Integrated bio-economic impact of the landing obligation on the Dutch North Sea sole fishery

Task 1.3 of the project Best Practices II

Katell G. Hamon, Heleen Bartelings

WAGENINGEN UNIVERSITY & RESEARCH

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To reduce the discarding practice in fisheries and promote better selectivity, the EU has introduced a landing obligation. The implementation of the landing obligation started in 2015 and since 1 January 2019, all catches of stocks under quota management must be landed (with some exemptions). The Dutch flatfish fishery has always had a large amount of plaice discards while targeting sole and is now faced with a challenge to reduce those discards. While the fishery still benefits from exemption for plaice, the results of this report show that a strict implementation of the landing obligation would have negative implications for the fishing sector without necessarily benefitting the fish stocks. The estimated survivability, higher than the one currently assumed in assessment, also means that the impacts will be larger. Tests to improve selectivity by using 90mm mesh sizes instead of the traditional 80mm show that more work is needed to develop gears that avoid unwanted catch while retaining targeted fish.

Key words: spatial modelling, SIMFISH, Landing Obligation, economic analysis

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Preface

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This study was carried out under the project Best Practices II, at the request of the Dutch fisheries organisation VisNed and was funded by the European Union, European Maritime and Fisheries Fund. The work was carried out in collaboration with Wageningen Marine Research and VisNed. We especially want to thank Wouter van Broekhoven for his active contribution to the definition of the scenarios.

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Summary

The landing obligation (LO) is supposed to be fully implemented since 1 January 2019. For the Dutch fishery targeting flatfish with beam trawls this means that all the catch of the quoted species should be landed. This is particularly an issue for the sole fishery, catching a large amount of undersized plaice, which represents the major part of the discards, but up to now, the fishery has benefited from an exemption for most of the plaice discards. This study aims at looking at the longer-term impacts of the LO on the fishery using a set of scenarios on survivability and selectivity changes (from other tasks of this project).

We used the SIMFISH model developed by Wageningen Economic Research (Bartelings et al. 2015). This model is a bio-economic model integrating the feedback effect between fish stocks and fishing fleets. It was applied to the Dutch beam trawl fishery comprising of three fleets based on vessel length (12-24m, 24-40m and >40m) targeting four species, sole, plaice, turbot and shrimp (sole, plaice and shrimp are explicitly modelled, turbot is taken as a fixed bycatch per unit of effort). The model was calibrated using 2013-2015 data, the LO or change in selectivity are included from 2019 onward and the projections ran until 2030. There are two LO scenarios, full implementation or full exemption (no LO). The full implementation includes extra costs linked to the processing, storing and landing of the extra fish (data taken from previous projects), extra revenue from the sale of the unwanted catch. In addition, smaller vessels (12-24m) are expected to have to increase their time at sea because they have to travel back and forth to unload the extra landings as their storage capacity is limited. There are three survivability scenarios, the 0% survivability (as it is currently used in the assessment model) and the lower or higher bound of the estimates made by Schram and Molenaar (2018). Those include change in future survivability (in case discards are still allowed) and change in past survivability which have an impact on the initial size of the stocks. Consequently, the stock sizes are corrected for survivability. The last set of scenarios are the two selectivity scenarios, using 80mm mesh sizes (this is the current practice in the fishery) or using larger 90mm mesh sizes. In the latter, the catchability at age of sole and plaice is corrected, leading to lower catch rates.

Impact of LO
The implementation of the landing obligation will have limited impact on the fish stocks while having a lasting effect on the Dutch beam trawl fleets. The extra costs associated with the sorting, storing and landing of extra, low value catch leads to poor economic performances of the fleets without alternative activities and ultimately the exit of up to 7 and 17% of the 24-40m and above 40m fleets respectively.

Impact of survivability
If past survivability has been underestimated (and the stocks are overestimated), the LO implementation would lead to worse outcomes than expected as a positive flow of surviving discards would be cut out. This would lead to worse ecological and economic outcomes.

Impact of selectivity
The use of 90mm nets leads to a change in the catch composition. To (try to) catch their quota of sole, fishers would need a lot of additional effort and would become limited by their plaice quota. This has a positive impact on the stock of sole (the quota not being caught) but negative economic and ecological consequences as more effort and higher costs are needed and more unwanted catches end up in the net and the nets are dragged longer on the bottom.

Limitations and recommendations
This task was completed at the end of the project while still overlapping with other parts of the projects that could have fed in the model. The data flow has been successful on selectivity and survivability data. However, the extra labour needed to sort and process the extra landings was taken out of a previous project and the estimates from the current project are twice as high as in the previous report (3.6 extra FTE in VisNed, unpublished data, instead of the 2 extra FTE included in the

model of the current study; Baarssen et al. 2015). This would have important implications for both the economic performances of the fleets (additional costs) as on the social aspects (would there be a loss of salary for everyone? How would it be to have extra crew on board? Would it be possible at all?).

All the trials made in the project and on which data were estimated and the fleet's cost structure are based on the use of pulse trawls while it will not be allowed anymore after 2021. The results should be adjusted to whatever gear is used as an alternative for pulse.

This study is a modelling exercise using a deterministic model and what-if scenarios. The results are projections, not predictions, and should only be compared amongst each other. A lot was added to the model for this study and sensitivity analyses for new parameters should also be performed.

1 Introduction

The current Common Fisheries Policy (CFP) aims at reducing discards by obliging fishers to land all catch including the potential discards, i.e. a landings obligation (LO). Under the LO, all discards of commercial species that are regulated by quotas have to be landed.

The LO has a particularly strong impact on the Dutch demersal fishing industry as it is a mixed fishery where catches can contain many different species. The LO for the demersal fisheries has been introduced in phases over a number of years: It started on 1 January 2016 for cod, haddock, whiting, Norway lobster, sole, plaice haddock and Northern prawn. For the non-target quota species the LO has been enforced since 1 January 2019. For the Dutch flatfish fishery, exemptions in place mean that the LO is for the most part not yet implemented and the impact on the fishery is still limited.

The Best Practices II project aims to help the Dutch demersal fisheries sector prepare and adapt to the implementation of the LO by providing technical and economic insights into the consequences of its implementation. BPII produces simulations of potential future developments of the main species of interest in terms of expected volume and value of the catches and stocks of interest.

This report deals with Task 1.3 of the project, presenting an analysis (and evaluation) of the economic impact on the fisheries under different scenarios (Task 1.3), based on results from project Tasks 1.1 and 1.2.

Innovations in fishing practices can improve fishing gear selectivity and can affect fish survival, both potentially mitigating negative consequences of the LO.
Other tasks in the project have provided results such as

- the projections of the expected stock sizes for different assumed levels of survival of the discards, considering that those are thrown overboard and not landed (Task 1.1, Task 1.2).
- the quantification of the effect of switching 80mm mesh size for 90mm mesh size nets on selectivity and of the economic profitability of using 2 different mesh sizes (Task 3.1).

Based on this we estimated the short (1-3 years) and medium-term impact (9-11 years) of the implementation of the landing obligations on the fleet performances and stock size. This is done using the bio-economic modelling tool SIMFISH developed by Wageningen Economic Research. This model contains a feedback loop between biology and economics and allows for longer-term projections (10 years).

The model is applied to the Dutch fleets targeting flatfish with beam trawls. Sole, plaice, shrimps and turbot are included in the model as source of revenue for the fleets and sole and plaice have a full feedback loop between catch and stocks.

2 Scenario definitions

Best practice II has focused on the implementation of the landing obligation under different assumptions regarding survivability of fish and selectivity of gear. To assess the medium-term (10 years) effect of the landing obligation, we combined those assumptions and defined the set of scenarios presented in Table 2.1. All scenarios contain three components detailed in the following sections:

- Landing obligation (LO): full implementation (=LO) or full exemptions (=no LO)
- Selectivity: 80mm (current) or 90mm
- Survivability: 0% (current), lower range of survivability estimates or upper range of survivability estimates.

The scenarios described in the following sections have been defined together with the fishing sector (represented by the PO organisation VisNed) in a stakeholder meeting and subsequent email communications in autumn 2018. Additional data have been made available later and are not included here but are included for discussion.

