STUDY

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Workshop on the European Green Deal – Challenges and opportunities for EU fisheries and aquaculture

Part II: Marine biodiversity aspects

Fisheries

Policy Department for Structural and Cohesion Policies
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RESEARCH FOR PECH COMMITTEE

Workshop on the European Green Deal – Challenges and opportunities for EU fisheries and aquaculture

Part II: Marine biodiversity aspects

Abstract

This study is the second in a series of three research papers, prepared for a PECH Committee Workshop. It examines the marine biodiversity aspects of the European Green Deal. It explores the challenges and opportunities for the EU fisheries and aquaculture sectors. The present research contains two case studies: the potential cohabitation between offshore wind farms, marine protected areas and fishing activities and the interactions between fishing and marine protected species.

This document was requested by the European Parliament's Committee on Fisheries.

AUTHORS
Sakana Consultants: Sébastien METZ
Joachim CLAUDET

Research administrator: Marcus BREUER
Project, publication and communication assistance: Ginka TSONEVA, Kinga OSTAŃSKA, Stéphanie DUPONT, Anton KÜCH (trainee)
Policy Department for Structural and Cohesion Policies, European Parliament

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ABOUT THE PUBLISHER

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LIST OF ABBREVIATIONS

ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas
CFP	Common Fishery Policy
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMR	Capture-Mark-Recapture
CO	Conservation Objective
CPUE	Catch per unit of effort
DCF	Data collection framework
DCMAP	Data collection multi-annual plans
DPMA	Direction des pêches maritimes et de l'aquaculture
EAFM	Ecosystem Approach to Fisheries Management
EBFM	Ecosystem-Based Fisheries Management
EC	European Commission
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EGD	European Green Deal
EU	European Union
GBF	Global Biodiversity Framework
GES	Good ecological status
ICES	International Council for the Exploration of the Sea
ICT	Information and communication technologies
Ifremer	Institut Français de Recherche pour l'Exploitation de la Mer
IUCN	International Union for Conservation of Nature

JRC	Joint Research Center
MHW	Marine heat wave
MPA	Marine protected area
MSFD	Marine Strategy Framework Directive
NEA	North East Atlantic
NGO	Non-Governmental Organisation
NOAA	National Oceanic and Atmospheric Administration
ObsMer	Observation des captures en Mer
OMMEG	OSPAR Marine Mammal Expert Group
OSPAR	Oslo-Paris Commission
OTEC	Ocean thermal eergy conversion
OWF	Offshore wind farms
PBR	Potential Biological Removal
PTM	Pair trawlers
PTB	Bottom pair trawlers
RNE	Réseau National Échouage
R&D	Research and Development
TAC	Total allowable catch
WGBYC	ICES Working Group on Bycatch of Protected Species
WGMME	ICES Working Group on Marine Mammal Ecology
WKEMBYC	ICES Workshop on fisheries Emergency Measures to minimize BYCatch of short-beaked common dolphins in the Bay of Biscay and harbour porpoise in the Baltic Sea
WKMOMA	ICES Workshop on estimation of MOrtality of Marine MAmmals due to Bycatch

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EXECUTIVE SUMMARY

This study aims to provide an **overview of the impacts, challenges and opportunities** for the European Union (EU) fisheries and aquaculture sectors created by the **European Green Deal** (EGD) regarding **marine biodiversity**. The main EGD policy initiatives impacting aspects of marine biodiversity are presented. The research analyses the overall challenges, opportunities and solutions for EU fisheries and aquaculture about marine biodiversity aspects of the EGD. It also illustrates best practices and lessons learnt for implementing core objectives of the EU Biodiversity Strategy for 2030. Finally, the report provides policy recommendations to the European Parliament centred on measures for effectively implementing the EU's biodiversity framework for fisheries and aquaculture sectors.

The main European Green Deal policy initiatives as regards marine biodiversity aspects

The **EGD** is a group of policies aiming to **reduce the European economy's fossil fuel dependency**, with the target of carbon neutrality by 2050. Several strategies presented in the Green Deal are expected to have strong implications regarding **marine spatial planning**, as they call for the development of new activities in already busy coastal areas: an improved network of marine protected areas, offshore wind farms (OWF) and aquaculture developments.

The **reinforcement of the Natura 2000 network** is a critical element of the European Green Deal, with an objective of 30% of the EU's sea waters protected by 2030, the implementation of strict protections for at least a third of the areas, and the definition of fisheries management measures in all areas. Currently covering close to 450 000 square kilometres, the network of marine protected areas (MPAs) has to be tripled to reach the 30% objective.

Another important element of the EGD package is the **EU Strategy on offshore renewable energy.** Its objective of **increasing the EU offshore wind capacity to 60 GW by 2030 and 300 GW by 2050** will have major implications both for marine spatial planning (MSP) requirements and the marine environment. The footprint of future developments is expected to require close to 50 000 to 60 000 square kilometres of OWF at the European level, without counting the security buffer area surrounding each wind farm and the corridors needed to connect these wind farms to the electric grid.

Reducing the bycatch of species threatened with extinction to a level that allows full recovery is a challenging objective, notably due to the development of **specific plans tackling the bycatch of protected species** in a short timeframe.

Challenges, opportunities and solutions for EU fisheries and aquaculture as regards marine biodiversity aspects of the European Green Deal

The continuous release of human-produced greenhouse gas emissions directly affects the ocean: **warming**, **acidification** and **deoxygenation**. Human-induced **climate change** is significantly **modifying the ecosystems' structure** and the distribution of marine species, with most species shifting poleward. An important **share of the coastal waters is in less than good status**, despite the implementation of the Marine Strategy Framework Directive. Developing an **Ecosystem Approach to Fisheries Management** (EAFM) is essential for better integrating all new usages in management advices.

Offshore wind farm installations, spatial protection measures and fishing activities

The **extent of OWF** of area-based conservation will **increase dramatically** in European waters in the coming decade, with a necessity to develop plans of **co-existence with fishing**. The impact pathways of **OWF** on marine biodiversity are complex and often **incompatible with conservation objectives**. Offshore wind energy production and multi-use fishing could become the European Union's new standard. While co-locating OWF and fishing would imply some local adaptations of the fishing sector and revised policies by insurance companies, this would align with the EU Biodiversity Strategy for 2030 and EGD. To effectively integrate spatial protection with multi-use fishing and OWF, systematic and participatory planning approaches exist and should be mobilised.

Minimising the interactions with marine protected species

Several cetacean subpopulations are considered **threatened or near threatened** in European waters. **Global warming** is inducing a **poleward shift** in the distribution of most species, accompanied by habitat reduction for some species and increased competition for prey. **Two species**, the harbour porpoise (*Phocoena phocoena*) and the common dolphin (*Delphinus delphis*), are subject to **an important level of bycatch in the EU**, threatening the sustainability of their populations. **Spatial measures** designed to avoid the overlap of fisheries and cetaceans are the **only measures able to eliminate the problem of bycatch**. Technical measures designed to limit accidental catch (acoustic deterrent, escape panels) are most of the time species-specific and do not avoid all bycatch.

Recommendations

Regarding the development of offshore wind farms (**OWF)** and **spatial protection measures:**

1) Reinforcing the **coordination between Member States** to develop coherent **marine spatial plans**, avoiding discontinuity between Member States. This is notably important for the development of a coherent network of MPAs.
2) Recognising that **industrial activities** are **not compatible** with **marine biodiversity conservation**.
3) Supporting **research activities** to elicit the **preferences in the use of marine space**, to better define the place of each industry. This could be achieved at sea basin level also to reinforce coordination between Member States.
4) Developing research to assess the **cumulative effects due to multiple OWF on marine biodiversity**: disruption of migration corridors, effect on local atmospheric conditions (wind, temperature), but also **on the fishing industry**: fishing assemblages, target species, fishing behaviour, the characteristics of the lost fishing opportunities and the varying characteristics of the different offshore.
5) Supporting **research** to identify key features at the sea basin level to avoid disruptions between **marine protected areas** due to **offshore developments** (wind energy notably).
6) Embracing systematic and **participatory planning** approaches for effectively **integrating spatial protection** with **multi-use fishing, aquaculture and OWF.**
7) Developing **support measures** for the fishing industry to be able to access **insurance policies** allowing them to **fish inside OWF** under conditions.

Regarding the **interactions of fishing activities** and **protected species**:

8) Reinforcing all **direct observation programmes** that are essential to estimate the cetacean populations, to allow population evaluations on a more frequent basis.
9) Improving the **EU-DCMAP** (Data collection multi-annual plans) to impose better sampling of segments at **risk of bycatch of protected species** (cetaceans, turtles and sea birds).
10) Supporting **research activities** in remote **electronic monitoring systems** to improve the information about **bycatch of protected species**.
11) Supporting **research activities** in identifying **new deterrent and avoidance techniques**, as most of them are species and gear specific.
12) Raising **awareness** of the importance for fishers to **report bycatch of protected species** for improving the **quality of the data available** to assess scientifically the population levels and for helping to understand the **factors explaining these bycatch.**
13) Providing **adequate training** to fishers for
    a) using all **mitigation measures** that can be deployed on their gear **for minimising the bycatch of protected species**.
    b) handling **properly protected species in the eventuality of a bycatch**, to maximise the chances of survival after release.

1. INTRODUCTION

The European Green Deal (EGD) is one of the six policy priorities of the European Commission (EC) for 2019-2024, setting out packages for achieving climate neutrality by 2050 and developing a resource-efficient economy [1]. The EGD echoes international agreements such as the United Nations Framework Convention on Climate Change, notably the Paris Agreement, and the Convention on Biological Diversity, with the recent adoption of the Kunming-Montreal Global Biodiversity Framework (GBF).

This study aims to assess the impacts, challenges and opportunities for the European Union (EU) fisheries and aquaculture sectors created by the EGD regarding marine biodiversity. The main EGD policy initiatives impacting aspects of marine biodiversity are presented. The research analyses the overall challenges, opportunities and solutions for EU fisheries and aquaculture with regard to marine biodiversity aspects of the EGD. It also illustrates best practices and lessons learnt for implementing core objectives of the EU Biodiversity Strategy for 2030. Finally, the report provides policy recommendations to the European Parliament centred on measures for effectively implementing the EU's biodiversity framework with regard to the fisheries and aquaculture sectors.

This study consists of the following sections:

Section 2 presents a summary of the communications published by the Commission to clarify the **scope of the European Green Deal**.

Section 3 describes the **key challenges and opportunities** facing the fishing and aquaculture sectors. It also presents possible solutions for the industry.

Section 4 is devoted to the issue of **combining offshore wind farm installations, spatial protection measures and fishing activities**. This section details the potential compatibility of offshore wind farm developments with the protection objectives assigned to marine protected areas. It also explores the compatibility with fisheries activities.

Section 5 addresses the topic of the **interactions between protected marine species and the EU fishing fleets**. This section details the main drivers and their likely impacts on changing reproduction patterns and shifting settlements of marine protected species, illustrates best-practice examples of cohabitation and

Section 6 provides **policy recommendations** relevant to EU decision-making so that marine biodiversity challenges are taken into account in future regulations linked to the European Green Deal.

[1] European Commission, The European Green Deal; COM(2019) 640 final of 11 November 2019

2. MAIN EUROPEAN GREEN DEAL POLICY INITIATIVES AS REGARDS MARINE BIODIVERSITY ASPECTS

KEY FINDINGS

- The **European Green Deal** (EGD) is a group of policies aiming at the **reducing the fossil fuel dependency of the European economy**, with the target of carbon neutrality by 2050.
- Several strategies presented in the Green Deal are expected to have strong implications in terms of **marine spatial planning**, as they call for the development of new activities in already busy coastal areas: an improved network of marine protected areas, offshore wind farms, aquaculture developments.
- The **reinforcement of the Natura 2000 network** is a critical element of the European Green Deal, with an objective of 30% of the EU's sea protected by 2030, the implementation of strict protections for at least a third of the areas, and the definition of fisheries-management measures in all areas.
- The **EU Strategy on offshore renewable energy** will have implications in terms of marine spatial planning and new pressures on the marine environment mainly because of its objective of **increasing the EU offshore wind capacity to 60 GW by 2030 and 300 GW by 2050**.
- The **reduction of bycatch of species threatened with extinction** to a level that allows full recovery is a challenging objective, notably due to the development of **specific plans tackling the bycatch of protected species** in a short timeframe.

2.1. The general context of the European Green Deal

The **European Green Deal** is a group of policy initiatives published by the European Commission in December 2019[2]. Its overarching aim consists in **making the European Union carbon neutral by 2050**. It consists of a multi-sectorial approach, with policy documents and strategies covering diverse sectors of the economy, such as transport, energy, agriculture, buildings, and industries such as steel, cement, information and communication technologies (ICT), textiles and chemicals.

Most policy documents published under the umbrella of the European Green Deal place this strategy as an essential part of the recovery plan for the different shocks the European Union (EU) has experienced in recent years, including the COVID-19 pandemic, the British exit from the Union and the economic consequences of the Russian invasion of Ukraine.

Meeting the objectives of the European Green Deal is expected to require significant financial investment. In its initial publications, the European Commission estimated that the 2030 climate and energy targets would require 260 billion euro of additional annual investment.

[2] European Commission, 2019. COM(2019) 640. *Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions*. The European Green Deal, Brussels, 11.12.2019, 24 pp.

2.2. The key initiatives

This section highlights the key initiatives expected to affect directly or indirectly marine biodiversity.

2.2.1. The EU Biodiversity Strategy for 2030

The European Commission introduced the **EU Biodiversity Strategy for 2030**[3] in June 2020 as a "*long-term plan for protecting nature and reversing the degradation of ecosystems*". The strategy aims at reinforcing existing legislation by setting new objectives and new mechanisms to improve the effectiveness of biodiversity protection throughout the EU around two commitments:

- the establishment of a more extensive EU-wide network of protected areas on land and at sea, and
- the development of an EU nature restoration plan.

Each of these commitments explicitly references the importance of marine biodiversity protection and lays precise objectives for the 2030 horizon.

a. The reinforcement of the EU-wide network of protected areas

The strategy echoes several commitments made at the international level by the European Union or by their Member States. One of the critical policy commitments is Aichi Target 11 under the Convention on Biological Diversity, stating that "*By 2020 […] 10 % of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider […] seascape*".

The strategy sets out key commitments to be achieved by 2030:

- **Legally protect a minimum** of 30% of the EU's land area and **30% of the EU's sea area** and integrate ecological corridors as part of a true Trans-European Nature Network. According to the European Environment Agency, the Natura 2000 network coverage in EU's seas was 9% at the end of 2021[4].
- **Strictly protect** at least **a third of the EU's protected areas**, which would de facto place 10% of the EU's sea area under a no-fishing zone.
- **Effectively manage** all protected areas, defining clear conservation objectives and measures and monitoring them appropriately.

b. The EU nature restauration plan

For its objective of a minimum of 30% of the EU sea area to be legally protected by 2030, with at least 10% of the EU sea area strictly safeguarded, but also for the identification of key actions that the Commission aims to develop or reinforce to achieve the objective:

- Implementing an **ecosystem-based management approach** to help reduce the adverse impacts of fishing, extraction and other human activities, especially on sensitive species and seabed habitats. The approach focuses on maintaining or reducing fishing mortality at or under Maximum Sustainable Yield levels.

