Sustainable Fisheries

Earth Observation value chain case study

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Today, aquatic food accounts for approximately 17% of the global consumption of animal proteins, and this proportion can exceed 50% in some African, Asian, and Pacific Islands countries. However, climate change and impacts from human activities such as pollution, habitat degradation and reductions in fish stocks, threaten marine resources and biodiversity. These impacts, together with pressure from a growing human population are increasingly threatening food security and the livelihoods of those who depend on fisheries. If managed sustainably, the fisheries and aquaculture sector can be a driving force for the Blue Economy. By adequately addressing rising socio-economic demands, supporting local livelihoods, and ensuring food security, all while responsibly safeguarding marine life, the sector has the capacity to be a key player in fostering a sustainable and responsible relationship between human activities and the marine environment.

Effective monitoring of marine ecosystems and fishing activities is paramount for sustainable fisheries management. This case study underscores the critical role of Earth observation to understand, monitor and predict the status of fish stocks, rates of fish exploitation, and environmental conditions. Such insights are indispensable for cultivating sustainable fishing practices in the face of growing challenges.

Description & impacts

Fishing and aquaculture have long played an essential role in providing food security and nutrition. Industrialisation and technological developments, particularly since the 1950s, have enabled marine production to grow substantially. According to the Food and Agriculture Organization (FAO), production increased from an estimated 19 million tonnes in 1950 to 178 million tonnes in 2020. While fisheries production has stagnated since the 1980s, aquaculture has been responsible for much of the growth in the recent decades. In 2019, the European Union (EU) was the fifth largest producer of fisheries and aquaculture in the world. The EU fleets, which operate worldwide, account for just over 5% of the global fishery production and just over 1% of the global aquaculture production. However, in terms of value, the EU is the leading trader and largest importer of fisheries and aquaculture products.

Globally, the growth of fishing and aquaculture has been accompanied by damaging practices that prioritise short-term increases in catch while neglecting future growth and causing harmful impacts on marine ecosystems and marine life. These practices include illegal, unreported, and unregulated (IUU) fishing, overfishing, poisons and explosives (e.g., cyanide fishing), loss of fishing gears (ghost fishing), benthic trawling (towing a net along the ocean floor), among others. Resulting in a multitude of intertwined challenges, including impacts on health and distribution of fished species, the viability of offshore aquaculture sites, competition among recreational, artisanal, and industrial fisheries and reduced profitability of overfished fish stocks, the need for sustainable management practices has never been greater.

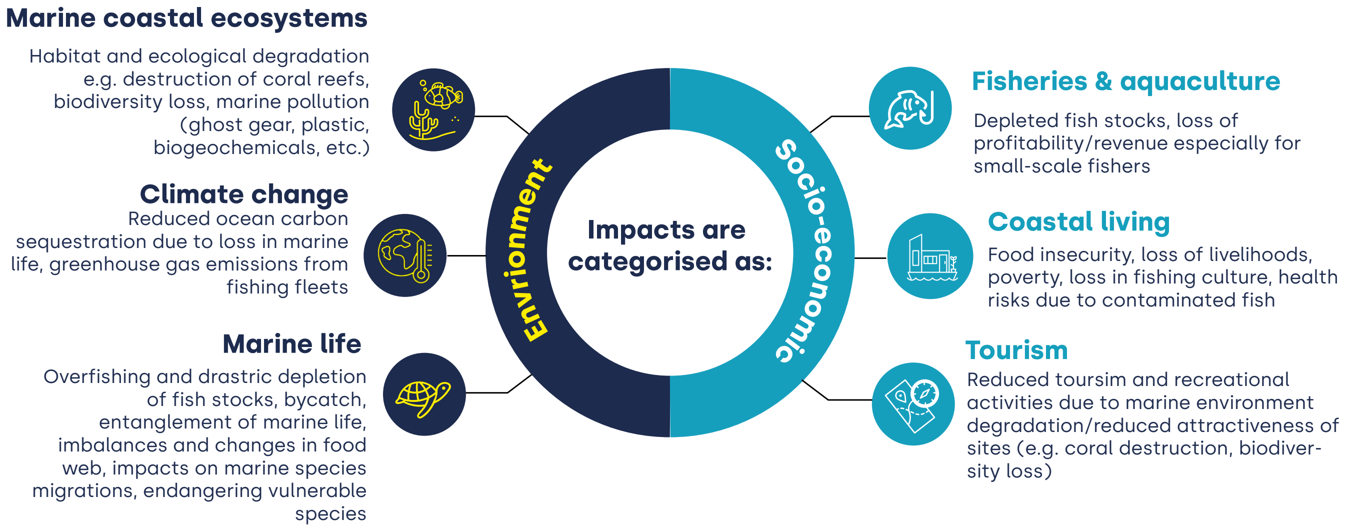


Figure 1: Environmental and socioeconomic impacts of destructive and unsustainable fishing practices

