Bio-economic impact assessment of multiannual management plans (MAPs) for the Spanish demersal fishing fleets in the Bay of Biscay

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Azti – Tecnalia

Introduction

Bay of Biscay (Figure 1) is a highly productive system. It creates the perfect conditions to multispecies fleets to make use of this productivity.

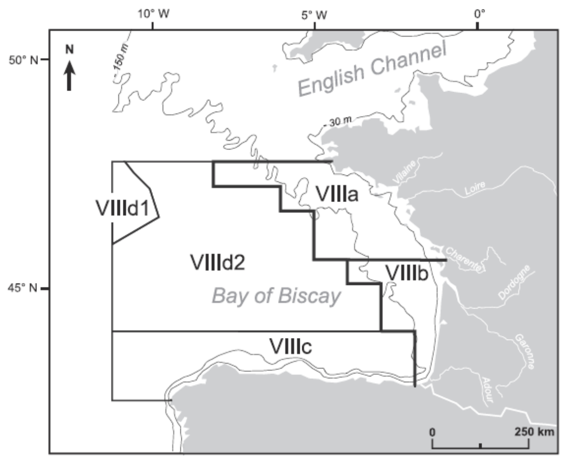

Figure 1. Case study area: Bay of Biscay

The demersal Spanish fleets operating in this area are composed of bottom trawlers, longliners and netters. These fleets are managed through TAC and TAE, apart from some other technical and physical measures. These two regulations (TAC and TAE) come from different origins.

The TAC was first implemented when Spain joined the EU in 1986. Setting TACs involves the fixing of maximum quantities of fish that can be caught from a specific stock over a given period of time. This operation requires cooperation among the various parties enabling those involved to come to an agreement regarding TACs and an allocation key for sharing them. The EU went on to share fishing opportunities in the form of quotas among Member States. A formula was devised to divide TACs according to a number of factors, including countries' past catch record. This formula is still used today, on the basis of what is known as the principle of 'relative stability' which ensures Member States a fixed percentage share of fishing opportunities for commercial species. Even if the share has been maintained stable over time, the growing scarcity of the key stocks has eroded significantly the fishing opportunities for these fleets.

The TAE is previous to the TAC regulation. In 1981 it was decided to list all the Spanish vessels operating in Divisions VIIIa,b,d and Sub-areas VI and VII, in order to create the access rights to these fisheries (a single fishing right per vessel). The idea was to maintain fixed these rights even if the number of vessel decreased. When Spain joined the EU the number of vessels in that list was close to 300 and the so-called “300 list” was created. These fishing rights became transferable by area.

Finally, concerning technical measures, some mess size limitations and minimum landing sizes for some stocks have been implemented.

Further information on how this fishery is managed can be found in , or in .

The purpose of this annex is to show the specific conditioning and data used, as well as to show part of the specific results obtained in the simulations process. In this process three management scenarios have been combined with two fleet dynamics scenarios which produced a total of six scenarios. Management scenarios include a scenario with maximum sustainable yield (MSY) fishing mortalities as target and a restriction in TAC variation of 15% until 2020 and two scenarios with the limits of MSY fishing mortality ranges as targets and biomass reference levels as safeguards. Fleet dynamics have been modelled using two different approaches, one based on observed data and a second one based on maximization of profits. All the scenarios have been run from 2014 to 2025.

The model used: FLBEIA

FLBEIA is a simulation BEM coupled in all its dimensions (economic, biologic and social), it is developed in R using FLR libraries . FLBEIA follows the MSE approach, which is widely used in fisheries management to analyse the performance of management strategies against predefined management objectives, by means of simulation before they are put in place. It consists of simulating the fish stocks and the fleets that exploit them together with the management procedure. The goal is to analyse the performance of different management strategies and identify those strategies that are robust to the uncertainties considered. The simulation algorithm is divided into two blocks, the Operating Model (OM) and the Management Procedure Model (MPM). In FLBEIA the OM is made up of the fish stocks, the fleets, the covariates and their interactions (see . The MPM describes the management process and is formed by the observation, assessment and management advice models. The stocks can be age structured or aggregated in biomass and there are no trophic interactions. Fleet activity is divided into *metiers* where *metiers* are defined as trips within a fleet that share the same characteristics in terms of gear used, fishing area and catch profiles.

The stocks can be age structured or aggregated in biomass. The interaction between fish population and catch is done in biomass and the relationship between catch and effort is based on a Cobb Douglas production model , at age level.

The stochasticity in the model is introduced using Monte Carlo simulation and can be introduced in any model parameter. In the simulations it has been introduced only in the biological side (in the stock recruitment relationship) and a Monte Carlo simulation has been performed with xx iterations. The coupled characteristic of FLBEIA implies that this uncertainty is spread through all the remaining dimensions of the model (economic and social).

Short term dynamics

Short term dynamic models how much effort is exerted and how it is distributed along metiers. There are two possibilities which define the two “extreme” situations.

The first possibility used to mimic mixed fisheries is based on the Fcube method and is used in FLBEIA to approximate mixed fisheries dynamics. The effort share along metiers is given as input data and only the total effort is estimated in each step. First, the effort corresponding to the TAC-share of each stock caught by the fleet is calculated, this returns one effort per stock. The final effort is selected based on the previously calculated efforts. The selection is done using different available options (min the minimum, max the maximum, mean the mean, previous the most similar to the previous year effort and stock-name the effort that produces a catch level equal to the quota share of the stock specified).

The second possibility used to simulate mixed fisheries dynamics calculates the total effort and the effort allocation among metiers that maximizes profit. The total effort is constrained by the capacity of the fleet (capacity unit has to be converted to the same unit as effort) and by the catch quota of some of the stocks.