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[3] European Commission, EU Biodiversity Strategy for 2030

[4] European Environment Agency, Natura 2000 Barometer

- The definition of measures to **limit the use of fishing gear most harmful to biodiversity**, including on the seabed. One of the key aspects of the strategy is to reconcile the use of bottom-contacting fishing gear with biodiversity goals.
- The **reduction of bycatch of species threatened with extinction** to a level that allows full recovery. This should also be the case for species in bad conservation status or not in good environmental status.
- The definition of **fisheries management measures in all marine protected areas** according to clearly defined conservation objectives and based on the best available scientific advice.

The strategy aims to strengthen the protection of marine ecosystems and restore them to achieve "*good environmental status*", including by expanding protected areas and setting up strictly protected areas for habitats and fish stocks recovery. It stresses the need for an ecosystem-based approach to managing human activities at sea. This means addressing the overexploitation of fishing stocks to or under **Maximum Sustainable Yield** levels (i.e. a level that will allow a healthy future for the fish stock's biomass); eliminating bycatches, or at least reducing it to levels compatible with the species survivability, in order to protect sea mammals, turtles and birds, especially those that are threatened with extinction or in bad status; and tackling practices that potentially damage the seabed, such as trawling or dredging.

2.2.2. The EU Strategy on offshore renewable energy

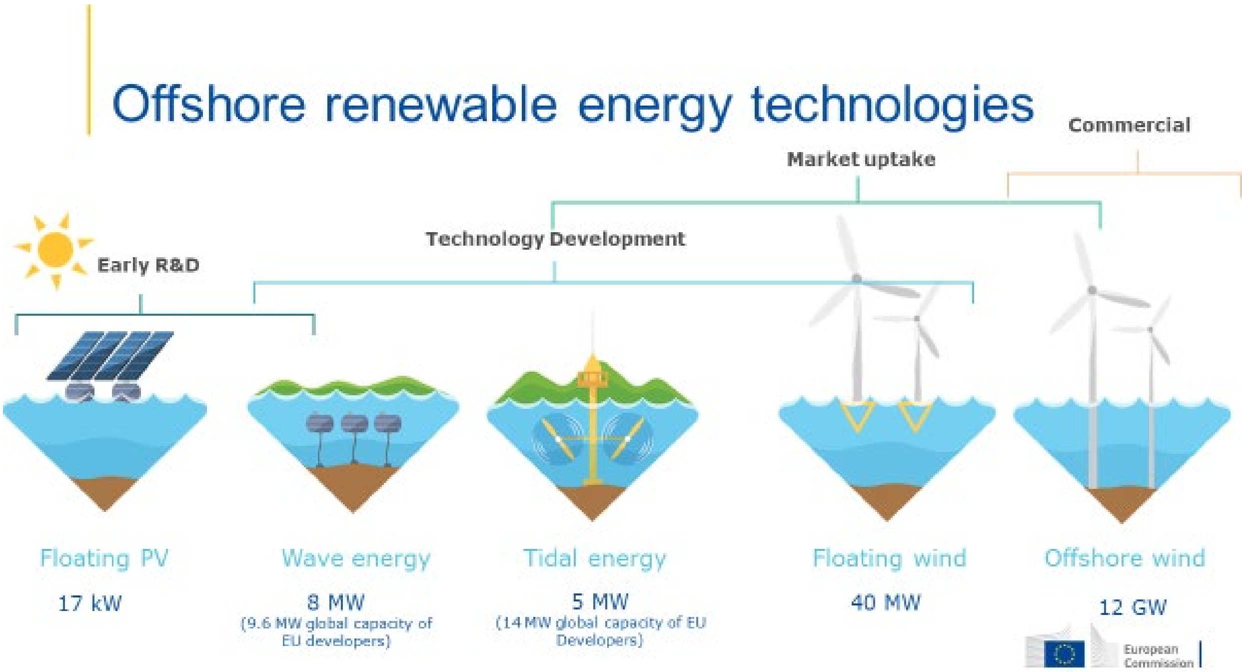
The **EU Strategy to harness the potential of offshore renewable energy for a climate-neutral future**[5] is part of a wider energy policy aiming at reducing greenhouse gas emissions by fostering a decarbonisation of the EU's energy system. This strategy will have implications in terms of marine spatial planning but also in terms of new pressures on the marine environment mainly because of its objective of **increasing the EU offshore wind capacity to 60 GW by 2030 and 300 GW by 2050**.

From the Commission's perspective, offshore renewable energy constitutes the renewable technologies with the greatest potential to scale up. Since the installation of the first offshore wind farm in Denmark in 1991, the development of the wind farm sector has reached an installed capacity of 12 GW (**Figure 1**). The Commission estimates that it could be possible to develop the sector further to reach an installed capacity of at least 60 GW of offshore wind and at least 1 GW of ocean energy by 2030, to reach 300 GW of offshore wind and 40 GW of ocean energy by 2050. The Commission presents this evolution as the necessary path towards the decarbonisation of electric generation in the EU and as a potential provider of renewable hydrogen for hard-to-abate sectors.

The strategy relies on the market uptake of mature technologies (e.g. offshore wind farms) but also on technologies that are at different levels of industry readiness: from floating wind farms that are considered technically mature but have yet to be implemented at an industrial level to technologies that are still in early stages of Research and Development (R&D), such as tidal and wave energy technologies. Other technologies are still at the early stages of development but could be promising for the future: algal biofuels (biodiesel, biogas, and bioethanol), ocean thermal energy conversion (OTEC) and floating photovoltaic installations (already deployed in landlocked waters but mainly at the research and demonstration stage at sea, with only 17 kW installed).

[5] European Commission, An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future.

Figure 1: Offshore renewable energy technologies' current production capacity and market maturity



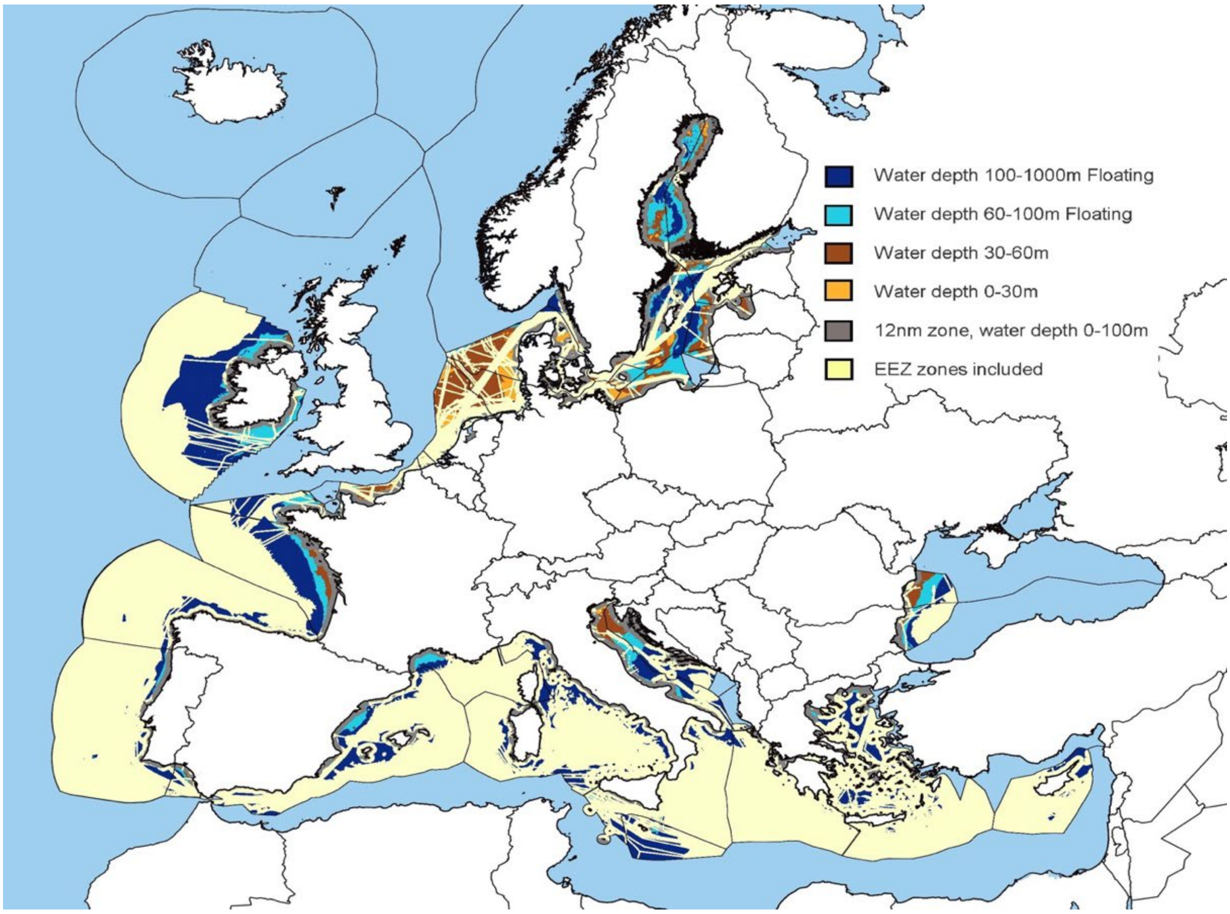
Source: JRC (2019)

Getting to 300 GW of offshore wind and 40 GW of ocean energy installed capacity by 2050 requires **a massive change of scale** for the sector in less than 30 years but is also going to require significant surfaces devoted to this activity in all EU sea basins. The capacity density of current developments is on average close to 5 to 6 MW per square kilometre for offshore wind farms (Deutsche WindGuard, 2018). Offshore developers contacted for this study indicated that this density is not related to the size of the individual turbines, as larger and more powerful wind turbines would need more spacing to compensate for the wake effect each turbine generates, which is corroborated by recent publications (see notably Volker et al. 2017 or Bulder et al. 2018). If such density could be achieved for all future development in the EU, the strategy would translate to the identification of 50 000 to 60 000 square kilometres of offshore wind farms at the European level, without counting the security buffer area surrounding each wind farm and the corridors needed to connect these wind farms to the electric grid. In comparison, the EU part of the sea is close to 5 million square kilometres, while the current area covered by the Natura 2000 network at sea is close to 450 000 square kilometres[6].

Bearing in mind that fixed foundation wind turbines are economically and technically viable by water depth between 0 and 60 metres and that the current developments of floating wind farms are considered technically possible for bathymetry above 1 000 m, although the economic viability is not proven for such depths. The combination of these physical constraints with some current uses (shipping and other offshore developments) led the JRC to define areas that could potentially be devoted to offshore power developments (**Figure 2**). By the JRC estimation (JRC 2019), close to 440 000 square kilometres could be technically suitable for fixed foundation wind turbines (bathymetry above 60 m). An additional 494 000 square kilometres could potentially host floating wind farms (bathymetry between 60 m and 1 000 m), with close to 75% of that surface showing bathymetry above 100 m.

[6] European Environment Agency, Natura 2000 coverage in Europe's seas

Figure 2: Offshore wind technical potential in sea basins accessible to EU27 countries



Source: JRC (2019)

2.2.3. The Farm-to-Fork Strategy

The **Farm-to-Fork Strategy,** for a fair, healthy and environmentally friendly food system[7] also has potential implications for marine biodiversity because of its objectives on sustainable seafood production and the development of sustainable aquaculture (including algae aquaculture), notably

- the **strategic guidelines** for a more sustainable and competitive **EU aquaculture** for the period 2021 to 2030[8] and
- the **strategy** towards a strong and sustainable **EU algae sector**[9].

These different strategies will impact marine spatial planning as the objectives defined in each strategy will call for the development of new aquaculture farms, mainly in coastal waters.

Without setting precise objectives, the algae strategy calls for increased seaweed aquaculture. The various macroalgae usages identified in the strategy (notably biofuel and blue chemistry) would necessitate a high level of biomass production, requiring substantive seawater surfaces devoted to macroalgae cultivation to allow such sectors' development. The macroalgae sector in the EU is currently based on exploiting wild stocks, with a very young macroalgae aquaculture sector.

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7 European Commission, A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system.
8 European Commission, Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030.
9 European Commission, Towards a Strong and Sustainable EU Algae Sector.

Depending on the development trajectory, macroalgae aquaculture may have positive effects, as described by Hasselström et al. (2018) or Forbes et al. (2022):

- the provision of nursery grounds for juvenile commercial fish and crustaceans;
- the removal of dissolved nutrients that may otherwise cause eutrophication;
- the protection of the underlying seabed from abrasion and disturbance from other human activities (fishing, shipping); and
- the provision of alternative livelihoods for coastal communities.

Nonetheless, as with all human activities, there are risks associated with macroalgae aquaculture that need to be considered:

- The introduction of non-indigenous macroalgae that may affect ecosystem structure and function: there are examples in Hawaii where the introduction of an Asian red macroalgae in the 1970s led to its propagation beyond the limit of the farm, where the macroalgae overgrow the local coral, leading to coral mortality (Smith et al. 2002). In Europe, wakame was introduced in 1981 in France and started to spread along the French coasts (Epstein and Smale 2017).
- The inter-breeding of native farm 'escapees' with wild species (known as crop-to-wild gene flow) may lead to the impoverishment in the genetic resources of wild stocks, as seen in wild salmon populations in Norway. This would impact ecosystem resilience and reduce the potential for new cultivar production.
- The introduction of non-indigenous stock and the transfer of native stock to new regions for aquaculture purposes can also lead to the unintentional introduction of 'hitch-hikers'[10], potentially including disease-causing pathogens and parasites.

2.2.4. Protecting and restoring marine ecosystems for sustainable and resilient fisheries

The Commission proposed an action plan for **Protecting and restoring marine ecosystems for sustainable and resilient fisheries**[11] in February 2023. Explicitly citing the EU Biodiversity Strategy for 2030 as the foundation of the plan, the Commission details the objectives associated with this action plan:

- contributing to getting and keeping fish stocks to sustainable levels;
- reducing the impact of fishing on the seabed;
- minimising fisheries impacts on sensitive species.

Besides specific measures aiming at reducing the fossil fuel dependency of the European fishing and aquaculture sector, this action plan is expected to have a significant impact on marine biodiversity because of two groups of measures besides the reinforcement of the CFP:

- The objective **to phase out mobile bottom fishing in all Marine Protected Areas** (MPAs) by 2030 to reduce the impact on the seabed, mandating Member States by the end of 2024 of:
    - o Adopting national measures or, where appropriate, proposing joint recommendations to the regional groups to **prohibit mobile bottom fishing in the MPAs** that are Natura

[10] Opportunistic species that accompany the species introduced.
[11] European Commission, EU Action Plan: Protecting and restoring marine ecosystems for sustainable and resilient fisheries.

2000 sites designated under the Habitats Directive that protect the seabed and marine species.

  - Providing an outline of the Member States intends to **ensure that by 2030 mobile bottom fishing is phased out in all MPAs**. The outline should provide, for at least 20% of each Member State's marine waters, a more detailed plan of national measures and joint recommendations to be developed including, at least, details to identify the areas where mobile bottom fishing should be prohibited, and details on the Member States and fleets concerned by the measures in those areas.

- The objective to **significantly reduce the level of accidental catches** observed in some fisheries. The action plan is setting an ambitious calendar requesting Member States to improve fishing selectivity and reduce the impact of fisheries on sensitive species
  - by the end of 2023: for harbour porpoise in the Baltic Proper and the Black Sea, the Iberian Atlantic and for the common dolphin in the Bay of Biscay;
  - by the end of 2024: for angel sharks, common skate, guitarfish, Maltese skate, great white shark, sand tiger shark, smalltooth sand tiger shark, spiny butterfly ray, sturgeons, marine turtles, Balearic shearwater and Mediterranean monk seal;
  - by 2030: for the remaining sensitive marine species at risk of incidental catches, prioritising those in 'unfavourable conservation status' or threatened by extinction.

