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Description	This deliverable is intended to give an overview of the EuroSea actions at the interface between science and policy, ensuring the EuroSea results are useful for policy and decision-makers both at the EU, regional, and national levels.
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Executive Summary

Science–policy interfaces are defined as social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making (Van de Hove, 2007). EuroSea has engaged with public authorities, industry, and inter-governmental bodies to demonstrate the capacity of the European ocean observing and forecasting system to meet user demands and serve society. Ocean observing and forecasting are not merely science-supporting activities but also science areas in their own right including a range of issues from technological to research, governance, ethical, and diplomatic. Predominantly funded at national level and for national needs, ocean observing and forecasting require European and global integration and support in order to fully harness the power of ocean knowledge and information.

EuroSea lessons learnt on science policy interface are presented through case studies and activities supporting this deliverable. The lessons learnt are summarized across the following areas:

- Understanding and coproduction – with the importance of active, iterative, and inclusive dialogue through established engagement and co-design methodologies, and continuous learning process;
- Socio-environmental systems – with the importance of integrating ocean observing and forecasting in social systems, including connection with the users of ocean knowledge and information;
- Flow of communication – with the importance of continuous and inclusive exchange of information while recognising the needs and competences of the actors of the science-policy process;
- Jargon and language – with the importance of realizing that sector-specific jargon may not only be unknown to policy or industry stakeholders but also to fellow scientists and plain language must always be used;
- Addressing uncertainty – with the importance of communicating it clearly and with an emphasis on its value as a proof of the robustness of the scientific method or demonstration of requirements for observations and modelling;
- Proof of impact – with the importance of communicating the value of observations in terms of connectivity, partnerships, and synergies, and not through the traditional linear input-output-outcome-impact model;
- Design of the messages – with the importance of clarity, brevity, and visual aids, as well as orientation towards the expected impact rather than the volume of scientific information, valorising the audience, and exemplifying messages with recent developments and publications in media.

EuroSea has allowed us to crystallize some acquirements and issues of the science-policy interface. However, this remains a relatively new area of activity for ocean observing and forecasting and will require further understanding with more lessons learnt to be derived. EuroSea continues this work aiming to not only demonstrate how our lessons learnt can be used and complemented, but also contribute to the overall narrative about the impact and value of the European ocean observing and forecasting system. Furthermore, we believe that through this document and the various science-policy activities of EuroSea, the European oceanographic community can contribute valuable best practices globally.

1. Introduction

1.1. Science-Policy Interface for Ocean Observing and Forecasting

The impact of science on policy and on society has come to the fore as a major justification of scientific activity (Edler *et al*, 2022). However, the drivers for scientists to do science and for policymakers to develop policies are very different. These differences make science-policy interface an area yet to be fully understood and exploited. On the one hand, scientists' choices about which research to pursue, their approaches to collaboration and communicating results, and how they evaluate research outputs and outcomes are shaped by their beliefs and discourses (Rudd, 2015). On the other hand, for the science to influence policy there needs to be a shared understanding of the relevance of the scientific outputs, as well as common concepts of mandate, validity, and reliability of science, in the respective policy arena (SAPEA, 2019). There may be different norms and expectations in the two communities as to what constitutes reliable evidence, convincing argument, procedural fairness, and appropriate characterization of uncertainty (Cash, 2003). While this deliverable only addresses two sides of the interface – the science and the policy, it is important to note that political and policy decisions are also made at the level of scientific organizations themselves, which makes these processes also part of science-policy interface, though internal to science. Those, however, are not addressed in this deliverable, which is focusing on the connection of the EuroSea outputs (as science) with stakeholders from decision and policymaking authorities (as policy).

Science–policy interfaces are defined as social processes which encompass relations between scientists and other actors in the policy process, and which allow for exchanges, co-evolution, and joint construction of knowledge with the aim of enriching decision-making (Van de Hove, 2007). Understanding of the science-policy interface mechanisms, what works and what does not, and how to ensure a transfer of best practices into a sustained legacy that is used, replicated, and improved – is key to developing a sustained European ocean observing and forecasting systems. The evolution, integration, and sustainability of ocean observing systems rely on stakeholders and policymakers who play a fundamental role in this process (Mackenzie *et al*, 2019). In the context of EuroSea, policymakers are actors within governmental settings who formulate, adopt, implement, or evaluate policies related to oceanographic activities and the use and management of ocean space and resources, at European, intergovernmental, national, and local levels.

There are several conditions which make science-policy interface efficient: relevance (responsiveness to the needs of decisionmakers), credibility (weight of scientific claims), and legitimacy (the proper process of bringing the information into the policy domain) (Edler *et al,* 2022; UNEP, 2020; Cash *et al,* 2003; Nutley *et al,* 2007). Moreover, a precondition underpinning successful evidence-informed decision-making is trust (Cvitanovic *et al*, 2021). Despite a well-established importance of trust, research points at a lack of specific approaches to building, managing and maintaining trust at the interface of environmental science and policy. Finally, communication tools selected to inform policy and decisionmakers bare influence on the uptake of the information (EuroSea Communication Plan, D8.1).

There are no established procedures for setting up effective science-policy interfaces for ocean observing and forecasting. These areas are delivering the backbone for ocean knowledge and information but are often disregarded in the context of policy. While policy is becoming increasingly attentive to science, the way the science is acquired (for example, through an array of ocean observing activities) often falls out of the science-policy dialogue. However, ocean observing and forecasting, while being science-supporting activities, are also science areas in their own right including a range of issues from technological to research, governance, ethical, and diplomatic. Therefore, EuroSea is operating in a relatively new area charting its science-policy path based not on a set of established best practices but rather on scattered examples with anecdotic evidence of impact from the prior work of its consortium partners. Building on such knowledge from its consortium, EuroSea has undertaken a range of science-policy activities described in this document.

Moreover, EuroSea is charting a new territory in not only documenting its actions at the science-policy interface, but also monitoring their impact. Defining and tracking impact is key for the generation of transferable practices (best practices) in the areas of ocean observing and forecasting. To that end, EuroSea developed an impact monitoring protocol to evaluate the progress of its work which aims at serving stakeholders by providing them with information they need. To achieve an enhanced ocean observing and forecasting system responsive to user needs, EuroSea engages in eight areas of impact (see Table 1). The impact areas are based on the expectations from the project (the European Commission's call and the G7 Tsukuba Communiqué) and the definition of the expected impacts in the EuroSea proposal. The impact assessment process is detailed in the EuroSea periodic reports. Essentially, it consists of measuring the effect of EuroSea actions against the eight impact areas. Policy relevance is cross-cutting through the eight EuroSea impact areas. However, area seven points directly at the impacts of EuroSea on policymaking.

Table 1. EuroSea impact areas

1. Improve integration and coordination of various components of the European observing system and strengthen GOOS	5. Develop innovation, including exploitation of novel ideas or concepts; shorten the time span between research and innovation and foster economic value in the blue economy
2. Increase data sharing and integration	6. Facilitate methodologies, best practices, and knowledge transfer in ocean observing and forecasting
3. Deliver improved climate change predictions	7. Contribute to policy making in research, innovation, and technology
4. Build capacity, internally in EuroSea and externally with EuroSea users, in a range of EuroSea areas	8. Raise awareness of the need for a fit for purpose and sustained ocean observing and forecasting system in Europe

'Gathering policy intelligence and building skills for increased impact is a collective exercise. It is therefore wise to promote institutional instruments for systematic organisational learning and exchanges of peer tacit knowledge' (European Union, 2020). The present deliverable represents a potential impact in this area – examining and learning from case studies of the EuroSea work at science-policy interface at national level, sea basin, European Union, or global levels, and making recommendations. The results of this analysis aim at being transposed to best practices on science-policy interactions in the development of ocean observing and forecasting systems.

1.2. Levels of Science-Policy Interface Interactions

The global ocean is an interconnected system and so is the ocean observing. Observations made with national funding for a specific need, within or outside a country's Exclusive Economic Zone (EEZ), can be relevant for other countries, regional projections, or global system models. EuroSea has been building on years of collaboration among Europe's national ocean observing implementers as well as regional and international initiatives which provide coordination instruments for the world's ocean observing and forecasting systems.

In the last years, European and global ocean observing services have significantly increased the provision of marine data and products at all geographical levels. Examples of such services are seen in the activities of the Copernicus Marine Service (CMEMS[1]) and the European Marine Data and Observations Network (EMODnet[2]; Figure 1 and 2). The work of EuroSea has been further enhancing the provision of data to these services, as well as the improvement of modelling outputs (in case of CMEMS) and the service evolution.

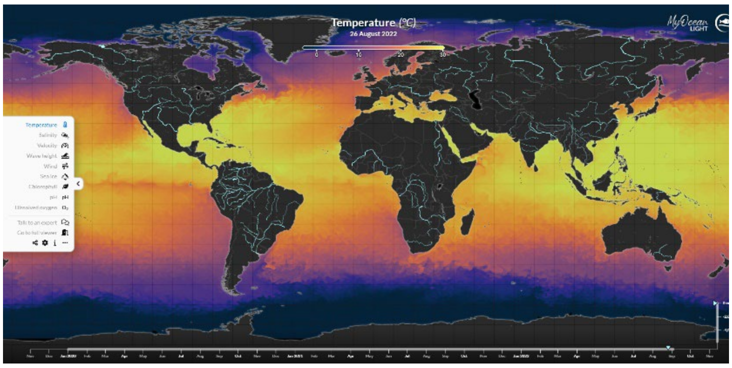

Figure 1. Snapshot live ocean nowcasts, hindcasts, forecasts, and models from Copernicus Marine Service, taken on 25 August 2022

Figure 2. Snapshot of marine in situ dashboard developed by Copernicus Marine Service in collaboration with EMODnet taken on 25 August 2022

Such services are only possible if there is a sustained provision of data from local to global levels, which is an ongoing challenge. The interconnectedness of the global and local ocean observing systems calls for clear and efficient ocean observing governance. In the case of EuroSea, the connection between ocean observations on the one hand and their governance on the other constitutes the science-policy interface. Policy relevance of the EuroSea activities spans local coastal management authorities, national environmental agencies, European research and innovation funding bodies, and international policy frameworks.