Table 2.1 *Definition of scenarios*

Landing obligation	Selectivity	0% survival	Lower range survival	Upper range survival
Full LO implementation (100% retained)	80mm	Scen1	Scen2	Scen3
	90mm	Scen4	Scen5	Scen6
LO with full exemptions (i.e., No LO = 0% retained)	80mm	Scen7	Scen8	Scen9
	90mm	Scen10	Scen11	Scen12

2.1 Landing obligation

In the model we apply the same landing obligation scenarios to all fleets and all gears. The landing obligation is investigated with 2 scenarios: full implementation, in which all the catch of sole and plaice is retained, or full exemptions, i.e. no implementation, where unwanted catch is discarded. No scenario with partial exemption is implemented in this project as it would have required additional work to estimate the variables in the table per métier. The full implementation scenario is only implemented from 2019 onward. Before that (2015-2018) no discards had to be landed. The current situation is close to the full exemption scenario as the Dutch flatfish fishery has currently an exemption for plaice which represents the largest part of the discards.

In case of full LO implementation, the TACs of sole and plaice are set on the catch, while for the non-implementation scenario (no LO) the TACs are set at the level of landings (with the expected unwanted catch based on the latest discards estimates already removed).

In addition to a difference in TACs, the LO scenario also has direct consequences for the economic performance of the fishery. Having more fish on board means extra labour costs to sort and process, extra landing costs and, for the smaller vessels that do not have the storage capacity to hold all the extra fish on board, extra steaming between fishing grounds and harbours to unload their catch (see the details of those extra costs in Table 2.2).

Table 2.2 *Costs and revenue directly linked to the full implementation of the LO*

Extra costs (Baarssen et al. 2015)	Extra revenue (Buisman et al. 2013 and VisNed, anectodal data Dec 2018)
Extra labour costs sorting and handling +28/36% labour costs + 2FTE for large cutter i.e. +0.23€/kg eurocutters / +0.38€/kg large cutters	Sale of previously discarded fish (undersized - no human consumption) 0.15€/kg
Extra processing discards ashore +0.30€/kg	
Extra steaming costs +30% steaming effort for vessels 18-24m (➔ loss of income)	

2.2 Survivability scenarios

The fishing industry has long claimed that a substantial proportion of the fish discarded survives after being thrown back at sea. The implications of a positive survivability are threefold:

1. In the application of the LO, exemptions can be granted on the basis of 'high'[1] survivability of discards.
2. The stock assessment every year assumes 0% survivability, so the biomass estimated by the ICES stock assessment would actually be lower than the current estimates.
3. The implementation of the LO would potentially lead to an increase of the mortality of the species with positive survivability.

Here we are interested in the third point. What would be the impact of wrongly assuming a null survivability? For this we use the results produced by Schram and Molenaar (2018), where the discards' survival probability for undersized plaice was estimated at 14% (95% CI 11-18%) and for undersized sole at 19% (95% CI 13-28%). Based on those estimates, we defined 3 survivability scenarios: the lower and upper limits of the confidence bounds of the available estimates of survival rate, and a 0% survival. The 0% survival scenario corresponds to the current assumptions used in ICES for stock assessment and TAC advice. The other scenarios are the lower and higher bounds of the ranges calculated by Schram and Molenaar (2018). Changing the assumptions on the past and current survival rates also means alternative initial biomass (because if the survivability is higher than what was assumed, this means that the stock was lower). We use the results of Verkempynck et al. (2018), regarding the initial biomass and reference points which we use to define the target fishing mortality (Ftarget). To be able to use the model outputs of Verkempynck on the initial stock size and reference points, the survival rate ranges were rounded at 10-20% for plaice and 10-30% for sole as shown in Table 2.3 (because Verkempynck et al. 2018 made their calculation for 0 to 100% survivability by 10% intervals).

Table 2.3 *Characteristics of the survivability scenarios*

	Sole				Plaice			
Scenario	Survival rate	F target[2]	B trigger[3]	Initial SSB	Survival rate	F target	B trigger	Initial SSB
0%	0	0.23	37	51	0	0.202	565	856
Lower range	0.1	0.23	37	50	0.1	0.202	565	850
Higher range	0.3	0.23	37	49	0.2	0.202	565	844

[1] What constitutes 'high' survivability remains unclear.

[2] There is a discrepancy between the current Fmsy for sole and the one calculated by Verkempynck et al.. We chose to use the one from Verkempynck et al. because it is consistent with the assumptions regarding the structure of the stock and the stock recruitment relationship. Despite having different reference points calculated for the different survivability scenarios, we only used the one provided for the scenario with 0% survivability as we want to show the differences linked to those assumptions with the current management (not assume that management targets have also been corrected).

[3] Btrigger of the assessment is used.

2.3 Selectivity

The simulations investigate the effect of changing mesh size from 80mm to 90mm for the métier TBB_DEF_70-99_0_0_. The selectivity at age is taken from Brunel et al. 2019 (this project) and is used to compute the theoretical catch composition with 90mm mesh size instead of the current 80mm (see Figure 2.1, Figure 2.2 and Table 2.4). The blue part under the curve represents the proportion of the fish retained in the net and the red part the proportion of fish that escapes (and is found back in the 'cover' part of the net during the experiment). For more details about the definition of the selectivity, see Brunel et al. (2019) (this project).

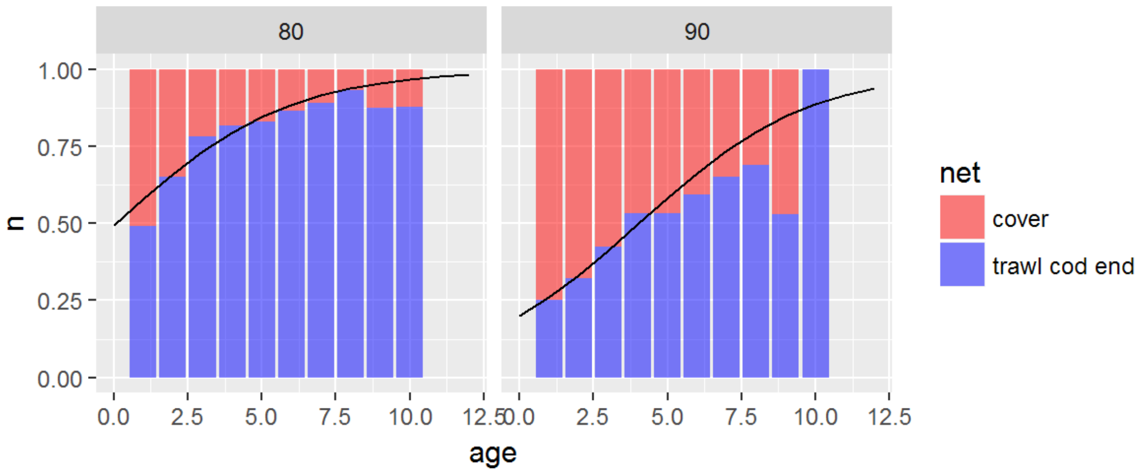

Figure 2.1 *Selectivity at age for the 80mm (left) and 90mm mesh size (right) for sole (from Brunel et al. 2019)*

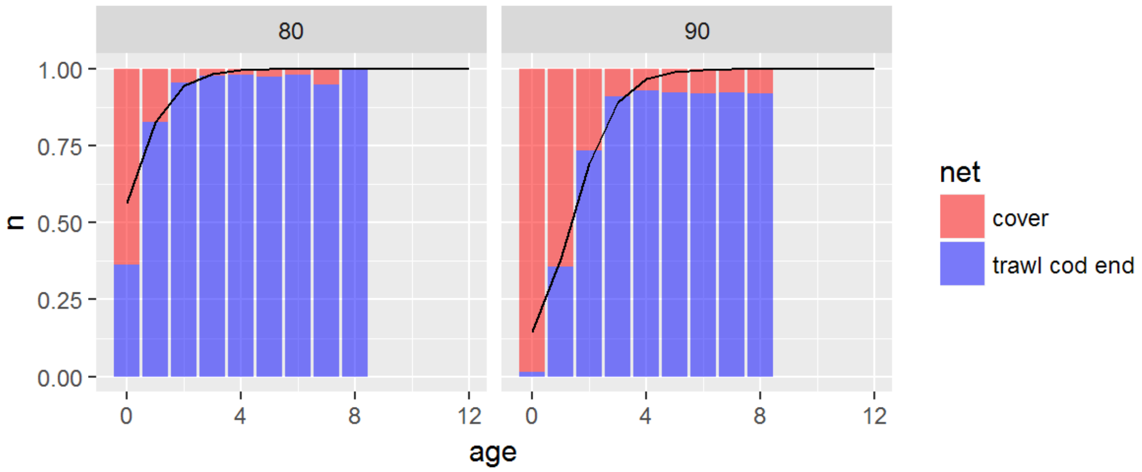

Figure 2.2 *Selectivity at age for the 80mm (left) and 90mm mesh size (right) for plaice (from Brunel et al. 2019)*

The selectivity with 90mm is expressed as a percentage of catch retained at age compared to the current selectivity and the catch $C_{f,90,s,a}$ per fleet f, for species s and age a is calculated as follow:

$$C_{f,90,s,a} = Sel_{90,s,a} C_{f,80,s,a}$$

Where the selectivity factors $Sel_{90,s,a}$ are given in Table 2.4.