3. CHALLENGES, OPPORTUNITIES AND SOLUTIONS FOR EU FISHERIES AND AQUACULTURE AS REGARDS MARINE BIODIVERSITY ASPECTS OF THE EGD

KEY FINDINGS

- The continuous release of human-produced greenhouse gas emissions has direct effects on the ocean: **warming**, **acidification** and **deoxygenation.**
- Human-induced **climate change** is **modifying significantly the structure of the ecosystems** and the distribution of marine species, with most species shifting poleward.
- An **important share of the coastal waters is in less than good status**, despite the implementation of the Marine Strategy Framework Directive.
- The development of an **Ecosystem Approach to Fisheries Management** is essential for a better integration of all new usages in management advices.

3.1. Climate and environmental changes

Since the Industrial Revolution, human-produced greenhouse gas emissions have constantly increased, notably carbon dioxide. These emissions are affecting the ocean in three main ways (Jewett & Romanou 2017):

- **Warming**: greenhouse gases in the atmosphere trap energy from the sun, contributing to global warming. The ocean absorbs more than 90% of this energy, causing ocean waters to warm. Incidentally, warmer waters also contribute to sea level rise.
- **Acidification**: Increasing concentration of carbon dioxide in the atmosphere leads to the ocean's absorption of carbon dioxide, which lowers the pH of the ocean, making seawater more acidic. The rate at which water absorbs carbon dioxide decreases as water temperature increases, making acidification generally stronger close to the pole than in equatorial and tropical regions. Acidification also modifies the bioavailability of essential nutrients, notably iron, which is expected to affect phytoplankton productivity negatively (Shi et al. 2012).
- **Deoxygenation**: Warm water cannot hold as much oxygen as cold water and is more buoyant than cooler water, limiting the mixing of oxygenated water from the surface with deeper waters, which naturally contain less oxygen. Moreover, warmer waters raise oxygen demand for living organisms. Combining all these effects leads to less available oxygen for marine organisms.

These critical physical and chemical changes directly affect the marine ecosystem, as **marine species distributions are heavily influenced by water temperature**. Acidification affects many animals' ability to make shells or skeletons, while low oxygen levels can contribute to hypoxia or dead zones. Many marine species have shifted their distributions in response to this ubiquitous warming, causing community reconfigurations and changes to entire ecosystems (Chaudhary et al. 2021). Under current climate change scenarios, most species are expected to move poleward, even if some exceptions may be identified (Baudron et al. 2020). For example, the hake stock distribution is shifting northward: only 4% of the hake stock was present in the North Sea when TAC were set, while recent studies show that a third of the hake stock is now situated in the North Sea (Baudron and Fernandez 2015). Changes in growth rates, shifts in the spawning season, and shifts in the spawning area (latitude) are observed for several species of commercial importance for European fishers such as sole (Fincham et al. 2013), sardine or anchovy (Menu et al. 2023). For sardines, data show a decrease in adult length and weight along the French coasts of the Mediterranean between 2002 and 2019: sardines have shrunk from 15 to 11 cm on average, their weight decreased from 30 g to 10 g, and individuals over two years old have disappeared (Menu et al. 2023).

Commercial and recreational marine fisheries are at high risk from climate-driven changes in the size and distribution of fish populations, causing potential confusion about applicable fishing regulations and modifying fishing patterns, potentially increasing operating costs for offshore fleets. **Coastal communities may also lose the ability to target species that they traditionally relied on** either because of displacement or extinction (Villasante et al. 2022).

Rising water temperatures, acidification, and deoxygenation can combine with natural ocean cycles to create **extreme marine events**. Marine heat waves (MHWs), dead zones, and coral bleaching are just some examples of these events, which are projected to become more common and severe. Sea-surface temperatures observed in July have constantly increased over the last 40 years, with July 2023 being the highest on record, with an average anomaly of 0.51 Celsius [12]. This trend of a warming ocean is accompanied by an increasing occurrence of MHWs, such as the one experienced during the summer of 2023 in the Mediterranean Sea and most parts of the North Atlantic Ocean (**Figure 3**).

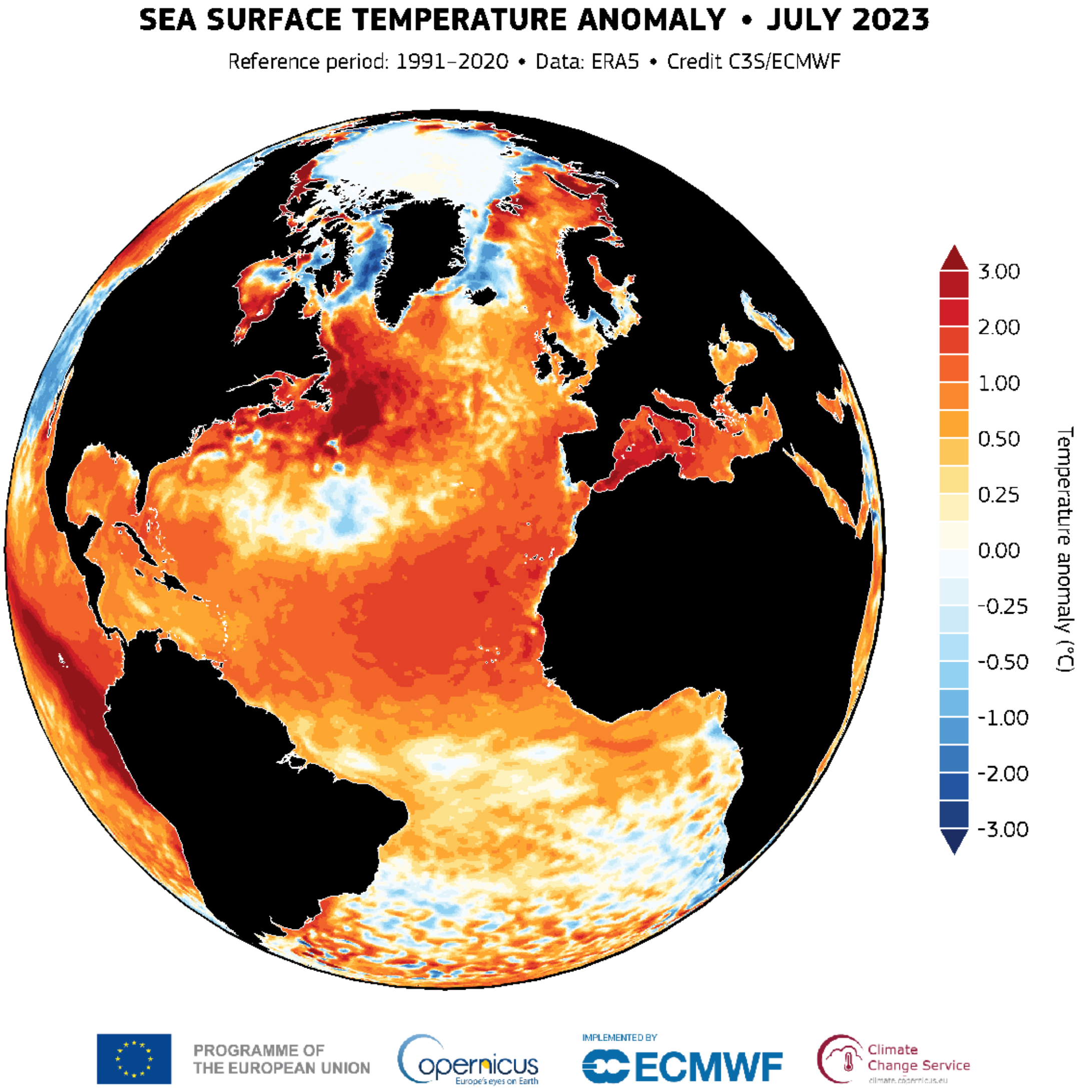
Smith et al. (2021) list several **marine heat waves** that have severely affected fisheries:

- Multiple MHWs were recorded between 2014 and 2016 in the Gulf of Alaska. The zooplankton community shifted from cold-water, lipid-rich copepods to less nutritious warm-water species, reducing food availability and thus the abundances of groundfish, including Pacific cod (*Gadus macrocephalus*) and Alaskan pollock (*Gadus chalcogrammus*). The effect of the MHWs on the life cycle of cod persisted for more than 5 years, as recruitment rates and spawning biomass remained well below pre-MHWs levels. This had major implications for the regional fishery and ecosystem services with reduced quotas for several years and closure of the federal fishery in 2020.

- The 2011 MHWs off Western Australia led to a short-term increase in butterflyfish (*Chaetodon assarius*), valuable to the aquarium trade, and a long-term decrease in abalone growth, resulting in close to a 50% reduction in recreational landings for at least 7 years, whereas farther north, mortalities and reduced recruitment of Roe's abalone (*Haliotis roei*), scallops (*Amusium balloti*), and blue swimmer crabs (*Portunus armatus*) necessitated closures affecting these fisheries for several years.

[12] The Copernicus Programme. Global sea surface temperature reaches a record high

Figure 3: Sea-surface temperature anomaly (°C) for July 2023, relative to the 1991-2020 reference period



Source: Copernicus Climate Change Service/ECMWF[13]

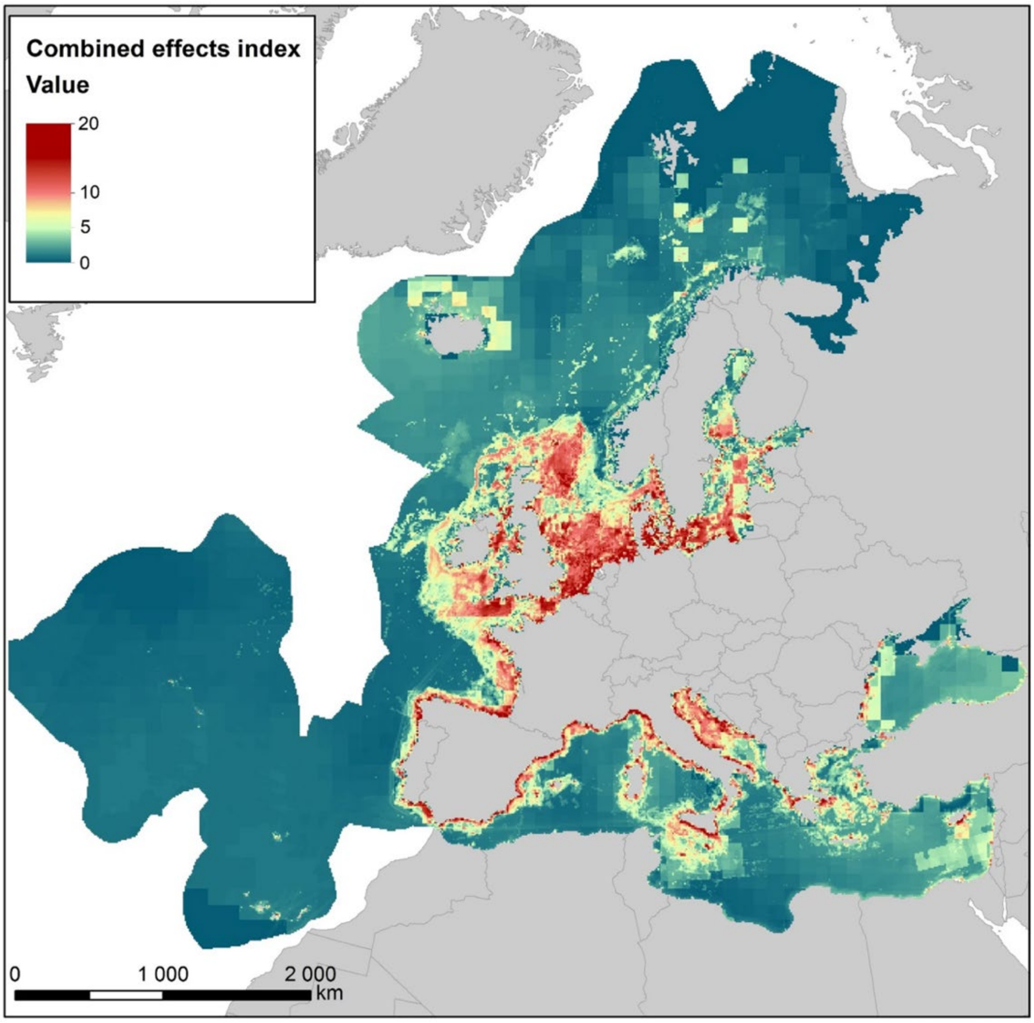
[13] The Copernicus Programme. Global sea surface temperature reaches a record high

3.2. Increase in human pressures

Achieving sustainable use of natural resources and halting the degradation of ecosystems are major global commitments (Borja et al. 2020; Claudet et al. 2020a). Reaching **good ecological status** (GES) of coastal and marine waters is the **main objective of the Marine Strategy Framework Directive**[14] and is vital for Blue Growth and the future development of sea uses.

Europe's seas are subject to widespread pressures from ongoing human activities, especially in shelf and coastal areas. Korpinen et al. (2021) analysed human pressures on a 10 km X 10km grid covering the entire European marine area and estimated a combined effect index to represent the cumulative effects of human activities on the ecosystem (**Figure 4**).

Figure 4: Combined effects of anthropogenic pressures in Europe's seas



Source: Korpinen et al. (2021)

Note: The marine area follows the European Environment Agency's delineation of the Marine Strategy Framework Directive assessment area

Their results suggest that **38% of the grid cells in coastal waters are in less than good status**. When applied to the entire sea area, the conclusion is that **high pressures** are spread to about **one fifth of Europe's seas** (19%). Even though the study's authors consider this may be an overestimation linked

[14] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy.

to their methodology due to the size of the grid cells, these results tend to indicate that a large proportion of Europe's marine environment is subject to anthropogenic pressures at levels likely associated with poor ecological status.

Their results also tend to indicate that **overall pressures related to fishing** ('extraction of species,' 'bycatch,' and 'physical disturbance') **are the most widespread effects identified in EU waters**, as well as global warming ('increased sea-surface temperatures') and shipping ('underwater noise'). Human pressures are not evenly distributed amongst marine areas:

- effects of land-based pollution are identified in coastal areas and in the semi-enclosed Baltic and Black Seas ('input of nutrients,' 'input of hazardous substances,' 'input of organic matter,' 'input of microbial pathogens');
- pressures related to bottom-trawling fisheries were most evident in the Mediterranean Sea, the Bay of Biscay, the Iberian coast, and the shallow North Sea (mainly 'physical disturbance').

Fisheries and shipping are the maritime sectors contributing most to potential physical disturbance on the seabed, respectively 55% for fishing and 20% for shipping. Effects of bottom-trawling of the seabed have been documented globally and are connected with significant effects on benthic biodiversity. The effects of shipping on physical disturbance occur in shallow seabed areas and close to the shore. In contrast, ports and anchoring sites are the main contributors to the physical loss of seabed (46% of this pressure's distribution). Another main contributor to 'physical loss' is dredging and dumping (25%), which is linked to maintaining shipping lanes and ports, and marine installations (such as wind turbines and oil rigs, 18%).

In addition, Korpinen et al. (2021) surveyed European marine experts to identify the sensitivity of European habitats and species to anthropogenic pressures (**Figure 5**). The survey indicated that Europe's marine ecosystems are specifically sensitive to extraction of species, increased sea-surface temperature, bycatch of non-target species by fisheries, physical loss of seabed, physical disturbance to seabed, and inputs of hazardous substances and nutrients.

