

# DELIVERABLE 5.8

## Synthesis of predicted impacts of changes in habitat and spatial management measures suggested in SEAWISE for online tool

*Version 1.0*



WP 5
Deliverable 5.8
Lead Beneficiary: HCMR
Topic: Shaping ecosystem based fisheries management
Grant Agreement No: 101000318
Dissemination level: PU
Date: 31.03.2025

Please cite this work as: Damalas, D., Astarloa Diaz, A., Bastardie, F., Batts, L., Binch, L., Bitetto, I., Bluemel, J., Depestele, J., Hervann, P.-Y., Kavadas, S., Lehuta, S., Letschert, J., Mahevas, S., Maina, I., Papadopoulou, N., Papantoniou, G., Poos, J.J., Püts, M., Romagnoni, G., Smith, C. J., Spedicato, M.-T., Tsagarakis, K., Tsikopoulou, I., van de Wolfshaar, K., Zupa, W. and Rindorf, A. (2025): SEAWISE synthesis of predicted impacts of changes in habitat and spatial management measures suggested in SEAWISE for online tool. Technical University of Denmark. <https://doi.org/10.11583/DTU.29246228>

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## Executive summary

An ecosystem approach to fisheries management requires the consideration of spatially explicit management measures and other impacts on species and the links between the distribution of fished species, their surrounding environment and productivity. Quantification of the spatial aspects of fisheries and ecology of commercially fished stocks may improve the accuracy of the predicted changes in fish productivity, fisheries yield and costs, benefits and selectivity.

The aim of this synthesis report was to synthesize all spatial aspects of stocks and fisheries spanning from environmental drivers to habitat change and management options. Furthermore, it aspires to identify any appropriate findings from WP5 that could be included in the online EBFM tool.

After a first round of investigation of available tools for predicting the impact of various spatial management options on fisheries distribution, yield, profitability, and selectivity<sup>1</sup>, SEAwisE focused on putting to the test spatial scenarios to capture the medium/long term effects of ecological and fisheries uncertainties with a **dynamic** modelling approach, deploying spatial bioeconomic models. This allowed for assessing potential changes in fishing effort such as new regulatory or ecological conditions.

Medium to long-term projections, accounting for (among others), the effects of climate change (IPCC scenarios), as well as hot-spots of commercial species (spawning/nursery grounds) and vulnerable marine life (benthos, seabirds, marine mammals, sea turtles, corals), have evaluated the feasibility of several fisheries spatio-temporal closures in the real world.

The fisheries considered were specifically:

- ◆ Demersal fisheries operating in **Western Waters** (Bay of Biscay), including vessels from Spain and France;
- ◆ Demersal fisheries operating in **Western Waters** (Celtic and Irish Sea), including vessels from Belgium, Germany, Spain, France, Ireland and England;
- ◆ Pelagic fisheries operating in **Western Waters** (Bay of Biscay), including vessels from Basque Country;
- ◆ Demersal fisheries operating in **North Sea**, including vessels from Belgium, Denmark, England, France, Scotland, Germany, Nederland, Scotland and Sweden;
- ◆ Demersal fisheries, operating in **Central Mediterranean Sea** (Adriatic and Western Ionian Sea), including vessels from Italy, Croatia, Slovenia, Albania and Montenegro;
- ◆ Demersal fisheries, operating in **Eastern Mediterranean Sea** (Eastern Ionian Sea), including vessels from Greece;
- ◆ Trawl fisheries operating in the **Western Baltic Sea**, including vessels from Denmark, Sweden, and Germany.

The scenarios investigated in SEAwisE suggest that prohibition of certain fishing practices, not only in currently designated MPAs but also in fit-to-purpose areas to limit the risk of incidental species and the degradation of benthic status, will significantly impact the overall fisheries economy and fish populations. However, this level of protection and displacement from regional scale closures seems more effective than restrictions in the currently designated MPAs only.

These fit-to-purpose areas need to be explicitly designed to safeguard vulnerable stages for exploited stock, bycatch risk of unwanted species, and sensitive benthic habitats while improving spatial and gear selectivity. Such **spatial conservation measures** will induce negative short-term effects on the fisheries (e.g.: decreased catches and increased operating costs due to effort displacement to surrounding or distant areas) as well as potentially harmful counterproductive effects on biodiversity in some occurrences. However, these may eventually be balanced out over the long term if stock and ecosystem recovery is accounted for.

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<sup>1</sup> D.5.7. "Synthesis of predicted impacts of changes in habitat and spatial management measures suggested **outside** SEAwisE for online tool" <https://doi.org/10.11583/DTU.28079366>

SEAwisE highlights that spatial management should be applied complementary to existing **non-spatial management measures** (e.g.: effort restrictions, quotas, technical measures), and of course **proper governance and incentives** to limit the resistance to change. It is worth mentioning that in the long term, a **changing climate** could be overwhelmingly affecting fish and fisheries' productivity and the marine ecosystems at large, suggesting that more drastic conservation measures may be needed.

Finally, a dedicated WP5 Synthesis workshop among SEAwisE partners and exchanges with the stakeholders in the course of meetings with the EU Fisheries Advisory Councils<sup>2</sup> provided feedback for the development of SEAwisE **EBFM tool and toolbox**, which contains the results of the spatially explicit approaches investigated in the course of SEAwisE realization.

		1. Our Ocean	2. HKE Nursery	3. All MPAs	4. Combined
<b>Bi indicators</b>	Total Bi	-0.004	0.000	0.002	0.069
	Fish biomass	-0.031	0.001	0.018	0.545
	Chondrichtyans biomass	0.000	0.000	0.000	0.001
	Mammal and bird biomass	0.000	0.000	0.000	0.000
<b>Catch indicators</b>	Total Catch	0.211	-0.159	-1.065	-13.901
	Fish catch	1.251	0.859	-0.115	-12.890
	Chondrichtyans catch	0.146	0.490	0.284	-14.434
	Mammal and bird bycatch	0.870	0.495	-2.770	-14.443

*Example of relative change (%RC) for biomass (Bi) and catches indicators under four scenarios relative to the baseline scenario in the eastern Ionian Sea.*

<sup>2</sup> [https://oceans-and-fisheries.ec.europa.eu/fisheries/scientific-input/advisory-councils\\_en](https://oceans-and-fisheries.ec.europa.eu/fisheries/scientific-input/advisory-councils_en)

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# 1. SEAwisE background

The SEAwisE project works to deliver a fully operational tool that will allow fishers, managers, and policy makers to easily apply Ecosystem-Based Fisheries Management (EBFM) in their own fisheries. With the input from advice users, SEAwisE identifies and addresses core challenges facing EBFM, creating tools and advice for collaborative management aimed at achieving long-term goals under environmental change and increasing competition for space. SEAwisE operates through four key stages, drawing upon existing management structures and centred on stakeholder input, to create a comprehensive overview of all fisheries interactions in the European Atlantic and Mediterranean. Working with stakeholders, SEAwisE acts to:

- ◆ Build a network of experts - from fishers to advisory bodies, decision makers and scientists - to identify widely-accepted key priorities and co-design innovative approaches to EBFM.
- ◆ Assemble a new knowledge base, drawing upon existing knowledge and new insights from stakeholders and science, to create a comprehensive overview of the social, economic, and ecological interactions of fisheries in the European Atlantic and Mediterranean.
- ◆ Develop predictive models, underpinned by the new knowledge base, that allow users to evaluate the potential trade-offs of management decisions, and forecast their long-term impacts on the ecosystem.
- ◆ Provide practical, ready-for-uptake advice that is resilient to the changing landscapes of environmental change and competition for marine space.

The project links the first ecosystem-scale impact assessment of maritime activities with the welfare of the fished stocks these ecosystems support, enabling a full-circle view of ecosystem effects on fishing productivity in the European Atlantic and Mediterranean. Drawing these links will pave the way for a whole-ecosystem management approach that places fisheries at the heart of ecosystem welfare. In four cross-cutting case studies, each centred on the link between social and economic objectives, target stocks and management at regional scale SEAwisE provides:

- ◆ Estimates of impacts of management measures and climate change on fisheries, fish and shellfish stocks living close to the bottom, wildlife bycatch, fisheries-related litter and conflicts in the use of marine space in the Mediterranean Sea,
- ◆ Integrated EBFM advice on fisheries in the North Sea, and their influence on sensitive species and habitats in the context of ocean warming and offshore renewable energy,
- ◆ Estimates of effects of environmental change on recruitment, fish growth, maturity and production in the Western Waters,
- ◆ Key priorities for integrating changes in productivity, spatial distribution, and fishers' decision-making in the Baltic Sea to create effective EBFM prediction models.

Each of the four case studies will be directly informed by expert local knowledge and open discussion, allowing the work to remain adaptive to change and responsive to the needs of advice users.

## 1.1 The role of this deliverable

The main objective of Task 5.6 (Synthesis of predicted impacts of spatial changes) is to summarise the impacts of spatial changes on fish productivity and fisheries by assembling geographic layers of key human pressures and predictions of species distribution and habitat type/extent from Tasks 5.1-5.5 and fisheries. These are then used as input to spatial restriction scenarios in a suite of spatial bioeconomic fisheries models to provide insights to the performance of different spatial management measures. Deliverable 5.8 summarises results from SEAwisE D.5.5, D.5.6 and D.5.7 and is the final deliverable in WP 5.

## 1.2 Contributors

Names and institutions of people involved in these roles are given in Table 1.

Table 1. Names and roles of contributors to this deliverable

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## 1.3 Acronyms and abbreviations

AER:	Annual Economic Report;
ARS:	Giant red shrimp
CFP:	Common Fishery Policy;
CC:	Climate Change
EBFM:	Ecosystem Based Fisheries Management
DOI:	Digital Object Identifier
DPS:	Deep water rose shrimp
FUI:	Fuel Use Intensity;
GFCM:	General Fisheries Commission for the Mediterranean;
GSA:	Geographical Sub-Area (GFCM sensu);
FRA:	Fisheries Restricted Area
HCR:	Harvest Control Rules
HKE:	European Hake
LO:	Landing Obligation
LSF:	Large Scale Fishery
MEDAC:	Mediterranean Advisory Council
MPA:	Marine Protected Area
MSE:	Management Strategy Evaluation
MSY:	Maximum Sustainable Yield ( $F_{MSY}$ : fishing at MSY)
MUT:	red mullet
OWF:	Offshore Wind Farms
PDF:	Portable Document Format
PET:	Protected, Endangered, Threatened
PGY:	Pretty Good Yield
RBS:	Relative Benthic Status
SDM:	Species distribution models
STECF:	Scientific, Technical and Economic Committee for Fisheries;
SRR:	Stock-Recruitment Relationship
SSB:	Spawning Stock Biomass
SSF:	Small Scale Fishery;
VME:	Vulnerable Marine Ecosystem
WP:	Work Package



## 2. Predicting effect of changes in ‘fishable’ areas on fish and fisheries

Deliverable 5.8 summarizes the work described in Task 5.5 with specific focus on the outcomes of D.5.6. “report on effects of spatial management measures suggested in SEAwise to safeguard species, habitats and choke species on fisheries selectivity and fuel cost”. Effects of spatial management on fish, fisheries and the ecosystem by selecting fit-to-purpose areas, rather than just considering current spatial management schemes in place was covered in D.5.7., and a brief overview of outcomes is included here. WP5 has used two approaches to effort redistribution, a static approach (effort is redistributed proportionally to current effort outside the closed area) and a dynamic approach (fisher behavioural models are used to redistribute effort).

In the static approach, the following spatial management schemes were investigated:

- Non-trawlable areas,
- EU Natura 2000 sites (phasing out bottom trawling by 2030),
- Nationally based designated areas (CDDA),
- 2019 EU Technical Measure Regulation,
- EU Deep-sea access regulation (COM 1614/2022),
- Areas designated by regional conventions (e.g. HELCOM, GFCM).

While in the dynamic approach, fit-to-purpose areas, were selected for closure on the basis of:

- the effect on other components of the ecosystem (benthos, bycatch)
- the effect on non-exploited marine living resources in general
- the impact on fisheries distribution, yield, profitability, selectivity, and fuel use
- fishers’ decision-making when displacing effort

The aforementioned investigations, allowed us to reason on two key questions raised in the beginning of this project:

- What are the costs and benefits of closing 30% of the sea-bottom to fishing (30 x 30 strategy) to fishers and the ecological system?
- How do the effects of spatial management differ from those of non-spatial management?

