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Scientific Technical and Economic Committee for Fisheries (STECF) –

Implementation of the Technical Measures Regulation (STECF-23-15)

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CONTENTS

Abstract

Commission Decision of 25 February 2016 setting up a Scientific, Technical and Economic Committee for Fisheries, C(2016) 1084, OJ C 74, 26.2.2016, p. 4–10. The Commission may consult the group on any matter relating to marine and fisheries biology, fishing gear technology, fisheries economics, fisheries governance, ecosystem effects of fisheries, aquaculture or similar disciplines. This report presents the findings of the STECF Expert Working Group 23-15: Implementation of the Technical Measures Regulation, from the meeting held from 22nd to 26th January 2024 at JRC Ispra.

EWG 23-15 have documented that the foundational building blocks of a bio-economic impact assessment of technical measures are present in the EU. However, it will take 2 – 5 years to fully operationalise the process of providing robust and transparent advice for these needs.

ToR 1 (Section 3) underscored the significant interest and depth of research within the realm of integrated ecological and economic fisheries models, notably in bio-economic modelling. These models represent valuable tools for evaluating the impacts of technical measures. Despite the availability of tools and data, albeit to varying extents across different sea regions, there lacks a dedicated framework to meet this specific advisory requirement. Consequently, the primary obstacle to operationalizing such advisory products lies in the scarcity of time and qualified personnel for conducting data analysis, stock assessment, and bio-economic modelling. Furthermore, there is a shortage of experts proficient in multidisciplinary approaches, particularly in participatory management, which hinders effective communication among diverse stakeholders.

EWG 23-15 have identified possible candidate models (ToR 3, Section 5), data sources (ToR 2, Section 4) and frameworks, which could support such a process (ToR 3, Section 5). However, this resource (data, time and expertise) hungry process would benefit from long-term investment in research and a dedicated Expert Working Group, as well as transitional support for fisheries to improve engagement and likelihood of success.

EWG 23-15 notes that the success of this process will be defined by the inclusion of human dimension to ensure the model captures realistic fleet behaviour, relevant to advice needs, and captures the drivers of patterns and their resulting impacts on the ecological, economic and social dimension of the system (ToR 4, Section 6).

Finally, EWG 23-15 highlights that to successfully assess transitional needs future work should not only focus on modelling but also on the human dimension which will require training programs, technical support for fisheries transition, and effective change management strategies in fisheries governance.

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SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF) - IMPLEMENTATION OF THE TECHNICAL MEASURES REGULATION (STECF-23-15)

Background provided by the Commission

Since the adoption of Regulation (EU) 2019/1241, DG MARE has convened three Expert Working Groups to monitor the implementation of the regulation. One of the main aims of this regulation is to optimise the exploitation pattern of commercial fisheries. The main mechanism to achieve this is through amendments to the annexes of the Regulation that set out provisions on the operation and specifications of fishing gears, including minimum mesh sizes and selectivity devices to be used. To this end, STECF was requested (EWG 22-19) to prepare available information regarding the optimal sizes and ages at which the main commercial species (taken individually) should optimally be caught, as well as the types and technical definitions of fishing gear that would be appropriate to achieve this aim.

To progress this work, DGMARE proposed to establish a further EWG 23-15. This EWG will build on the work, and findings, of EWG 21-07 and EWG 22-19. The work of EWG 23-15 will focus on the stocks identified in EWG 22-19 for which changes in technical measures were shown to provide potential gains in terms of yield and protection of juveniles. EWG 23–15 will explore the application of bio-economic modelling to identify the impacts of possible operational changes needed to realise the transition to higher yields. EWG 23-15 will also identify the technical support required to assess at the regional level, the potential socio-economic implications of fisheries-based transition plans for improving yields.

The experts attending the EWG 23-15 (economists, mixed fisheries stock assessors, modellers, and gear specialists) will consider a number of case studies and develop fisheries-based transition plans to inform future research goals and advice needs. A literature review will also enable EWG 23-15 to put the model results into the broader context of the implementation of technical measures.

EWG 23-15 is considered a scoping meeting and should involve stakeholders, particularly the Advisory Councils (ACs). The relevant ACs will be contacted and invited as observers to the EWG meeting. A dedicated session will be organised during the EWG to gather industry perspectives.

The findings from this group will feed into further EWGs with the longer term goals *inter alia*:

1) Explore how increased yields of hake (i.e., Atlantic northern hake stock) can be achieved, what long-term benefits and costs could be attained;

2) Identifying alternative pathways of gears changes to increase the size-selectivity of mixed fisheries and impacts of fishing gear diversification;

3) Assess, for each sector, likely costs and benefits associated with the progressive changes over time.

For this reason, EWG 23-15 will discuss the direction of future work, additional data/tools, stakeholder engagement, and advice needs. The EWG will need to consider the socio-economic barriers and implications to implementing technical measures changes. The outcomes of EWG 23-15, and future technical measure Expert Working Groups, should align with ongoing work at the International Council for the Exploration of the Sea (ICES) Working Group on Mixed Fisheries Methodology (WGMIXFISH-Methods; ICES 2023a), and in a number of national labs, where bio-economic models have been under production for some time, and are considered an important tool for future advice need. As momentum in this field of research grows, end users of the ICES mixed fisheries advice have identified bio-economic models as an important tool to deal with future management needs (ICES 2023b).

Request to the STECF

STECF is requested to evaluate the findings of the STECF Expert Working Group meeting and make any appropriate comments and recommendations.

STECF comments

EWG 23-15 met at the JRC in Ispra, Italy, 22-26 January 2024. The meeting was attended by 23 experts in total, including 4 STECF members and 2 JRC experts. As this was a scoping meeting, 15 observers from diverse backgrounds, including Advisory Councils, also attended the meeting. STECF considers that the EWG adequately addressed the ToRs and has the following specific comments on the ToRs addressed by EWG 23-15.

ToR 1– Provide a summary of the current knowledge on the tools available to assess the socio-economic implications of changes in technical measures. This review should provide context and support for the analysis to ensure meaningful conclusions can be drawn from the findings of the models identified in EWG 23-15.

STECF observes that the EWG provided an extensive overview of bio-economic models that are valuable tools for evaluating the socio-economic impacts of technical measures, along with a list of their applications in the North Sea, Western waters and Mediterranean Sea regions. On the other hand, for some sea regions (Black Sea and Cyprus waters), no bio-economic model was found applicable.

STECF notes the importance of integrating the modelling part of the impact assessment of the implementation of technical measures within a broader framework, where the identification of the policy objectives and a clear feedback loop with the fishers through stakeholder involvement are needed to obtain a robust, realistic and meaningful decision support tool within the current advice process.

STECF notes that the EWG provided general insights on the short- (additional costs) vs. long-term (uncertain predicted long-term gains) economic consequences of the reduction of unwanted catches due to the implementation of technical measures. To capture those short- vs long term trade-offs, it is important to have explicit fisher behaviour dynamics included in the models and appropriate scenarios developed with stakeholders.

STECF notes that the available knowledge on potential socio-economic impacts of improvements in selectivity is often based on studies related to the implementation of the landing obligation (LO), as the main objective of the LO is the reduction of unwanted catches by improvements in selectivity. However, the LO exemption measures that are in force complicate the ability to have meaningful socio-economic assessment outcomes.

ToR 2 – Identify, quality control, and summarise the data required to run a bio-economic assessment of gear changes. In particular, but not limited to, the species and fisheries identified in EWG 22-19, for which the highest gains can be achieved (outcomes of EWG 22-19), and species (target & bycatch) caught as part of these mixed fisheries.

STECF notes that the gear selectivity studies, the stock assessment data, the fleet data (catch, effort and economic data) and the social data are the data sources required to feed into the bio-economic models.

STECF notes that while much has been achieved in terms of availability, quality control and merging of gear selectivity studies, single species stock assessment data and fleet data (catch, effort and economic), there is still a gap in the provision and collection of social data. Therefore, the EWG identified the inclusion of social data in the impact assessment as a priority for sustainable fisheries management.

STECF notes that the EWG provided a thorough comparability analysis of the landings, effort and value metrics for the years 2017-2021, available in the fisheries dependent information (FDI) data set and annual economic report (AER) data set. Overall, improvements in consistency were observed over the years but the persistent discrepancies attributed to the different timing of the data calls, confidentiality issues, involvement of different institutions and inconsistent definitions, highlight the need for pursuing increased national coordination and EU-level workshops. STECF notes that this analysis only covers fleet data at European level and does not cover the Mediterranean.

ToR 3 – Identify the most suitable models, per ecoregion, to assess where possible:

a) the impacts of increasing the size-selectivity of gears on the species caught in mixed fisheries in terms of catch, effort, fishing mortality and recruitment.

b) the likely costs and potential benefits associated with gear changes for fleets on the short-term and longer-term.

Suitability will be assessed on data requirements, ease of parametrisation, short and long-term forecasting capabilities, adaptability for long-term goals.

STECF observes that the EWG provided a summary of the bio-economic models in the North Sea, the Celtic Sea, the Bay of Biscay and Atlantic Iberian Waters and the Mediterranean Sea region, that are currently applied for advice of fishing opportunities purposes and are adaptable to assess the impact of technical measures.

STECF notes that within each region, different challenges and varying degrees of model documentation were identified. The models applicable in the Bay of Biscay and Atlantic Iberian Waters and the North Sea region represent the largest coverage of species and fleets.

STECF observes that the EWG identified a multidisciplinary stepwise process to realise a bio-economic assessment of the potential impacts of technical measures. This process was further specified using Atlantic northern hake stock as an example. This hake stock was selected as a case study based on the findings of EWG 22-19, where it was identified as a stock likely to benefit from the implementation of specified gear measures, which may result in increased protection of juveniles, but which is also a potential choke species in many fisheries.

ToR 4 – Identify meaningful management scenarios that could be produced with these models, and the additional information/data/models that would be required to produce additional scenarios.

STECF observes that the EWG addressed this ToR by a dedicated discussion with stakeholders and through documents provided by advisory councils (ACs) to gather information on what their perspective is on sustainable management scenarios. STECF notes this resulted in a very comprehensive and valuable overview of the issues identified by stakeholders regarding the implementation of technical measures.

STECF notes that up until now, the role that economic and social aspects have played in fisheries management is unclear and management decisions are mainly based on biological targets. There is a general understanding that the inclusion of social data is essential to reflect decision-making and well-being of the fishing communities. Additionally, STECF observes that the harmonisation of management measures with third countries is important and that a management strategy evaluation approach should be applied to provide a better understanding of variability and uncertainty.

ToR 5 – Discuss direction of future work, additional needs, stakeholder engagement, and advice needs.

STECF notes that the EWG identified possible candidate bio-economic models, data sources and frameworks which are needed for the development of a relevant and meaningful tool for evaluating the impacts of technical measures, but there is currently no long-term commitment and interdisciplinary cooperation to support this. Assigning the roles and responsibilities, defining the deliverables and establishing the timelines for the way forward, will be discussed in detail at the next STECF Plenary.

STECF notes the need to continue the work on selectivity indicators, which will deliver metrics to measure progress in terms of improving fishing patterns.

STECF conclusions

STECF endorses the outcomes of EWG 23-15 presented during STECF PLEN 24-01 and concludes that all ToRs were appropriately addressed.

STECF acknowledges that the EWG, through the scoping meeting, has summarised the current knowledge on bio-economic models and their data needs, applicable within the North Sea, Western Waters and Mediterranean advice framework.

STECF concludes that the biggest need and challenge towards a relevant and realistic advice on the bio-economic impacts of technical measures implementation is the integration of bio-economic modelling results in the socio-economic context, including stakeholder perspectives. The addition of this human dimension is the main driver for the actual decision-making process.

STECF concludes that although data, tools, and expertise required to conduct a bio-economic assessment of the impacts of technical measures are available in diverse sea regions, there is currently no suitable financial framework, nor expert working group dedicated to support and coordinate this data-demanding, multidisciplinary process.

STECF acknowledges that a time-consuming stepwise procedure, in which the definition of relevant scenarios with stakeholders, economic conditioning of fleets and cross-checking the model outcomes with stakeholders are fundamental, is needed to fully operationalise a bio-economic assessment. However, as this is a work in progress, intermediate outputs can be delivered in the development of a relevant and meaningful impact advice tool over time. Moreover, in many cases there is no need to commence from the beginning as the first steps in this process were already initialised.

STECF concludes that the next step forward should be to commence a case study (e.g. the FLBEIA WGMIXFISH model for the Atlantic northern hake stock, within the Bay of Biscay) to follow through the stepwise procedure. This would benefit from a collaborative approach between STECF and ICES. The organisation of "who, what, when" will be discussed at the next STECF Plenary.

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REPORT TO THE STECF

EXPERT WORKING GROUP ON IMPLEMENTATION OF THE TECHNICAL MEASURES REGULATION (EWG-23-15)

Hybrid meeting, 22-26 January 2024

1 INTRODUCTION

Technical measures are a broad set of rules that govern how, where and when fishers may fish. They are established for all European sea basins, but they differ considerably from one basin to another, in accordance with the regional conditions. Since the adoption of the Technical Measures Regulation (EU) 2019/1241, DG MARE has convened three Expert Working Groups (EWGs) to monitor its implementation, aiming to optimize the exploitation pattern of commercial fisheries. One of the regulation's main mechanisms involves amendments to fishing gear specifications to achieve optimal exploitation patterns. To support this effort, STECF was tasked to prepare information on optimal catch sizes and ages for commercial species, as well as suitable fishing gear types.

To further this work, DGMARE proposed establishing EWG 23-15, building on previous groups' findings. EWG 23-15 focused on stocks where technical measure changes could improve yield and protect juveniles, exploring the use of bio-economic modelling to identify impacts of operational changes and assess socio-economic implications at the regional level.

While the science supporting fisheries management has generally been dominated by natural sciences, there has been a growing recognition that managing fisheries essentially means managing economic systems (Thébaud *et al*. 2023). Therefore, to enable the assessment of the sustainability and impact of management measures, such as technical measures, scientists and managers require effective tools. These tools should clearly describe the potential biological, economic, and social impacts, facilitate transparent discussions around short to long-term trade-offs, and provide assessable advice.

The group of models known as Integrated Ecological-Economic Fisheries Models (IEEFMs) could be used for this purpose by providing a mathematical representation of ecological and economic systems which can also integrate social dynamics (Nielsen *et al*. 2018; Prellezo, 2012). Some of these models can even enable the feedback between ecological and human systems, ecological and economic processes within a system, providing a dynamic platform by which to assess strategic (long-term), and tactical (medium term) management advice on marine resources and decisions according to best practices (Nielsen *et al*. 2018; FAO 2008; Plagányi 2007). Such models would be required to assess the complex impacts of management measures such as technical measures, which can lead to reallocation of effort from one activity to another within a fleet, potentially impacting other parts of the ecosystem (see for example Abbot and Haynie, 2012).

IEEFMs, in particular bio-economic models, have been extensively reviewed in a number of publications (i.e. Thébaud *et al*. 2023, Nielsen *et al*. in 2018), and this report does not aim to replicate that analysis. Instead, this report focuses on how to operationalize these models within the current advice process to inform decision-making, covering aspects like data, tools, processes, stakeholder engagement, and policy objectives.

Models parametrised with economic information, improve understanding of the development of fisheries, response to change, and trade-offs associated with management strategies. However, communicating results from these models can be challenging. Additionally, the inclusion of social data and stakeholder knowledge is crucial to understanding how policy options interact with stakeholder incentives and achieving management objectives.

Operationalising the use of IEEFMs requires long-term commitment and interdisciplinary cooperation. These models require substantial data and expertise (Figure 1.1.1**Error! Reference source not found.**), with no one-size-fits-all approach to model design. Ultimately, when operationalizing models to assess technical measures' impacts in fisheries, it is essential to consider trade-offs to meet specific system needs and management goals. Moreover, models should be adaptable to different contexts and user requirements.

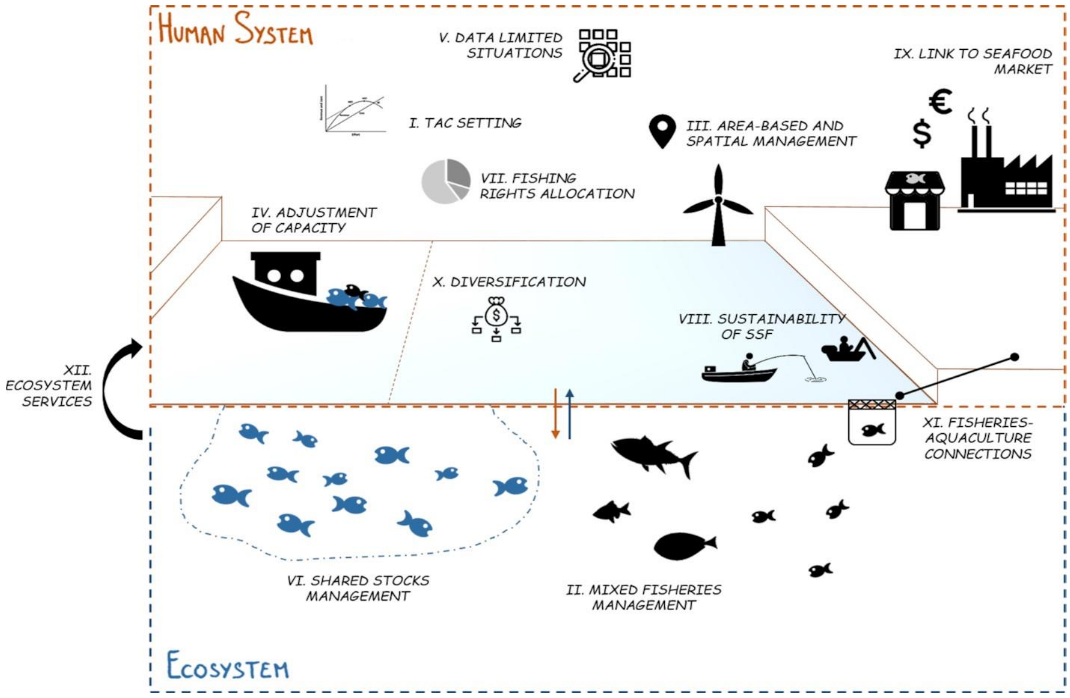

Figure 1.1: Graphical representation of the diversity of data required to model the ecological, economic and social impacts of management measures such as technical measures (source: Thébaud *et al.* 2023)

1.1 Terms of Reference for EWG-23-15

ToR 1- Provide a **summary of the current knowledge** on the tools available to assess the socio-economic implications of changes in technical measures. This review should provide context and support for the analysis to ensure meaningful conclusions can be drawn from the findings of the models identified in EWG 23-15.

ToR 2 – Identify, quality control, and summarise the **data required** to run a bio-economic assessment of gear changes. In particular, but not limited to, the species and fisheries identified in EWG 22-19 (STECF 2022a), for which the highest gains can be achieved (outcomes of EWG 22-19), and species (target & bycatch) caught as part of these mixed fisheries.

ToR 3 - Identify the **most suitable models, per ecoregion**, to assess where possible:

a. the impacts of increasing the size-selectivity of gears on the species caught in mixed fisheries in terms of catch, effort, fishing mortality and recruitment.

b. the likely costs and potential benefits associated with gear changes for fleets on the short-term and longer-term.

Suitability will be assessed on data requirements, ease of parametrisation, short and long-term forecasting capabilities, adaptability for long-term goals.

ToR 4 – Identify meaningful **management scenarios** that could be produced with these models, and the additional information/data/models that would be required to produce additional scenarios.

ToR 5 - Discuss direction of **future work**, additional needs, stakeholder engagement, and advice needs.