Table 2.4 Selectivity factor $Sel_{90,s,a}$ at age for 90mm mesh size for sole and plaice

age	1	2	3	4	5	6	7	8	9	10+
Sole	0.45	0.5	0.56	0.63	0.69	0.75	0.8	0.85	0.89	0.92
Plaice	0.46	0.73	0.91	0.97	0.99	1	1	1	1	1

As for the LO, the 90mm selectivity is applied from 2019 onward affecting the catch, landings, discards, revenue and variable costs. When selectivity is changed, the fleets adapt their effort within the limits set in the model. To allow for the fleets to compensate the loss of catches, the effort limits are raised as seen in Table 2.5. For the two larger fleets, we allow for 15 and 23% extra seadays (resp. for the TBB_2440 and TBB_40XX) when switching to 90mm nets. For the smaller vessels (TBB_1224), we also assume the possibility to increase the activity per vessel by 15% and we also include the possibility to increase the seadays by 30% in the LO scenarios.

Table 2.5 Max seadays limit per fishing vessel allowed in the model the different fleets

	TBB_1224	TBB_2440	TBB_40XX
Status quo (2015)	131	166	202
LO	170	166	202
90mm	150	190	250
LO+90mm	195	190	250

3 Methods and data

3.1 Description of the Spatially explicit model SIMFISH and model development

The method used in this study is based on the bio-economic model SIMFISH (Spatially Integrated Model for FISHeries) published in 2015 (Bartelings et al. 2015). The original model contains several modules linking medium- and short-term fleet dynamics to fish population dynamics while taking the economic and management developments into account. The advantage of this model is the integration of fleet and fish stocks dynamics. The activity of the fishing fleets impact the fish stocks which in turn, through catch rates impacts the choices made by the fishing fleet.

Figure 3.1 illustrates the model framework which consists of five interacting parts: fleet dynamics, prices, investment behaviour, population dynamics and management policies. The fleet dynamics model optimises the short-term behaviour of the fleets, i.e. determines the effort allocation to fishing areas and metiers in order to maximise the total profit of the fleets in the model. The annual profit is optimised through effort allocation given some restrictions on effort and maximum catch and landings. The fleet dynamics module mutually interacts with the other four modules.

The investment module determines the long-term development of the fleet size, namely the entry/exit behaviour based on past profits and the utilisation of fishing capacity. Investment behaviour impacts the potential effort which is proportional to the number of vessels in the fleets. The price module computes both fuel and fish prices which affect the profitability of fleets.

For each species the population dynamics module computes the available biomass per area. The population dynamics can be calculated with a global model (of polynomial or logistic form) or with an age-structured model. The population dynamics function is set separately for each species in the model. The spatial fish distribution (by age class) is exogenously defined but can change through time. The biomass is used to calculate total allowable catch (TAC) in the management module. The TACs are then divided in quotas constraining the activities of the fleets. With the spatial component of the model, area closures have been included as management measures. It is also possible to include effort limitation policies.

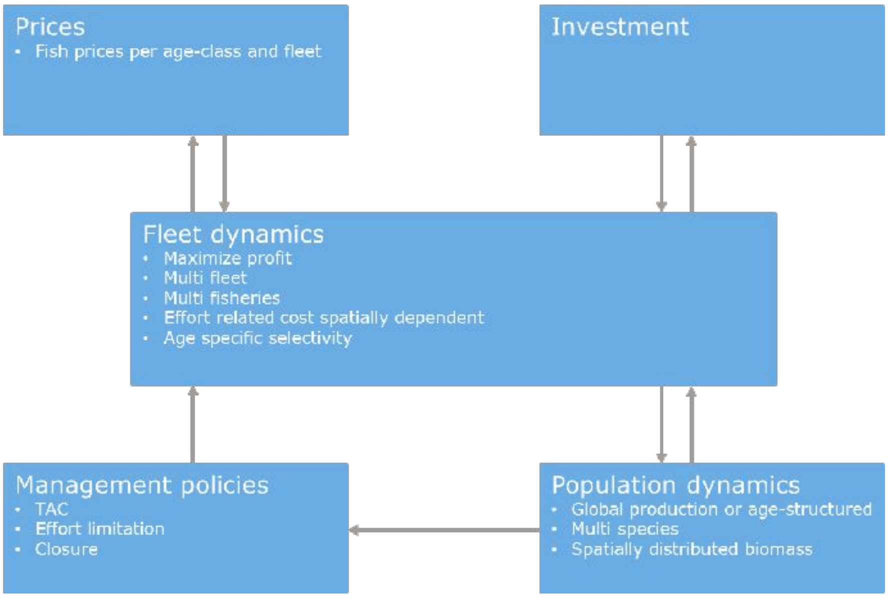

Figure 3.1 *Simplified framework of SIMFISH*

To analyse the impact of the landing obligation, gear selectivity and fish survivability we needed to extend the basic SIMFISH model as described in Bartelings et al. (2015) to include these features. The following features have been added:

1. Landing obligation

Since both over-quota discards and undersized discards are already included in the model, only economic costs and revenues related to the discard ban needed to be added. Revenues of landed discards are therefore added to the revenue calculation and increased fuel costs and crew costs due to the landing obligation are added to the model.

2. Selectivity

Selectivity has been added to the model by changing the catchability and adding an age-specific factor to the model. The data for this parameter are described in Section 2.2. In addition, the production function now calculates catch (instead of landings previously) and discards are now calculated as a proportion of catch using a fixed age and gear specific factor.

In the original SIMFISH model we assumed that the total catch of a species consists of both the catch of fleets taken into account in the model as well as catch by fleets not in the model. We assumed that the catch of fleets outside the model could be calculated as a fixed proportion of the catch of fleets within the model. This implicitly assumes that fleets not included in the model exhibit similar behaviour as fleets taken into account in the model. With regards to selectivity analysis this is no longer a probable assumption. We assume that the fleets not included in the model will not change their target age classes. Therefore the calculation of catch of other fleets will use a predefined age distribution parameter.

3. Survivability

In the past we implicitly assumed that survivability of discards was zero. We adjusted the stock calculation in the model to include a survivability parameter for the discards. Thus depending on the scenario the survivability of discards could be higher than zero. This in turn affects the quota calculations and therefore the future catch of a species.

3.2 Data and assumptions

Based on the selectivity of the different scenarios and the resulting catch composition in terms of species and size category (from Task 1.1 & 1.2), we estimate the medium-term impact of the landing obligation on the profitability of the flatfish demersal fleets with and without improvement in selectivity. The model is calibrated using 2015 data, and running until 2030. The changes in LO implementation and selectivity are implemented from 2019 onward. The costs of operation are based on recent data from Wageningen Economic Research Farm Accountancy Data Network and estimates of additional costs incurred because of the landing obligation are taken from the Best Practice I project (Baarssen et al. 2015). The level and composition of landings are taken from logbook data and Wageningen Marine Research sampling. Wageningen Marine Research sampling was also used to determine fish prices at age. Price elasticity was estimated using literature. Given that the model is an optimisation model maximising the total profit of the fleets, an analysis like this only has value if used in comparison to other projections by the same model to assess the relative effects of changes and cannot be seen as a prediction of future economic results.

3.2.1 Underlying biology/biological assumptions

Four species are included in this application of the North Sea flatfish fishery: sole, plaice, shrimp and turbot. Sole, and plaice are the main target species; shrimp is a complementary activity for a large part of the smaller vessels and is included because changes in the flatfish fishery can affect the shrimp fishery and vice-versa; turbot is only included as (valuable) by-catch.

The sole and plaice stocks are modelled using the dynamics used in ICES stock assessment. Here we have an age-structured model, using the natural mortality, weight at age and the maturity index of the assessment (ICES WGNSSK, 2017). The numbers at age are taken from Verkempynck et al. (2018) for the different survivability scenarios. The stock recruitment relationship is Beverton and Holt, consistent with Verkempynck et al. (2018). Shrimp is modelled using a polynomial growth function as in Bartelings et al. (2015). Turbot is not explicitly modelled and a fixed constant CPUE is used, using logbook data. The initial biomass of sole, plaice and shrimp is taken as an average of the 2013-2015 biomass.

