Marine Biodiversity

Earth observation value chain case study

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EU4OceanObs

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Description

The ocean and seas are home to a wealth of life. To this day, at least 240,000 **marine species** have been identified, and a large number is thought to still remain unknown. Some of the most diverse ecosystems with key functioning roles are in the ocean. Tropical coral reefs provide shelter and breeding grounds to **at least 25%** of all known marine life, and are an important source of food and chemical compounds for medicine. Seagrass meadows, mangroves and salt marshes, also known as blue carbon habitats, absorb large quantities of carbon dioxide, having a pivotal role in slowing down climate change impacts. Along with coral reefs, they work as natural barriers against wave energy and extreme weather events, providing coastal resilience services.

But despite its value, marine life is under severe anthropogenic pressure. Habitat destruction, pollution and overexploitation are harming marine biodiversity with impacts on the whole planet and human livelihoods. Moreover, human-generated greenhouse gas emissions are driving global warming, and around 90% of this heat is absorbed by the ocean. Ocean warming, deoxygenation and acidification have spread from the surface of the ocean to the abyss changing environmental conditions for marine species.

This use case highlights the critical role of Earth observation in monitoring marine biodiversity, in forecasting weather events and climate variations, and predicting human activity impacts on marine ecosystems, while fostering services and solutions towards conservation efforts. It also demonstrates the European Union's commitment towards marine life preservation through the available data and information services, funding programmes for research and innovation and in the establishment of marine environmental policies.

What is marine biodiversity and why is it important?

Marine biodiversity, the variety of life in the ocean, is essential for **ecosystems** to thrive. Considered at three levels - **ecosystem**, or the diversity of species, their interactions and their environment, the diversity of **species** in an ecosystem and the **genetic** diversity within the same species - biological diversity is synonym of adaptation and resilience in face of environmental disturbances. Diverse marine ecosystems can provide human societies with food, medicine, recreation, and support livelihoods through tourism and other important economic activities. For the millions of people living by the coast and relying on the ocean for food, economic security and well-being, biodiversity loss has far-reaching and severe negative consequences

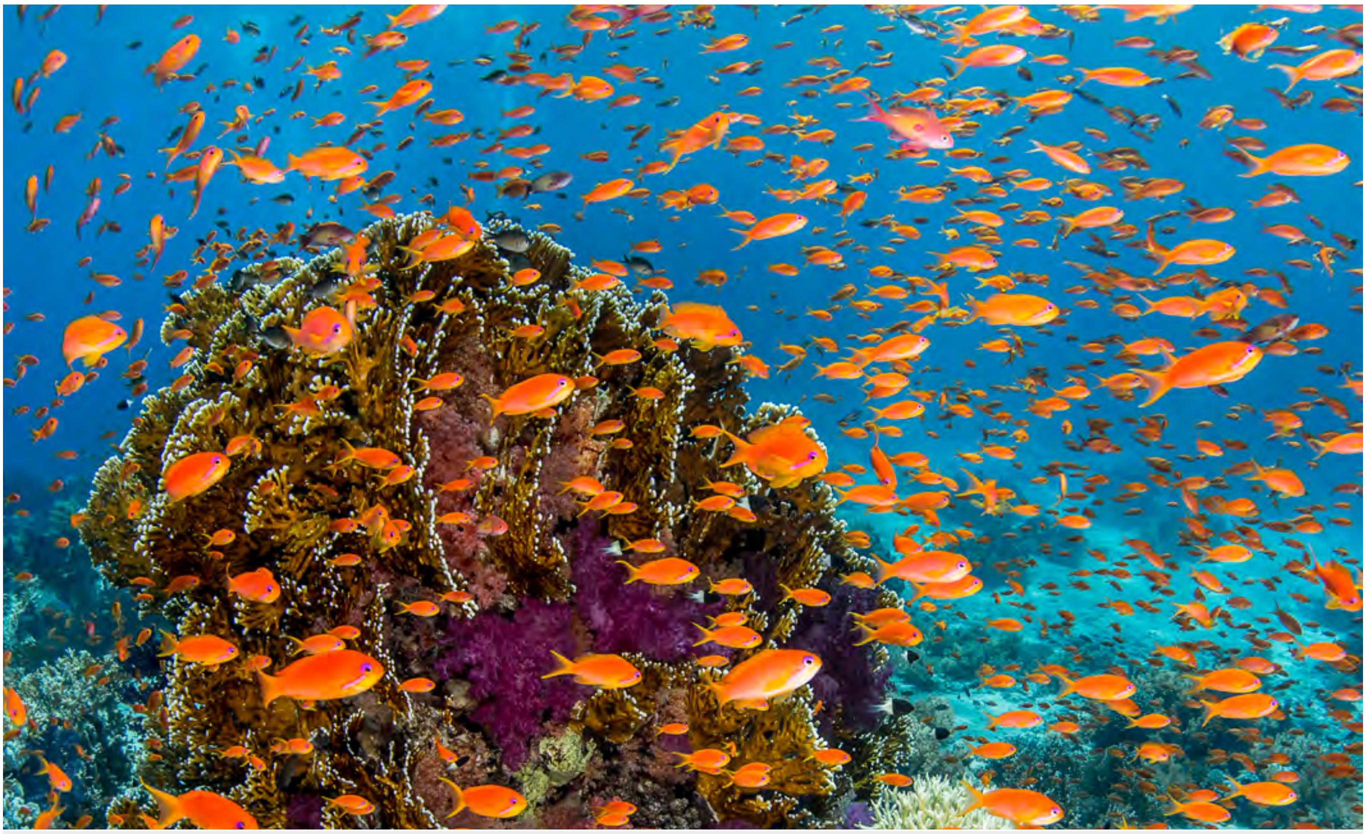
Below are some of the vital ecosystem functions marine species provide

- the recycling of nutrients by decomposing organic matter
- contributing to the regulation of climate and atmospheric gases
- serving as food to other organisms
- acting as buffers against wave energy

Ocean acidity has increased by ***40%*** *since pre-industrial times.*

Almost all coral reefs ***will degrade*** *from their current state, even if global warming remains below 2°C.*

Marine heatwaves, local prolonged periods of abnormally-warm ocean temperatures harmful to marine organisms, are becoming ***more frequent and more intense****.*



Credit : renata romeo

Why do we need Earth observation and derived information and services to protect and restore marine biodiversity?