The EU Common Fisheries Policy aims to develop a climate-neutral fisheries and aquaculture sector by 2050 and to protect and sustain marine ecosystems, fish stocks and livelihoods. Collecting data on the ocean, modelling ocean, marine life, and stock dynamics, and producing forecasts can help fisheries become climate neutral, reduce bycatch, protect sensitive species, and eliminate IUU fishing and overfishing.

Earth observation for sustainable fisheries management

Detection, monitoring and forecasting of fishing activities and fish stocks

Earth observation data are essential for managing sustainable fisheries and aquaculture, while safeguarding marine ecosystems. Measurements of key variables such as ocean colour, temperature or salinity, and ocean modelling and forecasting can help monitor and manage fishery and aquaculture activities. Combined with automatic identification system (AIS) data, vessel monitoring system (VMS) data or satellite imagery (e.g., satellite radar such as synthetic-aperture radar (SAR)) that provide information on maritime traffic on fishing grounds, Earth observation data can be used to assess the effectiveness of management measures such as marine protected areas and fishery regulations.

Space-based instruments that can provide key Earth observation data include:

- Spectroradiometers, such as the Ocean and Land Colour Instrument (OLCI) onboard the Copernicus Sentinel-3 A & B satellites, for measuring ocean colour
- Passive radiometers, such as microwave radiometers onboard the Copernicus Sentinel-3 A & B, for measuring sea surface temperature, sea surface salinity, or sea ice cover.
- Active radiometers, such as the scatterometer onboard the Copernicus Sentinel-1A satellite, for monitoring the wind speed and direction
- Radar, such as the Synthetic-Aperture Radar (SAR) onboard the Copernicus Sentinel-1A satellite, for the monitoring of wind, waves, and currents.

Earth observations	How they support sustainable fishery and aquaculture practices
Ocean colour data	Provides information on variables such as chlorophyll-a (a proxy for phytoplankton) and total suspended matter (concentration of inorganic particulate matter in seawater), essential for understanding and monitoring marine life, fish populations, water quality and other variables. For example, the concentration of chlorophyll-a, estimated from ocean colour data, is used to indicate primary production rates, regions with low levels of nutrients, which in turn have cascade effects on fish stocks. Indicates areas of eutrophication and harmful algal blooms, thus zones in which fished and aquaculture species might be contaminated.
Surface turbidity data	Used to monitor water quality in aquaculture systems.
Wind speed and direction, precipitation and other weather data	Provide information about safety-at-sea conditions for fishers and aquaculture farmers.
Ocean current data	Allows aquaculture stakeholders to evaluate nutrient residence time and adjust preventive measures to reduce water pollution.
Temperature data	Can be used in conjunction with other variables such as chlorophyll and salinity to predict where fish populations are most likely to be, as well as indicate the suitability of an area for aquaculture production and be used to give early-warnings about heat waves.
Salinity data	Can be used in conjunction with other variables, such as chlorophyll and temperature, to predict where fish populations are most likely to be found, as well as indicate the suitability of an area for aquaculture production.
Radar and optical high-resolution imagery	Helps identify areas of IUU fishing and high fishing intensity, and some pollution events such as oil spills and bilge water discharge.

Earth observation data are needed to develop and improve the accuracy of operational numerical models. These models provide estimates of various variables in marine ecosystems and be used to simulate key parameters in fish stock assessment, such as species' recruitment, growth or natural mortality, opening the way for near real-time predictions with sufficient spatial and temporal coverage. Thus, it is possible to highlight potential overfishing areas by comparing local catches or fishing effort and the expected fishing yield (level called Maximum Sustainable Yield (MSY)) estimated from potential marine productivity. Other indicators from Earth observation data (e.g. ship detection from optical and SAR imagery) and other fishing vessels data (VMS, AIS, etc.) can also be used to identify the presence of unsustainable fishing practices (e.g., bottom trawling in nurseries or vulnerable marine habitats) and their impacts on marine ecosystems and on the fisheries that depend on them. With the increasing availability of Earth observation data, marine ecologists and fishery scientists are beginning to integrate environmental information into stock assessment models and develop new approaches that combine environmental and spatial representations of fish habitats and dynamics of populations and ecosystems.

