STUDY

Requested by the PECH committee

European Parliament

Research for PECH Committee - Discard ban, landing obligation and MSY in the Western Mediterranean Sea - the Spanish case

Fisheries

Policy Department for Structural and Cohesion Policies
Directorate-General for Internal Policies
PE 629.179 - Novermber 2018

EN

Research for PECH Committee - Discard ban, landing obligation and MSY in the Western Mediterranean Sea - the Spanish case

Abstract

The demersal fisheries in the Mediterranean Sea are **heavily overfished but the landing obligation will not help to reach MSY** because it will not decrease fishing mortality. The new proposal of the Commission introduces ***total allowable effort*** as a new way to regulate Western Mediterranean demersal fisheries by significantly **reducing fishing time**. However, this new management measure must be complemented with increased gear selectivity, implementation of closed areas and local co-management plans. Different approaches to reduce fishing mortality may have different socio-economic impact.

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

AUTHORS

University of Alicante: Jose Luis Sánchez Lizaso, Ivan Sola, Francisco González Carrión
Spanish Institut of Oceanography : Jose María Bellido, Elena Guijarro García
University of Barcelona: Ramón Franquesa

Research manager: Carmen-Paz MARTÍ
Project and publication assistance: Adrienn BORKA
Policy Department for Structural and Cohesion Policies, European Parliament

LINGUISTIC VERSIONS

Original: EN

ABOUT THE PUBLISHER

To contact the Policy Department or to subscribe to updates on our work for the PECH Committee please write to: Poldep-cohesion@ep.europa.eu

Manuscript completed in November 2018

This document is available on the internet in summary with option to download the full text at: http://bit.ly/2QDA0JW

This document is available on the internet at:
http://www.europarl.europa.eu/thinktank/en/document.html?reference=IPOL_STU(2018)629179

Further information on research for PECH by the Policy Department is available at:
https://research4committees.blog/pech/
Follow us on Twitter: @PolicyPECH

Please use the following reference to cite this study:
J. L. Sánchez Lizaso, I. Sola, E. Guijarro-García, F. González-Carrión, R. Franquesa J.M. Bellido, 2018, Research for PECH Committee Discard ban, Landing Obligation and MSY in the Western Mediterranean Sea - the Spanish Case, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels
Please use the following reference for in-text citations:
Sanchez-Lizaso et al (2018)

DISCLAIMER

CONTENTS

LIST OF ABBREVIATIONS

B_{MSY}	Biomass that provides MSY
BioDyn	Biomass Dynamic Model
CFP	Common Fisheries Policy
CPUE	Catch Per Unit Effort
CR/BER	Current Revenue/Break-Even Revenue: A proxy of short term profitability
DLS	Data-Limited Stocks
$F_{0.1}$	A proxy for FMSY.
F_{cur}	Current fishing mortality
FLR	Fisheries Libraries in R
FMSY	Fishing mortality that will produce maximum sustainable yield
GADGET	Globally Applicable Area Disaggregated General Ecosystem Toolbox
GFCM	General Fisheries Commission for the Mediterranean
GNS	Demersal gillnet fleet
GSA	Geographical Sub-Area
GT	Gross Tonage
HOK	Longline demersal fleet
ICCAT	International Commission for Conservation of Atlantic Tuna
ICES	International Council for the Exploration of the Sea
INRH	Moroccan National Institute of Fisheries Research
LCA	Length Cohort Analysis
MAPAMA	Ministerio de Agricultura, Pesca, Alimentación y Medio Ambiente
MCRS	Minimum conservation reference sizes

MEY	Maximum Economic Yield
MSY	Maximum Sustainable Yield
NOAA	National Oceanic and Atmospheric Administration
OTB	Demersal trawl fleet
ROFTA	Return on Fixed Tangible Assets: A proxy of long term profitability
TAC	Total Allowable Catch
SCAA	Structured Catch At Age
SSB	Spawning Stock Biomass
STECF	Scientific, Technical and Economic Committee for Fisheries
VPA	Virtual Population Analysis
WGSAD	GFCM Working Group for Stock Assessment of Demersal species
WGSASP	GFCM Working Group for Stock Assessment of Small Pelagic species
XSA	Extended survivor analysis
Y/R	Yield per recruit

LIST OF TABLES

LIST OF BOXES

LIST OF MAPS

LIST OF FIGURES

EXECUTIVE SUMMARY

Background

The reform of European **Common Fisheries Policy** (CFP) sets the stage for fishery managers and stakeholders to take the initiative and responsibility to complement and implement plans for managing fisheries within their region. To facilitate management by those parties relevant knowledge needs to be developed, assessed and deployed in a regional context.

The final objective **is to implement the discard plans and multiannual plan**s, ensuring that fish populations are harvested at levels **which can produce the maximum sustainable yield** (MSY) taking into account the marine ecosystems. This is an outstanding scientific topic still under discussion by the scientific community but at the same time, there is the need to identify the different scenarios and practical options and steps to be considered.

In 2015, the Mediterranean and Black Sea (FAO Fishing Area 37) had the **highest percentage of unsustainable stocks among the 16 major world statistical areas (FAO 2018).** The Malta declaration Medfish4ever signed by Mediterranean ministerial representatives from both northern and southern coastlines in 2017 indicates that no later than 2020 and to the fullest possible extent, 100% of the key fisheries have to be managed with multi-annual management plans in order to restore and maintain the populations of fish stocks above fishing mortalities levels capable of producing maximum sustainable yield.

The European Commission has just proposed a **multi-annual plan for demersal fish stocks** in the western Mediterranean Sea and presented it to the Committee of Fisheries on 21 March 2018. The multi-annual plan is the fourth proposal adopted in line with the CFP. It covers the western Mediterranean Sea waters, which extend along the Northern Alboran Sea, the Gulf of Lion and the Tyrrhenian Sea, covering the Balearic archipelago and the islands of Corsica and Sardinia and concerns mainly France, Italy and Spain. It includes fish stocks that bring a **significant income** to the **fisheries sector in the region**. The EC proposal aims to restore these stocks to levels that can ensure social and economic viability for the anglers and the jobs that depend on it. The proposal has been submitted to the European Parliament and the Council in order to reach an agreement.

Aim

The aim of the present study is to provide a comprehensive analysis of the impact of Landing Obligation on the maximum sustainable yield taking into account the European Commission multi-annual plan for fish stocks in the western Mediterranean Sea. Results will be useful to put forward recommendations and policy-relevant advices for decision-makers. The approach is focused on five main aspects. These are:

- A summary of the **current state of MSY modelling** in the case-study region, including specific outcomes and main conclusions;
- A **quantitative bio-economic analysis** based on the specific case study in the region on the likely consequences of the landing obligation and the multiannual plan regarding the objectives of the CFP, especially the MSY;

- To **assess whether the CFP tools** are technically adequate and sufficient and the causes of their possible current under-utilization;
- A **qualitative and if possible quantitative assessment** of the main impacts that the **landing obligation and the multiannual plan** in the context of the MSY may have in the whole ecosystem of the region, identifying and analyzing the related uncertainties;
- Based on these analyses, **recommendations** will be made to the European Parliament providing the knowledge on the best way to implement the discards plans and multiannual plans according to the different scenarios at regional level.

The methodology used comprised a twofold methodological approach:

- Provision of a **general overview**, based on the collection and processing of information available on Spanish Mediterranean Fisheries. Information from other areas was also included when relevant;
- **Bio-economic modelling** on the impacts of effort reduction and selectivity change in Spanish demersal Mediterranean fisheries to complement published studies.

Results

Mediterranean fisheries are characterized by a high diversity of species and fishing methods. Spanish landings in the Mediterranean are **dominated by small pelagic species**, mostly sardine and anchovy. **Demersal species** represent a smaller proportion of total annual landings but they fetch **higher market values**. **Both landings and fleet** size show a **decreasing trend** in the Spanish Mediterranean.

The EU requests independent stock assessment advice from the General Fisheries Commission for the Mediterranean (hereafter GFCM) since the 1990s. The GFCM advises on all Mediterranean stocks and the Black Sea, but this has little or no impact on management within EU waters because there are few transboundary stocks.

Advice is also requested from the Scientific, Technical and Economic Committee for Fisheries (hereafter STECF), the European Commission's own scientific advisory committee. The statistical methods applied to each stock are most often the same in both organisations and there is agreement in their results.

Most stocks of the main commercial demersal species (hake, red mullet, red and blue shrimp, deep-water rose shrimp, sardine and anchovy) are evaluated with fully analytical methods, such as XSA (Extreme Survivor Analysis), Y/R (Yield per Recruit) or SCAA (Structured Catch At Age). Blackspot seabream was evaluated with four different methods, GADGET among them, but the WG opted for qualitative advice. Nevertheless, GFCM experts stressed recently the need to **advance the methodologies** used **for assessments** and to **improve data quality**. With regard to assessment methodologies the Group agreed to the idea of adopting **a protocol for data-limited stocks** (DLS), and applying an external peer review that could assist experts in the implementation of new methodologies. This would be supported with **further training opportunities**.

In brief, many of the shortcomings affecting the evaluation of Mediterranean stocks, i.e. data gaps, uncertainties in stock definition, biased observer data, multispecific fisheries, fishers' behaviour, to name a few, are also common to North Atlantic stocks. Furthermore, most Mediterranean **stocks** are exploited by **local fleets**, unlike Atlantic stocks. These facts point the lack of political will as the main explanation for the different outcomes regarding resource management in both seas.

A **bio-economic model** using data from GSA 06 as case study has been developed to analyse different scenarios of effort reduction combined with improved selectivity. The model considers the interaction between the trawler fleet (DTS) and the artisanal fleets (HOK and GNS/GTR) on the stocks of the main commercial species evaluated by the Scientific, Technical and Economic Committee for Fisheries (STECF) and the General Fisheries Commission for the Mediterranean (GFCM).

The model shows that **business-as-usual scenario** will produce a gradual increase of fishing mortality and a decrease in SSB and catches of the main species, with the subsequent **economic loss** (profits and crew wage) **for both trawler and artisanal fleets**. The economic losses will be larger for the trawler fleet due to their geater fuel dependence. But **fish markets** and landing ports are essentially **sustained by trawler** catches. Thus the loss of trawlers might cause the demise of the artisanal fleet as well, rather than providing new market opportunities for them.

A different scenario where **reduction of fishing time** to decrease fishing mortality of red mullet **to F_{MSY} levels** is implemented progressively results in **a long period of losses** in trawlers compared with the present situation.

The **best results** are obtained **combining selectivity improvement with** a reduction of **fishing time** equivalent to one or two fishing days per week.

The **economic impact of the Landing Obligation** is expected to be **low**, assuming that labour costs remain stable and that further investments for additional infrastructure will not be required. It should be considered that in the Mediterranean, catch volume is much smaller than hold capacity of fishing boats, thus the landing obligation will not affect the carrying capacity for target species.

Any reduction of fishing mortality will produce a reduction of revenues in the short term and an increase in the long term. However the **socio-economic impact** of the **reduction of fishing mortality** will **differ depending** on how the reductions are **distributed throughout** the **year**. Reducing fishing days on a weekly basis across all fleet segments will have a lower socio-economic impact than concentrating the reduction in a single season or in a lower number of boats.

The Common Fisheries Policy in the Mediterranean has been traditionally characterised by a suite of technical measures that have not change significantly with time. In this context the Mediterranean fleet has decreased in number but the improvement of engines, fishing gears and other technological devices have increased catchability. It seems **necessary** to **change** the **management strategy**, adding adaptive management measures to adjust fishing mortality to stock status.

The new proposal for a multi-annual plan for demersal fisheries in the western Mediterranean introduces the **concept of total allowable effort**, based in a maximum number of fishing days per year as a way to adjust mortality to stock status. However, the proposal does not regulate how to distribute the fishing days throughout the year and across the fleet. It is also important to **avoid**

shortages in traditional **markets** and to prevent the fishermen from closing traditional commercial circuits. Changes in trade could cause collateral effects that our model cannot simulate.

Furthermore, the **transfer** of fishing possibilities **between boats** would concentrate fishing rights in larger companies, reducing the fleet but also **changing the economic structure** of Mediterranean fisheries, with a severe **impact on employment**.

For all these reasons, the **reduction of fishing time** has to be **complemented** with **improved selectivity** for trawlers, **permanent closures** and **local co-management** plans that involve resource users in management.

A combination of the reduction of fishing time, the establishment of closed areas to protect populations of target species, the improvement of selectivity and local co-management plans should suffice to change the status of Mediterranean stocks and bring fisheries to MSY levels. The **introduction of output controls** for demersal fisheries will **create new problem**s rather than help to achieve this goal due to the high diversity of catches in Mediterranean demersal fisheries

According to the 2017 MaltaMedFish4Ever Ministerial Declaration on the future of Mediterranean fisheries, all relevant stocks have to be managed with multiannual plans by 2020. This means that a **new management plan** has to be prepared as well **for small pelagic species** in the western Mediterranean.

The objective of the **Landing Obligation** is to avoid discards of marketable fish incentivized by the CFP and it **will not affect discards of unregulated species**. In Atlantic fisheries, the Landing Obligation will reduce quota and, consequently, will reduce fishing mortality. Neverless, **in the Mediterranean the Landing Obligation** will not result in a reduction of unwanted catch and it **will not help to reach MSY**.

In general, the larger the size at first capture, the better, since gains due to growth are higher than losses by natural mortality. However, **Minimum Conservation References Sizes** (MCRS) only are useful when they contribute to reduce the mortality of juveniles, and this is not the case for some of the species with MCRS established in Council Regulation (EC) No 1967/2006, which **should be reviewed** accordingly.

GENERAL INFORMATION

KEY FINDINGS

- Demersal **resources** in the Mediterranean Sea are **heavily overfished**, although the situation has **improved slightly in last years**.
- **Stock assessment** in the Mediterranean is **based in single species** reference points that are not fully adequate for highly diverse demersal fisheries and have never been linked to management. It will be necessary to develop **new multispecies reference points** and to establish **a new management framework** that takes into account scientific information on stock status
- **Fisheries management** in the Mediterranean is **based on technical measures**, which have not prevented **the efficiency increase** in both vessels and gears **that have counterbalanced the fleet reduction**.
- Additional measures will be needed to ensure the sustainability of western Mediterranean fisheries, among them a **new management plan for small pelagic** species, which represent a significant amount of landings in the area.
- The **Landing Obligation will not help to reach MSY** because it does not contribute to reduce fishing mortality. Different studies show that discards may be reduced **improving the gear selectivity**.
- The new proposal from the Commission introduces **total allowable effort as a new approach** to reduce significantly fishing time and fishing mortality, allowing stocks to reach MSY in the medium term.
- The socio-economic impact of this reduction in fishing time will depend on the extent of the reduction and how it will be implemented. The best option is reducing fishing time on a weekly basis. The **largest negative socio-economic impact** will take place **if transferability of fishing possibilities between boats is allowed**.
- The reduction of **fishing time** has to be **complemented with selectivity improvements, permanent closures and local co-management plans** to protect both juveniles and spawners. This will reduce the need for effort reduction and it will contribute significantly to the sustainability of Mediterranean Fisheries.

Box 1: Mediterranean specificity

MEDITERRANEAN SPECIFICITY

The Mediterranean Sea, including the Black Sea basin, is the largest (over 3.4 million km^2) and deepest (average 1,460 m and maximum 5,267 m) enclosed sea on Earth. The Mediterranean Sea is a **hotspot of biodiversity**. It hosts approximately 7 -10% of the world's marine biodiversity and it holds a high percentage of endemic species (Bianchi and Morri 2000; Coll et al. 2010). It has **low productivity** and mainly **narrow continental shelves** that **limit the productivity of fisheries** in the region. Mediterranean fisheries are characterised by relatively **small vessels, multiple landing sites, multispecies catches with low CPUE and relatively high prices** (Lleonart & Maynou 2003). The sector is dominated by **small familiar businesses**, not only in the small scale fleet segment but also in the trawling and purse seine segments. Despite the degradation of fishery resources, **conflicts between countries are rare** and limited to few areas. This is because most of the resources (except for large pelagics managed by ICCAT) are sedentary and therefore their exploitation produces few externalities. The Mediterranean and Black sea fishing fleets transformed more than half its total revenue into capital, salaries, and profits, thereby having a positive impact on the regional economies and their fishing communities (STECF, 2017c). Moreover, Mediterranean fisheries have a long history that has influenced the **culture of coastal communities** and has a marked **influence in their identity**. To maintain this identity is also important to attract visitors (tourism) to the small fishing villages on the Mediterranean coast and find creative ways to increase the availability of attractive job opportunities for young people.

1. CURRENT STATE OF MSY MODELLING IN THE SPANISH MEDITERRANEAN

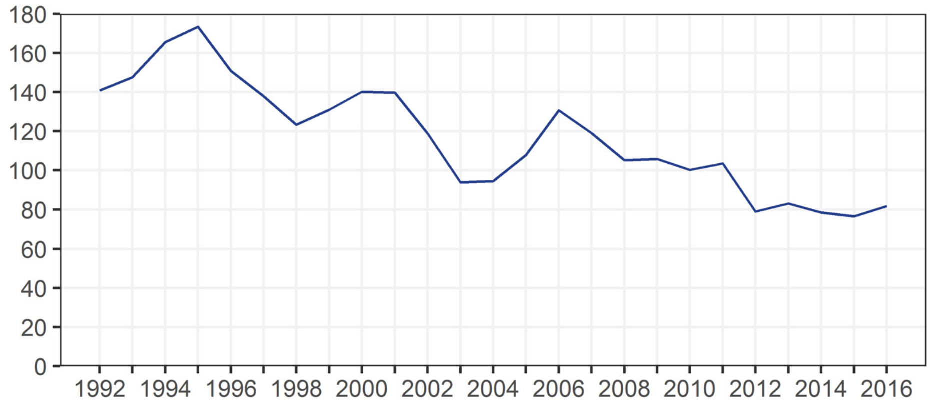
KEY FINDINGS

- Mediterranean fisheries are characterized by a **high diversity** of species and fishing methods. Spanish landings in the Mediterranean are **dominated** by **small pelagic** species, mostly sardine and anchovy. **Demersal species** represent a smaller proportion of total annual landings but they command a **higher market value**. Both landings and fleet size show decreasing trends in the Spanish Mediterranean.
- Stock assessment in the Mediterranean is carried out separately by GFCM and STECF, although in most cases the same statistical methods are applied to the different stocks. Stock status could not be provided in 2017 for two anchovy stocks because the data available were not enough. Except for sardine in GSA 1, for which exploitation is sustainable, and anchovy in GSA 1 and GSA 6, whose status is uncertain, the remaining 6 stocks evaluated with analytical methods are overexploited.
- Stock assessment Working Groups in GFCM have stressed the need to **improve data collection** and to **advance stock assessment methods**. This would include the implementation of assessment methods for data limited stocks, improving the quality of data used in the evaluations, external peer review of the assessments carried out in GFCM and **training opportunities** for experts.
- It is not possible to simultaneously achieve Maximum Sustainable Yield in mixed fisheries. With this perspective, it would be advisable to find **new scientific indicators** that contribute **to define optimal harvest** of Mediterranean demersal resources that consider its **multi-specific nature**.
- **Most** of assessed **stocks** in the Mediterranean are **overfished**. This issue affects small pelagic species, crustaceans and demersal species, although it is more pressing in the latter. However, fishing mortality and biomass trends suggest that the situation is improving slightly.

1.1. Spanish Mediterranean fisheries

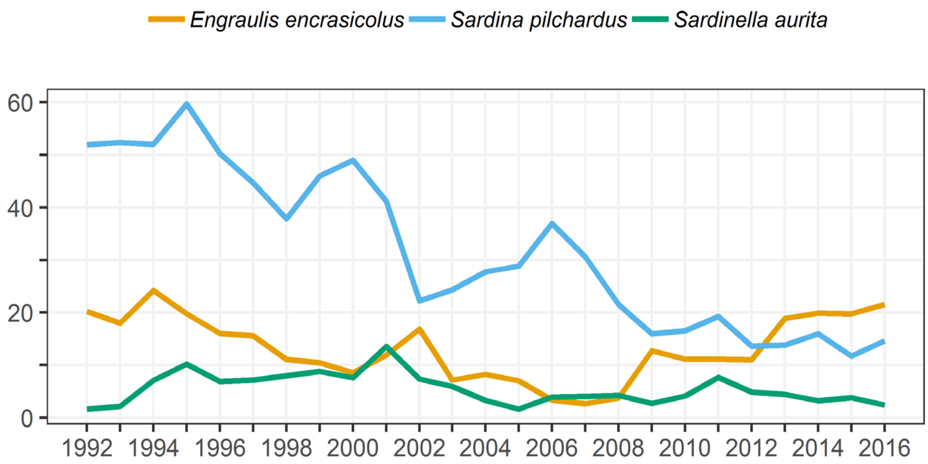
Spanish Mediterranean **landings are dominated by small pelagic** species (56% in 2016), mostly sardine and anchovy. Demersal species represented 34% of declared landings in 2016. According to Lleonart and Maynou (2003), over a hundred demersal species have commercial value but usually none of them represents more than 3% of total catch. Large pelagic species, mainly bluefin tuna and swordfish landings in 2016 are managed by ICCAT and represented 10% of declared landings in 2016. **Demersal species have a higher market price** and they amount to 60 % of the total value of landings, whereas small pelagic species represent 25 %. At the end of 2017 the Mediterranean Spanish fleet was composed by **2687 boats with 52781 GT**: 611 trawlers with 34887 GT, 217 purse-seiners targeting small pelagic species plus 6 purse-seiners targeting tuna with 9560 GT, 73 longliners with 2174 GT and 1780 small scale boats with 6161 GT (MAPAMA 2018).