Monitoring marine biodiversity helps to understand the ecological state of marine and coastal ecosystems and the overall state of the ocean. In other words, how are the ecosystems being disturbed, how are environmental and anthropogenic pressures impacting organisms and how may these react to future scenarios.

Species composition, distribution and richness provide direct information on the state of the species and populations of an ecosystem. Through the measurement of the physical, chemical and biological parameters of the ocean, Earth observation provides a global view of the living conditions of marine organisms and the biogeochemical processes happening in the ocean. Monitoring indicators such as chlorophyll-a concentration - a pigment present in **phytoplankton** – provides information on the abundance of marine primary producers, the base of the marine food chain. Other indicators such as ocean heat and carbon uptake, inform on the long-term physical and chemical environmental changes and are essential to understand climate change impacts on marine life.

'Ocean observations are not only an essential step for studying the ocean and its biodiversity, but also for developing effective strategies to protect and preserve marine ecosystems.'

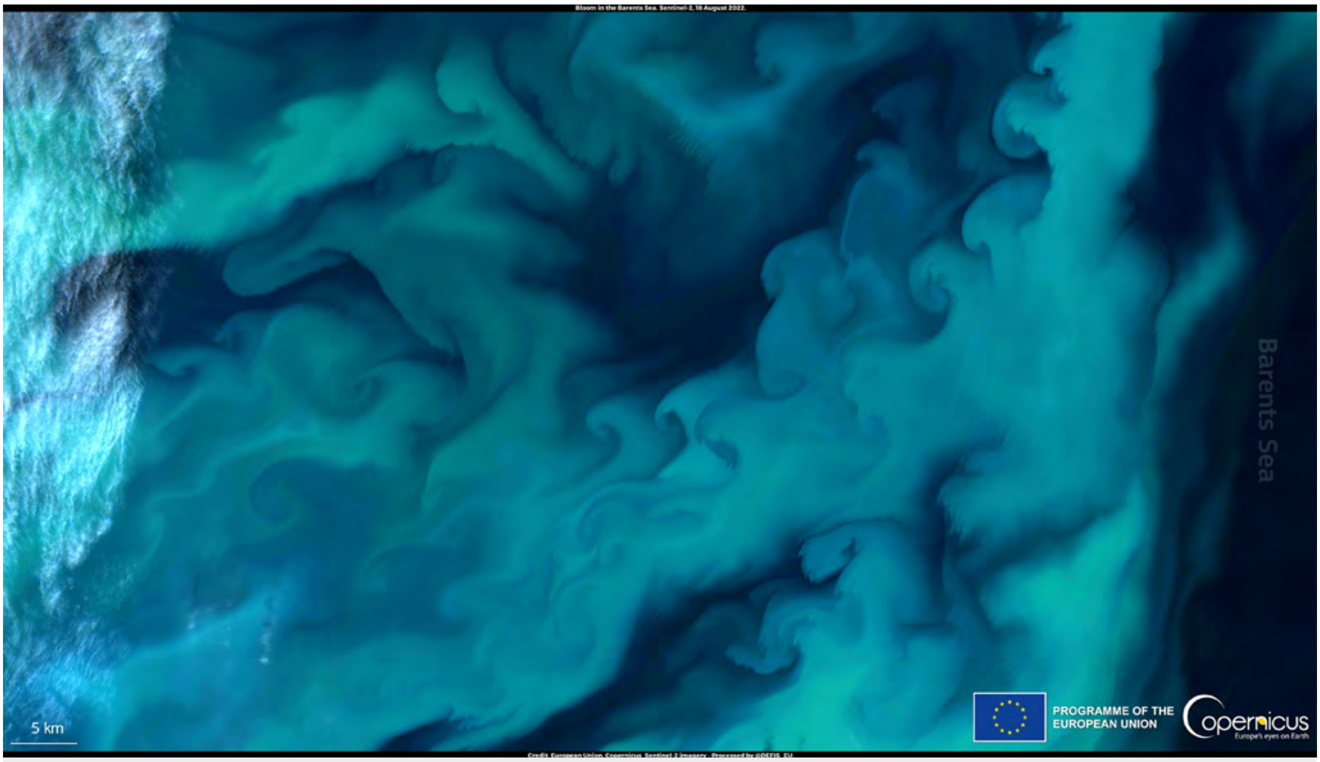


Figure 1: *Algal bloom in the Barents Sea reached an extent of more than 500,000 km², one of the largest in recent years. 18 August 2022. Credit: European Union, Copernicus Sentinel-2 imagery.*

Human actions are impacting marine and coastal ecosystems. Below are a few impacts of the loss of marine biodiversity on the environment and for society.