Long term dynamics

This describes the long term dynamics of the fleet or strategic behaviour; the investment or disinvestment of fishermen in new vessels or technological improvements. In FLBEIA the capital dynamics could be modelled through changes in fleet’s capacity or changes in fleet’s catchability (technological improvements). However, at present, models that dynamically change catchability are not available in FLBEIA. Catchability can vary over time but only if time dependent catchability is provided through input data. Capital can vary according to the model described in . This model relates the investment and disinvestment in new vessels with the ratio between revenue and break even revenue, that is the amount of revenue needed to cover both fixed and variable costs. The annual investment for each fleet is determined by the possible maximum investment multiplied but the profit share that will go to the investment itself; however, investment in new vessels will only occur if the operational days of existing vessels are equal to maximum days.

Then the investment decision will follow the rule below

$$If \begin{cases} \dfrac{REV-BER}{REV}<0 \;\; and \;\; \Pr ofshare\left|\dfrac{REV-BER}{REV}\right|<0.2 \;\; Investment=\Pr ofshare\times\dfrac{REV-BER}{REV} \\ \dfrac{REV-BER}{REV}<0 \;\; and \;\; \Pr ofshare\left|\dfrac{REV-BER}{REV}\right|>0.2 \;\; Investment=-0.2*Fleet_{t-1} \\ \dfrac{REV-BER}{REV}>0 \;\; and \;\; \Pr ofshare\left|\dfrac{REV-BER}{REV}\right|<0.1 \;\; Investment=\Pr ofshare\times\dfrac{REV-BER}{REV} \\ \dfrac{REV-BER}{REV}>0 \;\; and \;\; \Pr ofshare\left|\dfrac{REV-BER}{REV}\right|>0.1 \;\; Investment=0.1*Fleet_{t-1} \end{cases}$$

Where 0.1 stands for the limit on the increase of the fleet relative to the previous year and 0.2 stands for the limit on the decrease of the fleet relative to the previous year. The increase in number of vessels is then obtained dividing the final investment in new vessels, by the maximum number of days that a vessel operates in a year.

Inter Year flexibility

FLBEIA is able to simulate inter-year flexibility. Nevertheless this option has not been used in the simulations performed for the sake of the robustness of the final results.

Landing Obligation

FLBEIA is able to simulation the landing obligation as defined by the CFP by calculating the necessary effort to catch the quota of the more restrictive stock. In the simulations performed landing obligation has been simulated using this approach.

FLBEIA is able to simulate the exemptions anticipated in the CFP, and more specifically the inter-species flexibility and de minimis. Nevertheless, these two options have been not used in the final simulations due to different reasons.

In the case of de minimis and in the inter year flexibility, results obtained create some effects that we have not been able to explain. For the sake of the robustness of the final results the group has decided to switch off this option.

The case of the inter-species flexibility the reason for not using it is the existing un-clarification in terms of how to implement it, in particular in terms of if the donor stocks and the receivers stocks are constrained by any reason (beyond the “good” biological status of the receiver).

Conditioning and data used

BoB case study has been conditioned using different data sources. It implies that a big effort has been deployed to match these different sources and to cover the inconsistencies found between these data bases.

Fleets have been conditioned using IEO and AZTI data sources obtained through the DCF with a time series that goes from the year 2009 to the year 2013. The fleets explicitly considered in the simulations are only the Spanish fleets operating in this area. The number of vessels by segment is presented in Table 1 with a description of the fishing gear used.

FLBEIA considers the fleet as the economic unit from the costs side. It implies that the fixed costs are at fleet level and variable costs at metier level. The costs have been obtained from the Annual Economic Report . To adapt these values to the specific conditioning of the case study, the economic figures have been weighted by the proportion of vessels that each segment has and them converted into weighted averages of the fleets. From the income side FLBEIA considers that the economic unit is the metier. The reason is that each metier is providing a different catch profile (including landings and discards) that differs in the total income and the composition of it. The diverse casuistic of the BoB case study is wide.

Table 1. Fleets and metiers in the fishery (Spanish vessels): 2013

Fleet	Number of vessels	Metier	Effort (days)
DTS	23	OTB_DEF_>=70_0_0	2.456
		OTB_MCF_>=70_0_0	254
		OTB_MPD_>=70_0_0	35
		PTB_DEF_>=70_0_0	1.366
DFN	17	GNS_DEF_>=100_0_0	915
HOK	80	LLS_DEF_0_0_0	3.352

Source: IEO

Table 2. Economic conditioning of the fleets considered in the simulation

	Fleet			Units
Variable	**DTS**	**DFN**	**HOK**	
Fuel Cost	1.240	375	686	1000€/days
Crew Cost	33%	50%	34%	% from the fishing income
Variable Cost	875	1.006	979	1000€/days
Fixed Cost	15.449	30.186	7.984	1000€/vessel/year
Capital Cost	64.438	68.759	48.984	1000€/vessel/year
Depreciation	20.952	18.698	38.611	1000€/vessel/year
Max days	150	125	100	Days
FTE (direct)	11	8	5	FTE per vessel

Source: AER 2014. Note that given that these fleets also operate in the North Western Waters (Ices areas VI and VII), Fixed costs, the capital costs, depreciation and max days have been weighted by the fishing days that these fleets exerted in the VIIIabd.

Twelve stocks have been introduced in the biological operating model, Megrim (*L. whiffiagonis)*, Hake (*Merluccius merluccius*), Black anglerfish (*Lophius budegassa),* White anglerfish (*Lophius piscatorius)*, Western Horse mackerel (*Trachurus trachurus)*, Mackerel (*Scomber scombrus)* Blue Whiting (*Micromesistius poutassou*), Rays (*Leucoraja naevus*), Inshore squids (*Loliginidae*), Seabass (*Dicentrarchus labrax*), Cuttlefishes and bobtail squids (*Sepiidae, Sepiolidae*) and Red mullet (*Mullus surmuletus*)*.* All these stocks represent at least the 81% of the total catches and more than the 88% of the total income.

