



The bad, the good and the very good of the landing obligation implementation in the Bay of Biscay: A case study of Basque trawlers



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ABSTRACT

Landing obligation (LO) has become a core element on the Common Fisheries Policy (CFP). In this work a bioeconomic simulation tool is used to anticipate the effects of LO in a particular fleet that by its nature is likely to be highly affected by its implementation. These effects are measured in terms of biologic, economic and fleet indicators.

Results show how LO has a negative short term effect in the economic performance of the fleet (the bad). That the exemption and flexibilities foreseen in the CFP alleviate, in the short term, the effects of the choke species and the redistribution effects created (the good). Furthermore, results show that there are private incentives to improve the selectivity and to reduce the discard levels of the fleets. It is concluded how a breeding ground for a more sustainable and productive system is created (very good).

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1. Introduction

Landing obligation (LO) has become a core element on the Common Fisheries Policy (CFP) (EU, 2013). The aim of this discard ban is to reduce the waste of the sea-protein that discards create or at least the waste created in terms of human consumption (direct or not) (Article 2 of the CFP).

Historically, European Union (EU) discards policies have had different regulations and, hence, implications (Borges, 2015; Condie et al., 2014). In the EU Atlantic fisheries discards have been used, inter alia, as a way to avoid the over quota problem. If the catch exceeded the quota, discarding was the way to comply with the regulation. Under this scheme, CFP granted permission and furthermore the obligation to discard. When relative stability principle (the principle from which quota share among EU Member States is fixed) was agreed, the focus of the negotiators was on the commercially valuable stocks of their national fishing fleets. The reason for that was that under a discard granting scheme there was not an implementation issue in a multispecies fishery. In this context, the over catch (catch beyond the quota) could be (and was) discarded. LO is altering this equilibrium; before this CFP quota was a landing quota, now, under LO, it is a catch quota.

Quota constraints are not the only reasons for discarding. Minimum Landing Size (MLS) as biological references for sustainability

of the species (Rochet and Trenkel, 2005) and highgrading, that is, to retain the most valuable fish and discard the low or null valuable fish (Anderson, 1994), are also powerful reasons for discarding. Generally speaking, there are regulatory reasons (quotas), conservation reasons (MLS), market (highgrading) and other economic reasons (Pascoe (1997)) for discarding. Furthermore, these reasons are not fully separable by species, fleets and/or métiers (homogeneous sub-division of a fishery by fleet). The same stock caught during the same trip can be discarded due to the three reasons explained. Landing obligation bans, at least partially, this discard scheme (Article 15 of the CFP). Under a pre-defined calendar, stocks subject to total allowable catch (TAC) and quota regulations in the Atlantic area have to be landed, if caught.

Mixed fishery problems have been addressed in fisheries literature (Ulrich et al., 2011), and the conclusion is that there is always a choke species that can potentially limit the fishing effort. The term choke species was first introduced by Schrope (2010) and stands for the idea that the lowest quota in a mixed fishery constraints the opportunities of catching other stocks for which quota has not been exhausted, given a determined fishing effort level. Landing obligation implies that, effectively, this limit derived from the choke species enters into force. It creates limits to the effort from the “old” species. The current quota allocation of a particular stock cannot be enough to catch the target species of the fleet. It also creates effort limits to the “new” ones. For example, hake can become a choke species in the North Sea simply because its abundance has increased (Baudron and Fernandes, 2015).

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The arguments above imply that as pointed out in [Hatcher \(2014\)](#) discarding has an economic rationale and a likely reaction from the fishermen can be expected ([Batsleer et al., 2016](#); [Simons et al., 2015](#)). This rationality implies that banning discards will create economic consequences. The CFP anticipates these consequences and in particular those in the form of implementation costs (of the LO). Therefore, and with the aim of partially reduce these consequences the CFP in its article 15 anticipates some flexibilities and exemptions to the LO. *De minimis*: allows up to a 5% of discards under certain circumstances; species transfer: Allows up to a quota deduction of the target species of up to 9%; Year to year transfer: allows the catch of the next year's quota in the current year with a limit of 10%; High survival rate: allows to discard those species that have high survival rates after discarding.

The main objective of this work is to understand the economic dynamic of a particular fleet under LO and to compare it with a no LO situation in order to assess on the biological and economic consequences of the exemptions anticipated by the CFP. In particular, the paper focuses on *de minimis* exemption and the year to year transfer flexibility. Species transfer has not been tested given that it is not clear which stocks can, in theory, be exchanged. High survival rates, neither, given the lack of specific studies of discard survival in the fleet studied.

For doing so a bioeconomic simulation analysis is performed for a selected case study: the Basque–north–east of Spain–trawlers fishery operating in the Bay of Biscay. This case study can be described as a multispecies and mixed fishery, that from its nature, is a likely candidate to be heavily affected by the LO.

2. Material and methods

2.1. Background on the Bay of Biscay Basque trawling fishery

Bay of Biscay ([Fig. 1](#)) is a highly productive system that creates the perfect conditions to multispecies fleets to make use of this productivity.

The Basque trawling fleet operating in the Bay of Biscay (Basque fleet, onwards) is composed of bottom trawlers and their activity can be divided in four métiers. The first métier is the pair bottom trawl (PTB.DEF. ≥ 70) targeting hake. This métier uses a very high vertical opening bottom trawl to target, mainly, hake. A second métier is the bottom otter trawl targeting demersal species (OTB.DEF. ≥ 70). Hake, megrim, and anglerfish are the main target species in this métier. However this is a very mixed métier including many other species (pout, dogfish...). A third métier, only operates in the winter season of the year and is the bottom otter trawl targeting mixed cephalopod and demersal species (OTB.MCF. ≥ 70). Squids, cuttlefish, and mullets are the main target species in this métier although many other species (pout, seabass, hake...) are also harvested. Finally, there is a bottom otter trawl métier targeting a mix of demersal pelagic species (OTB.MPD. ≥ 70), it also operates in the winter season. Apart from hake, this métier also targets mackerel and horse mackerel. The historical (average of the years 2011–2013) landings and revenues composition of this fleet are summarized in [Fig. 2](#).

The fleet is managed through TAC and total allowable effort (TAE), apart from some other technical and physical measures ([Iriondo et al., 2013](#)). 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 ([Hoefnagel et al., 2015](#)). 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 some 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 ICES Divisions VIIIa,b,d and Sub-areas VI and VII (see [Fig. 1](#)), in order to create the access rights to these fisheries (a single fishing right per vessel). The idea was to maintain these rights fixed 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. A decrease in terms of number of vessels, around the 50% from where the "300 list" was created (according to [Prellezo \(2010\)](#)), has made that the current TAE system is not constraining the operational days of the fleet any more. Concerning technical measures, some mesh size limitations and minimum landing sizes for some stocks have been implemented. Further information on how this fishery is managed can be found in [Iriondo et al. \(2013\)](#), [Prellezo et al. \(2009\)](#) and in [Prellezo \(2010\)](#).

2.2. Description of the simulation model used

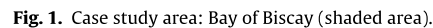
Simulations have been performed using FLBEIA ([Garcia et al., 2013](#); [García et al., 2016](#); [Jardim et al., 2013](#)). This is a simulation bioeconomic model coupled in all its dimensions (economic, biologic and social). It has been developed in R ([R-Core, 2014](#)) using FLR libraries ([Kell et al., 2007](#)). The model is divided into two components ([Fig. 3](#)): the operating model (OM) and the management procedure model (MPM). The first describes the real system and is composed of the stocks, fleets and covariates. These last can be used to account for the ecological interactions between the different stocks. However, in the simulations performed these interactions have not been considered.

MPM represents the management process and it is composed of the data collection, assessment procedure and management advice. In this case it is assumed perfect observation (no observation error is modelled). The management advice is different from stock to stock (see [Section 2.4](#)) and the implementation of this advice is based on the perfect implementation of the landing obligation, with or without flexibilities and exemptions (see [Section 2.9](#)).

The model follows the Management Strategy Evaluation approach (MSE), 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 ([Punt et al., 2014](#)). The approach of the simulation consists on projecting the fleets that exploit the stocks under different management schemes.

