

STECF AD HOC CONTRACT n. 25105

Ad-hoc contract concerning the efficiency
of permanent closure areas under 600m
depth in the western Mediterranean Sea

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Terms of Reference

Based on previous work from available literature, including STECF reports on closure areas in the western Mediterranean and on the feedback and additional information received from Member States, stakeholders and STECF chairs, the contractor is requested to:

1. Collate and summarize all literature available on permanent closures of deep-water areas in the Mediterranean Sea, in particular on the socio-economic impact of fisheries active below 600m depth.
2. Compile all of the available data (deep-water stocks distribution and deep-fisheries effort distribution) needed to parameterize spatial BEMTOOL model in the future in EMU 2, referring to the work done in 2022 to collate and analyse available data (fisheries dependent and if available non-fisheries dependent) to identify the spatio-temporal distribution of deepwater fisheries in the western Mediterranean and their socio-economic characteristics in terms of e.g. gross value of landings, gross profit margin, net profit margin and full time employment - and their seasonal and temporal evolution. Gaps in data will also be identified.
3. After the above collating and identifying of deep-fisheries distribution, the contractor shall draft a short report (20-page max) including maps and if possible inferences on stock recovery and socio-economic consequences as well as data summary (e.g. coverage, resolution for simulations between 2026 and 2030). The contractor's work should be based on all available literature, on the efficiency of the existing deep-water closure areas and the development of additional closure areas to protect juveniles and spawners of deep-water crustacean stocks in the region.

For each deep-water crustacean species, it can be assumed that during the peak of the spawning period of the species the fishing grounds exploited by the fleets represent a proxy of the spawning aggregations. In terms of data, the expert could use the shapefiles prepared by the ad-hoc contract conducted in April 2022 that looked at:

- AIS data (reference years: 2018-2020), to infer the activity and fishing effort of trawlers at a fine spatial level and quarter level. Maps of potential fishing grounds will be expressed in fishing days and will be used to identify hotspots of fishing effort. Subsequently, hotspots will be used to assess the spatial persistency over the most recent period possible (e.g. 2020- 2024).
- FDI data (reference years: 2020-2024) will be used to compare the CPUE (kg of landings per fishing day) of deep-water shrimps per quarter selecting: i) Italy, France and Spain; ii) Mediterranean Sea; iii) total days at sea; iv) total live weight landed of blue&red shrimp, nephrops and giant red shrimp. CPUE will be used to verify/confirm whether the maximum yields match with the peak of spawning season. As AIS data mostly come from vessels having a LOA>15m, we will assume that the behaviour of smaller vessels would be similar to larger ones.
- Any helpful spatial data available from public website and stakeholders such as Global Fishing Watch.

Introduction

In Mediterranean fisheries governance, permanent deep-water closures are spatial measures that indefinitely prohibit one or more fishing gears below a given depth or within specified deep-sea habitats to protect vulnerable marine ecosystems (VMEs) and essential fish habitats (EFH). In this basin the key legal instrument is the General Fisheries Commission for the Mediterranean (GFCM) network of Fisheries Restricted Areas (FRAs), complemented by EU and national rules (<https://www.fao.org/gfcm/data/maps/fras/en>).

Since 2005, the GFCM has applied a general ban on towed dredges and bottom trawls in all waters deeper than 1,000 m across the Mediterranean and Black Sea (Recommendation GFCM/29/2005/1). This measure is the only basin-wide closure explicitly targeting the deep sea and is intended to protect fragile benthic habitats such as cold-water corals and sponge grounds. Subsequent EU documents and technical summaries reaffirm this prohibition (Regulation (EU) No 1343/2011).

Beyond the 1,000-m depth line, the GFCM has designated multiple FRAs, some of which explicitly protect deep-sea features with permanent gear bans or restrictions (e.g. Santa Maria di Leuca (Italy), protecting *Lophelia pertusa* reefs and associated VMEs on the continental slope; Nile Delta cold seeps, and Eratosthenes Seamount). EU legal summaries and GFCM materials identify these as deep-sea FRAs with permanent restrictions on bottom-contact gears.

According to NGO reports (e.g. OCEANA) the Mediterranean's current 1,000-m ban on deep-sea bottom trawling (Figure 1) should be lowered to 800 m to better protect VME and EFH, while safeguarding seabed carbon. Drawing on recent AIS analyses, Oceana reports (<https://europe.oceana.org/wp-content/uploads/sites/26/2024/11/EXTENDING-THE-LIMIT-ON-DEEP-SEA-BOTTOM-FISHING-IN-THE-MEDITERRANEAN.pdf>) that relatively little trawling effort occurs deeper than 800 m, implying limited short-term socio-economic impacts from a stricter limit. The proposal would also align the Mediterranean with the North-East Atlantic's 800-m standard and complement emerging national measures in several Mediterranean EU state. GFCM has initiated pilot studies to evaluate the ecological and fisheries implications of an 800-m threshold and the results will be available in 2025.