Figure 1: Total annual Spanish Mediterranean landings (thousand tons).



Source: Spanish marine fishing statistics

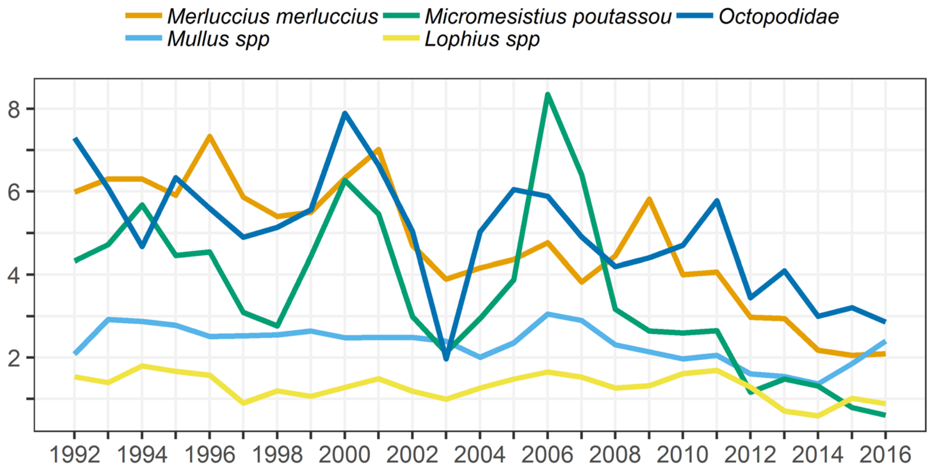
Figure 2: Spanish Mediterranean landings of small pelagic species (thousand tons)



Source: Spanish marine fishing statistics

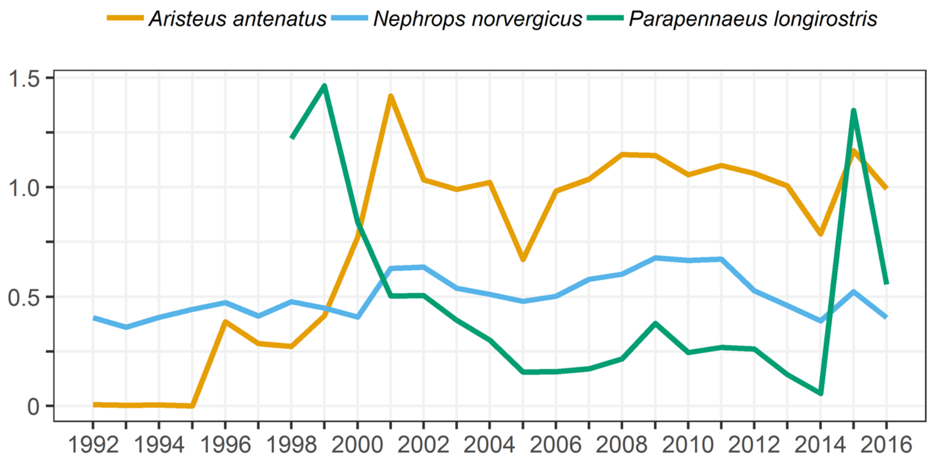
Spanish Mediterranean landings show a **clear decreasing trend** (Figure 1). They peaked in in **1995** with **173430 tons** and reached a historical low in 2015 with 76415 tons. Nevertheless they have been very stable between **2012 and 2016**, about **80000 tons** per year. Sardine landings drive this trend, with a maximum of 60000 tons in 1995 and a minimum of 12000 tons in 2015 (Figure 2). Anchovy, the other dominant species reached a minimum in 2007 but catches have increased somewhat over the last years (Figure 2). Among the **demersal species**, hake (*Merluccius merluccius*), blue whiting (*Micromesistius poutassou*) and octopuses (Octopodidae) also show a decreasing trend with great oscillations, whereas anglerfish (*Lophius* spp) and mullet (*Mullus* spp) landings oscillate without trend (Figure 3). The blue and red shrimp landings (*Aristeus antenatus*) increase with large oscillations and landings of Norway lobster (*Nephrops norvergicus*) and deep-water rose shrimp (*Parapenaeus longirostris*) oscillate without trend, the latter with two peaks of outstanding abundance in 2001 and 2015 (Figure 4).

Figure 3: Spanish Mediterranean landings of main demersal fish species (thousand tons)



Source: Spanish marine fishing statistics

Figure 4 : Spanish Mediterranean landings of main crustacean species (thousand tons)



Source: Spanish marine fishing statistics

1.2. Stock assessment in the Mediterranean

Mediterranean fishery science has been generally **less well funded** and sophisticated than in the Atlantic region which has long benefited from the support of the International Council for the Exploration of the Sea (ICES), with a much stronger capacity for monitoring and quantitative fishery assessments (Smith & Garcia 2014). Probably this may be related to the fact that Atlantic fisheries are targeted by international fleets in the high seas whereas Mediterranean fisheries are mostly coastal, targeted by local fleets and under jurisdiction of single states.

The EU requests independent stock assessment advice from the General Fisheries Commission for the Mediterranean (hereafter GFCM) since the 1990s. The GFCM advises on all Mediterranean stocks and the Black Sea, but this has little or no impact on management because there are few transboundary stocks. The General Fisheries Commission for the Mediterranean (GFCM) was established in 1949 and benefitted from limited financial support before becoming financially autonomous in 2004 (Smith & Garcia 2014).

Advice is also requested from the Scientific, Technical and Economic Committee for Fisheries (hereafter STECF), the European Comission's own scientific advisory committee (Commission Decision 93/6197). The statistical methods applied to each stock are most often the same in both organisations and there is agreement in their results. Great efforts have been made to assess Mediterranean stocks in last years but, despite such efforts, the **status of only a small proportion of the landed fish is known** due to the diversity of commercial species and stocks in the Mediterranean (Lleonart 2015).

Stocks of the main commercial demersal species (hake, red mullet, red and blue shrimp, deep-water rose shrimp, sardine and anchovy) are evaluated with fully analytical methods, such as Extended survival analysis(XSA), Yield per recruit (Y/R), Structured Catch at Age (SCAA). Blackspot seabream was evaluated with four different methods, GADGET among them, but the WG opted for qualitative advice.

In GFCM, Spanish Mediterranean stocks are evaluated in two Working Groups (WGs): WG for Stock Assessment of Demersal species (WKSAD) and the WG for Stock Assessment of Small Pelagic species (WGSASP). Table 1 shows the state of the different stocks. The WGSAD evaluates hake (*Merluccius merluccius*) in GSAs 1&3 (a transboundary stock in Spanish and Moroccan waters, GSA 5 and GSA 6; as well as red mullet (*Mullus barbatus*) in GSA 6, shrimp species (*Aristeus antennatus* and *Parapenaeus longirostris*) and blackspot seabream (*Pagellus bogaraveo*) in the Gibraltar Straight. In absence of reference points based on biomass, the WGSAD uses the empirical reference framework of the 33rd and 66th percentiles. Advice points to the reduction of F_{cur} towards $F_{0.1}$, a proxy for F_{MSY} representing the fishing mortality at which the increase of yield per recruit (Y/R) for an increase in one unit of fishing mortality is just 10% of the Y/R of the unexploited stock.

Hake stocks in Geographical Sub-Areas GSA1&3 and GSA 5 and red mullet in GSA 5 are evaluated in GFCM with fully analytical methods, Extended Survivor Analysis (XSA) and Yield per Recruit (Y/R, NOAA Fisheries Toolbox). Hake stock in GSA 6 is evaluated with XSA and a Structured Catch At Age (SCAA) model using a4a, which used a longer time series and produced very similar results to XSA was finally used for the advice in line with previous recommendations (WGSAD, 2016). Structured Catch At Age models assume that fishing mortality can be separable into year effect (also called fishing intensity) and age effect (also called fishery selectivity), their product being the resulting fishing mortality for a given age and year (Doubleday, 1976).

Blackspot seabream was evaluated with four different methods. GADGET (Globally Applicable Area Disaggregated General Ecosystem Toolbox), a full analytical assessment method that could be carried out with additional data provided by the Moroccan National Institute of Fisheries Research (INRH). However, only qualitative advice was provided on the grounds of lack of information on recruitment and the fact that the data used were mostly from the fishing grounds and stock identity is unknown (basically the same issues affecting the rest of the evaluated species). GADGET is a tool designed to model complex statistical marine ecosystems within a fisheries management and biological context. It admits one or more species, multiple areas, migration, predation, survey and commercial catches, among many other features (Bengley and Howell, 2004). VPA, Length Cohort Analysis (LCA) and the global model BioDyn were also used. LCA is used on species that cannot be aged. Individuals are separated into length classes instead (Jennings et al., 2001). BioDyn is a Biomass Dynamic Model (also called surplus production models, production models, stock production models or surplus yield models). They are not very data-demanding, using catch, effort and /or abundance data from the fishery or surveys. They aim to find the largest fishing mortality that can be compensated with population growth (Jennings et al., 2001, Hoggarth et al., 2006).

Red mullet (*Mullus barbatus*) in GSA 6 is evaluated with FLR (Fisheries Libraries in R), a collection of tools for quantitative fisheries science based on the R statistical language (http://www.flr-project.org/) and Y/R.

Red and blue shrimp (*Aristeus antennatus*) and deep-water rose shrimp (*Parapenaeus longirostris*) stocks in GSA 5 and GSA 6 were evaluated with Separable Virtual Analysis (VPA), XSA, Y/R and FLR, with short term projections. Separable VPA consists on splitting fishing mortality into two parameters, one of which refers to the age-dependent exploitation pattern and the second to an age-independent exploitation level. This is convenient to project different future fishing activities, i.e. keep constant the age-dependent exploitation pattern (or selectivity) and vary fishing intensity (the age-independent exploitation level) (Lassen and Medley, 2001). The WGSAD discussed the need to apply **data-limited stocks** (DLS) assessment methods in the future. STECF (2017b) also used XSA and Y/R models on deep-water rose shrimp from GSA 1.

The WGSASP evaluated the anchovy stocks in GSA 1 and GSA 6 and the sardine stocks in GSA 1, GSA 1&3 and GSA 6. Concerning exploitation reference points, the WGSASP based its advice on fishing mortality reference points ($F_{0,1}$ or F_{MSY}) when analytical assessments allowed for an accurate estimation, and otherwise on the empirical Patterson reference point for exploitation rate. Concerning biomass reference points, B_{MSY} was used when available. Otherwise, B_{lim} and $B_{threshold}$ were based on the empirical analysis of biomass estimates time series. Consistently with the previous years, B_{loss} was used as a proxy for B_{lim}; B_{loss} is defined as the lowest biomass from which a recovery has been confirmed (WGSASP, 2017).

For those stocks for which reference points were not available the precautionary approach used in previous years was applied when long time series of estimates were available: biomass status and the evaluation of current fishing mortality levels were established in relation to the abundance and fishing mortality levels observed in the time series. The main criteria were the stability of stock biomass levels; signals of change in growth and/or age/length composition; signals of recruitment impairment and changes in fishing mortality levels (WGSASP, 2017).

Sardine (*Sardina pilchardus*) in GSA 1 and GSA 6 were evaluated with XSA in both GFCM and STECF. In addition, the GSA 1 stock was also assessed with BioDyn and separable VPA was attempted. XSA was also used to assess together the stocks from GSA 1&3. Assessment of sardine stocks in GAS 1&3&4 was based on VPA.

Anchovy (*Engraulis encrasicolus*) in GSA 1 was evaluated according to the precautionary approach because data were not enough for an analytical assessment. Assessment of Anchovy from GSA 6 was tested with Extended survivor analysis (XSA) but the results were unsatisfactory and two SPICT biomass models (Surplus Production in Continuous Time models) were used. They model both stock and fisheries dynamics. The models used differed on how the timing of survey data was defined. STECF (2017a) used SPICT models as well.

STECF (2017a) presented also a survey index based assessment for horse mackerel in GSAs 1, 5, 6 & 7. Other species evaluated in STECF (2017b) were anglerfish (*Lophius piscatorius*) in GSAs 1, 5, 6, 7, with pseudocohort analysis using VPA equations and Norway lobster (*Nephrops norvegicus*) in GSA 6, using XSA and a separable VPA.

Table 1: Summary of available stock assessment in GSAs 1, 5 and 6

		GFCM				STECF			
Species	**GSAs**	**Year**	**Fc**	**F0.1**	**Fc/F0.1**	**Year**	**Fc**	**F0.1**	**Fc/F0.1**
Merluccius merluccius	1	2017	1,7	0,2	8,5	2014	1,2	0,21	5,71
	5	2017	1,48	0,17	8,7	2014	1,12	0,15	7,47
	6	2017	1,8	0,2	9	2014	1,39	0,26	5,35
Lophius budegassa	1					2013	0,25	0,16	1,56
	5					2013	0,84	0,08	10,5
	6					2013	0,91	0,14	6,5
Micromesistius poutassou	1	-	-	-	-	-	-	-	-
	6	-	-	-	-	2013	1,52	0,16	9,5
Mullus surmuletus	5	2017	1,07	0,42	2,55	2013	0,54	0,18	3
Mullus barbatus	1	2014	0,89	0,26	3,4	2013	1,31	0,27	4,85
	5	2012	0,93	0,14	6,64	2012	0,93	0,15	6,2
	6	2017	0,74	0,26	2,84	2013	1,69	0,45	3,75
Aristeus antennatus	1	2015	0,9	0,5	1,8	2014	1,4	0,41	3,41
	5	2017	0,62	0,31	2	-	-	-	-
	6	2017	0,64	0,33	1,94	2014	0,78	0,36	2,16
Nephrops norvegicus	5		-	-	-	2014	0,29	0,17	1,71
	6		-	-	-	2013	0,59	0,15	3,93
Parapenaeus longirostris	1	-	-	-	-	2012	0,43	0,26	1,65
	5	2017	0,88	0,77	1,14	2012	0,77	0,62	1,24
	6	2017	1,6	0,7	2,3	2012	1,4	0,27	5,18
Sardina pilchardus	6	-	-	-	-	2017	1,36	0,526	2,58
Engraulis encrasicolus	1	-	-	-	-	2009	1,05	0,45	2,33
	6	2014	1,08	0,53	2,04	2017	0,83	0,7	1,18

Source: own compilation from GFCM and STECF reports.

Table 1 summarises the main results of stock assessment in the Spanish Mediterranean done by CGPM and STECF. Most of the **assessed stocks** in the Mediterranean are **overfished**. This issue **affects** both **small pelagic, crustaceans and demersal stocks**, although it is more pressing in the latter. However, when analysing trends in fishing mortality and biomass (Table 2), results indicate that the situation is not getting worse for most of stocks or it is even improving slightly.

Table 2: Trends in biomass and fishing mortality of Mediterranean stocks in GSAs 1, 5 and 6

		GFCM			STECF		
Species	**GSAs**	**Year**	**F Trend**	**B Trend**	**Year**	**F Trend**	**B Trend**
Merluccius merluccius	1	2017	Stable	Increase	2014	No clear trend	No clear trend
	5	2017	No clear trend	No clear trend	2014	Stable	Decrease
	6	2017	Stable	Decrease	2014	Decrease	Decrease
Lophius budegassa	1				2013	Increase	Stable
	5				2013	Decrease	Stable
	6				2013	Decrease	No clear trend
Mullus surmuletus	5	2017	No clear trend	Decrease	2013	No clear trend	
Mullus barbatus	1	2014	Decrease	Stable	2014		No clear trend
	5	2012	No clear trend	No clear trend	2013	No clear trend	
Aristeus antennatus	1	2015	Stable	Stable	2014	No clear trend	No clear trend
	5	2017	No clear trend	No clear trend			
	6	2017			2014	Decrease	Increase
Nephrops norvegicus	5				2014	Decrease	No clear trend
Parapenaeus longirostris	1				2012		Increase
	5	2017		No clear trend	2012	No clear trend	Stable
	6	2017			2013	No clear trend	No clear trend
Sardina pilchardus	1	2017		Decrease	2013	Decrease	
	6	2017		Decrease	2016	Increase	Increase
Engraulis encrasicolus	1				2009	Increase	
	6		No clear trend	Increase	2016	No clear trend	Increase

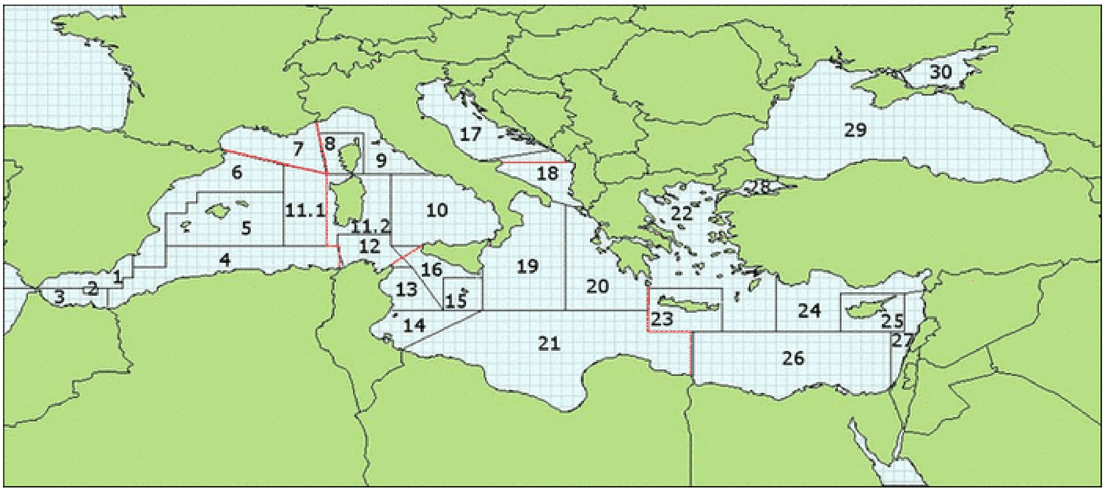
Source: own compilation from GFCM and STECF reports.

1.3. Improving Mediterranean fisheries science

So far **stock assessment** information **has not been incorporated to** Mediterranean **fisheries management**. To advance in this direction it is necessary to improve the quality and quantity of scientific information available to have a better advice based in better science. Only a **small fraction** of Mediterranean **stocks are regularly assessed**, and just a fraction of them are evaluated annually. GFCM experts stressed recently the need to advance the methodologies used for assessments and to improve the quality of data. The objective will be to cover at least 100% of priority species by 2020 (WGSAD, 2017). With regard to assessment methodologies, the Group agreed to the idea of applying external peer review that could assist experts in the implementation of new methodologies. However, more complex models are not always the best solution and it is **crucial** to work on the **improvement** of **data quantity and quality** to feed the models, mainly in fisheries dependent monitoring where sampling is probably not enough to adequately reflect the complexity of Mediterranean fisheries.

Training opportunities for new experts that may recruit into GFCM, STECF and national research institutes are also needed to increase capacity building in the region. To **enhance capacity-building and cooperation** has been included in the GFCM midterm strategy as one of the targets in order to further progress in the sustainable development of fisheries at the regional level.

Map 1 :*-Geographical Sub-Areas(GSA) division in the Mediterranean



Source: RES-GFCM/33/2009/2 on Establishment of Geographical Sub-Areas in the GFCM area amending the resolution GFCM/31/2007/2

Current delimitation of **stock boundaries** for many of the stocks assessed it is **not clear** in the Mediterranean. Stock assessment is based mainly on Geographical Subareas (GSAs) that may not be adequate for some stocks (Map 1). Some preliminary results have been obtained with STOCKMED project, but they need to be checked with further research. The WGSAD concluded that joining assessments of stocks inhabiting adjacent GSAs should be done only on the basis of species and stock specific scientific evidence, including all necessary information to demonstrate that a joint assessment is more appropriate than separate GSAs assessments. Identification of fished stocks that includes as well information on nursery and spawning areas helps to optimize management (Begg et al., 1999).

