

Project information	
Project full title	EuroSea: Improving and Integrating European Ocean Observing and Forecasting Systems for Sustainable use of the Oceans
Project acronym	EuroSea
Grant agreement number	862626
Project start date and duration	1 November 2019, 50 months
Project website	<a href="https://www.eurosea.eu">https://www.eurosea.eu</a>

Deliverable information	
Deliverable number	8.12
Deliverable title	<b>EuroSea Legacy Report</b>
Description	Highlights of the EuroSea achievements and key recommendations for the future
Work Package number	8
Work Package title	Communication: Engagement, Dissemination, Exploitation, and Legacy
Lead beneficiary	EuroGOOS
Lead authors	Dina Eparkhina
Contributors	Colin Keogh, Toste Tanhua, Nicole Koestner, Emma Heslop, Kieran Reilly, Anthony Noronha, Fiona-Elaine Straßer, Johannes Karstensen, Artur Palacz
Due date	30.11.2023
Submission date	30.11.2023
Comments	



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 862626.



## Table of contents

Executive summary.....	1
EuroSea Legacy report.....	2
Conclusion .....	25

## Executive summary

EuroSea is a holistic large-scale project encompassing the full value chain of marine knowledge, from observations to modelling and forecasting and to user-focused services. This report summarizes the legacy of EuroSea as planned and measured through a dedicated impact monitoring protocol, a holistic assessment of the project's successes in advancing and integrating European ocean observing and forecasting systems.

Since its start, EuroSea has been analysing how well the project progresses towards the identified areas of impact. Impact assessment is not performance evaluation. These terms overlap but are distinct: performance relates to the efficient use of resources; impact relates to the transformative effect on the users. The EuroSea legacy report is presented through an aggregation and analysis of the EuroSea work towards achieving its impacts. Overall, over 100 impacts have been identified and presented on the website and in a stand-alone impact report. The legacy report sheds light on 32 most powerful impacts (four impacts in each of the eight EuroSea impact areas).

EuroSea Impact Areas:

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

Ocean observing and forecasting is a complex activity bringing about a variety of technologies, human expertise, in water and remote sensing measurements, high-volume computing and artificial intelligence, and a high degree of governance and coordination. Determining an impact on a user type or an area, therefore, requires a holistic assessment and a clear strategic overview. The EuroSea impact monitoring protocol has been the first known such attempt in a European ocean observing and forecasting project. The project's progress has been followed according to the identified impact areas, through consortium workshops, stakeholder webinars, tracking, and reporting. At the end of EuroSea, we are able to demonstrate how well we have responded to the European policy drivers set out in the funding call and the grant agreement of our project, signed between the European Commission and 53 organizations, members of the EuroSea consortium. The project's impact is diverse, spanning areas from strengthening ocean observing governance to contributing to policymaking or boosting ocean research, innovation, and technology. Each impact area underscores EuroSea's commitment to a sustainable and informed approach to ocean observing and forecasting for enhanced marine knowledge and science-based sustainable blue economy and policies.

# EuroSea

LEGACY REPORT

---

## Improving and Integrating the European Ocean Observing and Forecasting System



EuroSea has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862626



Author Dina Eparkhina

Contributors Colin Keogh, Toste Tanhua, Nicole Koestner, Emma Heslop, Kieran Reilly, Anthony Noronha, Fiona-Elaine Straßer, Johannes Karstensen, Artur Palacz

To be quoted as follows Eparkhina, D. (2023) EuroSea Legacy Report. Open Access. EuroSea Deliverable, D8.12. EuroSea, 44 pp. DOI 10.3289/eurosea\_d8.12.

Publisher Published by EuroGOOS. Brussels. 2023

Completed in November 2023

DOI 10.3289/eurosea\_d8.12.

Graphic design Agata Smok

Cover image © FS MARIA S. MERIAN Credit: John Jamieson / GEOMAR

Inner-cover image © EuskOOS

## EUROSEA LEGACY REPORT

# Improving and Integrating the European Ocean Observing and Forecasting System

### EuroSea Consortium Partners



# Introduction

EuroSea works to improve the European ocean observing and forecasting system in a global context. Why is this necessary? Well, the ocean is essential in the Earth's system. However, we still have fundamental gaps in our ocean observing and forecasting capabilities. These gaps limit our capacity to sustainably manage our activities and sustain ocean resources.

Ocean observing is a big science and simply cannot be implemented by individual nations alone. We urgently need to ensure high-level integration for coordinated ocean observing that can be sustained in the long term.

EuroSea has been implemented towards two goals. First, to deliver ocean observations and forecasts to advance scientific knowledge about the ocean climate, marine ecosystems, and their vulnerability to human impacts. Second, to demonstrate how the ocean is an essential part of an economically viable and healthy society.



## EuroSea Vision

Advancing research and innovation towards a user-focused, truly interdisciplinary, and responsive European ocean observing and forecasting system that delivers the essential information needed for human wellbeing and safety, sustainable development, and blue economy in a changing world.

© Martin Visbeck/GEOMAR

## EuroSea in numbers



## EuroSea Mission

Co-designing 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.

© Paul Eimerhard/Unsplash

# EuroSea Impacts

**EuroSea is a holistic large-scale project encompassing the full value chain of marine knowledge, from observations to modelling and forecasting and to user-focused services.**

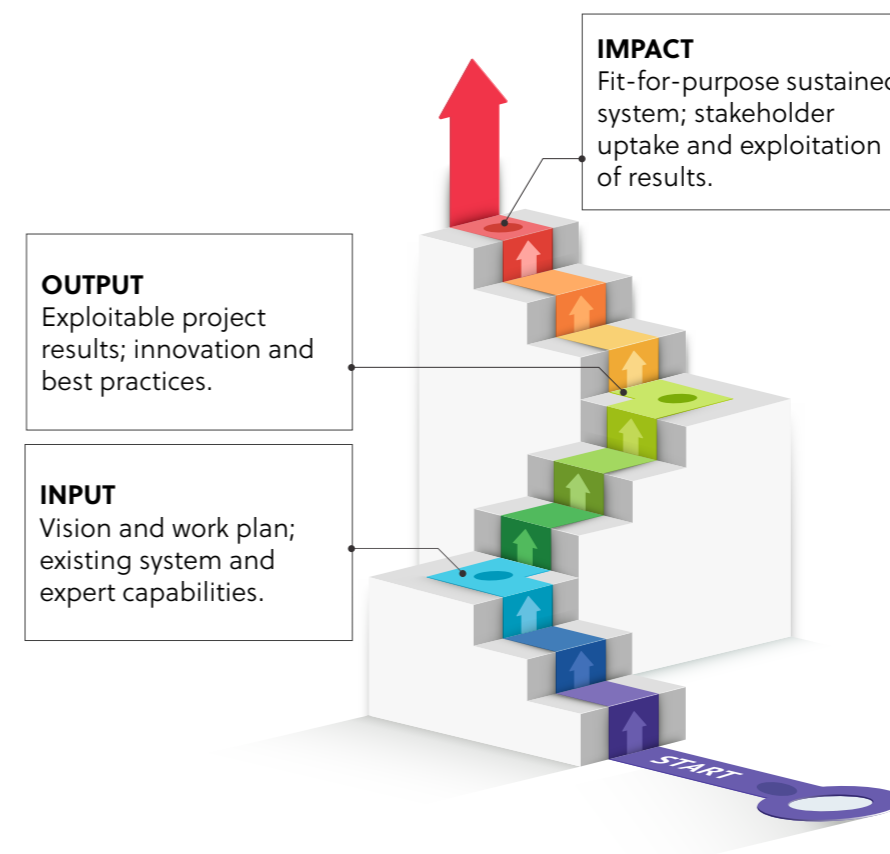
Since its start, EuroSea has been analysing the work done through the prism of the impacts we want to achieve. The legacy of EuroSea is summarized in over 100 impacts. 32 most powerful impacts are presented in this report – four impacts in each of the eight EuroSea impact areas.

## EuroSea Impact Areas:

- 1 Strengthen the European Ocean Observing System (EOOS), support the Global Ocean Observing System (GOOS) and the GOOS Regional Alliances;
- 2 Increase ocean data sharing and integration;
- 3 Deliver improved climate change predictions;
- 4 Build capacity, internally in EuroSea and externally with EuroSea users;
- 5 Develop innovations, including exploitation of novel ideas or concepts; shorten the time span between research and innovation and foster economic value in the blue economy;
- 6 Facilitate methodologies, best practices, and knowledge transfer in ocean observing and forecasting;
- 7 Contribute to policy making in research, innovation, and technology;
- 8 Raise awareness of the need for a fit for purpose and sustained observing and forecasting system in Europe.

EuroSea impact monitoring has been the first known such attempt in a European ocean observing and forecasting project. The project's progress has been followed according to the identified impact areas, through consortium workshops, stakeholder webinars, tracking, and reporting. At the end of EuroSea, we are able to clearly see how well we have responded to the European policy drivers set out in the funding call and the grant agreement of our project, signed between the European Commission and 53 organizations, members of the EuroSea consortium.