Figure 5: Sensitivity of marine habitats and species against anthropogenic pressures in Europe's seas

	Input of hazardous substances	Global change	Extraction of species by commercial fishing	Physical loss of seabed	Bycatch by bottom touching mobile gears	Physical disturbance to seabed	Inputs of nutrients	Introductions of non-indigenous species	Input of organic matter	Changes to hydrological conditions	Disturbance of species due to human presence	Input of microbial pathogens	Input of impulsive anthropogenic sound	Input of continuous anthropogenic sound	Bycatch by pelagic towed gears
Fish	4	3	5	3	4	3	3	3	3	3	2,1	3	3	3	4
Seagrasses	3	4	2	5	3,5	4	4	3	4	4	3,5	2	0,1	0	1
Infralittoral rock and biogenic reef	3	4	3	4	3	4	4	3	3	3	3	2	1	1	1
Coastal water column habitat	3	4	3	2	2	2,8	4	3	3	3	2	2,5	2	2	3
Cold-water corals and other coralligenous formations	3	3,5	3	4,3	4	4	3	3,8	3	3	2	2	1	0,5	1
Circalittoral rock and biogenic reef	3	3,5	4	4	4	4	3	3	3	2	2	2	1	1	0
Saltmarshes	3	4	1	5	0	4	4	3	3	4,25	4	2,5	0,8	0	0
Infralittoral mud	3	3	3	4	3	4	3	3	3	3	2	2	0	1	1
Infralittoral sand	3	3	3	4	3	4	3	3	3	3	2	2	0	0,8	1
Infralittoral coarse sediment	3	3	3	4	3	3	3	3	3	3	2	2	0,4	0,9	0,5
Infralittoral mixed sediment	3	3	3	4	3	3	3	3	3	3	2	2	0	0,75	1
Breeding birds	4	3	2,5	2	1	2	2	1	2	1	4	2	3	3	3
Circalittoral sand	3	3	3	3,5	4	3	3	2,8	2	2	2	2	0	1	0
Turtles	4	3,5	3	2	2	0,05	1	1	1	1,5	3	2	3	3	4
Small toothed cetaceans	4	3	3	1	1,5	1	1	1	0,5	0,05	3	2	5	4	3,9
Circalittoral mud	3	3	4	3,5	4	3	2,5	2,6	2	2	1	2	0	1	0
Seals	4	3	3	1,3	1,5	1	1,5	0	1,5	1	3,6	2	4	3	3
Circalittoral coarse sediment	3	3	3	4	4	3	2,5	3	2	2	1	2	0	0	0
Offshore circalittoral rock and biogenic reef	3	3	3	4	3	3,3	3	2	2	2	1	1	0,9	1	0
Circalittoral mixed sediment	3	3	3	4	4	3	2	3	2	2	1	2	0	0	0
Deep diving toothed cetaceans	4	3	2	0,8	2	1	1	0	0	1	3	2	5	4	3
Offshore circalittoral mud	3	3	4	3,3	4	4	2	2	2	2	1	1	0	0	0
Offshore circalittoral coarse sediment	3	3	4	2,8	4	3	2	2	2	2	1	1	0	0	0
Offshore circalittoral mixed sediment	3	2,5	4	3,3	4	3	2	2	2	2	1	1	0	0	0
Offshore circalittoral sand	3	3	4	3,3	4	3	2	2	2	1	0,5	1	0	0	0
Offshore water column habitat	2	3	3	1	1	0,6	3	2	2	1,5	0	2	2	2	3
Baleen whales	4	3	2	0	1	0	1	0,5	0	1	2,4	2	5	4	2
Seamounts	2	2,5	3	4	3	3	1	1	1	1	0	0	0	0	1
Bathyal seabed	3	2	3	2	3	1,5	1	1	1	1	0	0	0	0	0
Abyssal seabed	2	1,5	2	1	2	1	0,8	1	1	1	0	0	0	0	0

Source: Korpinen et al. (2021)

Note: The scores are medians from 0 (not sensitive) to 5 (very sensitive) across all regions and respondents. The colour scale represents the scores, from green (0) to red (5).

3.3. Potential emerging issues

Herbert-Read et al. (2022) have conducted a horizon scanning exercise with 30 scientists, policymakers and practitioners with transdisciplinary expertise in marine biodiversity issues. This scan identified three categories of horizon issues: (1) impacts on, and alterations to, ecosystems; (2) changes to resource use and extraction; and (3) the emergence of technologies. The 15 emerging issues are presented in this section (**Figure 6**).

Figure 6: The 15 horizon issues presented in thematic groups: ecosystem impacts, resource exploitation and new technologies

Source: Herbert-Read et al. (2022)

Note: Numbers refer to the order presented in the original article, rather than final ranking. Image of brine pool courtesy of the NOAA Office of Ocean Exploration and Research, Gulf of Mexico 2014. Image of biodegradable bag courtesy of Katie Dunkley.

a. Ecosystem impacts

Wildfire impacts on coastal and marine ecosystems: since 2017, several fires of massive scale and duration have released aerosols, particles and materials containing nutrients – such as nitrogen and phosphorus – but also trace metal (copper, lead, iron) transported to oceans via wind and rain. The expected effects are mixed depending on local conditions, but these wildfires could either induce temporary benefits, namely increased primary productivity, or nefarious consequences such as increased mortality of coastal organisms, coastal darkening (see next impact), eutrophication or algal bloom.

Coastal darkening: the penetration of light in coastal waters is affected by dissolved materials modifying the water colour and suspended particles. Climate change and human activities accelerate light attenuation due to browning from particles entering the ocean, re-suspended sediments due to dredging and other fishing activities, and algal blooms from eutrophication.

Increased toxicity of metal pollution due to ocean acidification: despite tight regulation, there is still continuing release of metal contaminants, notably in urban and industrial areas, while the high persistence of metals in contaminated sediments results in ongoing remobilisation due to storms and human activities disturbing sediments (coastal developments, mobile fishing gears). Ocean acidification is increasing the bioavailability of these metal particles which have diverse impacts: stimulating productivity in areas where trace metals are deficient (pelagic or deep-sea ecosystems) while inducing higher uptake of toxic metals by wild-caught and farmed bivalves such as oysters and mussels, which ultimately could affect human health.

Effects of altered nutritional content of fish due to climate change: the production of essential fatty acids (EFAs) in phytoplankton is impacted by ocean warming effects, reducing fish's nutrient quality, particularly in the tropics. EFAs are vital for maintaining animal and human health, and fish are the primary source of EFAs for many.

Equatorial marine communities are becoming impoverished due to climate migration: One of climate change's critical effects is ocean warming, which directly affects species distribution areas, resulting in a poleward shift of marine communities. In mid-latitudes, species moving closer to the poles are replaced by species moving from warmer waters. This phenomenon cannot happen in equatorial areas where once-reunited species become bimodal without connectivity.

b. Resource exploitation

The untapped potential of marine collagens and their impacts on marine ecosystems. Collagens are increasingly used in sectors such as cosmetics and pharmaceuticals. Originally taken from bovine and porcine sources, an increasing demand for collagens is pushing to identify new sources. Marine organisms, such as sponges and jellyfish, could be farmed to cover some of this demand while offcuts from the fishing industry could offer a sustainable approach to collagen production. However, this demand will likely drive the overfishing of sponges, sharks, and other cartilaginous fish, some of these species already under pressure.

Impacts of the expanding trade for fish swim bladders: there is an increasing demand for luxury dried seafood in Asian markets. In addition to shark fins, abalone and sea cucumbers, demand for swim bladders is expected to dramatically affect target and non-target species. Species that were targeted for this delicacy are already highly overexploited and for some close to extinction (notably *Bahaba taipengensis* or *Totoaba Macdonaldi*). Price levels for swim bladders have reached levels so lucrative (46 000 USD per kg) that sustainable management strategies are inefficient. This demand is expected to threaten target and non-target species, with potential bycatch of sharks, rays, turtles and other species of conservation.

Impacts of deep-water fishing on the biological ocean carbon pump: the ocean carbon pump is the process through which the ocean takes up excess carbon. Depleted resources traditionally targeted by fisheries and concerns about food security have generated interest in unexploited species living at depths of 200 to 1000 metres. Approximately 10 billion tonnes of fish, such as lanternfishes (Myctophidae), currently sequester carbon to the ocean floor, and the fishing industry may soon target these fish for aquaculture feed. The vertical migration of lantern fish transports carbon from the surface waters, where they feed, to the deep ocean waters (via death or excretion).

Extraction of lithium from deep-sea brine pools: ecosystem impacts from deep-sea resource extraction are a concern as the demand for lithium is expected to grow globally at least five-fold due to the battery need to match energy transition forecasts. If such exploitation were to occur on a large scale, deep-sea brine ecosystems with high levels of endemism could be harmed. Moreover, these fragile ecosystems are usually seen as potential genetic hotspots that could offer new genetic resources to medicine and blue chemistry.

c. New technologies

Colocation of marine activities or multipurpose projects: this consists of developing several activities in the same area and optimising spatial planning. An example could be the development of aquaculture activities inside a wind farm. There is a need to develop an appropriate toolbox to avoid these multifunctional structures negatively impacting the environment: there is a need to develop environmental and ecosystem assessment, but also to define management and regulatory frameworks.

Floating marine cities: a design concept which aims to overcome urban challenges, such as lack of housing or climate change. However, such developments may add more pressure on potentially fragile coastal areas.

Trace-element contamination in coastal sediments resulting from the global transition to green technologies: the increasing use of batteries associated with the green energy transition may increase the release of metals such as nickel and cobalt that would contaminate surface waters and reach the marine environment.

New underwater-tracking systems to study non-surfacing marine animals. These systems could offer improved information about the movements and distribution of marine animals, but their potential impacts on species' behaviour are as yet unknown.

Soft robotics for marine research could be used to collect data from deeper waters, currently not easily accessible, and facilitate the safe collection of species. However, the devices used may add pollutants to deep-sea regions, or be inadvertently swallowed by predatory species.

Long-term effects of new biodegradable materials in the marine environment are currently unknown. Several petro-sourced materials are currently replaced by biodegradable alternatives, for which the impacts remain largely unknown, notably in terms of microparticles.

3.4. Ecosystem Approach to Fisheries Management

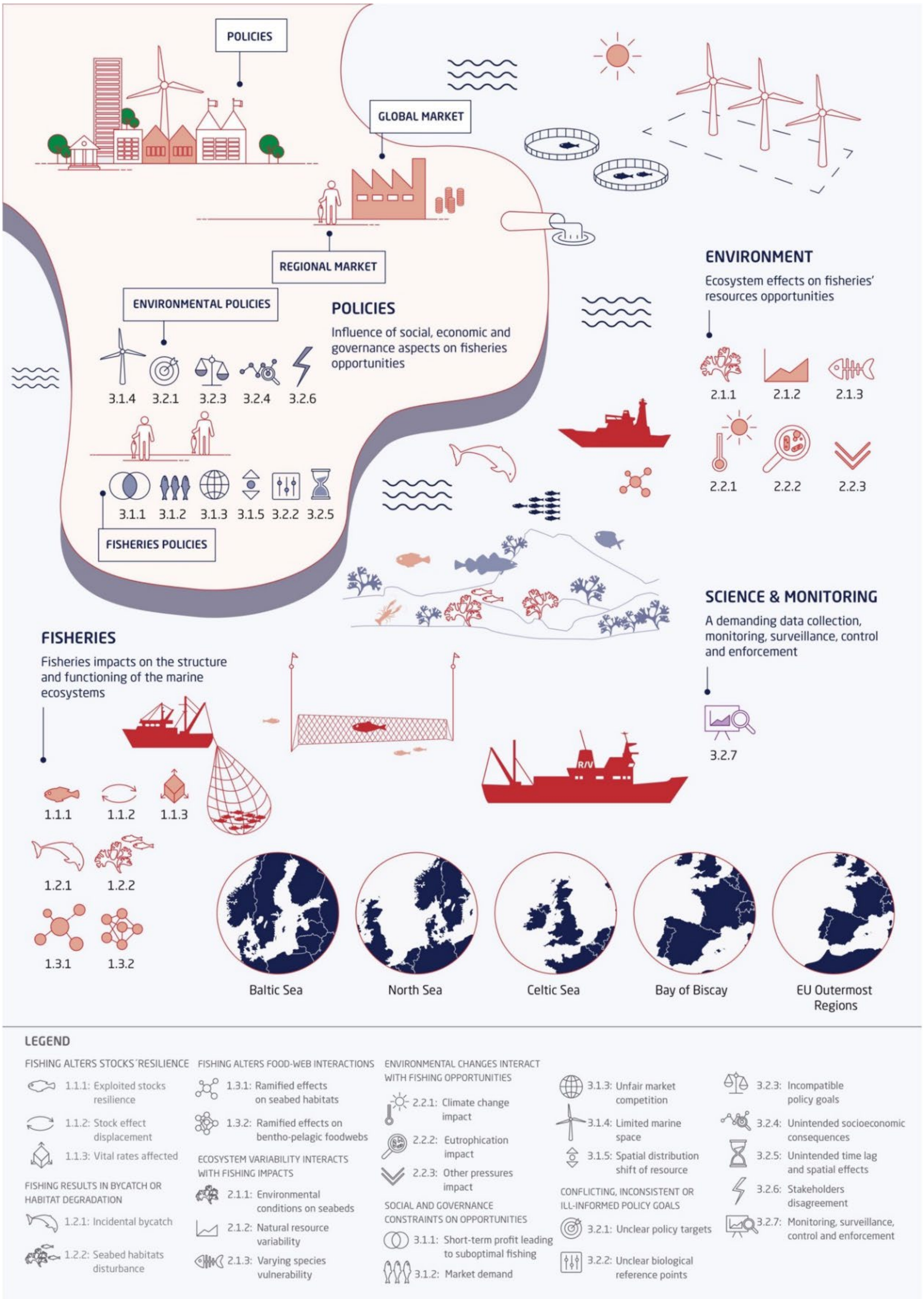
The Ecosystem Approach to Fisheries Management (EAFM) is a systematic approach to fisheries management in a geographically specified area that contributes to the resilience and sustainability of the marine ecosystem (Long et al., 2015). This recognises the ecological, economic, and social dimensions of sustainability affecting all fishery-related ecosystem components, including humans, and seeks to balance benefits among diverse societal goals. One of those goals is to maintain ecosystems in healthy, productive, and resilient conditions so that they can equitably support sustainable use, for example, employment opportunities or fish for human consumption, as well as providing habitats as supportive ecosystem services that will maintain long-term fishing opportunities and increase system biodiversity. EAFM is an integrated approach that recognises the full array of interactions within an ecosystem rather than considering single issues, species, or ecosystem services in isolation (Bastardie et al. 2021).

The different strategies and action plans laid out by the EC are expected to affect the fishing sector significantly. According to figures presented by the European Environment Agency (EEA), the development of protected areas should triple in surface. Imposing restrictions for demersal mobile gears will reduce the fishing grounds accessible by several fleet segments, leading to potential redeployments. Developing a large network of offshore wind farms will also affect fishers as wind farms usually only marginally accept fishing operations. The development of macroalgae aquaculture is also incompatible with fishing activities, as navigation will be prohibited inside macroalgae farms due to safety reasons. As depicted in **Figure 7** (taken from Bastardie et al. 2021), the EAFM approach integrates several ecosystem challenges within a single construction, such as:

- the impacts of fish extraction on exploited stocks' resilience;
- the losses of biodiversity after fishing activities (bycatch and habitat degradation);
- the alteration of food-web interactions due to fishing pressure;
- the anthropogenic and environmental changes interacting with fishing opportunities, such as climate change impacts or eutrophication;
- the social and governance constraints on fishing opportunities: market demand, spatial competition;
- conflicting, inconsistent or ill-informed policy goals across industries and stakeholders.