Table 3. Catches and values explained from 2011 to 2013 using the stocks selected

	2011	**2012**	**2013**
Catch	83%	83%	81%
Value	88%	89%	88%

Megrim has been simulated using an age structured model. The conditioning has been based on the stock assessment model used by ICES to give advice. This assessment is used by ICES only as trends and no F target has been defined yet. Hake has been simulated using age structured dynamics and the data necessary to condition the model has been taken from ICES assessment working group reports. From this group it also has been obtained the F_{MSY} (equal to 0.27) and the Expert Working Group (EWG 2505 agreed on using a preliminary ranges based (partially) on ICES methodology of 0.18 (F_{low}) and 0.37 (F_{up}). Western Horse mackerel, blue whiting and mackerel are widely distributed stocks exploited by several fleets apart from those considered here. Although the catch of these stocks is important for the fleets in the case study, the amount of catch harvested by them is small in comparison with the international catch. Hence, the catch of these fleets is supposed to have little impact on the dynamic of the three stocks. As it is practically impossible to include in the model all the fleets that catch these stocks, it has been assumed that the biomass of these stocks stays constant and equal to the average of the last three year biomass in the projection part of the simulation. In the historical period the conditioning has been done using data from working group reports.

The fleets in the case study harvest a great number of different stocks, and although big effort has been made to include as much stocks as possible not all the stocks captured by the different *metiers* have been considered (see Table 4 for the explicit stocks and average market price[1]).

The multi-species characteristic of the fisheries studied, makes very difficult to incorporate into the model all the stocks explicitly (not all the stocks caught are assessed; the data is not available at fleet level or even at aggregated level…). To overcome this limitation, an "Others" (OTH) stock which accounts for all the catches of the species not explicitly considered, but that are economically relevant, has been created. There are as many "others" stocks as metiers and an average price has been calculated for each of them. Finally catches of these "others" stocks are proportional to the effort deployed by each metier. But no stock dynamics are considered.

Scenarios

Six scenarios have been run, combining one management strategy with one of the fleet dynamic options. The management strategy scheme is shown in the figure below.

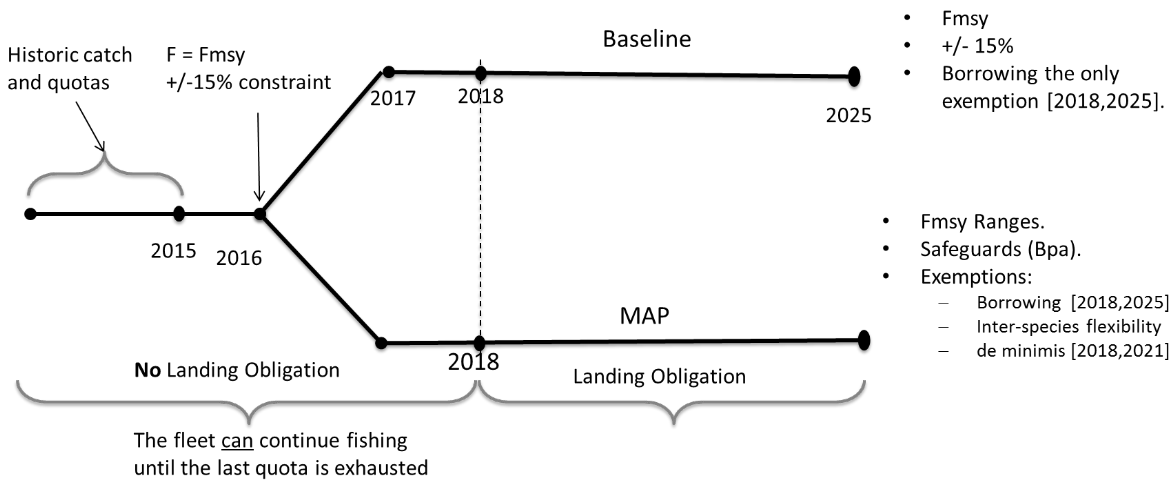

Figure 2. Management strategy scheme

The observed data ranges up to 2013 and the simulation started in 2014. From 2014 to 2016 all the scenarios share the same management strategy, namely:

- Historical TACs and quotas from 2014 to 2015.

[1] Source IEO and AZTI-Tecnalia.

- In 2016, TAC based on Fmsy with a +/-15% constraint in catch variation.

The management strategy was combined with the two fleet dynamics, traditional and profit maximization. From 2017 the management strategy has been divided in three different strategies which produced the six scenarios described in the table below.

Management Strategies from 2017:

- CFP: TAC advice is generated based on Fmsy and until 2020 there is +/-15% TAC variation constraint. Since 2020 the advice is based on Fmsy whatever the resulting catch is.
- MAP – Upper: TAC advice is generated based on the upper limit of Fmsy range. There is a biomass safeguard so that if a stock is or falls below safeguard levels, the strategy is to rebuild it above such levels in 5 years.
- MAP – Lower: TAC advice is generated based on the lower limit of Fmsy range. There is a biomass safeguard so that if a stock is or falls below safeguard levels, the strategy is to rebuild it above such levels in 5 years.

Mathematically the harvest control rule associated to the safeguards can be written as:

$$F_{adv} = \begin{cases} F_{tg} & \text{if } SSB_y \geq B_{pa} \\ min(F, F_{tg}) : SSB_{y+1}[F] = SSB_y + \frac{(B_{pa} - SSB_y)}{K} & \text{if } SSB_y > B_{pa} \end{cases} \quad (1)$$

Where K is equal to:

- Five if y is the first consecutive year were SSB was forecasted to be below Bpa.
- Five minus the number of consecutive years that SSB has been forecasted to be below Bpa. If this number is equal or lower than zero K is equal one, i.e F_{adv} is such that Bpa is reached right after the TAC year.

All together the scenarios can be summarized as shown in the table below.