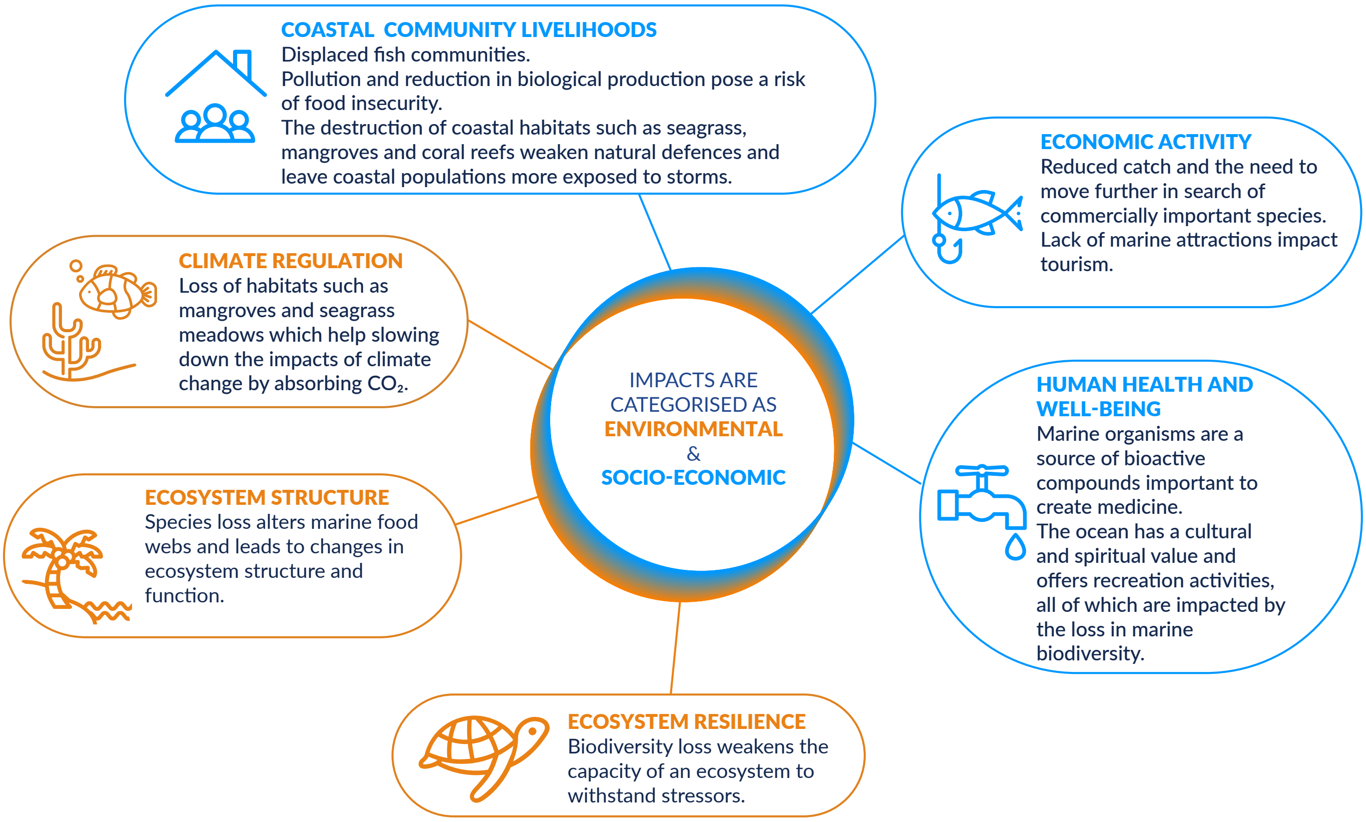


Figure 2: *Environmental and socio-economic impacts of the loss in marine biodiversity*

The ocean observing value chain supporting marine biodiversity

Earth observations are needed to accurately monitor, estimate marine biodiversity and assess how pressures impact the marine environment. In-situ measurements collect “on-site” data at a specific moment in time, providing direct information on species and their environment. In addition, in situ data are used to ground truth remote sensing observations and evaluate the accuracy of mathematical representations (numerical models) of the marine and coastal environment used in early warning systems and predictive modelling.

In-situ observation

Although labour-intensive, classic **in-situ observations** of marine life can be collected widely, from the surface to mid-ocean layers, all the way to the seafloor. These include among others, species observation, water and species sample collection, photo and video survey for species identification. With the development of autonomous techniques we are now able to reach deeper and more inhospitable locations of the ocean without depending on human effort.

A wide range of autonomous sensors such as drifting buoys, profiling floats and gliders, collect data on the sea water physical state, and other parameters which reflect the chemical and biological status of the ocean down to 4000 metres below the surface. Tags attached to marine animals provide data on physical variables and on the behaviour of the targeted animal. The international float program **Argo** has developed a **biogeochemical mission**, focused on collecting data on pH, oxygen, chlorophyll-a and suspended particles, using an autonomous fleet of instruments providing insight on biological productivity, ocean acidification, and ocean uptake of carbon dioxide at ocean layers beyond the surface.