### 2.1 Spatial data compilation

SEAwise compiled datasets of spatial information layers on:

- Conservation areas (NATURA2000, MPAs, etc.)
- Other restricted areas to fishing (wind farms, aquaculture sites, mining, drilling sites, etc.)
- Areas with spatial fisheries management (e.g. spatio-temporal closures) like FRAs and VME in the Med (GFCM measures)

The areas fall under the following categories, excluding part or all fishing activities:

- Non-trawlable areas: in the Med, non-trawlable areas are areas <50m depth (or inside 3nm from the coastline) or >1000m depth, in NEA non-trawlable areas are areas >800m in depth
- EU Natura 2000 sites (with or without an associated management plan)
- Nationally based designated areas (CDDA)

- 2019 EU Technical Measure Regulation (closed areas to fishing to certain gear types)
- EU Deep-sea access regulation (where demersal trawlers should not exceed the historical footprint) resulting in a closure of 87 boxes to bottom contacting gears fishing defined and enforced in 2022
- Areas designated by regional conventions (e.g. HELCOM, GFCM)

Furthermore, SEAwise has taken into account the EU Marine Action Plan suggestion to protect and restore marine ecosystems for sustainable and resilient fisheries (EC, 2023) which includes:

- ◆ a roadmap to **phase out all bottom trawling** activities in already designated areas by 2030 and from any newly designated MPAs.
- ◆ Setting 30% of the EEZ surface area under protection, including 10% strictly protected (**EU Biodiversity Strategy for 2030 - “30 x 30”**).

The data collected and processed within SEAwise for this task include:

- ◆ Species distribution (SEAwise D5.2)
- ◆ Fishing footprint (SEAwise D5.3)
- ◆ Habitat maps (Essential Fish Habitats, fish sensitive habitats/changes - SEAwise D5.4)
- ◆ PETS bycatch risk maps (SEAwise D4.2)
- ◆ Benthic impact layers SEAwise (D4.3)
- ◆ Marine litter density maps (SEAwise D4.5)

## 2.2 Spatial management scenarios

Spatial management measures (restrictions of marine space for fishing) and other uses of marine space (e.g. offshore wind farms) or unwished externalities (e.g. water pollution and dead zones) will result in fishing effort displacement. Scenario-based testing was conducted to examine the interrelated effects of management options and stock productivity. As several conservation areas (zones), mentioned in the previous section, lacked management plans outlining fishing restrictions, SEAwise assigned limitations to certain fishing techniques based on the perceived vulnerability of specific areas to these practices. This approach has allowed for an examination of how these restrictions would potentially affect fish and fisheries. The 'fishable area' was defined as the marine space left for fishing but also the space suitable for fishing given the physical constraints of the marine environment.

At the first step, a **static** approach evaluated fisheries displacement based on the expected profitability of a fishing zone. Afterwards, accounting for the **dynamic** nature of the exploitation, bioeconomic models were employed to investigate how changes in marine space usage will affect fisheries opportunities and the ecosystem in general (Fig. 2.2.1).

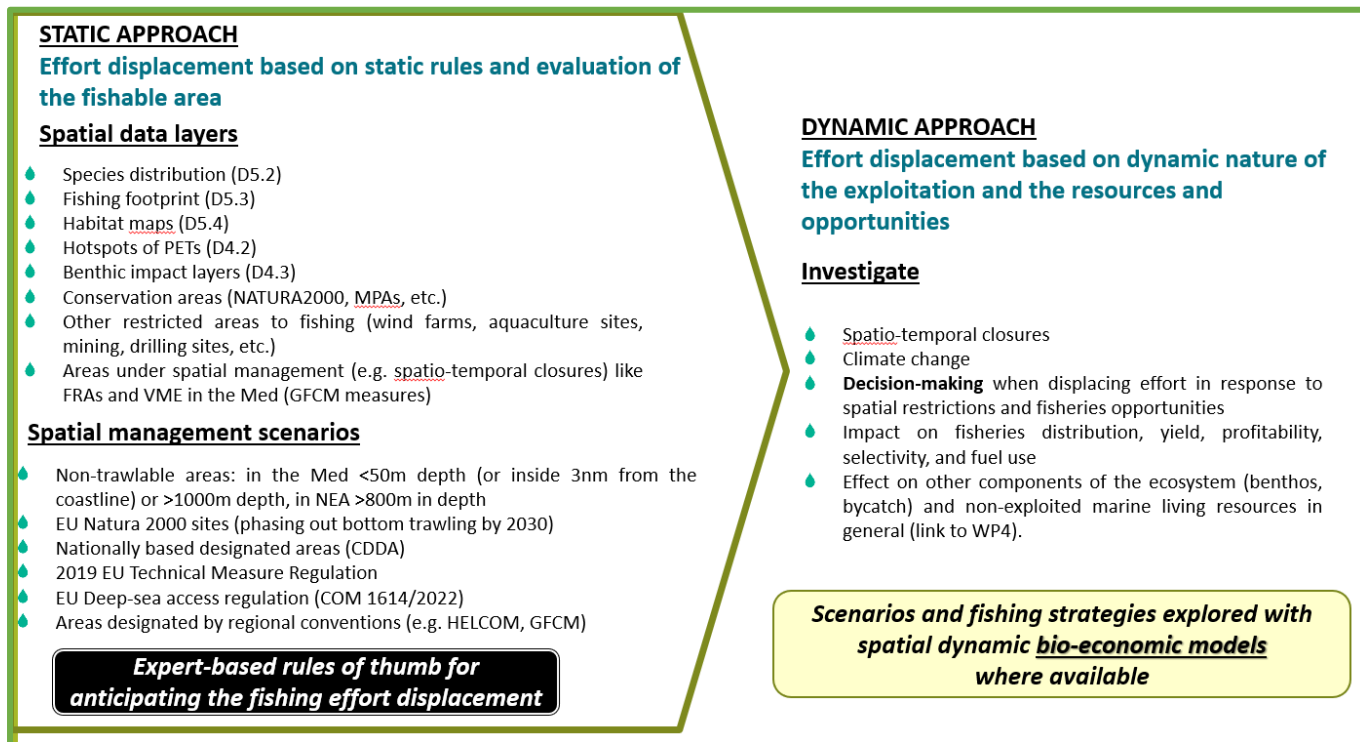


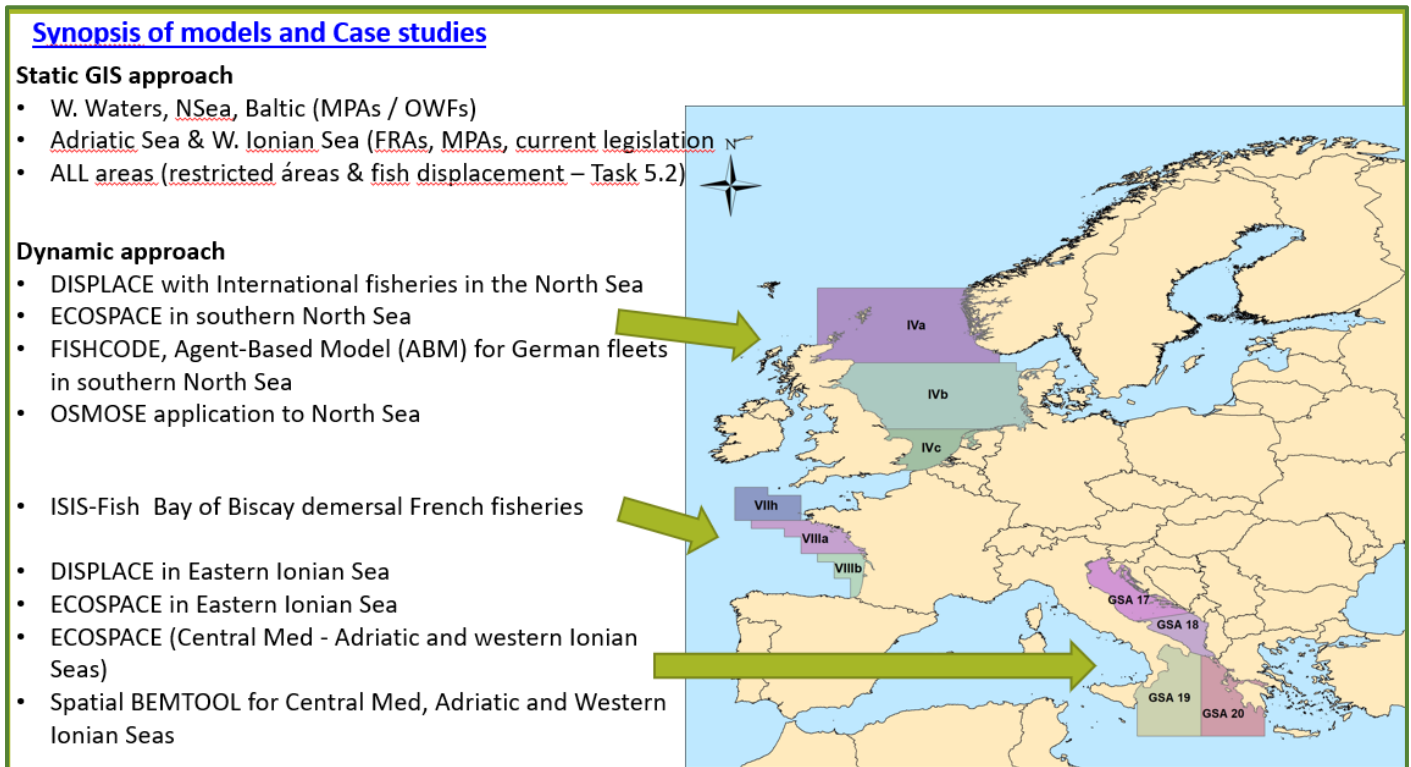
Figure 2.2.1. SEAWISE implementation steps to assess the effect of spatial management on fish, fisheries and the ecosystem

An overview of the case studies, fleets/fisheries, and modelling approaches investigated are provided in Table 2.2.1.

Table 2.2.1. Modelling approaches of changes in 'fishable' areas by region and fishery investigated in SEAWISE.

Modelling approach	Region	Fleet/Fishery
Static	Western Waters, North Sea, Baltic Sea	35 metiers
Static	Adriatic Sea (GSA 17-18) & W. Ionian Sea (GSA19)	OTB, others
Static	ALL	numerous
Dynamic with DISPLACE	North Sea	International fisheries
Dynamic with DISPLACE	Mediterranean Sea (East Ionian Sea GSA20)	OTB, PS, GNS, GTR, LLS
Dynamic with ECOSPACE	Mediterranean Sea (East Ionian Sea GSA20)	All
Dynamic with ECOSPACE	Mediterranean Sea (Adriatic and western Ionian Sea GSA17-18-19)	37 fleets
Dynamic with BEMTOOL	Mediterranean Sea (Adriatic and western Ionian Sea GSA17-18-19)	27 fleet segments
Dynamic with FISHCODE	Southern North Sea	Beam trawl, Otter bottom trawl
Dynamic with OSMOSE	North Sea	14 metiers
Dynamic with ECOSPACE	Southern North Sea	12 fleets
Dynamic with ISIS-Fish	Bay of Biscay	41 demersal fleets

A synopsis of modelling approaches and case studies investigated is given in Fig. 2.2.2.



**Figure 2.2.2.** Synopsis of modelling approaches and case studies investigated in SEAWise to assess the effect of spatial management on fish, fisheries and the ecosystem

## 3. Effects of spatial management measures

In addition to fishing, other human activities impact the marine environment (e.g. mining, drilling, tourism, maritime shipping) and induce habitat degradation (e.g. eutrophication, acidification). Moreover, climate change is accelerating warming of waters which in turn favors invasive thermophilic species establishment. All these challenges limit the space available for fishing. Conservation measures have been implemented to limit specific fishing techniques and areas to address the negative impact of fishing. SEAWise aimed to evaluate the optimal placement of spatial mitigation plans to safeguard short-term profitability and long-term ocean productivity while protecting sensitive species and vulnerable habitats.