Long-term Earth observation time series (spanning years to decades) are essential for developing these new approaches as well as the calibration and evaluation of results against past observations. In addition to proposing mechanisms and explanations for the observed variability, not only in time but also in the spatial dimension with increasingly high resolutions, these approaches are particularly suited to spatial management and real-time applications. For instance, decision-makers will use such information to fundamentally change policies to address poor practices and ease pressure on targeted and protected marine populations. Examples of such policy changes include reviewing quota restrictions, identifying and managing marine protected areas, and developing policies that can address issues such as bycatch and potential illegal, unreported and unregulated (IUU) fishing.

Access to and using Earth observation data for fisheries and aquaculture applications

The EU contributes to various Earth observation-based monitoring and forecasting programmes, services, and projects that provide access to data products and information to support sustainable fisheries and aquaculture. Data and information for fish stock evaluation and near real-time monitoring provide numerous user benefits and critical information for effective decision-making in various sectors (e.g., fisheries, tourism, transport, food safety). They also support authorities in decision-making at local, national, and international scales to ensure sustainable fisheries management.

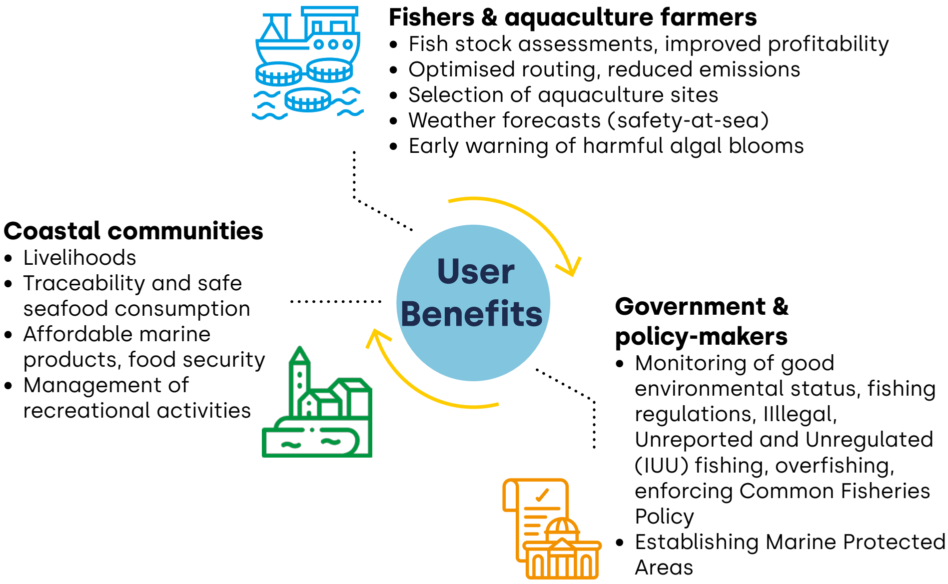


Figure 2: Earth observation-derived information, tools and services provide a range of benefits for different stakeholders in the fishing and aquaculture industry

The EU supports the following projects, services and initiatives providing monitoring and forecasting services and access to data and information to support sustainable fisheries and aquaculture in the global ocean and European waters:

The **Copernicus Marine Service** (marine.copernicus.eu) of the European Copernicus programme provides free and open access to in situ, satellite and modelled data that can be used to monitor, analyse and forecast the status and evolution of marine ecosystems as well as fish stocks. Copernicus Marine gives access to a number of variables, including global ocean colour, which can be used to monitor global ocean phytoplankton primary production, as well as other water quality parameters important for the aquaculture and fishing industries (e.g., temperature, turbidity, salinity, dissolved oxygen, etc.). Copernicus Marine's Ocean Colour Thematic Assembly Centre provides free and open access to satellite ocean colour high level data at spatial resolution of 4 km for the global ocean, 1 km for European seas and 300 m for coastal regions.

NECCTON (www.neccton.eu) is an EU-funded project advancing the Copernicus Marine Service's capability to predict and protect the biodiversity of marine ecosystems. New modelling products of fish biomass, pollution and benthic habitats will enable the Copernicus Marine Service to support marine protected area management, sustainable fisheries, and aquaculture operations.