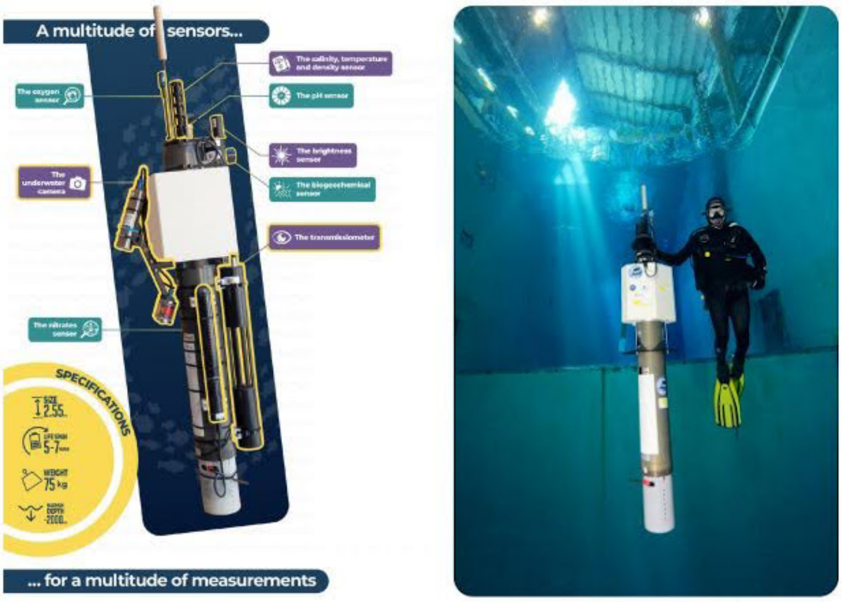


Figure 3: *A biogeochemical float with its 6 additional sensors (left). Argo biogeochemical float at the Ifremer facility (right). Source: Euro-Argo. Graphic credit: ERC REFINE. Photo credit: Olivier Dugornay.*

Satellite observations

Visible spectral radiometric measurements from space, otherwise referred to as ocean colour measurements, provide information on biological production and biogeochemical processes. Ocean colour is considered one of the **Essential Ocean Variables**, as it enables the monitoring of the state of the ocean and climate.

Optical radiometric sensors capture sunlight reflected from the surface of the Earth. In this way, when passing above the ocean, satellites detect chlorophyll-a, a pigment present in phytoplankton, which reflects a visible green-colour spectrum. Ocean colour is, at the moment, the only variable providing information on marine ecosystems through satellite imagery. This is an incredibly useful variable leading to information on biogeochemical cycles, phytoplankton community composition and distribution, micro and macroalgae location and dispersion, sediment transport, phytoplankton blooms and providing a good view of marine ecosystems and its processes at wide time and spatial scales.

Modelling and prediction

The modelling of biological and ecosystem processes, species distribution, primary production (phytoplankton) and food chain indicators, is an attempt to describe marine life, their environment and their complex interactions. Although very difficult - because marine organisms are complex - with still unknown interactions and living in a vast ocean, these models can be used to understand habitat suitability for species, to predict the impacts of future climate change on species' distributions, in evaluating the invasive potential of non-native species, and in conservation planning.

By knowing the changes happening in the physical and chemical state of the ocean, and ecological information, possible impacts on marine ecosystems can be predicted, thus anticipated thanks to monitoring systems.

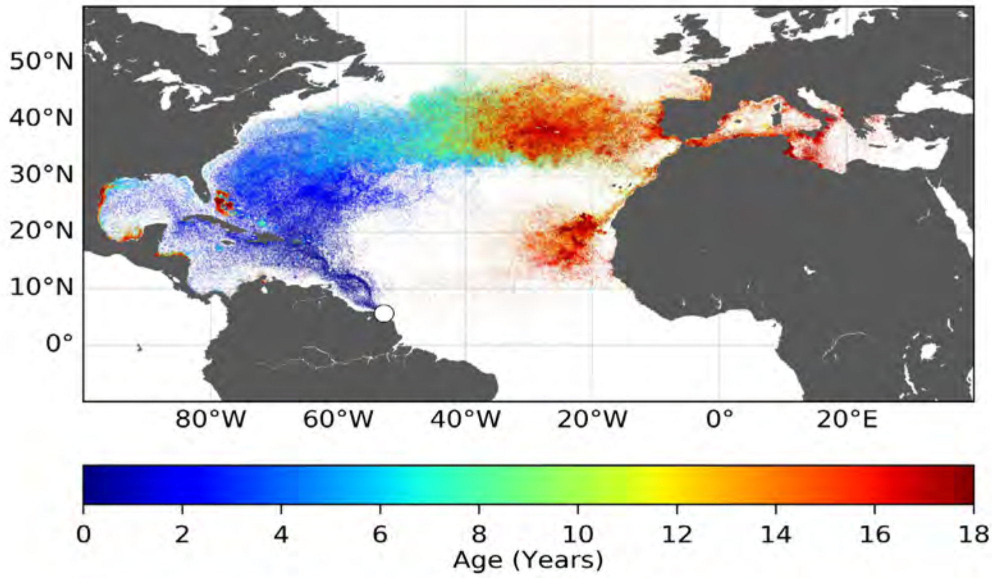


Figure 4: *Map of hatchling and juvenile leatherback turtles (Dermochelys coriacea) dispersion pattern over 18 years.* Credit: Tony Candela (Upwell, Mercator Ocean International)

Data and information

Observations,modelling and forecasting are essential steps to produce insights and analytics needed to support marine biodiversity protection and restoration measures. European services providing data and information on marine ecosystems include datasets of species presence and distribution, nutrient concentrations, trends of phytoplankton activity, chemical composition, fish stocks, among others. These products are used to support marine spatial planning, the delimitation of marine protected areas to enhance marine habitat conservation and in the creation of early warning systems for harmful algal blooms (overdevelopment of phytoplankton leading to the production of toxins) , **sargassum** strandings and the presence of contaminants in the different seas and basins - water quality monitoring. Ultimately, these are important services which help reduce the impact of hazards on marine ecosystems and on socioeconomic activities, recreation and well-being.