Two different approaches were employed depending on the data availability to estimate the possible effects of spatial restrictions:

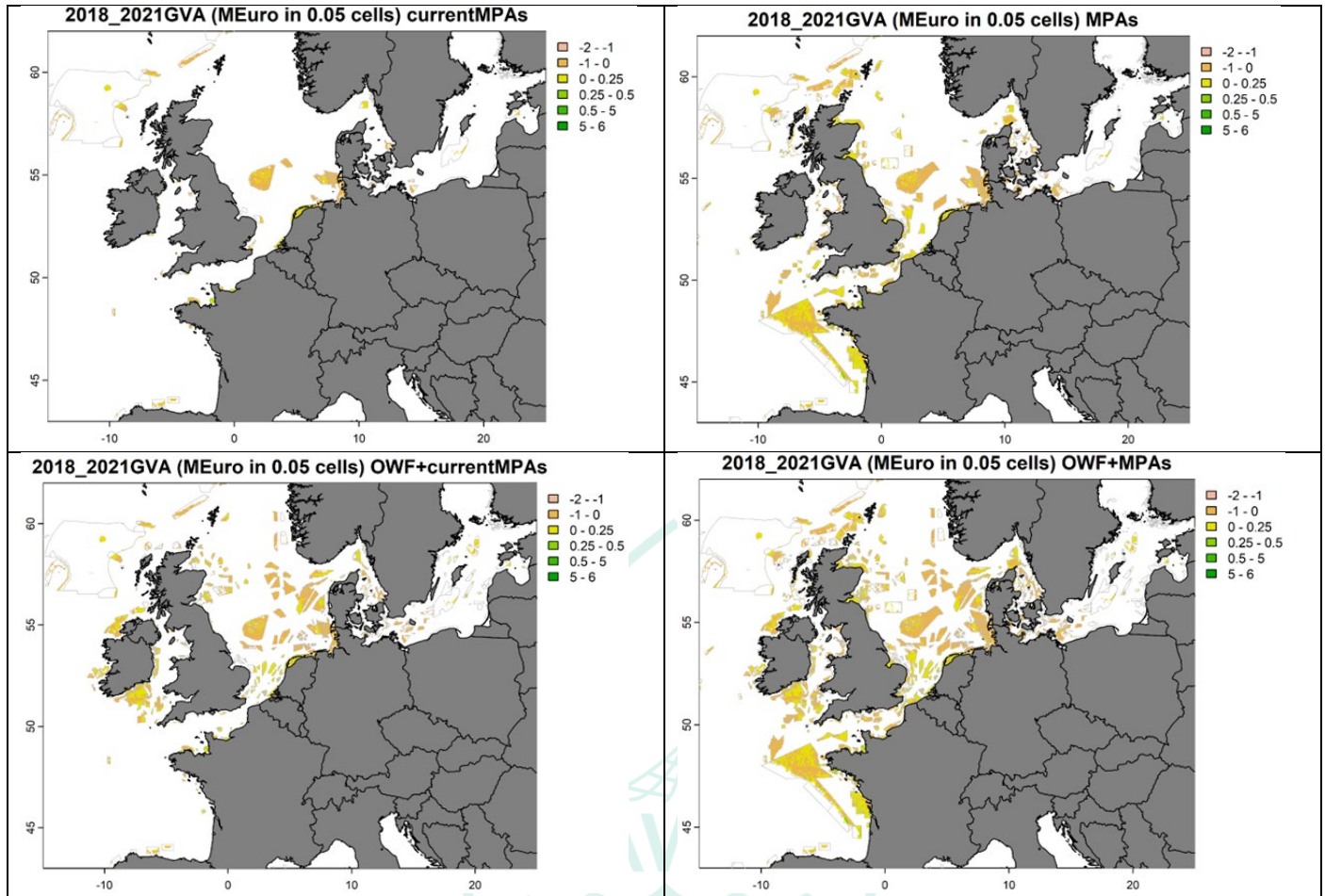
The **static approach** assumed effort displacement in the short term that is proportional to historical fishing effort distribution. This means that fisheries distribution is disconnected from changes in the underlying population dynamics and distribution of fish. In contrast, **dynamic** bioeconomic modelling accounts for fishers' decision-making. As empirical data on human decision-making is limited, most fisheries dynamics models aim to maximize economic gains. Some of the bioeconomic models deployed herein made an effort to capture the complex dynamic effects of fishers' behavior and motivation, as well as the unpredictable market demand fluctuations (Andrews et al. 2020, Wijermans et al. 2020).

### 3.1 Static approach: Western Waters, North Sea, Baltic Sea

The scenarios evaluated included the restriction of specific fishing techniques in current MPAs, as well as restriction of all fishing activities in MPAs and Offshore Wind Farms (OWF) concession areas. Outcomes were assessed on the basis of value of landings (by species/stocks/total) and the reduction of effort in comparison to 2018-2021.

Excluding fishing in the designated MPAs leads to unbalanced outcomes for the different regions; in the Bay of Biscay, fishable area will reduce by 36%, while in the Baltic Sea this number is close to 10%, as MPAs do not overlap with major fishing grounds. The result in the fisheries profitability is shown in Fig.3.1 in terms of Gross Value Added (GVA).

To assess the impact on benthic habitats restriction of all mobile bottom contacting gears was simulated for all designated conservation areas (MPAs) in the North Sea and Northwestern waters (Irish Sea, Bristol Channel and Celtic Sea North). The simulated MPAs covered 8% and 7% of the surface areas of the North Sea and NWW respectively, and were selected as sites which may be protected in the framework of Natura2000 habitats that are considered vulnerable to bottom trawling or have directive invertebrate species present (Van Hoey et al., 2024). Displaced fishing effort reduced the area with very low Relative Benthic State (RBS) while increasing those with very high RBS values. RBS values within MPAs will be higher, while area at regional level that has RBS > 0.8 does not change proportionally with the area closed. In the western waters case, the changes were very localized. When looking at level and distribution of RBS within ICES subarea or MSFD habitat type the difference between the scenarios was negligible, even where relatively large areas were restricted to fishing.



**Figure 3.1.** Estimates of averaged Gross Value Added (GVA) lying within the studied restricted areas alongside the spatial scenarios. (green is positive – yellow/orange is negative)

Bycatch risk was assessed for four protected cetacean species commonly found in Irish waters through a PSA approach (Astarloa et al. 2024): harbour porpoise (*Phocoena phocoena*), common bottlenose dolphin (*Tursiops truncatus*), common minke whale (*Balaenoptera acutorostrata*), and the short-beaked common dolphin (an ecotype of the common dolphin *Delphinus delphis*) (Astarloa et al, 2024). Fishing effort of netters, demersal trawls, beam trawls and dredges were displaced for the current SACs and SPAs in Irish waters in of a “future” scenario. Effort was displaced from sites with directive habitats or species considered vulnerable to those gears. These designations do not cover large areas and are mainly localized along the Irish coasts. Generally, the bycatch risk in mobile gears was low, where bycatch risk in netters was generally high for common bottlenose dolphin and short-beaked common dolphin and medium for harbour porpoise and minke whale. Findings indicated that for the gear and species investigated there was negligible change in the level and distribution of overall bycatch risk when spatial management was implemented. However, there were some notable patterns and localised changes in risk, particularly with the higher risk gear (set nets).

In the Bay of Biscay, the bycatch risk of short-beaked common dolphin and Balearic shearwaters (*Puffinus mauretanicus*) was assessed following the same methodology as in the Irish waters (Astarloa et al. 2024). Closures and static effort displacements were simulated for demersal trawlers, which were only excluded from coastal MPAs, and for gill netters which were excluded from larger areas, including also offshore MPAs. For common dolphin, the medium bycatch risk in demersal trawlers decreased in quarter 2 from 96% to 84% of the area with 10% no-take zone. Similarly, the medium bycatch in quarter 3 decreased from 84% to 75% with 9% no-take zone. High bycatch

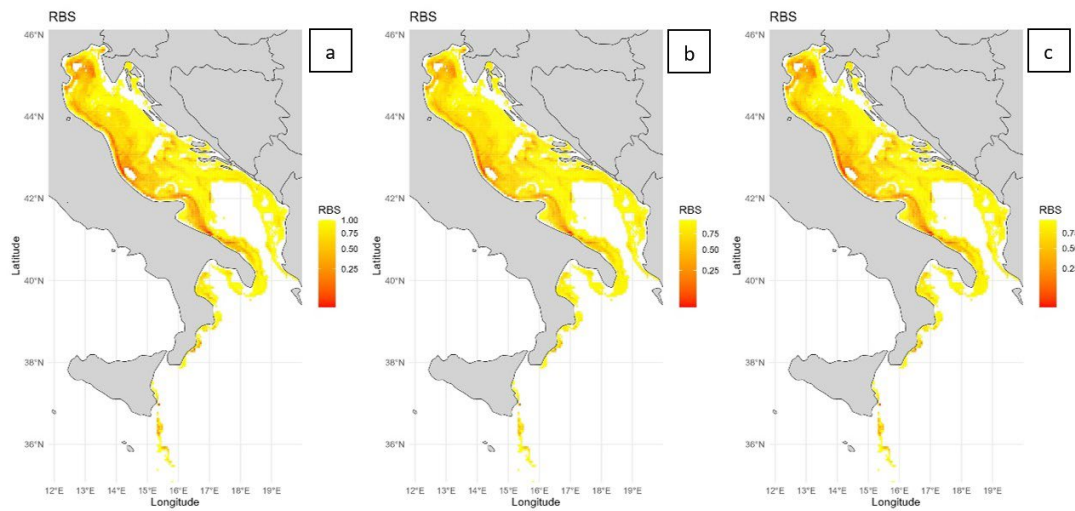
risk area (16%) was not affected by the MPAs in this quarter of the year. The bycatch risk in netters decreased in quarter 2 with 41% from medium to no bycatch, while medium bycatch risk in quarter 3 decreased from 88% to 43% with 41% no-take zone. High bycatch risk increased from 12% to 16% in quarter 3. For Balearic shearwater and gill netters, medium bycatch risk decreased from 100% to 56% with 44% no-take zone; for demersal trawlers, low risk decreased from 99.6% to 76%, but with no increase in risk, as all the remaining area become no take (24%). Overall, the bycatch risk was substantially reduced by the simulated implementation of (large areas of) the MPAs.

## 3.2 Static approach: Adriatic Sea (GSA 17-18) & W. Ionian Sea (GSA19)

Three major scenarios were investigated and compared to the baseline (status quo) scenario to assess the effect of fishing effort static displacement on trawler fleets in terms of changes in Gross Value Added (GVA):

- ◆ Sc. 0: **Baseline (SQ)** - closure areas already implemented (Natura 2000, FRAs, Marine Protected Areas, Areas of Biological Conservation, 3 NM permanent closures for trawlers and 4 NM and 6 NM);
- ◆ Sc. 1: **closure areas without any effort reduction** - the scenario simulates the implementation of spatio-temporal closures, such as *Isidella elongata* VME in the Southern Adriatic, the F FRA from 1000m to 800m depth, the Essential Fish Habitats (EFH) of HKE, DPS and ARS, the hotspot for the longnose spurdog (*Squalus blainville*), and the areas where the relative benthic state (RBS) is < 0.8.
- ◆ Sc. 2: **closure areas combined with  $F_{MSY}$  target** - Implements Scenario 1 closures, combined with fishing effort reduction measures in line with the Adriatic MAP in GSA 17 and 18, aimed to achieve FMSY for European hake by 2026. In the Western Adriatic (GSA 19), set to achieve FMSY for HKE19 by 2026, following the Adriatic MAP approach.
- ◆ Sc. 3: **closure areas combined with PGY target** – Implements Scenario 1 closures, combined with effort reduction based on multi-species Pretty Good Yield (PGY), optimizing fishing mortality to ensure at least 95% of the maximum yield for key stocks (European hake and deep-water rose shrimp).

Closing highly exploited areas (RBS < 0.8) showed significant effort redistribution, leading to large GVA displacement while deep-water restrictions (800m closures) had a limited impact on fishing effort redistribution. The GVA reduction was not uniformly distributed across regions and fleet segments, with GSA 19 experiencing the highest impact (having never faced effort regulations like those in the Adriatic), especially for the fleet vessels from 12-18 m length. The  $F_{MSY}$  scenario shows a more effective reduction of the proportion of the benthic impacted area (RBS < 0.8) showing a reduction of the risk level associated in some habitats of the Adriatic Sea (Figure 3.2, frame b). In the PGY scenario, the combined effect of fleet displacement and a lower reduction in fishing effort often leads to a lower reduction in the extent of impacted areas across the study regions in comparison to  $F_{MSY}$  scenario (Figure 3.2, frame c), due to the higher reallocation of effort in other areas explored by the fleets.



**Figure 3.2.** Maps of relative benthic state (RBS) estimated according to the simulated management scenarios: a) scenario 1 with proposed closures; b)  $F_{MSY}$  scenario with closures; c) PGY scenario with closures.

### 3.3 Static approach: All areas

The scenario investigated the effect of restricted areas and displacement of fish species. Species distribution deduced from SEAwisE Task 5.2 were overlaid to the restricted areas (MPAs, OWFs, and their combinations) to detect which species had the lowest density inside the restrictions and which had higher density outside the restricted areas. Most of the exploited species had an average density that was higher outside restricted areas (red in Fig. 3.3), whatever the scenario.



**Figure 3.3.** How many times more the density is bigger in a given type of area (closed or opened) given by the ratio of average density of each species in a type of area (either closed or opened) over the other type of area, the restricted areas being defined by the restriction scenarios.

