MAPPING OF MARINE PROTECTED AREAS AND THEIR ASSOCIATED FISHING ACTIVITIES (MAPAFISH)

Baltic and North Seas, Atlantic EU Western Waters and Outermost Regions

Final Report

European Maritime, Aquaculture and Fisheries Fund (EMFAF)

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LIST OF ABBREVIATIONS

Term	Description
AIC	Akaike Information Criterion
AIS	Automatic Identification System
ANOVA	Analysis of Variance
API	Application Programming Interface
BACI	Before-After-Control-Impact
CBD	Convention on Biological Diversity
CDDA	Common Database on Designated Areas
CINEA	European Climate, Infrastructure and Environment Executive Agency
CFP	Common Fisheries Policy
CO_2	Carbon Dioxide
CS	Case Study
C-square	Concise Spatial Query and Representation System
DG MARE	Directorate-General for Maritime Affairs and Fisheries
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
EU	European Union
EUNIS	European Nature Information Systems
FG	Focus Group
GBF	Global Biodiversity Framework
ICES	International Council for the Exploration of the Sea
IUCN	International Union for the Conservation of Nature
kWd	Kilowatt day
LPUE	Landings-Per-Unit-Effort
MPA	Marine Protected Area
MS	Member State
MSC	Marine Stewardship Council
MSFD	Marine Strategy Framework Directive
MSP	Marine Spatial Plan
MSPD	Maritime Spatial Planning Directive
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
OECM	Other Effective Area-based Conservation Measures
PELT	Pruned Exact Linear Time
SAC	Special Area of Conservation
SCI	Sites of Community Importance
SPA	Special Protection Area
VMS	Vessel Monitoring System
WGVHES	Working Group on the Value of Coastal Habitats for Exploited Species

ABSTRACT

The European Union (EU) Biodiversity Strategy for 2030 sets the target for protected areas in the EU at 30% of its sea area, one third of which needs to be strictly protected. While there is growing interest in studying the progress of ocean protection, there is a need for an overview of the status of marine protected areas (MPAs) and associated fishing activities in EU waters. This study identifies and characterises fishing activities within and surrounding more than 800 MPAs, and quantitatively assesses them to determine which fishing activities are compatible with MPA conservation objectives. Findings reveal that most MPAs allow some level of commercial or recreational exploitation of fisheries, which can include a range of fishing activities. Fishing activities are not necessarily incompatible with MPA conservation objectives, but this depends on the objectives and the type of fishing activity within MPAs. Using a case study approach, this study examines in more detail the spatial reallocation of fishing activities in response to MPA implementation in eight Member States, while also gathering and describing the perception of relevant stakeholders. The case studies demonstrate that MPA designation and implementation did not bring about any change in fishing behaviour. Changes in fisher behaviour, including fishing effort and landings, were evident only after specific fisheries regulations were put in place. Overall, all this information brought together within a single database, helps to improve the understanding of fishing activities in EU MPAs, while also providing the basis to inform future policy discussions. This work concludes that MPAs in the EU have not been established for fisheries management, but predominantly as a biodiversity conservation tool. The development of MPAs as a fisheries management tool will need to further consider and understand the broader impacts of no-take MPAs and fishing activities on marine ecosystems and include stakeholder involvement at all stages of the planning, designation, and implementation of the MPA. Overcoming the limitations of existing MPAs to address fisheries challenges must entail the designation of MPAs with management plans that are categorically built around conservation objectives that lead to fisheries sustainability.

RÉSUMÉ

La Stratégie de l'Union européenne (UE) en faveur de la biodiversité à l'horizon 2030 fixe l'objectif des zones protégées dans l'UE à 30 % de sa superficie maritime, dont un tiers doit être strictement protégé. Alors que l'intérêt pour l'étude des progrès de la protection des océans augmente, il est nécessaire d'avoir une vue d'ensemble sur l'état des aires marines protégées (AMP) et des activités de pêche associées dans les eaux de l'UE. Cette étude identifie et caractérise les activités de pêche à l'intérieur et autour de plus de 800 AMP, et les évalue quantitativement pour déterminer quelles activités de pêche sont compatibles avec les objectifs de conservation des AMP. Les résultats révèlent que la plupart des AMP autorisent un certain niveau d'exploitation commerciale ou récréative des pêches, qui peut inclure diverses activités de pêche. Les activités de pêche ne sont pas nécessairement incompatibles avec les objectifs de conservation des AMP, mais cela dépend des objectifs et du type d'activité de pêche au sein des AMP. En utilisant une approche par étude de cas, cette étude examine plus en détail la réallocation spatiale des activités de pêche en réponse à la mise en œuvre des AMP dans huit États membres, tout en recueillant et décrivant la perception des parties prenantes concernées. Les études de cas démontrent que la désignation et la mise en œuvre des AMP n'ont pas entraîné de changement dans les comportements de pêche. Les changements dans le comportement des pêcheurs, y compris l'effort de pêche et les débarquements, n'ont été observés qu'après la mise en place de réglementations spécifiques aux pêches. Dans l'ensemble, toutes ces informations réunies dans une base de données unique contribuent à une meilleure compréhension des activités de pêche dans les AMP de l'UE, tout en fournissant une base pour éclairer les discussions politiques futures. Ce travail conclut que les AMP dans l'UE n'ont pas été créées pour la gestion des pêches, mais principalement comme un outil de conservation de la biodiversité. Le développement des AMP en tant qu'outil de gestion des pêches devra prendre davantage en compte et comprendre les impacts plus larges des zones de non-prélèvement et des activités de pêche sur les écosystèmes marins, et inclure la participation des parties prenantes à toutes les étapes de la planification, de la désignation et de la mise en œuvre des AMP. Surmonter les limites des AMP existantes pour relever les défis liés aux pêches doit passer par la désignation de AMP avec des plans de gestion construits autour d'objectifs de conservation qui conduisent à la durabilité des pêches.

EXECUTIVE SUMMARY

The European Union (EU) Biodiversity Strategy is calling by 2030 to legally protect and effectively manage at least 30% of the surface area of the EU's marine waters, with at least one third of that area under strict protection. The strategy promotes a larger and well-connected EU-wide network of marine protected areas (MPAs) with effective fisheries–management measures. MPAs have been established to address many of the anthropogenic threats facing our seas. They are often promoted from a biodiversity conservation angle, but less from a fisheries perspective. In this context, this study responds to the need to better understand how MPAs can work in the context of fisheries. Looking at the status of MPAs and the associated fishing activities can provide support to stakeholders involved in the possible expansion of fishery management actions within MPAs in EU waters.

The overall goal of the MAPAFISH study was to collate existing and new information **to characterize MPAs and their associated fishing activities in the EU** (North Sea, Baltic Sea, Western Waters of the Atlantic including Macaronesia). More specifically, it provides an in-depth understanding of the distribution, spatial extent, structure and function of EU MPAs, the fishing activities undertaken within and surrounding such MPAs, and the challenges and opportunities for further implementing protection measures for MPAs. To achieve this goal, this study combines a large-scale assessment by collecting information on a wide number of MPAs and related fishing activities; and a case study approach focusing on a set of selected MPAs in which in-depth information has been gathered and analysed.

In this study, several **major areas were examined**. A first area of study included a description of the existing MPAs and their associated features. This was based on collating a range of elements that describe each MPA and that are known to determine the success of each MPA for both biodiversity conservation and fisheries. A second area of study investigated the fishing activities that occur throughout the MPAs, by characterising fishing activities within MPAs and surrounding areas and assessing the extent to which such fishing activities were compatible with identified MPA conservation objectives. To better understand the potential spatial redistribution (displacement) of fishing activities in response to MPA implementation, a third area of study consisted of an in-depth assessment of nine MPA case studies throughout the EU in eight Member States. Further, as part of the third study area, a conceptual model was developed to assess the potential effects of MPAs on the reallocation of fishing effort inside and outside the MPAs, allowing users to define various scenarios and identifying the potential outcomes associated with a particular MPA and its rules. A fourth area of the study examined the perceptions of different stakeholder groups to better understand the effects of fishery displacement from their perspective, and importantly the use of MPAs as a fisheries management tool. Finally, the study provides a synthesis of the key features of EU MPAs, and how to determine possible success, a discussion on the fishing activities and associated measures, and the challenges and opportunities in the designation and implementation of MPAs. The study concludes with several lessons learnt to foster the beneficial role of MPAs as fisheries management tools.

Data and information on MPAs were primarily collated from two existing MPA databases (Common Database on Designated Areas [CDDA] and Natura 2000). These were completed with questions related to 79 features and divided in different themes (notably MPA protection levels, fisheries data and activities, management and restrictions, stakeholder engagement, conservations goals and measures). To ensure all MPAs selected for further analysis were relevant to the objectives of the study, two important criteria were used: total surface area greater than 5 km^2 and where the marine share was greater than 95%. A second filtering step was then adopted with other criteria such as removing double counted records, areas in estuarine waters and those out of geographic scope. The selected records were included in a single **MAPAFISH database** developed within this study, with a **total of 819 MPAs investigated**.

The **first area of study** examined the MAPAFISH database and provided a detailed description of the key features structuring EU MPAs, the range of management processes, as well as the types of fishing activity and fishery measures. Because of the heterogeneity of the features structuring the MPAs investigated across the regions, **our results have not enabled us to define a set of 'common' features to explain the success of an MPA**, and therefore no description of how an 'average' MPA is structured in the EU is given. However, **in designation and implementation of MPAs, better outcomes are more likely with high stakeholder engagement and further representation of fishers in MPA management boards.** In this respect, despite a large set of EU MPAs (52%) being actively managed (i.e. management is ongoing, including monitoring and periodic review), this is largely by public administration. In addition, nearly half of MPAs (43%) does not have an MPA operational management body. Stakeholder involvement is an important tool but is underutilised in managing the MPAs.

Across the EU, MPAs have not been employed as fisheries management instruments but are predominantly a tool to protect habitats, species (notably seabirds) and other ecosystem components. The effect on fisheries (either recreational or commercial, from small-scale to large-scale) depends on the conservation objectives for the MPA. Indeed, the key objective of the MPAs is rarely to increase conservation of commercial species, but to conserve biodiversity which could indirectly benefit fisheries. In this respect, EU MPAs are rarely used to forge long-term sustainability of fisheries.

Across the EU, the majority of MPAs investigated have a management plan (62%) and defined conservation objectives (89%), though there is a substantial lack of reporting to show if such objectives are met (84.5%). Currently, seabirds are the primary ecosystem component recorded as part of the MPA conservation objectives, followed by marine mammals, and physical habitats and benthos. For the majority of MPAs, fisheries data have not been used in the planning and designation but may be used in the implementation of the MPA. Where fisheries data have been used, this is largely based on commercial fishing data from vessels equipped with vessel monitoring systems (VMS), which may reduce the input of small-scale and recreational fisheries data in such processes.

For the majority of MPAs, restrictions are mainly built as spatio-temporal measures. Further to this, the majority (59%) of the MPAs is classified under the International Union for the Conservation of Nature as 'habitat/species management areas'. Fisheries that comply with the conservation objectives for MPAs continue to operate within them. In this respect, **the majority of MPAs in the EU allow some level of exploitation by fisheries, which can include a range of recreational and commercial fishing activities.** The most common of these include low impact gears such as nets, pots, and hooks and lines. Trawling (demersal and pelagic) takes place in around 25% of MPAs, with seines in 20% and dredges in 17%. Nevertheless, there are clear regional differences in the type of fishing activities, with bottom-trawling-based fishing types dominating in the Greater North Sea, and passive fishing (nets, pots, hooks and lines) dominating in Macaronesia and the Baltic Sea. **Around half (50.5%) of the investigated MPAs has no fisheries restrictions in place**.

Most MPAs in the EU (83%) are minimally or lightly protected, while 11% are highly protected. Only **0.5% of MPAs are fully protected, with no extractive or destructive activities allowed**. Hence, no-take areas are still rare in EU MPAs. Nevertheless, many MPAs impose varied levels of restriction, with spatially explicit restrictions (27% of MPAs) being the most common (e.g. spatially localised gear restrictions or spatial zoning of the fleet). Such zoning, whereby MPAs have varied levels of restrictions imposed (e.g. no-take, multiple-use), is needed to support the EU Biodiversity Strategy and its key commitments by 2030.

Based on the selection of MPAs investigated, the **second area of study** provided a detailed analysis of the fishing activities that occur throughout the MPAs. This includes the characterisation of fishing activities within MPAs and surrounding areas, exploration of the relationship between fishing activities and different habitats, and the assessment of the extent such activities are compatible with identified MPA conservation objectives.

Through an analysis of VMS data, **our findings indicate that nearly 64% of MPAs across EU waters are not fished by large-scale commercial vessels.** For a large majority of the MPAs without fishing, there was no reported fishing in the surrounding areas (69%), whereas almost all fished MPA sites also recorded fishing activity in their direct surroundings (99%). In addition, analysis of MPAs where fishing activity was recorded both within the MPA and its direct surroundings, showed that **for the majority (74%) of sites, the standardised fishing effort was lower inside the MPA compared to its direct surroundings**. Although this analysis offers an interesting insight of the fishing activities, there is little understanding of the breadth and scope of small-scale and recreational fisheries within MPAs. Therefore, these results may be associated with a lack of some fisheries data related to small-scale and recreational fisheries. Further focus is needed to improve monitoring and data collection on the activities of small-scale and recreational fisheries throughout the EU, as both are quite common within MPAs and will probably result in a range of different impacts. The EU Control Regulation, which mandates positional and catch reporting of all vessels, from 2030, should improve data in this respect.

Regarding the interaction between fishing activities and habitats, there is **little evidence that (i) the implementation of MPAs reduces the exposure of a variety of habitats to fishing pressure, and (ii) that protection restricts fishing in particular habitats**. Despite this, within the Greater North Sea, Bay of Biscay and the Iberian Coast, a large part (>89%) of the spatial extent of habitats is located within fished MPA sites, whereas the dominant habitat classes in the Baltic Sea and Celtic Seas have a smaller fraction located in fished sites.

Capitalising on a recent, large-scale systematic review of fisheries impacts on marine ecosystems, completed under the EU's Horizon 2020 project SEAwise, information was combined on fishing gears, ecosystem components, and three metrics of evidence quality to provide a matrix of impact scores. Calculated **impact scores** may be applied to existing or potential MPAs to attain **incompatibility scores** and investigate the extent to which fisheries may affect the desired conservation outcomes. Both the impact and incompatibility scores provide a level of certainty in the direction of the impact (deleterious or beneficial) between fisheries and various ecosystem components. Findings reveal that **fishing activities are not necessarily incompatible with MPA conservation objectives, but this depends on the objectives and the type of fishing activity within the MPAs.** Fishing gears that impact the benthos (e.g. bottom trawls) or that are unselective and have large bycatch-associated mortality (e.g. some types of gill nets) are incompatible with MPA conservation objectives. However, fishing gears that do not have bottom contact, that have low levels of ecosystem impact (e.g. pelagic seines), and/or low bycatch rates (e.g. hook and lines) may be relatively compatible. The '**impact score matrix**' is a key resource for managers of existing MPAs but especially for planners and designers of future MPAs. By referring to this matrix, managers and planners can prioritise fisheries-related policy (e.g. whether to include or exclude certain fishing practices) according to the conservation objectives of the MPA.

The **third area of study** made an in-depth assessment of nine MPA case studies from eight EU Member States. This includes the examination of the potential spatial redistribution (displacement) of fishing activities in response to MPA designation and implementation; and the development and testing of a conceptual model to guide future fisheries and MPA management. All case study investigations began with a uniform systematic literature review to gather existing knowledge that was available for the specific MPA sites. Subsequent analyses were either dependent on the results of these reviews or utilised data to implement quantitative approaches.

Our assessment shows that **across Europe, MPA designation and implementation did not bring about change in fisher behaviour**. Changes in fisher behaviour including fishing effort and landings were evident only after specific fisheries regulations (e.g. gear-specific exclusions, or no-take zones) were put in place. These **findings indicate that modification in fishing activities due to MPAs require specific regulations and enforcement**. Indeed, managing fishing activities in MPAs is best achieved through the development of explicit and detailed fishery management plans that identify how best fishing activities across the entire MPA can operate. In addition, case studies illustrated how targeted regulations can overlook potential adverse effects on other conservation objectives. There can be trade-offs and conflicts between different conservation objectives (e.g. birds, mammals, habitats) and the interactions of these objectives with different fishing practices (e.g. pelagic versus bottom fisheries).

A **conceptual model** (‘**MAPAFISH tool**’) of the effects of MPAs on the reallocation of fishing effort in and outside the MPAs was developed within the study. The tool is based on different fishery management strategies (e.g. no, full, or partial protection) and the potential social, economic and ecological impacts of the effort reallocation. The tool allows users to define input scenarios based on their case study MPA. Based on the input, the model identifies the types of potential outcomes on fishery activity and ecosystem properties associated with the MPA and the fishery measures taken. In this study, the MAPAFISH tool was tested in four MPAs and was found to conform with expectations of the relevant experts. Findings show that costs and revenue consistently emerge as prominent indicators when an area is closed to fishing, both of which need to be balanced against MPA conservation outcomes. Consequently, to ensure continued success of MPA conservation outcomes, there is need to understand the types of stakeholders affected by MPAs, the communication required by MPA managers and the inclusion of fishers in MPA boards.

The **fourth area of study** described the perceptions of different stakeholder groups through interviews and focus group discussions to better understand the effects of displacement of fishing activities and the use of MPAs as a fisheries management tool. Findings show that there are **differences in perceptions between large-scale fishers and small-scale fishers**. Large-scale fishers are concerned that their exclusion from an area means that the displaced effort will increase in adjacent fishing areas to match the equivalent total catches and thus increase competition. Small-scale fishers, in contrast, are concerned that they are not going to be able to adapt and fish in other areas, if their current fishing grounds are closed. They stated that closing areas increases the risk of going out of business because of a lack of capacity to invest in alternative fishing methods. MPA stakeholders believe that while participation of fishers in the different stages of the MPA process (from MPA designation to implementation) is essential, **there has been late, limited or no involvement by fishers in the designation stage of the investigated MPAs across the EU**.

Findings also show that stakeholders have different views regarding the added value of MPAs to fisheries. **Most fishers feel that MPAs are not currently a useful tool for fisheries management**. This is because fisheries objectives on commercial stocks have so far not been included as an objective of establishing MPAs nor are they being monitored. In addition, fisheries stakeholders are concerned about the accumulated effect that all activities at sea have on the available space to fish, and particularly on traditional fishing grounds. Fishers consider that there is too much focus on protection of marine areas from fisheries activities. Thus, when setting conservation objectives, a key message from fisheries stakeholders is that the **impact of all activities at sea need to be considered**.

Overall, this study has provided a vast improvement to the baseline information available on the status of MPAs in the EU and the fishing activities within and surrounding them. It has notably underlined key areas in which improvements can be made. To foster the beneficial role of MPAs as fisheries management tools the following key findings and recommendations are made from the study.

Key results and findings from this study include:

- A database has been developed that provides a repository of information for 819 MPAs across the EU. The **MAPAFISH database** provides a tool to guide MPA management at different levels, supporting further evaluation of MPAs, and acts as a benchmark to understand how best to structure MPAs in the future.
- Having **buffer areas surrounding no-take MPAs** is vital, as this allows local small-scale fishers to undertake fishing activities, while also allowing areas within their remit to have reduced fishing pressure. Within these cases, fishing activities are undertaken near to 'home' ports with fisheries targeting small reef fish, reef invertebrates and small pelagic species.
- Fishers are in favour of, and willing to promote, MPAs as long as the **socio-cultural and economic sustainability** of the fisheries sector is one of the MPA objectives. Considering that other stakeholder groups (e.g. nature conservation), are advocating more fisheries restrictions in MPAs, buy-in from fishers is needed for MPAs to work.
- Perceptions of fishers show that the **legitimacy of MPAs** for the fishing sector increases in cases where closures are temporal, conservation objectives are specified, and fisheries restrictions are gear-specific and substantiated.
- Properly developed MPAs (and networks of MPAs) can change population sustainability, fishery yield and ecosystem properties. Ensuring such output will depend on managers understanding three critical **forms of connectivity** over space: larval dispersal, juvenile and adult swimming, and fishers' movement.

The main **recommendations** made from this study include to:

- Ensure there is better understanding and consideration of the wider impacts (both socio-economic and environmental) of no-take MPAs and fishing activities on marine ecosystems. There is a need for further development of EU MPAs as fisheries management tools (either utilising current MPAs or designating new areas in the future).
- Improve research and monitoring to further understand the range of fishing activities undertaken in EU MPAs. There is need to improve research and monitoring of fishing activities within and surrounding MPAs in the EU including enhanced data collection and establishment of long-term monitoring programmes to generate evidence and inform management decisions.
- Integrate key stakeholders further into the planning and implementation process around activities that operate in MPAs. There is need to enhance decision making and complement it with stakeholder knowledge, to further improve sustainable use of marine resources and increase buy-in in MPAs.
- Ensure socio-cultural and economic sustainability of the fisheries sector is included as one of the MPA conservation objectives.
- Develop further the MAPAFISH database into a more accessible and reproducible repository of data and information. The database, developed within this study, could support the wider research community to facilitate further independent research on EU MPAs.
- Use buffer areas surrounding no-take MPAs to permit local small-scale fishers undertake fishing activities, while also allowing areas within their remit to have reduced fishing pressure.
- Further understand three main forms of connectivity (larval dispersal, juvenile and adult swimming, and fishers' movement) to ensure MPA designation is developed around spatially oriented sustainability measures, and therefore utilised as effective fisheries management tools.

Finally, it is concluded that overcoming the limitations of existing EU MPAs to address fisheries challenges must entail the designation of **MPAs with management plans that are categorically built around conservation objectives that lead to fisheries sustainability**. Such mechanisms to ensure fisheries sustainability can include full restrictions to fishing activities, but also the enhancement of ecological factors that may lead to high success of fished populations such as conservation of key habitats, key food resources and key areas of reproduction.

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RÉSUMÉ EXÉCUTIF

La Stratégie de l'Union européenne (UE) en faveur de la biodiversité à l'horizon 2030 prévoit la protection juridique et la gestion efficace d'au moins 30 % de la surface des eaux marines de l'UE, dont un tiers au moins fera l'objet d'une protection stricte. La stratégie promeut un réseau européen d'aires marines protégées (AMP) plus étendu et bien connecté, assorti de mesures efficaces de gestion de la pêche. Les AMP ont été créées pour faire face aux nombreuses menaces anthropiques qui pèsent sur nos mers. Elles sont souvent promues sous l'angle de la conservation de la biodiversité, mais moins sous l'angle de la pêche. Dans ce contexte, cette étude répond à la nécessité de mieux comprendre comment les AMP peuvent fonctionner dans le contexte de la pêche. L'examen du statut des AMP et des activités de pêche associées peut aider les parties prenantes impliquées dans l'expansion possible des actions de gestion de la pêche au sein des AMP dans les eaux de l'UE.

L'objectif global de l'étude MAPAFISH était de rassembler les informations existantes et nouvelles afin de **caractériser les AMP et les activités de pêche qui y sont associées dans l'UE** (mer du Nord, mer Baltique, eaux occidentales de l'Atlantique, y compris la Macaronésie). Plus précisément, elle permet de comprendre en profondeur la distribution, l'étendue spatiale, la structure et la fonction des AMP de l'UE, les activités de pêche entreprises à l'intérieur et autour de ces AMP, ainsi que les défis et les opportunités de la mise en œuvre de mesures de protection pour les AMP. Pour atteindre cet objectif, cette étude combine une évaluation à grande échelle en collectant des informations sur un grand nombre d'AMP et sur les activités de pêche qui y sont liées, et une approche d'étude de cas se concentrant sur un ensemble d'AMP sélectionnées dans lesquelles des informations approfondies ont été collectées et analysées.

Dans cette étude, **plusieurs domaines majeurs** ont été examinés. Un premier domaine d'étude comprenait une description des AMP existantes et de leurs caractéristiques associées. Pour ce faire, nous avons rassemblé une série d'éléments qui décrivent chaque AMP et dont on sait qu'ils déterminent le succès de chacune d'entre elles en matière de conservation de la biodiversité et de la pêche. Un deuxième domaine d'étude a porté sur les activités de pêche qui se déroulent dans les AMP, en caractérisant les activités de pêche dans les AMP et les zones environnantes et en évaluant la mesure dans laquelle ces activités de pêche sont compatibles avec les objectifs de conservation des AMP. Afin de mieux comprendre la redistribution spatiale potentielle (déplacement) des activités de pêche en réponse à la mise en œuvre des AMP, un troisième domaine d'étude a consisté d' une évaluation approfondie de neuf études de cas d'AMP à travers l'UE dans huit États membres. En outre, dans le cadre du troisième domaine d'étude, un modèle conceptuel a été développé pour évaluer les effets potentiels des AMP sur la réaffectation de l'effort de pêche à l'intérieur et à l'extérieur des AMP, permettant aux utilisateurs de définir différents scénarios et d'identifier les résultats potentiels associés à une AMP particulière et à ses règles. Dans un quatrième domaine, l'étude a examiné les perceptions des différents groupes de parties prenantes afin de mieux comprendre les effets du déplacement de la pêche de leur point de vue, et surtout l'utilisation des AMP en tant qu'outil de gestion de la pêche. Enfin, l'étude présente une synthèse des principales caractéristiques des AMP de l'UE et de la manière de déterminer leur succès éventuel, une discussion sur les activités de pêche et les mesures associées, ainsi que les défis et les opportunités liés à la désignation et à la mise en œuvre des AMP. L'étude se termine par plusieurs leçons tirées de l'expérience afin de favoriser le rôle bénéfique des AMP en tant qu'outils de gestion de la pêche.

Les données et les informations sur les AMP ont été principalement recueillies à partir de deux bases de données existantes sur les AMP (Common Database on Designated Areas [CDDA] et Natura 2000). Ces bases de données ont été complétées par des questions portant sur 79 caractéristiques et divisées en différents thèmes (notamment les niveaux de protection des AMP, les données et activités de pêche, la gestion et les restrictions, l'engagement des parties prenantes, les objectifs et mesures de conservation). Pour s'assurer que toutes les AMP sélectionnées pour une analyse plus approfondie étaient pertinentes pour les objectifs de l'étude, deux critères importants ont été utilisés : une surface totale supérieure à 5 km^2 et une part marine supérieure à 95 %. Une deuxième étape de filtrage a ensuite été adoptée avec d'autres critères tels que l'élimination des enregistrements comptés deux fois, des zones situées dans les eaux estuariennes et de celles qui ne sont pas couvertes par le champ d'application géographique. Les enregistrements sélectionnés ont été inclus dans une seule **base de données MAPAFISH développée dans le cadre de cette étude, avec un total de 819 AMP étudiées**.

Le premier domaine d'étude a examiné la base de données MAPAFISH et a fourni une description détaillée des principales caractéristiques structurant les AMP de l'UE, de l'éventail des processus de gestion, ainsi que des types d'activité de pêche et des mesures de pêche. En raison de l'hétérogénéité des caractéristiques structurant les AMP étudiées dans les différentes régions, nos résultats ne nous ont pas permis de définir un ensemble de caractéristiques "communes" pour expliquer le succès d'une AMP, et par conséquent aucune description de la manière dont une AMP "moyenne" est structurée dans l'UE n'est donnée. Toutefois, lors de la désignation et de la mise en œuvre des AMP, de **meilleurs résultats sont plus probables si les parties prenantes sont fortement impliquées et si les pêcheurs sont davantage représentés dans les conseils de gestion des AMP**. À cet égard, bien qu'un grand nombre d'AMP de l'UE (52 %) soient gérées activement (c'est-à-dire que la gestion est en cours, y compris la surveillance et l'examen périodique), c'est en grande partie l'administration publique qui s'en charge. En outre, près de la moitié des AMP (43 %) n'ont pas d'organe de gestion opérationnel. L'implication des parties prenantes est un outil important, mais il est sous-utilisé dans la gestion des AMP.

Dans l'ensemble de l'UE, **les AMP n'ont pas été utilisées comme des instruments de gestion de la pêche**, mais constituent principalement **un outil de protection des habitats**, des espèces (notamment des oiseaux de mer) et d'autres composantes de l'écosystème. L'effet sur la pêche (récréative ou commerciale, à petite ou à grande échelle) dépend des objectifs de conservation de la ZMP. En effet, l'objectif principal des AMP est rarement d'améliorer la conservation des espèces commerciales, mais de conserver la biodiversité qui pourrait indirectement bénéficier aux pêcheries. À cet égard, les AMP de l'UE sont rarement utilisées pour assurer la durabilité à long terme des pêcheries.

Dans l'ensemble de l'UE, la majorité des ZMP étudiées disposent d'un plan de gestion (62 %) et d'objectifs de conservation définis (89 %), bien qu'il y ait un manque important de rapports montrant que ces objectifs sont atteints (84,5 %). Actuellement, les oiseaux de mer sont la principale composante de l'écosystème enregistrée dans le cadre des objectifs de conservation des AMP, suivis par les mammifères marins, les habitats physiques et le benthos. Pour **la majorité des AMP, les données relatives à la pêche n'ont pas été utilisées lors de la planification et de la désignation, mais peuvent l'être lors de la mise en œuvre de l'AMP.** Lorsque des données sur la pêche ont été utilisées, elles sont en grande partie basées sur des données de pêche commerciale provenant de navires équipés de systèmes de surveillance des navires (VMS), ce qui peut réduire l'apport de données sur la pêche à petite échelle et la pêche récréative dans ces processus.

Pour la majorité des AMP, les restrictions sont principalement des mesures spatio-temporelles. En outre, la majorité (59 %) des AMP est classée par l'Union internationale pour la conservation de la nature comme "zone de gestion des habitats/espèces". Les pêcheries qui respectent les objectifs de conservation des AMP continuent d'opérer à l'intérieur de celles-ci. À cet égard, la majorité des ZMP de l'UE autorisent un certain niveau d'exploitation par la pêche, qui peut inclure une série d'activités de pêche récréative et commerciale. Les plus courantes sont les engins à faible impact tels que les filets, les casiers, les hameçons et les lignes. Le chalutage (démersal et pélagique) est pratiqué dans environ 25 % des AMP, les sennes dans 20 % et les dragues dans 17 %. Néanmoins, il existe de nettes différences régionales dans le type d'activités de pêche, les types de pêche basés sur le chalutage de fond étant dominants dans la grande mer du Nord, et la pêche passive (filets, casiers, hameçons et lignes) étant dominante en Macaronésie et dans la mer Baltique. **Environ la moitié (50,5 %) des AMP étudiées ne sont soumises à aucune restriction en matière de pêche.**

La plupart des AMP de l'UE (83 %) sont peu ou faiblement protégées, tandis que 11 % sont hautement protégées. **Seules 0,5 % des AMP sont entièrement protégées, c'est-à-dire qu'aucune activité extractive ou destructrice n'y est autorisée**. Les zones de non-prélèvement sont donc encore rares dans les AMP de l'UE. Néanmoins, de nombreuses AMP imposent divers niveaux de restriction, les restrictions spatialement explicites (27 % des AMP) étant les plus courantes (par exemple, restrictions spatiales des engins de pêche ou zonage spatial de la flotte). Un tel zonage, dans lequel les AMP sont soumises à différents niveaux de restrictions (par exemple, zones de non-prélèvement, usages multiples), est nécessaire pour soutenir la stratégie de l'UE en faveur de la biodiversité et ses principaux engagements d'ici à 2030.

Sur la base de la sélection des AMP étudiées, le **deuxième domaine d'étude** a fourni une analyse détaillée des activités de pêche qui se déroulent dans les AMP. Cela comprend la caractérisation des activités de pêche dans les AMP et les zones environnantes, l'exploration de la relation entre les activités de pêche et les différents habitats, et l'évaluation de la mesure dans laquelle ces activités sont compatibles avec les objectifs de conservation identifiés dans les AMP.

Grâce à une analyse des données VMS, nos résultats indiquent que **près de 64% des AMP dans les eaux de l'UE ne sont pas pêchées par des navires commerciaux à grande échelle**. Pour une grande majorité des AMP sans pêche, aucune activité de pêche n'a été signalée dans les zones environnantes (69%), alors que presque tous les sites d'AMP pêchés ont également enregistré une activité de pêche dans leurs environs directs (99%). En outre, l'analyse des AMP où l'activité de pêche a été enregistrée à la fois dans l'AMP et dans ses environs directs a **montré que pour la majorité (74%) des sites, l'effort de pêche standardisé était plus faible à l'intérieur de l'AMP que dans ses environs directs**. Bien que cette analyse offre un aperçu intéressant des activités de pêche, l'ampleur et la portée de la pêche artisanale et récréative dans les AMP sont peu connues. Par conséquent, ces résultats peuvent être associés à un manque de données relatives à la pêche artisanale et récréative. Il est nécessaire d'améliorer le suivi et la collecte de données sur les activités de la petite pêche et de la pêche récréative dans l'ensemble de l'UE, car ces deux types de pêche sont très répandus dans les AMP et entraînent probablement une série d'impacts différents. Le règlement de contrôle de l'UE, qui rend obligatoire la déclaration de la position et des captures de tous les navires à partir de 2030, devrait permettre d'améliorer les données à cet égard.

En ce qui concerne l'interaction entre les activités de pêche et les habitats, il existe peu de preuves que (**i) la mise en œuvre des AMP réduit l'exposition d'une variété d'habitats à la pression de la pêche**, et **(ii) que la protection restreint la pêche dans des habitats particuliers**. Malgré cela, dans la grande mer du Nord, le golfe de Gascogne et la côte ibérique, une grande partie (>89%) de l'étendue spatiale des habitats est située dans des sites d'AMP pêchés, tandis que les classes d'habitats dominantes de la mer Baltique et de la mer Celtique ont une fraction plus petite située dans des sites pêchés.

En s'appuyant sur une étude systématique récente et à grande échelle des impacts de la pêche sur les écosystèmes marins, réalisée dans le cadre du projet européen Horizon 2020 SEAwise, des informations ont été combinées sur les engins de pêche, les composantes de l'écosystème et trois mesures de la qualité des preuves afin de fournir une matrice de scores d'impact. Les scores d'impact calculés peuvent être appliqués aux

AMP existantes ou potentielles afin d'obtenir des scores d'incompatibilité et d'étudier dans quelle mesure les pêcheries peuvent affecter les résultats souhaités en matière de conservation. Les scores d'impact et d'incompatibilité fournissent un niveau de certitude quant à la direction de l'impact (délétère ou bénéfique) entre les pêcheries et les différentes composantes de l'écosystème. Les résultats révèlent que les activités de pêche ne sont pas nécessairement incompatibles avec les objectifs de conservation des AMP, mais cela dépend des objectifs et du type d'activité de pêche dans les AMP. **Les engins de pêche qui ont un impact sur le benthos (par exemple les chaluts de fond) ou qui ne sont pas sélectifs et qui entraînent une forte mortalité associée aux prises accessoires (par exemple certains types de filets maillants) sont incompatibles avec les objectifs de conservation des AMP**. En revanche, les engins de pêche qui n'entrent pas en contact avec le fond, qui ont un faible impact sur l'écosystème (par exemple les sennes pélagiques) et/ou de faibles taux de prises accessoires (par exemple les lignes et les hameçons) peuvent être relativement compatibles. La "**matrice de score d'impact**" est une ressource essentielle pour les gestionnaires des AMP existantes, mais surtout pour les planificateurs et les concepteurs des futures AMP. En se référant à cette matrice, les gestionnaires et les planificateurs peuvent hiérarchiser les politiques liées à la pêche (par exemple l'inclusion ou l'exclusion de certaines pratiques de pêche) en fonction des objectifs de conservation de l'AMP.

Le **troisième domaine d'étude** consiste en une évaluation approfondie de neuf études de cas d'AMP dans huit États membres de l'UE. Cela comprend l'examen de la redistribution spatiale potentielle (déplacement) des activités de pêche en réponse à la désignation et à la mise en œuvre des AMP, ainsi que le développement et le test d'un modèle conceptuel pour guider la gestion future des pêcheries et des AMP. Toutes les études de cas ont commencé par une revue systématique et uniforme de la littérature afin de rassembler les connaissances disponibles pour les sites spécifiques des AMP. Les analyses ultérieures dépendaient des résultats de ces analyses ou utilisaient des données pour mettre en œuvre des approches quantitatives.

Notre évaluation montre que dans toute l'Europe**, la désignation et la mise en œuvre des AMP n'ont pas entraîné de changement dans le comportement des pêcheurs**. Les changements de comportement des pêcheurs, y compris l'effort de pêche et les débarquements, n'ont été évidents qu'après la mise en place de réglementations spécifiques en matière de pêche (par exemple, des exclusions spécifiques aux engins de pêche ou des zones de non-prélèvement). Ces résultats indiquent que la modification des activités de pêche due aux AMP nécessite des réglementations spécifiques et leur mise en œuvre. En effet, la meilleure façon de gérer les activités de pêche dans les AMP est de développer des plans de gestion de la pêche explicites et détaillés qui identifient la meilleure façon de gérer les activités de pêche dans l'ensemble de l'AMP. En outre, les études de cas ont montré comment des réglementations ciblées peuvent négliger les effets négatifs potentiels sur d'autres objectifs de conservation. Il peut y avoir des compromis et des conflits entre différents objectifs de conservation (par exemple, oiseaux, mammifères, habitats) et les interactions de ces objectifs avec différentes pratiques de pêche (par exemple, pêche pélagique contre pêche de fond).

Un modèle conceptuel ("outil MAPAFISH") des effets des AMP sur la réaffectation de l'effort de pêche à l'intérieur et à l'extérieur des AMP a été développé dans le cadre de l'étude. L'outil est basé sur différentes stratégies de gestion de la pêche (par exemple, pas de protection, protection totale ou partielle) et sur les impacts sociaux, économiques et écologiques potentiels de la réaffectation de l'effort. L'outil permet aux utilisateurs de définir des scénarios d'entrée basés sur l'AMP de leur étude de cas. Sur la base de ces données, le modèle identifie les types de résultats potentiels sur l'activité de pêche et les propriétés de l'écosystème associés à l'AMP et aux mesures de pêche prises. Dans cette étude, l'outil MAPAFISH a été testé dans quatre AMP et s'est avéré conforme aux attentes des experts concernés. Les résultats montrent que les coûts et les revenus émergent systématiquement comme des indicateurs importants lorsqu'une zone est fermée à la pêche, ces deux éléments devant être mis en balance avec les résultats de la conservation de l'AMP. Par conséquent, pour assurer le succès continu des résultats de conservation des AMP, il est nécessaire de comprendre les types de parties prenantes affectées par les AMP, la communication requise par les gestionnaires d'AMP et l'inclusion des pêcheurs dans les conseils d'administration des AMP.

Le quatrième domaine d'étude décrit les perceptions des différents groupes de parties prenantes par le biais d'entretiens et de discussions de groupe afin de mieux comprendre les effets du déplacement des activités de pêche et l'utilisation des AMP en tant qu'outil de gestion de la pêche. **Les résultats montrent qu'il existe des différences de perception entre les pêcheurs à grande échelle et les pêcheurs à petite échelle.** Les grands pêcheurs craignent que leur exclusion d'une zone signifie que l'effort déplacé augmentera dans les zones de pêche adjacentes pour correspondre aux prises totales équivalentes, ce qui accroîtrait la concurrence. Les petits pêcheurs, en revanche, craignent de ne pas pouvoir s'adapter et de ne pas pouvoir pêcher dans d'autres zones si leurs zones de pêche actuelles sont fermées. Ils affirment que la fermeture de zones augmente le risque de faillite en raison d'un manque de capacité à investir dans d'autres méthodes de pêche. Les parties prenantes des AMP estiment que si la participation des pêcheurs aux différentes étapes du processus de création d'AMP (de la désignation de l'AMP à sa mise en œuvre) est essentielle, les pêcheurs n'ont été impliqués que tardivement, de manière limitée, voire pas du tout, dans l'étape de désignation des AMP étudiées dans l'ensemble de l'UE.

Les résultats montrent également que les parties prenantes ont des points de vue différents sur la valeur ajoutée des AMP pour la pêche. **La plupart des pêcheurs estiment que les AMP ne constituent pas actuellement un outil utile pour la gestion de la pêche**. En effet, jusqu'à présent, les objectifs de pêche sur les stocks commerciaux n'ont pas été inclus dans la création des AMP et ne font pas l'objet d'un suivi. En outre, les acteurs de la pêche s'inquiètent de l'effet cumulé de toutes les activités en mer sur l'espace disponible pour la pêche, et en particulier sur les zones de pêche traditionnelles. Les pêcheurs considèrent que l'accent est trop mis sur la protection des zones marines contre les activités de pêche. Ainsi, lors de la définition des objectifs de conservation, un message clé des parties prenantes de la pêche est que l'impact de toutes les activités en mer doit être pris en compte.

Dans l'ensemble, cette étude a permis d'améliorer considérablement les informations de base disponibles sur le statut des AMP dans l'UE et sur les activités de pêche à l'intérieur et autour de celles-ci. Elle a notamment mis en évidence les domaines clés dans lesquels des améliorations peuvent être apportées. Afin de promouvoir le rôle bénéfique des AMP en tant qu'outils de gestion de la pêche, les principales conclusions et recommandations suivantes ont été formulées à partir de l'étude.

Les principaux résultats et conclusions de cette étude sont les suivants :

- Une base de données a été développée qui fournit un référentiel d'informations pour 819 AMP à travers l'UE**. La base de données MAPAFISH** constitue un outil permettant de guider la gestion des AMP à différents niveaux, de soutenir une évaluation plus poussée des AMP et de servir de référence pour comprendre comment structurer au mieux les AMP à l'avenir.
- Il est essentiel d'avoir **des zones tampons autour des zones de non-prélèvement des AMP**, car cela permet aux petits pêcheurs locaux d'entreprendre des activités de pêche, tout en permettant aux zones relevant de leur compétence d'avoir une pression de pêche réduite. Dans ces cas, les activités de pêche sont menées à proximité des ports d'attache et les pêcheries ciblent les petits poissons de récif, les invertébrés de récif et les petites espèces pélagiques.
- Les pêcheurs sont favorables et prêts à promouvoir les AMP tant que la **durabilité socioculturelle et économique du secteur** de la pêche est l'un des objectifs de l'AMP. Étant donné que d'autres groupes de parties prenantes (par exemple, la conservation de la nature) préconisent davantage de

restrictions de la pêche dans les AMP, l'adhésion des pêcheurs est nécessaire pour que les AMP fonctionnent.
- Les perceptions des pêcheurs montrent que la **légitimité des AMP** pour le secteur de la pêche augmente lorsque les fermetures sont temporelles, que les objectifs de conservation sont spécifiés et que les restrictions de pêche sont spécifiques aux engins de pêche et justifiées.
- Des AMP (et des réseaux d'AMP) correctement développées peuvent modifier la durabilité de la population, le rendement de la pêche et les propriétés de l'écosystème. Pour garantir ces résultats, les gestionnaires devront comprendre **trois formes essentielles de connectivité** dans l'espace : la dispersion des larves, la nage des juvéniles et des adultes, et les déplacements des pêcheurs.

Les principales **recommandations** formulées dans le cadre de cette étude sont les suivantes :

- Veiller à une meilleure compréhension et à une meilleure prise en compte des incidences plus larges (tant socio-économiques qu'environnementales) des zones de non-prélèvement des AMP et des activités de pêche sur les écosystèmes marins. Il est nécessaire de développer davantage les AMP de l'UE en tant qu'outils de gestion de la pêche (soit en utilisant les AMP actuelles, soit en désignant de nouvelles zones à l'avenir).
- Améliorer la recherche et la surveillance afin de mieux comprendre l'éventail des activités de pêche menées dans les AMP de l'UE. Il est nécessaire d'améliorer la recherche et la surveillance des activités de pêche à l'intérieur et autour des AMP de l'UE, notamment en améliorant la collecte de données et en mettant en place des programmes de surveillance à long terme afin de produire des preuves et d'informer les décisions de gestion.
- Intégrer davantage les principales parties prenantes dans le processus de planification et de mise en oeuvre des activités menées dans les AMP. Il est nécessaire d'améliorer la prise de décision et de la compléter par les connaissances des parties prenantes, afin d'améliorer l'utilisation durable des ressources marines et d'accroître l'adhésion aux AMP.
- La durabilité socioculturelle et économique du secteur de la pêche est l'un des objectifs de conservation des AMP.
- Développer la base de données MAPAFISH pour en faire un référentiel de données et d'informations plus accessible et reproductible. La base de données, développée dans le cadre de cette étude, pourrait aider la communauté des chercheurs au sens large à faciliter la poursuite de recherches indépendantes sur les AMP de l'UE.
- Utiliser des zones tampons autour des zones de non-prélèvement des AMP pour permettre aux petits pêcheurs locaux d'entreprendre des activités de pêche, tout en permettant aux zones relevant de leur compétence de bénéficier d'une pression de pêche réduite.
- Mieux comprendre les trois principales formes de connectivité (dispersion des larves, nage des juvéniles et des adultes, et mouvements des pêcheurs) pour s'assurer que la désignation des AMP s'articule autour de mesures de durabilité orientées dans l'espace, et qu'elles sont donc utilisées comme des outils efficaces de gestion de la pêche.

Enfin, il est conclu que pour surmonter les limites des AMP existantes de l'UE face aux défis de la pêche, il faut désigner des **AMP avec des plans de gestion qui sont catégoriquement construits autour d'objectifs de conservation qui conduisent à la durabilité de la pêche**. Ces mécanismes visant à assurer la durabilité de la pêche peuvent inclure des restrictions totales aux activités de pêche, mais aussi le renforcement des facteurs écologiques qui peuvent conduire à un succès élevé des populations pêchées, tels que la conservation des habitats clés, des ressources alimentaires clés et des zones clés de reproduction.

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GENERAL INTRODUCTION

Background

The need to protect or restore marine biodiversity, habitats and fish stocks, amid international targets to protect at least 30% of the world's oceans by 2030, have prompted the rapid establishment of new marine protected areas (MPAs) (Lubchenco and Grorud-Colvert, 2015). MPAs are a widely applied conservation tool, developed primarily to achieve biological and ecological objectives (Gaines et al., 2010), with establishment of a common management approach for protecting relevant habitats and associated stocks (Maes and Jacobs, 2015). MPAs can provide direct benefits not only to ecosystems, but also to many stakeholders, including fishers. MPAs have been shown - to enhance biological variables such as the abundance, size and diversity of species of fish and invertebrates, compared to areas without protection (Lester et al., 2009).

Within the European Union (EU), MPAs now cover approximately 12% of the seas, with less than 1% being strictly protected (Agnesi et al., 2020). However, recent EU-specific and global strategies have been launched to further the use and coverage of MPAs. The EU Biodiversity Strategy (EC, 2020) is calling by 2030 to legally protect and effectively manage at least 30% of the surface area of the EU's marine waters, with at least one third of that area (10% of EU's marine waters) under strict protection. The strategy promotes a larger and well-connected EU-wide network of MPAs with effective fisheries–management measures. These measures must be established in all MPAs according to clearly defined conservation objectives and based on the best available scientific advice (EC, 2020).

In the aftermath of the historic agreement reached at the United Nations Biodiversity Conference (COP15) in Montreal on a new global biodiversity framework (CBD, 2022), the EU adopted the marine Action Plan (EC, 2023). This action plan is part of the European Commission's efforts to achieve a more consistent implementation of the EU's environmental policy and the Common Fisheries Policy (CFP) with its three sustainability pillars: environmental, economic and social. This action plan has been developed to protect and restore marine ecosystems, including fish spawning and nursery areas, and effectively safeguarding the livelihoods of EU fishing communities. It also aims to foster increased cooperation between fisheries and environmental authorities, by enhancing dialogue and closer cooperation and coordination within the EU. This action plan places special emphasis on MPAs and the ways that fisheries management might help provide better protection and restoration.

The benefits accumulated from MPAs have been shown to be dependent on MPA design (Edgar et al., 2014; Gill et al., 2017; Grorud-Colvert et al., 2021). MPAs that provide the greatest benefits, in the longer term, for both fisheries and biodiversity, are those supported by protection standards, such as the inclusion of fully protected areas (no-take areas), where extractive activities and habitat modification are prohibited. Such no-take areas are sometimes surrounded by partially protected areas (multi-use areas), where different extractive activities can occur to varying degrees (e.g. commercial fishing may be restricted to only small-scale or artisanal fishing). In addition, recent work has shown that well-enforced, fully protected MPAs most dependably attain their conservation goals (Grorud-Colvert et al., 2021; Lester and Halpern, 2008). However, such features do not always result in MPA success (Gill et al., 2017; Lester et al., 2009). In this respect, planning of MPA placement and designation requires careful consideration of the characteristics of the local marine ecosystem and specific conservation objectives to determine the best placement, size and configuration (Green et al., 2013; Grorud-Colvert et al., 2021).

After establishment of MPAs with fishery measures taken, a common and important potential effect is the redistribution (reallocation) of the fishing activities to the surrounding areas because of loss of fishing grounds (Hattam et al., 2014; Cabral et al., 2017). Consequently, decreased fishing mortality within MPAs may be balanced by increased fishing mortality outside, in particular for species moving in and out of the MPA (Di Lorenzo et al., 2016). The possible intensification of fishing in the surrounding areas could also have negative effects, for instance on sensitive habitats or non-target species. Therefore, there is a need for a better understanding of the ecological and socio-economic effects of this spatial reallocation. The question is whether the reallocated fishing effort reduces the sustainability of remaining fishing grounds, and whether the costs and benefits would be balanced. To better understand the fishers' responses to MPA establishment, it is essential to explore the spatial distribution of fishing activities and stakeholders' perceptions. Models that predict the expected reallocation of fishing activities in reaction to the establishment of MPAs can assist managerial decisions and the potential need of complementary management measures in the surrounding areas. Moreover, it is important to identify the fishing activities that are more compatible with MPA conservation objectives. Such information could be used as a reference for good practices to be used in other MPAs.

MPAs are often strongly promoted from a biodiversity conservation angle, but less so from a fisheries perspective (Gaines et al., 2010). With the move towards an ecosystem approach to the management of seas and oceans (Grafton et al., 2023), it is necessary to look at the full range of tools for fisheries management. MPAs can be a useful component within the fisheries management toolbox. In this context, this study responds to the need to better understand how MPAs can work in the context of fisheries. Looking at some specific features of MPAs (e.g. existence of MPA management plan, conservation objectives and fisheries measures) can provide support to managers and policymakers involved in the foreseen expansion of fishery management actions within MPAs in EU waters. While there is growing interest in studying the progress of ocean protection and ensuing benefits, there is a need for an overview of the current state of play of MPAs and associated fishing activities in EU waters.

Objectives and outline

The overall purpose of this study was to collate existing and new information to characterize MPAs and their associated fishing activities in the North Sea, Baltic Sea and Atlantic EU Western Waters, including Macaronesia. To achieve this general purpose, specific objectives were to: (i) characterize the existing MPAs with a set of features; (ii) characterize the fishing activities present within MPAs and their surrounding areas and evaluate if such activities are compatible with the conservation objectives; and (iii) understand the response of the fishing activities to MPA implementation.

We combined (i) a large-scale assessment collecting information on a large number of MPAs and related fishing activities throughout the above mentioned marine regions; and (ii) a case-study approach focusing on a set of selected case studies in which in-depth information has been gathered and analysed to assess spatial redistribution of fishing activities in response to MPA implementation and perceptions of relevant stakeholders related to fisheries within the selected MPAs and their surrounding areas.

This report is divided into five main sections: the first provides a description of the existing MPAs in the EU and their associated key features that are largely known to determine 'success' of MPAs for both biodiversity conservation and fisheries goals. This description provides a thorough and up to date picture of the status of protection and management of MPAs in EU waters (**Section 1**). Based on the identified MPAs of Section 1, a detailed analysis is made of the fishing activities that occur throughout the MPAs, by characterising fishing activities within them and the surrounding areas and assessing the extent such fishing activities are compatible with identified MPA conservation objectives (**Section 2**). Through an in-depth assessment of nine case studies from eight EU Member States, the potential spatial redistribution (displacement) of fishing activities is examined in response to MPA implementation. A conceptual model is developed and tested to guide future fisheries and MPA management on the factors which may result in successful MPAs (**Section 3**). Further to this, the perceptions of different stakeholders were obtained through interviews and focus group discussions to better understand the effects of displacement of fishing activities and the use of MPAs as a fisheries management tool (**Section 4**). A synthesis of the key features of EU MPAs, fishing activities and associated measures, challenges and opportunities and the general lessons learnt derived from the previous sections are summarized in the last section (**Section 5**), while a selection of annexes offers additional information on key elements, including a 'methodology for stakeholder engagement' and links to the full case study reports.

1 STATUS OF MPAs FOR FISHERIES

Key highlights

- This work developed the MAPAFISH database, with concurrent analyses providing a detailed description of the key features structuring EU MPAs, the range of management processes, as well as the types of fishing activity and fishery measures.
- Around half (52%) of MPAs investigated are actively managed. Most MPAs (83%) are minimally or lightly protected, while 11% are highly protected. Only 0.5% of MPAs are fully protected, with no extractive or destructive activities allowed.
- Most MPAs (87%) allow some level of commercial or recreational exploitation of fisheries, which can include a range of fishing activities. The most common of these include low impact gears (for bottom habitats) such as nets, pots, and hooks and lines. Trawling (demersal and pelagic) takes place in around 25% of MPAs, with seines in 20% and dredges in 17%. In half of the MPAs (50.5%), no fishery management measures are in place.
- Around 62% of the MPAs (37% MPA surface area) investigated have a management plan. The availability of management plans correlates well with the MPA stage of establishment. For the majority of MPAs (89%), conservation objectives are defined.
- Seabirds are the primary ecosystem component recorded as part of the MPA conservation objectives, followed by marine mammals and the seabed (physical habitats and benthos). For the majority of MPAs (84.5%), it is unknown whether the targets of the conservation objectives are met.

The diversity, frequency, and scale of human impacts on marine ecosystems are increasing to the extent that such ecosystems, and the communities they hold, are threatened globally. The increasing need to contain such impacts, by protecting the biodiversity, habitat structure and fisheries stocks within such communities has resulted in increasing calls for the implementation of networks of MPAs. Within the EU, the Biodiversity Strategy for 2030 promotes both a larger and more connected network of MPAs. The strategy has also been developed to ensure that such protection provides the further development of a range of fisheries management measures, to ensure the economic sustainability of the EU fishing industry. Within this, the further implementation of effective MPAs represents a substantial component of the Biodiversity Strategy, as well as within the wider context of the European Green Deal (EC, 2019) and more recently the EU marine Action Plan (EC, 2023).

MPAs that are well managed and protected by exclusion of extractive activities and habitat modifications are expected to provide the greatest benefits, in the longer term, for both fisheries and biodiversity (Edgar et al., 2014; Gill et al., 2017). However, there is substantive evidence to show that a multitude of factors is likely to influence species response, and therefore adjacent fisheries success, following MPA protection (Babcock et al., 2010; Claudet et al., 2008). Such variance in factors between MPAs may add substantial uncertainty when developing predictions on both the conservation and fisheries of MPAs. Looking at some specific features of MPAs (e.g. existence of a MPA management plan, conservation objectives and fisheries measures) can provide support to managers and policy makers involved in the foreseen expansion of MPAs in EU waters. In developing successful new MPAs, it will be vital for MPA and fisheries managers to have an overview of the range of features structuring MPAs. Importantly, previous studies have shown that the 'success' (reaching conservation benefits) of MPAs increase with the accumulation of some key features, which include the presence of a fully protected area, the level of enforcement, MPA age and size, degree of MPA isolation, stakeholders' engagement, fishers' representative in the MPA board and promotion of sustainable fishing (Edgar et al., 2014; Di Franco et al., 2016).

In this context, the **overall objective of this section is to develop a description of the existing MPAs in the EU and their associated features**. This description is based on collating a range of elements that describe each MPA and that are known to determine the success of each MPA for both biodiversity conservation and fisheries.

1.1 Selection of MPAs for assessments

1.1.1 Data sources for MPAs

The existing MPAs of the Baltic Sea, the North Sea, the Atlantic EU Western Waters, including certain outermost regions (the Madeira archipelago and the Canary Islands), were identified mainly based on two existing MPA databases: the Natura 2000 database and the Common Database on Designated Areas (CDDA), available from European Environment Agency (EEA) ([1]). Therefore, the MPAs considered in this study were:

1) MPAs designated under Natura 2000. These MPAs are designated under the Habitats and/or Birds Directives and are being part of a network of nature protection areas in the territory of the EU. They are made up of Sites of Community Importance (SCI), Special Areas of Conservation (SAC) and Special Protection Areas (SPA) (total of 2,405 records); and

2) MPAs designated by EU Member States (MS) under other specific mechanisms, as recorded in the CDDA (total of 3,573 records).

These two data sources are the most comprehensive databases of EU MPAs, containing essential information for this study (e.g. geographical information, size, dates on implementation process). Moreover, a few additional MPAs which were not catalogued in the Natura 2000 or CDDA databases but were considered relevant for the study by the Member State experts, were taken into account (total of 39 records).

1.1.2 Selection of MPAs

To ensure all MPAs selected for further analysis are relevant to the objectives of the study, a two-step filtering process was applied to both databases. First, an objective methodology was applied to identify a set of marine orientated MPAs, followed by additional filtering applied by Member States' experts based on their knowledge and experience.

Step 1 filtering process: MPAs were selected from both Natura 2000 and CDDA databases based on the geographic information available (i.e. shapefiles) to determine their spatial distribution. For each database, MPAs (and geographic information about the EU coastline), were combined to allow the evaluation of the total surface area of the MPA (A) and the area of the MPA that overlaps with land (B). The proportion of the total MPA area that is marine was calculated using the ratio (A-B)/A ([2]). The MPAs selected for this study were those with a surface area of greater than 5 km² and where more than 95% of the total MPA area is marine (Figure 1).

([1]) European Environment Agency National Designated Areas Datahub

([2]) If an MPA is "fully marine" (equivalent to 100%), there is no overlap between the MPA and the land.