2 ToR 1 – Summary of current knowledge

This term of reference is dedicated to summarizing the existing knowledge of tools used to evaluate the bio-economic implications of adjustments in technical measures. Given the extensive review of Integrated Ecological-Economic Fisheries Models (IEEFMs), especially bio-economic models, in several peer-reviewed publications (e.g., Thébaud *et al*. 2023, Nielsen *et al*. 2018), this report does not seek to duplicate that analysis. Instead, EWG 23-15 focused on operationalising these models within the present advisory framework to provide decision support tools. The summary of available knowledge encompasses various building blocks required to implement such a system, including data, tool integration, procedural guidelines, stakeholder involvement, and alignment with policy objectives.

The outcomes of this ToR are shaped by the collective expertise present and are not intended to be exhaustive. However, they do represent a group of scientists working within in the current data, advisory, and policy systems within the North Sea, Western Waters and the Mediterranean. The diverse expertise encapsulated in this literature review ensures that all aspects—ranging from practical gear technologies to modelling, data, and policy—are given equal consideration. This information was collected through presentations and shared discussion at EWG 23-15. Most of the presentations focused on individual models and their applications in assessing management measures. Additionally, there was a more generalized presentation on the socio-economic assessment background within STECF and the economic considerations of short- vs. long-term implementation of Technical Conservation Measures (TCMs).

A summary of the presentations were grouped into the following subject areas:

a) Models and their applications

b) Policy

c) Socio-economic assessment

d) Stakeholder input

2.1 Models and applications

Models with economic information improve understanding of fisheries development, response to change, and trade-offs associated with management strategies. However, communicating results from these models can be challenging. Additionally, the inclusion of social data and stakeholder knowledge is crucial to understanding how policy options interact with stakeholder incentives and achieving management objectives.

An extensive comparative study of IEEFMs was completed by Nielsen *et al*. 2018, where 35 IEEFMs were evaluated and described in terms of model characteristics and performance, categorisation and descriptors, uses and trade-offs. An overview summary of these uses and trade-offs can be found in Table 2.1, and provides the reader with a valuable tool by which to quickly understand the capacity and limitations of available tools.

Table 2.1: Model use overview according to main cover of use and types of use, as well as major trade offs in relation to the use (Nielsen et al. 2018).

Model	Model Use and Type of Use																																		
	Main Coverage of Use								**Management Advice**					**Level of Implementation**				**Academic**				**Level of Model Development**				**Trade-Offs**									
	Data Coll.	Sing. Stock	Multi-Spec	Ecosyst.	Mix. Fisher.	ITQ / ITE	Socio-Econ	Social	National	ICES	EU	N. Amer.	Other	High	Medium	Low	No	Internal	Report	P-R Published	Freq. Cited	Age of model	Advanced	Big Devel. Group	Manual/Website	Developer	Educated	All	Simple	Complex	Specialized	Flexible	Technical/ System	Open Access	User-friendly
Crab Ocean Acidification Model		X			X	X			X			X					X			X		4 YEARS	X		No	X				X	X				
Crab ABC Model		X			X	X			X			X			X				X	X		2 YEARS	X		No	X				X	X				
Multispecies Stock-Production Model (MSPM)		X	X						X							X			X	X		19/10 YEARS	X			X				X		X		X	
N./S. Hake Stoch. Age-Struct. Opt. M. (N/S HAKE ASM)		X	X		X	X	X			X	X			X					X	X	X	7 YEARS	X			X	X		X			X		X	
EIAA	X	X			X		X		X		x			X					X	X		15 YEARS	X	X	X	X	X			X				X	
BEMEF (Extended EIAA)	X	X			X		X		X	X	X		X		X				X			2 (+15) YEARS	X		X	X	X			X	X	X		X	X
MAQ		X				X					X									X		2 YEARS	X			X				X		X	X		
MAQ ADJ		X				X	X				X			?	?	?				X		2 YEARS	X			X				X		X	X		
DISPLACE	X		X		X		X		X	X	X					X				X		2 YEARS	X		X	X	X			X	X	X		(X)	
ISIS-FISH Model		X	X		X	X	X		X	X	X		X	X						X	X	13 YEARS	X		X	X	X			X		X		X	X
BALTIC FLR-SMS	X		X		X		X		X	X	X					X			X	X		4 YEARS	X			X	X			X	X	X			
IAM			X		X	X	X	X	X	X	X				X				X	X		4 YEARS				X				X	X	X		X	
FISHRENT_TI-LEI		X	X		X	X	X		X	X	X					X			X	X		3 YEARS	X							X		X		X	
FISHRENT_IFRO		X	X		X	X	X		X	X	X					X				X		4 YEARS	X			X				X		X		X	
SRRMCF			X		X	X	X		X						X				X	X		?	X			X				X		X	X		

Model	Model Use and Type of Use																																		
	Main Coverage of Use								Management Advice					Level of Implementation				Academic				Level of Model Development				Trade-Offs									
	Data Coll.	Sing. Stock	Multi-Spec	Ecosyst.	Mix. Fisher.	ITQ / ITE	Socio-Econ	Social	National	ICES	EU	N. Amer.	Other	High	Medium	Low	No	Internal	Report	P-R Published	Freq. Cited	Age of model	Advanced	Big Devel. Group	Manual/Website	Developer	Educated	All	Simple	Complex	Specialized	Flexible	Technical/ System	Open Access	User-friendly
Coupled Lobster-Herring Model (NECLH)			X				X					X			X					X		4? YEARS				X				X	X		X		
Baltic Economic-Ecological Model		X	X				X				X						X		X	X		4 YEARS	X			X	X		X			X		X	
ELFSim GBR Australia			X		X	X	X						X	X					X	X	X	15 years	X				X			X		X		X	
Australia NPF_TigerPrawnModel, NPFTPBEM	X		X		X	X	X		X					X					X	X	X	5 YEARS	X			X	X			X	X		X		
Australia NPF Simplified Bio-Economic Model			X		X		X		X								X			X		2 YEARS	X			X	X			X		X		X	
MEFISTO		X	X		X		X		X		X		X		X			X	X	X		12 YEAR	X			X	X	X		X	X		X	X	X
FLBEIA		X	X		X		X	X	X	X	X			X				X	X	X		3 YEARS	X		X	X	X	X		X	X	X	X	X	
FCUBE	X	X	X		X		X		X	X	X			X						X	X	9 YEARS	X			X	X		X	X		X		X	
Georges Bank Food Web-CGE Model			X	X			X		X			X					X			X		4 YEARS	X			X				X		X	X		
Baltic Sea ATLANTIS			X	X	X		X			X	X						X	X	X			1 YEAR		X		X				X		X	X		
California Current ATLANTIS			X	X	X	X	X					X			X					X			X			X				X		X	X		
ECO²		X	X	X	X		X	X	X	X	X	X	X				X			X		2 YEARS							X	X		X		X	
North sea Ecopath with Ecosim			X	X	X		X		X	X	X			X					X	X	X	8 YEARS, 3 yearly updates	X		Key Run reports and data via ICES	X	X			X	X	X		X	X
Baltic sea Ecopath with Ecosim			X	X	X		X			X	X			X						X	X	3 YEARS	X			X	X			X	X	X		X	
Generic Ecosystem model			X	X	X											X				X		3 YEARS				X			X			X		X	

With a strategic emphasis on implementing the Integrated Environmental and Economic Fisheries models (IEEFMs) to evaluate the efficacy of technical measures and formulate transition plans, EWG 23-15 has expanded upon Nielsen *et al*.'s 2018 groundwork by examining various models in terms of their applications.

A total of seven models are described within this summary, along with a list of their applications across different sea regions: north western waters (NWW), south western waters (SWW), the North Sea (NS) and the Mediterranean Sea (MED) (Table 2.2). The varying numbers of applications per model is driven by the expertise attending EWG 23-15 and the usability of the models. The experts attending EWG 23-15 are imbedded in the advice production process within ICES, General Fisheries Commission for the Mediterranean (GFCM) and STECF; making them familiar with the models which are aligned with current data collection and advice needs, and are therefore the models most likely to be operationalised. The potential to operationalise these models are dealt with in section 5 of this report (ToR 3).

Additionally, it is worth highlighting that there are a number of sea areas and Member States for which no bio-economic model applicable to the assessment of technical measures regulation could be found (e.g. Black Sea, and Cyprus waters). Demonstrating that research into bio-economic models is not standard in all EU waters.

Table 2.2: Models described within this summary, number of applications summarised, and sea regions they cover: north western waters (NWW), south western waters (SWW), the North Sea (NS) and the Mediterranean Sea (MED).

Model	Number of applications described	Sea regions
FLBEIA	9	NWW, SWW, MED, NS
IAM	4	SWW, MED
MEFISTO	4	MED
SMART	2	MED
SIMFISH	1	NS
BEMTOOL	2	MED
DISPLACE	1	MED

2.1.1 Model focus 1 - FLBEIA - bio-economic simulation framework

FLBEIA (Garcia *et al*. 2017) is an R library (https://www.r-project.org/) based on FLR libraries (Kell *et al*. 2007). FLR provides the basic pieces to construct the model and FLBEIA assembles them to build a composable bio-economic model. FLBEIA follows the classical Management Strategy Evaluation (MSE) scheme where both the operating model (which simulates the real ecosystem), and the management procedure (which simulates the whole management process from data collection to the provision of management advice) are explicitly modelled in a feedback loop. It has been coded modularly using a bottom-up approach to facilitate its extensibility. For each of the processes that build up the model, the existing function(s) to represent them can be easily replaced by alternative ones as far as their input and output structure is maintained. FLBEIA software is open source (http://github.com/flr) and extensively documented (https://flr-project.org/doc/).

FLBEIA model allows seasonal steps along the year, which permits simulating different management calendars as an alternative to the traditional management at the end of the year (for setting the TACs for the January to December period). Management strategies implemented in FLBEIA cover a wide range of harvest control rules (HCRs). For example, model-based F rules (such as the ICES MSY rule) and biomass escapement strategies widely used for short-lived species (ICES 2013; Sánchez *et al*. 2019), or empirical (also known as model-free) trend-based rules (ICES 2021a; Sánchez-Maroño *et al*. 2021) and target-based rules (González-Costas *et al*. 2019). These HCRs can additionally include interannual variation limits or minimum and maximum thresholds.

FLBEIA has been used to evaluate management strategies for specific stocks (Citores 2021; González-Costas *et al*. 2019; ICES 2021a; Sánchez *et al*. 2019; Sánchez-Maroño *et al*. 2021) in a single-stock, single-fleet mode. However, its main strength is its multi-stock multi-fleet and multi-métier nature. Currently, is the main model used to provide mixed-fisheries considerations in ICES (see for example ICES, 2022a). In this case, the model is used in a deterministic mode to conduct a short-term forecast at stock and fleet-métier level. It has also been used in a mixed fisheries context including uncertainty to: (i) test the impact of the landing obligation (Prellezo *et al*. 2016 & 2017); (ii) test the performance of a multi-stock HCR, that operationalises the fishing mortality ranges in a multi-stock and multi-fleet context (García *et al*. 2019); or (iii) carry out a Global Sensitivity Analysis to identify the factors with the highest impact in the results (García *et al*. 2021). Additionally, it has been extensively used to implement long-term bio-economic simulations.

FLBEIAshiny is an additional package to visualise the main results in a simple way at stock, fleet and métier levels using Shiny (https://shiny.posit.co/) and can also be used to download the figures available in the Shiny App. FLBEIAshiny package is independent of FLBEIA and can be used with both FLBEIA output objects directly or with R data frames with the same columns as the ones used to summarise FLBEIA results.

2.1.1.1 FLBEIA example application 1 - WGMIXFISH

FLBEIA is used in the ICES WGMIXFISH to provide mixed fisheries advice for several ecoregions (e.g. ICES 2023c). The aim of ICES WGMIXFISH projections is to extend the single species advice by considering the implications of technical interactions and multiple species caught simultaneously by fishing units on fishing opportunities. WGMIXFISH has developed procedures to condition mixed fisheries models used for short-term forecasts in a standardized way to reflect single species advices as much as possible. Fleet and métier parameters, including catchability, landing/discard weights at age, and effort shares, are based on a specific data call that includes landings and effort data at the métier DCF level 6 as well as InterCatch data used to inform single species assessments. Stocks (numbers-at-age and biological parameters such as maturity, natural mortality and stock weights) and forecast assumptions are based on the information provided by the ICES single species working groups so the projections of the stocks align with those of the single species forecasts. The projections do not consider any socio-economic drivers or economic sub models and assume that fleet dynamics (effort allocation within a fleet) are static.

2.1.1.2 FLBEIA example application 2 - SEAwise

Within the SEAwise project (https://seawiseproject.org/), FLBEIA is also used in a number of ecoregions across Europe to assess the effect of environmental changes (climate) on the development of fisheries. In these models, fleets and métiers are conditioned according to the ICES WGMIXFISH routines, but also include information on fish prices and socio-economic data (e.g. the Annual Economic Report (AER) is used for economic conditioning of the fleets). This includes different costs (fixed, variable (decomposed in fuel and other) and capital costs), subsidies, employment, and number of vessels. This information feeds into a number of economic submodels that govern vessel exit/entry decisions and/or allow to forecast fish prices. In addition, a number of (economic) indicators is calculated based on the economic variables such as gross profit, current revenue to break even revenue, fuel consumption, employment, etc.

2.1.1.3 FLBEIA example application 3 - ProbyFish

FLBEIA was also used in the ProbyFish project (EU 2021) to assess the effect of technical measures on bycatch species in mixed fisheries. In this project, the fleets were conditioned as is done in ICES WGMIXFISH, and socio-economics were ignored. Gear selectivity studies were used to inform how catchability of métiers would change if selectivity devices were to be used. From this exercise the following caveats emerged:

- Fleets used in gear trial studies do not always match with the fleets used in mixed fisheries models. Mapping of the fleets is not straightforward and may depend on interpretation of the analyst.
- Gear trial studies may be focused on a number of species, and not cover all species included in the fleet of a mixed fisheries model. Hence, if species coverage differs, this requires to make some assumption on how selectivity would change for the "missing" species.
- Fleet dynamics should also be considered if catch compositions or catchabilities change. Most selectivity changes have also an impact on the commercial part of the catch, and may change the profitability of a fishery, and thus the exploitation pattern.

2.1.1.4 FLBEIA example application 4 - DAMARA

The DAMARA project (EU 2016) involved building a bio-economic model to develop a mixed-fisheries management plan for the Celtic Sea and in parallel to improve selectivity in the demersal fisheries in that area. The tool was designed to allow for comparative analysis to be drawn between different management interventions and as a tool for stakeholders to identify and quantify various biological, economic and social trade-offs inherent in the decision-making process.

The model utilised the FLBEIA framework and incorporated data sources from STECF Fisheries Dependent Information (FDI) for the métier based fishing activity merged with AER economic data. Ten scenarios were simulated including several that incorporated selectivity changes in fishing patterns.

2.1.1.5 FLBEIA example application 5 - BIOECON

In 2020 Bord Iascaigh Mhara initiated the project 'Bio-economic model to assess the impact of the Landing Obligation' (Dolder *et al*. 2021). The main aims of this project were to develop a multifunctional bio economic model to: estimate the impact of quota changes on all segments of the Irish fleet, simulate the impact of gear selectivity measures, simulate scenarios of future policy and to provide a clear visualisation tool for non-expert policymakers and stakeholders. The developed model is based in FLBEIA and allows analysis of all métiers and specified fleet segments of the Irish fleet. Over 40 species are modelled using a range of biological models. The socioeconomic aspects ensure analysis of direct and downstream impacts is possible at the national and regional levels in terms of value generated, profitability and employment.

2.1.1.6 FLBEIA example application 6 – Bringing selectivity into FLBEIA and BIOECON – BIM/MI/ATU development of stock forecasting tool linking length-based results of gear trials with age-based stock assessment models

The EU technical measures regulation (EU 2019/1241) allows for additional selective gears/ technical measures to be recommended by Member States and implemented provided equivalent selectivity is demonstrated with existing measures.

BIM, the Marine Institute and the Atlantic Technological University in Ireland are developing a tool that integrates the length-based results of a gear trial with age-based stock assessment models to forecast the short-term effects of a gear change.

They incorporate uncertainty from a 2019 catch comparison gear trial (Browne *et al.* 2019) in the form of between-haul variability as it likely reflects the real-world performance of the gear.

Using a method devised by Breen and Cook (2002) they incorporate uncertainty from the stock assessment in the length to age transformation, by including variability in age at length to better represent the population of fish encountered during the trial.

By confining forecasts to one year ahead they reduce uncertainty in the stock assessment as it is possible to confound the effect of a gear change over longer timescales (Eustace *et al.* 2007). The forecasted effects of the gear change have been incorporated in BIOECON a bio-economic model to further explore the effect of the gear change.

2.1.1.7 FLBEIA example application 6 – MSE NW MED

The method used in the study involves a bio-economic management strategy evaluation (MSE) approach to compare the performance of two technical solutions aimed at improving trawl selectivity. The primary objective was to assess the impact of these technical solutions on catch, biomass, recruitment, and fishing mortality. The study also involved a simple analysis of the differences in catch volume and value using fisheries production data obtained during field experiments. Additionally, the study utilized bio-economic modelling to inform economic impacts at larger temporal scales and aggregated at the fleet level. The technical details of the model application were built with FLBEIA and the underlying software components of the Fisheries Laboratory in R (FLR). The simulations were conducted under different scenarios, and the results were summarized in tables to compare the performance of the technical solutions in the short term and mid-term. The study also projected the economic indicators under different scenarios to assess the potential impact of the technical solutions on economic outcomes.

2.1.1.8 FLBEIA example application 7 – Greece

Available studies in Greece are a FLBEIA application in the area of Greece in the GSA20 (Eastern Ionian Sea) (Sgardeli *et al*. 2024) and one using custom-made projections for the GSA22 (Aegean Sea) (Sgardeli *et al*. 2023). Both studies involve demersal fisheries (bottom trawlers, longliners and netters) and among others, they involve the estimation of socioeconomic parameters.

2.1.1.9 FLBEIA example application 8 – Mediterranean swordfish

The study used simulations to evaluate different management scenarios for the Mediterranean swordfish stock (Tserpes *et al.* 2009). It generated swordfish-like populations based on the latest ICCAT assessment and re-ran the assessment with assumed catch misreporting. Various management scenarios were simulated, including seasonal closures and quota management. The analysis assumed either recruitment independent of stock size or a Beverton-Holt stock-recruitment relationship. Additionally, the study evaluated the effect of different regulations, such as minimum landing size regulations and fishing license control systems.

2.1.1.10 FLBEIA example application 9 – Aegean Sea

The study utilized a management strategy evaluation (MSE) approach to analyze the multi-species demersal fisheries of the Aegean Sea (Tserpes *et al.* 2016). It focused on four demersal species: hake, red mullet, striped red mullet, and pink shrimp. The analysis considered the economic viability of the fleets and explored alternative management measures in comparison to the existing status quo. The approach used the latest available fisheries data to obtain analytical stock estimates and forecasted the medium to long-term bio-economic effects of different management measures, assuming uncertainty in various biological and economic parameters. The study suggested that a decrease in fleet capacity in terms of vessel numbers is the only management scenario that ensures both resource sustainability and economic viability.

2.1.2 Model focus 2 - IAM

IAM (Impact Assessment Model for fisheries management) is an integrated bio-economic model that has been developed in IFREMER since 2009. The model assesses biological and socio-economic impacts of management strategies such as alternative TACs, multi-annual management plans, alternative governance systems (co-management, Individual Transferable Quotas), selectivity improvement scenarios and landings obligation or decommissioning schemes (Bertignac *et al.* 2016; Guillen *et al.* 2013).