3.2.2 Fleets

The three fleets included in the model are the Dutch data collection framework (DCF) fleets fishing mainly with beamtrawls (TBB). The three fleets are defined based on their vessel length (12-24m, 24-40m and >40m). The fleets were selected because they target flatfish (sole and plaice) and they are important fleets for the fishery. For the three fleets included in the model, catch and effort data were based on logbook data. Discard data per metier were estimated based on the Wageningen Marine Research sampling, also used to raise the data for ICES stock assessment. The economic data were based on the data submitted to STECF (2017). The fleets were parameterised based on data for 2013-2015. Additional data per metier (gear/mesh size) were extracted from the internal Wageningen Economic Research database (Farm Accountancy Data Network).

The fish prices used in the model are prices per market category, per metier averaged over the period 2013-2015. They are converted in at-age prices using Wageningen Marine Resource market sampling. We only use a price elasticity for sole (0.025) and for shrimp (0.36) as in Bartelings et al. (2015). The price of plaice is estimated to be pretty inelastic because of a high substitutionability. Given that turbot is taken as a bycatch, we do not set a price elasticity on its value. In addition to the price elasticity, an annual increase of fish prices by 1% is added for all species.

Real fuel prices are used for the period 2015-2018. After that period a 1% increase per year is assumed.

3.2.3 Management options

TACs are calculated for sole and plaice using the target F and the biomass. In case of positive survivability, the corrected biomass is used to calculate TACs and TACs will differ from historic values. The TAC of turbot is assumed constant at the 2015 value.

The LO is implemented in two variants: full implementation, meaning no exemptions and additional costs, or full exemption, meaning no additional costs (see scenario definitions for the specifics). The current situation is somewhere in between where most plaice is exempted. The fishery has currently little additional costs due to the landing obligation (based on discussion with the sector).

4 Results

Results are shown for 2 periods: short term, 2019-2021, i.e. directly after the implementation of the LO and/or the mesh size change and medium term, 2028-2030, about 10 years later as an average for the scenarios compared to the reference scenarios. All results are presented as percentage relative to the reference scenario. The size of the boxes corresponds to 25 and 75% percentile of the dispersion of the values obtained with the different scenarios.

4.1 Effect of the landing obligation

When looking at the effect of the LO, the reference scenarios are the ones without implementation. In Table 4.1, as shown by the arrows, scenario 1 is thus compared to scenario 7, scen2 to scen8, scen3 to scen9, etc.

Table 4.1 *Reference scenarios to look at the effect of the LO. Arrows point to the reference for each scenarios*

Landing obligation	Selectivity[1]	0% survival	Lower range survival[2]	Upper range survival[2]
Full LO implementation (100% retained)	80 mm	Scen1	Scen2	Scen3
	90 mm	Scen4	Scen5	Scen6
LO with full exemptions (i.e., No LO = 0% retained)	80 mm	Scen7	Scen8	Scen9
	90 mm	Scen10	Scen11	Scen12

Impact of the LO on the stocks

There is little impact to be seen on the sole and plaice stocks. Hardly any effect can be observed for plaice. The slight biomass increase for sole of maximum 6% after 10 years (Figure 4.1) is due to a lower sole quota uptake (up to 3% lower, Figure 4.2) limited by the plaice quota, which are fully used.

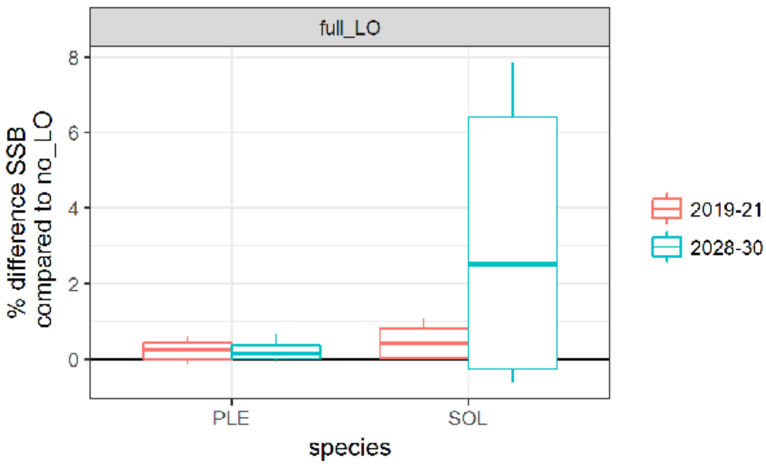

Figure 4.1 *Effect of the LO on the biomass of plaice (PLE) and sole (SOL) immediately after implementation (2019-2021) and ten years later (2028-2030)*

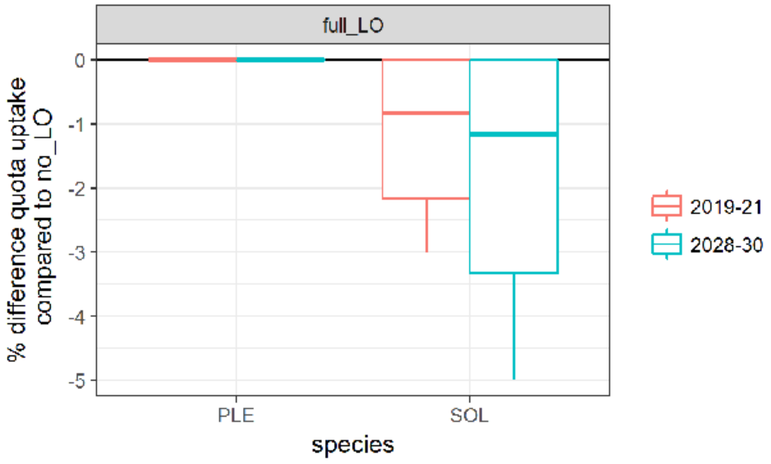

Figure 4.2 *Effect of the LO on the quota uptake of plaice (PLE) and sole (SOL) in the short (2019-2021) and medium (2028-2030) terms*

Impact of the LO on the fleets

- TBB 12-24m: this fleet reallocated part of their activity to shrimps, targeting less sole and plaice (Figure 4.3), this leads to higher revenues (+7 to 10% Figure 4.4) despite the lower landings of flatfish and the price of shrimp decreasing due to elasticity. However they also have about 27% extra fuel costs due to extra steaming needed to unload the extra landings of unwanted catch (Figure 4.5). The LO has a positive impact on the economic performance of this fleet in terms of gross cash flow (up to 10% increase in the short term, up to 4% in the medium term Figure 4.6) as well as NPV of profit (15 to 25% higher than without LO Figure 4.7). But it should be noted that the benefits are only felt by the vessel owners. Crew remuneration goes down 20% per crew (Figure 4.8) and days at sea would increase by 30% (Figure 4.9), meaning substantially less time on land.

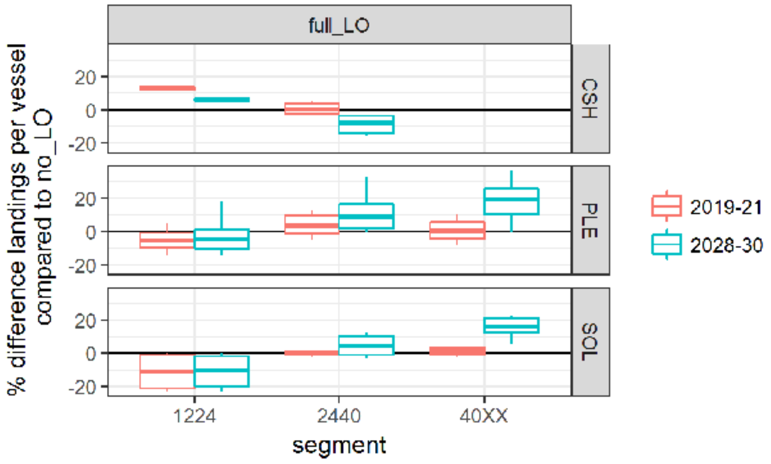

Figure 4.3 *Effect of the LO on the landings of marketable fish of shrimp (CSH), plaice (PLE) and sole (SOL) per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

- TBB 24-40m: This fleet maintains most of its activity, switching some of the activity from shrimp to flatfish (Figure 4.3). The extra costs of landing unwanted catch lead to poorer economic performances. The addition of 2 crew members to sort and handle the extra landings leads to higher labour costs but still compensation per crew member is on average 17 to 20% lower (Figure 4.8). The gross cash flow (value left to pay labour, the crew, and capital, the vessel owner Figure 4.6) stays about 50 to 60% lower than without LO. This leads to about a 40% lower net present value of profit after 10 years (Figure 4.7) and up to 6% of the fleet exiting within 10 years (Figure 4.10).