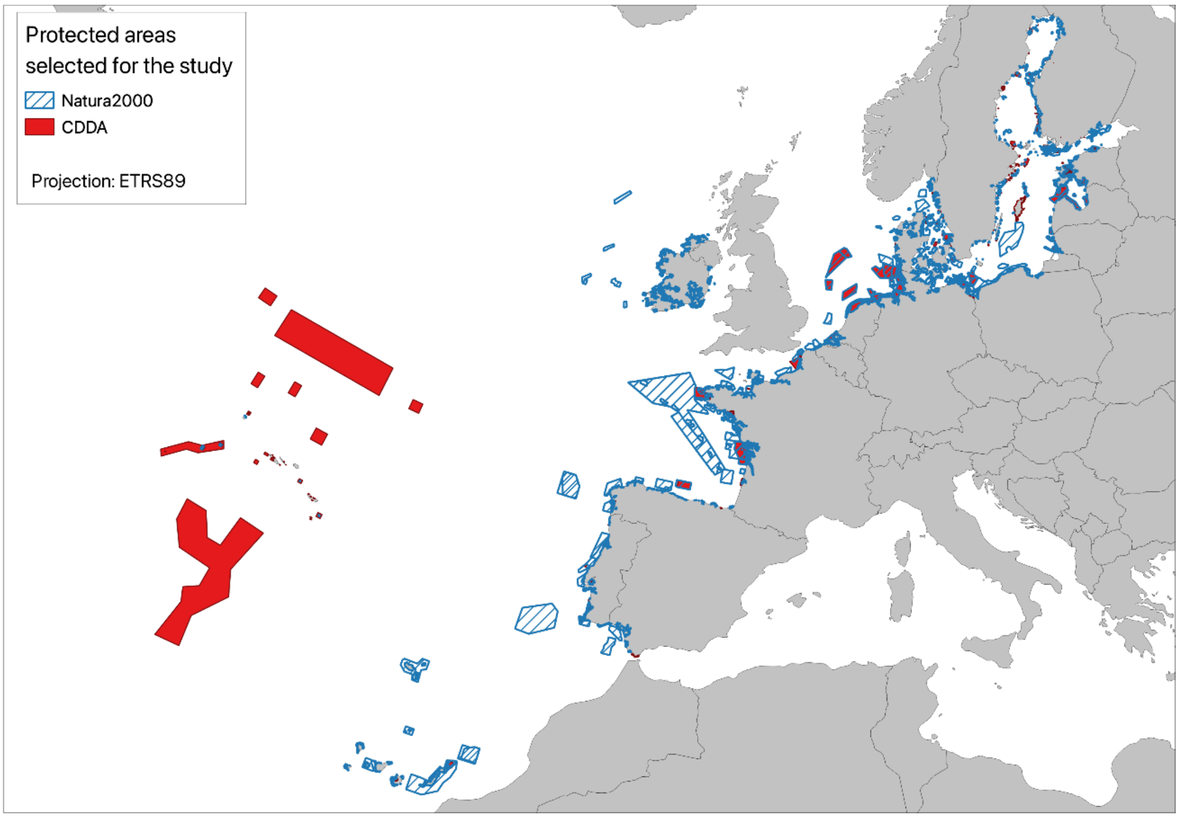


Figure 1. Map of MPAs selected from first filtering step using both Natura 2000 and CDDA databases, and additional MPAs selected by Member State experts (1,280 records).

At this stage, no distinction is made between either marine and brackish waters or offshore and coastal. These factors were assessed during the second filtering step, notably to exclude MPAs that would otherwise be too close to shore to provide reported information on fishing activities: some areas retained with these two spatial criteria are in shallow waters, sometimes in intertidal areas, where fishing activities are only performed by under 10 metre vessels for which very little information is available at the spatio-temporal resolution needed for the study.

The total number of MPAs selected after the first filtering step, excluding 39 records added by Member State experts, was 1,241 (Table 1). This represents 20.8% of the MPAs from both Natura 2000 and CDDA databases. Applying this first filtering step has removed 65% of MPAs from the Natura 2000 database (representing 0.2% of total marine surface area) and 89% from the CDDA database (representing 0.1% of total marine surface area). This shows that while the total number of MPAs remaining has notably reduced, the total marine area has not, indicating this filtering method provides a good selection of relevant MPAs for further analysis.

Step 2 filtering process: The second filtering step was based on additional checks applied by experts to exclude those MPAs that failed to meet the following additional criteria, which are not deemed relevant to the objectives of this study:

- **Double counted** (Natura 2000 and CDDA): Due to a slightly different naming, some MPAs were still present in both databases, but referring to the same area. Note that some initial filtering (on the MPA names) of double occurrences were carried out within both databases. From those double counted MPAs, one (the Natura 2000 site) was retained, the other classified under this exclusion criteria. The number of MPAs excluded under this criterion was 158.

- **Areas considered too old** to be included: areas designated before the implementation of vessel monitoring systems (VMS) do not allow the study to evaluate how the MPA has potentially altered the fishing activity (labelled "Old areas"). This also includes areas where no fishery knowledge exists, due to their historic designation. The number of MPAs excluded was 123.
- **Areas in estuarine waters** with no fisheries data available at the required spatio-temporal resolution (VMS data call requirements) to attain specific information on fishing activities: fishing activity in estuarine waters is in many cases reserved to small-scale vessels for which there is no VMS record (vessels below 12 m). The number of MPAs excluded was 49.
- **Areas considered too small** to be included (below 5 km²): the filter may retain protected areas that are smaller than 5 km² but almost entirely marine (greater than 95% marine). In some cases, the areas may be considered too small to be included in the study (notably regarding fishing activity data). The number of MPAs excluded was 5.
- **Terrestrial areas** (mostly MPAs overlapping with the intertidal areas below the coastline – not used in the current database but this is expected to have been used by some MS when categorising MPAs in their region). The number of MPAs excluded was 32.
- **Out of geographical scope**: MPAs included in database, but out of scope or at border of the geographical study area in relation to their location (the geographical framework used in the analysis was built based on the exclusive economic zone (EEZ) of the EU waters and on the two databases listed above). Most obvious examples were the exclusion of the 9 MPAs of Greenland, catalogued under Denmark's authority. The number of MPAs excluded was 12.
- **Unknown**: No catalogue information was available for 82 MPA records.

In total, this second step excluded an additional 461 MPAs from further analysis (i.e. 187 and 274 records from Natura 2000 and CDDA databases, respectively).

Following the application of the 2-step selection process, **the total number of retained MPAs from those originally listed in both the Natura 2000 and CDDA databases, including the additional MPAs considered as relevant by Member States' experts, was 819 MPAs** (Table 1). This subset includes 13.7% of the total MPAs reviewed, whilst retaining a high proportion (89.4%) of the total marine surface area covered by EU MPAs. It is noted, however, that for Lithuania, Latvia, Germany and Finland, information is only available from MPAs that cover less than 53% of the marine surface area covered within these Member States. These 819 MPAs were used in this study for further examination of their key features.

Table 1. Overview of the retained MPAs ('Relevant') from Natura 2000 and CDDA databases, and those added by Member State experts following a 2-step filtering process. Category 'Selected' = Number of MPAs larger than 5 km² and with 95% marine area; % Number = percentage of retained (relevant), compared to total number of MPAs; % Area = percentage of the marine MPA surface area under study, compared to all MPAs.

Member State	Natura 2000			CDDA			Additional	Total				
	All	Selected	Relevant	All	Selected	Relevant	Relevant	All	Selected	Relevant	% Number	% Area
Belgium	10	5	5	10	0	0	-	20	5	5	25.0	100
Denmark	197	113	113	88	23	3	-	285	136	116	40.7	97.4*
Estonia	95	38	38	400	69	2	-	495	107	40	8.1	72.3
Finland	217	60	34	675	85	32	-	892	145	66	7.4	48.9
France	292	134	85	605	16	9	-	897	150	94	10.5	97.7
Germany	114	70	29	144	29	0	-	258	99	29	11.2	52.9
Ireland	256	117	117	8	1	1	34	264	118	152	57.6	100
Latvia	20	8	8	28	7	0	-	48	15	8	16.7	51.5
Lithuania	19	11	6	14	7	0	-	33	18	6	18.2	40.1
Netherlands	36	16	12	27	1	0	3	63	17	15	23.8	98.8
Poland	35	15	15	24	3	3	-	59	18	18	30.5	100
Portugal	84	35	26	137	38	29	-	221	73	55	24.9	98.9
Spain	462	101	50	179	19	3	-	641	120	53	8.3	72.3
Sweden	568	128	126	1 234	92	34	2	1 802	220	162	9.0	84.5
TOTAL	**2 405**	**851**	**664**	**3 573**	**390**	**116**	**39**	**5 978**	**1 241**	**819**	**13.7**	**89.4**

*Percentage calculated without taking into account the Greenland MPAs, which was under category 'all'.

1.1.3 Data collection and collation

To collate all data and information on the MPAs identified, an input template was developed in Microsoft Excel by exploring the existing information in the Natura 2000 and CDDA databases, completed with questions related to 79 features (see Annex 1, which includes a definition of each category).

Most of the data and information were not available in the original databases or in the right format. The information has been divided into different themes (i.e. General information on MPA (e.g. protection level), fisheries data, commercial and recreational fishing activities, fisheries restrictions, level of enforcement, types of management, stakeholder engagement during designation and during process of management measures, MPA board, conservation measures, environmental components). The template has been split up into Natura 2000 areas, CDDA areas (where we excluded the MPAs that were already in the Natura 2000 table) and additional MPAs (MPAs added by Member State experts as relevant, but not yet listed in Natura 2000 or CDDA databases).

The data collection process has been executed using a stepwise approach, where first the template was tested and adapted for three MPAs in some Member States (e.g. Ireland, Belgium, Netherlands, Sweden, Spain), before it was used for final input. After this test step, the template was distributed to all EU Member State experts to be completed for all selected MPAs under investigation (n = 819). While completing the template, there was close contact between the MAPAFISH study team and the Member States' experts to look at interpretations and problems together.

Once the template was completed per Member State, the input information was quality checked. This quality check focused on completeness, clarity, and consistency with other Member States input. For compiling the required data and information for all selected MPAs, several pathways were followed, summarized as follows:

- The Member States with partners in the study (Belgium, Denmark, France, Ireland, Latvia, the Netherlands, Poland, Portugal, Spain and Sweden): The partner institute filled in the required information based on their knowledge and/or from their network within the Member States.

- The Member States without partners in the study: An external contract was regulated with local partners (Estonia, Finland); Scientists from the Member State contributed voluntary (Germany); Data and information were collected by the scientific consortium, based on correspondence with local expert contact (Lithuania).

After the quality check, the files were coupled with the MPA databases (Natura 2000 and CCDA). To structure the information gathered and collected within the study, a database was created (the '**MAPAFISH database**'), compiling the different types of information.

1.1.4 Data treatment and analysis

The analyses are based on the use of the MAPAFISH database and provide a detailed description of the features structuring EU MPAs, the range of management processes developed, as well as the type of fishing activities undertaken throughout EU MPAs and their surrounding areas. Main results are presented in percentage (%) and/or in absolute numbers, and displayed via histograms, pie charts and maps.

1.2 MPA classification: protection level and management

The retained group of 819 MPAs were classified in relation to the investigated features. For a coherent categorisation of the MPAs, we used both the nomenclature proposed in the International Union for the Conservation of Nature (IUCN) guidance (Day et al., 2019) and the classification proposed by Grorud-Colvert et al. (2021). The IUCN classification is more policy driven, whereas the one proposed by Grorud-Colvert et al. (2021) is more science driven. Both frameworks are relevant to use in this work and put the MPA classifications (management and protection level) in a slightly different perspective.

1.2.1 IUCN classification

Following the IUCN classification method, the majority of the MPAs investigated (59%) were classified under Category IV (Habitat/Species Management Area) (Figure 2). This category aims to protect particular species or habitats, and management reflects this priority. For instance, such MPAs might be implemented under the functioning of the Habitats Directive or Birds Directive ([3]). In relation to the highest category of protected area, only 44 MPAs (5.4%) are classified under Category I (strict Nature Reserve/Wilderness Area), which are all located in Estonia, Portugal and Sweden.

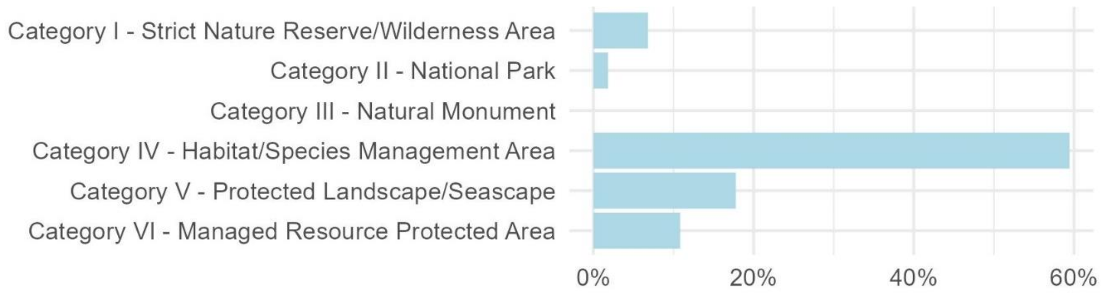


Figure 2. The IUCN categories in EU MPAs. Data source: MAPAFISH database (n = 819 MPAs).

Regarding the IUCN level of protection, 39.7% are identified as 'uniform multiple-use' (50.4% of area), with allowable activities or restrictions throughout the protected area (i.e. no zoning) (Table 2). **For those MPAs catalogued as uniform multiple-use, our analysis shows 23.7% have some fishery restrictions in place** (following the categories shown in Figure 13). Several MPAs (31%) are 'zoned multiple-use', representing a minor fraction in terms of surface area (8.4%). These MPAs have extractive activities allowed throughout the entire MPA, but with marine zoning restricting different uses in time or space to reduce user conflicts. **The total area for both 'No access' and 'No-take areas' combined (i.e. fully protected MPAs) represents only 0.6% of the number of MPAs examined and around 0.1% of the total MPA surface area** (Table 2). In 4% of MPAs examined (4.3% of surface area), there are also no-take areas implemented (zone multiple-use with no-take areas) (the size of those no-take areas is not catalogued), whereas 1.2% of the MPAs (0.8% of surface area) also have protection measures that do not involve spatial measures. These observations are in line with previous studies (e.g. Fenberg et al., 2012; Roessger et al., 2022). Those studies show that the number and area of fully protected MPAs in the EU is very low. In addition, 17.9% (34.6% of surface area) of the MPAs in the EU have no protection measures yet (Table 2).

([3]) The Habitats and Birds Directives form the cornerstones of EU biodiversity policy. They provide a strong legislative framework for all EU countries to protect the most valuable and threatened biodiversity. The Birds Directive (Directive 79/409/EEC) was adopted in 1979 and later amended in 2009 (Directive 2009/147/EC), whilst the Habitats Directive (Council Directive 92/43/EEC) was adopted in 1992.

Table 2. The level of protection (IUCN) for 819 EU MPAs investigated. Where % area = % marine surface area.

Protection level	Uniform multiple-use	Zoned multiple-use	Zoned multiple-use with no-take areas	Protection measures that do not involve spatial measures	No access	No-take	No protection	Unknown	Total
Belgium	-	-	-	-	-	-	5	-	**5**
Denmark	10	103	-	-	-	-	-	3	**116**
Estonia	23	10	7	-	-	-	-	-	**40**
Finland	28	11	-	-	1	-	-	27	**67**
Germany	-	10	2	-	-	-	6	11	**29**
Ireland	144	8	-	-	-	-	-	-	**152**
Latvia	-	-	-	8	-	-	-	-	**8**
Lithuania	-	-	3	-	-	-	3	-	**6**
Netherlands	-	3	5	-	-	-	7	-	**15**
Poland	-	-	-	-	2	-	16	-	**18**
Sweden	50	94	8	-	1	1	3	4	**161**
France	9	7	2	-	-	-	76	-	**94**
Portugal	35	7	4	-	-	-	9	-	**55**
Spain	26	1	4	-	-	-	22	-	**53**
Total	**325**	**254**	**35**	**8**	**4**	**1**	**147**	**45**	**819**
% of total MPAs	**39.7**	**31.0**	**4.0**	**1.2**	**0.5**	**0.1**	**17.9**	**5.5**	**100**
% area	**50.4**	**8.4**	**4.3**	**0.8**	**0.1**	**< 0.1**	**34.6**	**1.4**	**100**

1.2.2 Grorud-Colvert classification

In addition to the IUCN classification system, the 819 MPAs investigated were described in terms of (i) stage of establishment and (ii) protection level, according to the method of Grorud-Colvert et al. (2021), described in Annex 1.

Stage of establishment

The establishment of MPAs was categorised under one of four stages (proposed/committed, designated, implemented and actively managed) (Figure 3). The stage of MPA establishment was compared with the availability of management plans in each area (Table 3).

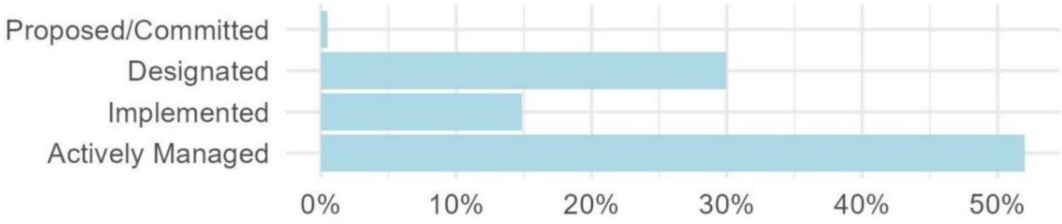


Figure 3. The stage of establishment of EU MPAs (in accordance with Grorud-Colvert et al., 2021). Data source: MAPAFISH database (n = 819 MPAs).

- **52% of the investigated MPAs (n = 426) were actively managed**, meaning that management is implemented and includes monitoring, periodic review and adjustments as needed to achieve biodiversity conservation and other ecological and social goals. Of these actively managed MPAs, 97.3% had management plans.

- **30% (n = 246) were in the designation stage**. These MPAs have been established and recognised through legal means, with clearly stated goals and processes to define allowed uses and associated regulations or rules to control impact. Of these, however, 89.8% do not yet have a management plan.

- **14.8% (n = 121) were at implementation stage**, i.e. transiting from existence on paper to being operational with management plans activated (where for 52.9% of those MPAs a management plan is available).

- **0.5% (n = 4) were in the stage of being proposed/committed**, so not yet established.

- **2.7% (n = 22) had status 'unknown'** and are therefore not available for further analysis.

Overall, the **availability of management plans in MPAs had a good correlation with the stage of establishment** (Table 3).

Table 3. The stage of establishment across availability of management plans (no, yes or unknown) (% of MPAs).

Stage	No (%)	Yes (%)	Unknown (%)
Proposed/Committed	100	0	0
Designated	89.8	8.5	1.7
Implemented	45.5	52.9	1.6
Actively Managed	1.6	97.7	0.7

Protection level

In accordance with the classification of protection level (minimally, lightly, highly and fully) for MPAs investigated (Figure 4):

- **38.5% of the investigated MPAs (n = 315) are minimally protected** (42.2% of total area of MPAs).
- **44.6% (n = 365) are lightly protected** (49.1% of total area of MPAs), with moderate to substantial extraction and other impacts allowed.
- **11% (n = 91) are highly protected** (5.8% of total area of MPAs), with light extractive activities and low total impact allowed.
- **0.5% (n = 4) of the investigated MPAs**, comprising two MPAs in Finland and two MPAs in Poland, totalling 169 km² (0.025% of total area of MPAs) **are fully protected**, with no extractive or destructive activities allowed.
- for 5.4% (n = 44) of the investigated MPAs (2.875% of the total area of MPAs), the level of protection is not catalogued and are therefore not available for further analysis.

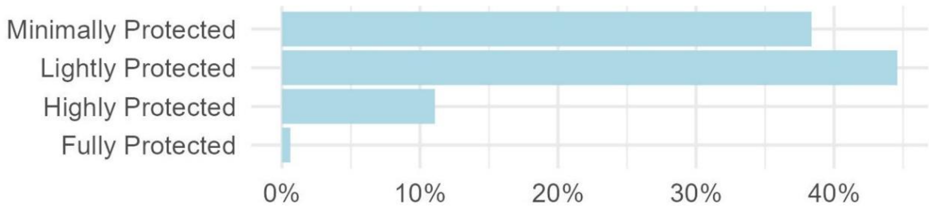


Figure 4. Level of protection in EU MPAs (in accordance with Grorud-Colvert et al., 2021). Data source: MAPAFISH database (n = 819 MPAs).

The level of protection within EU MPAs per ICES ecoregion (n = 819) is shown for the Greater North Sea, and Baltic Sea in Figure 5, and Celtic Seas, and Bay of Biscay and Iberian Coast and Macaronesia in Figure 6. Within the **Greater North Sea**, the largest number of MPAs protected are classed as 'lightly protected' (105; 56%), followed by minimally protected (48; 26%). A total of 18 MPAs are classed as 'highly protected', which occur in Denmark (9) and Sweden (9). No MPAs are classed 'fully protected' and a total of 15 are 'unknown'. Within the **Baltic Sea**, a slightly higher percentage of MPAs are classed as 'lightly protected' (197; 63%). The Baltic has also the highest number of MPAs classed as 'highly protected' (50; 16%), compared to Macaronesia (13%) and Greater North Sea (10%). Those MPA's were from Finland (28), Denmark (11), Sweden (10) and Germany (1). Four MPAs are classed as 'fully protected' (Finland 2; Sweden 2), whereas a total of 27 are 'unknown'.

In comparison to the Greater North Sea and Baltic Sea, information available for the **Celtic Seas, and Bay of Biscay and Iberian Coast** show a higher percentage of MPAs are classed as 'minimally protected' (157; 77%). Further to this, a total of 39 MPAs are classed as 'lightly protected' (19%), which are predominantly from Spain (26) and Ireland (10). Seven MPAs are classed as 'highly protected' (Portugal 5; Spain 2), whereas none are classed as 'unknown'. In **Macaronesia**, a total of 61 MPAs have been classified, of which 42 (Spain 22; Portugal 20) are 'minimally protected' (69%). Remaining MPAs have been classed as 'lightly protected' (Portugal 11) and a further eight 'highly protected' (Portugal 5; Spain 3). No MPAs are classed as 'fully protected' or 'unknown'. Of the remaining 56 classified MPAs, 52 were not allocated to an ICES ecoregion, whereas 4 are within the Oceanic Northeast Atlantic.

In accordance with the classification of **protection permanence** (permanent, conditional or temporary) and **protection constancy** (year-round, seasonal, rotating), the majority of MPAs had year-round (91%; constant protection throughout the year) or permanent protection (90%). Permanent protection means that those MPAs had the legal authority to provide the same level of protection to the site in perpetuity for future generations, unless reversed by unanticipated future legislation or regulatory actions.

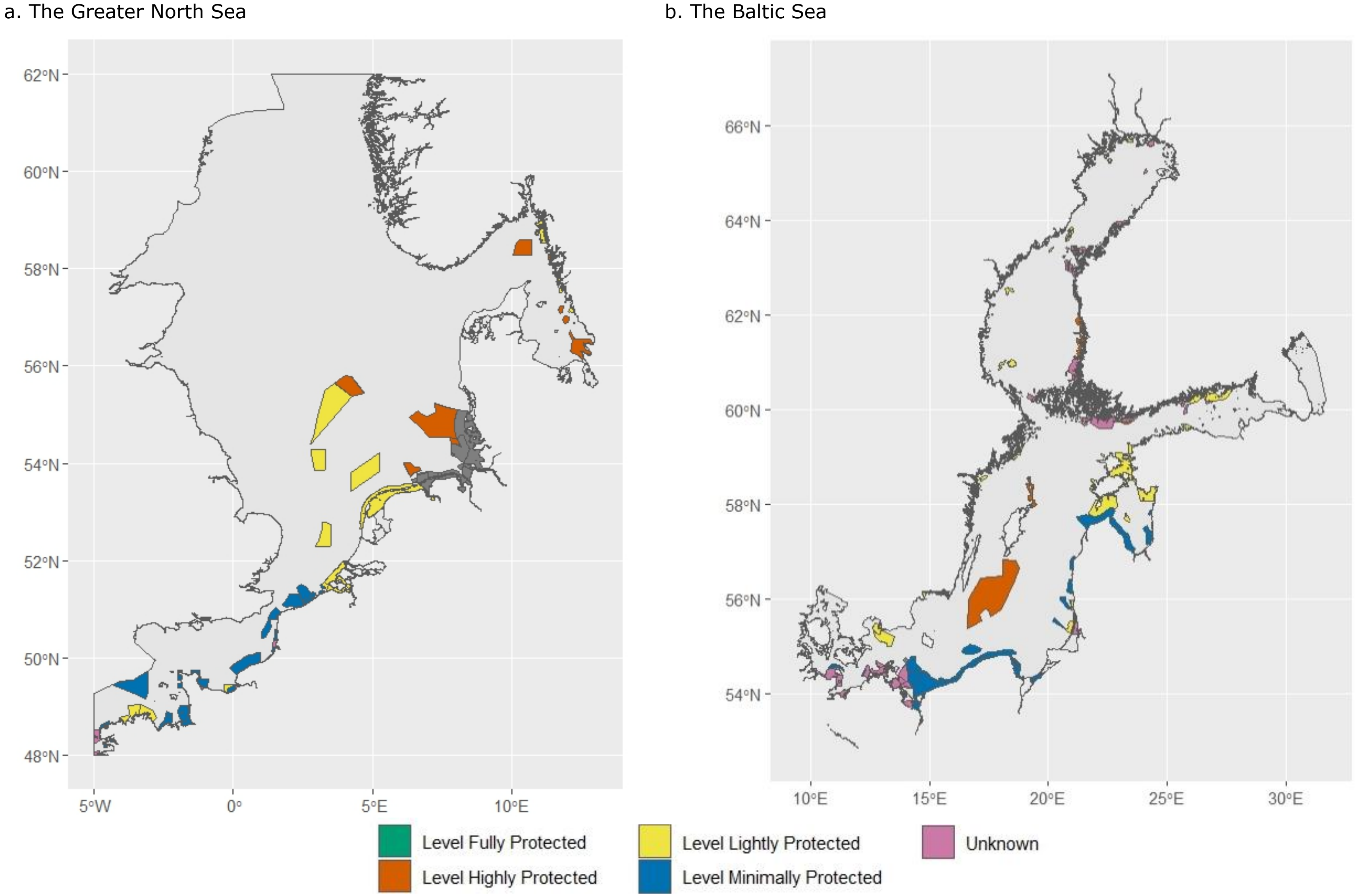


Figure 5. EU MPA protection level per ICES ecoregion: (a) the Greater North Sea (b) the Baltic Sea. Data source: MAPAFISH database.

a. The Celtic Seas, the Bay of Biscay and the Iberian Coast

b. Macaronesia

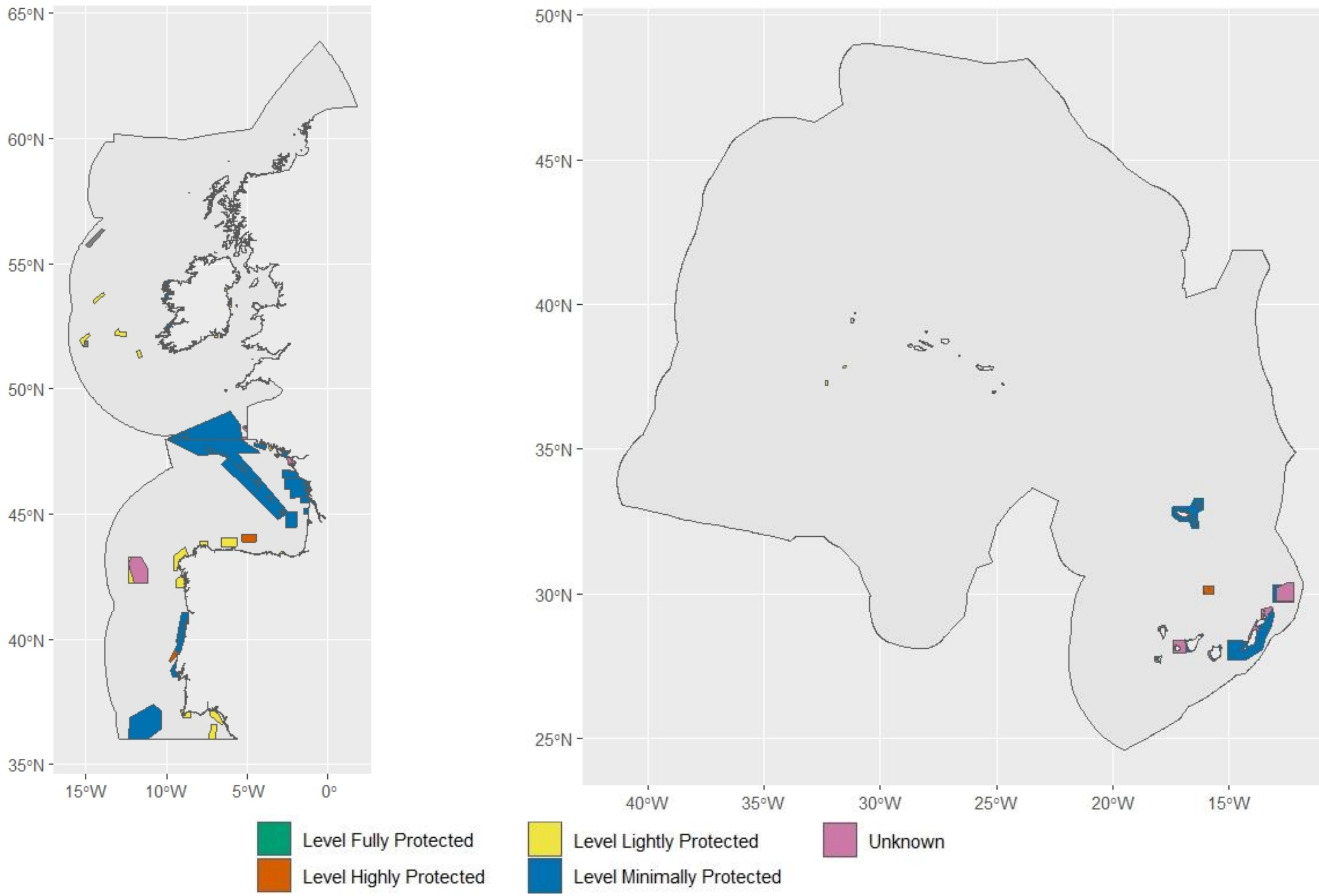


Figure 6. EU MPA protection level per ICES ecoregion: (a) The Celtic Seas, the Bay of Biscay and the Iberian Coast (b) Macaronesia. Data source: MAPAFISH database.

1.2.3 MPA site organisation

Our analysis shows ownership and management of EU MPAs is predominantly through public administration or government (95.7%). Only Finland (17 MPAs) and Denmark (three MPAs) have MPAs in private ownership. Of the MPAs investigated, **43% do not have an MPA board** ([4]), while 28% have one and for 23.5% it is unknown (Figure 7). MPA organisation differs across Member States: only in France it is standard to have an MPA board (for all MPAs), but it is also common in Denmark (71%) and Portugal (47%).

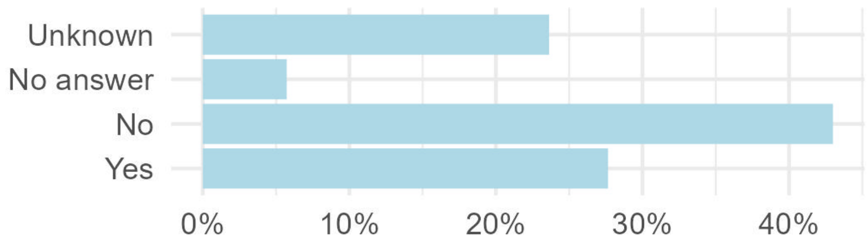


Figure 7. EU MPAs with (Yes) or without (No) a marine board for managing the MPA. Data source: MAPAFISH database (n = 819 MPAs).

The majority of MPAs investigated are government-led, with stakeholder involvement important in their management. For the designation process, our analysis shows stakeholders have been involved in 64% of the cases. In 48.7% of cases, the stakeholder involvement was fully open (= all types of stakeholders), whereas 13.6% was targeted (= stakeholders selected) (Figure 8).

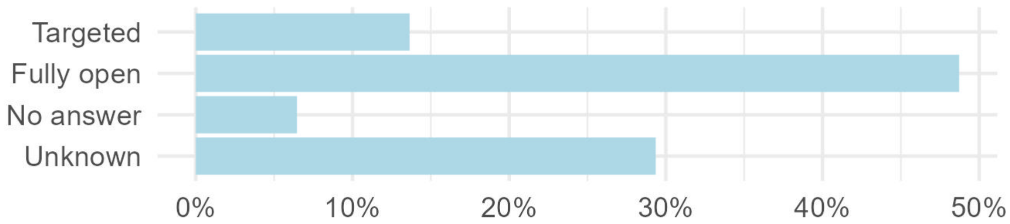


Figure 8. Type of stakeholder involvement in the designation process in EU MPAs. Data source: MAPAFISH database (n = 819 MPAs).

Stakeholder involvement in MPA management was either via being informed of the MPA (i.e. one-way communication – being informed but not having the ability to provide input) (33.3%) or via consultation (included in the decision-making and planning process) (32%) (Figure 9a).

During the process of developing management measures within an MPA, our analysis shows this was undertaken using targeted stakeholder involvement (23.9%), in comparison to the less targeted approach within the designation process (13.6%). Further to this, there is no real shift in the type of involvement recorded, with more consultation of stakeholders (45.3%), and less informing behaviour (i.e. passive engagement) (12.9%) being undertaken (Figure 9b).

([4]) Official MPA management structure for MPAs consisting of different stakeholders.

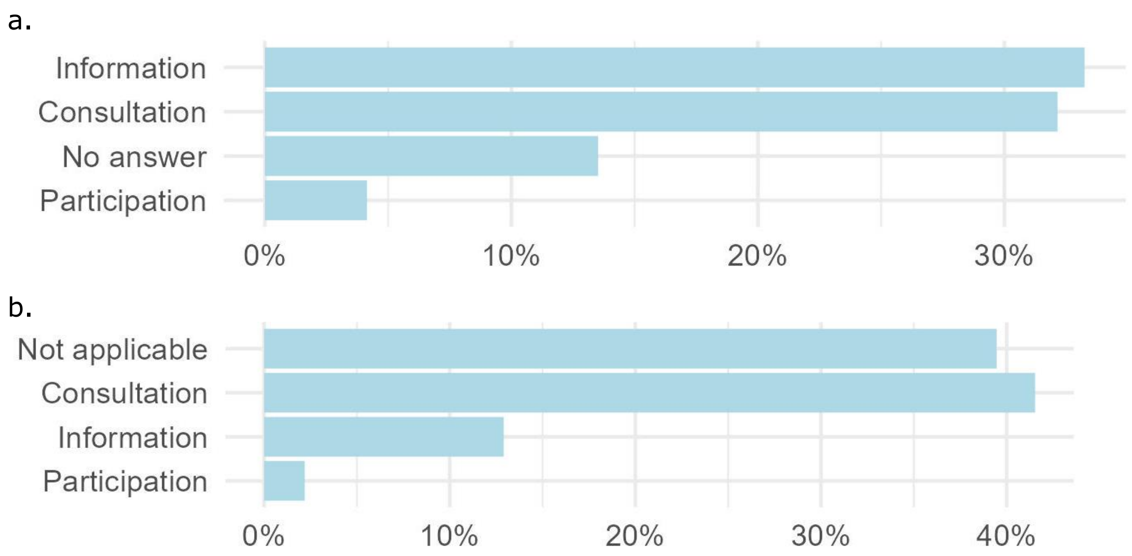


Figure 9. Stakeholder involvement in (a) designation process and (b) process of taking measures in EU MPAs. 'Not applicable' means that there is no process of measures for these MPAs. Data source: MAPAFISH database (n = 819 MPAs).

1.3 MPA management plans and conservation objectives

This section identifies MPAs that have a defined management plan and conservation objectives (environmental components). Having a management plan and defined conservation objectives are tools needed for actively managing MPAs.

1.3.1 Management plans

An MPA management plan is a site-specific planning and management tool that fulfils many functions and describes the goals, objectives, regulations and boundaries of the MPA. Management plans define the actions needed and the authorities responsible for implementing these actions. In total, **62% of the MPAs (36.8% MPA surface area) investigated in this study had a management plan**, with 35.8% (62.4% MPA surface area) having no management plan yet (2.2% unknown). An earlier study (WWF, 2019) indicated that only 1.8% of EU MPA areas was covered by MPA management plans, which is less than that found in this study (excluding the Mediterranean Sea). The EU legislation does not require MPAs to have management plans, but the Organisation for Economic Co-operation and Development (OECD) has identified management plans as good practice (OECD, 2017).

1.3.2 Conservation objectives and environmental components

Conservation objectives are defined for the majority of MPAs (89%). Of those MPAs with conservation objectives, 57.9% have a management plan, whereas 30.5% do not have a management plan. This assessment has examined four environmental aspects (i.e. ecosystem components, sensitive species, habitat types and essential fish habitats) recorded as part of the conservation objectives.

(i) Ecosystem components

A total of 11 ecosystem components were identified for consideration at the highest level: seabirds, marine mammals, physical habitats, fish (teleost), benthos, plants, fish (cartilaginous), reptiles, plankton, cephalopods, food web (Figure 10). A lower level of ecosystem components is available in the MAPAFISH database.

Seabirds are the primary ecosystem component recorded as part of the MPA conservation objectives: 39.7% of the MPAs listed this component. Marine mammals are the second group of ecosystem components, listed in 32.4% of the MPAs. Physical habitats and benthos are listed in 18.4% and 12.4% of the MPAs, respectively. Physical habitats being the seabed substrate and benthos being specific benthic animals or communities. Hence there is overlap here, as it is possible to protect the physical habitat without protecting the species associated with that habitat. This is probably why there are fewer MPAs for benthos. Fish were only specifically listed for 21% of the MPAs (13.8% of areas for teleost fish and 7.3% for cartilaginous fish, including sharks, skates and rays).

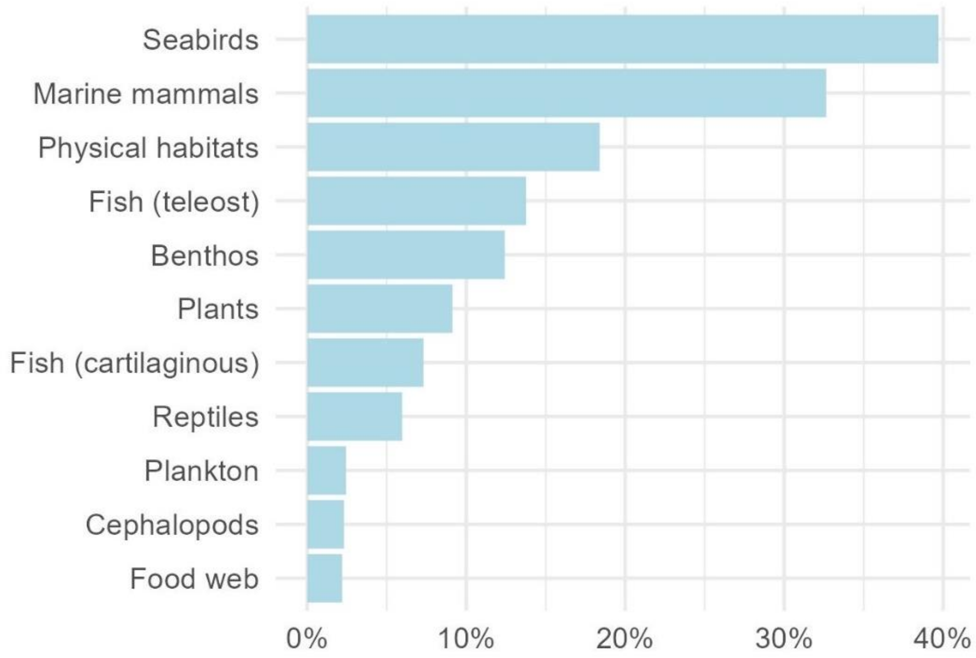


Figure 10. Ecosystem components recorded as part of the conservation objectives of EU MPAs. Data source: MAPAFISH database (n = 819 MPAs).

(ii) Sensitive species

A total of 20 sensitive species were selected for consideration based on their prioritisation in the EU marine Action Plan (except species distributed primarily in the Mediterranean and Black Seas which fall outside the geographic scope of the study) (Table 4). For these sensitive species, information from the Natura 2000 database was extracted about how many of the MAPAFISH MPAs under study these species in their conservation objectives or as a reason for designating the MPAs.

Most of the selected species are not listed as conservation targets or considered as a reason for MPA designation (Table 4). To gain a better understanding of whether the MPAs could contribute to the conservation of those species, an overlay between the MPA layer and the species distribution maps should be executed. However, this is beyond the scope of this study.

(iii) Habitat types

The majority of MPAs (57%) recorded the habitat type ‘Open seas and tidal areas’ as part of their conservation objectives. Other habitats listed in the conservation objectives were essentially coastal habitats, including cliffs, beaches (27%) and marshes (21.7%; total of categories 1300 and 1400) (Figure 11). For the Baltic region, the habitat known as ‘Boreal Baltic archipelago, coastal and land upheaval areas’ (type 1600; according to the Natura 2000 code) is important.

Table 4. Sensitive species list and number of EU MPAs, according to Natura 2000 database. "Not found": species not listed in Natura 2000 as a conservation target or species not considered as a reason for MPA designation.

Species	Common name	Number of MPAs
Acipenser oxyrinchus	Atlantic sturgeon	1
Acipenser sturio	European sea sturgeon	13
Carcharias taurus	Sand tiger shark / nurse shark	Not found
Carcharodon carcharias	White shark	Not found
Caretta caretta	Loggerhead turtle	19
Chelonia mydas	Green turtle	17
Delphinus delphis	Short-beaked common dolphin	Not found
Dermochelys coriacea	Leatherback turtle	Not found
Dipturus batis	Common (blue) skate	Not found
Dipturus intermedius	Flapper skate	Not found
Glaucostegus cemiculus	Blackchin guitarfish	Not found
Gymnura altavela	Spiny butterfly ray	Not found
*Monachus monachus**	Mediterranean monk seal	3
Odontaspis ferox	Smalltooth sand tiger shark	Not found
Phocoena phocoena	Harbour porpoise	125
Puffinus mauretanicus	Balearic shearwater	Not found
Rhinobatos rhinobatos	Common guitarfish	Not found
Squatina aculeata	Sawback angelshark	Not found
Squatina oculata	Smoothback angelshark	Not found
Squatina squatina	Angelshark	Not found

* Subpopulation in Madeira.

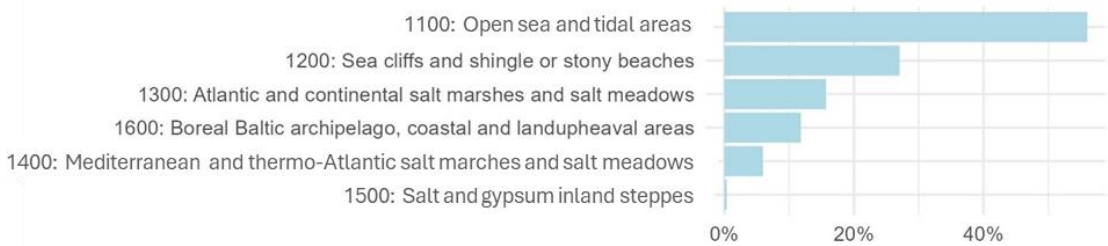


Figure 11. Overview of habitat types (according to the Natura 2000 code) recorded as part of the conservation objectives and utilised to designate EU MPAs. Type 8300 (Rocky habitats and caves) is not shown. Data source: MAPAFISH database (n = 819 MPAs).

Evidence that conservation targets are being met is available for only 10.5% of MPAs, whereas targets are not being met in 5% of MPAs. Hence, for the **majority of MPAs (84.5%), it is unknown whether the conservation objectives are being met**. The reasons for failing to meet conservation targets are seldom given, but incomplete ongoing monitoring is often cited. However, for 22 MPAs there is some evidence to explain the failure to meet conservation objectives: in Belgium, Denmark and the Netherlands, the fishery has an impact; in some MPAs in the Baltic (Sweden and Finland), eutrophication and invasive species have significant impacts.

(iv) Essential fish habitats

Essential fish habitats within an MPA can be nursery grounds for demersal and pelagic fishes or where certain fishery stock measures are taken. **The large majority of MPAs (91.2%) have no protection of essential fish habitats specified in the conservation objectives**. In 26% of the MPAs, a certain aspect of the fish stock (e.g. quantity, quality, biodiversity) is taken into account as part of the MPA conservation objectives. In the few cases (14%) where fish were part of the management plan, the MPA includes some or all of the relevant spawning areas (50%) and migration corridors (35%).

1.4 Fishing activities and fisheries management measures

1.4.1 Commercial fishing

To date, **many types of commercial fishing activities take place in MPAs**. Such activities include a range of metiers, with nets, pots, and hooks and lines being the most common (Figure 12). In addition, **trawling (demersal and pelagic) takes place in around 25% of MPAs, with seines in around 20% and dredges in around 17%**.

In relation to passive nets, gillnet fishing is the most common, followed by fyke net. Pot fishing is mainly catch directed (e.g. fish or shrimp pots). For hooks and lines, longline fishing is most common, followed by handline. In relation to trawling, demersal and pelagic otter trawl are most common. There are also clear regional differences in the types of fishing activity occurring in the MPAs where fishing is listed (Table 5).

Table 5. Regional differences in the type of fishing activity, listed by Member States experts in the MAPAFISH database as occurring in the EU MPAs. The values are in % of fishing type to the total list fishing type records within ICES ecoregion.

	Baltic Sea	Greater North Sea	Celtic Sea/ Bay of Biscay/ Iberian Coast	Macaronesia
Nets	42	25.5	14.5	16.8
Pots	10.1	12.5	17.9	18.9
Hooks and lines	19.8	12.5	12.9	32.2
Demersal trawls	2.3	17.2	17.6	0
Pelagic trawls	7.8	14.7	15.8	0
Seines	17.9	5.8	7.5	32.2
Dredges	0	11.9	13.7	0
No commercial fishing catalogued	61	38.7	4.4	30.8

The information available on commercial fishing activities correlates well with the quantitative fishery analyses (see Section 2), revealing mostly the same dominant fishing metier activities within the MPAs and ICES ecoregions (Table 5 and Table 8). Bottom-trawling-based fishing types dominate in the Greater North Sea, whereas passive fishing (nets, pots, hooks and lines) dominate in Macaronesia and the Baltic Sea. The number of MPAs with no commercial fishing activities is much lower (35.7%) than shown in the quantitative analyses (63.9%) (see Section 2), confirming that with VMS data, not all fishing activities (cf. passive fishing) are covered. It is also regionally different, with highest number of non-commercial fishing for Baltic Sea MPAs and lowest for Celtic Sea/Bay of Biscay/Iberian Coast.

In half of the MPAs (50.5%), no fisheries management measures (restrictions) were in place (Figure 13), which encompassed 41.8% of the total surface area of all MPAs. Where fisheries restrictions had been implemented, different types including both temporal and spatially explicit were evident. In around 9.5% of the MPAs, Member State experts did not know whether fisheries measures existed. These findings are in line with previous observations from the European Court of Auditors' special report (ECA, 2020). The examination of how Member States' legal provisions protected 21 long-established Natura 2000 MPAs in Spain, France, Italy and Portugal, showed that in nine MPAs (43%), Member States had imposed little or no specific restrictions on fishing activities.

Spatially explicit restrictions (in 27% of MPAs, but in 49.7% per area of MPA coverage), with spatially localised gear restrictions (in 16% of MPAs, but in 7.4% per area of MPA coverage) and spatial zoning of the fleet (in 11.5% of MPAs, but in 42.3% of area MPAs) are the most common restriction measures (Figure 14). The difference between the number of MPAs and area of MPAs is mainly because of the large size of some Portuguese MPAs (Macaronesia area). The other spatio-temporal restrictions (temporal zoning of fleet access or gear restrictions, spatio-temporal catch quotas) are implemented in a low percentage of MPAs (combined 7.1% of MPAs and 1.5% in terms of area of MPAs) (Figure 14).

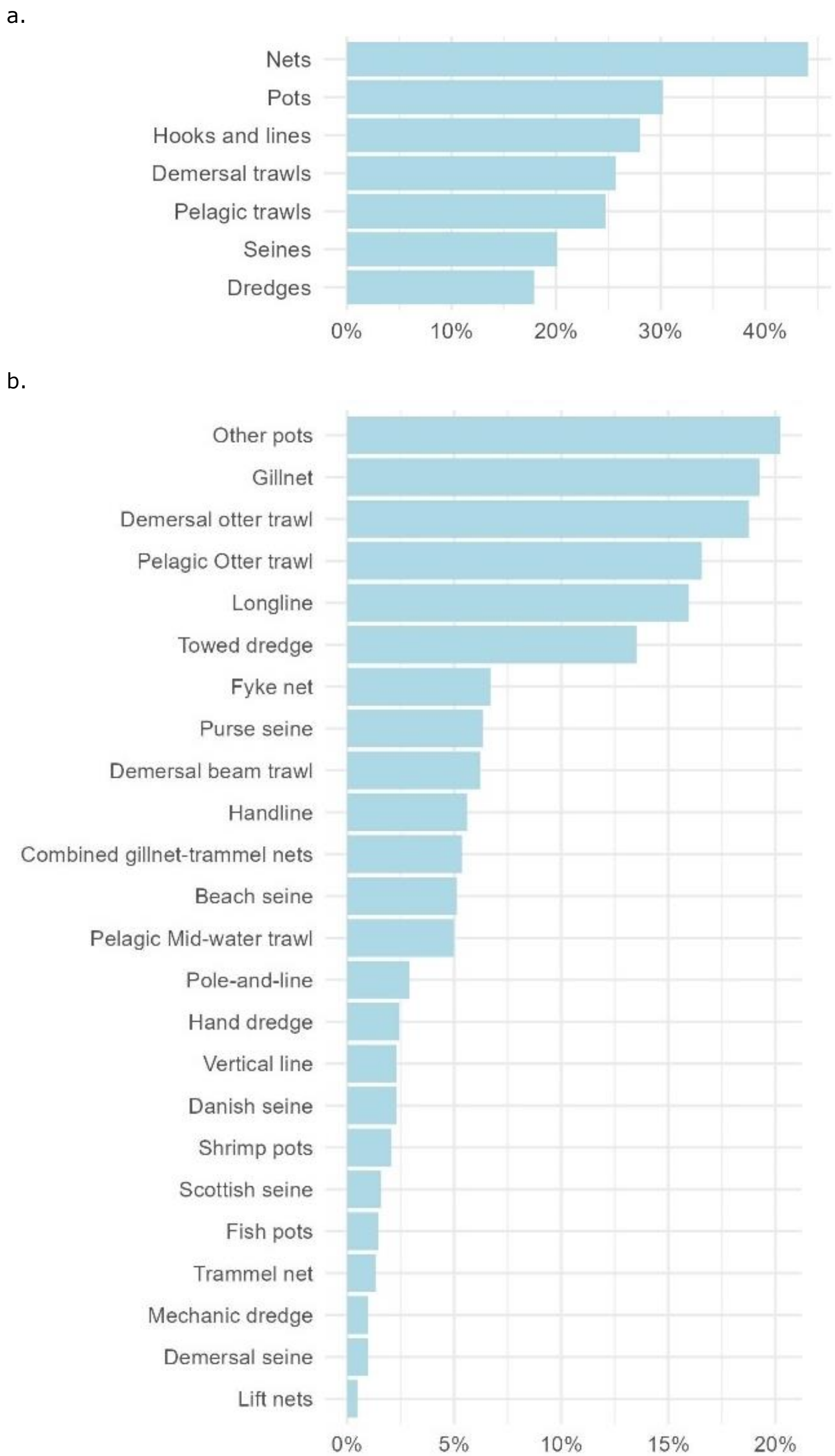


Figure 12. Commercial fishing activities (types of fisheries) undertaken in EU MPAs (%) (a) level 1 metiers (b) detailed metiers. Data source: MAPAFISH database (n = 819 MPAs).

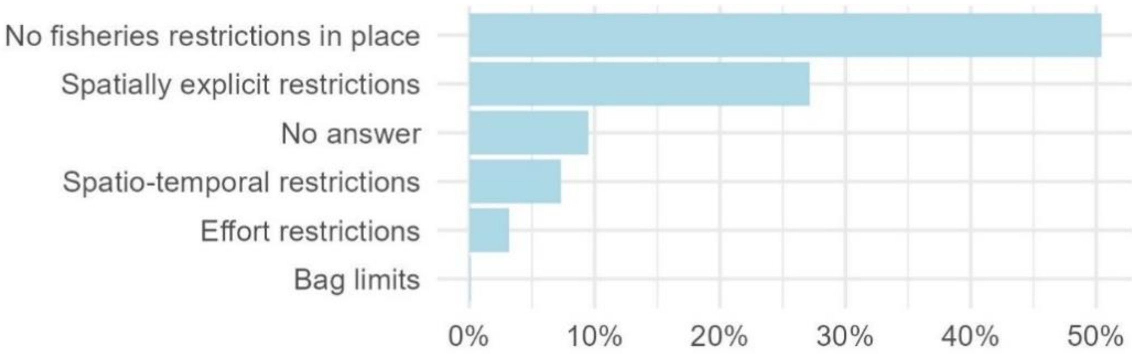


Figure 13. Overview of fishery measures (restrictions) undertaken in EU MPAs. 'No answer' = not known. Data source: MAPAFISH database (n = 819 MPAs).

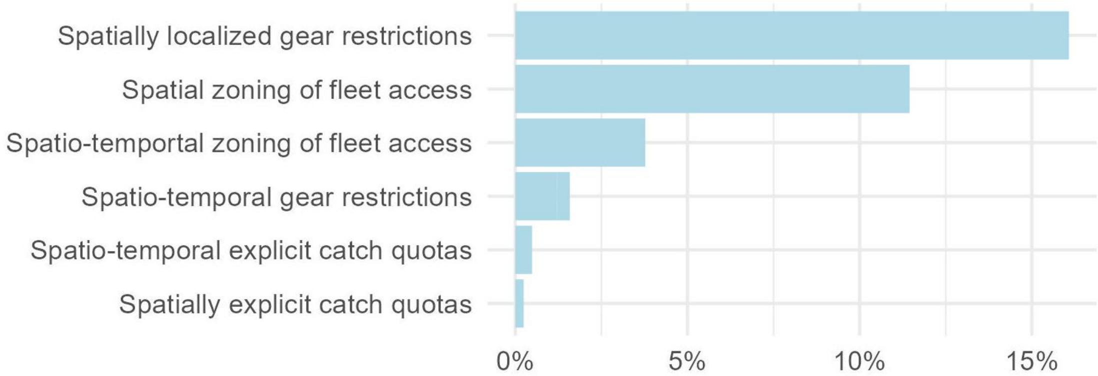


Figure 14. Types of spatio-temporal restriction undertaken in EU MPAs. Data source: MAPAFISH database (n = 819 MPAs).

Where spatio-temporal restrictions are imposed within MPAs, they are very diverse, as well as being site- and Member State-specific. The type of fishery measures (restrictions) in place within EU MPAs per ecoregion (n=819) is shown for the Greater North Sea, and Baltic Sea in Figure 15, and Bay of Biscay and Iberian Coast and Macaronesia in Figure 16.

Within the **Greater North Sea**, there are 'no fisheries restrictions' in place for 71 MPAs (38%), which includes France (43), Sweden (16), Denmark (6), the Netherlands (4) and Belgium (2). Further to this, a total of 61 MPAs are classed with 'spatially explicit restrictions', which include Denmark (43), France (6), Germany (6), Sweden (4), Belgium (1) and the Netherlands (1). A further nine MPAs are classed under 'spatio-temporal restrictions', which occur in Sweden (8) and Germany (1). In total, 14 MPAs are classed with 'effort restrictions' in the Netherlands (7), Denmark (5) and France (2), and 31 MPAs are classed as 'unknown'. By comparison to the Greater North Sea, the **Baltic Sea** has a rather similar percentage of MPAs classed with 'no fisheries restrictions' (35%; 110), which is dominated by Sweden (43), Estonia (24), Finland (18) and Poland (13). Further to this, a total of 99 MPAs are classed with 'spatially explicit restrictions', including Demark (58), Finland (21), Germany (8) and Sweden (7), Poland (4) and Estonia (1). By comparison, only 46 MPAs are classed with 'spatio-temporal restrictions' (Finland 20; Estonia 15; Sweden 8; Lithuania 3). 'Effort restrictions' are in place in only one MPA (Poland), and a further 57 are classed as 'unknown'.

In comparison to the Greater North Sea and Baltic Sea, information available for the **Celtic Seas, and Bay of Biscay and Iberian Coast** show a much higher number of MPAs are classed with 'no fisheries restrictions' (164: 81%), including Ireland (108), France (42) Spain (11) and Portugal (3). A total of 23 MPAs are classed with 'spatially explicit restrictions' (Portugal 11; Ireland 6; Spain 5; France 1), whereas four MPAs in Ireland are classed with 'spatio-temporal restrictions'. Further to this, Spain has 11 MPAs with 'effort restrictions' and one MPA with 'bag limits. No MPAs are classed as 'unknown'. In **Macaronesia**, a total of 26 MPAs (43%) are classed with 'no fisheries restrictions (Spain 22; Portugal 4) and 30 MPAs (49%) with 'effort restrictions' (Portugal 27; Spain 3). No MPAs are classed as 'unknown'. Of the remaining 56 classified MPAs, 52 were not allocated to an ICES ecoregion, whereas 4 are within the Oceanic Northeast Atlantic.

Additional information on the range of restrictions collected from Member State experts is listed below.

- In Germany, there are spatially localised gear restrictions in bottom trawl and shellfish fishing. Only passive gears are allowed in certain MPAs.
- In Denmark, restrictions in MPAs are on bottom trawling, mussel and clam fishing.
- In Estonia, the restrictions refer to fishing with fyke nets and gill nets, with mesh size greater than 200 mm prohibited. Fishing is prohibited when temporal access to the MPA is prohibited; therefore, the timing is MPA-site-dependent.
- In Spain, restrictions are in place for diverse fleets and gears but are not strictly related to the MPAs. A bag limit approach was mentioned in some Spanish MPAs, for example a limit is set for clam (*Donax trunculus*) per fisher and per day.
- In Finland, the restrictions are diverse and very site specific; however, in general, fishing is restricted in corridors for migratory fishes. Entering the area or a certain perimeter around islands during the breeding season for seabirds or seals is forbidden; this includes entry for fishing.
- In Ireland, mobile fishing gear is prohibited in 6 out of 152 MPAs. Risk assessments have also been completed for all 152 MPAs with respect to whether specific measures or interventions are needed to protect the ecological features in the sites.
- In MPAs in the Netherlands, the shrimp fishery has rules for maximum annual fishing hours, while spatial zones apply to other bottom contacting fisheries (VIBEG) agreement ([5]).
- In Poland, there is some spatial zoning of fleet access (but no further information was specified).
- In Portugal there is a diverse set of spatially localized gear restrictions, site dependent (no general rules). In some MPAs, commercial fishing is forbidden, except for tuna or live bait tuna fishing. In other MPAs, prohibition relates to the size of the boats or gear (nets); and in a few MPAs, use of bottom contacting gear is forbidden.
- In Sweden there are spatio-temporal closures for seabirds and seals. Gear restrictions forbid bottom trawling on sensitive habitats, and there are no-take areas within some of the MPAs. The restrictions are diverse and site dependent.
- In Belgium, France, Lithuania and Latvia, no specific fishery restrictions were reported by the experts, but this does not exclude that fishery management processes are going on or being in the state of implementation.

([5]) The Visserij in beschermde gebieden akkoord (VIBEG) is an agreement between the fishing industry, nature organisations and the Dutch Government, is assisting the implementation of the Natura 2000 goals in the Natura 2000 areas Vlakte van Raan and North Sea Coastal Zone.