2.1.2.1 IAM example application 1 – Nephrops fishery in the Bay of Biscay

Theoretical analysis of the question of selectivity highlights some trade-offs existing between optimal selectivity and effort costs (Macher & Boncoeur 2010). Optimal selectivity is negatively dependent on the level of effort cost. Application of the theoretical model to the case of the Bay of Biscay *Nephrops* fishery shows that the current level of the cost of real effort in the fishery is well below the breaking point, which makes high selectivity optimal. The expected private costs and collective benefits of increasing selectivity however provide economic incentives for fishermen to let other agents improve their selectivity.

2.1.2.2 IAM example application 2 – STECF

From a more operational point of view in support to decision process and impact assessment, the bio-economic model IAM has been developed within a full partnership approach with stakeholders up to 2009. It has been developed to support multi-criteria assessment of scenarios and in particular Impact Assessment (IA) of fisheries Multi-annual Management Plans and scenarios of transition to Maximum Sustainable Yield (MSY) at national and EU level. It has been applied in the western Waters fisheries (STECF 2015) and is now currently used in STECF to support the Mediterranean Management Plan IA (STECF 2022b). It has been developed within a fully integrated approach connecting the model to the existing available data/knowledge – in particular the Ifremer Fisheries Information System data bases – (which enable to parametrize the model at the vessel/métier level) and the ICES stock assessment data. Applications can also work with DCF data at fleet level derived from AER. Development of the full Decision Support framework is described in Macher *et al*. (2018). Steps and stakeholders' engagement at each step for operational multi-criteria Impact assessment of scenarios are described.

2.1.2.3 IAM example application 3 – Nephrops fishery in the Bay of Biscay

Among various applications (Bellanger *et al*. 2018; Briton *et al*. 2020, 2021; Guillen *et al*. 2013, 2014), the model was applied in the *Nephrops* fishery in the Bay of Biscay to explore the short- and mid-term potential impacts of several selective devices experimented to reduce catches under the minimum landing size including the *Nephrops* Grids (see Raveau *et al*. 2012). Impacts on *Nephrops* and hake stocks spawning biomass, and on the different fleets economic performances were assessed. A full cost-benefit analysis of the different devices was performed and highlight the trade-offs between biological and socio-economic issues and the stakes emerging from short-term losses and expected mid-terms benefits.

The model is fully described and accessible on GitLab - [Impact Assessment Model for fisheries management • IAM (ifremer-iam.github.io).](https://ifremer-iam.github.io) It is an annual simulation model, multi-species-multi-fleet or multi-vessel and multi-métier.

Capacities, resources and time available in Ifremer to run the model still remain limited and tools for updating and visualizing results are still under continuous development to increase possibility of operationalising a modelling framework.

Main applications for decision support are in the Bay of Biscay and in the Mediterranean Fisheries in the gulf of Lion (STECF 2015; STECF 2022b).

2.1.3 Model focus 3 - SIMFISH

SIMFISH (Bartelings *et al.* 2015) is a spatially explicit integrated bio-economic model developed by Wageningen Economic Research in EU projects VECTORS, MYFISH, SOCIOEC and CERES (amongst others) based on the FISHRENT model. The model is used to test alternative management measures (TACs, target Fs, effort limitations, landing obligation, biological safeguards, area closures). It considers multiple fleets and several fish stocks being exploited by different métiers and is spatially explicit. The model integrates short and long-term fleet dynamics and population dynamics in a full feedback loop running at the annual level. Long-term behaviour includes entry-exit of vessels in the different active fleets. Short-term dynamics include allocation of effort to the different métiers/areas, quota trading (lease) and price formation.

2.1.3.1 SIMFISH example application 1 – North Sea Demersal Fisheries

The model is currently applied to the North Sea flatfish and shrimp fisheries with sole, plaice and brown shrimp explicitly modelled and beam trawl fleets of the Netherlands, Britain and Germany exploiting the three species. The Bio-economic model SIMFISH has also been used for the impact assessment of change in gear selectivity (Hamon & Bartelings 2019). The advantage of this model is the integration of fleet and fish stocks dynamics. The activity of the fishing fleets impacts the fish stocks which in turn, through catch rates impacts the choices made by the fishing fleet. The model framework which consists of five interacting parts: fleet dynamics, prices, investment behaviour, population dynamics and management policies. The fleet dynamics model optimises the short-term behaviour of the fleets, i.e. determines the effort allocation to fishing areas and métiers in order to maximise the total profit of the fleets in the model. The annual profit (or total revenue or total landings) is optimised through effort allocation given some restrictions on effort and maximum catch and landings. The fleet dynamics module mutually interacts with the other four modules.

2.1.3.2 SIMFISH example application 2 – STECF management plans

This model was used to assess the impact of the North Sea flatfish management plan in STECF and to assess the multi annual plan of the North Sea demersal fisheries in STECF EWG 15-04 (STECF 2015)

2.1.4 Model focus 4 - BEMTOOL

BEMTOOL is a comprehensive multi-species, multi-gear bio-economic simulation model designed for Mediterranean fisheries. Consolidating various bio-economic models and biological modelling tools developed until 2013, it comprises six operational modules: Biological, Impact, Economic, Behavioural, Policy, and Multi-Criteria Decision Analysis (MCDA). Operating on a fine time scale (month) and adopting a multi-fleet approach, the model simulates diverse management trajectories' effects on both stocks and fisheries. It considers length/age-specific selection effects, discards, economic and social performances, compliance with landing obligations, and reference points. The model includes a decision module enabling stakeholders to weigh indicators and rank management strategies. It can simulate scenarios involving changes in selectivity, fishing effort, fishing mortality, and Total Allowable Catch (TAC). The default output includes a range of biological, pressure, and economic indicators. Uncertainty is addressed through a Monte Carlo paradigm.

2.1.4.1 BEMTOOL example application 1 – Ionian Sea

Russo *et al*. (2017) discusses the use of the BEMTOOL platform for forecasting harvesting and management strategies, the disentanglement of fishing mortality and minimum size limits, and the impact of different fishing bans on landings and revenues for various species. It also provides insights into the spatial management of fishing grounds and fleet segments. The study uses VMS data to process fishing set positions and assess trawling effort, and obtains landings and discards for target species from official DCF data. Revenues by species are estimated using average prices of each target species. The model outcome reveals that the rotated fishing ban would result in less severe reductions in landings and revenues for all species. Overall, the document provides a comprehensive analysis of the demersal fisheries of the Ionian Sea and their spatial, temporal, economic, and biological characteristics in terms of key species for fisheries.

2.1.4.2 BEMTOOL example application 2 - IMPLEMED

The IMPLEMED project, aimed at improving the exploitation pattern and reducing discard rates of regulated species, as well as non-commercial species, in trawl fisheries. T90 diamond mesh configuration and a sorting grid both in the extension piece of a typical Italian trawl were tested during experiments in GSA9 (Ligurian and north Tyrrhenian Sea). Task 4 was aimed at investigating the consequences of the implementation of T90 and selectivity devices in the trawl fisheries of the western Mediterranean, using the BEMTOOL bio-economic model and Cost-Benefit Analysis (CBA) on a set of biological, impact and economic indicators. BEMTOOL is a multi-species and multi-gear bio-economic simulation model for mixed fisheries developed for Mediterranean fisheries (Accadia *et al*. 2013). It consists of six operational modules characterized by different components: biological (age/length structured dynamic model; Lembo *et al*. 2009), Impact, Economic, Behavioural, Policy and Multi Criteria Decision Analysis (MCDA) (Rossetto *et al*. 2015 Spedicato *et al*. 2016; Russo *et al*. 2017). Sea trials conducted have shown that the T90 applied to the extension piece of the trawl net does not provide an improvement in selectivity with respect to the commercial net commonly used by fishermen. In contrast, an improvement of the selectivity was detected using the selection grid inserted in the extension piece. For GSAs 9-10-11 the model was implemented building on the work carried out in EWG 19-01 (STECF 2019a), EWG 19-14 (STECF 2019b) and EWG 20-13 (STECF 2020a), covering 19 fleet segments (DTS and PGP of the three GSAs) and four stocks European hake, red mullet in GSA 9, red mullet in GSA10 and deep-water rose shrimp). DCF data (FDI and Mediterranean and Baltic Sea Data Call, landings, discards, fishing effort, biological and economic parameters) and results from the assessments carried out during the EWG 20-09 (STECF 2020b) were used to parameterize the BEMTOOL model. The discard was included in the assessments and modelled in BEMTOOL.

2.1.5 Model focus 5 - MEFISTO

The MEFISTO model (Argelaguet *et al.* 2020) is a bio-economic model designed for fisheries management in the Mediterranean. Mediterranean fisheries in MEFISTO are traditionally managed with input measures, such as effort limitations and technological restrictions. Thus, unlike some European Atlantic fisheries models, MEFISTO does not include Total Allowable Catch (TAC) or quota as a management tool.

The population dynamics submodel includes an age-structured population model based on stock assessment data. The economic submodel incorporates harvest costs, fishing effort dynamics, and investment/disinvestment functions. Notably tailored to Mediterranean fisheries with a specific focus on the "share" system for retribution, where wages are proportional to gross revenues minus common costs. Optional parameters for simulation conditions, including stochastic variability around natural mortality values or uncertainty in stock/recruitment dynamics. The link between biological and economic components is modelled through the relationship between fishing effort and fishing mortality. Fishing effort can be expressed in terms of capacity, activity, or a combination (e.g., GT x days-at-sea).

Fishing mortality includes both the fishing mortality of landings and discards. Economic submodel operates at the level of the fishing vessel.

2.1.5.1 MEFISTO example application 1 - MED MSY

Sola *et al*. (2020) discusses the European Union's Multiannual Management Plan outlined in Regulation EU 2019/1022, aiming to reform Mediterranean demersal fisheries for maximum sustainability yields by 2025. Using a bio-economic model focused on the Western Mediterranean Sea, the study analyses the reform's objectives and explores alternative management strategies, such as reducing fishing effort and altering selectivity patterns. The results indicate challenges in achieving sustainability for all stocks, suggesting that the established fishing time is insufficient. The study recommends selective changes for faster recovery of biological and economic indicators, emphasizing the need for a well-planned reduction in fishing mortality for sustainable exploitation of Mediterranean demersal fisheries.

2.1.5.2 MEFISTO example application 2 - Aegean Sea

The methodology from Christos et al. (2018) involved data mining to analyse the biological component of the model, focusing on target or main stocks exploited by trawl and coastal vessels in the Aegean Sea. It excluded fleets not targeting these species and obtained market prices and stock assessment data from the Data Collection Framework and literature, respectively. MEFISTO was utilized to study the socio-economic and biological effects of alternative management measures and propose sustainable solutions for the fishery. The model considered the impact of discard bans and the potential market for former discards.

2.1.5.3 MEFISTO example application 3 - Mediterranean discard ban

Maynou *et al*. (2019) employs a bio-economic fisheries model to assess the co-viability of a Mediterranean demersal fishery. It focuses on seven target stocks under biological, social, and economic constraints. The study finds that the fishery is not co-viable due to the non-viability of certain target stocks. Additionally, it evaluates the impact of potential adaptations of the demersal fleet to comply with the landing obligation and compares simulation scenarios based on effort reduction, changes in selectivity patterns, and implementing a fisheries restricted area.

The study conducted simulations, spanning 2015 to 2030, to compare various scenarios aimed at improving the sustainability of Mediterranean demersal fisheries. These scenarios included efforts to reduce fishing, changes in selectivity patterns, and the implementation of fisheries restricted areas, with examination of full or partial compliance. The impact of a discard ban on fleet economics was also analysed. Each scenario underwent 1,000 simulations to account for uncertainties in the stock/recruitment relationship. The simulations were executed using FLR, incorporating FLCore and FLBRP biological libraries. The economic submodel, based on MEFISTO, was coded in R and is available from the authors.

2.1.5.4 MEFISTO example application 4 - Aegean Sea

The MEFISTO bio-economic model applied in a small-scale trap fishery in the south-eastern Aegean Sea was presented including 4 scenarios related to the technical measures' regulation, i.e. the effect of selectivity, effort displacement, effort reduction and spatial displacement. The effect of the four scenarios were related to three main outputs, i.e. catch, profits and spawning stock biomass (SSB) (Maravelias *et al*. 2018). The use of MEFISTO to bio economically model the effect on species included in the STECF EWG 22-1 was also presented (Maravelias *et al*. 2014).

2.1.6 Model focus 6 - SMART

The SMART model is a spatially explicit bio-economic model designed for demersal fisheries management, predicting the biological and economic impacts of different effort allocation scenarios (Russo *et al*. 2014). It integrates data from trawl surveys, commercial catches monitoring, and vessel activity remote sensing. The model uses spatial partitioning of fishing mortality by species and cell to assess each species' components. The smartR package, an R tool associated with SMART, facilitates spatial modelling and scenario simulations for fisheries management (D'Andrea *et al*. 2020). It includes a graphical user interface for exploring fishing grounds, effort patterns, and environmental data. The package incorporates modules for stochastic optimization, considering environmental and economic factors. Data requirements include environmental, fleet, fishing effort, and fishing ground data. The stock assessment in smartR follows a cohort model and statistical catch at age method, estimating critical descriptors of studied species within a framework of intermediate complexity. Scenario possibilities involve measures in effort and capacity, temporal closures, spatial restrictions, and marine protected areas. However, the model currently lacks implementation for assessing gear selectivity scenarios.

2.1.6.1 SMART example application 1 - Northern Ionian Sea

Carlucci *et al*. (2022) discusses the use of habitat modelling techniques to estimate the distribution of dolphins and sperm whales in the Northern Ionian Sea. It also describes the application of the SMART modelling approach to assess fishing traits and production in the area. The analysis focuses on fishing effort and production in the Northern Ionian Sea and Conservation and Control Areas (CCAs), highlighting differences in landing flows and economic value. The study provides insights into the intensity of fishing disturbances to cetaceans and their habitats, as well as the potential for spatial conservation measures without generating socio-economic conflicts.

2.1.6.2 SMART example application 2 - Trawlers in the Mediterranean

Russo *et al*. (2019) focuses on the overfishing of fish stocks in the Mediterranean Sea and the need for sustainable management. It applies a spatially explicit multi-species bio-economic modelling approach, SMART, to assess the potential effects of different trawl fisheries management scenarios in the central Mediterranean Sea. The study integrates spatial data about catches and stocks, fishing footprint from vessel monitoring systems (VMS), and economic parameters to describe the relationships between fishing and resources. The analysis of different trawl fishing scenarios indicates that alternative management scenarios are associated with a decrease in profit for the fleet in the year of entry into force, while the biological effects vary depending on the scenario. The study also discusses the potential consequences of different management scenarios on fish stocks and the economic performance of the fleet.

2.1.7 Model focus 7 - DISPLACE

DISPLACE is a spatial impact assessment tool designed to evaluate the effects of spatial fisheries closures on both the sustainability and economy of fisheries (Bastardie *et al*. 2014). Functioning as an agent-based model, DISPLACE simulates individual vessels, predicting how they would redistribute fishing effort in response to spatial or temporal closures under current fisheries management. The model aids in optimal decision-making concerning harvested fish and shellfish stock fluctuations, changes in available fishing space, and various fisheries management actions. It enables a detailed understanding of achieving stable profits and more energy-efficient fisheries, especially in scenarios where zonation reduces fishing opportunities due to factors like offshore wind farms, marine constructions, NATURA 2000 areas, shipping routes, and fish farming sites.

DISPLACE has been applied outside advice frameworks to many regions, including Danish fisheries in the North Sea, International Baltic Sea fisheries, Northern Adriatic Sea Italian fisheries, and the Eastern Ionian Sea. The tool supports the coordination of different spatial activities in marine areas, aligning with the goals of the EU Marine Spatial Planning (MSP) and other directives (see https://displace-project.org/blog/overview/).

2.1.7.1 DISPLACE example application 1 - Ionian Sea

The model has been applied in the North Sea and the Eastern Ionian Sea to investigate the effect of displacing fishing effort to alternative grounds based on various spatial and time-specific management options (Bastardie *et al*. 2023). The model incorporates spatial and temporal details to gain an understanding of integrated fisheries, behavioural, and resource dynamics. Additionally, the report discusses the preliminary findings from the application of the DISPLACE model in the Eastern Ionian Sea, highlighting the need for further examination of alternative scenarios to enhance fleet selectivity and safeguard vulnerable habitats.

2.1.8 Sea regions with no identified bio-economic models

This may be due to lack of representation at the meeting.

2.1.8.1 Black sea

According to the current knowledge on the tools available to assess the socio-economic implications of changes in technical measures, there are no available models for the Black Sea region.

2.1.8.2 Slovenia

According to the current knowledge on the tools available to assess the socio-economic implications of changes in technical measures, there are no available models in Slovenian waters.

2.1.8.3 Cyprus waters

Based on a literature review there is no thorough bio-economic model work published in peer review literature for the area of Cyprus. Most of the managerial actions taken by local authorities in the early days were based on direct observations of landings and economic performance of the fleets.

Back in 1980 a first evident reduction of landings kick-started the discussions of implementing the first management measures as an effort to alter the situation. Simultaneously artisanal fishery was growing rapidly to account from 40% of the total catch in 1961 to 74% in 1984. By 1982 the overfishing was apparent by the reduced average landing size of the species and the increased mortality of recruits by the trawl fishery in October-November.

It is worth mentioning that chronologically close to the reduced landings observations a human induced ecological phenomenon was taken place in Nile River -the main freshwater discharge point in the area- which was the filling of the Aswan Dam (one of the biggest dams in the world at that time). It took almost 7 years to fill up (1976) during which water flow of Nile River was reduced considerably. During that time landings of anchovy and sardine in Egypt were also reduced.

Considering all the aforementioned factors, local authorities in Cyprus expanded the existing closed period in 1982 to include October. By 1984, the outcomes of this enhanced management measure exceeded initial expectations. Catch rates saw a remarkable increase, ranging from 40% to 80% for any given level of effort. The economic performance of both trawl and artisanal fleets experienced significant improvement across all aspects related to fishing activity. These results indicated that implementing seasonal bans during the peak recruitment period, particularly to address cacometric overfishing, could yield more achievable outcomes compared to other technical regulations. The impact of this measure gained widespread attention at the time, leading the FAO (Fish. Tech. Pap. 250) to characterize it as the "Cyprus effect" (Garcia 1986, Garcia and Demetropoulos 1986). Following these findings, an unfortunate new consequence emerged, necessitating attention, as the influx of newcomers into the fishery and the adoption of modern equipment through technological enhancements increased pressure on resources.

By the year 2004, a noticeable decline in both resources and the economic performance of the fleet became apparent. During this period, a new ecological issue surfaced with the increasing abundance of Non-Indigenous Species (NIS), primarily Lessepsian immigrants that traversed the Suez Canal. To address this new situation, a series of technical measures and managerial actions were implemented in the subsequent years, based on fleet capacity and fleet performance reports.

In 2004, trawl licenses operating in National waters were reduced from 8 to 4 through a scraping buyback program. In 2008, a new set of measures came into effect, imposing further restrictions on depth and distance from the shore for trawlers. In 2010, a new technical measure was introduced for trawlers, involving an increase in the mesh size of the gear. Despite these efforts, the decline in the number of stocks remained significant. Consequently, in 2011, trawlers operating in National waters were further reduced from 4 to 2. Simultaneously, a technical regulation was applied to the Small-Scale Fleet (SSF) by increasing the mesh size of the set nets used.