Although the approach is not yet fully implemented at the EU level, EAFM will be key to better reflecting how these strategies may affect the fishing sector.

Figure 7: Conceptual model of fisheries as a component of an ecosystem that both affects, and is affected by, other components



Source: Bastardie et al. (2021)

Note: These other components are categorised under societal benefits and imposition, as well as environmental components, which encompass natural variation and changes brought about indirectly by human activity.

4. OFFSHORE WIND FARM INSTALLATIONS, SPATIAL PROTECTION MEASURES AND FISHING ACTIVITIES

KEY FINDINGS

- **Extent of offshore wind farms** of area-based conservation **will increase dramatically in European waters** in the decade to come, with a necessity to develop plans of co-existence with fishing.
- Impact pathways of **offshore wind farms** on marine biodiversity are complex and **often incompatible with conservation objectives**.
- **Offshore wind energy production and fishing multi-use** could become the new standard for the European Union.
- While **co-locating offshore wind farms and fishing would** necessarily **imply some local adaptions of the fishing sector and revised policies by** insurance companies, this would be in line with the EU Biodiversity Strategy for 2030 and the European Green Deal.
- To effectively integrate spatial protection with multi-use fishing and offshore wind farms, **systematic and participatory planning approaches** exist and should be mobilised.

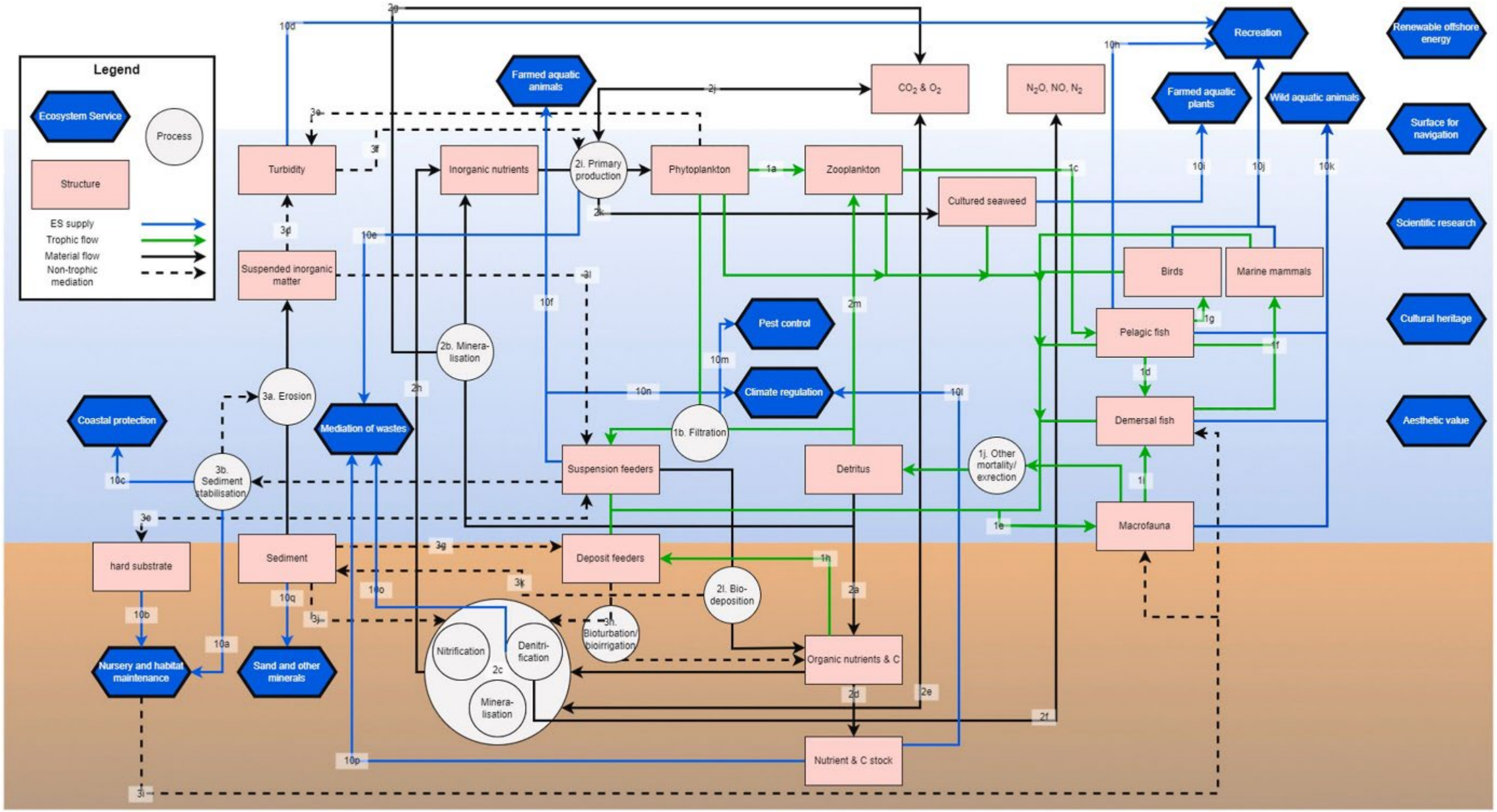
4.1. Co-existence of offshore wind farms, spatial protection measures and fishing activities

The extent of offshore wind farms will dramatically increase in the EU waters, with plans to increase the share of renewables to 42% of the total energy production. At the same time, EU Member States have to increase the extent of MPAs up to 30% of their coastal and marine waters, with a third (10% of coastal and marine waters) under strict protection. With this blue acceleration (Jouffray et al. 2020) there is an appetite to exclude fishing activities from offshore wind farms and consider them as de facto MPAs, while fishing is still allowed in most existing European MPAs (Claudet et al. 2021; Claudet et al. 2020b; Dureuil et al. 2018; Roessger et al. 2022). However, this requires a better understanding of the trade-offs between potential positive and negative impacts of offshore wind farms on biodiversity and whether fishing and renewables production should remain incompatible.

4.2. Combining the EU Biodiversity Strategy for 2030 and the EU Strategy on Offshore Renewable Energy: expected impacts

The impact pathways of offshore wind farms on marine biodiversity are complex (Van de Pol et al. 2023). While they create a new artificial habitat and increase local biomass (habitat effect) they modify the local ecosystems, their structure and functioning, and their trophic structure, and can favour the spread of non-native, often invasive, species (corridor effect). Besides, offshore wind farms can also alter biodiversity through noise, light and electromagnetism. They can also have large-scale effects on seabirds of high conservation concern (Garthe et al. 2023). By affecting marine biodiversity, the whole suite of ecosystem services provided to society can be impacted. Taking the Belgium part of the North Sea as case study, ecosystem services provided by ecosystems that can be impacted by offshore wind farms include farmed aquatic plants (for food, materials and energy), wild aquatic animals (for food, materials and energy), sand and other minerals, surface for navigation, mediation of wastes, nursery and habitat maintenance, climate regulation, coastal protection, pest control, recreation, aesthetic value, cultural heritage, and scientific research (**Figure 8**) (Van de Pol et al. 2023). This figure shows that ecosystem services supply relies on ecosystem processes and a complex and interrelated ecosystem structure. By affecting marine biodiversity with offshore windfarms, the whole suite of ecosystem services provided to society can be impacted.

Figure 8: Generic conceptual ecosystem services model for the Belgium part of the North Sea, including inputs from several experts

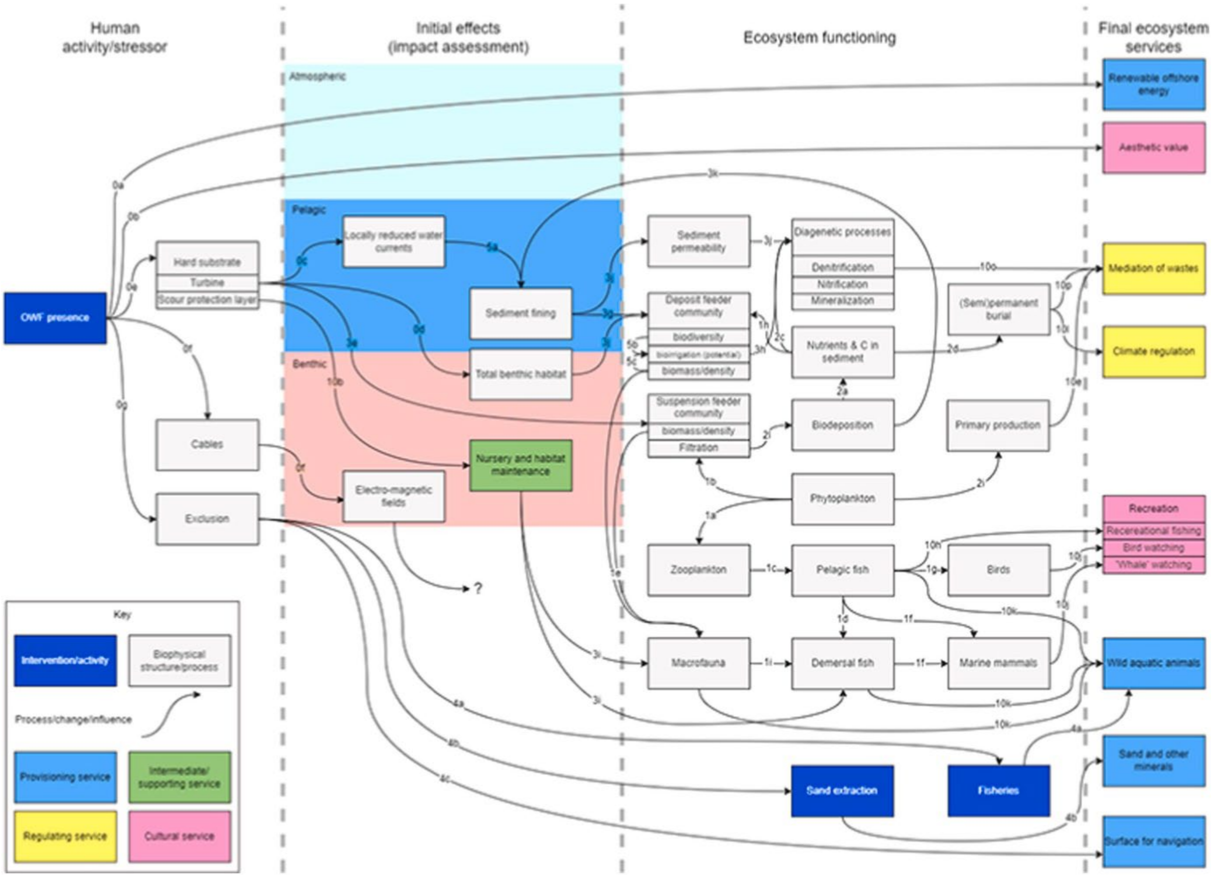


Source : Van de Pol et al. (2023)

Note: Blue hexagons, red boxes, and white circles represent ecosystem services, structures and processes, respectively. Blue arrows represent ecosystem services supply, green arrows represent trophic flows, black arrows material flows and dotted arrows represent non-trophic mediations. The model is non-directional and summarises ecological knowledge on ecosystem services supply.

Better showcasing the ecosystem services provided by the habitats that will host offshore wind farms helps understand the potential impact pathways of offshore wind farms on ecosystem services (**Figure 9**). This figure shows that cascading impacts from offshore wind farms are numerous and that some negative feedback can occur. Most ecosystem services are negatively affected. Fisheries (and aquaculture) are negatively impacted only if excluded from the offshore wind farm, but they can benefit from the offshore wind farm if allowed to operate within its boundaries.

Figure 9: Conceptual case-specific impact model of offshore wind farms presence on ecosystem services supply



Source : Van de Pol et al. (2023)

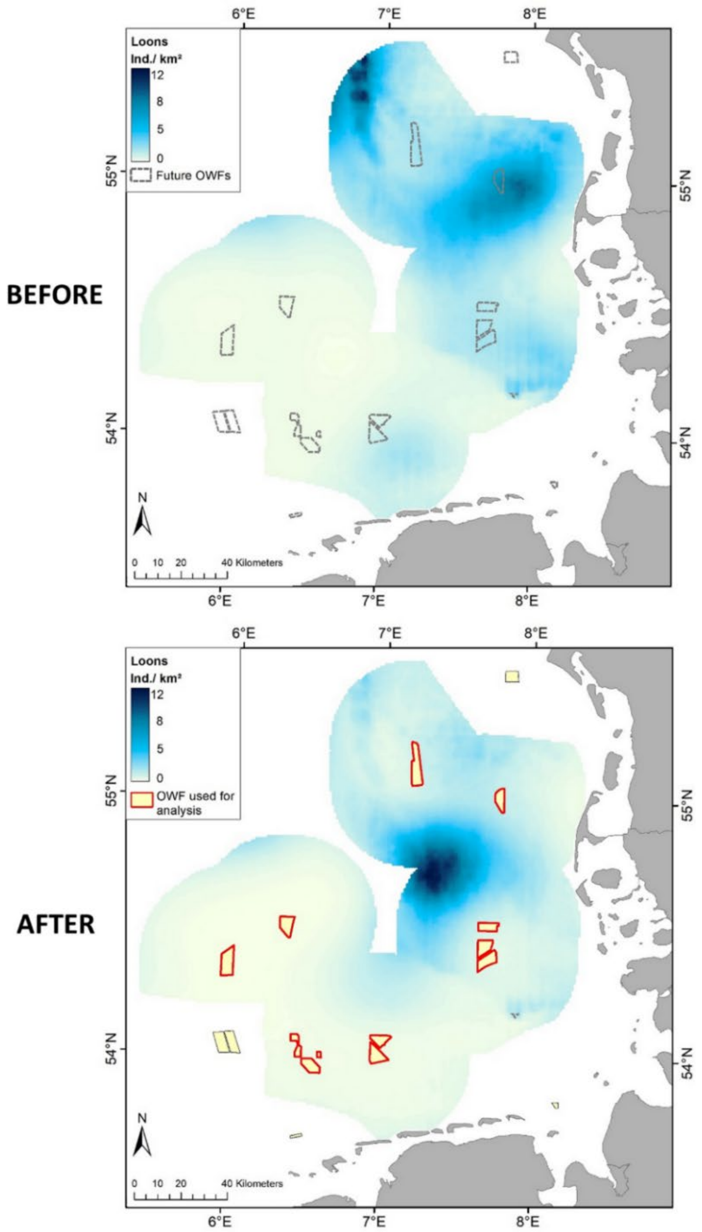
Note: The pathways are divided into the human activity/pressure of interest, the initial effects, ecosystem functioning and supporting services, and final ecosystem services. The white boxes, connected by arrows, represent structures and processes in the cause-effect chain(s) from the initial human activity to the supply of ecosystem services.

Detailing precisely all the impacts of offshore wind farms on marine biodiversity is difficult because we do not yet have the spatial replication and time depth necessary to generalise their impacts fully. However, in this respect, meta-analyses (Coolen et al. 2022) and models (Daewel et al. 2022) can be used.