Table 4. Scenarios in the simulation

Scenario	Management Strategy	Fleet Dynamic
cfp_smfb	CFP	Traditional
cfp_mp	CFP	Profit

		Maximization
mnf_up_**s**mfb	MAP – Upper Limit	Traditional
mnf_up_**mp**	MAP – Upper Limit	Profit Maximization
mnf_**lo**_smfb	MAP – Lower Limit	Traditional
mnf_lo_**mp**	MAP – Lower Limit	Profit Maximization

Table 5. Stocks considered and first sale prices for Spanish fleets

Code	Common name	Scientific name	Stock	Age	Average Price
ANK	Black anglerfish	*Lophius budegassa*	VI, VII, VIIIabd	all	5.53€
HKE	Hake	*Merluccius merluccius*	VI, VII, VIIIabd	<3	2.27€
HKE	Hake	*Merluccius merluccius*	VI, VII, VIIIabd	3	2.16€
HKE	Hake	*Merluccius merluccius*	VI, VII, VIIIabd	4	2.07€
HKE	Hake	*Merluccius merluccius*	VI, VII, VIIIabd	>4	2.89€
MEG	Megrim	*L. whiffiagonis*	VI, VII, VIIIabd	<7	4.02€
MEG	Megrim	*L. whiffiagonis*	VI, VII, VIIIabd	7	4.11€
MEG	Megrim	*L. whiffiagonis*	VI, VII, VIIIabd	>7	5.14€
MON	White anglerfish	*Lophius piscatorius*	VI, VII, VIIIabd	all	4.38€
HOM	Horse mackerel	*Trachurus trachurus*	Widely distributed	all	0.84€
MAC	Mackerel	*Scomber scombrus*	Widely distributed	all	1.68€
WHB	Blue Whiting	*Micromesistius poutassou*	Widely distributed	all	1.19€
MUR	Red Mullet	*Mullus surmuletus*	-	all	3.87€
SQZ	Squids	*Loliginidae*	-	all	5.71€
CTL	Cuttlefish	*Sepiidae*	-	all	3.29€
SKA	Skates	*Raja spp*	-	all	3.83€
BSS	Bass	*Dicentrarchus labrax*	-	all	7.14€
		Metiers			
OTH	Others	OTB_DEF_>70	-	all	1.16€
OTH	Others	OTB_MPD_>70	-	all	0.99€
OTH	Others	PTB_DEF_>70	-	all	1.96€

Source: AZTI

Results Bay of Biscay Spanish fleets

Traditional scenario

This traditional scenario is based on the Fcube method . The effort share along metiers is given as input data and only the total effort is estimated in each step. First, the effort corresponding to the TAC-share of each stock caught by the fleet is calculated, this returns one effort per stock. The final effort is selected based on the previously calculated efforts.

Only hake can be analyzed in terms of the relationship between effective fishing mortalities and target fishing mortalities. For hake in 2025 under the CFP management scenario (cfp_smfb) were around MSY targets. In the management plan scenario with F_{low} as target (mnf_lo_smfb) the fishing mortality is below the F limit until 2021 then it goes above and finally it converges in the limit. In the scenario with F_{up} as target (mnf_up_smfb) fishing mortality of Hake is always below the F upper limit. In general it can said that with the introduction of landing obligation in 2018 the fishing mortalities start to increase and finally converge to the F target, except for the case of F_{up}.

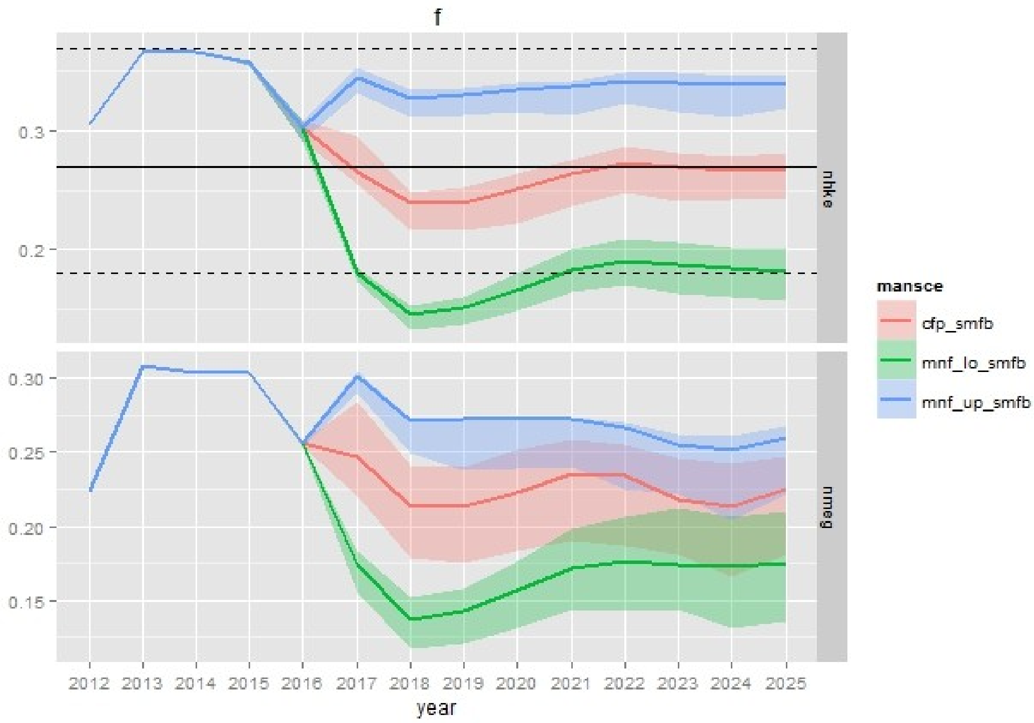

Figure 3. Reference fishing mortality time series in Traditional fleet dynamics case for the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles. The horizontal black lines correspond with F_{msy} (solid lines) and upper and lower limits (dashed lines) when they exist.

As it can be seen in Figure 3 for all the management scenarios the SSB is well above the safeguard. However for the case of F_{up}, in many cases SSB is well below the historical observations of the period analyzed. On the other hand for F_{low} scenario the trend is always increasing until year 2025 where it stabilizes.

