innovation Agenda (BlueMed SRIA)	European Union (EU) Common Fisheries Policy (CFP)	Marine Biological Observations work plan
Convention for the Protection of the Black Sea (Bucharest Convention)	European Union (EU) Common Fisheries Policy (CFP) Data Collection Framework	Mediterranean Oceanography Network for the Global Ocean Observing System (MONGOOS) Science and Strategy Plan
Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention)	European Union (EU) European Open Science Cloud (EOSC) Strategic Implementation Plan	Ministerial Declaration Towards a Common Maritime Agenda for the Black Sea (Burgas Declaration)
Convention for the Protection of the Marine Environment in the North-East Atlantic (OSPAR Convention)	European Union (EU) Habitats Directive	Ocean Best Practices System (OBPS) future vision
Convention on the Protection of the Marine Environment in the Baltic Sea Area (Helsinki Convention)	European Union (EU) Infrastructure for Spatial Information in Europe (INSPIRE) Directive	Ocean Biogeographic Information System (OBIS) vision for 2030
Convention on Biological Diversity (CBD) Strategic Plan for Biodiversity 2011-2020	European Union (EU) Integrated Maritime Policy (IMP)	OceanObs'19 conference
Copernicus Marine Environment Monitoring Service (CMEMS) recommendations for the evolution of the ocean observing system	European Union (EU) Marine Knowledge 2020 Agenda	OceanObs'19 conference Community White Papers
Essential Biodiversity Variables (EBVs)	European Union (EU) Maritime Spatial Planning (MSP) Directive	OceanObs'19 conference Living Action Plan
Essential Ocean Variables (EOVs)	European Union (EU) Marine Strategy Framework Directive (MSFD)	OceanPredict'19 forum
EurOCEAN 2010 conference Ostend Declaration	European Union (EU) Nitrates Directive	OceanPredict Strategyo
EurOCEAN 2014 conference Rome Declaration	European Union (EU) Report on the First Implementation Cycle of the MSFD	Ocean Science Decade Implementation Plan
EuroGEO Implementation Plan (2020-2022)	European Union (EU) Strategy for Marine and Maritime Research (MMRS)	Ocean Science Decade Programme "Predicting the Global Coastal Ocean"
EuroGOOS 2020-2030 strategy	European Union (EU) Urban Waste Water Treatment Directive (UWWTD)	Organisation for Economic Co-operation and Development (OECD) Ocean Economy to 2030
EuroGOOS perspective on Operational Modelling Capacity in European Seas	European Union (EU) Water Framework Directive (WFD)	Organisation for Economic Co-operation and Development (OECD) Rethinking Innovation for a Sustainable Ocean Economy

EuroGOOS Policy Brief European operational oceanography: Delivering services for Blue Growth and ecosystem-based management	Framework for Ocean Observing (FOO)	Our Ocean Conference 2020
European Black Sea Strategic Research and Innovation Agenda (Black Sea SRIA)	Galway Statement	Roadmap for establishing the Arctic Region Component of the Global Ocean Observing System (ARCGOOS)
European Centre for Medium-Range Weather Forecasts (ECMWF) Strategy 2016–2025	Global Assessment Report on Biodiversity and Ecosystem Services	Paris Agreement
European coastal and biological observing systems integration	Global Climate Observing System (GCOS) Implementation Plan	Partnership for Observation of the Global Ocean (POGO) Strategy Document
European Environment Agency (EEA) Marine Messages	Global Earth Observation (GEO) Blue Planet Initiative 2020 – 2022 Implementation Plan	Post-2020 global biodiversity framework
European Marine Board (EMB) Future Science Brief Enhancing Europe's Capability in Marine Ecosystem Modelling for Societal Benefit	Global Earth Observation System of Systems (GEOSS)	Prospects for the Next Decade for Sustained Observing and Forecasting Systems in the Mediterranean Sea
European Marine Board (EMB) Future Science Brief Strengthening Europe's Capability in Biological Ocean Observation	Global Ocean Observing System (GOOS) 2030 Strategy	Sendai Framework for Disaster Risk Reduction 2015-2030
European Marine Board (EMB) Position Paper Navigating the Future IV	Global Ocean Observing System (GOOS) 2030 Roadmap for Implementation	Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)
European Marine Board (EMB) Position Paper Navigating the Future V	GOOS – MBON - OBIS collaboration agreement	Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2010–2020 (North-East Atlantic Environment Strategy)
European Marine Board (EMB) Position Paper Next Generation European Research Vessels	Global Ocean Science Report (GOSR)	Sustaining Arctic Observing Networks (SAON) Strategy 2018-2028
European Ocean Observing System (EOOS) 2018 conference Call to Action for Evolving European Ocean Observing	Group of Seven (G7) Biarritz summary	Sustaining Arctic Observing Networks (SAON) Roadmap for the Arctic Observing and Data Systems (ROADS)
European Ocean Observing System (EOOS) Implementation Plan 2018-2022	Group of Seven (G7) Charlevoix blueprint	United Nations 2030 Agenda for Sustainable Development
European Ocean Observing System (EOOS) Strategy 2018-2022	Group of Seven (G7) Turin communiquétur	United Nations Convention on the Law of the Sea (UNCLOS)

European Partnership for a climate neutral, sustainable and productive Blue Economy	Group of Seven (G7) Tsukuba communiqué	United Nations Environment Programme (UNEP) digital ecosystem on the environment
European Research Infrastructure Consortia (ERICs) Comprehensive and Integrated Strategy of the European Marine Research Infrastructures for Ocean Observations	High Level Panel for a Sustainable Ocean Economy Blue Papers	United Nations Environment Programme Mediterranean Action Plan (UNEP-MAP) Mid-Term Strategy 2016-2021
European Strategy Forum on Research Infrastructures (ESFRI) Roadmap 2018	High Level Panel for a Sustainable Ocean Economy final report	United Nations Environment Programme (UNEP) Medium-Term Strategy (2018-2021)
European Strategy Forum on Research Infrastructures (ESFRI) Roadmap 2021	Intergovernmental Oceanographic Commission Capacity Development Strategy (2015–2021)	United Nations Ocean Conference 2020
European Union (EU) 7th Environment Action Programme	Intergovernmental Oceanographic Commission Strategic Plan for Data and Information Management (2017-2021)	Vision for an All-Atlantic Ocean Observing System (AtlantOS) in 2030A
European Union (EU) 8th Environment Action Programme	Intergovernmental Oceanographic Commission Medium-Term Strategy (2014-2021)	World Ocean Assessment (WOA)

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