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D 4.6.2 – Management scenarios of policy using BEMTOOL outputs

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Management scenarios of policy using BEMTOOL outputs

FAIRSEA – Fisheries in the Adriatic Region – a shared Ecosystem Approach

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Contents

Acronyms

AER	Annual Economic Report
DFN	Set-nets and gillnets
DPS	Parapenaeus longirostris, deep water rose shrimp
DTS	Demersal trawlers
F	Fishing mortality
Flow	Low value of the F_{MSY} range
F_{MSY}	Fishing mortality at the Maximum Sustainable Yield
Fupper	Upper value of the F_{MSY} range
FDI	Fisheries Dependent Information
GFCM	General Fisheries Commission for the Mediterranean
GSA	Geographical subarea
GT	Gross tonnage
HKE	Merluccius merluccius, European hake
HOK	Hooks
KW	Kilo Watt
MEY	Maximum Economic Yield
MSY	Maximum Sustainable Yield
MUT	Mullus barbatus, red mullet
NEP	Nephrops norvegicus, Norway lobster
OTB	Bottom Trawlers
PGP	Polyvalent passive gears
PP	Project Partner
R/BER	Current revenues to Break Even Revenues
ROI	Return of Investments
RP	Reference Point
SSB	Spawning Stock Biomass
SOL	Solea solea, common sole
STECF	Scientific, Technical and Economic Committee for Fisheries
TBB	Beam trawlers or Rapido trawler
WGSAD	Working Group on Stock Assessment- GFCM

1. INTRODUCTION

In FAIRSEA the module BIOECO is part of the integrated platform as informative layer to highlight potentialities of an Ecosystem Approach to Fishery (EAF) at different target groups.

Applications for showing the effects of different management measures through simulation provide the basis for informing policy makers of best practices and guidelines also transferable beyond the project scope.

Integrated bio-economic fisheries models (STECF, 2017; Nielsen et al., 2018) are crucial for designing multi-annual management plans (Bastardie et al., 2010; Mackinson et al., 2018; Spedicato et al., 2018) and assessing their effectiveness. By accounting for feedbacks from different components of the system, bio-economic models help to predict and potentially avoid unforeseen negative consequences of existing or proposed regulations (Eikeset et al., 2011; Woods et al., 2015).

The project foresaw in the Activity 4.6 BIOECO to provide tools useful for setting scenarios that allow to evaluate how fishery-driven impacts (e.g. fishing mortality, population and gear selectivity) and management or fishing strategies (e.g. closed season, changes in fishing opportunity) affect stock and fisheries dynamics in terms of landings, discards and economic performance. Monthly time scale, several fleet segments and their selectivity, species with stock assessments are the key elements for setting management scenarios in the whole Adriatic and sub-regions using BEMTOOL bioeconomic model.

The approach developed in this deliverable is based on simulations and forecast using scenario modelling to predict short and medium term changes in key bio-ecological, impact and economic indicators.

2. The BEMTOOL BIOECONOMIC MODEL

BEMTOOL is a multi-species and multi-gear bio-economic simulation model for mixed fisheries (Ulrich et al. 2012; Lizaso et al., 2020), developed for Mediterranean fisheries (Accadia et al., 2013). It consists of six operational modules characterized by different components: biological (age/length structured dynamic model, Lembo et al., 2009), Impact, Economic, Behavioural, Policy and Multi Criteria Decision Analysis (MCDA) (Rossetto et al, 2014; Spedicato et al., 2016; Russo et.al, 2017). BEMTOOL follows a multi-fleet approach simulating the effects of management scenarios on stocks and fisheries on a fine time scale (month). The model accounts for length/age-specific selection effects, discards, economic and social performances, effects of compliance with landing obligation and reference points. Compared to existing bio-economic tools, BEMTOOL presents a number of innovations, including the simulation of discard and escape survivability, the estimation of additional costs and, potentially, additional income due to the landing obligation (Spedicato et al., 2018). Six selectivity functions are implemented in BEMTOOL, plus a vector at length/age. The model can consider a large number of fleet groups. The implementation of a decision module based on Multi-Criteria Decision Analysis and Multi-attribute utility theory allows stakeholders to weigh model-based indicators and rank different management strategies.

The model can simulate management scenarios based on changes in fishing pattern, fishing effort, fishing mortality and TAC. A wide set of biological, pressure and economic indicators is the default output. The uncertainty implemented in the model following Monte Carlo paradigm allows a risk evaluation in terms of biological sustainability of the different management strategies accounting for the economic performances. BEMTOOL allows hence the inclusion of process and parameters errors (on recruitment, individual growth and natural mortality, maturity ogive, and fleet/gear selectivity), crucial to gauge management strategies from a MSE perspective (Spedicato et. al, 2017). Uncertainty can be applied according to three different probability distributions: normal, lognormal and uniform. BEMTOOLv.3 platform allows also the implementation of a scenario based on a TAC set according to an escapement strategy approach (GFCM, 2018). Reference points like F_{MSY}, MSY, MEY and the ones linked to the SSB can be estimated by the model.

BEMTOOL is able to take into account an increase in the fish price per kg depending on an increasing size as well as a change in the total catch due to a change in the characteristics of the fishing gear. Further information on the model applications can be found in STECF (2018). Recently BEMTOOL model has been used for simulating scenarios and predict the consequences of the implementation of the management measures foreseen in the MAP of the western Mediterranean in EMU2 (STECF, 2019a; 2019b; 2020a).

A scheme of the loop between the main components of BEMTOOL is reported in figure 2.1

In FAIRSEA BEMTOOL has been used for investigating the consequences of alternative scenarios to evaluate how changes/shifts in fishery-driven impacts (e.g. fishing mortality, fleet selectivity) and management or fishing strategies/tactics (e.g. closed season/areas, changes in fishing opportunity), affect stock and fisheries dynamics in terms of SSB, landings, discards and economic performance.

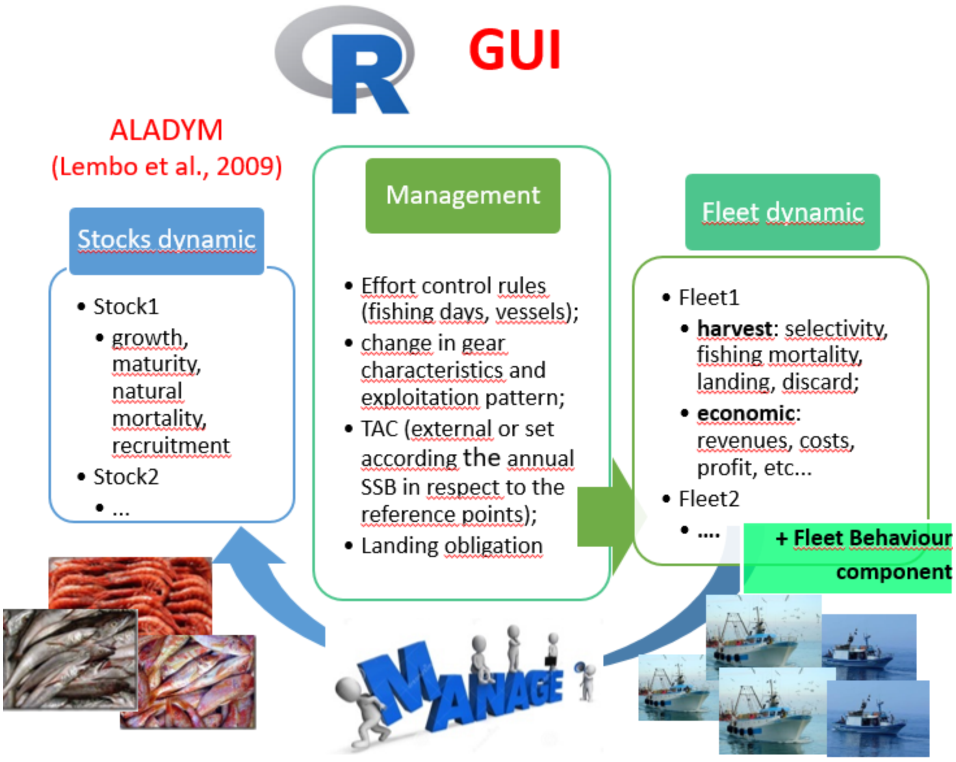


Fig. 2.1 A scheme of the loop between the main components of BEMTOOL.

2.1. Multi-Criteria Decision Analysis

The main challenge in fisheries management is that the different objectives point often out to different direction, with the long-term conservation objectives having short-term economic and social consequences. In BEMTOOL, a conceptual framework was developed to support a multi-criteria evaluation of alternative management scenarios.

Balancing different objectives is achieved in BEMTOOL using a multi-criteria decision analysis (MCDA) component implemented by combining two multi-criteria techniques: multi-attribute utility theory (MAUT) and the Analytic Hierarchy Process (AHP) (Rossetto et al., 2014).

MAUT relies on the idea that decision-makers attempt to maximize their utility with respect to a number of independent attributes (Keeney et al., 1993), each one representing a management objective.

The approach allows comparing alternative management scenarios on the basis of their ability to achieve a set of biological and socio economic goals. The analysis involves:

1) the identification of appropriate biological and socio-economic indicators and their organization into a proper hierarchy;
2) the definition of a set of mathematical functions to evaluate the satisfaction (utility) associated with each level of the different indicators (Figure 2.2); and
3) the determination of a set of weights derived through a pair-wise comparison of the indicators that represent the relative importance of each indicator to the overall utility (Fig. 2.3).

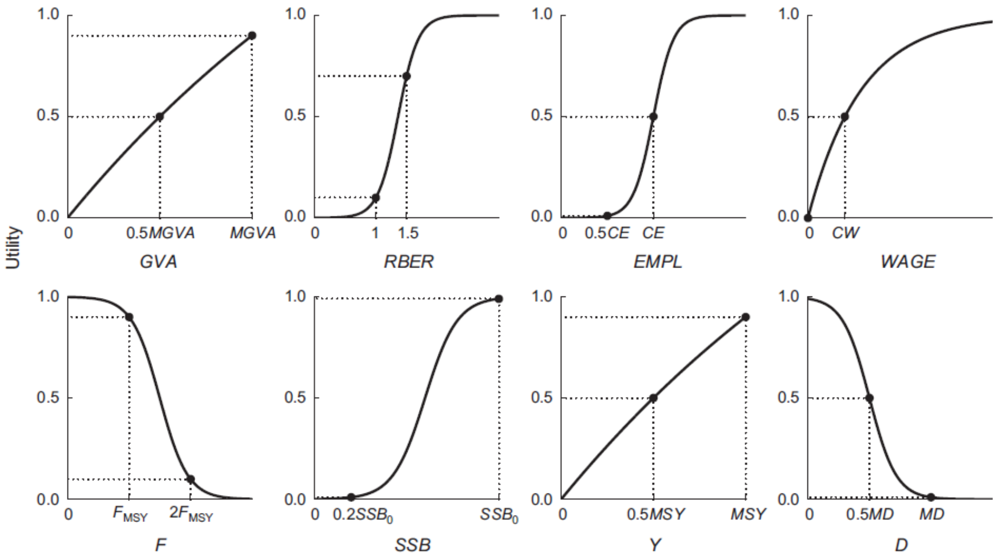


Figure 2.2 - Utility functions for the eight selected indicators: maximum GVA; current wage; current employment; F_{MSY}: fishing mortality at maximum sustainable yield; SSB_0: spawning stock biomass in unexploited conditions (F=0); Y: maximum sustainable yield; D: maximum discard rate.

The output of the MCDA in BEMTOOL is a combination of graphs (e.g. Fig. 2.3) synthetizing the utility of each scenario, taking into account the set of indicators estimated by the model. A different weighing set, reflecting a different perception about the relative importance of the different indicators by a stakeholder panel could be implemented following, for example, a consultation and a survey with stakeholders.

The flexible structure of the framework allows the incorporation of different management criteria and utility functions to adapt it to different decision problems.

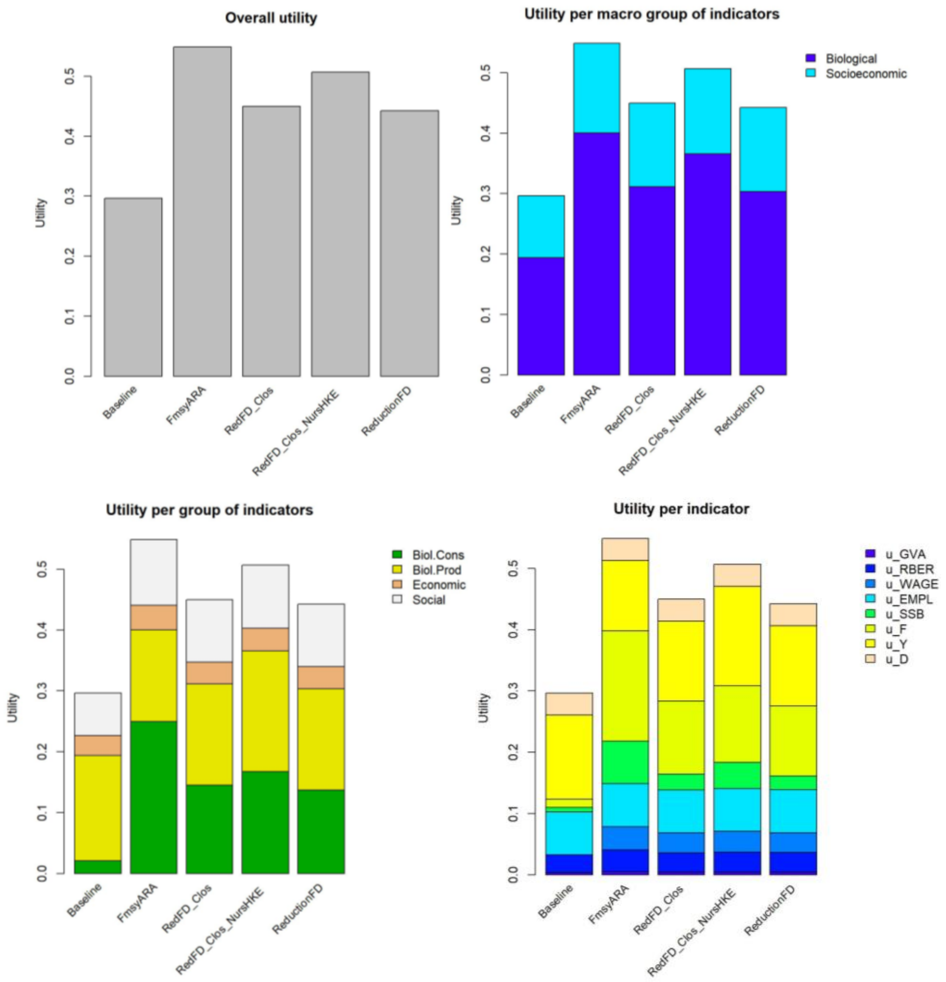


Fig. 2.3 Examples of the outputs of Multi Criteria Decision Analysis in BEMTOOL

This functionality of BEMTOOL has been used to compare the performance of the scenarios and also to account for the stakeholders inputs collected during the stakeholders' event in FAIRSEA.

3. SPECIES, STOCK STATUS AND FISHERIES

BEMTOOL utilises information from stock assessment as input, hence stocks that are analytically assessed can be explicitly modelled and considered as target species. Additionally, the fish population component of BEMTOOL, i.e. the ALADYM model (Lembo et al., 2009), is based on an age/size structure population dynamic, thus requiring information at age/size level. However, in BEMTOOL there is a so called "recruitment calibration" component of the model that allows the use of assessments from production models. In this case only the catches are used and the model calibrate the potential recruitment accordingly, taking into account mortality hypothesis.

The stocks included in the simulation of the different management scenarios are those with officially accepted assessments based on age-structured (analytical) assessment methods, but also on production model. In this case a particular function of BEMTOOL is used; details are given in the section 4. on model hindcasting.

The stocks included are: sole (GSA 17) (*Solea solea*, acronym SOL), European hake (GSA 17-18) (*Merluccius merluccius*, HKE), red mullet (GSA 17-18) (*Mullus barbatus*, MUT), Norway lobster (GSA 17-18) (*Nephrops norvegicus*, NEP), Deep-water pink shrimp (GSA 17-18-19) (*Parapenaeus longirostris*, DPS), European hake and Red mullet (GSA 19). These stocks were assessed and included in the Recommendation GFCM/43/2019/5 that put forward a set of rules for the management of the demersal fisheries in the Adriatic Sea.

Biological data of the target species are obtained from assessment reports from STECF EWG 20-15 (STECF, 2020b) and GFCM WGSAD report (GFCM, 2019; 2020). Previous STECF reports and GFCM WGSAD reports were also consulted. All the other species are however included in BEMTOOL as part of the production, with these other species contributing to the total landing and the total revenues of each fleet.

The effort and the socio-economic information by fleet was collected from FDI data (https://stecf.jrc.ec.europa.eu/dd/fdi), AER (https://stecf.jrc.ec.europa.eu/dd/fleet) and the FAIRSEA Data Call.