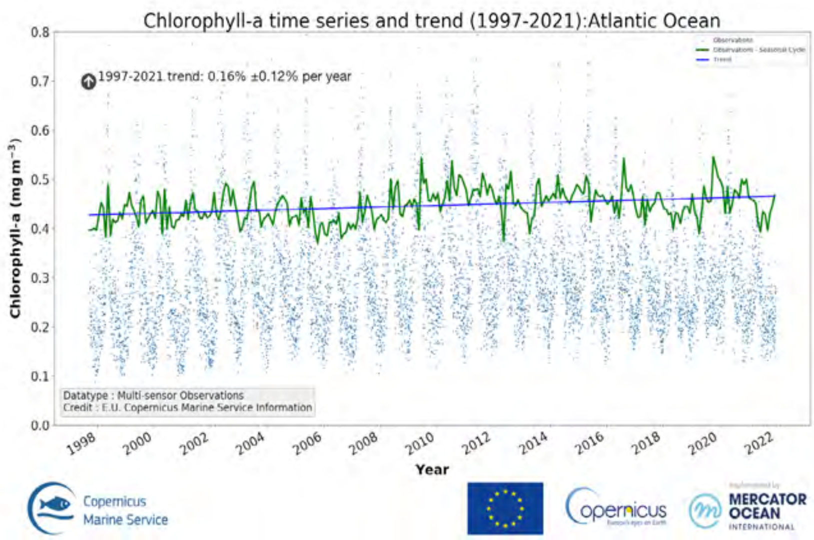


Figure 5: *Time series used as an indicator for primary production (phytoplankton) in the Atlantic Ocean for the last two decades. The graph shows a slight positive trend in chlorophyll-a presence.* Source: Copernicus Marine Service. © Mercator Ocean International

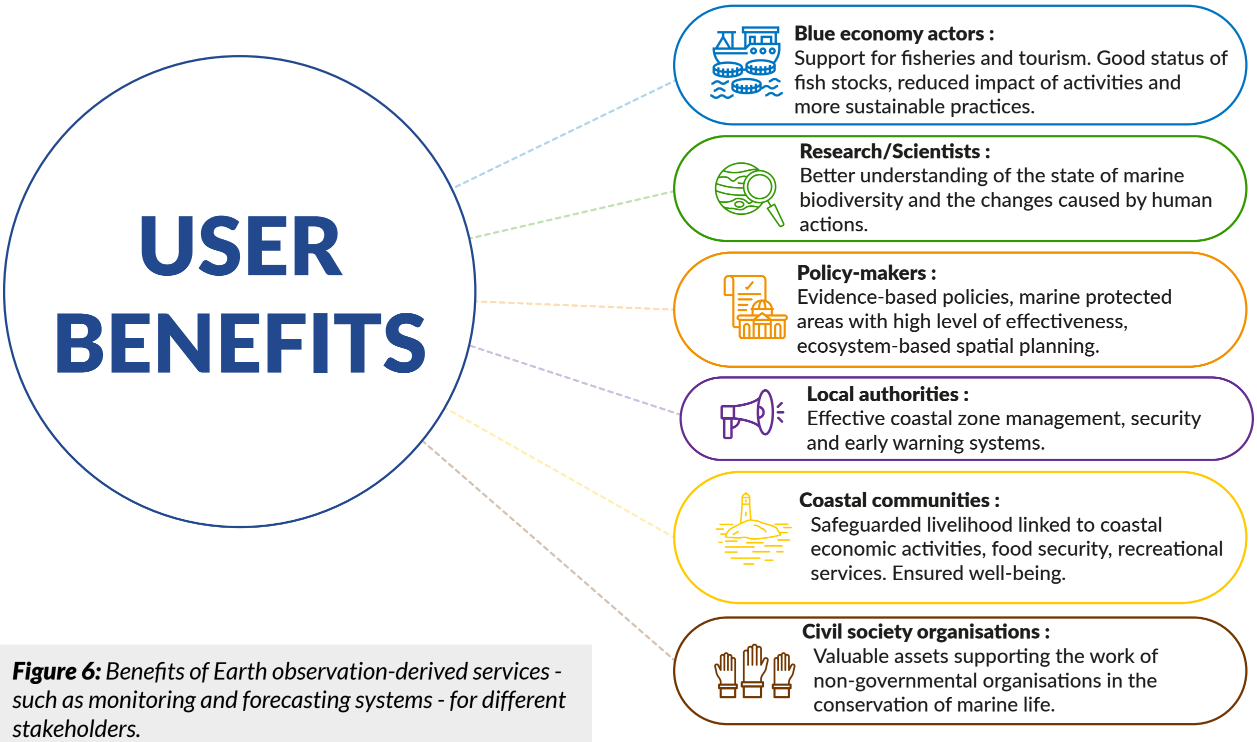


Figure 6: *Benefits of Earth observation-derived services - such as monitoring and forecasting systems - for different stakeholders.*

EU efforts supporting marine biodiversity

European and international policy and directives

The European Union (EU) is committed to reach sustainability goals and protect biodiversity on land and at sea. Different guidelines have been developed to ensure marine biodiversity protection, both led by the EU or set under the United Nations context.