- TBB 40-XXm: The decrease of the fleet size by 10 to 15% from what it would be without LO within 10 years (Figure 4.10) leads to an increase of fishing effort per vessel by about 10% (Figure 4.9), resulting in 10 to 20% higher landings of sole and plaice (Figure 4.3) and revenue (Figure 4.4) per vessel but it does not compensate the extra costs (fuel costs 10 to 20% higher Figure 4.5) and extra costs related to the landing of extra fish. This fleet economically performs poorer than without LO. In the short term the gross cash flow is between 60 and 80% lower than without LO (Figure 4.6) and a NPV of profit about 25% lower (Figure 4.7).

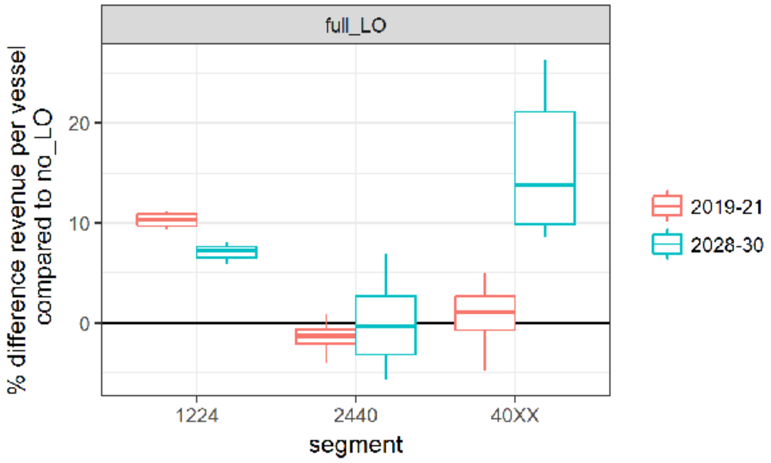

Figure 4.4 *Effect of the LO on the revenue per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

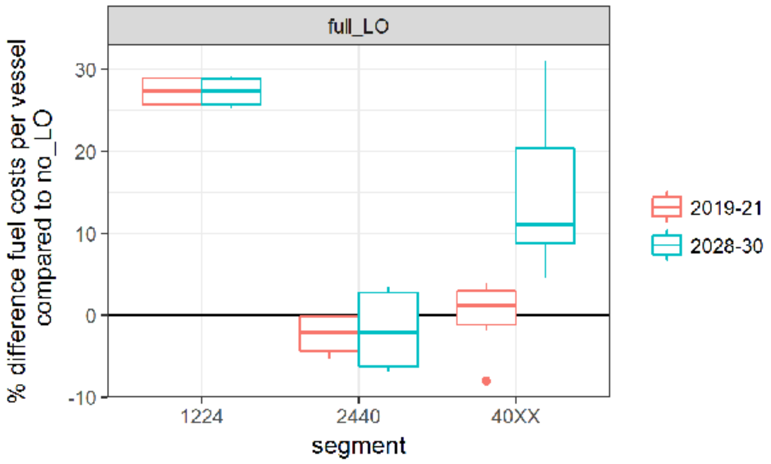

Figure 4.5 *Effect of the LO on the fuel costs per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

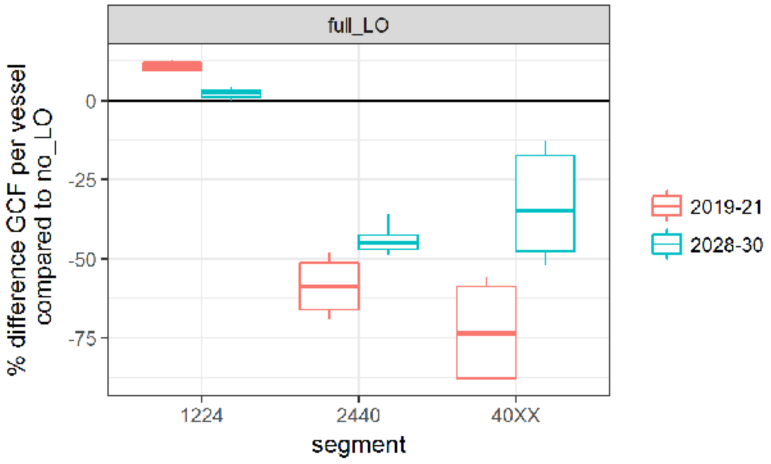

Figure 4.6 *Effect of the LO on the gross cash flow per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

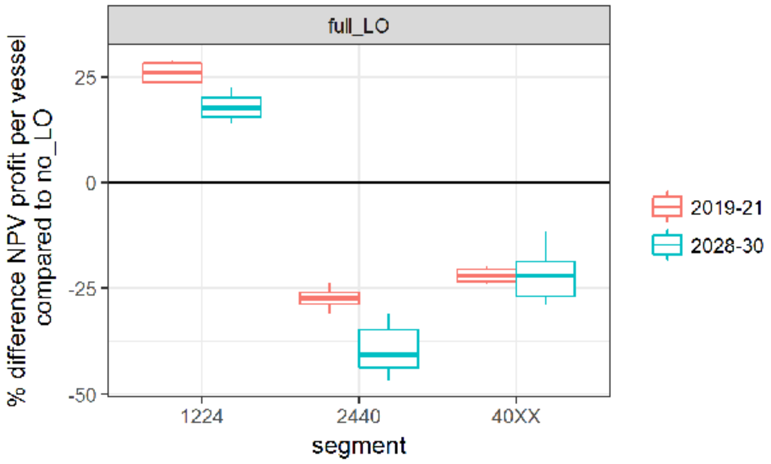

Figure 4.7 *Effect of the LO on the net present value (NPV) of profit per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

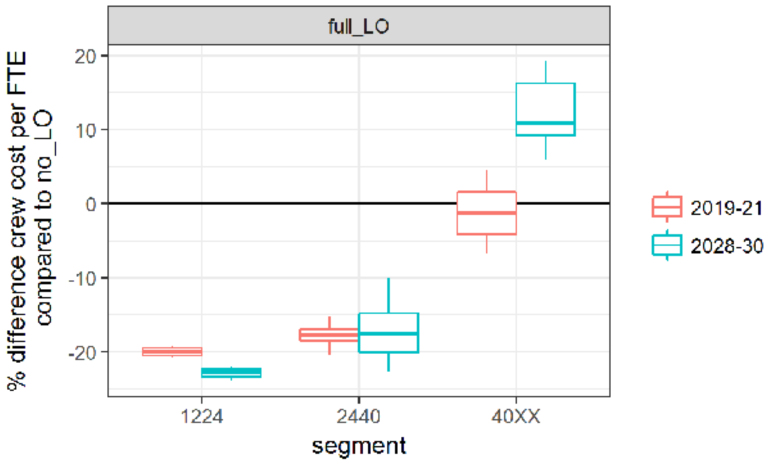

Figure 4.8 *Effect of the LO on the crew cost per FTE per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

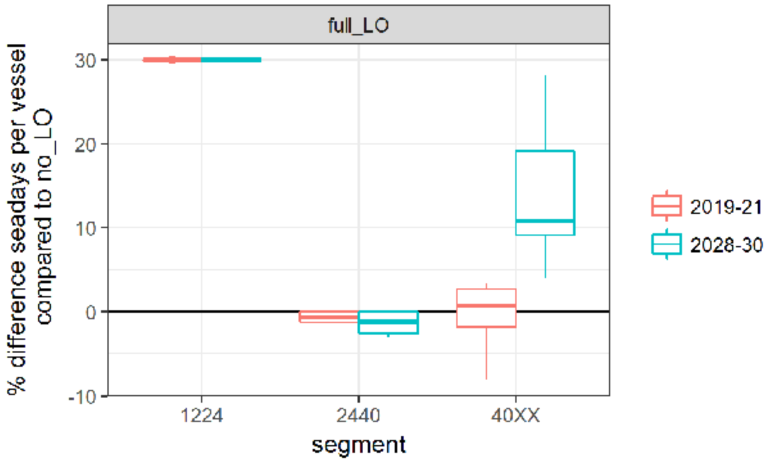

Figure 4.9 *Effect of the LO on the seadays per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