The **Copernicus Climate Change Service** (climate.copernicus.eu) of the European Copernicus programme, provides information and predictions about the past, present and future climate, as well as tools to enable climate change mitigation and adaptation strategies by policymakers. This is a useful information source for making predictions about how climate change may alter ocean conditions and fish stocks.

EUMETSAT (www.eumetsat.int), the European operational satellite agency for monitoring weather, climate and the environment from space, delivers near-real-time data on ocean colour. This data provides information on parameters such as chlorophyll-a, a proxy for phytoplankton and total suspended matter. These data are used to understand and monitor marine life, including fish populations, as well as key measurements of water quality and sediment dynamics.

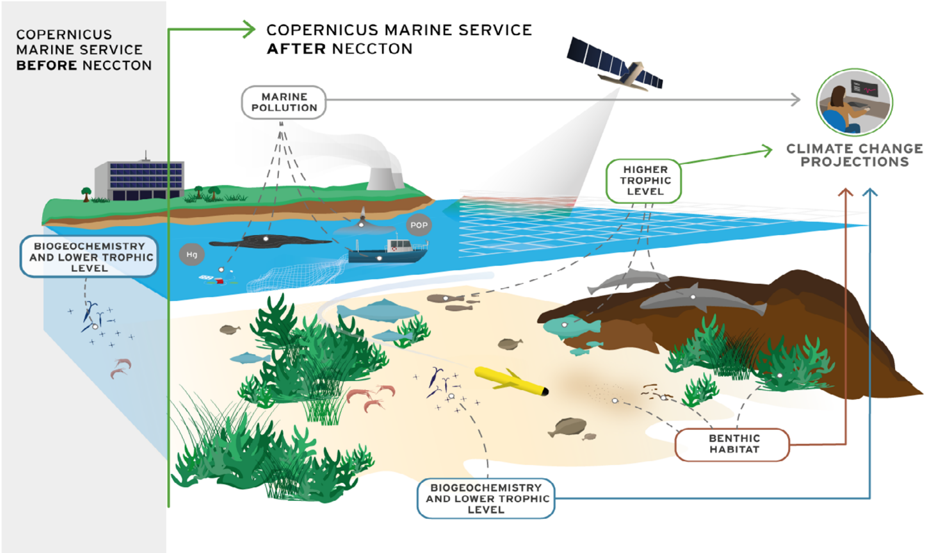


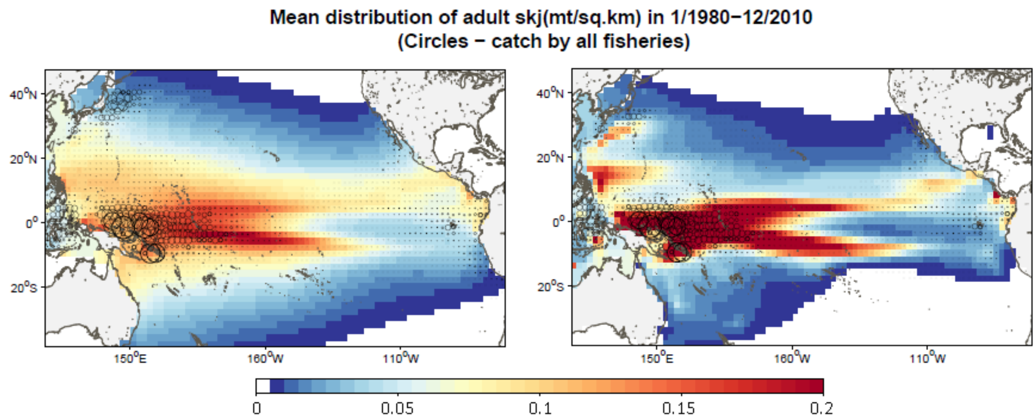
Figure 3. The achievements from the NECCTON project will feed into the Copernicus Marine Service which will enable a much wider range of uses and applications. The diagram shows the Copernicus Marine Service before and after the addition of the NECCTON products. Addition of the NECCTON products will mean that the Copernicus Marine Service is able to offer improved biogeochemical products, modelling of higher trophic levels, modelling of the benthic habitat, among others to support MPA management, fish stock management, support for aquaculture operations.