Globally, most **stocks** are **evaluated with monospecific models** due to the great data requirements and complexity of ecosystem models. It can be argued that decreasing F towards a F_{MSY} goal in the context of multispecies fisheries will undoubtedly have a positive impact in accompanying species. However, F_{MSY} depends on fishing mortality at age, gear selectivity, annual variability and other factors that can change too fast for management to respond timely (Maunder, 2002). Thus, **reaching MSY for all exploited stocks is not feasible** (Merino et al., 2015). Besides, it creates inconsistencies between targets for different stocks (Guillen et al 2013, Kempf et al, 2016; STEFC, 2016**). Models** developed for **mono-specific fisheries** are **not appropriate** for the evaluation and management of highly **diverse Mediterranean fisheries**. It is not possible to simultaneously achieve maximum sustainable yield in mixed fisheries. With this perspective, it would be advisable to find new scientific indicators that contribute to **define optimal harvest** of Mediterranean demersal resources that consider its multi-specific nature (STECF, 2018b).

However, all available information indicates that it is necessary to act precautionary to **significantly reduce fishing mortality** in order to improve the situation of Mediterranean stocks. The need to define the long term optimal harvest or to develop a better science for a better advice could not be an excuse to mantain current management. **Scientific advice has to be incorporated to the management of Mediterranean fisheries** and it will have a feedback improving the quality of Mediterranean fisheries sciences.

2. BIO-ECONOMIC ANALYSIS

KEY FINDINGS

- A bio-economic model of GSA 06 shows that a **business-as-usual scenario** will produce a gradual increase of fishing mortality and consequently a gradual decrease in SSB and catches of the main species and **economic loss** (profits and crew wages) for trawler and artisanal fleets.
- On the other hand, the **progressive reduction of fishing** time **to achieve F_{MSY}** for red mullet will produce a **long period of losses** in trawlers compared with present situation.
- The **best results** of the **bio-economic model** of GSA 06 are obtained with a **selectivity change combined** with a **reduction of fishing time** equivalent to one or two fishing days per week.
- The **economic impact** of the **Landing Obligation** will be **low** assuming that it will not increase labour costs and that it will not need investment for additional infrastructure.
- Any reduction of fishing mortality will produce a revenue reduction in the short term and an increase in the long term. However, the **socio-economic impact** of fishing mortality reduction will **differ** greatly depending on **how this reduction is implemented**. Reducing the **number of fishing days per week** will have a **lesser socio-economic impact** that concentrating the same time reduction in some seasons or on some boats.

2.1. Bio-economic modelling

Mediterranean demersal fisheries are characterized by their high diversity, with more than a hundred target species, low CPUEs and relatively high prices (Lleonart & Maynou, 2003). Although fishing is considered to be unsustainable for most Mediterranean stocks assessed, **economic indicators have improved** for the Spanish fleet during the last years (tables 3 and 4) (STECF 2017, MAPAMA 2018). However, rocketing fuel costs and low market prices of traditionally high-value species may challenge the viability of fisheries in the future (Merino et al 2015). In addition, the Landing Obligation, a possible reduction of fishing effort and requirements for an improved selectivity are challenges for Mediterranean fisheries in the next future.

A **bio-economic model** using data from GSA 06 as case study has been developed to analyse different scenarios of effort reduction combined with improved selectivity. The model is based on Sola and Maynou (2018b). They developed a bio-economic model to analyse the economic impact of the Landing Obligation and selectivity improvement, based on results obtained with a modified trawl designed to reduce unwanted catches and tested in the north of GSA 06 (Sola and Maynou, 2018a). The novelty of our approach lies on assessing the **interaction** between the **trawler fleet** (DTS) and the **artisanal fleets** (HOK and GNS/GTR) on the stocks of the main commercial species assessed by the Scientific, Technical and Economic Committee for Fisheries (STECF) and the General Fisheries Commission for the Mediterranean (GFCM).

Table 3: Evolution of Current Revenue(CR)/Break-Even Revenue(BER) in Spanish Mediterranean Fisheries

			CR/BER								
	Gear	Size	2008	2009	2010	2011	2012	2013	2014	2015	2016
BDTS	Otter Trawling	2	0,29	0,91	2,51	2,58	2,60	2,35	3,16	3,13	9,14
		3	0,76	1,16	0,12	0,23	1,43	0,78	1,59	1,97	5,38
		4	0,02	0,62	0,45	0,88	0,94	2,05	1,32	1,37	3,75
		5	0,43	0,33	0,37	0,14	0,82	-0,47	1,26	1,38	3,19
BPS	Purse seiners	2	3,99	1,62	7,15	11,34	7,23	20,64	13,31	6,28	9,11
		3	1,14	4,11	1,27	3,75	3,70	6,93	6,43	3,65	3,65
		4	0,74	0,69	0,73	1,46	1,63	6,53	3,19	2,68	4,02
		5	1,16	0,30	1,25	1,38	2,90	1,98	1,36	2,11	2,56
BDFN	Gillnets	2				3,13	4,92	6,87	-2,12	6,66	3,14
		3				0,18	0,85	1,31	0,62	-1,06	1,41
BHOK	Hooks	2	0,21	2,71	1,16	0,02	0,15	0,94	-2,72	1,06	13,17
		3	0,16	0,77	-1,57	0,07	5,45	0,65	0,35	1,31	3,52

Source: MAPAMA 2018 Informe anual de la actividad de la flota pesquera española, https://www.mapama.gob.es/es/pesca/planes-y-estrategias/informe-anual-actividad-flota-2018-esp-mapama_tcm30-450996.pdf

Table 4: Evolution of Return on Fixed Tangible Assets (ROFTA) in Spanish Mediterranean Fisheries

			ROFTA (%)								
	gear	Size	2008	2009	2010	2011	2012	2013	2014	2015	2016
BDTS	Otter Trawling	2	-82,02	-9,28	88,19	94,91	22,15	91,43	72,53	91,46	62,63
		3	-7,37	6,66	-39,88	-34,15	18,29	-11,06	19,23	33,44	73,14
		4	-37,72	-18,07	-20,92	-5,48	-3,79	12,82	13,15	16,34	47,81
		5	-11,93	-17,21	-8,21	-34,27	-4,26	-35,57	7,14	14,66	45,30
BPS	Purse seiners	2	135,78	37,75	55,16	155,78	483,00	395,60	36,82	74,28	107,68
		3	4,31	74,71	10,88	46,33	54,50	156,66	142,33	80,41	70,70
		4	-6,47	-11,57	-14,38	5,65	38,23	99,91	85,67	29,31	49,02
		5	2,09	-9,26	4,42	16,45	132,49	62,12	21,94	67,12	100,25
BDFN	Gillnets	2				110,22	106,46	177,41	-191,21	100,01	64,24
		3				-60,48	-7,98	11,43	-26,31	-95,26	21,20
BHOK	Hooks	2	-91,55	111,21	13,01	-180,80	-94,66	-9,24	-43,42	6,92	221,16
		3	-41,08	-9,76	-151,08	-51,14	45,17	-11,70	-126,00	6,43	12,79
		4	-5,02	-27,09	-12,19	7,65	1,20	95,90			
BPGO		3							27,55	-30,56	87,83

Source: MAPAMA 2018 Informe anual de la actividad de la flota pesquera española, https://www.mapama.gob.es/es/pesca/planes-y-estrategias/informe-anual-actividad-flota-2018-esp-mapama_tcm30-450996.pdf

The scenarios used to carry out this bio-economic simulation (Table 5) are in line with the reduction in fishing effort required to reach in the long term the F_{MSY} for red mullet; roughly a 73% reduction in the number of fishing days per year, or from 215 to 56 days (Fig. 5). The model considers a faster (20% annual reduction) o more gradual reduction (10% annual reduction), a selectivity change introducing the **T90 mesh**[1] (Sola and Maynou 2018a) and combined or not with effort reduction, and a 40% reduction of fishing effort in 3 years (equivalent to a two days per week reduction). The results of the Sola and Maynou (2018b) bioeconomic model will be used to i) assess the economic impact of the discard ban and Landing Obligation in GSA 06; ii) to estimate the reduction of discards by improving the selectivity pattern. We have selected *M. merluccius* and *M. barbatus* as case study species because the Landing Obligation will be first enforced on them.

[1] 50 mm mesh size with 90° turned mesh (T90) demersal trawl codends (Hansen, 2004).

Figure 5: Result of applying a 20% annual reduction of fishing mortality at age for M. barbatus to reach in the long term the F_{MSY}. The horizontal dotted line shows the F_{MSY} for M. barbatus

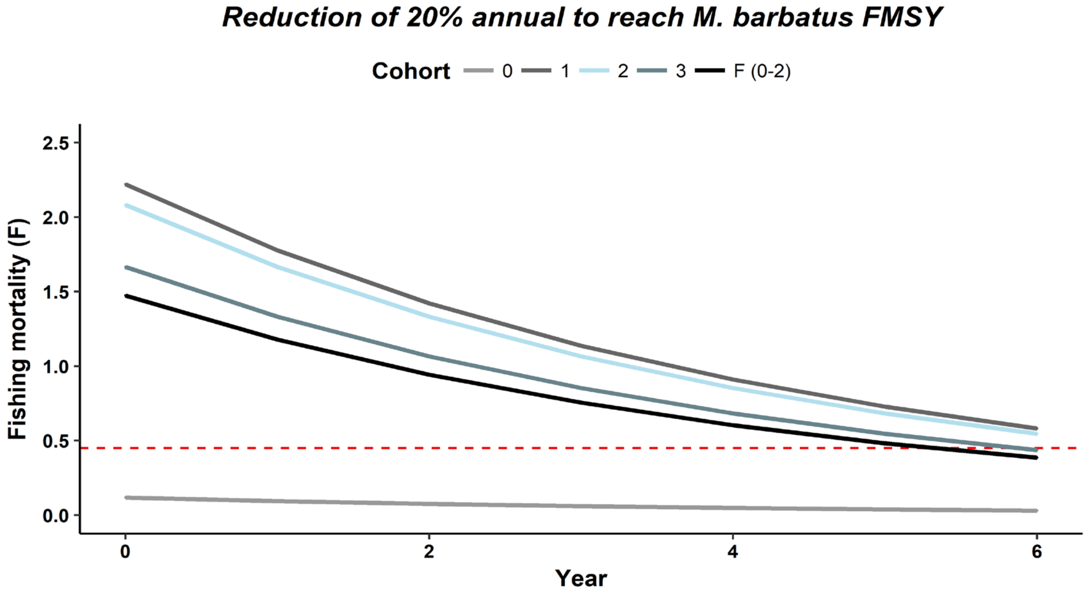


Table 5: Management scenarios considered in the bioeconomic model for demersal fisheries in GSA 06

Scenario 0	Business as usual, no management change.
Scenario 1	Reduction of 10% annual to reach M. barbatus F_{MSY}.
Scenario 2	Reduction of 20% annual to reach M. barbatus F_{MSY}
Scenario 3	Change selectivity with T90 mesh (see Sola and Maynou, 2018a)
Scenario 4	T90 + 10% annual effort reduction effort during 4 years
Scenario 5	T90 + 20% annual effort reduction effort during 4 years
Scenario 6	Reduction 2 days a week in 3 years
Scenario 7	Reduction 1 day per week in 3 years + T90
Scenario 8	Reduction 2 days per week in 3 years + T90

In addition, we selected red mullet F_{MSY} (fig. 5) because it represents an intermediate situation between hake, the most overfished species in the area according to the available stock assessment, and red shrimp, the less overexploited species. This scenario should approach the fishery to the Multispecies Maximum Sustainable Yield (Quetglas et al., 2017).

2.2. Results

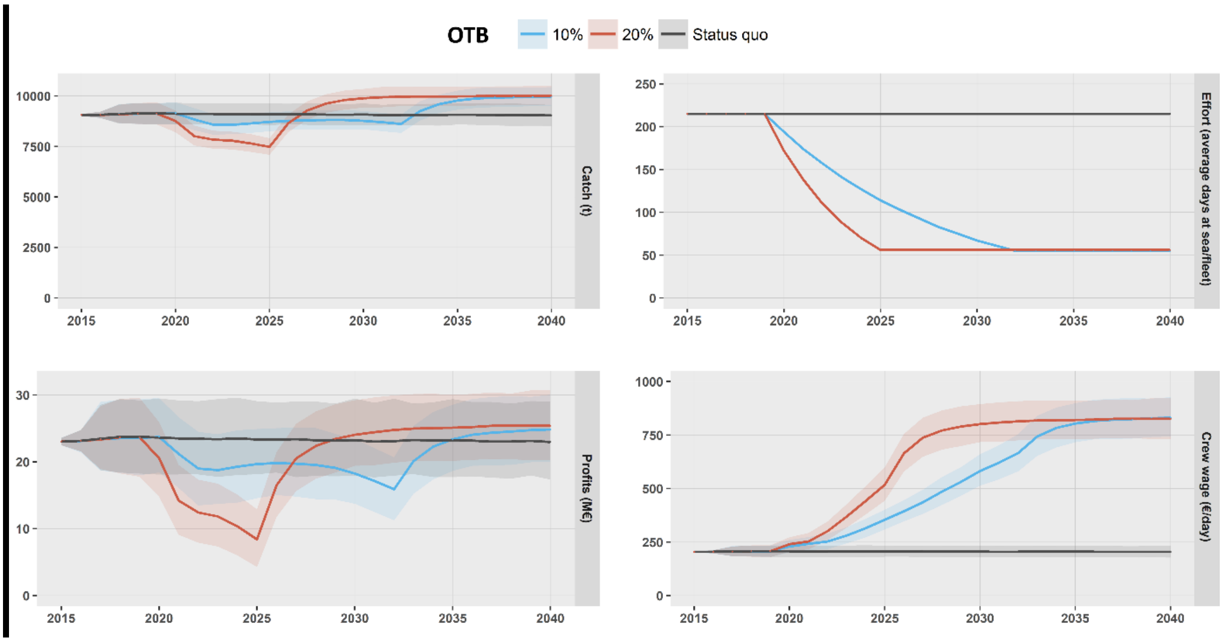
2.2.1. Reduction of fishing effort to reach M. barbatus FMSY.

Business-as-usual scenario (scenario 0) shows the overexploited status of the selected stocks, with F > $F_{MSY.}$ It shows a gradual increase of fishing mortality due to technological improvements and the corresponding catchability increase. A subsequent **gradual decrease in SSB and catches** of the main species and **economic loss** (profits and crew wage) for trawler and artisanal fleets is **expected**.

Management scenarios based on **gradual reductions of fishing effort to reach** *Mullus barbatus* **F_{MSY}** (Scn. 1 and 2) produced an **extended period** of declining catch and **economic loss** lasting several years for trawlers (Fig. 6) but not for artisanal fleets. These would see a one- to threefold catch increase in the medium to long term.

Figure 6: Results of the bio-economic model of catch (t), effort (average days at sea), profits (M€) and crew wage (€/day) for trawl fleet (OTB)

Scenario 0: Status quo, scenario 1: 10% annual reduction and scenario 2: 20% annual reduction



Scenario 1 led to a more progressive rebuilding of hake catches with a lower short-term loss than scenario 2 (increase of ~1% vs a 10% loss in 2025, respectively). On the other hand, scenario 2 predicted a better recovery of SSB for both species and therefore higher catches (Fig.2) in the medium to long term (4% vs 14% for hake, and -1.2% vs 11% for red mullet in 2030). In the long term, both scenarios would have reduced fishing mortality of hake and red mullet by roughly 68% (for more detailed information see Annex I: table 8 and table 11).

Figure 7: Results of the bio-economic model of catch (tn), fishing mortality (F_{1-3}), SSB (tn) assuming constant recruitment (Rec) for *M. merluccius* under historical series and scenarios.

Scenario 0: Status quo, scenario 1: 10% annual reduction and scenario 2: 20% annual reduction

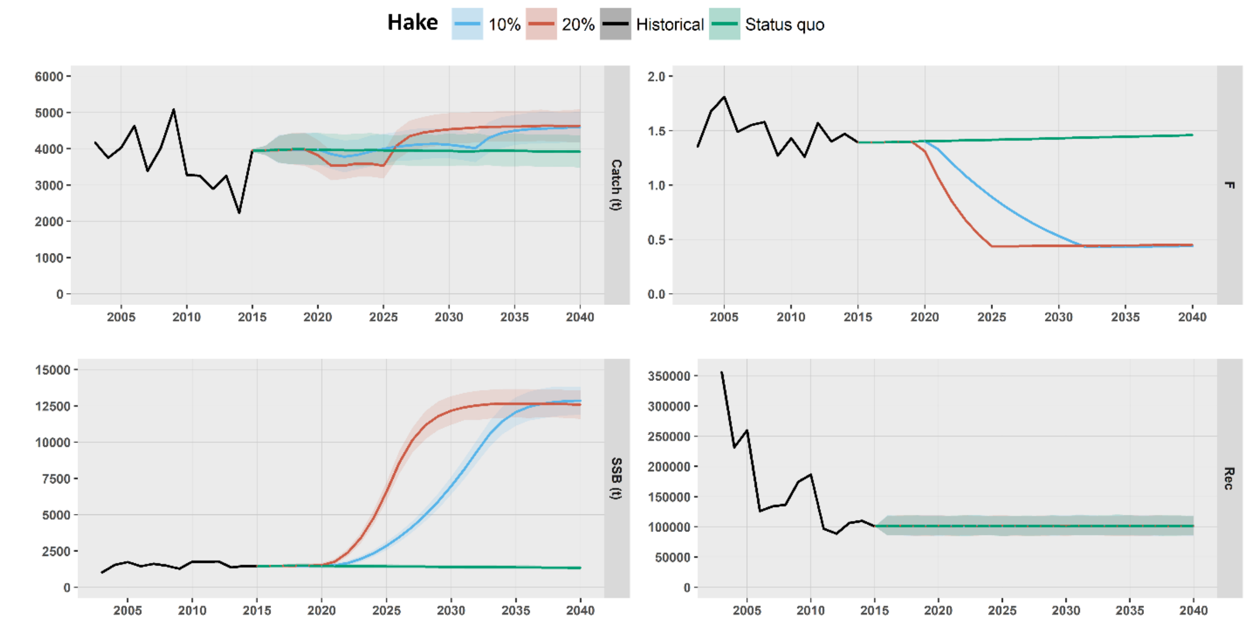


Figure 8: Results of the bioeconomic model of catch (tn), fishing mortality (F_{0-2}), SSB (tn) and constant recruitment (Rec) for *M. barbatus* under historical series and scenarios

Scenario 0: Status quo, scenario 1: 10% annual reduction and scenario 2: 20% annual reduction

Our results show that it is **not possible to achieve F_{MSY} simultaneously for all species assess**ed. Using as a reference an annual fishing effort reduction of 20%, as in the Multi-annual plan, it would take 6 years to reach F_{MSY} for *M. barbatus* (Fig. 8), 8 years for *M. merluccius* and 3 years for *A. antennatus*. The bioeconomic model also suggests that catches of hake and red mullet will increase as F_{MSY} for *M. barbatus* is attained (Fig. 7 and 8). This effect was not observed for red shrimp.

2.2.2. Selectivity change introducing the T90 mesh + effort reduction

The **modification of the selectivity** pattern with T90 net alone (Scenario. 3) or combined with an effort reduction (Scenarios. 4 and 5) would produce a **short term loss** for the trawl fleet compared to the current situation. However, in most scenarios **a rapid recovery of catch and profit** would be expected within few years (Fig. 9). Nevertheless, our results also indicate that if effort reduction is too large (Scenario. 5) the recovery takes longer and the long-term profits are also lower, although crew wages per day would increase.

Artisanal fleets would **improve their catch and profit in all scenarios** from the first year of the introduction of the management measures, as it can be seen for the demersal longline fleet in Fig. 10). Catch and profit for the artisanal fleet are directly related to effort reduction for the trawl fleet (Scn. 5).

According to our results, with the selectivity change (Scenario 3) fishing mortality of will decline further for red mullet (~54%) than for hake (~28%), but hake catch will increase more (36%) than red mullet catch (16%) (Fig. 11). This is due to the fishing pattern of the trawl fleet, which inflicts a larger mortality on hake below the minimum conservation reference size (MCRS) than for red mullet (Sola and Maynou, 2018a). Under scenario 4, catches would increase in the medium term compared to scenario 3 but a larger effort reduction (Scenario 5) will not produce better results. In addition, the three selectivity scenarios would significantly increase the spawning biomass (SSB) of the main species assessed (for more detailed information see Annex I: table 9 and 12).