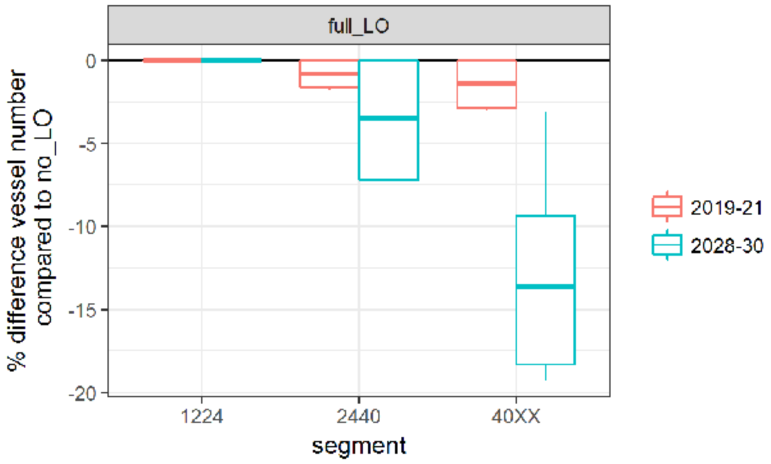

Figure 4.10 *Effect of the LO on the number of active vessels per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

4.2 Effect of survivability scenarios

After looking at the impact of the LO in general, we specifically look at the difference between the three survivability scenarios. We use the same references as in Table 4.1 but we plot the results per survivability scenario in order to identify differences in the way the LO will impact the fishery. The survivability scenarios are meant as past survivability which carries on in case of no LO and suddenly drops to 0 as the LO is fully implemented (as fish landed have a 0% survivability).

The positive impact of the LO on the biomass of sole and plaice in the 0% survivability case is reduced when survivability is positive (the higher the survivability, the lower the positive impact on biomass) (Figure 4.11). In the high survivability the plaice stock doesn't seem to benefit at all from the LO while the sole stock still increases by 1 to 4% within 10 years. The quota being adjusted to the stock size (initially lower the higher the survivability), quota uptake of sole is higher with survivability but the full quota cannot be taken because plaice quota remains limiting in all cases (see Figure 4.12). The fleet can therefore not increase their landings of plaice which decreases with scenarios of past survivability (Figure 4.13), survivability has little impact on sole or shrimp landings. This is expected as those species are hardly discarded.

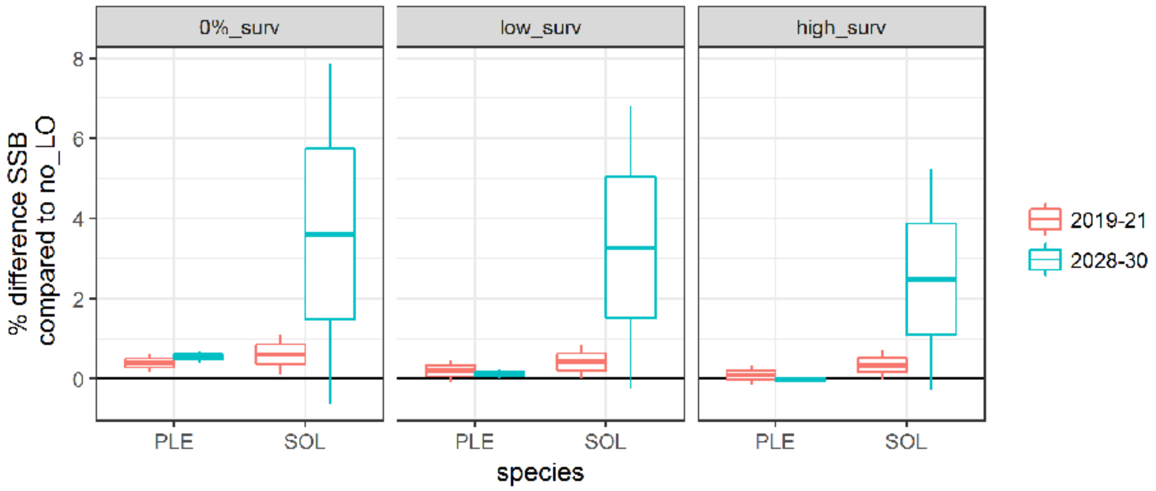

Figure 4.11 *Effect of the LO with the different survivability scenarios on the biomass of plaice (PLE) and sole (SOL) immediately after implementation (2019-2021) and ten years later (2028-2030)*

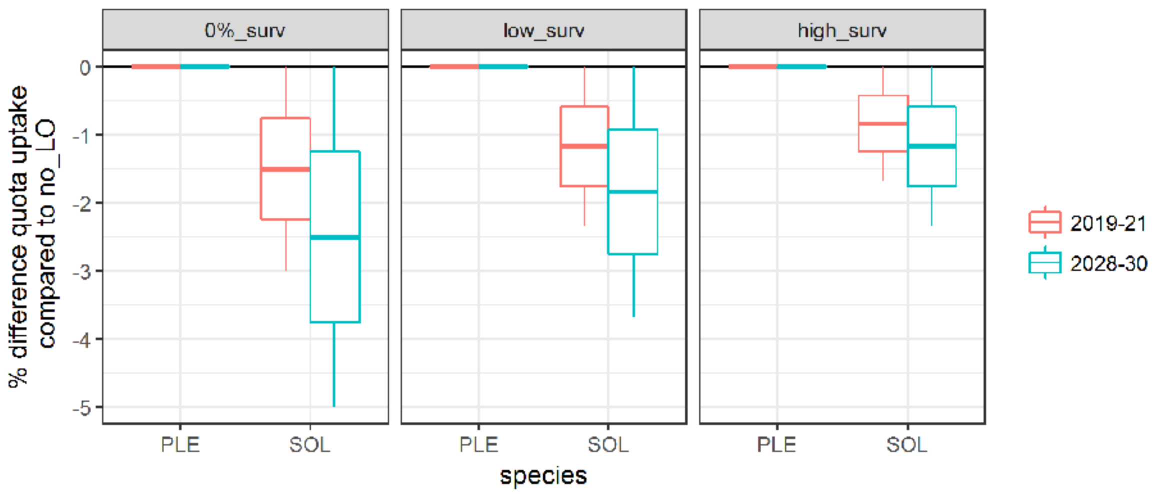

Figure 4.12 *Effect of the LO with the different survivability scenarios on the quota uptake of plaice (PLE) and sole (SOL) in the short (2019-2021) and medium (2028-2030) terms*

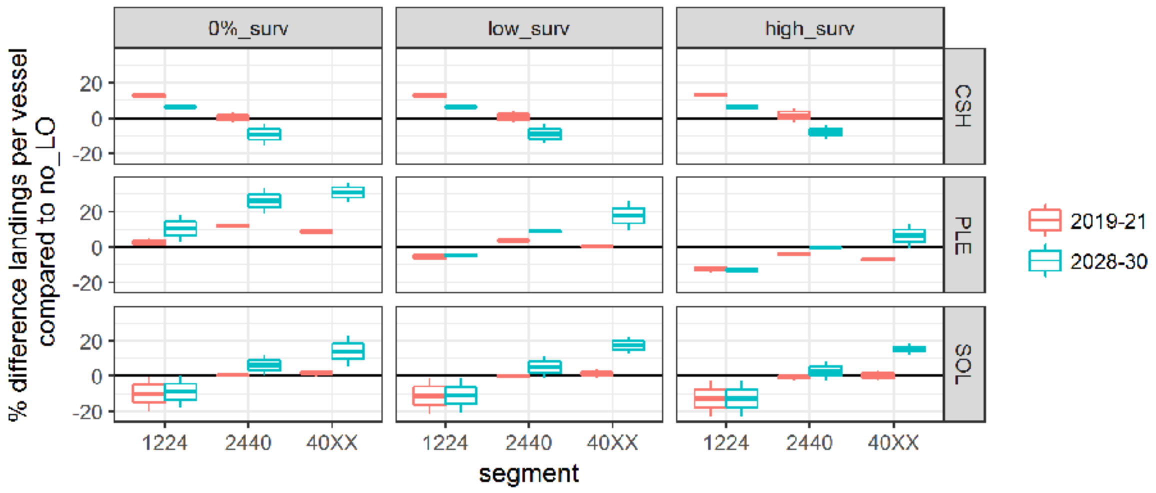

Figure 4.13 *Effect of the LO with the different survivability scenarios on the landings of marketable fish of shrimp (CSH), plaice (PLE) and sole (SOL) per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

The economic performances of the larger fleets (more dependent on plaice) decrease with the survivability. Lower plaice landings leads to lower revenue (Figure 4.14) and despite lower fuel cost (Figure 4.15) because effort is limited by the plaice quota, gross cash flow (Figure 4.16) and net present value of profit (Figure 4.17) also decrease for the fleets 24-40m and >40m. For those fleets, this means lower salaries for the crews (Figure 4.18). For the larger vessels, above 40m, this also mean an extra 5% of the fleet exiting the fishery in case of LO implementation (Figure 4.19). The only positive aspect on the social side is that the limited effort due to a quota shortage means less seadays (Figure 4.20).