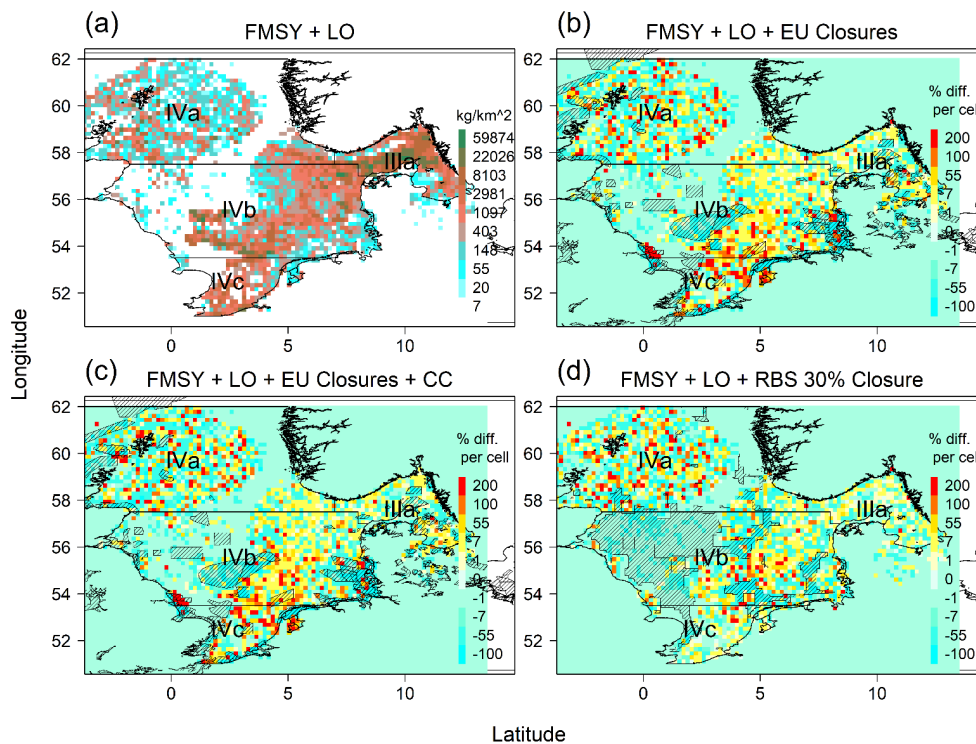
(Red is higher outside the restricted areas; green is higher inside the restricted areas)

### 3.4 Dynamic with DISPLACE: North Sea

All scenarios investigated assumed that fishing pressure will be within safe biological limits ( $F_{MSY}$ ) and that the landing obligation restrictions are respected (discard ban). Furthermore, exclusion of fishing activities was examined in EU closed areas (N2000 sites, MPAs), RBS (30% per habitat type, based on the RBS indicator) and CC (ad hoc climate change effect affecting growth and recruitment) combined in the following scenarios:

- Sc 1.  $F_{MSY}$  + Landing Obligation (LO) regime.
- Sc 2.  $F_{MSY}$  + LO regime + EU closed areas
- Sc 3.  $F_{MSY}$  + LO regime + closed areas (RBS)
- Sc 4.  $F_{MSY}$  + LO regime + EU closed areas + CC

Overall swept area by towed gears in contact with the seabed is not reduced but displaced by area closures. RBS increases in areas where bottom fishing does not occur and decreases in areas where it does. There are no obvious benefits from restricting access to the currently designated EU protected areas, as these areas did not have substantial bottom fishing with the exception of beam trawling for brown shrimp, which was not included in the analysis. Protecting high RBS areas may lead to a net gain in RBS with a large potential for recovery (preservation of 30% of the highest RBS area) and it is possible that climate change may positively impact the French fleet.



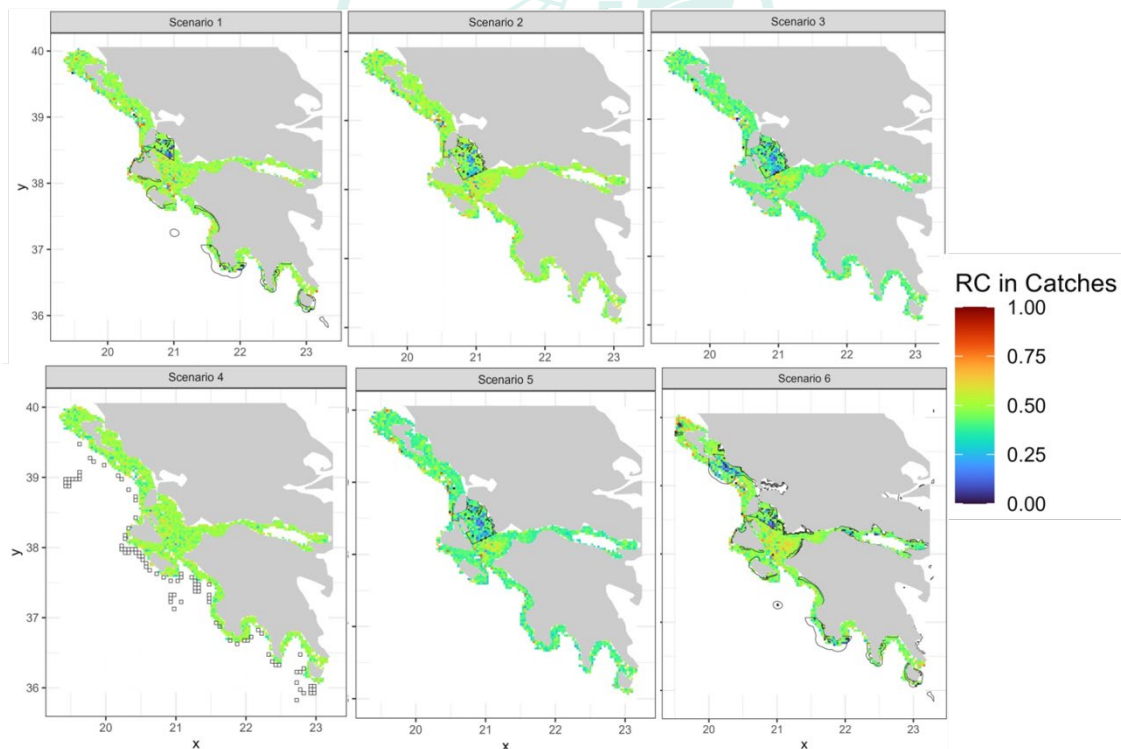
**Figure 3.4.** Modelled catches with DISPLACE in a 10y horizon from the activities of the international fisheries in the North Sea, without constrains (a), or with spatial plans including b) EU Closures (see section 3), c) 30% surface area closure to protected the highest Relative Benthos Status (RBS) areas, d) EU Closure plus assumption on effects of climate change (CC) on vital rates (growth and recruitment success).

### 3.5 Dynamic with DISPLACE: Mediterranean Sea (East Ionian Sea GSA20)

A range of management options were investigated, focusing on scenarios related to (i) spatiotemporal prohibitions to fishing to protect nursery grounds and other sensitive habitats, (ii) input control measures (fishing effort reduction) and (iii) climate change.

- Sc 0. Business as usual (status quo)
- Sc 1. Restricting bottom trawl (OTB) in the Natura2000 areas
- Sc 2. Restricting OTB from HKE nurseries.
- Sc 3. Restricting OTB from HKE nurseries and -15% on effort
- Sc 4. Restricting OTB from sensitive areas for benthos.
- Sc 5. Restricting OTB from HKE nurseries and -15% on effort + RCP 8.5 climate scenario
- Sc 6. Restricting bottom trawl (OTB) on all MPA areas

The most effective management measures were **closing Hake Nursery** grounds while **reducing** overall fishing **effort** (Sc.3 & Sc. 5 - Fig 3.5) and to effectively **monitor and control of SSF**. Including **climate change indicated that this may outweigh plausible benefits** of area closures.



**Figure 3.5.** Relative change (RC) in accumulated landings (for all métiers and species under investigation) for scenario 1-6. Landings are given as the accumulated tons respectively over 10-year simulation averaged over the 50 replicates for the all stocks included in the eastern Ionian Sea DISPLACE application. If RC is 0.5 means no difference with the baseline scenario; if RC is >0.5 values of scenario are higher than the baseline and lower otherwise

### 3.6 Dynamic with ECOSPACE: Mediterranean Sea (East Ionian Sea, GSA20)

The impact of a range of spatial closures in different time steps were evaluated with dynamic simulations up to 2050:

- Sc 0. baseline scenario including Fisheries Restricted Areas (FRAs), existing permanent and seasonal closures for trawling, purse seining and small-scale fisheries (SSF) (Bastardie et al., 2023), all defined based on local, national and/or EU regulations
- Sc 1. OTB closures in 14 Natura sites as proposed for Greece during the recent 9th Our Ocean Conference
- Sc 2. OTB closures in nursery areas for hake as designated in SEAWISE D5.2 (Sys et al., 2022).
- Sc 3. Annual spatial closures for OTB in all MPAs designated in the EIS.
- Sc 4. Scenario 2 combined with a 15% reduction in fishing effort for all fishing gears throughout the entire study area (GSA20) under climate change scenario RCP8.5.

It is likely that the broader impact of **small-scale fisheries may have been overlooked**, as decreasing SSF fishing pressure seems to contribute substantially to hake recovery.

OTB closures in 14 Natura sites led to increased catches but slight declines in biomass. OTB closures in nursery areas for hake led to **decreased total catches** but **increased fish catches and bycatch**. There were no changes in biomass. Closures in hake nursery areas combined with a 15% reduction in fishing effort under climate change scenario RCP8.5 **increased stock biomass and IUCN species biomass** but had a **detrimental impact on catches**. Accounting for climate change led to **declines in catches** and the **Biodiversity** (Fig. 3.6).

		1. Our Ocean	2. HKE Nursery	3. All MPAs	4. Combined
<b>Bi indicators</b>	Total Bi	-0.004	0.000	0.002	0.069
	Fish biomass	-0.031	0.001	0.018	0.545
	Chondrichtyans biomass	0.000	0.000	0.000	0.001
	Mammal and bird biomass	0.000	0.000	0.000	0.000
<b>Catch indicators</b>	Total Catch	0.211	-0.159	-1.065	-13.901
	Fish catch	1.251	0.859	-0.115	-12.890
	Chondrichtyans catch	0.146	0.490	0.284	-14.434
	Mammal and bird bycatch	0.870	0.495	-2.770	-14.443

*Fig. 3.6. Relative change (%RC) for biomass and catches indicators under the four scenarios against the baseline scenario in the eastern Ionian Sea.*

### 3.7 Dynamic with ECOSPACE: Mediterranean Sea (Adriatic and western Ionian Sea GSA17-18-19)

The aim was to evaluate the potential effects of new spatial closures in the study area and in particular: (i) Essential Fish Habitats (EFH) of key commercial species contributing to the improvement of exploitation patterns, (ii) the hotspot of a demersal shark bycatch species and (iii) the areas characterized by low levels of relative benthic status (RBS <0.8). Four scenarios were evaluated for change up to 2030:

- Sc 0. Status Quo (“SQ”) closure areas already implemented (Natura 2000, FRAs, Marine Protected Areas, Areas of Biological Conservation, 3 NM permanent closures for trawlers and 4 NM and 6 NM); fishing effort maintained at the levels of 2024.
- Sc 1. Closure areas planned and proposed (“SQ\_closure”). The scenario simulates the implementation of spatio-temporal closures, such as *Isidella elongata* VME in the Southern Adriatic, the F FRA from 1000m to 800m depth, the Essential Fish Habitats (EFH) of HKE, DPS and ARS, the hotspot for the longnose spurdog (*Squalus blainville*), and the areas where the relative benthic state (RBS) is < 0.8.
- Sc 2. closure areas combined with Fmsy target (“Fmsy\_closure”). As per Scenario 1 closures, combined with fishing effort reduction measures in line with the Adriatic MAP in GSA 17 and 18, aimed to achieve FMSY for European hake by 2026. In the Western Adriatic (GSA 19), set to achieve FMSY for HKE19 by 2026, following the Adriatic MAP approach.
- Sc 3. closure areas combined with PGY target (“PGY\_closure”). As per Scenario 1 closures, combined with effort reduction based on multi-species Pretty Good Yield (PGY), optimizing fishing mortality to ensure at least 95% of the maximum yield for key stocks (European hake and deep-water rose shrimp).