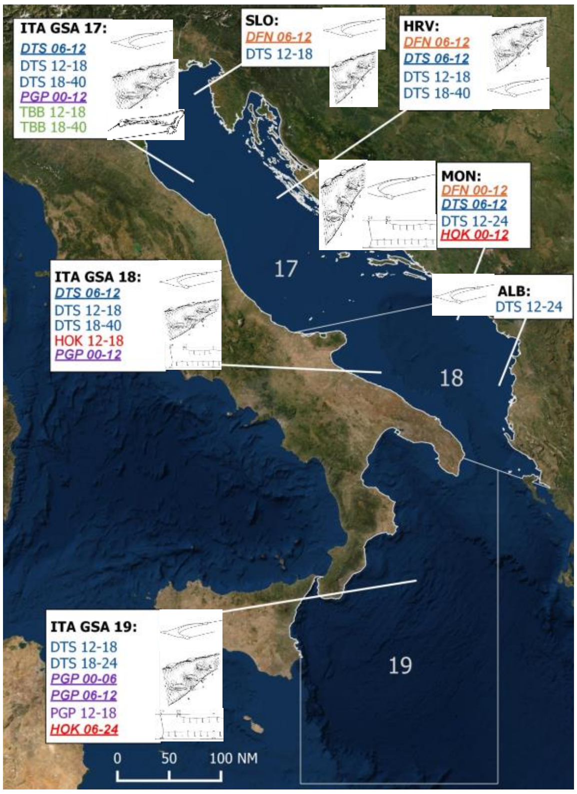
The main demersal fleets in GSA 17 include Italian demersal trawlers (DTS), mostly operating with OTB; Italian Rapido trawler (TBB), Croatian demersal trawler, the DFN fleet of Croatia operating with set-nets and gillnets, and the Italian PGP fleet. Slovenia has a relatively small fleet composed of DFN and DTS fleets. In GSA 18, demersal fleets include Italian and Montenegrin DTS, DFN and HOK, and Albanian DTS fleets. In GSA 19, only Italian fleets, mostly from DTS and PGP fleets. The higher number of fleets were present in the GSA17. Small scale fleets were explicitly taken into account (Fig. 3.1). The proportion of the landing by major gears in the same figure shows that the trawlers with 70% are by far the more relevant fishing type (Fig. 3.1).

The main fleets by country, gear type/fishing technology and GSA were included in the model that was finally accounting for 28 fleets.

Relationships between fleets and stocks is shown in figure 3.2 that also allows to figure out the interactions, especially in the Adriatic mixed fisheries, between fleet trawlers, at a wider spatial scale, and between fleet trawlers and small scale fleets at a more local scale.

Another important data exploration was conducted to understand the dependency of the fleets considered in the simulation and forecasts from the catches of assessed stocks, in terms of landings and revenues. Results are reported in the table 3.1.

The percentage of the target species on the total landings and total revenues by fleet (in green >30%) reveals a quite relevant dependency of some fleets from the assessed species considered in this study and included in the GFCM Recommendation.



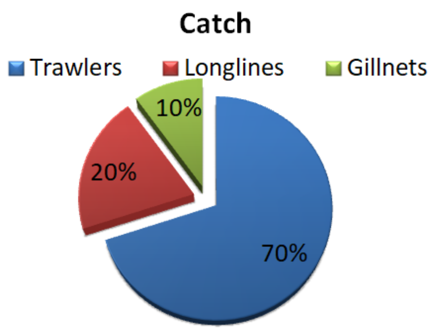


Figure 3.1 Association between fleets, gears and GSAs (left panel) and the proportion of catches by gear (right panel)

Table 3.1. Results of the dependency analysis of landings and revenues from the species of the study in the fleet segments considered.

Fleet	total landing	total revenues	Fleet	total landing	total revenues
SVN_17_DFN_0612	22.5	30.9	MNE_18_DFN_0012	8.7	3.6
SVN_17_DTS_1218	9	8.2	MNE_18_HOK_0012	12.3	6.3

ITA_17_DTS_0612	7.8	15.3	**ITA_18_DTS_0612**	22.6	43.6
ITA_17_DTS_1218	24.2	22.4	**ITA_18_DTS_1218**	29.7	43.1
ITA_17_DTS_1840	38.1	42.9	**ITA_18_DTS_1840**	65.9	49.9
ITA_17_PGP_0012	5.8	13.8	**ITA_18_HOK_1218**	34.4	44.9
ITA_17_TBB_1218	29.7	41.8	ITA_18_PGP_0012	6.5	4.2
ITA_17_TBB_1840	28.8	51.1	**ALB_18_DTS_1224**	46.3	50.5
HRV_17_DFN_0612	34.4	32.9	**ITA_19_DTS_1218**	38.9	25.5
HRV_17_DTS_0612	52.2	55.1	**ITA_19_DTS_1824**	41.0	35.8
HRV_17_DTS_1218	60.4	56.7	ITA_19_HOK_0624	6.0	1.8
HRV_17_DTS_1840	74.9	79.1	ITA_19_PGP_0006	9.6	13.0
MNE_18_DTS_0612	74.1	55.7	ITA_19_PGP_0612	11.9	15.1
MNE_18_DTS_1224	58.2	42.9	ITA_19_PGP_1218	0.8	3.4

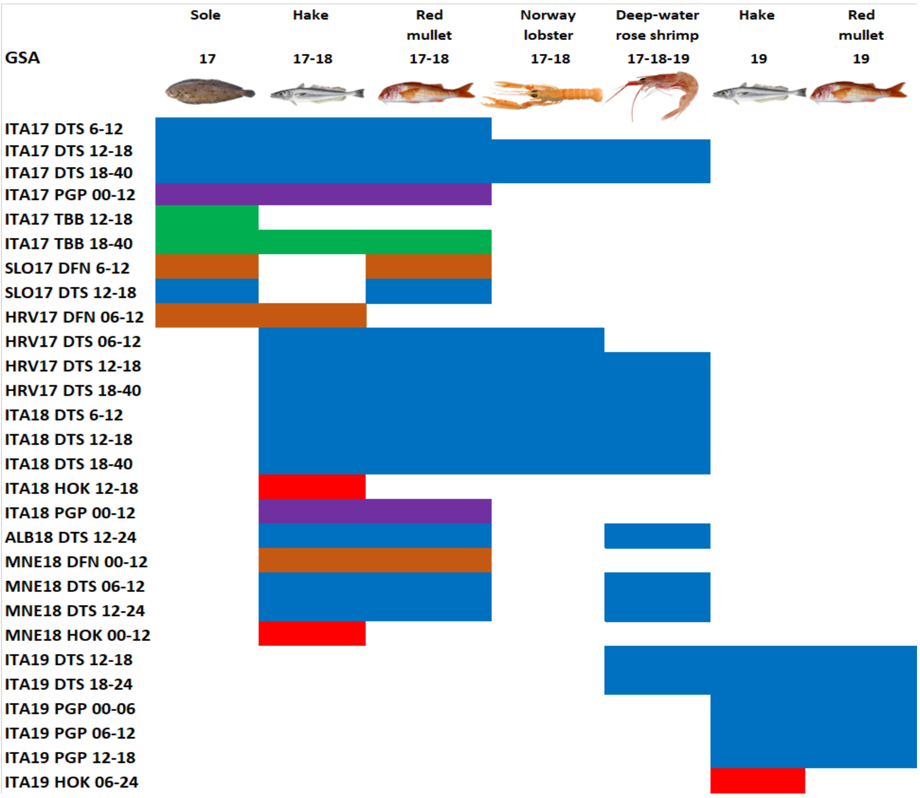


Figure 3.2. Scheme of the interactions among fleets that have common targets in the mixed fisheries of the Adriatic-Ionian region.

3.1. Summary of stock status

The last endorsed stock assessment (SAC, 2019 and STECF EWG 20-15) for the demersal stocks in the Recommendation GFCM/43/2019/5 were considered. The relevant results of the assessment for the model parameterization, i.e. the current fishing mortality (F_{curr}) and the reference point (F_{MSY}) are reported in the **Errore. L'origine riferimento non è stata trovata.**. The table also reports the upper and lower range of F_{MSY}, computed according to the formulas used in EWG 20-09:

$$F_{low} = 0.00296635 + 0.66021447 \times F_{0.1}$$
$$F_{upp} = 0.007801555 + 1.349401721 \times F_{0.1}$$

where $F_{0.1}$ is a proxy of F_{MSY}.

Of the seven stocks assessed (Table 3.2), sole (GSA17) and Norway lobster (GSA17-18) are close to a sustainable state. Deep water rose shrimp (GSA17-18-19), European hake (GSA17-18) and red mullet (GSA17-18) are overexploited ($F_{current}/F_{0.1}$ between 3.0 and 2.0), while red mullet in GSA 19 appears in a less severe overexploitation status. The available stock assessments cover different time periods.

Table 3.2. Current status (updated to the latest available assessment) of the target stocks.

Stock	Fcurr	F_{low}	F_{upper}	F_{MSY}	F_{curr}/F_{MSY}	Biomass	Assessment
Sole 17	0.50	0.33	0.67	0.49	1.0	↓	GFCM WGSAD 2019
European hake 17-18	0.41	0.12	0.25	0.18	2.3	↑	STECF_EWG 20-15
Red mullet 17-18	0.69	0.23	0.47	0.34	2.0	↑	STECF_EWG 20-15
Norway lobster 17-18	0.40	0.24	0.49	0.36	1.1	↓	STECF_EWG 20-15
Deep-water rose shrimp 17-18-19	1.49	0.33	0.68	0.50	3.0	↑	STECF_EWG 20-15
Red mullet 19	0.60	0.27	0.55	0.40	1.5	↔	STECF_EWG 20-15
European hake 19	0.32	0.10	0.20	0.14	2.2	↑	STECF_EWG 20-15

3.2. Transversal and socio-economic data

Table 3.3 reports the elements of the fishing pressure, productivity and economic components required in input to parameterize the BEMTOOL model.

Table 3.3. Effort, landings, revenues and socio-economic data needed in BEMTOOL for each relevant fleet segments exploiting the target species in the study area.

Effort variables	Landing and revenues	Socio-economic variables
Number of vessels	Total landing by target species	Depreciation costs
Monthly (or eventually annual) average fishing days per vessel	Total landing aggregated related to the other species	Opportunity costs
Monthly (or eventually annual) average GT per vessel	Total revenues by target species	Total capital costs
Monthly (or eventually annual) average KW per vessel	Total revenues aggregated related to the other species	Capital value
		Number of employees
		Maintenance costs
		Other fixed costs
		Total fixed costs
		Labour costs
		Other income
		Fuel costs
		Other variable costs
		Total variable costs

Official time series of transversal variables (landings, revenues, effort) by fleet, species, quarter and totals in the time frame 2004-2019 were obtained by the Fishery Dependent Data (FDI) data call and the STECF Annual Economic Report and by the FAIRSEA ad-hoc data call to National authorities.

Number of vessels, GT, kW were obtained from FDI Data Call, AER (EU Countries) and local values were obtained by the FAIRSEA Data Call.

Official time series of socio-economic variables by fleet segment (and fisheries) were obtained from National Statistics, Annual Economic Report and FAIRSEA data call. These regarded Depreciation cost, Opportunity costs, Total capital costs, Capital value, Number of employees, Maintenance cost, Other fixed cost, Total fixed cost, Labour cost, Other income, Fuel cost, Other variable cost Total variable cost in the time frame 2008-2018.

Comparisons and lacking data were also performed and gathered taking into account the works in previous projects (Spedicato et al., 2016). Data gaps for some years/fleets required data reconstruction based on available years.

4. THE HINDCASTING OF BEMTOOL

The results of the stock assessment for the considered stocks have been replicated in BEMTOOL.

The Recruitment was obtained from the stock assessment and used as input. Usually catch at age models provide this kind of information. However, for Norway lobster in the Adriatic a production model was used for the assessment and thus recruitment estimates were not available. These were obtained through the "recruitment calibration function" in BEMTOOL, which is based on an optimization algorithm to re-scaling a guess recruitment value, in order to align observed and simulated yield. The resultant output from the optimization function is a multiplier for the relative abundance value for the recruits vector to acquire an estimate of the absolute abundance of recruits for each year and for a particular species. The Spawning Stock Biomass (SSB) from the assessment was only compared to the SSB estimated by the BEMTOOL model using all the biological parameters (growth, maturity, sex ratio and natural mortality), which were obtained from the stock assessments.

Considering the need of modelling selectivity BEMTOOL was parameterised according to the Z mode (F at age + average M from stock assessment), through this loop the model could internally estimate F according to the following equation:

$$F_f(a) = (Z_{inp} - mean(M)) * Sel_f(a) * f_{act,f} * p_f$$

where *fact,f* in the forecast is the ratio between the product of the number of fishing days, the number of vessels and the average GT (or Kw) of the fleet segment *f* for each month of forecast to the product of the number of fishing days, the number of vessels and the average GT (or Kw) of the fleet segment *f* in the last year of the simulation. This quantity is considered as reference for the application of change in fishing effort. $Sel_f(a)$ is the fleet selectivity at a given length/age; p_f is the monthly ratio between the fleet segment catch to the total catch in the simulation (in the forecast it is fixed as an average of the last (n) years).

The fleet selectivity was modelled using a classical ogive (a), an ogive with deselection (b) or a normal distribution (c), depending from the fleet, the species and the time (years and month):

(a) $$Sel(j) = \frac{1}{1 + e^{\frac{\ln(9)}{SR} * (SL_{50\%} - j)}};$$

(b) $$Sel(j) = \frac{1}{1 + e^{\frac{\ln(9)}{SR} * (SL_{50\%} - j)}} * \frac{1}{1 + e^{-\frac{\ln(9)}{DR} * (DL_{50\%} - j)}};$$

where $SL_{50\%}$ is the length at first capture, $SR = SL_{75\%} - SL_{25\%}$ the selectivity range, $DL_{50\%}$ the 50 % deselection size.

(c) $Sel(j) = e^{-\frac{(j-mean)^2}{2*sd^2}}$

The discard was modelled using a reverse ogive (d) and fig. 4.1

(d) $Dis_f(a) = \frac{1}{1+e^{-\frac{\ln(9)}{DisR_f}*(DisL_{50\%,f}-a)}}$

where DisL50%,f is the size at which the 50% of the population is discarded by the fleet f, DisRf is the difference between size at which 75% and 25% of the population is discarded by the fleet f and a is the length-age class.

The fleet selectivity parameters were inferred from empirical cumulative functions on commercial Length-Frequency-Distributions (LFDs) from the MED Data Call, as well as the parameters of the reverse ogives for discards (see Fig. 4.1). For European hake an ogive with deselection was used for trawlers, with L50% parameter between 16-18 cm and a selection range of 8 cm; the deselection length was ranging between 40 and 70 cm. A normal distribution was used for longlines and nets with means and standard deviations ranging respectively between 45-47 cm and 20 cm for the former and around 35 cm and 10-15 cm for the latter. For deep water rose shrimp a classical ogive was used with a size at first capture around 17 mm carapace length and a selection range of 1 mm. For red mullet a classical ogive and a normal distribution were used for trawlers and nets respectively, with L50% ranging from 10 to 13 cm and selection range around 5 cm for the trawlers, while mean and standard deviation for the nets were around 14 and 2-3 cm respectively. For Norway lobster a classical ogive was used with a size at first capture was around 15 mm carapace length and a selection range of 5-6 mm. For common sole an ogive with deselection was used for all fleets, but with different parameters depending on the gear: L50% was about 17-20 cm for trawls with a selection range of 2 cm and a deselection length of 26-30 cm, while L50% was ranging around 24cm cm and the deselection length around 35 cm for nets.

Growth, maturity, length-weight relationship and sex ratio parameters were the same as for the assessments.

The comparison of SSB, F, landings and discards showed a good level of agreement between BEMTOOL and the stock assessment results, some examples are reported in the Figures from 4.2 to 4.5.