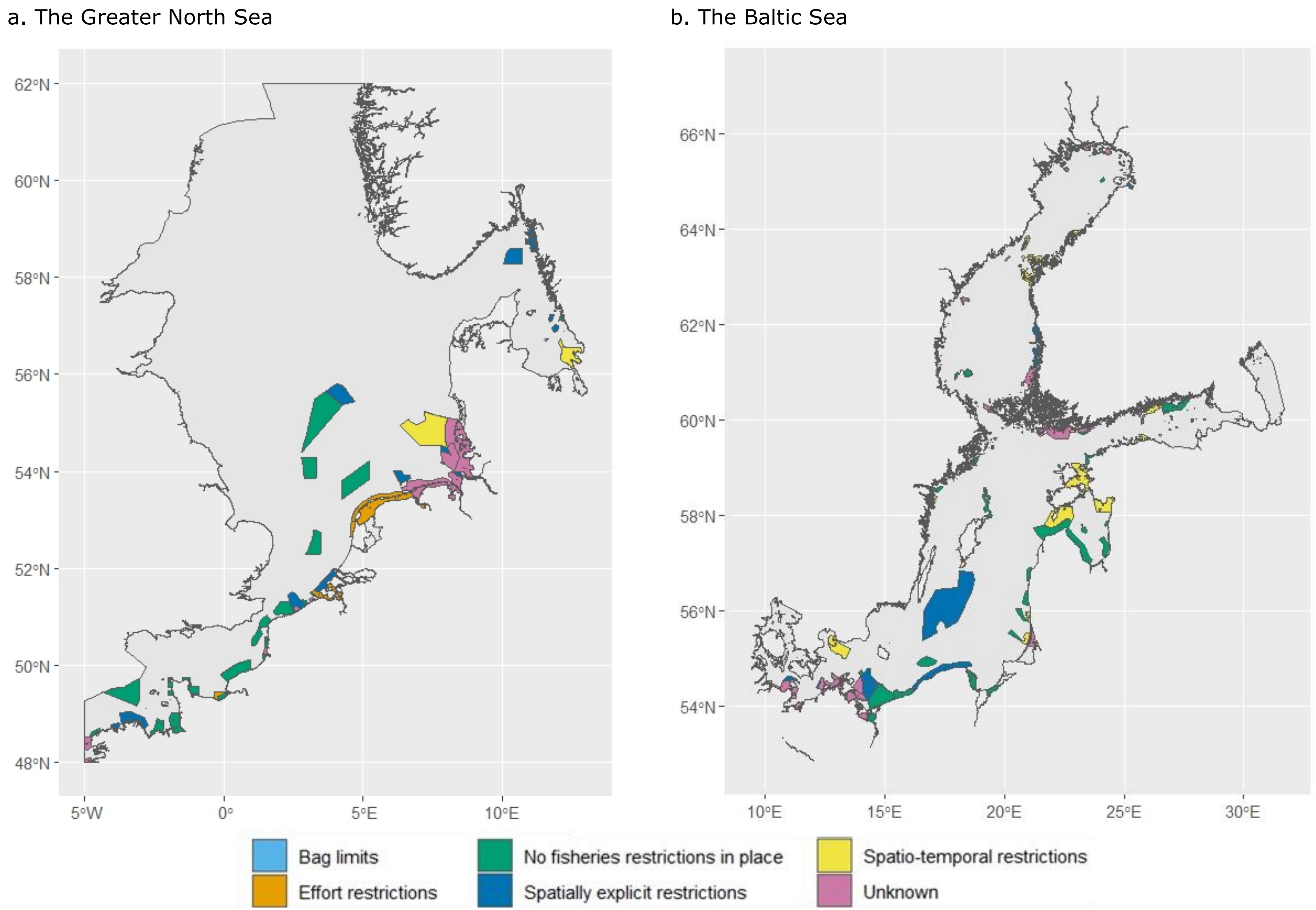


Figure 15. Overview of the fishery measures (restrictions) undertaken in the EU Member States per ICES ecoregion: (a) the Greater North Sea (b) the Baltic Sea.

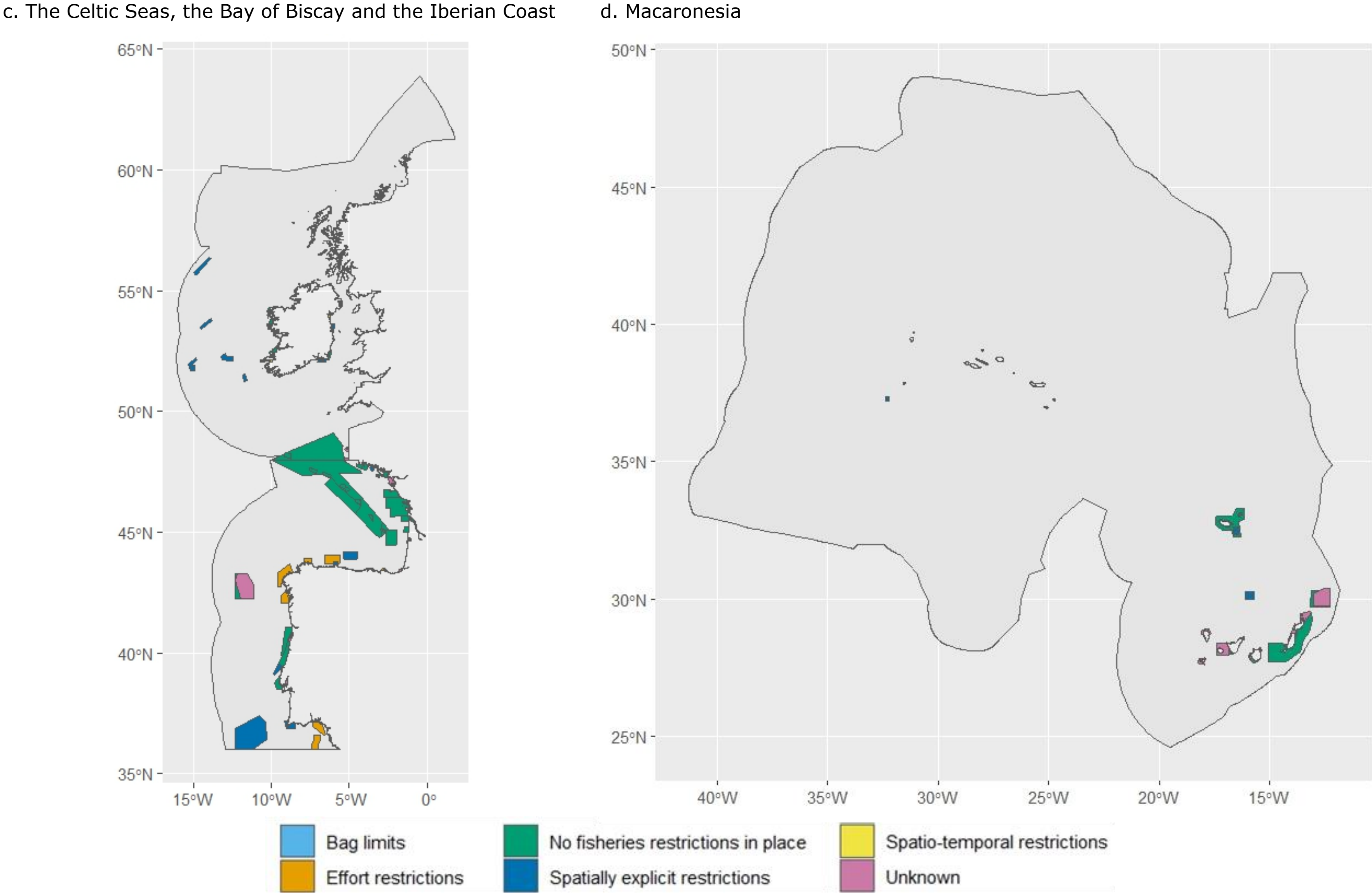


Figure 16. Overview of the fishery measures (restrictions) undertaken in the EU Member States per ICES ecoregion: (a) the Celtic Seas, the Bay of Biscay and the Iberian Coast (b) Macaronesia.

1.4.2 Recreational fishing

No recreational fishing activities were reported or seen as relevant to manage in 29% of the investigated MPAs. However, where recreational fishing is present, gears used are mainly hooks and lines (14%), nets (12%) and spearfishing (10%) (Figure 17.).

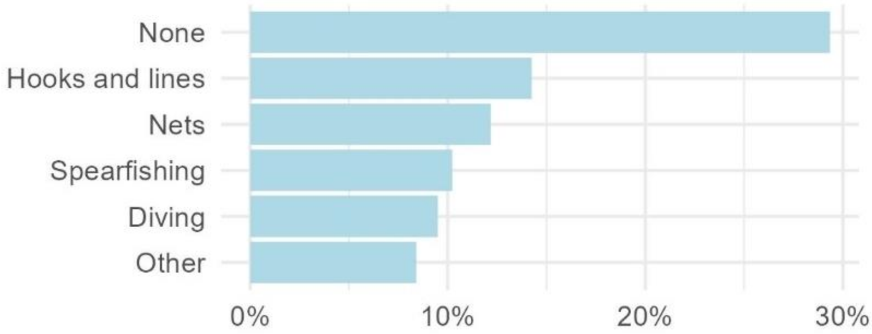


Figure 17. Overview of the most common recreational fishing activities undertaken in EU MPAs; 'Other': other type of recreational fishing, but not specified. **Data source: MAPAFISH database (n = 819 MPAs).**

1.5 MPA planning and socio-economic fishery data

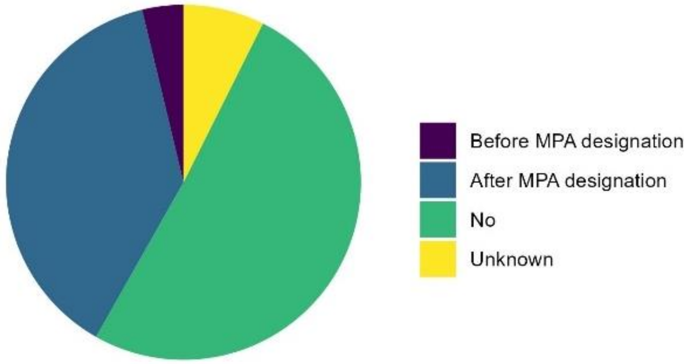
An evaluation was made to understand whether basic information and data needed for MPA planning and management has been collected, by means of monitoring activities in relation to the conservation objectives and/or data-collection initiatives in relation to the socio-economic fishery data.

Results obtained from the MAPAFISH database show conservation objectives related to environmental components are monitored in 48.5% of the MPAs investigated, while within 48.5% of the MPAs the monitoring stage (level of monitoring activity) is unknown. In 3% of the MPAs, no ecological/environmental monitoring is planned.

The availability of a monitoring programme or pilot studies for socio-economic fisheries data collection in the MPA planning and implementation was examined. In the majority of cases (59%), no fishery data have been used during the MPA planning process. Fisheries data have been mainly utilised after the MPA designation (37%) (Figure 18a). In the MPA cases where fishery measures were planned, fishery data were used before measures were taken in 25% of cases, and after measures were taken in 15% (Figure 18b). **In a high proportion of MPAs (49%), no fishery data are used to start fishery management actions within MPAs** (category 'No').

The type of fishery data used was highly variable and based mainly on VMS effort data and stakeholder consultation (Figure 19). Where fishery data analyses were performed, it was done for the larger area, including the MPA (i.e. wider than the MPA and buffer). This implies that the fishery activities are considered within the EEZ of the Member States or sub-area within the EEZ, where the MPA is located.

a.



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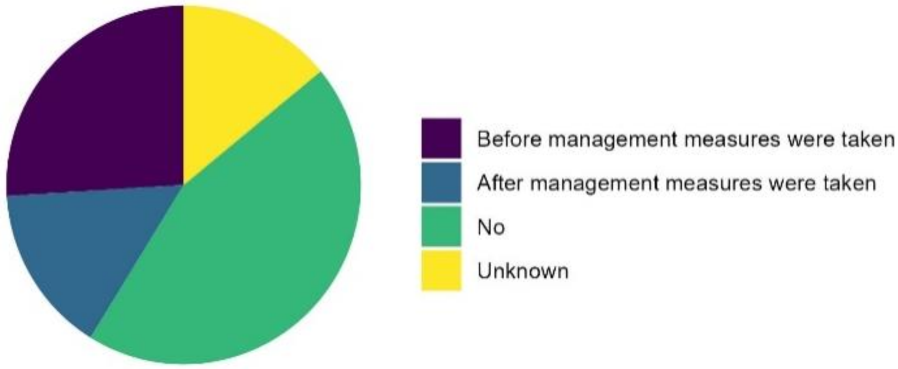
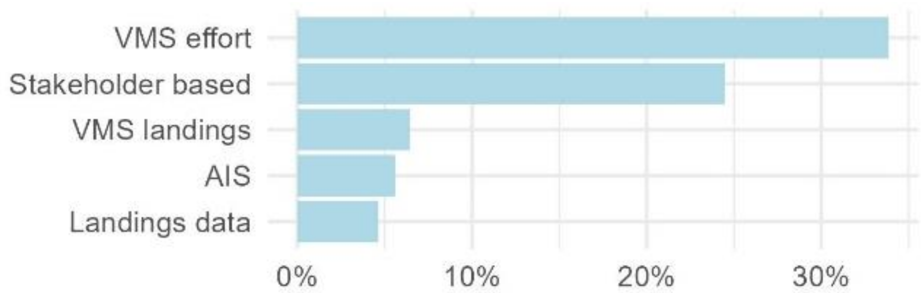


Figure 18. Use of socio-economic data related to fishery in (a) the MPA planning process, and (b) the process of taking fishery measures. Data source: MAPAFISH database (n = 819 MPAs).

a.



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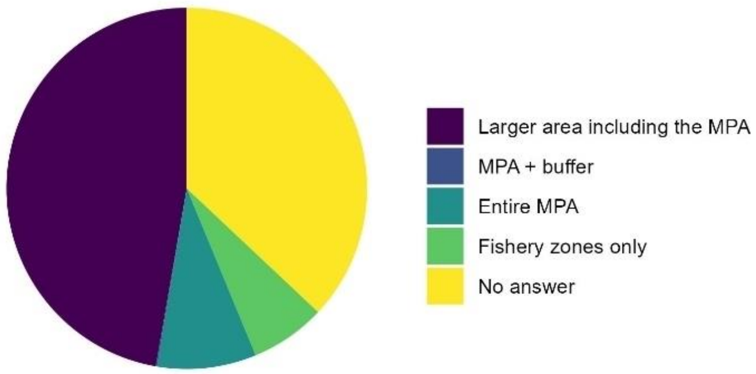

Figure 19. (a) Type of fishery data used in the MPA planning and/or fisheries measures process, and (b) the area for which fishery data analyses are performed. Data source: MAPAFISH database (n = 819 MPAs). Explanation of categories: Larger area including the MPA (wider than the MPA + buffer); MPA + buffer (area of the MPA and a specified buffer, which can be variable according to the studied MPA); Entire MPA (area of the MPA); Fishery zones only (area where management measurements will be taken).

1.6 Synthesis of MPA success in relation to MPA key features

The objective of this part of the study was the development of the MAPAFISH database, with concurrent analyses providing a detailed description of the features structuring EU MPAs (Baltic Sea, Greater North Sea, Atlantic EU Western Waters and in some EU outermost regions (Macaronesia)), the range of management processes developed, as well as the type of fishing activities undertaken throughout EU MPAs and their surrounding areas.

Due to the heterogeneity of the features underlying the structure of EU MPAs, the results have not been able to define a set of 'common' features to explain the success of an MPA, and therefore no description of how an 'average' MPA is structured in the EU is given. Such variation results from the different strategies in implementing MPAs across the Member States and regions, as well as differences in local policies and history of MPA planning and implementation.

Results from this study have shown that **MPA management has still a long way to go** to fully realise the associated objectives in the EU. Many MPAs are progressively and continuously being designated over time, but the **implementation of fisheries restrictions within those MPAs is still lagging behind** (Figure 20). There is a continuous process in implementing fishery measures, but this has been slower than MPA designation; there was an acceleration in this process between 2015 and 2019, but this then slowed down. This might be related to the Marine Strategy Framework Directive (MSFD) measure programmes that came into practice after the first MSFD cycle. The measures are mainly spatio-temporal measures, with a very low number of MPAs with a level of full protection (see Figure 4).

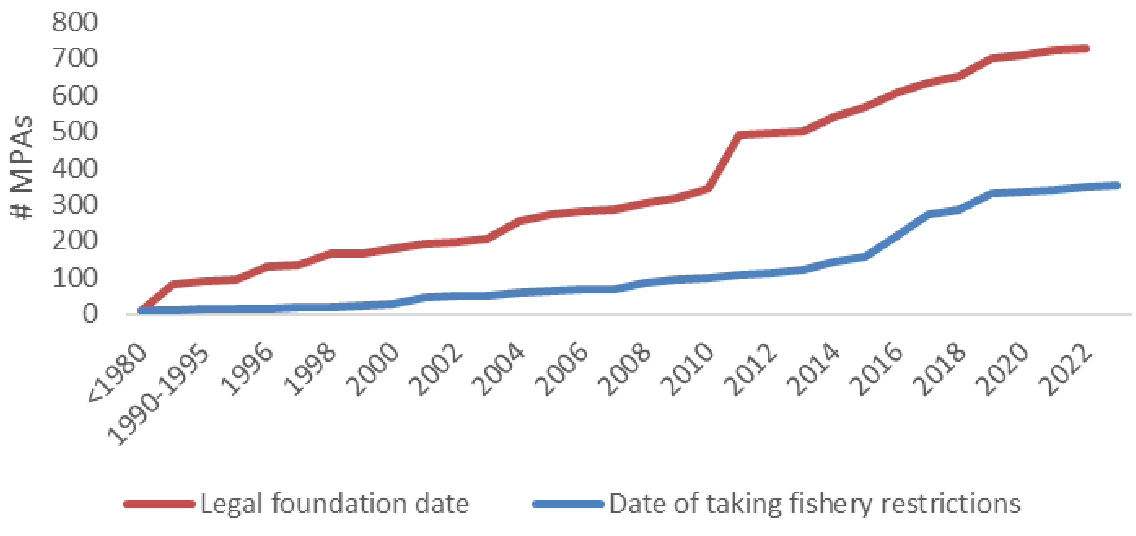

Figure 20. Temporal increase in the number of EU MPAs, based on dates of legal foundation (in red) and dates when any fishery restrictions were taken (in blue). Data source: MAPAFISH database (n = 819 MPAs).

To examine **the factors that may lead to 'success' of EU MPAs** (i.e. leading to successful biodiversity conservation and fisheries benefits), we focused on the existence of the following key features: (i) their level of protection; (ii) the identified level of enforcement within the MPA; (iii) the age of the MPA; (iv) the size of the MPA; (v) the degree of MPA isolation; (vi) the level of stakeholder engagement within the management of the MPA; (vii) fishers' representative in any identified MPA board; and (viii) the level of promotion of sustainable fishing undertaken within the MPA. Indeed, previous studies have shown that the success of MPAs in reaching conservation benefits increase with the accumulation of the earlier mentioned key features (Edgar et al., 2014; Di Franco et al., 2016). In our work, we collected information on key features and tried to link it to MPA success. First, for 85% of the MPAs it is unknown whether the conservation objectives are met, so the success of an MPA cannot be measured using this parameter. Therefore, another variable, the level of protection, is used here to evaluate whether certain key features help successful MPA management. A synthesis of the relation of the key features to the level of protection (as proxy for EU MPA success) is summarised in Table 6.

In the EU, fully protected areas are scarce (0.5%). This number is too low for finding patterns in the key features of those areas, and there is a lack of information for those areas in the MAPAFISH database. Overall, however, fully protected MPAs in the EU are small and relatively old (average age of 64 years) (Table 6). In addition, EU MPAs have a continuous presence along shores and sea-basins, so they are not isolated, as confirmed by the fact that only 3.8% of the MPAs are constrained by a physical barrier – mainly depth (75%). However, only 26.7% of the studied MPAs are identified as part of a network required to ensure connectivity and migration.

In general, based on the analysis of literature and MAPAFISH database, certain features (such as age and enforcement) correlate positively with a higher degree of protection (i.e. the success of the MPA). However, other features such as size, isolation, stakeholder engagement, and the promotion of sustainable fishing, show a weaker or no correlation. In particular, the level of enforcement coincides with the level of protection, resulting in a positive relationship between these two factors (Table 6). The protection level seems not be differing with average size of the MPAs, except that the fully and highly protected are on average smallest in size. So, protection level increases with age of the MPA, but the size of the MPA decreased with protection level. In addition, EU MPAs have a continuous presence along EU shores and sea-basins, so they are not isolated, as confirmed by the fact that only 3.8% of the MPAs are constrained by a physical barrier – mainly depth (75%). However, only 26.7% of the studied MPAs are identified as part of a network required to ensure connectivity and migration. Promotion of sustainable fishery is not higher by higher level of protection. It is even not taken into account in most MPA’s, except the Irish (but are classified as minimally protected) (Table 6).

In relation to stakeholder engagement, this work confirmed that active stakeholder engagement and representation of fisheries stakeholders in MPA boards are likely to lead to success of the MPAs. However, it is less clear if stakeholder engagement plays a key role in the level of protection, due to varying observed trends in the level of participation, consultation and informing (Table 6). From the MPA site organisation chapter (section 1.2.3), we also conclude that an increase in consultation of stakeholders was recorded when management measures were implemented compared to the phase of the MPA designation.

Overall, this study gives a first general insight into the possible role of those key features in MPA success in the EU. However, the quality of information and analyses could be improved. The MAPAFISH database is a useful tool, but could benefit from completing the information missing, populating it with new data and/or features and adding a wider number of MPAs. As there are no real common features on the overall scale, and MPA success is not really quantified (e.g. there are little data on whether MPAs are meeting conservation objectives), it does not mean that the key features listed in the literature are of no value. In the contrary, the EU MPA management in the studied regions should focus more on these features. If future analyses were to focus on specific Member States, a specific sub-region or region, examples of success could certainly be shared to form a common dataset.

Table 6. Synthesis of MPA success (protection level in accordance with Grorud-Colvert et al., 2021) in relation to MPA key features. Numbers are in % (compared to the total in the protection level category) for the following key features: conservation targets met, MPA characteristic (age and size), fisheries restrictions, stakeholder process, MPA organisation, and sustainable fishing promotion.

Key features		Fully protected	Highly protected	Lightly protected	Minimally protected	Unknown‡
Conservation targets met	Yes	0	11	20.5	0	0
	Partly	25	24.2	3.8	0	4.5
	Unknown	75	64.8	75.6	100	95.5
MPA characteristic	Average age (years)	64	24	17	12	21
	Average marine area (km²)	42	437	927	1022	812
Fishery restrictions	No	0	15.4	48.5	92.1	71.4
	Yes	100	84.5	51.5	7.9	28.6
	Fishery enforcement	100	84.6	82.5	12.1	4.8
Stakeholder process	Participation	-	8.8	0.3	7.9	-
	Consultation	-	33	40.5	28.9	-
	Informing	-	14.3	24.1	54.6	-
MPA organisation	MPA board	-	30.8	27.4	29.8	-
	Fishery representative	-	14.3	10	91.5*	-
Sustainable fishing promotion	Yes	0	9.9	9.9	66.3+	0
	No	100	90.1	90.1	33.7	100

Data source: MAPAFISH database (n = 819 MPAs).

* Higher number due to French MPAs, which are mainly minimally protected, but have all an MPA board with fishery representatives; + Higher number due to Irish MPAs, which are mainly minimally protected, but promote sustainable fishing practices.

‡ Protection level not classified.

2 FISHING ACTIVITIES WITHIN AND SURROUNDING MPAs

Key highlights

- Findings reveal that nearly two-thirds (64%) of investigated MPAs across EU waters were not commercially fished by large-scale vessels. In many of the MPAs without fishing, there was no reported fishing in the surroundings areas (69%), whereas almost all fished MPAs recorded fishing activity in their direct surroundings (99%).
- MPAs where fishing activity was recorded show that for the majority (74%) of sites, the standardised fishing effort was lower inside the MPA compared to its direct surroundings. Sites where fishing effort was higher inside MPAs were most frequently found within the Greater North Sea.
- There is little evidence to show that MPAs reduce the range of habitats exposed to fishing pressure. Within the Greater North Sea, Bay of Biscay and the Iberian Coast, a large part (greater than 89%) of the spatial extent of habitats, that are dominant within MPAs, is located within fished MPA sites. Whereas the dominant habitats of the Baltic Sea and Celtic Sea MPAs have a smaller fraction located in fished sites.
- Fishing activities are not necessarily incompatible with MPA conservation objectives, but this depends on the objectives and the type of fishing activity within MPAs. Fishing gears that impact the benthos (e.g. bottom trawls) or that have large bycatch-associated mortality (e.g. some types of gillnets) are incompatible.
- The 'impact score matrix' is a key resource for managers of existing MPAs but also for planners and designers of future MPAs. By referring to this matrix, they can prioritise fisheries-related policy according to the MPAs' conservation objectives.

The **overall objective of this section is to describe in detail the fishing activities that occur throughout the MPAs** investigated, by characterising fishing activities within MPAs and surrounding areas, exploring the relationship between fishing activities and different types of habitats, and assessing the extent such fishing activities were compatible with identified MPA conservation objectives.

This work is structured on the outcomes of a national-level data call to 14 relevant EU Member States ([6]) and two neighbouring states ([7]), for fishing effort and landings, by C-square ([8]) and bespoke MPA-specific polygons, covering a period from 2012 (first available VMS data) to 2021 (latest data available at the time of the call). These data were quality controlled and aggregated to produce an international-level dataset for the 847 ([9]) selected MPAs as well as corresponding direct surroundings. The direct surroundings were defined as the area within the marine realm and within 5 km of the MPA border. This was selected to represent the fishing activities that occur within an area of high probable interaction with the MPA (potential spillover) and that are not too removed from the MPA environmental context (e.g. hydrography and position of shelf).

([6]) Belgium, Denmark, Estonia, Finland, France, Germany, Ireland, Latvia, Lithuania, Netherlands, Poland, Portugal, Spain, Sweden.

([7]) Norway and the United Kingdom.

([8]) C-square is a system of spatially unique, location-based identifiers (geocodes) that provides a basis for simple spatial indexing of geographic features or data on the surface of the earth.

([9]) The number of MPA sites in this section differs from that in the previous section as the data call was made on a preliminary list of MPAs that ultimately changed. These analyses include some MPAs that were subsequently excluded from the previous sections.

2.1 Characterisation of commercial fishing activities

From the nationally aggregated VMS and logbook data provided from the data call, an internationally aggregated dataset on fishing effort (kilowatt days, kWd), landings (kg), and landings value (euros) was created. This dataset included these three variables for the MPAs themselves and their associated direct surroundings.

To manage the variation in reporting from various nations, several data-cleaning steps were applied to the national-level data. Records that lacked any estimate of fishing effort (in either days or kWd) were removed. When fishing effort was reported in days only, it was estimated in kWd by applying a country-, year-, and gear-specific estimate of the engine power. In addition to the landings (kg), the site-specific fishing data also contained revenue (euros). When data were missing for either revenue or landings (but effort was present), these values were estimated by using a year-, gear-, and country-specific estimate of the landings-per-unit-effort (LPUE), provided that the record contained either landings or revenue information, respectively. Some countries did not cover the entire time series (2012-2021), namely, Norway (2015–2021), Portugal (2014–2021), and Spain (2013–2021, only for site-specific data). For the C-square based data, the first available year was used as a template for the missing years. For the site-specific data, the first available year was also used as a template for the missing years, but only for sites with significant (greater than 10%) fishing activity in terms of catch (kg), revenue (euro), fishing time (days) or fishing effort (kWd) from that country. Finally, any record that reported zero landings (kg), but did report fishing effort (kWd) was treated as a probable error in linking VMS and logbook data; such landings were set to 'N/A' to represent missing data.

To characterise the commercial fisheries occurring in and around MPAs, a subset of the dataset was used (based on information available from the MAPAFISH database) that included fishing data only for the periods when MPAs were in place. For each MPA, a simple heuristic was applied to calculate an annual average for the effort, landings and value metrics. If a year of designation was available from previous tasks, the average of all years following the year of designation is used. If the year of designation was unknown, the most recent three years (2019–2021) were used to establish annual averages.

The results showed that nearly two-thirds of MPAs across EU waters were not commercially fished: of 847 MPAs, 541 (63.9%) were not fished (Table 7) ([10]). **In many MPAs without fishing, there was also no fishing in the surrounding areas** (n = 373; 68.9%), **whereas almost all fished MPA sites recorded fishing activity in their direct surroundings as well** (n = 304; 99.3%). Furthermore, when standardised to area, the majority of investigated MPAs had lower median fishing effort within MPAs compared to their direct surroundings.

The percentage of unfished versus fished MPAs differed between International Council for the Exploration of the Sea (ICES) ecoregions (Table 7). Fishing occurs in a range of MPAs, with the highest proportions found in the Bay of Biscay / Iberian Coast and Greater North Sea, where 78% and 71% of the sites were fished, respectively (Figure 21). According to the study of Perry et al. (2022), based on Global Fishing Watch ([11]) data from EU and UK waters, 26.2% of MPAs are at high-risk from fishing activity,

([10]) An area of particular note is the Azores archipelago where none of the 25 listed MPAs had any reported fishing activity. While these MPAs were included in the data call, the lack of fishing activities across all sites indicates that these zeros could be erroneous. The omission of fisheries data from the Azores area could have been an oversight based on the wrong spatial extent being set during national level data collation, or perhaps (more likely) the majority of fisheries are not covered by the VMS programme.

([11]) https://globalfishingwatch.org/

particularly impacting nine benthic habitat types, mainly including bottom-towed gears. These findings are consistent with the current MAPAFISH quantitative analyses.

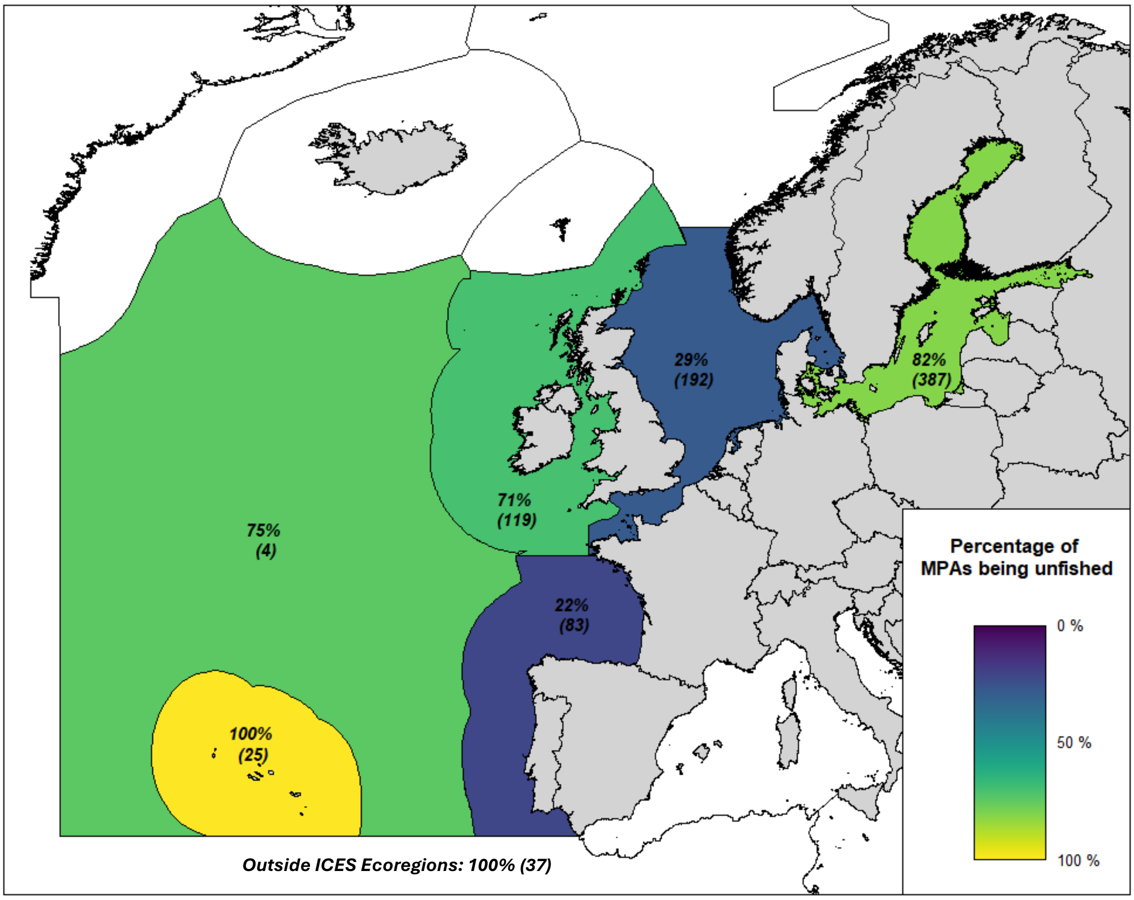

Figure 21. Overview of the total number of MPAs and the percentage of such MPAs that have no recorded fishing activity within the ICES ecoregions.

Both total average landings (tonnes) and total average fishing effort (kWd) are generally higher inside MPAs than in their direct surroundings (Table 8). An exception is the fishing effort in the Celtic Seas, which is higher outside the MPAs than within them. Importantly, when different metiers were examined, the contribution of bottom-towed gears to total fishing activity was highest in the Greater North Sea, both inside the MPAs and in their surrounding areas.

There was a large range in fishing activity between ecoregions, indicating substantial variability in fishing among MPA sites (Table 8). This site-specific variability may partly result from differences in the total area of MPAs when compared to their direct surroundings. Therefore, site-specific comparisons of fishing activity within MPA sites and their direct surroundings were conducted. In this analysis, relative effort varies between 0 and 1, with values greater than 0.5 indicating higher fishing effort inside the MPA compared to its direct surroundings, and vice versa. In this analysis, we included only MPA sites with recorded fishing activity in both the MPA and its direct surroundings. Applying these criteria resulted in varying proportions of sites being retained across different ICES ecoregions (18% of the MPA sites in the Baltic Sea versus 71% in the Greater North Sea). The analysis showed that for **the majority (74%) of sites, the standardised effort was lower inside the MPA compared to its direct surroundings** (Figure 22). However, we observed that in 25% of the sites across all four ICES ecoregions, fishing effort was higher within the MPA, with this occurring most frequently found within the Greater North Sea (37%).

Table 7. Number of MPAs with recorded fishing activity within MPAs and their direct surroundings (5 km area adjacent to the MPA borders), after designation.

Ecoregion	MPA not fished			MPA fished			Total
	Total	Direct surroundings fished	Direct surroundings not fished	Total	Direct surroundings fished	Direct surroundings not fished	
Baltic Sea	317	69	248	70	70	0	**387**
Greater North Sea	56	35	21	136	134	2	**192**
Bay of Biscay and Iberian Coast	18	15	3	65	65	0	**83**
Azores	25	0	25	0	0	0	**25**
Celtic Seas	85	47	38	34	34	0	**119**
Oceanic Northeast Atlantic	3	0	3	1	1	0	**4**
Outside ICES ecoregions*	37	2	35	0	0	0	**37**
Total	**541**	**168**	**373**	**306**	**304**	**2**	**847**

* Sites outside ICES ecoregions are predominantly (Spanish) sites near the Canary Islands.

Table 8. Fishing activity inside MPAs and their direct surroundings (DS), for the total fishing activity, and the bottom-towed gears and pelagic and passive gears separately. Fishing activity is summarised as registered landings (tonnes) and fishing effort (kWd), providing the mean [minimum – maximum].

			Total fishing activity		Bottom-towed gears		Pelagic and passive gears	
Region*	MPA/DS	N	Landings (Tonnes)	Fishing effort (kWd)	Landings (Tonnes)	Fishing effort (kWd)	Landings (Tonnes)	Fishing effort (kWd)
Baltic Sea	MPA	70	414 [0 – 5,639]	7,086 [0 –79,034]	229 [0 – 3,932]	3,030 [0 – 39,227]	207 [0 – 5,580]	3,624 [0 – 77,693]
	DS	139	321 [0 – 3,372]	5,692 [19 – 74,561]	110 [0 – 1,885]	2,371 [0 – 45,932]	214 [0 – 3,224]	2,972 [3 – 37.274]
Greater North Sea	MPA	136	1,435 [0 – 30,254]	242,096 [10 – 4,528,489]	774 [0 – 9,627]	227,579 [0 – 4,522,760]	231 [0 – 3,710]	6,434 [0 – 90,995]
	DS	169	878 [0 – 5,159]	159,413 [30 – 2,902,690]	495 [0 – 5,131]	146,181 [0 – 2,795,421]	262 [0 – 2,531]	6,157 [0 – 106,242]
Bay of Biscay and Iberian coast	MPA	65	2,015 [0 – 27,429]	1,548,293 [20 – 18,697,701]	804 [0 – 9,451]	969,276 [0 – 11,197,693]	1061 [0 – 15,974]	410,316 [3 – 6,793,970]
	DS	80	1,183 [1 – 7,787]	1,209,642 [165 – 11,918,189]	423 [0 – 3,481]	774,678 [19 – 7,311,830]	697 [2 – 5,347]	295,376 [137 – 4,962,811]
Celtic Seas	MPA	34	1,111 [0 – 25,886]	28,214 [20 – 381,395]	43 [0 – 496]	17,350 [0 – 179,839]	468 [0 – 8,437]	8,654 [2 – 128,099]
	DS	81	276 [0 – 7,197]	39,745 [34 – 795,086]	52 [0 – 1,596]	27,622 [10 – 545,728]	200 [0 – 5,781]	11,668 [11 – 213,756]
Oceanic Northeast Atlantic	MPA	1	0	1,049	0	1,502	0	295
	DS	1	0	129	0	172	0	43
Outside ICES ecoregions (Spanish sites near the Canary Islands)	DS	2	7 [0 – 15]	3,201 [227 – 6,174]	0	0	8 [0 – 17]	3477 [284 – 6,669]

* The ICES ecoregions "Azores" is excluded from this table, as there is no fishing activity reported inside and surrounding the MPAs.

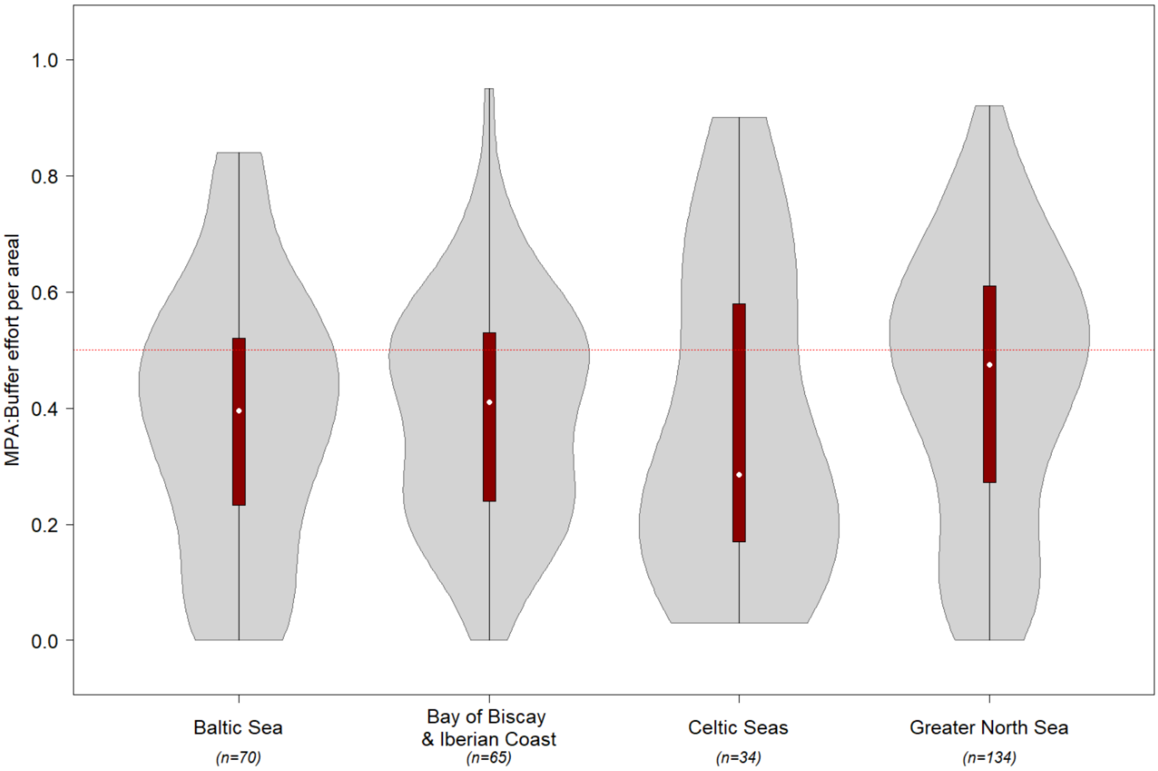

Figure 22. Ratio of standardised (total) fishing effort between MPA sites and their direct surroundings, for those sites that have fishing activity recorded in both the MPA and its direct surroundings. Red horizontal line indicates when effort is equal; all observations above the red line show sites where the standardised effort is higher within the MPA compared to its direct surroundings. The white point represents the median; the red boxes are the interquartile ranges, such that the edges of the boxes are the 25th and 75th percentiles, and the 'whiskers' (lines coming off the top and bottom of the boxes) extend out to the range of the dataset. The grey-shaded areas represent the density distribution, or relative number of observations across the range of observed values.

2.2 Interaction between habitat type and fishing activities

The distribution of seabed habitats within MPA sites and their direct surroundings differed substantially between ICES ecoregions (Figure 23). However, within individual ICES ecoregions, the **coverage of habitats between MPAs and their direct surroundings was very similar**. This suggests that a 5 km distance from the MPA border was an appropriate distance and did not significantly alter the environmental characteristics associated with fishing opportunities between MPA and direct surroundings. Within the Azores, sites predominantly feature 'Deep – Soft' habitats, whereas sites in the Greater North Sea cover a much broader range of habitat classes with 'Circalittoral – Soft' being the dominant class. Large portions of sites in the Baltic Sea and the Celtic Seas have an unknown habitat type, while large parts of sites in the Oceanic Northeast Atlantic and outside ICES ecoregions are classified as unknown substrates in deep waters (Deep – NA).

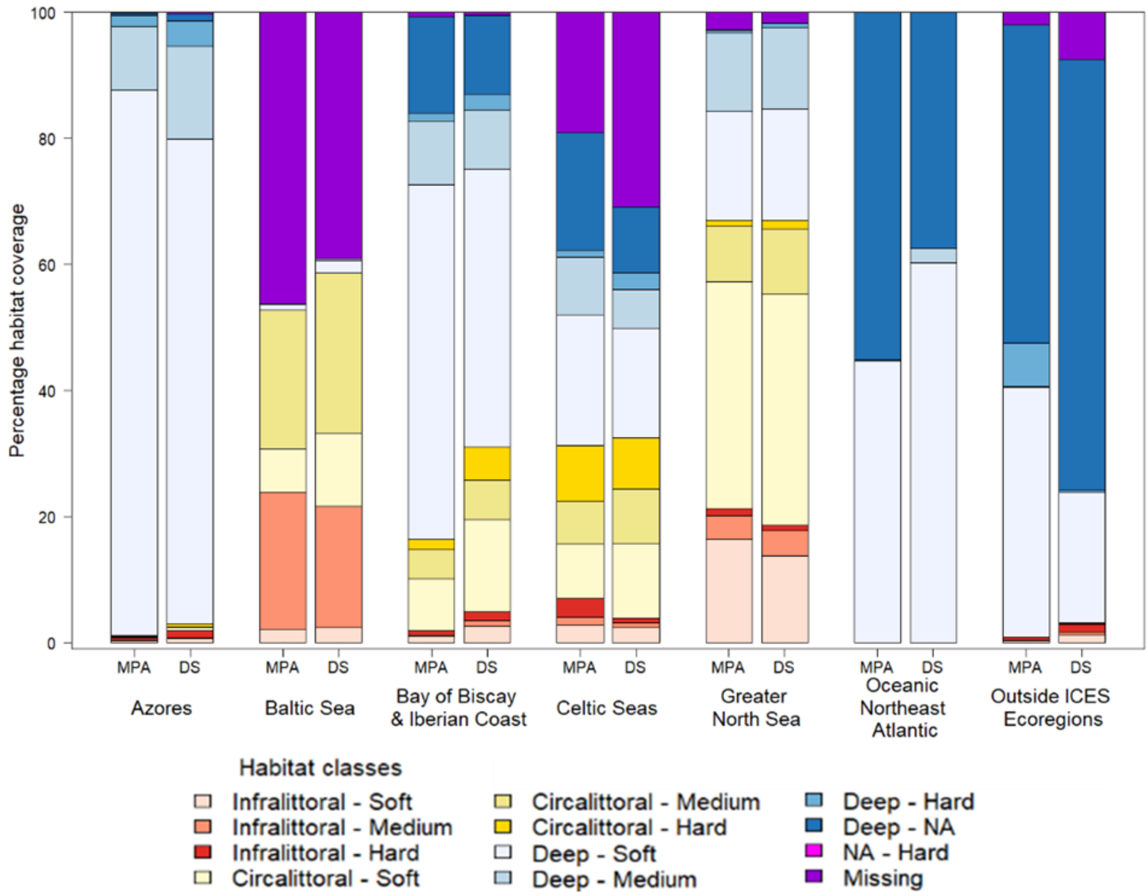

Figure 23. Habitat class coverage within MPAs and their direct surroundings (DS), for each ICES ecoregion. Habitat coverage is provided as the percentage of the total area of all MPAs / Direct Surroundings within an ICES ecoregion. Habitat categories are aggregations of the European Nature Information Systems habitat definitions, and data are spatially aggregated from EUNIS seabed habitat maps (version 2021) from EMODnet (Vasquez et al., 2021).

A threefold spatial overlay was used to investigate the relationship between fishing and habitat classes in the ICES ecoregions (Figure 24). This analysis showed that MPA sites, particularly in the Baltic Sea and, to a lesser extent, in the Celtic Sea, are generally subjected to less fishing compared to other ecoregions. This finding was concurrent with the earlier, habitat-agnostic results.

The **dominant habitat classes in MPA sites within the Greater North Sea and Bay of Biscay/Iberian Coast have a large proportion (greater than 89%) of their spatial extent located within fished MPA sites.** In contrast, the dominant habitat classes in the Baltic Sea and Celtic Seas have a smaller fraction located in fished sites. The **percentage of habitat area in fished sites appears similar when comparing MPAs to their direct surroundings**. Notable exceptions are circalittoral soft and medium habitats in the Baltic Sea, where the percentage of area in fished direct surroundings is substantially lower than in MPAs. This general concurrence in habitat areas between fished sites is surprising. Given that one of the major reasons for designating MPAs is the protection of habitats, one would expect the percentage of areas exposed to fishing within MPAs to be lower than in areas outside the MPAs. The absence of this expected trend is likely due to the limited number of no-take MPAs, with most MPAs having gear regulations that allow some form of fishing to continue. Interestingly, **there is only one instance where a dominant habitat class is more heavily fished in the direct surroundings than within the MPA sites**: a habitat class in the Celtic Seas, which is fished in 39.2% of MPAs compared to 74.1% in the direct surroundings of MPAs. This may indicate a preference for fishing this habitat class, which is limited or prevented within MPA sites.

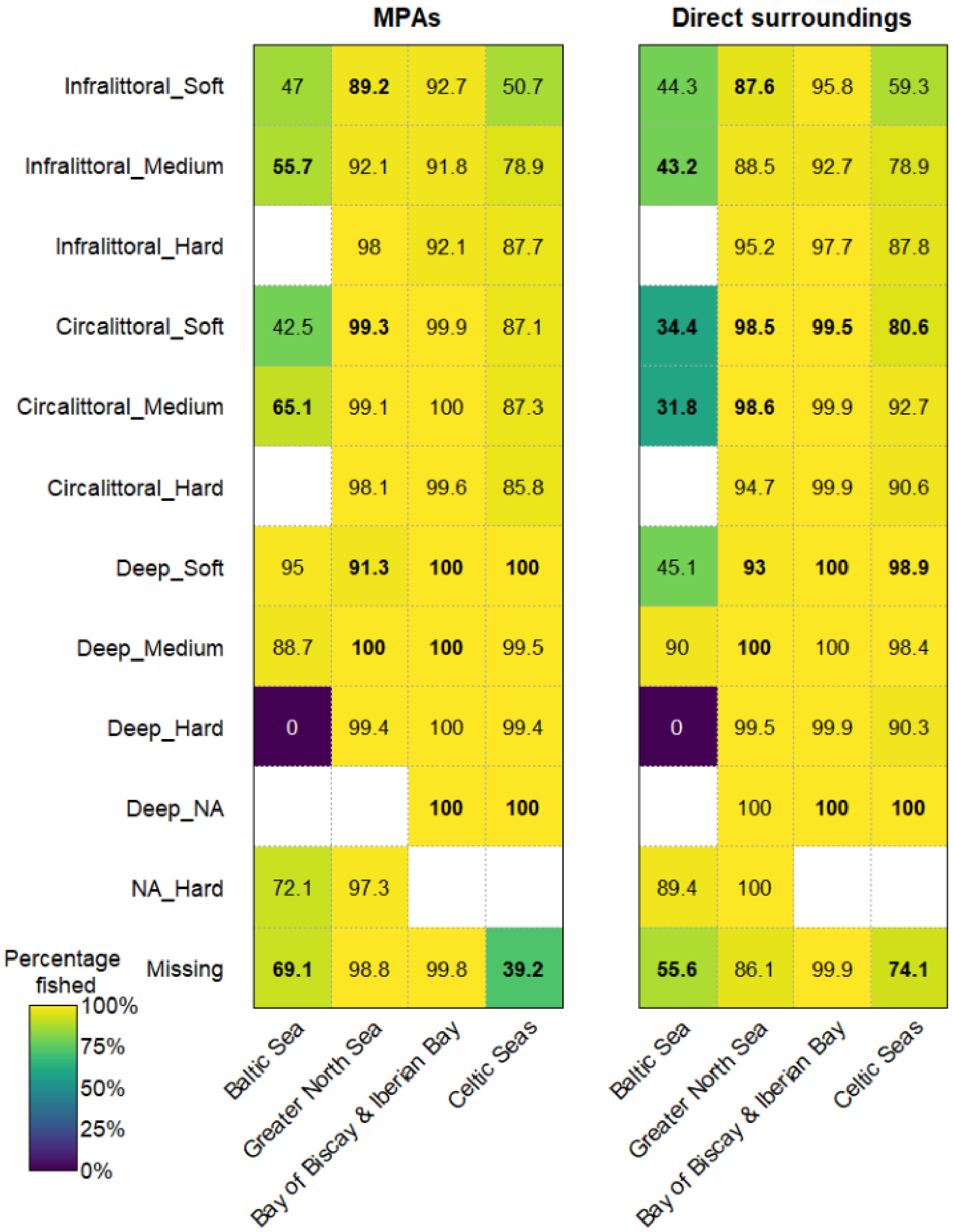

Figure 24. Habitat–fishing interaction, presented as the percentage of the total surface area for each habitat class within the fished sites relative to the surface area of that habitat across all sites within each of the four relevant ICES ecoregions. Bold numbers represent habitat classes that have a coverage > 10% within sites in that ICES ecoregion.

2.3 Breakpoint analysis in fishing activity time series

In addition to characterising fishing activity within MPA sites and their direct surroundings, trends in fishing activity were also investigated over time. This analysis was justified by the apparent temporal differences in both fishing effort (kWd) and catch efficiency (kg·kWd^{-1}) across the MPA time series. For example, examining three MPA sites

- Panache de la Gironde (France), Vlakte van de Raan (Netherlands), Sejerø Bugt og Nekselø) (Denmark) - shows varying trends: fishing effort decreases, increases, or remains stable over time, respectively (Figure 25). Interestingly, catch efficiency increases over time in both the French and the Dutch MPAs, while it remains relatively stable in the Danish MPA site, but decreases in the last years. To better understand these temporal patterns, we aimed to detect changes in fishing effort and to link them to site-specific policy changes (such as MPA designation dates and the implementation of fisheries regulation) by using a breakpoint analysis.

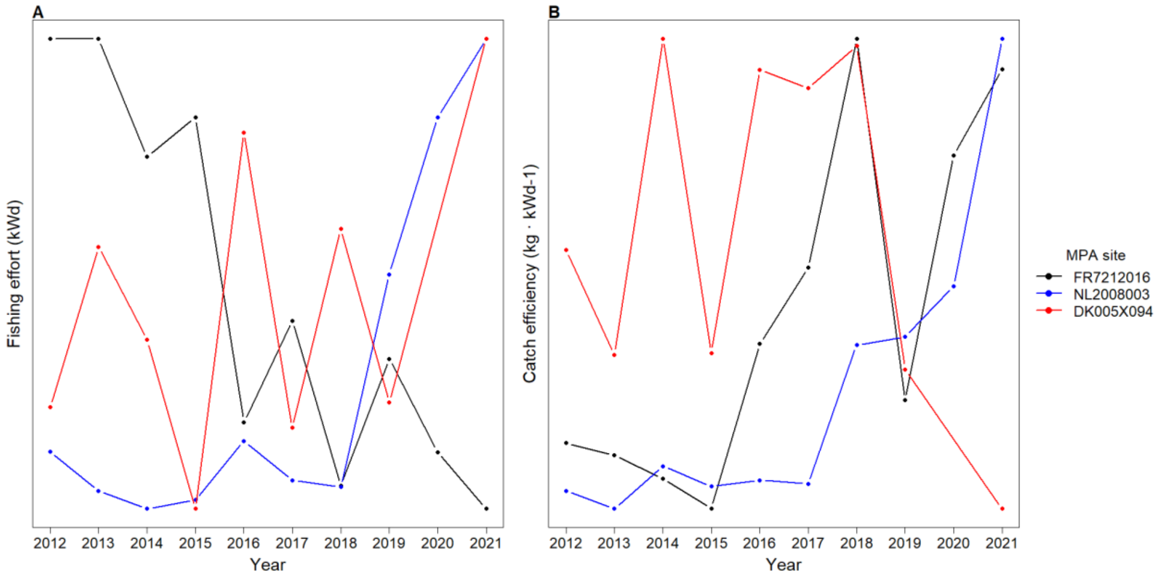

Figure 25. Exemplary time series of three MPA sites for A) fishing effort (kWd) and B) catch efficiency (kg · kWd^{-1}). Note: French (black), Dutch (blue), Danish (red).

To identify the most optimal method for breakpoint analysis of our relative short-time series, we chose the 'cpt.meanvar' function, which uses the Pruned Exact Linear Time (PELT) algorithm with an Akaike Information Criterion (AIC) penalty from the changepoint package (Killick et al., 2012; Killick and Eckley, 2014). We also performed a complementary analysis using the 'breakpoints' function from the *strucchange* package (Zeileis et al., 2002; Zeileis et al., 2003). Both methods differ in how they identify breakpoints in the time series and in their data requirements. The 'meanvar' method detects changes in both the mean and variance and can identify multiple breakpoints but cannot handle missing years. In contrast, the 'breakpoints' identifies changes in the slope, can handle missing years, but is restricted to identifying only one breakpoint. This combination of approaches is likely to identify potential breakpoints in our time series, regardless of the direction and nature of the changes.

A breakpoint analysis was performed on MPA and direct surroundings sites that: (i) were included in the data call; (ii) were classified as relevant within the analyses described in Section 1; and (iii) had some reported fishing activity. A total of 1,224 sites met these criteria, comprising 500 MPAs and 724 direct surroundings. For all records, attempts were made to identify breakpoints in the time series of fishing effort (kWd), landings (kg), and catch efficiency (kg·kWd^{-1}) using both methods. The analysis identified 378 records with a matching breakpoint in fishing effort by both methods, while both methods agreed on 135 records where no breakpoint could be identified (Table 9). The remaining records either had two non-matching breakpoints identified (308), or only one breakpoint identified while the other method did not identify any breakpoints (403). For landings and catch efficiency, the methods showed lower levels of agreement. Generally, the ability to reliably detect breakpoints looks weak, likely due to both methods requiring three consecutive years of data before and after any breakpoint, limiting detection to the period 2015-2018. In addition, the two methods may identify the start of the breakpoint slightly differently, meaning that non-matching breakpoints could reflect minor semantic differences where a difference of one year might indicate the same underlying change.

Table 9. Results of breakpoint analyses on fishing activity time series.

	Fishing effort (kWd)	Landings (kg)	Catch efficiency ($kg \cdot kWd^{-1}$)
Both methods did not run	0	108	108
No breakpoints (both methods)	135	110	115
Only one method could run	0	93	75
Matching breakpoints identified	378	274	274
Non-matching breakpoints identified	308	217	219
Only one method identified a breakpoint	403	422	433

Overall, this work demonstrates that **breakpoint analysis can be a useful method for evaluating the impact of MPA designation or fisheries regulations on fishing within MPAs**. This analysis effectively compares and contrasts fishing activities and their changes in response to management actions. However, the connection between management changes and shifts in fisheries was not strongly evident, with limited evidence from the majority of MPAs in EU waters.

2.4 Characterisation of recreational fishing activities

A key challenge in effective MPA management is monitoring of human activities within designated sites. Although there have been major improvements in the reporting of industrial activities (Halpern et al., 2015), such as fishing (Selig et al., 2022; this study), shipping, and aquaculture (Clawson et al., 2022), robust global reporting mechanisms for recreational and tourism activities remain lacking. These activities, supported by cultural ecosystem services, play a key role in the success of MPAs. In the future, the EU Control Regulation (EU) 2023/2842) ([12]), which mandates positional and catch reporting of all vessels from 2030, is expected to enhance data collection in this area.

In this study, we attempted to characterise rates of recreational fishing before and after MPA designation by utilising geo-tagged social media reports of fishing activity from the photo-sharing platform Flickr (www.flickr.com). Flickr is recognised as a robust sampling platform for studies of cultural ecosystem services that require some spatial information about experiences, provided the spatial resolution is at least 10 km and temporal resolution is no smaller than a couple of weeks to a month (Mancini et al., 2018; Höpken et al., 2020; Muñoz et al., 2020).

The R package *photosearcher* was used to access the Flickr Application Programming Interface (API) and to generate monthly samples of the number of photographs posted that were taken within MPAs (geo-tagging linked to MPA polygons) and the number of photographs tagged with keywords associated with recreational fishing. Keywords from all coastal European languages were initially searched without any geographic restrictions, and these were narrowed down to only those languages for which photographs could be retrieved. This refined set of relevant keywords was then used in subsequent searches (‘fish’, ‘pêche’, ‘fishing’, ‘pescatore’, ‘pescador’, ‘fiska’, ‘fiske’, ‘fischen’, ‘vissen’, ‘pescar’).

The temporal trends in posting rates were described using Morlet wavelet decomposition (Tomac and Slavič, 2023) before examining changes in posting patterns over time in MPAs designated during the period when photograph data were available (2010–2022)

([12]) *OJ L, 2023/2842, 20.12.2023*

(intervention sites). To account for general changes in posting patterns, we used MPAs that were not designated during this time period as controls (control sites). The R package *CausalImpact* was employed to construct Bayesian structural time-series models to detect how temporal changes in posting patterns related to MPA designation dates. Each intervention site (524) was compared to all control sites (395) to generate distributions of posterior intervention effect estimates for each intervention site. The pooled intervention effects were then meta-analysed to describe the general effect of MPA designation, iteratively considering all effects, as well as only positively or negatively affected cases.

The results show a **consistent seasonal pattern of visitation**, consistent with seasonal tourism flows in Europe, which was disrupted by the Covid-19 pandemic and is contained within an overall trend in the usage of Flickr as a platform (see Figure A2.1, Annex 2). Probably because of the scarcity of posts related to fishing and fisheries, none of the periodicity or trends observed in the visitation data were detected (see Figure A2.2, Annex 2).

The results show a **significant causal effect of site designation on the number of monthly Flickr fishing photos posted**, which could be estimated for 38 of the 524 intervention sites. The pooled causal effect was 0.025 (SE = 0.022, Z203 = 1.6, p = 0.25) and not significantly different from zero, but the effects were heterogenous (test for heterogeneity: Q203 = 2726, $p < 0.0001$). An attempt was made to account for the heterogenous effects by adding MPA area (logged) as a covariate; however, this did not resolve the issue or differentiate our pooled effect from zero.