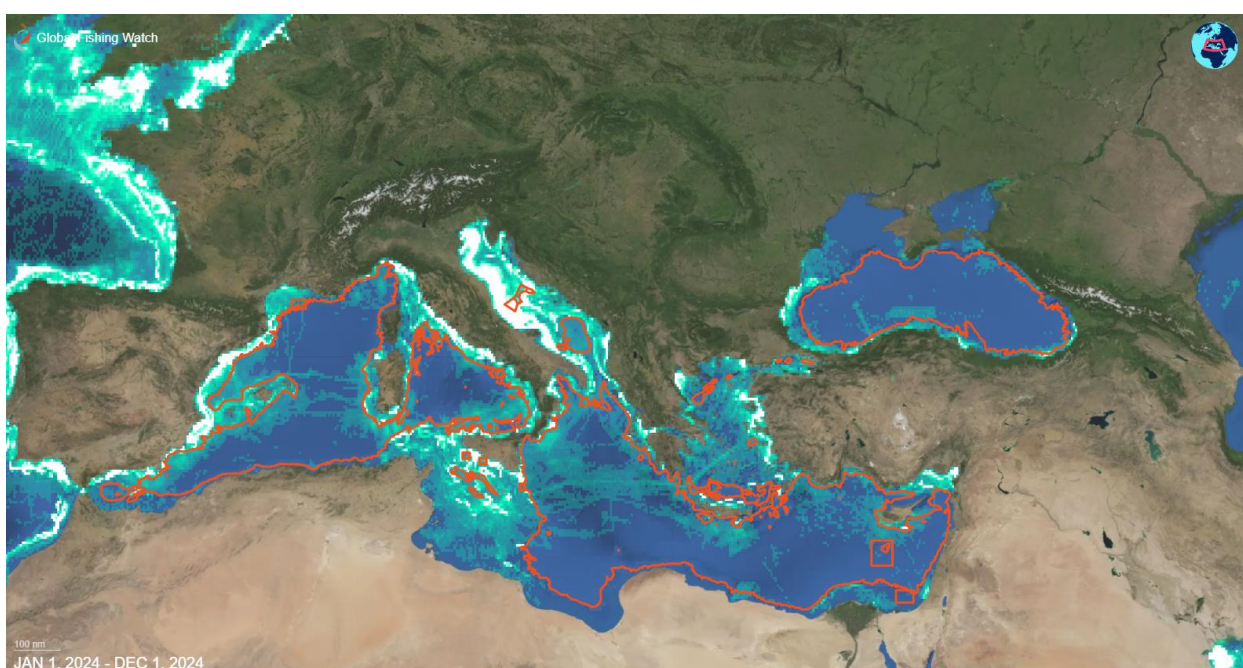


Figure 1 – Apparent fishing effort distribution in 2024 (AIS data) in Mediterranean Sea (aqua-greenish cells) and GFCM FRAs (orange line), including the 1000 m deep-water FRA (1,730,000 square kilometers) (REC. GFCM/29/2005/1). The map has been created using the Oceana / Global Fishing Watch “deep trawling” interactive tool at: <https://globalfishingwatch.org/map/index?longitude=26&latitude=19&zoom=1.49>¹

Literature quantifying long-term fleet dynamics, effort displacement, and catch composition changes following deep-water closures is limited for the Mediterranean compared with the Northeast Atlantic.

The aims of this ad hoc contract are:

- to collate and review all literature and grey literature works on closure areas in the Western Mediterranean, including STECF reports and on the feedback and additional information received from Member States, stakeholders and STECF chairs, detecting information on the socio-economic impact of fisheries active below 600m depth.
- to describe all of the available data (deep-water stocks distribution and deep-fisheries effort distribution) needed to parameterize spatial BEMTOOL model in the future in EMU 2, detecting possible gaps, to facilitate a refined evaluation of the socio-economic impact of the 600 m closure on demersal fisheries operating in Western Mediterranean Sea.

Literature review –ToR 1

In this chapter are summarised the reports considered relevant to provide information on the impact of a potential closure below the 600 m of depth on demersal deep-water fisheries operating in Western Mediterranean Sea.

GFCM pilot study on Spanish deep-sea fisheries operating at 800–1,000

The GFCM pilot study on Spanish deep-sea fisheries operating at 800–1,000 m, set against the basin-wide 1,000 m trawl ban and Spain’s new 800 m ban (since 9 May 2024), is ongoing. Preliminary results were presented during the GFCM Sub-regional Committee for the Western Mediterranean in May 2025. They show a long-term contraction of the bottom-trawl fleet and effort, with fishing at 500–1,000 m accounting for ~20% of trips; the main deep-water target is *Aristeus antennatus*, contributing ~6% of trawl biomass but ~30% of revenue (2022–2024). Methods combine Socioeconomic and local ecological knowledge (LEK) questionnaires with VMS (2015–2024) and sales notes, selecting vessels that spent ≥10% of days at 800–1,000 m and were active there in 2023. Results indicate that landings from 800–1,000 m were small (around 0.7% biomass; 1.9% value in 2015–2023) and dropped sharply in 2024 (about 0.1% biomass; 0.4% value) after the ban, while landing per unit of effort (LPUE) shows a significant increasing trend. Next steps include completing questionnaires, refining VMS/sales analyses by GSA/port, and a focused 2024 pre-/post-ban comparison.

¹ Global Fishing Watch uses data about a vessel’s identity, type, location, speed, direction and more that is broadcast using the AIS and collected via satellites and terrestrial receivers. AIS was developed for safety/collision-avoidance. GFW analyzes AIS data collected from vessels that our research has identified as known or possible commercial fishing vessels, and applies a fishing presence algorithm to determine “apparent fishing activity” based on changes in vessel speed and direction. The algorithm classifies each AIS broadcast data point for these vessels as either apparently fishing or not fishing and shows the former on the GFW fishing activity heat map. AIS data as broadcast may vary in completeness, accuracy and quality. Also, data collection by satellite or terrestrial receivers may introduce errors through missing or inaccurate data. GFW’s fishing presence algorithm is a best effort mathematically to identify “apparent fishing activity.” As a result, it is possible that some fishing activity is not identified as such by GFW; conversely, GFW may show apparent fishing activity where fishing is not actually taking place. For these reasons, Global Fishing Watch qualifies designations of vessel fishing activity, including synonyms of the term “fishing activity,” such as “fishing” or “fishing effort,” as “apparent,” rather than certain. Any/all GFW information about “apparent fishing activity” should be considered an estimate and must be relied upon solely at your own risk. GFW is taking steps to make sure fishing activity designations are as accurate as possible. GFW fishing presence algorithms are developed and tested using actual fishing event data collected by observers, combined with expert analysis of vessel movement data resulting in the manual classification of thousands of known fishing events. GFW also collaborates extensively with academic researchers through our research program to share fishing activity classification data and automated classification techniques.

Ad hoc contract STECF n. 2217

The ad-hoc contract 2217 was carried out in 2022 and was aimed to evaluate the efficiency of closure areas under 600 m and 800m depth in the Western Mediterranean Sea. In the contract this evaluation was made applying BEMTOOL bio-economic model (Rossetto et al., 2015 and Bitetto et al., 2025) simulations to estimate the efficiency of closure areas under 600m and 800m depth in the Western Mediterranean Sea (GSAs 1,2,5,6,7,8,9,10,11).

AIS activity data (Global Fishing Watch, GFW), MEDISEH nursery/spawning layers, FDI/AER socio-economic series, and STECF assessments were integrated in the model. In EMU1 the model replicated dynamically two stocks (ARA 1 and ARA 6-7) and DTS fleet segments (VL12–18, VL18–24, VL24–40) for Spain and France. In EMU2 the model parameterized for STECF EWG 21-13 and 22-01 was used, including trawlers (DTS) and polyvalents (PGP) fleet segment of all vessels lengths, and simulated dynamically 7 stocks (among them ARA9-10-11 and ARS9-10-11).

The ad hoc contract simulated the effects of closing fishing areas deeper than 800 m and deeper than 600 m, applying an approach spatially implicit modifying the fleet selectivity based on the overlap of the fishing footprint of vessels by GSA and the sensitive areas for red shrimps (nursery and spawning grounds from MEDISEH project).