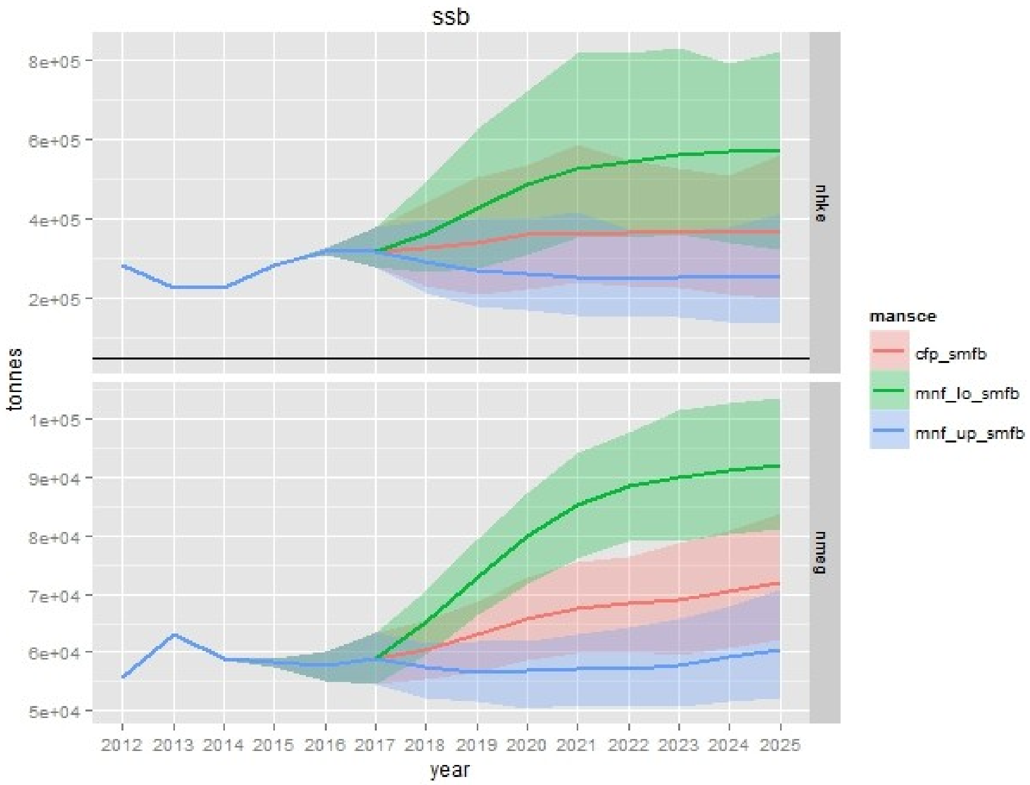

Figure 4. Spawning Stock Biomass time series in Traditional fleet dynamics case for the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles.

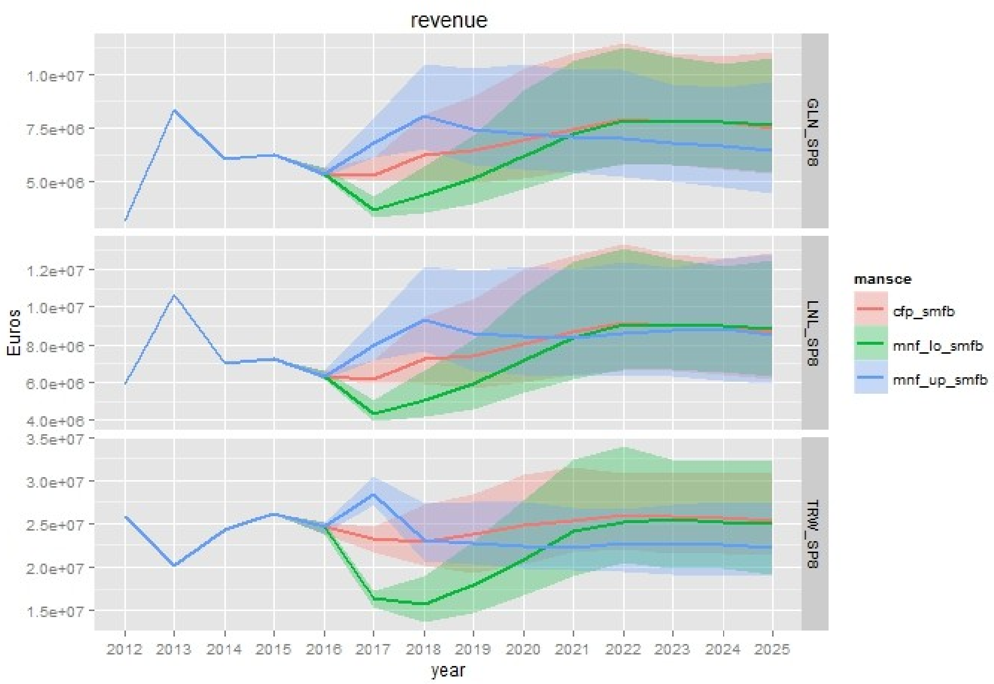

Figure 5 Revenue time series in Traditional fleet dynamics case and the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles. Note that TRW_SP8 stands for the Spanish DTS fleet operating in the ICES Divisions VIIIabd, LNL_SP8 for Spanish HOK operating in the VIIIabd and GLN_SP8 for DFN operating in the VIIIabd.

Figure 5 represents the revenue obtained by the three fleets from all the catches landed and sold for direct human consumption. The main characteristic result is that for gillnetters and trawlers the CFP and the F_{low} scenario converge into similar values. However F_{up} scenario provides after year 2020 lower revenues than the other two management scenarios.