Strategic EuroSea vision goes beyond the current state of the art in ocean observing and forecasting, promoting a comprehensive and integrated approach. By considering the entire value chain and fostering collaboration in every step, EuroSea has been a paramount stepping stone for more effective, efficient, and impactful ocean observing and forecasting in Europe and worldwide. **This holistic approach ensures that every part of the value chain, from data collection to product delivery, is integrated and optimized.** Moreover, recognizing the significance of Findable, Accessible, Interoperable, and Reusable (FAIR) ocean data, EuroSea has promoted equitable, open, and fair data services.



The emphasis on improving collaboration and cooperation between different elements of the value chain addresses crucial challenges in ocean observing. The project's impact is diverse, spanning areas from strengthening ocean observing governance to contributing to policymaking or boosting ocean research, innovation, and technology. Each impact area underscores EuroSea's commitment to a sustainable and informed approach to ocean observing and forecasting for science-based sustainable blue economy and policies.



## Impact area 1:

EuroSea has strengthened the European Ocean Observing System (EOOS) and supported the Global Ocean Observing System (GOOS) and the GOOS Regional Alliances

EuroSea, aligned with GOOS and the UN Decade of Ocean Science for Sustainable Development 2021-2030, helped influence and integrate ocean observing and forecasting on a global scale. Through collaborative efforts with organizations like EuroGOOS and the EOOS framework, EuroSea has created roadmaps, guiding documents, and standards, ensuring that its vision translates into real-world impacts. Our integrated approach includes improvements in governance structures, better coordination and resource allocation, and decision-making support to make ocean observing a public utility for the benefit of all users.



## Towards a sustained and fit-for-purpose EOOS

EuroSea has supported the development of the framework for the European Ocean Observing System (EOOS), building on years of cooperation and intensive stakeholder consultations prior to EuroSea. Through EuroSea, the EOOS framework governance has been advanced and now includes the implementers of European ocean observations (Operations Committee), ocean observing funders and supporters (Resources Forum), and stakeholders (Advisory Committee).

The 2<sup>nd</sup> EOOS Technology Forum was supported by EuroSea to discuss the technological innovations in the European ocean observing and data systems. The GOOS National Focal Points for Europe were engaged in EOOS through the Operations Committee. Furthermore, through EuroSea new EOOS strategy and roadmap for implementation 2023-2027 were developed.

## Integration of European observing networks

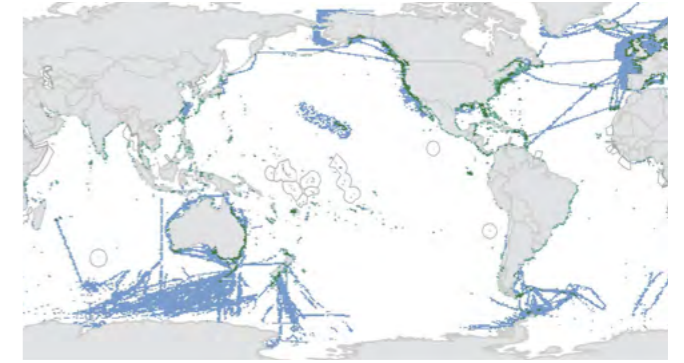
EuroSea has improved integration and coordination in various ocean observing networks. The advancement of Technology Readiness Levels across a range of them signifies the maturity and deployment readiness of each technology. EuroSea's focus has not just been on individual technologies but also on multi-platform observations and a broad thematic scope reflecting the richness of marine observations and monitoring in Europe.

Through EuroSea, Technology Readiness Levels were advanced for such critical observing networks and research infrastructures as bio-geo-chemical and deep Argo floats, gliders, ship-based hydrographic measurements, Eulerian observatories, tide gauges, high-frequency radars, autonomous surface vehicles, and augmented observatories.

Furthermore, a set of best practices has been developed on data management and network operations. Some best practices have already been internationally adopted by the GOOS Observation Coordination Group.



Oceanographic cruise © Vanessa Cardin/ OGS



Spatial coverage of known active long-term biological observations globally as co-developed by EuroSea and international partners © GOOS

## Recommendations on legal frameworks related to ocean observing

EuroSea analysed existing hard and soft law frameworks and mechanisms and their link to the provision of ocean observations and user-focused products and services. The 1982 United Nations Convention on the Law of the Sea (UNCLOS) requires coastal states to give consent to other states to conduct marine scientific research (including ocean observations) on their continental shelves or in their exclusive economic zones (UNCLOS, Art. 246(2)). However, this requirement is not compatible with many oceanographic operations. EuroSea proposed tangible steps to be taken by the European Union to simplify these procedures.

## Mapping of bio-ecological ocean observations

The dynamic landscape of bio-ecological (bio-eco) marine monitoring across Europe necessitates a consolidated overview. EuroSea mapped bio-eco marine monitoring networks and capabilities as a holistic representation and a foundation for bolstering European marine bio-eco monitoring.

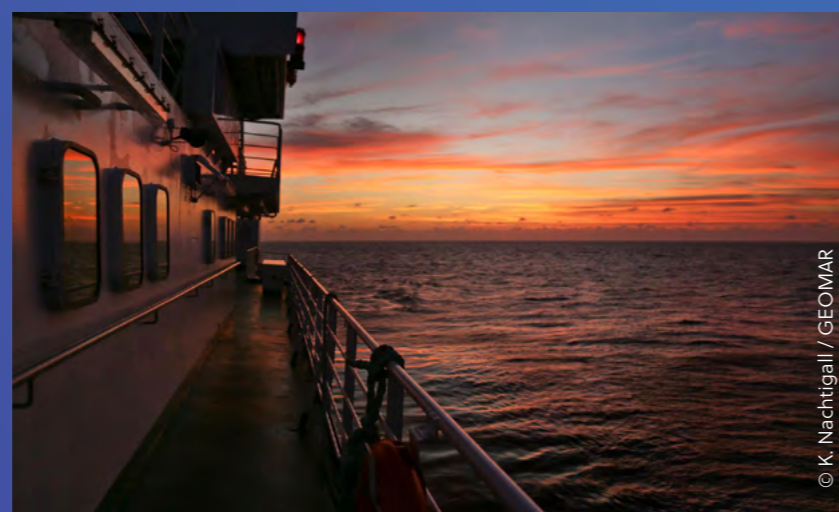
Active bio-eco programs in Europe were brought together through EuroSea to assess gaps and opportunities and plan actions together. Institutions or agencies can now leverage the strengths of other networks, avoid redundancy, and create a more cohesive marine monitoring strategy. This is in stark contrast to isolated systems where data might be siloed. Instead of a haphazard approach, we now have a clear indication of where efforts need to be concentrated, which will help achieve European and global policy objectives linked to marine biodiversity.



EOOS Conference 2018, co-organized by EMODnet, EuroGOOS, and European Marine Board, was a precursor of the EuroSea actions to consolidate the EOOS governance and launch several influential activities © Picture by Dirk Leemans provided by the European Commission under a creative commons license



Argo float deployment © Tarron Lamont and Gavin Tutt



## Impact area 2:

### EuroSea has increased ocean data sharing and integration

EuroSea has continued the European oceanographic community's ambitious goal to consolidate diverse ocean data that have traditionally been siloed. The collated data, spanning from tide gauges to advanced observatories, are being meticulously harmonized to foster interoperability and uniform metadata standards and vocabularies are created. This undertaking is primarily anchored in a three-fold collaboration with key European ocean data aggregators and services: European Marine Observation and Data Network (EMODnet), Copernicus Marine Service, and SeaDataNet.

## European leadership in ocean best practices

EuroSea has boosted the development of standardized protocols and best practices within EuroGOOS Task Teams and other European initiatives. Thanks to that the global Ocean Best Practice System of the Intergovernmental Oceanographic Commission of UNESCO was enriched with European best practices.

Furthermore, multiple new datasets were provided to Europe's Copernicus Marine Service and the European Marine Observation and Data Network (EMODnet). EuroSea also developed guidelines to help users find in situ marine data or datasets best suited to their needs and brought the user requirements to the data infrastructures.

While individual datasets from tide gauges, gliders, or high frequency radars might exist separately, EuroSea has brought them together under a common standardization and FAIRness framework, making the data more accessible and used across platforms and services. EuroSea contributions to the European data management have helped increase the marine data aggregation and dissemination for real-world user applications.