In EMU1, the closure of areas below 800 m and 600 m generally increased ARA SSB (e.g., about 4% and +17% in GSA 1 by 2040 respectively for 800 and 600 m closures) and modestly reduced fishing mortality. A reduction in gross value added (GVA) is achieved for Spanish trawlers operating in GSA 1 bigger than 24 m of length and all Spanish trawlers operating in GSA 6; not significant impact was observed for French vessels.

In EMU2, the closure of areas below 800 m of depth returns small improvements for ARS, while larger benefits were estimated for the 600 m closure (e.g., ~+21% SSB by 2025; ~-20% F), with smaller changes for ARA; revenues and GVA showed heterogeneous responses, often favouring segments with lower overlap to spawning grounds (all fleet segments except the ones operating in GSA 11 longer than 24 m).

Overall, the 800-m closure delivers incremental conservation benefits with limited short-term revenue impacts, smaller than those projected for a 600-m threshold.

However, the study presents some limitations, some of them also highlighted in the ad hoc contract itself:

1. For EMU 1 the case study was limited only to trawlers fleet segments and simulated dynamically only two stocks.
2. The economic data for Spanish fleet segments are estimated, because the official data at GSA level were not available for the ad hoc contract.
3. The closures are simulated through an implicit approach, with no possibility to mimic effort reallocation.

ABIOMMED

ABIOMMED (<https://www.abiommed.eu>)—"Support coherent and coordinated assessment of biodiversity and measures across the Mediterranean for the next 6-year cycle of MSFD implementation" (DG Environment, Grant Agreement No. 11.0661/2020/839620/SUB/ENV.C2)—is an EU project coordinated by Dr. Kalliopi Pagou at the Hellenic Centre for Marine Research (HCMR). Running for 24 months from 1 July 2021, it supported Mediterranean competent authorities and UNEP/MAP in preparing the subsequent Marine Strategy Framework Directive cycle. The project undertook (sub)regional assessments of Good

Environmental Status (GES) under the 2017 GES Decision, quantified—particularly ex-post—the effects of Programmes of Measures (PoMs) by linking monitoring to measures, and identified new (sub)regionally coordinated measures where required. ABIOMMED established stakeholder bodies, convened working groups and meetings, and promoted active engagement to ensure operational uptake. It produced harmonized (sub)regional GES assessments and evidence on PoMs effectiveness, and formulated coordinated measure proposals. The ABIOMMED consortium also analysed pressures and socio-economic dimensions, refined targets, and delivered guidance and tools to facilitate cooperation, to provide support to competent authorities and to strengthen regional and subregional platforms for MSFD implementation across the Mediterranean.

At the time of writing, the ABIOMMED project deliverables were not publicly available; the full set has been formally requested by the contractor to the project coordinator, but the material was not received on time for the contract deadline.

Although the full deliverables of the project were not available, the relevant results for the ad hoc contract were recently published in Sbrana et al. 2025. The paper describes the application of SMART model in Western Mediterranean (among other Mediterranean areas), covering EMU 2 (GSA 9, 10 and 11). The model covers trawlers vessels above 12 m of lengths and is feed with VMS, logbook and AIS data (Global Fishing Watch).

The study highlights that the 90% of the profits of trawlers > 12 m of length in the EMU2 are reached exploiting only the 58% of the fished area in the status quo. Moreover, the paper explores the impact of different alternative spatial management scenarios, including the closure of areas deeper than 800, 700 and 600 m. Specifically, the reallocation of the effort consequent to the closures is simulated. In these scenario, where the bathymetry determines the area subjected to regulation, fishing vessels are forced to leave deeper fishing grounds and move closer to the coast. For 600 m closure scenario a relevant decrease in catches of deep-sea crustaceans (the Norway lobster, Blue and red shrimp, and Giant red shrimp) is obtained. The results on EMU 2 show that a decrease of -15% in profits (landing value – variable and fixed costs) is expected when closing the areas deeper than 600 m, while a decrease about 4-5% is expected when closing the 800 m areas.

However, the study presents some limitations, some of them also discussed in the paper itself:

1. It did not examine the effects on population dynamics in the mid and long terms but focused instead on the immediate consequences of fishing effort redistribution.
2. It does not cover trawlers below 12 m of length as well as vessels using other gears (polyvalent, hooks).

STECF EWG 25-11 and STECF Ad-Hoc Contract 25103

STECF EWG 25-11 is the 14th of a suite of STECF EWG meetings dedicated to the evaluation of the fishing effort and catch limit regime in the Western Mediterranean Sea. During this series of working groups, four bio-economic models have been applied: in EMU1 IAM (Merzereaud et al., 2023) and Isis-Fish (Pelletier et al. 2009) and in EMU2 BEMTOOL (Bitetto et al., 2025) and SMART (Russo et al., 2014). Isis-Fish and SMART models are spatially explicit and, then, able to properly simulate spatial closures, as the closure of areas below 800 and 600 m of depth.

During the EWG 25-11 only Isis-Fish was run, as in the previous meetings on EMU1 (GSAs 1-2-5-6-7), while SMART was run in the subsequent phase on EMU2 (GSAs 9-10-11). Among the scenarios included in the

ToRs of the EWG 25-11 and of the ad hoc contract 25103 there was the deep-waters closure, implemented as 600 m closure (Scenario D).

Isis-Fish covers European hake stock in GSAs 1-5-6-7 and simulates trawlers, netters and longlines belonging to French and Spanish fleets. The permanent closure of the fishing grounds below 600m depth is experimented, with the 800 m closures implemented since 2025. The results show no extra reduction of the average hake fishing mortality compared to status quo. However, it slightly increases fishing mortality of age 0 hake, possibly because of effort reallocation to more coastal areas where juveniles concentrate. Changes induced in catches are limited.

The Isis-Fish application in EWG 25-11 presents some limitations, also discussed in the EWG report itself:

- The ISIS-Fish model would benefit from a more accurate description of Spanish liners and netters fleets providing that spatial data are made available in due time before the EWG takes place.
- Other species of commercial interest would also be needed so the income from landings could be more accurately modeled and account for the impact of effort redirection on other target species.

SMART model covers 12 species and the Italian vessels above 15 m of length operating in GSAs 9, 10 and 11. The ad hoc contract simulated closures of the areas below 600 m, 700 m and 800 m of depth (scenarios D600, D700 and D800). The results show that the profitability and the number of fleet segments operating under viable conditions ("in green") increase substantially in D-series scenarios, reflecting cost reductions and improved biological status of key stocks. By 2030, the effects stabilize, with D700 emerging as the scenario combining strong profitability and sustainable exploitation levels.