Being a holistic and large-scale ocean observing and forecasting project, EuroSea has been concerned with improving the dialogue at the science-policy interface at all these levels. EuroSea 'Report on initiatives, strategies and roadmaps that contribute to foresight in ocean observation' analysed more than 120 initiatives and strategies delivered at international, European, and regional levels, which should inform the work of EuroSea, most of them directly focused on policy (EuroSea deliverable D1.1[3]). Moreover, being predominantly funded at national level and for national needs, Europe's ocean observations require strong and sustained support by its nations. This calls for an increased promotion of value of the European and global ocean observing integration to the EU Member and Associated States.

[1] https://marine.copernicus.eu/
[2] https://emodnet.ec.europa.eu/en
[3] https://eurosea.eu/deliverables/

In addition to the geographical and governance levels, EuroSea also considers the societal sectors which contribute to the relevance of its work. The approach of Responsible Research and Innovation (RRI) is used to ensure multiple stakeholders are engaged in the EuroSea activities. RRI suggests that research and innovation are underpinned by shared values and co-created by all stakeholders committing themselves to the scientific and technological process for the common interest and benefit. This approach helps to build trust, create networks, enhance synergies and communities of practice, and jointly enable scientific and societal progress and responsibility. The following principles of RRI are considered in the EuroSea work[4]:

- Public engagement – to bring together a diversity of relevant actors including industries, policymakers, non-governmental organisations, civil society, and citizens and foster their dialogue and interaction
- Gender equality – to integrate the gender dimension in the development of research and innovation activities to unlock their full potential through an open and inclusive cooperation
- Science education – to explain aims, activities and results of science and technology bringing science closer to society and promoting the scientific and societal progress
- Open access – to share scientific processes and outcomes and advance all together in research and innovation tackling societal challenges
- Ethics – to respect and promote fundamental human rights and the highest ethical standards shared by the European society
- Governance – to design models of the RRI implementation to integrate all these six articulations into the activities

EuroSea has been addressing coherence across different levels of the ocean observing governance in the way its work is communicated to its stakeholders. Coordinated by Work Package 8, EuroSea engagement and communication activities promote a set of key EuroSea messages which are relevant to all users of the project's results (see Figure 3, further details in EuroSea deliverable D8.1[5]).

[4] EuroSea fact sheet on Responsible Research and Innovation in Ocean Observing and Forecasting https://eurosea.eu/outputs-reports/

[5] https://eurosea.eu/deliverables/

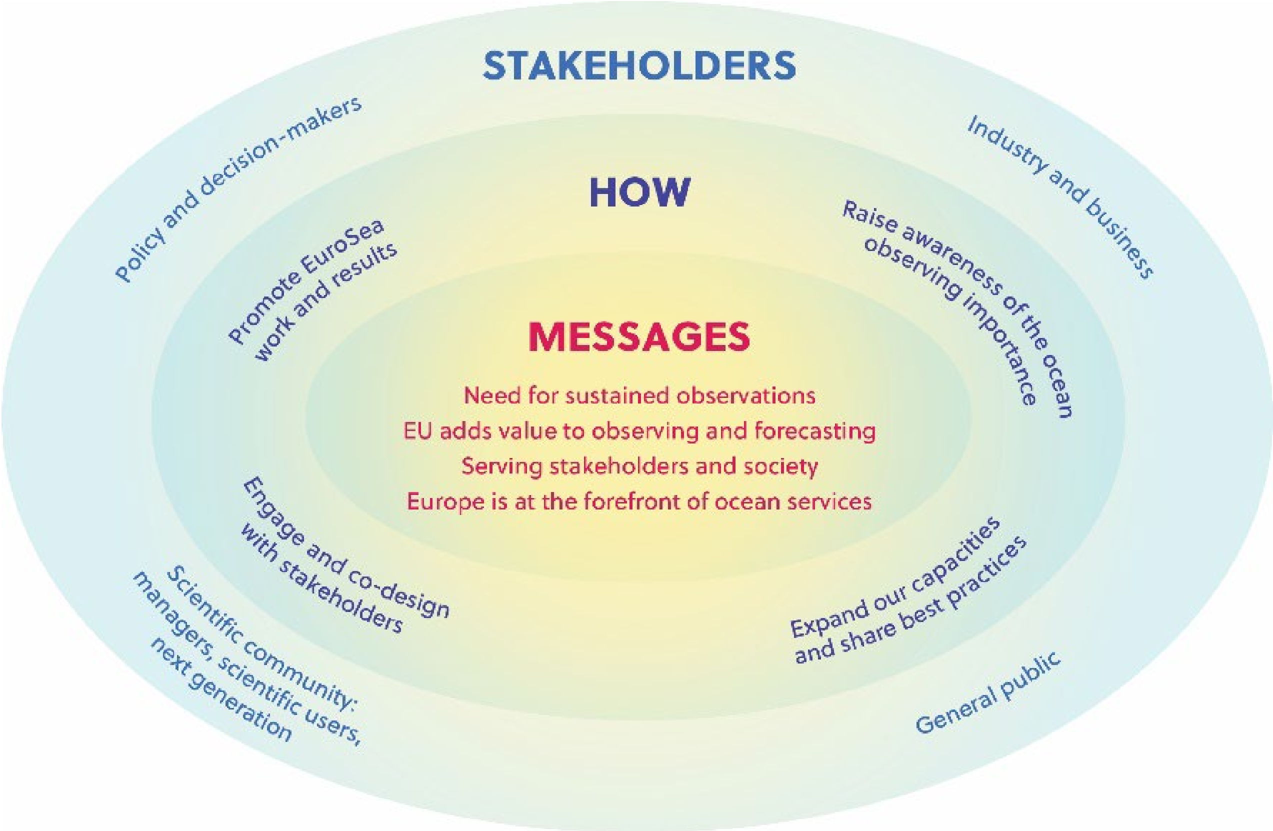

Figure 3. EuroSea big messages, categories of communication tools, and key stakeholder groups – extract from EuroSea Communication Plan, D8.1

The EuroSea key messages are promoted at national, European, and global levels through the science-policy interface in order to increase awareness of the opportunities and challenges of sustained and integrated European ocean observing and forecasting system. European integration is a necessary contribution to fair, just, adequate, and sustained observations of the ocean for all users, regardless of their geographic location. Moreover, such integration must be promoted considering the principles of Responsible Research and Innovation.

2. EuroSea Supporting Decisions and Policies: Case Studies

2.1. Serving National Decisionmakers through Oceanographic Products and Services

EuroSea has set out to 'co-design European ocean observing and forecasting services and products that deliver information and support decision-making in the areas of climate, coastal and maritime activities, and ocean health' (EuroSea mission[6]). Co-design is a rapidly growing endeavour now widely applied in science and sustainability. It seeks to connect researchers with diverse societal actors to collaboratively and iteratively produce knowledge, action, and societal change (Chambers et al, 2021). The IOC Global Ocean State Report calls on governments, organisations, scientists, philanthropy, the private sector, and civil society

[6] https://eurosea.eu/objectives/

to facilitate co-design of ocean science by involving ocean science information users and producers (IOC, 2020).

From the outset, EuroSea has been engaging with the stakeholders and users of its results in co-design, which helps ensure the EuroSea services respond to their demands. The focus of EuroSea is on oceanographic services for the Blue Economy as well as policies and legislations related to ocean observations. This section presents two examples of EuroSea work with national/local policy and decisionmakers undertaken in the EuroSea demonstration work packages. The demonstrators aim at showing how the EuroSea actions of integrating ocean observing and forecasting systems result in innovative oceanographic products and services. Each case study addresses the novelty brought by EuroSea to serve specific needs of the authorities. The results of this work are also considered in terms of Technology Readiness Levels (TRL) and how the work should continue post-project (Figure 4).

FRAMEWORK PROCESSES BY READINESS LEVELS

Readiness Levels	Requirements Processes	Coordination of Observational Elements	Data Management & Information Products
Mature			
Level 9 "Sustained"	Essential Ocean Variable: • Adequate sampling specifications • Quality specifications	System in Place: • Globally • Sustained indefinitely • Periodic review	Information Products Routinely Available: • Product generation standardized • User groups routinely consulted
Level 8 "Mission qualified"	Requirements "Mission Qualified:" • Longevity/stability • Fully scalable	System "Mission Qualified:" • Regional implementation • Fully scalable • Available specifications and documentation	Data Availability: • Globally available • Evaluation of utility
Level 7 "Fitness for purpose"	Validation of Requirements: • Consensus on observation impact • Satisfaction of multiple user needs • Ongoing international community support	Fitness-for-Purpose of Observation: • Full-range of operational environments • Meet quality specifications • Peer review certified	Validation of Data Policy • Management • Distribution
Pilot			
Level 6 "Operational"	Requirement Refined: • Operational environment • Platform and sensor constraints	Implementation Plans Developed: • Maintenance schedule • Servicing logistics	Demonstrate: • System-wide availability • System-wide use • Interoperability
Level 5 "Verification"	Sampling Strategy Verified: • Spatial • Temporal	Establish: • International commitments and governance • Define standardized components	Verify and Validate Management Practices: • Draft data policy • Archival plan
Level 4 "Trial"	Measurement Strategy Verified at Sea	Pilot project in an operational environment	Agree to Management Practices: • Quality control • Quality assurance • Calibration • Provenance
Concept			
Level 3 "Proof of concept"	Proof of Concept via Feasibility Study: • Measurement strategy • Technology	Proof of Concept Validated: • Technical review • Concept of operations • Scalability (ocean basin)	Verification of Data Model with Actual Observational Unit
Level 2 "Documentation"	Measurement Strategy Described • Sensors • Sensitivity • Dependencies	Proof of Concept: • Technical capability • Feasibility testing • Documentation • Preliminary design	Socialization of Data Model • Interoperability strategy • Expert review
Level 1 "Idea"	Environment Information Need and Characteristics Identified: • Physical • Chemical • Biological	System Formulation: • Sensors • Platforms • Candidate technologies • Innovative approaches	Specify Data Model • Entities, Standards • Delivery latency • Processing flow

Figure 4. Technology Readiness Levels in the Framework for Ocean Observing. Credit: GOOS

Sea Level Visualization Tool for Decision Making and Investment Planning

Main targets in decision/policymaking	- UK Environment Agency
Key engagement actions	- Co-development with main user, UK Environment Agency - Session at the UK Parliamentary and Scientific Committee - Video presenting the tool and its usability - Promotion via online media, interviews, and articles
Key results	- Main user, UK Environment Agency, fully satisfied – this tool informs decision making and investment planning - Tool has achieved Technology Readiness Level 7 - Potential to apply the tool in other areas than tested and further enhance with additional features

This case study addresses a custom-built prototype decision-making tool for flood risk managers in the Hull area of the UK (Figure 5). Hull had been impacted by major flood events in 1953 and 1969, resulting in the installation of the Hull Tidal Surge Barrier in 1980. However, this did not eliminate all flood risk in the area and further inundation has occurred, most notably in 2013, when several hundred properties were damaged. Although Hull is protected from river and coastal flooding by tens of kilometres of flood defences, their condition is poor and there is a real risk of breach should the Tidal Surge Barrier fail. EuroSea has engaged in co-development with the UK Environment Agency to predict the risks of flooding.