Ocean glider © Michael Schneider / FS METEOR / GEOMAR

## Marine plastic debris monitoring

Marine debris, including plastic waste, is a growing concern worldwide, affecting marine ecosystems, biodiversity, and human health. Despite the significance of the issue, there has not been a globally coordinated system to observe and measure marine debris comprehensively. EuroSea, in collaboration with EU4OceanObs, set up IMDOS – Integrated Marine Debris Observing System to bring about a coordinated global framework. This will help to consistently monitor marine debris and inform policy, conservation, and cleanup efforts. Through global partnerships and multi-stakeholder cooperation, IMDOS provides guidance towards a harmonized and holistic approach for monitoring marine debris worldwide. Launched as a joint project of GOOS, GEO Blue Planet and UNEP Global Partnership on Marine Litter, IMDOS seeks further funding and sustainability as a functional, globally-recognized entity. This initiative has prompted the addition of Marine Plastics Debris to the list of GOOS Essential Ocean Variables (EOVs). Marine Plastics Debris EOV is expected to evolve rapidly in response to changing societal and scientific requirements and innovation in ocean observing. It is therefore critical to ensure authoritative guidance for its development and curation.



Integrated Marine Debris Observing System (IMDOS) [www.imdos.org](http://www.imdos.org)



Dissolved oxygen concentration as seen on 26 October 2023 in Copernicus Marine MyOcean Viewer



Observing System status as seen by OceanOPS-GOOS on 25 October 2023

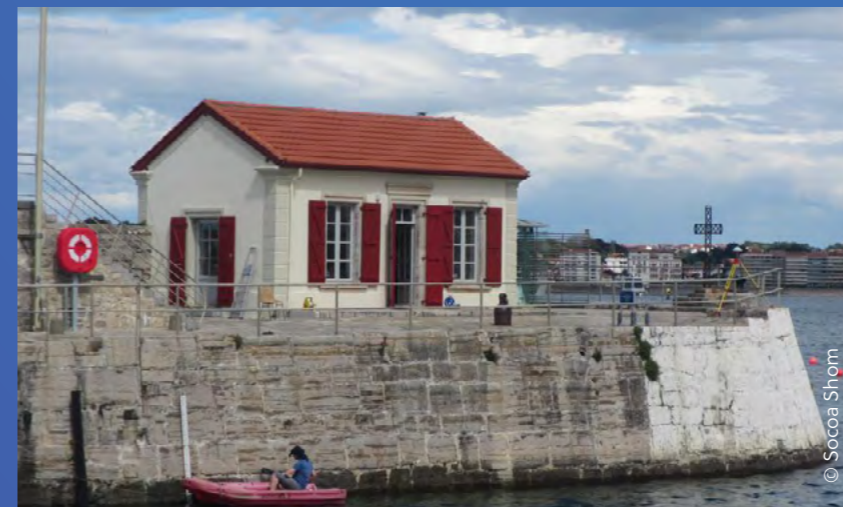
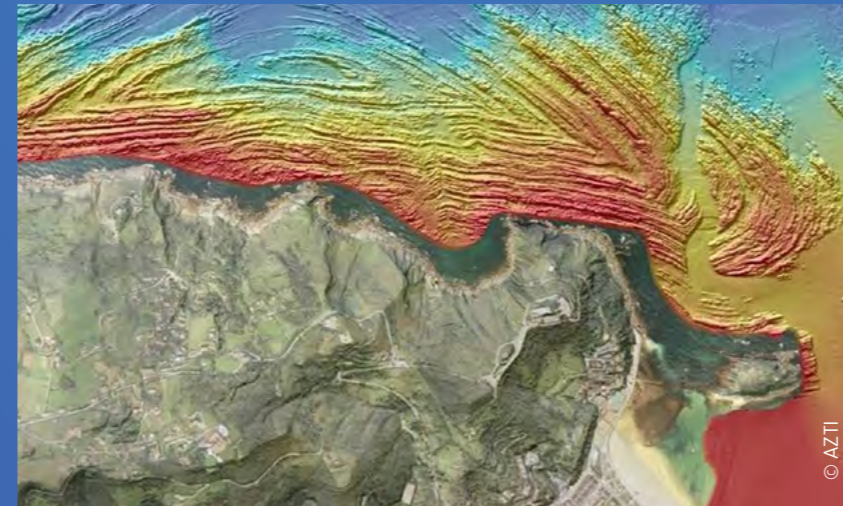
## Improving modelling of marine biogeochemistry

EuroSea analysed the use and efficiency of in situ observations to constrain regional and global forecasts developed by the Copernicus Marine Service. It is only via an integrated approach that marine data can be assimilated into a dynamical model of biogeochemical parameters. Satellite observations bring higher spatial resolution, but very few observations exist below 2000 m depth. Many deep ocean basins are still not accurately observed, preventing to have reliable estimate of the ocean state and variability.

EuroSea helped finetune in situ observation priorities for the Copernicus Marine Service and assess uncertainties. Several Ocean Observing System Experiments were conducted to estimate the effect of additional in situ observations on various marine data services and forecasts which are required by the users. Furthermore, new observations conducted through EuroSea or unlocked through partnerships were assimilated in the existing forecasting systems.

## Monitoring the status of the European ocean observing system

Europe is not yet equipped with a tool able to deliver a complete and accurate view of the status of the ocean observing system in its seas. EuroSea has analysed the existing ocean observing and data aggregation initiatives in Europe and globally and proposed ways forward. Through partnerships boosted by EuroSea, a vision of an integrated European capacity to monitor the ocean observing system status was developed. This should be done in its complexity and along each link of the value chain, from planning to data product delivery, in close collaboration with stakeholders and users. The vision includes an improved partnerships framework, full endorsement of FAIR principles for data and metadata, and essential feedback loops between ocean observing networks, infrastructures, and data aggregators. EuroSea has significantly advanced the development and harmonization of best practices and vocabularies across the ocean observing networks and infrastructures towards consistent long-term monitoring of the observing system, from operation at sea to data uptake by users.



## Impact area 3:

# EuroSea has delivered improved climate change predictions

Carbon measurements in the ocean play a pivotal role in understanding global carbon cycles, assessing anthropogenic impact, and developing strategies for climate change mitigation. Traditionally, carbon observations in oceanic systems have been constrained by technological limitations, patchy spatial coverage, and a lack of detailed knowledge of regional variability. EuroSea enhanced the observing system and its outputs for more accurate and specific carbon measurements – a significant stride in European and global marine biogeochemistry and climatology.

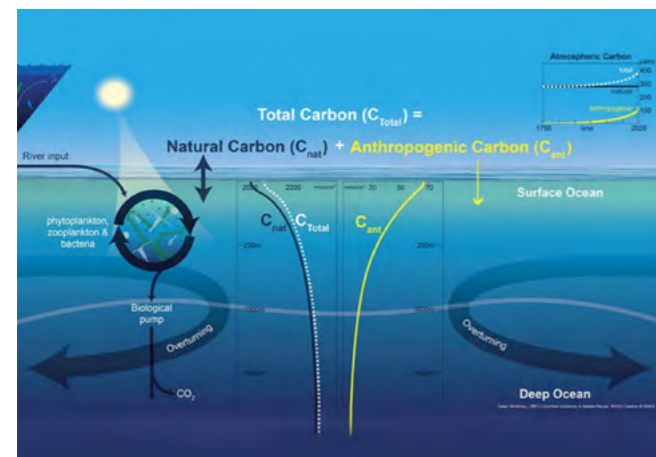
## Estimating the value of ocean carbon fluxes

The ocean has already taken up about 30% of the anthropogenic carbon and is the key regulator of climate. The carbon uptake by the ocean is in various ways a service to humankind. EuroSea assessed the monetary value of the ocean carbon uptake applying different pricing models. This was done considering the net global carbon uptake that determines the anthropogenic carbon content as well as the patterns and value of regional carbon uptake in the nations' Exclusive Economic Zones (EEZ). Both are important for the nations' climate action planning. EuroSea made recommendations for improved carbon sampling for both the global commons and for national EEZ regions, and encouraged European nations to provide appropriate resources by means of corresponding EU directives.

## Forecasting services for fisheries and aquaculture

EuroSea significantly advanced the observing and forecasting capabilities for extreme marine events for aquaculture, fisheries, tourism, and environmental agencies.

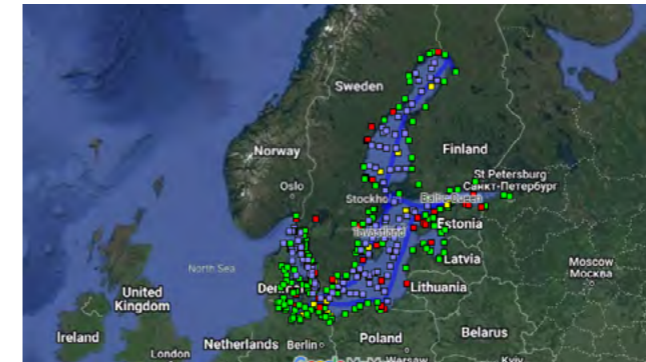
Extreme marine events, such as heat waves, deoxygenation, or extreme waves, threaten population, infrastructures, and ecosystems, but are hard to predict. EuroSea has delivered forecasting products for a range of users, while helping the Copernicus Marine Service finetune ocean indicators and tools to support environmental assessments. An international best practice for an observational and warning system for the aquaculture sector was developed. This created new market and management opportunities for both private and public sectors. An aquaculture web portal was developed allowing users to monitor essential ocean variables for a dedicated area, marine heat waves and other extreme events, and receive alerts.