Figure 9: Results of the bio-economic model of catch (t), effort (average days at sea), profits (M€) and crew wage (€/day) for trawl fleet (OTB) under scenarios

Scenario 0: Status quo, scenario 3: selectivity change to T90, scenario 4: selectivity change plus 10% annual reduction during 4 years and scenario 5: selectivity change plus 20% annual reduction during 4 years

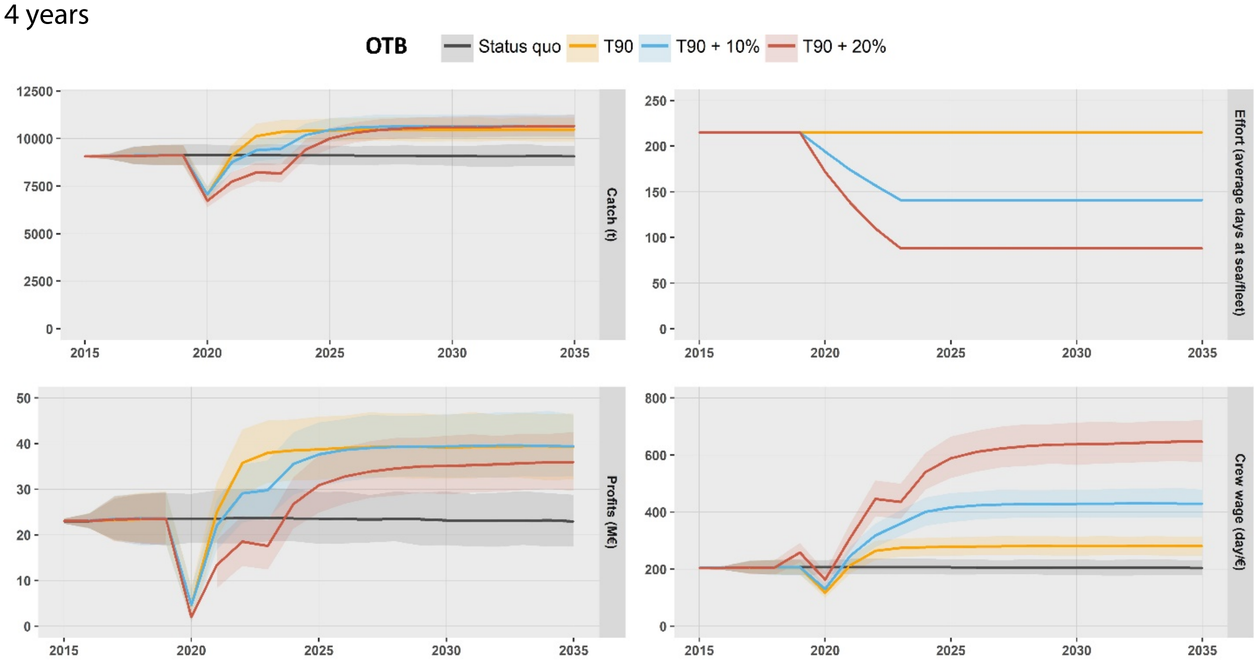


Figure 10: Results of the bioeconomic model of catch (t), effort (average days at sea), profits (M€) and crew wage (€/day) for demersal longline fleet (HOK) under scenarios

Scenario 0: Status quo, scenario 3: selectivity change to T90, scenario 4: selectivity change plus 10% annual reduction during 4 years and scenario 5: selectivity change plus 20% annual reduction during 4 years

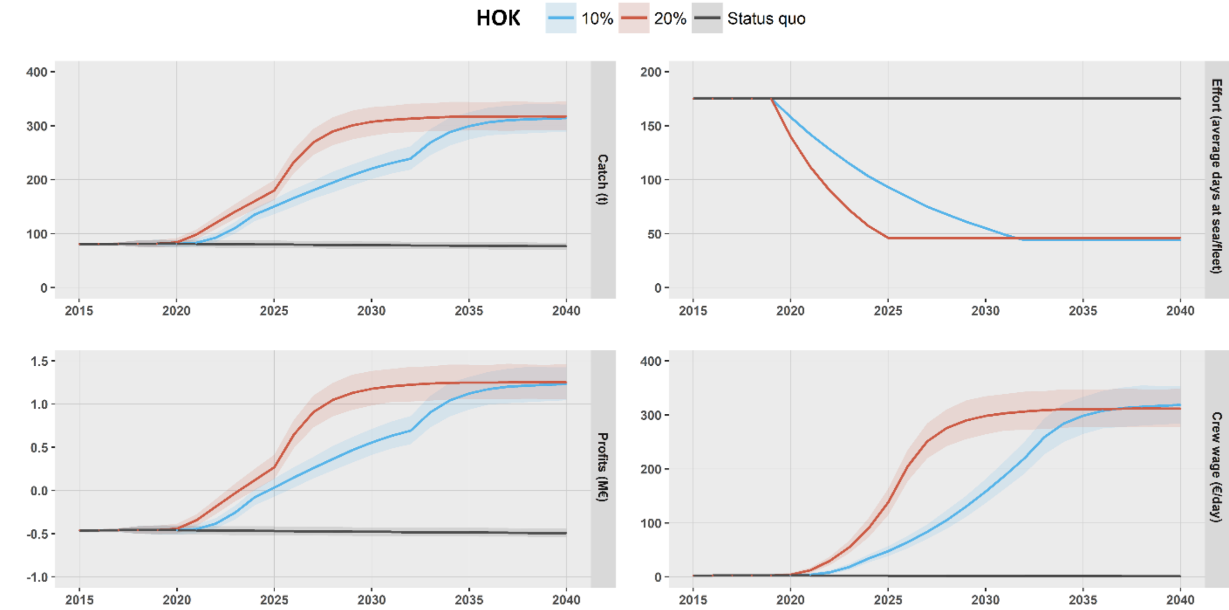
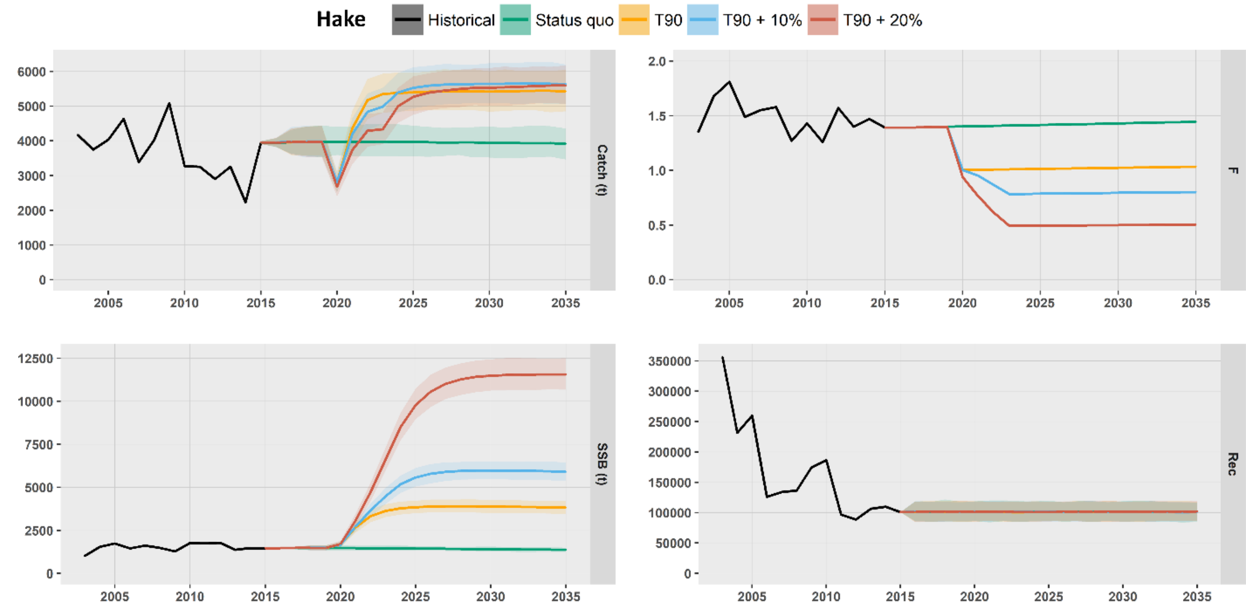


Figure 11: Results of the bioeconomic model of catch (tn), fishing mortality (F_{1-3}), SSB (tn) and constant recruitment for *M. merluccius* under historical series and scenarios

Scenario 0: Status quo, scenario 3: selectivity change to T90, scenario 4: selectivity change plus 10% annual reduction during 4 years and scenario 5: selectivity change plus 20% annual reduction during 4 years



2.2.3. Reduction of two days per week

The **progressive reduction** of two **days a week** (Scenario 6) would produce a small **short-term loss but also significant improvements** from the biological and economic points of view. **Combining this strategy** with an improvement in **selectivity** (Scenarios. 7 and 8) on the trawl fleet would produce **larger losses** in the short-term **but larger benefits in the medium and long term** (Fig. 12 and Annexes I: table 14) estimated to be between 68% and 72%. Average **daily wages** could also increase by **76% to 148%,** respectively, under Scn. 7 and 8. Results for **artisanal fleets** are best when both selectivity improvement and effort reduction are applied to the trawl fleet (scenarios 7 and 8), than when only the effort reduction is implemented (Fig. 13 and Annex I: table 17 and 20).

In terms of biological parameters, scenarios with a **selectivity change** (Scenarios. 7 and 8) result in **larger spawning biomass and catches** in the main species in the mid-term compared to the effort reduction without selectivity improvement (Scenario. 6), as it can be seen for hake in Fig. 14.

Figure 12: Results of the bio-economic model of catch (t), effort (average days at sea), profits (M€) and crew wage (€/day) for trawl fleet (OTB) under scenarios

Scenario 0: Status quo, scenario 6: 40% effort reduction, scenario 7: selectivity change plus 20% effort reduction and scenario 8: selectivity change plus 40% effort reduction

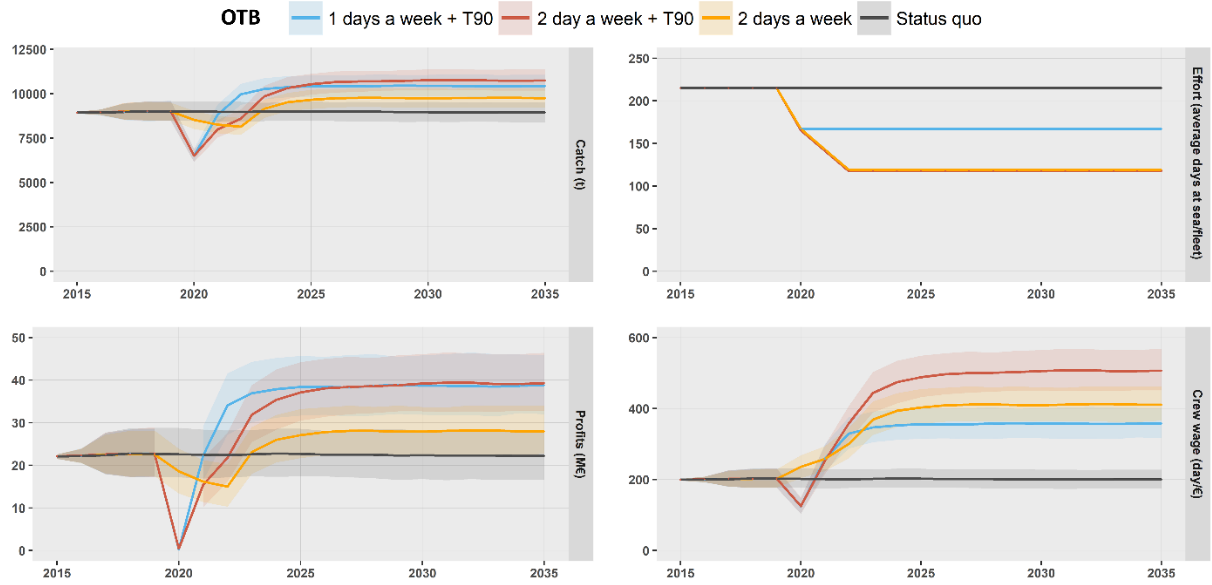


Figure 13: Results of the bioe-conomic model of catch (t), effort (average days at sea), profits (M€) and crew wage (€/day) for demersal gillnet fleet (GNS) under scenarios

Scenario 0: Status quo, scenario 6: 40% effort reduction, scenario 7: selectivity change plus 20% effort reduction and scenario 8: selectivity change plus 40% effort reduction

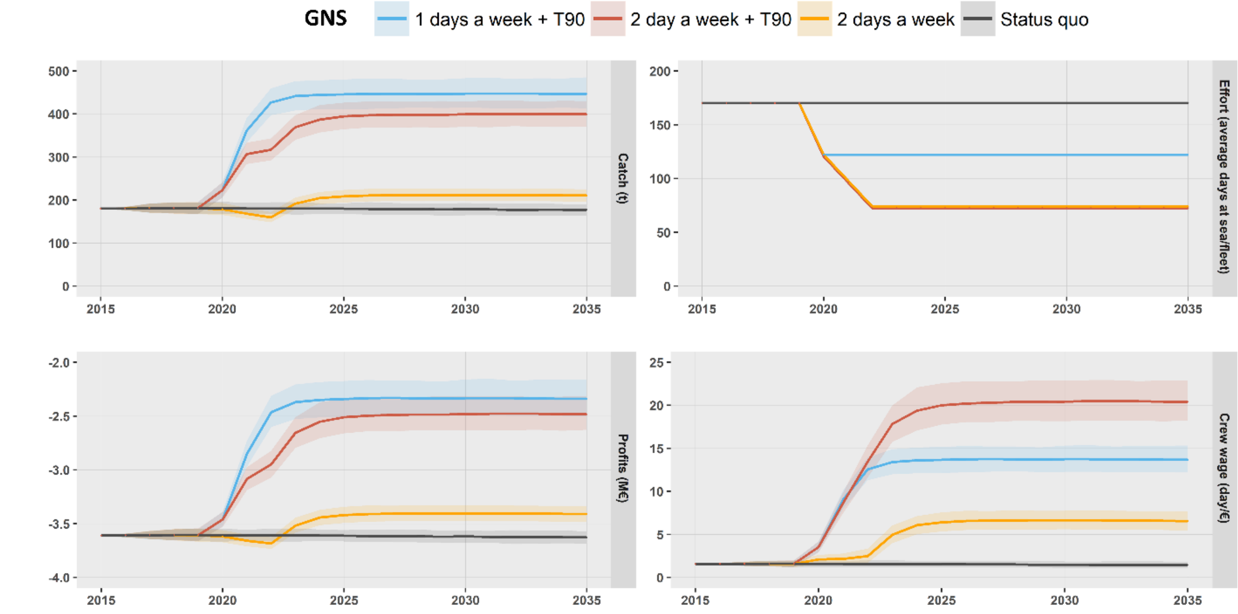
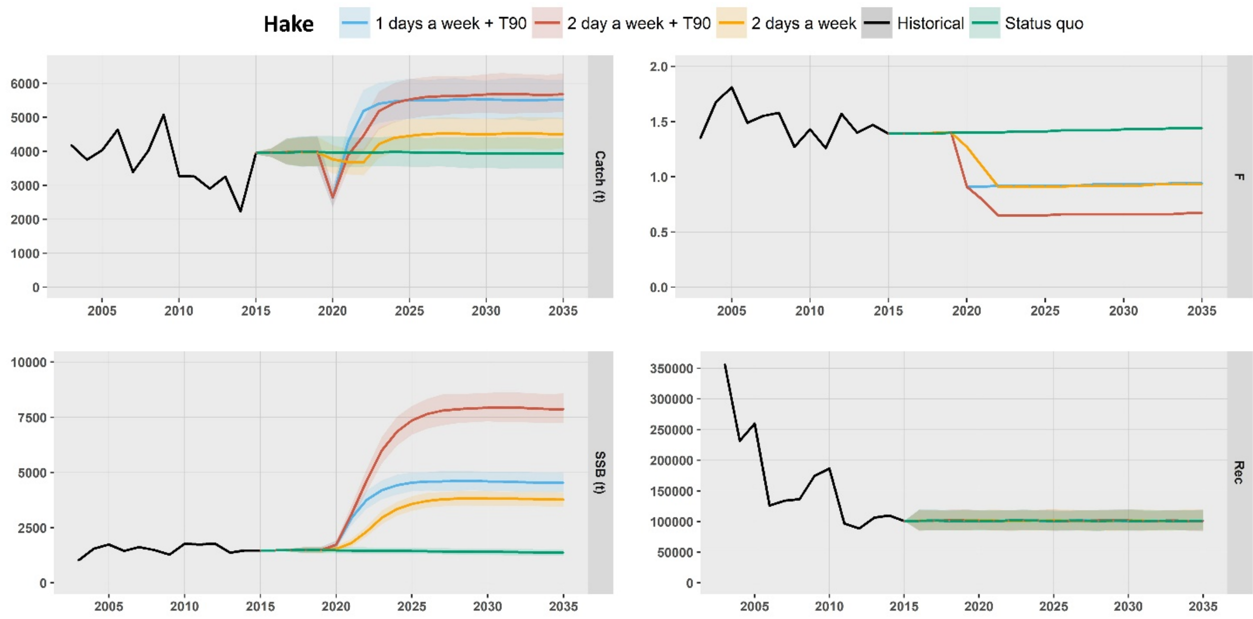


Figure 14: Results of the bioeconomic model of catch (tn), fishing mortality (F_{1-3}), SSB (tn) and constant recruitment for *M. merluccius* under historical series and scenarios

Scenario 0: Status quo, scenario 6: 40% effort reduction, scenario 7: selectivity change plus 20% effort reduction and scenario 8: selectivity change plus 40% effort reduction



2.3. Discards and Landing Obligation economic impact

The impact of the Landing Obligation on the profitability of bottom trawlers in the same case study fishery used here has been investigated with Sola and Maynou's bio-economic model (2018b). Their results show that the **economic impact** of landing catches that were formerly **discards** is expected to be **low** and the fleet could cope with it, regardless of the possible commercial use of these unwanted catches. However, Sola and Maynou (2018b) assume that the Landing Obligation will not increase labour costs and will not require investment for additional infrastructure. Former discards that cannot be utilized industrially due to the lack of market and have to be destroyed by producers will generate an estimated cost of 0.50 € per kg (Sartor et al. 2016) that it is expected to be a low economic loss compared to the income of the trawl fleet. Their results also show that with the implementation of **T90 mesh in the trawl fleet**, the amount of **hake** and **red mullet discards** would **decline by 90%** (Sola and Maynou, 2018b) because the new selectivity pattern would allow the escape of individuals below the minimum reference size (MCRS).

2.4. Social and economic effects

Any **reduction of fishing mortality** will produce a **reduction of revenues in the short term** and an **increase in the long term**. The higher the reduction of mortality, the higher the short term losses, and the higher the long term wins (Irazola et al 1996) and the faster the fishery will approach to MSY. The **best results** according to our model are achieved under **scenarios** that contemplate **selectivity change combined or not with effort reduction** (scenarios 3, 4, 7 and 8), since they **reduce the period of losses** compared to the present situation and produce reasonably **good results** in the **medium and long term**, for **both biological** and **economic** indicators. The benefits of an improvement of selectivity to reduce the catches of undersized hake and red mullet contributing to stock rebuilding have been shown before (Sola and Maynou, 2018a). Changes in selectivity pattern have been recommended as a more practical and efficient way to recover Mediterranean fish stocks than mere effort reduction measures (Colloca et al, 2014, Maynou, 2014). Maynou (2014) simulated the strong reduction of fishing mortality that is needed to achieve MSY in the Mediterranean for hake, the most overexploited species. He concluded that **business-as-usual** scenario in **not viable biologically** or **economicall**y and that the necessary large **reduction of fishing mortality has to be complemented** with selectivity changes, closed areas and closed seasons.

In Geographical Sub-Area 5, Merino et al (2015) concluded that reducing both fishing mortality and fishing costs would improve the health of fish stocks while increasing the economic profits of a Balearic bottom trawl fishery as much as 146%. If all fish stocks were exploited at their MSY (or below) level, the reduction in fishing effort would have to equal 71% of current values, but to maximize equilibrium profits from the fishery (MEY), a 48% reduction of fishing effort would suffice (Merino et al 2015).