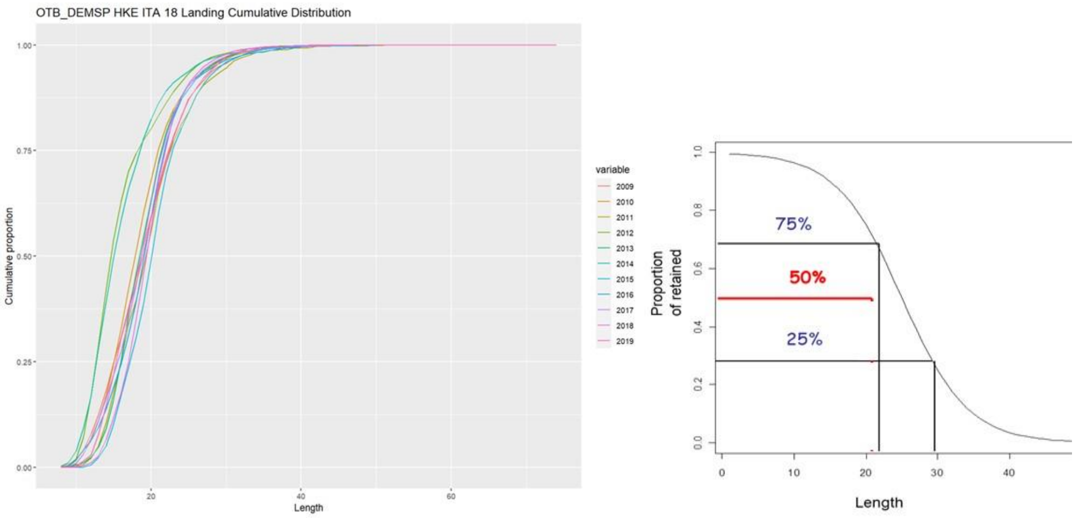
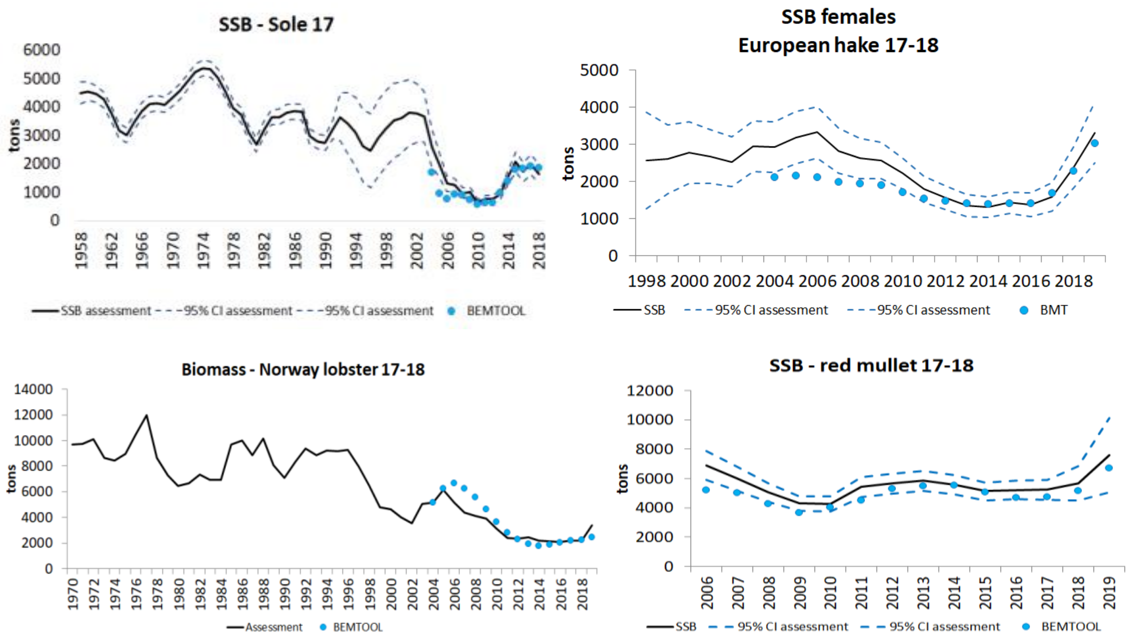


Fig. 4.1 – Right panel: example of yearly fleet selectivity curve for demersal trawlers in GSA18. Right panel the reverse ogive function used to simulate discards.



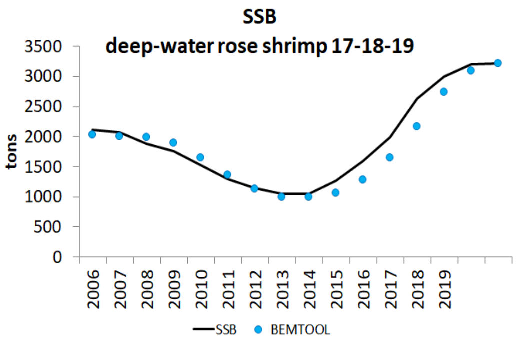
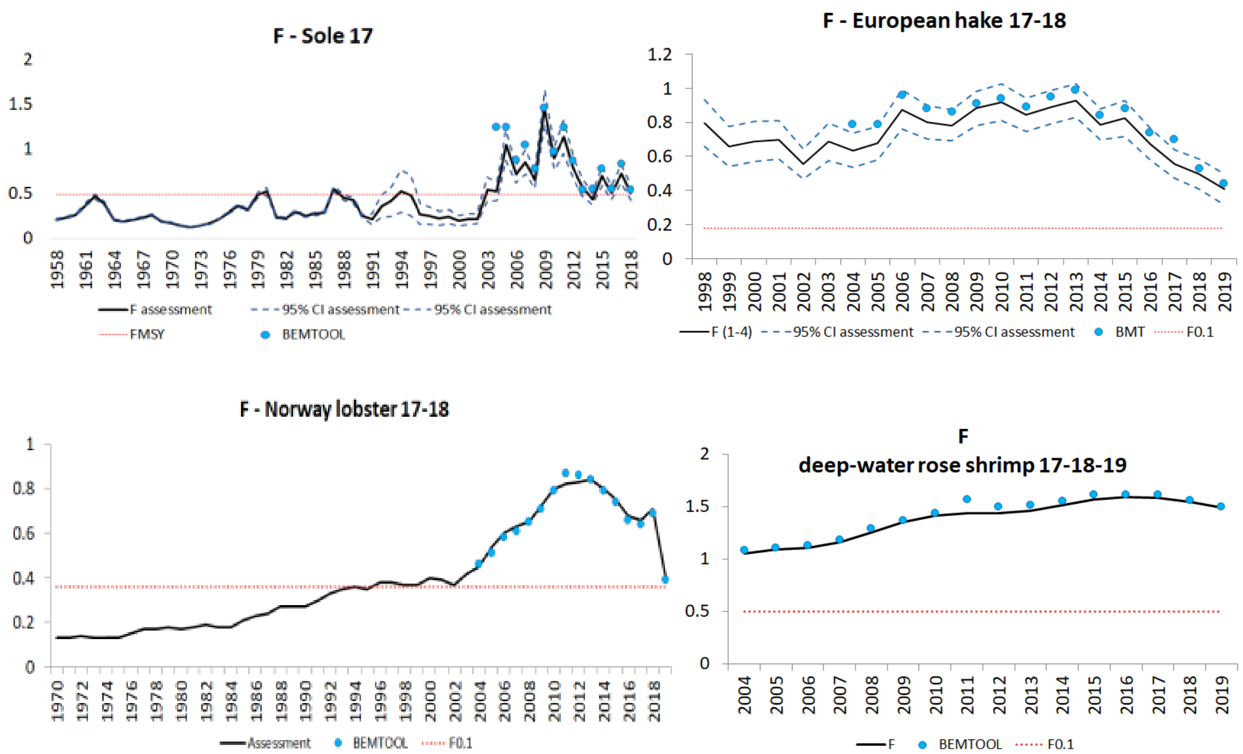


Fig. 4.2 – Comparison between time series of Spawning Stock Biomass (SSB) of the target species simulated by BEMTOOL and estimated from the assessment.



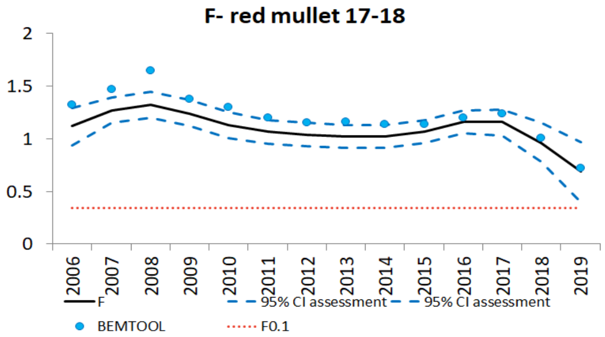
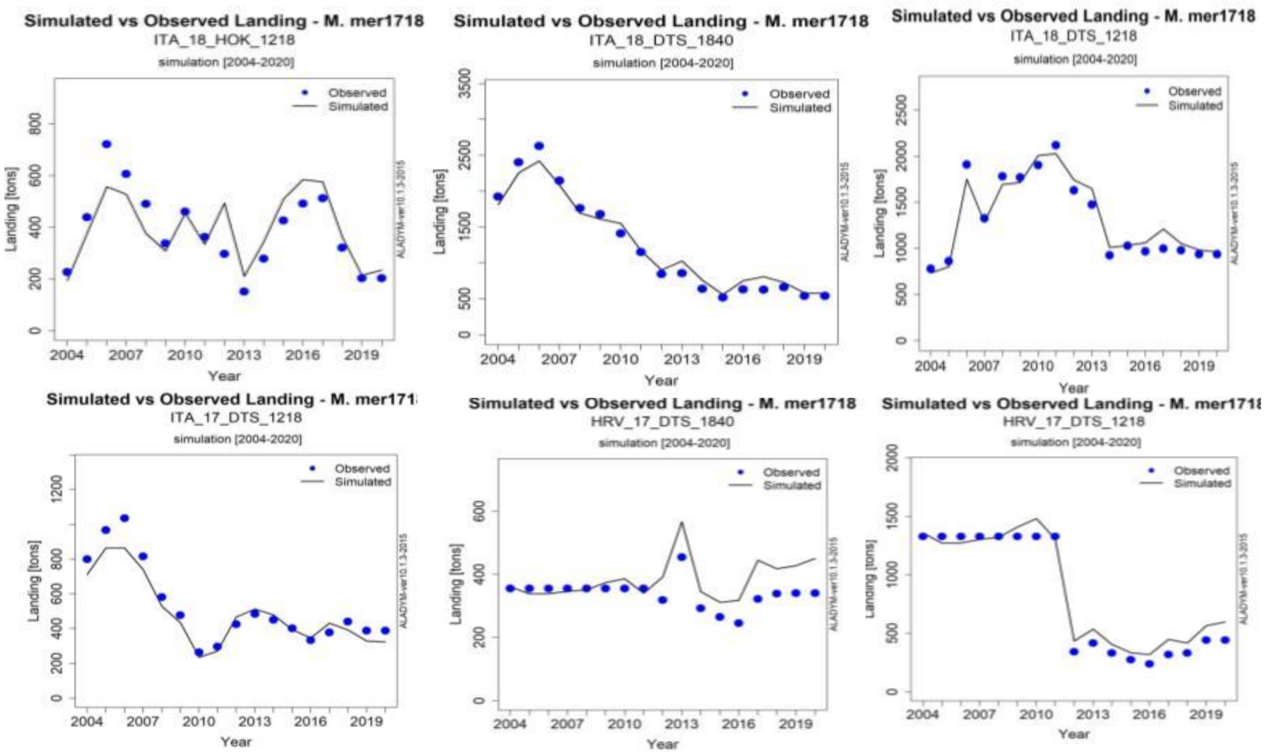


Fig. 4.3 – Comparison between time series of fishing mortality (F) of the target species simulated by BEMTOOL and estimated from the assessment.



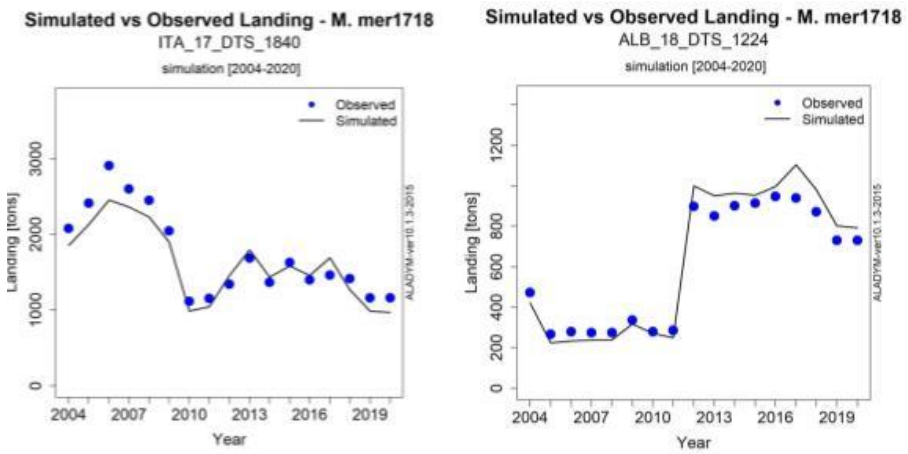


Fig. 4.4 – Comparison between time series of landings of European hake by fleet (trawlers from GSA17 and GSA18, Italy, Croatia and Albania and longliners from GSA18) simulated by BEMTOOL and from the data.

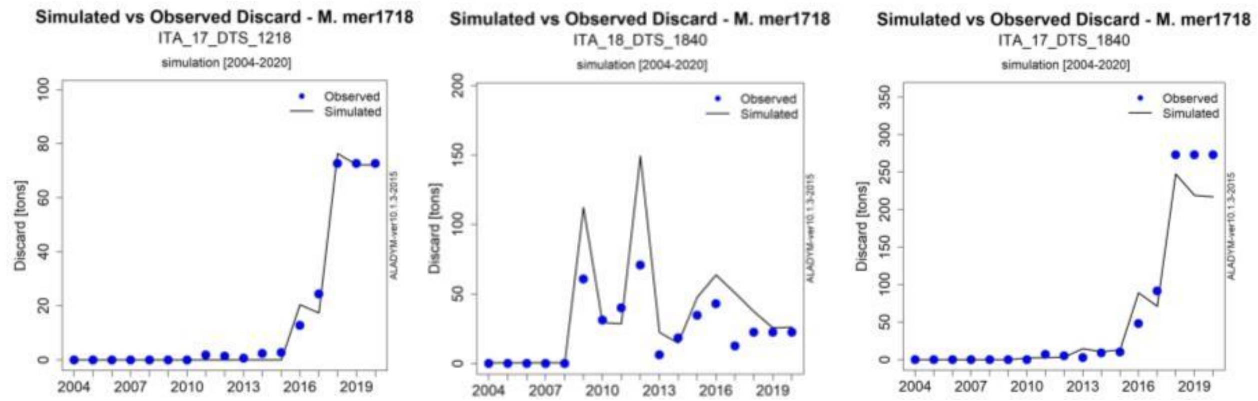


Fig. 4.5 – Comparison between time series of discards of European hake by fleet (trawlers from GSA17 and GSA18) simulated by BEMTOOL and from the data.

5. THE RECOMMENDATION GFCM/43/2019/5

The GFCM Recommendation GFCM/43/2019/5 set the rules for a fishing effort regime in the Adriatic Sea. The main elements are below reported.

In 2020 and 2021, a transitional fishing effort regime shall be established. During this transition phase 2020-2021 at least 12% reduction for OTB and 16 % for TBB with respect to the annual effort exerted in 2015 or to the three-year average within the 2015–2018 period shall be achieved.

A five-year fishing effort regime shall be established for 2022–2026. Each year, on the basis of SAC advice, the GFCM shall establish yearly effort quotas, thus contributing to reaching F_{MSY} and staying within safe biological limits. Minimum Conservation Reference Size shall apply for the target species of the Recommendation in GSA17-18:

a) for deep-water rose shrimp, at 20 mm carapace length (CL);
b) for Norway lobster, at 20 mm CL or 70 mm total length (TL);
c) for common sole, at 20 cm TL; and
d) for red mullet, at 11 cm TL.

The provisions in paragraphs 11 and 12 of the Recommendation shall not apply to national fleets operating with OTB and fishing for less than 1 000 days during the reference period.

Closure of coastal zone (6 NM) (alternatively 30 continuous days FB) + existing FRAs + new FRAs shall be established.

Effort allocation formula is as below reported that is considering the relative inputs of each country in terms of fishing effort:

$$[\text{CPC a reduction} = \text{Overall reduction} * (\text{CPCa}^2/ (\text{CPCa}^2+\text{CPCb}^2+ \text{CPCc}^2+\text{CPCd}^2+\text{CPCe}^2))]$$

For the number of fishing days reported via the DCRF Task V-2 in 2017, on the basis of the reference year 2015 or of the average over 2015–2018, a global reduction of 12 percent for OTB and 16 percent for TBB is established for 2020–2021.

The above formula is used to allocate the fishing days quota by CPC and gear as reported in table 5.1 below.

Table 5.1 Allocation of the fishing days quota by country

		Number of fishing days					
Gear type	**Geographical subareas (GSAs)**	**EU 2020**	**EU 2021**	**Albania 2020**	**Albania 2021**	**Montenegro 2020**	**Montenegro 2021**

Single boat bottom otter trawls (OTB)	17–18	147 606	137 046	23 124	22 748	Not applicable[1]	Not applicable[2]
Beam trawls (TBB)	17	8 663	7 910				

1 Montenegro shall not exceed the effort limit of 3 000 fishing days per year in accordance with paragraph 13.

2 Montenegro shall not exceed the effort limit of 3 000 fishing days per year in accordance with paragraph 13.

6. MANAGEMENT SCENARIOS

When designing BEMTOOL scenarios we considered several elements, in addition to and interpreting the Recommendation GFCM/43/2019/5 and its management targets. In particular, the nature of the Adriatic-Ionian mixed fisheries with interactions among fleets and target stocks and the awareness that efforts towards the improvement of the exploitation pattern might mitigate other too restrictive measures. One of the main aspect is, in addition, the concept of mitigating species underutilization under scenario of fishing effort reduction, given that some species are close to a sustainable exploitation and other are not (see figure 6.1 for an overview). Further, following the inputs received during the stakeholder meetings, we also considered the risk that limiting the fishing activity over a certain level in the short term might cause unrecoverable economic losses making the fishery economically unsustainable with negative consequences for the employment. The concept of mitigating possible underutilization of the stock in a more sustainable condition, while reducing the fishing mortality toward the F_{MSY} of the more overexploited ones, was tackled setting a weighed reference point.