Effectively, **no significant changes in recreational fishing activities, either generally or individually, were detected beyond the background variation observed (noise) observed in European MPAs** based on Flickr photograph posting. This is due in part to the scarcity of fishing photos posted; however, this scarcity can be addressed with appropriate experimental design. In our case, generic controls were used to try and detect population-level (a population of MPAs) effects of MPA designation. Nonetheless, by using properly paired MPA and control areas - where controls are selected based on conditions important to recreational fishing - a collection of site-specific evidence may reveal a broader population-level response. A working document with details of the analyses and signal filtering of Flickr data, is provided in Annex 2.

2.5 Compatibility of fishing activities with MPA conservation objectives

One of the main objectives of this work was to assess the compatibility of various fishing activities with the different ecosystem components that are the subject of MPA conservation objectives and, subsequently, to provide a method for describing the degree of incompatibility between specific fishing activities and conservation objectives within given MPAs.

Building on a recent, large-scale systematic review of fisheries impacts on marine ecosystems by Beukhof et al. (2022), information on fishing gears, ecosystem components, and three metrics of evidence quality were combined to provide an **impact score matrix**. The impact scores represent both the direction of the impact and certainty of that direction based on the entropy of published evidence, which measures randomness, variation or disagreement in the direction of impacts from existing studies. These impact scores were then subsetted and summed for each MPA in the MAPAFISH database, according to the stated conservation objectives of the MPA and the types of fishing activity occurring within it. The resulting number, termed an '**incompatibility score'**, reflects the potential impacts of reported fishing activities on the ecosystem components for which the MPA was established.

To test the validity of incompatibility scores, we utilised a subset of the MAPAFISH database that contained sufficient reported information to compare how well scores predicted whether MPAs had achieved their stated conservation objectives. The results show that the

incompatibility scores had no bearing on the probability of an MPA achieving its conservation objectives. However, the **reporting on the achievement of conservation objectives is extremely variable,** and many such goals may only be attained long after designation of the MPA – a factor not accounted for in our analysis.

In summary, these **impact scores can be applied to existing or potential MPAs to calculate incompatibility scores and assess the extent to which fisheries may affect the desired conservation outcomes**. Future research should explore the utility of these incompatibility scores, particularly in relation to the time and age of MPAs.

Impact scoring

A set of impact scores was generated for the interactions between various fishing gears and different elements of the ecosystem. These scores are intended to be site-agnostic, making them applicable to any area or situation where fishing occurs. To calculate these scores, we employed a meta-analysis of evidence from a systematic review of EU fisheries.

A comprehensive, systematic, scoping review of fishing impacts on the ecosystem has previously been completed under the Horizon 2020 project SEAwise ([13]) (Beukhof et al., 2022). This review considered all European fisheries and examined all primary literature on ecosystem impacts in a much more comprehensive way than would have been possible within MAPAFISH.

The SEAwise database contained very detailed information, including data on the fishery, the ecosystem component, the pressure exerted, and the quality of the study. Information on the fishery included the gears used and the type of pressure being measured in the study (e.g. bottom disturbance, noise or litter). Details on ecosystem component included various taxonomic classifications, life-history stage and the mechanism by which the pressure acted on the ecosystem component (e.g. growth, reproduction, survival, structural complexity). Qualitative judgements of the quality of the evidence were made by assessing how well the spatial and temporal scales, as well as the study design (sampling and analyses), aligned with the levels of inference being drawn. The database was made publicly available ([14]) and was used in this study to derive indicators of the direction of the interactions (positive or negative) between different fisheries and ecosystem components. A summary of the range and types of information available from the SEAwise database is shown in Figure 26 below.

([13]) https://seawiseproject.org/ (accessed 4 December, 2023).

([14]) https://ono.dtuaqua.dk/SeawiseReviews/ (accessed 4 December, 2023).

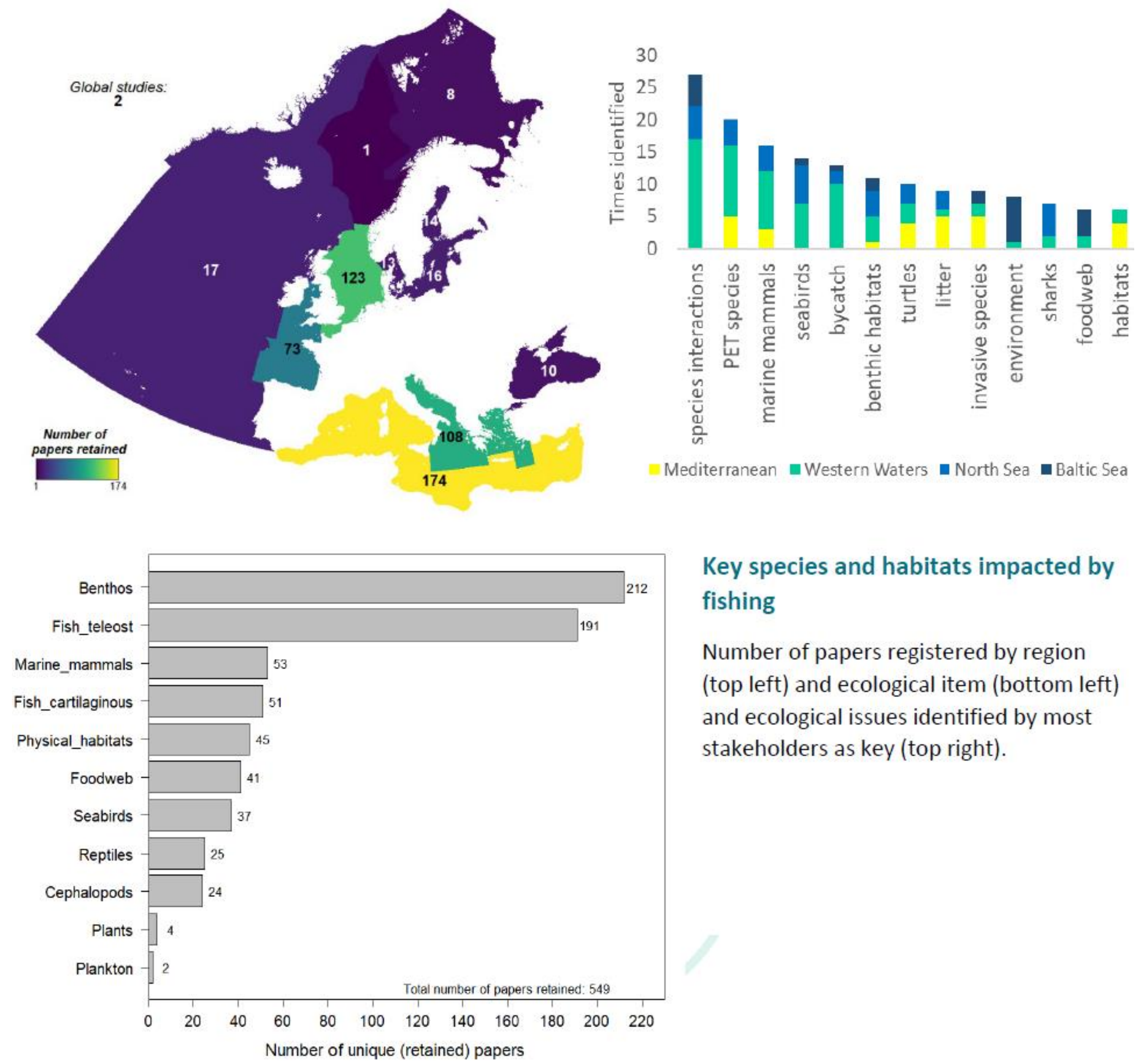

Figure 26. Key species and habitats impacted by fishing, showing the scale of literature coverage across Europe, ecosystem components and their importance to stakeholders (source: graphical abstract of SEAwise report; Beukhof et al., 2022).

Incompatibility of fishing activities with conservation objectives

The level of compatibility (or incompatibility) was calculated between fishing activities in MPAs and their stated conservation objectives. This involved applying the literature-derived impact scores to the specific contexts of individual MPAs to generate an overall incompatibility score for each MPA.

The impact scores, calculated for each fishing gear ([15]) and ecosystem component ([16]) were combined with information from a subset of 847 MPAs. An incompatibility score could only be calculated for those sites where conservation objectives were defined, and the relevant ecosystem components were available. After applying these criteria, 553 MPAs were available for further analysis. For all MPA sites, descriptions of ecosystem components

([15]) Fishing gears: bottom trawls, bottom seines, dredges, gillnets, hooks and lines, pelagic trawls, pelagic seines, and traps.

([16]) Ecosystem components: Seabirds, reptiles, plants, plankton, physical habitats, marine habitats, foodweb, fish (teleost), fish (cartilaginous), cephalopods, benthos.

and habitat types, which were part of the conservation objectives, were recoded and used to match those ecosystem components from the literature review.

For each MPA, the impact score matrix was subset to include only the ecosystem components relevant to the conservation objectives. Similarly, a subset of the matrix was created according to which gears were active in the MPA after designation. The values in the resultant subset of the matrix were summed to get the overall incompatibility score. While the cumulative impacts of different pressures are likely not simply additive, there is insufficient information available on how the gear, pressure, ecosystem component and life-history stage interact. Therefore, varying forms of interactive relationships were not included in the incompatibility scores.

While the existing SEAwise database included information on the direction of the relationship between the pressure exerted and the response measured, it did not evaluate whether this interaction was beneficial or harmful to the ecosystem components studied. Therefore, MAPAFISH contributed by extracting a new variable from the pre-reviewed publications that specifically addressed the impact of interactions between fisheries and ecosystem components. This new variable was categorised into four impact levels: positive, negative, multiple (representing a conditional response, such as an optimum-type response) or none (where no significant effect was observed). These levels were then simplified into three categories: positive, negative and ambiguous.

A series of impact scores were calculated based on the available evidence regarding the impacts of different fishing gear categories on ecosystem components. All methods utilised the quality scoring from the review to weight the evidence. The methods differed in how they combined positive and negative values and in how they used the total evidence, ambiguity and/or level of disagreement in the literature to adjust the strength of a score for each gear and ecosystem component combination. These methods and their resultant index matrix were internally reviewed by key subject-matter experts. Anomalous outcomes were highlighted and subsequently investigated using supporting literature. This information was also shared with members of the ICES Working Group on the Value of Coastal Habitats for Exploited Species (WGVHES), who critiqued the methods, discussing their merits and shortcomings. This feedback provided quality control for the additional data extractions and greatly improved the methodology for representing the strength and uncertainty of evidence from the literature.

The chosen method first weights individual pieces of evidence by the reported quality of each study, then evaluates the absolute difference between positive and negative impacts. This difference is adjusted based on the level of disagreement in the literature, which is measured by calculating the entropy of the evidence of impacts per fishery-ecosystem component interaction and modifying the absolute difference by the inverse of this entropy. The use of entropy to reflect uncertainty in the literature was inspired by Galparsoro et al. (2022). This method is defined in more detail in Annex 3.

The strongest evidence of a negative impact on an ecosystem component comes from the interaction between bottom trawls and benthos, while there is no evidence for fisheries impacts on plankton, other than a small amount from pelagic seines (Figure 27). Interestingly, the evidence for a negative impact of traps on benthos is comparable to that of dredges. Although this may seem counterintuitive it, illustrates how these scores reflect our certainty about the direction of the impact based on available evidence, rather than empirical/mechanistic relationships or the magnitude of the impact. The ecosystem component 'seabirds' shows positive interactions with certain types of fishing, primarily pelagic trawls and pelagic seines. This likely results from the access to food from escaped or damaged fish. While the direct negative effects of gill nets and hooks and lines on top predators is captured in this methodology, the broader impact of fishing down potential food-source populations may not be fully reflected in the reviewed literature.

Figure 27. Impact scores for fishing gears interacting with ecosystem components. Green shading represents a positive interaction while purple represents a negative interaction. Scores reflect certainty in the literature, not a magnitude of effect. The intensity of the colour reflects the magnitude of the score, which is also labelled as the number in the centre of the cell. Darker shades indicate stronger evidence; lighter colours are impacts with mixed or ambiguous responses of the ecosystem component to the gear. Yellow/orange cells are where there is no evidence of any interaction available in the literature review.

Using the impact scores, incompatibility scores were derived to identify where fishing activities within MPAs were incompatible with conservation objectives of those MPAs. Two sources of data on fishing activities were combined: (i) observed fishing activities identified from the national submissions to our data call, and (ii) activities stated in management reports. When incompatibility scores derived from observed fishing activities and management reports were both non-zero, there was generally good agreement between the scores (Figure 28).

Inconsistencies were reported between scores derived from observed fishing activities and activities stated in management reports. In the first instance, inconsistencies can be associated with there being zero scores for observed fishing activities, but non-zero scores derived from reports. In such cases we might assume that some fishing activities have been censored in the responses to our data call, due to too few vessels being reported to be undertaking such activities. The disagreement may also be associated with management reports referring to fishing activities in the MPA, but that are not captured in the VMS data (which informed our data call). Another possibility is that the analyses informing the management reports included areas surrounding the MPA, making them less specific to the MPA area.

A second type of inconsistency occurs when activities stated in management reports show zero scores, while observed fishing activities lead to non-zero scores. This could be because fishing activities were not monitored or analysed for the management reports and were instead based on expert opinion, interviews or surveys. Alternatively, the fishing activities in our dataset, which was compiled from a MS-wide data call, may have occurred after the data for the corresponding reports were collected. Lastly, many management documents rely on domestic data, specific to the Member State in which the MPA is situated, so fishing of other EU vessels would not be recorded. This highlights a major strength of the international dataset we used.

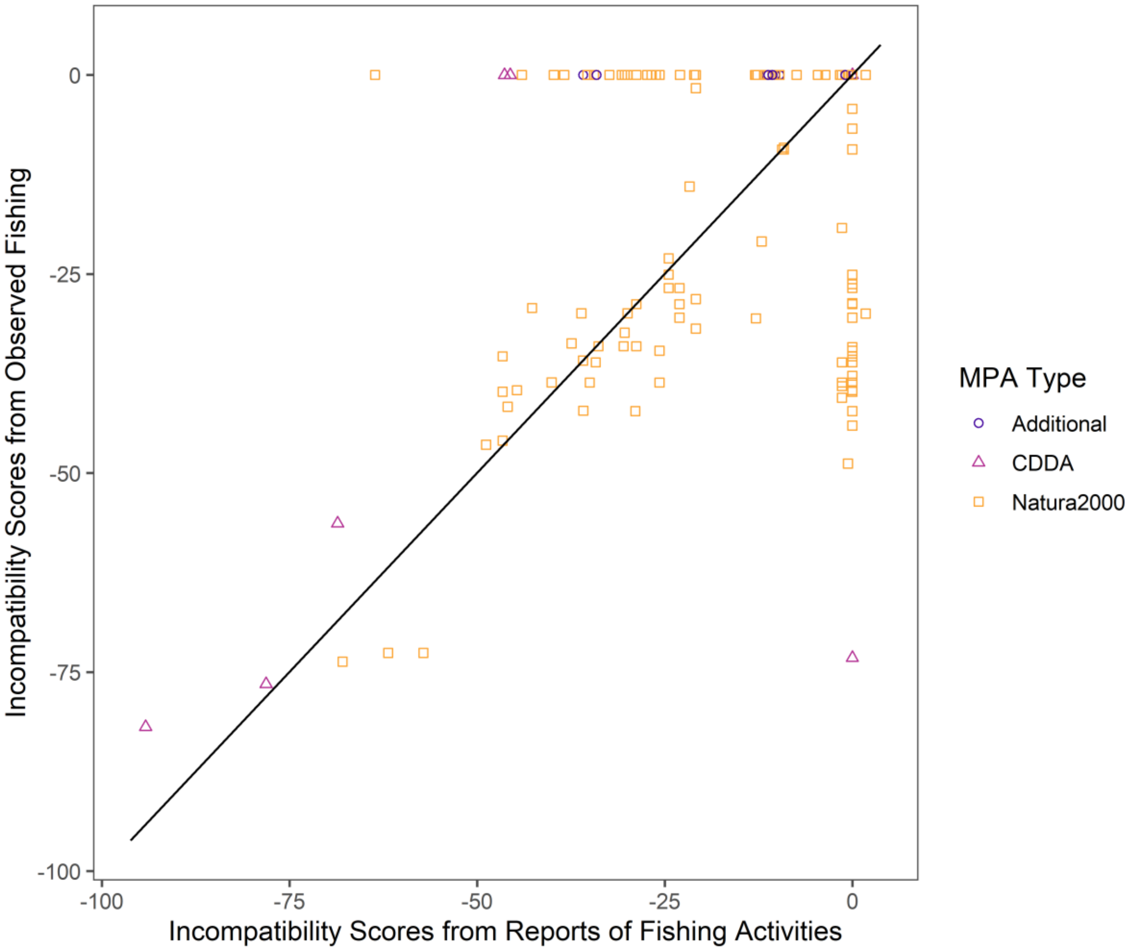

Figure 28. The relationship between the MPA/fisheries incompatibility scores calculated from management and monitoring reports of fishing activity within MPAs (x axis) or from observed fishing activities identified via a bespoke data call (y axis). Colours and shapes represent the broad categories of EU MPAs investigated. The black line represents the 1:1 relationship between the two variables.

To ensure full representation of fishing activities in the MPAs, for sites where observed fisheries resulted in incompatibility scores of zero, we first retained all non-zero values from the observed fishing activities. We then substituted the remaining zero cases for scores derived from the management reports. This corresponds to many of the points along the horizontal line corresponding to zero on the y-axis, moving to the centre, diagonal, one-to-one line. When both sources reported zero fishing activity, a zero-incompatibility score was retained. The resultant dataset has incompatibility scores for 334 MPAs, of which 47 have an impact score of zero. All impact scores are naïve of any impact for the interactions between specific gears and ecosystem components where we have no information on the type of impact.

To validate the incompatibility scores, we selected MPAs that met several criteria: they had conservation objectives defined and monitored, were actively managed, were deemed relevant, had valid incompatibility scores calculated, and their records were based on direct documentation, not pairing with similar unreviewed MPA sites (primarily from Denmark). This produced a validation dataset of 25 MPAs from five Member States, primarily in Northern Europe (Figure 29).

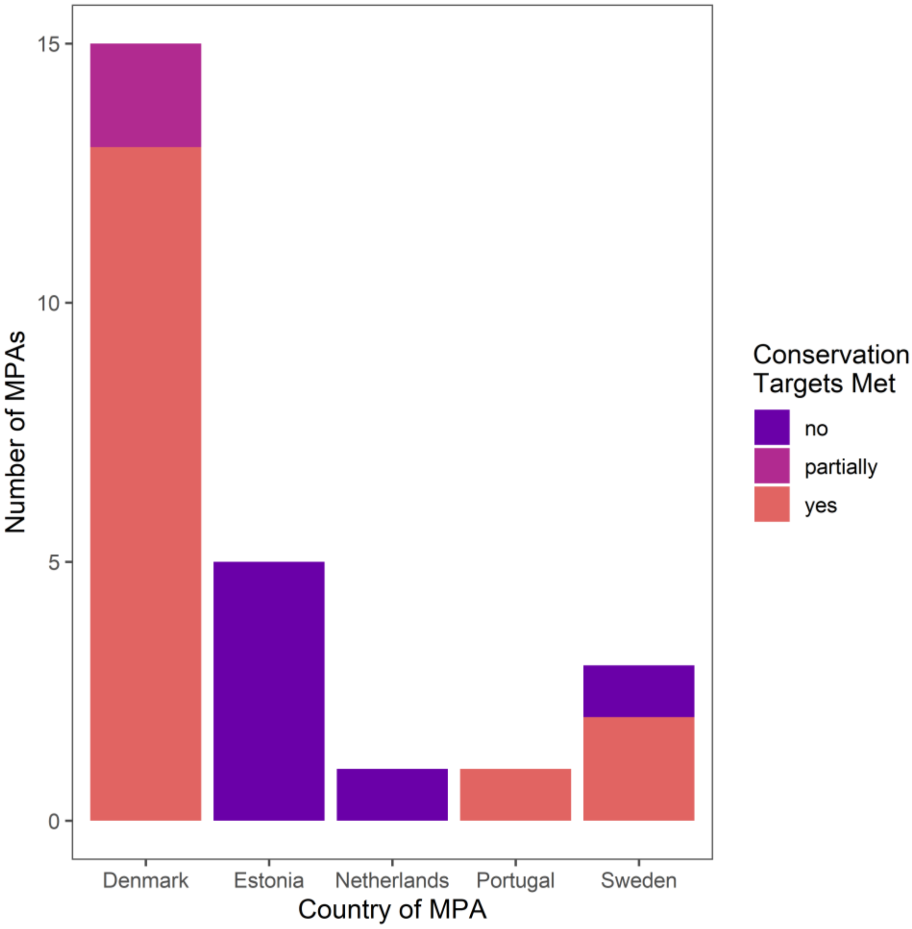

Figure 29. Origin and status of MPAs suitable for validation of the incompatibility scores.

From this validation dataset we can visualise and test the difference in incompatibility scores across the three potential conservation outcomes (Figure 30). While MPAs that have met their conservation targets have a denser distribution of incompatibility scores closer to zero, the ranges of scores in the dataset substantially overlap. As a result, we cannot detect a significant difference between the different outcomes (Kruskal-Wallis $\chi^2 = 0.33$, $p = 0.85$).

The lack of a detectable difference should not undermine the utility of the incompatibility scores. The validation dataset is both very small and biased towards sites from Northern Europe, particularly Denmark. Additionally, variations in the definition of conservation targets (e.g. "provide refuge from fisheries" versus "increased food availability") suggest that this variable is not an appropriate for validation. Achieving a management objective ("provide refuge from fisheries") may not necessarily be the same as observing a biological response ("increased food availability").

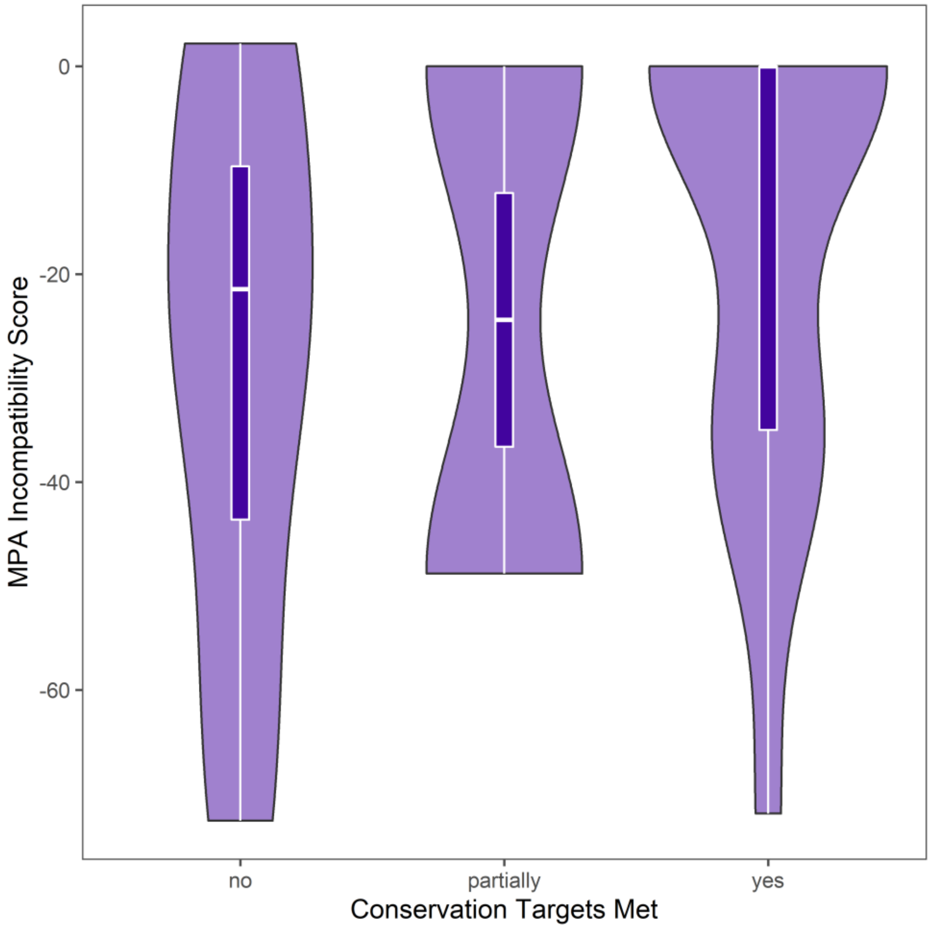

Figure 30. Distributions of incompatibility scores for three different statuses of conservation targets. The violins (light shading) represent the density of scores while the box and whisker plots inside illustrate the median (middle line), quartiles (edges of boxes and range (whiskers).

There were limitations to the current implementation of the incompatibility score. The current implementation includes the impact of gears as soon as any effort is reported in the area following site designation. This approach does not account for the relative effort expended with that gear within the MPA, leading to minor incursions will have a disproportionate effect on the final score. Future implementations should consider methods to weight the impact scores by a metric of relative per-area effort that is applicable across contexts. Furthermore, while based on the best available knowledge, the matrix of impact scores used to derive incompatibility scores contains many knowledge gaps. These gaps limit the **utility of the incompatibility score** in cases where conservation objectives match with ecosystem components in our matrix that have no evidence for certain gear categories. Finally, **both the impact and incompatibility scores reflect our certainty in the direction of the impact between fisheries and ecosystem components, but they do not reflect the magnitude or severity of the impact**. Therefore, trading off different gear and conservation objectives by attempting to minimise score magnitudes is not relevant – rather, **these scores provide a level of certainty about the qualitative interaction (deleterious or beneficial) between fisheries and ecosystem components, helping to inform decisions whether to include or exclude certain practices depending on the objectives**.

Despite the limitations described above, **the impact score matrix remains a valuable resource for managers of existing MPAs, and especially for planners and designers of future MPAs**. By using this matrix, managers and planners can prioritise fisheries-related policies based on the conservation objectives of the MPA in question, informed by the certainty derived from the complete record of relevant primary literature.

3 FISHERIES RESPONSE TO MPAs

Key highlights

- Across all investigated EU regions, in the majority of case studies, there were no indications that MPA designation led to changes in fishing effort or landings. It was only after specific fisheries regulations were put in place that fisher behaviour changed.
- Management plans can ensure the balance between local fisheries sustainability and ecological integrity. There can be trade-offs and conflicts between different conservation objectives (e.g. birds, mammals, habitats) and the interactions of these objectives with different fishing practices (e.g. pelagic versus bottom fisheries).
- To ensure the continual success of MPA conservation outcomes, there is need to understand the types of stakeholders affected by MPAs, the communication required by MPA managers and the utility of their inclusion in MPA boards.
- A conceptual model was developed (the 'MAPAFISH tool') to better understand some of the effects of MPAs on the reallocation of fishing effort inside and outside MPAs. The tool is based on different fishery management strategies and the potential social, economic and ecological impacts of the effort reallocation.
- The tool allows users to define an input scenario and identifies the potential outcomes associated with the designated MPAs and fishery measures. Our results show that costs and revenue consistently emerge as prominent indicators when an area is closed to fishing, both of which need to be balanced against MPA conservation outcomes.

When new management measures are applied following the designation and implementation of MPAs, certain fishing activities may be lost or reallocated to other areas. The resulting displacement of fishing activities might have impacts on fishers and the marine environment (Vaughan, 2017). Currently, in half of the investigated EU MPAs, no fisheries measures are in place (see Figure 13). As stated in the EU Biodiversity Strategy, fisheries-management measures must be established in all MPAs according to clearly defined conservation objectives and on the basis of the best available scientific advice. The number of fisheries measures that might affect the fishing activities is expected to increase rapidly in the coming years to better support achievement of the MPA conservation objectives.

Therefore, it is key to better understand the nature of potential fisheries displacement, and its potential impacts. This section focuses on describing the results and providing interpretation to help managers and decision makers understand the potential challenges faced by fisheries and associated with the designation and implementation of MPAs.

The **overall objective of this section is to better understand the response of the fishing activities to MPA designation and implementation**. To achieve this goal, we undertook an in-depth assessment of nine case studies examining specific MPAs throughout the EU in eight Member States. This assessment discusses the issues, challenges and the way forward for furthering the success of such MPAs. Then, in understanding the factors which may result in successful MPAs, we develop and test a conceptual model.

3.1 Overview of the case studies

A total of nine case studies were selected across the EU to help assess the spatial redistribution of fishing activities in response to MPA implementation (Figure 31). A summary of each case study is provided in Table 10 and the following sub-sections. Within each case study, a systematic literature review protocol was developed. An example of the protocol used for the Madeira archipelago, Portugal is provided in Annex 4. Further details of each case study are provided in Annex 5 (in a different volume doi: 10.2926/5489670).

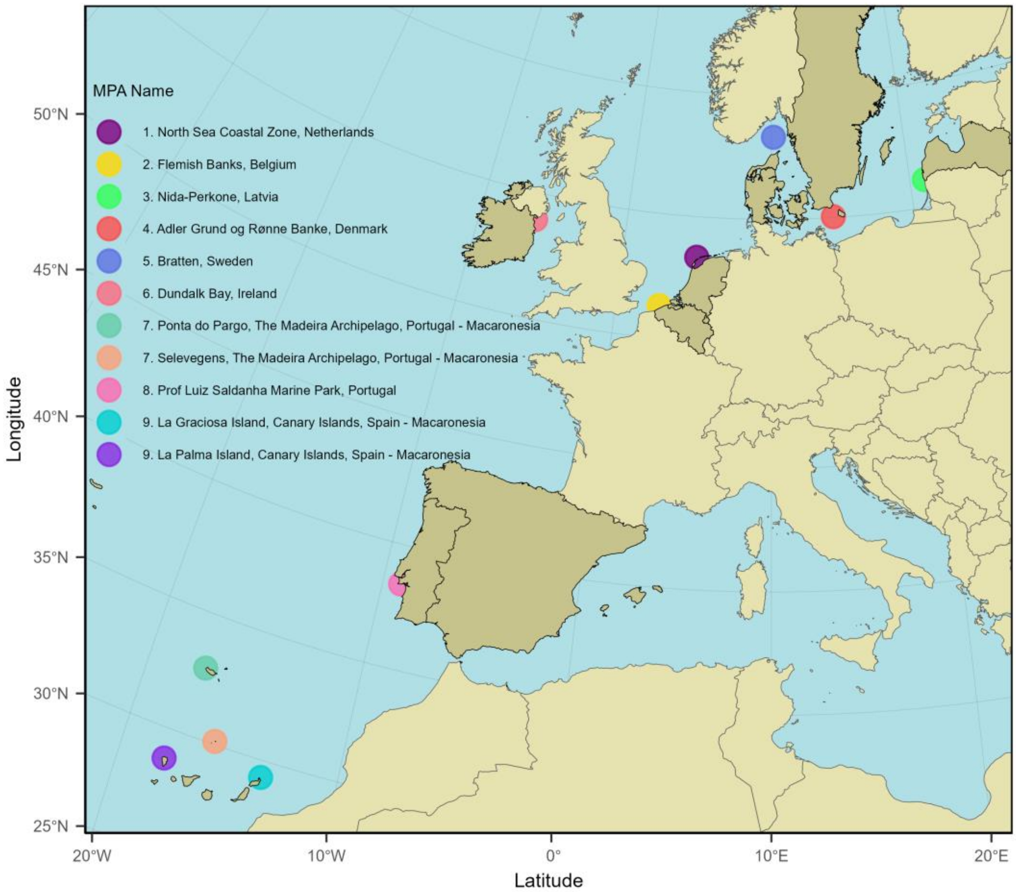

Figure 31. Map showing the geographic location of case studies.

3.1.1 North Sea Coastal Zone, The Netherlands

Covering an area of approximately 1,445 km^2, the North Sea Coastal Zone (NSCZ) spans the entire northern coastal strip from the North Holland Bergen to the Ems above Rottum. The area encompasses shallow waters comprising sandbanks, mudflats, salt meadows and shifting dunes, and was designated for various habitats and diverse animal species under Natura 2000. The Netherlands has implemented MPAs to restore and conserve the environmental status and condition of the North Sea, including seafloor communities (EEA, 2018). The Fisheries in Protected Areas Agreement (Visserij in beschermde gebieden akkoord: VIBEG) was established in 2011 to balance nature conservation and fisheries within Natura 2000 sites. As a result of this agreement, five separate areas totalling approximately 144 km^2 within the NSCZ were granted a fully protected status within the MPA, making them inaccessible for brown shrimp fisheries operating in the region.

Although the fully protected areas were formally closed in 2013, restrictions were only adhered to from 2017 onwards. From 2017, there was a notable reduction in fishing effort in the shrimp-fishery sector, where the decline in fishing activity was most pronounced within the fully protected areas. This case study illustrates that the **establishment of fully protected areas led to a significant reduction in fishing effort within those zones, without direct displacement of fishing activities to other areas, and an overall decrease in fishing effort in the entire area** studied. These findings argue against the concerns typically associated with the implementation of fully protected areas. However, further investigation is needed to ascertain the specific reasons behind the reduction in fishing activity and whether limitations in space were the main factors leading to the reduction of fishing effort. Understanding these factors is crucial for determining whether future establishments of fully protected areas lead to similar outcomes. The full report of this case study is provided in Annex 5.1.

Table 10. Summary of MPA case studies selected across the EU.

Regional sea	Location	MPA	Size km^2	Start Designation	Designated	Management	Regulated fishing activity
North Sea	The Netherlands	1. North Sea Coastal Zone	1,445	2011	2017	Fisheries In Protected Areas Agreement (2011)	Five separate areas (total 144 km^2) within the MPA, which are fully protected from fishing activity since 2013
	Belgium	2. Flemish Banks	1,100	2008-2011	2012 (SAC)	Belgium marine spatial plan (2014)	Fishing exclusion (f.e.) zones within the MPA
Baltic Sea (including the Skagerrak)	Latvia	3. Nida-Perkone	367		2010	Nature Conservation Plan (NCP; 2011). Currently being revised to be adopted in 2025	No specific fisheries restrictions in place within the MPA. Updated NCP may include fisheries restrictions
	Denmark	4. Adler Grund og Rønne Banke	321	2008	2009 (SCI) 2016 (SAC)	Implemented in 2016	Regulations to ban fishing with mobile bottom-contacting fishing gears on and around reefs in the MPA, came into force 2017
	Sweden	5. Bratten	1,209	2003	2011 (SCI) 2014 (SAC)	Nature management plans (2011) to protect reefs and sea-pen and burrowing megafauna communities	No-take zones excluding fishing activities covering 27% of the MPA were implemented in 2017
Celtic Sea	Ireland	6. Dundalk Bay	52	1994	2002 (SCI) 2019 (SAC)	5-year Fishery Natura Plans for cockles first implemented in 2011	Restrictions on fishing gear and spatio-temporal restrictions with explicit catch quotas for various species, including cockles
Macaronesia	Portugal, The Madeira Archipelago	7a. Selvagens	2,677		1971 (extended in May 2022)	2009 Planning and Management Plan for the Selvagens Islands, under Government Council Resolution No. 1292/2009. New protection status under Decree-Law No. 8/2022/M	All fishing activities banned within the MPA in 2022
		7b. Ponta do Pargo	15		2018	The MPA area was created under Regional Legislative Decree No. 19/2018/M	Partially protected area (professional, recreational, fishing and harvesting are permitted under specific regulations)

Regional sea	Location	MPA	Size km^2	Start Designation	Designated	Management	Regulated fishing activity
Iberian Coast	Portugal	8. Professor Luiz Saldanha Marine Park	53	1998	2005	The MPA area was created under Regulatory Decree No. 23/98 and although the marine park was designated in 1998, the marine park was approved in 2005 under Council of Ministers Resolution 141/2005	The MPA split into eight zones with varying regulations, from a fully protected area where no activities are allowed, to partially protected areas that allow sustainable artisanal fishing, but prohibit large commercial fishing operations
Macaronesia	Spain, Canary Islands	9a. La Graciosa Island	704		1995	The MPA was designated according to Ministerial Order of May 19, 1995 (BOE no. 131 of June 2, 1995) and Decree 62/1995 of March 24 (BOC no. 51 of April 26)	The MPA has three zones and is designed as 'marine reserves with fishing interest' for the conservation of coastal fisheries resources. This includes a no-take area (12 km^2), buffer area and restricted area. Non-selective fishing gears are banned (e.g. traps, longlines, trammel nets)
		9b. La Palma Island	35		2001	The MPA was designated according to Ministerial Order of July 18, 2001 (BOE no. 185 of August 3, 2001)	This MPA is divided into two different zones: a no-take zone (8.27 km^2) and a restricted zone. Permitted fishing outside the no-take zone include pole and line, surface trolling and tuna and live bait for tuna fishing

3.1.2 Flemish Banks, Belgium

An area in the south-west part of the Belgian North Sea called 'Vlaamse Banken', or Flemish Banks, was designated as a SAC under the Habitats Directive in the framework of Natura 2000 in 2012. This was later formalised within the process of the Marine Spatial Plan (MSP). The area, covering approximately 1,100 km^2, was allocated mainly to protect two habitat types (Pecceu et al., 2021). The first is classified as 'sandbanks which are slightly covered by sea water all the time'. The second is classified as 'Reefs' and include gravel beds and the tube-building polychaete, *Lanice conchilega* biogenic aggregations that occur within sandbank systems (Pecceu et al., 2021). The designation of this area also aims to protect harbour porpoises and common and grey seals (Verhalle and Van de Velde, 2020).

The first management measures for the Flemish Banks were approved in Belgian legislation in 2014. Specific conservation objectives were adopted in 2017 and revised in 2021. These were aligned with the environmental targets set under the MSFD (Pecceu et al., 2021). There are currently three management areas defined where fishery restrictions (exclusion zones) will be implemented (by 2025). Areas were defined based on fishery activity data (VMS) of all countries active in the area. The Netherlands and Belgian fishery are the most active within the area, executing mainly beam trawl fishery. Findings indicate that since the designation of the Flemish Banks as a SAC, a small decline but **no relative change in total fishing effort has been observed**. In general, it appears that **fishers did not adjust their behaviour neither following the designation nor when fishing measures are pending**. The area holds important fishing grounds, therefore announcing possible measures and closures is not sufficient to lead to behavioural changes. The full report of this case study is provided in Annex 5.2.

3.1.3 Nida-Perkone, Latvia

The Nida-Perkone MPA was designated as a Natura 2000 site in 2010 and is located in the south-western territorial sea of Latvia on the coastline of Rucava and Nīca parish. The site covers an area of approximately 367 km^2 and protects EU essential habitats such as reefs.

There are no specific fisheries restrictions in the Nida-Perkone MPA, and the fishery is regulated similarly to other marine areas in Latvia. Specific conservation objectives for the 2009-2018 period were adopted in 2011. An updated Nature Conservation Plan (NCP) is currently being developed nationally and will cover all Latvian MPAs. The Nature Conservation Agency (NCA) coordinates the work, and the new NCP will be adopted in 2025. A fishery targeting an invasive species of round goby has developed within the region, which has now become an essential resource for the coastal fishery. Several management activities have been implemented for the round goby resource, including the design of specialised fishing gears and methods to minimise bycatch of non-target species. In addition, seasonal and spatial fishing restrictions have also been introduced.

Findings indicate that (i) the round goby is the dominant species within the ichthyofauna assemblage of the MPA; and (ii) market opportunities and national fisheries policy promoted the rapid growth of a specialised goby fishery. This case study provides an example where the **fishery sector has looked to justify exploitation of an invasive species within the MPA, which could on the one hand improve the health of the ecosystem, but on the other increase bycatch risk for marine mammals and birds**, which are also one of the focus groups associated to conservation objectives of the Nida-Perkone MPA. The full report of this case study is provided in Annex 5.3.

3.1.4 Adler Grund og Rønne Banke, Denmark

The Adler Grund og Rønne Banke (AGRB) MPA located south-west of the Danish Island of Bornholm in the Baltic Sea, covers approximately 321 km^2 over a contiguous, irregular rectangular area. As part of the Natura 2000 European network of protected areas, the AGRB MPA was first proposed as a SCI in the end of 2009 and subsequently designated as such in January 2011. It was further designated as a SAC in April of 2016. The AGRB MPA was established to represent rare, threatened or characteristic habitats and species. In the case of the AGRB MPA one species, the harbour porpoise, and two habitat types, rocky reefs and sandbanks, are named as the key components that the MPA contains.

Management regulations to ban fishing with mobile bottom-contacting fishing gears on and around reefs in the MPA, came into force 2017. This case study investigated whether the designation of the site as a Natura 2000 or the subsequent fishing regulations had an effect on fisheries effort or landings in the MPA, and if so, whether these effects were dependent on the habitat being fished.

The case study showed that while the designation of the AGRB MPA triggered changes to some human activities in the area, **fisheries effort (and subsequent landings) appears to respond only to specific fisheries regulations**. Furthermore, **regulations on mobile bottom-contacting fishing gears had a significant effect on the effort taking place inside the MPA**. The overall reduction in effort within the MPA may not necessarily lead to increased effort outside the MPA, because fishing opportunities for key species are, in general, decreasing in the region. Any effort that is displaced from the MPA will also be restricted by the marine spatial plan’s exclusion of fisheries from areas allocated to other uses, such as wind energy installations.

The AGRB MPA illustrates how trade-offs must be made when deciding between no-take MPAs and targeted restrictions, while also attempting to address/ prioritise all conservation objectives assigned to an MPA. In this case, the mobile bottom-contacting gear regulations aimed to reduce impacts on reefs, indirectly reduced impacts on sand banks, but potentially indirectly increased gill-net activities in the broader region, increasing the risk of bycatch of harbour porpoise. The full report of this case study is provided in Annex 5.4.

3.1.5 Bratten, Sweden

The Bratten MPA was designated as a Natura 2000 site (SCI) for reef structures in 2011 and later in 2012 became part of the Convention for the Protection of the Marine Environment of the North-East Atlantic’s (OSPAR’s) network of MPAs. The MPA covers an area of approximately 1,209 km^2 and is situated within one of the important fishing grounds in the Skagerrak for northern shrimp (*Pandalus borealis*) and demersal fish. Located outside territorial waters in the Swedish EEZ, the area is intensively fished mainly by bottom trawlers from Sweden and Denmark.

The development of fisheries regulations followed extensive stakeholder consultation, including representatives of the fishing industry, sport fishermen, various national authorities and research institutions from Sweden, Norway and Denmark. The management measures include the establishment of no-take zones covering 27% of the area, where all fisheries are prohibited, and for control purposes compulsory use of an automatic identification system (AIS) for all vessels fishing in the area. The regulations for commercial fisheries were implemented since 2017. Similarly, conservation measures for recreational fisheries were enforced in 2017 through the Swedish national legislation by closing several of the zones to recreational fisheries (i.e. no-take zones).

This study shows that the dominating *Pandalus* fishery was affected by the implementation of no-take zones. Other fish and crustacean fisheries were less common in the Bratten MPA in terms of effort but indicate similar trends. In the Bratten MPA, the Swedish *Pandalus* trawlers ceased to fish in the no-take zones and intensified their efforts in the passages between zones and to the north-east within the MPA. There was **no significant reduction in fishing effort found in the MPA, and no indications of displacement to areas outside the Bratten MPA** were found. Rather, the variability in effort within the MPA correlated with the effort and fishing opportunities linked to the overall variation in availability of northern shrimp between years within the Skagerrak. The fishery regulations in the Bratten MPA were negotiated with fishers' organisations from Sweden and Denmark, and authorities considered the arguments from the fishers that it was important to keep passages through the area open. This may explain that effort could be withheld within the MPA, and that compliance with the regulations has been high. In addition, the regulations have been strongly enforced by detailed vessel monitoring covering essentially all vessels operating in the MPA. Specific details of this case study are provided in the full report in Annex 5.5.

3.1.6 Dundalk Bay, Ireland

Formed under the Natura 2000 European network of protected areas aiming to protect habitats and species of importance at the European scale, Dundalk Bay was designated as a SCI in 2002 under the Habitats Directive (92/43/EEC) and later as a SAC in 2019. The bay had also been designated as a SPA under the Birds Directive (2009/147/EC) in 1994. Within Dundalk Bay, the area designated as a SAC consists of approximately 52 km^2, of which 92.8% is a marine area. Since 1990s, a hand gathering and dredge cockle fishery operated in the Bay.

From 2008, when Habitats Directive Article 6 appropriate assessments were completed, the Department of Agriculture, Food and the Marine, the Marine Institute, the Bord Iascaigh Mhara and the industry developed a cockle fishery management plan to regulate the fishery. Since 2011, five-year fishery plans (Fishery Natura Plans; FNP) have been developed, each subject to new appropriate assessments. The current FNP (2021–2025) is in its third year. Annual monitoring of bird populations, benthic fauna and cockle biomass is undertaken.

The case study shows that the **favourable conservation status of ecological features in the site can be maintained with the co-existence of managed fisheries**. Management of fishing activity has been achieved through explicit and detailed fishery management plans that define how the fishery can operate sustainably and consistent with the conservation objectives in the site. Limiting entry to fisheries in Natura 2000 sites increases the potential for fishing stakeholders to make better and long-term decisions. This can be achieved through a cooperative approach between conservation and fishery authorities and fishers. Specific details of this case study are provided in the full report in Annex 5.6.

3.1.7 The Madeira Archipelago, Portugal - Macaronesia

This case study focused on two MPAs in the Madeira archipelago, namely Selvagens and Ponta do Pargo. The Selvagens MPA was designated in 1971 (extended in May 2022) and is the largest MPA in the North Atlantic, covering an area of approximately 2,677 km^2. It includes all archipelago of the Savage Islands, 280 km south of Madeira Isle. The MPA is completely no-take to all fishing activities although no management plan is currently implemented. In 2018, in Madeira Isle, the Ponta do Pargo Protected Area was created within 15.4 km^2 to protect, enhance, and sustainably utilise resources in the region, complying with the provisions of the National Strategy for the Sea and the requirements of the MSFD. In this respect, with the respective licences, commercial fishing, recreational fishing, and artisanal harvesting are allowed in this MPA.

A number of gear restrictions within the Madeiran islands limit the range of fishing activities that can be undertaken. Bottom trawls (or the use of towed gear that interacts with the benthos), gill nets, entangling nets or trammel nets are prohibited or limited to depths greater than 200 m. These permanent restrictions have been implemented to protect deep-water coral reefs, which are included in the list of endangered habitats in the framework of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention).

This case study aims to explore fisheries’ spatial reallocation in response to the implementation of these MPAs. The analysis was based on a systematic literature review and an exploration of AIS data. **Findings reveal no evident fisheries reallocation**. In Ponta do Pargo MPA, where fishing is permitted, the study observes ambiguous changes in fishing patterns (pole and line, drifting longlines and purse-seine), making it challenging to attribute shifts in fishing dynamics (e.g. effort and gear usage) solely to MPA implementation. Conversely, the extension of Selvagens MPA did not significantly alter fishing activities, indicating potential stability or resilience in fishing practices within this area, where pole and line was the most relevant fishing gear.

Overall, while both MPAs aim to conserve marine biodiversity, their effectiveness and impact on fisheries differ. In the Ponta do Pargo MPA, where fishing is allowed, changes in fishing patterns could be attributed either to natural variations or to the implementation of the MPA, making it difficult to draw conclusions, , while Selvagens MPA’s extension appears to have limited immediate effects on fishing activities. Within the region, there is a lack of fisheries data, little to no regular ecological monitoring of MPAs, and outdated management plans for most MPAs. Despite this, with its diverse MPAs, tailored MPA strategies, and preservation of traditional and small-scale fisheries, the region appears to be on track to fulfil the EU Biodiversity Strategy for 2030 targets for protection. Specific details of this case study are provided in the full report in Annex 5.7.

3.1.8 Professor Luiz Saldanha Marine Park, Portugal

The Professor Luiz Saldanha Marine Park (Parque Marinho Professor Luiz Saldanha [PMLS]) was the first marine park to be created in continental Portugal, with the adoption of its management plan in 2005. The PMLS covers approximately about 53 km^2, encompassing waters up to 100 m in depth and spanning from Praia da Figueirinha (south-west of the city of Setúbal) to Cape Espichel and Praia da Foz. The objectives of the PMLS have been to increase the marine biodiversity of the area, promote the recovery of local seagrass communities (Cunha et al., 2014), stimulate scientific research applied to the conservation, information, awareness raising and environmental education as well as promote ecotourism and traditional regional economic activities such as fishing with lines and hooks. The creation of the park, however, has been publicly criticized during it creation and implementation, especially by commercial fishers, due to the long history of fishing in the PMLS area by local vessels from Sesimbra and Setúbal.

Due to the small size of commercial vessels operating in and around the PMLA, existing AIS and VMS datasets could not be used to monitor and evaluate the reallocation of fishing activities before and after implementation of the MPA. Instead, the main aim of this case study was to evaluate indirect measures, such as changes in landings and market prices, resulting from the implementation of the marine park.

This case study shows that the **implementation of the PMLS did not cause any negative impacts on total landings and the average price of species captured in and around the MPA**, as these indicators maintained or even improved their trends after the implementation. However, the implementation of the MPA may have been only one of the factors that led to these positive trends. What can be concluded based on the existing data is that the fishing activities that were most directly impacted by the creation of the park did not collapse, as was feared by the local community. Either by effort displacement (which had to happen in the vicinity of the MPA, since the park is mostly associated with small-scale vessels) or by adapting to the restrictions created, there are clear indicators that the port of Sesimbra, and especially the small-scale fleet, continued to prosper and even improved their landings and revenues after the creation of the park. The PMLS can be seen as a positive example of MPA implementation in the EU, despite the existing limitations in terms of enforcement and management. Specific details of this case study are provided in the full report in Annex 5.8.

3.1.9 La Palma Island and La Graciosa Island Canary Islands, Spain – Macaronesia

This case study focussed on two MPAs in the Canary Islands, namely La Graciosa Island and islets to the north of Lanzarote (hereafter, La Graciosa Island MPA) and La Palma Island MPA in La Palma (hereafter, La Palma Island MPA). All Canarian MPAs are designed as 'marine reserves with fishing interest' for the conservation of coastal fisheries resources. However, vulnerable species and sensitive habitats were not considered when the MPAs were established.

La Graciosa Island MPA

La Graciosa Island MPA covers an area of approximately 704 km^2 around La Graciosa Island and the northern islets of Lanzarote. The MPA was designated in 1995 to protect the sea around the Chinijo archipelago to satisfy demands of the local fishing sector.

The MPA has three zones: a no-take area, a buffer area and a fisheries restricted area. Non-selective fishing gears (e.g., traps, longlines, trammel nets) are banned throughout the MPA. The no-take area covers approximately 12 km^2 and represents only the 1.7% of the MPA, which is far from the initial proposal in this marine area (Bacallado et al., 1989). In this zone, only authorised scientific activities are allowed. The buffer area, covering a one-mile radius from the no-take area boundary, only permits tuna fishing to be undertaken by pole and line. In the restricted zone, which covers the majority of the La Graciosa Island MPA, a range of activities are allowed. This includes authorised local fishers (La Graciosa Island and Lanzarote) using traditional fishing gears and recreational fishers only with trolling (external and internal waters) and hook and line (internal waters) are allowed.

Local fishers had little input into the design process of the MPA (Chuenpagdee et al., 2013; De la Cruz Modino and Pascual-Fernández, 2013). The lack of formal discussions and clear information, and the lack of empowerment to negotiate regulations, made the fishing association hesitant to support the MPA designation.

La Palma Island MPA

La Palma Island MPA covers an area of around 35 km^2, extending down to a depth of 1,000 metres and encompassing 15 km of coastline. The MPA was established in 2001 by the Spanish Ministry of Agriculture, Fisheries and Food (Ministerio de Agricultura, Pesca y Alimentación [MAPA]) and is divided into two different zones: a no-take zone and a restricted zone. A range of fishing activities are allowed within the MPA, and these differ depending on the level of fishing restrictions. In the no-take zone, any fishing activity, harvesting and scuba diving are prohibited, unless for authorised scientific purposes. Artisanal vessels utilising the restricted areas (surrounding the no-take zone), tmust be registered in a census. Where fishing is permitted, activities include pole and line, surface trolling and live bait for tuna fishing. In addition, within the restricted area, any types of recreational fishing are prohibited, except fishing from the shore outside the no-take reserve. The recreational fishers are allowed to fish only from the coast in the restricted area with a daily fishing quota of 5 kg.

Although no fishing effort data prior to MPA designation were available within this analysis, the results show the **displacement of the majority of fishing gears after**

2008 to the external MPA boundaries and offshore fishing grounds. Such spatial distribution data shows that **changes to fishing regulations have had substantial impacts on the fishing strategies undertaken** within both La Graciosa Island MPA and La Palma Island MPA. However, the artisanal fleet adaptations to fishing regulations since the establishment of the MPAs have not been quantified in economic or social terms. Specific details of this case study are provided in the full report in Annex 5.9.

3.2 Main findings of the assessment

The main objective of this work has been to assess the potential spatial reallocation of the fishing activities (displacement) in response to MPA designation and implementation. While the intention was to undertake standardised analyses across nine geographically diverse case studies, data availability and resolutions varied greatly. Therefore, all case study investigations began with a uniform systematic literature review to gather all existing knowledge that was available for the specific MPA sites. Subsequent analyses were either dependent on the results of these reviews (where data were lacking), or utilised quantitative data to implement post-hoc before-after, before-after-control-impact (BACI), or mixed model tests of the effects of MPAs, MPA-based fisheries regulations and adherence to these regulations on fisheries. These various approaches and their specific results are all provided as case-study reports (Annex 5). An overview of the case studies is provided in the previous section (Section 3.1). In the rest of this section, we describe, compare and contrast some of the main findings from the nine case studies.

Across the **North Sea and Baltic Sea**, the five case studies reveal six common findings, each shared by at least two case studies.

1. **MPA designation and fishing activity**: MPA designation does not affect fishing activity directly. Modification of fishing activity requires specific regulations and enforcement. No changes in fisher behaviour were reported in response to MPA designation or implementation in Belgium (Flemish Banks), Denmark (Adler Grund og Rønne Banke), or the Netherlands (North Sea Coastal Zone). In Sweden (Bratten), the trawl fishery decreased in the closed zones, but no similar trend was observed in the rest of the MPA.
2. **Fishing effort and concentration**: The designation of MPAs and/or fisheries regulations within them does not reduce overall fishing effort and may lead to localised concentrations of effort. For example, in Sweden there was an increase in the *Pandalus* fishery in the channels between the no-take areas. In Belgium, increased pressure from other industries in areas outside the Flemish banks MPA may lead to greater fishing effort in existing grounds.
3. **Impact on different segments of the fishery**: Some MPAs and/or fisheries spatial regulations affect only a segment of the fishery, or no fishery at all, where there was no existing fishery. In Denmark, reefs are protected from bottom trawl gears within sub-areas of the MPA that were not previously fished by trawl gear. Similarly, in Sweden, fishing effort in the no-take areas was very low for gears other than those targeting *Pandalus*.
4. **Impact on fishing habitats**: The exclusion of fishers from a given area (e.g. restricted zones) had little to no impact on the types of habitats being fished. For example, in both the Netherlands and Denmark, there was no substantial change in habitats fished inside the MPA and surrounding areas.
5. **Fishing efficiency**: Where fishing efficiency was examined, there was no change attributable to the establishment of MPAs. In Denmark, no increase in catch efficiency was reported for any gear within or surrounding the MPA. In Latvia, following an initial increase in catch efficiency due to targeting of an invasive species, efficiency reached an equilibrium.

6. **Trade-offs and conflicts**: There can be trade-offs and conflicts between different conservation objectives (e.g. birds, mammals, habitats) and the interactions of these objectives with different fishing practices (e.g. pelagic versus bottom fisheries). For example, in Latvia, increased fishing for the invasive round goby led to a risk of increased bycatch. In Denmark, MPAs designed to protect bottom habitats and the harbour porpoise, imposed fishing regulations primarily on gears interacting with benthic habitats.

Across the **Atlantic EU Western Waters including Macaronesia**, the four case studies have six common findings, each of which are shared by at least two case studies.

1. **MPA designation and fishing activity:** There is no direct evidence to show that MPA designation affects fishing activity (e.g. effort, habitat use). The studies indicate that while MPA designation does not lead to a reduction in fishing activity, it is associated with a reallocation of fishing activity outside of MPAs. For example, in Portugal (Professor Luiz Saldanha Marine Park), the MPA implementation did not negatively impact landings for several main commercial species. Within Ireland (Dundalk Bay), there was no displacement of fishing activity, which is addressed through a specific management process. Additionally, small-scale fisheries in Spain (La Graciosa Island and La Palma Island) and Portugal (the Madeira archipelago) continue to operate within the MPAs.
2. **Fisheries monitoring data**: Fisheries monitoring data are collected sporadically, with limited long-term management of such monitoring in MPAs. In Spain (La Graciosa Island and La Palma Island) and Portugal (the Madeira archipelago and Professor Luiz Saldanha Marine Park), the high number of active small-scale vessels operating without VMS and AIS limited spatial analysis of the fleet. In contrast, Ireland (Dundalk Bay) has routine fisheries monitoring, including high-frequency VMS data.
3. **Primary objective of MPA**: The primary objective of MPA designation has not been to manage fish and fisheries directly but rather protect habitats. Although managing fishing for economic gain is an important objective, it remains secondary. Several case studies, including those in Ireland (Dundalk Bay), Portugal (the Madeira archipelago) and Spain (La Graciosa Island and La Palma Island), showed that the main management objective was to protect marine habitats.
4. **Managing fishing activities**: Effective management of fishing activities is achieved through the development of explicit and detailed fishery management plans. These plans should address how to manage regional fishing activities across the entire MPA. For instance, in Portugal (Professor Luiz Saldanha Marine Park), certain fishing activities, such as commercial diving, spearfishing, trawling, dredging, purse-seining, and discarding fish, are highly regulated. Detailed management plans also exist in Ireland (Dundalk Bay) and Spain (La Graciosa Island and La Palma Island).
5. **Buffer zones**: Fishing activities are geographically bounded, making it necessary to create buffer zones in MPAs that overlap with historically important fishing grounds. In Portugal (Professor Luiz Saldanha Marine Park), the management plan includes limits and protection measures for various activities to support small-scale fisheries with high socio-economic value. In Spain (La Graciosa Island and La Palma Island), buffer areas are established to allow authorised local fishers to use traditional gears.
6. **Cooperative management approach**: A cooperative approach between conservation groups, fishing authorities and fishers is likely to be successful in attaining conservation objectives than top-down management. In Spain (La Graciosa Island MPA), the lack of formal discussions and clear information during the design process, along with a lack of empowerment to negotiate regulations, made the fishing association hesitant to support the MPA designation. Similarly, in Portugal, the creation of Professor Luiz Saldanha Marine Park faced public criticism, especially from commercial fishers, due to the long history of fishing in the area by local vessels from Sesimbra and Setúbal.

Across all investigated EU regions, in the majority of case studies, there was a shared understanding that **MPA designation did not bring about change in fishing effort or landings. It was only after specific fisheries regulations were put in place that fisher behaviour changed** (e.g. gear-specific exclusions, or no-take zones). In fact, on the Belgian Flemish Bank, where fisheries regulations (which can include no-take areas, but also a range of other restrictions) are defined (yet pending for about 5 years), this does not impose a change in fisher behaviour. Furthermore, in the Netherlands' open coast MPA, fishing behaviour in a trawl-ban area did not change in response to regulations coming into force legally; only after control activities and financial penalties were imposed was there a real and abrupt change observed.