Finally, in 2013, a new buyback scraping program was initiated for SSF leading to the decommissioning of 107 vessels in 2013 and 67 vessels in 2016. This resulted in a reduction in the artisanal fleet capacity from 500 to 328. This marked the conclusion of an extended period of relatively strict technical interventions in commercial fishery in Cyprus.

2.2 Policy

The effective operationalisation of any advice product requires an understanding of the advice needs and policy framework to ensure that what is produced is relevant and meaningful. Therefore, at the EWG 23-15 DGMARE contextualised Regulation (EU) 2019/1241, in terms of the goals of the EWG, highlighting that technical measures can be adapted to better suit the specificities of each region, which can be achieved in two ways:

- The use of the Commission of the implementing powers, however quite limited as instructed in the regulation (Art 24).
- The preferred option, using regionalisation, to modify the regional annexes, as this entails a bottom-up approach in the proposals. This gives more flexibility compared to the previous framework.

In return for this flexibility, there is a legal mandate to report to the Council and the Parliament on how technical measures are being implemented, and what is more, whether the objectives and the targets are being met. This reporting obligation entails the ability to measure the progress, essential to see if we are on the good path, or rather, we can identify areas in which efforts are needed. STECF 20-02 (STECF 2020c) proposed an indicator, which was used in the first implementing report. Following that legal mandate to report (Art 31), the first report on the implementation of the technical measures regulation was adopted in September 2021[1]. This first report concluded that while this regulation is a good tool to implement the CFP and to contribute to environmental objectives, we need to speed up and increase efforts to improve selectivity and protection of habitats and species.

This report also presented the basis under which the CFP will contribute to the Action Plan to conserve fisheries resources and protect marine ecosystems. This communication was adopted on February 2023[2], and meant a political commitment to making fishing practices more sustainable by improving our current fishing patterns, which is amongst the objectives of the technical measures regulation[3]. It was also emphasized that the second report on the implementation is in preparation; as in the first, a wide consultation to Member States, Advisory Council and all interested stakeholders was launched to gather their views, opinions and comments. Scientific input will also be essential: STECF (optimization, to measure progress), and second advice of ICES on innovative gears[4].

DGMARE commented on the next steps and strands of work in terms of this expert group:

- continuing the work on selectivity indicators, which will deliver metrics to measures progress in terms of improving fishing patterns,
- work to help optimising the fishing patterns, considering the trade-offs.

2.3 Socio-economic assessment

2.3.1 General economic background – Short vs long-term considerations

Implementing more selective fishing gears presents a seemingly straightforward solution to address unwanted catches, offering economic benefits by reducing sorting and landing costs, and potentially enhancing future catch possibilities. However, this transition poses challenges for fishers, given the uncertainties around comparative costs and benefits. The decision to adopt a more selective gear is complex for fishers due to potential short-term revenue losses, uncertainties about long-term gains

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2021:583:FIN and the accompanying staff working document: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=SWD:2021:268:FIN

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52023DC0102

[3] Art 3: objectives, Art 4: targets.

[4] https://www.ices.dk/news-and-events/news-archive/news/Pages/InnovativeGear.aspx

Although technical measures may reduce unwanted catch of protected and upsized species protected species and undersized fish, it may also impact revenue. Implementation of technical measures may reduce catches of target species creating lost fishing opportunities and lost revenue. Measures may also reduce the amount of fish caught for fishmeal, again reducing a revenue stream. Figure 2.1 shows an example of two such scenarios compared to the status quo of overfishing to rebuild a stock to MSY stock level, scenario 1 with a lower reduction of catches over a longer period of time, and scenario 2 with a sharper reduction at the beginning (Döring & Egelkraut, 2008). Balancing short-term losses with uncertain long-term benefits necessitates a thorough cost-benefit analysis, as observed during the landing obligation implementation (Simons *et al.* 2015).

In evaluating technical measures, the focus should be on comparing short-term losses with potential long-term gains. Transition plans could help mitigate negative impacts, perhaps by gradual implementation or financial support. European funds like the European Maritime, Fisheries, and Aquaculture Fund (EMFAF) could aid in easing the transition. Enhancing the understanding and management of these transitions requires careful consideration of short-term economic impacts against uncertain future benefits, with a focus on ensuring the sustainability of fisheries while supporting fishers' livelihoods.

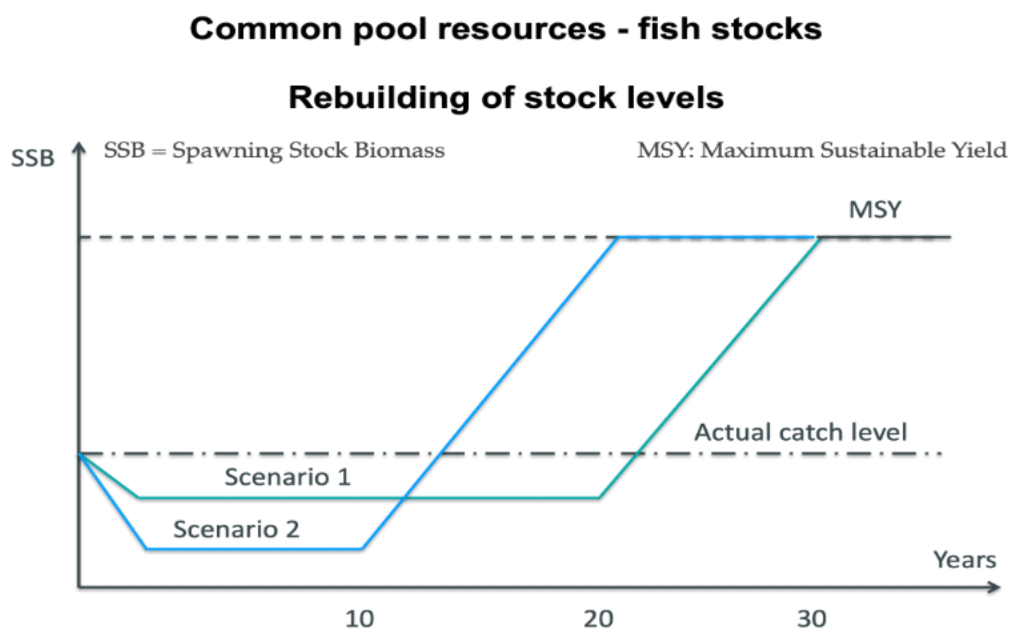

Figure 2.1: Comparison of three rebuilding scenarios (source: Döring & Egelkraut, 2008).

2.3.2 The 'economics' of improved selectivity – experiences from the Landing Obligation (LO)

A limited literature review on economic consideration of improvement in selectivity by the EWG revealed that most of the literature are from assessments of the possible socio-economic impacts of the implementation of the LO. The main objective of the LO is the reduction of unwanted catches and improvement in selectivity is seen as one of the main instruments to achieve that.

STECF has discussed the problems regarding the implementation of the LO many times over the last years (see e.g. STECF 2021) and had issued a literature review (STECF 2022c). The main result was that, contrary to what was expected and what has happened, most of the papers assumed full implementation of the LO and, therefore, that there would have been short-term costs (also e.g. Simons *et al*. 2015; Hoff *et al*. 2019). In the long-term the model results showed gains. This is comparable to the two scenarios in Figure 2.1.

The situation is different when mitigation measures are considered, for example, exemptions from the LO. Then the model calculations gave a mixed picture: in some cases, fishers can expect long-term gains, while in other cases the situation does not improve. However, in such a situation they would also not have to cope with the short-term costs or at least on a much lower level than compared to the full implementation of the LO (Prellezo & Villasante, 2023).

The problem with the socio-economic assessments of the LO is that there is nearly always the assumption of a full implementation. These results of the assessment, that fishers will have short term costs, could be one reason why a variety of exemptions were included in the basic regulation Art. 15 and in many, in some areas in all, fisheries exemptions were requested and granted by derogated acts from the European Commission (EC). The widespread use of exemptions, associated to other measures such as the lack of at-sea monitoring and increased TACs among others, has led to the present minimal implementation of the LO. This in turns precludes the short-term costs predicted in the economic models, and therefore lower levels of implementation should have been considered instead.

This shows that when implementing technical measures in the future, managers from the EC and MS should consider that incentives may be strong in the fishing sector to avoid the implementation. In this context, it is important for economic modelling to consider different likely low implementation scenarios instead of full implementation to predict short–term costs. If significant short-term costs are indeed predicted in realistic low implementation levels, it would be important to discuss the transitions phase and possible mitigation measures with the sector to alleviate at least some of the short-term costs. Acceptance of measures by the fishers could be an important aspect when discussing the implementation of technical measures. Compliance should also improve when fishers are involved in the implementation, their concerns regarding short-term costs are recognized and mitigation measures may accompany the implementation.

2.4 Stakeholders

There is a recognition that how policy options interact with stakeholders' incentives impacts the likelihood of achieving management objectives. Ideally, we would be able to use a fully integrated model that would allow feedback between ecological and human processes, models idyllically would be user friendly, and parameterised with the input of stakeholders to ensure some level of reality. Such involvement is beneficial to all parties, leading to improvement of models and more effective implementation of advice, but demands substantial resources which must be built into governance processes. Therefore, any future work to develop a bio-economic model as a decision support tool to inform stakeholders and managers on the impacts of technical measures should involve stakeholders.

2.4.1 Steps in connecting stakeholders' views and stock assessment modellers for the anchovy in the Gulf of Cádiz

A NextGeneration EU funded project called Math4fish (https://math4fish.ieo.csic.es/) is endeavouring to improve and develop stock assessment and Management Strategy Evaluation tools as well as to include stakeholders' views in this modelling effort. The project is working with hake, sole and anchovy but here, we will focus on anchovy in the Gulf of Cádiz (ICES division 9.a South). Anchovy in this area is a very important resource from economic and ecological perspectives and currently the advice for this area is provided by scientists separating the catch opportunities for the two areas: 9.a South and 9.a West (ICES 2023d) but the final quota agreed is established for the whole area and then it is divided between Portugal and Spain not following the West and South split. Considering the division 9.a as one management unit has allowed fishers to obtain profits when fishing anchovy is not profitable by selling their quota from South to West area and vice versa. This has been quite convenient considering that currently the stock status in the West has been increasing while decreasing in the South. Nevertheless, there are plans to define the Southern and Western components as different management units and more than ever an economic analysis is needed to assess the potential transition.

In Math4fish project, a Management Strategy evaluation framework has been developed using FLBEIA for the Southern component (see Pérez-Rodriguez *et al*., 2023) and at the same time we have been approaching to fishers and the administration through in person and online meetings guided by expert social scientists. The main purpose of these meetings was to start a co-creation process that allows us to develop pertinent tools considering the situation that the fishery is currently facing. Math4fish has helped to initiate this process and due to the demand of the fishers regarding the need of economic indicators, another project proposal was prepared to co-create a bio-economic model together with stakeholders. That project, called BioEcon4Fish, has been funded with the main research objective to develop bio-economic tools to simulate management strategies for sustainable harvesting of anchovy in the Gulf of Cádiz through a participatory co-creation process including scientists, representatives of the fishing communities and competent authorities. These management strategies will explore the trade-offs between environmental sustainability and socio-economic profitability. To achieve this general objective, several specific objectives were proposed including the use of FLBEIA model as a basis to incorporate socio-economic indicators and trying to follow the best practices to incorporate stakeholders' knowledge in this modelling exercise.

2.4.2 Integrating social aspects and link to community

One of the tasks of the EU Project Benthic Ecosystem Fisheries Impact Study (BENTHIS; Merzereaud and Macher, 2014) was to look at the investment behaviour of fishers and the lessons on key factors influencing the investment behaviour. In Hamon *et al*. (2017), 18 drivers of behaviour were identified in six broad categories: economic (3), technical (1), regulatory (6), social (4), governance (2) and ecological drivers (2). Those were based on interviews with fishers in different case studies all over the regional seas.

Those drivers and others from the literature were summarized in the report of the 2023 workshop on innovative gears (ICES, 2023e). The ToR c of this workshop focused on the drivers of uptake. Studying specific cases would have required stakeholder consultation and socio-economic data collection and could not be dealt with given the short time-line of the request. Still, the workshop experts progressed the state of the art by presenting a novel approach based on the PESTEL (Political, Economic, Social, Technological, Ecological and Legal) framework to understand the different drivers influencing gear uptake (either facilitating it or impeding it). The initial use of PESTEL in factsheet and feedback from the experts during the workshop, identified that in most cases, numerous, combined factors influence gear uptake. The systematic collection of socio-economic data is required before any conclusions can be drawn as to what factors encourage or impede the uptake of specific innovative gears. The framework of analysis was improved during the workshop and a comprehensive table of PESTEL factors was made (see Table 4 in Appendix of ICES, 2023e), including concrete examples and literature.

3 TOR 2 – DATA

This term of reference focused on the identifying, quality control, and summarise the data required to run a bio-economic assessment of gear changes. In particular, but not limited to, the species and fisheries identified in EWG 22-19 (STECF 2022a), for which the highest gains can be achieved (outcomes of EWG 22-19), and species (target & bycatch) caught as part of these mixed fisheries.

To operational this data hungry system a number of data products may be required:

- Gear studies
- Stock data (assessments and forecasts)
- Fleet data (catch, effort and economic)
- Social data

This section highlights some of sources that may be needed, however, this is model and case study dependant, and should be read that way.

3.1 Fishing gear selectivity studies

Estimates of fishing gear selectivity are an important data source required to assess the impacts of technical measures. EWG 22-19 (STECF 2022a) focused on estimates of absolutely selectivity, such as L50 and selection range (SR). Since the implementation of the LO, the catch comparison method has been widely used to implement additional technical measures on the basis of equivalent selectivity. Importantly, the method allows commercial-like performance of fishing gears (Holst & Revill, 2009). The catch forecasting tool described in Section 3.1.1.6 (above) utilises the results of a catch comparison trial (Browne et al., 2019) i.e., proportional differences in catch at length. Where the absolute selectivity (L50 and SR) of two or more gears has been estimated then proportional differences in catch at length may be calculated. The tool therefore facilitates the utilisation of a broader range of gear trials to be included in assessments of Technical Measures.

As with previous technical measures working groups gear technologist were present advising and updating the group on innovations. This section is a summary of the information provided.

3.1.1 Selectivity studies from AZTI

Cuende *et al*. (2020 a,b) presents selectivity results for different square mesh panel (SMP) designs aimed to improve fish-SMP contact probability and release efficiency for these species. Among the designs tested, the results demonstrate that modifying SMP size and position can increase fish contact probability with the SMP. Cuende *et al*. (2020c) investigates the size selection process through SMP and codend meshes for blue whiting based on fish morphology and behaviour. The results demonstrate that SMP size selection can be explained by different fish contact angles with SMP meshes, which allows making accurate predictions for fish size selectivity. Cuende *et* al. (2022b) explores the effect of alternative SMP and codend mesh combinations on the size selectivity of hake and blue whiting and on the fishery exploitation pattern for a variety of fish population scenarios. The results demonstrate that changes both in SMP and, especially, codend designs can have a significant effect on the size selectivity and exploitation patterns of hake and blue whiting. This paper also outlines new ways for investigating and illustrating the effect of multiple gear changes on the size selectivity and exploitation pattern indicators by means of diagrams named treatment trees. These may aid in the identification of promising gear designs and help the industry in the pursuit of specific catch goals. In Cuende *et* al. (2022c) a trawl configuration for species separation is tested. This new configuration intends to guide those species that hold themselves close to the lower panel of the trawl through a horizontal grid into a lower codend, while the rest of the species are directed to an upper codend. The findings in Cuende *et* al. (2022c) demonstrate that, under the conditions in which this fishery operates, the trawl configuration tested is not able to efficiently separate species based on their behaviour. Finally, in Cuende *et* al. (2022b) the effect of shortening codend lastridge ropes on codend size selectivity compared to a standard codend is tested, and fish escape chances estimated based on fish morphology. The results show that a codend with shortened lastridge ropes can improve the size selectivity of horse mackerel and blue whiting, while the selectivity of hake was not affected. The results indicate species dependent variability in the ability to utilize open meshes located at different places.

Bycatch of common dolphin (*Delphinus delphis*) in commercial trawl fisheries in the Bay of Biscay (NE Atlantic) is of concern and its mitigation a priority. Active acoustic deterrent devices (pingers) attached to fishing gear seem to be promising for bycatch mitigation, as they have demonstrated to effectively reduce cetacean bycatch in some set-net fisheries. However, the low occurrence of common dolphin bycatch in many trawl fisheries, coupled with the extensive amount of time needed to monitor them, makes it difficult to prove the effectiveness of pingers. Remote electronic monitoring (REM) systems in fisheries can substantially increase onboard observation, providing access to extensive databases to comprehensively address bycatch mitigation studies. In Puente *et al*. (2023), the effectiveness of DDD®03H Dolphin Dissuasive Device (hereinafter DDD pingers) to reduce common dolphin bycatch was evaluated in a demersal pair trawler in FAO Division 27.8.c. In 195 fishing days, one of the vessels in the pair operated with a set of DDD pingers whereas the other operated without them, and the bycatch of common dolphin was monitored through the REM system. In total, 660 fishing hauls were conducted of which 223 hauls had the DDDs attached. The results showed that the DDDs reduced common dolphin bycatch by more than 90%, with both bycatch frequency and the number of individuals bycaught per haul being significantly lower. The results also showed that common dolphin bycatch in this fishery is related to factors such as the fishing zone and depth, whereas the type of net deployed, time of day and haul duration were found to not significantly affect the bycatch of this species.

3.1.2 Selectivity studies from CIBM

3.1.2.1 EcoeFISHent

Focused on demonstrable and replicable cluster implementing systemic solutions through multilevel circular value chains for eco-efficient valorization of fishing and fish industries side- streams - Horizon 2020 Innovation Action Grant agreement ID:101036428. In the EcoeFISHent project (https://ecoefishent.eu/) larger square meshes in the codend and grid in the extension piece will be tested. The aim of the project is the improvement of the exploitation pattern and reducing the catch of juveniles of the Giant red shrimp (*Aristaeomorpha foliacea*), Blue and red shrimp (*Aristaeus antennatus*), and Norway lobster (*Nephrops norvegicus*). At the moment, no bio-economic modelling studies are planned to be performed.

3.1.2.2 DecarbonyT

Focused on Decarbonisation of the fishing fleet in the Mediterranean and Black Sea Start decarbonisation journey in fisheries · Track carbon emissions · Visualize emission hotspots · Foster collaboration · Work across the harvesting chain. Framework Contract for the provision of scientific advice for the Mediterranean and the Black Sea. EASME/EMFF/2020/OP/0021 SPECIFIC CONTRACT NR. 07. The aim of DecarbonyT project (https://decarbonyt.eu/) is to assess to what extent the use of optimized trawling gears in the Mediterranean and Black Sea can lead to lower fuel use intensity (l/kg fish) and carbon footprint (kg CO2eq/kg fish).

The consequences of the implementation of upgrading less fuel intensity towed gears in the trawl fisheries, will be investigated by using biological, impact and economic indicators. The approach will be based on simulations and scenarios’ modelling to predict short-, medium- and long-term changes.

3.1.2.3 MINOUW

Focused on demonstrable and replicable cluster implementing systemic solutions through multilevel circular value chains for eco-efficient valorization of fishing and fish industries side- streams - Horizon 2020 Innovation Action. The MINOUW project (https://minouw-project.eu/) is made up of over 15 different maritime science institutes and bodies from across Europe, and brings together scientists, fisherman, NGOs and policy makers. It aims to encourage the adoption of fishing technologies and practices that reduce unwanted catches, and contribute to the eventual elimination of discards in European fisheries.