It is also worth recalling the preference expressed in the stakeholders meetings in terms of scenarios, summarised in the figure 6.2 and fully reported in the deliverable 4.8.3.

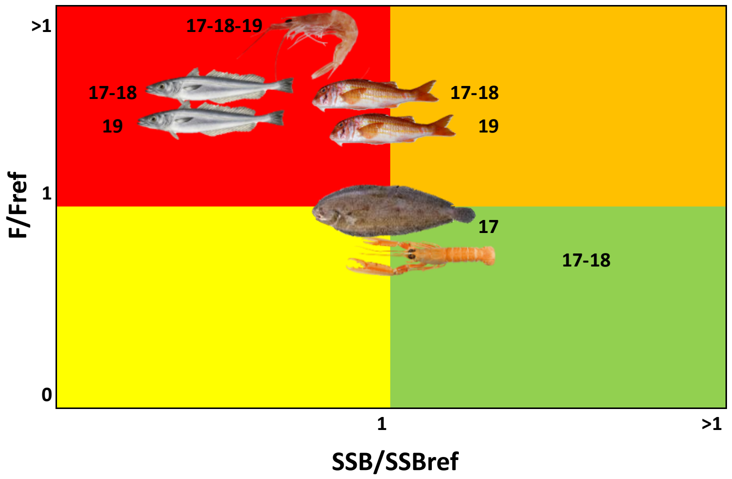


Fig. 6.1 Kobe plot representing the status of the stocks in relation to the reference points

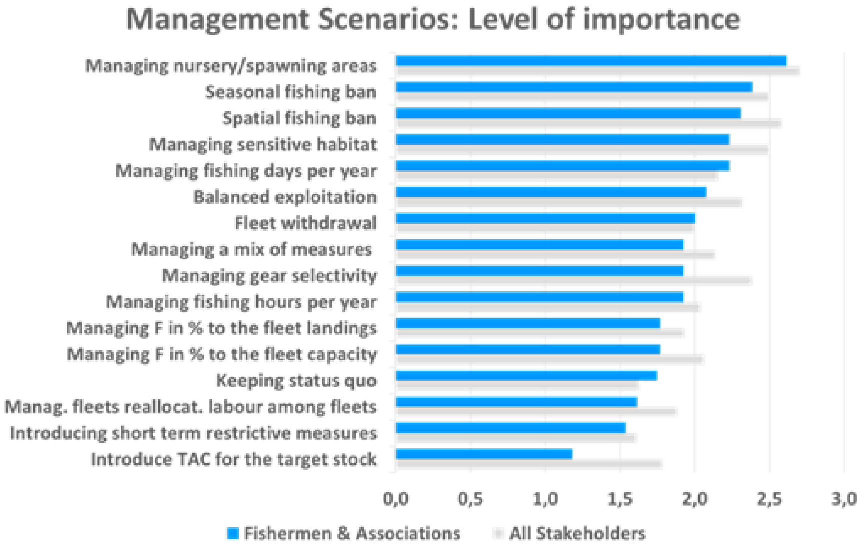


Fig. 6.2 Level of importance of the different management scenarios from a stakeholders' perspective

A strategy to mitigate possible underutilization of certain stocks, when reductions of fishing effort affect mixed fisheries in which species with a different level of exploitation are the targets, was defined on the basis of a combined (all target species) F target, considering the landing value of each stock and its F_{MSY}:

$$F_{MSY,combined} = \frac{\sum_{s=1}^{4}(ValueLand_{2013,s} * F_{MSY,s})}{\sum_{s=1}^{4} ValueLand_{2013,s}}$$

The level of a comined $F_{current}$ (2021) is 0.64, while the $F_{MSY,combined}$ is 0.35.

After the transition phase (2020-2021), in which the reduction of fishing activity measures had been already applied, the scenarios were set as follows:

- S0: status quo (**no variations** compared to 2021);
- S1: linear reduction of 40% of Fishing Days (FD) until 2026 for trawlers and rapido toward the **$F_{MSY,combined}$ (0.35 value),** we used a combined RP considering the target species of the GFCM Recommendation **instead of** European **hake F_{MSY} (0.18).**
- S2 (combination of measures): fleet selectivity improvements **+** spatial closure areas (within 6 nautical miles, until December) taking into account the presence of nurseries of the main target species within the 6 nautical miles and the fishing footprints in the area from AIS (global fishing watch) **+** 2 months of fishing bans for other gears (PGP 17-18 and DFN Croatia fishing ban in February

and May; HOK GSA 18 in March and May) **+** linear reduction of 25% in FD for trawlers and rapido fleets;

- MEY (Maximum Economic Yield); that has been introduced in the evaluation to give an insight in a reference point that account also of economic considerations. **MEY** considers the «**optimum**» taking into account **the fishing effort** of all the fleets in terms of **fishing days** and **three economic indicators**: the Gross Value Added (GVA), the net profit and the Return of Investments (ROI). MEY allows to evaluate the effort levels that maximize the differences between revenues and total costs. The **needed reduction,** in terms of effort in fishing days, is taken at the levels **where the three curves reach the maximum.** So MEY could be reached with a reduction of the whole fishing effort of 20%.

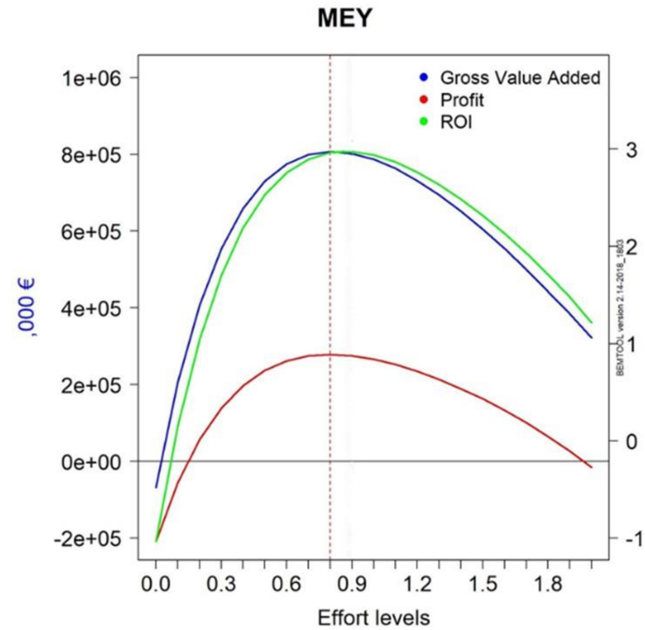


Fig. 6.3 MEY. The «optimum» takes into account the fishing effort of all the fleets in terms of fishing days and three economic indicators: the Gross Value Added (GVA), the net profit and the Return of Investments (ROI).

In the evaluation of the scenarios also the F_{MSY} range values, i.e. Flow and Fupper, that represent the uncertainty around $F_{MSY,}$ were considered.

The performance of the scenarios was evaluated on the basis of spawning stock biomass, catch, F, revenues, profits, wages, employment and current revenues to break-even revenues (CR/BER). The latter is an economic indicator that shows how close the current revenue of a fleet is to the revenue at the economic break even. Ratios > 1 indicate that enough income is generated to cover operational costs (variable and non-variable costs) and therefore break-even. If the ratio is less than 1, insufficient income is generated to cover operational costs and therefore the fleet is in a loss.

7. FORECASTS UNDER THE DESIGNED MANAGEMENT SCENARIOS USING BEMTOOL

7.1. Assumptions on biological and impact functions by stock

Stock-recruitment relationships (S-R) of the assessed stocks were estimated using a segmented regression approach (e.g. Barrowman and Myers, 2000):

$$R = \alpha \cdot \min(S, S^*)$$

and a non-linear least square on the pairs of recruits and spawners from stock assessments.

The estimation was implemented in R software. Table 5.1 reports the parameters of the stock recruitment relationships, i.e. slope and break point of the segmented regression by stock.

Uncertainty was applied on the S-R parameters slope and break points (BP), using a normal distribution of the errors, so that the variation around the mean was ranging between 5 and 15%.

Figure 5.1 shows the stock recruitment relationship by each stock included in the scenarios.

Table 5.1 Parameters of the stock recruitment relationships

Stock	slope	BP
Sole 17	92.6	1120
European hake 17-18	283.2	1200
Red mullet 17-18	247.8	4000
Norway lobster	130	1900
Deep-water rose shrimp 17-18-19	3360	2300

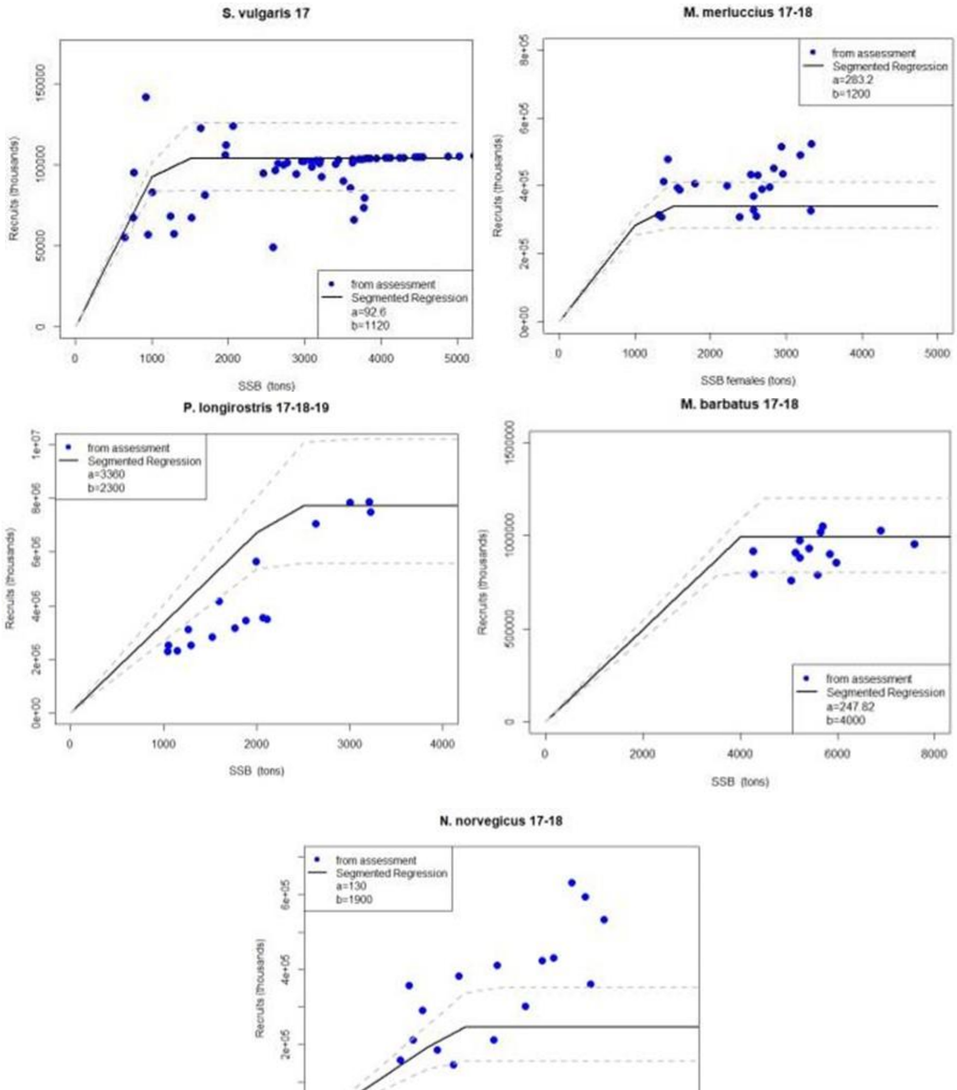


Fig. 5.1 Stock recruitment relationships by stock assessed. Parameters of the segmented regression are reported in table 5.1 and in the boxes of the single panels.

7.2. Assumptions on socio-economic functions by fleet

Generally, the BEMTOOL formulations of the economic indicators are in line with the Annual Economic Report on the EU Fishing Fleet. The relevant economic indicators taken into consideration in AER 2020 and in BEMTOOL are:

i. Revenues, GVA (Gross Value Added) and their ratio;
ii. Gross profit and gross profit margin (%);
iii. Net profit and net profit margin (%);
iv. Capital productivity (ROI or Return on Fixed Tangible Assets ROFTA);
v. Break-even revenue and CR/Break-even revenue.

Three options can be adopted to derive the total landing and the corresponding total revenues by fleet based on the landing and revenues of the assessed stocks:

a. total landing/revenues (assessed stocks + other species) proportional to the landings of assessed stock;
b. landing/revenues of the other species estimated from landing of the assessed stocks according to a linear relationship;
c. landing/revenues of the other species depending on landing of the assessed stocks according to a power relationship (Lleonart et al., 2003).

The price dynamic can be modelled as:

1. a constant function,
2. a function of the variation of landing (modified from Salz et al., 2011),
3. a function of landings, accounting for the amount of imports and the mean size of the landings (modified from Lleonart et al., 2003).

Variable costs can be simulated as a function of annual fishing activity or taking into account also one or more additional variables, like fuel price, landings in weight or landings in value (Accadia & Spagnolo, 2006; Saltz et al., 2011).

The fixed or non-variable costs, not depending on the fishing activity, are based on the annual GT or, alternatively, on the number of vessels.

The capital costs depend on the annual GT or on the capital value or, alternatively, on the number of vessels (e.g. Accadia & Spagnolo, 2006; Saltz et al., 2011; Frost et al., 2013).

The labour costs are modelled according to the crew share system; they are thus estimated as a percentage (crew share) of the difference between revenues and variable costs (including fuel costs).

Costs due to investments in new equipment or technology, such as those required for the application of new regulations, can be considered.

Within BEMTOOL behavioural module the investment in vessels and in technology, as well as changes in the fishing activity, can be driven by fishermen response to changes in the profitability related to the introduction of new management measures (Saltz et al., 2011; Frost et al., 2013).

In the parameterization of the forecasts for the scenario modelling the following options have been selected.

Total landing (assessed stocks + other species) and total revenues were assumed proportionally changing with the landing of the assessed stocks, by means of a correction factor based on historical data.

Price dynamic was modelled as a function of the variation of landing (modified from Salz et al., 2011), through an elasticity coefficient.

The variable costs (fuel and other) have been assumed to vary proportionally to the annual fishing days, while fixed and the maintenance costs depending on the annual GT on the basis of the historical data.

The capital costs depend on the annual GT (Saltz et al., 2011; Frost et al., 2013).

In 2019 the AER revisited and updated the calculation method used for depreciation costs and capital value. The opportunity cost was based on capital value and inflation and interest rate, through the formula:

$$Opportunity\ cost\ = capital\ value * \frac{1 + interest\ rate}{1 + inflation\ rate} - 1$$

Annual values of interest rate and inflation rate were obtained from sdw.ecb.europa.eu/ and https://it.inflation.eu/, respectively (consulted on 30/07/2019). Total capital costs was calculated as the sum of opportunity and depreciation cost.

The labour costs have been assumed in line with the crew share system on the difference revenues minus variable costs, and the depreciation costs depending on the annual GT.

7.3. Assumptions on fleet selectivity

In order to quantify the contribution of these closure areas the same approach followed in the STECF EWG 20-13 was applied (STECF, 2020). The information of effort allocation (Global Fishing Watch, GFW, https://globalfishingwatch.org/) was crossed with the spatial information on the area within 6 nautical miles and the area occupied by the nurseries (from MEDISEH project; Giannoulaki et al., 2013) of the target species by GSA, quantifying the overlaps between these Essential Fish Habitats (EFH), the strip of 6 nautical miles and the proportion of the effort in these spatial subunits

The fleet selectivity was then translated into a change (increase) of the length at first capture, proportionally reshaping the exploitation pattern of the relevant species by GSA and trawler fleet with an increase of 6-7% for the species as European hake and deep water rose shrimp, which nurseries are located more offshore, while it was higher for red mullet (about 25%).