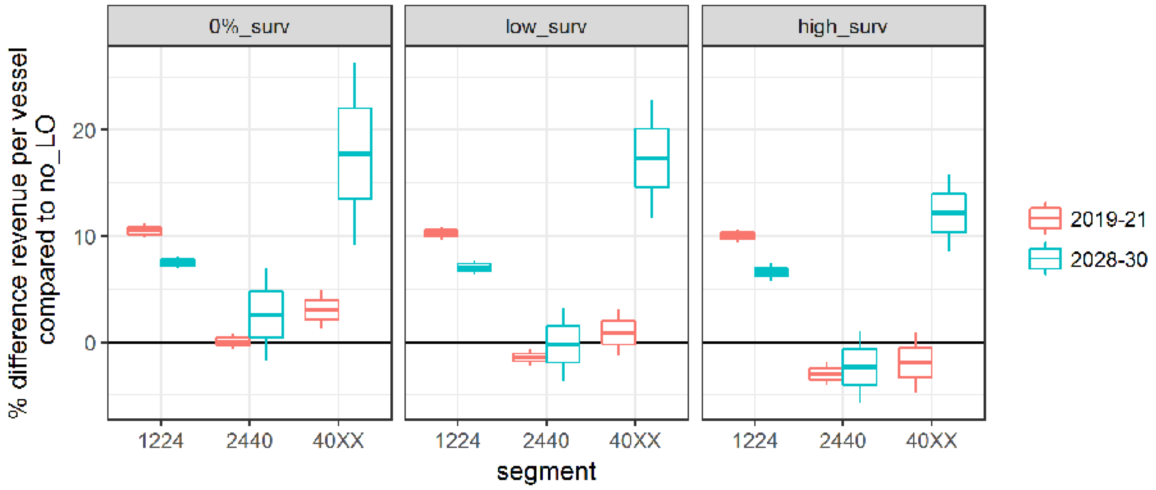

Figure 4.14 *Effect of the LO with the different survivability scenarios on the revenue per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

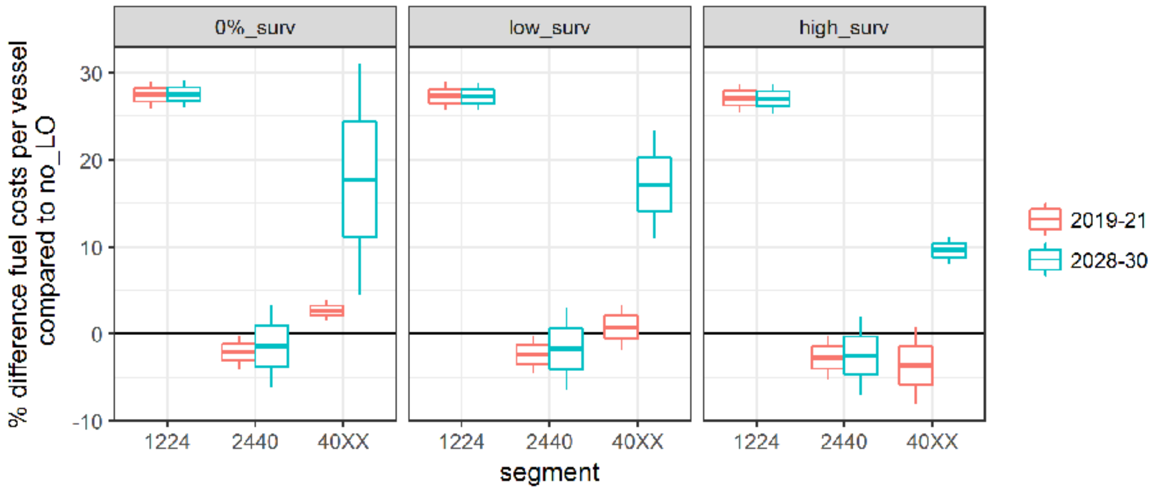

Figure 4.15 *Effect of the LO with the different survivability scenarios on the fuel costs per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

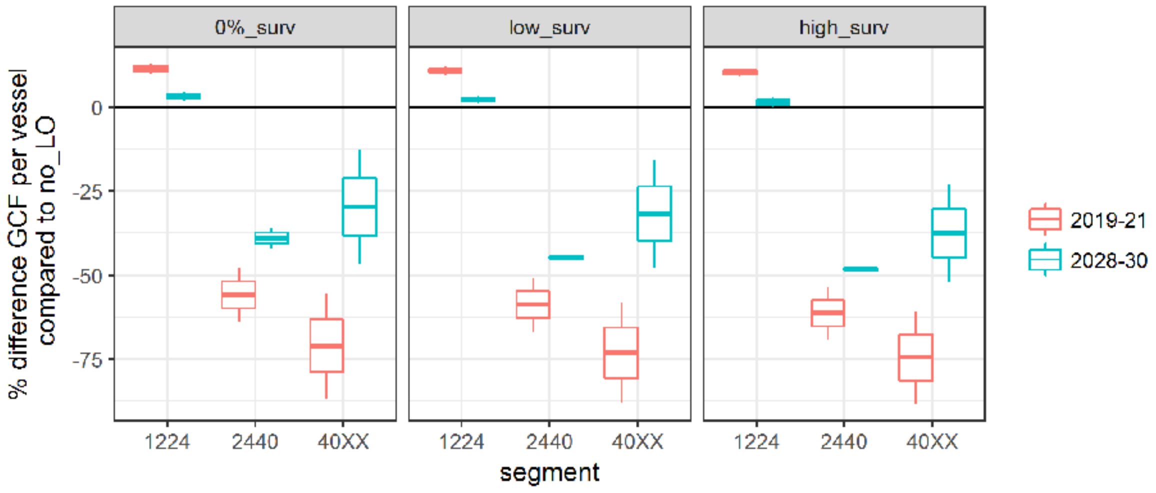

Figure 4.16 *Effect of the LO with the different survivability scenarios on the gross cash flow per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

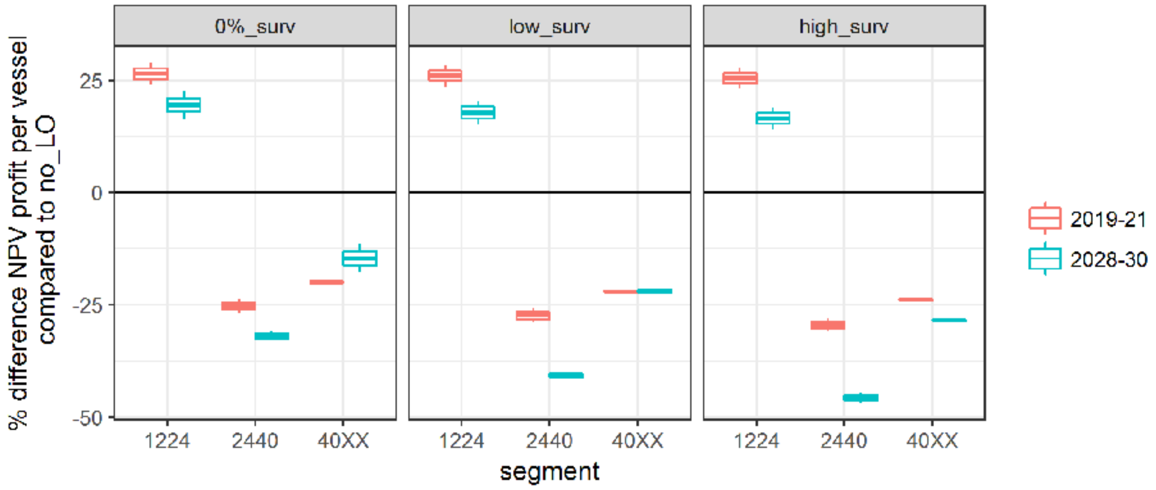

Figure 4.17 *Effect of the LO with the different survivability scenarios on the net present value (NPV) of profit per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