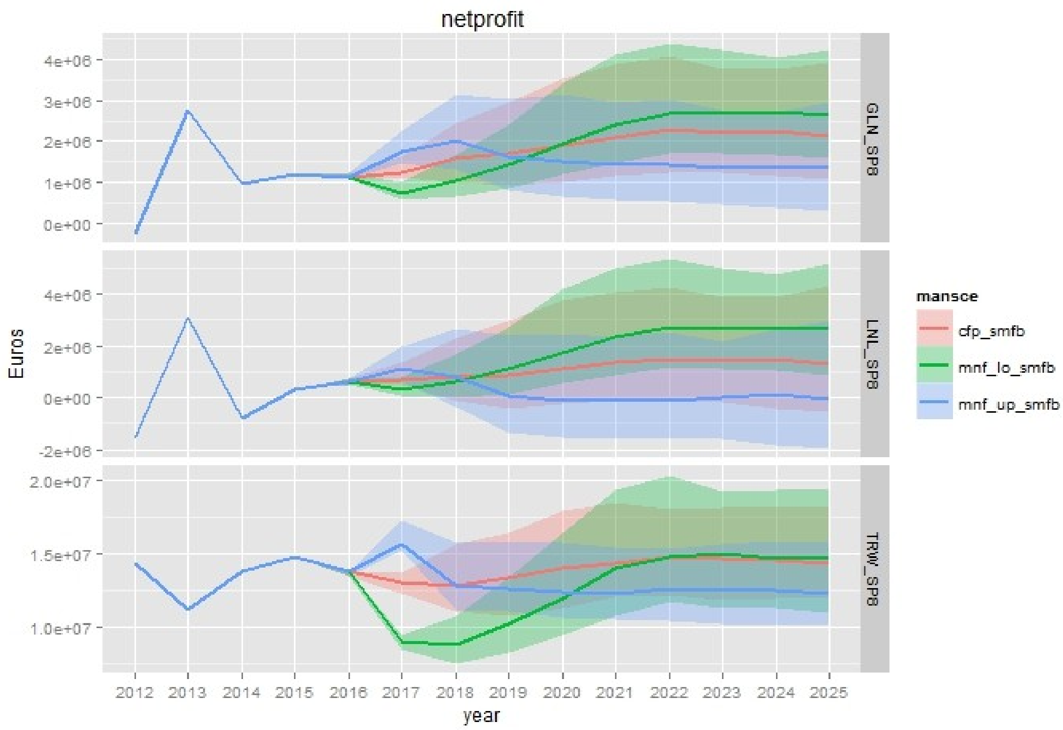

Figure 6. Net-Profit time series in Traditional fleet dynamics case for the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles.

Net profit is quite characteristic of what we have seen for revenues, for the three fleets, sooner or later (depending on the fleet) net profits will be higher for the case of CFP or F_{low} management scenarios. It can be a sign that the fishery is exhorting an effort above what is economically optimal. It is also important to remark that for the F_{up} scenario and for longlines, the probability of negative net profit is not zero.

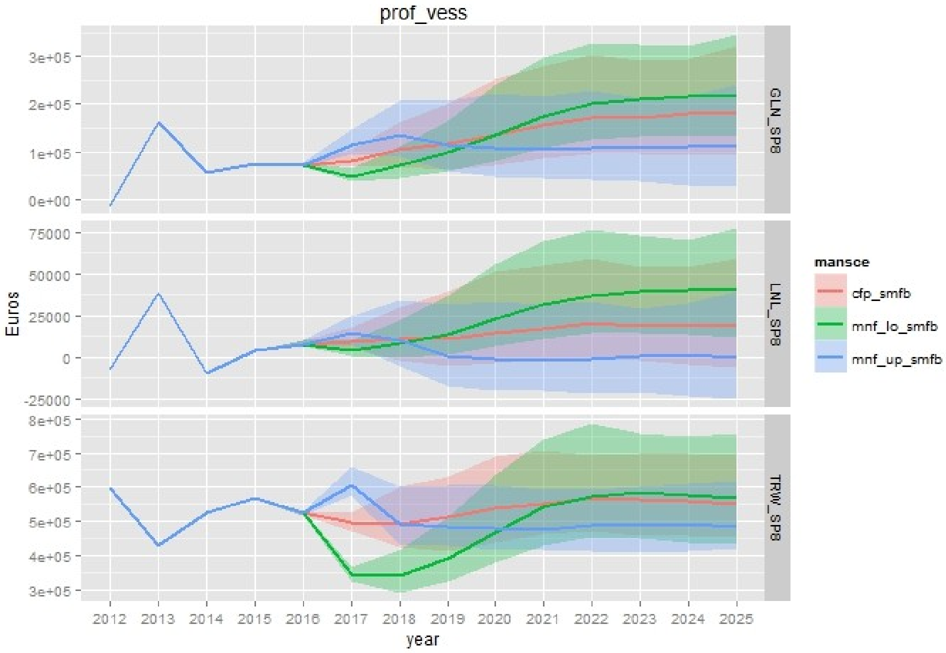

Figure 7. Net profit per vessel time series in Traditional fleet dynamic for the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles.

Finally, and given that the model simulate the entry exit behavior of the fleet, the net profit per vessel is shown in Figure 7 where it can be observed how for F_{low} and CFP management scenarios there is an increasing general trend for the profit per vessel indicators. Again for F_{up} there are cases in where this net profit can be negative, in particular for the case of longliners.

Maximum profit scenario

In this case total effort and effort allocation among metiers is calculated in such a way that maximizes profit. The total effort is constrained by the capacity of the fleet (capacity unit has to be converted in the same unit as effort) and by the catch quota of some of the stocks.

Only hake can be analyzed in terms of the relationship between effective Fishing mortalities and target fishing mortalities. For hake in 2025 under the CFP management scenario (cfp_mp) were around MSY targets. In the management plan scenario with F_{low} as target (mnf_lo_mp) the fishing mortality is below the F limit until 2021 then it goes above and finally it converges in the limit. In the scenario with F_{up} as target (mnf_up_mp) fishing mortality of Hake is always below the F upper limit.

In general it can be said that there are not differences between this case and the traditional one.