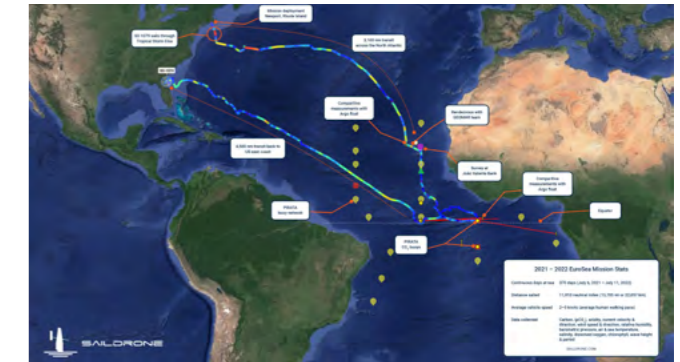
Carbon cycle in the ocean. © Crisp, D., et al. (2022) doi.org/10.1029/2021RG000736



Aquaculture site in Ireland © David Branigan / Marine Institute



Oceanographic stations of the EuroGOOS Baltic Operational Oceanographic System as of 26 October 2023 © EuroGOOS BOOS



EuroSea Sailability mission © Sailability

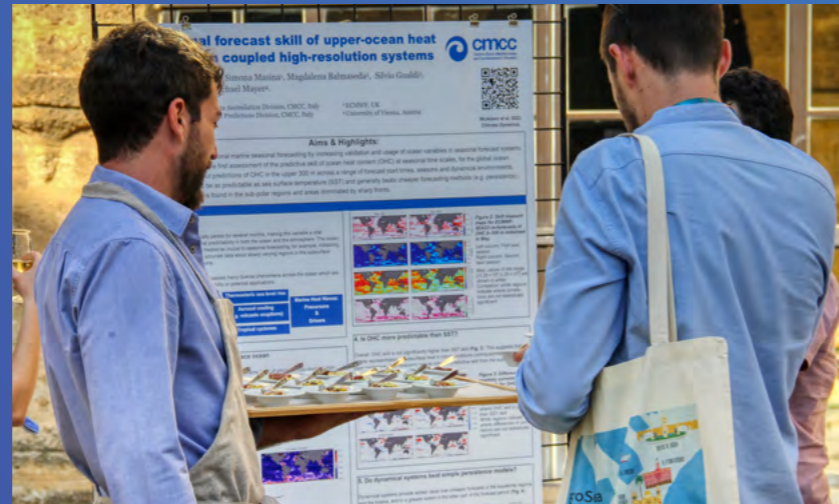
## Improving marine monitoring for European directives

Traditionally, ocean observing activities linked to marine research or operational services are assessed separately from the activities required for the Member States' reporting on the European Union 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 for the assessments.

EuroSea bolstered the assimilation of near-real-time data into numerical models used for the environmental assessments for the Marine Strategy Framework Directive. A study was conducted in the Baltic Sea leading to interest from other sea basins to replicate the approach taken. Through EuroSea, observations from the EuroGOOS Baltic Operational Oceanographic System and HELCOM monitoring networks were integrated, allowing to substantially improve the Copernicus Marine Service forecasting products for the Baltic Sea environmental assessments.

## Assessing the ocean carbon flux

The ocean carbon flux is characterized by sink and source regions. A prominent source region is the Tropical Atlantic, while prominent sink regions are the ocean deep convection areas. EuroSea studied the carbon uptake in these regions to better understand the drivers of carbon fluxes and disentangle seasonal variability from a long-term one. To do so, EuroSea broadened the spatial-temporal coverage of observations and increased the quality of the estimates through a large amount of field work and analysis. The Tropical Atlantic Observing System (TAOS) was improved, biogeochemical Argo floats and Sailability were added, and the existing platforms were augmented with new sensors. These significant improvements in the observational and analytical capacities have enabled important advancements in estimating air-sea carbon fluxes at the basin scale.



## Impact area 4:

**EuroSea has built capacity, internally within the consortium and externally with EuroSea users, in a range of key areas**

EuroSea, in recognizing the variety of potential applications of its results, conducted targeted training programmes for its diverse user base. This includes oceanographers, fisheries scientists, blue economy businesses, technical experts, and the next generation of stakeholders. By catering to the specific needs of each group, EuroSea has ensured a broader and more effective utilization of its results. Furthermore, consortium trainings were organized to enhance capacities within the project, from effective communication and engagement to intellectual property rights and business development.

## Strengthening soft skills for stakeholder-focused ocean observing system

EuroSea has delivered a holistic improvement of the European ocean observing and forecasting system throughout the value chain of marine knowledge, with a focus on innovation. Through the enhancements in the coordination, governance, integration, and assimilation of all components of the value chain, EuroSea has delivered observing and forecasting innovations and developed strategies for the exploitation of its results.

The EuroSea consortium benefited from capacity enhancement trainings in the areas deemed critical for the success of EuroSea: stakeholder engagement, effective communication, and business exploitation. The knowledge obtained directly benefited all EuroSea activities and allowed to boost the exploitation of results and visibility.

## Enhancing European ocean data capacity

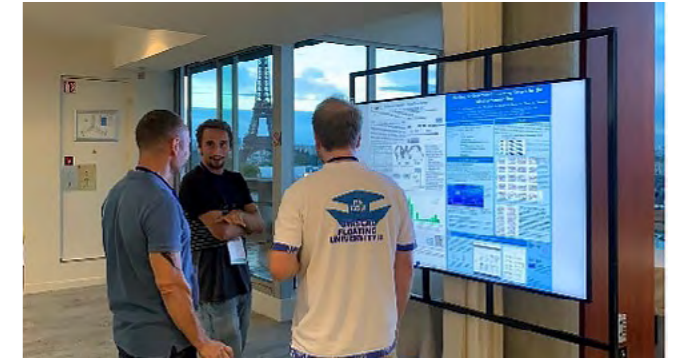
European ocean data collection is driven by a vast diversity of needs and requirements, spanning institutional plans, national obligations, European directives, and international programmes, conventions, and agreements.

EuroSea continued to strengthen pan-European ocean data integration from information about the location and availability of various data sets, to guidance on establishing FAIR data sharing procedures and practices. This is instrumental to achieving a unified truly pan-European ocean data capacity for the benefit of all. Furthermore, European ocean data systems are crucial for global ocean observing products and services and the success of the international ocean data initiatives.

Through EuroSea, three main European ocean data aggregators and services, Copernicus Marine Service, European Marine Observation and Data Network (EMODnet) and SeaDataNet, have been able to gain more users, while marine infrastructures and observing networks have been encouraged to harmonize their metadata, allowing users to seamlessly switch from one infrastructure to another and drastically extend access to more data.



EuroSea impact workshop at the 3<sup>rd</sup> Annual Meeting, May 2023, Cadiz, Spain © Dina Eparkhina



Early and advanced career ocean researchers and professionals discuss EuroSea outcomes at the EuroSea final Annual Meeting in 2023, Paris, France © Dina Eparkhina

## Fostering capacity in stakeholder co-design and foresight

EuroSea has pushed a shift in the way ocean observing activities are evaluated, moving from reactive problem-solving to proactive planning. This implies that stakeholders are engaged not just to respond to immediate challenges but are looking ahead to anticipate and prepare for future technological and sustainability opportunities.

EuroSea conducted numerous stakeholder workshops to facilitate knowledge exchange, reflection, and collective solutions. A special focus was given to foresight activities, enhancing the EuroSea consortium's capacity in understanding the policy and management drivers, while striving to make the ocean observing planning both more responsive and more strategic.

Europe is positioning itself as a leader in marine technology and sustainable practices. This does not only ensure that the European ocean observing system remains state-of-the-art but also sets a benchmark for global standards. Proactive planning, integrated approach to technology and sustainability, active stakeholder engagement, and emphasis on European leadership – all signify a forward-looking, holistic strategy that moves beyond the current state of the art in ocean observing systems.

## Engaging the next generation of stakeholders

The future of European ocean observing and forecasting lies in robust governance mechanisms, sustainability of observations, and a growing capacity of the next generation of stakeholders to respond to new technological and societal challenges and opportunities.

EuroSea has extensively contributed to leaving a strong legacy with early career ocean professionals. Workshops, activities, exhibitions, poster and training sessions were held. New partnerships have been created, for example, with the UN Ocean Decade Early Career Ocean Professionals (ECOP) programme, the SEA-EU European inter-university initiative, or the WASCAL Floating University.