Main results from MINOUW project are:

- T90 netting on the bottom trawl extension piece to reduce unwanted catches.
- Juvenile and Trash Excluder Device (JTED) to limit capture of unwanted species during trawling.
- Artificial lights in trawl fisheries targeting shrimps in Northern Tyrrhenian Sea: effects on target species and by-catch.
- Modified slipping procedures to improve survivorship of sardines in the purse seine fishery.
- Modifications to the metallic grid bivalve dredge, featuring a Bycatch Reduction Device.
- Use of a guarding net to reduce catches of unwanted species in monofilament trammel nets from the Algarve (southern Portugal).
- Modifications to spiny lobster trammel net to reduce unwanted catches.
- Modifications to trammel net to reduce unwanted catches.
- Technological solution (guarding net) to limit the unwanted catches in the caramote prawn set net fisheries in the Ligurian Sea (W Mediterranean).
- Circle hooks to reduce unwanted catches in surface drifting long-line fisheries targeting swordfish.

3.1.3 Other selectivity studies in the Mediterranean

3.1.3.1 Artificial lights in trawl fisheries targeting shrimps in Northern Tyrrhenian Sea: effects on target species and bycatch

The aim of Sbrana *et al*. (2018) study was to evaluate whether artificial lights are efficient in increasing the catch of target species, and, at the same time, in decreasing by-catch and discards. The use of artificial lights on the headline of the trawl net seems to be effective in reducing the capture of European hake under the MCRS (minimum conservation reference size) in the fishery targeting deep-water pink shrimp. The use of artificial lights placed on the headrope of the trawl net can be a simple and economical solution to reduce unwanted catches of European hake without loss of the commercial fraction. However, further research is needed to better understand these effects, and their causal mechanisms, and how to use them to optimise the catch performance of trawls.

3.1.3.2 Technological solution (guarding net) to limit the unwanted catches in the caramote prawn set net fisheries in the Ligurian Sea (W Mediterranean)

Sartor *et al*. (2018) experiments showed that the addition of a guarding net to traditional trammel nets can reduce bycatch significantly. The guarding net fitted to trammel nets proved to be an effective solution to decrease discards and unwanted catches. The economic loss due to the slightly reduced catch of commercial species was offset by decreased sorting time and labour costs.

3.2 Stock data (assessments & forecasts)

The single species stock assessment is considered the best available information on the sustainable management of each individual stock, therefore the outputs of these assessments should form the basis of any bio-economic model. This data is produced by organisations such as GFCM and ICES and would need to be requested for inclusion in any future exercise. Inclusion of stocks in a bio-economic model is not a straight forward process and requires time to quality control and test, and should be considered when planning future work. Single species stock assessors would need to supply assessment outputs, forecasts settings, forecast outputs, code, and age length keys.

3.3 Fleet data (catch, effort, economics and social)

There are a number of possible sources of fleet data with European fisheries, depending on the sea region and the fishery. At ICES fleet data, catch and effort, has been used to produce mixed fisheries advice since 2014. This data is complex and has taken many years to streamline into the quality-controlled product it is today. However, there are limitations to this data: spatially and temporally, it is high aggregated; it does not include economic or social indicators and it does not cover the Mediterranean. Therefore, this section of the report will cover the current work being completed to provide fleet data (catch, effort and economics) at a European level, and work that will need to be done in the future to include social data.

Once these data sources are streamlined EWG time would be required to merge the data sources, and quality control on an annual basis. It may be possible to embed this process within already established working groups, depending on the sea region.

3.1.1 Summary of FDI AER alignment analysis in FDI EWG

The EWG 23-10 conducted an analysis comparing AER and FDI data sets for the years 2017-2021 (STECF, 2023a). The study revealed improved data codification and consistency, but some discrepancies persist due to timing issues, confidentiality, and inconsistent definitions. Two preliminary attempts by STECF focused on landings data for Belgium and Italy, revealing potential confidentiality issues and provisional data variations. Another analysis compared landings values for Mediterranean countries under three separate data calls, highlighting inconsistencies. To enhance future submissions, inactive vessels' absence was addressed in the Data Transmission Monitoring Tool (DTMT). Despite small differences in fleet segments reported between AER and FDI, specific discrepancies for countries like Portugal and Greece were noted. The total number of fleet segments exhibited a slight decline during the 2017-2021 period.

The comparison of effort (days at sea) and landings (tonnes and values) between FDI and the Fleet socio-economic data call reveals improved consistency in data sets for fishing days and days at sea over the years, though some discrepancies persist. The analysis, conducted at the country level, calculates percentage differences between the two data sets, with results generally showing consistency but occasional variations exceeding ±5%. Cyprus exhibits high effort, potentially attributed to differences in reporting methods between FDI and AER data calls, particularly in the small-scale fleet. The overall trend indicates enhanced consistency, yet notable discrepancies in certain years and countries, emphasizing the need for continued data reconciliation efforts.

The comparison of landings data between FDI and Fleet socio-economic data from 2017 to 2021 indicates discrepancies exceeding ±5% for 4 to 6 MS in weight of landings and 8 to 11 MS in value of landings, varying by year. However, the aggregated weight and value of landings for all MSs are generally within ±5%, except for 2017 where FDI figures are 30% higher, largely influenced by Spain's data submissions. Discrepancies for certain EU Member States, such as Latvia, Estonia, and Germany, are attributed to the non-disclosure of information about distant fishing fleets in Annual Economic reports for confidentiality reasons.

The EWG conducted a detailed analysis comparing fishing effort and landings data between FDI and AER at the fleet segment level. For days at sea, improvements in consistency were observed over the years, with fewer discrepancies in the period 2019-2021. Fishing days showed increased correspondence between FDI and AER, especially in 2018, though discrepancies persisted for certain fleet segments. The analysis of weight and value of landings indicated varying differences between FDI and AER, with a decreasing trend in segments with less than 5% difference. However, differences were noted, influenced by factors such as segment codification and data inclusion/exclusion in FDI. The analysis covered the years 2017-2021, highlighting fluctuations in consistency among fishing techniques and suggesting ongoing efforts for data reconciliation.

The EWG conducted a comparison of effort and landings between FDI and Fleet socio-economic data at the level of gear type within fleet segments. However, due to the voluntary nature of gear type data in the AER dataset, a comprehensive analysis was deemed unfeasible. Recognizing comparability issues, the EWG recommended increased national coordination in defining inactive vessels, clustering procedures, and data provision for FDI and AER calls. With over 10 MS facing comparability challenges, a coordinated EU-level approach was suggested, drawing on successful workshops on transversal variables. The EWG proposes organizing workshops, in collaboration with the JRC, to harmonize methodologies and approaches for allocating vessels, landings, and effort to fleet segments and métiers in FDI and AER data calls.

In summary, the EWG's comprehensive analysis of AER and FDI data sets from 2017 to 2021 indicated notable improvements in data codification and consistency, reflecting advancements in fisheries data management. Despite these positive trends, persistent discrepancies attributed to timing, confidentiality, and inconsistent definitions highlight the need for ongoing reconciliation efforts. Analyses at various levels, including country, fleet segment, and gear type, revealed enhanced consistency in efforts and landings data, with occasional variations. Addressing inactive vessels in the DTMT tool could improve future submissions, while specific challenges for countries like Portugal and Greece underscored the importance of continued data refinement. The EWG's recommendations for increased national coordination and EU-level workshops demonstrate a commitment to resolving comparability issues and fostering harmonized methodologies, ensuring reliable fisheries data across Member States.

3.1.2 Results of RCG ISSG survey related to comparison of the definitions within the data submitted to FDI and AER data call

The Regional Coordination Groups (RCGs) Intersessional Subgroups (ISSG) developed a questionnaire, after the FDI methodological meeting, aimed to understand the consistency between AER and FDI data calls across MSs. The survey included 11 questions and was sent to National Correspondents. Ireland has not been included in this survey results overview as only responded for the AER part. Key findings revealed that only 7 out of 21 countries use identical methods/definitions for AER and FDI calls. Regarding fleet reference, Estonia and Poland apply different approaches. Four countries include inactive vessels in AER but not in FDI capacity tables. All MSs have adopted a similar approach to vessel identification since 2022. Discrepancies exist in excluding data for specific regions, fleet segmentation methods, and species completeness. The survey concludes as a preliminary overview, showcasing the potential to link both data calls.

The workshop on harmonizing the AER and FDI data, which was held on 11th and 14th of December 2023, was one of the steps toward achieving the ultimate goal of harmonizing the two data calls with the aim of asking for transversal variables only in the FDI data call in the future. To reach this goal, there has been work going on to identify the inconsistencies between the data calls, and a survey was also sent out to MS to understand the methodology and definitions used when they submit data to AER and FDI. The workshop was online to allow the experts to carefully work on inconsistencies in the data provided on a national level and find solutions on how to fix these issues. Experts invited to join this workshop were those who are responsible for the submission of the data to the AER and FDI data calls, as it was planned that most of the discussion and work would take place on a national level.

Each EU Member State representative made a presentation about the inconsistencies found regarding their own data. In all MSs, there were different procedures for improving the harmonization of the data that will be submitted for future data calls.

One of the main circumstances leading to discrepancies between the reported data in both data calls is that the data is reported by different institutions. Meetings between the institutes are planned to develop procedures and scripts for identifying differences, working on alignment between the two data calls, and establishing a quality control procedure that can be run before data are submitted to cross-check between the data calls.

In some cases, the data calls were prepared by two different persons applying slightly different estimation methods in the case of missing value of landings or other variables. For future reports, the goal is to apply the same estimation routines for the same variable and then derive both FDI and AER datasets from the same master file by aggregating according to the call-specific requirements.

Other sources of inconsistencies listed by the participants were the following:

- **Clustering** issues (AER clustering procedures create inconsistencies between the two data calls).
- **Inactive vessels** missing from FDI (unlike AER, data in FDI did not report inactive vessels separately).
- **Poor data** for gears, which are considered less important at national level and are not considered in the FDI due to the significant difficulties and obstacles to collecting robust data for these small fishing segments. Some secondary fishing gears, which are only occasionally used, were not reported in the FDI data call.
- **Geo indicator** was reported differently in both data calls.
- Definition of **Fishing technique**.
- **Inconsistency between AER and FDI capacity templates** was observed mainly in fields where completion was not mandatory. There are seven variables in the AER capacity templates that are not required by FDI, these are: GEAR; FISHERY; ACTIVITY; CLUSTER_NAME; COMMENTS; FRAME_POPULATION; SURVEY_NAME.
- **The FDI capacity template contains TOTTRIPS and MAXSEADAYS variables** and AER required those variables in map_fs template. Both variables in both data calls are aggregated at the same segmentation level.

The following steps may overcome the discrepancies:

1) Use the same original basic fishery data for both data calls.

2) Handle missing value information with a standardized AP calculation procedure from now on.

3) Reporting inactive vessels in the FDI data call.

4) Consider reporting the transversal data in AER unclustered and keeping the clusters for economic and social variables.

5) Amend the FDI template to include the columns and variables that are now in the AER data call or cluster the segments for the FDI data call.

3.1.3 WKTrade4

The WKTRADE4 (https://www.ices.dk/community/groups/Pages/wktrade4.aspx)convened three times between September and November 2023 with the objective to:

1) Operationalizing the linkage of available VMS, STECF FDI, and AER economic data to estimate landings and economic performance indicators for each fishery.
2) Describing practical steps to determine economic costs and benefits associated with bottom fishing at a fine spatial scale.
3) Demonstrating the applicability of proposed approaches for estimating spatial fisheries performance indicators across different scales and gear types.
4) Addressing tasks across all European marine regions, including the Mediterranean and Black Seas.
5) Documenting the opportunities and limitations of spatial fisheries performance indicators and input data capacity.

During the working group comparisons were made between different approaches of using FDI and AER data for spatial analysis, operationalized links between data calls for the NAO region, and outlined methodological limitations. They noted progress in the framework but highlighted the need for improved data resolution and alignment. The group found low spatial resolution in FDI data, especially in the Mediterranean and Black Seas, and gaps in VMS/logbook data for these regions. They suggested acquiring better resolution data, collating national studies, and using existing economic data samples for more precise analyses in the future.

3.4 Social data

The inclusion of social data was identified as a priority by EWG 23-15. The inclusion of social data will enable the evaluation the welfare changes resulting from policy interventions on non-market economic services, such as conducting surveys on willingness to pay for the conservation of marine protected species that interact with fisheries (Wallmo and Lew, 2012). Additionally, managing fisheries entails overseeing economic and social systems (Charles, 2005).

These priorities have prompted a shift towards broadening the scientific base of ICES to fully integrate social science. This integration, encompassing the socio-ecological perspective (Link et al., 2017), has spurred new initiatives within ICES, including the Strategic Initiative on Human Dimension (SIHD).

The collection of social data within the DCF is a recognition that effective fisheries management and policy development is dependent on having a good understanding of the social importance of fisheries and of social processes that are developing over time.

3.4.1 DCF social data

With the DCF social data is collected based on the Regulation No 2017/1004, the EU multiannual programme for the collection of fisheries and aquaculture data introduced the collection of social variables for the EU fishing fleet under the Data Collection Framework (EU MAP). The social variables to be collected every three years are: Employment by gender; Full-Time Equivalent (FTE) by gender; Unpaid labour by gender; Employment by age; Employment by education level; Employment by nationality; Employment by employment status; FTE National.

Following the guidance for social variables (see https://datacollection.jrc.ec.europa.eu/documents/d/dcf/eumap_guidance_social), all MS should report the variables "Employment by gender", "FTE by gender" and "Unpaid labour by gender" disaggregated as "male", "female" and "Unknown" (only if needed)".

Considering the needs for monitoring of employment by age classes and Eurostat practice, the "Employment by age" should be reported at least into the following age classes: <=14; 15-24; 25-39; 40-64; >=65; "Unknown". Following the recommendations from the workshops and EWGs related to the social variables, some MS further disaggregated the age class 40-64 into 40-54 and 55-64.

Also, the social variable "Employment by education level" it is, so far grouped in the "low" "medium" and "high level, using the International Standard Classification of Education (ISCED 2011). Data collected under EUMAP by MS should allow to provide data at least for the following groups at EU level: "Low" for education levels 0-2 (ISCED2011 and ISCED1997); "Medium" for education levels 3-4 (ISCED2011 and ISCED1997); "High" for education levels 5-8 (ISCED2011), levels 5-6 (ISCED1997); "Unknown".

Taking into account national needs and EU requirements it is recommended to separate the social variable "Employment by nationality" to at least the following groups: "National"; "EU"; "EEA"; "Non-EU/EEA"; "Unknown".

Finally, the Regional Coordination Group on Economics Issues (RCG ECON) recommends the social variable "Employment by employment status" to be reported at least by two categories: "Owner" (vessel owner involved in vessel activity/operation); "Employee" (all engaged workers onboard, excluding owners); or "Unknown" and possible disaggregation on a voluntary basis between full and part time employees.

3.4.2 ICES Working Group on Social Indicators (WGSOCIAL)

The ICES Working Group on Social Indicators (WGSOCIAL, https://www.ices.dk/community/groups/Pages/WGsocial.aspx) is dedicated to enhancing the integration of social sciences into ICES Ecosystem Overviews and integrated ecosystem assessments by developing culturally relevant social indicators.

Recognizing that people and their livelihoods are integral parts of ecosystems, WGSOCIAL aims to understand and assess the social dimensions within ecosystem evaluations. Despite this importance, social metrics for such assessments are often lacking across ICES regional seas and member countries. Indicators, a key metric type, have traditionally monitored fish stock sustainability and marine ecological components. WGSOCIAL sees social indicators as potent tools to broaden ecosystem modelling and assessment to encompass the social dimension.

The group's objectives include coordinating the development of social-ecological models and social indicators for monitoring and assessment, both internally and in collaboration with other ICES groups and external partners. WGSOCIAL is actively identifying and addressing social indicators and data gaps to prioritize data collection, research, institutional requirements, and training across member countries. Their efforts aim to fill data gaps and enhance ecosystem assessments, including integrated ecosystem assessments (IEAs), by providing complementary social indicators alongside economic and ecological ones. WGSOCIAL is a part of Strategic Initiative on the Human Dimension, SIHD (https://www.ices.dk/community/groups/Pages/SIHD.aspx), which aims to strengthen the human dimension in ICES work. WGSOCIAL first meeting was held in 2018 with the goal of improving the integration of social sciences in ICES Ecosystem Overviews and Integrated Ecosystem Assessments (IEAs) through the development of culturally relevant social indicators.

4 ToR 3 – Models, applications and requirements

This term of reference focused on identifying the most suitable models, per ecoregion, to assess where possible:

a. the impacts of increasing the size-selectivity of gears on the species caught in mixed fisheries in terms of catch, effort, fishing mortality and recruitment.
b. the likely costs and potential benefits associated with gear changes for fleets on the short-term and longer-term.

Suitability will be assessed on data requirements, ease of parametrisation, short and long-term forecasting capabilities, adaptability for long-term goals. Based on the expertise present at EWG 23-15 and the outcomes of the summary of knowledge documented in ToR 1, the suitability of bio-economic models to assess impact of technical measures were discussed for four sea regions: North Sea; Celtic Sea; Bay of Biscay & Atlantic Iberian Waters; and Mediterranean.

4.1 Summary of model applications

Within this area there are a number of applications of bio-economic models. This overview is provided by sea region as the fisheries and management within each region pose different challenges and may require different models. EWG 23-15 concluded that the skill set is available in each sea region to apply a bio-economic model to assess the impact of technical measures (among other possible policy questions). However, EWG 23-15 found varying degrees of documentation available per model and region. In particular, for the Mediterranean EWG 23-15 were unable to clearly identify the process and frameworks in which the model development and application were placed, or even how the model was used for advice, due to lack of documentation and experts. Therefore, this section focuses on the suitability of models for future adaptation, and not the time and resources that would be requires to update it.

4.1.1 Bay of Biscay and Iberian Waters

Bay of Biscay and Iberian Coast ecoregion covers the south-western areas of the EU (**Figure 4.1: The Bay of Biscay and Iberian Coast eco-region and ICES statistical rectangles (source: ICES 2022b).**Figure 4.1). This summary was sourced from the ICES fisheries overview (ICES 2022b). It includes areas of the deeper eastern Atlantic Ocean, as well as coastal areas from Brittany in the north to the Iberian Peninsula and Gulf of Cadiz in the south. The following areas constitute this ecoregion: The Bay of Biscay (divisions 8.a and 8.b, and part of subdivisions 8.d.2 and 8.e.2); The Cantabrian Sea (Division 8.c); and the western coast of Spain, the Portuguese coast, and the Gulf of Cadiz (Division 9.a and part of Subdivision 9.b.2). At its south-eastern limit, this ecoregion is connected to the Mediterranean Basin by the Strait of Gibraltar. Deep-water currents composed of Mediterranean water have a strong influence on the southwest Iberian and Gulf of Cadiz circulation patterns. Within this area only one model, FLBEIA (García *et al*. 2017), is commonly applied which could be adapted to assess the impact of technical measures (Table 4.1). This model is currently part of a quality control advice framework at ICES with a full documented and transparent process (ICES 2023c).