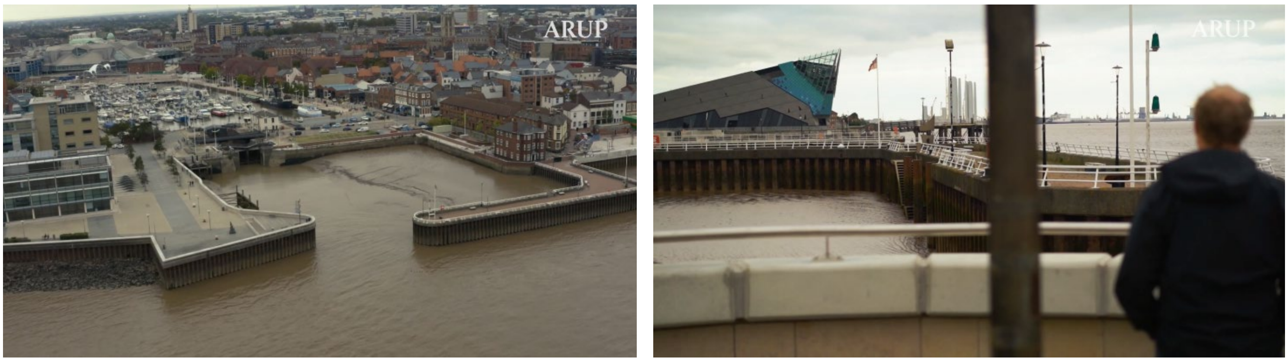

Figure 5. Coastal protection in Hull, UK. Images from the video showcasing the EuroSea Sea Level Visualization tool. Credit: ARUP

The UK Environment Agency holds the primary responsibility for flood risk management in the Hull area. Other key stakeholders of this activity are the local county council, which manages surface water flooding issues, and the regional water company, which plays an important role in water drainage and sewerage. To evaluate and plan for future flood risk, these stakeholders must consider the possible impacts of a range of hazards from the sea, whilst also understanding how these might change in the future. This will help to achieve an optimum level of flood protection that balances the reduced risk of inundation with the increased cost of the defences. Such analysis involves:

- Complex modelling of sea level, waves, and storms to understand how they flood in-land;
- Economic modelling of the flood impacts;
- The development and costing of engineering solutions and modelling how effective those measures will be in reducing the impacts of flooding.

This complexity means that the processing, time, and cost of analysis are prohibitively large, while the organisations with responsibility for managing coastal flood risk have limited time and budgets. As a result, efficiencies have to be found in the risk assessment process. This would mean that fewer future sea level rise scenarios are considered - typically focusing on the medium estimates for sea level rise, but that would be risky given the high degree of uncertainty present in current sea level rise projections. A more robust approach is required to bring more of the sea level rise science through to decisionmakers.

EuroSea, through the partnership between ARUP, the University of Cambridge, the UK's Environment Agency, and the National Oceanographic Centre, developed a new streamlined approach to modelling the interactions between sea level hazards, economic activity, and risk in the Hull area, propagating more of the science through the risk assessment process. The model output has been incorporated into a bespoke desktop decision-making software tool – the Sea Level Planning and Visualization Tool (Figure 6). This tool aims at informing decision making and investment planning.

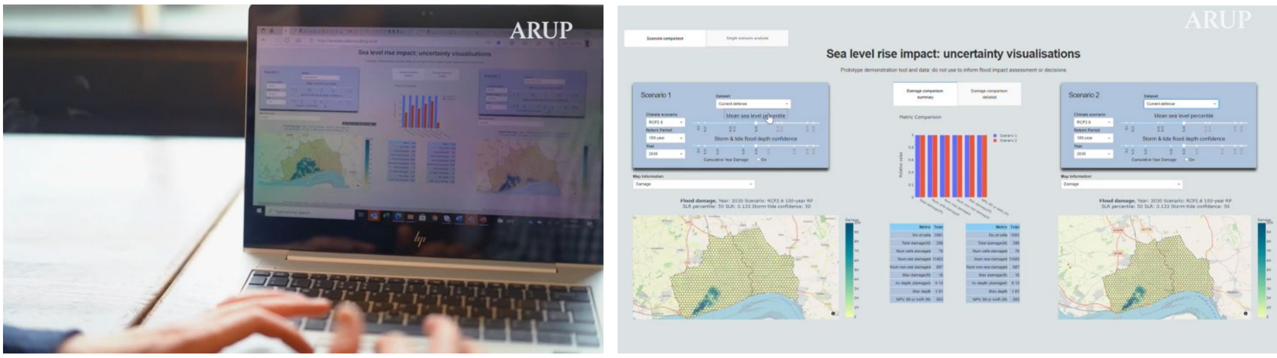

Figure 6. EuroSea Sea Level Visualisation tool. Credit: ARUP

The case study represents several innovations. A key novelty of the Sea Level Planning and Visualization Tool lies in the sheer number of modelled scenarios incorporated into it. The tool allows to use these in various combinations with an associated financial cost, resolved to a small (400m) geographical scale. Furthermore, the tool was delivered at a relatively low development cost, given the budget constraints of coastal flood risk managers. The tool includes:

- Full range of sea level rise scenarios, including variation between greenhouse gas emission scenarios and the inherent uncertainty of a given scenario, together with possible storm surges heights and a range of extreme wave conditions;
- Calculation of the pathways of water onto the land through overflow and wave overtopping of high ground or defences;
- Determining how the flood water spreads on land; and
- Attribution of an economic cost.

This corresponds to 21,350 model runs, comprising 122 sea level rise increments, 7 extreme water level return periods, and 25 wave conditions, all of which generated 10 million data points, 1000 reporting cells, 100,000 properties, and associated economic calculations for each property. The case study established the feasibility of the modelling framework (in terms of number of model iterations and parameters) and their incorporation into a visual tool to communicate uncertainty.

The tool has achieved TRL7, in that the prototype tool has been developed and demonstrated in the appropriate environment. To move beyond TRL7, it is important to understand how the innovative modelling approach performed against more traditional deterministic modelling. To do this validation, past historical flood data, other model studies, and expert knowledge of the area must be used to identify if the modelling process is producing results of sufficient accuracy for planning purposes. If not, the framework developed is adaptable so that different methodologies can be introduced at each of the modelling stages, and the balance between model accuracy and efficiency can be fine-tuned based on the needs of the end user. This validation work would be an essential precursor to achieving TRL8 or 9.

Further possible enhancements of the tool include (subject to achieving follow-on funding):

- Incorporation of mitigation measures resulting from early warning systems; and
- Quantification of the social value impact and indirect impacts (on road traffic, schooling, business losses).

The UK Environment Agency, key user of this tool, received it with great satisfaction. Co-development work took place via several on-line meetings, starting from the planning phase. The final prototype was accessed by the Agency so they were able to circulate it within their organization, test it, and gain feedback.

Furthermore, EuroSea and partners engaged in an interactive dialogue with the UK Parliamentary and Scientific Committee to discuss the usability of this prototype in other areas. The tool was presented to the Scientific and Parliamentary Committee in an on-line session, followed by a questions and answers session. The Committee elicited positive feedback and considerable interest in developing similar systems for other regions.

These opportunities to engage showed a high interest of policymakers for such decision-making tools. The issues addressed by this case study are common to flood risk managers and the proposed solutions can have applications elsewhere. Several lessons learnt were derived from this case study, which are presented in the respective section of this document.

Oceanographic Services for Ports and Cities

Main targets in decision/policymaking	- Ports of Barcelona (Spain), Taranto (Italy), and Buenaventura (Colombia)
Key engagement actions	- First prototype co-developed by Nologin and Puertos del Estado in co-design with the Port of Barcelona - Communication plan to support the launch - Video presenting the tool and its usability - Presentation of the tool at the World Ocean Council's Sustainable Ocean Summit 2022
Key results	- Operationally tested in Barcelona with tests planned in Taranto and Buenaventura - Prototype allows customisation with third-party module plug-ins - Potential to extend user base to private companies and research institutions

Maritime activities in harbours and cities require quick decision making and projections hours and days ahead. Uncertainty in daily planning and execution in harbours may lead to bottlenecks in the logistic chains. Wave storms, storm surges, and coastal pollution events require timely planning to reduce casualties and economic losses at the coastal fringe.

EuroSea developed a tool to address these challenges, called Oceanographic Services for Ports and Cities (OSPAC; Figure 7). The tool aims to support decision making and planning by providing the following services:

- Real-time monitoring of oceanographic conditions;
- Short-term range forecasts (e.g. 72 hours ahead);
- Real time and forecast alerts; and
- On-demand services for oil-spill and floating debris (application for air quality is in progress).