However, the socio-economic impact of reducing fishing mortality will differ with the possible strategies. **Technical measures** with the same biological effect **may have** a quite **different socio-economic impact** (Box 2). It must be borne in mind that **fish** in the Mediterranean is mainly **commercialised fresh** and **prices** are relatively **high** (Lleonart and Maynou, 2003). Modifications in market supplies will affect prices. Thus it is important to consider not only the **fishing time** reduction but also how to **distribute** this **reduction** throughout the year to ensure that it does **not affect market supplies** and to prevent the fisherman from closing traditional commercial circuits. Reductions have to be implemented in a transparent and equitable manner, without closing the fisheries. Changes in trade could cause collateral effects that the bio-economic models cannot simulate and with potential to generate serious economic losses to fishermen and alter fish supplies for consumers. Concentrating the **reduction in a season** may cause a **price decrease** (Samy Kamal et al, 2015a) due to the irregular supply of fresh fish to the market. On the other hand, if the effort reduction do not affect to the continuous supply to the market (i.e. **reducing** one or two **days per week**) the **increase of prices** may reduce the negative effects in the short term (Samy Kamal et al, 2015b).

A quite relevant aspect is also the **distribution** of **fishing possibilities** between vessels. Business-as usual scenario will produce a progressive reduction of the fleet but allowing the **transfer** of **fishing time between boats** will **accelerate** the **fleet reduction** and the concentration of fishing rights in a lower number of companies. The economic losses will be larger for trawlers than for the artisanal fleet, because of their dependence on fuel cost. However, **trawlers sustain economically the fish markets** and the landing ports. In absence of trawlers, artisanal fisheries could also disappear rather than gaining market opportunities because landing and marketing logistics depend on the trawlwer fleet.

Box 2: Socioeconomic impact of a 20% reduction in fishing mortality

20% REDUCTION OF FISHING MORTALITY

The reduction of fishing mortality may be achieved with a reduction of 20% in the number of boats (assuming they have an average fishing capacity),or with a seasonal closure of 10 weeks or with a reduction of 1 day per week (in the Spanish Mediterranean it is allowed to fish only 5 days per week).

Fleet reduction: To reach a reduction of 20% of fishing mortality it will be necessary to **destroy almost 500 boats** in the Spanish Mediterranean with an average fishing power (120 trawlers, 307 small scale boat, 44 purse-seiners and 22 long-liners). The fleet reduction will **need subsides**, will reduce the number of companies and the number of **jobs**, will concentrate fishing rights in a lower number of companies and it may become **irreversible**.

Seasonal closure: A temporal closure of around two months will produce a similar fishing mortality reduction but during **this period** there will be **no income for fishermen** and no **supply of fish to the market**. After reopening the fishery catches will be higher but prices will be lower. There is **a risk of losing market share**. It will be difficult to apply and maintain the closure without **subsidies** that may become **structural**.

One day per week reduction: The short term reduction in catches will be compensated by **higher prices**. It will **maintain the supply of fish to the market and the number of jobs and companies**. It may be introduced **without subsidies**. It is applied on a voluntary basis in some harbours in Spain by anglers. It will produce **better working conditions** and it is easy to enforce.

3. ARE CFP TOOLS TECHNICALLY ADEQUATE AND SUFFICIENT IN THE MEDITERRANEAN SEA?

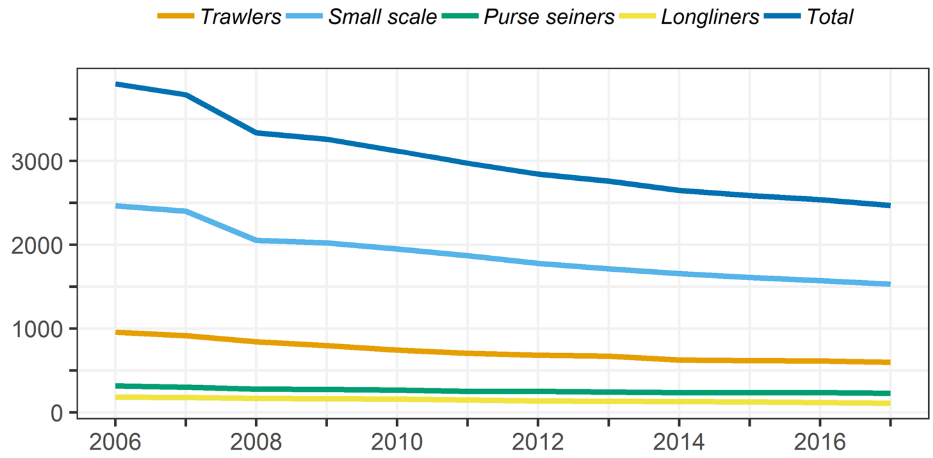
KEY FINDINGS

- The Common Fisheries Policy in the Mediterranean has been **based on technical measures** that have been relatively stable for a long time. CFP have not prevented **the efficiency increase** in both vessels and gears **that have counterbalanced the fleet reduction**.
- The new proposal from the Commission introduces **total allowable effort as a new approach to reduce** significantly fishing time and **fishing mortality**, allowing stocks to reach MSY in the medium term.
- The reduction of **fishing time** has to be **complemented with selectivity improvements, permanent closures and local co-management plans** to protect both juveniles and spawners. This will reduce the need for effort reduction and it will contribute significantly to the sustainability of Mediterranean Fisheries
- Additional measures will be needed to ensure the sustainability of western Mediterranean fisheries, among them a **new management plan for small pelagic** species, which represent a significant amount of landings in the area.

In most European fisheries, fishing possibilities are linked to stock status with output limits through total allowable catches. Output limits are flexible and may adapt fishing mortalities to stock status but they may be ineffective due to several reasons, among them insufficient enforcement or to discarding of marketable fish in mixed fisheries. If fishers have completed their quota of a given species but continue fishing for other species, they will discard or land illegally catches of the species for which the quota is completed (Batsleer et al., 2015). The Landing Obligation seeks to stop this practice but it introduces additional problems, namely the so called choke species and new enforcement challenges. The issues associated to implementation of **TACs and quotas** become **more difficult** to sort with increasingly **diverse fisheries**, and this is the main reason why TAC and quota have never been considered useful for the highly diverse Mediterranean demersal fisheries.

The Common Fisheries Policy in the Mediterranean has been characterised by a suite of **technical measures** that have been maintained relatively **stable for a long time**. Meanwhile, fishing mortality has increased over the last decades due to the notable **improvement** of engines, fishing gears and other **technological devices** that have resulted in a **larger catchability** and pushed several stocks to overfished status. When fleet profits have decreased in the past, **fishing mortality** has been adjusted with a **fleet reduction** (Fig. 15), from **3919 boats** in **2006** to **2468** in **2017** (a **37% reduction**), across all fleet segments (trawlers, purse seiners and small scale boats). In comparison, the whole Spanish fleet has been reduced by 30% during the same period (from 13331 to 9299 boats). However, and judging from the results presented by the different stock assessment Working Groups, this has not been enough to allow the recovery of populations (WGSAD, 2017; WGSASP, 2017), although current **economic indicators** for Spanish Mediterranean fleet and the **trends** of assessed stocks are mainly **positive** (see Tables 2, 3 and 4).

Figure 15: Evolution of Spanish fleet in the Mediterranean



Souce: Data from "*Censo de Flota Pesquera Operativa*" at December 31st each year

This situation suggests that management of Mediterranean fisheries has to change to **adjust fishing mortality to stock status**. This can be achieved with the implementation of catch limits for highly selective fisheries without accidental catches, as it is the case of pelagic species, but demersal fisheries require a different strategy.

The new proposal for a multi-annual plan for demersal fisheries in the western Mediterranean introduces the concept of **total allowable effort**. It is based in fixing a maximum number of fishing days per year as a way to adjust fishing mortality to stock status. A significant reduction of fishing time should be applied in the next years to reduce fishing mortality to F_{MSY}. However, **the proposal** does not regulate how to **distribute** the **fishing days** throughout the year and across the fleet. Concentrating **the reduction** in a **single season** will have the same effects as existing seasonal closures: higher catches and probably **lower prices after the reopening** (Samy Kamal et al., 2015a). If the **reduction is distributed weekly, market** supply is **guaranteed** all year round and **prices may increase**, thus reducing the short term social and economic impact (Samy Kamal et al., 2015b). In addition, a weekly reduction will not require subsides, unlike many current seasonal closures in the Mediterranean. As of today, fishers in some Spanish regions are voluntarily reducing fishing time in one day per week without subsidies.

If provisions are made to **transfer allowable effort between boats**, the social impact will be even larger. Mediterranean fishing companies are usually small familiar enterprises, but this may change with the introduction of transferability of fishing days. The transfer of fishing possibilities between boats **may concentrate fishing rights** in larger companies reducing the fleet and changing the economic structure of Mediterranean fisheries with a very **high impact** on **employment**. There is a risk that fishing could disappear in some Mediterranean towns, which would loose an important part of their historical heritage. Concentration of fishing rights and loss of access to the fishery for some towns are among the side effects of the Icelandic ITQ system (Eythorsson, 1996; Willson, 2014).

The multi-annual plan proposed for demersal fisheries in the western Mediterranean also includes other technical measures to complement the total allowable effort:

- **a 3-month annual closure to trawlers in all waters shallower than 100 m.** A similar regulation was been established in Spain between 1975 and 1988 but, to our knowledge, its effectivity has never been evaluated. This measure may be useful to protect **nursery areas** but **permanent closures** are a much better option **to protect sensitive habitats and spawning grounds**. Trawling in the Spanish Mediterranean has traditionally been limited to areas deeper than 50 m but the Common Fisheries Policy (CFP) currently allows fishing at shallower depths if distance to shore is 3nm or more.

- **the establishment of additional closure areas** to protect high concentrations of juvenile fish and spawning grounds. The benefits of closures for stock enhancement and biodiversity conservation are known (Sánchez Lizaso et al., 2000) but the **current** extension of **areas closed to** fisheries is **too small** (Sánchez Lizaso, 2015). Moreover, in most countries, areas are closed to protect some particular habitat, i.e. shallow water reefs but, to be effective, protection measures must expand **to include** a significant proportion of **all different marine habitats** (Sánchez Lizaso, 2015).

The Commission will also be empowered to adopt **delegated acts** establishing additional technical conservation measures, particularly those addressed to **improve selectivity**. Improvement of trawl selectivity would have noticeable and complex direct and indirect effects on target and non-target demersal species (Coll et al 2008) and will reduce the mortality on target species juveniles (Sola & Maynou, 2018). **Increasing the size** at which commercial species are captured will result in a **higher economic yield** for the fleets and **larger biomass** at sea of the exploited stocks, but most importantly it will contribute as well to restore ecosystem structure and resilience (Colloca et al., 2013). Moreover, the current reference points are based on $F_{0.1}$. As consequence, changes in selection pattern will change the reference points (STEF, 2016) **reducing the distance between current and target fishing mortality**. Scott and Sampson (2011) show that relatively subtle changes in selection can produce substantial differences in MSY and F_{MSY}. Hence, drastic reductions in fishing effort may be unnecessary to achieve F_{MSY} if Mediterranean fisheries are oriented towards more selective fishing practices (Maynou, 2014).

The proposal also states that management measures based on total allowable catch shall be introduced if changes in the fishing effort regime do not suffice to meet the objectives or targets. However, it is likely that if the fishing effort regime does not produce the expected results it will be due to an insufficient adjustment of fishing effort. A **combination of** the **reduction of fishing time,** the establishment of **well-designed closed areas** and an improvement of **selectivity** should lead to a **significant improvement** of Mediterranean fisheries. On the other hand, the introduction of **output controls** with Total Allowable Catches (TACs) and quotas for Mediterranean demersal fisheries **will create new problems** due to the high catch diversity.

It should be kept on mind that this proposal addresses demersal stocks, which are currently in very poor shape, but **additional measures** are also needed to improve the management of other resources, i.e. **the small pelagic species**.

EU fisheries policy recognises the need to involve resource users in management and consequently shift towards **co-management**. A good way to involve stakeholders would probably be the adoption of local management strategies. Prior studies have shown positive achievements in the implementation co-management plans at local level in certain fisheries (Lleonart et al 2014; Gorelli et al, 2014; Sala 2017; STEF, 2018). Enhancement of local co-management in the future may be a positive course of action.

4. LANDING OBLIGATION IN THE CONTEXT OF THE MSY

KEY FINDINGS

- Mediterranean fisheries are highly diverse in terms of number of species caught. This is reflected in the **great diversity of discards**, particularly in **bottom trawl** fisheries.
- Only a **small fraction of discards** of regulated species **corresponds to undersized fish**. A portion of the valuable and legal size catch is discarded to maintain price stability if supply exceeds demand.
- The **Landing Obligation in the Mediterranean will not help to reach MSY** and will not contribute to reduce the **impact of fishing** in Mediterranean ecosystems.
- **Minimum conservation reference sizes** (MCRS) established in Council Regulation (EC) No 1967/2006 **should be reviewed**.
- To **reduce discards** and mortality of both target and non-target species it would be better to replace the landing obligation **with discard plans** including an **improvement of selectivity and spatial-temporal closures**

The **Landing Obligation** included in the new EU Common Fisheries Policy prohibits the discarding of species subject to catch limits and those subject to Minimum Conservation Reference Size (MCRS) in the Mediterranean Sea. The objective is **to mitigate discard incentives for valuable fish due to the CFP** and it will not affect discards of unregulated species.

Because of the high **species diversity** in the Mediterranean, discards in the bottom trawl fisheries are greatly diverse too. Of the roughly **300 species caught** in the Mediterranean, only **around 10% are** consistently **marketed**, and a further 30% are occasionally retained (depending on size and market demands), whereas up to 60% of demersal trawl catches are always discarded (Bellido et al., 2014). Table 6 summarises the annual discard estimates for species with Minimum Conservation Reference Sizes (MCRS) in Spanish Mediterranean bottom trawl fisheries. However, it has to be considered that discards in the Mediterranean are highly variable in time and space (Tsagarakis et al 2017). Table 4 shows that **unmarketable individuals** (those with size smaller than MCRS) represent **only a small fraction of discards** of regulated species (listed in Annex 3 of Council Regulation (EC) No 1967/2006). Part of the valuable catch above MCRS is discarded to maintain price stability if supply exceeds demand (Mallol, 2005). This applies mostly to the genuses *Trachurus* and *Pagellus*. Probably the inclusion of these species in Annex 3 of Council Regulation (EC) No 1967/2006 was not justified and should be revised.

In Atlantic fisheries the Landing Obligation will count against the quota and consequently **a reduction of fishing mortality is expected**. However, **the Mediterranean is a different case** and the Landing Obligation for discards may not be the solution to reduce unwanted catch and fishing mortality (Bellido et al 2014). Besides, catch volume in the Mediterranean is much smaller than the hold capacity of fishing vessels. Thus the Landing Obligation will not limit the carrying capacity for target species.

Table 6: Yearly estimates of discards of regulated species in Spanish Mediterranean bottom trawl fisheries

Scientific name	Landings tons	Total discards tons	Undersized discard tons	Total discard vs landings %	Undersized discards vs landings %	Undersized vs total discards %
M. merluccius	3298	250	151	7.6	4.6	60,4
P. longirostris	250	3	0	1.3	0.1	0,0
N. norvegicus	411	21	0	5.1	0.0	0,0
Mullus barbatus	898	20	2	2.2	0.2	10,0
Mullus surmuletus	534	6	0	1.0	0.0	0,0
Pagellus acarne	305	513	234	168.1	76.7	45,6
Pagellus bogaraveo	58	347	211	592.8	361.2	60,8
Pagellus erythrinus	344	375	29	108.8	8.4	7,7
T. trachurus	1780	605	313	34.0	17.6	51,7
T. mediterraneus	816	585	353	71.7	43.2	60,3

Source: Modified from Bellido et al (2014)

The minimum conservation reference sizes (MCRS) established in Council Regulation (EC) No 1967/2006 should be reviewed. In general, the larger the length at first capture, the better, since the gains due to growth are higher than the losses by natural mortality. However, **MCRS only** are **useful if** they effectively **reduce the mortality of juvenile**s. This is the case for species with high survival rates, like small pelagic species fished with purse seiners or some demersal species caught with bottom trawls, like octopus (not included in Council regulation) or Norwegian lobster. The MCRS may also be justified to avoid that **juveniles** of certain species with very high market demand, even if survival is very low, become the **target of the fishery**. , i.e. **hake**. However, the Landing Obligation may actually favour a black market for hake juveniles (Bellido et al., 2017) and probably the percentage of discards for this species is low enough to be included in the *de minimis* exception.

Other species are **discarded** simply **because** there is **no market** for them, as it is the case for horse mackerel and *Pagellus spp*. Landing all their catch does **not contribute to reduce fishing mortality**, but it will create new problems and a distraction from the main objective, a significant reduction of fishing effort.

Moreover, the **Landing Obligation** will **not** contribute to **reduce the impact on the ecosystem** because it will increase the energy removal from the system that will be exported to land. Several species, including some of commercial value, may be affected (Sarda et al, 2015). In this sense, Heat et al (2014) concluded that **landing the entire catch** while fishing as usual will have **conservation penalties** for seabirds, marine mammals and seabed fauna**,** and **no benefit for fish stocks**.

Finally, it has to be considered that landing such volumes of marine debris can generate important environmental **pollution in land**. This is a particularly sensitive issue on the Mediterranean coast, with many touristic areas and where the weather is warm almost throughout the year (Bellido et al., 2017). If marine debris is not disposed of by quick removal in appropriate conditions it can cause **poor hygienic and sanitary conditions**, adversely affecting the welfare of local communities (Bellido et al., 2014; 2017).

In brief**, Landing Obligation** will not contribute to reach MSY in Mediterranean fisheries since it **will not reduce fishing mortality**, it will **increase the impact on the ecosystem** and will create **new problems** of management and control. To reduce discards and mortality of both target and non-target species it would be **better to replace** the landing obligation with **discard plans** including an **improvement of selectivity** and **spatial-temporal closures.**

5. RECOMMENDATIONS

1. The main problem of Mediterranean fisheries is the **lack of connection between assessment and management** (Lleonart and Maynou, 2003). It is necessary to introduce progressively, an **adaptive management** system based in the **best scientific knowledge.**

2. It is necessary to find **new reference points for Mediterranean fisheries introducing a multispecies approach that are not only based in single species MSY**. Simultaneously trying to manage several stocks at single species F_{MSY} levels is likely to fail and create inconsistencies between targets for different stocks (STECF, 2016). Moreover, if fishing opportunities shall be set at levels consistent with a fishing mortality that is reduced within the range of F_{MSY} for the most vulnerable stock as it is stablished in the proposal of management plan, this stock will act as a choke species, losing fishing opportunities on other stocks and the profitability of the fleet.

3. In any case, **it is necessary to implement a significant and well planned reduction of fishing mortality** over the next years to approach different stocks to MSY. Different approaches to achieve the same reduction of fishing mortality may have quite **different socio-economic impacts that must be considered**.

4. The **Landing Obligation in the Mediterranean will not help to reach MSY** and will **not** contribute to **reduce the impact of fishing** in the Mediterranean **ecosystem**.

5. **Minimum Conservation Reference Sizes (MCRS) in the Mediterranean should be reviewed**. In general, the larger the length at first capture, the better since the gains due to growth are higher than the losses by natural mortality. MCRS are only useful when they contribute to reduce juvenile mortality. This will happen only when the survival of juveniles returned to the sea is high or when juveniles may become the target of the fishery. This is not the case for many of the species included in Annex III, such as species belonging to the genuses *Trachurus* and *Pagellus*, whereas other absent species like *Octopus vulgaris* should be included in this annex.

6. It is necessary to **improve the selectivity of Mediterranean demersal fisheries** to reduce both juvenile mortality and discards, improving the stock status of target species and reducing the impact on the ecosystem. Moreover, improving selectivity will modify reference points and decrease F_{cur} towards F_{MSY}. It must be borne in mind that the selectivity change will cause losses in the short term because a fraction of the catch is going to escape but benefits in the medium and long term.

7. The **reduction of fishing time** is also required **to reduce current fishing mortality,** but the socioeconomic impact of this reduction must be considered. Reducing the number of fishing **days per week** will have a **lower socioeconomic impact** than concentrating the fishing posibilities in some seasons or in a smaller number of vessels.

8. Changes in selectivity and effort reduction should be complemented with **permanent closures** designed **to protect a significant portion of all marine habitats**. Otter trawling

should not be allowed at depths shallower than 50 m regardless of distance to shore. **Temporal closures** may be useful **to protect nursery grounds**.

9. A combination of the reduction of fishing time, the establishment of closed areas to protect populations of target species, the improvement of selectivity and local co-amagement should suffice to change the status of Mediterranean stocks and bring fisheries to MSY levels. The introduction of **output controls** for demersal fisheries **will create new problems rather than help to achieve this goal** due to the high diversity of catches in Mediterranean demersal fisheries.