2.3. Fleets included

The analysis is centered on the Basque fleet, however this is not the only fleet considered in the simulation. Fleets included are those used in [ICES \(2014a\)](#), that is, those included in the ICES working group assessing the northern stock of hake and megrim. It includes trawlers, gillnetters and longliners operating in the ICES sub-areas VIII and VII, from UK, Ireland, France and Spain. There is a group of "others" that accounts for the fishing mortality of hake and megrim that is not covered by the fleets explained above. It implies that all the fishing mortality of hake and megrim stocks has been included, although divided by fleets.



Costs of fishing of the Basque fleet has been obtained from the Annual Economic Report of the EU fishing fleet (STECF, 2014). The specific fleet segment considered has been the demersal trawlers between 24 and 40 m of length. To adapt these values to the specific

2.4. Population dynamics

Twelve stocks have been introduced in the biological operating model (Table 2): Megrim (*Lepidorhombus whiffiagonis*), Hake

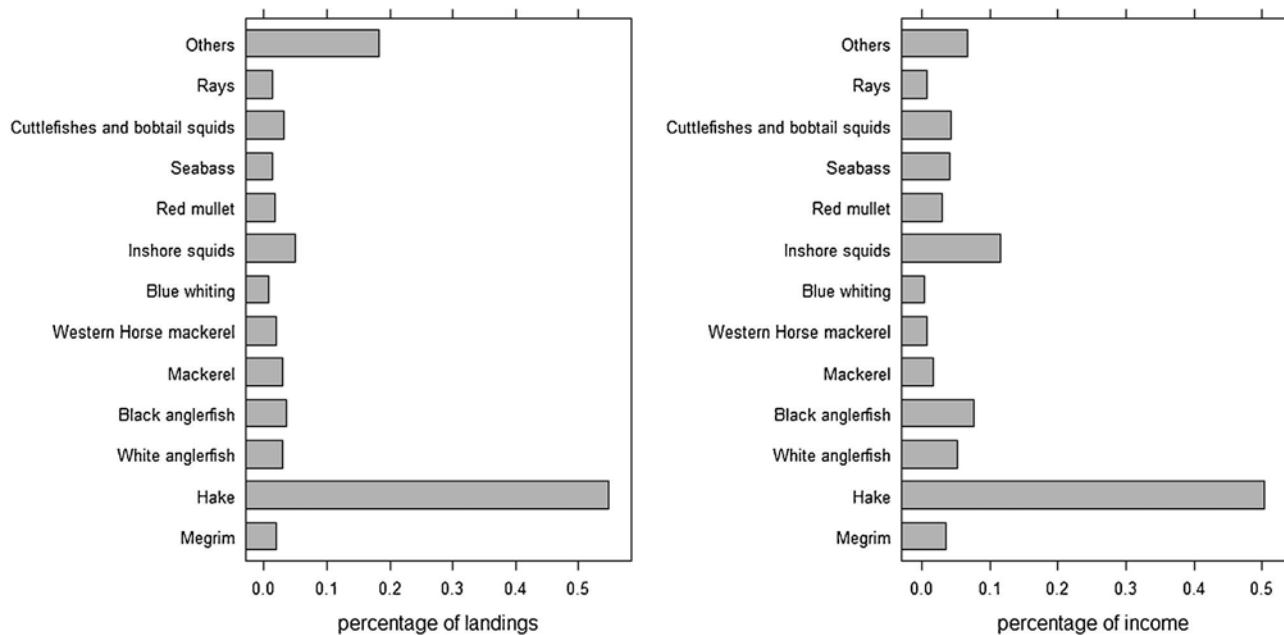


Fig. 2. Species relative importance in terms of landings (left) and revenue (right) for the Basque fleet.

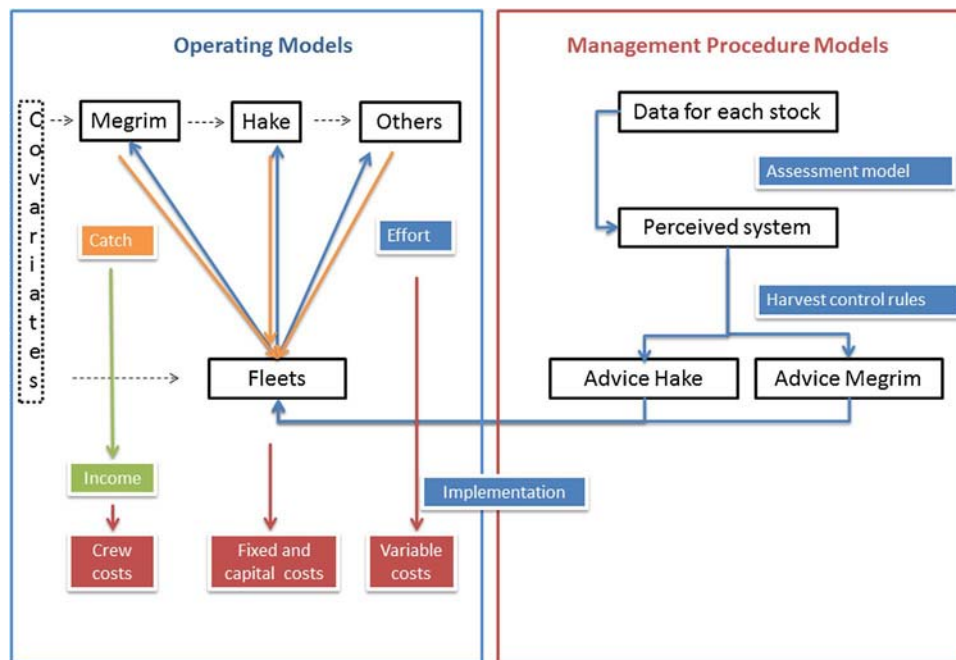


Fig. 3. Explanation of the simulation performed using the FLBEIA bioeconomic model. The simulation includes different operating models for the stocks and fleets (left) of the fishery, the management procedures model (right) and the implementation of the management procedure assuming landing obligation or not.

(*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*). These stocks cover the 81% of the total catches and more than the 88% of the total revenue of the Basque fleet (Fig. 2).

Hake has been simulated using an age structured dynamic and the data necessary to condition the model has been taken from ICES assessment working group reports (ICES, 2014a). The stock recruitment relationship (S-R) used is a Bayesian segmented regression

(Butterworth and Bergh, 1993) (Barrowman and Myers, 2000) which is consistent with the methodology used by ICES on estimating the reference points of this stock (ICES, 2014a). The population has been projected combining this S-R relationship with the exponential survival equation provided in Quinn and Deriso (1989). The reference target point used is the MSY fishing mortality (F_{MSY}). The value for hake is 0.27 and has been calculated by ICES (2014a). The TAC advice is generated using the Harvest Control Rule (HCR) provided by ICES in the framework of the Maximum Sustainable Yield (MSY) (ICES, 2012). This HCR implies that F_{MSY} for hake is advised unless the biomass falls below a trigger biomass (46,200 t (ICES, 2014a)). If this happens a linear reduction of this biomass is advised

Table 1
Costs data of the fleet considered in the simulation.

Variable	Basque Fleet	Units
Fuel Cost	1,240	€/days
Crew Cost	33%	% from the fishing income
Other Variable Cost	875	1000€/days
Fixed Cost	15,449	€/vessel/year
Capital Cost	64,438	€/vessel/year
Depreciation	20,952	€/vessel/year
Max days	150	days

Source: AER 2014, considering the fleet segment of demersal trawlers (24–40 m). Note that given that these fleets also operate in the North Western Waters (ICES areas VI and VII), fixed costs, capital costs, depreciation and max days have been weighted by the fishing days that these fleets exerted in the VIIIabd.

in order to recover the biomass. There is also a third reference point, the limit biomass (33,000 t (ICES, 2014a)). If the biomass falls below this last limit, the F advised should be zero (TAC = 0).