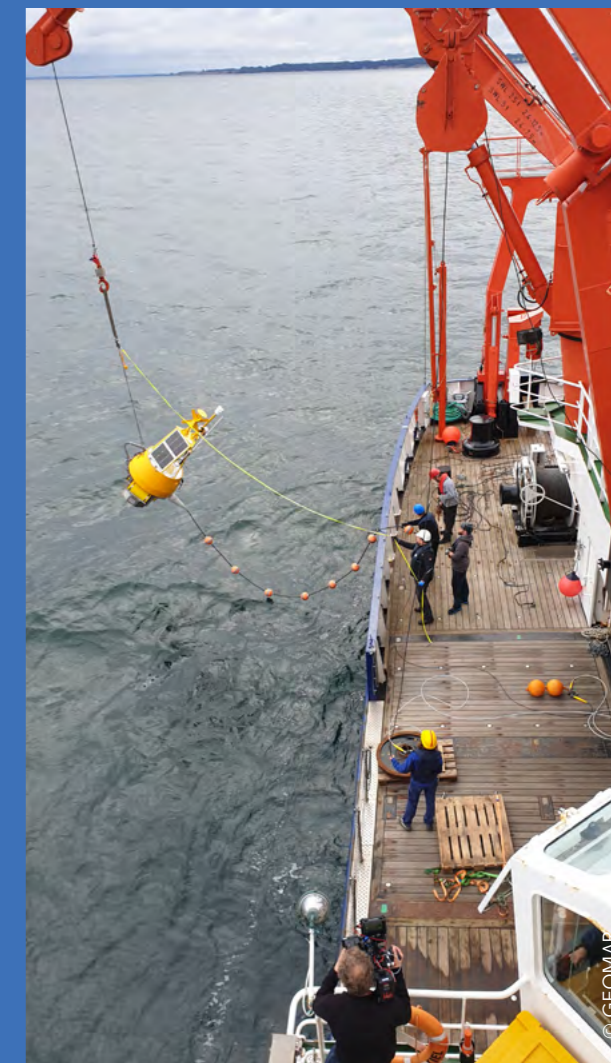
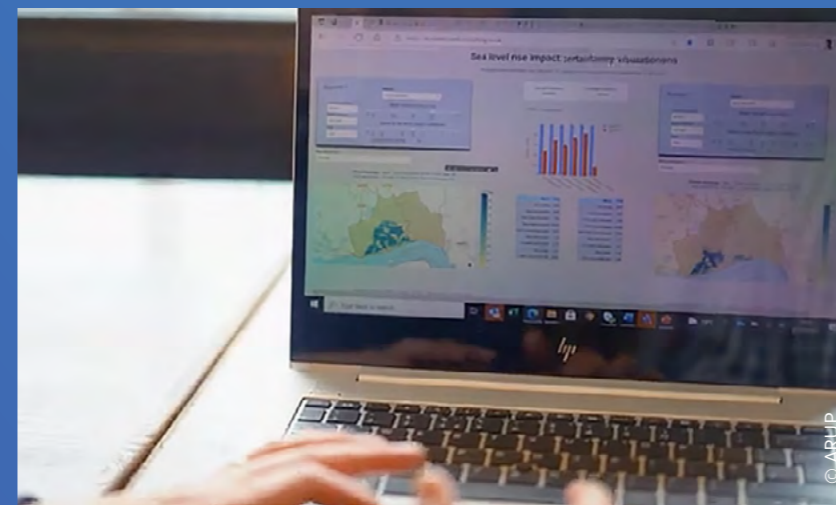
Engagement of the next generation did not only focus on early career professionals or university students. EuroSea broadened its engagement towards a large-scale societal ocean literacy, through its itinerant exhibition showcased in public areas during the European Researchers Nights and on numerous other occasions across Europe. In addition, a partnership was created with the global Ocean Observers initiative which promotes the use of educational materials designed on the basis of ocean observing activities.



Visual recording of EuroSea workshop on engagement and communication



EuroSea poster session at the final symposium, September 2023, UNESCO, Paris, France © Dina Eparkhina



## Impact area 5:

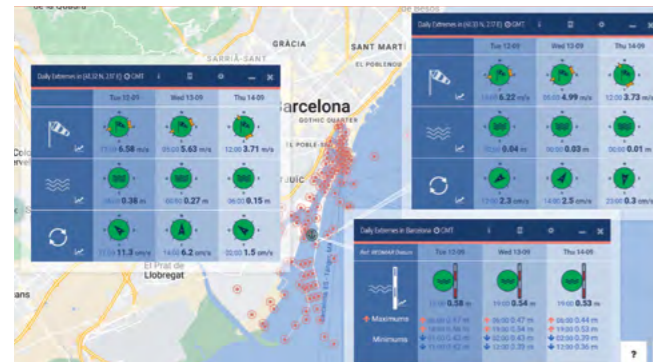
EuroSea has developed innovations, exploited novel ideas and concepts, and shortened time span between research and innovation, fostering blue economy

EuroSea strategic vision for the entire ocean observing value chain changes the way oceanic data is collected, processed, and utilized. By emphasizing a cohesive and integrated approach, EuroSea has addressed traditional inefficiencies and bottlenecks from collection to end-product delivery. With a unified approach, data seamlessly moves from observation to model assimilation and products, ensuring timely and accurate information.



## Innovative breakthroughs to mitigate climate change impacts

The EuroSea partnerships and integrated approaches have allowed several innovations to transform the way policy, decision makers, and industry are informed. Four EuroSea results received particular recognition of the European Commission's Innovation Radar which identifies high potential innovations. Examples of the EuroSea innovations are numerous. Among them, the EuroSea low maintenance tide gauges with their easily adaptable sensor options, radar and GNSS antennas using GPS, and technology that lasts. This can revolutionize sea-level observations in remoted areas or in developing economies. Another key product is the EuroSea Oceanographic Services for Ports and Cities (OSPAC) software, which was developed to provide ports and city authorities with real-time monitoring and alerts of sea conditions critical for navigation and security. The EuroSea innovative sea-level planning and scenario visualization tool is yet another key result. The tool allows local authorities and city planners to harness the power of ocean observing and high-volume computing to evaluate complex socio-economic and environmental impacts of the sea-level rise.



EuroSea Operational Services for Ports and Cities (OSPAC) [www.ospac.es](http://www.ospac.es)

## From single to multi-platform observations for tailored ocean forecasting services

The transition from traditionally singular or isolated ocean observing methods to a multi-platform approach signifies a monumental leap in ocean forecasting. This collaborative strategy integrates data from various sources, capitalizing on the strengths of each platform, to generate more accurate, comprehensive, and timely forecasts and services.

The EuroSea multi-platform approach drives a paradigm shift in ocean forecasting methods. By integrating diverse observational platforms, EuroSea addresses the inherent limitations of singular methods, offering richer, more reliable data and information. The immediate benefits include more accurate predictions and forecasts and a robust system less prone to individual platform vulnerabilities. With the integration of multiple platforms, the technology readiness levels of the ocean forecasting system are drastically increased reflecting its enhanced reliability and applicability for broader and more complex scenarios.



Autonomous Surface Vehicle Saildrone © Edson Silva Delgado / Saildrone



Land-sea interface © Michael Rea



EuroSea aquaculture monitoring buoy © Avramar

## Critical measurements for user-focused services

Essential Ocean Variables (EOVs) are critical parameters needed for a comprehensive assessment of the ocean state. The EOV framework is a common reference point for various stakeholders fostering better collaboration between entities involved in ocean observing. It also gives principle baseline for policy and decision-makers to develop informed strategies.

EuroSea studies boosted the application of the global EOV framework for specific European policies and user needs. Systematic EOV observations enhance data consistency and advance Technology Readiness Levels for both ocean observing and forecasting. Through EuroSea, different initiatives have been able to align their protocols and standardize their EOV observation requirements, ensuring consistent data collection methods, facilitating comparative studies and analyses, and fostering co-development of oceanographic products and services.

## Innovative monitoring and forecasting for blue economy sectors

EuroSea developed innovative monitoring systems using state-of-the-art sensor technology and established international practices for manufacturing, deployment, and maintenance of observing platforms. One such system was designed for aquaculture as a high-value blue economy sector. The novel EuroSea monitoring system measures vital parameters such as oxygen, temperature, and pH and couples in situ observations with advanced modelling capabilities to issue alerts of extreme marine events in near real time. Prior to this, aquaculture operations might have had limited data on environmental conditions, leading to suboptimal farming conditions, reduced growth rates, or loss of stock. The EuroSea monitoring system provides continuous data on critical parameters, issues timely warnings, and allows targeted mitigation strategies. The system was successfully tested in diverse locations in Ireland and Spain and proves perfectly adaptable for varying marine environments. This scalability paves the way for broader global adoption, offering tailored solutions to aquaculture operators worldwide.