EU

- **Biodiversity strategy for 2030** : Outlines the EU's European Union's commitment to protect nature and reverse degradation. Within the main actions is the intention to increase the EU-network of protected areas both on land and at sea.
- **Marine Strategy Framework Directive** : Focuses on the protection of marine ecosystems and biodiversity by helping EU countries achieve good environmental status through compliance of eleven qualitative descriptors.
- **Nature Restauration Law** : Calls for member states to restore at least 30% of habitats from poor to good condition. Covered habitats include forests, grasslands, wetlands, rivers, lakes and coral beds.
- **Birds Directive and Habitats Directive** : Aim to protect wild bird species, habitats and all its species, so that these obtain favourable ecological status and are allowed to recover degradation.
- **Common Fisheries Policy** : Revised in 2023, this law focuses on protecting sustainable fishing practices, techniques, yields, targeted fish species as well as aquaculture practices, closely following scientific advice.
- **Integrated Maritime Policy** : Provides an harmonised approach to maritime issues by strengthening the link between different policy areas of blue growth, marine data and knowledge, maritime spatial planning, integrated maritime surveillance and sea basin strategies.
- **Water Framework Directive** : Requires the protection of water bodies in order to achieve good status for Europe's rivers, lakes and groundwater.

International

- **United Nations Covention on Biological Diversity** : Global strategy signed by 150 countries at the Rio Earth Summit in 1992 setting on three main goals - the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from the use of genetic resources.
- **Convention on Migratory Species** : Under the United Nations Environment Programme, the convention provides guidance for the conservation and sustainable use of migratory wild animals and their habitats.
- **High Seas Treaty - Biodiversity Beyond National Jurisdiction** : International commitment to increase protection of marine diversity by establishing a large-scale of marine protected areas in the high seas, enforces strict protocols for impact assessments before consenting exploitation activities and it establishes the sharing of marine genetic resources, capacity building and technology transfer between the parties.

EU-supported data infrastructures and services

European data infrastructures provide data and information on habitats and species ecological status, the management of marine protected areas and support policy implementation.

Copernicus Marine Service (marine.copernicus.eu)
The marine service of the EU's Copernicus programme provides access to data on the physical and biogeochemical features of the ocean, essential ocean variables and monitoring indicators such as the ocean heat content, sea surface temperature, carbon uptake and phytoplankton production. Recently a new feature allowing the visualisation of marine protected areas in the world has been added to the data visualisation tool MyOcean Pro, which facilitates the visualisation of the status and the extension of marine protected areas.

European Marine Observation and Data Network (EMODnet)
is the European Commission's in-situ marine data service providing information on bathymetry, geology, physics, chemistry, biology, seabed habitats and human activities. EMODnet Biology provides open and free access to interoperable data and data products on temporal and spatial distribution of marine species (angiosperms, benthos, birds, fish, macroalgae, mammals, phytoplankton, reptiles, zooplankton) and species traits from European regional seas

Marine Information System for Europe (WISE-Marine)
Provides data and information on the state of Europe's seas, on the pressures affecting them, and on the measures being taken to preserve the marine environment in Europe and regarding the different regional sea's conventions.

European Ocean Biodiversity Information Systems (EurOBIS)
A biogeographic database with data on all marine organisms. Operated by the Flanders Marine Institute (VLIZ), and developed in 2004, EurOBIS includes data collected by all European institutes and researchers in European waters and beyond.

European Marine Biological Resource Centre (EMBRC)
Enables access to services, facilities, and technology platforms in more than 70 marine stations in 9 European countries, in support of robust, cost-effective and efficient marine research. The centre is also responsible for the European Marine Omics Biodiversity Observation Network (EMO BON) aiming at filling in the gaps in marine biodiversity observation while sharing the data and knowledge acquired.

International Council for the Exploration of the Sea (ICES)
Is an intergovernmental marine science organisation, working to develop impartial evidence on the state and sustainable use of the ocean and seas. Composed by a large community of scientists, marine institutes and member countries, the council receives data from different centres and shares scientific understanding of marine ecosystems and the services they provide. The aim is to use this knowledge for conservation, management, and sustainability goals advisory. It provides access to data such as biological communities, fisheries and lists of vulnerable ecosystems of the Atlantic and North Pacific Ocean, and on the Arctic, Black and Mediterranean seas.