The SMART application in the ad hoc contract 25103 presents some limitations:

- It does not consider vessels below 15 as well as gillnets and trammel nets;
- It does not include the projections of gross value added and gross profit, but only gross profit margin in relative terms.

Report on the economic impact of eventual restrictions of bottom trawling at depths shallower than 1000 m in the Northern GSA06

This report (Carretón et al., 2023), commissioned by ICATMAR (Institut Català de Recerca per a la Governança del Mar) presents a preliminary analysis of the economic impact of a change in the depth limit for bottom trawling to 600 m in the fleet of the Northern GSA06, using VMS geolocation data of the fleet paired with landings data of the last five years. This 2023 technical report was prepared to inform management discussions on proposed depth-based trawling restrictions in the northwestern Mediterranean (Northern GSA 06). It synthesised VMS/logbook, scientific survey and port-level economic data, and was shared with regional authorities and stakeholders to quantify revenue and employment impacts under alternative depth limits (notably 600 m versus 800 m) and to document likely knock-on effects for the co-managed blue-and-red shrimp fishery and associated port economies.

The reports shows that a permanent closure of deep-water grounds—particularly at or shallower than 600 m—would impose severe socio-economic costs on fleets that operate below this depth, with the deepest impacts concentrated in the historical blue-and-red shrimp (*Aristaeus antennatus*) trawl fishery of Northern GSA06. This fishery contributed €15.4 M in 2022 (about 28% of trawl revenues) and derives most earnings between 500–800 m; 78% of vessels' shrimp revenues were made deeper than 500 m. Port-level losses under a 600 m limit were estimated to reach 89% in Tarragona and Port de la Selva, 88% in Llançà, and 82% in Roses and Vilanova, with even the least-affected port (l'Ametlla de Mar) losing 59%. For the broader

trawl fleet, average yearly revenue losses under a 600 m limit were 35% in the North zone and 27% in the Center, reflecting strong spatial dependence on deep grounds. Because shrimp grounds are narrow canyon slopes, enforcing a 600 m limit is likely to render hauls impracticable (gear and vessel cannot reliably remain beyond the contour), making a practical cessation of the fishery plausible.

The report notes that an 800 m limit would cause minimal aggregate revenue loss (about 1% or less), suggesting a materially different socio-economic footprint than a 600 m closure. Given the fleet's small, family-owned structure and the fishery's role as a flagship co-managed fishery, such closures risk forced reconversion, loss of accumulated social capital, and ripple effects along port economies.

Global Fishing Watch – maps of effort distribution (update to STECF ad hoc 2217)

The effort data in “apparent fishing hours” have been downloaded from the GFW website (download date: 28 October 2025) for the years 2021-2024, to update the effort maps reported in the STECF Ad Hoc contract 2217.

Figure 2 reports the number of apparent fishing hours (logarithmic scale) of trawlers operating in GSAs 1, 2, 5, 6, 7, 8, 9, 10 and 11 (Western Mediterranean). Figure 3 reports the effort exerted by trawlers below 800 m (panel a) and below 600 m (panel b), corresponding to 1.64% (average among 2021-2024) and 8.5 %.

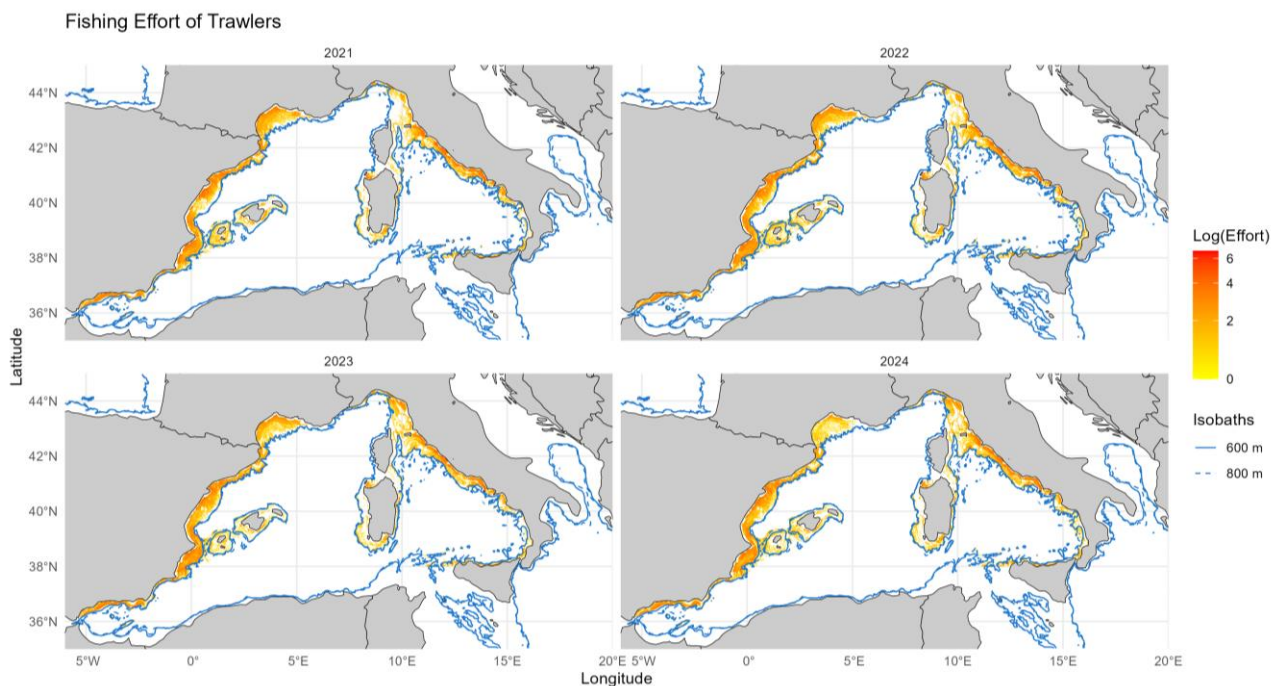


Figure 2 – Apparent fishing effort (hours) of trawlers (GFW) in logarithmic scale by year (2021-2024). The blue lines are the 600 m and 800 m isobaths.