Megrim has been simulated using an age structured dynamic. The conditioning has been based on the stock assessment model used by ICES to give advice. Currently, this is used by ICES only as trends (ICES, 2014a). The S-R relationship used is a deterministic segmented regression. The population has been projected combined this S-R relationship with the exponential survival equation provided in Quinn and Deriso (1989). Megrim has not a defined F_{MSY} , however, TAC advice is provided using the ICES annex IV decision rule (ICES, 2012). The TAC advice is obtained using a biomass index of the previous 5 years. If the index of the last two years is a 20% higher than the index of the first three years (of this 5 years period) the TAC advised is increased in a 15%. If the index of the first three years is a 20% higher than the index of the last two years the TAC advised is reduced in a 15%. In any other case in between these two cases, TAC is not changed.

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 Basque fleet, the amount of catch harvested by it is small in comparison with the international catch of these stocks. Hence, the catch of this fleet is supposed to have little impact on the dynamics of them. For the historical period the conditioning has been done using data from working group reports (ICES, 2014b). However, as it is practically impossible to include in the model all the fleets that catch these stocks, in the projection part of the simulation it has been assumed that the biomasses of these stocks stay constant and equal to the average of the last three years biomasses (2011–2013). For, rays, inshore squids, seabass, cuttlefishes, bobtail squids and red mullet there is no assessment. However, it has been important to consider that their catches are related to the effort deployed by the fleets. Given that, an arbitrary biomass has been set with the only condition that this has to be consistent with the catches at all the levels of fishing effort observed in the past.

In the historical period discards data has been obtained from two sources. For hake and megrim the discard data used in the ICES assessment group has been included in the model, and the fleet share used by it included. However, for the Basque fleet this data has been conditioned by métier using the data obtained from AZTI's discard sampling program. Discards of hake are, between a 20% and 30% of the TAC and discards of megrim are around the 15% of the TAC of megrim. The Basque fleet discards approximately a 4.4% of their hake quota. According to Rochet et al. (2014) a 99% of these hake discards are of individuals under the MLS. For the case of megrim, the discards levels in the métiers of the Basque fleet are negligible.

In the simulated period discards of these stocks have been modelled calculating a catch retention ogive. It is done dividing landings at age by catches at age of the historical period (years 2011–2013).

When LO is not active discards are the sum of the catches under the MLS or the minimum conservation reference size (MCRS) and those coming from the over-quota (catches by stock beyond the quota share of each fleet). When LO is in place catches under the MLS or MCRS count against the quota and it is considered that the revenue coming from them is zero. They are considered as extracted from the natural system with a zero survival rate. Finally, when LO is in place there are no over-quota discards unless exemptions (*de minimis*) are considered.

12 stocks are not enough to capture the multi-species characteristic of the fleet studied, given than more than 30 species are landed and sold. Nevertheless, and in terms of conditioning the model, it is very difficult to incorporate all the stocks explicitly. 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 métiers. No stock dynamics are considered, although, catches of these “others” stocks are proportional to the effort deployed by each métier assuming an arbitrary “big” added biomass.

2.5. Uncertainty

Stochasticity in the model is introduced using Monte Carlo simulation and has been incorporated only in the biological side (in the S-R relationship). For hake and megrim a lognormal multiplicative error around the S-R curve (with a variation coefficient equal to the one observed in the historical period) has been used. 250 iterations have been run.

For the case of hake there is another source of uncertainty derived from the Bayesian stock recruitment model fit. At each iteration of the simulation, parameters are drawn from the joint posterior distribution of the Bayesian model fit.

2.6. Fishing effort

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 (Cobb and Douglas, 1928) at age level with constant return to scale (i.e. elasticity of effort and biomass equal to 1). Historical catchability is calculated using historical biomass and effort data in the Cobb-Douglas function, i.e. catchability is equal to catch divided by the product of biomass and effort. In the projection, catchability is assumed to be constant and equal to the 2011–2013 average. This procedure has been used for all the métiers and all the explicit stocks, individually.

In the simulation process it is also modelled how much effort is exerted. The approach taken is based on the Fcube method (Ulrich et al., 2011). The effort corresponding to the TAC-share of each stock caught by the fleet is calculated. It has been assumed that the effort share along métiers is fixed and that the selection of the effort level is done in each step.

2.7. Capital: number of vessels

The investment or disinvestment in new vessels (capital changes) has also been simulated following the model described in Salz et al. (2011). This model relates the investment and disinvestment in new vessels with the ratio between revenue and break even revenue. The break-even revenue stands for the amount of revenue needed to cover both, fixed (in Table 1 it includes repairs, maintenance, insurance premium and administration costs) and variable costs. Variable costs are those changing with the value of landings, such as the crew remuneration, and those changing with the fishing effort, such as fuel cost and other variable costs (Table 1).

Table 2

Stocks considered and first sale prices.

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

The annual investment for each fleet is determined by the possible maximum investment multiplied by the profit share (ps in Eq. (1)). Profit share stands for the percentage of the profits that are re-invested in the fishery; however, investment in new vessels will only occur if the operational days of existing vessels are equal to maximum days (Table 1). If they are not, the algorithm increases the effort of the current fleet. If they are equal to the maximum days, the investment decision follows the rule below:

$$\text{If } \begin{cases} \frac{REV - BER}{REV} < 0 \text{ and } ps \left| \frac{REV - BER}{REV} \right| < 0.2 \text{ Investment} = ps \times \frac{REV - BER}{REV} \\ \frac{REV - BER}{REV} < 0 \text{ and } ps \left| \frac{REV - BER}{REV} \right| > 0.2 \text{ Investment} = -0.2 \times Fleet_{t-1} \\ \frac{REV - BER}{REV} > 0 \text{ and } ps \left| \frac{REV - BER}{REV} \right| < 0.1 \text{ Investment} = ps \times \frac{REV - BER}{REV} \\ \frac{REV - BER}{REV} > 0 \text{ and } ps \left| \frac{REV - BER}{REV} \right| > 0.1 \text{ Investment} = 0.1 \times Fleet_{t-1} \end{cases} \quad (1)$$

in Eq. (1) REV stands for the revenues obtained by the fleet and BER stands for the break-even revenue (the level where the fleet expects to generate neither profits nor losses from the total number of landings). Profit-share (ps) has been set at 0.3 and comes from conversations with the vessel owners in where it has been stated how approximately a 30% of the profits are re-invested in the fishery. However, this value can be quite variable and in reality depends on external (e.g. overall economy situation) and/or particular (e.g. expected future revenues, expected retirement date) factors. 0.1 stands for the limit on the increase of the fleet relative to the previous year. The reason for that limit is that the observed change in the number of vessels of this fleet from year to year has never been beyond a 10% (Prellezo, 2010). The increase in the number of vessels is then obtained dividing the final investment in new vessels by the maximum number of days that a vessel operates in one year. Furthermore, in the projection the number of vessels does not increase, it implies that this limit is not active and that is not affecting the results obtained. Finally, 0.2 stands for the limit on the decrease of the fleet relative to the previous year. The number of 0.2 is, again, based on the historical observations of the number of vessels of this fleet from one year to other. The fleet has never been reduced in more than a 20% per year in terms of number of vessels (Prellezo, 2010).

2.8. Prices of fish

Prices of fish (Table 2) have been assumed to be constant. For the stocks for which their dynamics have been explicitly model, prices at age group are used. For the other (OTH) groups, average prices by metier have been calculated.

2.9. Scenarios analysed

Simulations have been performed under four different scenarios. The baseline scenario assumes full implementation of the LO from 2018 to 2025 without any exemption or flexibility. The implementation of this scenario is based on considering that the effort of this metier cannot be increased once the quota share of the first species is reached. The second scenario is based on the implementation of the *de minimis* exemption on top of the LO scenario. This second scenario implies that there is a 5% of allowable discards that do not count against the quota. It has been implemented in the same way as the LO scenario with the only change that the quota is increased by a 5%. However, this extra quota cannot be landed (nor sold) and has to be discarded but and it has to be considered when producing the TAC advice. The third scenario is to allow for inter-year flexibility of quota (with a limit of 10% of the initial quota) on top of the baseline scenario. It has been implemented in the same way as the baseline scenario with the only change that the quota of year t can be increased up to a 10% with the obligation to reduce the catches produced in t in the year $t+1$. However, in contrast with the *de minimis* scenario, this extra quota can be landed and sold. Finally, a fourth scenario is considered using the exemption and the flexibility simultaneously, on top of the baseline scenario. The exemptions and flexibilities are assumed to be the same for all the fleets of the fishery.