Results suggest that (Figs 3.7, 3.8) closures without effort reduction provide moderate **increase in the biomass of juvenile commercial species when protecting Essential Fish Habitats** (especially red shrimps), with negligible effects on ecosystem indicators across guilds and elasmobranchs. Closures combined with effort reduction (Fmsy) results in substantial **increased biomass and reduction of catch of adults, and decreased juveniles' bycatch. Moreover, Apex fish predators, subapex demersal predators, benthic feeding invertebrates and demersal sharks show positive effects with increase in biomass.** The closures combined with effort reduction (PGY) resulted in moderate increase of biomass, reduction of catch of adults, and reduction of **juveniles' bycatch** (hake, red shrimps). **Biomass of Apex fish predators increases**, but for other guilds and elasmobranch groups biomass changes are marginal.

		Biomass				Catch			
		SQ_closure vs SQ	Fmsy_closure vs SQ_closure	PGY_closure vs SQ_closure	PGY_closure vs FMSY_closure	SQ_closure vs SQ	Fmsy_closure vs SQ_closure	PGY_closure vs SQ_closure	PGY_closure vs FMSY_closure
Juveniles	Hake GSA 17-18	1.6%	-3.9%	-8.6%	-4.9%	7.3%	-34.2%	-19.1%	22.9%
	Deep-water rose shrimp	1.0%	2.6%	1.9%	-0.7%	3.3%	-17.6%	-1.7%	19.3%
	Red Shrimps	10.6%	7.9%	2.4%	-5.1%	28.9%	-18.2%	-7.5%	13.1%
Adults	Hake GSA 17-18	-0.8%	22.3%	10.0%	-10.0%	0.3%	-6.6%	-1.2%	5.8%
	Deep-water rose shrimp	-3.2%	17.2%	3.8%	-11.4%	2.5%	-5.1%	-4.4%	0.7%
	Red Shrimps	14.4%	27.4%	8.0%	-15.2%	3.0%	-8.2%	-3.8%	4.8%

Fig. 3.7. Predicted changes (%) in biomass and catch by species and life stage for the key commercial species considered for the EFH under the different scenarios. Blue cells indicate negative change, red cells the positive ones

Biomass indicators	SQ_closure vs SQ_no_closure	Fmsy_closure vs SQ_closure	PGY_closure vs SQ_closure	PGY_closure vs FMSY_closure
Total Biomass (excl. detritus)	0.0%	0.1%	0.0%	-0.1%
Total fish Biomass	-0.1%	0.2%	-0.1%	-0.3%
Apex fish predators	-0.5%	12.4%	6.6%	-5.2%
Apex vertebrate predators	0.0%	0.0%	0.0%	0.0%
Sub-apex demersal predators	-0.1%	1.8%	0.4%	-1.4%
Sub-apex pelagic predators	-0.2%	-0.1%	-0.1%	0.0%
Benthic feeding invertebrates	0.2%	1.2%	0.6%	-0.6%
Planktivorous fish and invertebrates	-0.1%	-0.9%	-0.7%	0.2%
Rays and Skates	-0.1%	0.2%	0.2%	-0.1%
Demersal Sharks	-0.2%	1.8%	0.8%	-1.0%

Fig. 3.8. Predicted changes (%) for ecosystem indicators (total biomass total fish biomass), by guilds and for key demersal elasmobranch groups across the different scenarios. Blue cells indicate negative change, red cells the positive ones.

### 3.8 Dynamic with BEMTOOL: Central Mediterranean Sea (Adriatic and western Ionian Sea GSA17-18-19)

In BEMTOOL, the fleet units integrate fisher behaviour ('specialists' and 'switcher') together with the operating area (GSA), main gear (trawl) and vessel length class (> or < 18 m). Three major scenarios were investigated and compared to the baseline (status quo) scenario:

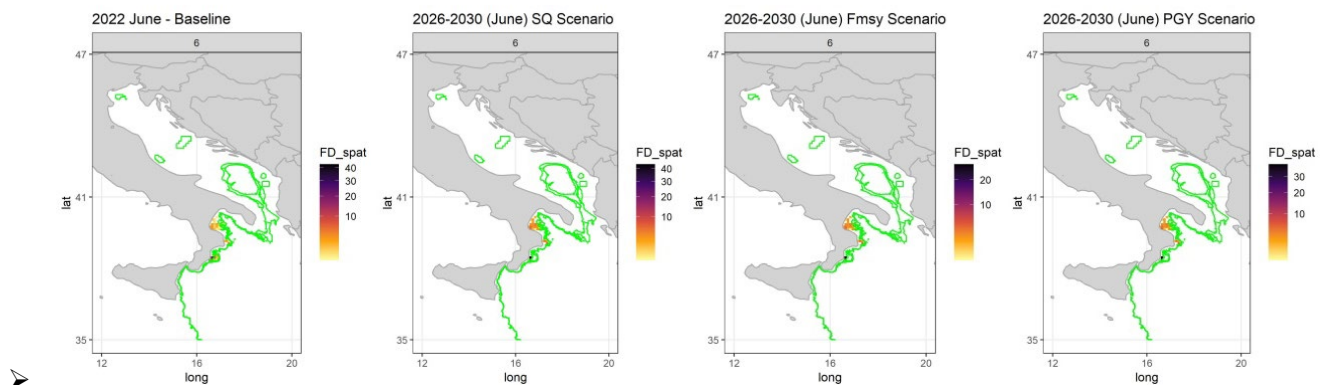
- Sc 0. **Baseline (SQ)** - closure areas already implemented (Natura 2000, FRAs, Marine Protected Areas, Areas of Biological Conservation, 3 NM permanent closures for trawlers and 4 NM and 6 NM);
- Sc 1. **Closure areas combined with Fmsy:** closure areas considered are the bamboo coral (*Isidella elongata*) area

identified as Vulnerable Marine Ecosystem (VME, Resolution GFCM/43/2019/6) in the southern Adriatic Sea, FRA between 1000 to 800 meters depth, Essential Fish Habitats (EFH) of HKE, DPS and ARS, the hotspot for the longnose spurdog (*Squalus blainville*) and areas where the relative benthic state (RBS) is < 0.8. The spatial measures above described are combined with the fishing effort regimes in line with the Adriatic MAP in GSA 17 and 18, aimed at reducing the fishing effort to achieve Fmsy of European hake by 2026. In Western Adriatic Sea this scenario was set to achieve Fmsy of HKE19 in 2026, similarly to the Adriatic MAP.

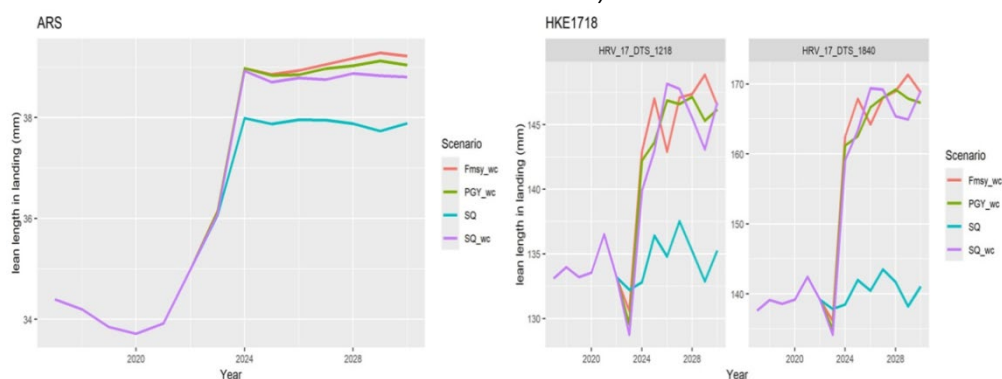
Sc 2. **Closure areas combined with PGY:** same closure areas considered for Scenario 1, with an effort reduction based on the multi-species Pretty Good Yield (PGMY defined as the combinations of fishing mortalities for individual stocks that provide 95% of the yield for a stock in a single-species analysis (European hake and deep-water rose shrimp).

Sc 3. **Effects of closures only:** that is the SQ with closures described in Sc. 1(SQ\_wc).

The outcomes showed reallocation of fleet effort (Fig. 3.9) which resulted in increases in fuel consumption of the GSA17 fleet >18m and a decrease fuel consumption of the GSA19 fleet >18m. The Fmsy scenario resulted in decreased fuel consumption for all fleets. The closures **improved exploitation patterns** on Deep-sea shrimps, hake in GSAs 17-18, and giant red shrimp, by **reducing the fishing pressure on juveniles** (Fig. 3.10).



**Figure 3.9.** Effort reallocation (fleet unit operating in the Center GSA19-specialists above 18m) under Sc. 0) the baseline scenario (effort distribution as in 2022 without additional closures), Sc. 1) SQ with additional closures, Sc. 2) Fmsy with additional closures and Sc. 4) PGY with additional closures.).



**Figure 3.10.** mean length across the scenarios SQ (without spatial closures), SQ\_wc (with closures), Fmsy\_wc, PGY\_wc for ARS (left panel) for fleet unit 18 and for HKE1718 for Croatian fleet segments (right panels).

For the above implementation, a spatial module for BEMTOOL bioeconomic model software was explicitly developed for SEAWISE (available at: <https://github.com/COISPA/SpatialBMT> upon request to [bitetto@fondazionecoispa.org](mailto:bitetto@fondazionecoispa.org))

### 3.9 Dynamic with FISHCODE: Southern North Sea

Eight scenarios of spatial fishing restrictions were simulated:

- Sc 1. Baseline (status quo)
- Sc 2. By-catch (protecting endangered species from bycatch)
- Sc 3. Future OWF (planned OWFs and development sites up to 2040)
- Sc 4. Future OWF + bycatch reduction
- Sc 5. Benthic state (NTZs to protect benthic habitats based on RBS)
- Sc 6. Potential MPAs (suggested – not established)
- Sc 7. Future OWF + benthic state
- Sc 8. Future OWF + potential MPAs

Simulations (Fig. 3.11) showed that closing existing MPAs to bottom fishing led to strongest decrease of fishing effort while closing existing MPAs to bottom fishing result in concentration of fishing effort in the remaining open areas, as well as longer steaming times and lower profits. This affects the German shrimp fishery greatly. Spatial displacement of beam trawler fleet and very large increases of fishing pressure in some local areas can potentially lead to negative consequences for ecosystems, emphasizing that spatial management needs to be accompanied by non-spatial management measures to reduce effort.