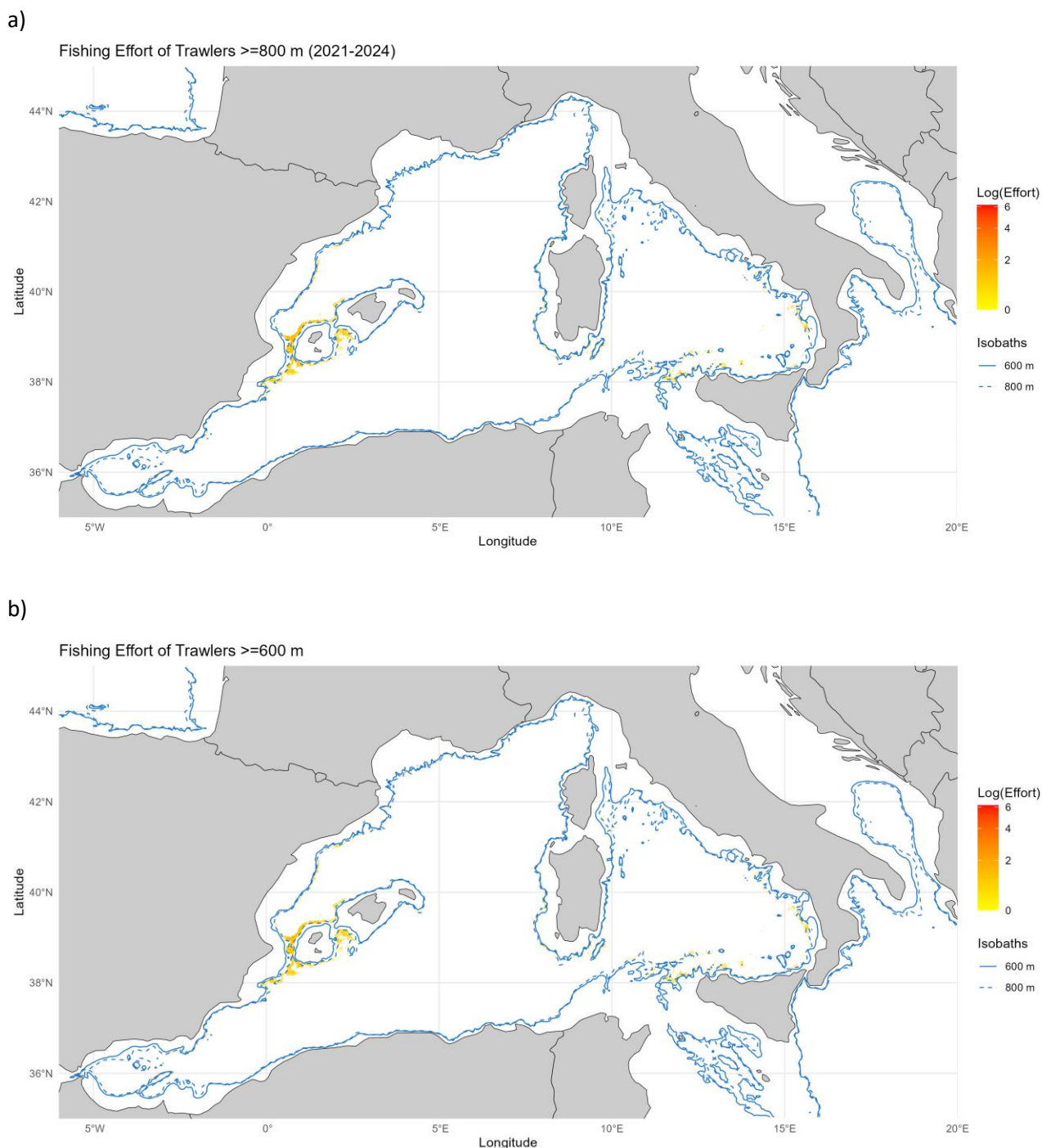


Figure 3 – Apparent fishing effort (hours) by trawlers (Spain, Italy and France) operating in Western Mediterranean at depths deeper than 800 m (panel a) and deeper than 600 m (panel b), corresponding to 1.64% and 8.5% of the total effort on average across 2021–2024.

Synthesis

In Table 1 and 2 are summarized the main information extracted from the analysed papers and reports, divided by effort management unit (EMU) of the Western Mediterranean.

On the basis of the reviewed material show that in EMU1 the closure of the areas below 800 m of depth affects marginally only Spanish fleet. However, the 600 m closure would affect more importantly (around – 30-35%) the profit of Spanish fleet. In EMU2 a reduction in the red shrimps landing is expected in the short term (especially for GSA 10 and 11 DTS > 24 m), with consequent decrease in profit and GVA.

As an additional information, based of the most recent GFW data on effort of trawlers operating in Western Mediterranean Sea, the effort at depths lower than 800 m is limited, while below 600 m is 8.5%.

Table 1- synthesis of the literature review on the socio-economic impact of the deep-water closures for EMU1.

Management Unit	Source	Fleets covered	Stocks covered	Main findings	Limitations
EMU1	STECF ad hoc 2217 (BEMTOOL)	DTS >12 m; Spain and France	ARA1 and ARA67	increased ARA SSB (+4 and +17% in GSA1) and Spanish GVA decreased	- only trawlers and two stocks were dynamically modelled - Spanish economic data were estimated (not available) - closures were simulated without effort reallocation
EMU1	STECF EWG 25-11 (Isis-Fish)	Trawlers, gillnets and longlines; Spain and France	HKE1-5-6-7	No further hake F reduction vs SQ; age-0 F slightly rises (effort shifts inshore), and catch changes are minimal.	- Spanish liners and netters need to be more accurately spatially described; - Only hake modelled.
EMU1	ICATMAR report	Trawlers GSA 6	Focus on ARA fishery	Average yearly revenue losses under a 600 m limit were 35% in the North zone of GSA 6 and 27% in the Center	- No model used for projections - Not possible to take into account stock recovery in the medium and long term - Only revenues considered as economic indicator
EMU1	GFCM pilot study on deep-sea fisheries in Spanish waters	Trawlers GSA 6 (Spain)	Focus on ARA fishery	30% of the revenues coming from 500-1000 m of depth. No effect of ban 800-1000 m, but results may be masked by the recovery trend stocks due to management measures in force	Preliminary results

Table 2- synthesis of the literature review on the socio-economic impact of the 600 m closure for EMU2.