These are the four scenarios tested. All of them are a characterisation of the article 15 of the CFP (EU, 2013); however, in order to understand the full dynamic and the consequences of each one, a benchmark scenario has been created. In this benchmark scenario the fishery is simulated without the landing obligation constraint. In this case the simulation is based on having the quota of hake as the one that is going to limit the effort level. If any of the others quotas are exceeded, this excess has to be discarded.

3. Results

Understanding the results is difficult due to the mix of many stocks under different dynamic assumptions, many different fleets, and an overall non-linear dynamic system. However, a logical way (but not unique) of presenting the results is to first analyse the results in terms of the stock's performance (if the management objectives are reached or not). The main reason for this is that these results are based on the overall effects of all the fleets involved in this fishery (Section 3.1). Once the stocks level are analysed, in the second and third steps results will be focused, mainly, on the Basque fleet. The second step (Section 3.2) will be focused on the evolution of the inputs to the fishery (the fishing effort and capital) of the Basque fleet. The third step (Section 3.3) will be focused on the fleet performance (catches and economic results of them). Nevertheless, this is a feedback process in where any order can be completely adequate to understand each of the dimensions individually studied.

Results are presented in medians even if a stochastic procedure has been performed. In the Supplementary material all the graphs including the confidence intervals are presented.

3.1. Stocks objectives

Article 2.2 of the CFP (EU, 2013) establishes the objective of maintaining populations of fish stocks above biomass levels capable of producing MSY. However, in many stocks the biomass estimates (Fig. 4) have been considered as unreliable. This is why the objective has turned to estimating a fishing mortality (F) consistent with achieving Maximum Sustainable Yield (F_{MSY}).

In the case study there is only one numerical target objective for the main species, and is 0.27 for the northern stock of hake. As it can be seen in Fig. 5 hake is below or reaching the F target in the baseline scenario.

As expected, exemptions and flexibilities will raise this F above the target. Year transfer is generating a higher F than the *de minimis* in the short term and the other way around in the long term. The reason is that the year transfer has its main effect the first year that it is applied. In subsequent years, the transfer made in the previous period has to be subtracted from the TAC. The year transfer exemption implies that the main effect occurs in the first year applied (in where a 10% of the quota can be caught), however, this effect vanishes in the succeeding years of the simulation.

Megrim has not a defined F_{MSY} . Scientific advice is provided using what is called the ICES annex IV decision rule (ICES, 2012) (see Section 2.4). In the F trends presented in Fig. 5 it can be see a major difference between the No LO scenario (benchmark) and the baseline scenario. The main reason for this difference is that under LO the quota uptake for megrim is lower than one. This occurs because hake is the one constraining the effort of the majority of the fleets. LO is constraining the effort and reduces the pressure exerted on megrim. As in the case of hake, *de minimis* exemption is active all over the simulated years. Year transfer also, although its main effect can only be seen in the first year during which LO is implemented (2018).

In the simulation, the probability of the Spawning Stock Biomass (SSB) of hake of being below B_{lim} (limit reference point for the SSB) has also been calculated as a proxy for biological risk. The result obtained is that this risk is zero for all the scenarios tested.

3.2. Fishing effort

Fig. 6 is a summary of the fishing effort evolution under LO for the average of all the fleets considered and for the specific fleet analysed (Basque fleet). Fishing effort under the baseline scenario is lower than in the benchmark no LO scenario for the average of

all the fleets. Exemptions and flexibilities increase this effort and in fact in these scenarios fishing effort is even higher than in the no LO scenario. Year to year transfer has a high impact in the first year in which it is applied (2018) but after this year, it is the *de minimis* exemption which is allowing the highest effort.

Basque fleet presents a different trend than the overall one in terms of fishing effort. There is a period that goes from year 2018 to 2020 in where effort without LO is around or even higher than the baseline, however after year 2020, all LO scenarios always produce higher effort than the no LO scenario. Flexibilities and exemptions are able to increase the overall level of the effort above the case of no LO. Another important result is that beyond year 2020 the evolution of the efforts of all the scenarios under LO for this fleet is flat. In other words, effort is constrained by some stock, as predicted, in general terms, by Ulrich et al. (2011).

Considering the capital evolution, there are no changes in the number of vessels for the Basque fleet, in the baseline and year transfer scenarios (26 vessels). However, for the *de minimis* scenario (and also for the both exemptions scenario), from year 2020 onwards a small reduction can be anticipated. In fact, according to the simulations, in the year 2025 there will be an average reduction of one vessel.

3.3. Fleets performance

The overall effect in terms of catches (Fig. 7) is that LO is producing less catches in the short term (years 2018 and 2019) and more catches in the long term (year 2020 onwards for hake and megrim). The reason for this is that the SSB (Fig. 4) is higher with LO than without LO, at least after the year 2020. In a situation in where the SSB is higher and the F target (in this case for hake) is achieved, this “extra” SSB is converted into a higher TAC in a big ratio. In particular, and for the case of hake, given that the F in the year 2020 is around 0.27 (F_{MSY}) with and without LO, a change in 11,000 t in hake's SSB allows a higher overall catch of around 4000 t.

The exemptions and flexibilities play a similar role. In the short term (years 2018 and 2019) exemptions are able to produce more catches than the LO scenario. Nevertheless, there has to be a penalty for catching above the MSY target even if this is just temporal (the harvest control rule always advices on F_{MSY}). This penalty comes in the form of a slightly but constant reduction of the SSB, which after several years, will produce lower absolute catches. It will happen in 2022 for year transfer and in 2025 for *de minimis*, for both stocks.

Discards are the other side of the coin. For the case of the Basque fleet, in the baseline scenario discards are zero. Both exemptions together produce positive discards (7% of the catch of hake in the first year and 5% the remaining ones) that are higher than using only the *de minimis* exemption. In this last case the discards of hake are around a 5% (the level of the *de minimis* assumed). The scenario with the lowest positive discards is the year transfer scenario with approximately a 2% of the total hake catch of this fleet. Megrim is not discarded by the Basque fleet in any scenario given that the quota uptake is always lower than 100%. It implies that for megrim, the year transfer flexibility and the *de minimis* exemption are not used by the Basque fleet.

In Table 3 a summary of the discounted gross value added (GVA) is given. GVA is an indicator of what society is obtaining from the economic activity of the fleet and includes the remuneration to the capital (profit) and the remuneration to the crew. From Table 1 it can also be computed subtracting from the revenues, the crew, fuel, other variable costs and fixed costs. The discount factor used to calculate the present value is 3.5% which is an average of the interest rate of sovereign long term debt bonds in Spain for the historical period considered.