The **HiSea platform** (hiseaproject.com) is an EU-funded platform which provides information to assist the operations and maintenance of aquaculture and ports. Using data from the Copernicus Marine Service, the platform offers a range of forecasts useful for aquaculture farmers, including wave and wind conditions, water quality, jellyfish proliferation, and harmful algal blooms. Although the project ended in 2021, the platform is still accessible.

Fish Habitat (fish-habitat), an initiative of the Joint Research Centre of the European Commission, centralises access to maps of essential habitats for important species such as bluefin tuna, hake (nurseries) and blue shark (bycatch mitigation), and provides a potential fish production indicator on regional and global scales. These products can be used as a decision-support tool for fisheries closures, bycatch reduction actions, and improvement of fish stock estimates.

SEAPODYM - Spatial Ecosystem and Population Dynamics Model (http://www.seapodym.eu) is a numerical model initially developed to investigate physical-biological interaction between fish populations and the ocean pelagic ecosystem (https://github.com/PacificCommunity/seapodym-codebase). Initiated in the mid-1990s by the Oceanic Fisheries Programme of the Secretariat of the Pacific Community (SPC) and developed under several European projects, the model describes spatial dynamics of zooplankton, micronekton (small marine animals that are prey of larger species), and exploited fish species such as tunas. In 2006, Collecte Localisation Satellite (CLS) partnered with SPC to combine these modelling approaches with satellite observation and real-time data collection to develop operational real-time applications towards sustainable management and monitoring of marine resources. New applications for small pelagic species are also being developed at Mercator Ocean International.

Figure 4: Colour maps: average spatial distributions of adult skipjack biomass (mt/km^2) predicted by SEAPODYM as an optimal solution of parameter estimation using catch and length information (on the left) and catch, length and tagging data (on the right). Adapted from "Predicting skipjack tuna dynamics and effects of climate change using SEAPODYM with fishing and tagging data». Senina I. et al. (2016).



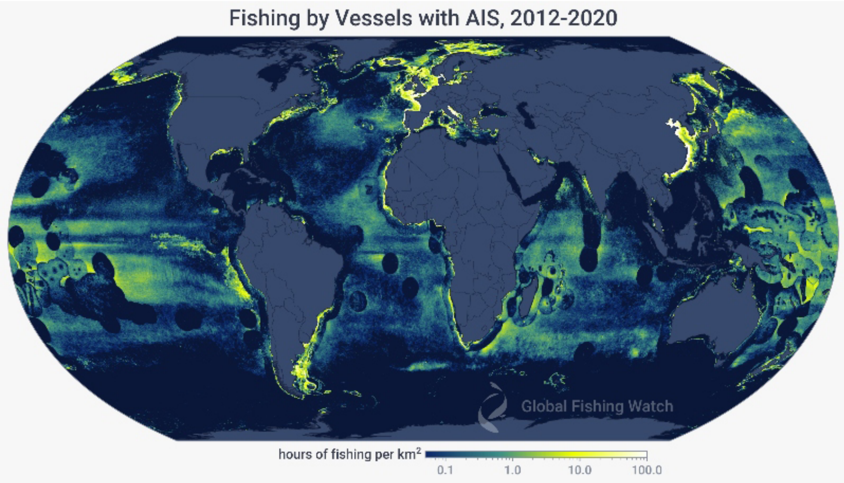


Figure 5: Fishing activity of more than 70,000 fishing vessels across nine years (2012 - 2020). These data are publicly available in Global Fishing Watch's data repository: https://globalfishingwatch.org/datasets-and-code/

The EU-funded project **Blue-Cloud's collaborative virtual environment** (blue-cloud.org) provides computing facilities at the European level for scientists to develop, test, and improve ocean-based models. The project makes available a set of services to better understand and manage the many aspects of ocean sustainability through a series of virtual lab environments and demonstrators related to fisheries, including improving data management and analytic capabilities for fisheries through the Global Fisheries Atlas and the Global Record of Stocks and Fisheries, as well as a tool to monitor aquaculture in marine cages and in coastal areas, among others.

The **EU Digital Twin of the Ocean** (EU DTO) aims to build virtual representations of real ocean processes and environments by integrating ocean observations and other data (e.g. climate, data from fishing vessels, socio-economic, etc.) with artificial intelligence tools and advanced modelling powered by supercomputing. Digital twin applications will allow different stakeholders to test and predict the impact of different management scenarios. For example, digital twin applications for fisheries management can help improve assessments of the state of fish stocks, optimise routing and reduce emissions, improve fisheries productivity while minimising environmental footprint. For aquaculture management, digital twins can help monitor and predict changes in water quality as well as optimise aspects such as designing net and moorings for specific areas. This approach could reduce incidences of net deformations that reduce the amount of space and oxygen in the cage and increase stress levels of the caged fish. See Iliad digital twin pilot application that aims to improve the assessments of important stocks in the North Sea Region and help in making progress towards the construction of catch prediction models.