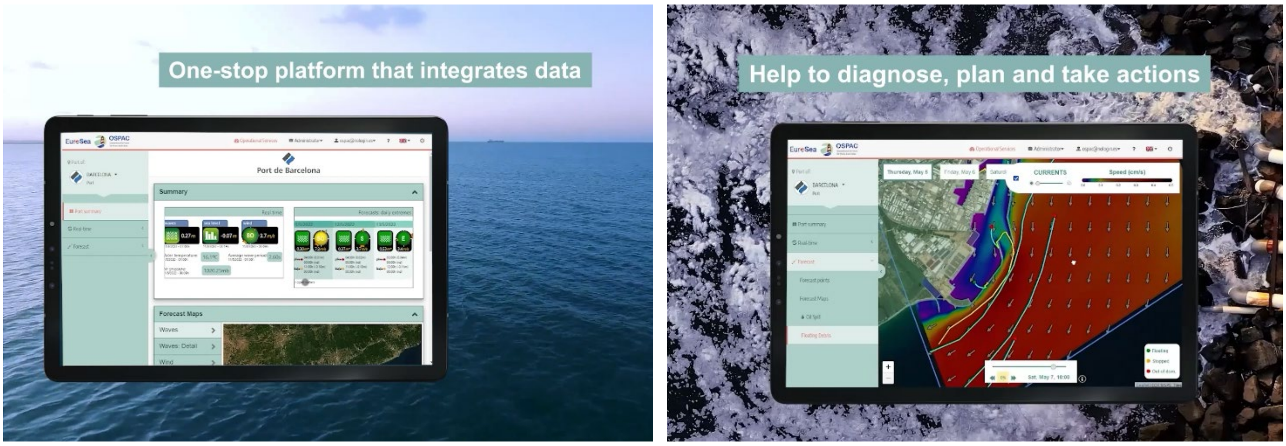

Figure 7. EuroSea OSPAC tool. Credit: Nologin/Puertos del Estado

OSPAC benefits from the existing networks and forecasting services by integrating data into customizable products. The tool provides a warning system evaluated every 20 minutes, giving near-real time feedback. The warning system can also be set for forecasting. In this case the user defines a set of model points of interest. Once a new forecast cycle is available, the warning is made for 72 hours ahead. Several on-demand forecasts are available, namely for oil spills and marine debris. Air quality forecasts are currently under development.

OSPAC will reach TRL7 by the end of EuroSea having been tested operationally in Barcelona, Spain. At the end of the project, it is planned to implement OSPAC in the harbours of Taranto, Italy, and Buenaventura, Colombia. Beyond EuroSea, the tool will need to reach TRL9 and be maintained. To allow new users and further customisation, OSPAC is open to third-party modules and supports third-party plug-ins. The use of OSPAC can be extended to research centres or universities as well as private companies. When adapted to new locations, OSPAC will require sustained provision of real time in situ data.

The Barcelona port authority has had an active role in the co-design of the OSPAC operational deployment for the Barcelona pilot site, together with the scientific organizations in EuroSea. The co-design process has had three stages:

- Requirements stage, with the aim of defining the challenges derived from met-ocean drivers (i.e. cranes cannot work once a wind-speed is exceeded, ship manoeuvring at the harbour mouth can be hampered by certain ocean currents, etc.) and an initial mock-up of the user interface;
- Development phase, in which the modules have been developed through several iterations with a selection of end-users by finetuning specific features (i.e. user customisation, interpretation of the results, communication protocols and module administration); and

- Testing phase, that will last until the end of the EuroSea project, in which the service is tested in a real environment by a wide range of users, managed by selected administrators from the Barcelona port and the City Council.

The frequency of the iterations was monthly for the first two phases. At the present third stage, it is expected that the end-user feedback will increase proportional to the number of users. Henceforth, minor but more frequent updates are also expected.

Dirección General Marítima (DIMAR, Colombia) has recently joined EuroSea and it has become an active end-user, providing valuable feedback and suggestions for improvement via monthly meetings with the OSPAC developers. The Buenaventura harbour (one of the most important harbours in Colombia) was selected as a pilot site due to its growing marine traffic volume that requires bounding the uncertainty of the met-ocean drivers. In particular, tidal-induced currents, wind currents, and ocean waves are relevant in that area. These drivers differ severely from the ones in Barcelona and Taranto (both at the Mediterranean Sea, in a micro-tidal basin), providing an excellent candidate to test the feasibility of OSPAC in a different environment.

This way EuroSea ensured OSPAC meets the expectations of the co-developers who require real-time alerts and daily forecasts allowing the harbour operators to schedule their activities. EuroSea used state of the art approaches to integrated real-time observations into models delivered in high resolution (70m horizontal resolution), as requested by the co-developers.

Beyond the port authorities, EuroSea also engaged with the Barcelona City Council who found the oil-spill and floating debris services of OSPAC useful for their environmental management planning. In the case of an oil-spill incident, several scenarios need to be assessed in a short-time range to minimise pollution.

2.2. Transferring State-of-the-Art Science to Regional Authorities

EuroSea has supported the work of the European oceanographic community in integrating with relevant areas of ocean science, technology, governance, and innovation – in a broad range of sectors. One example of this work is presented in this case study. Traditionally, the ocean observing activities (linked to marine research or operational services) are assessed and used separately from the activities required for the Member States' reporting on the environmental laws and directives. This is causing inefficiencies in how the environmental monitoring reporting is conducted and lack of access to the latest ocean data and information, which are therefore not used by the environmental assessments. This case study is bridging the gap between the ocean observing activities of the Baltic Operational Oceanographic System (BOOS) of the European Global Ocean Observing System (EuroGOOS) on the one hand, and the environmental assessments by the Baltic Marine Environment Protection Commission (HELCOM) on the other.

Main targets in decision/policymaking	- Baltic Marine Environment Protection Commission (HELCOM) and ministries in the Baltic Sea states
Key engagement actions	- Meetings with the HELCOM working groups and expert groups - Report on demonstration of BOOS assessments (EuroSea deliverable D6.2[7])
Key results	- Raised awareness among the HELCOM working groups and expert groups of the opportunities of using BOOS and CMEMS data and services for improving the HELCOM assessments

The Baltic Marine Environment Protection Commission, also known as the Helsinki Commission (HELCOM), is an intergovernmental organisation and a regional sea convention in the Baltic Sea area. HELCOM was established in 1974 to protect the marine environment of the Baltic Sea from all sources of pollution. It serves as a regional platform for environmental policy making. The HELCOM Contracting Parties are the countries surrounding the Baltic Sea, along with the EU. Every six years, through the participation of all contracting parties and support from the HELCOM expert and working groups, a holistic report on the State of the Baltic Sea is prepared. The report provides key information for taking further steps to reach good environmental status. Furthermore, it serves as a regional baseline for implementing the UN Sustainable Development Goals as well as serves the purposes of the EU Marine Strategy Framework Directive for those countries around the Baltic Sea that are EU Member States.

EuroSea has brought together several experts participating in the HELCOM working groups and expert groups who at the same time develop operational oceanographic products and services in the Baltic Operational Oceanographic System (BOOS) of the European Global Ocean Observing System (EuroGOOS). The HELCOM assessment reports do not take into account the near-real time data available in BOOS. At the same time, it is evaluated that the confidence of some HELCOM assessment (indicator) reports is moderate or low due to insufficient monitoring data. In addition to the data availability and uptake for the HELCOM reports, the expert also highlighted that the assessments do not use readily available products from the Copernicus Marine Environment Monitoring Service (CMEMS). This is due to the difference in the indicators used by CMEMS and HELCOM for the environmental status and human-induced pressures. In HELCOM, indicator-based assessments have legal implications. If good environmental status cannot be achieved, measures have to be taken by respective ministries. HELCOM core indicators (Figure 8) form the basis for the assessment, but they are still under development. Aligning the indicators between HELCOM and CMEMS will benefit better products and information about the ocean state and variability.

Examples of areas needing improvement are the assessment of abnormal events (e.g. heatwaves, upwelling, salt-water inflow, distribution of salinity) and eutrophication (e.g. nutrients, chlorophyl-a, oxygen). All these parameters are available from CMEMS but are not used for the assessments because HELCOM follows specific guidelines for the periods, seasons, layers, and calculations. Furthermore, there is a difference between the indicators established and used by the operational oceanography community and the ones used for the environmental assessments.

The indicator results are influenced both by human-induced pressures and by natural variation. When chlorophyll-a is assessed, it is important to determine to what degree it was affected by humans or nature. HELCOM requires to have certainty about the impact of human-induced pressures because this can lead to

[7] https://eurosea.eu/deliverables/

management and legal decisions by the countries which are Contracting Parties to HELCOM. Furthermore, climate change and future predictions should be taken into account – if conditions change recommendations will have to be adjusted. For example, HELCOM makes recommendations to its governments on the level of nutrient inputs. After, the governments implement them. Those who are Member States of the European Union implement them via the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) designing programmes of measures. Later, it is assessed whether these measures result in the reduction of the nutrient input that was agreed upon at the HELCOM level. However, there are several indicators used for the eutrophication status assessment. In addition to the concentration/input of nutrients, there are also phytoplankton blooms, chlorophyll-a, or indirect indicators like oxygen and water clarity. Both the hydrographic and weather conditions should be considered. It is therefore complex to determine a good status as the indicators are influenced by many parameters and variability, and this should be taken into account.

Figure 8. Status of pressure-based core indicators for eutrophication, hazardous substances and non-indigenous species by sub-basin. Green circles indicate good status, red circles indicate not good status, and white circles indicate that the core indicator is applicable or relevant to the sub-basin, but has not been assessed. Empty points indicate that the indicator is not applicable or relevant. For coastal indicators, pie charts show proportion of coastal assessment units per sub-basin in good status (green), not good status (red) and not assessed (white). Credit: HELCOM, 2018

The long-established and slow procedures for acquiring data and information for the HELCOM assessments need to be updated with new capabilities available in CMEMS and BOOS. EuroSea has supported the interface between HELCOM and BOOS and several meetings have taken place. The EuroSea analysis of the benefits of integrating BOOS and HELCOM systems was presented at biannual meetings of the HELCOM working groups. This gave an opportunity to collect feedback from HELCOM and address the way forward. At the end of EuroSea a report will be released on the benefits of the BOOS-HELCOM integrated system and recommendations for transferring this to other sea areas (EuroSea deliverable D6.6[8]). BOOS has set out to publish the HELCOM-relevant data and maps on its website to be readily usable for the assessments. Through the EuroSea work BOOS is also feeding back to CMEMS to analyse the areas for improvement. Some CMEMS models are readily usable for the assessments (e.g. waves, sea level, currents). Other products are prepared through re-analysis, whereby previously reported data are used, partly those from HELCOM, to re-run the model. The results are much better, as is the delivery time. BOOS is demonstrating to HELCOM that the products and information they need for their assessments can be delivered much faster and in required quality. Speeding up the data delivery will improve the assessments of the good environmental status by making them not only more accurate but also more up-to-date.