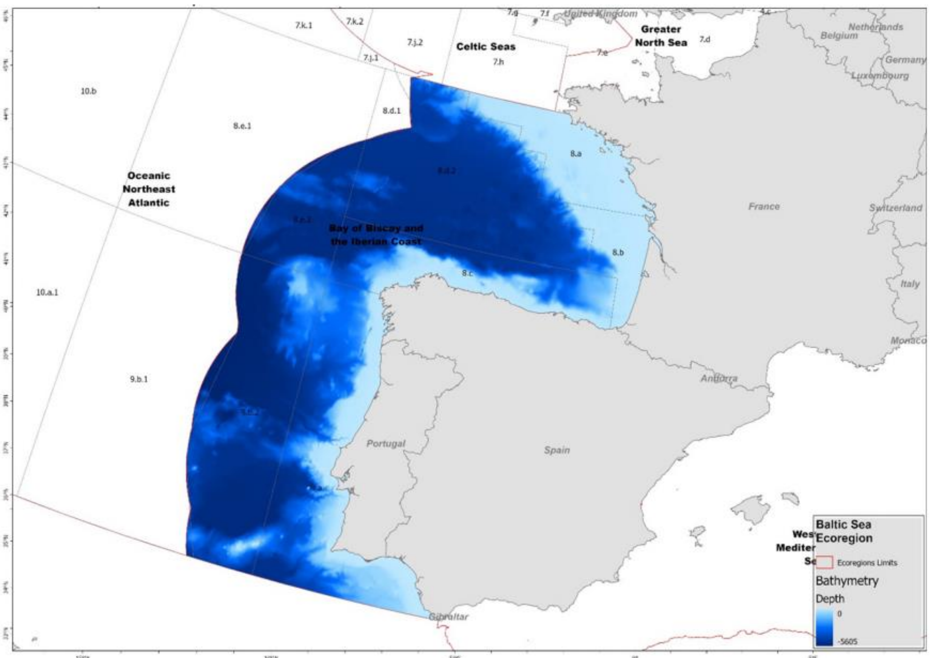

Figure 4.1: The Bay of Biscay and Iberian Coast eco-region and ICES statistical rectangles (source: ICES 2022b).

Table 4.1: Summary of bio-economic models currently applied for advice purposes in the Bay of Biscay and Atlantic Iberian Ecoregion.

Name of Model	Area coverage	Purpose	Species Coverage	Fleet Coverage	Reference	Data (yr. range)	Forecast period (no, of years)	Used for assessing impact of tech. measures	Possible future tool
FLBEIA	Bay of Biscay	Mixed fisheries advice	ank.27.78abd, bss.27.8ab, hke.27.3a46-8abd, hom.27.2a4a5b6a7a-ce-k8, mac.27.nea, meg.27.7b-k8abd, mon.27.78abd, nep.fu.2324, pol.27.89a, sdv.27.nea, sol.27.8ab, whb.27.1-91214, whg.27.89a.	ES_GNS_10<24m, ES_GNS_24<40m, ES_GTR_10<24m, ES_LLS_10<24m, ES_LLS_24<40m, ES_MIS_all, ES_OTB_>=40m, ES_OTB_24<40m, ES_PTB_24<40m, FR_G___<10m, FR_G___10<24m, FR_G___24<40m, FR_LL__<10-24, FR_LL__24<40m, FR_MIS_all, FR_OTB_<10m, FR_OTB_10<24m, FR_OTB_24<40m, FR_OTM_>=40m, FR_OTM_10<24m, FR_OTM_24<40m, FR_SSC_10<40m, OT_*_-9	Link to advice sheet: https://doi.org/10.17895/ices.advice.21641396	Catch (2018 – 2022) Effort (2018 –2022)	2023-2024 (2 yrs.)	No	Yes
	Iberian waters	Mixed fisheries advice	ank.27.8c9a hke.27.8c9a lbd.27.8c9a meg.27.8c9a mon.27.8c9a	PT_GNS, PT_GTR, PT_MIS, PT_OTB, SP_GNS, SP_GTR, SP_MIS, SP_OTB, SP_LLS, SP_OTB_24m, SP_PTB	Link to advice sheet: http://doi.org/10.17895/ices.advice.21532947	Catch (2018 – 2022) Effort (2018 –2022)	2023-2024 (2 yrs.)	No	Yes
IAM	Bay of Biscay demersal fisheries	Impact assessment of management measures – support to STECF Impact Assessment MAP– + co-viability approach	Most developed application- bss.27.8ab, hke.27.3a46-8abd, nep.fu.2324, sol.27.8ab, + 18 "static species" modelled as a linear function of effort	Most developed application – vessel-based parameterization- 710 French vessels modelled – of 44 fleets/length classes - 13 métiers	Providing Integrated Total Catch Advice for the Management of Mixed Fisheries with an Eco-viability Approach | Environmental Modeling & Assessment (springer.com) + support to STECF, 2015 IA western Waters	2014-2016 (+ recent Updated fleet-métier-stocks version with 2021-2022 data but not finalized)	simulation (2017-2025)	With previous version of the model - test of selective devices– see Raveau *et al.* (2012)	Not planned with this vessel-based version -but yearly updates with a fleet-métier-stocks version will be planned to support bio-economic advice in MIXFISH METHOD and ADVICE–, still missing time, resources and annual organization to perform this kind of assessment annually

4.1.2 Celtic Sea

The Celtic Seas ecoregion covers the north western shelf seas of Europe (Figure 4.2). This summary was sourced from the ICES fisheries overview (ICES 2021a). It includes areas of the deeper eastern Atlantic Ocean and coastal seas that are heavily influenced by oceanic inputs. The ecoregion ranges from north of Shetland to Brittany in the south. Three key areas constitute this ecoregion: northern parts; the Malin shelf, west of Scotland, eastern Rockall Bank, and north of Scotland (parts of Subdivision 2.a.2, divisions 4.a and 6.a, and Subdivision 6.b.2); the Celtic Sea, Bristol Channel, Western English Channel, southwest and west of Ireland (Division 7.b and Subdivision 7.c.2; parts of divisions 7.e, 7.f, 7.g, 7.h, and subdivisions 7.j.2 and 7.k.2); and the Irish Sea (Division 7.a). In the north there are strong links with the North Sea, in the southeast a strong link with the channel area, and in the south a strong link with the Bay of Biscay. The eastern part of the Rockall Bank is within the geographic scope of the ecoregion although it is separated from the western European shelf by the Rockall Trough.

Within this area only one model (FLBEIA) was found to adaptable to assess the impact of technical measures (Table 4.2**: Summary of bio-economic models currently applied for advice purposes in the Celtic Seas ecoregion.**). Although this model has not been applied for advice purposes, it is the focus of WGMIXFISH to operationalise this model in coming years for this area (ICES 2021b). In Ireland an FLBEIA framework has been built to incorporate economic data (including employment, and downstream impacts) and the modelling of gear selectivity in a user friendly package to all ease of use and dissemination.

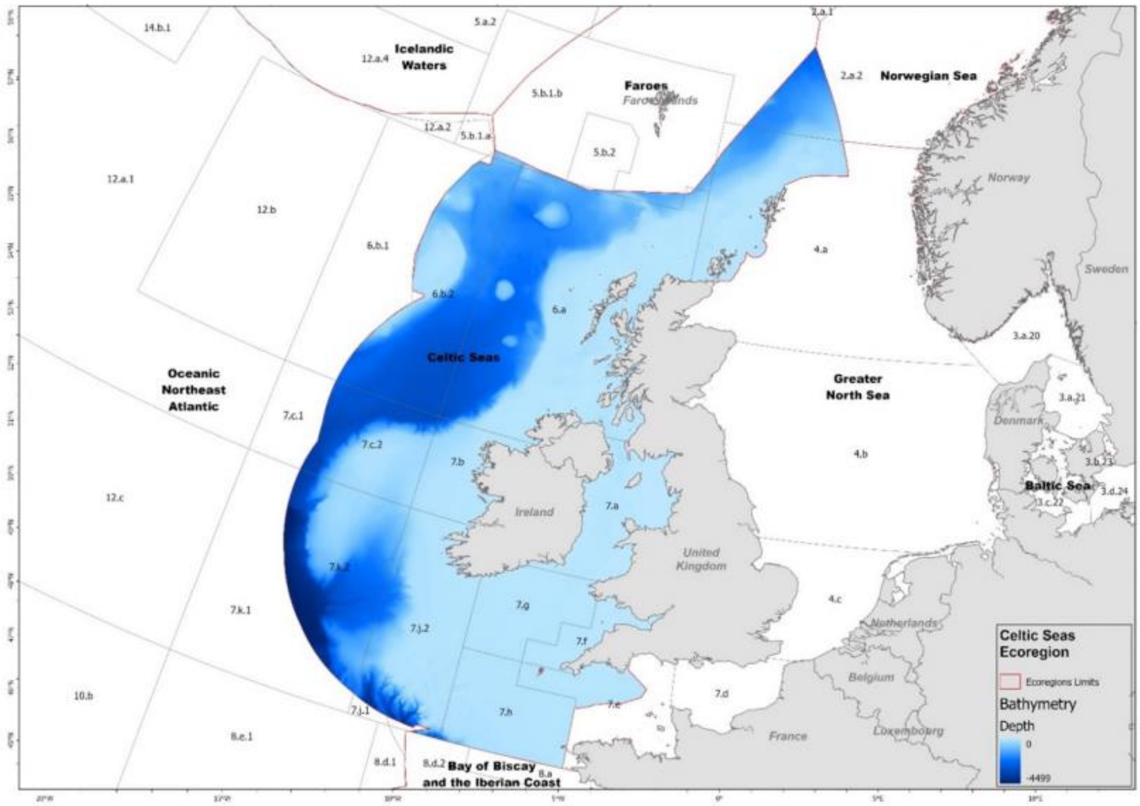

Figure 4.2: The Celtic Seas ecoregion and ICES statistical rectangles (source ICES 2021b).

Table 4.2: Summary of bio-economic models currently applied for advice purposes in the Celtic Seas ecoregion.

Name of Model	Area coverage	Purpose	Species Coverage	Fleet Coverage	Reference	Data (yr. range)	Forecast period (no, of years)	Used for assessing impact of tech. measures	Possible future tool
FLBEIA	Celtic Seas	Future mixed fisheries advice	NA	NA	Link to advice sheet: https://doi.org/10.17895/ices.pub.8719	NA	NA	No	Yes

4.1.3 North Sea

The Greater North Sea ecoregion includes the North Sea, English Channel, Skagerrak, and Kattegat (Figure 4.3). This summary was sourced from the ICES ecoregion overview (ICES 2022c). The Greater North Sea is a relatively shallow sea area on the European continental shelf, with the exception of the Norwegian Trench that extends parallel to the Norwegian shoreline. Pelagic species (primarily herring and mackerel) account for a significant portion of the total commercial fish landings in the region. Landings of benthic and demersal finfish species (primarily haddock, sandeel, flatfish, and cod) are also significant. Around 6600 vessels from nine nations operate in the Greater North Sea, with the largest numbers coming from UK, Norway, Denmark, the Netherlands, and France. Total landings peaked in the early 1970s and have since declined. The following country paragraphs highlight features of the fleets and fisheries of each country but are not exhaustive descriptions.

Within this area only three models (FLBEIA, SIMFISH, FishRent(TI)) are applied, each of which could be adapted to assess the impact of technical measures (Table 4.3). One model, FLBEIA, is currently part of a quality control advice framework at ICES with a full documented and transparent process (ICES 2023c).

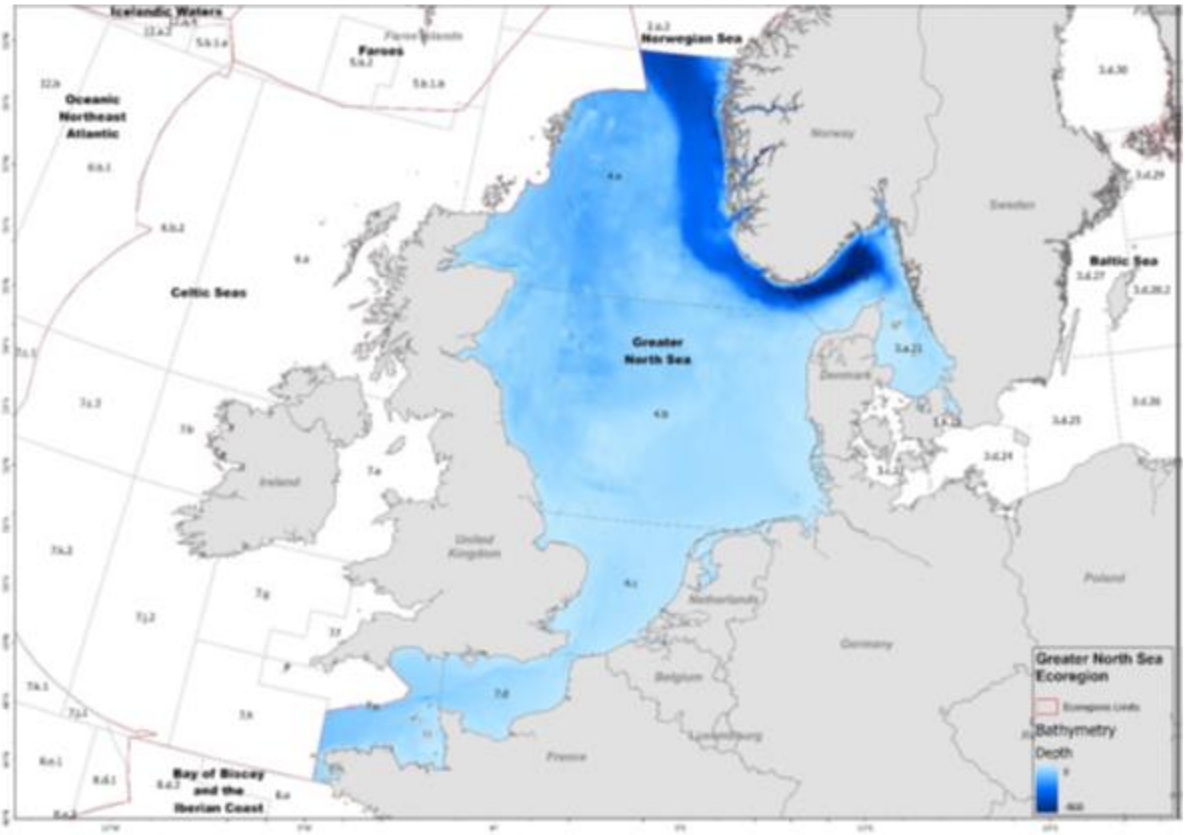

Figure 4.3: The Great North Sea ecoregion and ICES statistical rectangles (source ICES 2022c).

Table 4.3: Summary of bio-economic models currently applied for advice purposes in the Greater North Sea Ecoregion.

Name of Model	Purpose	Species Coverage	Fleet Coverage	Reference	Data (yr range)	Forecast period (no, of years)	Used for assessing impact of tech measures	Possible future tool
FLBEIA	Mixed fisheries advice Covering: 7d; 4a-c	bll.27.3a47de cod.27.46a7d20 had.27.46a20 ple.27.420 ple.27.7d pok.27.3a46 sol.27.4 sol.27.7d tur.27.4 whg.27.47d wit.27.3a47d nep.fu 5-10, and 32,33, 34 and area4 outside FU	43 fleets (3 BE; 6 DK; 5 EN; 5 FR; 3 GE; 6 NL; 8 NO; 4 SC; 1 SW; By gear group: beam, otter, static, pots, pelagic, seine and vessel length	Link to advice sheet: https://doi.org/10.17895/ices.advice.24212022	Catch (2009 – 2022) Effort (2009 –2022)	2023 and 2024 (2 yr)	No	Yes
SIMFISH	Mixfisheries/spatial management Covering: 7d; 4a-c	ple.27.420 (age structured dynamic) sol.27.4 (age structured dynamic) tur.27.4 (fixed bycatch) csh population model	NL_TBB_1824, NL_TBB_2440 & NL_TBB_40XX (AER fleets)	https://doi.org/10.18174/495567	Catch: 2013-2015; effort:2013-2015; economics: 2013-2015	2016-2030 (15 years)	Yes	Yes
FishRent (TI)	Mixfisheries/spatial management	cod.27.46a7d20 (age structured dynamic), pok.27.3a46 (age structured dynamic), had.27.46a20 (age structured dynamic)	Defined with alternative fleet segmentation approach: German Saithe & Cod fishery, Norwegian North Sea Saithe & Cod fishery, UK Demersal seiners	https://fishrent.thuenen.de/	Catch 2013- 2022; Effort 2013-2022; Economic 2013 to 2022	2020-2060	Yes	Yes

4.1.4 Mediterranean

4.1.4.1 Regional overview

The Mediterranean and Black Sea are segmented into five subareas (Western, Central, Adriatic, Eastern and Black Sea), which have been further divided by the General Fisheries Commission for the Mediterranean and Black Sea (GFCM) into 30 sub areas (https://www.fao.org/gfcm/data/maps/gsas/en/) (Figure 4.2). As outlined to Annex IX of the Technical Measure Regulation (EU) 2019/1241) the TMR (Technical Measures Regulation) dictates the baseline mesh size for towed gears and static nets in the Mediterranean Sea. For trawlers a 40mm square mesh codend (or 50 mm diamond mesh codend under specific requirements) is provisioned. In the case of static nets, the prescribed mesh size is set at 16mm. Furthermore, the mesh size of surrounding nets, purse seines and hook numbers for long lines are also specified in Annex IX of the TMR. Provisions are in place for spatiotemporal closures and efforts to reduce fishing activity.

While progress in bio-economic modelling has seen occasional implementations and model development projects, the most advanced work has been undertaken in the Western Mediterranean as part of the WestMED Management Plan, where a process was formulated. In a lesser extend efforts were made in Adriatic under GFCM WKMSE and Management Plan: Small pelagic fisheries in the Adriatic Sea to exploit bio-economic analysis. In contrast, regional approaches seem to be lacking in the rest of the basin. The WestMED example and its associated process stands out as a valuable case study, offering lessons learned that could guide the expansion of a Bio-Economic modelling into other areas.

Concurrently, MS are taking internal actions to address various aspects of the Technical Measures Regulations within their respective areas of competence and fisheries. When Member States and third countries are engaged in shared stocks, a notable issue arises in the misalignment in the data format of socioeconomic information collected under the GFCM Data Collection Reference Framework (DCRF) program. It is crucial to emphasize the paramount importance of involving third countries in the collaborative effort to streamline a bio-economic model under such circumstances.

Within the four of these areas, models were found to have been applied for advice purpose. In the Western Mediterranean there are two applications of a bio-economic model for advice purposes, IAM and MEFISTO (Table 4.2); three in Central Mediterranean MEFISTO, BEMTOOL and FLBEIA (Table 4.3); one in the Adriatic, BEMTOOL (Table 4.4); and one Eastern Mediterranean, MEFISTO (Table 4.5).