Management Unit	Source	Fleets covered	Stocks covered	Main findings	Limitations
EMU2	STECF ad hoc 2217 (BEMTOOL)	Trawlers and polyvalents	ARA, ARS, HKE, DPS, NEP9, MUT9 and MUT10	The closure increases the GVA of the segments with lower overlap to spawning grounds (GSA 10 and GSA 11 DTS > 24 m).	The closures are simulated through an implicit approach, with no possibility to mimic effort reallocation
EMU2	ABIOMMED	Trawlers > 15 m	ARA, ARS, NEP, DPS, MUT, HKE and others (not in the MAP).	• decrease in catches of deep-sea crustaceans • decrease of -5 and -15% in profits	• projections useful only for the short term • not covering vessels < 12 m of length and other gears than trawlers
EMU2	STECF ad hoc 25103	Trawlers and longlines > 15 m	ARA, ARS, NEP, DPS, MUT, HKE and others (not in the MAP).	The profitability and the number of fleet segments operating under viable conditions increases	• Not covering vessels < 12 m as well as gillnets and trammel nets. • No GVA and GP projections

Collation of available information to parameterize spatial BEMTOOL –ToR 2

Spatial BEMTOOL

Within SEAwisE project (seawiseproject.org) a spatial component of BEMTOOL was specifically developed to consider the impact of spatio-temporal management measures on the stocks and the fleet segments in the Adriatic and Western Ionian Sea. This spatial component was designed as an external tool that can communicate with the main BEMTOOL model, receiving the population structure by month and F by fleet segment in the hind cast phase and returning the fleet selectivity, catch, new effort by métier, population structure and SSB updated with the spatial measures in the forecast.

Figure 4 summarises how Spatial BEMTOOL communicates with the main BEMTOOL model. BEMTOOL replicates, the latest stock assessment. The spatial component spatializes the population by age and time at monthly time scale integrating the GAM modelled species distributions and the fishing footprint from AIS and FDI data. The fleets in the model is differentiated according to the fishing strategy, in a way that it is possible to identify the impact of management on them, in addition to the impact on the stocks.

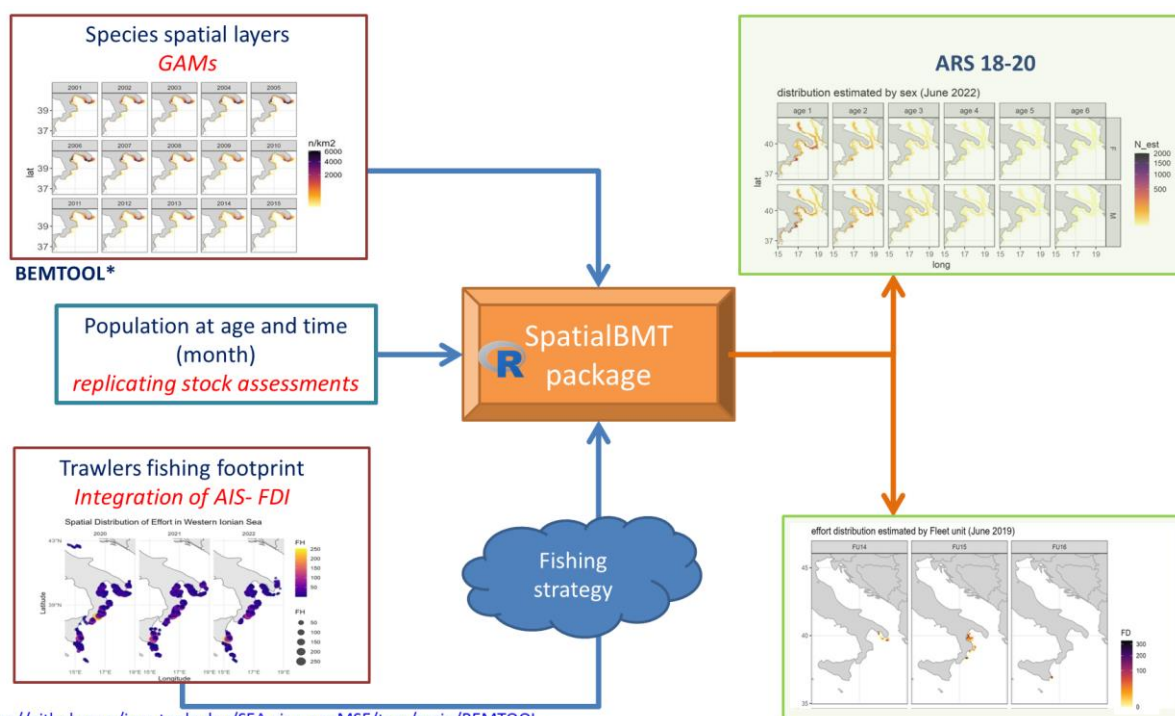


Figure 4 – Scheme summarising how Spatial BEMTOOL communicates with the main BEMTOOL model.

Fleets

Spatial BEMTOOL is able to simulate spatial effort and landing, informed by AIS and or VMS data and to project the reallocation of the effort when a spatio-temporal closure is assumed. Thus, using the available information on Global Fishing Watch, the trawlers > 12 m operating in GSAs 9, 10 and 11 could be potentially spatialized, while the other vessels are not spatialized, although they are included in the main BEMTOOL model (Table 3).

Table 3 - Combinations fleet segments-metier included in the main BEMTOOL model (EMU2) by GSA, gear type, including demersal trawlers (DTS), polyvalent passive gears (PGP) and hooks (HOK), and by vessel length (VL). The fleet segments underlined are the ones that could be potentially spatialized with spatial BEMTOOL.

GSA	Fleet segment	Metier
10	DTS_VL0612	OTB_DEF
<u>10</u>	<u>DTS_VL1218</u>	OTB_DEF and OTB_DWS/MDD
<u>10</u>	<u>DTS_VL1824</u>	OTB_DEF and OTB_DWS/MDD
<u>10</u>	<u>DTS_VL2440</u>	OTB_DEF and OTB_DWS/MDD
10	PGP_VL0018	GNS-GTR
10	PGP_VL0018	LLS
10	HOK_VL0024	GNS-GTR
10	HOK_VL0024	LLS
11	DTS_VL0612	OTB_DEF
<u>11</u>	<u>DTS_VL1218</u>	OTB_DEF and OTB_DWS/MDD
<u>11</u>	<u>DTS_VL1824</u>	OTB_DEF and OTB_DWS/MDD
<u>11</u>	<u>DTS_VL2440</u>	OTB_DEF and OTB_DWS/MDD
11	PGP_VL0018	GNS-GTR
9	DTS_VL0612	OTB_DEF
<u>9</u>	<u>DTS_VL1218</u>	OTB_DEF and OTB_DWS/MDD

GSA	Fleet segment	Metier
9	DTS_VL1824	OTB_DEF and OTB_DWS/MDD
9	DTS_VL2440	OTB_DEF and OTB_MDD
9	PGP_VL0018	GNS-GTR
9	PGP_VL0018	LLS

The AIS data from Global Fishing Watch from 2017 to 2024 can be used as spatial effort information of the fleet operating in the study area. The AIS data need to be merged with the GFCM and the EU fleet Registers (<https://www.fao.org/gfcm/data/fleet/register/en/> and https://webgate.ec.europa.eu/fleet-europa/index_el) to associate to each vessels the primary gear (e.g. OTB), the vessel length information, the operating area and the registration port. This step is of paramount importance to simulate fisher behavior in the Spatial BEMTOOL model.