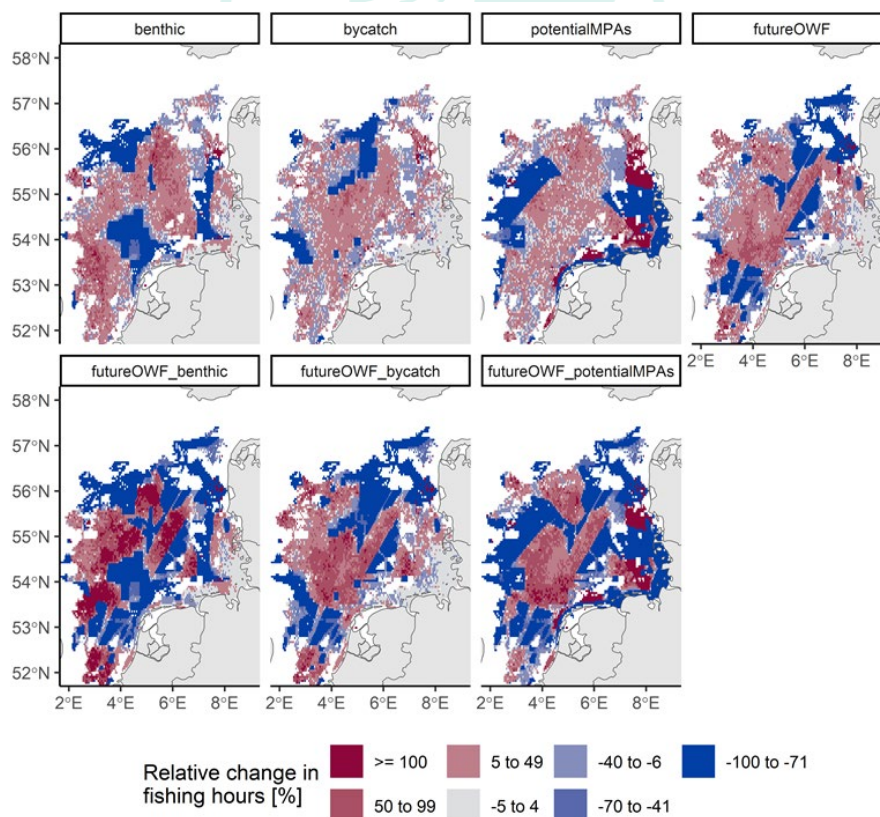


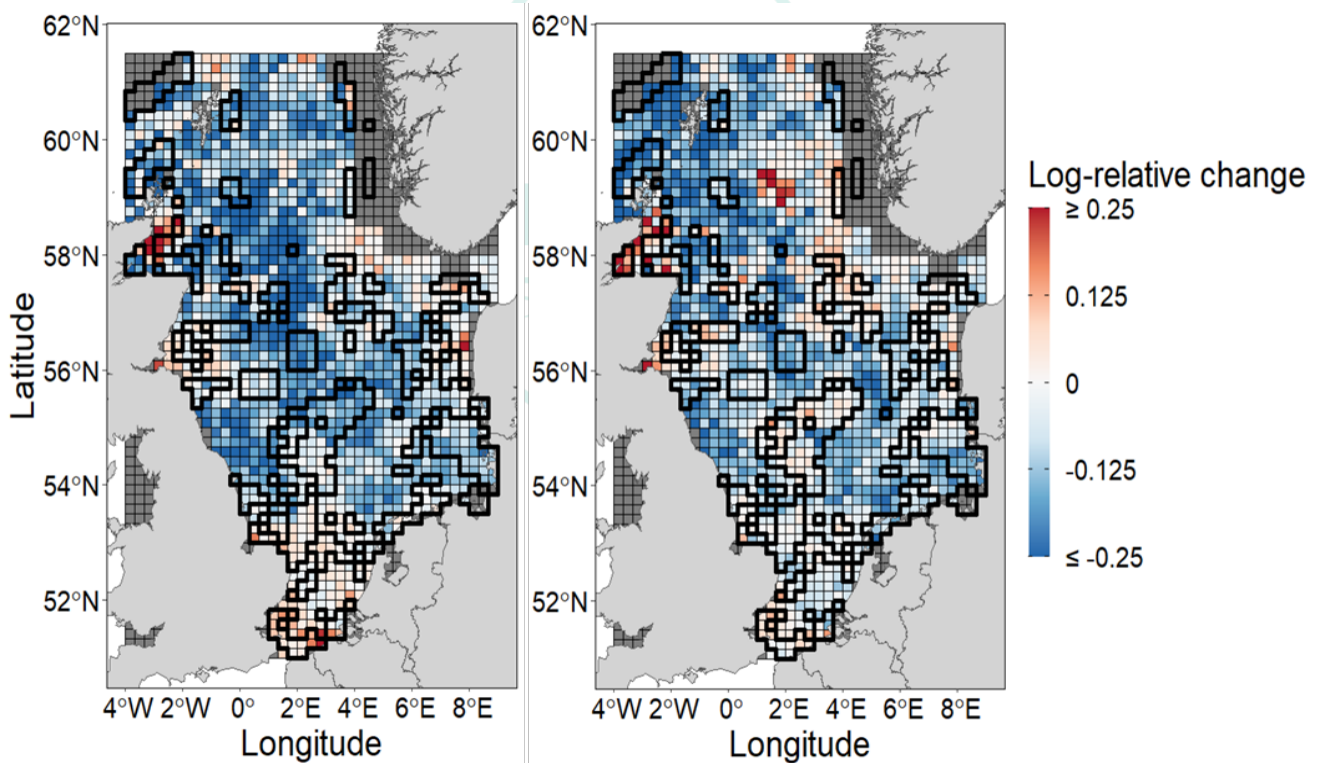
Figure 3.11. Relative change of spatial fishing (ratio of scenario / baseline) effort in all scenarios compared to the baseline.

### 3.10 Dynamic with OSMOSE: North Sea

Five major scenarios were compared against the baseline scenario, while effort was optimized to achieve MSY:

- Sc 0. Baseline (status quo - no MPAs)
- Sc 1. Spatial closures (N2000 sites)
- Sc 2. MPAs (potential future spatial closures from MPAs)
- Sc 3. OWF (potential future spatial closures from windparks)
- Sc 4. CC (no MPAs)
- Sc 5. CC + spatial closures

Simulations (Fig. 3.12) showed that **effort reduction** leads to slight **increase in demersal species biomass**, significant **decrease in pelagic species biomass** and **increase in the biomass** of protected, endangered, and threatened (**PET**) **species**. Climate change will decrease productivity, and this effect is more pronounced on both biological and catch indicators **than area closure in 2060**. **Changes in the food web** are also expected.



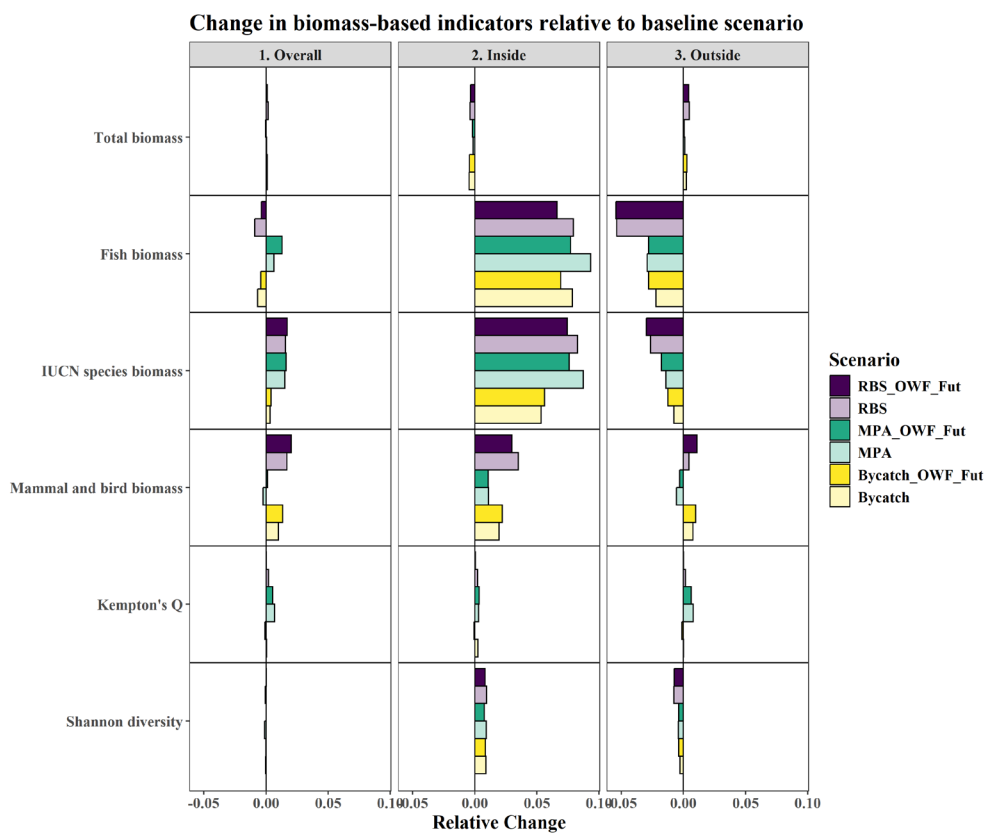
**Figure 3.12.** Relative change in spatial catch aggregated for bottom trawling metiers in the final year of OSMOSE run. Baseline scenario is compared to RCP8.5 2060 (A) and RCP8.5 2060 + spatial.

### 3.11 Dynamic with ECOSPACE: Southern North Sea

Scenarios tested included closures of sensitive areas (benthic habitats, hotspots of PET species), future OWFs and MPAs, in comparison to the current status quo:

- Sc 0. SQ = current OWFs
- Sc 1. RBS (closure over sensitive benthic habitat based on RBS indicator)
- Sc 2. Future OWFs (planned OWFs and development sites up to 2040)
- Sc 3. MPA (suggested – not established)
- Sc 9. Bycatch (protecting endangered species from bycatch)
- Sc 4. All above + future OWFs

Closures benefitted commercial stocks as well as sensitive habitats while fisheries are negatively impacted (Fig. 3.13). There was a positive effect on **stock enhancement** (+15% biomass), but a **decline in catches**. **Losses of catches inside the MPAs were not outweighed** by increases in other areas. **Larger coherent protection zones** seem more efficient than small ones scattered within the region for **reducing the bycatch risk and the effect on sensitive benthic habitats**.



**Figure 3.13.** Impact of closures on biomass-based ecological indicators. Mean indicator values are relative to baseline (i.e. only current OWFs closed) and show the change within and outside the closures as well as the overall impact

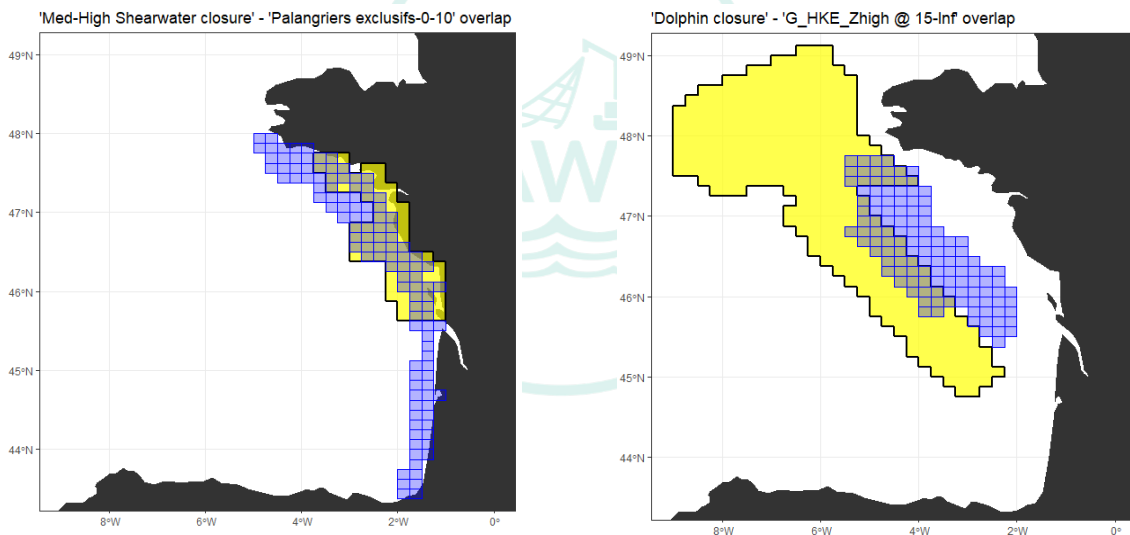
### 3.12 Dynamic with ISIS-Fish: Bay of Biscay (Western waters)

Various closure areas were tested in combination with management rules: (i) a status quo scenario, SQ, representing the average historical conditions and used as a reference, (ii) a Min scenario consisting in the adoption of the ICES  $F_{MSY}$  harvest control rule and the full implementation of the landing obligation, and (iii) a PGY (pretty good yield) scenario, the same as the min scenario, but allowing  $F_{upper}$  instead of  $F_{MSY}$  if all stocks considered in this multispecies

oriented rule have their respective biomass above their MSY  $B_{trigger}$ :

- Sc 0. SQ
- Sc 1. SQ – Dolphins (golfe de Gascogne + Celtic Sea) - hotspot area for dolphins closed
- Sc 2. SQ – Shearwater high - hotspot area of high Balearic shearwater abundance closed (Fig. 3.14)
- Sc 3. SQ – Shearwater Medhigh - hotspot area of medium to high Balearic shearwater abundance closed
- Sc 4. 'Min' -  $F_{MSY}$  target and strict landing obligation combined with
  - a. 'Min' + Dolphins
  - b. 'Min' + shearwater high
  - c. 'Min' + shearwater Medhigh
- Sc 5. 'PGY' - Pretty Good Yield and landing obligation combined with
  - a. 'PGY' + Dolphins
  - b. 'PGY' + shearwater high
  - c. 'PGY' + shearwater Medhigh

The dolphin closures **negatively affects economy of larger vessels** by restricting their offshore fishing grounds on the continental slope. **Coastal fleets** practicing both active and passive gears may benefit and be anticipated to **improve their economic return**. The **balearic shearwater closures** effects were **negligible for the fleets**.



**Figure 3.14.** Overlap between 2 spatial closures simulated in ISIS-Fish (yellow) and the zones of métiers partially overlapping them (blue). Left: Medium-high abundance Balearic shearwater MPA and the zone used by the fleet of Exclusive longliner of 0-10m long using line gears; Right: MPA Mers celtiques -Talus du golfe de Gascogne and the zone of high activity for gillnetters that mainly target hake.