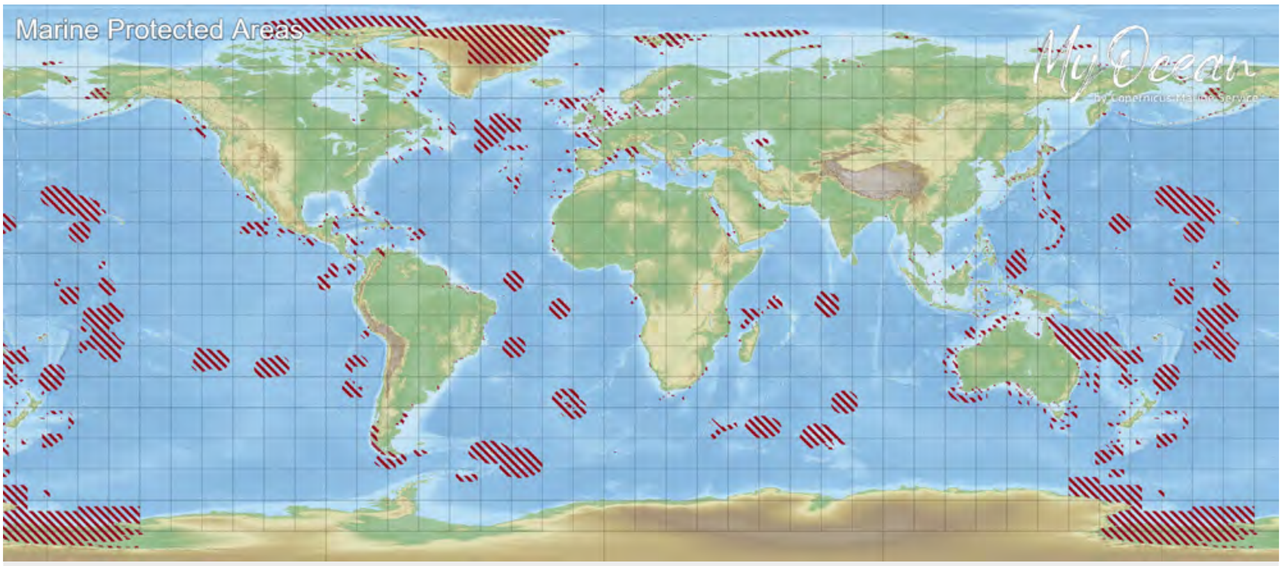


Figure 7: *World's Marine Protected areas. Only 1% of the high seas (areas beyond national jurisdiction and which account for around 60% of the ocean) is protected. Data source: The World Database on Protected Areas (WDPA) and World Database on Other Effective Area-based Conservation Measures (WD-OECM). Visualisation*
Source: MyOcean viewer - Copernicus Marine Service. © Mercator Ocean International. 2024.

Research and innovation projects

The following list presents some of the projects being funded under the EU Horizon 2020 and Horizon Europe programmes

Marine Protected Areas Europe (MPA Europe) :
A project mapping the optimal locations for marine protected areas, species richness and potential locations of important marine resources for human consumption (e.g.fish,algae).

Marine Systems Approaches for Biodiversity Resilience and Ecosystem Sustainability (MARINE SABRES)
This project is creating a simpler and easier-to-use model of the interactions between human activities and ecosystems (socio-ecological systems) to better inform ecosystem-based management decisions.

New Copernicus capability for trophic ocean networks (NECCTON)
Focuses on creating new and more accurate models simulating the marine ecosystem, and its organisms, from the top predator of food chains to the organisms living on the seafloor. Developments will be integrated in the Copernicus Marine Service data centre to be delivered widely and freely.

MARine COastal BiOdiversity Long-term Observations (MARCO BOLO) :
This initiative aims to connect existing observation programmes, to optimise and improve methods, and further develop technologies to improve European marine, coastal and freshwater biodiversity observation capabilities, linking them to global efforts to understand and restore marine ecosystems.

Observing and Mapping Marine Ecosystems - Next Generation Tools (OBAMA NEXT) :
The main objective of this project is to develop a user-friendly toolbox which delivers full descriptions of marine organisms, their state, their ecosystem and services to support evidence-based marine ecosystem management.

BioEcoOcean (**LINK**):
A project aiming to create and test a Blueprint for Integrated Ocean Science for the global ocean. This will become a tool to guide ocean observing programmes from the early planning stages, to data collection, to integrating results into policy and decision making.

Climate Change and Future Marine Ecosystem Services and Biodiversity (FutureMARES) :
Research project studying the relations between climate change, marine biodiversity and ecosystem services to be able to provide science based policy advice on how best restore and preserve marine ecosystems and create sustainable nature-inclusive harvesting activities for seafood, fisheries and aquaculture.

European Digital Twin Ocean (EU DTO) :
Aims to provide a consistent high-resolution, multi-dimensional descriptions of the ocean, including its physical, chemical and biological dimensions. A key project under this initiative - EDITO-Model Lab will deliver three inter-compatible workflows that allow to map biodiversity indicators in Marine Protected Areas (MPAs) for the Wadden and Northern Adriatic Seas.

Europa Biodiversity Observation Network: integrating data streams to support policy (EUROPA BON)
This project aims to identify user and policy needs, data gaps, and data and workflow blockages in order to improve biodiversity monitoring schemes.

Large scale RESToration of COASTal ecosystems through rivers to sea connectivity (REST-COAST)
Focusses on improving coastal restoration interventions through new technical, financial, management and transfer tools, responding to the needs of coastal vulnerable regions and society.

Copernicus Evolution - Research for harmonised and Transitional water Observation (CERTO)
Completed in 2023 the project worked on providing a "harmonised capability to monitor water quality from lakes, through deltas, coastal waters and to the open ocean".

Marine Biodiversity Assessment and Prediction Across Spatial, Temporal and Human Scales (BIOcean5D)
This four-year project seeks to explore marine life through five dimensions: 3-dimensional space, time and human impact. The project will focus on collecting data from coastlines and land-sea interfaces in Europe.

D4Science - Blue Cloud (LINK) :
A zooplankton and phytoplankton virtual lab with the objective to provide a methodology to generate products and models based on observations.

Integration of the Biodiversity Monitoring Data into the Digital Twin Ocean (DTO BIO flow) :
Aims to improve biodiversity data availability by integrating EMODnet datasets into the European Digital Twin Ocean, and creating a digital replica of marine biological processes, transforming new and existing data flows into evidence-based knowledge.

Advancing area-based management tools to accelerate the protection and restoration of marine biodiversity across the European sea basins (BioProtect) :
Under the Atlantic-Arctic Lighthouse, BioProtect aims to co-develop and demonstrate adaptable ecosystem-based solutions to accelerate the effective protection and restoration of biodiversity in marine and coastal ecosystems. The project will develop innovative, replicable and scalable ecosystem-based solutions that will accelerate the protection and restoration of biodiversity in European seas.

Marine biodiversity monitoring networks and partnerhips

The following list presents some of the international coordination networks and monitoring parternships supported by the EU:

All-Atlantic Ocean Research and Innovation Alliance (AAORIA) :
is the result of science diplomacy efforts involving countries from both sides of the Atlantic Ocean, including the EU. One of its action areas is to coordinate Atlantic Ocean observing and improving modeling capacities, including in support of marine ecosystems and biodiversity.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)
is an independent intergovernmental body established by States to strengthen the science-policy interface for biodiversity and ecosystem services for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development.