Results show how from the economic side (GVA) Basque fleet is better off with LO than without LO. In other words, the long term

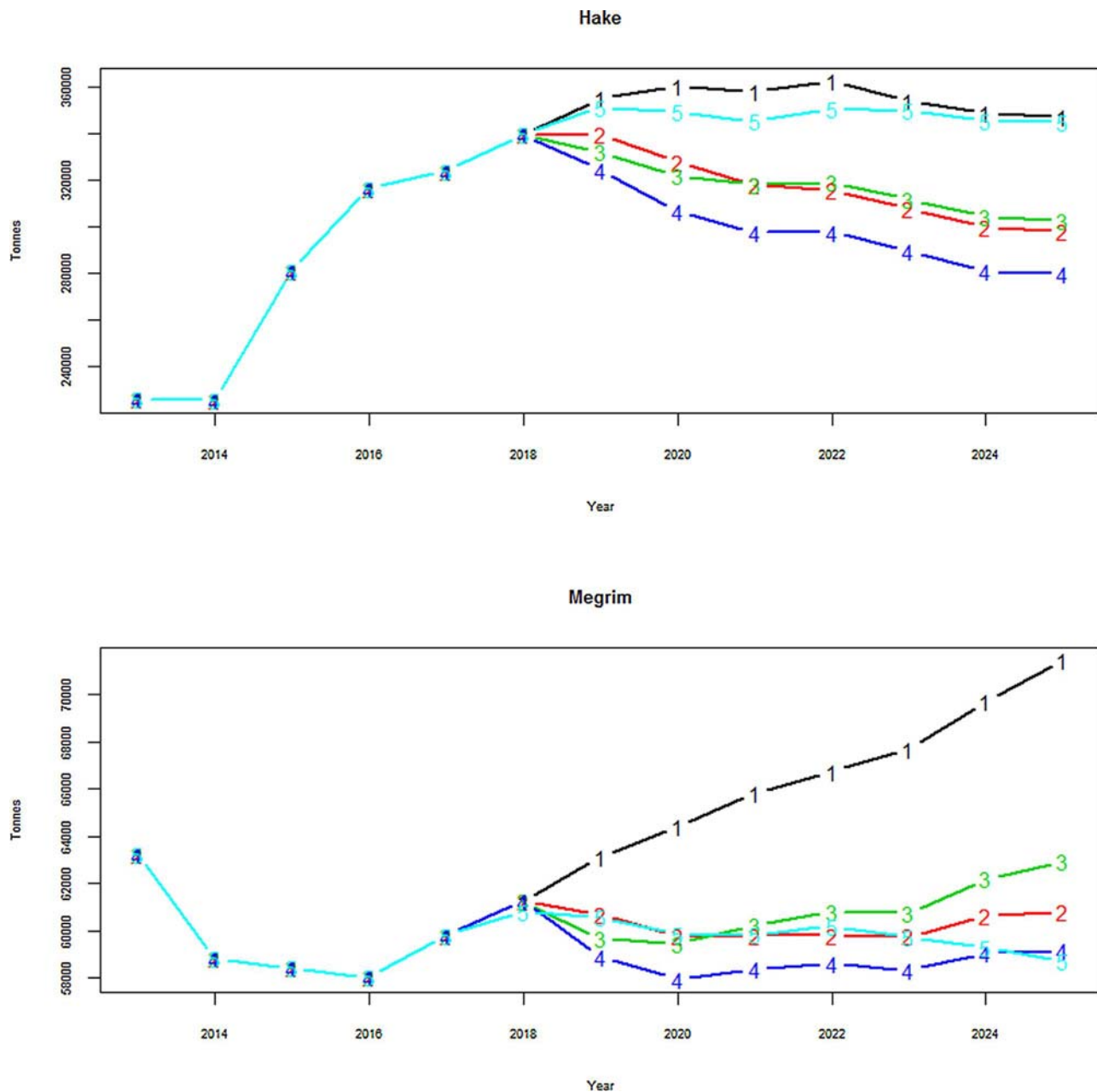


Fig. 4. Spawning Stock Biomass (SSB) for hake and megrim from years 2013 to 2025. Baseline scenario is represented by a 1, *de minimis* scenario by a 2, year transfer scenario by a 3, both exemptions by a 4, no landing obligation by a 5 and the target FMSY of hake by a 6.

Table 3

Discounted GVA from 2018 to 2025.

Scenario	Discounted GVA and year (1000 €)
Baseline	19,767
<i>De minimis</i>	18,419
Year transfer	19,605
Both exemptions	18,320
No LO	18,320

gains outweigh the short term losses. It can be also seen in the trend of this GVA (Fig. 8) in where from year 2020 LO scenario is better off than no LO (benchmark scenario). In this particular case the discounted GVA at the end of the period will be the same (Table 3), however this result is just a matter of coincidence given that as it can be seen in Fig. 8 the trends of GVA of both scenarios differ.

Exemptions are only short term solutions and only the year to year transfer (catching more of the target species) is the one provid-

ing results comparable with the no LO scenario, at least, in the short term. *De minimis*, is always providing a lower economic result than any other scenario. To understand this result the combinations of different redistributive effects have to be analysed.

3.4. Redistributive effects of the LO

There are some effects that have to be analysed when LO is considered. These effects will redistribute the gains and losses of the different fleets, based on their differences in terms of target species, selectivity and level of discards.

The first effect is the direct landing obligation effect. Discards of megrim by the Basque fleet are small as it has been mentioned in Section 2. However, overall discards of this stock are positive. There are discards of this stock made by other Spanish fleets and UK fleets that operate in ICES sub-area VII (Fig. 1), but that fish the same stock (megrim is a unique stock in ICES sub areas VI–VII

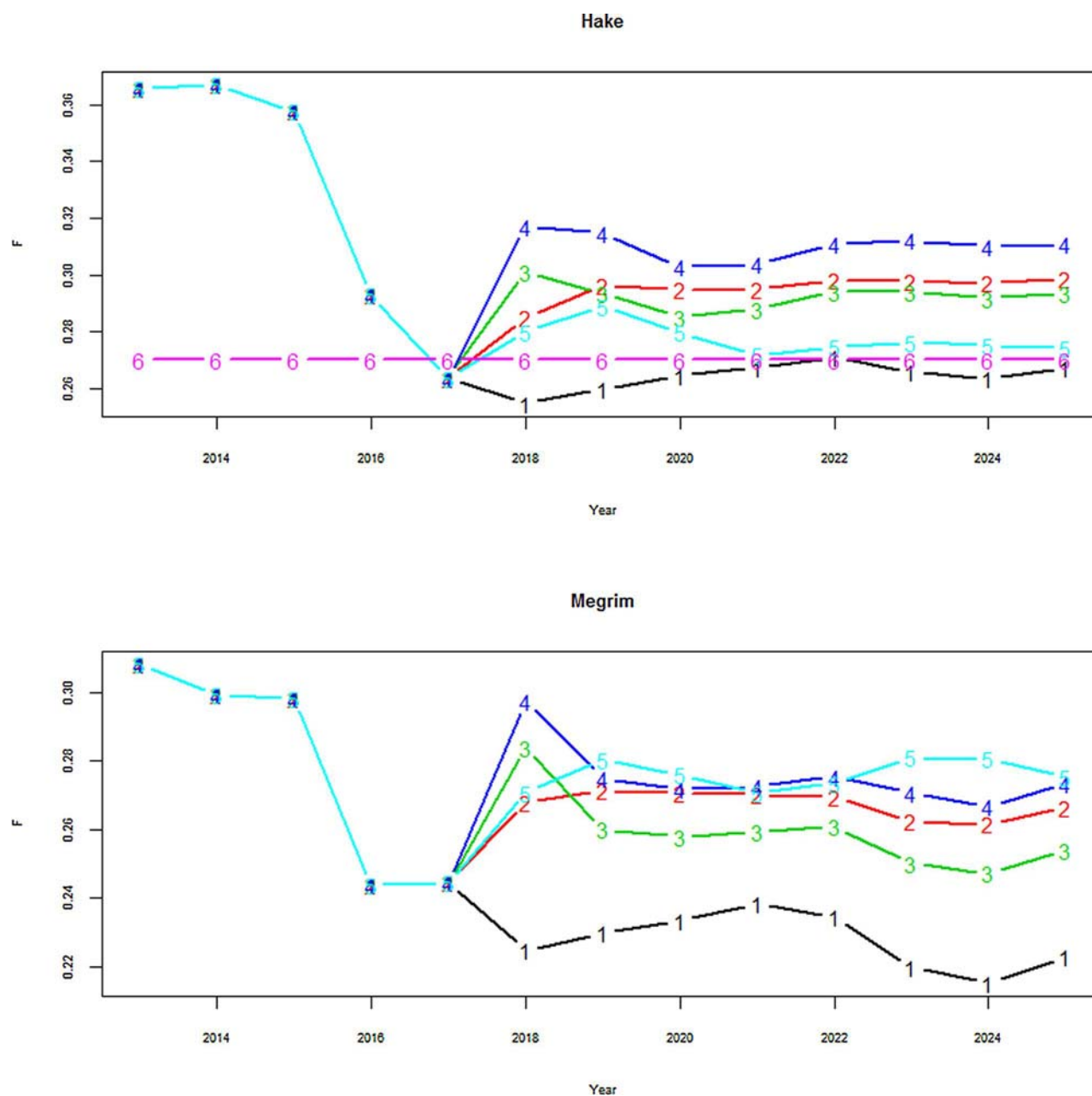


Fig. 5. Fishing mortality (F) for hake and megrim from years 2013 to 2025. Baseline scenario is represented by a 1, *de minimis* scenario by a 2, year transfer scenario by a 3, both exemptions by a 4, no landing obligation by a 5 and the target F_{MSY} of hake by a 6.