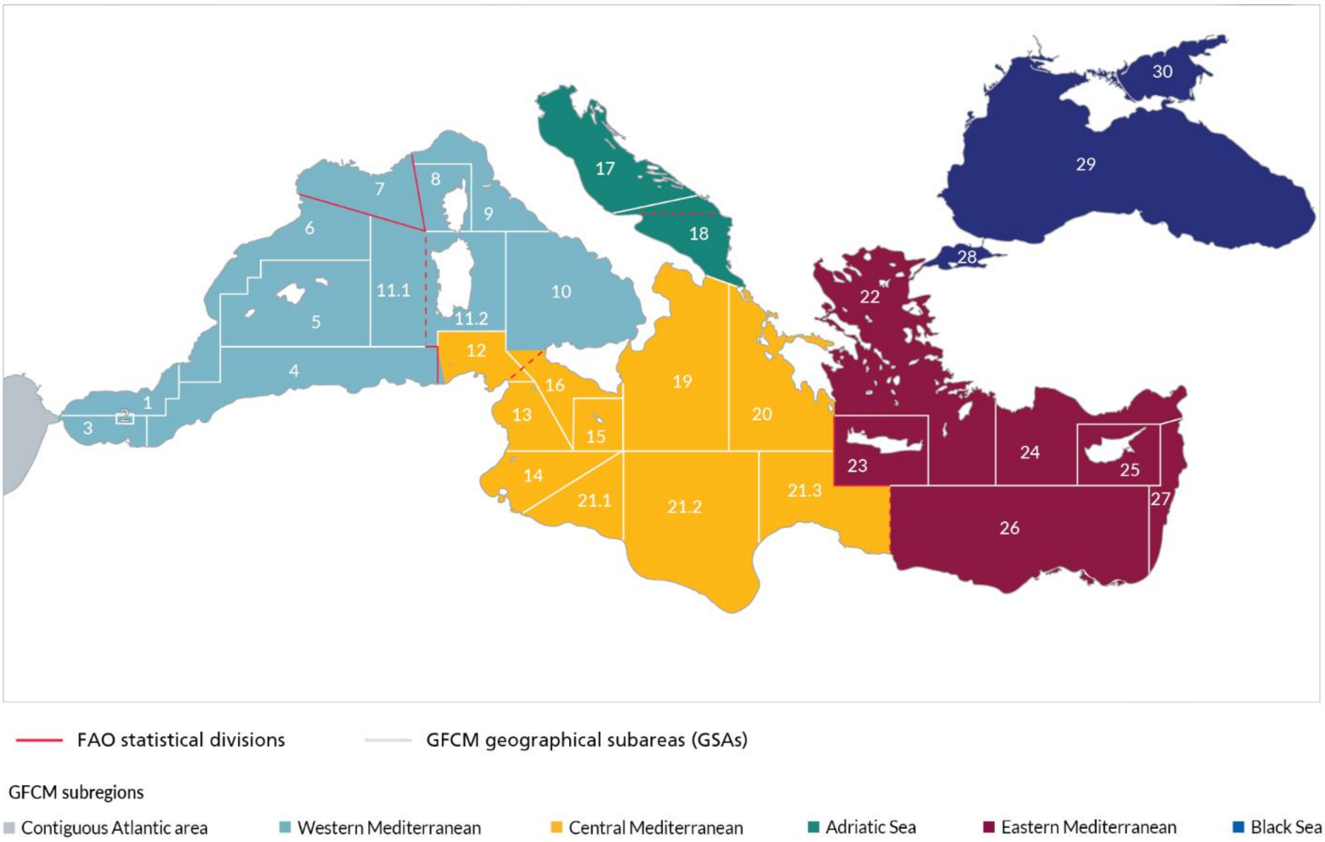

Figure 4.2: Geographical segmentation of the Mediterranean and Black Sea into five subareas (source https://www.fao.org/gfcm/data/maps/gsas/en/)

Table 4.2: Summary of bio-economic models currently applied for advice purposes in the West Mediterranean.

Name of Model	Area coverage	Purpose	Species Coverage	Fleet Coverage	Reference	Data (yr range)	Forecast period (no, of years)	Used for assessing impact of tech measures	Possible future tool
IAM	EMU1 (GSAs 1-2-5-6-7)	STECF Evaluation of fishing and catch Effort Regime	HKE, MUT, NEP, ARA + other static species	French and Spanish fleets	https://stecf.jrc.ec.europa.eu/ewg2211		(latest application: 2022-2030)	Yes – change in effort and/or catchability of different fleets segments – trawlers-netters-liners – inducing change in global selectivity	Yes, but still limited resources available and capable to run new scenarios
MEFISTO	GSA6	Scientific advice	HKE MUT	Bottom trawls in fleet segments VL1218 and VL1824	https://doi.org/10.1111/fme.12365	2015 (1 year)	15 yr	Yes	Yes
	GSA 6	Scientific Advice	HKE, MUT, red shrimp, anchovy, sardine	Purse seine, OTB	https://doi.org/10.1093/icesjms/fsu061	2010	10	Yes	Yes
	GSA 5	Scientific advice	red shrimp (*Aristeus antennatus*); (2) Norway lobster (*Nephrops norvegicus*); (3) striped red mullet (*Mullus surmuletus*), and;(4) hake (*Merluccius merluccius*)	Bottom trawls	https://doi.org/10.1016/j.fishres.2014.06.010	2012	20	yes	yes

Name of Model	Area coverage	Purpose	Species Coverage	Fleet Coverage	Reference	Data (yr range)	Forecast period (no. of years)	Used for assessing impact of tech measures	Possible future tool
MEFISTO	GSA 5	Scientific advice	Mixed fisheries advice, SSF	SSF	https://doi.org/10.1016/j.ocecoaman.2016.09.013	2014		Yes	Yes
	GSA 6	Scientific advice	hake (*M. merluccius*), red mullet (*M. barbatus*), anglerfish (*Lophius piscatorius*), blue whiting (*Micromesistius poutassou*), red shrimp (*A. antennatus*), Norway lobster (*N. norvegicus*), and deep-water pink shrimp (*P. longirostris*)	trawler (OTB) and artisanal fleets (HOK and GNS)	https://doi.org/10.3389/fmars.2020.00459	2015	25	Yes and West MAP	Yes
	GSA 6	Scientific advice	*Merluccius merluccius, Lophius budegassa, Parapenaeus longirostris, Mullus barbatus, Aristaeus antennatus, Nephorps norvegicus, Micromesistius poutassou*	OTB	https://doi.org/10.3989/scimar.04715.06A	2015	15	Yes	Yes
BEMTOOL Bem Tool	**GSA6**	Mixed fisheries advice	HKE MUT DPS	DTSVL0612 DTSVL1218 DTSVL1824 DTSVL2440 HOKVL0624PGPVL0006PGPVL0612PGPVL1218	https://data.europa.eu/doi/10.2926/194244	2020	From 2021 to 2030	Yes – Used for investigating the consequences of the implementation of T90 mesh configuration in the extension piece and selection grid in the trawl fisheries of the western Mediterranean	Yes
	GSA9-10-11	Mixed fisheries advice	HKE MUT DPS	DTSVL0612 DTSVL1218 DTSVL1824 DTSVL2440 PGPVL0006PGPVL0012PGPVL1218	https://data.europa.eu/doi/10.2926/194244	2020	From 2021 to 2030	Yes – Used for investigating the consequences of the implementation of T90 mesh configuration in the extension piece and selection grid in the trawl fisheries of the western Mediterranean	Yes
FLBEIA	GSA06	Mixed fisheries advice	Multispecies: HKE MUT, NEP DPS ARA		https://doi.org/10.1016/j.ocecoaman.2021.105853	2009-2019	2020-2030	Yes – Used to investigate the effect of two modifications to trawl nets in the NW Mediterranean	Yes

Table 4.3: Summary of bio-economic models currently applied for advice purposes in the Central Mediterranean.

Name of Model	Area coverage	Purpose	Species Coverage	Fleet Coverage	Reference	Data (yr range)	Forecast period (no, of years)	Used for assessing impact of tech measures	Possible future tool
DISPLACE	GSA20	Mixed fisheries advice	Multispecies: HKE, MUT MUR DPS ANK, HOM, PAC	GTR, LLS, OTB	https://doi.org/10.11583/DTU.24331198	2020	7 years	Yes	Yes
SMART	**GSA 19**	Conservation measures for cataceans	MUR, MUT, HKE, ARA, ARS, BOG, DPS, EOI, HOM, MON, NEP, SQM	OTB	https://doi.org/10.3389/fmars.2022.1005649	2016-2019	No forecast	economic and the biological value of a given fishing area (spatial overlap between eligible CCAs and fishing grounds)	Yes
SMART	**GSA 16**	establishment of the Fisheries Restricted Areas (FRAs)	MUR, MUT, HKE, ARA, ARS, BOG, DPS, EOI, HOM, MON, NEP, SQM	OTB 12-18, 18-24	https://doi.org/10.3390/su14084743	2016-2019	No forecast (comparison before and after the establishment of the FRA)	estimate the different effects in terms of short economic performances on single fleets operating close to the Italian territorial waters which are assumed to be more strongly affected by the FRAs.	Yes
SMART	**GSAs 12-16 and parts of GSAs 19 and 21**	spatial and temporal closures, effort control, capacity regulation	MUT, HKE, DPS, ARS	OTB 12-18, 18-24	https://doi.org/10.3389/fmars.2019.00542	2012-2016	2018-2022	yes Yes	Yes

Table 4.4: Summary of bio-economic models currently applied for advice purposes in the Adriatic.

Name of Model	Area coverage	Purpose	Species Coverage	Fleet Coverage	Reference	Data (yr range)	Forecast period (no, of years)	Used for assessing impact of tech measures	Possible future tool
BEMTOOL	**GSA 18**	Mixed fisheries advice	DPS, HKE, MUT, ARS	DTBVL1224 DTBVL1218 GNS+GTRVL0012 GNS+GTRVL0018 LLSVL0018 LLSVL0012	*https://doi.org/10.3389/fmars.2017.00193*	Catch (2007 – 2016) Effort (2007 – 2016)	2017-2023 (6 yr)	Different fishing ban	Yes

Table 4.5: Summary of bio-economic models currently applied for advice purposes in the Eastern Mediterranean.

Name of Model	Area coverage	Purpose	Species Coverage	Fleet Coverage	Reference	Data (yr range)	Forecast period (no, of years)	Used for assessing impact of tech measures	Possible future tool
MEFISTO	GSA22	Scientific advice	HKE MUR MUT	Coastal and trawl	https://doi.org/10.1111/fme.12060	2006 (1 year)	15 yr	Yes	Unknown

4.2 Process of operationalisation

The overarching objective of EWG 23-15 is to provide a pathway to operationalise a bio-economic model(s), which could be used to provide advice on the potential ecological, economic and social impacts of the technical measures' implementation. In particular, EWG 23-15 was focused on building a process, which can in the longer term address questions such as:

1) Explore how increased yields of hake (i.e., Atlantic northern hake stock) can be achieved, what long-term benefits and costs could be attained.
2) Identifying alternative pathways of gears changes to increase the size-selectivity of mixed fisheries and impacts of fishing gear diversification.
3) Assess, for each sector, likely costs and benefits associated with the progressive changes over time.

EWG 23-15 discussed the steps required to realise a bio-economic model capable of addressing these questions. As a multidisciplinary science it would require input from biologists, economics, social scientists, gear technologist, stakeholders, and policy makers (Figure 4.3). Such a model would be data hungry and would need to be embedded within a system which has the expertise and capacity to build, parameterise, quality control any model. A system which is updated annually and is capable of adapting to stakeholder input. Table 4.6 provides an overview of the processes required to realise advisory tool to addresses these needs. Followed by an example of the processes and challenges that may be involved in developing such a model at a regional level, both in the North Sea (Section 4.2.1), in the Mediterranean (Section 4.2.3), as well as a bespoke stock specific example which highlights data needs and pipelines for northern hake (Section 4.2.2). The outcomes of EWG 23-15, and future technical measure expert working groups, should align with ongoing work at ICES WGMXIFSH-Methodology (ICES 2023e), GFCM (STECF 2022b) and in a number of national labs, where bio-economic models have been under production for some time.

From the outset an impact assessment should be guided by clear objectives across biological, economic, and social dimensions. Transparency in goal-setting ensures clarity and inclusivity among all stakeholders, thereby fostering sustainable outcomes. Sustainability evaluations must encompass biological, social, and economic dimensions to address the multifaceted nature of the process, accounting for species, fleets, vessels, communities, and distributional effects. While specific reference points may not always be necessary for economic and social goals, quantifying trade-offs remains crucial. Even small successes can incentivize broader engagement within the community.

The outputs from the model alone would not be sufficient. EWG will need to consider the socio-economic barriers and implications to implementing technical measures changes. Stakeholder engagement is pivotal, as fishers often support management measures once they understand them. Establishing clear communication channels and feedback loops is imperative, especially when communicating uncertainty and potential risks. Building trust and engagement involves comparing short-term gains with long-term benefits, while also addressing distributional effects. Review processes are key so that only effective measures are retained, and there is equal treatment across fleets based on the functional effectiveness of the technical measure.

Regarding the political process, the origin of technical measures should ideally stem from the source, with encouragement from the EU for industry-led initiatives. However, the current process lacks clarity and can be hindered by delays and poor-quality studies. Consolation with Advisory Councils often falls short in addressing issues effectively, with emergency measures sometimes implemented without adequate information. A tool to aid in selecting the appropriate model at the end of the regulatory process is essential. Additionally, consideration should be given to incorporating PETS (Protected Species Exclusion Tools) and MPAs (Marine Protected Areas) in future assessments. While tools, data streams, expertise, and development platforms can evolve concurrently, the ultimate goal should be a simulation approach. This approach allows for understanding uncertainty and comparing performance relative to a reference case, even if observation or assessment errors are excluded.

Biological, economic and social objectives should be clear. If an impact assessment is requested for the goals must be clear, and the objective should be clear to all engaged and effected by the process to ensure that outcomes. Sustainability should be assessed in three dimensions biological, social and economic, accounting for the complex multidimensionality of the process (species, fleets, vessels, community and distributional effects). We don't always need clear reference points for economic and social goals, however, having the trade-offs should be quantified. Small success will be an incentive to engage a wider group. Simulation approach should be the goal as this will provide the tools to build an understanding of uncertainty. As our aim is to compare the performance relative to our reference case, in this case it is ok if we do not include the observation/assessment errors in the simulations.

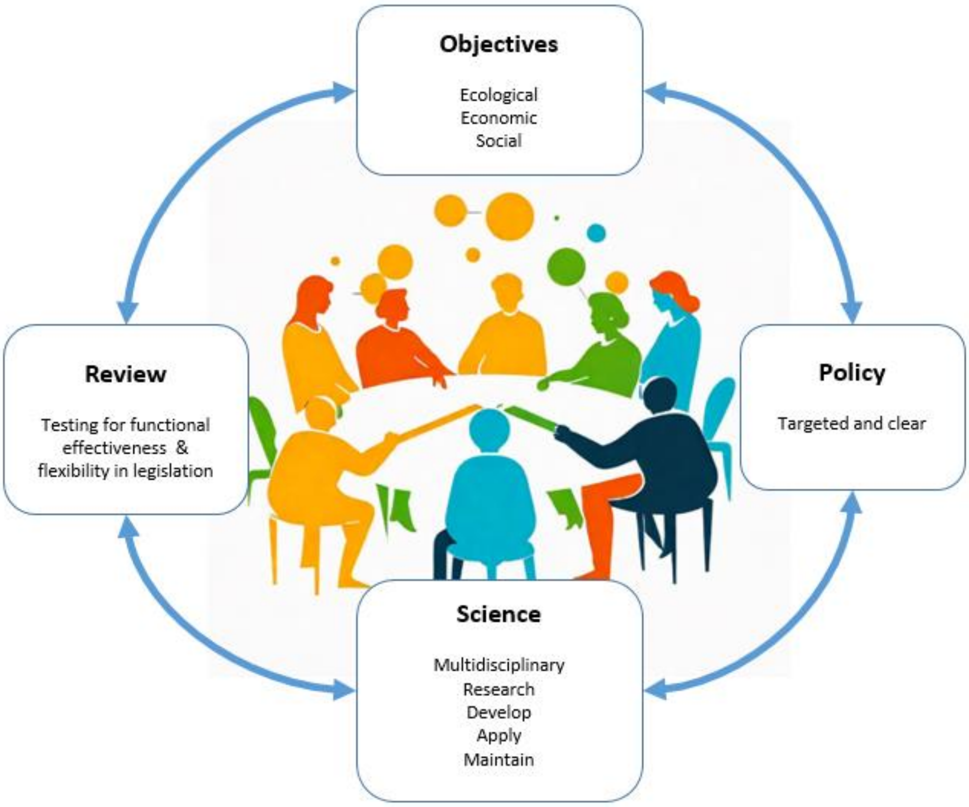

Figure 4.3: Multidisciplinary advice products such as bio-economic model require iterative development processes with space for feedback and real-time feedback from stakeholders and end-users.

Table 4.6 Step required to operationalise a bio-economic assessment of the impact of technical measures. The success of this process will be defined by appropriate participatory processes and feedback loops with the relevant stakeholders are needed and required to be led by experts.

Step	Title	Details	Needs	Key Actors	Time frame
1	**Setting objectives**	Define collectively the objectives of the work undertaken, both the objectives of the regulation and of the advice product.	Engagement with all key actors.	Stakeholders; biologist, economists, social scientists, DGMARE	2-5 years
2	**Defining scenarios and indicators**	Define management scenarios to be tested. The management goals, harvest control rules, measures to be tested, and the area of application of the change. Define indicators: (i) fleet dependency to stock/métier (ratio of stock/métier revenues and the total fleet revenues); and (ii) the contribution of the fleet to the total catch of a métier/stock, one or the other depending on specific cases.	Taken from regulation and collective definition of objectives.	Stakeholders; biologist, economists, social scientists, DGMARE	2-5 years
3	**Defining the fleet**	Define fleets and métiers (to be modelled) based on the best available information. Appropriate data aggregation level is key as it will impact the robustness of the forecast, the ability to translate outcomes into advice and the magnitude of uncertainty.	Required data (see ToR 3) and experts to build fleet objects based on defined scenarios, and objectives (i.e. WGMIXFISH, FDI, AER, Social data)	Stakeholders; biologist, economists, social scientists	2-5 years
4	**Defining the stocks**	Define stocks, to be included in the model, based on advice needs, and where possible accounting for bycatch and discard species, including non-quota species.	Stock assessment model outputs, forecast settings, forecast outputs. Ideally at the level of aggregation which will provide estimates of fishing mortality at length per métier, so that selectivity can be modelled.	Biologists	2-5 years
5	**Defining the selectivity**	Conduct a selectivity study (for landings, discards and costs) to estimate métier specific selectivity at age. Translate finding into mortality matrix or scalers that can be applied in scenarios.	Trials, analysis, input to model.	Stakeholders; biologist; economists, social scientists, gear technologists	2-5 years

Step	Title	Details	Needs	Key Actors	Time frame
6	**Define the assumptions**	The assumptions will affect the robustness of the model and the usability of the outputs. Assumptions such as the projection period, including uncertainty in some parameters (e.g. biological parameters, fleet quotas, availability, selectivity or prices), should be defined and communicated with advice, so that limits are clear.	Defined by objectives and tested with sensitivity analysis.	Biologist; economists, social scientists, gear technologists	2-5 years
7	**Conditioning the model**	Condition the selected model.	Bio-economic model.	Biologists; economists, social scientists, gear technologists	2-5 years
8	**Run the model**	Run simulations under the different scenarios and assumptions, and complete sensitivity analysis.	Bio-economic model.	Biologists; economists, social scientists, gear technologists	2-5 years
9	**Visualisation of outputs**	Production and visualization of results. Multidisciplinary data of this nature should be disseminated in structure. Create table-figures- shiny to explore results from a mutli-criteria perspective and given different level of aggregation.	Visualisations tools.	Biologists; economists, social scientists, gear technologists	2-5 years
10	**Share, discuss & report results**	Disseminate results and advice.	Final advice product.	biologist; economists, social scientists, gear technologists, stakeholders, DGMARE	2-5 years

4.2.1 Example of a region specific process - North Sea

The Table 4.7 gives an overview of current issues that need to be resolved to make the FLBEIA model operational given the current state of the ICES WGMIXFISH FLBEIA model applied in the North Sea ecoregion in order to assess the impact of technical measures. This model includes fleets and métiers that have age specific catchabilities for each category I stock. However, the fleets and métiers implemented in this model mainly reflect the fleets described in the North Sea cod recovery plan (ICES 2021b), and are not always appropriately defined to implement technical measures related to gear modifications. In addition, the model considers only two spatial units (the North Sea (4.a-c) and the English Channel), and should be modified to allow to investigate the effect of spatial based technical measures. Currently, fleets lack an economic parametrization which is required to assess the impact of technical measures, and the dynamics of fleets are static causing that effort shares between métiers are constant, and fleets are not able to adjust their behaviour according to changes in fishing opportunities, spatial closures, or changes in the profitability of certain gears. Finally, a standardize routine on how to include results of gear trials into fleet/métier specific catchabilities should be developed. The table below describes how these issues should be addressed, including specific actions and resources. Next to this general modification of the model, a fixed routine should be developed on how to address specific requests (see text described in ToR3, Section 4.1.3). Although not currently used for advice at ICES, the challenges to implement the DISPLACE model were also considered (Table 4.8).