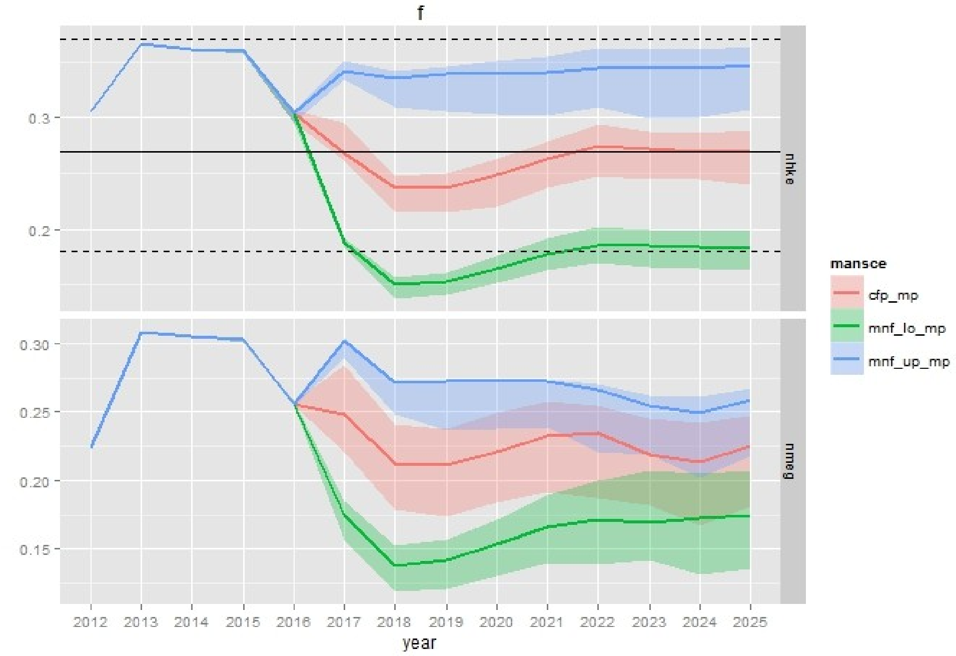

Figure 8. Reference fishing mortality time series in maximum profit fleet dynamics case for the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles. The horizontal black lines correspond with F_{msy} (solid lines) and upper and lower limits (dashed lines) when they exist.

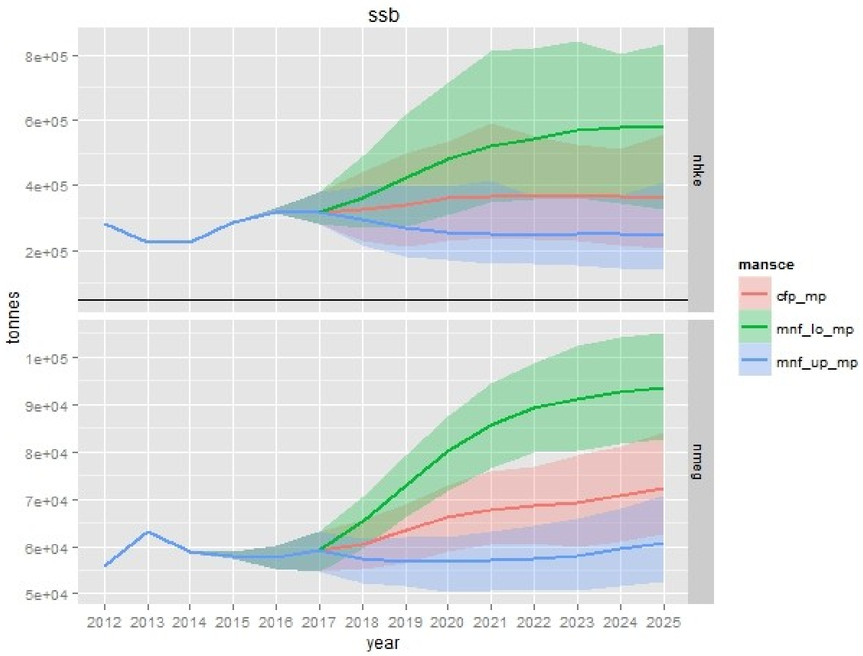

Figure 9. Spawning Stock Biomass time series in maximum profit fleet dynamic case for the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles.

As it can be seen in Figure 9 for all the management scenarios the SSB is well above the safeguard. However for the case of F_{up}, in many cases SSB is well below the historical observations (of the period analyzed). On the other hand for F_{low} the trend is always increasing until year 2025 where it stabilizes.

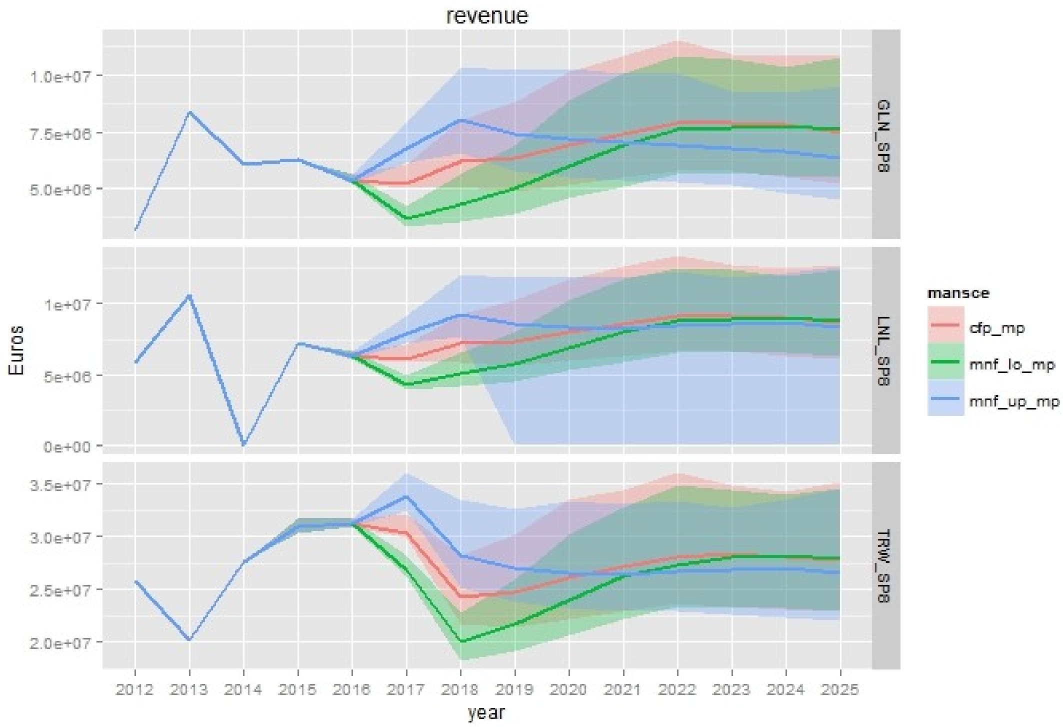

Figure 10. Revenue time series in maximum profit fleet dynamics scenarios and the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles.