10. The multiannual plan for the western Mediterranean addresses some of the problems of demersal stocks but **additional measures** are required to improve the management of **other relevant resources** in this area, such as **small pelagic species,** to change their status to safe MSY levels.

REFERENCES

Batsleer, J.; K. G. Hamon, H. M. J. van Overzee, A. D. Rijnsdorp, J. J. Poos, (2015) *High-grading and over-quota discarding in mixed fisheries* Rev Fish Biol Fisheries 25:715–736

Begg GA, Friedland KD, Pearce JB. (1999). *Stock identification and its role in stock assessment and fisheries management: an overview*. Fisheries Research. Oct 1;43(1-3):1-8.

Begley, J and Howell, D. (2004). *An overview of Gadget, the Globally applicable Area-Disaggregated General Ecosystem Toolbox*. ICES CM 2004/FF:13

Bellido JM, A Carbonell, M Garcia, T Garcia, M González, (2014). *The obligation to land all catches – consequences for the Mediterranean. In-depth analysis*. European Parliament, Policy Department B: Structural and Cohesion Policies, Brussels 52 pp, Publication year: (2014) http://bookshop.europa.eu/en/the-obligation-to-land-all-catches-consequences-for-the-mediterranean-pbQA0114340/ , ISBN: 978-92-823-5604-3, DOI: 10.2861/59268

Bellido J.M, M. Garcia, T. Garcia, M. González Aguilar & Ana Carbonell, (2017). *Could the obligation to land undersized individuals increase the black market for juveniles: evidence from the Mediterranean?* Fish Fish. 18, 185–194. doi: 10.1111/faf.12166

Bianchi, C. N. & Morri, C. (2000): *Marine biodiversity of the Mediterranean Sea: situation, problems and prospects for future research*, Mar. Pollut. Bull., 40, 367–376,

Coll, M., N. Bahamon, F. Sardà, I. Palomera, S. Tudela, P. Suuronen. (2008). *Improved trawl selectivity: effects on the ecosystem in the South Catalan Sea (NW Mediterranean)*. Marine Ecolgy Progress Series 355:131-147

Coll M, Piroddi C, Steenbeek J, Kaschner K, Ben Rais Lasram F, Aguzzi J, et al. (2010) The Biodiversity of the Mediterranean Sea: Estimates, Patterns, and Threats. PLoS ONE 5(8): e11842. https://doi.org/10.1371/journal.pone.0011842

Colloca, F., M. Cardinale, F. Maynou, M. Giannoulaki, G. Scarcella, K. Jenko, J. M. Bellido & F. Fiorentin. (2013). *Rebuilding Mediterranean fisheries: a new paradigm for ecological sustainability*. Fish and Fisheries 14: 89-109

Doubleday, W.G. (1976). *Environmental fluctuations and fisheries management*. ICNAF Sel. Pap. 1: 141–50

Eythórsson E. Theory and practice of ITQs in Iceland. Privatization of common fishing rights. Marine Policy. 1996 May 1;20(3):269-81.

FAO. 2018. *The State of World Fisheries and Aquaculture 2018* - Meeting the sustainable development goals. Rome.

GFCM, 2015. *Report of the Working Group on Stock Assessment of Demersal Species (WGSAD)*. Rome, Italy, 23–28 November, 60 pp

Gorelli G, Company JB and Sardà F. (2014) *Management strategies for the fishery of the red shrimp Aristeus antennatus in Catalonia (NE Spain)*. Marine Stewardship Council Science Series 2: 116 – 127

Guillen, J., C. Macher, M. Merzéréaud, M. Bertignac, S. Fifas, O. Guyader, (2013). *Estimating MSY and MEY in multi-species and multi-fleet fisheries, consequences and limits: an application to the Bay of Biscay mixed fishery*. Marine Policy 40: 64–74

Hansen, U. J. (2004). Performance of a Trawl Made From 90º Turned Netting (T90) Compared With That of Traditional Codends. Gydynia: ICES Fishing Technology and Fish Behaviour Working Group Meeting

Heath, M.R., Cook, R.M., Cameron, A.I., Morris, D.J., and Speirs, D.C. (2014). *Cascading ecological effects of eliminating fishery discards*. Nature Communications, 5, Article number: 3893.

Hoggarth, D.D.; Abeyasekera, S.; Arthur, R.I.; Beddington, J.R.; Burn, R.W.; Halls, A.S.; Kirkwood, G.P.; McAllister, M.; Medley, P.; Mees, C.C.; Parkes, G.B.; Pilling, G.M.; Wakeford, R.C.; Welcomme, R.L. (2006). *Stock assessment for fishery management – A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP)*. FAO Fisheries Technical Paper. No. 487. Rome, FAO. 261p.

Irazola, M.; A. Lucchetti, J. Lleonart, A. Ocaña, J.M Tapia, S. Tudela (1996) *La pesca en el siglo XXI. Propuestas para una gestión pesquera racional en Catalunya*. CCOO Federación de transporte Barcelona 289 pp.

Jennings, S., Kaiser, M.J. & Reynolds, J.D. (2001). *Marine Fisheries Ecology*. Blackwell Science, Oxford

Kempf, A. J. Mumford, P. Levontin, A. Leach A. Hoff K. G. Hamon, H. Bartelings, M. Vinther, M. Stäbler, J. J. Poos S. Smout, H. Frost, S. van den Burg, C. Ulrich, A.Rindorf. (2016) *The MSY concept in a multi-objective fisheries environment – Lessons from the North Sea*. Marine Policy 69; 146-158

Lassen H, Medley P. (2001). *Virtual population analysis: a practical manual for stock assessmen*t. Food & Agriculture Org.

Lleonart, J. (2015). *Mediterranean fisheries, stocks, assessments and exploitation status*.
In: IEMed Yearbook "Panorama of Mediterranean Fisheries", p. 276-281.

Lleonart J., Maynou F. (2003) - *Fish stock assessments in the Mediterranean: state of the art*. Sci. Mar., 67 (S1): 37-49.

Lleonart J., Demestre M., Martín P., Rodón J., Sainz-Trápaga S., Sánchez P., Segarra I., Tudela S. (2014). *The co-management of the sand eel fishery of Catalonia (NW Mediterranean): the story of a process*. In: Lleonart J., Maynou F. (eds), The Ecosystem Approach to Fisheries in the Mediterranean and Black Seas. Sci. Mar. 78S1: 87-93. doi: http://dx.doi.org/10.3989/scimar.04027.25A

Mallol, S. (2005). *Anàlisi dels descartaments efectuats per la flota d'arrossegament en el Golf de Lleó*. Thesis. Univ. Girona, Spain. 279pp.

MAPAMA 2018. Informe anual de la actividad de la flota pesquera española, https://www.mapama.gob.es/es/pesca/planes-y-estrategias/informe-anual-actividad-flota-2018-esp-mapama_tcm30-450996.pdf

Maunder MN. (2002). *The relationship between fishing methods, fisheries management and the estimation of maximum sustainable yield*. Fish and Fisheries. Dec 1;3(4):251-60.

Maynou F. (2014). *Co-viability analysis of Western Mediterranean fisheries under MSY scenarios for 2020*. ICES J. Mar. Sci. 71: 1563-1571.
https://doi.org/10.1093/icesjms/fsu061

Merino, G. A. Quetglas, F. Maynou, A. Garau, H. Arrizabalaga, H. Murua, J. Santiago, M. Barange, R. Prellezo, D. Garcia, J. Lleonart, G. Tserpes, C. Maravelias, N. Carvalho, M. Austen, J.A. Fernandes, P. Oliver, A.M. Grau, Improving the performance of a Mediterranean demersal fishery toward economic objectives beyond MSY, Fish. Res. 161 (2015) 131–144, http://dx.doi.org/10.1016/j.fishres.2014.06.010.

Quetglas A, Merino G, Ordines F, Guijarro B, Garau A, Grau AM, Oliver P, Massutí E. (2017). *Assessment and management of western Mediterranean small-scale fisheries*. Ocean & Coastal Management. 133:95-104.

Sala, J. (2017). Roses' no-take marine zone effectiveness and spatiotemporal hake population assessment using GIS tools. Masther Thesis ICM-CSIC 40 pp.

Samy-Kamal M, Forcada A, Sánchez-Lizaso JL. (2014) Trawling fishery of the western Mediterranean Sea: Métiers identification, effort characteristics, landings and income profiles. Ocean & Coastal Management. 102:269-84.

Samy-Kamal. M.; A. Forcada; J.L. Sánchez Lizaso. (2015a). *Effects of seasonal closures in a multi-specific fishery*. Fisheries Research. 172, pp. 303 - 317.

Samy-Kamal, M.; A. Forcada; J.L. Sánchez Lizaso. (2015b). *Daily variation of fishing effort and ex-vessel prices in a western Mediterranean multi-species fishery: implications for sustainable management*. Marine Policy. 61, pp. 187 - 195.

Sánchez Lizaso, J.L. (2015). *Closed areas for fisheries management: How much is enough?*. Mediterranea. Num Esp, pp. 41 - 52.

Sánchez-Lizaso, J.L.; Goñi, R.; Reñones, O.; García, J.A.; Galzin, R.; Bayle, J.; Sánchez-Jerez, P.; Pérez, A.; Ramos, A. (2000). *Density dependence in marine protected populations: A review*. Environmental Conservation. 27, pp. 144- 158.

Sardà F, Coll M, Heymans JJ & Stergiou KI (2015) *Overlooked impacts and challenges of the new European discard ban*. Fish and Fisheries 16: 175–180

Sartor, P., Carbonara, P., Lucchetti, A., and Sabatella, E. C. (2016). *Indagine Conoscitiva Sullo Scarto della Pesca alle Specie Demersali Nei Mari Italiani. Valutazioni Propedeutiche Per l'implementazione Delle Disposizioni Comunitarie in Tema di Obbligo di Scarto*. Quaderni Nisea, 40.

Scientific, Technical and Economic Committee for Fisheries (STECF), (2016). *Annex I length indicators*. Annex to the STECF 16-22 report (EWG 16-13).

Scientific, Technical and Economic Committee for Fisheries (STECF) (2017a). *Mediterranean Stock Assessments* 2017 part I (STECF-17-15), 432 pp. Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-67487-7, doi:10.2760/897559, JRC109350.

Scientific, Technical and Economic Committee for Fisheries (STECF) (2017b). *Mediterranean assessments 2016- part 2* (STECF-17-06); Publications Office of the European Union, Luxembourg; EUR 28359 EN; doi:10.2760/015005

Scientific, Technical and Economic Committee for Fisheries (STECF) (2017c) – The 2017 *Annual Economic Report on the EU Fishing Fleet (STECF-17-12)*. Publications Office of the European Union, Luxembourg, , ISBN 978-92-79-73426-7, doi:10.2760/36154, PUBSY No. JRC107883

Scientific, Technical and Economic Committee for Fisheries (STECF) (2018a) *Assessment of the implementation report of the management plan for boat seines ('sonsera') in the autonomous region of Catalonia (STECF-OWP-18-01)*. Publications Office of the European Union, Luxembourg, ISBN 978-92-79-79375-2, doi:10.2760/681058, JRC110676

Scientific, Technical and Economic Committee for Fisheries (STECF) (2018b)– *Fishing effort regime for demersal fisheries in the western Mediterranean Sea* (STECF-18-09). Publications Office of the European Union, Luxembourg

Scott, R.D. and Sampson, D.B. (2011) *The sensitivity of long-term yield target in fishery age selectivity*. Marine Policy 35, 79–84.

Smith AD, Garcia SM. 2014) *Fishery management: contrasts in the Mediterranean and the Atlantic*. Current Biology. Sep 8;24(17):R810-2.

Sola I, Maynou F. (2018a). *Assessment of the relative catch performance of hake, red mullet and striped red mullet in a modified trawl extension with T90 netting*. Sci. Mar. 82S1. https://doi.org/10.3989/scimar.04711.04A

Sola I, Maynou F. (2018b). *Bioeconomic analysis of the effects of modifying the trawl extension piece with T90 netting* Sci. Mar. 82S1
https://doi.org/10.3989/scimar.04715.06A

Tsagarakis K, Carbonell A, Brcic J, Bellido JM, Carbonara P, Casciaro L, Edridge A, García T, González M, Krstulovic´ Šifner S, Machias A, Notti E, Papantoniou G, Sala A, Škeljo F, Vitale S and Vassilopoulou V (2017) *Old Info for a New Fisheries Policy: Discard Ratios and Lengths at Discarding in EU Mediterranean Bottom Trawl Fisheries*. Front. Mar. Sci. 4:99.

Willson M. E. (2014) *Icelandic Fisher Women's Experience: Implications, Social Change, and Fisheries Policy, Ethnos*: Journal of Anthropology, 79:4, 525-550, DOI: 10.1080/00141844.2013.783606

Working Group on Stock Assessment of Demersal Species (WGSAD) (2017) *Final Report* FAO headquarters, Rome, Italy, 13–18 November 2017 70 pp

ANNEX I: Results of the simulations of the bioeconomic model of GSA 06

Hake

Table 7 : Average catch percentages of *M. merluccius* with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.3	0.0	-4.1	-29.4	-29.6	-32.6	-5.2	-33.9	-33.9
2021	-0.5	-2.9	-11.2	9.8	5.5	-5.9	-7.2	7.6	-2.5
2022	-0.7	-4.7	-11.2	30.3	21.6	8.0	-7.4	30.3	11.8
2023	-0.8	-2.8	-9.7	34.7	25.2	9.2	6.2	35.7	30.0
2024	-0.6	-0.5	-9.9	35.5	35.5	25.8	10.8	37.4	36.0
2025	-0.8	1.2	-11.3	35.9	38.9	32.7	12.3	38.4	38.7
2026	-1.0	2.7	2.6	36.4	40.4	35.6	13.4	38.3	40.3
2027	-0.8	3.7	9.2	36.7	41.2	37.2	13.9	38.2	41.0
2028	-1.1	4.6	11.6	36.9	41.5	38.4	13.9	38.9	41.1
2029	-1.3	4.7	13.0	36.8	41.6	39.2	13.6	39.2	41.6
2030	-1.1	4.0	13.9	36.4	41.7	39.4	13.4	38.8	42.2
2031	-1.5	2.8	14.6	36.7	41.8	39.6	13.7	38.6	42.7
2032	-1.4	1.4	15.2	36.8	42.0	40.0	14.1	38.4	42.7
2033	-1.0	8.6	15.6	37.0	42.0	40.5	14.0	38.3	42.1
2034	-1.2	12.3	15.8	37.0	41.8	40.8	13.7	38.6	42.0
2035	-1.2	13.9	15.8	36.6	41.5	40.9	13.6	38.8	42.5
2036	-1.3	14.5	16.0	-	-	-	-	-	-
2037	-1.6	15.0	16.3	-	-	-	-	-	-
2038	-1.5	15.4	16.4	-	-	-	-	-	-
2039	-1.5	15.7	16.2	-	-	-	-	-	-
2040	-1.7	15.9	16.2	-	-	-	-	-	-

Table 8: F percentages of *M. merluccius* with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	0.2	0.2	-6.4	-28.2	-28.2	-32.9	-9.3	-35.0	-35.0
2021	0.4	-5.1	-24.1	-28.1	-32.0	-45.4	-22.1	-35.0	-43.6
2022	0.6	-14.0	-39.2	-27.9	-38.1	-56.1	-35.0	-34.3	-53.6
2023	0.8	-22.2	-51.2	-27.8	-44.0	-64.8	-35.0	-34.3	-53.6
2024	1.0	-29.5	-61.1	-27.7	-43.9	-64.8	-35.0	-34.3	-53.6
2025	1.2	-36.4	-68.8	-27.5	-43.7	-64.7	-35.0	-34.3	-53.6
2026	1.4	-42.7	-68.8	-27.4	-43.7	-64.6	-35.0	-34.3	-52.9
2027	1.6	-48.3	-68.7	-27.2	-43.5	-64.5	-34.3	-34.3	-52.9
2028	1.8	-53.4	-68.6	-27.1	-43.5	-64.5	-34.3	-33.6	-52.9
2029	2.0	-58.0	-68.5	-26.9	-43.3	-64.4	-34.3	-33.6	-52.9
2030	2.2	-62.1	-68.5	-26.8	-43.2	-64.3	-34.3	-33.6	-52.9
2031	2.4	-65.8	-68.4	-26.7	-43.1	-64.3	-34.3	-33.6	-52.9
2032	2.6	-69.2	-68.3	-26.5	-43.0	-64.2	-33.6	-33.6	-52.9
2033	2.9	-69.1	-68.3	-26.4	-42.9	-64.1	-33.6	-32.9	-52.9
2034	3.1	-69.0	-68.3	-26.2	-42.7	-64.0	-33.6	-32.9	-52.1
2035	3.2	-69.0	-68.2	-26.1	-42.7	-64.0	-33.6	-32.9	-52.1
2036	3.4	-68.9	-68.1	-	-	-	-	-	-
2037	3.6	-68.9	-68.0	-	-	-	-	-	-
2038	3.9	-68.8	-68.0	-	-	-	-	-	-
2039	4.1	-68.7	-67.9	-	-	-	-	-	-
2040	4.3	-68.7	-67.8	-	-	-	-	-	-

Table 9: Average SSB percentages of *M. merluccius* with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.4	-0.2	2.5	12.6	12.5	15.3	4.1	16.5	17.1
2021	-1.1	2.0	19.3	80.8	84.1	107.5	22.0	98.1	110.0
2022	-1.6	12.7	61.7	124.7	146.7	219.2	57.3	153.7	212.6
2023	-2.1	32.7	128.2	146.0	203.1	348.9	99.8	183.4	305.6
2024	-2.5	60.5	223.0	156.0	250.1	476.1	126.5	198.9	364.0
2025	-2.9	94.4	346.3	160.6	276.5	562.1	142.1	207.2	398.8
2026	-3.5	135.5	481.0	163.1	291.3	615.2	151.3	210.1	418.4
2027	-3.9	184.2	584.8	163.9	298.9	645.5	156.5	210.7	428.9
2028	-4.3	240.2	654.2	164.3	302.4	663.4	158.8	211.8	433.2
2029	-5.0	304.8	696.7	163.8	303.7	673.4	159.3	212.2	435.6
2030	-5.4	375.3	722.1	162.5	303.8	677.9	158.4	210.7	437.3
2031	-5.8	453.4	737.3	162.2	303.2	680.0	158.1	210.0	437.8
2032	-6.5	537.9	746.4	161.6	302.6	681.4	158.0	208.4	438.2
2033	-6.6	620.5	752.0	161.1	301.9	682.5	157.5	207.3	435.3
2034	-6.9	681.0	754.7	160.3	300.5	682.9	156.4	206.6	433.8
2035	-7.4	722.1	755.5	159.0	298.9	682.6	155.1	206.2	433.0
2036	-7.8	746.2	754.7	-	-	-	-	-	-
2037	-8.3	760.1	754.4	-	-	-	-	-	-
2038	-8.8	768.0	753.4	-	-	-	-	-	-
2039	-9.1	772.0	751.9	-	-	-	-	-	-
2040	-9.6	774.1	749.4	-	-	-	-	-	-

Red mullet

Table 10: Average catch percentages of *M. barbatus* with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.2	0.5	-2.5	-37.7	-37.9	-40.8	-3.7	-41.9	-41.9
2021	0.0	-2.0	-8.6	-2.0	-5.1	-16.6	-5.6	-4.5	-14.7
2022	0.5	-2.9	-9.7	11.4	4.0	-10.2	-7.0	11.0	-7.4
2023	0.2	-3.1	-10.1	14.6	5.6	-10.3	3.0	15.9	7.8
2024	-0.2	-2.2	-11.5	15.6	13.6	3.8	5.0	17.3	14.7
2025	-0.4	-2.1	-12.9	16.3	16.9	10.8	5.9	17.6	17.5
2026	-0.2	-1.8	0.1	16.6	18.4	14.0	5.6	17.5	18.8
2027	0.0	-1.6	6.2	16.2	19.1	15.7	5.7	17.7	19.1
2028	0.0	-1.3	9.3	16.5	19.2	16.5	5.4	17.8	19.0
2029	0.0	-0.9	10.6	16.7	18.5	16.8	5.7	17.6	18.8
2030	0.3	-1.2	11.2	16.6	18.2	16.9	5.6	17.7	19.1
2031	-0.6	-1.6	11.8	16.4	18.4	17.1	5.9	17.7	19.2
2032	-0.1	-2.0	11.8	16.7	18.6	17.3	5.3	17.9	19.2
2033	-0.3	5.2	11.7	16.8	18.5	17.3	6.2	18.3	19.2
2034	-0.3	8.7	11.3	16.3	18.4	17.5	5.7	18.0	19.0
2035	-0.2	10.6	11.3	16.1	18.7	17.6	5.9	18.0	18.9
2036	-0.1	11.4	11.3	-	-	-	-	-	-
2037	0.0	11.9	11.4	-	-	-	-	-	-
2038	-0.5	12.0	11.5	-	-	-	-	-	-
2039	-0.1	12.1	11.7	-	-	-	-	-	-
2040	-0.3	12.4	11.9	-	-	-	-	-	-