Table 4.7: Challenges to overcome to develop bio-economic model using FLBEIA assess impact of technical measures in North Wester and South Wester Waters.

Issue/problem	**Steps to be taken**	**Actions planned**	**Resources**	**Priority**	**Timeframe**
Review fleet definitions to better align with reality of the fishery and technical measures (related to gear modifications can be implemented in the model).	Access to disaggregated catch and effort data. Expert knowledge.	Use of ICES RDBES database. ICES Workshop (WKFLEET).	Scientists: software development. Workshops with stakeholders (in particular fisheries managers).	High	2 years
Increase the spatial heterogeneity of resource distribution and fisheries in the model to allow investigating the impact of spatial based technical measures.	Define spatially disaggregated fleets and métiers. Spatially explicit stock assessment models.	Use of ICES RDBES database. Implement developments within single species models. Use of survey data to identify the spatial distribution of stocks.	Scientists: software development	Moderate	3 – 5 years
Economic conditioning of fleets in the model, including variable costs per unit effort at the métier level and fixed costs.	Access to disaggregated economic data or data expert knowledge to parametrize fleets.	Develop routines to link AER data to fleets implemented in FLBEIA. Workshops.	Software development. Collaboration with ICES WGECON.	High	2-3 years
Implement alternative fleet dynamic models in the FLBEIA software that allow to investigate the response of fishers to technical measures.	Increase realism of fleet dynamics (effort allocation according to fishing opportunities).	Implement profit maximization behaviour, or other routines (e.g. reinforcement learning).	Scientists: software development.	High	2 years
Increase the number of stocks and spatial extend of the model to better understand operations of particular fleets.		- Implement all available ICES category I and III stocks.	Scientists: data collection, method development and review.	Low	2 – 5 years

Issue/problem	Steps to be taken	Actions planned	Resources	Priority	Timeframe
		- Consider including static stocks like is currently done with *Nephrops.* - Merge FLBEIA models of different ecoregions.			
Develop routing to translating technical measures to FLBEIA framework: a. Gear selectivity, b. Spatial/temporal closures	Translate gear trial studies to mixed fisheries models,	Literature review on gear trial studies, meta-analysis, implement gear modification in software,	Scientists: Research & Software development,	High	2 – 5 years
Peer review	Quality control model and data,	Benchmark workshop,	Technical skilled people and stakeholders,	High	NA

Table 4.8: Challenges to overcome to develop bio-economic model using DISPLACE to assess impact of technical measures in North Wester and South Wester Waters.

Issue/problem	Steps to be taken	Actions planned	Resources	Priority	Timeframe
Include more countries in the model	Access to logbook and VMS data	International collaboration	Series of workshops	High	2 – 5 years
Fleet dynamics	Define heuristic decision tree's relevant for each fleet/vessel included in the model	Workshop with experts of particular fisheries	Workshop	High	2 – 5 years
Implement more realistic fleet dynamic models in the software	Increase realism of fleet dynamics (for medium/long-term projections)		Software development	High	2 – 5 years
No vessel exit/entry dynamics	Include capital dynamic model, and investment decision making	Implement all available ICES category I and III stocks; considering including more static stocks Merge models of different ecoregions	Data collection, method development and review	Low	2 – 5 years
Economic parametrization of vessels					2 – 5 years
Translating technical measures to FLBEIA framework a. Gear selectivity b. Spatio(temporal) closures	Translate gear trial studies to vessels included in the model	Literature review on gear trial studies, meta-analysis, implement gear modification in software	Research & Software development	High	2 – 5 years
Peer review	Quality control model and data	Benchmark workshop	Skilled people	High	NA

4.2.2 Example process and thought exercise: Northern HKE

A road map to test the bio-economic impact of the implementation of a specific technical measure in the fleets affected by this change. It is important to bear in mind that for the following steps to work, appropriate participatory processes with the relevant stakeholders (i.e., fishers that will use the gear modifications proposed) are needed and required to be led by experts. Followed by the challenges that must be overcome (Table 4.9).

STEP 1) Define the technical change to be tested – these could be taken directly from the preview EWG 22-19 where gear the outcome of gear trial studies were applied to fleet objects to determine the gears which may provide the highest gains in terms of protection of juveniles.

STEP 2) Source the fleet data - dependent on the gear to be modified. This requires to estimate fleet dependency to stock/métier and fleet's contribution to the total catch of a métier/stock from WGMIXFISH (ICES 2023d) and WGBIE (ICES 2023f). Economic and social data would have to be sources and applied to fleet (AER and DCF Social data call)

STEP 3) Define fleets and métiers – this process is never static and should be benchmarked and occur in an established framework such as ICES WKMIXFLEET (https://www.ices.dk/community/groups/Pages/WKMIXFLEET.aspx) and WGMIXFISH-METHODS (i.e. ICES 2023e) to give an improved definition of the fleets and métiers in the different WGMIXFISH case studies.

STEP 4) Define the assumptions for the projection period - including uncertainty in some parameters (e.g. biological parameters, fleet quotas, availability, selectivity or prices, growth). Is the selectivity at age of the reference métier with initial and alternative gear configuration of the proposed technical measure in step 1 available? If not, then a selectivity study is needed.

STEP 7) Define sensitivity analyses (e.g. fuel prices evolution).

STEP 8) Condition the current FLBEIA WGMIXFISH model - including the data defined in previous steps and assuming that the fleets' behaviour in the future will correspond to the situation before applying a specific technical measure (base or reference case).

STEP 9) Condition the alternative scenario - using the same configuration as for the reference case but modifying the fleet related aspects that are expected to change if following the specific technical measure that want to be tested, that is selectivity pattern in this specific case.

Table 4.9: Challenges to overcome to develop bio-economic model using FLBEIA assess impact of technical measures in North Wester and South Wester Waters

Issue/problem	How	Actions planned	Resources	Priority	Timeframe
Update fleet definitions to better align with the technical measure to be addressed	Use disaggregated catch and effort data. Fleet definitions based on expert knowledge.	1) Use of ICES RDBES database to condition fleets 2) ICES Workshop (WKFLEET)	1) Software development 2) Stakeholder workshop	High	1 – 2 years

4.2.3 Example of a region specific process - Mediterranean

West Med review group (STECF 2022a) has experience with mixed fisheries/fleets/bio-economic models. However, they only meet for 5 days and currently have no capacity for additional work. To operational a bio-economic model to assess the impact of technical measures would require a permeant group of people with dedicated time to the development of such models. This work would include data preparation and quality control; model parameterisation, run and sanity checked; new scenarios to be developed; and peer review of results. This advice product would have to be requested to secure resources and to have capacity. Needs to be an annual procedure, preparation done outside of meeting scheduled between July – November, therefore experts would need to know meeting dates in January so they could prepare their work load for the year. Framework contract would be a starting point but not the solution.

5 ToR 4 – Management scenarios

This term of reference focused on the identification of meaningful management scenarios that could be produced with these models, and the additional information/data/models that would be required to produce such scenarios. During EWG 23-15 there was a dedicated session with scientists and stakeholders to gather information on what their understanding of a scenario is, and how it should be set. Scenario setting is an important step in the development of any advice product as it clear defines the objectives and information required. When scientists translate stakeholder/policy perspective into a scenario it ensures that the output of the model is a useful decision support tool, which is more likely to be applicable to management and real life fisheries.

5.1 Inclusion of the human dimension

The discussion during the session highlighted that observer's, stakeholders and managers are united in the focus on sustainable management. The discussions highlighted the need for scenarios to address all three dimensions of fisheries management: ecological, economic, and social. Participants felt that to date economic and social aspects (or generally the human dimension) have not played a prominent role. With most management decisions focusing on biological targets. However, fisheries management, is the management of where fishers and fish interact, therefore effective fisheries management should have the human dimension to the forefront. It is obvious, however, that observers/stakeholders are heterogeneous group and, therefore, objectives may differ. Therefore, forums, time and expert's guidance are required to build trust and to gather perspectives on the scenarios required to provide advice.

All participants agreed that the inclusion of social data was key to the development of sustainable ecological and economic management of fisheries (i.e. employment) with the acknowledgment that time and resources need to be made available to incorporate social data into established frameworks which already provide bio-economic advice. In their answers scientists highlighted employment/social impacts. It became also obvious that "Stakeholders' perspective" is very important especially in the assessment of social aspects. Observers also mentioned social impacts, but it was not that clear how important it is for the small group that participated in the session. The models should test short vs. long-term effects/impacts. Wellbeing is often mentioned when discussing improvements for the fishing sector, but it doesn't fit into our available indicators/variables of the DCF. Complexity is an issue as models need to simplify. An open question is often how fishers would change their behaviour when implementing measures. Therefore, the application of qualitative social science methods may help to get some inside on possible changes in behaviour.

5.2 Future advice product

It was widely accepted during the session that any bio-economic assessment or advice product should have clear ecological, economic and social goals. Time and resources are required to fully implement the human dimension.

Future advice products should provide an analysis of trade-offs, in particular observers highlighted that information on potential future choke species would be very useful, and a bio-economic model parameterised correctly should be able to provide information on the impacts of technical measures, but also the potential lost opportunities due to gear change and/or choking effects. It was also noted that all modelling comes with uncertainty, and this session highlighted the appetite for that uncertainty to be estimated and clearly disseminated with any future advice products. And, where possible, a management strategy evaluation approach should be applied, with multiple simulations, to provide a better understanding of trade-offs variance and uncertainty.

5.3 Technical measures and policy

During the session observers noted that the harmonization of rules with third countries (e.g. UK in the Irish Sea) is important. Shared maritime space and complex disparate technical measures requirements can reduce the feasibility of implementation, and affect the ability of scientists to model what the future impact might be. Harmonisation would provide stability, and should be discussed within the assumptions of any future models built.

Innovation was highlight was a key aspect of this process, it is recognised by all that fishery specific technical solutions are required, focus on reaching MSY and not just to bring less fish on board, and can have socio-economic impacts. Both experts and observers noted that concrete proposals for improvements are often missing when receiving results of studies in a consultation process. The consultations process is often limited to just reactions on a proposal and not collect proposals for measures to reach a certain objective.

However, it was noted that innovation is sometimes not possible because of the rules and there is often no implementing act. Innovations can then only be tested in research projects. Measures should be practicable and fishers involved in the decision making. Participants proposed a bottom-up approach in the process. Regional groups should propose measures via joint recommendations for all fleets. This could be also done on MS level for own fleets. Joint recommendations are not unified, the quality of studies to justify measures vary and some are relatively poor. It would be helpful when fishers/practitioners 'believe in the measure' – but is that possible? Also, for example, bankers should be relatively sure about the long-term gains so that fishers may receive loans for investments. A top-down management influences often more fishers than may be intended. Emergency measures stay forever and getting rid of a regulation is also very complicated.

5.4 Summary of observer perspective raised during the observer meeting during EWG 23-15 (January 23rd) and through provided documents by ACs (internal documents – not included in the report)

Representatives of all Advisory Councils registered as observers to the EWG 23-15 which was organized to discuss a way forward for future assessments of changes in TCM (especially data needs, models available, how scenarios may look like, etc.). The observers were asked in this first meeting to give their perspective on the implementation of the TCM. The EWG sees this as a very valuable input for the decision which fisheries may be good case studies for the socio-economic assessment and what issues the ACs see regarding the implementation of the TCM. The following notes were taken during the meeting with the observers where they presented their position on the TCM. The notes are accompanied by information obtained from documents provided by the observers. The EWG notes that this is our understanding of the issues and may not fully reflect what was raised.

- An important problem seems to be that there is a lack of flexibility for the fishers. The proposed/adopted Technical Measures are/were often very detailed, complicated to implement and sometimes even contradict(ed) each other. This often leaves no room to manoeuvre for the fishers to optimize their activities within a certain management framework. Fishers also catch fish for markets and need flexibility as, for example, in times of low prices for a species it doesn't make sense to catch that species. Another reason regarding more flexibility is the problem of the fixed quota distribution (following relative stability). However, in this case fishers may at least be able to exchange quota to address some of the issues with choke effects, running out of quota etc.

- Although flexibility is demanded, it was also raised that fishers need stability regarding the TCM implemented in a fishery (and not changes every year) as it may take some time to optimize activities within the management framework.
- There is still the issue with the definition of what are 'targeted fisheries'. Depending on which species/fisheries are selected it can change the rules/measures fishers have their activities to adapt to. This is, however, not a new problem and is discussed for many years especially also regarding the implementation of the landing obligation.
- In some areas there is a complicated TCM framework which makes it difficult to implement new measures. Sometimes regulations are even contradicting each other. What is possible following the TCM may be, for example, not possible under measures following from Art. 15 of the basic regulation (landing obligation). ACs have raised this point several times to make the EC aware that this needs to be solved.
- ACs provided input regarding the implementation of TCM but it is often unclear how this advice was used in the process. ACs report that advice was never or rarely taken up.
- There were sometimes legal issues with the implementation of new fishing gears. For example, in case of some voluntary measures control agencies claimed that the new type of fishing gear is not allowed in the current legal framework. So, it was declared illegal and the control agency issued fines.
- Several participants mentioned that voluntary measures to improve selectivity are or were implemented in their respective area. Those mostly focused on gear modifications to reduce unwanted fish bycatch or the bycatch of birds or marine mammals.
- There is a general expectation that the implementation of TCM would lead to short-term costs, which is also shown by studies of individual cases in the past. If that is the case, there was a claim that those losses should be compensated.
- Biggest problem is the Zero-Catch advice as no bycatch is allowed and, therefore, fishers must do everything to avoid bycatch of a species.
- It needs mixed fisheries consideration and advice, therefore, a more global look at a fishery.
- EU and UK measures need to be aligned as the UK implemented different measures than the EU in some areas.
- There is not 'one size fits all' solution. It needs to be fisheries/fleet specific technical measures to be sure to achieve the objective(s).
- Hake could be a good example for socio-economic assessments in the future because of the role of hake in many fisheries (e.g. choke species).

6 TOR 5 – FUTURE

This ToR focused on the direction of future work, additional needs, stakeholder engagement, and advice needs. ToR 1 (Section 2) underscored the significant interest and depth of research within the realm of integrated ecological and economic fisheries models, notably in bio-economic modelling. These models represent valuable tools for evaluating the impacts of technical measures. Despite the availability of tools and data, albeit to varying extents across different sea regions, there lacks a dedicated framework to meet this specific advisory requirement. Consequently, the primary obstacle to operationalizing such advisory products lies in the scarcity of time and qualified personnel for conducting data analysis, stock assessment, and bio-economic modelling. Furthermore, there is a shortage of experts proficient in multidisciplinary approaches, particularly in participatory management, which hinders effective communication among diverse stakeholders.

EWG 23-15 have identified possible candidate models (ToR 3, Section 4), data sources (ToR 2, Section 3) and frameworks which could support such a process (ToR 3, Section 4). However, this resource (data, time and expertise) hungry process could befit form long-term investment in research and dedicated Working Groups, as well as transitional support for fisheries to improve engagement and likelihood of success.

Below is a summary of some of these proposals:

- **Ongoing research in parallel** - Implement master's programs targeting motivated students in marine sciences, mathematics, economics, and political sciences. These programs would focus on fisheries management specialization, including gear technology, socio-economics, international law, and communication skills. Additionally, they would cover fisheries modelling, from basic principles to utilizing tools for stock assessment and bio-economic analysis.

- **Comprehensive training programme** - Recent discussions have centred on operationalizing bio-economic modelling, highlighting challenges such as data availability, computational time, and stakeholder engagement. Both modellers and social scientists have identified a lack of expertise in computational/statistical assessment of fish resources. Therefore, there's a need for comprehensive training, possibly through master's programs, in fisheries assessment and management. Transitioning to modified or alternative fishing gears faces numerous barriers, including lack of familiarity, fear of losing market share, high investment costs, and ineffective technology infrastructure.

- **Transitional support for fisheries** - Successful transition requires promoting cost-effective gear designs, conducting studies on best practices, providing technical training to fishers, establishing appropriate incentives, and fostering cooperation among stakeholders.

- **Change Management in Fisheries** – By better understanding the humans involved in the process, we will better assess transitional needs. Therefore, future work should not only focus on modelling but also on the human dimension. Pol & Eayrs (2019) suggest that fishers, scientists and managers are reluctant to change and they identify deficits in information and motivation as the drivers of this reluctance. They suggest changing management strategies to improve voluntary uptake of fishing gears that promote sustainability, while mandatory implementation of selective gears was identified as one means of successfully implementing change. The TMR lays down mandatory baseline mesh sizes with the facility for alternative gears to be implemented on the basis of equivalent selectivity. Since the TMRs introduction in 2019 Member States have therefore been motivated to recommend the addition of multiple alternative gears to the TMR.

7 CONCLUSIONS

In conclusion, EWG 23-15 have found that the foundational building blocks of a bio-economic impact assessment of technical measures currently exist within the EU. However, it will take 2 – 5 years to full operational the process of providing robust and transparent advice for these needs.

ToR 1 (Section 2) underscored the significant interest and depth of research within the realm of integrated ecological and economic fisheries models, notably in bio-economic modelling. These models represent valuable tools for evaluating the impacts of technical measures. Despite the availability of tools and data, albeit to varying extents across different sea regions, there lacks a dedicated framework to meet this specific advisory requirement. Consequently, the primary obstacle to operationalizing such advisory products lies in the scarcity of time and qualified personnel for conducting data analysis, stock assessment, and bio-economic modelling. Furthermore, there is a shortage of experts proficient in multidisciplinary approaches, particularly in participatory management, which hinders effective communication among diverse stakeholders.

EWG 23-15 have identified possible candidate models (ToR 3, Section 4), data sources (ToR 2, Section 3) and frameworks which could support such a process (ToR 3, Section 4). However, this resource (data, time and expertise) hungry process could befit form long-term investment in research and dedicated Working Groups, as well as transitional support for fisheries to improve engagement and likelihood of success.

EWG 23-15 notes that the success of this process will be defined by the inclusion of human dimension to ensure the model captures realistic fleet behaviour, relevant to advice needs, and captures the drivers of patterns and their resulting impacts on the ecological, economic and social dimension of the system (ToR 4, Section 6).

Finally, EWG 23-15 highlights that to successfully assess transitional needs future work should not only focus on modelling but also on the human dimension which will require training programs, technical support for fisheries transition, and effective change management strategies in fisheries governance.

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List of Tables

List of Figures

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The Scientific, Technical and Economic Committee for Fisheries (STECF) has been established by the European Commission. The STECF is being consulted at regular intervals on matters pertaining to the conservation and management of living aquatic resources, including biological, economic, environmental, social and technical considerations.

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