## Impact area 6:

EuroSea has facilitated methodologies, best practices, and knowledge transfer in ocean observing and forecasting

EuroSea has enhanced the European ocean observing and forecasting system for seamless knowledge transfer and streamlined methodologies. As a holistic and integrated ocean observing and forecasting project with a user-centric focus, EuroSea has been pivotal in fostering European ocean best practices and standards for marine data collection and management, development of ocean climate indicators, augmentation of marine environment forecasts, and visualizing the ocean's societal and economic role.

## Decadal insights into the life below water through breakthrough modelling

EuroSea defined user-focused indicators of ocean state and variability needed to set requirements for European marine knowledge services, from observations to products and forecasts. The EuroSea indicators for the Copernicus Marine Service and Copernicus Climate Change Service span seasonal forecasts of weather statistics, climate variability and change, coastal sea level rise, ocean health, and productivity.

This work has advanced the scientific understanding of climate monitoring and sea-level rise, improving the accuracy of numerous model outputs. We are now able to forecast ocean state and variability six months ahead with new unseen certainty, as well as reconstruct the ocean dozens of years into the past. This allows achieving a long-term understanding of the ocean change and decadal variability and analyse trends in such key policy-relevant parameters as the ocean heat content and sea level.



Effects of sea level rise © George Clerk

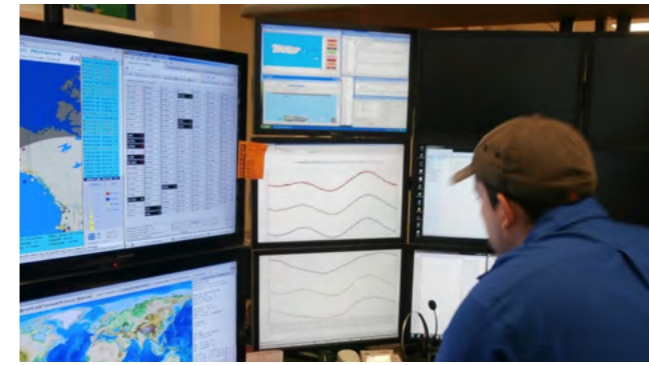
## Global ocean best practices for local impacts

EuroSea endeavoured to develop best practices in research, development, and innovation areas as a collaborative effort to enhance ocean observing applications. The establishment of best practices ensures consistency, accuracy, repeatability, and reliability in marine research and technology and helps avoid isolation and inconsistencies.

EuroSea has promoted the development and international endorsement of best practices by the Global Ocean Observing System (GOOS). This has enriched the GOOS Ocean Best Practices System and enlarged the user base of the EuroSea results. Globally adopted EuroSea best practices lead to standardized methodologies in ocean observing and forecasting worldwide and consistency in data collection and management, and foster international partnerships.



Deep-sea Remotely Operated Vehicle (ROV) operations using best practice for ROVs. © Schmidt Ocean Institute



Ocean monitoring fieldwork © Mark Bushnell



Traces of ocean © Rod Waddington

## Making ocean observing more responsive and influential

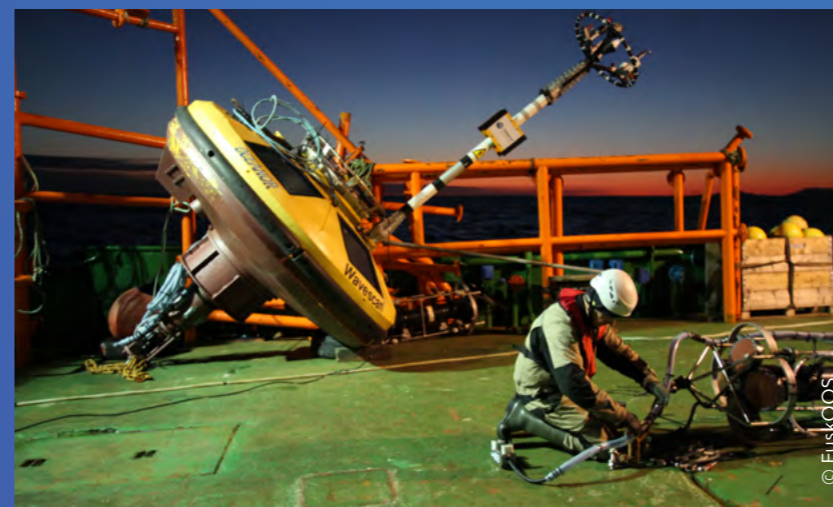
Understanding the impact of particular observations on ocean forecasts can significantly refine the way forecasts are generated. By analysing which observations contribute most to the forecasting accuracy, we can optimize observational campaigns, resources, and strategies.

EuroSea developed scientific frameworks to prioritize the most impactful observations leading to greatly improved reliability and accuracy of ocean forecasts. This work plays a crucial role in informing decisions about where to deploy observational instruments or which data to prioritize in order to obtain accurate forecast outcomes. Furthermore, this helps determine emerging priorities to guide future observational campaigns, ensuring more efficient data collection and better utilization of resources. Evaluating the impact of specific observations on ocean forecasts signifies a major step forward in the field of oceanography and forecasting. This approach leads to more accurate and reliable predictions, better resource management, and an enriched understanding of the ocean dynamics.

## Collecting lessons learnt for a lasting impact

EuroSea has not just meticulously documented its successes and best practices, but also various lessons learnt. As an integrated ocean observing and forecasting project, EuroSea has enhanced the European capacity in understanding the drivers and interfaces prerequisite for its work. EuroSea lessons learnt are open access and available to anyone who is dealing with marine knowledge systems. These span the interfaces between science and policy, private and public ocean observing activities, and responsible research and innovation.

The EuroSea lessons learnt have also been documented on such critical areas as general public outreach in ocean science, the engagement of the next generation of stakeholders, or the visibility of ocean observing and forecasting through effective communication. EuroSea legacy resides not only in a more robust and responsive ocean observing and forecasting system, but also in the ripple effects of its holistic and well documented approach.



## Impact area 7:

EuroSea has contributed to policy making in research, innovation, and technology

EuroSea has played a proactive role in promoting ocean observing priorities to policymakers. A significant initiative was the collection of insights and lessons learnt documented in a report. Moreover, spearheaded by EuroSea, collaboration with nine other EU projects culminated in the production of a joint policy brief addressing the value chain of marine data for sustainable blue economy.

## Upscaling science-policy interface for ocean observing and forecasting

In promoting an integrated and fit-for-purpose ocean observing and forecasting system, EuroSea has been aiming to bridge the gap between research, observations, and policy decisions. Science-policy interface plays a critical role in translating scientific knowledge into actionable policies that can be practically implemented and successful. However, this interface is historically fraught with challenges, including communication gaps, misunderstandings of scientific complexity and uncertainty, varying priorities, and misapplications of research findings. EuroSea addressed these challenges, providing insights and best practices in the context of ocean observing and forecasting. A dedicated report on lessons learnt on science-policy interfaces provides actionable insights into how to improve this dialogue and ensure that scientific findings are appropriately translated into policy actions. EuroSea lessons learnt can be applied beyond European ocean observing projects, offering a blueprint for effective science-policy interfaces in other sectors or regions.



Speakers at the EuroSea workshop at the European Maritime Day 2022 co-organized jointly with several key European ocean observing and forecasting initiatives

## Boosting sustainability of observations for a sustainable blue economy

To ensure a sustained provision of ocean information for blue economy or policymaking, the observing system itself should be sustained. EuroSea showcased the importance of a full-value chain approach to ocean observing sustainability, from data acquisition to modelling and forecasting and tailored services for users.

A sustainable blue economy allows society to obtain value from the ocean and coastal regions whilst respecting and protecting the ocean's long-term capacity to regenerate. With the development of blue economy, scientific research also grows in scale, resulting in a higher demand for ocean observations. Furthermore, as the ocean is the main driver of climate and weather, improved forecasts based on adequate ocean data are becoming critical for the safety and prosperity of the population. Ocean observing cannot be ensured by individual nations alone due the intrinsic interconnected nature of the ocean environment. EuroSea has strengthened the European integration throughout the ocean knowledge value chain, boosting the sustainable blue economy opportunities.