2.3. Improving Science-Policy Dialogue at European level

Scientific research, experimentation, data collection, monitoring, and modelling provide the knowledge, frameworks, and evidence needed to model and explore the environmental consequences of policy and development proposals and thus to chart a sustainable future ocean (Pendleton *et al*, 2020). Therefore, ocean observing and forecasting are paramount to deliver the knowledge and information needed for policymaking. However, there is insufficient policy awareness of the needs, challenges, and opportunities of the ocean observing enterprise (Eparkhina *et al*, 2021). It is for these reasons that advocacy is among key strategic objectives of both the Global Ocean Observing System (GOOS) and its European component EuroGOOS.

EuroSea has been promoting the opportunities offered by its activities, which can underpin the implementation of the EU policies, strategies, and legislative instruments. Establishing trust and visibility vis-à-vis the European Commission has been identified among the key priorities of the EuroSea stakeholder engagement from the project's outset. Several activities have been conducted by the time of this deliverable and several more are planned. Among the planned ones is the high-level EuroSea conference hosted by GOOS and the Intergovernmental Oceanographic Commission of UNESCO in Paris on 21 September 2023.

This section describes several case studies of the EuroSea work at science-policy interface at the European level. The European Commission has been identified as the principle European policy stakeholder for EuroSea and within it several Directorates-General (DG) have been approached. Primary engagement took place with DG Maritime Affaires and Fisheries and DG Research and Innovation.

[8] https://eurosea.eu/deliverables/

Main targets in decision/policymaking	- European Commission
Key engagement actions	- Report on funding and coordination of Europe's ocean observing and monitoring activities (2020) - Policy brief 'Nourishing Blue Economy' co-developed with other EU projects within the Horizon Results Booster (2021) - EuroSea Steering Committee meeting with several European Commission's DGs (2021) - EuroSea Anniversary Webinars (2020, 2021) - Science-policy workshop at the European Maritime Day (2022) - Science-policy session at the global Ocean Best Practices Workshop of the UNESCO-IOC (2022)
Key results	- Raised visibility of the EuroSea relevance to policy - Policy feedback on the EuroSea activities and expectation of impacts - Uptake of EuroSea study on national funding of ocean observing and monitoring in the development of the Commission's initiative 'Ocean Observations – Sharing Responsibility'

There is an increased demand from relevant policy processes for easier access to the findings of ocean science and for information on ocean science efforts and capacity related to research and observations (IOC, 2020). The European Union has set out ambitious Green Deal and Biodiversity Strategy objectives, which require full support from the scientific community. EuroSea is reinforcing core ocean observing and forecasting services to deliver on these policy needs. Dialogue between scientists and policymakers helps to ensure the European ocean observing and forecasting efforts are fit for purpose to deliver the knowledge and information needed.

The European Green Deal resets the Commission's commitment to tackling climate and environmental-related challenges (European Commission, 2019). It includes a set of proposals to make the EU's climate, energy, transport, and taxation policies fit for reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. It also aims to protect, conserve, and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts.

Since 2020, the European Commission is developing a new initiative titled Ocean Observations - Sharing Responsibility in recognition of the essential role ocean observing plays for the knowledge base for the Green Deal (Figure 12). This initiative aims to achieve a common EU approach for measuring once and using the data for many purposes. It proposes joint planning of observation activities and a framework for collaboration on a national and European scale.

EuroSea welcomes a European policy framework for ocean observations that can help ensure that the observing system is able to respond to the societal and policy needs in a sustained way. The call for ocean observing coordination, integration, and sustainability has been promoted via various EuroSea activities at the science-policy interface. Notably, two reports delivered the EuroSea recommendations to the European Commission and are featured below. In addition, EuroSea submitted its response to the EC public consultation on the initiative's inception impact assessment in 2020.

Figure 9. Group of EU projects linked to ocean observing and forecasting convened by EuroSea through the Horizon Results Booster

Figure 10. Report on funding and coordination in Europe's ocean observing and monitoring prepared through EuroSea

First, we would like to mention the EuroSea-led policy brief titled Nourishing Blue Economy and Sharing Ocean Knowledge – Ocean Information for Sustainable Development[9], developed in 2021 with other EU-funded projects through the Horizon Results Booster (Figure 9). The publication explains that the ocean observing system cannot rely on short-term project funding in order to sustainably support marine data services required for the European policies and the blue economy. It is important to unify the ocean observing strategies across the EU Member States concerning their support towards observations. Observations should be made more accessible across Europe from the Exclusive Economic Zones of the Member and Associated States into the open ocean. In addition, marine data policies, guidelines, and standards require further unification.

Second is the EuroGOOS-EOOS-EuroSea report 2021 on funding and coordination in Europe's ocean observing and monitoring based on the European GOOS national focal points survey[10] (Figure 10). The study was done based on a survey of the GOOS-coordinated European national focal points for ocean observing (details on GOOS on p. 23). This work is part of the European Ocean Observing System (EOOS) Framework (Figure 11), led by EuroGOOS and the European Marine Board and supported by EuroSea, which brings together an extensive community of ocean observing funding and implementing activities in Europe[11]. The report highlighted the issue of funding uncertainty for ocean observing. According to 27 respondents acting as GOOS national focal points for Europe, national governments fund over 70% of marine monitoring but less than 50% of ocean observing (Lara-Lopez *et al*, 2021). Furthermore, only 48% of ocean health, 42% of ocean climate, and 37% of operational service observations have access to medium (3-5 years) or long-term funding (6-10 years). The report provides some insights into the state of play of national ocean observing and marine monitoring and makes recommendations. It advises to enhance communication to demonstrate the societal benefits of ocean observing from global to local level and articulate the potential risks from losing the observing capabilities.

[9]https://eurosea.eu/download/nourishing-blue-economy-and-sharing-ocean-knowledge/?wpdmdl=3973&refresh=62613af0066111650539248
[10]https://www.eoos-ocean.eu/publications/european-goos-national-focal-points-survey-funding-and-coordination-across-ocean-observing-and-marine-monitoring-in-europe/
[11] https://www.eoos-ocean.eu/approach/governance/

The report was used by the European Commission to develop their initiative ‘Ocean Observation – Sharing Responsibility’, as shared by the EC officers at various meetings, among others at the European Maritime Day 2022 Conference.

Figure 11. EOOS Framework website showing the European GOOS National Focal Points report and the EOOS Technology Forum, both funded by EuroSea

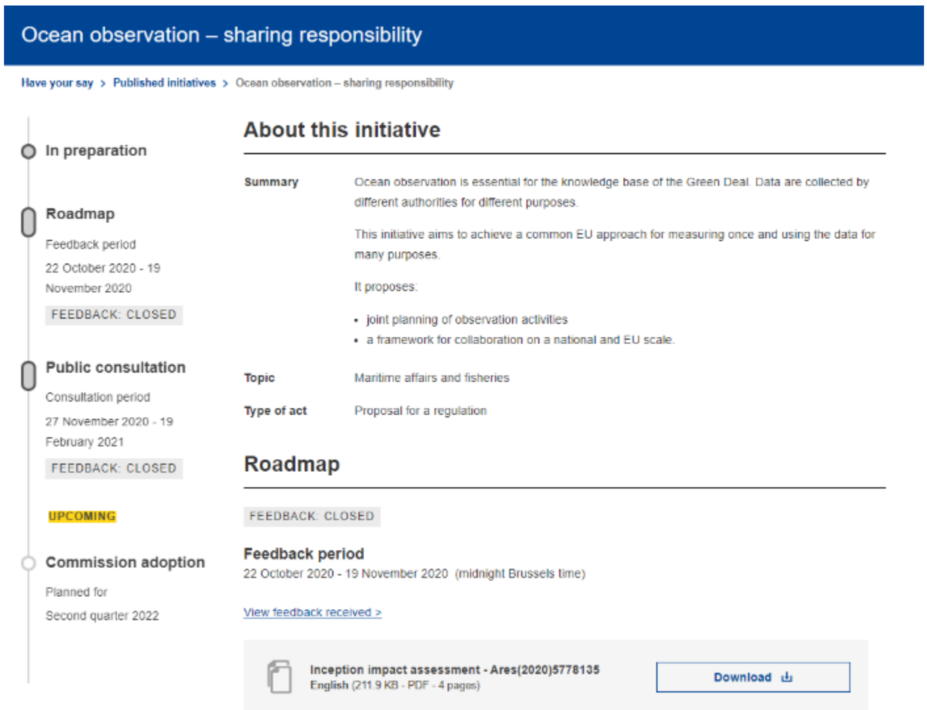

Figure 12. European Commission web page dedicated to the Ocean Observation – Sharing Responsibility initiaive (printsceen as of 28 July 2022)

Policy dialogue is not only being promoted through statements and reports. EuroSea has been organizing events to discuss the project's activities with policymakers. On-line during the pandemic or on-site or hybrid when the restrictions were waived, these events have been valuable opportunities to establish and maintain trust between EuroSea and its policy users and discuss matters first hand. These include the EuroSea Anniversary Webinars (Figure 13 and 14), on-line meetings with various EC Directorates-General, or on-site events like a workshop at the European Maritime Day 2022. These activities are detailed below.