Table 11: F percentages of *M. barbatus* with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.2	0.5	-2.5	-37.7	-37.9	-40.8	-3.7	-41.9	-41.9
2021	0.0	-2.0	-8.6	-2.0	-5.1	-16.6	-5.6	-4.5	-14.7
2022	0.5	-2.9	-9.7	11.4	4.0	-10.2	-7.0	11.0	-7.4
2023	0.2	-3.1	-10.1	14.6	5.6	-10.3	3.0	15.9	7.8
2024	-0.2	-2.2	-11.5	15.6	13.6	3.8	5.0	17.3	14.7
2025	-0.4	-2.1	-12.9	16.3	16.9	10.8	5.9	17.6	17.5
2026	-0.2	-1.8	0.1	16.6	18.4	14.0	5.6	17.5	18.8
2027	0.0	-1.6	6.2	16.2	19.1	15.7	5.7	17.7	19.1
2028	0.0	-1.3	9.3	16.5	19.2	16.5	5.4	17.8	19.0
2029	0.0	-0.9	10.6	16.7	18.5	16.8	5.7	17.6	18.8
2030	0.3	-1.2	11.2	16.6	18.2	16.9	5.6	17.7	19.1
2031	-0.6	-1.6	11.8	16.4	18.4	17.1	5.9	17.7	19.2
2032	-0.1	-2.0	11.8	16.7	18.6	17.3	5.3	17.9	19.2
2033	-0.3	5.2	11.7	16.8	18.5	17.3	6.2	18.3	19.2
2034	-0.3	8.7	11.3	16.3	18.4	17.5	5.7	18.0	19.0
2035	-0.2	10.6	11.3	16.1	18.7	17.6	5.9	18.0	18.9
2036	-0.1	11.4	11.3	-	-	-	-	-	-
2037	0.0	11.9	11.4	-	-	-	-	-	-
2038	-0.5	12.0	11.5	-	-	-	-	-	-
2039	-0.1	12.1	11.7	-	-	-	-	-	-
2040	-0.3	12.4	11.9	-	-	-	-	-	-

Table 12: Average SSB percentages of *M. barbatus* with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.2	0.0	3.3	42.2	42.1	44.2	4.9	45.7	45.5
2021	-0.2	2.7	16.8	100.7	104.7	122.4	17.3	113.3	122.8
2022	-0.1	10.2	40.5	124.2	141.3	190.2	36.2	144.1	184.3
2023	-0.5	20.4	71.9	130.2	169.0	256.0	50.1	154.0	226.7
2024	-1.0	32.8	111.9	131.9	187.1	308.5	53.8	156.3	246.2
2025	-1.2	46.3	161.4	132.7	194.9	335.6	54.7	156.5	253.9
2026	-1.2	61.7	204.5	132.8	198.0	347.9	54.4	156.1	257.0
2027	-1.3	79.2	227.3	131.9	198.9	353.7	54.1	156.0	257.1
2028	-1.4	99.2	237.9	131.9	198.3	355.9	53.7	155.6	256.2
2029	-1.4	121.6	242.2	131.8	196.4	356.3	53.6	154.9	255.3
2030	-1.7	146.0	244.1	131.2	195.3	355.9	53.4	154.7	255.4
2031	-2.3	173.1	244.9	130.6	195.3	355.9	53.2	154.3	254.9
2032	-2.2	203.0	244.5	130.7	195.1	355.6	52.6	154.2	254.2
2033	-2.5	227.2	243.5	130.1	194.3	354.9	52.9	154.3	253.3
2034	-2.6	239.8	241.9	129.0	193.8	354.6	52.3	153.4	252.3
2035	-2.7	245.9	241.0	128.2	193.8	354.1	52.1	153.1	251.7
2036	-2.7	248.4	240.3	-	-	-	-	-	-
2037	-2.9	249.5	239.7	-	-	-	-	-	-
2038	-3.3	249.3	239.4	-	-	-	-	-	-
2039	-3.2	249.1	239.3	-	-	-	-	-	-
2040	-3.4	248.9	239.0	-	-	-	-	-	-

Trawl fleet (OTB)

Table 13: Average catch percentages of trawl fleet (OTB) with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.2	0.1	-4.0	-22.6	-22.6	-26.3	-5.3	-27.7	-27.7
2021	-0.2	-3.1	-12.2	-0.2	-4.1	-15.1	-8.2	-2.3	-11.3
2022	-0.2	-5.7	-14.1	10.9	2.8	-9.8	-9.5	10.6	-4.5
2023	-0.4	-5.5	-14.7	13.4	3.7	-10.4	1.8	14.0	9.3
2024	-0.4	-4.7	-16.2	14.0	11.6	3.2	5.8	15.1	14.6
2025	-0.6	-4.2	-18.0	14.3	14.5	9.7	7.3	15.6	17.0
2026	-0.5	-3.6	-5.3	14.7	15.8	12.9	8.3	15.6	18.3
2027	-0.5	-3.3	1.7	14.8	16.3	14.6	8.5	15.5	18.7
2028	-0.7	-3.0	5.4	14.9	16.6	15.5	8.5	15.9	18.8
2029	-0.7	-3.1	7.4	14.8	16.5	16.0	8.4	16.1	19.1
2030	-0.6	-3.6	8.3	14.7	16.5	16.1	8.3	16.0	19.4
2031	-0.9	-4.4	8.9	14.7	16.6	16.1	8.4	15.9	19.5
2032	-0.8	-5.3	9.2	14.7	16.8	16.4	8.4	15.8	19.5
2033	-0.7	1.6	9.3	14.9	16.8	16.6	8.6	15.7	19.2
2034	-0.8	5.5	9.3	14.8	16.6	16.7	8.5	15.8	19.2
2035	-0.7	7.6	9.3	14.7	16.6	16.8	8.3	15.8	19.3
2036	-0.7	8.5	9.5	-	-	-	-	-	-
2037	-0.9	9.0	9.6	-	-	-	-	-	-
2038	-1.0	9.3	9.6	-	-	-	-	-	-
2039	-0.8	9.5	9.6	-	-	-	-	-	-
2040	-1.1	9.7	9.7	-	-	-	-	-	-

Table 14: Average profits percentages of trawl fleet (OTB) with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.5	0.1	-13.3	-80.4	-80.4	-91.5	-17.7	-98.7	-98.2
2021	-1.0	-10.1	-40.0	6.5	-6.5	-43.1	-28.3	-2.2	-32.5
2022	-1.2	-19.1	-47.5	51.8	23.4	-21.4	-33.6	49.6	-4.4
2023	-1.5	-18.5	-50.1	61.5	26.3	-25.3	2.2	61.8	39.9
2024	-1.0	-16.6	-56.3	63.5	50.7	13.6	15.0	66.2	55.3
2025	-1.7	-15.7	-64.6	64.6	59.6	31.0	19.9	68.4	62.7
2026	-1.8	-14.9	-30.4	65.9	63.6	39.2	23.0	68.4	67.1
2027	-1.5	-15.2	-13.3	66.7	65.5	43.7	24.3	68.0	68.4
2028	-2.1	-15.9	-5.5	67.3	66.6	46.7	24.3	69.7	69.3
2029	-2.4	-18.1	-1.1	67.0	66.9	48.7	23.5	70.6	70.2
2030	-2.1	-21.9	1.5	66.3	67.1	49.1	23.5	69.7	71.9
2031	-3.1	-26.7	3.2	66.7	67.4	49.7	24.3	69.7	72.8
2032	-2.8	-31.9	4.6	67.0	67.9	50.6	24.8	69.3	72.8
2033	-2.0	-13.8	5.5	67.5	67.9	51.6	24.8	68.9	71.5
2034	-2.3	-4.2	5.8	67.5	67.4	52.4	23.9	69.7	71.5
2035	-2.0	0.4	6.0	66.9	67.0	52.5	23.9	70.2	72.4
2036	-2.4	2.5	6.4	-	-	-	-	-	-
2037	-3.0	3.8	7.2	-	-	-	-	-	-
2038	-2.9	4.9	7.3	-	-	-	-	-	-
2039	-2.5	5.7	7.2	-	-	-	-	-	-
2040	-3.3	6.2	7.2	-	-	-	-	-	-

Table 15: Average crew wage percentages per day of trawl fleet (OTB) with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	0.2	11.2	16.0	-43.3	-37.0	-36.7	16.7	-38.5	-38.4
2021	0.0	16.7	22.2	3.5	19.3	20.1	27.9	27.2	24.5
2022	-0.1	23.1	45.3	27.9	54.2	72.9	48.8	62.7	76.7
2023	-0.3	37.2	78.3	33.1	74.1	68.8	82.9	71.1	118.9
2024	0.0	54.2	113.8	34.2	94.1	109.8	95.1	74.1	133.9
2025	-0.4	72.3	150.2	34.8	101.4	128.1	99.5	75.6	140.7
2026	-0.5	92.4	221.0	35.5	104.7	136.7	102.6	75.5	144.9
2027	-0.3	113.3	256.3	35.9	106.3	141.5	103.7	75.4	146.5
2028	-0.6	136.2	272.5	36.2	107.2	144.6	103.8	76.6	147.0
2029	-0.8	159.0	281.7	36.0	107.4	146.7	103.2	77.1	148.0
2030	-0.6	181.3	287.1	35.7	107.6	147.1	102.9	76.5	149.5
2031	-1.1	203.4	290.5	35.9	107.8	147.8	103.7	76.4	150.3
2032	-1.0	226.1	293.4	36.1	108.3	148.7	104.3	76.1	150.5
2033	-0.5	264.2	295.3	36.3	108.3	149.8	104.3	76.0	149.3
2034	-0.7	284.6	296.0	36.3	107.9	150.6	103.7	76.4	149.3
2035	-0.6	294.3	296.3	36.0	107.5	150.7	103.5	76.7	150.0
2036	-0.8	298.7	297.2	-	-	-	-	-	-
2037	-1.1	301.5	298.9	-	-	-	-	-	-
2038	-1.1	303.8	299.1	-	-	-	-	-	-
2039	-0.8	305.4	298.8	-	-	-	-	-	-
2040	-1.3	306.6	298.8	-	-	-	-	-	-

Demersal longline fleet (HOK)

Table 16: Average catch percentages of demersal longline fleet (HOK) with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.2	-0.1	2.9	6.0	5.9	8.9	4.4	10.2	10.2
2021	-0.6	2.4	20.9	61.1	64.5	88.9	24.0	80.0	90.8
2022	-1.0	13.9	47.5	118.5	143.0	188.9	25.5	153.4	145.6
2023	-1.4	36.1	73.0	138.0	203.7	233.3	63.5	180.2	223.1
2024	-1.7	67.7	96.9	144.4	250.2	322.5	86.4	190.2	261.6
2025	-1.9	86.3	121.4	146.8	272.3	373.0	95.8	194.7	280.6
2026	-2.2	104.6	185.6	148.3	282.1	399.6	100.9	197.9	289.4
2027	-2.5	123.2	230.5	149.4	287.4	414.5	103.1	199.1	294.0
2028	-2.6	141.1	255.4	149.7	290.2	422.3	104.4	198.4	297.4
2029	-3.2	157.9	269.5	149.7	291.1	428.4	105.0	198.3	298.2
2030	-3.6	173.2	277.6	148.8	291.3	430.9	104.8	198.8	299.0
2031	-3.6	185.1	282.1	148.6	291.4	431.6	105.1	198.8	299.7
2032	-4.2	195.6	285.0	148.6	291.4	433.2	105.0	198.2	299.9
2033	-4.5	231.4	287.2	148.4	291.6	434.7	104.5	197.2	299.6
2034	-4.4	256.0	288.7	148.1	290.9	435.9	103.8	196.4	299.1
2035	-4.7	270.6	289.4	147.6	290.0	436.4	103.2	196.3	298.5
2036	-5.0	278.8	289.0	-	-	-	-	-	-
2037	-5.3	282.3	289.6	-	-	-	-	-	-
2038	-5.7	285.3	290.4	-	-	-	-	-	-
2039	-5.9	286.7	289.9	-	-	-	-	-	-
2040	-6.1	287.6	289.5	-	-	-	-	-	-

Table 17: Average profits (M€) in absolute numbers of demersal longline fleet (HOK) with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.46	-0.46	-0.44	-0.42	-0.42	-0.41	-0.44	-0.40	-0.40
2021	-0.46	-0.45	-0.34	-0.08	-0.06	0.08	-0.33	0.03	0.09
2022	-0.46	-0.38	-0.19	0.27	0.42	0.69	-0.31	0.48	0.44
2023	-0.47	-0.26	-0.03	0.39	0.79	0.96	-0.09	0.65	0.91
2024	-0.47	-0.07	0.12	0.43	1.07	1.50	0.05	0.71	1.14
2025	-0.47	0.04	0.27	0.45	1.20	1.80	0.11	0.74	1.25
2026	-0.47	0.15	0.65	0.46	1.26	1.95	0.13	0.76	1.31
2027	-0.47	0.26	0.91	0.46	1.29	2.04	0.15	0.76	1.34
2028	-0.47	0.37	1.05	0.47	1.31	2.09	0.16	0.76	1.36
2029	-0.48	0.47	1.13	0.47	1.31	2.13	0.16	0.76	1.36
2030	-0.48	0.56	1.18	0.46	1.32	2.14	0.16	0.76	1.37
2031	-0.48	0.63	1.21	0.46	1.32	2.15	0.16	0.76	1.37
2032	-0.48	0.70	1.22	0.46	1.32	2.16	0.16	0.76	1.37
2033	-0.48	0.90	1.24	0.46	1.32	2.16	0.16	0.75	1.37
2034	-0.48	1.05	1.25	0.46	1.31	2.17	0.15	0.75	1.37
2035	-0.49	1.13	1.25	0.45	1.31	2.18	0.15	0.75	1.36
2036	-0.49	1.18	1.25	-	-	-	-	-	-
2037	-0.49	1.20	1.25	-	-	-	-	-	-
2038	-0.49	1.22	1.26	-	-	-	-	-	-
2039	-0.49	1.23	1.26	-	-	-	-	-	-
2040	-0.49	1.23	1.25	-	-	-	-	-	-

Table 18 : Average crew wage (€/day) in absolute numbers of demersal longline fleet (HOK) with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	2.6	2.7	4.1	4.2	4.7	6.2	4.9	7.3	7.4
2021	2.5	3.7	12.4	20.0	25.9	42.7	14.7	34.6	47.5
2022	2.4	8.3	29.6	36.4	59.3	108.7	21.0	63.5	97.7
2023	2.2	18.2	54.8	42.0	91.8	167.0	43.9	74.1	145.9
2024	2.1	34.5	90.3	43.9	114.9	227.4	57.9	77.9	169.8
2025	2.1	48.2	138.3	44.5	124.6	261.5	63.4	79.8	181.4
2026	2.0	64.3	204.7	45.0	128.9	279.1	66.5	81.0	186.9
2027	1.9	83.6	250.8	45.3	131.2	289.0	67.9	81.5	189.8
2028	1.9	105.7	275.6	45.4	132.5	294.3	68.7	81.2	192.0
2029	1.7	130.9	289.7	45.4	132.9	298.6	69.1	81.2	192.4
2030	1.6	159.0	298.2	45.1	133.0	300.3	69.0	81.4	193.0
2031	1.6	188.3	303.1	45.1	133.0	300.9	69.2	81.4	193.5
2032	1.5	220.5	306.3	45.1	133.0	302.0	69.1	81.2	193.6
2033	1.4	258.5	308.8	45.0	133.1	303.0	68.8	80.8	193.3
2034	1.4	284.6	310.4	45.0	132.8	303.9	68.4	80.4	193.1
2035	1.3	299.7	311.1	44.8	132.4	304.2	68.0	80.4	192.7
2036	1.2	308.3	310.7	-	-	-	-	-	-
2037	1.2	312.2	311.4	-	-	-	-	-	-
2038	1.0	315.4	312.2	-	-	-	-	-	-
2039	1.0	317.0	311.8	-	-	-	-	-	-
2040	0.9	318.1	311.4	-	-	-	-	-	-

Demersal gillnet fleet (GNS)

Table 19: Average catch percentages of demersal gillnet fleet (GNS) with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-0.2	0.1	3.7	26.8	26.6	29.5	-1.0	23.3	23.1
2021	-0.4	3.2	2.1	94.7	98.9	87.0	-6.8	99.6	69.5
2022	-0.3	8.7	7.8	124.8	135.3	111.6	-11.6	135.8	75.0
2023	-0.6	12.8	17.1	130.3	142.5	115.2	6.1	144.0	104.0
2024	-0.9	19.1	24.1	131.4	162.4	148.0	13.1	145.7	113.6
2025	-1.1	25.3	29.5	132.2	168.6	161.0	15.5	146.3	117.8
2026	-1.1	31.1	55.7	132.8	171.6	167.0	16.6	146.8	119.3
2027	-1.2	36.7	69.8	132.7	172.8	170.5	16.9	147.3	119.9
2028	-1.3	41.7	76.9	132.8	173.3	171.9	17.0	147.0	120.1
2029	-1.5	46.1	80.8	133.3	172.5	173.0	17.1	146.7	120.0
2030	-1.6	49.6	82.4	132.8	172.1	173.5	17.0	147.2	120.5
2031	-1.9	51.6	83.2	132.4	172.7	173.6	17.2	147.3	121.0
2032	-2.1	53.2	83.7	133.0	173.2	174.2	16.9	147.2	120.8
2033	-2.3	66.8	83.9	133.1	173.0	174.7	17.0	147.3	120.8
2034	-2.2	74.2	84.0	132.5	172.7	175.1	16.7	146.9	120.5
2035	-2.3	78.4	84.1	132.1	172.8	175.4	16.5	146.8	120.4
2036	-2.4	80.4	84.1	-	-	-	-	-	-
2037	-2.5	80.9	84.3	-	-	-	-	-	-
2038	-2.9	81.5	84.6	-	-	-	-	-	-
2039	-2.8	81.6	84.5	-	-	-	-	-	-
2040	-3.0	81.9	84.6	-	-	-	-	-	-

Table 20: Average profits (M€) in absolute numbers of demersal gillnet fleet (GNS) with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	-3.61	-3.61	-3.58	-3.4	-3.4	-3.4	-3.4	-3.4	-3.4
2021	-3.61	-3.58	-3.59	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9
2022	-3.61	-3.54	-3.53	-2.6	-2.5	-2.6	-2.6	-2.5	-2.6
2023	-3.61	-3.49	-3.42	-2.5	-2.4	-2.6	-2.5	-2.4	-2.6
2024	-3.61	-3.43	-3.34	-2.5	-2.2	-2.2	-2.5	-2.2	-2.2
2025	-3.62	-3.36	-3.27	-2.5	-2.1	-2.1	-2.5	-2.1	-2.1
2026	-3.62	-3.30	-3.02	-2.5	-2.1	-2.0	-2.5	-2.1	-2.0
2027	-3.62	-3.24	-2.88	-2.5	-2.1	-2.0	-2.5	-2.1	-2.0
2028	-3.62	-3.18	-2.82	-2.5	-2.1	-2.0	-2.5	-2.1	-2.0
2029	-3.62	-3.13	-2.79	-2.5	-2.1	-2.0	-2.5	-2.1	-2.0
2030	-3.62	-3.09	-2.77	-2.5	-2.1	-2.0	-2.5	-2.1	-2.0
2031	-3.62	-3.07	-2.76	-2.5	-2.1	-2.0	-2.5	-2.1	-2.0
2032	-3.63	-3.05	-2.76	-2.5	-2.1	-2.0	-2.5	-2.1	-2.0
2033	-3.63	-2.92	-2.75	-2.5	-2.1	-2.0	-2.5	-2.1	-2.0
2034	-3.63	-2.84	-2.75	-2.5	-2.1	-1.9	-2.5	-2.1	-1.9
2035	-3.63	-2.81	-2.75	-2.5	-2.1	-1.9	-2.5	-2.1	-1.9
2036	-3.63	-2.79	-2.75	-	-	-	-	-	-
2037	-3.63	-2.78	-2.75	-	-	-	-	-	-
2038	-3.63	-2.78	-2.74	-	-	-	-	-	-
2039	-3.63	-2.78	-2.74	-	-	-	-	-	-
2040	-3.64	-2.77	-2.75	-	-	-	-	-	-

Table 21: Average crew wage (€/day) in absolute numbers of demersal gillnet fleet (GNS) with the introduction of the different management measures in 2020 (scenarios 1 to 8) compared to 2019 without any modification.