Policy brief co-developed by EuroSea and nine other EU projects on the value chain of marine knowledge for sustainable blue economy



EuroSea consortium at the project's kick-off meeting, November 2019, Brussels, Belgium



EuroSea Symposium on Ocean Observing and Forecasting, September 2023, UNESCO, Paris, France

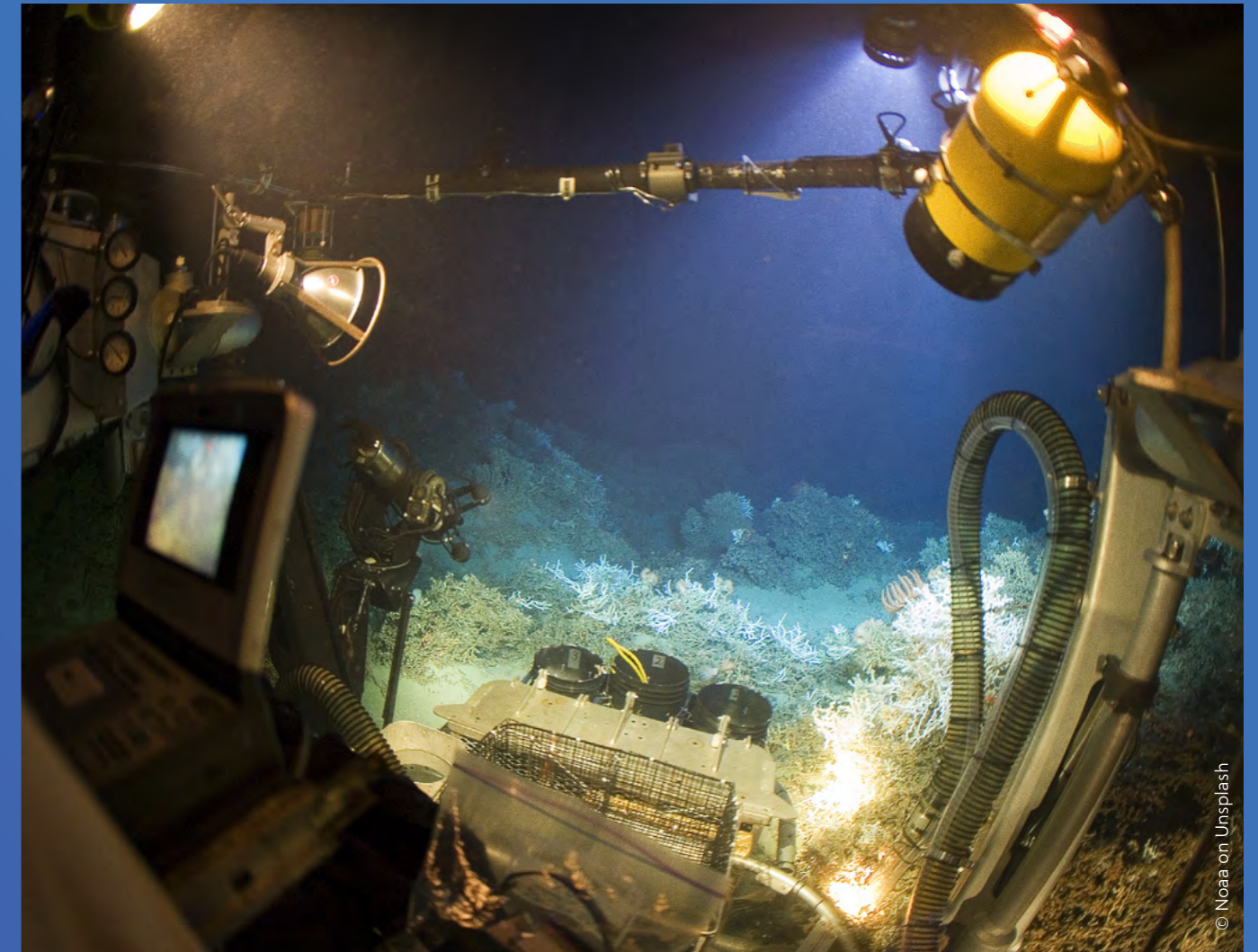
## Connecting the dots in Europe's fragmented ocean observing landscape

EuroSea analysed initiatives, strategies and roadmaps that contribute to foresight and priority-setting in ocean observing at international, pan-European, and sea basin scales. The ocean observing landscape is interconnected at all levels. Numerous organizations, initiatives, reports, and events, determine stakeholder needs linked to the climate change mitigation, provision of ecosystem services, or understanding of the ocean state and variability. EuroSea has demonstrated an imperative need to continue support for the coordination and partnerships in ocean observing and forecasting. Most ocean observations are funded at a national level and represent a vast array of activities not always aligned or optimized for the best value for money and a common European benefit. EuroSea has acted as a key forum to promote the alignment and coordination of an integrated European Ocean Observing System.

## Ocean observing dialogues for stronger international partnerships

EuroSea workshops, events, webinars, and the final symposium have been emphasising the importance of the European ocean observing and forecasting at the international level. EuroSea was visible from the UNFCCC's Conferences of the Parties (COP) or the UN expert meetings in New York City to meetings in Brussels, Paris or Cadiz, or through numerous on-line webinars and workshops.

Ocean observing can only be advanced by the means of nourishing dialogues and promoting partnerships. EuroSea has demonstrated to its European Union funders that ocean observing coordination gives tangible benefits and fosters innovation. But the European Union actions must be underpinned by a solid national coordination as ocean observations are implemented through multiple funding streams. Creating synergies in the national, regional, and European ocean observing activities is the only way to advance marine knowledge systems for the benefit of all users.



## Impact area 8:

EuroSea has increased awareness of the need for a fit for purpose and sustained ocean observing and forecasting system in Europe

EuroSea's efforts amplified awareness of the importance of a user-focused and sustainable ocean observing and forecasting system for Europe. Stakeholder webinars, itinerant exhibition, videos, outreach, and reports shed light on the EuroSea societal drivers and R&I solutions in a language and visuals accessible for all publics. Furthermore, the EuroSea Gender and Diversity Board raised the issue of critical gaps in equity and inclusion across the disciplines and activities in the ocean observing value chain.

## Integrative communication strategy for an end-to-end marine knowledge system

For an integrated ocean observing and forecasting system, EuroSea needed an integrative communication strategy, bridging the gap between scientific developments, stakeholder engagement, user uptake, and visibility to policymakers. EuroSea communications addressed the quadruple helix of targets in a comprehensive and inter-connected way. A challenge of the approach was the commitment to crafting content that speaks directly to the needs and interests of specific stakeholder groups, making the science more relevant and actionable for them.

Through visual storytelling, events, brochures, posts, and videos, EuroSea has created original and appealing communication and outreach both broadly accessible and specifically tailored when needed. Through a modern, inclusive, and data-driven approach, EuroSea is redefining how scientific initiatives communicate and collaborate with their stakeholders.

## Showcasing the role of ocean observing in our lives

The EuroSea itinerant exhibition has been touring Europe with showcases in dozen locations in Spain, Germany, Ireland, France, and Italy. In addition, it has also been released as a colourful brochure and disseminated both digitally and in print. The impact of this EuroSea tour of Europe has been documented and showed invaluable lessons learnt on how to communicate ocean observing to citizens.

What's more, early career researchers and students were inspired through their visits of the exhibition. Answering to their demand, we published visual information materials on the variety of job profiles in the EuroSea domains.

To share our experience with other marine science initiatives, we showed the EuroSea exhibition at the international marine science communication conference CommOCEAN as an example of science outreach.



EuroSea visual overview developed at the project's kick-off meeting, November 2019, Brussels, Belgium



Ripple effect © Spettacolopuro

## Co-creating EuroSea narratives with the consortium

EuroSea has been a real community-building project, developed through co-creation, exchange, and empowerment of its consortium experts. A combination of nationally-funded and private partners, early career and senior researchers, ocean observing managers and communicators, European and international initiatives – all that created a unique pool of creativity in EuroSea. The project's kick-off meeting aligned the consortium on common messaging and narratives of the project through visual recording and workshops.

The visual EuroSea storytelling was used throughout the four years of the project, getting enriched as the project's activities matured. This generated a genuine feeling of belonging to a wide and inclusive EuroSea community for everyone involved. In addition, a comprehensive EuroSea communications kit was made available for the partners and media, with brief and ready-to-use texts, images, and links to spread the word about EuroSea.

## From results to impacts – innovative impact monitoring protocol

EuroSea impact monitoring offers a holistic assessment of the project's endeavors in advancing and integrating European ocean observing and forecasting. Impact assessment is not performance evaluation. These terms overlap but are distinct: performance relates to the efficient use of resources; impact relates to the transformative effect on the users.

EuroSea created a first known impact monitoring protocol for a European ocean observing initiative. Established in the project's early stages, the impact monitoring protocol helped focus the EuroSea delivery on tangible user benefits. Clear demonstration of impacts is important to prove the return of investment by public resources into ocean observing and forecasting. Furthermore, impacts initially intended can generate valuable spill-offs, which can be harvested and capitalized on. Throughout the four years of EuroSea, the impact monitoring has become a collective activity distilled to the level of each task, deliverable, and event. The final assessment is presented on the website and in a comprehensive impact report.



EuroSea big messages, communication tool categories, and key stakeholder groups



EuroSea photo booth as part of the itinerant exhibition

# References

Balmaseda, Magdalena A. and McAdamn, Ronan (2021) Derive observable ocean climate indicators from seasonal forecast. Open Access. EuroSea Deliverable, D4.3. EuroSea, 21 pp. DOI 10.3289/eurosea\_d4.3.