## 4. EBFM online tool and toolbox

For the dissemination of projects' outcomes both to the general public and decision makers, two online tools were (are) developed in SEAwise:

- SEAwise Toolbox (by ICES team): <https://ices-tools-dev.shinyapps.io/SEAwiseTool/>
- EBFM Tool (by Mindfully Wired team): <https://seawiseproject.org/tool/>

To incorporate WP5 related findings in them, a series of meetings were planned to provide feedback for the development of EBFM tool and toolbox, related to the spatial modelling and predictions realized in WP5:

- A WP5 Synthesis workshop organized on 28th of November 2024 to identify the most suitable indicators to put forward. The minutes of the workshop and the recording can be found [here](#).
- A SEAwise hybrid workshop at MEDAC (Mediterranean Advisory Council) on 24<sup>th</sup> February 2025 in Rome (<https://en.med-ac.eu/events.php?id=271>) to present the projects' findings and the functionality of the online tools to Mediterranean fishers and relevant fisheries stakeholders.
- The hybrid NWWAC-SEAwise review workshop took place on 11 March 2025 in Paris (<https://www.nwwac.org/listing/nwwac-seawise-workshop.5149.html>), where mainly the outcomes of the StrathE2E and FLBEIA model runs were presented as being reported in Kempf et al (2024). The NWWAC feedback was positive on the comprehensiveness of the EBFM tool and toolbox, and requested its expansion with spatial scenarios, such as the examples presented during the NWWAC Horizontal WG meeting in Gent on 2 July 2024 (<https://www.nwwac.org/listing/nwwac-horizontal-working-group.4394.html>). Meetings with the remaining ACs were scheduled for: North Sea Advisory Council (24.03.2025), Pelagic AC (01.04.2025), and South Western Waters AC (23.04.2025).

## 5. Synthesis of results

A summary of the outcomes from the various case studies is given in Table 5.1.

**Table 5.1.** Predicted changes in ‘fishable’ areas by region and fishery investigated in SEAwise.

Modelling approach & scenarios & region	Fleet/Fishery	Outcomes
<b>All regions</b>		
<b>Static</b>  Scenario: Effect of restricted areas and displacement of fish species (based on SEAwise D.5.2)	numerous	Most of the exploited species have an average density that is higher outside restricted areas, whatever the scenario, and hence impacts on fished stocks are minimal.
<b>Western Waters, North Sea, Baltic Sea</b>		
<b>Static</b>  Scenario: Effect of restricted areas proposals (MPAs and/or OWFs)	35 metiers	Fishing restrictions in designated MPAs would represent a reduction by up to 36% of the fishable surface area in the Bay of Biscay, but 10% in the Baltic Sea, where MPAs do not overly major fishing grounds
<b>Central Mediterranean Sea (Adriatic and western Ionian Sea GSA17-18-19)</b>		
<b>Static</b>  Sc 0. Status Quo (“SQ”) closure areas already implemented. Sc 1. Scenario 1 - Closure areas planned and proposed (“SQ_closure”) Sc 2. Scenario 2: closure areas combined with $F_{MSY}$ target (“Fmsy_closure”) Sc 3. Scenario 3 - closure areas combined with PGY target (“PGY_closure”)	13 fleets	<ul style="list-style-type: none"> <li>Highly exploited areas (RBS &lt; 0.8) show significant effort redistribution, leading to large GVA changes.</li> <li>Deep-water restrictions (800m closures) had limited impact on fishing effort redistribution</li> <li>GVA reduction is not uniformly distributed across regions and fleet segments, with GSA 19 experiencing the highest impact</li> <li><math>F_{MSY}</math> scenario shows a higher improvement of the RBS benthic status in comparison to the PGY scenario due to the greater effort reduction.</li> <li>Higher effort displacement imposed in PGY scenario is responsible of the reduction of the RBS in other areas explored by the displaced fleets.</li> </ul>
<b>Dynamic with ECOSPACE</b>  Sc 0. Status Quo (“SQ”) closure areas already implemented; fishing effort maintained at the levels of 2024. Sc 1. Scenario 1 - Closure areas planned and proposed (“SQ_closure”) Sc 2. Scenario 2: closure areas combined with Fmsy target (“Fmsy_closure”) Sc 3. Scenario 3 - closure areas combined with PGY target (“PGY_closure”)	37 fleets	<ul style="list-style-type: none"> <li>Sc 1: moderate <b>increase in the biomass of juveniles</b> when <b>protecting Essential Fish Habitats</b> (especially red shrimps)</li> <li>Sc 2: closure areas with effort reduction (Fmsy) → <b>increased biomass of adult and decreased juveniles’ bycatch of commercial species; increase of biomass of apex predators and subapex demersal predators and of demersal sharks.</b></li> <li>Sc 3: <b>minor reduction of juvenile bycatch</b> (hake, red shrimps), <b>moderate increase of adults biomass while catch is reduced. Increase of apex predators biomass.</b></li> </ul>
<i>Simulations up to 2030</i>		

<p><b>Dynamic with BEMTOOL</b></p> <p>Sc. 0. SQ (baseline)                  Sc. 1. (Fmsy with closures, Fmsy_wc)                  Sc. 2. (PGY with closures, PGY_wc)                  Sc. 3. SQ with closures (SQ_wc)</p>	<p>27 fleet segments</p>	<ul style="list-style-type: none"> <li>• Reallocation of fleet effort → increased fuel consumption of GSA17 fleet &gt;18m; decreased fuel consumption of GSA19 fleet &gt;18m</li> <li>• Fmsy scenario → fuel consumption decreases for all fleets</li> <li>• Closures → <b>improve exploitation patterns on Deep-sea shrimps, hake</b> in GSAs 17-18, and <b>giant red shrimp, reducing the fishing pressure on juveniles.</b></li> </ul>
<b>North Sea</b>		
<p><b>Dynamic with DISPLACE</b></p> <p>Sc 0. <math>F_{MSY}</math> + Landing Obligation (LO) regime.                  Sc 1. <math>F_{MSY}</math> + LO regime + EU closed areas                  Sc 2. <math>F_{MSY}</math> + LO regime + closed areas (RBS)                  Sc 3. <math>F_{MSY}</math> + LO regime + EU closed areas + CC</p>	<p>International fisheries</p>	<ul style="list-style-type: none"> <li>• <b>Swept area is displaced</b> but not reduced</li> <li>• RBS increases in areas in closed areas and decreases in fished areas outside closed areas</li> <li>• <b>No obvious benefits</b> for fish stocks from <b>EU closure areas</b> as these areas are <b>not significant for bottom fish</b></li> <li>• <b>Protecting high RBS areas</b> may lead to a preservation of 30% of the highest RBS area.</li> <li>• Climate change positively impacts the revenue of the French fleet</li> </ul>
<p><b>Dynamic with FISHCODE</b></p> <p>Sc 0. base                  Sc 1. By-catch                  Sc 2. Future OWF                  Sc 3. Future OWF+bycatch                  Sc 4. Benthic                  Sc 5. potentialMPAs                  Sc 6. Future OWF+benthic                  Sc 7. Future OWF+potentialMPAs</p>	<p>Beam trawl, Otter bottom trawl</p>	<ul style="list-style-type: none"> <li>• <b>Closing existing MPAs to bottom fishing</b> led to strong declines in fishing effort and concentration of fishing effort in the remaining open areas, as well as longer steaming times and <b>lower profits. Heavily affect the German shrimp fishery.</b></li> <li>• <b>Spatial displacement</b> of the beam trawler fleet and very large <b>increases of fishing pressure</b> in some local areas led to <b>negative consequences for ecosystems.</b></li> <li>• Spatial management <b>needs to be accompanied by non-spatial management measures to reduce effort displacement to be beneficial.</b></li> </ul>
<p><b>Dynamic with OSMOSE</b></p> <p>Sc 0. Baseline (no MPAs)                  Sc 1. spatial closures                  Sc 2. MPAs                  Sc 3. OWF                  Sc 4. CC (no MPAs)                  Sc 5. CC + spatial closures</p> <p><i>Effort optimized to achieve MSY</i></p>	<p>14 meters</p>	<ul style="list-style-type: none"> <li>• <b>Effort reduction led to a slight increase in demersal species biomass, significant decrease in pelagic species and increase in the biomass of protected, endangered, and threatened (PET) species</b></li> <li>• <b>Climate change</b> led to a decrease in productivity and was more important for both biological and catch indicators <b>than area closure by 2060</b></li> <li>• <b>Changes in the food web occurred</b></li> </ul>
<p><b>Dynamic with ECOSPACE</b></p> <p>Sc 0. SQ = current OWF                  Sc 1. RBS                  Sc 2. Future OWF                  Sc 3. MPA                  Sc 4. Bycatch                  Sc 5. All above + future OWF</p>	<p>12 fleets</p>	<ul style="list-style-type: none"> <li>➤ Closures had a positive effect on <b>stock biomass (+15%) while catches decreased</b></li> <li>➤ <b>Losses of catches inside the MPAs were not outweighed by increased productivity</b></li> <li>➤ <b>Larger coherent protection zones</b> were more efficient than small ones scattered within the region <b>for reducing the bycatch risk and the effect on sensitive benthic habitats</b></li> </ul>
<b>Mediterranean Sea (East Ionian Sea GSA20)</b>		

<p><b>Dynamic with DISPLACE</b></p> <p>Sc 0. Business as usual (status quo)                  Sc 1. Restricting bottom trawl (OTB) in the Natura2000 areas                  Sc 2. Restricting OTB from HKE nurseries.                  Sc 3. Restricting OTB from HKE nurseries and -15% on effort                  Sc 4. Restricting OTB from sensitive areas for benthos.                  Sc 5. Restricting OTB from HKE nurseries and -15% on effort + RCP 8.5 climate scenario                  Sc 6. Restricting bottom trawl (OTB) on all MPA areas</p>	<p>OTB, PS, GNS, GTR, LLS</p>	<ul style="list-style-type: none"> <li>• The most effective management measures were <b>closing Hake Nursery grounds, reducing overall fishing effort and effective monitoring and control of SSF</b></li> <li>• Including effects of climate change <b>outweighed plausible benefits of closed areas.</b></li> <li>• SSF are negatively impacted by the closures while OTB vessels benefited particularly when restrictions occur in MPAs for all fishing gears.</li> </ul>
<p><b>Dynamic with ECOSPACE</b></p> <p>Sc 0. Status quo                  Sc 1. Restricting bottom trawl (OTB) on the Natura areas                  Sc 2. Spatiotemporal closure for OTB in HKE nursery areas                  Sc 3. Restricting bottom trawl (OTB) on All MPAs                  Sc 4. Spatiotemporal closure for OTB in HKE nursery areas, RCP8.5 and -15% effort</p> <p><i>Simulations up to 2050</i></p>	<p>All</p>	<ul style="list-style-type: none"> <li>• Closures of hake nursery areas led to <b>increased catches</b> and a slight <b>decline in biomass.</b></li> <li>• Combining the closures with climate change and a decline in effort led to <b>increases in stock biomass, IUCN species biomass</b> and large <b>declines in catches.</b></li> <li>• <b>Decreasing</b> fishing pressure from <b>SSF</b> may have a greater impact on <b>stock recovery.</b></li> <li>• Climate change is expected to lead to <b>declines in catches and biodiversity.</b></li> </ul>
<p><b>Dynamic with ISIS-Fish</b></p> <p>Sc 0. SQ                  Sc 1. SQ – closure for Dolphins (golfe de Gascogne + Celtic Sea)                  Sc 2. SQ – closure area Shearwater high (High abund. Balearic shearwater MPA)                  Sc 3. SQ – closure area Shearwater Medhigh (med-High abund. B.c shearwater MPA)                  Sc 4. ‘Min’ - Fmsy target and strict landing obligation                 <ol style="list-style-type: none"> <li>‘Min’ + closure area Dolphins</li> <li>‘Min’ + closure area shearwater high</li> <li>‘Min’ + closure area shearwater Medhigh</li> </ol>                 Sc 5. ‘PGY’ - Pretty Good Yield and landing obligation                 <ol style="list-style-type: none"> <li>‘PGY’ + closure area Dolphins</li> <li>‘PGY’ + closure area shearwater high</li> <li>‘PGY’ + closure area shearwater Medhigh</li> </ol> </p>	<p>41 demersal fleets (including Spanish, UK and Belgium fleets)</p>	<ul style="list-style-type: none"> <li>➤ <b>Preventing Dolphin interaction:</b> <ul style="list-style-type: none"> <li>- <b>Negatively affects economy of larger vessels</b> by restricting their offshore fishing grounds on the continental slope.</li> <li>- <b>Coastal fleets</b> practicing both active and passive gears may benefit and be anticipated to <b>improve their economic return</b></li> </ul> </li> <li>➤ <b>Balearic shearwater closures</b> effect remain <b>negligible.</b></li> </ul>

Below, the results are synthesised with a specific focus on EU policy objectives and general considerations regarding the role of spatial and non-spatial management measures.