Year	Sc.0	Sc.1	Sc.2	Sc.3	Sc.4	Sc.5	Sc.6	Sc.7	Sc.8
2020	1.6	1.7	2.2	2.7	3.0	3.6	2.7	3.0	3.6
2021	1.6	2.1	2.6	6.2	7.9	9.2	6.2	7.9	9.2
2022	1.6	2.8	4.1	8.3	12.2	15.3	8.3	12.2	15.3
2023	1.5	3.5	6.7	8.8	14.6	20.6	8.8	14.6	20.6
2024	1.5	4.7	10.1	8.8	16.6	25.8	8.8	16.6	25.8
2025	1.5	6.0	14.2	8.9	17.2	28.0	8.9	17.2	28.0
2026	1.5	7.5	20.3	8.9	17.5	28.9	8.9	17.5	28.9
2027	1.5	9.3	23.8	8.9	17.6	29.4	8.9	17.6	29.4
2028	1.5	11.2	25.3	8.9	17.7	29.7	8.9	17.7	29.7
2029	1.5	13.4	26.2	8.9	17.6	29.9	8.9	17.6	29.9
2030	1.5	15.7	26.6	8.9	17.6	29.9	8.9	17.6	29.9
2031	1.5	18.0	26.8	8.9	17.6	29.9	8.9	17.6	29.9
2032	1.5	20.6	26.9	8.9	17.7	30.0	8.9	17.7	30.0
2033	1.4	23.9	27.0	8.9	17.7	30.1	8.9	17.7	30.1
2034	1.4	25.7	27.1	8.9	17.6	30.2	8.9	17.6	30.2
2035	1.4	26.7	27.1	8.9	17.6	30.2	8.9	17.6	30.2
2036	1.4	27.2	27.1	-	-	-	-	-	-
2037	1.4	27.3	27.1	-	-	-	-	-	-
2038	1.4	27.5	27.2	-	-	-	-	-	-
2039	1.4	27.5	27.2	-	-	-	-	-	-
2040	1.4	27.6	27.1	-	-	-	-	-	-

ANNEX II: Results of the simulations of the bioeconomic model of GSA 06

Reduction of fishing effort to reach *M. barbatus* F_{MSY}.

Figure 16: Results of the bioeconomic model of catch (t), effort (average days at sea), profits (M€) and crew wage (€/day) for demersal longline fleet (HOK) under scenarios

Scenario 0: Status quo, scenario 1: 10% annual reduction and scenario 2: 20% annual reduction

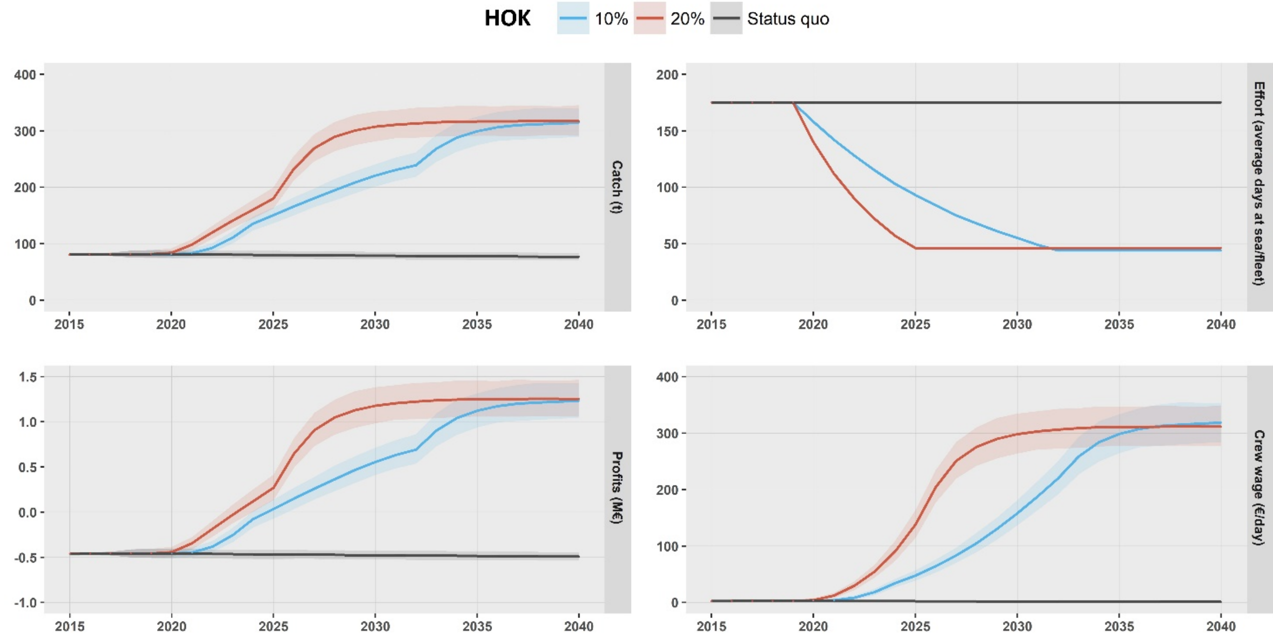
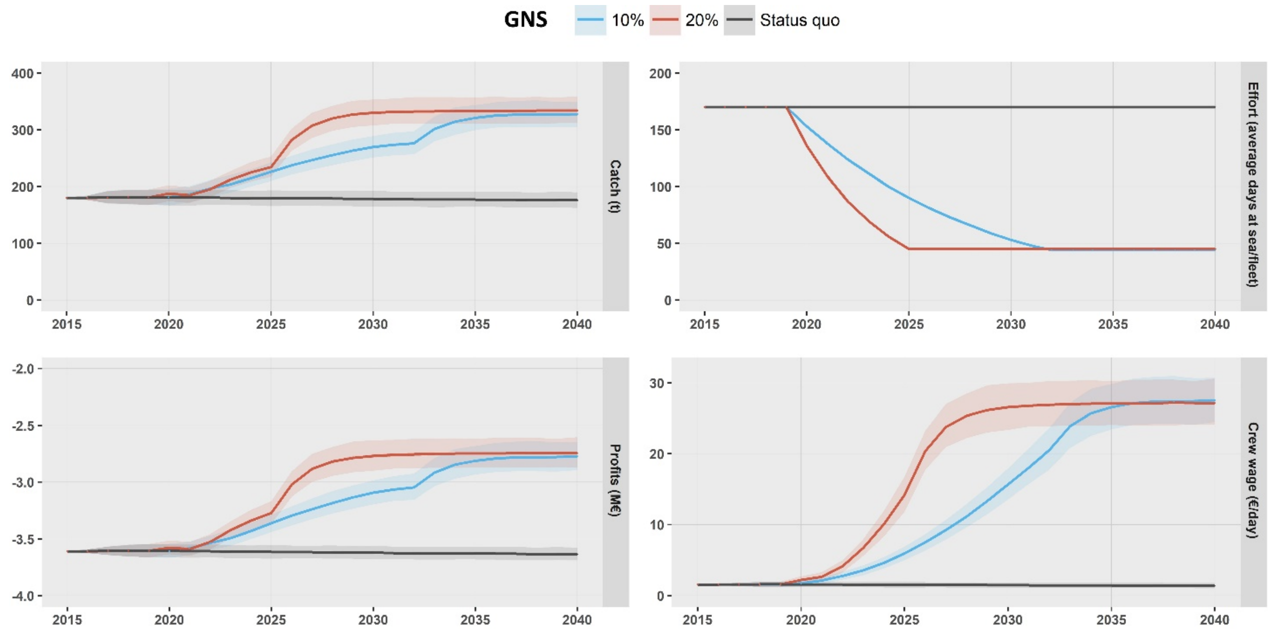


Figure 17: Results of the bioeconomic model of catch (t), effort (average days at sea), profits (M€) and crew wage (€/day) for demersal gillnet fleet (GNS) under scenarios

Scenario 0: Status quo, scenario 1: 10% annual reduction and scenario 2: 20% annual reduction



Selectivity change introducing the T90 mesh + effort reduction

Figure 18: Results of the bioeconomic model of catch (tn), fishing mortality (F_{0-2}), SSB (tn) and constant recruitment for M. barbatus under historical series and scenarios

Scenario 0: Status quo, scenario 3: selectivity change to T90, scenario 4: selectivity change plus 10% annual reduction during 4 years and scenario 5: selectivity change plus 20% annual reduction during 4 years

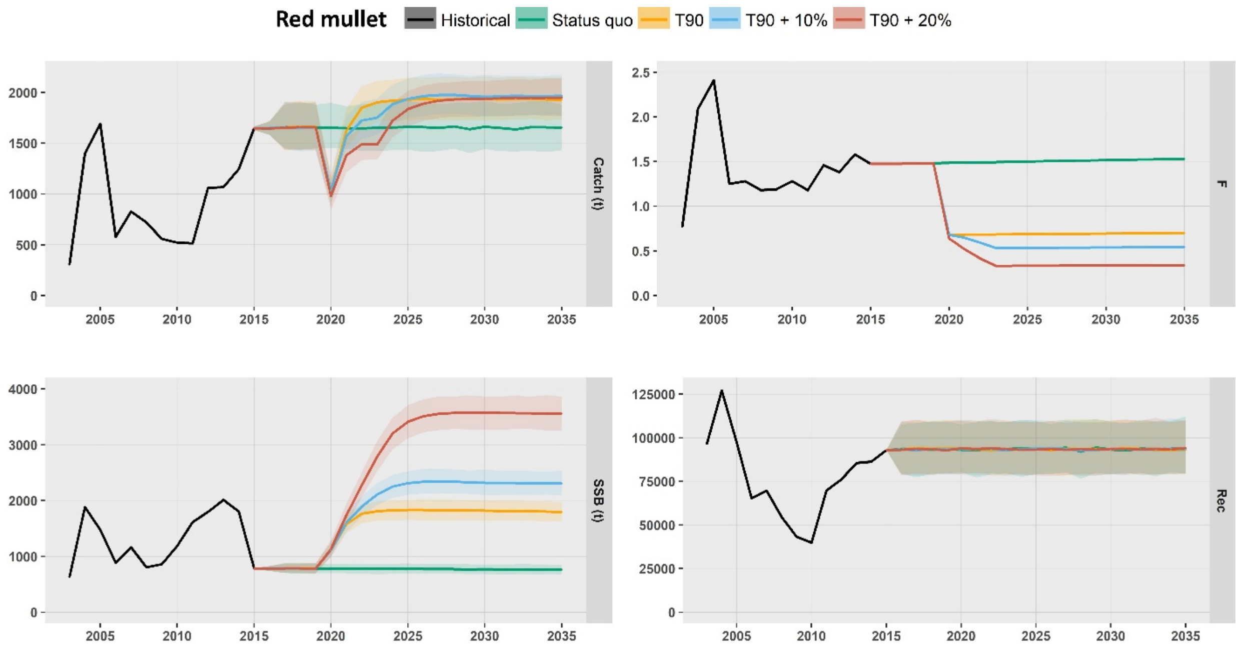
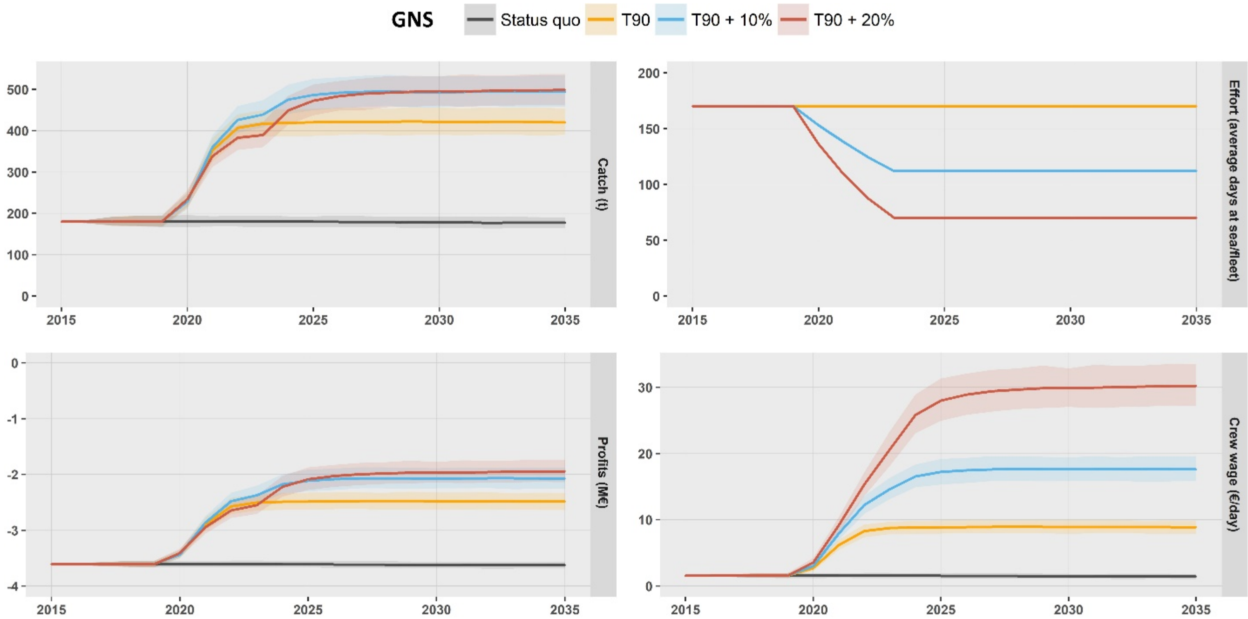


Figure 19: Results of the bioeconomic model of catch (t), effort (average days at sea), profits (M€) and crew wage (€/day) for demersal gillnet fleet (GNS) under scenarios

Scenario 0: Status quo, scenario 3: selectivity change to T90, scenario 4: selectivity change plus 10% annual reduction during 4 years and scenario 5: selectivity change plus 20% annual reduction during 4 years



Reduction of two days per week

Figure 20: Results of the bioeconomic model of catch (t), effort (average days at sea), profits (M€) and crew wage (€/day) for demersal longline fleet (HOK) under scenarios

Scenario 0: Status quo, scenario 6: 40% effort reduction, scenario 7: selectivity change plus 20% effort reduction and scenario 8 selectivity change plus 40% effort reduction

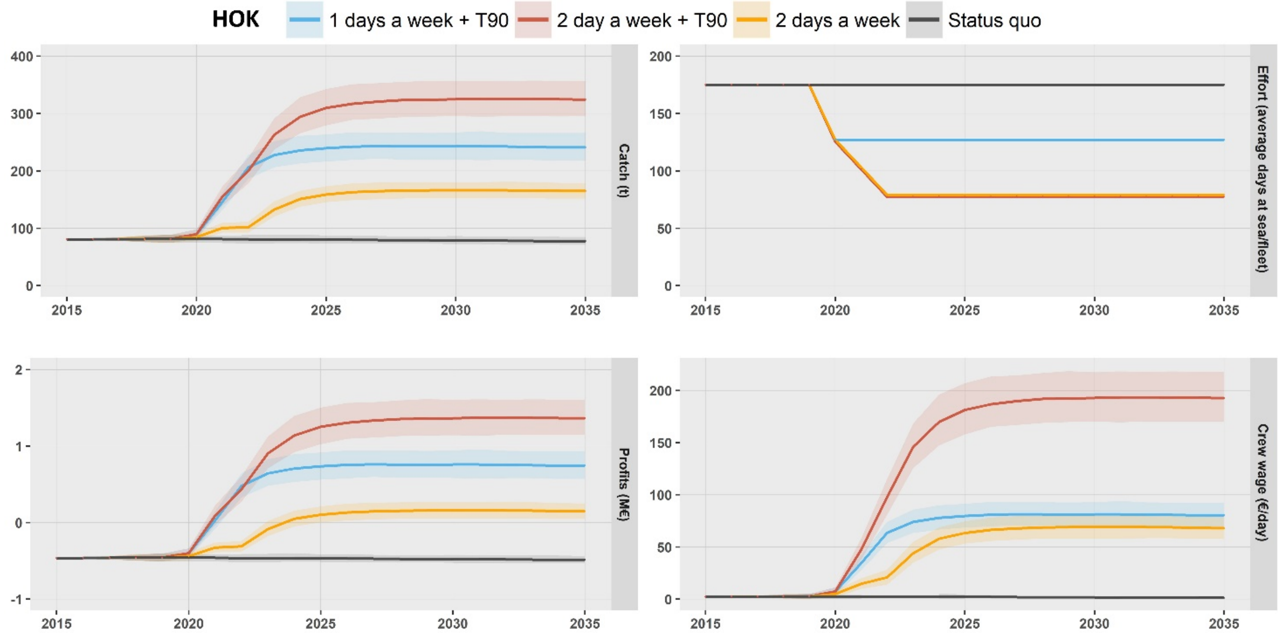
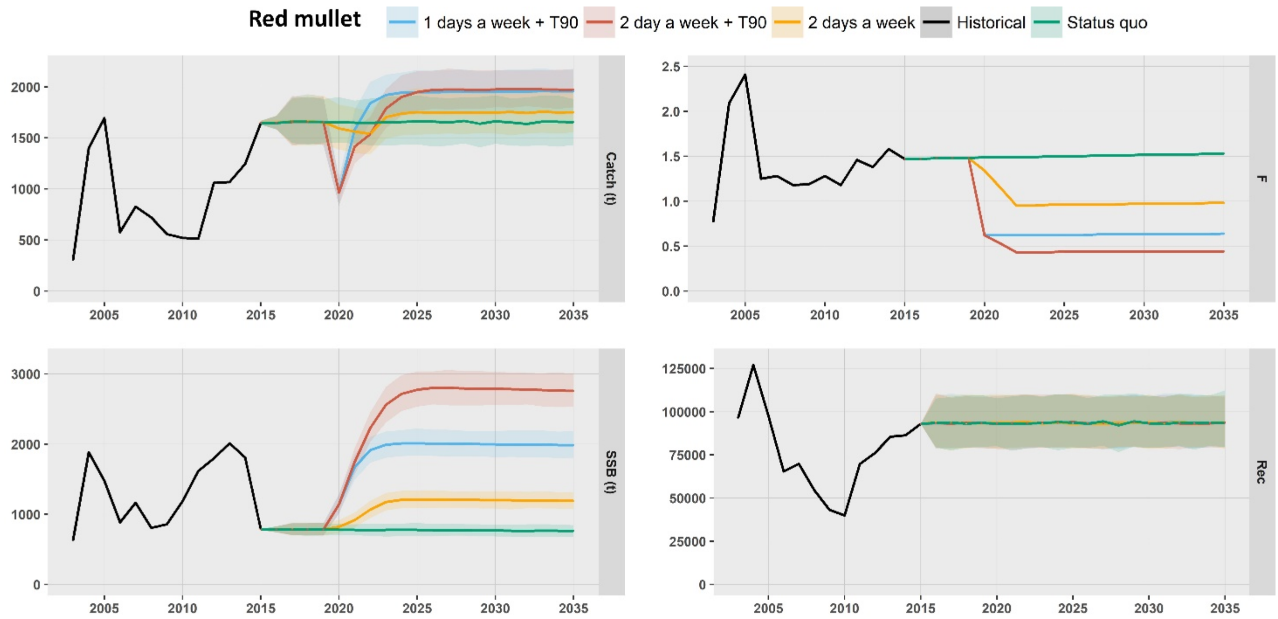


Figure 21: Results of the bioeconomic model of catch (tn), fishing mortality (F_{0-2}), SSB (tn) and constant recruitment for M. barbatus under historical series and scenarios

Scenario 0: Status quo, scenario 6: 40% effort reduction, scenario 7: selectivity change plus 20% effort reduction and scenario 8 selectivity change plus 40% effort reduction



The demersal fisheries in the Mediterranean Sea are **heavily overfished but the landing obligation will not help to reach MSY** because it will not decrease fishing mortality. The new proposal of the Commission introduces ***total allowable effort*** as a new way to regulate Western Mediterranean demersal fisheries by significantly **reducing fishing time**. However, this new management measure must be complemented with increased gear selectivity, implementation of closed areas and local co-management plans. Different approaches to reduce fishing mortality may have different socio-economic impact.

PE 629.179
IP/B/PECH/IC/2018-069

Print ISBN 978-92-846-4119-2 | doi:10.2861/431330 | QA-03-18-432-EN-C
PDF ISBN 978-92-846-4118-5 | doi:10.2861/20951 | QA-03-18-432-EN-N