and Villabdo). When LO is implemented, those fleets with positive discards have to land all the megrim caught, and this catch count against the quota. Overall (Fig. 7) catches of megrim are lower under the baseline than in the no LO scenario. And this happens until the year 2020. It has a positive impact on the biomass (Fig. 4) and hence on the TAC advised which is used by the Basque fleet to catch more. If the baseline scenario is better off than the no LO scenario, any exemption or flexibility is worse for the same fleet, simply because this redistributive effect will be lower.

The second effect is the redistributive choke effect. Some fleets will have a new choke species derived from the landing obligation. In this particular case, hake acts as the major choke species of many fleets (see Supplementary material). It reduces the effort and makes these fleets incapable of fishing their quota share. The overall effect is that fishing mortality of megrim will be reduced and biomass will grow (Fig. 4). This redistributive effect has the same effect as the

direct landing obligation effect but in this case the source of the redistribution is the effort constraint.

There is also a third effect that counts in favor of Basque trawlers economic performance. Even if the harvest control rule to advise next year's F is the same with or without LO, the TAC under LO is given in terms of catch in contrast with what was done without LO in where it was given in terms of landings. This is called the uplift redistributive effect (see Fig. 9). This effect is not neutral to the fleets given that they have different characteristics, and in particular, different discard levels. In a situation of unbalanced discards levels of a given stock, those fleets with a ratio of their discards to the total discards of the stock, lower than their quota share of this stock, will be relatively benefited from the uplift. For example, for the case of hake the uplift size is of approximately 14,000 t of hake, close to the approximately 14,800 t of hake discards accounted in the simulation (these two numbers cannot be the same because the

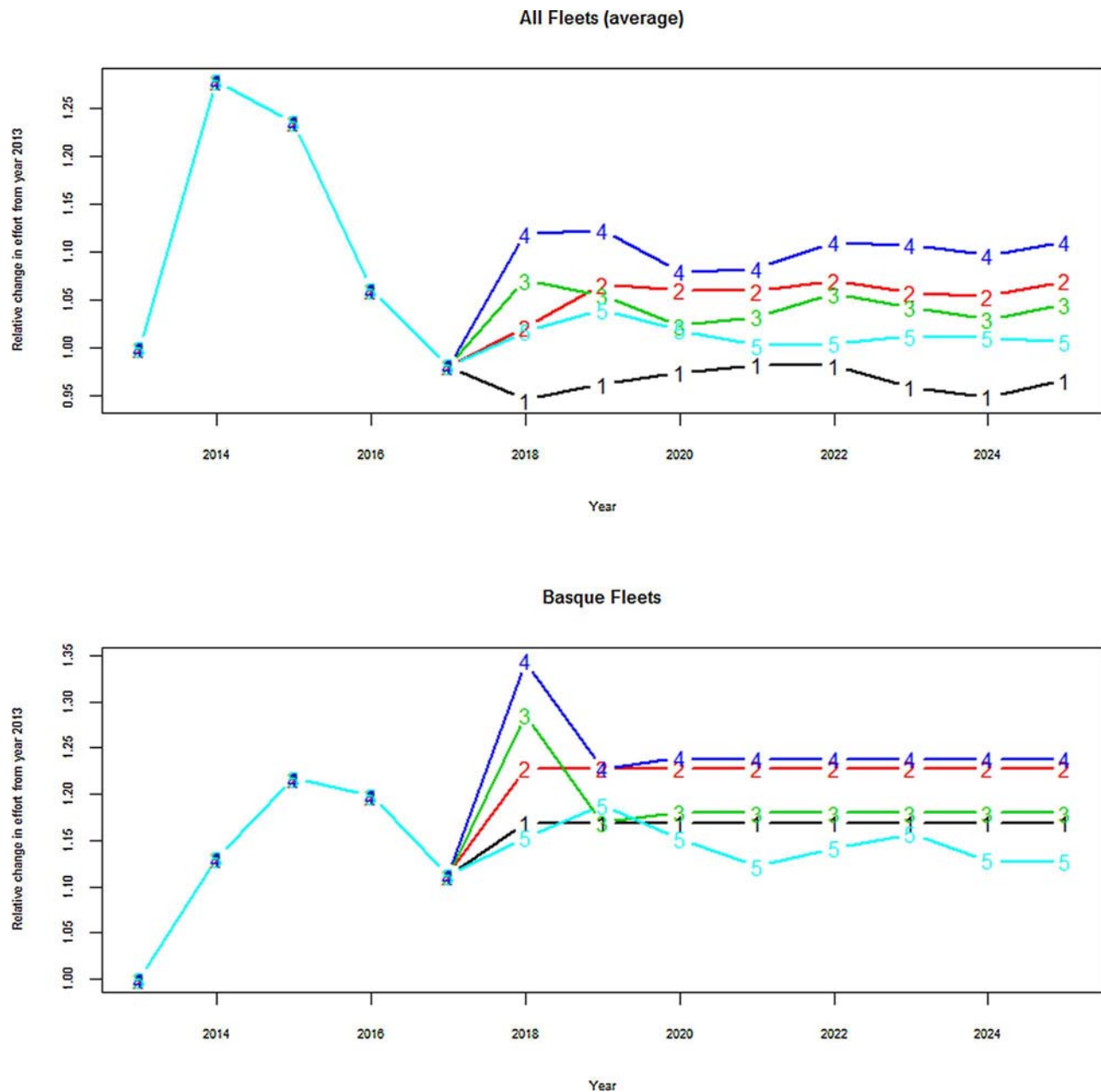


Fig. 6. Change in relative fishing effort relative to the year 2013. All fleet's average and Basque trawling fleet. Baseline scenario is represented by a 1, *de minimis* scenario by a 2, year transfer scenario by a 3, both exemptions by a 4 and no landing obligation by a 5.

system is not linear). A fleet with a relative gain is the Basque fleet with a discard level of hake of 4.4% and a quota share of 6.7% (see the Supplementary material for the remaining fleets). Megrim will cause a similar uplift effect that will be positive for the Basque fleet given that the quota share of megrim is higher than its discard rate.

4. Discussion

LO has become the core measure of the CFP in place. From the fishing fleet perspective results in the short term should be negative (Hatcher, 2014) and in the long term are still to be explored due to the uncertain evolution of the ecosystem productivity. However, discards bans have the effect (if fully implemented) that all the catches will account against the quota, reducing the pressure on the stock and hence having a positive benefit on the biomass of them. This is true given that ecosystem considerations have been

not taken into account. If considered, the final result will require a further evaluation according to Sardà et al. (2015)

Short term impact of the LO comes from the necessary conclusion that there is always a choke species that limits the fishing effort (Ulrich et al., 2011). However, the choke species will depend on the particular fleet analysed, and will limit the effort that can be applied by each particular fleet. In the case study presented other fleet's choke effects are affecting positively to the fleet studied by what it has been called the redistributive choke effect. The Basque fleet is also suffering from the choke effect (from other stocks) but, overall, its situation is better off with than without LO (at least in the mid-term).