Barcelo-Llull, Barbara, et al (2022) Analysis of the OSSEs with multi-platform in situ data and impact on fine-scale structures. Open Access. EuroSea Deliverable, D2.3. EuroSea, 93 pp. DOI 10.3289/eurosea\_d2.3.

Eparkhina, Dina (2022) Lessons Learnt on Science-Policy Interfaces. Open Access. EuroSea Deliverable, D8.3. EuroSea, 32 pp. DOI 10.3289/eurosea\_d8.3.

Eparkhina, Dina, Moreau, Kelle, Köstner, Nicole (2020) Communication Plan. Open Access. EuroSea Deliverable, D8.1. EuroSea, 11 pp. DOI 10.3289/eurosea\_d8.1.

Gomez, Begona Perez, et al. (2021) New Tide Gauge Data Flow Strategy. Open Access. EuroSea Deliverable, D3.3 . EuroSea, 25 pp. DOI 10.3289/eurosea\_d3.3.

Krieger, Magali and Turpin, Victor (2022) Gliders metadata. Open Access. EuroSea Deliverable, D3.10. EuroSea, 54 pp. DOI 10.3289/eurosea\_d3.10.

Lara-Lopez, A., Heslop, E & Lips, I. (2021) European GOOS National Focal Points Survey: Funding and Coordination across Ocean Observing and Marine monitoring in Europe. A European Ocean Observing System (EOOS) Report.

Larkin, K., Marsan, A-A., Tonné, N., Calewaert, J-B., (Eds.). 2019. EOOS Conference 2018 report and Call to Action. Connecting European ocean observing communities for end-to-end solutions. The Egg, Brussels, 21-23 November 2018. ISBN: 9789492043719

López-García, P. et al (2022) Ocean Gliders Oxygen Standard Operating Procedure, Version 1.0.0. OceanGliders, 55pp. DOI: 10.25607/OBP-1756.

Obaton, Dominique and Liétard, Cécile (2023) EuroSea Data Integration. Open Access. EuroSea Deliverable, D3.17. doi.org/10.3289/eurosea\_d3.17

Palacz, Artur (2022) Marine Plastics EOVI and common sampling protocol. Open Access. EuroSea Deliverable, D1.5 . EuroSea, 32 pp. DOI 10.3289/eurosea\_d1.5.

Piniella, Ángel Muñiz and Heymans, Sheila JJ (2021) Report on initiatives, strategies and roadmaps that contribute to foresight in ocean observation. Open Access. EuroSea Deliverable, 1.1. EuroSea, 40 pp.

Revelard, A. and Tintoré, J. (2023) EuroSea Strategic vision. Open Access. EuroSea Deliverable, D3.8 . EuroSea, 65 pp. DOI 10.3289/eurosea\_d3.8.

Rickels, Wilfried (2023) Economic benefit of regional ocean carbon uptake. Open Access. EuroSea Deliverable, 7.5. EuroSea, 70pp. DOI 10.3289/eurosea\_d7.5

Rubio, Anna, et al. (2021) European High Frequency Radar network governance. Open Access. EuroSea Deliverable, D3.4. EuroSea, 41 pp. DOI 10.3289/eurosea\_d3.4.

Tanhua Toste et al. (2021) Nourishing Blue Economy and Sharing Ocean Knowledge. Horizon Results Booster. Policy Brief.

Testor, Pierre et al (2022) Estimate of magnitude and drivers of regional carbon variability for both regions. Open Access. EuroSea Deliverable, D7.3. EuroSea, 37 pp. DOI 10.3289/eurosea\_d7.3

Turpin, Victor (2022) Maps and metrics on observing systems and metadata. Open Access. EuroSea Deliverable, D1.6. EuroSea, 50 pp. DOI 10.3289/eurosea\_d1.6.

Van Doorn, Rijk and Veloso, Paula Fernandes (2023) Report on the use of legal frameworks for ocean observing systems. Open Access. EuroSea Deliverable, D1.7 . EuroSea, 23 pp. DOI 10.3289/eurosea\_d1.7

**This report references only a small fraction of the EuroSea outputs – discover all project's deliverables and publications on our website: [eurosea.eu](https://eurosea.eu)**





EuroSea workshop at the project's kick-off meeting, November 2019, Brussels, Belgium



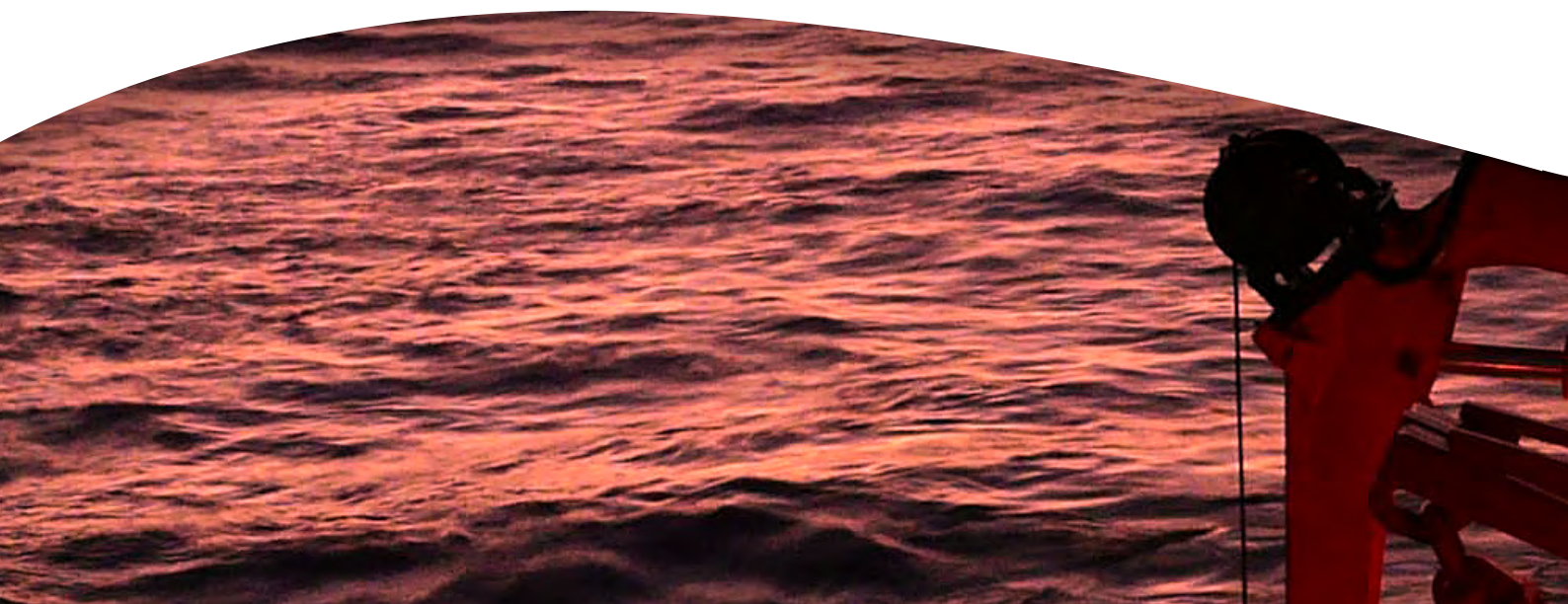
Discover the pivotal work reshaping Europe's ocean landscape in a global context.

Dive into the **EUROSEA LEGACY REPORT**, an illuminating exploration of the imperative need for enhanced ocean observing and forecasting systems.

Visit our website [www.eurosea.eu](http://www.eurosea.eu)

Follow @Euro\_Sea on X

Discover our YouTube channel



## Conclusion

Strategic EuroSea vision goes beyond the current state of the art in ocean observing and forecasting, promoting a comprehensive and integrated approach. EuroSea has been a paramount stepping stone for more effective, efficient, and impactful ocean observing and forecasting in Europe and worldwide.

The EuroSea legacy resides in advancing the European ocean observing and forecasting system throughout the marine knowledge value chain. This spans enhancing the acquisition of European Findable, Accessible, Interoperable, and Reusable (FAIR) ocean data, identifying and fulfilling the in situ data requirements to improve the modelling and forecasting outputs, and aggregating these capabilities in user-focused oceanographic services. This has been achieved through the work of over 160 EuroSea experts, representatives of 53 organizations from 16 countries. In addition, EuroSea dedicated a special attention to the governance of the ocean observing and forecasting system. New coordination mechanisms have been set up through the European Ocean Observing System framework, while recommendations were made on the legal aspects of ocean observing. Moreover, the EuroSea achievements and findings have been documented in open source publications, best practices, reports, and project's deliverables on lessons learnt.

The advancement of the European ocean observing and forecasting system can be achieved through a combination of stronger cooperation between different elements of the value chain, technological developments, and increased ocean observing activities. The EuroSea approach towards the integration of these elements, fostering collaborative planning and priority-setting, and considering the expected impacts throughout the process, has offered a unique holistic overview of the European ocean observing and forecasting system and its opportunities beyond the state of the art.