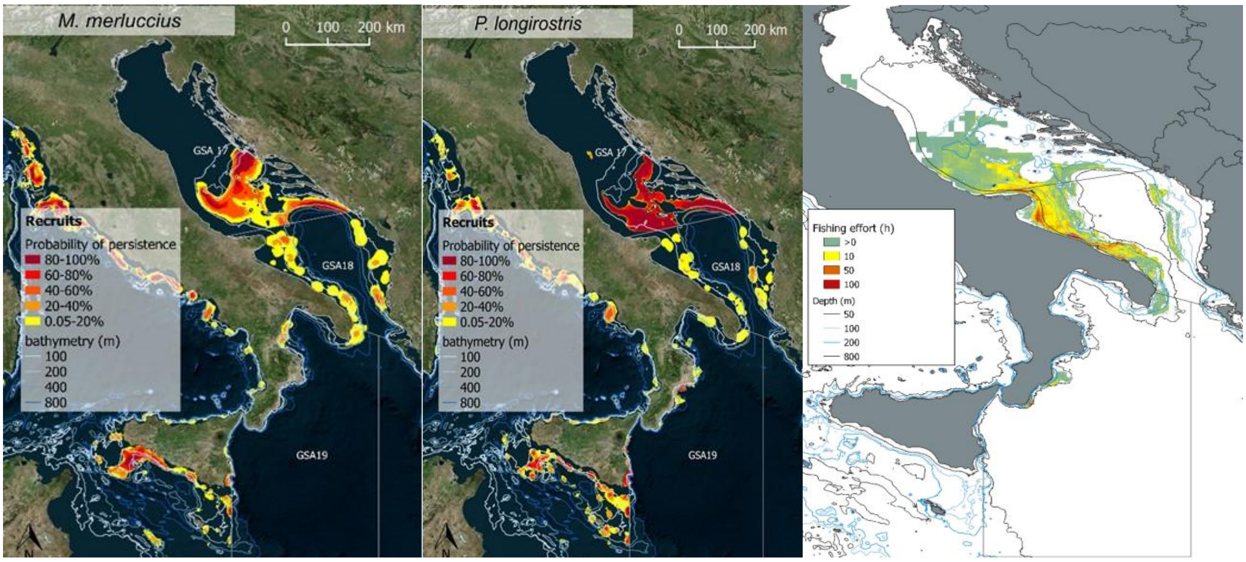
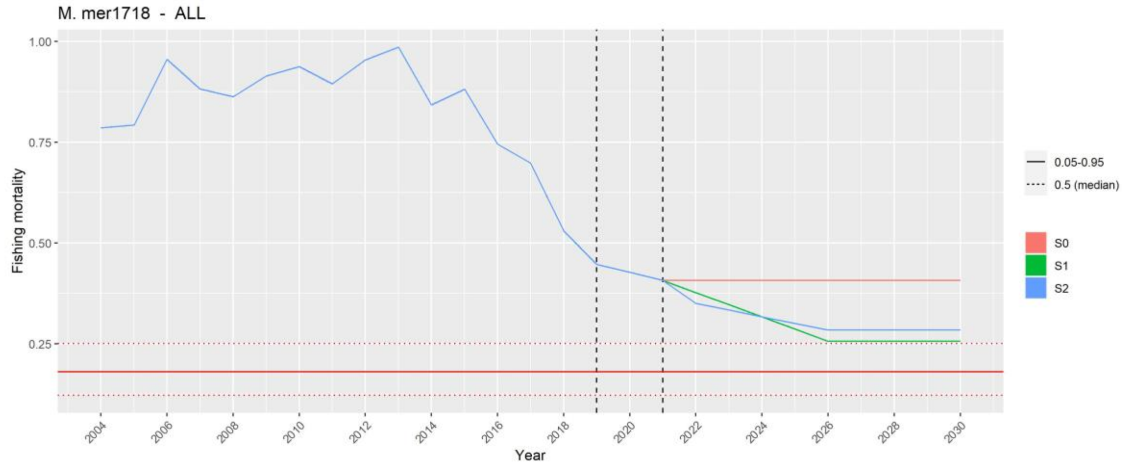


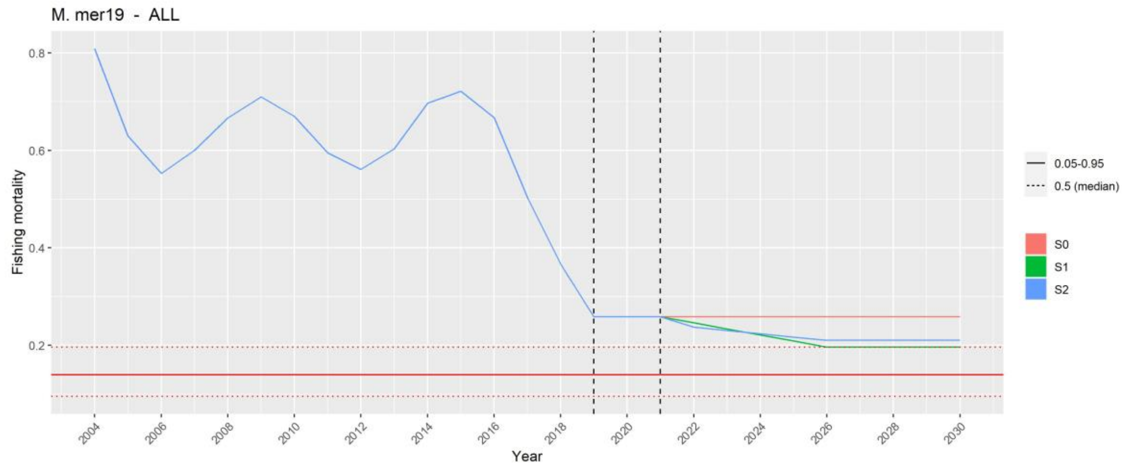
Figura 4.3. Nursery areas of European hake *M. merluccius* and deep water rose shrimp *Parapenaeus longirostris* from the MEDISEH project (Giannoulaki et al., 2013) (left panels). In the right panel the distribution of the fishing footprints in the GSA18 (from Global Fishing Watch) is shown.

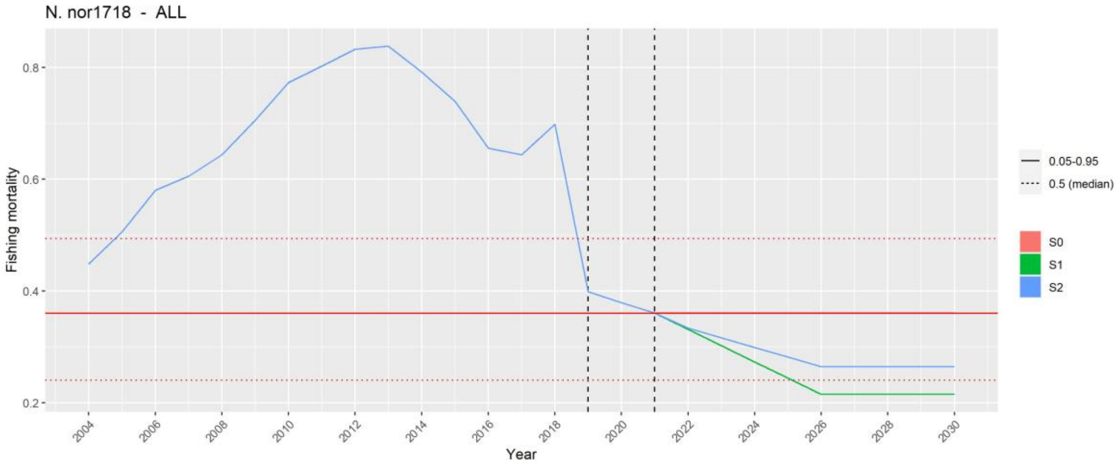
8. RESULTS

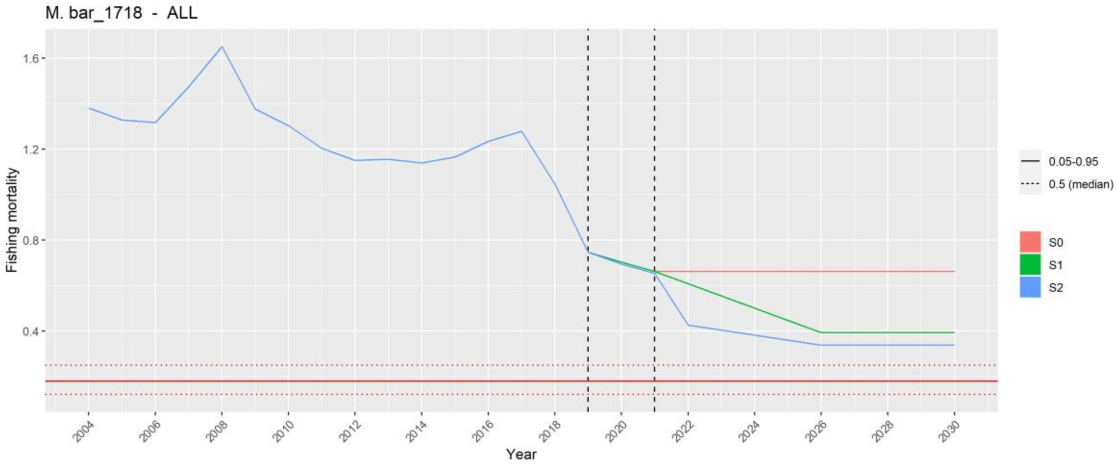
8.1. Effects of the scenarios on the fishing mortality and reference points achievements

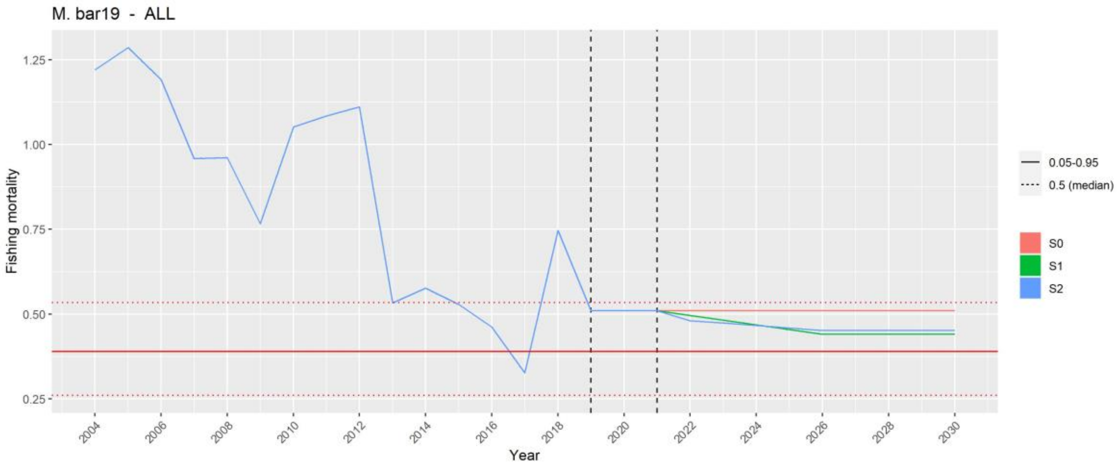
European hake stocks in GSA17-18 and in GSA19 will get close to Fupper both in scenarios S1 and S2 (Fig. 8.1). For Norway lobster the two scenarios would bring fishing mortality F close to Flow or even lower (S1) with a risk of underutilization of this stock. Similar situation is evident for sole, given that the stock is close to a sustainable exploitation. For red mullet in GSA17-18 the fishing mortality would approach Fupper, but remain higher, while in GSA19 F would be in the range between Fupper and F_{MSY} both in scenario S1 and S2. For deep water rose shrimp F will decrease compared to the status quo (S0) but will remain higher than Fupper.






N. nor1718 - ALL
Fishing mortality
Year
0.05-0.95
0.5 (median)
S0
S1
S2


M. bar_1718 - ALL
Fishing mortality
Year
0.05-0.95
0.5 (median)
S0
S1
S2


M. bar19 - ALL
Fishing mortality
Year
0.05-0.95
0.5 (median)
S0
S1
S2

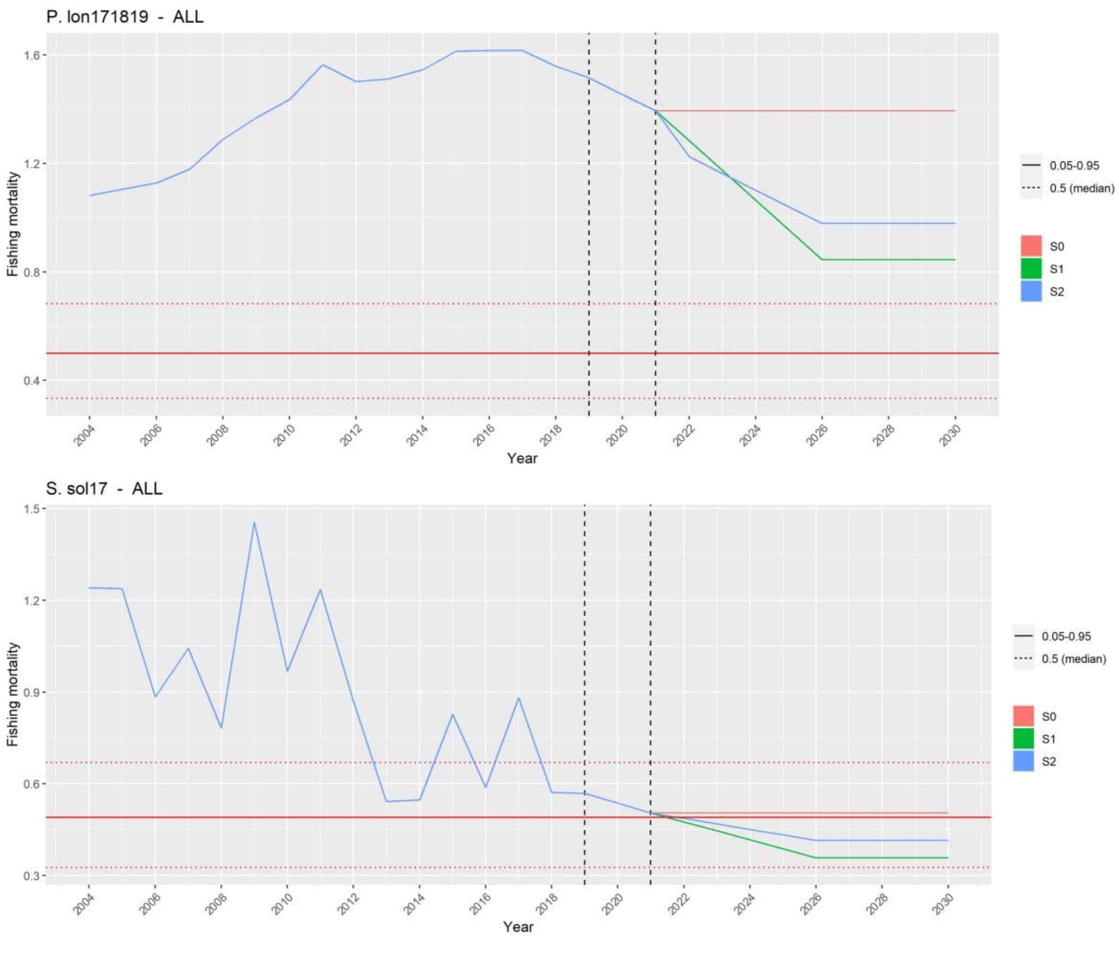
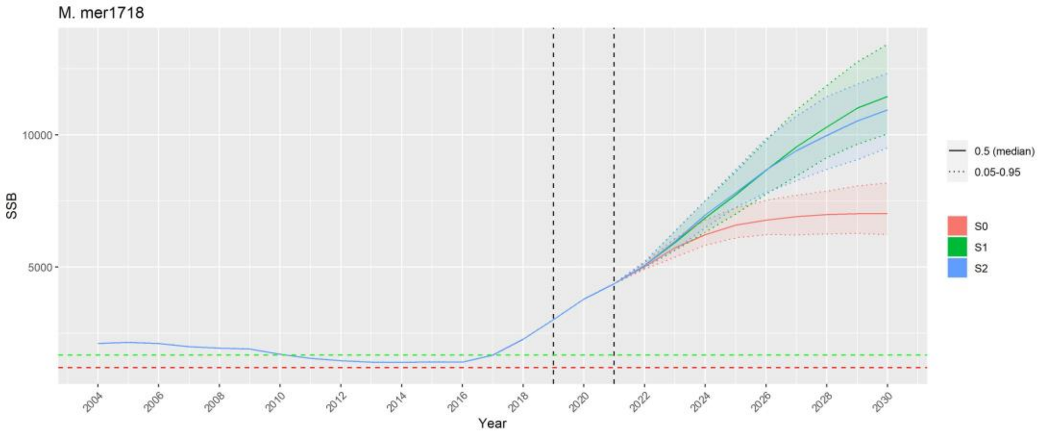


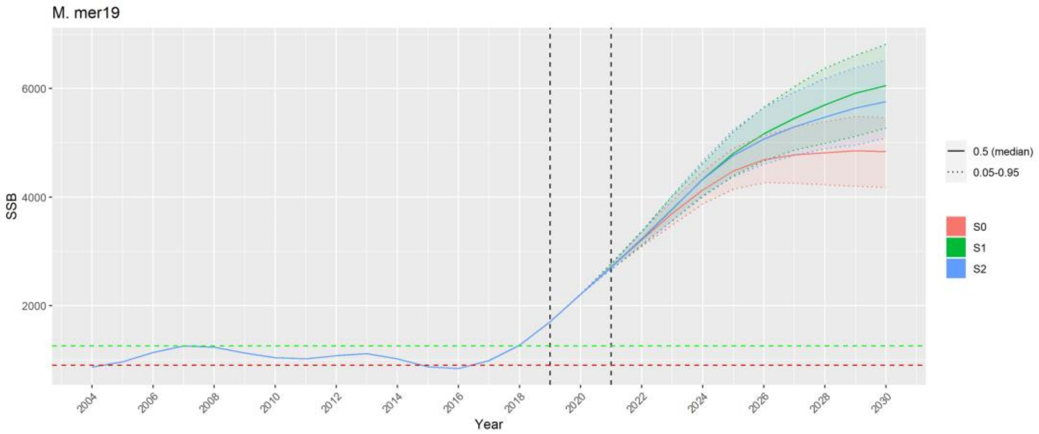
Fig. 8.1 Effects of the scenarios on the fishing mortality of the target stocks