The advisory process is also playing a role in this context. Difficulties on providing reliable assessment increase when a structural shift is to be happening in the data collected. Independent to that, advice is based on harvest control rules that aim a clear objective (F_{MSY} , or proxies of it). These rules and objectives are the same

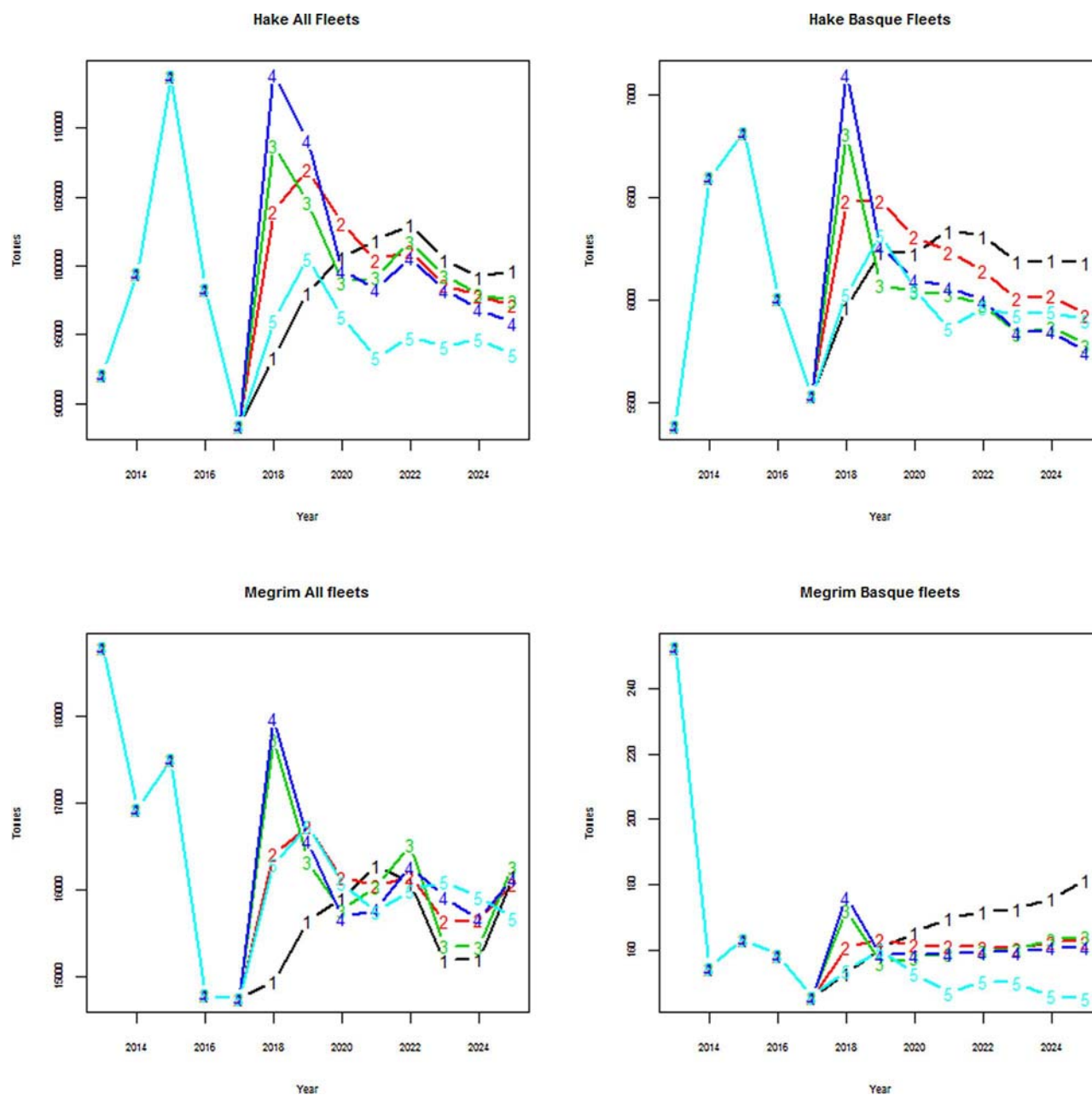


Fig. 7. Overall and Basque trawlers catch of hake and megrim from years 2013 to 2025. Baseline scenario is represented by a 1, *de minimis* scenario by a 2, year transfer scenario by a 3, both exemptions by a 4 and no landing obligation by a 5.

under LO or not. However, these F targets have to be converted into absolute terms (catches). It implies that TAC advice should consider and uplift (given that under LO all the catches have to be landed). In this context, those fleets with a discard ratio lower than their quota share will have a “benefit” from the discards made by the other fleets in the same fishery. In fact, this is positive for the fishery itself given that there is a clear incentive to improve selectivity to reduce discards. This incentive does not preclude the existing incentives to avoid the choke effects caused by the LO. Furthermore, incentives on more selective fishing methods could potentially increase the system productivity and overtake any effect on the energy turnover of the ecosystem (Sardà et al., 2015).

An important finding in the literature of discards bans is the one obtained by Condie et al. (2013). In this work it is said that discards bans, alone, are not necessarily driving the fishery to a more productive system. The findings of the work presented here

do not contradict the results given in the simulation performed for the Bay of Biscay. Our simulations are a mix of a discard ban and HCRs that force the system to go to the maximum sustainable yield at individual stock level. If those HCRs were not in place, a different strategic game would be created with likely different results.

Ecosystem considerations are not the only source of uncertainty. In fact this work has been carried out using stochastic procedures. However, uncertainty has not been analysed explicitly in the main text (it is included in the supplementary material). On this aspect of the simulation the result that should be stressed is that the probability of falling below B_{Lim} for the stocks assessed is zero in all scenarios. In that sense it can be said that the fisheries management using the harvest control rules explained in the methodology is precautionary enough. However, it is important to highlight all the warning signals of saying so in a MSE context (Kraak et al., 2010).

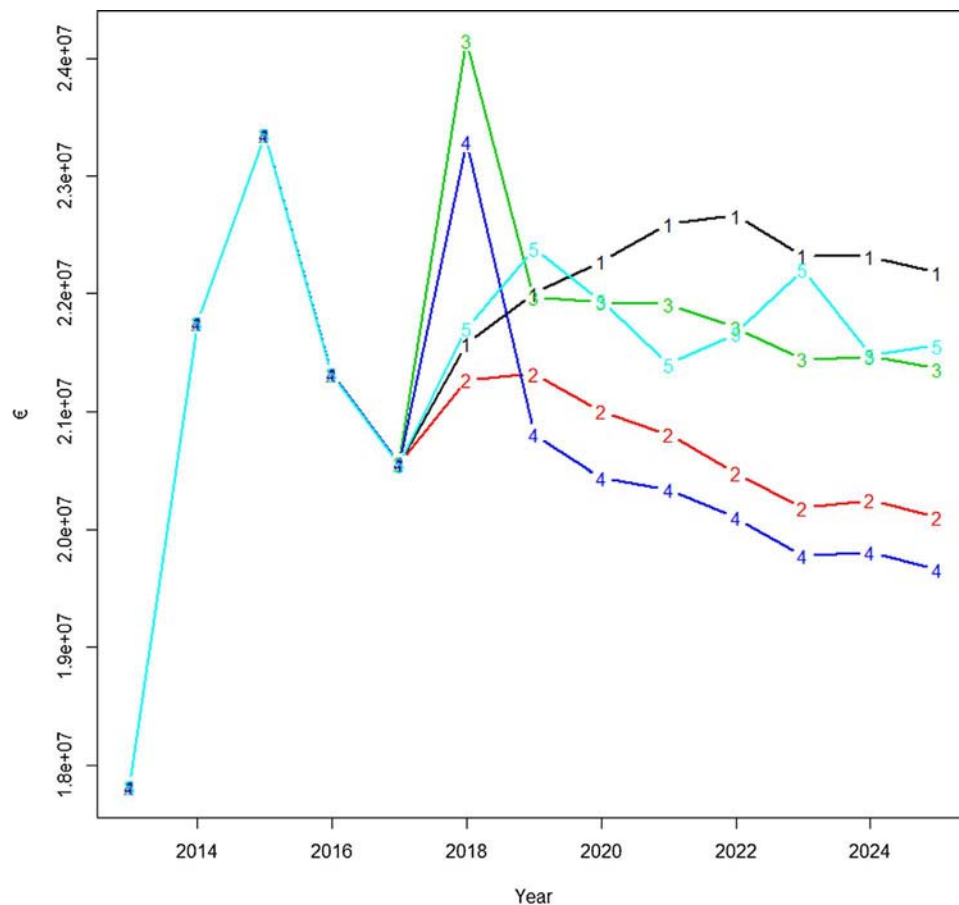


Fig. 8. Gross value added (GVA) of the Basque trawling fleet from years 2012 to 2025. Baseline scenario is represented by a 1, *de minimis* scenario by a 2, year transfer scenario by a 3, both exemptions by a 4 and no landing obligation by a 5.