In a second phase, the fishing footprint information is utilized to detect the main fishing grounds of the three GSAs through a cluster analysis (Bastardie et al., 2024); the FDI spatial landings and effort data (<https://data.jrc.ec.europa.eu/dataset/00ae6659-ddde-4314-a9da-717bb2e82582>), although this dataset has a low resolution, could be used to corroborate the identified fishing grounds.

The vessels are firstly grouped in < 18 m of length and ≥18 m of length and then their effort has to be mapped to detect its fishing strategy. Two fishing strategies are implemented in spatial BEMTOOL:

- “Specialists”, characterized by habitual patterns of fishing practices: same target species, one gear and one metier throughout the year, consistent annual fishing pattern from year to year and frequency to visit only one fishing grounds;
- “Switcher”, prone to modify the fishing strategy: changing the gear, changing métier (from OTB_DWS, deep-water trawling, to OTB_DEM, coastal trawling), changing fishing grounds, moving far from the port.

The Fleet Unit (FU) is finally defined as a combination of sub-area, vessel length group (above/below 18 m), and fishing strategy (e.g., Center_GSA10_above18m_switcher).

Stocks

The population by age class and time simulated by the existing BEMTOOL model in EMU2 can be spatialized in spatial BEMTOOL (Figure 5) using two possible options, according to the data availability:

1. Using the MEDITS observed data by length class and cell by year (<https://data.jrc.ec.europa.eu/dataset/f25092c4-3f0f-449f-ba60-5fbfe385defc>);
2. Using spatial distribution models for the whole population and, when available, for the sensitive stages of the population (recruits and/or spawners). In this case, recruitment (e.g. < 12 cm) and spawning length ranges are used to spatially distribute the individuals by length/age classes according to the sensitive stage.

Option 2 allows to model more accurately where the sensitive areas for the target stocks are located, respect to option 1 (using rough data).

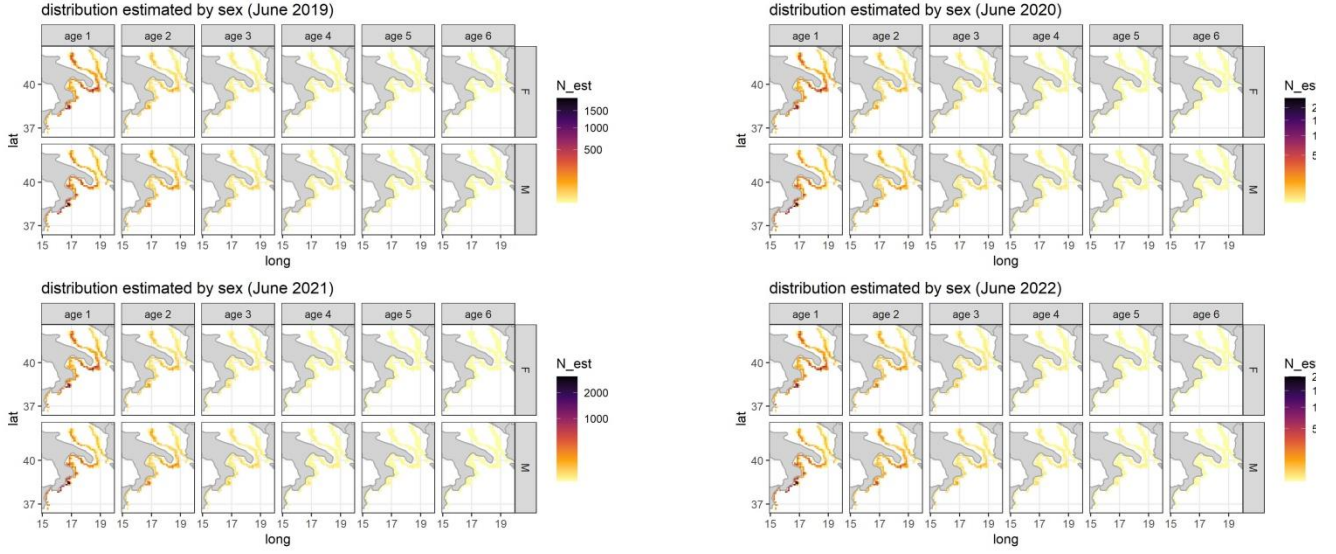


Figure 5 – Example of stock distribution by age and sex (of ARS, giant red shrimp in Western Ionian Sea and Southern Adriatic Sea) for 2019-2022. SEAwise project.

Fleet dynamics

The fishing strategy associated with each fleet unit is used to drive the re-allocation of the effort according to management measures (e.g., catch limits on specific target assemblages, such as red shrimps in the Ionian Sea; FRAs, etc.). Specifically, the specialists' effort distribution was based on the minimisation of an objective function based on the distance of the cells from the registration port (Figure 6). The switcher effort distribution was determined by the model maximizing the profit.

Depending on the category assigned to each fleet unit, the objective function that guided the behaviour of each fleet unit was based on a set of weights that were differently defined. The objective function was:

$$P\left(visited_{cell_{FU,t}} = cell_i\right) = \frac{w(cell_i) * P(visited_{cell_{FU,t-1}} = cell_i)}{\sum_{i \in Grid} w(cell_i) * P(visited_{cell_{FU,t-1}} = cell_i)}$$

where $P\left(visited_{cell_{FU,t}} = cell_i\right)$ is the probability that the fleet unit FU visit cell i at time t, based on the weights $w(cell_i)$.

$$\text{For specialists: } w(cell_i) = 1 - \frac{dist(home_{port}, cell_i)}{\sum_{i \in Grid} dist(home_{port}, cell_i)}$$

$$\text{For switchers: } w(cell_i) = \frac{profit(cell_i)}{\sum_{i \in Grid} profit(cell_i)}$$

For specialists, the distance was estimated using the `dist.obstacle` function of `GeoDist` R package that allows to determine the shortest path from points (home port) to points (cells in fishing grounds) with Dijkstra (data-tree-structure) algorithm, commonly used to find the shortest paths on a grid of vertices and knots with weights.