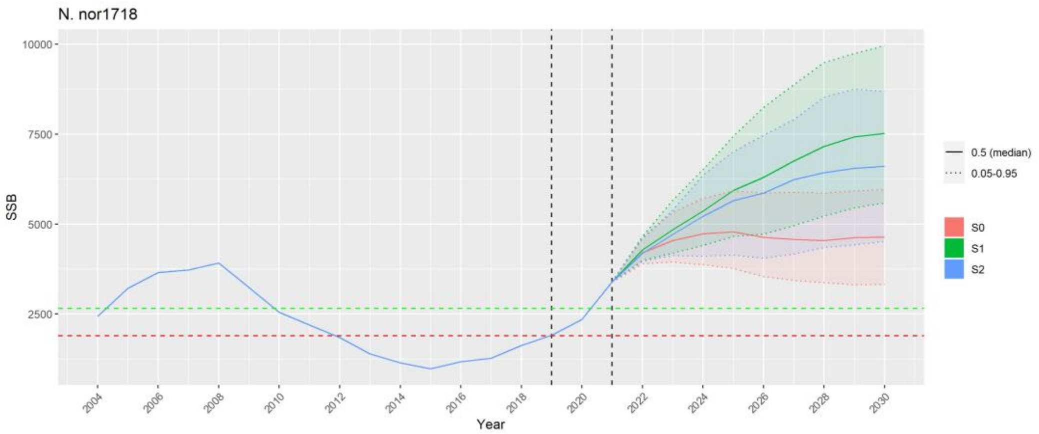
8.2. Effects of the scenarios on the stocks

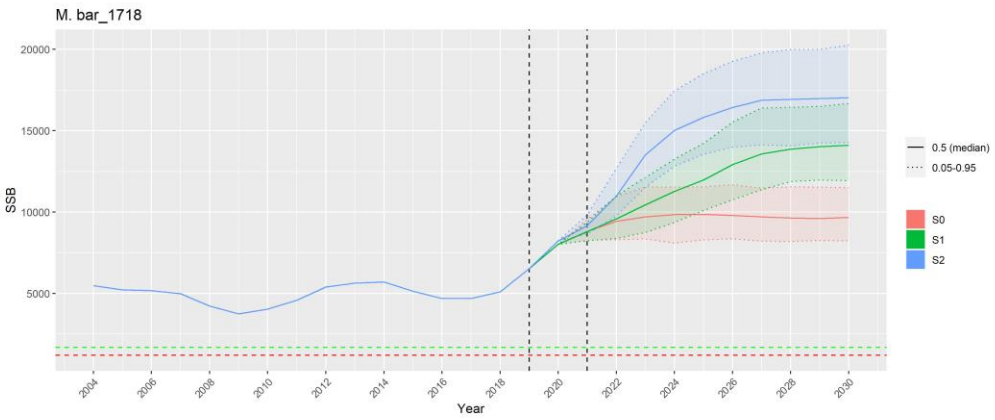
For all the stocks a positive effect of the management measures is apparent, as the SSB will increase in all the scenarios compared to the status quo (S0) (Fig. 8.2). Such increase would be more remarkable for the stocks with a higher ratio between Fcurrent and F_{MSY}, as European hake or deep water rose shrimp. Scenario S2 performs quite similarly to scenario S1 that however shows slightly higher levels of SSB for European hake and Norway lobster. For red mullet scenario S2 would perform better than S1, because of the effects determined by the improvements of the exploitation pattern that would be more pronounced for these stocks. For the other stocks S2 and S1 behave rather similarly.

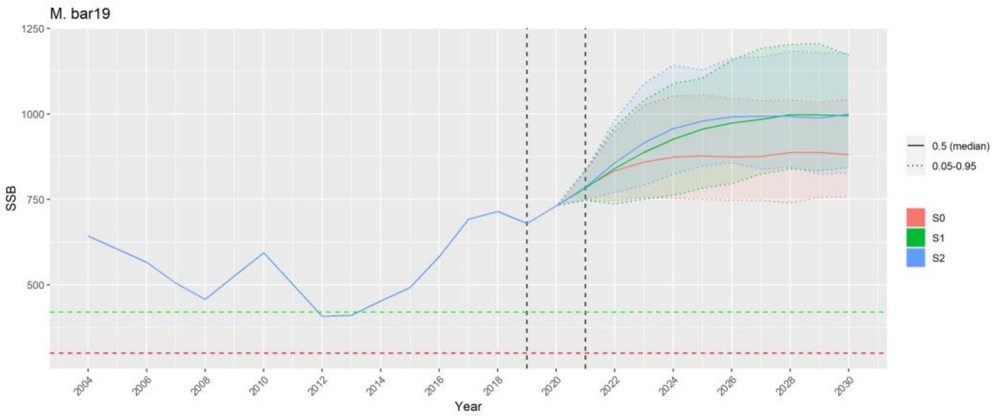
It is important to point out that an increased SSB might contribute to recover the productivity of the overexploited stocks in the medium term, thus potentially contributing to yield improvement in the medium term.

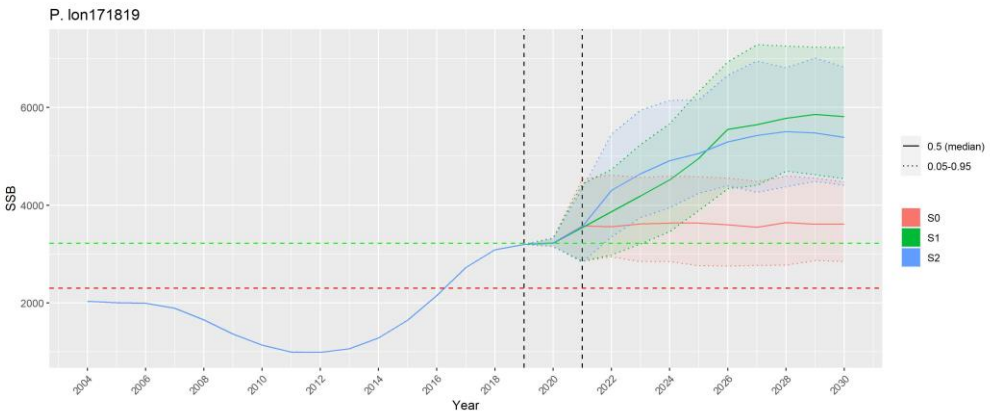







M. bar_1718
SSB
Year
0.5 (median)
0.05-0.95
S0
S1
S2


M. bar19
SSB
Year
0.5 (median)
0.05-0.95
S0
S1
S2


P. lon171819
SSB
Year
0.5 (median)
0.05-0.95
S0
S1
S2

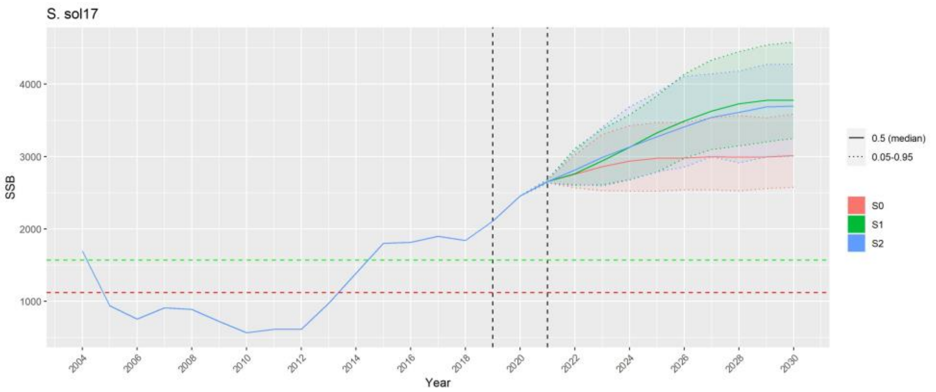


Fig. 8.2 Effects of the scenarios on the SSB of the target species. The dotted red line corresponds to Blim the biomass corresponding to the breakpoint of the stock recruitment relationship. The dotted green line represents Bpa, the precautionary biomass, computed as1.4*Blim, according to ICES.

8.3. Effects of the scenarios on the productivity and economic performances of the fleets

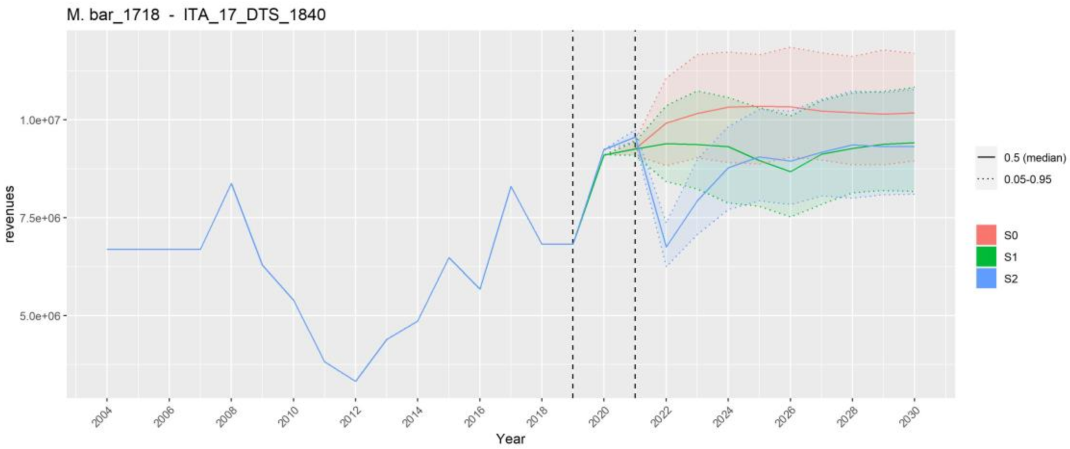
As regards the consequences of the management measures on production and revenues, profits and other economic indicators, the situation is different according to the fleet (see figure 8.3 with some examples for revenues).

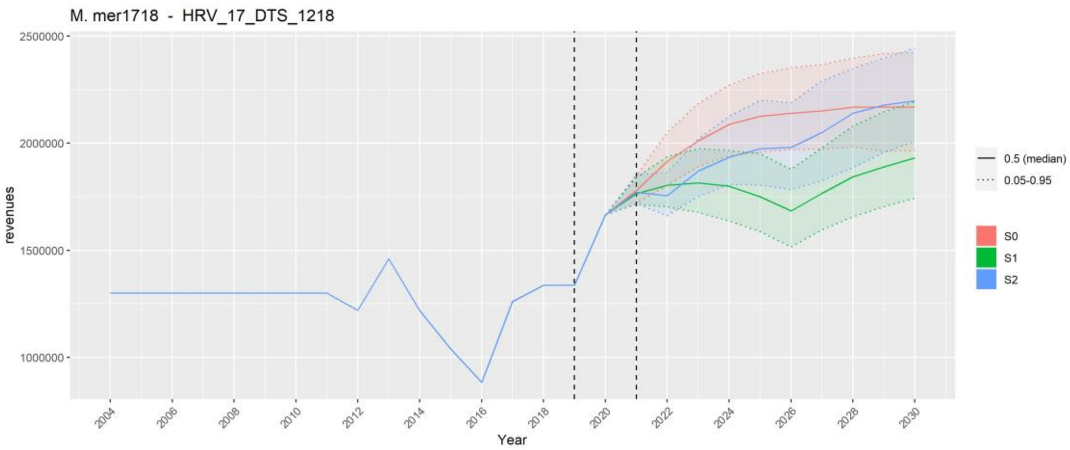
As regards the revenues by species, in general the scenario S2 performs better than S1, as the losses are mitigated by an integrated approach that would also allow the stock to recover faster, because also the exploitation pattern improves.

The fleets operating with longlines or nets will take some advantages from the management measures, although in the scenario S2 it is planned a closed season for these fleets. But, it is expected that the productivity increases in the medium terms and in the meanwhile the effort of trawlers is limited.

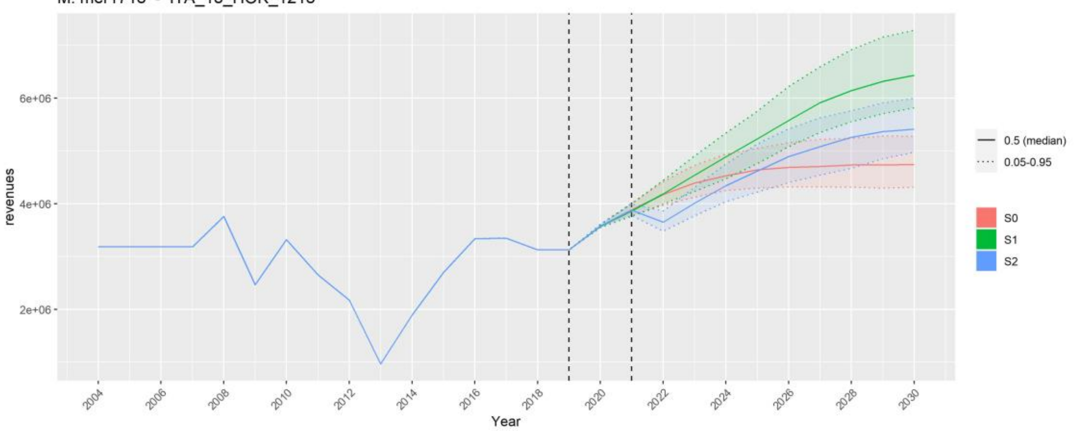
The trawl fleets, indeed, will be more negatively impacted in the short term, while in the medium term revenues can recover, thanks to the increased productivity of the stocks, and would get close to the revenues of the status quo.

For trawlers generally scenario S2 has a mitigated impact compared to S1, while for the other fleets the scenario S1 is better, because the activity of the trawlers is reduced. This is due to the interactions in mixed fisheries and it is evident more for species like European hake and red mullet. For the latter, the losses in the short term are more pronounced, but the recovery is expected since the 2nd year from the implementation of the measures. Sole, instead, is fished sustainably and consequently the fisheries by beam trawlers would be more negatively impacted by the management measures compared to the other fleets for underutilization issues, while the fisheries that use nets would be positively impacted. For trawlers S2 is better than S1, for small scale fisheries it is the opposite.