The role of the exemptions to the LO is also crucial in the final result. They are seen (and probably designed) as way to give more time to adapt fishing operations to the new regulatory scheme (i.e., LO). If a comparison is made, for example, between a year transfer and the baseline, the main difference is that now vessels can sell the extra catches. There are two benefits from using this flexibility: first, the choke problem is potentially reduced and, second, the extra effort is not converted into discards (zero value) but in revenue. Both, altogether, are able to overtake the cost of the extra effort applied and convert it into value added. However, this only a short term effect.

In the mid-term and without any consideration made in terms of the ecosystem functioning as a whole, the results obtained from applying any kind of exemption or flexibility are, simply, negative. Fishing beyond F_{MSY} (even in one year) implies that there will be a penalty in the future. This penalty will come in the form of lower biomasses, that has the mixed effect of increasing the cost of fishing the same level of catches and reducing the total catch due to the lower abundances and the subsequent lower TACs.

Constrained effort under LO may benefit biomass evolution of certain stocks (as for the case of megrim in the case analysed), and accounting for all the catches against the quota is also positive (direct LO effect). Additionally, landing obligation may also have a redistributive effect. It, relatively, benefits those fleets with low discards and penalize those with high discards, at least, if these discards are made on the “key” species (those choke species and or with low TACs). The uplift effect is a clear example of this redistributive effect. Overall, it can happen that one fleet could be positively

affected by the LO (even if the effort is constrained) as the case of the Basque fleet.

The exemptions and flexibilities to the landing obligation play the role of returning back the system to the original situation up to some degree. In the short term, there is no doubt that they reduce the choke species problem by relaxing the effort constrain imposed by the LO. In the long term they are negative for the system and also for some fleets. In fact, those fleets that take advantage of the redistributive effect generated by the LO (the Basque fleet analysed) are worse off under the exemption and flexibility scenarios (*de minimis*, year transfer and both exemptions) simply because the redistributive effects are weaker.

On top of the general result that fishing beyond the MSY will have negative economic social and private consequences, promoting flexibilities over exemptions is better from the economic side (see Table 3). There are many reasons that lead to this conclusion. Firstly, the total amount of discards allowed is lower when flexibilities are used than when exemptions are used. Secondly, the fishery benefits from policies in where “landing more” is promoted (year to year transfer), over policies in where “catching more” is promoted (*de minimis*). For this particular issue, future potential increased values of these landings (e.g., landings under MLS) will re-inforce this conclusion.

Fishing vessels are heavily dependent on the likely adaptation of their fishing tactics and fishing technologies to avoid discards (Simons et al., 2015). Even if, as it has been shown in the analysis carried out, in the mid-term one fleet can take economic advantage of the (assumed) passiveness of the other fleets, in the short term the Basque fleet will be worse off under LO than without it. Only if

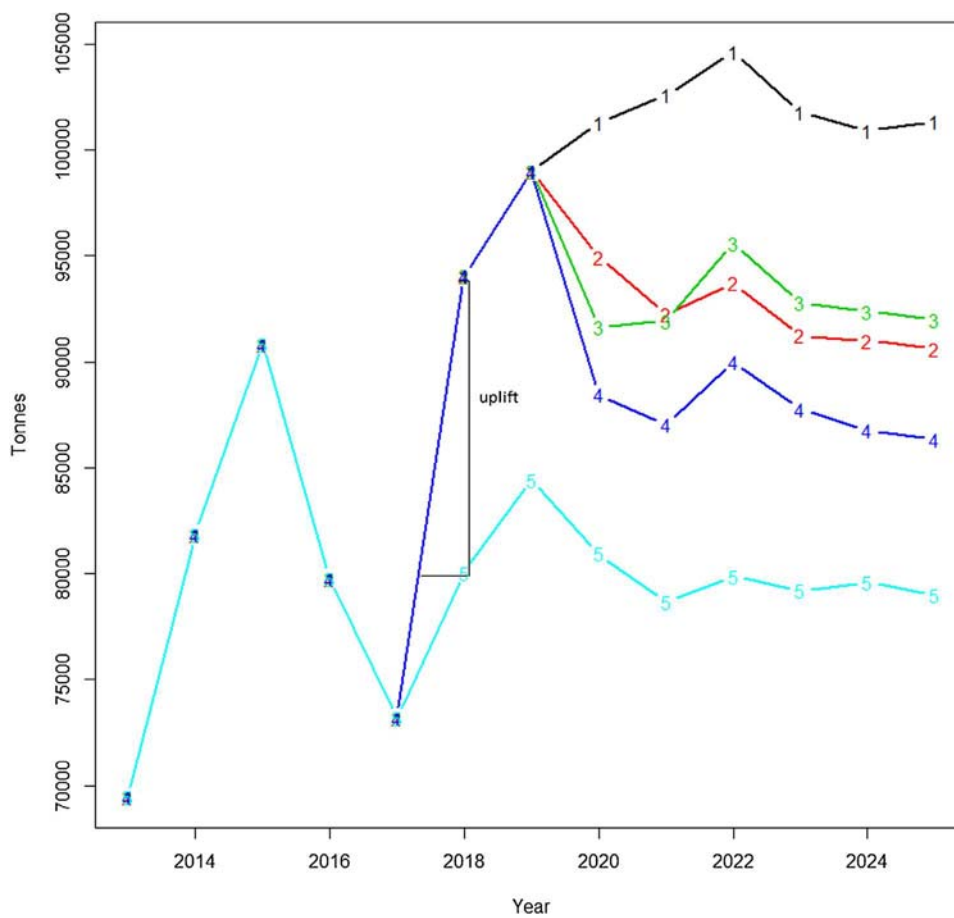


Fig. 9. Hake TAC advised from years 2012 to 2025. Baseline scenario is represented by a 1, *de minimis* scenario by a 2, year transfer scenario by a 3, both exemptions by a 4 and no landing obligation by a 5.

the other fleets do not react (by changing their overall selectivity pattern) the Basque fleet will take advantage of the constraints that the LO is creating on the other fleets of the fishery. However, other fleets are likely to react (unless the cost of this reaction is too high) because they have the incentives for doing so. As has been shown in the previous sections these incentives come in the form of reducing the choke effect and in the form of the economic damage caused by the uplift redistributive effect. Furthermore, as it can be seen in Batsleer et al. (2016) landing obligation will force fleets to react.

5. Conclusions

The landing obligation proposed by the EU CFP is likely to reduce the discards of the stocks under TAC and quotas. However, it will have short term negative economic consequences on the fleets (the “bad” of the title). Exemptions and flexibilities are likely to reduce these economic impact but with a long term penalty. In the long term results are not clear, given the existing uncertainty on how the ecosystem productivity will evolve.

However, in between (in the midterm), LO will create a strategic game in where less discards and better selectivity could be economically awarded. LO will not affect equally all the fleets involved and, hence, there will be, in relative terms, winners (the “good” of the title) and losers, at least in economic terms. If exemptions are used (in this case all the fleets have exactly the same amount and implemented in the same year), the winning-losing effects will be alleviated. If they are high enough, the fishery will back to the original situation (no LO). The higher the percentage of the exemption or flexibility (*de minimis* or both exemptions together) the weaker

will be the redistributive effects and the final result will be closer to the no LO situation.

In conclusion, a breeding ground for more selective and with less discards system is likely to be created (the “very good” of the title) by the incentives in place.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.fishres.2016.04.016>.

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