The **Global Fishing Watch map (**globalfishingwatch.org) is an open-access online platform for visualising and analysing vessel-based human activity at sea. Powered by satellite technology such as the EU's Copernicus Sentinel-1 satellite and machine learning, the map merges multiple types of vessel tracking data, including radar and optical high-resolution imagery, providing a view of global human activity at sea.

GEO Blue Planet Working Group on Fisheries (geoblueplanet.org/fisheries): works with countries to identify the needs and the gaps in data availability and knowledge sharing for fisheries stakeholders and communities. The group is co-led by the GEO Blue Planet EU Office and works with stakeholders to support the implementation of actions to promote informed socio-economic strategies, bridging the gap between scientific knowledge and decision-makers. The scope of this working group covers all scale and type of fisheries: capture fishery (artisanal and commercial) and culture fishery (coastal aquaculture and offshore fish farming). Also see workshop on Earth observations for tuna fisheries.

EcoScope - Ecocentric management for sustainable fisheries and healthy marine ecosystems (ecoscopium.eu/) is an EU-funded project (2021 – 2025) developing an interoperable platform, a robust decision-making toolbox, a series of online courses and a mobile application to promote an efficient, ecosystem-based approach to the management of fisheries. The e-platform will integrate in situ, satellite and model data from external data providers, including from Copernicus Marine, EMODnet, marine in situ infrastructures (Euro-Argo, EMSO LifeWatch ERIC, Danubius), and many other sources (FAO, ICES, GOOS, etc.). It will also assimilate data, model results and indicators produced within the framework of the EcoScope project, in relation to environmental, human and economic drivers, indicators and assessments and ecological models.

Figure 6: Earth observation-based monitoring and forecasting value chain for sustainable fisheries

EARTH OBSERVATION PLATFORM

EU Copernicus Sentinel Satellites
(OLCI, radar, radiometer)

Copernicus
Europe's eyes on Earth

Improve calibration

NEED FOR IN SITU OBSERVATIONS

- Quantitive and qualitative data on fish stocks
- Information on fish landing
- Information on fleet size
- Accurate physical and biological ocean data (e.g. temperature, currents, primary production)

DATA

Ocean Data Products

Improve validation & accuracy of models

ANALYSIS

Ocean productivity algorithm/model

Harmful algal bloom monitoring

Ecosystem modelling (nutrient concentration, trophic web)

Meteorological modelling

Hydrodynamic modelling

Climate projections

Detection model

Predictive model

INFORMATION

Fish presence probability
Harmful algal bloom occurence

Evolution of fish stocks
Ecosystem health and marine biodiversity

PRODUCTS / SERVICES

Harmful algal bloom warning alert
Optimising fish locations or aquaculture sites
Spatio-temporal evolution of fish stock
Illegal, unreported and unregulated fish and overfishing alerts

END USER BENEFITS

Target

Public & local authorities

Fishers & aquaculture farmers

Coastal communities

Policy-makers, EU Common Fisheries Policy

Decision points

Define marine protected areas

Define fishing quotas

Optimise fish vessel routing

Monitor fisheries regulations, overfishing, Illegal, unreported and unregulated fishing

Benefits

Job and food security

Productive sustainable fisheries

Restoration of fish stocks and safeguarding of marine biodiversity and ecosystems

Reduced greenhouse gas emissions

Gaps in monitoring and forecasting for sustainable fisheries management

Despite all the significant progress made, there are gaps in monitoring and forecasting capacity and capabilities, which include:

- Limited optical satellite coverage by cloud coverage or limited light at high latitudes
- Uncertainties associated with and accessbility to biological surveys (scientific spatial fisheries data) and fisheries data reported by EU member states (commercial spatial fisheries data)
- Uncertainties associated with understanding and modelling marine ecosystem functioning
- Lack of in-situ data on presence of fishes (target and bycatch species), human activities impacting fisheries as well as other aspects related to artisanal fisheries to improve understanding of status of resources and exploitation rates
- Limited computing facilities and space for data storage for scientists

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