EuroSea is holding Anniversary Webinars every November (the month of the start of EuroSea) to inform both policy and scientific stakeholders about the EuroSea progress and take stock of the achievements. The webinars are important milestones for the EuroSea impact assessment. They allow to not only track progress across the EuroSea impact areas (see page 6), but also report on this to a wide range of EuroSea stakeholders. The webinars include talks and discussions about the EuroSea innovations in the areas of operational oceanographic services as well as ocean observing and forecasting for ocean health and climate. The webinars are also a platform to promote the EuroSea role in the European and global observing and forecasting landscape. European Commission policy officers attend the webinars as speakers and panellists and participate in interactive dialogues with the audience. Recordings of the webinars are available on the EuroSea YouTube channel[12]. The third anniversary webinar will take place on 24 November 2022.

Figure 13. Speaker card from the EuroSea 1st Anniversary Webinar on 20 November 2020

Figure 14. Announcement card of the EuroSea 2nd Anniversary Webinar on 25 November 2021

Another opportunity to discuss the applicability of the project to policy was the European Maritime Day 2022. EuroSea together with sister project Blue-Cloud and the European Marine Observation and Data Network (EMODnet) held a joint workshop titled Ocean Observations, Marine Data and Services for the European Green Deal (Figure 15 and 16). The workshop promoted the EuroSea recommendations delivered with other EU projects in a joint policy brief (see page 19). Furthermore, the event showcased the existing and expanding services by Blue-Cloud, EMODnet, and the Copernicus Marine Service, which support the Green Deal objectives. The workshop was an important occasion to unite the representatives of the observing

[12] https://www.youtube.com/channel/UCS4yuekKpYA8QVtr7vrl50Q

community to speak with one voice with policymakers. Furthermore, an interactive panel addressed the needs of all types of users, from industry to academia and SMEs.

Figure 15. Flyer of the EMD2022 workshop organized by EuroSea, EMODnet, and Blue-Cloud, with contributions from Nautilos, EurofleetsPlus, iAtlatic, AtlantECO, and Odyssea projects

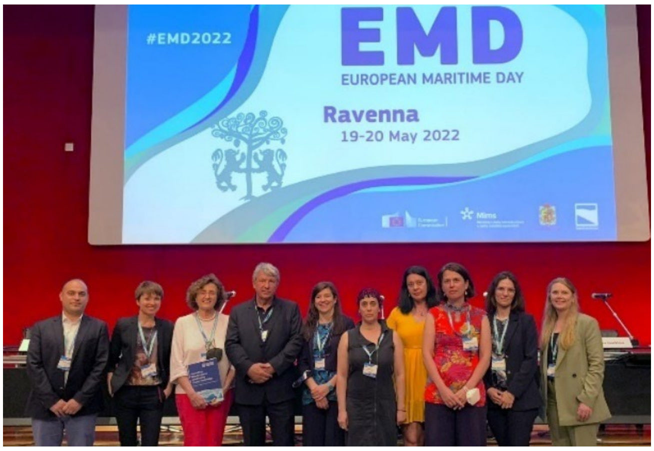

Figure 16. Speaker linep at EMD2022 workshop, from left: Marco Filippone (FUGRO), Dina Eparkhina (EuroSea/EuroGOOS), Nadia Pinardi (EuroSea/University of Bologna), Dick Schaap (MARIS), Alessandra Giorgetti (EMODnet Chemistry), Joana Beja (EMODnet Biology), Andreea Strachinescu (European Commission), Laurence Crosnier (Copernicus Marine Service), Sara Pitonet (Blue-Cloud), and Kate Larkin (EMODnet)

EuroSea maintained dialogue with the European Commission also through a dedicated 'Policy Feedback Meeting' co-organized by EuroSea and the EC in October 2021 with the representatives of several EC services and the members of the EuroSea Steering Committee. The EC representation included the following Directorates-General and agencies: DG Environment, DG Research and Innovation, DG Maritime Affairs and Fisheries, DG Defence Industry and Space, Joint Research Centre, and Research Executive Agency. The meeting discussed EuroSea contributions to the implementation of the following European policy initiatives:

- European Coordination of ocean observing;
- Digital Twins of the Ocean;
- Common Fisheries Policy;
- Directives: Marine Strategy Framework Directive, Marine Spatial Planning, Marine Litter, and Plastic;
- Climate Change and Adaptation; and
- Blue Economy.

The meeting highlighted the importance of the EuroSea work as contributor to policy on the example of collaboration with other EU projects related to observations and forecasting through the Horizon Results Booster (see p. 19) and the enabling of data delivery from the observing networks through EuroGOOS and GOOS. Specific oceanographic tools supporting decision-making in maritime domain, like the Sea-Level Visualization tool (see p. 10), were also emphasized.

To derive lessons learned through its policy engagements, EuroSea organized a session titled Ocean Best Practices and Ocean Policies at the global Ocean Best Practices Workshop VI in October 2022. Ocean Best

Practice System is an international effort coordinated by IOC-UNESCO to deliver best available experience on procedures and practices for the oceanographic community across a broad spectrum of topics. The EuroSea session discussed the establishment of best practices for the interaction between ocean science and policy. Ocean governance experts, policymakers, scientists, and managers of ocean observing and forecasting activities joined as speakers and engaged in an interactive dialogue with the audience. The lessons learned shared in this session contributed to the respective section of this document.

2.4. Raising Awareness of the Ocean Observing Opportunities and Needs Globally

Ocean observing is international but is supported and maintained predominantly at national level. The United Nations (UN) institutions and processes play an important role as platforms where Member States can jointly discuss and agree on priorities and agendas related to ocean observing. These in turn can lead to national implementation and a stronger international collaboration and partnerships.

EuroSea brings together experts who are routinely engaged as advisers in various UN consultative processes. Two specific processes are addressed in the below case study and are the EuroSea community inputs to (i) the Open-Ended Informal Consultative Process on Oceans and the Law of the Sea, and (ii) UN Framework Convention on Climate Change (UNFCCC).

Main targets in decision/policymaking	- United Nations
Key engagement actions	- Talk and discussion at 2022 Open-Ended Informal Consultative Process on Oceans and the Law of the Sea (UNCLOS) - Meetings during COP26 of the United Nations Framework Convention on Climate Change (UNFCCC)
Key results	- Promotion of adequate instruments under UNCLOS in recognition of the evolved capability of the global ocean observing system - Raised visibility of EuroSea and European cooperation in ocean observing and forecasting at the UN level

The United Nations govern the uses of the ocean and its resources through the UN Convention on the Law of the Sea (UNCLOS). There are 162 States parties to UNCLOS including the European Union. UNCLOS comprises provisions related to delimitation, navigation, protection, and preservation of the marine environment, management of living and non-living resources, marine scientific research, transfer of marine technology, and settlement of disputes.

UNCLOS contains a number of references to 'competent international organizations' - among them the Intergovernmental Oceanographic Commission (IOC) of UNESCO. The ocean observing component of IOC is its long-term programme titled the Global Ocean Observing System (GOOS). Therefore, GOOS has a link into the UNCLOS and other UN processes. EuroSea is strongly connected with GOOS in several ways. GOOS, through its funding body IOC, is a partner in EuroSea. In addition, several EuroSea experts are involved in GOOS.

GOOS has an important coordination function for global ocean observations, delivers the status of the observing system capability, and promotes emerging observing activities[13]. It operates across the domains of climate, operational services, and ocean health. The reports and recommendations prepared by GOOS undergo an approval by the IOC Assembly. Composed of 150 Member States, the Assembly meets biennially and sets out the IOC policy and main lines of work. The recommendations adopted by the IOC Assembly do not impose any obligations for implementation by the Member States. The GOOS work within IOC is therefore consultative. In addition to the IOC Assembly, GOOS also has access to various other UN processes.

In June 2022, the EuroSea recommendations were presented by GOOS at the 22nd meeting within the UN Open-Ended Informal Consultative Process on Oceans and the Law of the Sea (Figure 17 and 18). The United Nations Convention for the Law of the Sea (UNCLOS) defines maritime zones and makes provisions regulating the functioning and claims of nations on the world's ocean. UNCLOS is essential for the marine sector and maritime activities.

The Open-ended Informal Consultative Process on Oceans and the Law of the Sea aims to facilitate the review by the UN General Assembly of developments in ocean affairs and UNCLOS. Emphasis is made on identifying areas where coordination and cooperation at the intergovernmental and inter-agency levels should be enhanced. The 22nd meeting of the Consultative Process focused on ocean observing.

Figure 17. Extract from the EuroSea presenation to 22nd meeting on "Ocean observing" within the UN Open-Ended Informal Consultative Process on Oceans and the Law of the Sea (6-10 June 2022)

Figure 18. Extract from the EuroSea presenation to 22nd meeting on "Ocean observing" within the UN Open-Ended Informal Consultative Process on Oceans and the Law of the Sea (6-10 June 2022)

At the meeting, EuroSea highlighted a set of issues with the current state of ocean observing and its connection with UNCLOS. Adopted in 1982, UNCLOS does not take into account the expansion of ocean technologies and observing capabilities. Among other issues not tackled by UNCLOS is the accessibility to the Arctic Ocean. In addition, legal gaps and uncertainties exist with respect to the regulation of Marine Scientific Research (MSR) by UNCLOS, including the lack of clarity of certain terms, and the consent regime. MSR regulated by UNCLOS does not consider the needs of operational oceanography, but is only focusing on the data collection for fundamental scientific research. At the national level, the implementation of UNCLOS as regards MSR is not consistent with the actual practice and the needs of the services derived from ocean observing. The MSR planning and consent requirements by UNCLOS cannot be met in the operational oceanography setting, with an increased amount of autonomous technologies, changing and adaptable schedules and routes for the observing instruments and vessels, or animal borne observing networks.

[13] https://www.goosocean.org/

EuroSea stressed that it is important for the ocean observing and forecasting efforts to see the recognition in UNCLOS that ocean observing is not only done for marine scientific research but for a variety of other needs, such as operational oceanographic services. These include, for example, observations employed to detect hurricanes and tsunamis, forecast the weather, or systematic time series needed for the understanding and monitoring of climate change.

Another EuroSea engagement with the UN was in November 2021 when EuroSea promoted the connection between the European ocean observing and forecasting systems and global requirements for knowledge at the 26th UN Climate Change Conference of the Parties (COP26; Figure 19).