The majority of the Atlantic EU Western Waters case studies, including Macaronesia (the Madeira archipelago, Canary Islands) did not have quantitative fishing-specific data available (i.e. VMS) to analyse. Instead, for these case studies, fishing effort data was estimated through analysis of publicly available AIS. The AIS is a tracking system used by vessel traffic services. Even small vessels use it for safety and security reasons, and it can be used to estimate fishing effort for small-scale fisheries. These data showed that there has been little reduction in fishing effort following MPA implementation. In this respect, fishing data showed that fishing activities were able to be undertaken across the coastline away from the MPA boundaries (e.g. Professor Luiz Saldanha Marine Park, La Palma Island), into deeper waters surrounding (e.g. the Madeira archipelago) or further away (e.g. La Graciosa Island) from MPA boundaries. Importantly, there was no evidence that such small changes in fishing effort were directly associated with reductions in landings or the economic output from regional fisheries. Conversely, there was no quantitative data to show that the implementation of MPAs led to an increase in the landings of regional small-scale fisheries.

Although fisheries data before implementation of MPAs were not available for a range of case studies (3 out of 9), the results have shown that patterns of fishing are structured by the boundaries of the MPAs. In this respect, there is very little evidence of poaching or non-compliance with fishing restrictions (with exception to the Netherlands open coastal example mentioned above). This may be due, in part, to the majority (50.5%) of MPAs within the EU not having fishery restrictions placed on them (Figure 13). In addition, where fishery restrictions are in place within MPAs the majority are relatively open to small-scale artisanal fisheries, but also in places, to large-scale commercial fishing activity.

Three of the five Baltic and North Sea case studies find that **there is no direct evidence of a decrease in effort corresponding to spatial closures**. In Sweden's Bratten MPA, the Swedish *Pandalus* fishers stopped fishing in the trawl-exclusion zones, but intensified efforts in the passages between closed zones and to the northeast within the MPA. Furthermore, there was no significant reduction in fishing effort found in the MPA as a whole when the exclusion zones came into force and no detectable displacement to areas outside the Bratten MPA. Similarly, in the Netherlands, individual vessels were allocated to an impacted and non-impacted group according to whether their usual fishing grounds fell within the trawl-ban area and there was no relative difference in fishing effort in the impacted group compared to the non-impacted group after the fishers began to adhere to the regulations. While the Belgian case study did not quantify the level of displacement, it was noted that the increase in competition for marine space from other growing industries (specifically windfarms) reduces the opportunities for displacement of fishing activities to other areas, and so the potential for concentrated effort in few areas remain.

There was some evidence of reallocation of fishing activity with implementation of fishing regulations. In Bratten Sweden, mainly the prawn (*Pandalus*) fishery was affected by the implementation of no-take zones, as other fish and crustacean fisheries were less common in the MPA. However, the *Pandalus* fishery is mixed and landings of saithe, cod and witch flounder are important.

In the Adler Grund og Rønne Banke MPA (Denmark), very little, to no fishing activity took place in the mobile bottom-contacting gears regulation zones. While mobile bottom-contacting gears decreased significantly in the MPA as a whole, there was no significant change within the subset of regulated areas. In addition, in the Netherlands and Denmark, where effort per habitat was expressly investigated, there were no significant changes found in response to fisheries regulations within the MPAs. In Denmark, this was limited to a comparison of relative change between the MPA and a selected control site, with only data from within these areas. No significant difference in effort was found for the two main habitat types that were fished between MPA and controls. In the Netherlands, while there was a significant increase in the rates of fishing on gravels, the magnitude of this increase was minor.

The case studies allowed us to identify the **need for managers to trade-off between the interactions of different conservation objectives and different fishing gears/practices**. For example, in Latvia, years after the Nida-Perkone MPA was designated, the round goby (*Neogobius melanostomus*) invaded the areas and became prevalent. This encouraged an increase in fishing activities targeting the invasive fish, primarily for commercial reasons but supported by some conservation-minded managers. However, such increased fishing effort had to be traded off against the risks of bycatch of birds and marine mammals, which are also of conservation interest in the area. This trade-off introduced conflict between fishers and scientists/advice-givers, who urged caution. In a less extreme case, the Adler Grund og Rønne Banke MPA was designated for the protection of two benthic habitat types and the harbour porpoise. The fisheries restrictions imposed within the MPA reduced effort from bottom trawl gears, which reduces impact upon the two benthic habitats; however, these regulations are unlikely to benefit the harbour porpoise. On the contrary, a regional increase in gill net activity may have increased risks of entanglement for harbour porpoise (Carlén and Evans, 2022). Lastly, Dundalk Bay (Ireland) comprises both a SAC, for protection of intertidal habitats and a SPA, for protection of waterbirds and seabirds, while also allowing economically important commercial hydraulic dredging for cockles (*Cerastoderma edule*). However, such benthic invertebrates (associated with the intertidal habitats) form an important source of prey for protected bird species; depletion of such prey populations may have a negative impact on bird populations within the bay (Clarke and Tully, 2014). Therefore, within Dundalk Bay, management plans have been developed to ensure continual monitoring and assessment of cockle stocks and benthic habitats amid bird population assessments, to ensure the balance between local fisheries sustainability and ecological integrity. Such case studies illustrate how **targeted regulations can overlook potential adverse effects on other conservation objectives.**

To ensure the continual success of conservation outcomes developed for MPAs across the EU, **there is need to understand the types of stakeholders affected by such MPAs**, **the communication required by MPA managers and the utility of their inclusion in MPA boards**. For example, within Ireland, fishers can form fisher associations, which represent local fishers and the main stakeholders' MPA managers must interact with them – this shows the regional importance of inclusion of such stakeholders in MPA boards. In comparison, within the Madeira archipelago, the Canary Islands and Portugal (continental), although fisher associations are apparent, stakeholders are more likely to be single fishers or small groups of fishers. For the vast majority of Baltic Sea and North Sea fishing fleets, the type of fishing (large commercial vessels) means that stakeholders are much more likely to represent large commercial fishing companies or be partners within large producer organisations.

The **designation and implementation of MPAs did not indicate to have negative impacts on regional fisheries**. However, MPA implementation may not result in positive impacts to surrounding fisheries. For example, in the Danish and Latvian case studies, there were no increases in catch efficiency brought about by the presence of the MPA or fisheries regulations. In Latvia, the LPUE of round goby increased with the introduction of the MPA but reached a plateau with fishing pressure. In Denmark, there was no change in LPUE detected either within the MPA or in the control areas. Within Portugal (Professor Luiz Saldanha Marine Park), fishing activities that were most directly affected by the creation of the MPA did not collapse, as was feared by the local community. On the contrary, Horta e Costa et al., (2013) observed that the small-scale vessels operating in the region either adapted to the restrictions created or there was effort displacement.

3.3 Conceptual model for fishing effort displacement

The EU Biodiversity Strategy for 2030 promotes a large and well-connected EU-wide network of effectively managed MPAs. Key commitments by 2030 include the legal protection and effective management of at least 30% of the EU's marine waters, 10% of which must be under strict protection. Achieving this goal will require the creation of new MPAs and other spatial protection measures. After establishment of MPAs with fishery measures in place, a potential effect is the redistribution of the fishing activities to the surrounding areas due to the loss of fishing grounds (Hattam et al., 2014; Cabral et al., 2017). Therefore, developing a tool that helps government authorities, fishers, managers and other stakeholders to have an indication of the potential outcomes associated with the designated MPAs and fishery measures is key.

To this end, a conceptual model ([17]) of the effects of MPAs on the reallocation of fishing effort in and outside the MPAs (displacement), was developed in this study, the 'MAPAFISH tool'. The tool is based on different fishery management strategies (e.g. no, full, or partial protection) and the potential social, economic and ecological impacts of the effort reallocation. The model allows users to define an input scenario – establishment of a particular MPA and its rules. Based on this input, the model identifies the types of potential outcomes associated with the MPAs and fishery measures taken.

3.3.1 Model development

Displacement effects: from mechanisms to questions

To derive a set of questions to determine the magnitude and effects of displacement for a potential MPA, a 3-step approach was used:

1. Establish the magnitude of displacement.
2. Define the mechanisms through which displacement can have effects.
3. Define descriptors of interest for impact assessment (e.g. biodiversity, noise pollution, seafloor disturbance, fishery revenue) that could be affected by one or more of the mechanisms by which displacement changes the system.

Next, a series of questions were formulated, the answers to which establish the magnitude of impact of displacement on the different indicators. To do so, a numerical score (similar to a Likert scale) was assigned to each answer–impact combination, to (semi-) quantify the magnitude and likelihood of each potential impact.

By multiplying the score for the magnitude of displacement by the score for the magnitude of the mechanism and by the appropriate impact score, a total score is obtained for each mechanism–impact combination. Summing these per impact leads to a total score for each impact.

([17]) Conceptual models are a tool for visualising relationships, and capturing complex, tacit, and/or experiential knowledge in an accessible way. Conceptual models may take various forms and may be produced qualitatively or informed/constrained by data. They are useful for building a common understanding and identifying issues/questions relevant to multiple parties.

These questions, answers, and the calculations are then implemented within an interactive Microsoft Excel-based tool, which allows the user to answer a set of questions and presents a prioritised list of the most relevant potential displacement effects given the user input. The model functioning (i.e. whether it reflects reality and how well the calculations are calibrated) was tested using the input from case study experts. Further details on the methodology for the MAPAFISH tool can be found in Annex 6.

Step 1. Establishing the magnitude of displacement

The aim of the questions in this first step is to get an indication of the degree to which displacement will occur. These questions should relate to the degree to which the area is closed to the fishery, and the degree to which the area was used by the fishery prior to closure.

Step 2. Mechanism by which effects can occur

Following discussions among key-subject matter experts, four essential mechanisms were identified by which displacement leads to changes in the socio-ecological system (environmental, technical and social):

- increased steaming time if fishers are displaced to fishing grounds further from port
- increased fishing effort if fishers are displaced to less productive fishing grounds
- increased fishing pressure in locations that the fishers are displaced to
- adaptation of fishing methods (gear, fishing speed, timing, seasonality, etc.) to the new situation

Step 3. Impacts: relevant descriptors to measure effect size

In total, 14 qualitatively different descriptors of interest were identified for which potential impacts of displacement can be established:

- biodiversity
- food web
- seafloor integrity (including carbon sequestration)
- noise pollution
- greenhouse gas emissions from fossil fuels
- catch composition
- bycatch quantity
- costs
- revenues
- business structure
- working rhythm
- polyvalence (strategies)
- competition
- community and value chain

These descriptors were chosen based on scientific literature and in discussion with key-subject matter experts in fisheries ecology and economy.

Relevance of impact–mechanism combinations

For each potential impact, we identified the relevance of each of the possible mechanisms structuring such impact (Table 11).

Table 11. Impact–mechanism combinations. When combination is relevant, a short description of the causality is given. NA means that combination is not applicable.

Indicator impact	Mechanism: Steaming time	Mechanism: Fishing Effort	Mechanism: Fishing location	Mechanism: Fishing methods
Biodiversity	More disturbance above water (seabirds) (Schwemmer et al., 2011)	More effort means more impact above and below water (Hiddink et al., 2017)	New areas have different species composition including potentially protected and/or vulnerable species/habitats	Different species selectivity and/or impact per unit effort of different gears
Food web	NA	More effort means more impact above and below water (Hiddink et al., 2017)	Fishing increase in particularly sensitive area (e.g. spawning ground) (ICES, 2017)	Different species selectivity of different gears
Seafloor integrity	NA	Higher effort leads to more seafloor disturbance (Hiddink et al., 2017)	Different sensitivity and/or different fishing history (historically more/less disturbed) (ICES, 2017)	Gears differ in seafloor impact per unit effort (Eigaard et al., 2016)
Noise	More noise from steaming (Chahouri et al., 2022)	Noise hotspots in different locations	Sensitivity of ecosystem to noise pollution could be different in new locations	Different vessels and gears make different levels of noise
Greenhouse gas emission from fossil fuels	More steaming leads to higher carbon dioxide (CO_2) emissions	More fishing leads to higher CO_2 emissions	NA	Fishing gear affects fuel consumption
Catch composition	NA	NA	Potentially different species present in different locations	Different fishing methods have different efficiencies for each species
Bycatch quantity	NA	Higher fishing effort per unit landing may lead to more total bycatch. (Pons et al., 2022)	Different location could have higher bycatch rates because of its ecology	Different methods may have higher bycatch rates because of technical differences
Costs	Higher fuel costs for longer trips	NA	NA	Investment in new gears required
Revenue	With longer steaming time there is less time for fishing, hence lower revenue	Less marketable fish per hour fished if productivity is lower	Different location, different species composition with different market prices	Different gears with catchability of species with different market prices

Indicator impact	Mechanism: Steaming time	Mechanism: Fishing Effort	Mechanism: Fishing location	Mechanism: Fishing methods
Business structure	Favours larger businesses because changes in landing port are easier to accommodate for larger companies	NA	Owner-operators are often strongly connected to fishing grounds. Larger fishing companies are not and are hence favoured	Larger fishing companies have higher investment budgets and hence required gear changes favours larger companies over smaller
Working rhythm	Longer steaming times require continuous fishing, reducing the prevalence of the traditional Monday to Friday rhythm	Longer fishing times require continuous fishing, reducing the prevalence of the traditional Monday to Friday rhythm	NA	NA
Polyvalence (strategies)	NA	Specialist fishers whose important fishing grounds are closed will spend more effort searching for alternatives, leading to more effort. This favours fishers who are already generalists	Specialist fishers will have more trouble adapting than generalists and are hence at a disadvantage	Specialist fishers will have higher adaptation costs compared to generalists
Competition	NA	Higher effort required when fishers displace to less productive fishing grounds will increase the competition experienced among fishers	A reduction in the total availability of fishable area increases the competition experienced among fishers	NA
Community and value chain	Longer trips may reduce the prevalence of the traditional Monday to Friday rhythm, which may be at odds with community and/or religious practices	Longer trips may reduce the prevalence of the traditional Monday to Friday rhythm, which may be at odds with community and/or religious practices	NA	NA

Conceptual model (link to the MAPAFISH tool)

The conceptual model was built in Microsoft Excel and works by answering a set of questions presented in Annex 6 using a drop-down menu with multiple-choice options (Figure 32). The questions utilised allow to qualitatively determine the likelihood and intensity of displacement; assess the strength of each of the four mechanisms (steaming time, fishing effort, fishing location and fishing methods); and further specify the relevance of each mechanism for each impact. We chose to implement the model in Microsoft Excel because it is readily available to our user base and does not require the installation of software or specific expertise.

The answers to these questions are then used to calculate the total impact on the different indicators. These calculations (relations between questions and indicator; weights of impact; etc.) were discussed with experts in fisheries ecology and economy. The results are presented within four Excel tables outlined below.

The first table summarises the most important insights (Figure 33). For each indicator, the Excel table shows the mean risk-impact score (ranked from high to low and visualised using a traffic-light color-coding scheme) and the number of questions relevant to that indicator that were answered. In addition, the answer 'this is unknown' is one of the multiple-choice options for each question.

Next, each indicator can be inspected in more detail using the Excel table 2 (Figure 34). Here, any indicator of interest can be selected in the first column. The table will then automatically update to show the top contributing questions for this indicator, along with the impact score and a short explanation of the impact.

Finally, the questions that were answered with 'unknown' are listed in two tables. In Excel table 3 (Figure 35), any indicator of interest can be selected, upon which the table will automatically be updated to show which questions relevant to that indicator were answered with 'this is unknown'. In Excel table 4 (Figure 36), the total list of questions that were answered with 'unknown' is listed.

Question ID	Question	Answer (select from drop-down menu)
Question_1	What is the importance of the MPA area for the affected fisheries?	The majority of fishing activity is in the MPA.
Question_2	Will it be fully or partly closed?	
Question_3	Will there be other restrictions for fishing wi	
Question_4	Are there viable populations of target specie that can be exploited by fisheries?	Yes, but only few.
Question_5	Which of the following most strongly drives the current fishing activities in the area to be designated as an MPA?	This is unknown and/or uncertain (Q5).

Less than 10% of fishing activity is in the MPA.
Between 10 and 50% of fishing activity is in the MPA.
The majority of fishing activity is in the MPA.
The fisheries exclusively fish in the MPA.
This is unknown and/or uncertain (Q1).

Figure 32: Questionnaire sheet with an example of a drop-down menu for question 1.

Table 1: Ranking of indicators' risk-impact & number of unknowns

Rank	Indicator	Risk-Impact score	Unknowns
1	Revenue	2,44	8
2	Costs	2,25	8
3	Competition	2,11	8
4	(different	2	7
5	Catch composition	1,9	7
6	CO2-emissions	1,8	6
7	Working rhythm	1,75	9
8	Biodiversity	1,69	10
9	Noise	1,67	6
10	Bycatch quantity	1,63	7
11	Business structure	1,56	8
12	Food-web	1,5	10
13	Seafloor integrity	1,38	8
14	Community	1,38	6

Key findings

As shown in table 1, the three indicators with the highest risk-impact score are Revenue, Costs, and Competition. Additionally, the indicators had at least one answer to a question that indicates a very high-risk. These can be inspected in more detail in table 2.

To mitigate these negative impacts, it is advized to study whether the MPA policy can be tailored in such a way that these negative effects can be minimized without hampering other indicators. In table 2, any indicator of interest can be selected to see what the main causes are for the impact on this indicator. This can be helpful in identifying how the MPA policy can be improved to minimize negative effects.

In addition to the mean Risk-Impact shown table 1, the column 'Unknowns' indicates how many questions relevant to each individual indicator were answered with 'this is unknown'. These unknowns indicate knowledge gaps that consequently result in uncertainties. In order to facilitate well-informed management decisions, it is advisable to minimize these knowledge gaps. Thus, it is recommended to, wherever feasible, conduct further research into these areas of uncertainty, enabling the formulation of effective policy decisions. Table 3 (specific indicator of interest) and 4 (total) list the questions that were answered with unknowns.

Figure 33: Traffic-light table with the different indicators ranked from high to low mean risk-impact and the number of relevant unknowns (left) and an explanation of the key findings (right).

Table 2: Top contributors to risk-impact of indicator of interest

Select indicator	Contributer rank	Key Contributing Question	Key Contributing Answer	Impact Score	Explanation of Key Impact
Revenue	Top Contributor	Will there be other restrictions for fishing within the MPA?	Yes, there will be additional restrictions on fishing within the MPA, including limitations on fishing gears and equipment.	4	All restrictions have an impact on the revenue. With gear restrictions, the gear may not be optimal. Periodic closure will decrease revenue in that period. Catch quotas limit how much can be caught.
	2nd Contributor	If the alternative fishing areas are further away, will that reduce the time fishers have available to fish, on an annual basis?	Yes, if the new areas are further away, it will reduce the time fishers have available to fish on an annual basis due to increased travel time.	4	The reduced time available for fishing annually due to further alternative fishing areas might impact revenue. Less available fishing time could result in lower catch quantities and catch values, potentially affecting overall fishing revenue.
	3rd Contributor	What is the importance of the MPA area for the affected fisheries?	Between 10 and 50% of fishing activity is in the MPA.	3	The more important the MPA area is, the bigger the impact on the revenue will be since fishers will not be able to catch fish within the MPA anymore.
	4th Contributor	Will it be fully or partly closed?	The MPA will be partly closed, allowing some fishing activities to take place.	3	The extent of MPA closure relates to fishing revenue. Full closure will lead to revenue loss as fishers will not be able to fish in their preferred area anymore.
	5th Contributor	How significant is the total reduction in productive fishable grounds?	The total reduction in productive fishable grounds is of average significance.	3	The fishers will depend on alternative fishing grounds for their revenue. The larger the reduction, the bigger the impact.

Figure 34: Table with the top contributing questions to the indicator 'revenue', which is, in this hypothetical scenario, the most heavily impacted indicator.

Table 3: Questions that were answered with 'this is unknown' for indicator of interest

Indicator of interest	Question number	Question
Biodiversity	Question_4	Are there viable populations of target species in alternative areas that can be exploited by fisheries?
	Question_5	Which of the following most strongly drives the current fishing activities in the area to be designated as an MPA?
	Question_7	Compared to other areas that the fishers use to steam between their home port and fishing grounds, what is the density of seabirds in the MPA and the routes towards it?
	Question_13	Compared to other areas where the fishers operate (or could operate), how high is the abundance of the target fish species in the MPA?
	Question_15	Compared to other areas where the fishers operate (or could operate), what is the catchability for the target species in the MPA?
	Question_16	To what extent are there fishers that are highly specialized on certain target species who will have to increase their effort in searching productive new grounds?
	Question_18	Compared to other areas where the fishers operate, how large is the biodiversity in the MPA?
	Question_19	How does the bycatch rate (bycatch biomass per unit of effort) within the MPA compare to alternative areas?
	Question_20	Compared to other areas where the fishers operate, what is the frequency of occurrence of spawning aggregations of species that are caught in or disturbed by the fishing gears used in the MPA?
	Question_32	If innovation is required, to what extent is the community capable of innovation (financial and willingness)?

Figure 35: Screenshot of table 3, which lists the questions relevant to an indicator of interest that was answered with 'this is unknown'.

Table 4: All questions that were answered with 'this is unknown'

Question number	Question
Question_4	Are there viable populations of target species in alternative areas that can be exploited by fisheries?
Question_5	Which of the following most strongly drives the current fishing activities in the area to be designated as an MPA?
Question_7	Compared to other areas that the fishers use to steam between their home port and fishing grounds, what is the density of seabirds in the MPA and the routes towards it?
Question_9	To what extent would it be feasible and beneficial (less steaming time) for fishers to change port?
Question_11	To what degree do longer trips raise logistical issues for fishermen?
Question_12	To what degree are fishing-free weekends important for the local community?
Question_13	Compared to other areas where the fishers operate (or could operate), how high is the abundance of the target fish species in the MPA?
Question_15	Compared to other areas where the fishers operate (or could operate), what is the catchability for the target species in the MPA?
Question_16	To what extent are there fishers that are highly specialized on certain target species who will have to increase their effort in searching productive new grounds?
Question_18	Compared to other areas where the fishers operate, how large is the biodiversity in the MPA?
Question_19	How does the bycatch rate (bycatch biomass per unit of effort) within the MPA compare to alternative areas?
Question_20	Compared to other areas where the fishers operate, what is the frequency of occurrence of spawning aggregations of species that are caught in or disturbed by the fishing gears used in the MPA?
Question_32	If innovation is required, to what extent is the community capable of innovation (financial and willingness)?

Figure 36: Screenshot of table 4 showing list of all questions that were answered with 'this is unknown'.

3.3.2 Model testing

The conceptual model was developed by researchers from Ireland (Marine Institute) and the Netherlands (Wageningen Marine Research), who had substantial experience in fisheries and MPA projects in their respective Member States.

To help calibrate and ensure the model's applicability across different scenarios, it was tested using input from case study experts from various Member States: Adler Grund og Rønne Banke in Denmark, the Belgian Flemish Banks, and the Spanish case studies (see Section 3.1). The instructions for applying the model were sent out to the case study experts. The model testing was intended to test the applicability of the tool and the relevance of the results (i.e. did it match findings and expectations?).

A summary of the model's results is presented below for these diverse case studies.

Denmark - Adler Grund og Rønne Banke

Within this case study, revenue, costs and polyvalence are the indicators identified as most at risk (i.e. these indicators had the highest risk-impact according to the model) following displacement of fishing activities, while there is much uncertainty (i.e. questions in the model were answered with 'this is unknown') for biodiversity and the food-web. Initially, this last column was not included, but after receiving feedback from the Danish case study expert it was added to the table. Other than that, the feedback to the main findings were positive, confirming the model outputs met the expectations of the expert.

Belgium – Flemish Banks

The indicators mostly at risk in relation to the fishery sector are costs, competition and revenue. Working rhythm and business structure will not be at risk for the sector. In relation to conservation, biodiversity and food-web are indicators identified as most at risk following displacement of fishing activities. The questions most often answered with 'this is unknown' concerned whether fishers would need to change ports, which would lead to changes in steaming time. This is therefore the most uncertain topic in this case study. Case study experts gave useful feedback on the content of the questionnaire that the model used, and furthermore agreed with the model output, seeing it as a valuable tool.

Spain, Canary Islands - La Palma Island and La Graciosa Island

The questionnaire was completed for two MPAs in the Canary Islands, Spain. In both cases, the cost is the indicator identified at most risk following displacement of fishing activities. According to the case study leaders, these findings were as to be expected, in line with the latest case study findings.

Model testing has shown **costs and revenue consistently emerge as prominent indicators**, as one would anticipate when a fishery area is closed. Additionally, certain indicators, such as seafloor integrity or polyvalence, show significant variation in ranking across different case studies. This variation suggests that the model calibration is not significantly biased towards such indicators. Case study **experts have also confirmed that the model output aligns with their expectations**. These findings give confidence in the effective operation and reliability of the MAPAFISH tool.

4 STAKEHOLDER PERCEPTIONS ON FISHERIES AND MPAs

Key highlights

- Large-scale fishers are concerned that their exclusion from an area means that the displaced effort will increase in adjacent fishing areas to match the equivalent total catches and thus increase competition. Small-scale fishers expressed that they are not going to be able to adapt and fish in other areas, if their current fishing grounds are closed, with more risk of going out of business because of a lack of capacity to invest in alternative fishing methods.
- There has been late, limited or no involvement of fishers in the designation phase of the studied MPAs, although several stakeholders believe their participation is key.
- Stakeholders have different views regarding the added value of MPAs to fisheries. Most fishers feel that EU MPAs are not currently a useful tool for fisheries; fisheries objectives on commercial stocks have so far not been included nor monitored.
- Fishers consider that there is too much focus on protection of marine areas from fisheries activities. When setting conservation objectives, fishers highlight that the impact and accumulated effect of all activities at sea need to be considered.

MPAs have implications for the EU fishing industry as they may entail partial protection or whole site closure to fishing activity. The potential effects on fishing activity range from a loss of income for the entire or part of the fleet, to beneficial effects on the seabed and thus on biodiversity, and recovery of populations and an increase of the attractiveness of the area for local and external fishers, amongst others. The success of MPAs ultimately depends on the engagement of stakeholders involved in the establishment and management of protected areas. Accordingly, it is key to understand the perceived impacts that these MPAs can have and insights about MPAs as a fisheries management tool.

To better **understand the effects of displacement of fishing activities and use of MPAs as a fisheries management tool, the perceptions of different stakeholder groups were investigated** through interviews and focus group discussions. Stakeholders were grouped in four categories: fishers (organisations), governments, research and academia, and civil society (Table 13; Annex 7). In total, twenty-seven interviews were conducted between mid-December 2022 and early March 2023 for the selected MPA case studies in Belgium, Denmark, Ireland, Latvia, the Netherlands, Portugal, Spain and Sweden (see Section 3.1 for an overview of the case studies). Further, eleven focus groups were conducted between May and August 2023: five focus groups were conducted for fishers from case studies in Ireland, the Netherlands, Spain and Sweden, whereas six focus groups were conducted for multi-stakeholders from case studies in Belgium, Denmark, Latvia, the Netherlands, Portugal (continental) and Sweden (Table 14; Annex 7).

The following sub-sections describe the stakeholders' perceptions about potential displacement of fishing activities (Section 4.1), and MPAs as fisheries management tools (Section 4.2). More specifically, the results focus on the economic, ecological, social and technological factors influencing fisher behaviour in response to the designation of MPAs, based on fishers' experience.

Further details of the methodology for stakeholder engagement and associated focus group guidelines are provided in Annex 7 and Annex 8, respectively. Specifically, the structure of each focus group and an outline of the main themes discussed is shown in Table 15 (Annex 7). A summary of the stakeholder categories and number involved in each focus group is shown in Table 16 (Annex 7).

4.1 Stakeholder perceptions towards displacement of fishing activities

One main argument underlying fishers' resistance to permanent closure of fishing areas is the fact that fish are not bound to one area, and current techniques require that fish be followed ('hunted'). Belgian fishers see that in certain recruiting periods, closure might lead to larger-sized species; but they feel that there should always be sufficient fishing grounds to allow them to "*follow nature*". Danish fishers are likewise concerned about the fact that fish move and that in future scenarios their target fish may be within the MPA. A Swedish fisher remarked that the shrimp in the Skagerrak '*wanders around, [...] sort of everything moves in a sort of a circle'*, along the Swedish coast to the Norwegian coast down the Danish coast and back again, but that instead of *"following this circuit"*, in the last 6-7 years Norwegian, Danish and Swedish big shrimp boats have been fishing all year a bit south of Bratten and up to the Norwegian border, expressing that *"no one cares until something serious happens"*.

The Dutch fishers see a main consequence of an area closure as simply the crowding-out effect or 'spatial-squeeze' because fishers are forced to fish elsewhere: "*I fish mainly on the Wadden Sea, where I think the fishing pressure has certainly not decreased, I think rather slightly increased*."

In Denmark, the displacement discussion in the focus group was based on expectations, as spatial closure is not expected to occur in the immediate term. Therefore, for fishers, displacement is of less concern. Nevertheless, fishers maintained that exclusion of fishers from one area will lead to a shift in that effort elsewhere. **Large-scale fishers state that if they are excluded from an area, it is probably an area of a more efficient fishery, and therefore the displaced effort will increase to match the equivalent catches, increasing fuel consumption**. However, representatives from environmental non-governmental organisations (NGOs) do not expect environmental impacts in areas outside of fisheries-regulated MPAs; rather they expect that a reduction in overall effort is more likely.

Fishers operating small-scale boats are concerned that closures of their fishing grounds mean that they are unable to adapt and fish in other areas, with more risk of going out of business because of a lack of capacity to invest in alternative fishing methods. In the Danish multi-stakeholder focus group there was agreement among the three stakeholder groups present (governmental, fishers and environmental NGOs) that reduction instead of displacement of effort would specifically relate to small-scale fisheries. In the Belgian case study, there was also emphasis on displacement not being easy, as selection of fishing grounds is based on fishers' knowledge and experience. Furthermore, they note that experiments with passive fishing have failed, so they see no alternative to demersal beam trawl.

In Sweden, fishers in the focus groups stated that the displacement of fishing ground has resulted in smaller areas to fish in, which allows for fewer vessels to operate, since fishing boats trawl next to each other and not in a row. Several interviewed fishers point at the fact that fish migrate independently of borders and that fishers are hunters losing their *"range"* to fish with the increased planning and demarcation of space at sea. For example, "*The thing that has happened in Kattegat with offshore wind farms is exactly the same as they did with the Indians. We have used these waters and trawled in these waters for over 100 years. Several people will go bankrupt*".

The fishing pressure (displacement) north of Bratten is higher now since the imposition of restrictions in MPA Bratten and has affected both the Danish and Swedish fisheries. The areas that are planned for offshore wind farms in Skagerrak overlaps with important areas for shrimp and Norway lobster fisheries. The Swedish fishers focus group remarked that if all MPAs in Sweden are closed to bottom trawling, and additionally the projected windfarms in Skagerrak are realized, all fishing grounds will disappear, which they stated would force the fishers to seek new fishing grounds in Danish and Norwegian waters. Two out of three fishers did not see it viable that fishers would be allowed to fish in windfarms.

In the Latvian case, fishers in the Latvian focus group remarked that "*Nowadays [the] coastal fishery is an ethnographic occupation*". They see that fishers and their gear become old, coastal fishing intensity reduces. Setting strict protection status in coastal waters involving fisheries ban will destroy coastal fishery in those areas (that is, destroy economic viability, leaving mainly the cultural relevance of the profession). The fishers see this causing catastrophic consequences to the local communities. One interviewed Swedish fisher expects that if area closure results in steaming time of more than four hours, 90% of the coastal small-scale fishery will disappear and fisheries will become more concentrated.

4.2 Stakeholder perceptions towards the use of MPAs as fisheries management tools

Among many other benefits, MPAs are argued to protect and increase fish stocks for spawning and export of larvae, recruits and adults into adjacent fishing grounds (Di Lorenzo et al. 2016, 2020; Van Hoey et al., 2024). They are also reported to reduce the risk of fishery collapse by maintaining a more diverse age structure and genetic base, and hedge against inevitable uncertainties (Roberts et al., 2003; Roberts and Hawkins 2012). Here, perceptions of stakeholders were sought to understand whether they were receiving such benefits and could consider the MPAs as tools for fisheries management. Findings show that there is correlation of views on a number of topics, including that **EU MPAs were not being used as fisheries management tools but rather mainly for biodiversity conservation** (Mangi and Austen 2008). For instance, the Danish focus group believed that the use of MPAs as a fisheries management tool still needs to be demonstrated as most MPAs are currently designed for biodiversity conservation purposes. However, stakeholders see the potential for shared fisheries and biodiversity conservation goals to be achieved via the implementation of MPAs, and multi-use areas as an alternative to complete closures. Stakeholders also perceive that there is need for improved communication and involvement by various stakeholders in MPA designation, increasing need for EU-wide maritime spatial planning to be clear and open to discussion, and need to ensure international competition is reduced.

Perceptions of Belgium fishers show that they consider temporal closures as more effective than permanent closure when spatial fishing density is low. They stated that this is because nature is constantly evolving, and fish have changing migration patterns that fishers need to follow. If not, it leads to economic stagnation in the sector. The Portuguese MPAs examined were not designated as fisheries management tools but for nature conservation purposes only. Interviewees considered that, in general, conservation objectives in terms of biodiversity have been achieved. In turn, fishing restrictions imposed in some sub-areas of these MPAs have led to increased fish landings. In Spain, both conservation and fisheries aspects were considered in the designation process of the two MPAs, and fishers were involved from the inception phase. Nevertheless, only modest positive results are reported in terms of fisheries production. In Ireland, the MPA was designated for conservation purposes only. Resources have been managed via strict management measures, with strong support from fishers. Thus, in most cases, MPAs have not been used strictly as fisheries management tools. Further, in most MPAs, fisheries objectives have not been integrated with conservation measures in a unified approach. In general, the **involvement of fishers at the designation stage has been very limited**. However, fishers tend to be involved in later stages of the MPA process. The lack of involvement of fishers in the designation process can be explained by the predominance of conservation objectives over fisheries objectives, again because MPAs were set-up with a conservation focus.

As marine management tools, MPAs are considered too general, and more specificity is needed (Denmark). MPAs can have very different purposes and regulations on human activities (e.g. following the Birds or Habitats Directives with various regulations on hunting and/or fishing). Danish stakeholders recognise other spatial management tools, such as trawl bans for maritime safety, fisheries exclusion from energy installations and temporal fishery closures to protect spawning aggregations, which may be considered as other effective area-based conservation measures (OECMs).

4.2.1 Involvement of fisheries sector in the designation of MPAs

Despite the fact several stakeholders believe that participation of fishers in the different stages of the MPA process (from MPA designation to implementation) is regarded as essential, **there has been late, limited or no involvement of fishers in the designation stage of the investigated MPAs** across the EU.

In the various inshore MPAs of the Madeira archipelago, authorities recognised that the involvement of fishers in their designation was very limited. Nonetheless, this has not affected the success of the MPAs. In the Professor Luiz Saldanha Marine Park, the engagement of fishers was limited at the time of designation. Authorities considered that the small-scale fishers should be more involved because they are the sector most affected by the creation of the park. Moreover, their involvement in the implementation of the conservation measures and collaboration with the administration and scientists is essential if the MPA is to have the intended results. In La Graciosa Island MPA, the fishing sector represented by the 'cofradía' (fishing guild) reported that they were not involved in the designation process and that they have not been adequately informed by the national administration. The regulations are being enforced without prior consultation with the fishing sector.

In the case of the Professor Luiz Saldanha Marine Park, environmental NGOs regretted that fishers were not included in the designation process. Nevertheless, fishers have contributed greatly over the years by sharing their knowledge and cooperating with scientists. Scientists in turn confirmed that local stakeholders were not heard during the designation of the MPA. They were engaged only during public consultation on the final proposal. Further to this, scientists believe that the inclusion of fishers at the early stages of the process would have resulted in better decisions to help fishers to adapt to the management measures. They believe that there is a lot of work to be done with the community in general and fisheries in particular to build respect for the park and to solve some of the problems currently faced in the MPA.

In the case of Dundalk Bay, the national administration reported that fishers were not involved in the designation process. It appears that only the national administration and the research agency, playing a consultative role, were included. Nonetheless, all the stakeholders were involved in a consultation process after the areas had been designated. Fishers reported they were not aware of the designation of this area as a SAC and SPA. They became aware of it when fishing was about to be closed to avoid the risk of impact to habitats and species and agreed with the closure of the fishery while data was collected to establish a base line for evaluation and management. They supported the elaboration of the management plan that restricts the number of vessels in the fishery. This is a restriction that they consider necessary and impedes the entry of newcomers. Other means as temporary closures of the fishery are accepted if they guarantee resource sustainability. The fishers agree that better management of the commercial fishery that was brought about by the designation of the site has stabilised the fishery. There is a regional inshore forum where fishers are represented, but it is considered to be too wide for the management of the cockle fishery since the representatives are experts in other types of fisheries, and not completely aware of the particular needs of this fishery.

In most cases within the North Sea and Baltic Sea region, the focus groups concluded that the **designation process has not sufficiently, or too late, included the participation of the fishing sector in the decision-making process and**

information flows (Belgium, Denmark, Netherlands, Sweden). Participation of fishers in the diverse stages of the MPA process is regarded as having key importance, from designation to implementation. This includes the role of fishers as data providers and collaborators with scientists and managers. Linked with the low participation of fishers in the designation and implementation phases is the complaint by fishers that communication between them and administration and the fishing sector is poor and that it should be improved.

The designation process in the Belgian case study was reported by the fishery sector to be one-sided, with too much "power" from ecological studies with disregard for socio-economic arguments. A municipal officer considered the fisheries' lobby group was too small to voice their opinions.

In Denmark, fishers reported no involvement in the MPA designation process and a disregard of fisher's input. On the other hand, a Danish environmental NGO was involved in both national and international consultations.

In the Netherlands, fishers were involved in the design process to the point of renegotiation of protected areas. In the Swedish case study, local small-scale fisheries were involved less than the fisher organisations, with a reported loss of generations-long fishing grounds, while failing to see the contribution of closure to the conservation objectives. The national administration acknowledged in hindsight that parallel processes should have been run when it came to designation of the MPA, for setting conservation objectives while considering fisheries regulations. This would have improved legitimacy of the Natura 2000 area.

In the case of Latvia, fishers were not directly involved in the decision-making process since there were no planned fisheries restrictions in any of the Latvian MPAs. The Latvian Fishermen Federation's position was that the MPA should not affect the coastal fishery. Under these circumstances, the involvement, communication and participation during the designation process was deemed sufficient. Fishers are collaborating and providing valuable information for science. Collaboration was good because those involved knew each other from formal and informal discussions.

According to a Swedish public officer, within the Swedish Bratten MPA, neither fisheries nor NGOs were particularly involved in the actual designation of the area, and in hindsight it was deemed better to have parallel processes in the designation of the protected areas, involving all stakeholders. The administration board received harsh criticism from NGOs for not banning fishing in the entire Bratten area (associated with the precautionary principle). As 20% of shrimp landed nationally comes from this protected area, it saw a clear need for a solution to allow fishing but without damaging conservation targets.

4.2.2 Engagement of multiple stakeholders

There is a need for clarity on long-term maritime spatial planning for whole sea basins that span several Member States. The Danish fishers and NGOs report a case-by-case race for space by stakeholders, in which the stakes are high. They agreed that the designation of MPAs is done after space at sea is already appropriated in the maritime spatial plan 'by putting stickers' for other purposes than fisheries or nature, leaving few alternative spaces for the fishers. They also feel that the **establishment of an MPA must consider the local context**. The MPAs of Adler Grund and Rønne Bank (Denmark) are situated along a national EEZ border with connecting MPAs on the German side. Also, situated close by is a Polish MPA, meaning that a large area is protected. Therefore, regulating where there is already low fishing activity is still valid.

A major concern of the fisheries sector is the accumulated effect that all activities at sea have on the available space to fish, and particularly on traditional fishing grounds. This includes impacts from alternative energy parks, shipping lanes and agriculture. The Belgium fisheries sector argued that the energy sector cannot guarantee multi-use in windfarm areas. For conservation purposes, it is important that MPAs are undisturbed (Sweden). Fishers also refer to a level playing field when comparing seabed disturbance for the establishment of wind parks to seabed disturbance by trawlers.

Identifying and measuring all factors that influence the state of the seas is considered complex and continuous. **Fishers consider that there is too much focus on protection of marine areas from fisheries activities, while fisheries cannot be the main reason for environmental problems**.

In the Madeira archipelago, stakeholders other than fishers are less engaged that fishers. Nevertheless, the administration recognises that: *"…all relevant stakeholders directly and indirectly affected should be initially identified and involved in the process at different levels"*. Such stakeholders include scientists, government agencies, professional and recreational fishers, and maritime tourism operators.

In La Graciosa Island, fishers considered that the fishing sector should have priority over other stakeholders in the management of the MPA. One scientist confirmed that some key agents that could have contributed substantially to the designation process were not engaged e.g. research institutes and academia. They also pointed out that other sectors of the marine environment should be more involved, e.g. the tourism sector and recreational fishing. In La Graciosa Island, one regional administration officer considered it essential to include all parties in decision-making. The recreational sector (diving) was involved after regulations on underwater activities were put in place in the late 1990s. In the opinion of this administration officer, marine conservation, diving, recreational fishing, etc. should be involved too. In La Palma, in contrast, national administration officers reported that all relevant parties were included in the designation process.

In the Dundalk Bay case study, a national administration officer stated that "*stakeholder engagement is mandatory for some sectors (governmental and marine agencies), however public consultations only happen after the designation of the area is published*". Further to this, the officer commented that the consultation process is more active in terrestrial conservation, but that there are very few stakeholder groups when it comes to the marine sector. Thus, even if there were willingness to include all stakeholders, only a few are associated with the sector and can partake in the participatory process. One scientist thought that there was consultation at the designation phase and stakeholders were assured that their activities will not be affected. However, these promises only concerned the designation phase and not the implementation, where activities could be affected according to law.

In the Danish case study, a fisheries representative questioned the relative weight given to participating stakeholders and that too much importance had been given to fringe organisations with very little at 'stake'. An environmental NGO emphasised the importance of involving international scientists to ensure independent, impartial scientific advice is used during the designation of MPAs and implementing fisheries regulations.

In both the Danish and Dutch cases, nature conservation stakeholders are of the opinion that fishers' involvement makes conservation outcomes less achievable. This is because of the limitations imposed on the protections put in place, which may heavily favour the interests of fishers. On the other hand, in the Swedish case, the involvement of fishers was considered beneficial for adapting the shapes of protected areas to fisheries practices.

A Belgian policy advisor suggested that the procedure to designate some MPAs should be restarted, with more information on areas to be protected, starting small, and ensuring acceptable consequences for fisheries (i.e. assess local habitat conditions and ensure the conservation objectives of MPAs consider historical fishing rights). In this respect, he commented that in Belgium the fisheries regulations for MPAs were negotiated within the framework of a Marine Spatial Plan. Reaching a Joint Recommendation took several years of negotiation with the countries having fishing measures in Belgium waters. The European Council rejected the Joint Recommendation because of opposition from some European countries, resulting in MPAs without fisheries regulations.

For the Dutch case, a recreational fisheries representative mentioned the **importance of clear rules and transparency for the whole multi-stakeholder process**, believing the process to be undermined by lack of time to study documents and draft documents properly; perceived bilateral discussions for private alternations of texts and the lack of proper agenda setting, e.g. the determination of ecological and legal building blocks prior to negotiations.

Regulation for fishing activity seems to be stringent, while **measures applied to other uses of the seas, such as recreational fisheries, seem much weaker**. Diverse actors feel this is an issue that should be addressed.

The Dundalk Bay case highlighted the need for proper stakeholder representation and proper mandates for the representatives at the table to ensure that agreed actions are implemented. This is important for legitimacy and mutual trust. Not only must communication be enhanced, but also the capacity of the sectors to associate themselves and be properly represented. To back up compliance with agreements made by representatives, self-control models such as eco-labels that provide market-based incentives (e.g. Marine Stewardship Council Fisheries Standard) ([18]) are alternatives to legislation, making the group responsible for individual compliance for third-party certification or licensing.

For (re)starting the MPA process with a clean slate, a Dutch policy officer remarked on the importance that each party needs to really see the usefulness, necessity and urgency of *"picking things up"*. In the Dutch case, the loss of trust (and legitimacy of the process) was seen as a gradual process and associated with increased levels of disagreement between partners.

In several case studies of the North Sea and Baltic Sea, fisheries stakeholders consider that their **historic rights and knowledge of the seas are not respected**. As a Swedish fisher remarked: *"You have to realise that we have been there for 100 years, so we are part of it all. I like to say that there is as much cultural landscape in the Kosterfjord as there is on land. There is no difference. After all, cultural landscapes are something that humans have created over a long period of time"*. The Latvian fishers feel that if no-take areas will be introduced in future, compensations should be based on the loss of fishing grounds, not landings.

In the Danish and Dutch cases, fisheries representatives state that the general perception that the "*sole purpose of fishing is to destroy nature*" means that their input is disregarded. A Swedish stakeholder remarked that fishers' knowledge on changes in the sea and species migration patterns are not taken into account (*"until it is too late, then regulations [are] set up*").

Within the Canary Islands, fishers consider that the livelihood of the small-scale fishing community should be the priority of management and that other uses of the seas should

([18]) The Fisheries Standard measures the sustainability of wild-capture fisheries. The Standard is open to all wild-capture fisheries, including those from the developing world (msc.org).

be regulated equally strictly, or even eradicated from the MPA. Fishers seem to tolerate tourism activities, but **recreational fishing and its management are regarded as a threat**; for example, recreational fishers exceeding their daily catch limits per person. Other non-authorised professional fishers are also regarded as unfair competitors that should be eradicated from the MPA. Large-scale commercial fishers operating in the surrounding areas are also regarded as a threat to the sea bottom. Recreational fishers in turn consider that some prohibitions like spearfishing are not supported by science and request studies to support this type of decision.

In the Dutch case, the importance of diplomacy for guaranteeing a level playing field was mentioned. A Dutch national policy officer remarked that the process of obtaining EU funds for the soft retirement of fishers took six years before the necessity of remediation was sufficiently argued as part of a total package of policy instruments for sustainability, including innovation and MPAs. Speeding up the process will support an efficient stakeholder process. A Dutch environmental NGO pleaded for integration of EU directives with the CFP, as "*the world has evolved, and a shift of values has taken place with nature being considered more important than food provision".* Dutch stakeholders noted the difficulty of harmonising regulations among Member States, leading to sensitivities among fishers, e.g. the weekend fishing restrictions (Uitvoeringsregeling Visserij - Fishing Implementation Rules, articles 22 and 50) on Dutch but not German fishing grounds.

4.2.3 Stakeholders have different world views, different core values

Differences in world views and values became apparent in the case of the Netherlands, where fishers expressed their concern that the decreasing space at sea for fisheries threatens the economic viability of their family enterprises, community life and a minimum income for crew family after retirement. NGOs emphasised changing societal values, causing biodiversity requirements to supersede the need for food provision (Netherlands, Belgium). Latvian fishers in the multi-stakeholder focus group mentioned that coastal fisheries are not a developing and growing industry, and strict fisheries bans may have catastrophic consequences for local communities.

One factor that was not mentioned by stakeholders but observed by the focus group moderator in the Netherlands is language as a social and cultural carrier, influencing communication among stakeholders. In the Dutch case, emotions were expressed in different ways by the different stakeholders (indignation, indifference, bitterness, refusal to participate).

In the Latvian focus group, NGOs recognised that **communication has improved because many historical and ongoing projects have served and are serving as a communication platform for NGOs and other stakeholders**. Latvian fishers observed the absence of extreme conflict during the focus group and recognised that **the ability to live together and communicate is the basis for good cooperation**. Likewise, Belgian stakeholders reported on the advantage of the Belgian approach, where people talk to each other on a regular basis and the understanding among the fishery sector is also growing. They do see a future where stakeholders can have common points of view.

4.2.4 Conflicting interests between stakeholders

When setting conservation objectives, a key message from all case studies is that the impact of all activities at sea need to be considered. The large interests of alternative-energy projects were particularly mentioned as not being considered sufficiently for the (long term) large-scale effect they may have and their potential effects on habitat, fisheries and conservation objectives. The Belgian focus group members asked the EU to remember that wind turbines also have consequence for the environment and especially for the operations of the fishing industry. The wind energy sector has a significant impact on the availability of fishing grounds in addition to restrictions imposed in MPA policy. Both policy targets should be considered together with the food supply needs from sea (fisheries). In the Danish multi-stakeholder focus group, there was a difference of opinion between fishers, who indicated that all pressures should be regulated in MPAs, including all fisheries; and those who stated that multi-use spaces should consider the impact of each activity separately and include an area that is completely protected (i.e. no-take zones). In the same focus group environmental NGOs pointed out that, conservation objectives are applied at a national level to a subset of MPAs, rather than being tailored to each site, which makes these goals rather intangible and measuring site-scale performance very difficult.

In La Graciosa Island there seems to be conflict between commercial fishers and the recreational fisheries sector. The current permissiveness granted to the recreational sector within the reserve is seen as a problem for the control system. In words of one fisher: *"They can obtain permits very easily in contrast with the requirements that professionals must meet".* In turn, discrepancies between fishers for the rights to fish in the MPA derive from the criteria to be part of the authorised census of fishing vessels, i.e. which are authorised to engage in professional activities in the MPA. Fishers consider that the census criteria should be defined further, with priority given to vessels originating from the base port closest to the MPA.

In the Madeira archipelago, interviewees commented that the reduction of fishing areas implies losses of income for fishing communities, often in the short and medium term, because of increased fishing effort and/or reduction in the volume of catches. In the Professor Luiz Saldanha Marine Park, an NGO representative commented that there was a clear benefit to small-scale fisheries because of the larger volume of catches. Nevertheless, the MPA has created conflict between small-scale fisheries sub-sectors that were not monitored and damaged fishers' relations because of the loss of fishing grounds.

In the Professor Luiz Saldanha Marine Park, an integral management plan comprising all conservation objectives and fisheries management objectives has in general yielded positive results in terms of increased catches. This has attracted other fishers from outside the MPA, which historically fished in the surrounding areas. This is a source of conflict that needs to be addressed. However, for this park, shared use of the marine space between stakeholders would occur and be a part of the normal process of management of MPAs. Often, the ocean is deemed the obvious choice for renewable energy production and extraction of minerals, but this competes with fisheries for space. This adds another level to the discussion. Scientists consider that closer interaction with local communities and stakeholders will help solve some of these problems. Scientists also report that there is competition for the fishing areas between the diverse fishing gears within the Professor Luiz Saldanha Marine Park. However, stakeholders deemed the most significant and unfair competition is from illegal fishers, who undermine the benefits for local professional fishers. In the Professor Luiz Saldanha Marine Park, one researcher indicated that conflicts between the fisheries sector and conservationists could have been avoided if all parties had been heard during the designation and/or implementation process. In addition, in La Palma, commercial fishers report unfair competition from poachers and recreational fishers. Some fishers are discontent because of the exclusion of their fishing gears.

Fishers within the Canary Islands consider that much of the surveillance effort focuses on small-scale fishers, with little focus on recreational fishers. This is believed to create an uneven playing field in the MPA. Moreover, as pointed out by professional fishers, the surveillance system should better address the issue of illegal fishing by some recreational fishers and other professional fishers.

In Dundalk Bay, one government officer reported conflicts arising from Northern Irish vessels entering Irish waters. These vessels were participating in the Dundalk Fishery, and Irish fishers were arguing that they should not operate there. The case was resolved by the Supreme Court of Ireland and after a couple of years foreign vessels were excluded from the fishery. Lastly, for fishers within the North Sea and Baltic Sea, coastal small-scale fisheries would likely disappear if fishers had to travel several hours to get to fishing grounds (as a result of reallocation following MPA designation), to the benefit of large-scale fisheries.

In the Bratten case, the negative influence of conflicts of interests on the MPA designation process was highlighted, whenever attempts are made to '*please all interests*'. The focus group noted that conflicts of interest are obvious and co-existence is difficult. From the conservation side it was emphasized that MPAs are undisturbed, i.e. are not in co-existence with wind power or fishery. A further undefined 'stakeholders' organization noted undesired political pressure on individual public administrators by Swedish and Danish fishing organisations. Early involvement of stakeholders and two-way information exchange are seen as fundamental for a successful MPA.

4.2.5 Management plans

In La Graciosa Island, there is no management plan in place to establish specific objectives (e.g. recovery of specific species, socio-economic viability of each artisanal fishing unit). Nonetheless, MPA management is currently geared to the establishment of specific management objectives; for example, to outsource technical work from public research entities that would enable improvement of the quality and completeness of data. Data to be collected include bionomic cartography data, monitoring of species of fishing interest and socio-economic characterisation of fishing. Commercial fishers from La Graciosa Island considered that, as a priority, they should be involved in the MPA decision-making process. Further to this, an NGO in Professor Luiz Saldanha Marine Park considers it essential that fishers are involved in the management of the MPA. A representative group of fishers considered that some areas should be open to fishing of all gears with seasonal closures (e.g. during the recruitment season) and some areas fully closed, depending on the needs of the MPA.

Fishers of the Canary Islands' MPAs regard the lack of communication as the main problem for the management of the MPAs. Scientists are aware of the communication between administration and fishers, which fishers consider to be a source of conflict. **Effective channels of communication that will allow fishers to air their problems and convey advice for decision-making are deemed as urgently needed**. Other parties should also be engaged in a better communication process.

In the Dundalk Bay case, there is also no MPA management plan in place. One officer commented on the difficulties of creating an integral management plan for all activities in the area. Monitoring all activities in one area would be difficult, as these change over time and plans would require constant updating. However, the MPA does have a fishing management plan with fishing restrictions – the preparation of which demanded a large effort from authorities and fishers. Fishers within Dundalk Bay consider that lack of communication is a drawback in the management of the cockle fishery. The government body does not communicate with them directly. In some cases, they have to read the local media to get to know about management decisions affecting the fishery. Government representatives have never shown up in meetings with stakeholders. There is an agency that acts as an intermediary in some cases. Fishers feel that in the event of a new designation, they should be involved from the beginning; this was not the case when the current SAC and SPA were designated. Fishers would be reluctant to adhere to new rules if communication fails.

Swedish and Belgian public officers mentioned that first nature conservation was considered for protected area conservation, only after which fishers were involved to establish fisheries regulations. A Danish representative of a fisheries organization also remarked on not having been involved in the MPA designation process, which was based on the "*perceived knowledge of environmental conditions*", not allowing for fisheries input. The interviewed Belgian public officer remarked that management plans were difficult to adjust for fishers – the main outlines cannot be changed, and adjustments can be made only to "*the corners and edges*" [of the plan]. On the other hand, a Belgian scientist remarked that the proposed fisheries measures were a part of a larger process for the designation of the first Marine Spatial Plan in which the fisheries sector was intensely involved.

4.2.6 Perceived added value of fisheries contribution to nature conservation

In La Graciosa Island, local fishers are in most cases committed to the MPA and, in general, compliant in terms of respecting restrictions. Nonetheless, officers report that in some cases data are not reported completely and accurately, and some fishers hardly accept restrictions. On the other hand, external fishers from other islands are in general not as committed and have vested economic interests only. The restriction of gear, such as pots and trammel nets, seem to have contributed positively to the preservation of habitats in the MPA. According to one scientist: *"I believe that the fishermen have contributed to the success by collaborating with the requirements of the MPA and adapting to the restrictions"*.

In La Palma, the artisanal sector requested the creation of the MPA and accepted the prohibitions on fishing. According to one officer, "*The fishers have been the petitioners of the MPA and, therefore, the success is due to this sector-administration collaboration*". In Dundalk Bay, NGOs considered that fishers contribute to the success or failure of the MPA site. One problem is that fishers were not aware of their site being designated or why they were designated, until a fishery management plan was put in place or licences established. There seems to be good buy-in and acceptance of current and potential restrictions. Fishers know that they have to adhere to the rules and that their efforts will secure their fishing in the future.

Commercial fishers within the North Sea and Baltic Sea felt that fishing should be respected in the protected area, as such activities are vital for food sovereignty: "*we are an asset*" (Sweden). In addition, such fishers felt that the main threats to conservation objectives were from environmental impacts, not anthropogenic ones. For Latvian MPAs, there was high risk because of the development of local oil terminals, as well as invasive round gobies to local species, mainly mussels and the wider food web (e.g. birds feeding on mussels). Latvian fishers stated that there were potential risks of bird bycatch in the coastal fishery – especially from recreational fisheries, because many current fishing gears are made of finer materials that are more difficult for birds to avoid. Representatives of fisheries in Latvia and the Netherlands report a general resentment against spatial bans.

A Danish fisher's representative stated that regulations to reduce fisheries should be less drastic than area closure. More targeted regulations on fishing activities with direct environmental impacts (e.g. ban rock-hopper gear to prevent trawling on reefs, use of pingers and other gear technologies to reduce bycatch) have been supported and implemented by the fishers. It was argued that top-down designed laws or drawing lines on a map will not lead to success in nature protection. He asks for directly involving fishers and relying on the fisher's community consensus to avoid fishing that is detrimental to the environment. Further to this, a Danish fisher considered that creating fisheries regulations that apply only to small, incongruent areas within the greater MPA make them ineffective for protecting anything more than small pockets. These were considered to have very limited value and offer only fragmented protection. In the Swedish case, fishers were acknowledged for their contribution in highlighting several areas with reef habitat that were unknown to other stakeholders.

Co-existence between MPAs and fisheries is considered more likely with more selective and less destructive, low-impact fishing gear (Sweden). In the case of the Netherlands pulse fishing was regarded a viable and less destructive alternative method to the beam trawler. However, the quota system, that is adapted to specific species (e.g. sole, plaice and shrimp) and requires the demersal beam trawl, was seen by the Belgium focus group as a barrier to changing fishing practices (e.g. passive fishing). Previous attempts to switch to passive fishing gears failed because of lack of knowledge and experience of fishers with these techniques. In this respect, in terms of the feasibility of using passive fishing, this should be seen as a potential addition to the current demersal fleet, not a fishing activity that can appropriate such fishing (e.g. within Belgium and the Netherlands). Further barriers included revenue, which was too low to be profitable and finding a crew was a challenge. Fishers consider that a lot of ideas are not realistic. "*You can't just switch fishing gear on command*" (Belgium).

Proponents of utilising lower-impact fishing gears (Denmark) recognised that fishers shifting gear types (i.e. from trawler to gill-netter or vice-versa) is not a viable option. This is because of the capital investment in specialised vessels and deck equipment, the catch efficiencies for various species, and the specialised knowledge that operators of different gears have gained from experience working with these fishing methods over years, and in some cases generations. Small-scale fishers that are excluded from local grounds will likely go out of business, resulting in lower overall effort, rather than a displacement of effort.

4.2.7 Perceived added value of MPAs to conservation objectives

In the Madeira archipelago, an officer commented that the implementation of MPAs in most cases implies restrictions on fishing in 20% to 50% of fishing grounds. These areas are usually either recruitment or spawning grounds for the stocks. In La Graciosa Island, an officer pointed out that it cannot be claimed that expected conservation results are currently achieved. The current objectives are very broad and consist of protection and regeneration of fishing and shellfish resources, preserving the livelihood of the artisanal fishing community. In La Graciosa Island, the perception of fishers is that the resource has decreased, and less income is obtained. Professional fishers considered that recreational fishing and the lack of its licensing management is impeding the meeting of conservation objectives. In La Palma, fishers considered that the main objective was to preserve the livelihood of the fishing community. Fishers perceive that government is giving free rein to other stakeholders. Fishers consider that the government should monitor the current state of the fishing sector and worry more about the problems of professional fishing activity. In Dundalk Bay, a scientist believed that conservation objectives will be achieved because activities are carefully managed within the area.