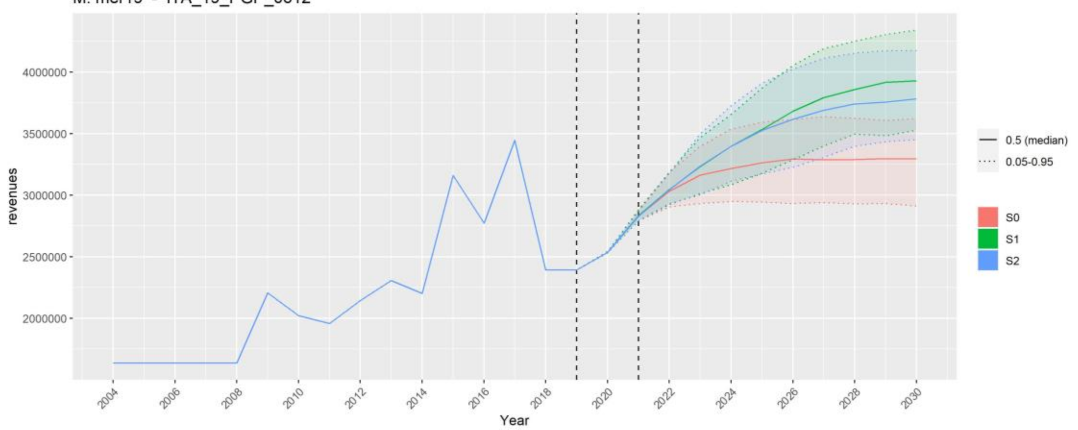




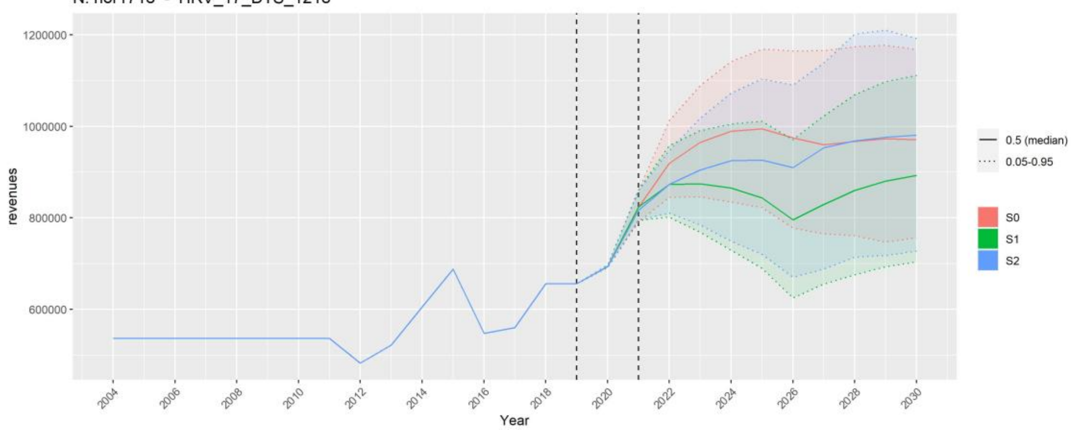
M. mer1718 - ITA_18_HOK_1218



M. mer19 - ITA_19_PGP_0612



N. nor1718 - HRV_17_DTS_1218



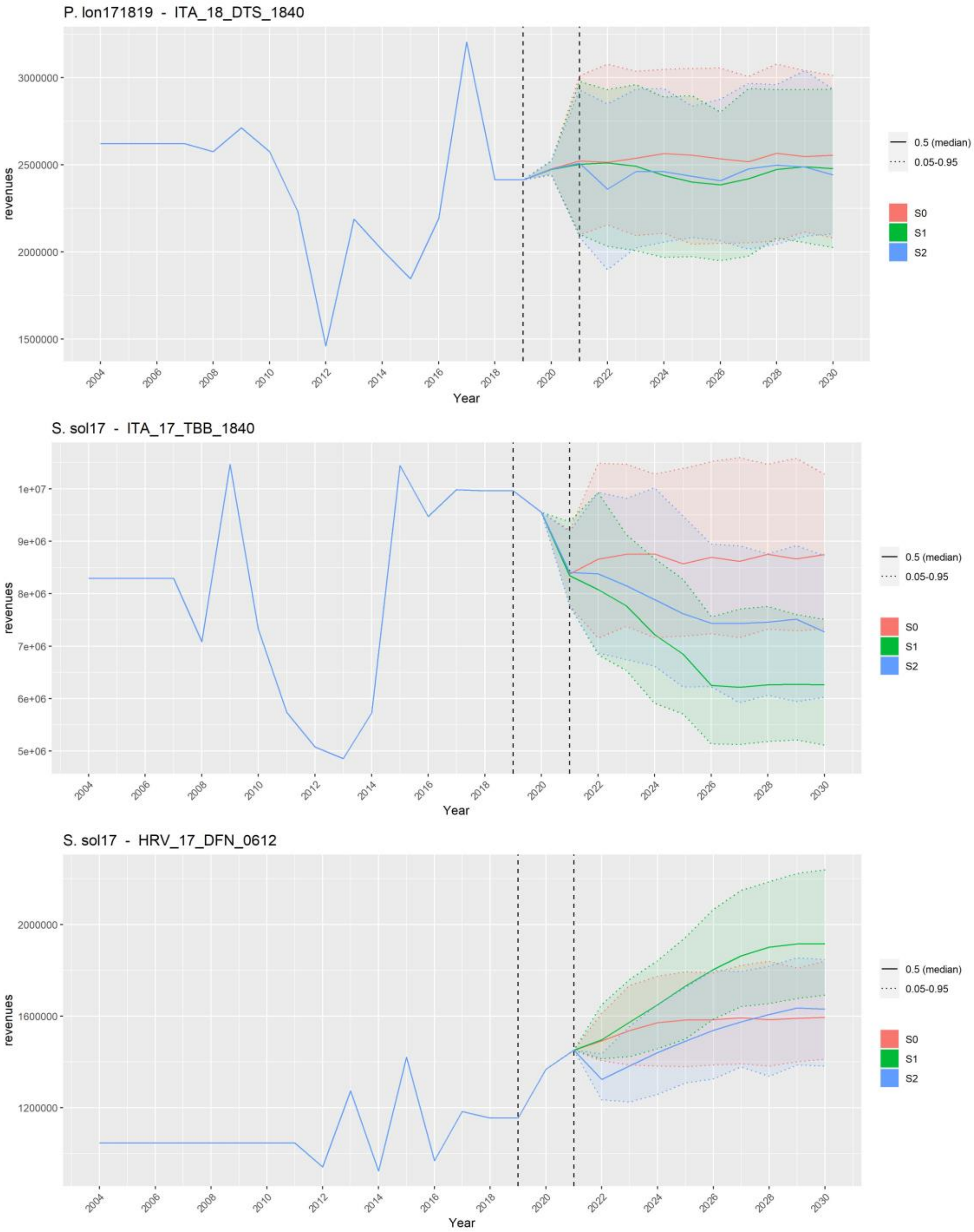
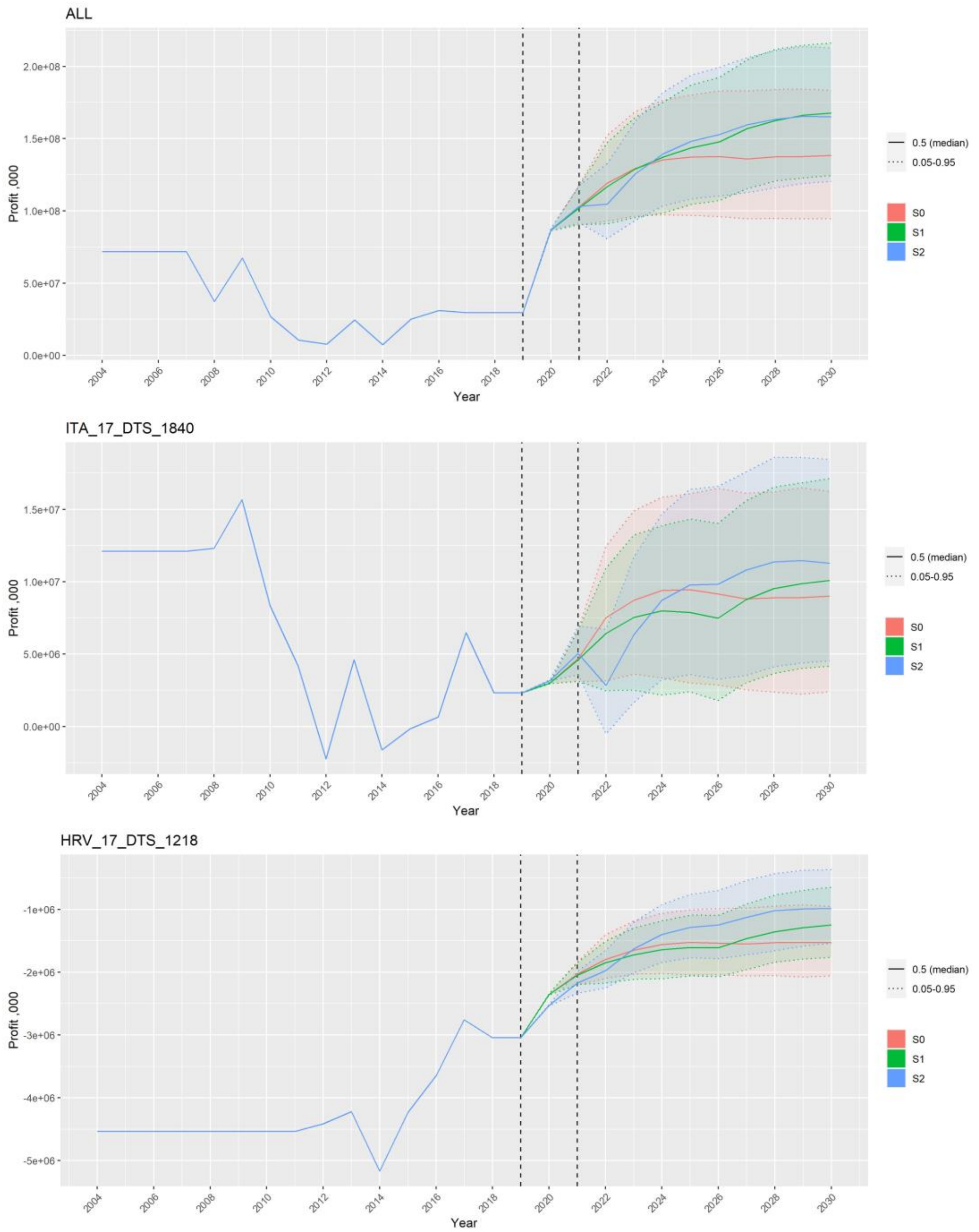


Fig. 8.3 Effects of the scenarios on the revenues of the target species. Some fleets are reported as an example.

The situation for the profits is similar to that of revenues, the scenario S2 is in general better or at least similar to scenario S1 (Fig. 8.4), except for the fleets less impacted, for which the scenario S1 has more positive effects compared to S2.



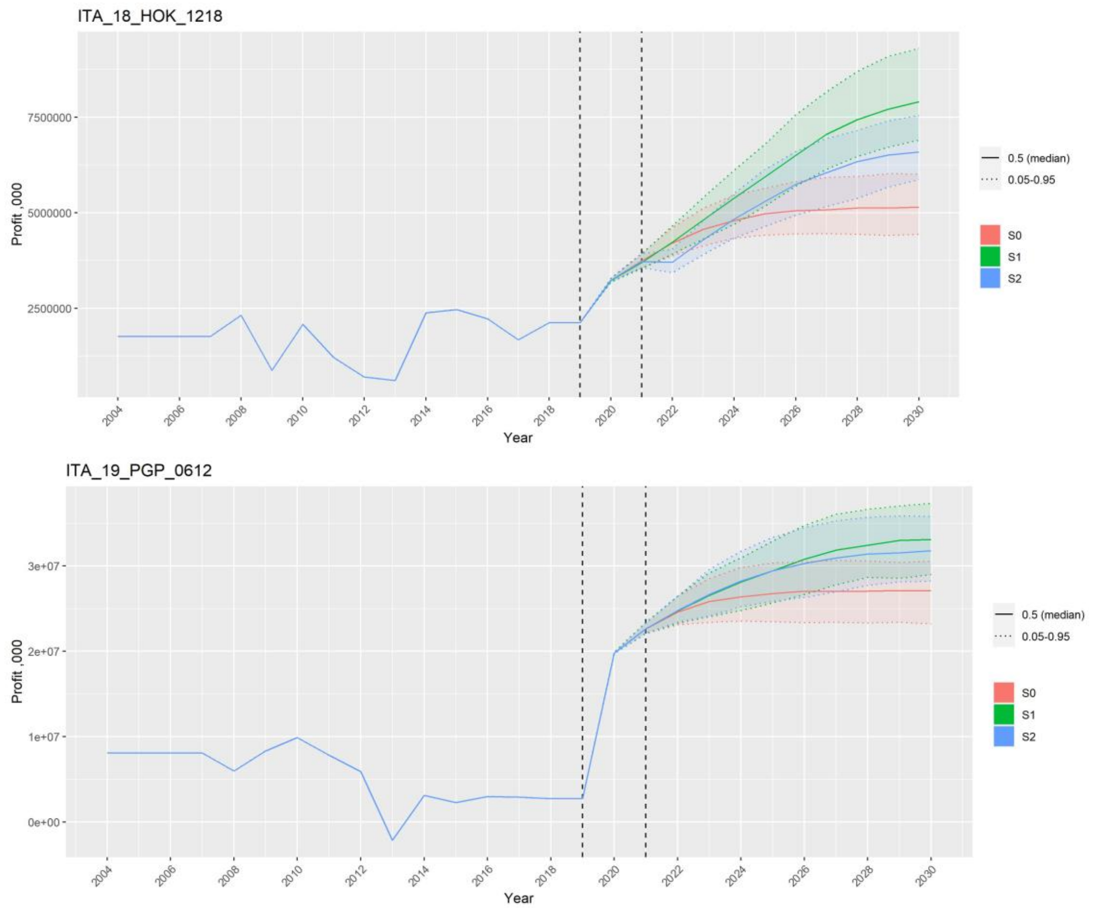
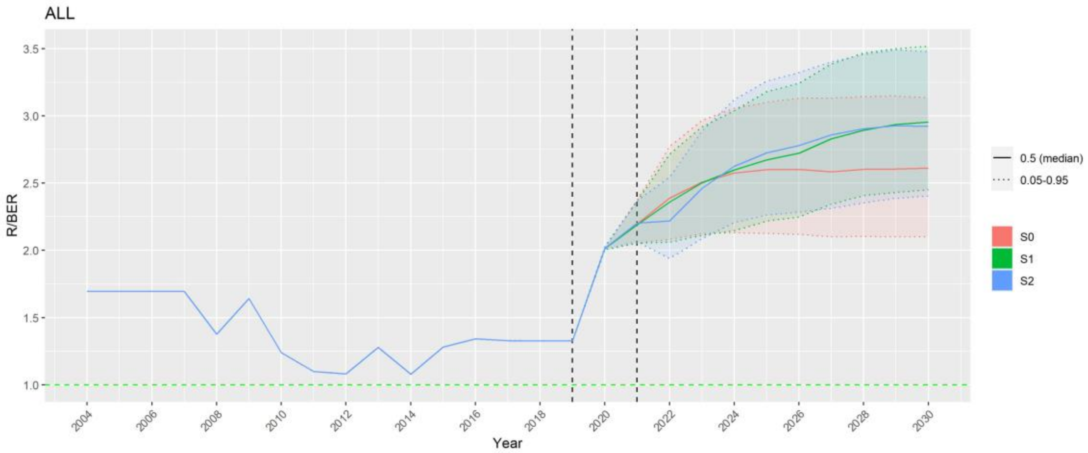
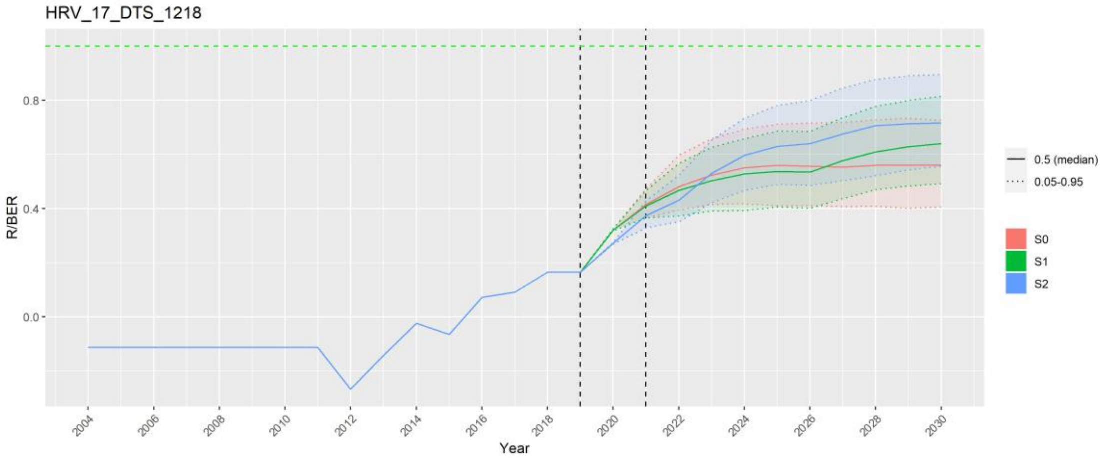


Fig. 8.4 Effects of the scenarios on the profits. Some fleets are reported as an example.

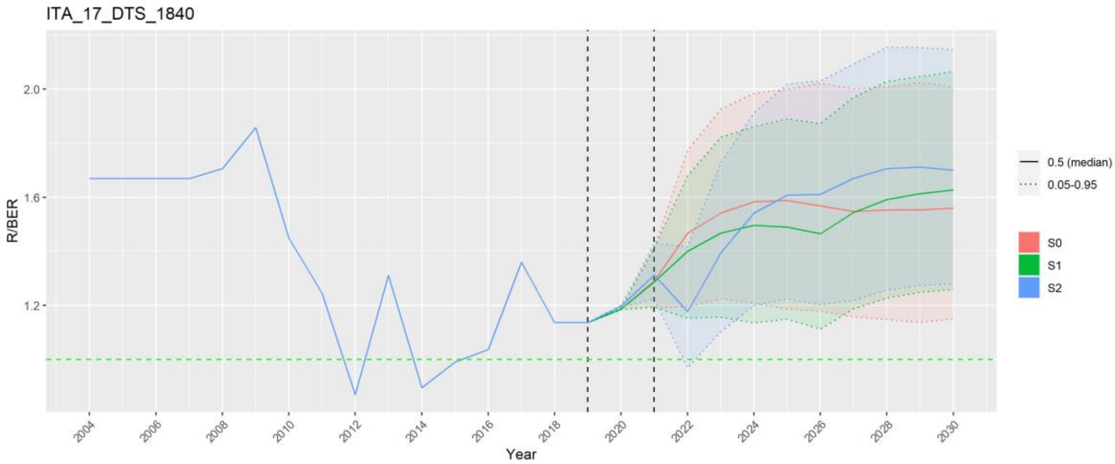
As regards the indicator R/BER, the scenario S2 performs generally better compared to both scenario S1 and, for several fleets, also to scenario S0 (Fig. 8.5). An exception is represented by the beam trawl fleet, which is dependent by the catch of sole. In this case both for S1 and S2 the situation would deteriorate compared to the status quo, though S2 performs better than S1 and R/BER would not fall below 1, as for scenario 1, though the uncertainty is high.