Offshore wind farms can strongly influence primary production, secondary production, and oxygen levels outside the wind farm areas. Air vortices caused by wind turbines can change the flow and stratification of water and the climate on the surface. Cascading effects on ecosystems include changes in the distribution of nutrients, phytoplankton and zooplankton, and biomass in the sediments, which is the food base of many benthic organisms. In the deepest areas, the amount of biogenic carbon in the sediments can increase locally and the oxygen concentration, in an area where it is already very low, can decrease. These impacts and consequences on ecosystems can extend far beyond the wind farms themselves (Daewel et al. 2022).

In addition, **offshore wind farms have a strong impact on migrating seabirds**. For instance, in the North Sea, observations showed that seabirds disappeared almost entirely (by 94%) within an offshore wind farm and 1 km around, and seabirds' abundance declined by 52% up to 10 km away from the offshore wind farm (**Figure 10)** (Garthe et al. 2023).

Figure 10: Modelled distribution of loons (individuals per km²) before and after construction of wind farms



Source: Garthe et al. (2023)

Creating artificial habitats, where ecosystems are largely impacted and where non-indigenous species can spread are therefore incompatible with conservation objectives, as underlined in the International Union for the Conservation of Nature's (IUCN) global conservation standards to MPAs[15]. Thus, considering offshore wind farms as de facto marine protected areas does not seem realistic. Rather, they could be seen as fishable areas.

15 IUCN, Applying IUCN's Global Conservation Standards to Marine Protected Areas (MPA)

4.3. Towards multi-use and implementation of the EU action plan: Limiting mobile gears in both protected areas and offshore wind farms

Offshore wind energy production and fishing multi-use could become the new standard for the European Union. While, until now, the offshore wind industry has shown little interest in multi-use solutions (unless clear added value is demonstrated and no risks to their operations are involved), the commercial fishing sector is proactive towards multi-use projects and acts as a driving force for multi-use developments (Schupp et al. 2021). This would necessarily imply some local adaptations of both the fishing sector and revised policies insurance companies. For the fishing sector, for instance, this very likely would imply to accept to ban bottom-towed gears in offshore wind farms. However, this would be in line with the EU Biodiversity Strategy for 2030 that implies transformations towards sustainability. For the insurance companies, who sometimes are reluctant to cover fishing within offshore wind farms, this would also imply a paradigm shift. However, this transition could be fostered through the Green Finance component part of the European Green Deal.

Building on an international stakeholder consultation process in relation to multi-use of space by offshore wind farms and fisheries, Schupp et al. (2021) identify management recommendations to progress the decision process towards an effective multi-combination of fisheries and offshore wind farms (Table 1).

Table 1: Management recommendations to remove barriers or enhance drivers for the multi-use combination of fisheries and offshore wind farms

Type of intervention	Management recommendations
Policy framework improvements	1) Undertake multi-use opportunity mapping; encourage overlap between the two industries and demonstrate the potential benefits of co-existence.
	2) Provide financial incentives for the multi-use combination (e.g. via state subsidy contracts).
	3) Encourage innovation by reducing the scope of full-scale assessments for small-scale multi-use pilots.
Regulatory framework improvements	4) Further improvements in assessment methodologies as part of the environmental impact assessment and cumulative impact assessment processes.
	5) Draw up a mutually agreed co-existence plan between the two industries as part of the marine licencing process.
Good practice guidance	6) Develop good practice technical guidance on co-design of offshore wind farms to accommodate multiple uses, including commercial fisheries.
Empirical studies	7) Fund and/or encourage in situ gear trials and Research and Development projects (R&D).
Consultation and capacity building	8) Reinforce and formalise direct stakeholder dialogue to exchange best available information and technology on all aspects of the multi-use combination.
	9) Increase stakeholder's knowledge and financial capacity via educational resources and community funding, respectively.

Source: Adapted from Schupp et al. (2021)

4.4. Best practices for integrating offshore wind farms with spatial protection measures

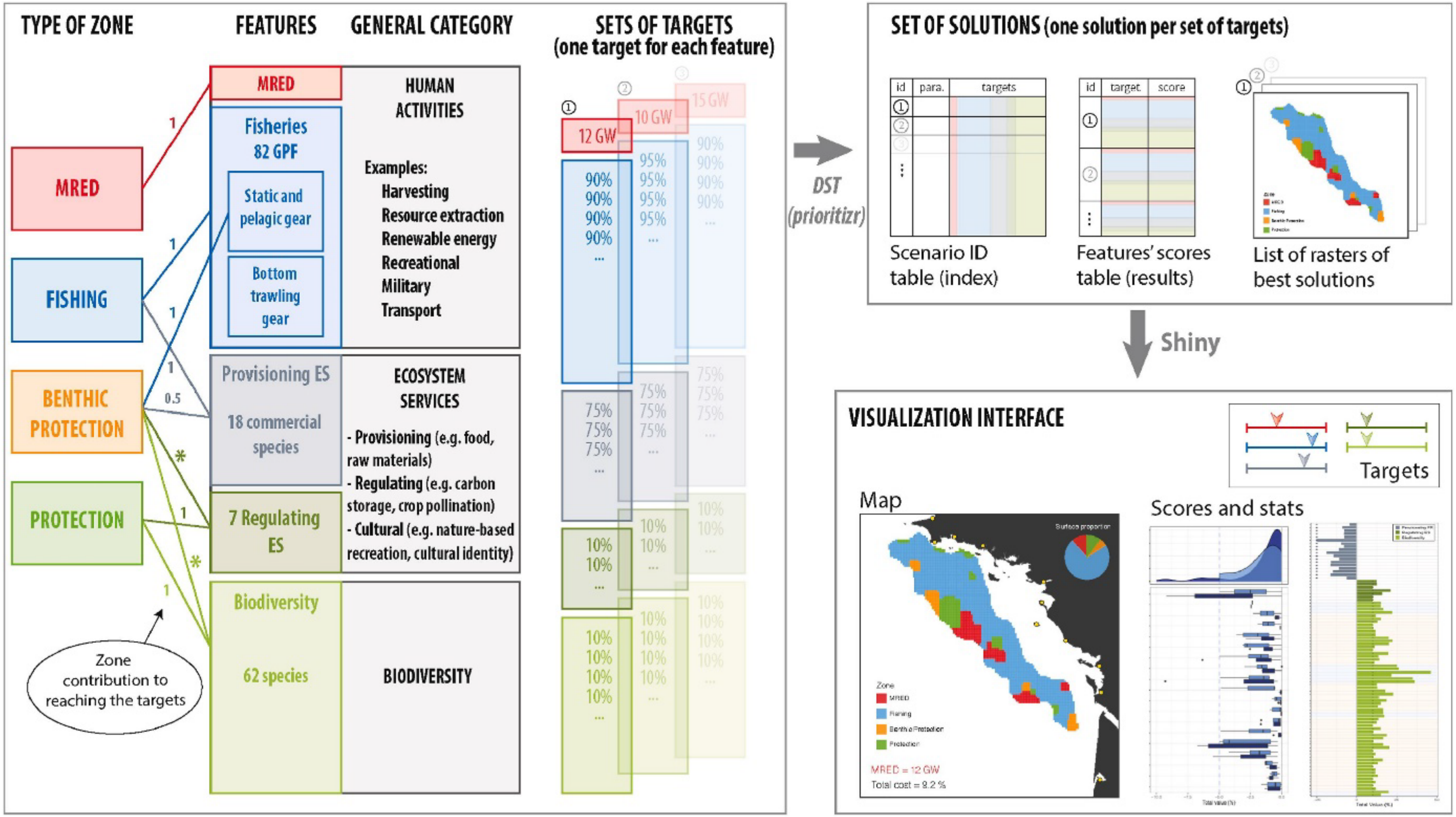
In order to integrate multi-use fishing and offshore wind farms with spatial protection measures, systematic planning needs to be implemented, in a transparent manner, and with equity in mind. Following the ecosystem services assessment and management recommendations (**Table 1**) detailed above could help build a decision support tool, aimed at designing scenarios that can be discussed and improved during stakeholder consolations.

Boussarie et al. (2023) have developed such a flexible spatial planning framework to prioritise protected areas and wind farms, including biodiversity and ecosystem services (**Figure 11**). Plying their framework in a case study in the Bay of Biscay, they demonstrate that equitable scenarios for fishers are not necessarily costlier and provide alternative spatial prioritisations.

4.5. Conclusions

It is tempting to exclude fishing activities from offshore wind farms and consider them as de facto MPAs. However, this requires a better understanding of the trade-offs between potential positive and negative impacts of offshore wind farms on marine biodiversity and whether fishing and renewables production should remain incompatible. Here, we have shown that the impact pathways of offshore wind farms on marine biodiversity are complex and often incompatible with conservation objectives. Thus, considering offshore wind farms as de facto marine protected areas, or including them in existing marine protected areas, does not seem realistic. Rather, offshore wind energy production and fishing multi-use could become the new standard for the European Union. While this would necessarily imply some local adaptations of the fishing sector and insurance companies, this would align with the EU Biodiversity Strategy for 2030 and the European Green Deal. To effectively integrate spatial protection with multi-use fishing and offshore wind farms, systematic and participatory planning approaches exist and should be mobilised.

Figure 11: Overview of the prioritisation framework developed by Boussarie et al. (2023)



Source: Boussarie et al. (2023)

Note: After defining the different types of zones and spatial layers constituting the features, sets of targets are chosen and used as input in the planning software prioritise to obtain a set of solutions. This set of solutions, constituted of an index table, a results table and a list of rasters containing the best solution for each set of targets, is then used in a Shiny app to modify on-demand the sliders corresponding to targets and visualise the results (map and associated scores and statistics). Stars indicate that the zone contributions to reaching the targets are variable depending on the feature.

5. MINIMISING THE INTERACTIONS WITH MARINE PROTECTED SPECIES

KEY FINDINGS

- Several **cetacean** subpopulations are considered **threatened or near threatened** in European waters.
- Global warming is inducing a **poleward shift of the distribution of most species**, accompanied with habitat reduction for some species and an increased competition for preys.
- Two species, the **harbour porpoise** (*Phocoena phocoena*) and the **common dolphin** (*Delphinus delphis*), are subject of **important level of bycatch** at the EU level, threatening the sustainability of their populations
- **Spatial measures** designed to avoid the overlap of fisheries and cetaceans are the only measures able to **eliminate the problem of bycatch**.
- **Technical measures** designed to limit accidental catch (acoustic deterrent, escape panels) are most of time **species-specific** and **do not avoid all bycatch**

5.1. Reproduction patterns and settlements of marine protected species

Thirteen of the European cetaceans' subspecies or subpopulations were recently confirmed as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Near Threatened (NT) by the IUCN. The situation could be even worse as many species' status remains unclear at the European level (for 12 over the 23 species assessed, the lack of data led to a Data Deficient (DD) status). Climate change may induce a new combination of threats that will have deep consequences on the survival rates of those cetaceans already threatened by overexploitation, habitat loss or human activity interactions.

Under the growing impacts of climate change, some species have already exhibited a poleward shift while others appear unaffected. These changes may benefit certain species, while others will be under extreme pressure induced by new combinations of possible threats, including ecosystem-level changes, increased inter-specific competition, genetic alterations and health challenges (**Figure 12**).

Figure 12: Trends in observed impacts of climate change on cetacean distribution, habitat and migration

Region	Species	Observed Impacts: maximum latitude	habitat availability	migration dates	time spent in high latitude	visual/acoustic detections	strandings	other
Arctic	Bowhead whale		↓					
	Narwhal		↓					
	Beluga		↓	↓		↑ ↓		
Subarctic	Humpback whale	↑		↑		↑		
	Fin whale	↑		↑		↑		
	Common minke whale	↑				↑		
	Blue whale	↑		↑				
	Sperm whale	↑						
	Killer whale					↑ ↓	↓	
	Grey whale			↓				
	North Pacific right whale							
	North Atlantic right whale					↑		
Other	Bryde's whale					↑		
	Humpback whale					↑		
	Fin whale					↑		
	Blue whale					↓		
	Antarctic minke whale							
	Killer whale						↓	
	Northern bottlenose whale						↓	
	Long-finned pilot whale						↓	
	Short-finned pilot whale							
	Sowerby's beaked whale						↓	
	White beaked dolphin						↓	
	Harbour porpoise						↑	
	Short beaked common dolphin	↑					↑	
	Common bottlenose dolphin							
	Cuvier's beaked whale							
	Striped dolphin							
	Pacific white-sided dolphin	↑	↓			↓		
	Northern right whale dolphin	↑	↓					
	Dall's porpoise	↑	↓					
	Atlantic spotted dolphin							
	Tropical/subtropical species						↑	

Source : van Weelden et al. (2021)

Note: Green with upward arrow signifies an increase (earlier regarding migration), red with downward arrow signifies decrease (later regarding migration), orange signifies no change and light blue signifies other changes with no clear trend.

Sea-surface temperature is an important marker of cetaceans' distribution: some species are exclusive to warm tropical waters, while others are present in temperate zones and some only exist at the poles. Sea water warming is therefore expected to influence the distribution of many sensitive species, the more mobile or adaptable cetaceans being expected to be able to respond to the changes: a shift northward of colder water species with an increase of thermophilic species to their expense and if migrating further North is not possible, a local extinction (see for example Chambault et al. 2020). The white-beaked dolphin (*Lagenorhynchus albirostris*), a cold-water species, is declining in abundance around UK waters shifting northwards away from the British Isles. In contrast, more short-beaked common dolphins and striped dolphins, warm-water species, have been seen farther into British waters (Evans 2020, Williamson 2021).

While relocating, warm-water cetaceans are expected to be more frequent or abundant in mid-latitudes. Species diversity will increase even if cold-water species follow their preferred sea-surface temperatures in higher latitudes. These changes in species composition may induce new intra and inter-specific competition for the resources between predators and fisheries that usually may have little spatial overlap, some out-competing others. In recent years, Humpback whales (*Megaptera novaeangliae*) and fin whales (*Balaenoptera physalus*) have increasingly been recorded in the North Sea including the southern part where they were previously vagrant (Berrow and Whooley, 2022). Increasing large whale populations in the North Sea will require a sufficient stock of small pelagic prey such as sand eels, sprat and herring, already targeted by fisheries.

With a general range shift, many species may be at risk from threats they are currently not facing or at a lower level, adding to the existing decline factors. Climate changes could also reinforce impacting human behaviours in some areas leading to conflict with cetaceans' survival, for example when climate change accelerates human-induced habitat degradation or loss. An increased occupancy of the coastal zone of the northern European seas will expose cetaceans to a more industrialised environment with a greater variety of human activities (pollution, marine traffic, fisheries, seismic exploration, offshore construction).

The opening of new routes thanks to sea ice melting could provide opportunities for migratory species to forage in arctic waters, with earlier arrival and later departure. Opening of the Artic Ocean between the North Pacific and the North Atlantic may led to the grey whale occurring again in the Atlantic after a gap of almost four hundred years (Evans 2020). Loss of sea ice in polar regions does provide opportunities for migratory species such as baleen whales to forage in arctic waters earlier and to remain later in the feeding season.

In counterpart, the increase in human activity and in land use of a warmer north (transport, agriculture, industries tourism, commercial fisheries) may cause physical risk (boat strikes, acoustic injuries, noise pollution, fisheries interactions), cause contamination of the coastal environment increasing cetaceans' injury and mortality. Harbour Porpoise (*Phocoena phocoena*) exhibit in the North Sea a longer calving interval, lower pregnancy rates, a higher incidence of severe lesions and higher pollutants burdens through PCBs, DDT, Hg and PBDEs[16] compared to areas with less human impacts (Nachtsheim et al. 2021).