In the Canary Islands, fishers regard monitoring of the resources to be of key importance for the wellbeing of resources in the MPA and that this may benefit them. They suggest the implementation of adaptive management, so that when resources are in good state new licences should be granted to fishers, or allowances to fish in protected areas. Fishers point out that reporting of monitoring of the state of the resources is not transparent. This puts the decision-making process into question. Scientists report that there is no continuous monitoring of the fishing resources and socio-economic factors. The studies that have been carried out are not available for stakeholders. Scientists propose the creation of a monitoring committee. They also report that the fishing sector seems concerned by the constant demand for information on their activities.

The Dundalk MPA is regarded as a success by commercial fishers and administration because there is a monitoring system in place. A baseline study was conducted when the government decided to establish a management plan for the fishery. Fishers are happy with the level of cooperation with the research body and feel that their traditional ecological knowledge of the area is employed by scientists. They also welcome the opportunity to participate in surveys.

Scientists working with environmental NGOs within the Professor Saldanha Marine Park stated that the EU should have in place policies concerning MPAs requiring evaluation of the implementation, with mechanisms to adapt and change if deemed necessary. The EU should support multidisciplinary teams that can conduct the implementation within an integrated and long-term perspective. Better enforcement is regarded as a need and there should be clear mandates for Member States to implement management, reinforcing enforcement. **Efforts should be devoted to the development of integrated management plans comprising the diverse activities taking place in the MPA, monitoring plans, and enforcement.** Funds and staff are required for this. Funds should also be provided for projects aimed at building better governance in the MPAs, with involvement of all actors concerned.

The fishing industry is not convinced of possible positive effects of closed MPAs on the fish stocks (e.g. spillover). However, fishers are in favour of temporal closure (Belgium, Latvia, Netherlands) and clear information on the specific objectives for designation of MPAs and how closures will contribute to the conservation objectives. The objectives need to take into consideration side effects; for example, fish migration routes through MPAs.

In addition, the environmental NGO's in the Danish focus group emphasised that there is no scientific proof that MPAs will have a positive effect on fish stocks, as so far fisheries has not been included in MPA management plans. Future MPAs could be designated for the purpose of ensuring commercial fish production by protecting areas of spawning aggregations of or areas with small fish. A Latvian NGO mentioned that in impact assessment there are many unknowns, and a Dutch NGO that too little monitoring is done, that neither impact nor the lack of impact can be measured, but that this does not affect the precautionary principle. The Swedish, Dutch and Danish multi stakeholder focus groups argued for inclusion of the precautionary approach in long term management plans, not to prove beneficial effects, which has not been done for MPAs so far, but to avoid potential negative long-term effects, a point that is lost in the work and management plans for MPAs. Strict protection may, even if it takes a long time, lead to spillover of resources and benefits into surrounding areas (Netherlands, Sweden). In the Swedish focus group, the example of Fiji was mentioned, where MPAs aim not only to conserve biodiversity but also small-scale fisheries. The destruction of habitats and species because of the massive development of hydroelectric power with dams in Swedish rivers is considered a mistake that should not be repeated. Development of wind power is also complicated when considered in relation to ongoing commercial fisheries, where knowledge about cumulative effects, and large-scale effects is scarce.

An interviewed Swedish fisher stated that trawling may help counteract eutrophication (oxygen-poor seabed), as trawled areas are always alive. Importantly, they also stated that there is no evidence that the closure of an area will result in more fish stock, giving the example of an area within Oslofjorden that after years of closure was opened and found *'dead, with no life at all'*. According to the fisher, it took some years of pulling the seabed with chains before the shrimp returned. Rather, fishers stated that MPAs are more likely to meet conservation objectives from the habitat perspective because the regulations ensure protection from direct impact on bottom habitats by prohibiting other marine activities such as dredging and sand extraction.

In the Danish case, NGOs stated that although a range of MPAs within the region were large, the level of no-take (or at least restrictions to trawl fishing) applies only to up to half of the designated area. In addition, such stakeholders also specified that there may be a border effect of fisheries on the outside of the MPA that have an impact across the border into the MPA and on larger fishes that move across the MPA border (or have a home range larger than the borders of the MPA). Furthermore, other conservation objectives should have been included in MPA designation, referring to species outside of those specified in regulations (e.g. not in the Habitats Directive). Such species included Haploops, deep eelgrass, kelp forests and fishes. In this respect, the NGOs stated the need to understand the full biodiversity of marine communities, and then protect that, rather than only those things that are externally specified. Extend protections to "*potential distribution of species*" not just current realised distribution (to improve conditions, not just maintain).

4.2.8 Perceived added value of MPAs to fisheries

Establishing MPAs may lead to an increase in biomass inside the protected area, which could induce a net transfer into the adjacent fishing areas (spillover effect), thereby increasing catch in the surrounding fishing grounds (Di Lorenzo et al., 2016, 2020; Van Hoey et al., 2024). This sub-section presents the views of stakeholders on whether the EU MPAs are adding value to fisheries. Findings show that **stakeholders have different perspectives regarding the added value of MPAs to fisheries**.

Within the Professor Luiz Saldanha Marine Park, no-take zones have enabled the increase of biomass of some commercial fish species, larger landings inside the MPA, and the protection of biodiversity from fishing. Nonetheless, the activities of some small-scale fishers have been impaired by the management decisions. However, some fishers operating outside the no-take zones and partially protected areas have instead benefited from the MPA.

One researcher linked with the Madeira archipelago case study commented that MPAs are supposed to create refuge and nursery habitats for commercially important species that have a positive impact on areas outside the MPA (through spillover). Scientists in the Professor Luiz Saldanha Marine Park commented that there has been an evolution in fish auction landings, which are now higher than when the MPA was created. Results of research have confirmed this positive trend. In La Graciosa Island, the perception of the professional fishing and tourism (diving) sector is that, although there are areas that have not recovered, there is a significant improvement in certain areas of the MPA. In La Graciosa Island, a scientist reported slightly positive results concerning fishing production but considered that the potential of this MPA is far from working properly. This is due mainly because the dimensions of the MPA cannot sustain the remainder of the protected marine space. In Dundalk Bay, administration officers informed that commercial fishing activities are heavily regulated since there are goals and conservation measures. Thus, it is expected that conservation measures will be achieved.

Within the Canary Islands, the administration considers that the state of fishing resources has improved since the creation of the MPAs. Scientists agree with this but only for one of the two MPAs (La Palma Island). Within Dundalk Bay, fishers believe that the fisheries are managed sustainably and believe that the management approach should be replicated in other inshore areas as this could benefit both the ecosystem and the fisheries. In 2008, the stock status of cockle seemed low, and the fishery was temporarily closed for a couple of years, which was a measure that the fishers accepted, knowing that stocks would recover for the next fishing season.

Most interviewed fishers within the North Sea and Baltic Sea feel that EU MPAs are not currently a useful tool for fisheries, with those currently restricting fisheries for the purpose of conserving other species often not fit for purpose. In this respect, Danish fishers remarked that MPAs should also consider conserving/increasing productivity of fisheries species, especially specific life-history stages. MPAs should be more flexible to ensure that they are protecting what they were established for (e.g. real-time closures or periodic review of MPAs against conservation effects). On the other hand, Latvian and Dutch fishers relate to MPAs as benefiting Marine Stewardship Council (MSC) accreditation.

4.2.9 Increasing political pressure with decreasing space at sea

Diminishing maritime spatial areas cause spatial squeeze, and fishing areas become increasingly more restricted, the political pressure on the MPA designation and implementation process increases. Further, the socio-cultural, economic and ecological interests also start to conflict, e.g. perceived priority given to alternative energy projects. In the quest for space at sea, small-scale fishers feel that there is unequal playing field when coastal areas are closed. Several MPA cases within the North Sea and Baltic Sea highlighted the negative influence of conflicts of interests on the MPA designation process, whenever attempts are made to '*please all interests*'.

Referring to the Skagerrak, the Swedish fisheries focus group warned that wherever protected areas for offshore wind farms overlap with important areas for shrimp and Norway lobster fisheries, these fishing grounds are threatened. Subsequently, closing all MPAs in Sweden for bottom trawling, would force Swedish fishers to seek new fishing grounds in Danish and Norwegian waters.

The role of diplomacy was mentioned by the Dutch national policy officer regarding the process of obtaining EU funds for the soft retirement of fishers, a process that took six years before the necessity of remediation was sufficiently argued as part of a total package of policy instruments for sustainability, including innovation and MPAs. Speeding up the process will support an efficient stakeholder process.

Belgian and Dutch fishers feel that they should be trusted more as guardians of the sea. It was observed that such trust would not negate the need for area closure as marine ecosystems encompass more than the commercial fish stocks; so that, in addition to seasonal closure, permanent closure is needed to prevent seabed turbulence.

5 INTEGRATING FISHERIES INTO EU MPA MANAGEMENT

Key highlights

- MPAs in EU waters are largely not designed for fisheries management and still have a long way to go to support sustainable fishing. Some spatio-temporal restrictions have been implemented mainly to ensure the conservation of seabirds, marine mammals and the seabed.
- The marine area in which there is complete cessation of historical fishing activities (through the implementation of full no-take restrictions) is small compared to the multitude of fishing activities that are allowed within the majority of MPAs.
- The initial stages of MPA designation and implementation can be very challenging and can be exacerbated by low participation from local and regional fishery stakeholders.
- High stakeholder engagement and representation of fisheries stakeholders in MPA boards are likely to lead to MPA success. If fisheries stakeholders understand why conservation objectives have been set, they are more likely to comply with them and adapt their fishery activities.
- Further development of EU MPAs as fisheries management tools (either utilising current MPAs or designating new areas in the future) will need to further understand and consider the wider impacts of fishing activities on marine communities.
- Overcoming the limitations of existing MPAs to address fisheries challenges must entail the designation of MPAs with management plans that are categorically built around conservation objectives that lead to fisheries sustainability.

Data obtained through the development of the MAPAFISH database containing a total of 819 MPAs, and supporting analyses with a literature review and stakeholder engagement was used to: (i) provide a detailed characterisation of the existing EU MPAs; (ii) determine and describe the fishing activities present within MPAs and their surrounding areas; and (iii) understand the response of the fishing activities to MPA designation and implementation. In this context, the **main objective of this section is to summarize the key features of MPAs, the fishing activities and associated measures, the challenges and opportunities and the general lessons learnt** derived from the previous sections.

Such information is vital to support ongoing and establishment of future fisheries management measures, while also supporting the assessment and potential adjustment of MPA management plans. Such work addresses the interface between fisheries management and biodiversity conservation, provides support for MPAs with multiple objectives and improves integration of fisheries in MPA management and therefore contributes to the long-term sustainability of biological resources within EU waters.

5.1 The key features of EU MPAs: How to determine possible success?

To examine the factors that may lead to 'success' of EU MPAs (i.e. leading to successful biodiversity conservation and fisheries benefits), we focused on the following key features: (i) their level of protection; (ii) the identified level of enforcement within the MPA; (iii) the age of the MPA; (iv) the size of the MPA; (v) the degree of MPA isolation; (vi) the level of stakeholder engagement within the management of the MPA; (vii) fishers' representatives in any identified MPA board; and (viii) the level of promotion of sustainable fishing undertaken within the MPA. Indeed, previous studies have shown that the success of MPAs in reaching conservation benefits increases exponentially with the accumulation of these key features (Edgar et al., 2014; Halpern, 2014; Di Franco et al., 2016).

Due to the wide variation in MPAs, the results have been unable to define a set of 'common' features to explain the success of an MPA, and therefore no description of how an 'average' MPA is structured in the EU has been provided. Such variation results from different strategies in implementing MPAs across the EU Member States, as well as differences in local policies and history of MPA planning and implementation. Some features such as age and enforcement) seem to correlate better with a higher degree of protection (i.e. success of the MPA), than other features such as size, stakeholder engagement, isolation, and the promotion of sustainable fishing.

This work confirmed that high stakeholder engagement and representation of fisheries stakeholders in MPA boards are likely to lead to success of MPAs. For example, an increase in stakeholder consultation was recorded when management measures were implemented compared to when the MPA was first designated. In addition, across the EU, the level of enforcement coincides with the level of protection, resulting in a positive relationship between these two factors (see Table 6). In contrast to other studies (Di Franco et al., 2016), promotion of sustainable fishing in MPAs seems not to have an influence on MPA success. Overall, this study gives a first insight into the possible role of several key features in MPA success in the EU. However, due to the quality of information available (MAPAFISH database contains missing or unknown values) more detailed analyses at Member State and regional/sea basin levels could be useful.

On the other hand, our results on the general characterisation show that **MPAs in EU waters, which were largely not designed for fisheries management, still have a long way to go to support sustainable fishing.** Undoubtedly, many MPAs have been designed and implemented across the EU, and the number continues to grow. However, the number of MPAs in which fishery restrictions have been implemented is substantially lagging behind the total number of MPAs (see Figure 20). In this respect, within the majority of EU MPAs, restrictions are mainly built as spatio-temporal measures. Further to this, the majority (59%) of EU MPAs are classified under IUCN as 'habitat/species management areas. A small number are designated as protected landscapes/seascapes or as managed resource protected areas. It is clear that the majority of MPAs are not employed as fisheries management tools. This results in MPAs that have been designated as areas of protection for habitats and/or seabirds, but with little impetus on fisheries (either artisanal or commercial), the marine communities associated with fishing activities or the long-term sustainability of fisheries within the EU.

In EU MPAs, **restrictions have been implemented mainly to ensure the conservation of seabirds, marine mammals and the seabed (substrate and benthos), with lower focus on fishery management.** This is despite fisheries potentially impacting a substantial range of vital ecosystem components, including physical habitats (e.g. through the actions of trawling and dredging) as well as the diversity, abundance and long-term population structure of benthic and fish communities. The lack of MPA designation and (in)compatibility of MPA management plans with the activities of fishing may then reduce the likelihood that the stated conservation objectives of an MPA are met.

For almost all MPAs investigated (89%) conservation objectives have been defined, though there is little evidence to show that conservation objectives are met, with lack of evidence for nearly 85% of MPAs. In addition, seabirds are the primary ecosystem component highlighted in MPA conservation objectives, while marine mammals and physical habitats are also important relative to the conservation objectives. Where habitats have been listed in conservation objectives, these are focused mainly on open seas and tidal areas, or on coastal habitats (e.g. beaches, cliffs and wetlands). **Only 21% of MPAs have fishes (teleost and/or cartilaginous) listed within their conservation objectives.** Furthermore, the list of sensitive species (prioritised in the EU marine Action Plan) (Table 4) is poorly recorded in the conservation objectives of the Natura 2000 MPAs.

Overall, **52% of EU MPAs are considered actively managed** (i.e. MPA management ongoing, including monitoring, periodic review and adjustments made as needed to achieve conservation goals), while 15% are in the process of being implemented, and 30% are in the designation stage. Management of MPAs is most likely by public administration, though nearly half of MPAs do not have an MPA board. The majority of MPAs investigated within this study are governmental led, with stakeholder involvement as an important tool in their management. At designation, stakeholders have been involved in 64% of the cases – with just under half of MPAs having a stakeholder involvement that encapsulates any stakeholder (i.e. public), whereas a small percentage utilise targeted specific stakeholders. In terms of fisheries, it seems that for the majority of EU MPAs, fishery activities are not investigated during the planning phase. However, in MPAs where fisheries data have been used, this has been carried out after MPA designation. In terms of the type of fishery data used, this is largely based on VMS effort data and stakeholder consultation and includes the MPA and adjacent waters, implying that fishery activities are considered within the EEZ of the Member State or sub-region within the EEZ where the MPA is located.

Nearly 40% of the investigated MPAs are uniform multiple-use (i.e. no zoning) to ensure multiple users are able to undertake one type of activity within the MPA (e.g. net fishing), while just over 30% of MPAs are zoned as multiple use. This means that some extractive activities are allowed throughout the entire site, but that marine zoning restricts the uses in time or space in order to reduce user conflicts and adverse impacts. In addition, within the MPAs, some level of commercial exploitation of fisheries is listed, including fishing with nets (gillnets and fyke nets), pots (fish or shrimp pots) and hook and line (including longlining), trawling (demersal and pelagic otter trawl), seines and dredges. In managing such extraction, although both input and output controls are apparent within EU MPAs, 27% of fisheries restrictions are associated with spatial restrictions. There are less likely to be output restrictions, such as daily bag limits and effort restrictions. **Around 50% of investigated EU MPAs have no fisheries restrictions in place**, which is in line with Roessger et al. (2022), indicating that only 0.03% of the OSPAR MPA network is covered with full or high protection levels and 60% of MPAs are unprotected.

EU MPAs have a range of fishery restrictions, but almost none are entirely no-take/no-access. In fact, of the 819 MPAs investigated within this study only five (less than 1%) MPAs were considered as complete no-take/no-access areas; and in 4% of MPAs, there is zoned multiple-use with no-take areas. Such zoning (e.g. no-take), whereby MPAs have varied levels of restrictions imposed, is needed to support the EU Biodiversity Strategy and its key commitments by 2030 for the legal protection and effective management of at least 30% of the EU's marine waters, one third of which (10% of marine waters) must be under strict protection (EC, 2020).

5.2 The fishing activities and associated measures in EU MPAs

This work, based on VMS data analysis, has found that **fishing pressure inside EU MPAs is not substantial, with nearly 64% of MPAs across EU waters not fished by large-scale commercial vessels**. In many of the MPAs without fishing, there was also no reported fishing in the surroundings areas (68.9%), whereas almost all fished MPA sites also recorded fishing activity in their direct surroundings (99.3%). Indeed, 73.8% of MPAs are "low-risk" when it comes to fishing, but of the 26.2% of MPAs that are high-risk, fishing covers 86% of the MPA area, and is more prevalent in larger, offshore sites (Perry et al., 2022). While this implies that MPAs within the EU are relatively robust with respect to commercial fishing activities, the results might be associated with the lack of VMS data for a large array of the MPAs than overall lack of fishing activities within MPAs (although some countries such as Denmark and Sweden reported activities from both VMS and AIS-based methods, effectively showing a portion of the smaller fleet). A number of Member States' fisheries employ small-scale or recreational fishing vessels, the vast majority of which are not obliged to utilise VMS. Also, a lot of the MPAs are coastal, where large-scale vessels are less active.

Where this study was able to quantitatively map commercial fishing activities within MPAs in detail (i.e. commercial activities of all active fishing fleets reported through VMS), this work found that **much of the fishing effort is higher outside than inside MPAs (except in the Greater North Sea).** This pattern of lower fishing inside than outside MPAs was apparent when standardising such fishing activities to the area of the MPA – median fishing effort was lower within MPAs relative to their direct surroundings. Such patterns indicate that there are restrictions in the range of fishing types within several MPAs (e.g. spatio-temporal restrictions). For example, within the majority of MPAs, where fishing is allowed, restrictions are overly based on input controls (i.e. the diversity of permitted fishing gears) instead of output controls associated with the size and breadth of the catch. This resulted in gears that were likely to substantially impact the conservation objectives to be restricted (i.e. nets, dredges, benthic trawls), whereas adjacent and away from the majority of MPAs, such gear restrictions were not in place.

There are regional differences in the presence or absence of fishing in EU MPAs. Within MPAs centred on the Bay of Biscay, Iberian Coast and the Greater North Sea, the analysis of VMS data showed that fishing is much more likely to be allowed. In comparison, MPA sites in the Baltic Sea and Celtic Sea were generally less subjected to fishing activities. Such differences in the likelihood of fishing activities between MPA sites is likely to be due to differences in how MPAs are viewed and utilised as fishery-restriction measures. However, such differences in fishing pressure may also be associated with the size and setting of the MPA (i.e. large versus small, coastal versus offshore) as well as the predominant fishing activities undertaken within the Member State. For example, within the Celtic Sea, MPAs are coastal and relatively small in size. This is a juxtaposition to the main fishing activities within the region, with a predominance of large-scale pelagic longline or purse seine and deepwater benthic trawls. In such instances, these fishing activities are unlikely to overlap with the majority of MPAs within the region.

Further to the regional differences in the level of fishing in MPAs, geographic differences in the predominant type of fishing activity undertaken will differentially impact the level of fishing in MPAs. For example, there was a dominance of bottom-towed gears in the North Sea, while pelagic and passive gears dominate throughout most other regions. In this respect, the exclusion of large-scale fisheries operating in MPAs occurs in some regions (e.g. Macaronesia; except for the large-scale tuna fishery (longline based)). In several regions throughout the EU, fishing activities are based on much more small-scale metiers (e.g. pots, nets, handline). For such fisheries, there are far fewer wide-spread restrictions within MPAs.

There were several metiers that showed little impact on ecosystem components within MPAs and can be thought of as being relatively compatible with MPA implementation. Such low levels of impact are likely associated with the fishing gear not impacting the range of habitats and associated communities within MPAs (pelagic fishing) or may also be due to the gear having already been banned within the MPA and therefore having no reported impact on the specific MPA. In this respect, for several regions, a range of fishing gears have inherently been restricted. For example, even without MPA protection, within the Madeira archipelago there are a range of gear restrictions that have been implemented on fishing activities greater than 200 metres depth to protect deepwater coral reefs (Regulation (EC) No 1811/2004 ([19]); Council Regulation (EC) No 1568/2005 ([20])). Such restrictions have been enacted to

([19]) *OJ L 319, 20.10.2004, p. 1–2*

([20]) *OJ L 252, 28.9.2005, p. 2–3*

preserve deepwater habitats and may be expected to reduce any overall fishing impacts on such habitats.

There was no substantial pattern to show that MPAs reduced the range of habitats available for fisheries across the EU. However, there were regional differences in the extent of habitats covered within MPAs. For the dominant habitat classes in MPA sites, within the Greater North Sea and Bay of Biscay and Iberian Coast these have a large part (greater than 89%) of their spatial extent located within fished MPA sites, whereas the dominant habitat classes in the Baltic Sea and Celtic Seas have a smaller fraction located in fished sites. However, this work was only able to find one example where a larger fraction of a dominant habitat class is found more outside than inside an MPA sites (i.e. Celtic Sea), which may indicate that fishing activities within this habitat could be hampered by the MPA site.

5.3 Designation and implementation of MPAs: challenges and opportunities

This work has shown that in the majority of MPAs investigated, there was no indication that MPA designation and implementation led to changes in fishing behaviour. However, reallocation of fisheries can occur following the implementation of specific fisheries restrictions in MPAs (spatio-temporal). Though reallocation may occur differently dependent on the historical fishing effort and the available habitat surrounding the designated area. For areas in which coastal habitats are available, fishing effort is likely to move away from MPA-designated areas into these adjacent coastal habitats. Such reallocation may mean that the type of fishing activity historically undertaken is not substantially reduced, with the majority of effort moved along the coastline. However, where adjacent habitats are dissimilar to those historically fished, then the types of fishing activity may change. For example, the abandonment of fishing activities undertaken in relatively shallow coastal waters (e.g. small-scale netting, potting) to activities that are more likely associated with pelagic habitats (trawling, longline, purse seine). Such changes in fishing may mean fishers switching gear types, the depth and distance from shore, as well as the length of time at sea.

Successful reallocation of fishers following MPA designation and implementation is likely associated with the small spatial extent of MPAs, as well as the low number of fishing activities that are substantially restricted within EU MPAs. In this respect, **the total marine area within the EU in which there is complete cessation of historical fishing activities (i.e. through the implementation of full no-take restrictions) is small compared to the multitude of fishing activities that are allowed within the majority of MPAs within the EU**. In addition, there are very few MPAs that cover a very large footprint (e.g. 100s of kilometres), and therefore little likelihood that EU fishers have to move substantial distances from historical fishing grounds following the establishment of no-take MPAs. Such small total restriction and the small spatial footprint of the majority of EU MPAs then reduces the likely negative effects of designation and implementation on historical fishing activities. Based on the interviews and focus groups, fishers expressed concern about losing substantial fishing grounds because of MPA restrictions, but this was largely because of very rapid developments in offshore windfarms, where, in the majority of the cases, fishing is not allowed.

The limitations of existing MPAs in the EU to solve fisheries problems are due to MPAs not being implemented to positively impact fishing communities (by sustaining and enhancing suitable fisheries resources). There are few EU MPAs designed or managed to directly help to meet the challenges fisheries are facing. Despite this, the vast array of MPA designation is associated with specific habitats, of which some of these will form important shelter or food for a range of important commercial fisheries species. This study did not show evidence that reallocation of MPAs can cause fishers to have a substantial loss of revenue or a collapse of fishing communities (e.g.

within the Professor Luiz Saldanha Marine Park). Such lack of proof and/or data may be more associated with the lack of regular monitoring of the impact of MPAs on fishing and fisheries resources. However, this may also be due to the low spatial footprint and high number of fishing activities able to be undertaken within EU MPAs.

Across the EU, for the majority of MPAs, the degree of stakeholder buy-in and support for MPA designation and implementation is likely determined by the degree of stakeholder inclusion in consultation at the start of MPA development (i.e. planning and designation). In this respect, based on the interviews and focus groups, we learnt that **if stakeholders understand why conservation objectives have been written, they are more likely to comply and support such conservation objectives and adapt their fishery activities.** Where stakeholders have not been part of the process of designation, implementation and management, levels of distrust or misunderstanding increase and may lead to low compliance and little support for future MPA designation.

A conceptual model was developed to better understand some of the effects of MPAs on the reallocation of fishing activities. Based on several potential social, economic and ecological impacts of the effort reallocation, the model allows users to define an input scenario which then identifies the types of potential outcomes associated with the proposed MPA and fishery measures taken. For example, the model showed that **costs and revenue consistently emerge as prominent indicators when an area is closed to fishing – both of which need to be balanced against the conservation outcomes of the MPAs.** The tool developed in this study, allows users to evaluate this balance and can guide MPA managers in their MPA management.

Wider participation, comprising other sectors in the planning, designation and implementation of MPAs may minimise potential conflicts. As stakes are high, the designation process benefits from clear rules, regular interactions to promote mutual understanding of stakeholders' core values and world views, as well as to create a shared sense of urgency. To strengthen commitment and safeguard legitimacy of the MPA (process), interactions should not be limited to the negotiation table but should involve a wide range of stakeholders. Fishers requested regular two-way exchange of information between fishers and public authorities and scientists respectively. In this respect, there is a plea within the EU for further long-term MPA planning that is focused on the whole sea basin. Such planning must consider accumulated impact assessments involving all sectors with activities at sea. Such future proofing of management plans for the EU may then avoid future conflict and reduce politicisation of the planning, designation, implementation and management of MPAs. The MSP process could be a platform to facilitate this further to bring balance between fishery (food supply), wind farms (energy supply) and conservation at both EU and regional levels, and MPA management could be incorporated. Timely and transparent communication and the involvement of all actors from the very start is key to the success of an MPA, as it may contribute to more legitimacy and stewardship with conservation objectives (Mosley and Wong, 2021).

5.4 Lessons learnt and recommendations

The MAPAFISH study has provided a vast improvement to the baseline information available on the status of MPAs in the EU and the fishing activities within and surrounding them. It has notably underlined key areas in which improvements can be made. This subsection provides an integrative approach which presents the key lessons learnt and recommendations that stem from the findings of this study to foster the beneficial role of MPAs as fisheries management tools.

(i) **Ensure there is better understanding and consideration of the wider impacts (both socio-economic and environmental) of no-take MPAs and fishing activities on marine ecosystems.** There is a need for further development of MPAs as fisheries management tools (either utilising current MPAs or designating new areas in the future). In this respect, no-take marine areas are one possible mechanism of reducing impacts or taking impacts away from marine ecosystems. However, the use of such restrictions must also be balanced against the socio-economic impact of no-take areas to local and regional fishing communities. This may involve ensuring areas surrounding the no-take areas are able to be fished, or at least there is an understanding of the potential output from the no-take area (e.g. spillover), which is able to be utilised by fishing activities.

(ii) **Improve research and monitoring to further understand the range of fishing activities undertaken in EU MPAs.** This work has shown that for the most part, MPAs in the EU are not fished by large-scale commercial vessels. However, this may be due in part to the type of data available to assess fishing in the MPAs – with a predominance of VMS data. This will exclude fishing activities that are small scale, coastal or undertaken by fishers that are not obliged to utilise VMS (i.e. recreational). There is a need to improve research and monitoring of fishing activities within and surrounding MPAs in the EU including enhanced data collection and establishment of long-term monitoring programmes to generate evidence and inform management decisions.

(iii) **Integrate key stakeholders further into the planning and management process around activities that operate in MPAs.** Across the EU, the initial stages of MPA designation and implementation can be very challenging and can be exacerbated by low participation from local and regional stakeholders (e.g. fishers). Such issues are likely to be less substantial if the social impacts of MPA implementation are well managed. The lack of buy-in is more likely associated with a governance structure in MPA management that is still considered top-down and where public consultation confers limited participation, decision power and knowledge recognition to local stakeholders. There is need to enhance decision making and complement it with stakeholder knowledge, to further improve sustainable use of marine resources and increase buy-in in MPAs.

(iv) **Ensure socio-cultural and economic sustainability of the fisheries sector is included as one of the MPA conservation objectives.** Findings from this study show that fishers are in favour of, and willing to promote MPAs as long as the socio-cultural and economic sustainability of the fisheries sector is one of the MPA objectives. Considering that other stakeholder groups (e.g. nature conservation), are advocating more fisheries restrictions in MPAs, buy-in from fishers is needed for MPAs to work. In this respect, the legitimacy of MPAs for the fishing sector increases in cases where there are no fisheries restrictions; when closures are temporal; conservation objectives are specified, and fisheries restrictions are gear-specific and substantiated.

(v) **Develop further the MAPAFISH database into a more accessible and reproducible repository of data and information.** The database, developed within this study, could support the wider research community to facilitate further independent research on EU MPAs. The MAPAFISH database provides a repository of information for 819 MPAs across the EU and a tool to guide MPA management at different levels (MPA stakeholders, MPA managers and the policy level, i.e. country, region, EU), supporting further evaluation of MPAs, and acts as a benchmark to understand how best to structure MPAs in the future. The database will become more vital in the EU, as the diversity of protected areas (and therefore the factors that structure them) increases. For example, there has been a rapid increase in the number and size of windfarms being designated and implemented throughout the EU, potentially being considered as Other Effective Area-based Conservation Measures. These newly built structures, the habitats they create and the potential for reductions in fishing throughout their footprint result in such farms providing conservation or fishery objectives and are therefore becoming one of the management tools within the EU (ICES, 2021). This rapid development of windfarms could entail substantial implications for EU fisheries and future EU food provision, due to increasing loss of fishery grounds amid uncertainty in the fisheries benefits associated with contemporary MPAs.

(vi) **Use buffer areas surrounding no-take MPAs to permit local small-scale fishers undertake fishing activities, while also allowing areas within their remit to have reduced fishing pressure.** The existence of ‘buffer’ areas surrounding areas restricted to fishing can be vital in enhancing fishers’ compliance with MPAs, as illustrated in some case studies (Macaronesia in particular). Within these cases, fishing activities are undertaken near to ‘home’ ports with fisheries targeting small reef fish, reef invertebrates and small pelagic species. In these areas, only small-scale or artisanal fisheries are allowed, mainly associated with historical fishing activity.

(vii) **Establish MPAs with management plans that are categorically built around conservation objectives that lead to fisheries sustainability**. This could overcome the limitations of existing MPAs in the EU to address fisheries challenges. Such mechanisms to ensure fisheries sustainability can include full restrictions to fishing activities, but also the enhancement of ecological factors that may lead to high success of fished populations (e.g. conservation of key habitats, key food resources and key areas of reproduction). In particular, the key element is understanding that properly developed MPAs (and networks of MPAs) can change population sustainability, fishery yield and ecosystem properties. However, ensuring such output will depend on managers understanding three critical forms of connectivity over space: larval dispersal, juvenile and adult swimming, and fishers’ movement (Van Hoey et al., 2024). Within the EU, furthering the understanding of all three main forms of connectivity will ensure MPA designation is developed around spatially oriented sustainability measures, and therefore utilised as effective fisheries management tools.

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ANNEX 1: COLLECTION OF DATA AND INFORMATION ON MPA FEATURES

A data input template has been developed in Excel by exploring the existing information in the Natura 2000 and CDDA databases, completed with questions related to eight key features that are largely known to determine 'success' of MPAs for both biodiversity conservation and fisheries goals ([21]).

Within the template, we have asked for extra information on 79 features which has to be gathered to complete the goals of the study (Table 12). Most of the extra information was not available in the original databases or in the right format. The information has been divided into different themes (General information on MPA (e.g. protection level), fisheries data, commercial and recreational fishing activities, fisheries restrictions, level of enforcement, types of management, stakeholder engagement during designation and during process of management measures, MPA board, conservation measures, environmental components). The template has been split up into Natura 2000 areas, CDDA areas (where we excluded the MPAs that were already in the Natura 2000 table) and additional MPAs (MPAs added by experts as relevant, but not yet listed in Natura 2000 or CDDA databases).

The data collection process has been executed using a stepwise approach, where first the template was tested and adapted for three MPAs for some Member States (e.g. Ireland, Belgium, Netherlands, Sweden, Spain), before it was used for final input. After this test step, the template was distributed to all EU Member States to be filled in for all selected MPAs under investigation (n = 819). While completing the template, there was close contact between the MAPAFISH consortia and the Member State experts to look at interpretations and problems together. Once the template was completed per Member State, the input information was quality checked. This quality check focused on completeness, clarity and consistency with other Member State input. If needed, additional information or clarifications were asked. For compiling the required information for all MPAs, several pathways were followed, summarized as follows:

- The Member States with partners in the study (Sweden, Latvia, Poland, Denmark, the Netherlands, Belgium, France, Ireland, Spain, Portugal): The partner institute filled in the required information based on their knowledge or from their network within the Member States.

- The Member States without partners in the study:
    - External contract was regulated with local partner (Finland, Estonia)
    - Scientists from Member State contributed voluntary (Germany)
    - Information was collected, based on some correspondence with local expert contact (Lithuania)

After the quality check, the files were coupled with the MPA databases (Natura 2000 and CCDA) to execute analyses. To structure the data and information gathered and collected within the study, **a database was created (the 'MAPAFISH database')**, compiling the different types of data and information.

([21]) These are: (i) whether MPAs possess a fully protected area; (ii) the level of enforcement; (iii) MPA age; (iv) MPA size and when feasible; (v) degree of MPA isolation; (vi) stakeholders' engagement, (vii) fisher's representative in the MPA board; and (viii) promotion of sustainable fishing (see more details in Edgar et al. (2014) and Di Franco et al. (2016)). The collected information should help to determine the level of protection within those MPAs. As in the review of Grorud-Colvert et al. (2021) is done and also propose a framework by which levels of protection can be evaluated and improved.

Table 12. Overview of information collected for the MPAs under study, with indication of the definitions of the fields.

	Question	Data needs	Description
1	General	SITECODE COUNTRY SITENAME	
2	Site type	A=SPA, B=pSCI,SCI or SAC, C=both pSCI/SCI/SAC AND SPA (If they partly overlap, two forms are filled in)	
	General information on the MPAs		
3	Relevant within this study?	Yes	
		No	MPAs can be excluded using the following criteria: double occurrence (e.g. same area but slight different MPA names between the databases); limited fisheries activities inside the areas (if data are already available); very small areas (e.g. surface area < 5 km²); "old" areas for which no fisheries knowledge is known or fisheries data is available to study effects of the MPA; terrestrial areas; areas in estuarine waters as fisheries data is not available at the required spatio-temporal resolution; areas out of the geographical scope; or where no catalogue information was available
4	What type of MPA? (IUCN)	Category I - Strict Nature Reserve/Wilderness Area	Protected area managed mainly for science or wilderness protection. Strict Marine Reserve: Protected areas that are strictly set aside to protect biodiversity and also possibly geological/geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring. Wilderness area: Protected areas that are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.
		Category II - National Park	Protected area managed mainly for ecosystem protection and recreation. Large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.
		Category III - Natural Monument	Protected area managed mainly for conservation of specific natural features. Protected areas set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature

	Question	Data needs	Description
			such as an ancient grove. They are generally quite small protected areas and often have high visitor value.
		Category IV - Habitat/Species Management Area	Protected area managed mainly for conservation through management intervention. Protected areas aiming to protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.
		Category V - Protected Landscape/Seascape	Protected area managed mainly for landscape/seascape conservation and recreation. A protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.
		Category VI - Managed Resource Protected Area	Protected area managed mainly for the sustainable use of natural ecosystems. Protected areas that conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.
5	Level of protection? (IUCN)	No protection measures (yet)	
		Uniform Multiple-use	MPAs or zones with a consistent level of protection, allowable activities or restrictions throughout the protected area. Extractive uses may be restricted for natural or cultural resources.
		Zoned Multiple-Use	MPAs that allow some extractive activities throughout the entire site, but that use marine zoning to allocate specific uses to compatible places or times in order to reduce user conflicts and adverse impacts
		Zone Multiple-Use With No-Take Area(s)	Multiple-use MPAs that contain at least one legally established management zone in which all resource extraction is prohibited.
		No-Take	MPAs or zones that allow human access and even some potentially harmful uses, but that totally prohibit the extraction or significant destruction of natural and cultural resources.
		No Impact	MPAs or zones that allow human access, but that prohibit all activities that could harm the site’s resources or disrupt the ecological and cultural services they provide. Examples of activities typically prohibited in no-impact MPAs include resource

	Question	Data needs	Description
			extraction of any kind (fishing, collecting, or mining); discharge of pollutants; disposal or installation of materials; and alteration or disturbance of submerged cultural resources, biological assemblages, ecological interactions, physiochemical environmental features, protected habitats, or the natural processes that support them.
		No Access	MPAs or zones that restrict all human access to the area in order to prevent potential ecological disturbance, unless specifically permitted for designated special uses such as research, monitoring or restoration.
6	Stage of establishment (Grorud-Colvert)	Stage Proposed/Committed	At this stage, the intent to create an MPA is made public. An MPA must be announced in some formal (although non-binding) manner by means of a statement by the government, community, conservation etc. (From the MPA Guide, Grorud-Colvert et al., 2021).
		Stage Designated	The MPA is established or recognized through legal means or other authoritative rulemaking. A designated MPA must have defined boundaries, legal gazetting or equivalent Indigenous or traditional authorization or customary recognition and clearly stated goals and process to define allowed uses and associated regulations or rules to control impact. (From the MPA Guide, Grorud-Colvert et al., 2021).
		Stage Implemented	The MPA has transitioned from existence on paper to being operational in the water with management plans activated. Biodiversity conservation benefits begin to accrue at this stage, not before. (From the MPA Guide, Grorud-Colvert et al., 2021).
		Stage Actively Managed	MPA management is ongoing, including monitoring, periodic review and adjustments made as needed to achieve biodiversity conservation and other ecological and social goals. (From the MPA Guide, Grorud-Colvert et al., 2021).
7	Level of protection? (Grorud-Colvert)	Level Fully Protected	No extractive or destructive activities are allowed; all abatable impacts are minimized. Minimizing impacts requires attention to the scale of the protected area and the scale of the activity. Not allowed: mining, dredging and dumping, fishing/ Minimal allowed: Anchoring, Intrastructure, Aquaculture and non-extractive activities. (From the MPA Guide, Grorud-Colvert et al., 2021).
		Level Highly Protected	Only light extractive activities with low total impact are allowed, with all other abatable impacts minimized. Some allow a small amount of subsistence or small-scale fishing with minimal impact, depending on the number of fishers and gear types [up to five or fewer low-impact gears; for example, use by few fishers of highly selective gear such as hand lines or collection by freedivers may be compatible with highly protected status (Not allowed: mining, dredging and dumping/ minimal allowed: anchoring, fishing and non-extractive activities/ low: infrastructure and aquaculture. (From the MPA Guide, Grorud-Colvert et al., 2021),

	Question	Data needs	Description
		Level Lightly Protected	Some protection of biodiversity exists, but moderate to substantial extraction and other impacts are allowed. These MPAs can achieve some protection of biodiversity for certain species or habitats, but the number and impacts of activities allowed are greater than for highly protected areas. A larger number of fishing gear types might be used, or fishing occurs with less selective gear types (such as gill, trammel, or small-scale drift nets). Tourism could have moderate impacts on habitats and species, such as damage caused by high-intensity recreational diving. Aquaculture may occur by means of semi-intensive, unfed methods or small-scale and low-density fed methods. The vast majority of MPAs worldwide are lightly protected or minimally protected. (Not allowed: mining, Moderate: dredging and dumping, anchoring, infrastructure, aquaculture, fishing, non-extractive activities). (From the MPA Guide, Grorud-Colvert et al., 2021).
		Level Minimally Protected	Extensive extraction and other impacts are allowed, but the site still provides some conservation benefit in the area. Extensive extraction and other impacts occur in a minimally protected area, but the area still achieves sufficient biodiversity conservation to satisfy the IUCN definition of an MPA. For example, the area must not allow large-scale fishing. Minimally protected MPAs often allow many or high-impact gear types for extraction and may include medium- to high-density aquaculture and/or large-impact anchoring or infrastructure. (not allowed: mining, moderate: dredging and dumping, non-extractive activities, high: anchoring, infrastructure, aquaculture and fishing). (From the MPA Guide, Grorud-Colvert et al., 2021).
8	Permanence of protection?	No protection measures (yet)	
		Permanent	MPAs or zones whose legal authorities provide some level of protection to the site in perpetuity for future generations, unless reversed by unanticipated future legislation or regulatory actions.
		Conditional	MPAs or zones that have the potential, and often the expectation, to persist administratively over time, but whose legal authority has a finite duration and must be actively renewed or ratified based on periodic governmental reviews of performance.
		Temporary	MPAs that are designed to address relatively short-term conservation and/or management needs by protecting a specific habitat or species for a finite duration, with no expectation or specific mechanism for renewal. Examples: Temporary MPAs include some fisheries closures focusing on rapidly recovering species (e.g. scallops).
9	Constancy of protection?	No protection measures (yet)	
		Year-Round	MPAs or zones that provide constant protection to the site throughout the year.

	Question	Data needs	Description
		Seasonal	MPAs or zones that protect specific habitats and resources, but only during fixed seasons or periods when human uses may disrupt ecologically sensitive seasonal processes such as spawning, breeding, or feeding aggregations. Examples: Seasonal MPAs include some fisheries and endangered species closures around sensitive habitats.
		Rotating	MPAs that cycle serially and predictably among a set of fixed geographic areas in order to meet short-term conservation or management goals (such as local stock replenishment followed by renewed exploitation of recovered populations).
10	Is it explicitly part of a designed network_level1	Yes	A designed network = A collection of individual MPAs operating cooperatively and synergistically at various spatial scales and with a range of protection levels that are designed to meet objectives that a single reserve cannot achieve.
		No	
		Unknown	
11	Add the IDs of the linked MPAs		Natura2000 IDs can be found in the Natura2000_select file.
12	What is the purpose of the network element?	Migration	E.g. to allow active migration of organism throughout the network (fish, birds, cetacean, reptiles, …).
		Passive dispersal connectivity	E.g. to allow passive migration of organism, as planktonic animals.
		Life-history connectivity	E.g. to allow the dispersal of life stages of organisms (e.g. larvae).
13	Is the MPA bounded by a national border?	Yes	
		No	
14	Is there another MPA on the adjacent side of the border?	Yes	
		No	
15	Add the IDs of the adjacent cross-border MPAs		Natura2000 IDs can be found in the Natura2000_select file.
16	Physical barrier?	Yes	This question is to know whether this MPA is isolated from other MPAs by a physical barrier (on land e.g. mountains; at sea e.g. deep waters).
		No	

	Question	Data needs	Description
17	What kind of barrier?	[Open question]	
18	Other commercial activities present within the MPA?	Aggregate extraction	Besides fisheries, what other activities were present in the area. (multiple choice).
		Aquaculture	
		Cables	
		Shipwrecks	
		Dredging	
		Hydrocarbon Extraction	
		Pipelines	
		Dredge spoil dumping	
		Dumped munitions	
		Wind Farms	
19	Other human threats for the MPA?	Pollution	
		Marine litter	
		Boating	
		Land-based activities	
	Fisheries Data		
20	Fisheries data collected/analysed - for the designation of the MPA?	Yes, before MPA designation	Here we want to know when the fishery data was collected and analysed (before or after the designation of the MPA).
		yes, after MPA designation	
		No	
		Unknown	
21	Fisheries data collected/analysed - for setting up fisheries measures?	Yes, before management measures were taken	Next, we want to know whether the fisheries data was collected and analysed before or after the management measures.

	Question	Data needs	Description
		Yes, after management measures were taken	
		No	
		Unknown	
22	Was a zero point assessment made at the start of the designation of the MPA?	Yes	Zero-point assessment to monitor changes.
		No	
23	For which area the fisheries data was collected?	Fishery zones only	For what area, the fisheries data was collected.
		Entire MPA	
		MPA + buffer	
		Larger area including the MPA	
24	What type of fisheries data was used?	Stakeholder based	
		AIS	
		VMS effort	
		VMS landings	
	Commercial fishing activities		
25	Gear_level_comm1	Demersal trawls	Please indicate for which métiers fisheries data was collected. Information is asked in different levels.
		Pelagic trawls	
		Dredges	
		Seines	
		Nets	
		Pots	

	Question	Data needs	Description
		Hooks and lines	
26	Gear_Level_comm2	Beam trawl	Here we want to know more in detail which gears were used.
		Otter trawl	
		Mid-water trawl	
		Towed dredge	
		Mechanic dredge	
		Purse seine	
		Danish seine	
		Scottish seine	
		Demersal seine	
		Beach seine	
		Fyke net	
		Lift nets	
		Gillnet	
		Trammel net	
		Combined gillnet-trammel nets	
		Longline	
		Vertical line	
		Trolling line	
		Pole-and-line	
27	Was there a particular fishery affected by the MPA?_level1	Yes	
		No	

	Question	Data needs	Description
28	Was there a particular fishery affected by the MPA?_level2 (specify)		Open question if the previous answer was 'yes'.
29	What was the fishing intensity inside the MPA?	High fishing intensity	
		Medium fishing intensity	
		Low fishing intensity	
		Unknown	
30	What was the fishing intensity just outside the MPA?	High fishing intensity	
		Medium fishing intensity	
		Low fishing intensity	
		Unknown	
31	Is there a licence system in place?_comm	Yes	Is there a licence system in place for the commercial fleet?
		No	
32	What type of licence system_comm	Generic	
		Generic MPA	
		Site specific	
	Recreational fishing activities		
33	Gear_level_rec1	Hooks and lines	Please indicate for which métiers fisheries data was collected for the recreational fleet. Information is asked in different levels.
		Spearfishing	
		Nets	
		Diving	
		Other	

	Question	Data needs	Description
34	Gear_level_rec2	Angling	
		Fyke nets	
		Gillnet	
35	Is there a licence system in place_rec?	Yes	
		No	
36	What type of licence system_rec	Generic	
		Generic MPA	
		Site specific	
	Fisheries restrictions		
37	Restrictions level 1	Spatially explicit restrictions	Restrictions in space.
		Spatio-temporal restrictions	Restrictions both in time and in space.
		Effort restrictions	Restrictions in effort.
		Bag limits	
		No fisheries restrictions in place	
38	Restrictions_level2	Spatial zoning of fleet access	Depending on what you have selected in restrictions level 1, you will get more options. For some answers in level1, level 2 will be empty.
		Spatially localized gear restrictions	
		Spatially explicit catch quotas	
		Spatio-temportal zoning of fleet access	
		Spatio-temporal gear restrictions	

	Question	Data needs	Description
		Spatio-temporal explicit catch quotas	
39	Describe the fisheries restrictions for commercial fisheries	[Open question]	
40	Describe the fisheries restrictions for recreational fisheries	[Open question]	
41	Legal basis for fisheries restrictions	National legislation	
		Delegated act	
42	Fisheries restrictions are in place since (year)		
	Level of enforcement		
43	Is there enforcement?	Yes	
		No	
		Unknown	
44	What kind of enforcement?	Acoustic monitoring buoys	
		Unmanned surface vehicles	
		VMS	
		AIS	
		Effective at-sea enforcement by guards	
		Cameras	
45	Who is responsible for the enforcement?	[Open question]	

	Question	Data needs	Description
46	What are the consequences of infringements?	[Open question]	
	Types of management		
47	Is there a management plan in place?	Yes	A MPA management plan is a site-specific planning and management tool that fulfils many functions and describes the goals, objectives, regulations and boundaries.
		No	
48	Site ownership	Local consortium	Who owns the site?
		Public administration	
49	Site management	Government-led	Managed primarily by the government under a clear legal framework.
		Decentralised	Managed in a shared approach by the government with significant decentralisation and/or influences from the private sector.
		Community-led	Managed primarily by local communities under collective management arrangements.
		Private-led	Managed primarily by the private sector and/or NGOs granted property/management rights.
		No clear governance framework	No clear effective governance framework in place.
	Stakeholder engagement during designation		
50	When were the stakeholders involved?	Designation of the MPA	Multiple options.
		Specific measures	During the process of developing specific measures for the MPA.
		General management (MPA board)	
51	Designation_What kind of stakeholder engagement?	Targeted	
		Fully-open	
52	Designation_How was stakeholder engagement organised?	Consultation	A two-way process where you include the stakeholders in the decision making and planning process. Stakeholders will provide information, opinions and ideas that will directly affect the direction of the project.

	Question	Data needs	Description
		Informing	Informing stakeholders of decisions, progress and status of the project. This is more of a one-way communication; you are keeping stakeholders informed of project status and progress.
		Participation	Direct contribution and involvement in the project.
53	Designation_Which stakeholders?	Government bodies	
		Local community groups	
		Local communities	
		Fishers	
		Fishers' organisation	
		Civil Society Organisations (NGOs)	
		Dependent industries (from fisheries)	
		Other businesses	
54	Were there conflicts (with stakeholders) during the setting up of the MPA?	Yes	
		No	
		Unknown	
55	What were the issues (during setting up MPA)?	[Open question]	
56	How were the issue solved (during setting up of MPA)?	[Open question]	
	Stakeholder engagement during process of management measures		
57	Measures_What kind of stakeholder engagement?	Targeted	

	Question	Data needs	Description
		Fully-open	Stakeholder engagement during process of management measures.
58	Measures_How was stakeholder engagement organised?	Consultation	A two-way process where you include the stakeholders in the decision making and planning process. Stakeholders will provide information, opinions and ideas that will directly affect the direction of the project.
		Informing	Informing stakeholders of decisions, progress and status of the project. This is more of a one-way communication; you are keeping stakeholders informed of project status and progress.
		Participation	Direct contribution and involvement in the project.
59	Measures_Which stakeholders?	Government bodies	
		Local community groups	
		Local communities	
		Fishers	
	MPA Board		
60	Is there an MPA board?	Yes	Is there an MPA board?
		No	
61	Who is represented in the MPA board?	Government bodies	Who is represented in the MPA board?
		Local community groups	
		Local communities	
		Fishers	
		Fishers organisation	
		Civil Society Organisations (NGOs)	
		Dependent industries (from fisheries)	

	Question	Data needs	Description
		Other businesses	
62	Promotion of sustainable fishing	Yes	Promotion of sustainable fishing
		No	
		Unknown	
	Conservation measures		
63	Are there conservation objectives defined?_level1	Yes	
		No	
		Unknown	
64	Are the conservation objectives monitored?	Yes	
		No	
		Unknown	
65	Who is responsible for monitoring the status of the conservation objectives?		nobody, government etc.
66	If the conservation objectives were monitored, please specify what is monitored?	[open question]	Was there a scientifically grounded evaluation on basis of the zero point assessment?
67	Are the targets of the conservation objectives met?	Yes	

	Question	Data needs	Description
		No	
		Unknown	
68	Conservation objectives met_what are the consequences?	top-down trophic cascade	
		increased food availability	
		refuge from predation	
		refuge from fisheries	
69	Conservation objectives NOT met_Is there an explanation or hypothesis why not?	[open question]	
70	How are the results of the scientific assessment disseminated?	scientific report	
		publicly discussed with the stakeholders	
		other	
	Environmental components		
71	Which habitats -_level 1	1100 Open Sea and tidal areas	This question is multiple choice. In the next question, the habitat levels were asked more in detail.
		1200 Sea cliffs and shingle or stony beaches	
		1300: Atlantic and continental salt marshes and salt meadows	

	Question	Data needs	Description
		1400: Mediterranean and thermo-Atlantic salt marshes and salt meadows	
		1500: salt and gypsum inland steppes	
		1600: Boreal Baltic archipelago, coastal and land upheaval areas	
72	Which habitats -_level 2	HA1110	Sandbanks which are slightly covered by sea water all the time
		HA1120	Posidonia beds (*Posidonion oceanicae*)
		HA1130	Estuaries
		HA1140	Mudflats and sandflats not covered by seawater at low tide
		HA1150	Coastal lagoons
		HA1160	Large shallow inlets and bays
		HA1170	Reefs
		HA1180	Submarine structures made by leaking gases
		HA1210	Annual vegetation of drift lines
		HA1220	Perennial vegetation of stony banks
		HA1230	Vegetated sea cliffs of the Atlantic and Baltic Coasts
		HA1240	Vegetated sea cliffs of the Mediterranean coasts with endemic Limonium spp.
		HA1250	Vegetated sea cliffs with endemic flora of the Macaronesian coasts
		HA1310	Salicornia and other annuals colonizing mud and sand
		HA1320	Spartina swards (*Spartinion maritimae*)
		HA1330	Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)

	Question	Data needs	Description
		HA1340	Inland salt meadows
		HA1410	Mediterranean salt meadows (*Juncetalia maritimi*)
		HA1420	Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi*)
		HA1430	Halo-nitrophilous scrubs (*Pegano-Salsoletea*)
		HA1510	Mediterranean salt steppes (Limonietalia)
		HA1520	Iberian gypsum vegetation (Gypsophiletalia)
		HA1530	Pannonic salt steppes and salt marshes
		HA1610	Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation
		HA1620	Boreal Baltic islets and small islands
		HA1630	Boreal Baltic coastal meadows
		HA1640	Boreal Baltic sandy beaches with perennial vegetation
		HA1650	Boreal Baltic narrow inlets
		HA8330	Submerged or partially submerged sea caves
73	Ecosystem component_level1	Marine mammals	Information on the ecosystem components present in the area were asked in different levels of detail. If you add marine mammals, in the next level you need to add whether there are cetaceans or seals.
		Seabirds	
		Fish (teleost)	Any member of a large and extremely diverse group of ray-finned fishes. Level2: flatfish, roundfish, demersal, pelagic or reef
		Fish (cartilaginous)	They include sharks, rays, and skates (elasmobranchii) and chimeras (holocephali). Level 2: Skates, Rays, Sharks, Chimaeras
		Cephalopods	
		Reptiles	level 2: turtles

	Question	Data needs	Description
		Benthos	level 2: Benthic infauna and Benthic epifauna
		Physical habitats	level2: mud, sand, gravel, mixed or unknown
		Plankton	level2: Phytoplankton, Zooplankton
		Plants	Level2: Macroalgea, macrophytes
		Food web	
74	Ecosystem component_level2	Cetaceans	If cetaceans are selected, in the next level you need to answer whether these are baleen whales or toothed cetacean (or both).
		Seals	
		Flatfish	
		Roundfish	
		Demersal	
		Pelagic	
		Reef	
		Skates	
		Rays	
		Sharks	
		Chimaeras	
		Turtles	
		Benthic infauna	
		Benthic epifauna	level3: corals, sponges, sea pens, other
		Mud	
		Sand	

	Question	Data needs	Description
		Gravel	
		Mixed	
		Unknown	
		Phytoplankton	
		Zooplankton	
		Macroalgae	
		Macrophytes	
75	Ecosystem component_level3	Baleen whales	
		Toothed cetacean	
		Corals	
		Sponges	
		Sea pens	
		Other	
76	Please specify what is included concerning fish stocks	quantity	multiple choice
		quality	
		diversity	
		none of these options	
	Other aspects for environmental components		
77	Protection of fish stocks_level1	Yes	Protection of fish stocks_level1
		No	

	Question	Data needs	Description
78	Protection of fish stocks_level 2	juvenile	Protection of fish stocks_level2
		(sub)adult feeding	
		spawning	
		migration corridor	
	Other		
79	What is the level of uncertainty of your answers?	[open question]	indicate high if you have crosschecked the information (consulted the policy administration), low if that wasn't the case.

ANNEX 2: FLICKR METHODS

The effect of marine protected area designation on the reported visits to these locations

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Introduction

There are a wide range of policies and regulations which can be used to designate a site to foster biodiversity restoration or protect it[1(22)]. In some cases, site designation will be associated with management of human activities taking place in those locations. Management schemes can range from a full exclusion of all human activities, to developing operational guidelines for some marine sectors to minimize their biodiversity footprint. It can be challenging and costly to assess whether these management actions contribute to the designated site management objectives, let alone its conservation objective. There are currently more than 17,000 marine protected areas (MPAs) designated around the world, yet only 23% of them have clear management plans and only about 1% of them have had management effectiveness evaluations[2,3]. A key hurdle to effective MPA management is the monitoring of human activities taking place in the designated sites. There have been major improvements in the reporting of industrial activities[4] such as fishing[5], shipping, or aquaculture[6]. However, we still lack robust global reporting mechanisms and processes for recreational and tourism activities. Yet, those activities, underpinned by cultural ecosystem services, are to play a key role in the success of MPAs. Cultural ecosystem services, including services associated with recreational fishing[7], are an important socioeconomic foundation to help communities living with MPAs extract value from designated sites, at times to replace lost activities associated with MPA management objectives (such as fisheries exclusion). They are also to play a key role in decoupling economic growth from natural resources exploitation, a primary objective of the European Green Deal[8].

It is therefore crucial to develop approaches to monitor cultural ecosystem services provision in MPAs and whether site designation impacts those services. With the advance of computational social science[9], social media sampling has provided an opportunity to assess where and when people visit sites of special interests (such as protected areas) and appraise the assets of interests when they are visiting these locations. Social media sampling provides a mean to sample self-reported visits to MPAs (and other locations). It also acts as a vast unstructured interview, letting millions of social media user express motivations and sentiments about experiences in those destinations as well as letting them describe (with text, images or videos) the features on which they concentrated during those experiences[1,10–15]. Benchmark studies over the past decade have been able to outlined the constraints and limitations of different social media platforms[9,12,14]. In studies of cultural ecosystem services which require some spatial information about experiences, Flickr (https://www.flickr.com/) is recognized as a robust sampling platform, as long as spatial resolution needed is no less than about 10km scale and temporal resolution is no smaller than a couple of weeks to 1 month[14,16,17]. While other platforms are in development[15], Flickr remain a safe environment to assess relative changes in use of particular locations, particularly because its API has remained informatively opened and access stable for the past decade. For example, a recent global study used Flickr sampling

[22] List of references at the end of this annex

to show that MPAs on average tend to provide more cultural ecosystem services than neighbouring locations[1]. Other platforms (Twitter and Reddit) are useful to collect qualitative information about cultural ecosystem services but are limited in the spatial information that can be retrieved from posts[9,10,15].

Here we use Flickr to assess whether the number of photos posted, used as a proxy for visitation, in a designated site changed after designation was enacted. In addition, we assessed whether Flickr users reported more on fishing activities after designation.

Methods

MPA selection and their designated year

Here we restrict the study to the project's list of designated sites. No information was available for those sites beyond a unique identifier for each site and their geometry provided as multipolygons. We therefore developed a procedure to retrieve the identity of these sites based on the global database of protected sites curated by UN-WCMC and IUCN[2] which was used in a previous study[1]. As site identifier code (SITECODE) did not relate to global protected area identifiers, we matched sites by their geometry. We intersected the multipolygons of the project sites with all WDPA MPA sites and looked for the WDPA MPA site which had the largest overlap. We then compared the size of the project's sites and the candidate WDPA MPA retained at that first stage. This was to eliminate intersection situations where two sites might overlap largely simply because one (smaller) was completely contained in another (much larger). For each project site, we retained WDPA MPAs that overlapped by more than 99% with the site and for which the difference in size between the site and the WDPA MPA was less than 1%. Most project sites did not have a perfectly overlapping WDPA MPA site, we assume that it may be caused by original polygons having undergone reprojection multiple times. However, this procedure left one and only one WDPA MPA possible for each project site when one could be retrieved. Some project sites where not MPAs (i.e. mostly included land) and therefore were not retained here. We could then retrieve the designation year for each site from the UNWCMC-IUCN WDPA database.