ALL
R/BER
Year
0.5 (median)
0.05-0.95
S0
S1
S2



HRV_17_DTS_1218
R/BER
Year
0.5 (median)
0.05-0.95
S0
S1
S2



ITA_17_DTS_1840
R/BER
Year
0.5 (median)
0.05-0.95
S0
S1
S2

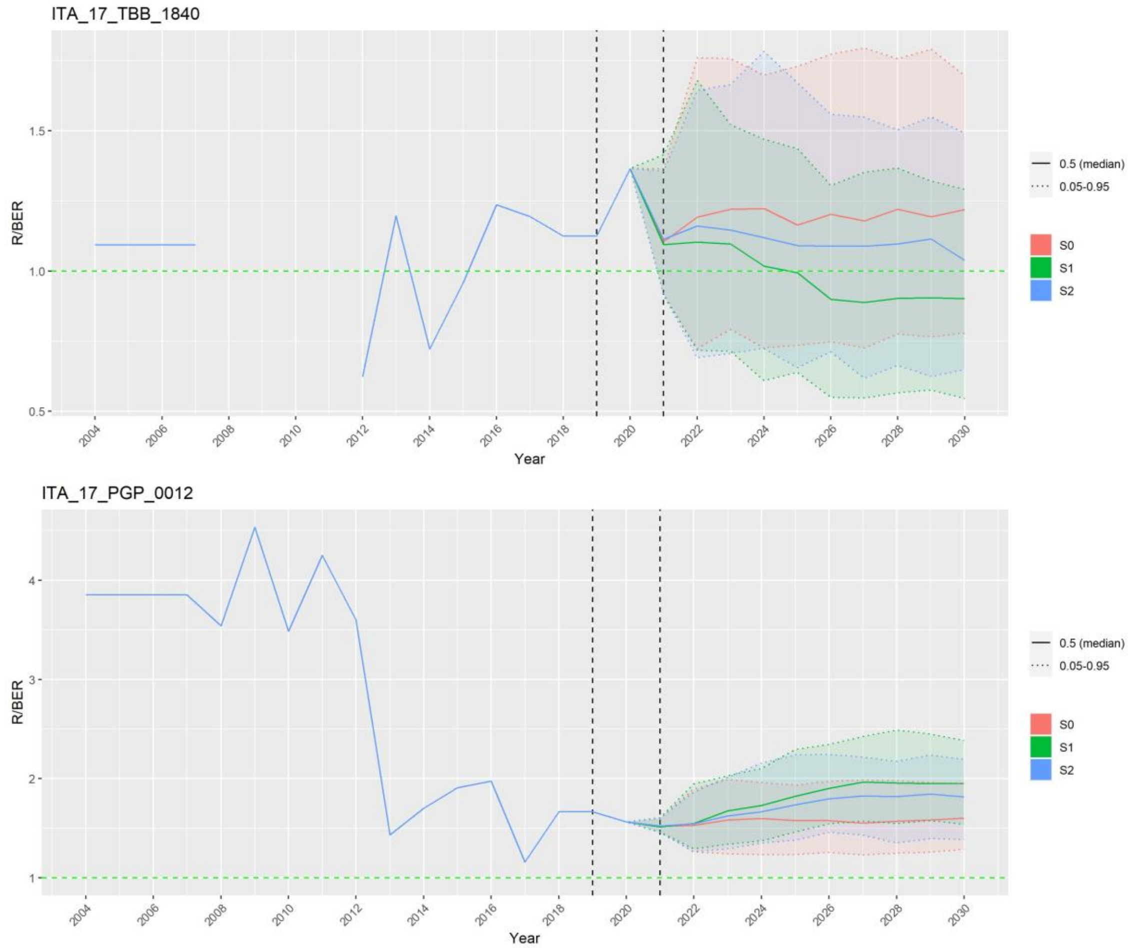


Fig. 8.5 Effects of the scenarios on the current revenues to break even revenues. Some fleets are reported as an example. The dotted green line indicates the value of R/BER=1.

Overall the predictions highlight that the situation of the wages could be not negatively impacted by the management measures and it would be possible to see some improvements in the future under the current crew share system of wage. The situation would be deteriorated only for the beam trawlers, especially under scenario S1 (Fig. 8.6).

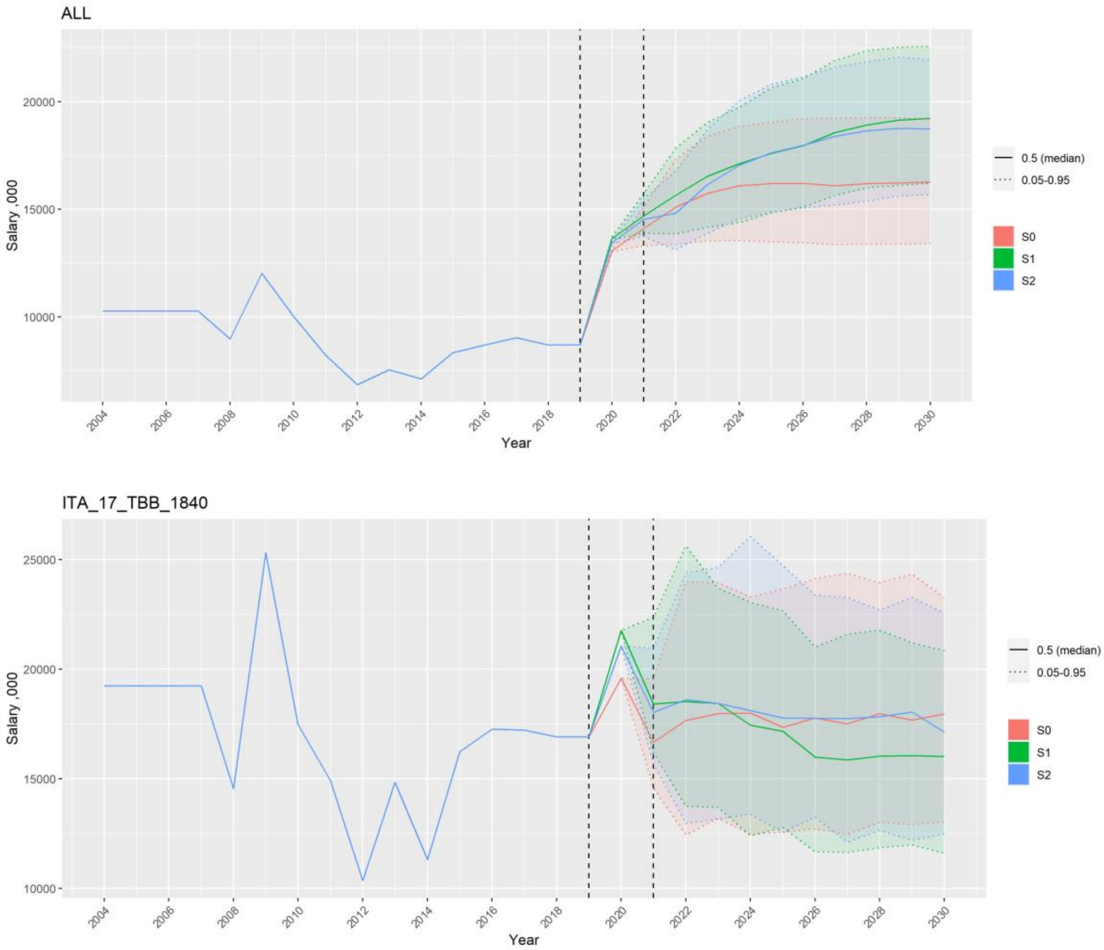


Fig. 8.6 Effects of the scenarios on the wages for all the fleets and for the beam trawlers targeting common sole in GSA17 (western side).

Overall also the forecasts for the employment highlight a possible deterioration of the situation mostly due to the losses in the short term that could determine a limitation in job opportunities. Also in this case the scenario S2 would have a mitigated impact compared to scenario S1 (Fig. 8.7). However it is also worth to mention that mechanisms of economic compensation by subsidies or incentives to mitigate this possible effect have not been simulated.

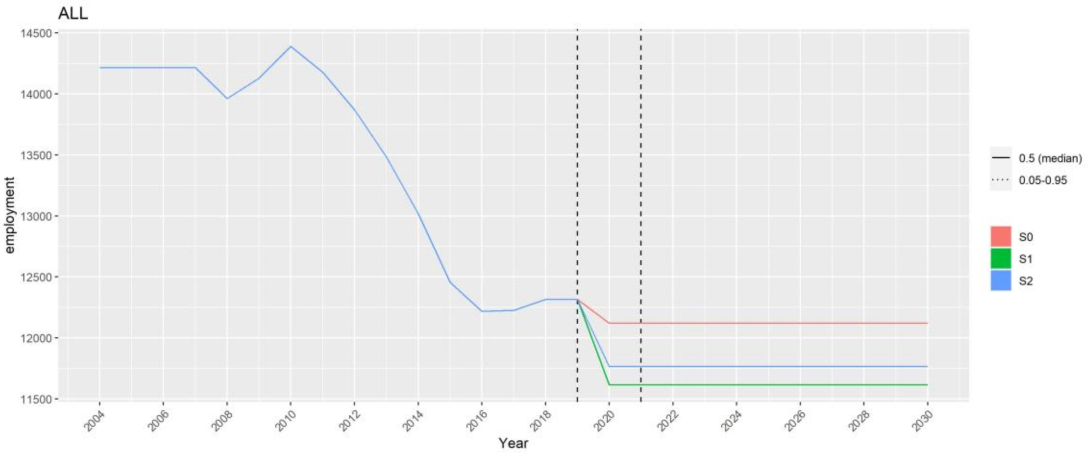


Fig. 8.7 Effects of the scenarios on employment. All fleets together are reported.

9. DISCUSSION AND CONCLUSIONS

The use of the BEMTOOL bio-economic model allowed to evaluate how different management strategies (e.g. decreasing of fishing opportunity, improving the exploitation pattern, implement closed season and areas) affect stock and fisheries dynamics in terms of fishing mortality, spawning stock biomass, landings, discards and economic performance in the short and medium term.

This confirm the usefulness of integrated bio-economic fisheries models for designing multi-annual management plans (Bastardie et al., 2010; Mackinson et al., 2018; Spedicato et al., 2018) and assessing their effectiveness. Further, gathering feedbacks from different elements of the fisheries system it is possible to better focus on the suitable management strategies to face proposed regulations (e.g. Woods et al., 2015).

We analysed the effect of two scenarios, one based on the limitation of fishing activity (S1) up to 40% and another one (S2) integrating different management measures: improvement of the exploitation pattern and reduction of the fishing activity, in this case up to 25%. Then we compared these scenarios with the status quo S0. On the basis of the stakeholder consultation an integrated reference point was introduced. It was obtained combining and weighing the landing values and F_{MSY} of the target stocks of the GFCM Recommendation. This strategy was adopted to mitigate possible underutilization of certain stocks, given that reductions of fishing effort would have affected a mixed fisheries, in which stocks with a different level of exploitation are the targets, and in our case some stocks are even heavily overexploited, while other are close to a sustainable exploitation.

In the two scenarios analysed, in addition to the status quo, there are pros and cons. In scenario 1, for example, the fishing mortality would get closer to the reference points for certain stocks, but for other ones it would be even lower with a risk of underutilization of the stock productivity. The SSB would improve in both scenario S1 and S2 compared to the status quo, for stock as red mullet, for which closed areas would be more effective, the situation of SSB would be even better in the integrated scenario S2.

Regarding the economic indicators the situation is different according to the fleet and the species, but for most of the indicators scenario S2 performs better than scenario S1. This is true especially for the trawlers, as S1 is often better for fleets using nets or longlines. These fleets would take higher advantage by the trawler limitation in S1 as in S2 the fishing activity of the small scale fisheries is also limited for two months by year. This overall effect is due to the mixed fisheries and it is evident for species like European hake and red mullet.

A sharp decrease of the economic indicators, as for example revenues and profits is sometimes apparent for some species and trawler fleets. For species as red mullet, the losses in the short term are more pronounced, but the recovery is expected since the second year from the implementation of the measures, and in the medium term such decrease is mitigated by the increase of stock productivity due to the stock recovery. Sole, instead, is fished sustainably and consequently the fisheries by beam trawlers would be more negatively impacted by the management measures compared to the other fleets for underutilization issues. In this case, both for S1 and S2, the situation would deteriorate compared to the status quo, though S2 performs better than S1 and R/BER would not fall below 1, as for scenario 1, though the uncertainty is high.

Overall the predictions highlight that the situation of the wages could be not negatively impacted by the management measures except for beam trawlers and it would be possible to see some improvements in the future under the current crew share system of wage. The forecasts of the employment highlights a possible deterioration of the situation mostly due to the losses in the short term, determined by limitations in job opportunities, also in this case the scenario S2 would have a mitigated impact compared to scenario S1.

A traffic light approach applied to the total revenues by fleet, as an example (Tab 9.1), confirms that expected results from scenario S2 are better than scenario S1 considering as baseline the value of this indicator at 2026 under the S0. Also under scenario S2 some fleets would have a higher negative impact, like beam trawlers in GSA17 and trawlers with LOA 1218 in the GSA18. Overall total revenues of small scale fleets would be also higher than under the status quo scenario S0, both for S1 and S2.

Thus, all the results highlight that the integrated scenarios could provide more wise solutions under the economic perspective, not compromising the biological objectives. Indeed, the fishing mortality of European hake, the most exploited species, would get close to Fupper, likewise under scenario S1, in which, however, the economic impact would be higher.

A strategy based on the improvement of the exploitation pattern, increasing selectivity and protecting the nursery areas, combined with a reasonable reduction of fishing activity could represent a trade-off toward the objectives of a biological and economic sustainability. This is also close to the indications provided by the stakeholders for the implementation of management scenarios in BEMTOOL. Inputs stressed to avoid the lone limitation of the fishing activity as a mid-term management strategy, giving more weight to the economic component, a concept summarised in the results of the Multi Criteria Decision Analysis (Fig. 9.1) under different weighing of the indicators.

Tab.9.1 «Traffic light» for the indicator total revenues by fleet. The baseline is represented by the values of the Scenario 0 (Status Quo) at 2026.

>10%
fra -10 e +10%
<10%
Not included in the measure

Fleets	Baseline (S0)	S1	S2
ITA_17_DTS_0612	2238388	-13%	2%
ITA_17_DTS_1218	35238534	-16%	-7%
ITA_17_DTS_1840	72833816	-16%	-7%
ITA_17_PGP_0012	56570272	19%	7%
ITA_17_TBB_1218	1323453	-24%	-14%
ITA_17_TBB_1840	16474714	-26%	-15%

HRV_17_DFN_0612	5683889	19%	-1%
HRV_17_DTS_0612	3648411	-15%	-1%
HRV_17_DTS_1218	9114401	-14%	-1%
HRV_17_DTS_1840	8288759	-14%	-5%
SVN_17_DFN_0612	406827	19%	12%
SVN_17_DTS_1218	668133	33%	37%
ITA_18_DTS_0612	3035453	-12%	-4%
ITA_18_DTS_1218	54811757	-17%	-13%
ITA_18_DTS_1840	22981105	-14%	-10%
ITA_18_HOK_1218	10676328	22%	4%
ITA_18_PGP_0012	16042782	24%	29%
ALB_18_DTS_1224	13589332	-11%	-3%
MNE_18_DFN_0012	690786	23%	32%
MNE_18_DTS_0612	133618	33%	30%
MNE_18_DTS_1224	1271082	33%	31%
MNE_18_HOK_0012	232149	23%	21%
ITA_19_DTS_1218	28599689	-14%	-8%
ITA_19_DTS_1824	6140850	-13%	-9%
ITA_19_PGP_0006	61323943	14%	10%
ITA_19_PGP_0612	66418730	15%	11%
ITA_19_PGP_1218	387031	12%	9%
ITA_19_HOK_0624	46326519	11%	8%

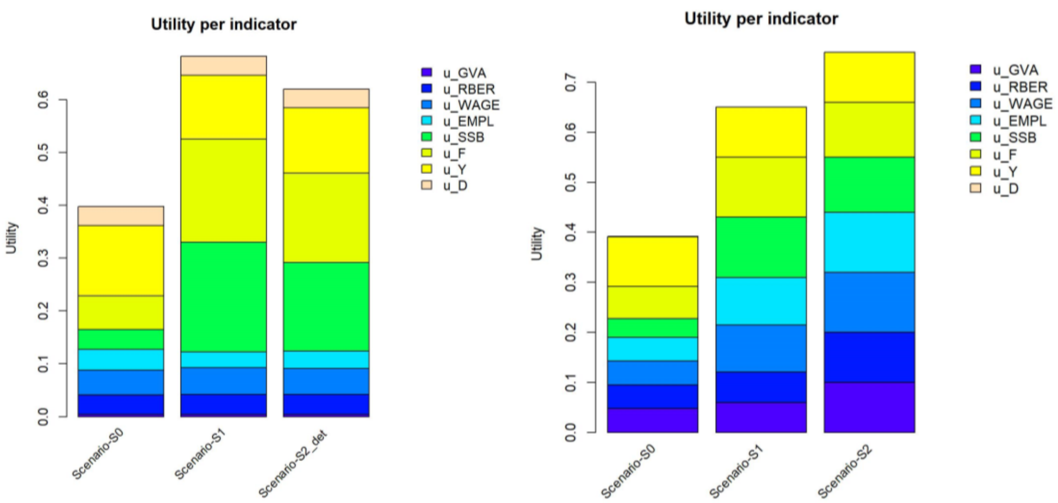


Fig. 9.1 – Results from the MultiCriteria Decision Analysis.

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