Figure 19. Extracts from the COP26 website

Figure 20. Cover of the Glasgow Climate Pact agreed at COP26

On this occasion EuroSea was represented at the meeting of the Research and Sustainable Observations section of the COP Subsidiary Body for Scientific and Technological Advice (SBSTA)[14]. The SBSTA is one of two permanent subsidiary bodies of COP. SBSTA carries out methodological work under the Convention, the Kyoto Protocol and the Paris Agreement, and promotes collaboration in the field of research and systematic observation of the climate system. SBSTA addresses the impacts, vulnerability, and adaptation to climate change, promotes the development and transfer of environmentally-sound technologies, and conducts technical work to improve the guidelines for preparing and reviewing greenhouse gas emission inventories.

At the meeting, EuroSea highlighted the Essential Climate Variables as established by the Global Climate Observing System[15] and raised the issue of uncertainty in how to prioritize them and how to demonstrate the effectiveness of the observing system. EuroSea also stressed the importance to promote the need for ocean observations as a core capability to provide ocean knowledge.

The COP26 Glasgow Climate Pact mentioned the ocean only sparingly (Figure 20). It noted 'the importance of ensuring the integrity of all ecosystems, including in forests, the ocean and the cryosphere […]'. The Pact also welcomed the informal reports by SBSTA on the ocean and climate change dialogue. Relevant work programmes and constituted bodies under the UNFCCC were invited to consider how to integrate and strengthen ocean-based action in their existing mandates and workplans. SBSTA was invited to hold an annual dialogue, starting at its fifty-sixth session in June 2022, to strengthen ocean-based action and to prepare an informal summary report thereon and make it available to the Conference of the Parties at its subsequent session.

[14] https://unfccc.int/process/bodies/subsidiary-bodies/sbsta
[15] https://gcos.wmo.int/

EuroSea could approach SBSTA at COP26 through the project's coordinator who had a UN observer mandate to act as expert in this consultative meeting. Scientists attending the meetings of SBSTA should have support from their Member States or other accredited bodies, and there is no entry into this process for a project like EuroSea as such. Furthermore, the process to influence policy at this level is hard work for scientists and require a combination of many factors. Such scientists need recognition and seniority in their national role as experts, and also the time and dedication to informally and formally promote their vision and priorities.

3. Learning from Engagement with Policy and Decision Makers

The outputs of ocean observing and forecasting systems are required at various stages of the policy cycle (Figure 21). These include:

- Assessing the impact of policy action;
- Determining risks and uncertainties;
- Formulating policy;
- Monitoring and evaluating the implementation.

Furthermore, the policy feedback is important to inform the design or enhancement of the observing and forecasting systems to respond to the policy needs both now and into the future. Sustained provision of information derived from ocean observing is required for a reliable, responsive, and progressive uptake in policy. For a sustained provision of information, the observing system should be itself - sustained.

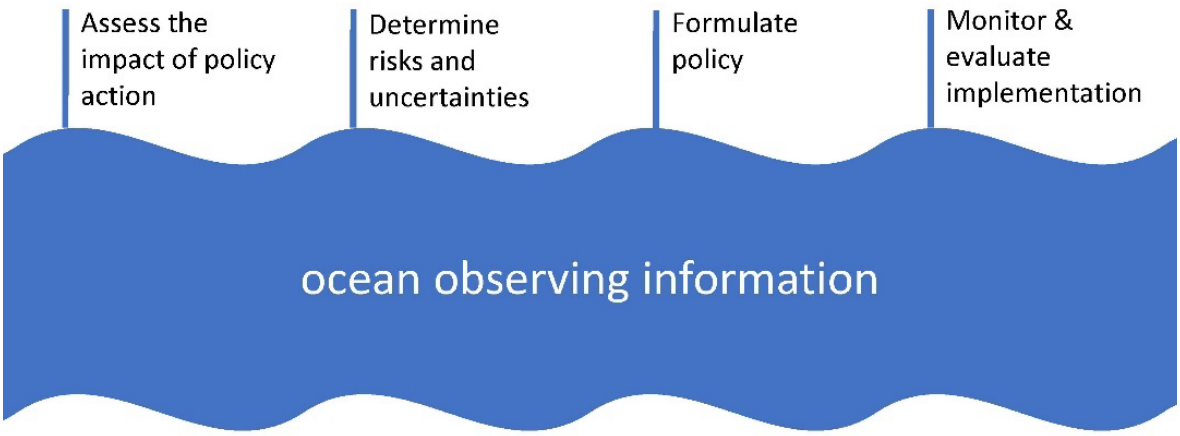

Figure 21. Ocean observing information is required at various stages of the policy process (represented on the top of the wave crests). To ensure a sustained provision of information, the observing system should be sustained (represented as a continuously flowing process). Credit: D. Eparkhina.

Benefits of continuous science-policy dialogue are two-fold. On the one hand, this helps ensure the policy requirements are met by the observing system. On the other hand, the capability of science base to meet the policy requirements is assessed.

There is not much use in policies which are not implementable due to the lack of a shared understanding, between science and policy, of the issues at hand and the gaps and challenges associated with the knowledge required to solve them. In turn, ocean observing and forecasting systems must be able to adapt and respond to the policy objectives and demonstrate their broad societal benefits.

The understanding of the purpose of ocean observing has been rapidly evolving – from the focus on basic research and military navigation, to sustained operational services for a wide variety of users. This evolution calls for a stronger recognition of the role and mandate of ocean observing as a societal service and not merely as a sector-specific or research activity. Furthermore, sustainability of observations relies on sustainable and robust science-policy interface built on trust, recognition of value, and institutionalized policy feedback mechanisms.

We have reviewed various levels of science-policy interface for ocean observing and forecasting, as represented and enacted by the large-scale project like EuroSea. The requirements from the policy users may differ depending on the geographical or governance scope, but the underlying EuroSea message remains the same: 'we cannot manage what we cannot measure'. Ocean observing and forecasting are not the end-goal but the baseline capabilities for knowledge and information. Promoting the importance of observations and forecasts is, therefore, often difficult and their role may be overlooked or not fully comprehended. EuroSea has been stressing the importance of sustainability in ocean observing as a prerequisite for the delivery of sustained services.

There is a clear need to continuously learn from interactions at the science-policy interface. Most of the scientists in the European ocean observing and forecasting systems are funded by governments and they are required to communicate what they do. Communication and dissemination in science are becoming increasingly important and are in many cases an obligation imposed by the funder. However, communication and science-policy interface are not the same thing. To communicate science, it is enough to clearly and concisely frame the messages and present them in a way appealing to your audience. Science-policy interface, on the other hand, requires not only communication but also engagement and asks for a more systematic and focused effort of building and maintaining trust and analysing the relevance, credibility, and legitimacy of scientific advice in a specific policy area (see p. 5). Communication does not necessarily need to be long-term. Engagements at the science-policy interface, however, need to be regular to gain traction with the policy actors. Furthermore, as policy cycles are relatively short-term, messages and ideas the science brings to policy need to be re-iterated and adapted continuously to systematically reach the changing realm of policy actors.

At the interface between science and policy there are two main processes. First, there needs to be a demand for evidence-based policymaking, putting forward the issues which require scientific input. Simultaneously, science should inform policy and should be able to translate scientific outputs into policy advice. EuroSea has taken action through both of these approaches. In some cases, EuroSea has come forward to policy or decisionmakers to highlight the priorities of its community. In others, EuroSea has tried to address the policy needs by co-developing oceanographic tools or services with decisionmakers.

The introduction to this document gives an overview of the requirements to be filled by science in order to influence policy. However, neither science nor policy are homogeneous and ready-made bodies. Policymaking spreads both vertically (in the sense of the hierarchy of the decisive power) and horizontally (in the number of actors with the decision-making mandate). As regarding the latter, there is a range of policy actors at national level who are concerned with ocean observing. For example, multiple ministries fund various parts of ocean observing or make decisions regarding the ocean observing priorities or reporting.

Similarly, there are many factors that influence the way scientific actors can achieve a common position in speaking with policy. There may be power imbalances due to financial and logistical issues which influence participation of certain science actors in the science-policy interface. Geographical, disciplinary, or institutional diversity must be considered to allow for a balanced science representation. There can be lack of clarity on the participation of experts in their individual capacity or as government representatives. Another issue to be addressed is the inclusion of interdisciplinary and transdisciplinary knowledge in the ocean observing and forecasting science. Such disciplines as social sciences, philosophy, humanities, and the arts can provide valuable contributions to the development of ocean observing and forecasting systems responsive to the needs of societal and environmental systems.

Science is a social and political process, not just a process of discovery. The social, moral, and ethical dimensions of science call for scientists to build capacity for collaboration with a broad range of disciplines and stakeholders. However, it should be noted that the inclusion created through collaboration is never complete. Understanding the implications of knowledge for those who are 'in' and those who are 'out' must always remain an important aspect of the collaborative capacity that we seek to build (Clark *et al*, 2016).

Some lessons learnt from the EuroSea work at the science-policy interface are presented in this document. In addition to several case studies featured here, EuroSea also conducted two specific activities to distil the lessons learnt from science-policy interface.

First, there was an interactive workshop addressing the impact of EuroSea innovations, which took place at the EuroSea Annual Meeting in May 2022 (Figure 22). EuroSea impact area 'Contribute to policy making in research, innovation, and technology' was one of the two impact areas addressed in this ideation session. Secondly, there was a science-policy session organized at the global Ocean Best Practices Workshop in October 2022 (Figure 23 and 24), which asked scientists, governance scholars, and policymakers to share their views on the science-policy interface.