Sampling reported MPA usage 2010-2022

For each retained site, we sampled the Flickr API monthly from 01 January 2010 to 31 August 2022 using search functions available in the R library photosearcher[11] for all photos posted that were reported as photographed within the polygons of each site. We therefore end up with 152 monthly counts of posted photos for each site. We further sampled the Flickr API monthly over the same period for photos tagged with a keyword associated with recreational fishing activities ("fish", "pêche", "fishing", "pescatore", "pescador", "fiska", "fiske", "fischen", "vissen", "pescar"). Those keywords were selected to cover typical tags associated with fishing activities in the manner those are reported on Flickr. All coastal European languages were trailed first and only languages for which any photo could be retrieved, regardless of location, were kept in the tag keyword search.

Assessing the effect of a designation intervention

We first described temporal patterns in posts in the data collected above using Morlet wavelet decomposition[18]. We then implemented an intervention analysis as a mean to appraise whether MPA designation caused changes in the report of MPA use on Flickr. To do so, we implemented a series of Bayesian structural time series models using the R library CausalImpact[19]. Briefly, this approach aims to assess whether a known intervention on a times series affected its temporal pattern by comparing the behaviour of the time series on which the intervention occurred, and the behaviour of control time series sampled over the same time period. This approach uses a counterfactual inferential paradigm[20] and assumes that there are control time series not affected by the intervention. Given the observed common average pattern in Flickr posts across all sites, driven by seasonal variations, we used some of the sites as control. Only a proportion of the identified sites were designated during the sampling period (2010-2022). Therefore, the posting pattern in the other sites should not be affected by the designation intervention in the sites designated during the 2010 to 2022 period. We therefore selected sites designated between 2010 and 2022 as 'intervention' sites and those designated prior to 2005 as 'control' sites. We deliberately left a hiatus period between control and intervention site selection (2006-2009) to avoid any potential acclimatation period in posting pattern if sites had been designated very close to the start of the sampling period.

Here we compared each intervention site (n=524) to all control sites (n=395). We therefore have a distribution of posterior intervention effect estimates for each site, given all control sites. Finally, we meta-analysed these intervention effects to estimate a pooled intervention effect of MPA designation. We first carried out an overall meta-analysis for the causal effect estimates. We then carried out separate meta-analyses for positively affected sites and negatively affected sites using the function rma in the R library metafor[21]. We used for each repeated intervention analysis, the variance associated with the estimated causal effects (sd of the effect estimate).

Results

Population-level Flickr posting temporal patterns at selected designated sites

We averaged the number of posts observed at all sites and found an inter-annually consistent intra-annual seasonal pattern associated with tourism and recreation flows in Europe[22] (Figure A2.1b, seasonal component). As reported previously, this pattern was perturbed by the COVID-19 pandemic[15,23–26] (Figure A2.1b, random component peak in 2020 and Figure A2.1c, significant wavelet at 6-month during the start of the pandemic). The trend (Figure A2.1b) is associated with the known change in usage of Flickr.

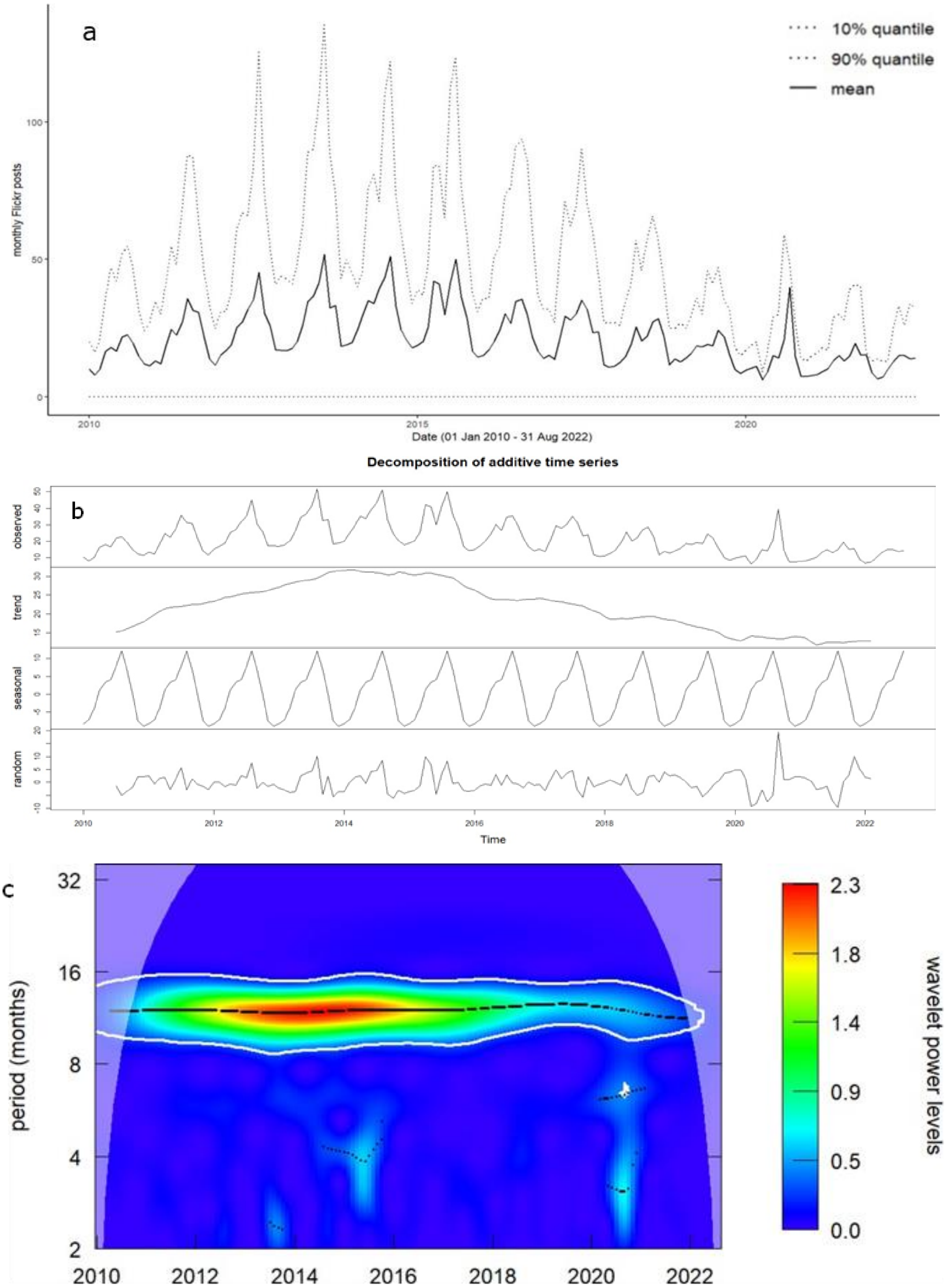

Figure A2.1. (a) Observed temporal pattern in monthly Flickr posts across all of 1581 project sites (mean across all sites and site quantiles). (b) Decomposition of this time series in seasonal trend and unexplained components. (c) Morlet wavelet decomposition of the average time series confirming the 12-month period signal and a 6-month event during the start of the COVID-19 pandemic (white line outlines period significantly different from white noise).

We do not retrieve the same seasonal patterns in the fishing photos when looking at an aggregated level. As “fishing” posting are sparse, the time series can be more influenced by stochastic events (Figure A2.2).

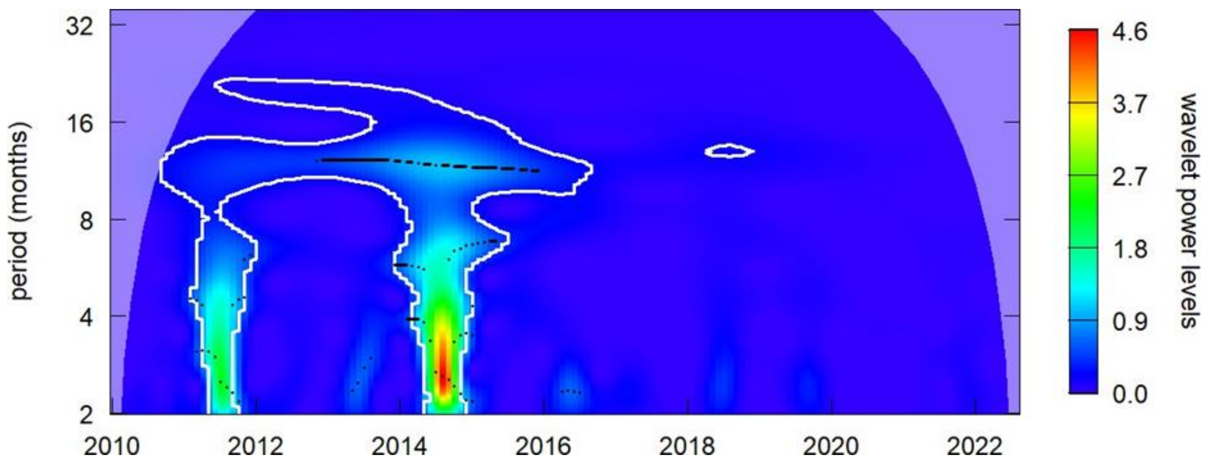

Figure A2.2. Morlet wavelet decomposition of the average time series of mean number of posts on Flickr in the MPAs about fishing. There is a lack of consistent intra-annual patterns.

Intervention analysis: the effect of site designation on posting patterns

We confirmed first that the central tendency in temporal pattern was indeed the same between control and intervention sites. As these long-term mean behaviours are comparable (Figure A2.3), control sites could indeed be used as counterfactuals to contrast the effect of site designation in intervention sites.

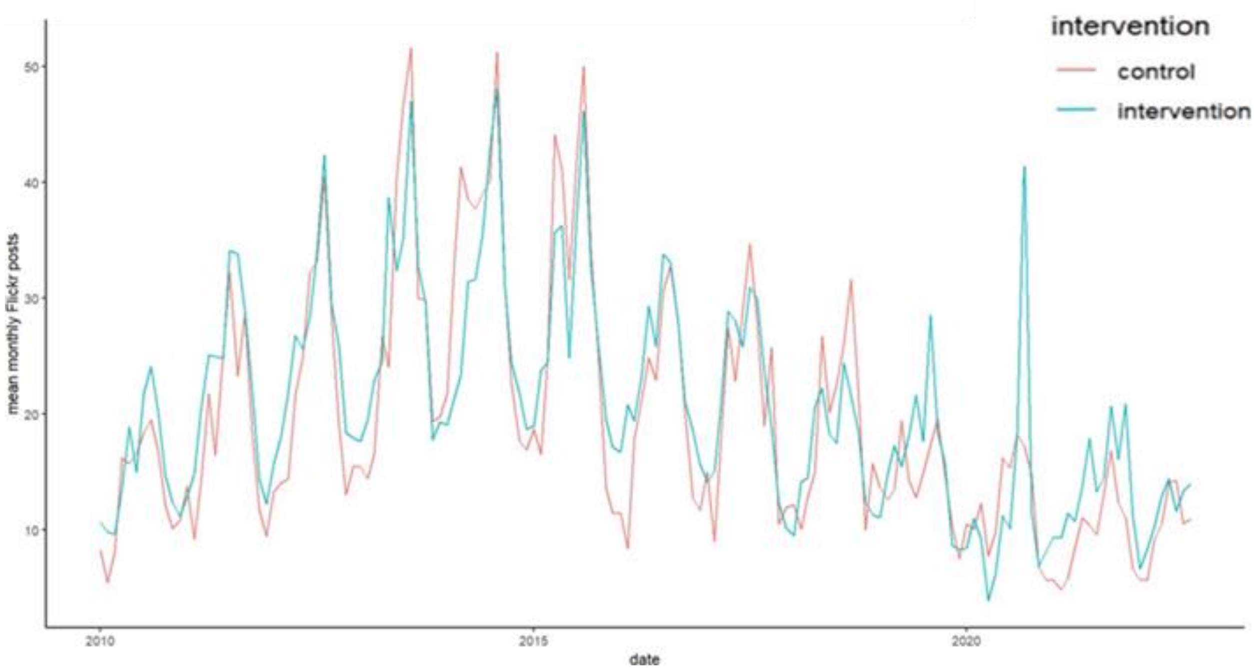

Figure A2.3. Concordance in intra-annual posting patterns between control and intervention sites.

We found that a significant causal effect of site designation on the number of monthly Flickr photos posted could be estimated for 137 of the 524 intervention sites. The pooled causal effect was 0.122 (SE=0.068, Z_{480}=1.8, p=0.07) and not significantly different from zero, but the effects were heterogenous (test for heterogeneity: Q_{480}=3045, p<0.0001). Adding a covariate effect of the log of the site area does not solve this heterogeneity issue (Q_{479}=2986, p<0.0001). We can derive a significant pooled effect for the 59 sites (Appendix A.1) for which a positive causal effect was estimated (effect: 1.15 SE= 0.190 Z_{58}=6.05 p< 0.0001). The pooled effect was for negative causal effect sites (Appendix A.1) was much larger (effect: -32.4 SE= 4.502 Z_{77}=-7.21 p< 0.0001). However, in both cases heterogeneity shows that unknown covariates need to be considered to further estimate covariate-level specific pooled effects.

We found that a significant causal effect of site designation on the number of monthly Flickr fishing photos posted could be estimated for 38 of the 524 intervention sites (Appendix A.2). The pooled causal effect was 0.025 (SE=0.022, Z_{203}=1.6, p=0.25) and not significantly different from zero, but the effects were heterogenous (test for heterogeneity: Q_{203}=2726, p<0.0001). Again, the size of the sites did not inform this heterogeneity. We could estimate a significant pooled effect for the 18 sites (Appendix A.1) for which a positive causal effect was estimated (effect: 0.53 SE= 0.147 Z_{17}=3.58 p=0.0003). The pooled effect was for the 20 negative causal effect sites (Appendix A.2) was much larger (effect: -0.145 SE= 0.039 Z_{19}=-3.64 p=0.0003). However, in both cases heterogeneity shows that unknown covariates need to be considered to further estimate covariate-level specific pooled effects.

Discussion

Sampling human ecology on social media is to be treated in the same way as any other ecological sampling processes[27,28]. It is not a census, it comes with type I and II errors, and, if samples are representative and the study design helpful to account for tested effects and untested data structures, then we can make population-level inferences. As others have highlighted before, given the constraints and limitations associated with the probability of reporting experiences on a social media platform like Flickr, it is important to focus analytical efforts on longitudinal questions[13]. This includes paired design where locations of interests are paired to appropriate controls, or repeated measure design where multiple locations with similar characteristics are sampled to appraise human behaviour in relation to those characteristics[15]. In this study, we aimed to derive a population-level insight about the effect of site designation on the visitation patterns at this site and, if possible, reports of fishing.

Posts about fishing that can be retrieved in a quality assured and controlled manner are sparse on Flickr. However, sparsity does not equate uninformative. We can model rare events and longitudinal changes in rare events and still derive population-level inferences about their dynamics. Intervention analyses helped identify changes in Flickr posting patterns in MPA after their site designation. However, this effect was not homogeneous. Most sites did not see a change in posting patterns, and for those that had a positive or negative effects: i) we are likely missing some information about site characteristics which could explain the heterogeneity in the effect size detected, and ii) increase in the number of photos posted did not necessarily led to an increase in fishing posts. We now need to further assess drivers of site designation effect variability.

It is to be noted that in previous work on Flickr posting patterns in MPAs[1], a crucial feature needed to appraise posting variance was the designation of appropriate control sites so that a paired design could be applied to the longitudinal analyses. It will be valuable to determine appropriate control sites for the sites considered which account for fishing features.

The relevance of social media sampling to understand recreational fishing

There are several other platforms that can be used to recover insights about recreational fisheries. However, those are currently limited to mainly understanding temporal patterns at very coarse spatial scale (e.g. national or NUTS-3 level[29]). To respect the privacy of users, platforms for which more information about users can be collected are not providing fine-scale spatial information about posts (primarily at the bequest of users). This does not mean though that those are not useful, they provide a mean to understand fishing seasons, and how they might change, and reveal the component of the fishing experience that is important to recreational fishers. For example, Twitter posting pattern, along with patterns of searches on Google Trends in the United Kingdom can show concordantly how people use mackerel coinciding with known seasonal patterns (Figure A2.4).

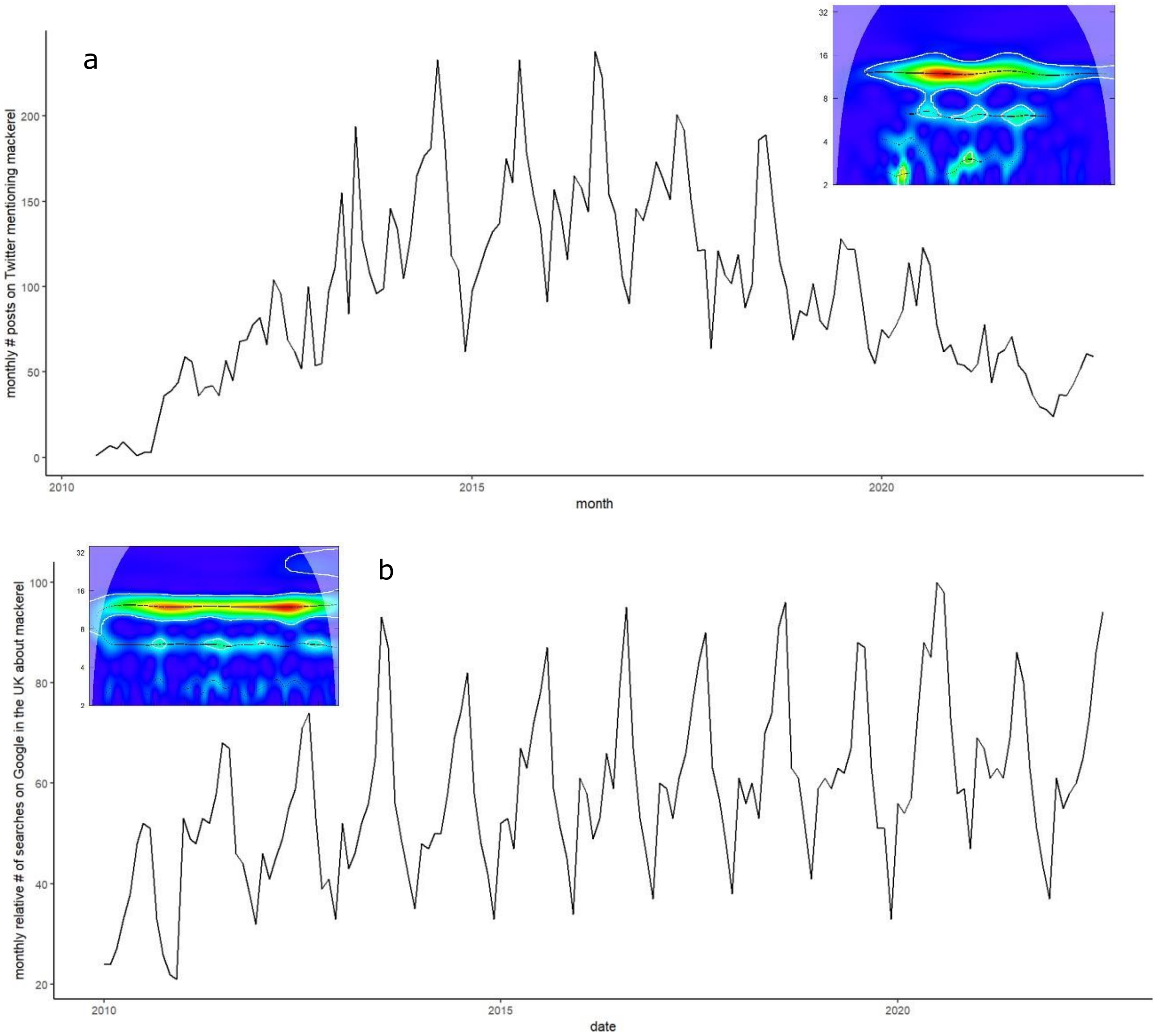

Figure A2.4. Monthly number of tweets about mackerel coming from the UK (a) and relative monthly number of searches on Google about mackerel in the UK (b). a wavelet decomposition of each time series is given in an inset (period: month).

While we were unable to routinely identify the effects of MPA designation on the rates of recreational fishing displayed on the Flickr platform, we demonstrate the utility of utilising social media posts for discerning real-world trends (such as interruption caused by the covid-19 pandemic). Furthermore, in a minority of cases, differences between control and MPA sites were found, indicating changes under some conditions. However, these changes were not tightly coupled enough to MPA site designation to enable attribution. Future studies should try to use other social media sources with longer persistent time series, while accounting for the lower spatial resolutions available. In addition to the alternate sources, future work should also investigate other drivers of change (e.g. regulation, instead of designation) as well as accounting for concurrent drivers of change, such as other tourism activities or indices of local impacts from climate change.

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Appendix A.1. Summary table of intervention analyses on the number of Flickr posts for each of the 481 tested intervention sites for which an intervention effect could be estimated.

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
CDDA_555690826	0	0.021	0.486	0.514	null
CDDA_555690827	-1.838	1.282	0.057	0.943	null
CDDA_555639823	-0.05	0.144	0.238	0.762	null
CDDA_555639833	-31.198	179.543	0.45	0.55	null
CDDA_555641546	0.032	0.033	0.156	0.844	null
CDDA_326991	-0.424	2.131	0.436	0.564	null
CDDA_555632419	1.011	4.047	0.283	0.717	null
CDDA_379211	0.054	1.71	0.489	0.511	null
CDDA_379207	0.002	0.039	0.48	0.52	null
CDDA_147544	0.333	0.09	0.008	0.992	positive
CDDA_379209	0.007	0.12	0.437	0.563	null
CDDA_379271	-0.009	0.023	0.134	0.866	null
CDDA_379206	-0.012	0.164	0.448	0.552	null
CDDA_379208	0.001	0.03	0.49	0.51	null
CDDA_326975	0.119	3.866	0.463	0.537	null
CDDA_379210	0.018	0.02	0.028	0.972	positive
CDDA_326968	-0.202	0.342	0.146	0.854	null
CDDA_379212	-0.095	0.257	0.25	0.75	null
CDDA_177812	0.901	0.367	0.013	0.987	positive
CDDA_379223	-0.015	0.548	0.477	0.523	null
CDDA_379220	0	0.018	0.486	0.514	null
CDDA_555559631	5.827	22.715	0.394	0.606	null
CDDA_555597297	-59.674	92.291	0.04	0.96	negative
CDDA_555597232	1.524	0.384	0.005	0.995	positive
CDDA_555562005	0.17	0.112	0.047	0.953	positive
CDDA_555589628	-6.016	11.046	0.049	0.951	negative
CDDA_555589788	-162.53	66.362	0.017	0.983	negative
CDDA_555561999	2.164	53.352	0.468	0.532	null
CDDA_555595770	1.026	0.377	0.012	0.988	positive
CDDA_30111	0.151	0.097	0.021	0.979	positive
CDDA_555690907	10.744	9.485	0.034	0.966	positive
CDDA_555638667	-0.006	0.014	0.245	0.755	null
CDDA_555638665	1.038	0.045	0.001	0.999	positive
CDDA_555638668	0.469	2.166	0.376	0.624	null
CDDA_555638669	0.018	0.096	0.346	0.654	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
CDDA_555638670	0.058	0.044	0.039	0.961	positive
CDDA_555638666	0.408	0.212	0.014	0.986	positive
CDDA_319259	-0.271	1.073	0.493	0.507	null
CDDA_555632837	-2.475	15.97	0.336	0.664	null
CDDA_396166	-0.605	0.509	0.111	0.889	null
CDDA_396162	-4.406	3.158	0.049	0.951	negative
CDDA_396160	-0.017	0.297	0.448	0.552	null
CDDA_396163	-13.195	13.824	0.179	0.821	null
CDDA_555560491	0.799	5.214	0.371	0.629	null
CDDA_555590816	-0.039	0.161	0.301	0.699	null
CDDA_555590814	0.2	0.808	0.333	0.667	null
CDDA_555590815	0.457	0.157	0.001	0.999	positive
CDDA_555514089	0.203	0.089	0.023	0.977	positive
CDDA_555545814	-0.17	0.357	0.38	0.62	null
CDDA_555545808	2.449	0.357	0.001	0.999	positive
CDDA_555514087	-0.066	0.197	0.241	0.759	null
CDDA_555514096	-0.225	1.743	0.406	0.594	null
CDDA_349380	-1.887	3.738	0.114	0.886	null
CDDA_151243	-42.887	34.42	0.06	0.94	null
CDDA_348878	-50.607	10.421	0.002	0.998	negative
CDDA_555588903	1.486	12.025	0.333	0.667	null
CDDA_555588841	-279.3	80.317	0.011	0.989	negative
CDDA_348795	-10.647	3.137	0.01	0.99	negative
CDDA_389283	20.103	10.902	0.019	0.981	positive
CDDA_555588892	-6.531	11.866	0.191	0.809	null
CDDA_348970	-3.663	2.358	0.044	0.956	negative
CDDA_555700930	-0.926	2.713	0.175	0.825	null
CDDA_555544835	-0.464	0.388	0.014	0.986	negative
CDDA_106786	0.437	0.1	0.005	0.995	positive
CDDA_106878	0.19	0.018	0.001	0.999	positive
CDDA_1390	0	0.47	0.465	0.535	null
CDDA_1391	-0.096	3.331	0.494	0.506	null
CDDA_555639331	0.655	0.284	0.007	0.993	positive
CDDA_106875	-1.093	1.098	0.127	0.873	null
CDDA_555597474	-0.595	0.5	0.063	0.937	null
CDDA_152342	0.43	0.299	0.018	0.982	positive
CDDA_379997	-0.166	0.267	0.14	0.86	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
CDDA_555589293	0.032	0.612	0.467	0.533	null
CDDA_1396	0.032	0.614	0.457	0.543	null
CDDA_555595325	0.675	0.922	0.08	0.92	null
CDDA_555597798	-6.604	5.874	0.068	0.932	null
CDDA_32614	-0.353	2.036	0.437	0.563	null
CDDA_32616	-2.572	1.613	0.009	0.991	negative
CDDA_32584	3.972	0.504	0.002	0.998	positive
CDDA_555702436	1.228	1.393	0.027	0.973	positive
CDDA_555551745	-1.479	4.882	0.197	0.803	null
CDDA_10421	0.014	0.016	0.063	0.937	null
CDDA_106791	-1.276	13.013	0.411	0.589	null
CDDA_30804	-7.391	8.186	0.15	0.85	null
CDDA_555544779	-8.489	13.581	0.273	0.727	null
CDDA_182790	0.011	0.031	0.208	0.792	null
CDDA_555551373	1.459	1.433	0.075	0.925	null
CDDA_555562414	-0.623	0.888	0.137	0.863	null
CDDA_32603	-0.309	0.649	0.314	0.686	null
CDDA_555702439	-82.879	45.154	0.005	0.995	negative
CDDA_30762	-4.643	8.567	0.318	0.682	null
CDDA_152545	0.257	0.937	0.273	0.727	null
CDDA_555551375	-4.965	2.585	0.012	0.988	negative
CDDA_555551600	-4.273	7.065	0.193	0.807	null
CDDA_555639763	0.126	0.11	0.018	0.982	positive
CDDA_10419	0.788	0.061	0.001	0.999	positive
CDDA_555551184	-1.045	2.514	0.389	0.611	null
CDDA_32632	-6.105	6.497	0.274	0.726	null
CDDA_32623	-0.275	0.864	0.233	0.767	null
CDDA_6882	-0.126	1.816	0.445	0.555	null
CDDA_30733	-0.186	0.216	0.066	0.934	null
CDDA_555702438	-1.309	1.733	0.037	0.963	negative
CDDA_106842	1.868	1.254	0.044	0.956	positive
CDDA_173145	-0.006	0.231	0.483	0.517	null
CDDA_32615	0.218	0.019	0.002	0.998	positive
CDDA_555639793	0.36	0.14	0.008	0.992	positive
CDDA_32625	0.009	0.352	0.499	0.501	null
CDDA_555587579	-0.197	1.452	0.381	0.619	null
CDDA_555550497	0.257	15.214	0.438	0.563	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
CDDA_555559389	-0.211	0.602	0.308	0.692	null
CDDA_555587464	-7.606	4.442	0.026	0.974	negative
CDDA_555633195	0.01	0.046	0.272	0.728	null
CDDA_555562146	-0.151	0.502	0.485	0.515	null
CDDA_555641241	0.015	0.045	0.41	0.59	null
CDDA_555691373	-0.322	1.936	0.495	0.505	null
CDDA_555691330	-0.002	0.014	0.451	0.549	null
N2000_BEMNZ0001	29.09	52.971	0.221	0.779	null
N2000_BEMNZ0005	0.017	0.141	0.36	0.64	null
N2000_DK00VA200	-0.176	0.223	0.138	0.862	null
N2000_DK00VA261	0.045	0.033	0.045	0.955	positive
N2000_DK00VA301	2.922	3.667	0.182	0.818	null
N2000_DK00VA307	-0.034	0.225	0.41	0.59	null
N2000_DK008X201	3.143	6.154	0.208	0.792	null
N2000_DK008X047	0.037	9.965	0.466	0.534	null
N2000_DK005X221	-5.094	22.081	0.392	0.608	null
N2000_DK005X276	-6.727	9.788	0.18	0.82	null
N2000_DK003X209	-2.356	20.924	0.342	0.658	null
N2000_DK005Y229	2.711	7.178	0.318	0.682	null
N2000_DK005Y220	-0.816	4.715	0.333	0.667	null
N2000_DK006X233	-60.684	79.615	0.219	0.781	null
N2000_DK006X234	0.326	3.648	0.49	0.51	null
N2000_DK006X238	14.462	13.852	0.113	0.887	null
N2000_DK006X242	-1.52	2.593	0.171	0.829	null
N2000_DK006X260	11.904	2.467	0.001	0.999	positive
N2000_DK008X183	-0.894	2.083	0.311	0.689	null
N2000_DK00AY176	14.222	29.115	0.254	0.746	null
N2000_DK008X198	0.044	0.203	0.358	0.642	null
N2000_DK00DX155	-0.086	1.893	0.481	0.519	null
N2000_DK00DX322	-0.771	0.725	0.117	0.883	null
N2000_DK00DX151	3.026	0.301	0.001	0.999	positive
N2000_DK00FX010	-0.372	0.855	0.234	0.766	null
N2000_DK00FX113	3.342	4.731	0.149	0.851	null
N2000_DK00EY133	5.03	2.237	0.015	0.985	positive
N2000_DK00FX122	7.522	8.709	0.143	0.857	null
N2000_DK00VA254	0.011	12.682	0.458	0.542	null
N2000_DK00VA259	0	0.021	0.484	0.516	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_DK00VA260	0.069	0.127	0.463	0.537	null
N2000_DK00FX112	13.474	9.05	0.062	0.938	null
N2000_DK00VA306	3.192	4.231	0.248	0.752	null
N2000_DK00VA171	-2.286	9.942	0.469	0.531	null
N2000_DK00VA305	1.732	6.32	0.399	0.601	null
N2000_EE0040472	-0.016	0.585	0.497	0.503	null
N2000_EE0040486	-4.111	4.296	0.255	0.745	null
N2000_FI1400047	0.034	0.702	0.461	0.539	null
N2000_FI1100601	0.045	0.03	0.03	0.97	positive
N2000_FI0100026	0.088	3.393	0.491	0.509	null
N2000_FI0100107	0.137	0.055	0.02	0.98	positive
N2000_FI0200073	-3.904	6.188	0.135	0.865	null
N2000_FI0200062	0.084	0.052	0.037	0.963	positive
N2000_FI0800136	-0.035	0.246	0.401	0.599	null
N2000_FI0400002	0.129	0.069	0.026	0.974	positive
N2000_FI0401001	-1.68	5.772	0.223	0.777	null
N2000_FI1000017	-2.597	0.456	0.001	0.999	negative
N2000_FI1400021	0.109	0.069	0.034	0.966	positive
N2000_FI0200080	-0.683	4.61	0.369	0.631	null
N2000_FR2300121	-10.557	29.254	0.29	0.71	null
N2000_FR2300139	73.836	63.015	0.09	0.91	null
N2000_FR2310045	21.2	28.783	0.135	0.865	null
N2000_FR2500077	-23.228	33.667	0.061	0.939	null
N2000_FR2500080	7.901	13.527	0.189	0.811	null
N2000_FR2500081	1.144	0.877	0.047	0.953	positive
N2000_FR2500084	3.832	19.43	0.326	0.674	null
N2000_FR2500086	-125.44	11.829	0.001	0.999	negative
N2000_FR2500079	0.89	5.017	0.335	0.665	null
N2000_FR2500088	23.451	24.589	0.048	0.952	positive
N2000_FR2502019	8.825	2.415	0.014	0.986	positive
N2000_FR2502018	0.48	1.104	0.215	0.785	null
N2000_FR9400570	3.414	2.171	0.045	0.955	positive
N2000_FR9400574	6.609	4.93	0.037	0.963	positive
N2000_FR2502021	-22.448	26.215	0.137	0.863	null
N2000_FR5200653	-63.187	40.61	0.042	0.958	negative
N2000_FR3102004	1.116	0.056	0.001	0.999	positive
N2000_FR3102005	-13.738	42.959	0.221	0.779	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_FR3100478	10.679	15.941	0.151	0.849	null
N2000_FR3102002	-7.793	26.712	0.288	0.712	null
N2000_FR5300009	-26.177	23.907	0.028	0.972	negative
N2000_FR5300028	4.77	4.022	0.049	0.951	positive
N2000_FR5310055	-6.631	7.727	0.373	0.627	null
N2000_FR5310057	-27.942	20.287	0.135	0.865	null
N2000_FR5300012	-270.88	81.111	0.005	0.995	negative
N2000_FR5300033	0.238	3.002	0.238	0.762	null
N2000_FR5202011	-20.329	18.184	0.05	0.95	negative
N2000_FR5300061	10.607	21.919	0.293	0.707	null
N2000_FR5302007	-6.766	5.131	0.056	0.944	null
N2000_FR5302008	3.796	9.239	0.244	0.756	null
N2000_FR5300066	24.929	21.552	0.055	0.945	null
N2000_FR5310086	15.454	18.353	0.091	0.909	null
N2000_FR5310011	3.589	17.07	0.413	0.587	null
N2000_FR5310070	15.09	16.381	0.06	0.94	null
N2000_FR5310092	-0.953	4.462	0.357	0.643	null
N2000_FR5312003	-8.452	5.204	0.003	0.997	negative
N2000_FR5310095	7.775	6.259	0.038	0.962	positive
N2000_FR5312011	-14.894	4.022	0.001	0.999	negative
N2000_FR5310071	-0.23	2.981	0.462	0.538	null
N2000_FR5312004	0.022	2.418	0.479	0.521	null
N2000_FR5312009	4.482	10.285	0.259	0.741	null
N2000_FR5300027	-16.256	51.888	0.172	0.828	null
N2000_FR5300031	2.462	2.634	0.18	0.82	null
N2000_FR5300032	-8.201	20.844	0.282	0.718	null
N2000_FR5312005	-0.257	1.101	0.459	0.541	null
N2000_FR5312010	12.304	9.819	0.034	0.966	positive
N2000_FR5410012	-44.322	70.933	0.274	0.726	null
N2000_FR5400469	19.982	127.07	0.43	0.57	null
N2000_FR5310056	5.675	4.723	0.087	0.913	null
N2000_FR5310093	7.965	8.763	0.07	0.93	null
N2000_FR7200677	11.549	32.701	0.127	0.873	null
N2000_FR7200775	-2.444	6.587	0.235	0.765	null
N2000_FR7200776	-71.686	64.527	0.031	0.969	negative
N2000_FR7200811	1.532	0.361	0.005	0.995	positive
N2000_FR7200813	-7.233	16.753	0.182	0.818	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_FR7200812	0.022	0.477	0.383	0.617	null
N2000_FR7212017	0.03	0.478	0.371	0.629	null
N2000_FR7212018	21.387	20.43	0.089	0.911	null
N2000_FR7212013	-3.068	17.678	0.318	0.682	null
N2000_FR7212016	2.615	0.405	0.004	0.996	positive
N2000_FR9101413	-47.447	71.975	0.045	0.955	negative
N2000_FR9101436	-7.002	12.722	0.111	0.889	null
N2000_FR9101463	-6.233	9.294	0.112	0.888	null
N2000_FR9101482	19.965	10.646	0.03	0.97	positive
N2000_FR9102014	0.387	1.988	0.34	0.66	null
N2000_FR9102012	-3.542	3.622	0.108	0.892	null
N2000_FR9102013	-41.844	61.143	0.303	0.697	null
N2000_FR9101493	1.698	3.125	0.155	0.845	null
N2000_FR9112038	-0.47	0.651	0.155	0.845	null
N2000_FR9301592	-67.054	113.94	0.157	0.843	null
N2000_FR9301573	-262.54	112.551	0.01	0.99	negative
N2000_FR9301624	-29.825	38.415	0.111	0.889	null
N2000_FR9310019	-100.59	88.542	0.021	0.979	negative
N2000_FR9301613	-17.94	36.981	0.346	0.654	null
N2000_FR9301999	-105.76	66.646	0.035	0.965	negative
N2000_FR9302001	-5.69	2.886	0.022	0.978	negative
N2000_FR9301997	1.033	3.78	0.095	0.905	null
N2000_FR9400587	-0.93	2.454	0.245	0.755	null
N2000_FR9402014	-20.848	10.338	0.019	0.981	negative
N2000_FR9402013	-9.19	15.242	0.085	0.915	null
N2000_FR9402017	-24.706	19.632	0.048	0.952	negative
N2000_FR9402016	-5.213	7.096	0.146	0.854	null
N2000_FR9402018	8.689	12.783	0.113	0.887	null
N2000_FR9402015	-1.678	17.505	0.406	0.594	null
N2000_FR9402010	-1.597	3.711	0.243	0.757	null
N2000_FR9410022	-1.544	2.298	0.049	0.951	negative
N2000_FR9410023	-1.161	10.352	0.399	0.601	null
N2000_FR9410021	-0.649	10.124	0.463	0.537	null
N2000_FR9410096	-23.504	14.967	0.016	0.984	negative
N2000_FR9412011	-12.715	15.223	0.051	0.949	null
N2000_FR5200626	6.579	0.692	0.001	0.999	positive
N2000_FR5300019	-12.124	41.264	0.46	0.54	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_FR5300046	-2.94	4.628	0.079	0.921	null
N2000_FR5300049	5.029	9.192	0.15	0.85	null
N2000_FR5200627	-5.04	14.366	0.189	0.811	null
N2000_FR5300018	-14.005	14.651	0.07	0.93	null
N2000_FR5300021	5.613	7.358	0.094	0.906	null
N2000_FR5310072	-8.636	12.698	0.13	0.87	null
N2000_FR7200679	21.845	25.523	0.108	0.892	null
N2000_FR5200659	-24.864	17.468	0.042	0.958	negative
N2000_FR5202013	5.427	5.302	0.088	0.912	null
N2000_FR5210090	-5.358	7.65	0.072	0.928	null
N2000_FR5300010	-102.4	23.677	0.004	0.996	negative
N2000_FR5300011	-15.645	9.624	0.041	0.959	negative
N2000_FR5310050	-2.431	4.818	0.257	0.743	null
N2000_FR5310052	0.084	1.161	0.408	0.592	null
N2000_FR5410013	-0.527	4.767	0.423	0.577	null
N2000_FR5410100	-194.57	53.804	0.005	0.995	negative
N2000_FR5412026	-217.17	33.52	0.001	0.999	negative
N2000_FR9112005	1.555	5.124	0.342	0.658	null
N2000_FR9112007	-13.021	8.081	0.015	0.985	negative
N2000_FR9301602	-46.643	222.152	0.226	0.774	null
N2000_FR9301628	-20.666	25.781	0.071	0.929	null
N2000_FR9301995	-10.411	10.798	0.069	0.931	null
N2000_FR9301996	-24.066	37.631	0.084	0.916	null
N2000_FR9301998	1.949	3.66	0.253	0.747	null
N2000_FR5200621	-116.72	245.59	0.076	0.924	null
N2000_FR5300015	12.709	19.447	0.153	0.847	null
N2000_FR5300023	3.138	13.145	0.156	0.844	null
N2000_FR5300017	-3.223	9.34	0.293	0.707	null
N2000_FR5310074	-1.176	6.128	0.349	0.651	null
N2000_FR5300052	-53.052	27.256	0.015	0.985	negative
N2000_FR5310073	-12.303	21.177	0.074	0.926	null
N2000_FR5412020	-10.496	17.007	0.235	0.765	null
N2000_FR5412025	28.972	19.584	0.011	0.989	positive
N2000_FR5210103	-127.61	96.415	0.032	0.968	negative
N2000_FR5212007	1.644	5.275	0.312	0.688	null
N2000_FR2500085	-2.671	7.061	0.328	0.672	null
N2000_FR5212009	-26.478	52.485	0.099	0.901	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_FR9400591	-29.513	43.696	0.468	0.532	null
N2000_FR2502020	3.325	12.941	0.272	0.728	null
N2000_FR9101414	-6.471	4.996	0.043	0.957	negative
N2000_DE1447302	-0.524	3.546	0.314	0.686	null
N2000_DE1541301	0.379	1.983	0.376	0.624	null
N2000_DE1934302	-0.946	3.806	0.393	0.607	null
N2000_DE1346301	-9.171	20.972	0.455	0.545	null
N2000_DE1003301	0.993	0.045	0.001	0.999	positive
N2000_DE1343301	-0.02	0.052	0.23	0.77	null
N2000_DE1345301	-11.176	23.812	0.482	0.518	null
N2000_DE1446302	0.37	2.409	0.408	0.592	null
N2000_DE1542302	-1.898	6.402	0.298	0.702	null
N2000_DE1544302	0.485	5.149	0.302	0.698	null
N2000_DE1540302	-4.362	5.931	0.111	0.889	null
N2000_DE1749302	-1.555	7.233	0.276	0.724	null
N2000_DE2031301	1.3	13.092	0.422	0.578	null
N2000_DE2049302	-93.984	31.97	0.011	0.989	negative
N2000_DE2251301	0.003	0.294	0.501	0.499	null
N2000_DE2417370	0.643	12.345	0.389	0.611	null
N2000_DE2507331	-11.403	17.914	0.148	0.852	null
N2000_DE1747301	-24.182	38.006	0.21	0.79	null
N2000_IE0000133	-2.932	2.068	0.019	0.981	negative
N2000_IE0000181	0.349	0.363	0.063	0.937	null
N2000_IE0000328	-0.075	0.73	0.402	0.598	null
N2000_IE0000458	-0.794	2.852	0.273	0.727	null
N2000_IE0000335	1.851	2.196	0.048	0.952	positive
N2000_IE0000507	0.016	0.043	0.184	0.816	null
N2000_IE0000671	-0.007	0.38	0.494	0.506	null
N2000_IE0000764	-54.348	11.655	0.004	0.996	negative
N2000_IE0001090	-0.316	0.864	0.124	0.876	null
N2000_IE0000697	-0.11	1.159	0.431	0.569	null
N2000_IE0002259	0.845	0.341	0.012	0.988	positive
N2000_IE0002262	-13.347	6.146	0.005	0.995	negative
N2000_IE0002264	-4.542	9.974	0.257	0.743	null
N2000_IE0002269	1.838	2.802	0.167	0.833	null
N2000_IE0002287	-9.369	5.591	0.016	0.984	negative
N2000_IE0002953	-1.201	0.333	0.012	0.988	negative

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_IE0003000	-15.92	11.641	0.017	0.983	negative
N2000_IE0003015	0.01	0.023	0.236	0.764	null
N2000_IE0002268	0.242	1.914	0.398	0.602	null
N2000_IE0002998	-4.883	17.786	0.337	0.663	null
N2000_IE0003002	-0.117	0.169	0.094	0.906	null
N2000_IE0004031	-47.804	25.749	0.008	0.992	negative
N2000_IE0004032	-16.916	10.071	0.015	0.985	negative
N2000_IE0004152	-4.148	6.462	0.064	0.936	null
N2000_IE0004159	2.852	0.451	0.003	0.997	positive
N2000_IE0004230	0.262	0.223	0.076	0.924	null
N2000_IE0000191	-1.697	0.598	0.015	0.985	negative
N2000_IE0000210	-24.28	7.541	0.005	0.995	negative
N2000_IE0000213	-4.119	5.969	0.068	0.932	null
N2000_IE0001501	1.28	0.198	0.003	0.997	positive
N2000_IE0002161	0.034	0.205	0.441	0.559	null
N2000_IE0004188	-8.935	15.042	0.133	0.867	null
N2000_IE0002172	-1.632	3.027	0.153	0.847	null
N2000_IE0004077	-45.541	24.185	0.01	0.99	negative
N2000_IE0000707	0.491	2.015	0.302	0.698	null
N2000_IE0000205	-1.173	6.923	0.386	0.614	null
N2000_IE0000206	0.054	5.892	0.48	0.52	null
N2000_LV0900300	-3.971	3.093	0.062	0.938	null
N2000_LV0900100	-0.026	0.297	0.439	0.561	null
N2000_LV0900500	0.27	0.522	0.254	0.746	null
N2000_LV0900700	-0.1	0.466	0.397	0.603	null
N2000_LV0900400	-13.761	14.354	0.187	0.813	null
N2000_LTNERB001	0.234	5.791	0.453	0.547	null
N2000_NL2008002	0.482	0.157	0.001	0.999	positive
N2000_NL2016166	0.011	0.102	0.416	0.584	null
N2000_NL2008003	3.383	4.117	0.15	0.85	null
N2000_NL2008001	0.278	0.818	0.322	0.678	null
N2000_PTZPE0060	-10.569	46.65	0.2	0.8	null
N2000_PTZPE0061	-244.69	134.83	0.028	0.972	negative
N2000_PTZPE0064	2.071	7.597	0.26	0.74	null
N2000_ES0000524	-0.183	0.091	0.023	0.977	negative
N2000_ES0000525	-13.202	23.257	0.177	0.823	null
N2000_ES0000527	-5.079	13.529	0.222	0.778	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_ES0000523	-0.267	1.514	0.44	0.56	null
N2000_ES0000529	-0.868	0.267	0.012	0.988	negative
N2000_ES0000530	-92.024	34.555	0.006	0.994	negative
N2000_ES7020017	-163.5	204.9	0.231	0.769	null
N2000_ES7020057	-0.156	0.808	0.345	0.655	null
N2000_ES7020124	3.127	1.776	0.044	0.956	positive
N2000_ES0000519	-9.868	17.819	0.212	0.788	null
N2000_ES0000515	-16.478	20	0.097	0.903	null
N2000_ES0000521	-36.901	39.199	0.105	0.895	null
N2000_ES0000490	-67.896	19.406	0.007	0.993	negative
N2000_ES0000516	-100.05	80.461	0.066	0.934	null
N2000_ES0000517	-18.371	14.609	0.048	0.952	negative
N2000_ES0000522	-56.026	26.589	0.019	0.981	negative
N2000_ES1110001	-2.464	2.567	0.062	0.938	null
N2000_ES1140004	1.343	14.431	0.429	0.571	null
N2000_ES1140010	-2.312	3.937	0.096	0.904	null
N2000_ES1140016	-50.405	8.307	0.001	0.999	negative
N2000_ES1200055	2.952	29.519	0.385	0.615	null
N2000_ES6200029	-14.218	29.601	0.203	0.797	null
N2000_ES5310082	0.754	3.757	0.281	0.719	null
N2000_ES0000526	-39.934	58.166	0.063	0.937	null
N2000_ES0000532	-0.481	16.408	0.484	0.516	null
N2000_ES7010016	153.424	112.052	0.073	0.927	null
N2000_ES0000502	2.433	12.129	0.33	0.67	null
N2000_ES1200047	-139.76	56.59	0.012	0.988	negative
N2000_ES0000531	14.182	67.156	0.39	0.61	null
N2000_ES7010035	-4.248	16.121	0.425	0.575	null
N2000_ES7010017	-70.519	132.829	0.286	0.714	null
N2000_ES7010053	8.743	9.793	0.188	0.812	null
N2000_ES7010022	-24.904	22.345	0.118	0.882	null
N2000_ES7010056	-1.233	39.489	0.489	0.511	null
N2000_ES7010021	-20.62	24.671	0.146	0.854	null
N2000_ES7011002	-3.281	19.84	0.464	0.536	null
N2000_ES7010066	-14.985	17.284	0.168	0.832	null
N2000_ES7020116	24.202	19.458	0.097	0.903	null
N2000_ES7020123	-2.404	8.066	0.38	0.62	null
N2000_ES7020126	2.888	2.069	0.077	0.923	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_ES7020122	-20.76	75.18	0.341	0.659	null
N2000_ES7020125	-0.812	1.232	0.26	0.74	null
N2000_ES5110017	-41.95	21.345	0.024	0.976	negative
N2000_ES0000492	-26.69	153.299	0.101	0.899	null
N2000_ES0000494	7.781	29.661	0.241	0.759	null
N2000_ES0000498	-0.051	0.079	0.097	0.903	null
N2000_ES0000497	-11.901	24.325	0.286	0.714	null
N2000_ES0000504	-87.443	141.227	0.307	0.693	null
N2000_ES0000500	-10.216	5.274	0.073	0.927	null
N2000_ES0000508	-64.507	140.164	0.076	0.924	null
N2000_ES0000510	-58.98	46.548	0.043	0.957	negative
N2000_ES0000514	-1.579	30.742	0.439	0.561	null
N2000_ES0000506	-112.38	42.542	0.02	0.98	negative
N2000_ES0000507	-50.186	26.643	0.025	0.975	negative
N2000_ES0000495	-17.541	7.373	0.015	0.985	negative
N2000_ES1110005	-3.684	42.562	0.469	0.531	null
N2000_ES0000512	-347.37	121.127	0.009	0.991	negative
N2000_ES0000513	-551.56	154.153	0.009	0.991	negative
N2000_ES0000518	5.216	20.948	0.219	0.781	null
N2000_ES0000520	77.473	107.4	0.148	0.852	null
N2000_ES1110012	-0.077	1.944	0.48	0.52	null
N2000_ES0000496	5.717	7.866	0.081	0.919	null
N2000_ES0000499	19.309	30.978	0.117	0.883	null
N2000_ES1140012	-10.552	3.24	0.009	0.991	negative
N2000_ES1110006	0.137	5.462	0.465	0.535	null
N2000_ES1300007	19.308	12.147	0.024	0.976	positive
N2000_ES5140001	-130.43	56.465	0.015	0.985	negative
N2000_ES5140007	-5.966	19.298	0.249	0.751	null
N2000_ES5310111	-5.08	9.123	0.073	0.927	null
N2000_ES5310108	-1.361	0.649	0.024	0.976	negative
N2000_ES5310110	-2.168	2.397	0.049	0.951	negative
N2000_ES6110009	2.031	17.275	0.204	0.796	null
N2000_ES6120009	-282.5	61.069	0.005	0.995	negative
N2000_ES6110010	-13.955	15.7	0.232	0.768	null
N2000_ES6120032	-26.644	62.934	0.271	0.729	null
N2000_ES6120017	-0.974	2.2	0.188	0.812	null
N2000_ES6140014	0.321	1.043	0.344	0.656	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_ES6140013	0.655	1.958	0.275	0.725	null
N2000_ES6150014	-5.478	11.241	0.196	0.804	null
N2000_ES6150029	0.423	9.701	0.44	0.56	null
N2000_ES6170036	1.432	3.869	0.223	0.777	null
N2000_ES6170030	-3.49	11.169	0.228	0.772	null
N2000_ES6170037	4.501	2.312	0.022	0.978	positive
N2000_ES6200048	-100.03	28.669	0.006	0.994	negative
N2000_ES0000501	-8.983	1.982	0.002	0.998	negative
N2000_SE0110086	-4.819	6.455	0.18	0.82	null
N2000_SE0520171	0.404	20.002	0.483	0.517	null
N2000_SE0510186	0	0.014	0.49	0.51	null
N2000_SE0520020	-0.213	1.248	0.384	0.616	null
N2000_SE0520048	-1.23	6.16	0.414	0.586	null
N2000_SE0110088	-19.356	24.405	0.202	0.798	null
N2000_SE0110085	0.421	3.157	0.411	0.589	null
N2000_SE0110111	-0.069	5.403	0.452	0.548	null
N2000_SE0210212	-3.026	4.524	0.2	0.8	null
N2000_SE0330108	0.042	6.829	0.463	0.537	null
N2000_SE0330308	-5.864	4.607	0.049	0.951	negative
N2000_SE0330301	-0.061	0.07	0.07	0.93	null
N2000_SE0340097	4.073	3.778	0.123	0.877	null
N2000_SE0410068	-4.786	6.226	0.153	0.847	null
N2000_SE0410175	-0.41	0.551	0.195	0.805	null
N2000_SE0420360	-61.735	50.447	0.066	0.934	null
N2000_SE0430095	-0.278	12.514	0.38	0.62	null
N2000_SE0430149	-0.607	0.78	0.132	0.868	null
N2000_SE0430162	0.202	0.336	0.314	0.686	null
N2000_SE0430183	0.405	1.965	0.313	0.687	null
N2000_SE0430187	-2.075	1.873	0.031	0.969	negative
N2000_SE0520012	-0.069	0.238	0.361	0.639	null
N2000_SE0520173	0.194	0.368	0.252	0.748	null
N2000_SE0520057	0.001	0.031	0.491	0.509	null
N2000_SE0520058	0.213	0.575	0.116	0.884	null
N2000_SE0520150	-4.397	8.99	0.257	0.743	null
N2000_SE0520170	-6.572	18.849	0.393	0.607	null
N2000_SE0520175	-7.881	10.957	0.157	0.843	null
N2000_SE0810011	-2.18	2.997	0.178	0.822	null

Appendix A.2. Summary table of intervention analyses on the number of Flickr fishing posts for each of the 204 tested intervention sites for which an intervention effect could be estimated.