Figure 10 represents the revenue obtained by the three fleets from all the catches landed and sold for direct human consumption. The main characteristic result is that for gillnetters and trawlers the CFP and the F_{low} scenario converge into similar values. However $\mathbf{F_{up}}$ scenario provides after year 2021 lower revenues than the other two management scenarios.

Net profit is quite characteristic of what we have seen for revenues, for the three fleets, sooner or later (depending on the fleet) net profits will be higher for the case of CFP or F_{low} management scenarios. It can be a sign that the fishery is using a total effort above what is economically optimal. It is also important to remark that for the F_{up} scenario and for longlines, the probability of negative net profit is not zero.

Finally (and given that the model simulates the entry-exit behavior), the net profit per vessel is shown in Figure 10, in where it can be observed how for F_{low} and CFP management scenarios there is an increasing general trend for the profit per vessel indicators. Again for F_{up} there are cases in where this net profit can be negative, in particular for the case of longliners.

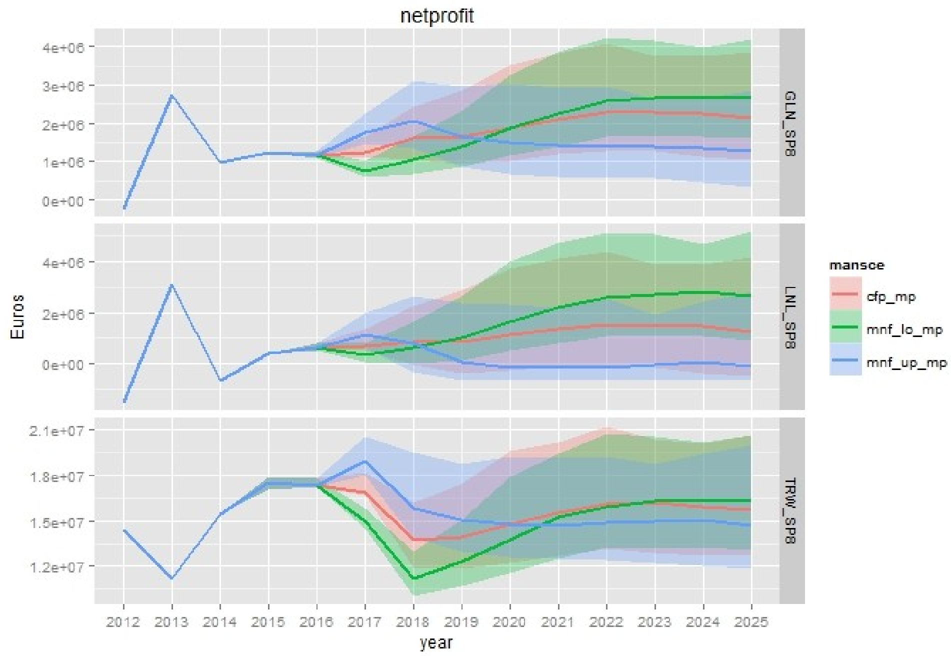

Figure 11. Net-Profit time series in maximum profit fleet dynamics scenarios for the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles.

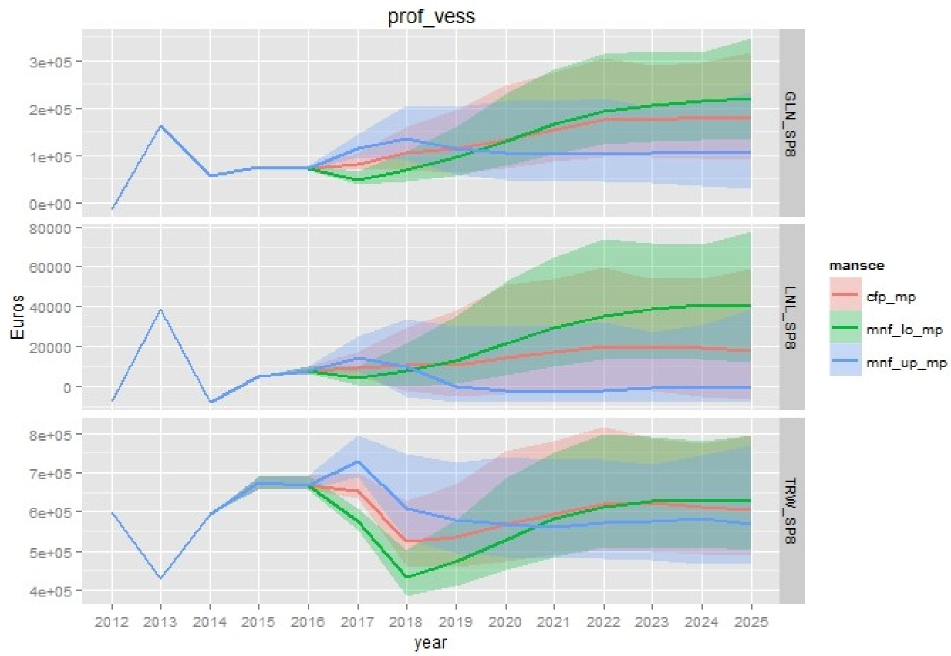

Figure 12. Net profit per vessel time series in Traditional fleet dynamic for the three management scenarios. The solid lines indicate the median and the shades delimit the 5% and the 95% quantiles.

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