Cetaceans typically require a large amount of patchy prey species so their distribution tends to reflect where prey productivity is higher. Most exploited and non-exploited fish have responded to the recent sea warming by shifting their mean latitude, depth, or both (see section 3.1). Changes in salinity and ocean acidification are also expected to impact marine biota negatively. The modification of the prey's

[16] PCBs = polychlorinated biphenyls, DDT = Dichlorodiphenyltrichloroethan, insecticide; Hg =:chemical element mercury; PBDEs = polybrominated diphenyl ethers

seasonal distribution and/or abundance will impact the foraging opportunities of cetaceans. Adaptation to climate-induced food changes is likely to vary from species to species. Some species may more easily adapt to changes, having more flexible diets enabling them to adjust to prey changes in distribution and composition. Redistribution of harbour porpoises (*Phocoena phocoena*) in the North Sea with a notable shift from the northwest to the southwest region likely due to the change in the distribution and availability of prey, such as sandeel (Nachtsheim 2021). Killer whales (Orcinus orca) regularly occur in the Northern North Sea and the Norwegian Sea. Changes in migration patterns and stock sizes of herring and mackerel almost certainly determined the movements of Killer whales between Norway, Iceland and Northern Scotland (Evans 2020). The critically endangered Strait of Gibraltar Killer Whales subpopulation has a highly specialised diet based on eastern Atlantic Bluefin Tuna, an endangered species and any decrease in its abundance puts the population at greater risk (IUCN).

By forcing populations to move to other grounds, climate change may induce new gene flow and create variability in previously genetically isolated populations enhancing species' ability to adapt to changes. Cetaceans with limited habitat ranges or diets, non-mobile species' populations, on the other hand, could become genetically isolated and have severe consequences for their genetic variability.

Climate change is expected also to affect cetaceans' health. Higher temperatures may stress organisms, increasing their susceptibility to some diseases. Warmer waters can increase pathogen development and spread infectious diseases into new areas. With arctic meltwater and increased rainfall events, higher rates of land-based runoff in downstream coastal areas are predicted, leading to a higher concentration of contaminants in aquatic environments. Ecotoxicity has potentially severe consequences on the reproductive organs, immune system and metabolism of cetaceans. The decline in health and body condition of marine mammals and reproductive changes will lead to population declines.

Migratory species are travelling between feeding and breeding areas, migration timing being set to maximise the exploitation of temporarily abundant prey resources. As prey adapt also to a warming planet, their life cycles could be altered and induce mismatches between their abundance and cetaceans. Unsuccessful fattening will affect their ability to undertake long migration and to endure the energetic demands associated with gestation, birth and nursing. Fewer calves will be born or survive the migration.

Since marine predators are critical for the management of prey populations, the disappearance of cetaceans from certain regions could also lead to major alterations in community structure and ecosystem function. At a smaller scale, the absence of various odontocetes may reduce the foraging opportunities of many marine birds, which rely on toothed whales to drive fish towards the surface while feeding (van Weelden et al. 2021).

5.2. The cohabitation of protection of marine species and fishing activities

Four types of interactions between cetaceans and fishing activities have been described in the scientific literature: disturbance, depredation, collisions and accidental catch.

Disturbance: mobile demersal fishing gears (bottom trawl, dredge) may be responsible for underwater noise pollution above cetacean damage thresholds, affecting the effectiveness of echolocation (Daly & White 2021).

Depredation: depredation by cetaceans – when they partially or completely remove catches from fishing gear – is a growing cause for concern in several European fisheries. In the Mediterranean and the Black Sea, interactions between cetaceans and fisheries involve mainly coastal fisheries and species such as common bottlenose dolphins (*Tursiops 42odelling*), which are typically found on the continental shelf, common dolphins (*Delphinus delphis*), and the harbour porpoise (*Phocoena phocoena relicta*) (Gonzalvo and Carpentieri 2023). Interactions between EU-flagged tropical tuna longliners and cetacean involve short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*) (Rabearisoa et al. 2018).

Collisions: Collisions between sips and cetacean are complex to monitor as some of them happen without the crew's knowledge. They concern all vessels operating at sea: fishing vessels, freight cargos and passenger transports. Very limited information regarding the impact of collisions (Schoeman et al. 2020)

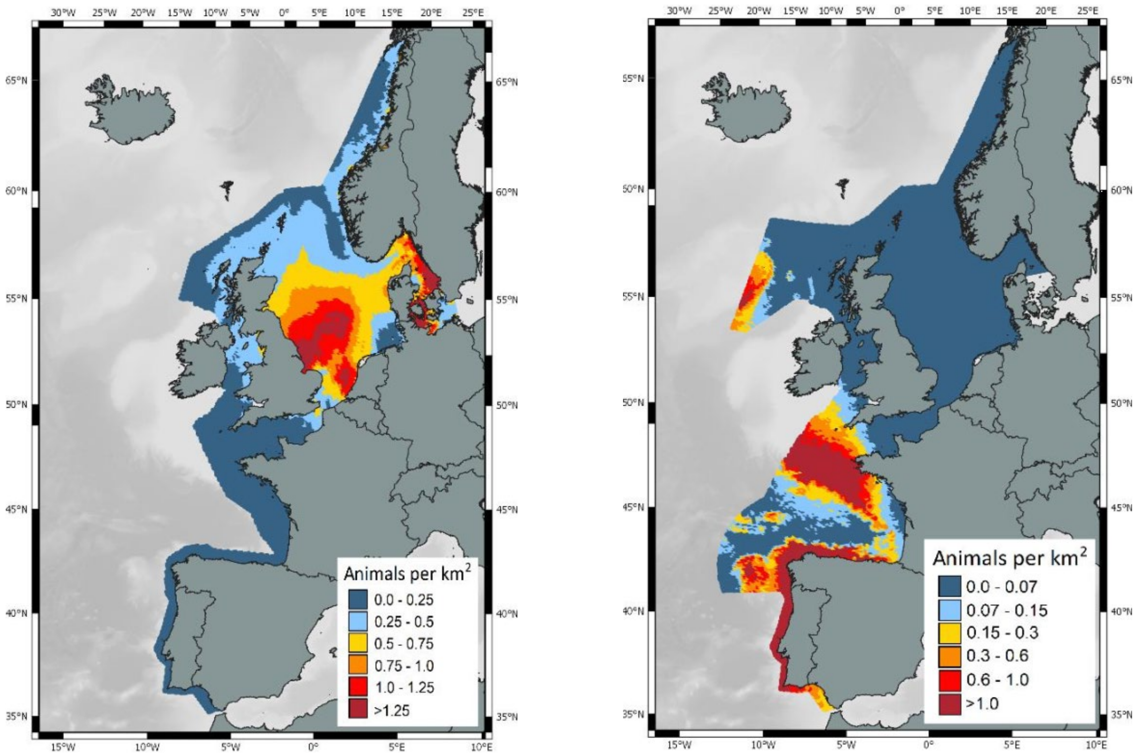
Accidental catch: Accidentally catching cetaceans is a worldwide threat involving many kinds of fishing activities, from coastal article fisheries to industrial operations, with different used gears and target species. (Leaper and Calderan 2017). Except in cases where fishers notice rapidly having caught a cetacean, the outcome is usually lethal for the cetacean due to drowning.

Overall, accidental catch is the most problematic interaction from a marine biodiversity perspective due to its lethality for cetaceans. Accidental catch in trawl, purse seine, longline, gillnet and pot/trap fisheries has been identified as a major threat to many species. Other gear types, such as those used in troll and squid jigging fisheries, are considered to be more selective in targeting species and, therefore, have less bycatch risk.

The two species at high risk of accidental catch in EU waters are the harbour porpoise (*Phocoena phocoena*) and the common dolphins (*Delphinus delphis*). In North East Atlantic the main concentrations of harbour porpoises are currently observed in the North Sea and the Baltic Sea, while high concentrations of common dolphins are found in the Bay of Biscay, the Celtic Sea and around the Iberian Peninsula (**Figure 13** and Lacey et al. 2022).

Accidental catch is however difficult to observe as fishers tend not to report it, and only the presence of on-board observers has permitted them to get better knowledge. Fear of retaliation is a strong motive for fishers not to report the incidents, lowering the ability to fully understand the extent of the issue (Cazé et al. 2022). In addition, several Member States in the EU allow recreational gillnet fishing, with the provision that catch is used only for subsistence and not sold. These fisheries are generally conducted close to shore and with limitations on net lengths. These recreational fisheries constitute a large but unquantified amount of fishing effort and an additional source of unmonitored bycatch, particularly for harbour porpoises, which inhabit nearshore habitats (Rogan et al. 2021).

Figure 13: Predicted surfaces of estimated density for harbour porpoise [left] and common dolphin [left] in SCANS-III (2016) [top]



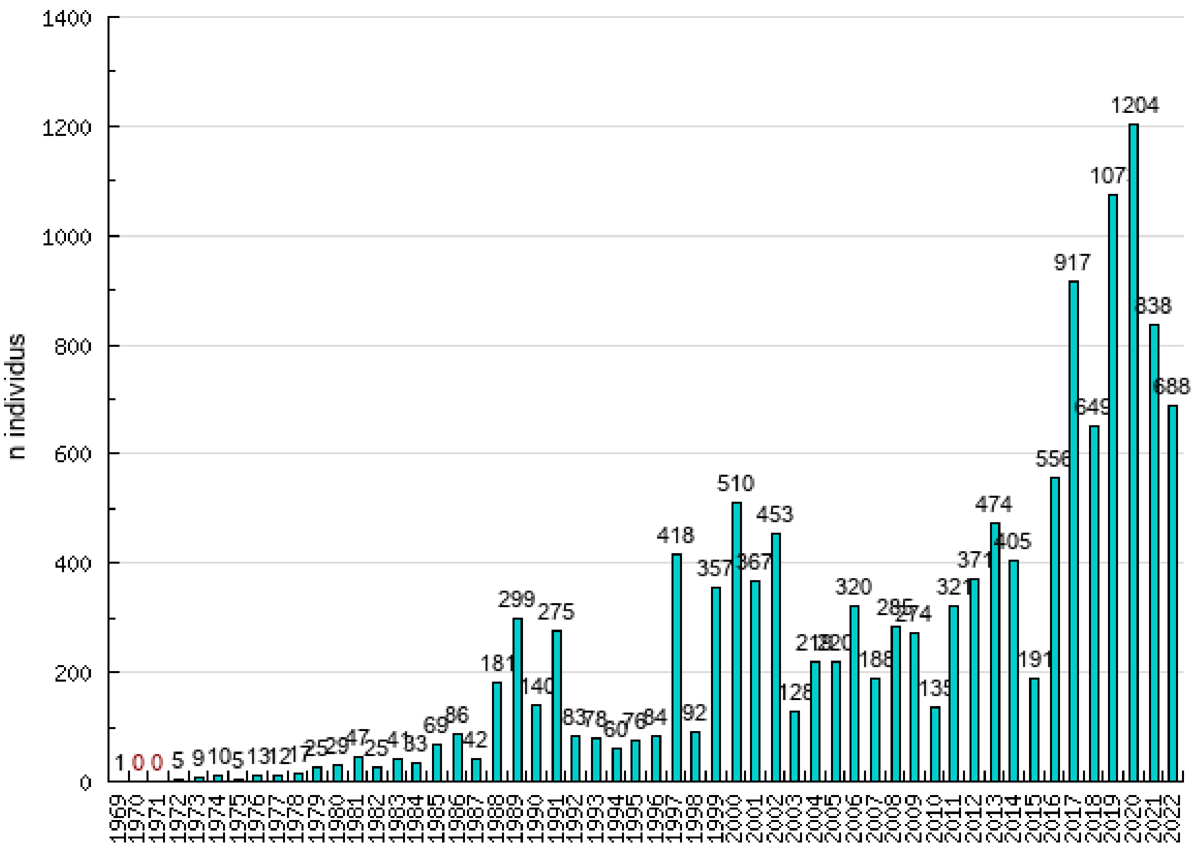
Source: Lacey et al. (2022)

Estimations of the level of accidental catch are mainly derived from observing stranded animals. Peltier et al. (2019) studied stranded dolphins in the Bay of Biscay, showing that most of the animals autopsied had traces of fishing gear. However, stranded animals only represent a fraction of the bycatch as most dead cetaceans are expected never to reach the shore. Reports on stranding have continuously increased in the last 20 years (**Figure 14**), despite the implementation of conservation measures in EU waters. EU Regulation 812/2004[17] laid out two approaches to address the bycatch of cetaceans in fisheries: a requirement to use acoustic deterrent devices in certain gill net fisheries, but only on vessels of 12 m in length or greater; and a requirement for independent observers to monitor bycatch in other fisheries, but only on vessels longer than 15 m (ICES, 2019). These measures are now part of the Technical Conservation Measures Regulation[18]. According to information from the Observatory Pelagis, more than 1 400 strandings were observed between January and April 2023, surpassing any records by far, indicating that the situation is becoming critical.

[17] Council Regulation (EC) No 812/2004 of 26.4.2004 laying down measures concerning incidental catches of cetaceans in fisheries and amending Regulation (EC) No 88/98

[18] Regulation (EU) 2019/1241 of the European Parliament and of the Council of 20 June 2019 on the conservation of fisheries resources and the protection of marine ecosystems through technical measures, amending Council Regulations (EC) No 1967/2006, (EC) No 1224/2009 and Regulations (EU) No 1380/2013, (EU) 2016/1139, (EU) 2018/973, (EU) 2019/472 and (EU) 2019/1022 of the European Parliament and of the Council, and repealing Council Regulations (EC) No 894/97, (EC) No 850/98, (EC) No 2549/2000, (EC) No 254/2002, (EC) No 812/2004 and (EC) No 2187/2005

Figure 14: Stranding of Short-beaked common dolphin (*Delphinus delphis*) along the Atlantic coast of France between 1969 and 2022



Source: Observatoire Pelagis (2023)[19]

In 2020, it was estimated that more than 7 000 harbour porpoises died due to bycatch in the areas assessed by the OSPAR Commission. Thresholds were estimated to have been exceeded in all assessment units (Greater North Sea, Western Scotland and Ireland, Irish and Celtic Seas, Iberian Peninsula). In the same year, an estimated 6 400 common dolphins were accidentally caught in the North-East Atlantic, exceeding the threshold for this single assessment unit (Taylor et al. 2022). For both species, these levels of lethality are too high for the population to remain sustainable.

On 2 July 2020, the European Commission issued letters of formal notice to Sweden, Spain and France for failing to correctly transpose the obligations related to the Habitats Directive regarding the establishment of a coherent monitoring scheme of cetacean bycatch and the subsequent taking of conservation measures. In parallel, the Commission requested ICES to provide a list of emergency measures to prevent the bycatch of common dolphin (*Delphinus delphis*) and Baltic Proper harbour porpoise (*Phocoena phocoena*) in the Northeast Atlantic (ICES 2020).

On 15 July 2022, considering that France and Spain had not taken the necessary measures since their letter of formal notice, the European Commission sent them a reasoned opinion requesting that the two countries take the necessary measures to "*prevent the incidental catch of dolphins and other protected species*" within two months (European Commission, 2022).