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
CDDA_555559631	1.076	0.723	0.059	0.94	null
CDDA_555597297	0.065	0.262	0.268	0.73	null
CDDA_555589788	-0.18	1.499	0.392	0.61	null
CDDA_555561999	0.124	0.054	0.026	0.97	positive
CDDA_555690907	0.066	0.03	0.029	0.97	positive
CDDA_555632837	0.093	0.014	0.003	1	positive
CDDA_396163	-0.01	0.056	0.377	0.62	null
CDDA_555560491	-0.02	0.058	0.347	0.65	null
CDDA_151243	0	0.082	0.437	0.56	null
CDDA_348878	0.001	0.055	0.497	0.5	null
CDDA_555588903	-0	0.048	0.497	0.5	null
CDDA_555588841	-0.49	0.619	0.08	0.92	null
CDDA_389283	-0	0.089	0.488	0.51	null
CDDA_555588892	0	0.033	0.497	0.5	null
CDDA_555700930	0.013	0.039	0.3	0.7	null
CDDA_555597474	0.022	0.082	0.204	0.8	null
CDDA_555597798	0.016	0.084	0.28	0.72	null
CDDA_555551745	-0.02	0.075	0.267	0.73	null
CDDA_555702439	-0.01	0.041	0.304	0.7	null
CDDA_555551375	-0.01	0.104	0.499	0.5	null
CDDA_555551600	-0.09	0.141	0.133	0.87	null
CDDA_555702438	-0.03	0.022	0.017	0.98	negative
CDDA_555587579	-0.03	0.046	0.236	0.76	null
CDDA_555691373	0.003	0.017	0.359	0.64	null
N2000_BEMNZ0001	0	0.192	0.496	0.5	null
N2000_DK008X047	-0.03	0.148	0.34	0.66	null
N2000_DK00FX113	-0.11	0.319	0.321	0.68	null
N2000_DK00VA171	-0.03	0.148	0.355	0.65	null
N2000_FR2300121	-0.14	1.222	0.388	0.61	null
N2000_FR2300139	-3.12	1.493	0.027	0.97	negative
N2000_FR2310045	0.334	0.431	0.119	0.88	null
N2000_FR2500077	0	0.027	0.483	0.52	null
N2000_FR2500080	-0.02	0.036	0.198	0.8	null
N2000_FR2500081	-0.02	0.039	0.15	0.85	null
N2000_FR2500086	0.109	0.075	0.053	0.95	null
N2000_FR2500088	-0.01	0.029	0.158	0.84	null
N2000_FR9400574	-0.13	0.169	0.071	0.93	null
N2000_FR2502021	-0.12	0.064	0.051	0.95	null
N2000_FR5200653	-0.11	0.534	0.489	0.51	null
N2000_FR3102005	-0.94	0.818	0.071	0.93	null
N2000_FR3102002	-0.16	0.101	0.062	0.94	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_FR5300009	-0.04	0.097	0.201	0.8	null
N2000_FR5300028	0.001	0.224	0.457	0.54	null
N2000_FR5310057	-0.14	0.084	0.013	0.99	negative
N2000_FR5202011	0.096	0.037	0.024	0.98	positive
N2000_FR5300061	0.764	0.078	0.001	1	positive
N2000_FR5302008	0.23	0.121	0.018	0.98	positive
N2000_FR5310086	-0.02	0.284	0.436	0.56	null
N2000_FR5310011	-0.02	0.066	0.252	0.75	null
N2000_FR5310070	0.066	0.626	0.437	0.56	null
N2000_FR5310092	0.187	0.07	0.008	0.99	positive
N2000_FR5310095	0.102	1.501	0.448	0.55	null
N2000_FR5310071	0.024	0.037	0.108	0.89	null
N2000_FR5312009	0.254	0.121	0.013	0.99	positive
N2000_FR5300032	-0.08	0.057	0.057	0.94	null
N2000_FR5312010	-0.1	0.046	0.014	0.99	negative
N2000_FR5400469	-0.07	2.014	0.471	0.53	null
N2000_FR7200677	-0.01	0.368	0.448	0.55	null
N2000_FR7200776	0.952	0.137	0.001	1	positive
N2000_FR7200813	0.008	0.109	0.476	0.52	null
N2000_FR7212018	-0.17	0.31	0.075	0.93	null
N2000_FR7212013	-0.02	0.184	0.375	0.63	null
N2000_FR9101413	-0.12	0.232	0.108	0.89	null
N2000_FR9101436	0.099	0.458	0.241	0.76	null
N2000_FR9101463	0.011	0.032	0.235	0.77	null
N2000_FR9101482	0.068	0.126	0.125	0.88	null
N2000_FR9102013	0.035	0.12	0.22	0.78	null
N2000_FR9301592	2.548	0.066	0.001	1	positive
N2000_FR9301573	-0.15	0.195	0.092	0.91	null
N2000_FR9301624	-0.1	0.113	0.153	0.85	null
N2000_FR9310019	-7.23	6.767	0.04	0.96	negative
N2000_FR9301613	-0.06	0.341	0.354	0.65	null
N2000_FR9302001	-0.07	0.044	0.047	0.95	negative
N2000_FR9301997	-0.08	0.035	0.031	0.97	negative
N2000_FR9402013	-0.02	0.037	0.118	0.88	null
N2000_FR9402017	-0.06	0.109	0.14	0.86	null
N2000_FR9402018	-0.02	0.109	0.367	0.63	null
N2000_FR9402015	0.11	0.033	0.012	0.99	positive
N2000_FR9402010	0.036	0.032	0.066	0.93	null
N2000_FR9410021	-0	0.195	0.482	0.52	null
N2000_FR9410096	-0.04	0.097	0.145	0.86	null
N2000_FR9412011	-0.29	0.236	0.029	0.97	negative
N2000_FR5300019	-0.02	0.196	0.432	0.57	null
N2000_FR5300046	-0	0.155	0.467	0.53	null
N2000_FR5300049	-0.15	0.125	0.043	0.96	negative

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_FR5200627	-0.06	0.077	0.087	0.91	null
N2000_FR5300018	-0.02	0.209	0.428	0.57	null
N2000_FR5300021	-0.37	0.938	0.147	0.85	null
N2000_FR5310072	0.011	0.243	0.495	0.51	null
N2000_FR7200679	-0.17	0.202	0.06	0.94	null
N2000_FR5200659	0.038	0.038	0.083	0.92	null
N2000_FR5210090	-0.05	0.031	0.025	0.98	negative
N2000_FR5300010	-0.28	0.864	0.26	0.74	null
N2000_FR5300011	1.246	0.057	0.001	1	positive
N2000_FR5310050	0.071	0.074	0.055	0.95	null
N2000_FR5410013	-0.03	0.115	0.301	0.7	null
N2000_FR5410100	-0.45	0.821	0.126	0.87	null
N2000_FR5412026	-0.65	1.398	0.096	0.9	null
N2000_FR9112005	0.001	0.023	0.492	0.51	null
N2000_FR9112007	0.017	0.162	0.438	0.56	null
N2000_FR9301602	-0.78	0.575	0.043	0.96	negative
N2000_FR9301628	0.028	0.04	0.118	0.88	null
N2000_FR9301995	0.054	0.352	0.331	0.67	null
N2000_FR9301996	-0.01	0.166	0.414	0.59	null
N2000_FR9301998	-0.02	0.067	0.202	0.8	null
N2000_FR5200621	0.545	0.111	0.003	1	positive
N2000_FR5300015	0.021	0.068	0.279	0.72	null
N2000_FR5300023	-0.16	0.085	0.013	0.99	negative
N2000_FR5300017	0.808	0.044	0.001	1	positive
N2000_FR5310074	-0.02	0.015	0.01	0.99	negative
N2000_FR5300052	0.463	0.078	0.001	1	positive
N2000_FR5310073	-0.02	0.056	0.261	0.74	null
N2000_FR5412020	0	0.014	0.489	0.51	null
N2000_FR5412025	-0.11	0.158	0.088	0.91	null
N2000_FR5210103	0.812	0.309	0.018	0.98	positive
N2000_FR2500085	-0.2	0.374	0.135	0.87	null
N2000_FR5212009	-0.31	0.547	0.074	0.93	null
N2000_FR9400591	-0.03	0.255	0.382	0.62	null
N2000_FR2502020	0.044	0.081	0.148	0.85	null
N2000_FR9101414	0.008	0.037	0.27	0.73	null
N2000_DE1345301	0.012	0.058	0.285	0.72	null
N2000_DE1446302	-0	0.033	0.469	0.53	null
N2000_DE1542302	-0.02	0.179	0.371	0.63	null
N2000_DE1544302	-0	0.041	0.486	0.51	null
N2000_DE1540302	0.001	0.136	0.491	0.51	null
N2000_DE2031301	-0.08	0.2	0.13	0.87	null
N2000_DE2049302	-0.31	0.214	0.043	0.96	negative
N2000_DE2507331	-0.01	0.119	0.344	0.66	null
N2000_IE0000458	0.001	0.035	0.496	0.5	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_IE0000764	0.002	0.235	0.5	0.5	null
N2000_IE0002262	0.046	0.014	0.008	0.99	positive
N2000_IE0002264	-0.02	0.105	0.219	0.78	null
N2000_IE0002269	-0	0.025	0.477	0.52	null
N2000_IE0002287	-0.01	0.053	0.361	0.64	null
N2000_IE0003000	-1.1	0.683	0.01	0.99	negative
N2000_IE0002268	-0.08	0.025	0.015	0.99	negative
N2000_IE0002998	0.018	0.064	0.245	0.76	null
N2000_IE0004031	-0	0.162	0.492	0.51	null
N2000_IE0000210	0	0.02	0.491	0.51	null
N2000_IE0004188	-0.02	0.122	0.316	0.68	null
N2000_IE0002172	-0.02	0.056	0.17	0.83	null
N2000_IE0004077	-0.02	0.07	0.294	0.71	null
N2000_IE0000707	-0.01	0.041	0.356	0.64	null
N2000_IE0000205	-0.02	0.045	0.167	0.83	null
N2000_LV0900400	-0.02	0.056	0.242	0.76	null
N2000_LTNERB001	-0.02	0.058	0.343	0.66	null
N2000_PTZPE0060	0.029	0.202	0.312	0.69	null
N2000_PTZPE0061	-0.16	0.409	0.167	0.83	null
N2000_ES0000525	-0	0.041	0.501	0.5	null
N2000_ES0000527	-0.04	0.058	0.106	0.89	null
N2000_ES0000530	0.147	0.177	0.21	0.79	null
N2000_ES7020017	0.01	0.295	0.441	0.56	null
N2000_ES0000519	-0.13	0.076	0.047	0.95	negative
N2000_ES0000515	-0.3	0.376	0.097	0.9	null
N2000_ES0000521	-0.4	0.239	0.042	0.96	negative
N2000_ES0000490	0.003	0.316	0.438	0.56	null
N2000_ES0000516	-0.19	0.278	0.101	0.9	null
N2000_ES0000517	-0.09	0.057	0.055	0.95	null
N2000_ES0000522	-0.02	0.093	0.29	0.71	null
N2000_ES1140004	-0.05	0.056	0.101	0.9	null
N2000_ES1140016	0.011	0.054	0.352	0.65	null
N2000_ES1200055	0.067	0.194	0.263	0.74	null
N2000_ES6200029	0.002	0.312	0.399	0.6	null
N2000_ES0000526	-0.93	0.627	0.055	0.95	null
N2000_ES0000532	-0	0.283	0.482	0.52	null
N2000_ES7010016	0.363	0.5	0.201	0.8	null
N2000_ES0000502	0.018	0.04	0.157	0.84	null
N2000_ES1200047	0.099	0.145	0.287	0.71	null
N2000_ES0000531	0.255	0.254	0.082	0.92	null
N2000_ES7020116	-0.07	0.445	0.366	0.63	null
N2000_ES7020123	0.033	0.14	0.336	0.66	null
N2000_ES0000492	0.026	0.172	0.296	0.7	null
N2000_ES0000494	-0.04	0.058	0.118	0.88	null

Intervention site	Effect	sd	Posterior p value	Posterior probability of a causal effect	Direction
N2000_ES0000497	-0.07	0.089	0.106	0.89	null
N2000_ES0000504	-0.17	0.325	0.117	0.88	null
N2000_ES0000508	0.061	0.206	0.245	0.76	null
N2000_ES0000510	0.058	0.086	0.114	0.89	null
N2000_ES0000514	-1.03	0.89	0.109	0.89	null
N2000_ES0000506	-0.07	0.171	0.201	0.8	null
N2000_ES0000507	-0.08	0.087	0.097	0.9	null
N2000_ES0000495	-0.08	0.057	0.052	0.95	null
N2000_ES1110005	0.07	0.09	0.082	0.92	null
N2000_ES0000512	-1.59	1.66	0.107	0.89	null
N2000_ES0000513	-0.05	0.311	0.366	0.63	null
N2000_ES0000518	-0.01	0.12	0.398	0.6	null
N2000_ES0000520	-0.12	0.511	0.326	0.67	null
N2000_ES0000496	0.026	0.036	0.107	0.89	null
N2000_ES0000499	-0.05	0.117	0.236	0.76	null
N2000_ES1110006	0.001	0.039	0.486	0.51	null
N2000_ES1300007	-0.01	0.09	0.384	0.62	null
N2000_ES5140001	-0.14	0.118	0.069	0.93	null
N2000_ES5310111	-0.55	0.141	0.007	0.99	negative
N2000_ES5310110	-0.39	0.109	0.006	0.99	negative
N2000_ES6110009	0	0.029	0.496	0.5	null
N2000_ES6120009	-0.43	0.57	0.091	0.91	null
N2000_ES6110010	0.203	0.044	0.001	1	positive
N2000_ES6120032	0.071	0.164	0.265	0.74	null
N2000_ES6120017	0.013	0.039	0.289	0.71	null
N2000_ES6150014	0	0.033	0.491	0.51	null
N2000_ES6150029	-0	0.048	0.49	0.51	null
N2000_ES6170036	0.013	0.044	0.458	0.54	null
N2000_ES6200048	0.042	0.519	0.456	0.54	null
N2000_SE0330308	-0.01	0.04	0.318	0.68	null
N2000_SE0420360	-0.01	0.119	0.472	0.53	null

ANNEX 3: CALCULATION OF INCOMPATIBILITY INDICES BETWEEN FISHING AND MPAs

To define the steps involved in calculating the incompatibility scores between fisheries and MPA conservation objectives more explicitly, the below equations and explanations are provided. This text relies on the context provided in Section 2.5.

First each piece of evidence from the SEAwise review was weighted such that:

$$\left(\frac{QS_{spatial}}{3} + \frac{QS_{temporal}}{3} + \frac{QS_{design}}{3}\right) \div 3 \; = WE$$

Where WE is the weighted evidence that is calculated for each record of the review from an average of the three quality scores (QS) made by expert evaluation in the original review. These are individually divided by three to standardise their values to proportions of one (original possible values were 1, 2, or 3). This results in records with full scores across all three qualities being considered fully ($WE = 1$) and any lower scores reduces the contribution of an individual record to the lowest possible value of 0.333. This weighted evidence is recorded independently for positive, negative and ambiguous responses ($WE_{Pos|Neg|Amb}$). The weighted evidence of individual records is summed up by category, according to the interactions between fishing gear and ecosystem component, resulting in three matrices of total weighted evidence for each of the positive, negative and ambiguous impacts ($TWE_{Pos|Neg|Amb}$).

The raw impact scores (TWE_{net}) are simply the result of subtracting the matrix of negative weighted evidence (TWE_{Neg}) from the positive weighted (TWE_{Pos}). These raw impact scores do not account for the disagreement and ambiguity in the literature. To reflect this uncertainty, we calculate the entropy of evidence for each corresponding combination of fishing gear and ecosystem component:

$$\left(\sum_{i=1}^{k} \frac{n_k}{n_T} \times \ln \frac{n_k}{n_T}\right) \times \, -1 \; = Ent$$

Where Ent is the entropy of the evidence for a given interaction of gear and ecosystem component. k is the number of possible impact responses (positive, negative or ambiguous) so that $\frac{n_k}{n_T}$ is the proportion of all evidence for a given interaction of gear and ecosystem that is either positive, negative or ambiguous, in turn. The individual contributions of the positive, negative and ambiguous evidence are summed and multiplied by negative one to calculate the entropy of the evidence in each category. This entropy is a measure of the randomness or variation in the evidence and has possible values from 0 to $\ln k$, where 0 represents certainty and $\ln k$ represents a uniform distribution where all impact outcomes (positive, negative, ambiguous) are equally likely. In order to modify the raw impact score, we want a value that represents certainty and ranges from zero to one, therefore we transform the entropy to certainty via:

$$1 - \left(\frac{Ent}{\ln k}\right) = Cert$$

Where $Cert$ is a matrix of certainty values for the combinations of fishing gear and ecosystem component.

The raw impact scores (TWE_{net}) are then multiplied by their corresponding certainty value ($Cert$) to attain our final matrix of impact scores.

ANNEX 4: SYSTEMATIC REVIEW PROTOCOL

A systematic review protocol was developed and refined for each case study. Here we present an example of the protocol used for the Madeira archipelago, Portugal.

Introduction

Knowledge about specific marine protected areas (MPAs) is often sparse and spread across a multitude of sources. Academic articles often address specific components of an MPA, while governmental reports are often difficult to access because of language barriers, knowledge of their existence and sometimes more general nature (for example, on the scale of legislature covering multiple MPAs).

The objectives of this systematic review are to coalesce these disparate sources and improve the questions asked by, and interpretations of results from, subsequent analyses for the specific context of how the Madeira archipelago MPAs influence fisheries in and around its borders.

Methods

A search was made of all primary literature and research reports from national government agencies or independent research institutions that pertain to fishing activities in and around the Madeira archipelago MPAs prior to, during or subsequent to its establishment or the implementation of fisheries restrictions.

Studies using data were limited to maximum 20 years prior to the establishment of the MPA. Records in English and Portuguese should be considered eligible.

For academic articles, both Scopus and Web of Science indexing databases have been searched. For governmental and other institutional reports, the following sources have been investigated: European Environmental Agency, European Commission, FAO, IUCN and Portuguese and Madeira counterparts (e.g. Instituto das Florestas e Conservação da Natureza IP-RAM and the Direção Regional das Pescas).

Searches for academic articles employed a combination of three clusters of search terms joined internally by "OR" operators and joined together using the "AND" operator. The three clusters are organised into themes of "Location", "Fishing", and "Catch/Landings/Impact". These search terms were searched for within the fields "Title-Abs-Key", from Scopus and within the fields "TI", "AB" and "AK", from Web of Science. The Web of Science fields intentionally excludes the "Keyword plus" and "Topic Search" fields (of which the latter includes the former) because of the opaque method used to algorithmically augment keywords based on those provided in the search string.

Location	Fishing	Catch/Landings/Impact
Madeira	Fishing	effort
"Rocha do navio"	Fisher*	catch*
"Ilhéu da viúva"	angling	landing*
"Porto Santo"	angler*	profit
Desertas	spearing	income
Selvagens	spearfishing	revenue
"Ponta do Pargo"	trawl*	harvest*
Macaronesia	Harvest*	Yield
"Ponta de São Lourenço"	Intertidal	
Savage	Longline	
PTMAD0003	"Artisanal Fisher*"	
PTMAD0004	"Artisanal harvesting"	
PTDES0001	"Small-scale"	
PTSEL0001	"Pole and line"	
PTMMD0001	Traps	
PTZPE0062	"Recreational fisher*"	
PTZPE0063	"Purse-seine"	
PTZPE0064	"Small-scale"	
555514096	"trammel net*"	
388974	"nets"	
555545816		

Searches of grey literature were made by searching for the subset of the "Location" search terms that are particular to the MPA within the relevant institutes' libraries and repositories.

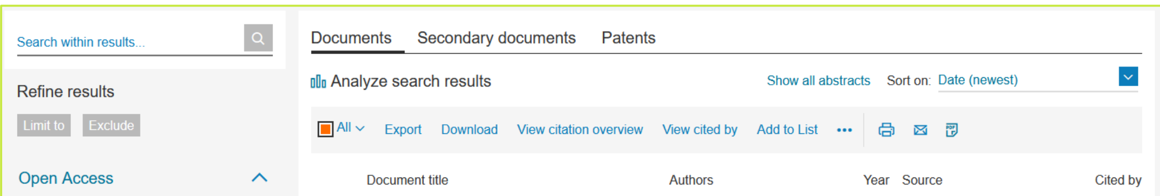
Study records

This record management strategy is adopted from the Horizon 2020 project SEAwise (Deliverable Report 1.1). The first step in record management is to coordinate searches across different sources, download the records' metadata, and de-duplicate records.

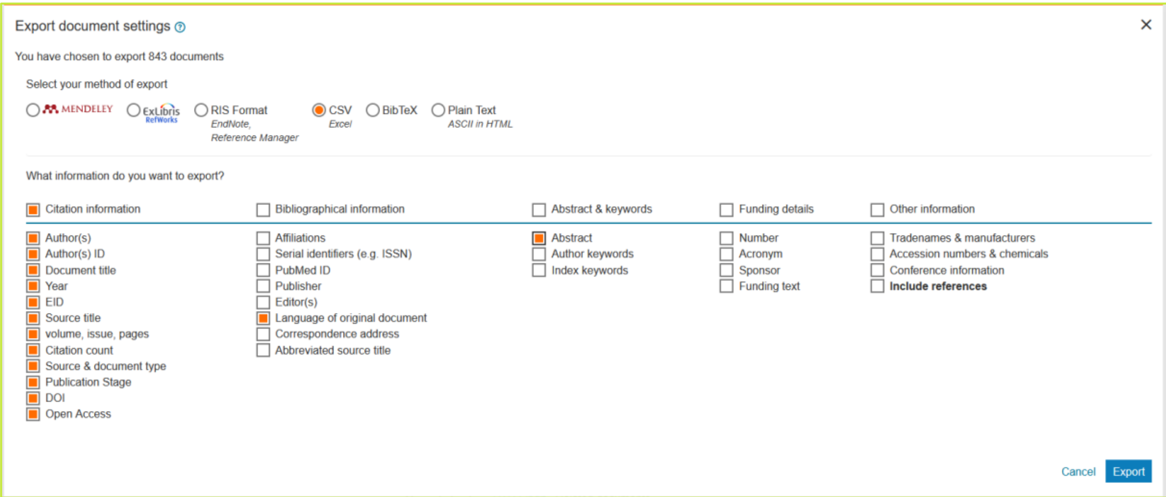
Scopus

To collect all records from Scopus:

1. Check the "All" box at the top of the search results, to make the "Export" link available.



2. In the export option, select "CSV" as the format, and ensure both "Language" and "Abstract" boxes are checked in addition to the default citation information.

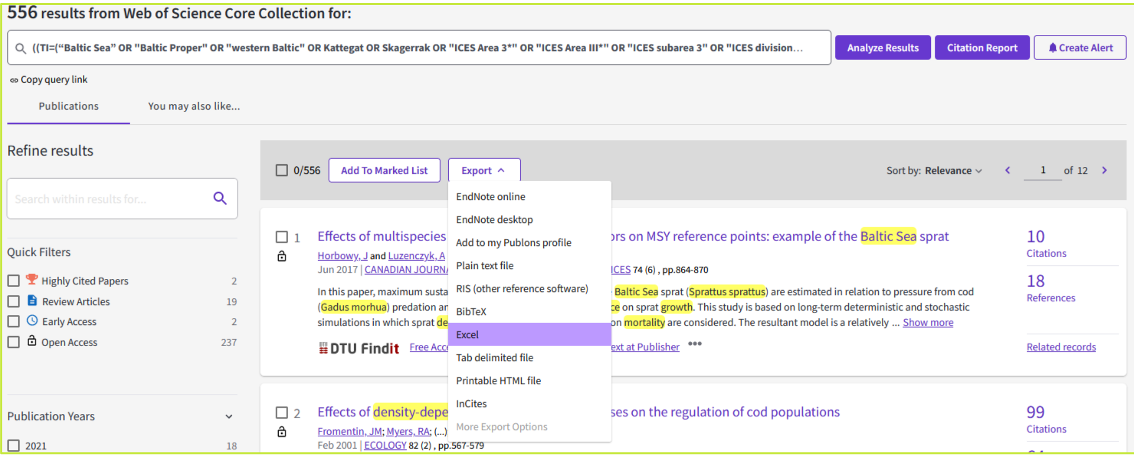


3. Select export to download the comma separated file containing all records and save it with an appropriate name (e.g. "Madeira_Scopus_20220915.csv").

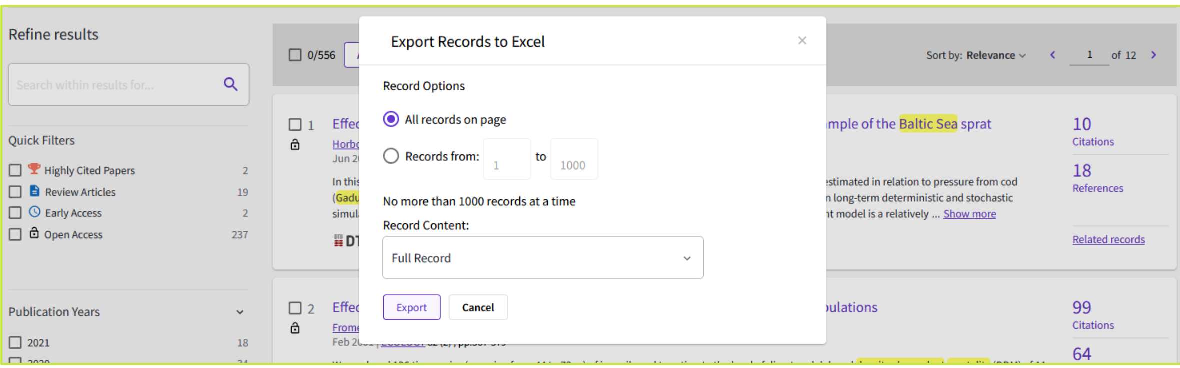
Web of Science

To collect all records from Web of Science:

1. Do **not** select the check-box at the top of the search results indicating selecting all records.
2. Select "Export" and then choose "Excel" from the drop-down menu.



3. Select "Records from: 1 to 1000".
4. From the "Record Content" dropdown menu select "Full Record", then click "Export".



5. Save the .xls file with an appropriate name (e.g. "Madeira_WoS_20220915.xls").

Merging and De-duplicating records

Academic records

The below R-script was used to merge and de-duplicate records from Scopus and Web of Science searches.

```
#===
# Packages and Dependencies
#====
# install.packages("xlsx")
library(xlsx)
#=====

#===
# Read in Records - Change filenames and directories to match your own circumstances
#====
cs_sco <- read.csv(file = "Madeira_Scopus_20220915.csv", header = TRUE)
cs_wos <- read.xlsx(file = "Madeira_WoS_20220915.xls", header = TRUE, sheetIndex = 1)
#=====

#===
# Reformat and simplify Scopus Record format
#====
colnames(cs_sco)[colnames(cs_sco) == "ï..Authors"] <- "Authors"
colnames(cs_sco)[colnames(cs_sco) == "Language.of.Original.Document"] <- "Language"
colnames(cs_sco)[colnames(cs_sco) == "Source"] <- "Database"
cs_sco[, c("Author.s..ID", "Art..No.", "Page.count", "Cited.by", "Publication.Stage", "EID", "Link")] <- NULL
#=====

#===
# Convert WoS record format to Scopus Record format (and remove extra fields)
#====
colnames(cs_wos)[colnames(cs_wos) == "Article.Title"] <- "Title"
colnames(cs_wos)[colnames(cs_wos) == "Source.Title"] <- "Source.title"
colnames(cs_wos)[colnames(cs_wos) == "Start.Page"] <- "Page.start"
colnames(cs_wos)[colnames(cs_wos) == "End.Page"] <- "Page.end"
colnames(cs_wos)[colnames(cs_wos) == "Open.Access.Designations"] <- "Open.Access"
colnames(cs_wos)[colnames(cs_wos) == "Publication.Year"] <- "Year"
cs_wos$Database <- as.character(rep_len("Web of Science", nrow(cs_wos)))
cs_wos <- cs_wos[, c(colnames(cs_wos)[colnames(cs_wos) %in% colnames(cs_sco)])]
#=====

#===
# Merge all records and delete duplicates
#====
all <- rbind(cs_sco, cs_wos)
dedup <- all[!duplicated(all$DOI) | all$DOI == "", ]
dedup <- dedup[!duplicated(dedup$Title), ]
#=====

#===
# Assign unique identifier to all records
#====
dedup$MF_ID <- paste0("MF_", "Madeira", "_", formatC(1:nrow(dedup), width = 3, format = "d", flag = "0"))
#====
```

Grey literature

Metadata from grey literature searches was entered into the above merge and deduplication procedure according to the metadata that is available.

Upon final collation and deduplication all records were given a unique ID consisting of the project abbreviation, case study country abbreviation and a three-digit unique integer, each separated by an underscore, i.e.: "MF" + "_" + [CountryInitials] + "_" + [unique number of four digits] (e.g. "MF_DK_001").

Selection and Screening

Once collated and de-duplicated, the academic records' titles and abstracts were screened to exclude those that matched the pre-defined exclusion criteria outlined below. Because of resource constraints, a single individual was responsible for screening within this CS review. This provides consistency but does not account for bias.

Criteria symbols	Exclusion criteria	Explanation
Retain	NA	No reason defined for excluding the article based on this level of search
A	No fisheries responses	No reports of fishery activities, effort, catches, landings or profit
B	Too old	Reports of activities too long before the implementation of fisheries restrictions will have reduced utility with regard to how the MPA impacted fishing vs changes over time
C	Wrong location	Some records may be returned based on search terms that are not relevant to the case study at hand
D	Wrong subject	Some records may be returned with subjects that are not relevant to study (i.e. ecology, agriculture, medicine, and management in hospitality)

Data Collection

The information to be collated was in four broad categories, namely bibliographic information, standard extraction, before/after implementations, and absolute values from before or after restrictions. The bibliographic information came primarily from the download of records from databases but was supplemented by records from grey literature sources. Standard extraction fields were extracted from all records. Before/after implementation fields were only extracted for those records that employed a comparison between before and after fishing restrictions are imposed in the MPA. Absolute values were collected from before/after studies but were extracted for descriptive studies that only analyse one period, either before or after, fisheries restrictions were imposed. The specific fields of information extracted are listed in the table below. Many are limited to a set of responses, and some of them are free text. A descriptive explanation of what should be extracted was included in the extraction form.

Bibliographic data	Standard extraction	Before/After implementation	Absolute values from either before or after restrictions
MF ID	Exclusion criteria	Change in effort (Categorical)	Effort units
Authors	CS study	Change in effort (% change)	Effort quantity
Title	Relation to MPA	Change in landings (categorical)	Target species
Year	Fishing activities	Change in landings (% change)	Catch/landings

Bibliographic data	Standard extraction	Before/After implementation	Absolute values from either before or after restrictions
Source title	Sampling method used for data collection	Change in value (% change in gross value)	Catch/landings units
Volume	Analytical method used for inference	Years of data (#before _ #after)	Catch/landings quantity
Issue	Concluding statement or quotable quote	Target-species shift	Landings value
Page start	Comments	Control used	
Page end			
DOI			
Link			
Abstract			
Language			
Document type			
Open access			
Database			

The same individual completed all extractions to ensure consistent interpretations and use of extraction fields. If the task had to be shared, a subsample of 10 papers was extracted by all participants, and an alignment meeting held to ensure consistency. Subsequent informal checks were encouraged to maintain alignment during the extraction phase.

The first step was to find and download the full-text record and save this with a filename matching the “MF_ID” assigned to the record. During the extraction, the details of the full text were considered against the exclusion criteria once again, and the result of this consideration was recorded in the extraction form.

Data synthesis

Key risks for bias in this study are the use of before/after comparisons without accounting for general trends (e.g. no controls), as well as a bias towards commercial fishing activities – because of the availability of data. The first risk is directly addressed and evaluated in data extraction. The second can only be evaluated in analyses of the results and the absence of evidence is not indicative of importance or proof of non-activity.

No quantitative analyses / meta-analyses are planned from this review. The results of this review have been reported qualitatively as background information on the history and development of fisheries in the area pertaining to the selected MPAs.

ANNEX 5: CASE STUDY REPORTS

In total, nine case studies in the Baltic Sea, North Sea, Atlantic EU Western Waters and some outermost regions (Madeira and Canary Islands) were selected to gather more information on the response of the fishing activities to MPA designation and implementation (Table A1).

The selection of case studies is well-spread in the different sea basins, cover an array of Member States, but also vary in the type of species (e.g. fish, crustacea, bivalves) and level of MPA protection (e.g. no-take, multi-zone, with buffer areas). In the case studies, the fisheries response to MPAs are analysed based on qualitative and/or quantitative analytical approaches, using available data and/or a stakeholder survey.

Table A1. Case studies on the assessment of potential spatial redistribution (displacement) of fishing activities in response to MPA designation and implementation. The full case study reports are published in a separate volume (doi: 10.2926/5489670**).**

Nr	Case Studies	Country	Regional Sea
1	North Sea Coastal Zone	The Netherlands	North Sea
2	Flemish Banks	Belgium	North Sea
3	Nida-Perkone	Latvia	Baltic Sea
4	Adler Grund og Rønne Banke	Denmark	Baltic Sea
5	Bratten	Sweden	Skagerrak
6	Dundalk Bay	Ireland	Celtic Sea
7	The Madeira Archipelago	Portugal	Macaronesia
8	Professor Luiz Saldanha Marine Park	Portugal	Iberian Coast
9	La Palma Island and La Graciosa Island	Spain	Macaronesia

ANNEX 6: METHODOLOGY MAPAFISH TOOL

Questions utilised to develop MAPAFISH tool

Questions should: (i) determine the likelihood and intensity of displacement; (ii) assess the strength of each of the four mechanisms; and (iii) further specify the relevance of each mechanism for each impact.

Questions to determine the likelihood and intensity of displacement

- What is the importance of the MPA area for the affected fisheries?
- Will it be fully or partly closed?
- Will there be other restrictions for fishing within the MPA (gears, periods, permits, etc)?
- Are there viable populations of target species in alternative areas that can be exploited by fisheries?
- Which of the following most strongly drives the current fishing activities in the area to be designated as an MPA: (Absence of the target species elsewhere/efficiency of the gear in the area/proximity to port relative to alternative areas/don't know).

Questions to assess the strength of the four mechanisms

Steaming time

- Compared to other areas where the fishers operate, how close is the MPA to the home port(s) of the fishers?
- Compared to other areas which the fishers use to transit between their home port and fishing grounds, what is the density of seabirds in the MPA and the routes towards it?
- Compared to other areas which the fishers use for fishing and/or steaming, what is the density of marine mammals in the MPA and the routes towards it?
- To what extent would it be feasible for fishers to change port?
- To what extent does the introduction of the MPA force fishers to make longer trips?
- To what degree do longer trips raise logistical issues for fishermen?
- To what degree are fishing-free weekends important for the local community?

Fishing effort

- Compared to other areas where the fishers operate (or could operate), how high is the abundance of the target fish species in the MPA? (higher/similar/lower)
- If the new areas are further away, will that reduce the time fishers have available to fish, on an annual basis? (Yes/no)
- Compared to other areas where the fishers operate (or could operate), what is the catchability for the target species in the MPA? (lower/ similar/ higher)
- To what extent are there fishers that are highly specialized on certain target species who will have to increase their effort in searching productive new grounds?

Fishing location

- Compared to the other areas where the fishers operate (or could operate), how is the abundance of vulnerable and/or protected species and/or habitats which are sensitive to the fishing activity, inside the MPA? (higher/similar/lower)
- Compared to other areas where the fishers operate, how large is the biodiversity in the MPA? (lower/similar/higher)
- Compared to other areas where the fishers operate, what is the bycatch rate (bycatch biomass per unit effort) in the MPA? (lower/similar/higher)

- Compared to other areas where the fishers operate, what is the frequency of occurrence of spawning aggregations of species that are caught in or disturbed by the fishing gears used? (lower/similar/higher)
- Compared to other areas where the fishers operate, what is the historic fishing intensity in the MPA? (lower/similar/higher)
- Compared to other areas where the fishers operate, what is the abundance of specific sensitive benthic species or features (such as oyster beds and boulders) in the MPA? (lower/similar/higher)
- Compared to other areas where the fishers operate, what is the abundance of species which are known to be sensitive to underwater noise (e.g. marine mammals) in the MPA? (lower/similar/higher)
- How significant is the total reduction in productive fishable grounds?

Fishing methods (vessel types, gear and mesh sizes)

- Do fishers historically use different methods (e.g. vessel type, gear, mesh size) in areas alternative to the MPA (no/yes)?
- Are gear changes required to catch the target species in the new area?
- How do these methods compare to the methods used in the 'old situation' in terms of impact on (lower – same - higher impact) the seafloor?
- How do these methods compare to the methods used in the 'old situation' in terms of impact on (lower – same - higher impact) noise levels?
- How do these methods compare to the methods used in the 'old situation' in terms of impact on (lower – same - higher impact) CO_2 emissions?
- How do these methods compare to the methods used in the 'old situation' in terms of impact on (lower – same - higher impact) bycatch rates?
- How do these methods compare to the methods used in the 'old situation' in terms of impact on (lower – same - higher impact) the food-web?
- If innovation is required, to what extent is the community capable of innovation (financial and willingness)?

ANNEX 7: METHODOLOGY FOR STAKEHOLDER ENGAGEMENT

This work relied on stakeholders' insights about MPAs as a fisheries management tool. Activities with case study (CS) teams were organised to provide materials and methodologies to gather stakeholders' insights. In total, fifty-nine potential interviewees were approached to fulfil the minimum requirement of 2 interviews per case-study. Most of these invitations were sent between mid-November and December 2022. Interviewing with stakeholders took place between November 2022 and March 2023. Interviewees were required to reply to a predefined set of questions and select and rank the five most relevant factors associated with MPAs that may affect fishers' behaviour, and then further elaborate on the rationale of their choices. These choices were intended to be employed for discussion during the focus groups (FGs).

Twenty-seven interviews were conducted between mid-December and early March for the following case studies: North Sea Coastal Zone, The Netherlands (one); Flemish Banks, Belgium (two); Nida-Perkone, Latvia (one); Adler Grund og Rønne Bank, Denmark (two); Bratten, Sweden (two); Dundalk Bay, Ireland (six); the Madeira archipelago, Portugal (three); Professor Luiz Saldanha Marine Park, Portugal (continental) (four) and La Graciosa Island and La Palma Island, Canary Islands, Spain (six). Following the finalisation of the interviewing phase the CS leaders submitted the transcripts and summaries. The consortium ranked the most important factors associated with MPAs and selected the most important. Focus group leaders were then invited to select those more relevant for their CSs to be further discussed in the two types of focus groups, i.e. one group with different stakeholders, and the second one comprising only fishers. A workshop on how to conduct FGs was led and a document containing guidelines for the execution of these groups was distributed amongst participants. In total, five FGs were conducted for fishers from CS in Ireland, the Netherlands, Spain and Sweden, whereas six FGs were conducted for multi-stakeholders from CS in Belgium, Denmark, Latvia, The Netherlands, Portugal (continental) and Sweden.

Interviews

For the interview round with key stakeholders in each case study, a questionnaire for conducting semi-structural interviews was developed by the consortium and distributed among the case study leaders. The first part of the interview referred to the level of participation in the designation process of the MPA and its governance, the second part concerned the implications for fisheries and management of the MPA.

The questionnaire comprised open-ended and closed questions. The former aimed to capture stakeholder opinions on, e.g. the consequences of not involving all stakeholders into the designation process. The latter were statement-based for the stakeholder to choose from. Questionnaires included an appendix with a list of factors associated with MPAs which affect fishers' behaviour. This list was proposed by the consortium and has proven to be of great utility to systematise the collection of points of views of stakeholders, to rank the most important factors to be further discussed during the FGs. Questionnaires for Portuguese and Spanish CS were translated into their native languages by the CS teams, and consortium, respectively.

Interviewees were asked to choose the five most important factors influencing fishers' behaviour from a list of ecological, social, and economic factors influencing fishers' decisions.

Table 13: Overview of stakeholder participation in formal interviews.

Stakeholder category	Fishers	Admini-stration	Research & academia	NGOs	Category Total
North Sea Coastal Zone, The Netherlands	1	-	-	-	1
Flemish Banks, Belgium	-	1	1	-	2
Nida-Perkone, Latvia	1	-	-	-	1
Adler Grund og Rønne Bank, Denmark	1	-	-	1	2
Bratten, Sweden	1	1	-	-	2
Dundalk Bay, Ireland		2	2	2	6
The Madeira Archipelago, Portugal - Macaronesia	-	2	1	-	3
Professor Luiz Saldanha Marine Park, Portugal	1	-	2	1	4
La Graciosa Island, Canary Islands, Spain – Macaronesia	1	1	2	-	4
La Palma Island, Canary Islands, Spain - Macaronesia	1	1	-	-	2
Total	**7**	**8**	**8**	**4**	**27**

Following the finalisation of the interviewing phase the CS leaders submitted the transcripts and summaries. The consortium ranked the most important factors associated with MPAs for all interviews. The five highest ranked factors were:

- Healthy benthic ecosystems provide more food and habitats (e.g. shelter for juveniles, spawning areas etc.).
- Loss of trust in the community and fishers (MPA fails to reach its conservation goals, and negatively impacts fishing).
- Shift in fishing grounds may result in an increase in fuel consumption due to longer trips outside the MPA boundary. New grounds may be also less productive and hence not profitable, or simply less of the more valuable species.
- Protects benthic communities and fish that depend on them.
- MPA implementation requires changing fishing grounds or changing fishing gear.

Focus groups

Originally, two Focus Groups (FGs) were planned to be organized by each of the case study teams.

- A multi-stakeholder focus group with the participation of different relevant actors, including fishers, other interest groups, scientists, and local or/and national administrators, as per the stakeholders mapping conducted in previous steps.
- A fisheries focus group with the participation of fishers and fishers' representatives only.

For conducting the focus groups, a set of guidelines was prepared which explained the purpose and dynamics of a FG, and instructions on whom to invite to the FG (criteria, characteristics). The guidelines furthermore provided templates for logistics, the roles of moderator and assistant, and general organisation before and after conducting the FG. The FGs were planned for a duration of 1.5 hour each and include a plenary introduction of the goal of the study, presentation of the factors to be discussed; and a plenary wrap-up.

After the distribution of the guidelines, a workshop was organized for the case study leaders, to address remaining questions.

FG leaders were invited to select the themes most relevant for their CSs to be further discussed in the two types of FGs, i.e. one group with different stakeholders, and the second one comprising of only fishers. The guidelines for the FGs made a recount of the ranking of most important factors associated with MPAs that affect the behaviour of fishers. FG leaders were free to use these factors as main theme for the FGs, or come up with another theme suitable for the case study. It was agreed that FGs would be held between late May and June 2023. But due to stakeholders' availability this process extended to July and August 2023.

Not all case studies conducted both focus groups, mostly for budgetary and logistic reasons.

Table 14: Overview of conducted focus groups

Type of stakeholder group	Fishers	Multi stakeholder	Total
North Sea Coastal Zone, Netherlands	1	1	2
Flemish Banks, Belgium	-	1	1
Nida-Perkone, Latvia	-	1	1
Adler Grund og Rønne Bank, Denmark	-	1	1
Bratten, Sweden	1	1	2
Dundalk Bay, Ireland	1	-	1
The Madeira archipelago, Portugal – Macaronesia	-	-	0
Professor Luiz Saldanha Marine Park, Portugal	-	1	1
La Graciosa Island, Canary Islands, Spain – Macaronesia	1	-	1
La Palma Island, Canary Islands, Spain – Macaronesia	1	-	1
Total	**5**	**6**	**11**

Table 15: Structure of the focus groups, containing the themes and the leading questions.

Flemish Banks, Belgium
Theme and questions of multi stakeholder focus group, 13 June 2023
MPA implementation requires changing fishing grounds or changing fishing gear; Is it necessary / possible for BE fishery to change fishing grounds/fishing techniques?; Where can EU policy support/contribute more to enable change?

Flemish Banks, Belgium
Are the stakeholder processes sufficiently taking into account the needs of the sector in relation to MPA implementation? Healthy benthic ecosystems provide more food and habitats (e.g. shelter for juveniles, spawning areas etc.). Will MPA designation contribute to healthier seas and possibly more food supply through fisheries? What is, in your opinion, the best way to improve fish stocks: a temporary or full closure?

Adler Grund og Rønne Bank, Denmark
Theme and questions of multistakeholder focus group , 22 June 2023
How has the current implementation of MPAs affected trust in their use as a marine management tool? Shifts in fishing grounds may result in an increase in fuel consumption due to longer trips outside the MPA boundary. New grounds may also be less productive and hence not profitable, or require higher-effort and impact to achieve the same catch.

Nida-Perkone, Latvia
Theme and questions of multistakeholder focus group, 22 August 2023
MPA and fisheries interactions – do fishers see MPA as benefit or threat to fishery? What benefits do you think there are due to MPA status? Are there any potential threats to fishery? How do you see the future coexistence between marine protection and other sectors. What could be the best ways to improve fish stock status?

North Sea Coastal Zone, the Netherlands
Theme and questions of fishers focus group, 14 July 2023
Effects of fishing area closure on the fishing activity and behaviour of fishers In the case study it was found that the total activity had significantly decreased after area closure. For hindered fishers (who used to fish in now-closed areas) as well as non-hindered fishers, and also inside closed areas as well as outside. Do you recognize this? How would you explain this? What effects does this have on your catches? Do fishers take a spillover effect into account?

North Sea Coastal Zone, the Netherlands
Theme and question of multi stakeholder focus group, 17 July 2023
Effects of VIBEG ([23]) policy negotiations on stakeholders and challenges in the implementation of EU policies in the North Sea

([23]) The VIBEG agreement is assisting the implementation of the Nature2000 goals in the Nature 2000 areas Vlakte van Raan and North Sea Coastal Zone in The Netherlands. It incorporates the interest of the Dutch fishing industry. The

North Sea Coastal Zone, the Netherlands
What are the effects, both positive and negative, of how the VIBEG negotiations have unfolded for fisheries and nature? Which specific moments or events during the process have stayed with you? What was their significance? Have the VIBEG negotiations influenced the trust and willingness to collaborate among different stakeholders? What are the implications for the effectiveness of nature conservation policies and achieving the set Natura 2000 goals?

Bratten, Sweden
Theme and questions of multi-stakeholder focus group, 22 May 2023 and fisher focus group, 30 June 2023
Conflict or co-existence: The future of marine protected areas, fishing and wind power What are your experiences of how the area protection in Bratten has worked for nature conservation and fishing? What conflicts do you think exist today regarding marine area protection, fishing and wind power? Is there a possibility of coexistence between marine area protection, fishing and wind power?

Professor Luiz Saldanha Marine Park, Portugal (continental)
Theme 1: The future of marine protected areas and fishing
Q1 – What are your experiences of how the area protection in Arrábida has worked for nature conservation and fishing? Q2 – What conflicts do you think exist today regarding marine area protection and fishing? Q3 – Where can EU policy support/contribute more to enable change? What would you wish from them?
Theme 2: Coexistence Q1 – How do you see the future coexistence between marine protection and other sectors. Q2 – What could be the best ways to improve this coexistence?

La Graciosa Island, Canary Islands, Spain
Theme 1: Loss of trust in the community and fishers (MPA fails to reach its conservation goals, and negatively impacts fishing) Q1 – Which do you think are the reasons that have caused a loss of confidence of the fishermen in the case study MPAs management? Q2 – If these problems persist, how do you imagine the future of the case study MPA for the new generations? Q3 – How this loss of confidence could be improved?

agreement is the result of long and intensive discussions between the fishing industry, nature organisations and the Dutch Government. A steering group between the stakeholders in continuously exchanging information and develops actions to improve the environmental situation (https://maritime-spatial-planning.ec.europa.eu/practices/vibeg-agreement-and-steering-group-stimulating-sustainable-fisheries-dutch-north-sea).

La Graciosa Island, Canary Islands, Spain
Q4 – What tools or specific proposals should be implemented to improve the management quality of the case study MPA?
Theme 2: Discrepancies in which fishers benefit from the MPA compared to others (winners/losers) leading to possible conflict. Also, possible conflict between MPA proposers, e.g. NGOs and fishers. Q1 – What do you think to be the main conflicts among the case study MPA stakeholders? Q2 – How these potential conflicts could be minimized? Q3 – The aims of the case study MPA are supposedly focused to the conservation of artisanal fishing livelihoods and marine resources. Do you think that legislation is being put in place to achieve these aims? Q4 – Do you think that the MPA case study is applicable to all users or it is only beneficial to certain sectors to avoid conflict?

La Palma Island, Canary Islands, Spain
Theme 1: Loss of trust in the community and fishers (MPA fails to reach its conservation goals, and negatively impacts fishing) Q1 – Which do you think are the reasons that have caused a loss of confidence of the fishermen in the case study MPAs management? Q2 – If these problems persist, how do you imagine the future of the case study MPA for the new generations? Q3 – How this loss of confidence could be improved? Q4 – What tools or specific proposals should be implemented to improve the quality management of the case study MPA?
Theme 2: Discrepancies in which fishers benefit from the MPA compared to others (winners/losers) leading to possible conflict. Also possible conflict between MPA proposers, e.g. NGOs and fishers Q1 – What do you think to be the main conflicts among the case study MPA stakeholders? Q2 – How these potential conflicts could be minimized? Q3 – The aims of the case study MPA are supposedly focused to the conservation of artisanal fishing livelihoods and marine resources. Do you think that legislation is being put in place to achieve these aims? Q4 – Do you think that the MPA case study is applicable to all users or it is only beneficial to certain sectors to avoid conflict?

Focus group with multiple stakeholders in the Canary Islands
Theme 1: Loss of trust in the community and fishers (MPA fails to reach its conservation goals, and negatively impacts fishing) Q1 – Which the reasons do you think that have caused a loss of confidence of the fishermen in the management of the case study MPAs? Q2 – How this loss of confidence could be improved? Q3 – Which is the current status of the conservation goals in the Canary Islands MPAs? Q4 – Which tools or specific proposals should be implemented to improve the quality of the management in the case study MPA?

Focus group with multiple stakeholders in the Canary Islands
Theme 2: Discrepancies in which fishers benefit from the MPA compared to others (winners/losers) leading to possible conflict. Also possible conflict between MPA proposers, e.g. NGOs and fishers. Q1 – What do you think to be the main conflicts among the case study MPA stakeholders? Q2 – How can these potential conflicts be minimized? Q3 – The aims of the case study MPA are supposedly focused to the conservation of artisanal fishing livelihoods and marine resources. Do you think that legislation is being put in place to achieve these aims? Q4 – Do you think that the MPA case study is applicable to all users or it is only beneficial to certain sectors to avoid conflict?

Dundalk Bay, Ireland
Theme 1: Thoughts and Feelings on the designation of the bay as a protected area? Q1 – Did the designation change anything in particular in the way fishers operate in the area? Q2 – What were fishers expecting from the designation? Q3 – What changed since the establishment of the protected area? Did it cause fishers some difficulties? Theme 2: Thoughts and Feelings on the Fishery Natura Plan?
Q1 – How effective is the management plan? Are fishermen satisfied or dissatisfied with it? Has it been sustainable for them over the years? Q2 – Did fishermen have any issues with the restrictions put in place for the cockle fishery? Q3 – Has the cockle fishery ever had issues with the razor clam fishery in the bay? What are the main differences in restrictions between them? Q4 – Do they feel like the MPA accomplished what it wanted? Q5 – Has it created any conflicts over the years?

Table 16: Overview of the focus groups and numbers involved in undertaking groups.

Stakeholder category	Professor Luiz Saldanha Marine Park	La Graciosa	La Palma	Dundalk Bay
Fishers		8	8	5
Multiple stakeholders	3*	6 people: 2 researchers; 2 government officers; 2 recreational fishers		

Note: (*) One fisher representative could not join due to illnesses

ANNEX 8: FOCUS GROUP GUIDELINES

Stage 1: Preparing the focus group

Defining a focus group

A focus group is a discussion led by a skilled moderator with a group of 6-10 people. The session is structured around predetermined questions, but the discussion is free-flowing and spontaneous. Ideally, comments by each participant will stimulate and influence the thinking and sharing of others. Some people may even find themselves changing their thoughts and opinions during the session. The goal is to generate a maximum number of different ideas and opinions from as many different people as possible (within the maximum group capacity of 6-10 people). The session will be minimally 90 minutes in total.

Multiple focus groups on the same topic are necessary to produce valid results, which is why each CS will have:

One focus group with different types of stakeholders (fishers, NGOs, policymakers)

One focus group with only fishers.

A focus group is NOT:	
- a debate - conflict resolution session - an interest group - educational session	- group therapy - problem-solving session - an opportunity to collaborate - a promotional opportunity

The development of a survey is undertaken with the assumption that people will know how they feel about particular topics. Such surveys are then developed to further understand such topics. However, sometimes it takes a small group setting (i.e. focus group) for someone to be able to articulate their own opinion. Focus groups create an accepting environment that puts participants at ease and allows them to answer questions thoughtfully. In the case of an online focus groups, the safe environment can be created good introductory questions and taking time for the answers. Surveys are good for collecting information, but focus groups reveal deeper insights. Planning is crucial for a well-run focus group, and this annex provides detailed instructions for conducting a high-quality focus group and making sense of the information collected.

	Interview	Focus group
Role researcher	- "investigator" - center-stage	- "facilitator" or a "moderator" - peripheral
Discussion	- Between researcher and participant - Based on conceptual framework	- Between participants - people are encouraged to talk to one another: asking questions, exchanging anecdotes and commenting on each other's experiences and points of view

Purpose of the focus groups: to understand how and why

To give examples from practice on the main findings of the study,

To include fishers' knowledge and perspectives on the relationship between MPAs and fisheries

To get deeper understanding of collective views (coming form group discussion) and the meanings that lie behind those views (including experiences and beliefs):

how and why people respond to conservation issues regarding MPA and fisheries
how they think (different points of view) and why they think that way

Designing focus group questions

Previously to the focus group, the statements must have been translated into questions. When creating questions for a focus group, the recommended number of questions is eight. The questions should be short, focused on one dimension, unambiguous, open-ended or sentence completion, non-threatening or embarrassing, and worded in a way that requires more than a simple "yes" or "no" answer. The statements that were chosen to be the core of the two rounds of discussion for each CS can be found below.

Template for focus group topics and related questions:

Date of focus group		Time	
Topic for Discussion Round 1		…	
Introduction of topic 1		…	
Aspects to discuss		[Question 1] …. [Question 2] …. Etc. (max 4)	
Topic for Discussion Round 2		…	
Introduction of topic 1		… (Or continuation of topic 1)	
Follow-up questions		[Question 5] …. [Question 6] …. Etc. (max 4)	

For each statement, it is advisable to elaborate a short introduction of the topic and how it is relevant for the case-study. Use follow-up questions to keep the discussion animated. The above table can be used when taking notes. The quality of the notes defines the quality of the output of the focus group.

Recruiting and preparing for participants

In an ideal focus group, all the participants are very comfortable with each other but none of them know each other. Homogeneity is key to maximizing disclosure among focus group participants. Homogeneity is important because it can help to create a sense of comfort and safety among participants, which can lead to greater disclosure and more candid discussion. The first criterium for the selection of participants to each of the two focus groups is their involvement and/or relevancy regarding the CS and the relation between MPA and fisheries. You can use the stakeholder analysis conducted for relevancy both in how the stakeholder is impacted, and power to influence the MPA process (1 least impact or power; 5 most impact or power).

Consider the following in establishing selection criteria for individual groups:	
- Gender	- Will both men and women feel comfortable discussing the topic in a mixed gender group?
- Age	- How intimidating would it be for a young person to be included in a group of older adults? Or vice versa?
- Power	- Would a fisherman be likely to make candid remarks in a group where an environmental activist is also a participant?

When inviting participants, it can help to reduce barriers to attending, when possible, by offering, for example, evening or weekend sessions for those who work during the day, transportation (in case of an offline session), or by hosting the session online.

List of participants

Once you know the persons that will participate, collect their basic personal information

Template for participants list:

Date		Name moderator			
Time		Name assistant			
Location					
	Respondent 1	Resp. 2	Resp. 3	Resp. 4	Etc.
First name					
Age					
Gender					
Provenance					
Education					
Family composition					
Occupation					
Etc.					

Stage 2: Conducting the focus group

Ideally, the focus group is conducted by a team consisting of a moderator and assistant moderator. The moderator facilitates the discussion; the assistant takes notes and runs the tape recorder or makes sure the Teams recording is on. At a minimum, all participants should complete a consent form. If the focus group study involves a university partner or is part of a larger research study you may also be required to secure approval from a Human Subjects Committee.

There are three types of focus group questions

- engagement questions	- introduce the topic and make participants comfortable (e.g. what is your favorite fish)
- exploration questions	- get to the main discussion, e.g. topics chosen
- exit questions	- ensure that nothing important was missed (e.g. Is there anything else you would like to say about why....)

<u>Moderator</u>

The ideal moderator should be able to listen attentively, include all participants in the discussion, have knowledge of the topic, keep personal views and ego out of facilitation, and manage challenging group dynamics. The moderator should also be relatable to the group but still able to maintain authority.

The focus group moderator has a responsibility to adequately cover all prepared questions within the time allotted, and that all participants get to talk and fully explain their answers. Some helpful probes include questions like: "Can you talk about that more?"; "Help me understand what you mean"; and "Can you give an example?". Furthermore, it is good practice for a moderator to summarize long, complex, or ambiguous comments. This demonstrates active listening and clarifies the comment for the group.

Because the moderator holds a position of authority and perceived influence, s/he must remain neutral, refraining from nodding/raising eyebrows, agreeing/disagreeing, or praising/denigrating any comment made. During a discussion, it may prove difficult to deal with some challenging participants. Some appropriate strategies for dealing with specific cases tactfully are:

> Self-appointed experts: "Thank you. What do other people think?"
> The dominator: "Let's have some other comments."
> The rambler: Stop eye contact; look at your watch; jump in at their inhale.
> The shy participant: Make eye contact; call on them; smile at them.
> The participant who talks very quietly: Ask them to repeat their response more loudly.

<u>Assistant-moderator</u>

An assistant moderator should be able to record the session, take notes, and observe subtle nonverbal cues, but should allow the moderator to lead the discussion.

<u>Prepared session script</u>

Start the session with a prepared script to welcome participants, remind them of the purpose of the group and set ground rules.

Agenda	Description	Duration	Accumulated duration
Introduction	Welcome Ground rules Overview of topic(s)	10 min.	10 min.
Getting to know the participants	Engagement question(s) See 1.3	10 min.	20 min
Discussion Round I (Topic 1)	See 1.3 Wrap-up (summary)	25 min. 5 min.	50 min.
Break	Offline: make sure there is coffee or tea	5 min.	55 min.
Discussion Round II (continuation of Topic 1 or introduction of Topic 2)	See 1.3 Wrap-up (summary)	25 min. 5 min.	1 h. 25 min.
Wrap up	Thanking participants, next steps	5 min.	1 h. 30 min

Introduction

Good afternoon/evening and welcome to this session. The reason we are having these focus groups is to find out about marine protected areas related to fisheries, particularly [topic(s) chosen]. We need your input and want you to share your honest and open thoughts with us. Thanks for taking the time to join. My name is [moderator] and assisting me is [name assistant-moderator]. I am from [institution] and work as a [role]. I have … years of experience in ………

[Name assistant-moderator] has …

[short introduction / explanation of roles regarding on moderator and assistant].

[in case there are more questions: the meeting forms part of a research project for the European Commission on marine protected areas and its influence on fisheries. In nine Member States, focus groups will be held regarding case studies of MPA's in fishing grounds in Europe – Belgium, Denmark, Ireland, Latvia, the Netherlands, Portugal (2), Spain and Sweden -].

Ground rules

We will first explain the ground rules that we have for today:

- We want you to do the talking:
- We would like everyone to participate.
- There are no right or wrong answers, only differing points of view.
- All person's experiences and opinions are important.
- We want to hear a wide range of opinions.
- We want you to feel comfortable sharing when sensitive issues come up.
- What is said in this room stays here
- Listen respectfully as others share their views, even if you don't agree,
- Rules for cellular phones: phones turned off or silent. If you must respond to a call, please do so as quietly as possible and rejoin us as quickly as you can.
- My role as moderator will be to guide the discussion, not to participate.
- If it's okay with everyone, we will be recording the discussion. People often say very helpful things in these discussions, and we can't write fast enough to write it all down. We will be on a first name basis tonight, and we won't use any names in our reports. You may be assured of complete confidentiality.

Overview of topic(s)

A couple of statements were chosen to be the core of today's discussion. These statements were, namely, indicated to be most important for their impact by the interviewees and are important factors to take into account in designing an MPA.

Getting to know the participants

We've placed name cards on the table in front of you to help us remember each other's names. Let's find out some more about each other by going around the table. Please tell us your name and what your affiliation with fisheries is.

Discussion rounds I and II

At the beginning of each round, give a (very) short introduction to the topic, then make all participants give their views on the topic by asking questions. It is preferable to have an extensive discussion among participant on one question only, then having to too many questions. Do a quick wrap-up with main conclusions from the discussion. Are there things to be added?

Wrap up

End the focus group with a thank you to all participants and inform them about how this information will be used in (the following steps) this project.

Stage 3: After the focus group

Immediately after all participants leave, the moderator and assistant moderator debrief while the recording is still on. Label or download all recording with the date, time and name of the group and make a copy.

- Note themes, hunches, interpretations, and ideas
- Compare and contrast this focus group to other groups

Systematic analysis process

- Make transcription of discussions
- Prepare report of the individual focus group in a question-by-question format with amplifying quotes
- Share report for verification with other researchers who were present at the focus group
- Look for emerging themes by question and then overall

Report

- Consider narrative style versus bulleted style
- Describe findings and use quotes to illustrate
- Sequence could be question by question or by theme
- Share report for verification with other researchers
- Revise and finalize report

Supplementary 1: Moderator Skills

Skills of the right moderator

- Exercise mild unobtrusive control
- Adequate knowledge of topic
- Appears like the participants

Be mentally prepared

- Alert and free from distractions
- Has the discipline of listening
- Familiar with questioning route

Use purposeful small talk

- Create warm and friendly environment
- Observe the participants for seating arrangements (offline meeting) or continued attention (online meeting)

Use pauses and probes

- Be not afraid of silence: 5 second pause

Probes:

- "Would you explain further?"

- "Would you give an example?"
- "I don't understand."

Record the discussion

- Tape recorders / digital recording
- Written notes

Control reactions to participants

- Verbal and nonverbal
- Head nodding
- Short verbal responses (avoid "that's good", "excellent")

Use subtle group control: Experts / Dominant talkers / Shy participants / Ramblers

Use appropriate conclusion (three step)

- Summarize with confirmation,
- Review purpose and ask if anything has been missed,
- Thanks, and dismissal

Use an assistant moderator to

- Handle logistics
- Take careful notes throughout the discussion
- Monitor recording equipment.
- Offline sessions:
- Help with equipment and refreshments
- Arrange the room
- Welcome participants as they arrive
- Sit in designated location
- Give an oral summary
- Debrief with moderator
- Give feedback on analysis and reports

Supplementary 2: Taking notes

Note taking is a primary responsibility of the assistant moderator! The moderator should not be expected to take written notes during the discussion.

Clarity and consistency of note taking

Anticipate that others will use your field notes. Field notes sometimes are interpreted days or weeks following the focus group when memory has faded. Consistency and clarity is essential.

Field notes contain different types of information. It is essential that this information is easily identified and organized. Your field notes will contain:

Quotes

Listen for notable quotes, the well said statements that illustrate an important point of view. Listen for sentences or phrases that are particularly enlightening or eloquently express a particular point of view. Place name or initials of speaker after the quotations. Usually, it is impossible to capture the entire quote. Capture as much as you can with attention to the key phrases. Use three periods … to indicate that part of the quote was missing.

Key points and themes for each question

Typically, participants will talk about several key points in response to each question. These points are often identified by several different participants.

Sometimes they are said only once but in a manner that deserves attention. At the end of the discussion round the assistant-moderator will share these themes with participants for confirmation.

Follow-up questions that could be asked

Sometimes the moderator may not follow-up on an important point or seek an example of a vague but critical point. The assistant moderator may wish to follow-up with these questions at the end of the focus group.

Big ideas, hunches, or thoughts of the recorder

Occasionally the assistant moderator will discover a new concept. A light will go on and something will make sense when before it did not. These insights are helpful in later analysis.

Other factors

Make note of factors which might aid analysis such as passionate comments, body language, or non-verbal activity. Watch for head nods, physical excitement, eye contact between certain participants, or other clues that would indicate level of agreement, support, or interest.

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