## 5.1 Lessons from SEAWise for “30 x 30”

The EU Fisheries package (EC, 2023) as part of the international Biodiversity Strategy for 2030 and the EU Green Deal, suggested 30% protected area per EEZ surface area, including 10% strictly protected. As this strategy contains several biodiversity-related commitments and actions to be delivered by 2030, it is commonly referred to as the ‘30 x 30’ (or 30 by 30). In addition, European Union passed a nature restoration law (EU, 2024), aiming to restore 20% of degraded ecosystems by 2030 and 100% by 2050. EU Member States are to implement restoration measures in at

least 20% of EU areas by 2030 and by 2050, for all ecosystems that need restoration. For marine ecosystems specifically, priority should be given to marine habitats such as seagrass beds or sensitive seabed substrates and restoring habitats of threatened marine species such as dolphins, porpoises, sharks and seabirds. Finally, mitigation measures accounting for climate change should be devised. In doing so, EU countries are to set up National Restoration Plans within two years of the Regulation coming into force (2026).

SEAwise investigated several fisheries spatial management schemes, from enforcing restrictions on already existing areas (Natura 2000 sites, nationally designated conservation areas, offshore wind farms), to restrictions in new protected areas that meet environmental targets (e.g. identified as hot-spots of marine life or essential marine habitats). Here we synthesise impacts on the ecological system, as this is the main focus of '30 x 30' as well as the EU nature restoration law. The scenarios ranged from simplistic fishing effort displacement outside the closed areas, to more dynamic effort displacement accounting for fishers' decision-making.

Designated areas already in place include:

- ◆ Natura 2000 sites,
- ◆ nationally designated MPAs
- ◆ Other restricted areas to fishing (wind farms, aquaculture sites, mining, drilling sites, etc.)
- ◆ areas under spatial management (e.g. spatio-temporal closures) like FRAs and VME in the Med (GFCM measures)

New areas investigated in SEAwise include:

- ◆ future OWFs
- ◆ all N2000 sites as no-take zones (NTZ) for bottom trawlers
- ◆ no-take zones (NTZ) to protect areas with sensitive benthic habitats (based on the RBS indicator)
- ◆ no-take zones (NTZ) to protect hot spot areas of protected/endangered species (avoidance of possible bycatch of PETs: marine mammals, seabirds, sharks, corals)
- ◆ no-take zones (NTZ) to protect commercial stocks nurseries (Essential Fish Habitats)

All the above were explored either individually or in combination with climate change effects and fishing (MSY, PGY).

## North Sea

The impact of spatial closures is highly varying among regions and fisheries. Phasing out bottom trawling in Natura 2000 sites, may not deliver the benefits expected, as the DISPLACE explored scenarios deemed the measure **inadequate for both enhancing stocks or restoring marine habitats**, as the level of fishing effort with gears in direct contact with the seabed is quite limited. However, FISHCODE, ECOSPACE and OSMOSE approaches were not as conclusive, highlighting the **importance of the placement and size of the closed areas**, as **larger coherent protection zones seem more efficient**. They also stress that displacement of effort to 'unprotected' areas may have **devastating ecological consequences**, if total fishing effort is not reduced and therefore is concentrated in a smaller area. This points to **complementing any spatial restrictions with measures such as** effort restrictions, catch quotas or technical measures.

## Mediterranean Sea

**EFH areas as No-Take-Zones for bottom trawling** delivered **positive results** for the commercial stocks by a reduction of juvenile catches, which in turn provided stock enhancement. However, these benefits are noticeable **only if accompanied by** effort reduction. Furthermore, the huge size of the SSF fleet, and its unknown fishing footprint,

questions whether “phasing out bottom trawling by 2030” will actually fulfill the aspirations of the measure. On the other hand, the measure will most likely lead to an **increased biomass of PETs**, suggesting that it can favor sensitive benthic habitats and key predators (sharks). The long-term effect of **Climate Change** may **counterbalance any positive gains from the closures**, and additional approaches may be required to restore marine habitats and protect vulnerable marine species.

### Western Waters

**No-Take-Zones** based on areas of high abundance of **threatened species** is expected to **deliver positive results for these species**. Restricting longline fisheries from areas of medium-high abundance of Balearic shearwaters during summer-autumn seems an easy measure to implement, as the impact on the fleet profitability is estimated to be negligible. On the other hand, closing dolphin hot spot areas will significantly negatively affect the large-scale fleet (LSF: bottom/pelagic trawlers, netters), which may lead to a high level of **resistance is expected** from the fisheries industry. As the success of any management measure is based on its acceptance, compliance to the restrictions rests on changing fishers mindset and/or adequate monitoring, control and surveillance. Static effort re-allocation **reduced local bycatch risk and benthic impacts**. **Regional effectiveness** was variable, and depended on the **size of the closed areas** for reducing bycatch risk and highlighted that effort-related depletion contributed more to benthic state than spatial re-allocation.

SEAwise concludes that for the ‘30 x 30’ goal and moreover ‘*phasing out bottom trawling from all N2000 sites by 2030*’ to deliver what it is aspired: restoring marine habitats and protecting threatened species, four specific issues need to be considered:

1. **Prohibition of high risk fishing practises in fit-to-purpose areas** limits the risk for incidental species capture and the degradation of the marine habitats.
2. **Fit-to-purpose areas need to be explicitly designed** to achieve the desired results for fish stocks, bycatch risk of unwanted species, and sensitive benthic habitats. Negative effects are expected for large-scale fisheries and harmful effects can occur on biodiversity in the ‘unprotected’ areas. ‘*Phasing out bottom trawling from all N2000 sites by 2030*’ will most likely benefit the small-scale (static gear) fishing fleet.
3. Spatial management did not achieve the desired results without accompanying **non-spatial management measures** (e.g.: effort restrictions, quotas, technical measures), and **proper governance and incentives** to limit the resistance to change.
4. **Climate change** may overwhelmingly affect marine ecosystems, diminishing the effect of area closures and suggesting that other conservation measures may be needed.

## 5.2 Reflection on fisheries spatial management vs non-spatial management

The EU Common Fisheries Policy (CFP) states that Ecosystem-Based Fisheries Management (EBFM) needs to be implemented (EU, 2013). Ecosystem Based Fisheries Management is defined by Link and Marsac as a “*systematic approach to fisheries management in a geographically specified area that contributes to the resilience and sustainability of the ecosystem, that recognizes the physical, biological, economic, and social interactions among the fishery-related components of the ecosystem, including humans and seeks to optimize benefits among a diverse set of societal goals*” (Link & Marsac, 2021). The EU Habitats Directive (92/43/EEC) and the recently introduced management objectives, in implementation of the international Biodiversity Strategy for 2030 and the EU Green Deal (EC, 2023), have placed spatial management high on the agenda of fisheries managers, as they put forward spatially explicit targets (protecting 30% of the surface area of the EU waters; 10% under strict protection).

Spatial management in fisheries implies a geographically defined area in which all or certain fishing activities are temporarily or permanently banned or restricted in order to improve the exploitation and conservation of harvested living aquatic resources or the protection of marine ecosystems. Spatial management (e.g. spatial restrictions) can support EBFM as it can remove fishing pressure from sensitive habitats allowing not only restoration of marine habitats but also enhancement of commercial fish stocks.

Fisheries spatial management in European waters date back more than six centuries (e.g. 1337 A.D. medieval Italy; 1627, Kingdom of Naples, Italy; 1793, France; 1825, Ionian Sea, Greece) (Lentini, 2010; NHRF, 2010; Osio, 2012). A recent study (Aminian-Biquet et al., 2024), suggested that although 11% of EU waters are under some type of protected status, only 0.2% are strictly protected. Additionally, more than 80% of these protected areas do not meet conservation targets as they provide only “marginal” protection against bottom trawling (among others).

SEAwisE has simulated various spatial management scenarios in several EU marine regions and fisheries (see Chapter 3 and 5.1 above). Specific focus was given into exploring the impact of fit-to-purpose areas, designed on the basis of protecting critical habitats and threatened species. To this end the work realized in SEAwisE WP4 provided valuable insights on which marine regions are more suitable for achieving EBFM.

SEAwisE has shown that there is **no single type of fisheries management that can be applied across regions and fisheries which can guarantee fulfilment of EBFM goals**. Although introduction of No-Take-Zones may benefit habitats and species within its protected range, effort displacement to ‘unprotected’ areas may lead to a deterioration of the ecosystem outside the NTZs.

**Spatial restrictions must therefore be complemented by non-spatial management** measures such as effort restrictions, catch quotas and technical measures.

Inside protected areas, sensitive marine habitats (benthos) and PET species benefit by restrictions, as their status improved in almost all cases.

Although SEAwisE explored fisheries spatial management both in a static and dynamic approach, it did not put to test time or space reactive closures (‘Real time closures’). These require decision making in real-time and continuous update of the management measures (e.g.: reallocating restricted area, ban/permit certain fishing gears, seasonality).



## 6. Discussion and Conclusion

SEAwisE assessed how closing marine regions across EU waters to fishing impacts the marine habitats, threatened species, commercial stocks and fishers. To this end, SEAwisE identified relevant geospatial data (commercial species distribution-Task 5.2; fishing footprint-Task 5.3; hotspot areas of sensitive habitats/species - WP4; economic aspects of fisheries-WP2; conservation areas-Deliv. 5.5 – 5.6; climate data-public repositories and previous EU funded projects). Spatial restriction effects were modelled either with a static approach with expert-based rules of thumb for anticipating the fishing effort displacement, or by deploying dynamic spatially explicit bio-economic models (DISPLACE, ECOSPACE, BEMTOOL, OSMOSE, FISHCODE, ISIS-Fish). Medium to long term spatial management scenarios were explored in order to measure if and how can they achieve the EBFM goals while ensuring viability of the fisheries sector. All scenarios were tested against a baseline scenario, which in most cases was the current management status (status quo).

Spatial restrictions usually induce contraction of available fishing grounds and associated opportunities. However, if successfully applied, restoration of marine habitats may reinstate healthy ocean productivity and marine populations (Duarte et al., 2020). It is debateable if locally enhanced marine environment, due to the aforementioned spatial measures, will achieve the EBFM goals in the entirety of EU waters, as is aspired by the nature restoration law<sup>3</sup> (EU, 2024). SEAwisE research suggests that, in the short-term, spatial restrictions will reduce fishing opportunities. Further, effort will be reallocated outside traditional fishing grounds leading to increases in fuel consumption. Additionally, fleet selectivity will be altered as the catch composition (species, size of specimen) will change, and operating costs will increase. However, this could eventually be balanced over the long term if the closure leads to stock recovery. Displacement of effort to surrounding areas may have harmful and undesirable effects on biodiversity in some cases, emphasising the need for non-spatial management measures, such as effort restrictions and quotas outside the protected zones. Accounting for climate change is a necessity, as in the long term, unprecedented sea conditions could be overwhelmingly affecting fish and fisheries productivity and the marine ecosystems at large, suggesting that additional conservation measures may be needed. In practical terms, appropriate governance and incentives to limit the resistance to change are key to a fully compliant fishing industry.

Here, SEAwisE provides useful examples on how to select fit-to-purpose areas that can fulfil the '30 x 30' strategy and the EU nature restoration law. Such areas should be designated on the basis of which ones are more prone to protect critical habitats and threatened species, rather than achieving the 10% or 30% target by accounting for the restricted areas around offshore wind farms or the Natura 2000 sites.

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<sup>3</sup> "restore 20% of degraded ecosystems by 2030 and 100% by 2050"

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## 8. Document Information

EU Project	No 862428	Acronym	SEAwisE
Full Title	Shaping ecosystem based fisheries management		
Project website	<a href="https://www.seawiseproject.org/">https://www.seawiseproject.org/</a>		
Deliverable	N°	D5.8	Title Synthesis of predicted impacts of changes in habitat and spatial management measures suggested in SEAwisE for online tool
Work Package	N°	5	Title Spatial management impacts on ecological systems and fisheries
Work Package Leader	Dimitrios Damalas, HCMR		
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Reviewers			

Due date of deliverable	31.03.2025
Submission date	31.03.2025
Dissemination level	PU <sup>4</sup>
Type of deliverable	R <sup>5</sup>

Version log			
Issue Date	Revision N°	Author	Change
12.03.2025	0.1	D. Damalas	First version
17.03.2025	0.2	D. Damalas	Revised version
28.03.2025	0.3	Anna Rindorf	QA
31.03.2025	1.0	D. Damalas	Final version

<sup>4</sup>Dissemination level: **PU**: Public

<sup>5</sup> Nature of deliverable: **R**: Report