Figure 22. Participants of the EuroSea impact workshop organized by EuroSea Work Package 8 Engagement, Dissemination, Exploitation, and Legacy at the annual meeting in May 2022, including members of the EuroSea consortium and several members of the EuroSea International Scientific and Technical Advisory Board and EuroSea Innovation and Stakeholder Committee

Figure 23. GOOS announcement of the EuroSea session Ocean Best Practices and Ocean Policies at the Ocean Best Practices global workshop 2022

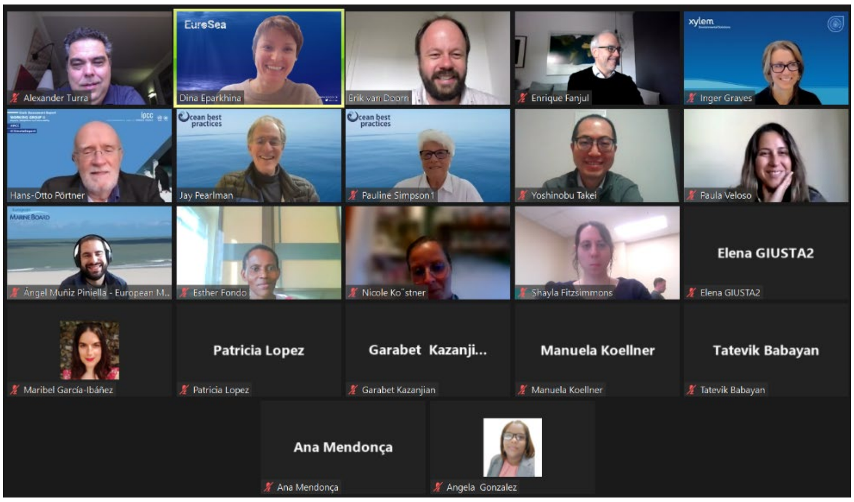

Figure 24. Participants and speakers at the second part of the EuroSea session Ocean Best Practices and Ocean Policies at the Ocean Best Practices global workshop 2022 on 17 October 2022

The lessons learnt derived from these activities are presented across the following areas:

- Understanding and coproduction;
- Socio-environmental systems;
- Flow of communication;
- Jargon and language;
- Addressing uncertainty;
- Proof of impact;
- Design of the messages.

Importantly, these lessons learnt are not an exhaustive list of all areas and aspects to take into account when developing and maintaining science-policy interfaces for ocean observing and forecasting. The first three years of EuroSea have allowed us to crystallize some achievements and issues of the science-policy interface. However, as a relatively new area of activity for ocean observing and forecasting, science-policy interfaces will require further understanding and more lessons learnt will be derived.

Understanding and coproduction

Active, iterative, and inclusive communication between experts and decision makers proves crucial to systems that mobilize knowledge that is seen as salient, credible, and legitimate in the world of action (Cash et al, 2003). On the one hand, scientific experts should not assume they know what questions decision makers would see as salient. On the other hand, decisionmakers should not assume that questions relevant to them are the ones experts can credibly answer. This must be carefully considered in science-policy interface mechanisms. Knowledge-making and decision-making are continually reshaping one another in what has been called ‘coproduction’. While engaging in science-policy interface, actors from both science and policy should try to be open to the understanding of the others’ perspective. Once a basic understanding is achieved, coproduction can happen, using established engagement and co-design methodologies.

A precondition underpinning successful science-policy interface is trust. It is recommended to communicate the facts as they are and if mistakes are made acknowledge them.

There can be a tendency to 'reinvent the wheel' when scientists engage in science-policy interface without a prior consideration of the existing methods to achieve mutual understanding and approach coproduction. EuroSea has tried to mitigate this through a stakeholder engagement training for the consortium. This is a continuous learning process in which it is important to analyse experiences and iterate the next rounds of engagements based on those.

Socio–environmental systems

Ocean observing and forecasting systems should be responsive to the demands of social systems. This relationship can be called 'socio-environmental systems'. Ocean observing and forecasting are a foundational and integral part of the knowledge and information value chain. Connection to all users of the ocean knowledge and information is therefore important. Furthermore, understanding stakeholder interests and needs is an ally in linking with policymakers, who are themselves influenced and responsive to the requirements of a large number of societal actors and sectors. Engagement with particular groups requires tailored and distinct approaches to communication. Opportunities for collaboration, as well as barriers, are context specific. Assumptions, norms, incentives, and expectations of stakeholders must be considered.

In the EuroSea consortium industry partners have been acting as enablers and demonstrators of the strengths and weaknesses of the ocean observing and forecasting collaboration. Moreover, EuroSea helped industry and scientists to address the differences in scales and timing. Some industries (just as some policymakers) require immediate solutions. But these problems have a longer term (e.g. unsustainable aquaculture) and scientists have a capacity to help address them bringing about the state-of-the-art research, development, and innovation. Such collaborations are valid proofs of impact and potent examples to be used in science-policy engagements.

Flow of communication

Communication flow should be frequent. Furthermore, dialogue should be opened up as early as possible through a stakeholder engagement process. Establishing dialogue early on allows for both science and policy actors to better understand the scope, the terminology, and, ideally, engage in a process of co-development of solutions. Inclusive science-policy consultation process helps ensure the feeling of ownership of the knowledge output and remove the question of legitimacy. Furthermore, communication should include follow up and reference to previous successful experiences. Frequent and well-prepared science-policy interactions form a precedent and contribute to building trust and reliability. Stakeholder engagement tactics need to be tailored to specific stakeholder needs and competencies. Opportunities for and barriers to collaboration among stakeholders are context specific (Clark et al, 2016). Strategies, therefore, need to be tailored to particular situations. Mediation can be considered to promote communication among potential collaborators who have no history of talking with one another.

Jargon and language

Jargon and language must be carefully considered. EuroSea is using multiple terms and acronyms which should be avoided at any cost while speaking outside of specific scientific audience. Not only policymakers or industry, but also the scientists who are not dealing with particular observing networks or collaboration mechanisms can be unaware of some of the terminology used by EuroSea. As a rule of thumb, we recommend considering that everyone who is not expert in your own particular field of expertise should be considered as general public and approached using plain language.

Addressing uncertainty

Addressing uncertainty is another key communication issue. Uncertainly should not be considered by policy or decisionmakers as lack of knowledge. The degree and level of uncertainty can be used to show the robustness of the scientific method. This can also demonstrate requirements for observations and modelling. There is a certain danger of overexposing model outputs as decision-making tools, because oceanographic models can poorly communicate uncertainty or where more observations are needed.

Proof of impact

The impact of science is typically defined as a change in the thinking or behaviour of societal actors (Edler *et al*, 2022). However, a classical input-output-outcome-impact model is not suitable for ocean observing and forecasting. Moreover, such linear view of the impact generation is not applicable to most areas of science and technology. The impact of science is a long-term process that may not always be clearly identifiable and attributable to particular actions.

Ocean observing is complex. This is due to variable ocean dynamics involving a wide range of spatial and temporal scales: from seconds to long-term climate scales and from local to global scales. It is reflected in the complexity of different actors providing observations at different local, national, regional, and international levels. This calls for agreements on common agendas and principles as well as a robust governance to avoid duplication and harness the potential of observations. In terms of the proof of impact, it may be impossible to demonstrate a direct value of a particular set of observations or oceanographic activities. The impact of observations can be demonstrated through emphasising the value of connectivity, partnerships, and synergies as paramount enablers of ocean observing services and information.

Design of the messages

It is important to frame the messages clearly, stepping out of the 'scientific truth' and developing statements that are understandable. Furthermore, it is not the volume but the value and clarity of information that should prevail. We recommend to not overwhelm the audience with details, rather to focus the message on the key expected impact. Easily understandable visual aids should be used, where possible, to explain or summarize the main points.

When speaking with stakeholders, the focus should be on the problem that can be addressed by your proposal, not all possible other problems or solutions. Furthermore, it should be considered whether it is more important to point out the problem or a solution or both. In some cases, it may be better to only point out the problem and suggest co-creation scenarios or call for a dialogue to find a solution together. As in all kinds of communication, the audience should feel valued.

The access to policymakers should be established considering the area most interesting and relevant for them. Once the entry point to dialogue is found and the targets have your attention, other aspects can be brought forward too. Published media articles (web articles, social media posts, newspapers, etc) are useful demonstrators of the importance of the messages that are being promoted to policy. The more media traction, the more valuable the messages may appear to the audience.

The robustness of the scientific methods and findings is a positive message and should be brought forward. This will help demonstrate the messages are reliable. While the messages should be clearly formulated and concise, it is important to have all background information at your disposal. In some cases, policy and decisionmakers may not be experts, but in others they may be. Questions of clarification may be generic but also very specific and technical. It important to foresee such possibility and be adequately prepared. When presenting examples, it is recommended to base them on recent developments not a distant past.

4. Conclusion

Science-policy interface for ocean observing and forecasting needs to be considered through various levels and scales. Ocean observing and forecasting are a basis for knowledge and information and are a fundamental need. However, communicating this need is complex just as are complex the observing and forecasting systems themselves.

We have shed some light on the notions of science-policy interface and their application to the specific sector of ocean observing and forecasting. It is important to consider this sector as an integral part of the knowledge and information value chain. Spanning out from that is the critical need to recognise the users of ocean knowledge and information in the communication and engagement activities that promote ocean observing and forecasting.

Impact of observations is not linear. In the majority of cases it is impossible to determine the impact of a set of observations on a user satisfaction or a policy area. The impact of observations can be demonstrated through emphasising the value of connectivity, partnerships, and synergies, which enable fit-for-purpose oceanographic information, products, and services.

Ocean observing is complex due to the nature of the environment in which it operates. Ocean dynamics are variable and involve a wide range of spatial and temporal scales: from seconds to long-term climate scales and from local to global scales. It is reflected in the complexity of different actors providing observations at different local, national, regional, and international levels. This calls for agreements on common agendas and principles as well as a robust governance to avoid duplication and tap the full potential of observations.

EuroSea has allowed us to crystallize some acquirements and issues of the science-policy interface. However, this remains a relatively new area of activity for ocean observing and forecasting and will require further understanding with more lessons learnt to be derived. The last year of the project will provide numerous new occasions to apply our lessons learnt and consider how this toolbox can be further enriched. Two notable science-policy outputs which are foreseen for EuroSea are the final high-level conference (UNESCO Headquarters, Paris, 21 September 2023) and the development of the EuroSea legacy portfolio and a Legacy Report. These outputs will represent not only the demonstrators of how our lessons learnt can be used and complemented, but also contribute to the overall narrative about the impact and value of the European ocean observing and forecasting system. Furthermore, we believe that through this document and the various science-policy activities of EuroSea, the European oceanographic community can contribute valuable best practices globally.

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