[19] Réseau National Echouages, Histogrammes & Cartes d'Echouages

5.3. Best practices and lessons learnt

5.3.1. A generic framework for assessing and managing bycatch of protected species

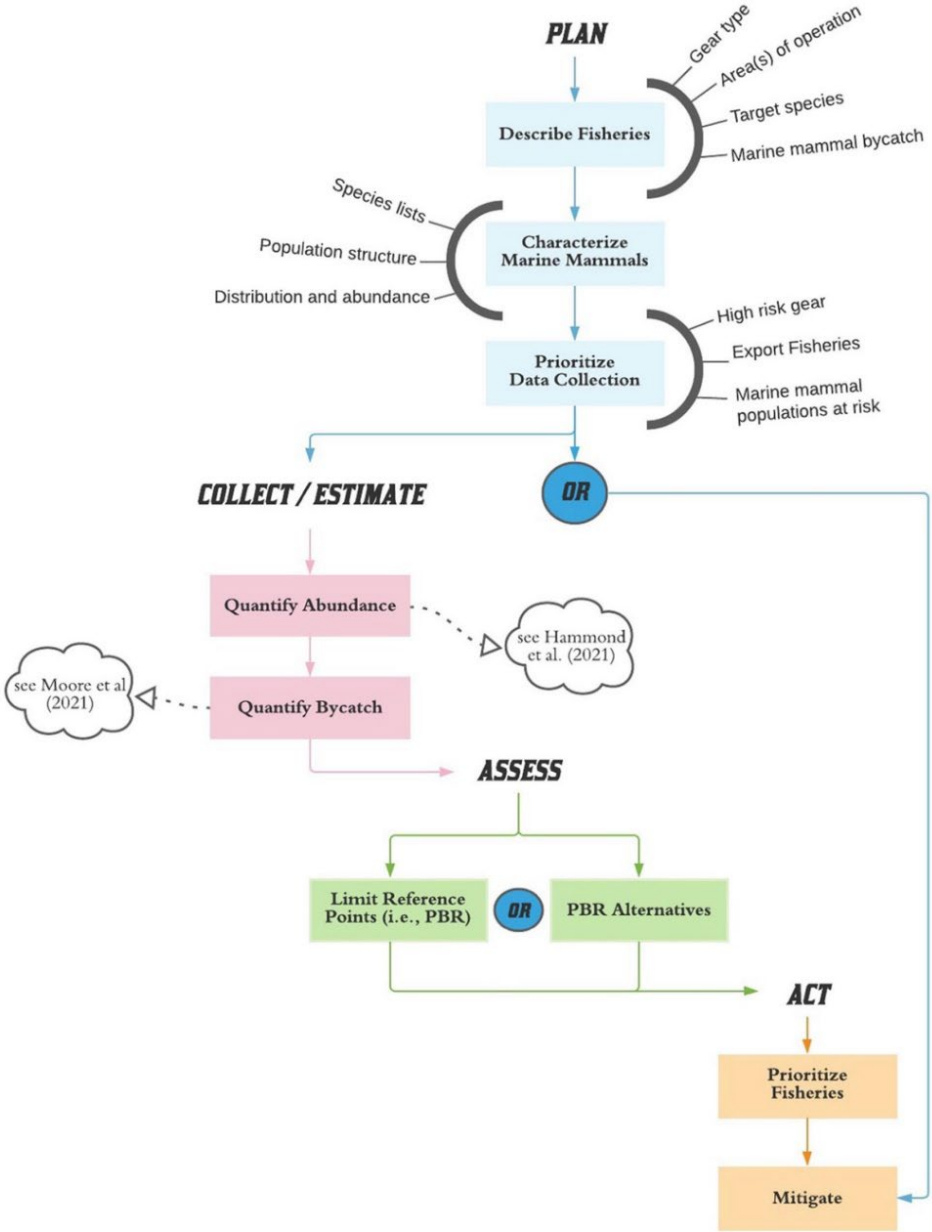
Wade et al. (2021) have described a generic framework to assess and manage bycatch of marine mammals, describing all the steps required to define adaptation and mitigation measures to lower bycatch levels. Such framework could in fact be implemented to define management measures to avoid the accidental catch of any protected species (cetaceans, seals, birds). Building on the idea that using reference points to evaluate bycatch levels is the method requiring the least amount of data compared to other methods, the framework consists of four main steps: (1) planning for an assessment of bycatch, (2) collecting appropriate data (e.g. abundance and bycatch estimates), (3) conducting the assessment of bycatch by calculating a reference point, and (4) using the results of the assessment to guide protected species bycatch reduction (**Figure 15**).

Collecting appropriate data is one of the critical steps for this framework to be fully implemented. Wade et al. (2021) insist notably on the survey design to ensure that fishing in all spatial areas or seasons is sampled. Amongst the best practices in sampling designs, it is common to sample at higher rates in areas with the greatest amount of fishing effort or in areas that are suspected or known to have the highest rate of marine mammal bycatch.

Some observer programmes currently implemented in Europe do not match these requirements. For example, Peltier et al. (2021) note that an observer programme dedicated to marine mammal bycatch was implemented in France from 2005 until 2009. It was then merged with an at-sea observer programme the Data Collection Framework. Designed to collect information on commercial catch, this revised observer programme was no longer dedicated to cetacean bycatch. It was less likely to assess the extent and magnitude of the issue. Within the framework of the EU DCF (Data collection framework), fishing operations are classified into métiers according to their target species, gear used, fishing season and fishing. Of these métiers, those considered to pose the greatest risk of cetacean bycatch are generally under-sampled by general observer programmes, leading to underestimating cetacean bycatch.

Two main biases were identified in non-dedicated fishery bycatch observation programmes with low enforcement: (1) the deployment effect that results from skippers' discretion to accept an observer on board, which produces non-random sampling and non-representative data and (2) the observer effect, i.e. a change in fishing practices when an observer is present, which also results in the collection of non-representative data (Peltier et al. 2021).

Figure 15: A flow chart illustrating the process for assessing and managing bycatch of marine mammals



Source: Wade et al. (2021)

5.3.2. Managing bycatch of marine protected species

There are three, semi-hierarchical categories of approaches generally considered for addressing cetacean depredation and bycatch (Fader et al. 2021 and **Table 2**):

(1) reducing the spatiotemporal overlap between cetaceans and fishing operations to minimise encounters;

(2) deterring cetacean from the gear or reducing their ability to perceive, locate, or access bait or catch, for example by disrupting the echolocation abilities of cetaceans or deploying protective sleeves around captured fish; and

(3) reducing the probability of injury and mortality despite becoming hooked or entangled, for example with weak terminal gear or hooks that allow cetaceans to break free but retain target catch.

Table 2: Outline of the hierarchical categories of bycatch mitigation solutions available to fisheries affected by depredation and bycatch

Category 1: Reduce spatiotemporal overlap a priori (e.g. time-area closures, dynamic ocean management)	
Strengths: 'Win-win' if depredation/bycatch is avoided and minimal impact on fishery profitability; low up-front costs; straightforward enforcement	Challenges: Habitats of target species and whales often overlap; likely costs to fishery (e.g. reduced fishing effort of fishing in sub-optimal areas)
If cannot avoid overlap …	
Category 2: Reduce likelihood of gear contact and bycatch (e.g. acoustic deterrence, catch protection, operational changes, move-on rules)	
Strengths: May address depredation and bycatch; fishers may continue fishing in high Catch per Unit of Effort (CPUE) areas; ideally minimal changes to fishing operations	Challenges: Habituation or learning may reduce effectiveness; often logistically challenging; potential harm to animals; potentially large up-front costs
If cannot avoid bycatch…	
Category 3: Reduce injury or mortality of bycaught animal (e.g. weak hooks, handling guidelines)	
Strengths: Potential for reducing bycatch without impacts on target catch operations; low costs after initial investment	Challenges: Up-front costs to change gear; reluctance of fishers to implement; does not reduce depredation; may require high observer coverage

Source: adapted from Fader et al. (2021)

Reduce spatiotemporal overlap a priori

Avoiding overlap between protected species and fishing operations while maintaining target catch rates and fishery profitability is ideal (i.e. *Category 1* in **Table 2**). Identifying the ecological drivers of co-occurrence between cetaceans and target species could allow fishers to avoid overlap and subsequent interactions. This "*dynamic ocean management*" has been suggested to reduce negative human-wildlife interactions, such as the bycatch of sea turtles and ship strikes of migrating baleen whales. Applied to fisheries, this would lead to area closures, as there are no technological solutions to identify the locations of cetaceans in real time. This may also lead to sub-optimal situations for the affected fishing fleets, as these closures would require fishing effort to relocate to sub-optimal areas with reduced bycatch and depredation rates and lower catch rates of target species (Fader et al. 2021). There are however situations where the entire area should be closed if such measure should apply: in the case of common dolphin in the Bay of Biscay, because of the lack of precise data on bycatch, it is not possible to assess which part of the area is more prone to encounters, leading to an ad-hoc ICES Working Group to explore the closure of the entire subarea 8. (ICES 2020).

Reducing this spatial overlap may also consist in changing the gear used while staying in the area. By using a gear with lower risk, fishing vessels may remain active in the area while generating far less encounters with cetaceans. This would for example consist in switching from gillnet to pots or longline during the peak season of overlap. This gear switch could however only be possible if deploying the new gear is a profitable activity for fishing vessels. If not, closing an area would have important economic consequences either by stopping entirely several fishing vessels, or by displacing the effort they generate outside of the closed area. In the case of the common dolphin in the Bay of Biscay, the socio-economic implications of an area closure would be complex to evaluate, as vessels would potentially need to access other quotas to fish outside the subarea 8.

Reduce likelihood of gear contact and bycatch
When broad-scale avoidance of depredators is not possible, the next logical strategy is to reduce the probability of gear contact and bycatch by deterring depredators, limiting their ability to detect or access catch, or altering fishing operations to limit contact (*Category 2* in **Table 2**).

Most passive deterrents (nets with enhanced acoustic reflectivity, spherical beads attached to longlines) tested have proven to be only partially effective on cetaceans, as the animals likely quickly habituate and may even be attracted to the presence of deterrents that notify them of the location of catch. Active deterrents such as pingers are facing the same drawback. Strategies to disrupt echolocation abilities or otherwise mask detection of gear can similarly be susceptible to learning and habituation.

Other avoidance strategies involve operational changes to limit opportunities for interaction, such as fishers leaving areas of known depredation, a strategy formally known as "*move-on rules*". This kind of strategy is only effective if fishers can identify the presence of cetaceans in the vicinity of their fishing operation, which is not always possible, notably in gillnet fisheries. In some cases, it has been established that cetaceans are attracted by the sound of fishing vessels deploying or retrieving their fishing gear, which adds to the challenge of avoiding them.

A new type of active acoustic deterrent is currently tested with better prospects as it builds on cetacean communications. The deterrent is passive until it receives an echolocation signal to which it responds by species-specific information. In the Baltic, the Porpoise Alerting Devices, which are playback of predator sounds are significantly reducing the level of bycatch (Chladek et al. 2020). In the Bay of Biscay, the DolphinFree beacon is emitting an understandable and interpretable signal to alert them to the presence of the net and the associated risk of mortality[20]. First results of the DolphinFree beacon are also promising with a high level of bycatch reduction for gillnets and trawls.

Reduce injury or mortality of bycaught animal
If avoiding depredators or minimising contact with gear is not possible, modifying the terminal gear to release hooked animals or facilitating the shedding of entangled gear may be the only option to mitigate bycatch impacts (*Category 3* in **Table 2**).

This category concentrates all gear modification strategies: exclusion grids on trawls, excluding devices on gillnets, longlines modifications, vertical lines reduction, sinking groundlines, ropeless traps/ pots/ shielding of target catch with umbrella stones devices or the use of weakened gears: weak hooks and circle hooks, weak ropes.

Some of these strategies have been successful, such as the weak hooks to limit the bycatch of cetaceans in longline fisheries targeting tropical tuna. Excluding grids on trawls have shown however mitigated

[20] Observatoire Pelagis, Project DolphinFREE

results over the years as their implementation on board fishing vessels had technical and operational complexity. To date, there is no weakened solutions available for gillnets.

5.4. Conclusions

Climate change is adversely affecting most cetacean species by adding more pressure on their habitat or by increasing the level of threats, they directly face (competition for preys, diseases).

Several Interactions with fishing operations are placing some cetacean species at risk of high level of human-derived mortality, notably when cetacean approach fishing gears in operation. Information on bycatch is however scarce due to a lack of direct third-party observation, which hinders the ability to know the exact extent of the problem both in terms of mortality level and spatiotemporal distribution of the encounters.

Strategies to avoid these bycatches have been defined by several groups, but they tend all to reduce to three key strategies: avoidance, deterrence, and gear modifications. Avoidance is by far the most effective option but with a potentially high socio-economic impact on the fishing vessels involved in the fishery. Deterrence has been mildly successful, although new systems building on bio-inspired solutions can potentially limit the level of bycatch in high risk fisheries, but have to prove their efficacy at sea basin level. Gear modifications are still to be explored to be fully available for European fisheries.

6. POLICY RECOMMENDATIONS

The following recommendations are set out:

Regarding the development of **offshore wind farms** and **spatial protection measures**

1) **Reinforce the coordination** between Member States to develop coherent **marine spatial plans**, avoiding discontinuity between Member States. This is notably important for the development of a coherent network of marine protected areas.
2) Recognise that **industrial activities** are **not compatible** with **marine biodiversity conservation**.
3) **Support research** to elicit the **preferences in the use of marine space**, to better define the place of each industry. This could be achieved at sea basin level to reinforce coordination between Member States.
4) Develop research to assess the **cumulative effects due to multiple offshore wind farms on marine biodiversity**: disruption of migration corridors, effect on local atmospheric conditions (wind, temperature), but also **on the fishing industry**: fishing assemblages, target species, fishing behaviour, the characteristics of the lost fishing opportunities and the varying characteristics of the different offshore.
5) **Support research** to identify key features at the sea basin level to avoid disruptions between **marine protected areas** due to **offshore developments** (wind energy notably).
6) To effectively **integrate spatial protection** with **multi-use fishing, aquaculture** and **offshore wind farms**, embrace systematic and participatory planning approaches.
7) **Develop support measures** for the fishing industry to be able to access **insurance policies** allowing them to **fish inside offshore wind farms** under conditions.

Regarding the interactions of **fishing activities** and **protected species**:

8) **Reinforce all direct observation programmes** that are essential to estimate the cetacean populations, to allow population evaluations on a more frequent basis.
9) **Improve the EU-DCMAP** (Data collection multi-annual plans) to impose better sampling of segments at **risk of bycatch of protected species** (cetaceans, turtles and sea birds).
10) **Support research** in remote **electronic monitoring systems** to improve the information about **bycatch of protected species**.
11) **Support research** in identifying **new deterrent and avoidance techniques**, as most of them are species and gear specific.
12) **Raise awareness** of the importance for fishers to **report bycatch of protected species** to improve the quality of the data available to assess scientifically the population levels and help understand the factors explaining these bycatch.
13) Providing **adequate training** to fishers to:
    a) **use all mitigation measures** that can be deployed on their gear **to minimise the bycatch of protected species**;
    b) **handle properly protected species in the eventuality of a bycatch**, to maximise the chances of survival after release.

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This study is the second in a series of three research papers, prepared for a PECH Committee Workshop. It examines the marine biodiversity aspects of the European Green Deal. It explores the challenges and opportunities for the EU fisheries and aquaculture sectors. The present research contains two case studies: the potential cohabitation between offshore wind farms, marine protected areas and fishing activities and the interactions between fishing and marine protected species.

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