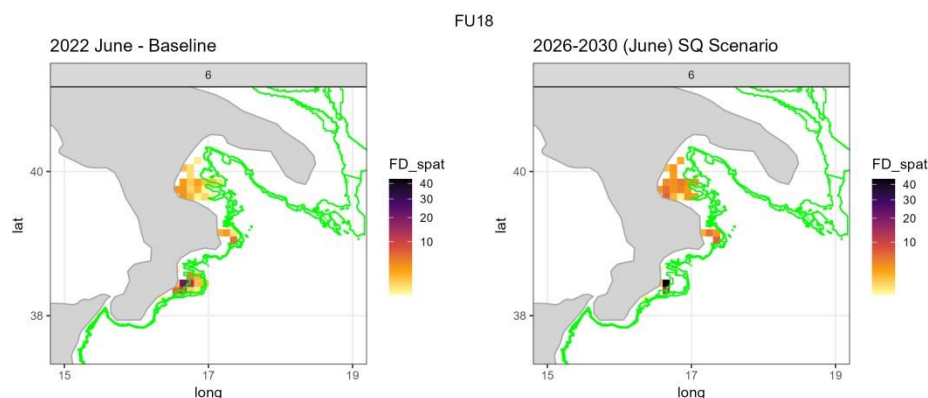


Figure 6 – Example of effort reallocation (specialists fleet units FU4, North GSA17-specialists above 18m, FU6, South GSA17-specialists above 18m, and FU18, Center GSA19-specialists above 18m) under 1) the baseline scenario (effort distribution as in 2022 without additional closures), 2) SQ with additional closures.

Example of outcomes of Spatial BEMTOOL

During the GFCM SRC of Adriatic Sea in 2025 some key results achieved in SEAwisE project, applying spatial BEMTOOL model to the demersal fisheries in Adriatic Sea. The analysis focused on Italian fleets operating in GSAs 17 and 18, classifying corresponding fleet units (and fishing communities) by vessel size, home port, and fishing strategy. Various management scenarios (e.g. Baseline, Status Quo, Fmsy, and Pretty Good Yield) in combination with of Otranto channel and 800-1000 m FRAs, were tested to assess their impact on effort distribution, fuel consumption and stock recovery. Results showed that the spatial closures considered have limited impact on fuel use for the fleets operating in the area (Figure 7).

During the GFCM SRC of Central Mediterranean Sea in 2025 some key results achieved in SEAwisE project, applying spatial BEMTOOL model to the deep-water fisheries in Western Ionian Sea were presented. In SEAwisE project new potential closure areas in western Ionian Sea, protecting vulnerable habitats and ARS essential fish habitats, were explored in combination with effort reduction to evaluate the impact of effort reallocation on fuel costs and exploitation rate. The results show how the tool distinguishes the impacts on different fleet segments, revealing who is most exposed to spatial measures (e.g. decrease/increase in fuel consumption, due to the closure) versus who is marginally affected, taking into account the effect of effort displacement driven by fishers reaction to management.

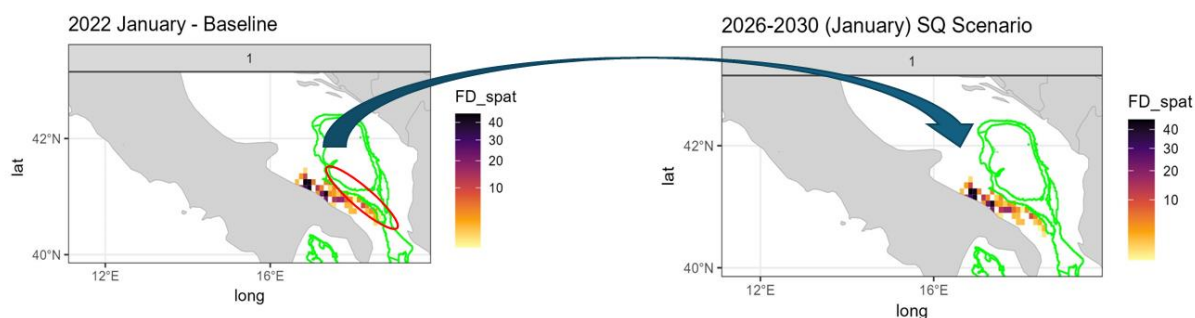


Figure 7 – Effort reallocation of the (Italian) fleet unit operating in the South of GSA 18 due to 800 m FRA closure as simulated by Spatial BEMTOOL. The fleet is only marginally impacted in terms of fuel consumption by the considered FRAs (< 1% effort deployed there).

Summary of available data and data gaps

Spatial BEMTOOL is a novel spatially explicit tool developed in the context of SEAwise project to complement the BEMTOOL bio-economic model and allow to properly simulate the bio-economic consequences of the spatial management measures.

The additional data (respect to the data needed to run BEMTOOL model) needed to apply Spatial BEMTOOL in any area are:

- AIS data (GFW), possibly complemented by VMS data (to inform the model on the spatial effort distribution);
- GFCM and EU Fleet Register (to be crossed with the GWF data and better define the fleet units in terms of vessel length, registration port and main gear);
- FDI effort and landing spatial data (to simulate effort and landing distribution in absolute terms);
- MEDITS data (TA, TB and TC, to identify how the relevant stocks are distributed in the study area, including sensitive areas);
- Logbook data (to refine spatial landing estimation).

Currently all the listed data are publicly available, except the logbook and VMS data.

Conclusions

The present ad hoc contract provided an overview of the relevant literature and grey literature on the spatial closures 600 and 800 m of depth in Western Mediterranean Sea.

For each study the main findings have been summarised, including the limitation of the report/model/study.

On the basis of the work carried out during the series of STECF EWG meetings dedicated to the evaluation of the fishing effort and catch limit regime in the Western Mediterranean Sea, as well as the work carried out by the STECF ad hoc contracts 2217 and 25103, two spatially explicit bio-economic models are currently parameterized for EMU1 (Isis-Fish) and EMU2 (SMART).

The present ad hoc contract was required to collate the available information to parameterize a new spatial component that complements the main BEMTOOL bio-economic model, applied since 2019 in EMU2 and in ad hoc contract 2217 also in EMU1. This component have been developed in SEAwise project and is able to communicate with the main BEMTOOL (not-spatial) model, allowing to take advantage of the case study currently in place in EMU2. This communication between BEMTOOL and spatial BEMTOOL allows to take into account the fisher behaviour and to have gears other than trawlers (including vessels below 12 m of length) included in the evaluation of the impact of spatial measures (around 25% hake production). Moreover, because the spatial module of BEMTOOL is built on top of the core BEMTOOL model, it can identify possible improvements in the catches of target stocks driven by stock recovery and provide projections not only in the short term but also in the medium term.

The data available for the Spatial BEMTOOL application were finally listed, highlighting the publicly available data and the data that would need to be specifically required for the application.

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