Group on Earth Observations (GEO BON)
is a global network of researchers dedicated to improving the acquisition, coordination, and delivery of biodiversity information at the global, regional, and national levels. Its marine thematic node - MBON - the Marine Biodiversity Observation Network - fosters and coordinates a global community of practice for collecting, curating, analyzing, good management, and communicating marine biodiversity data and related services to the scientific community, policymakers, the public, and other stakeholders.

The State of Marine Biodiversity Monitoring in Europe

'The State of Marine Biodiversity Monitoring in Europe' workshop took place online in June 2024, as part of the marine biodiversity monitoring harmonisation study, launched by the European Commission, co-implemented by the study team and the European Commission's Joint Research Centre (JRC), and managed by the European Climate, Infrastructure and Environment Executive Agency (CINEA). This collaborative study between the study team, the JRC, and relevant stakeholders, aims to analyse the state of marine biodiversity monitoring and to recommend ways forward towards a better future set-up, acknowledging existing initiatives and stakeholder needs. The study, concluding in December 2024, is part of a wider activity led by the European Commission to improve marine biodiversity monitoring across European marine waters.

For more information and the workshop recommendations report, **click here**.

Earth observation value chain supporting marine biodiversity

EARTH OBSERVATION

IN-SITU OBSERVATIONS

Biological and environmental data collection:
phytoplankton groups, genetics, species and fisheries surveys, physical parameters (temperature, salinity, depth, currents)

IMPROVE CALIBRATION

SATELLITE OBSERVATIONS

EU Copernicus Sentinel 2 and 3
(Ocean and Land Colour Instrument)

International satellites:
Pleiades, World view, Landsat-8, SPOT

IMPROVE VALIDATION & ACCURACY OF MODELS

DATA

Primary production
Chlorophyll-a concentration
Ocean carbon uptake
Species presence

Data assimilation
+
Physical and biological relationships

ANALYSIS & METHODS

MODEL

- Ecosystem models
- Biogeochemical models
- Fishery models

TIME SERIES

State of phytoplankton
Seasonal changes,
Species distribution, etc.

INFORMATION

Species ecological status
Plankton community composition
Species distribution
Fish stocks information

Presence of invasive species
Nutrient concentration
Species richness
Primary production (phytoplankton)
Carbon cycle

PRODUCTS & SERVICES

Ecosystem status
Marine Protected Areas (MPAs) needs
Water quality bulletins
Algal bloom and sargassum strandings forecasts
Fisheries stock assessment

END USER BENEFITS

Targets

- Decision-making
- Research
- Public authorities
- Blue economy
- Fisheries

Decision points

- Delimitation of protected areas
- Impact assessment
- Sustainable marine resource management
- Water treatment
- Aquaculture farm regulation
- Monitoring species distribution for hazard prediction
- Ecosystem based marine spatial planning - fact-based marine spatial planning

Benefits

- Effective marine protected areas
- Abundance of fish stocks
- Limited human impact
- Good water quality
- Good ecosystem status
- Sustainable marine resource management

Figure 8: *The Earth observation value chain supporting marine biodiversity, its conservation and restoration.*

Gaps & limitations in marine biodiversity observations and monitoring services

- In-situ biological sampling is costly and provides a very local perspective.
- Satellite imagery is limited to the surface of the ocean.
- Limited optical capacity of satellites and difficulty in capturing images in the presence of clouds, or other sources of “noise”.
- Data gaps still exist in areas where satellites haven’t been able to collect images or where scientists haven’t been - the deep sea is one example.
- Good interaction between physics and biogeochemical models is still a challenge (data assimilation).
- Lack of knowledge in the way certain climate processes impact organisms.

Recommendations

Better (and more) observational datasets :
Better and more observations, specially from locations where there are no observations, help calibrate and constrain climate and ecosystem models, improving predictive capacity.

Ecosystem approach to climate change impacts and biodiversity conservation :
Impacts happening in one corner of the world can have repercussions far away. We know today that land, marine and atmospheric systems are interconnected. Therefore, impacts happening in one system will most likely impact the whole ecosystem.The way we look at solutions, and how we create regulations (for climate, ocean or land environments) should include this systemic approach.

User-friendly datasets and information :
Ensuring the full understanding of the ecosystem, species or population status by the different communities (policy-makers, local authorities, regulators, coastal communities) is important to ensure suitable solutions are found for each problem society is faced with. The development of more visual tools and infographics can help breach the gap between the knowledge and the action.

Strong observational and data standardisation network :
Currently, data is collected everywhere and it is widely accessible. Something possible only in the last few decades - thanks to the development of new and effective technologies and the creation of services providing free and open data. However, there is a higher need for collaboration between legislative parties, data collection entities and environmental research centres, in order to ensure accuracy levels, homogeneity in information or avoid information overlap and resource waste.

Better approach of end users needs :
Understanding decision-makers and local environmental authorities data and information needs can help refine products and services and improve usability.

More active interaction between scientists and environmental agencies and policy-makers :
Modelling and forecasting marine species and their ecosystems is complex. The inclusion of end users in the process can help non-scientists better understand the limitations and the level of certainty for predictions and lead to more effective risk management.

Inclusion of seasonal climate projections :
To better understand the current climate changes and the way these may impact marine life and ecosystems, and to include current projections in management decisions, different scenarios should be analysed according to, for example, marine heatwaves, sea level projections or ice melting seasons.

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