Social impact

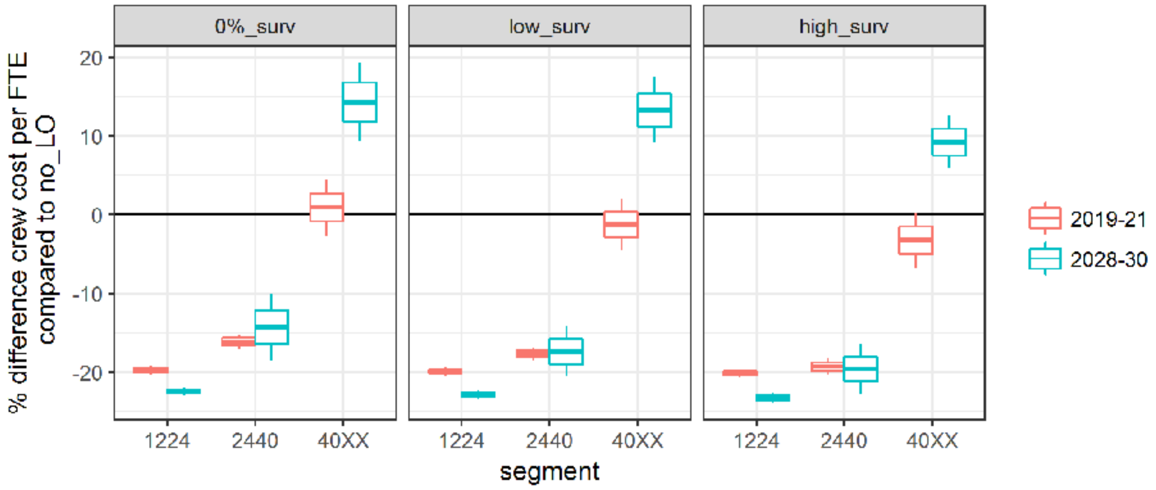

Figure 4.18 *Effect of the LO with the different survivability scenarios on the crew cost per FTE per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

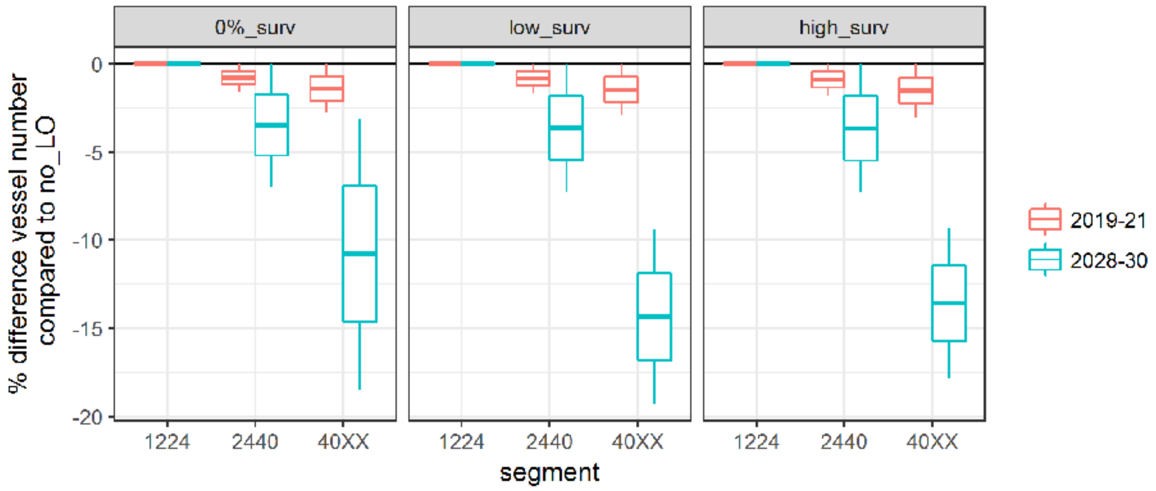

Figure 4.19 *Effect of the LO with the different survivability scenarios on the number of active vessels per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

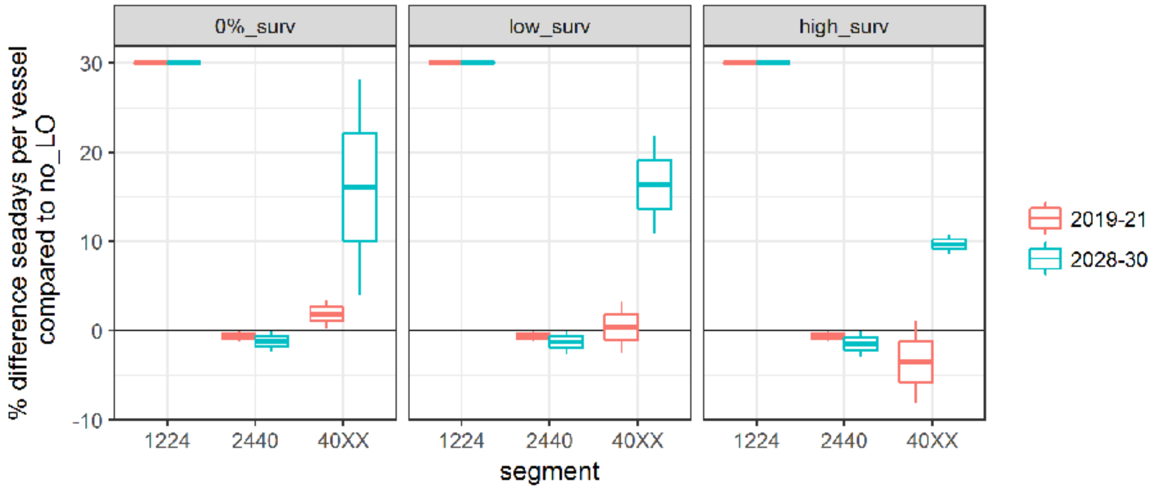

Figure 4.20 *Effect of the LO with the different survivability scenarios on the seadays per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms*

4.3 Effect of a change in selectivity

In this section we look further at the impact of the change to 90mm mesh size from 2019 with or without the LO. For this section the 90mm scenarios are compared to the 80mm ones (see Table 4.2).

Table 4.2 *Reference scenarios to look at the effect of the change of selectivity. Arrows point to the reference for each scenarios, the scenarios in the boxes are the reference scenarios.*

Landing obligation	Selectivity[1]	0% survival	Lower range survival[2]	Upper range survival[2]
Full LO implementation (100% retained)	80 mm	Scen1	Scen2	Scen3
	90 mm	Scen4	Scen5	Scen6
LO with full exemptions (i.e., No LO = 0% retained)	80 mm	Scen7	Scen8	Scen9
	90 mm	Scen10	Scen11	Scen12

Impact of the 90mm on the stocks

Using the 90mm nets instead of the 80mm leads to a positive effect on the stock of sole (from 3 to 9% higher than with the 80mm fishery Figure 4.21), this is due to lower landings of sole and a quota uptake 15% lower in the first years and 5 to 8% lower after 10 years (Figure 4.22). This impact is greater than the impact of the LO on the sole stock, especially in the short term. For plaice, the initial effect is slightly negative (-2%) but disappears in the short term.

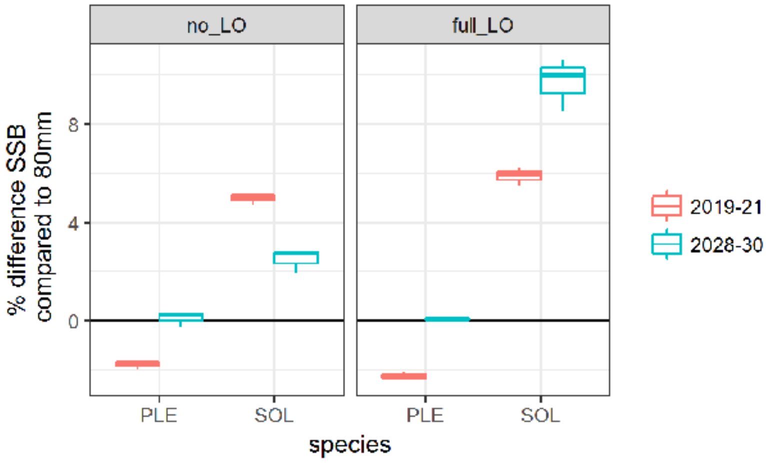

Figure 4.21 *Effect of the change to 90mm mesh size nets on the biomass of plaice (PLE) and sole (SOL) immediately after implementation (2019-2021) and ten years later (2028-2030) in case of no LO implementation (left) or full implementation (right)*

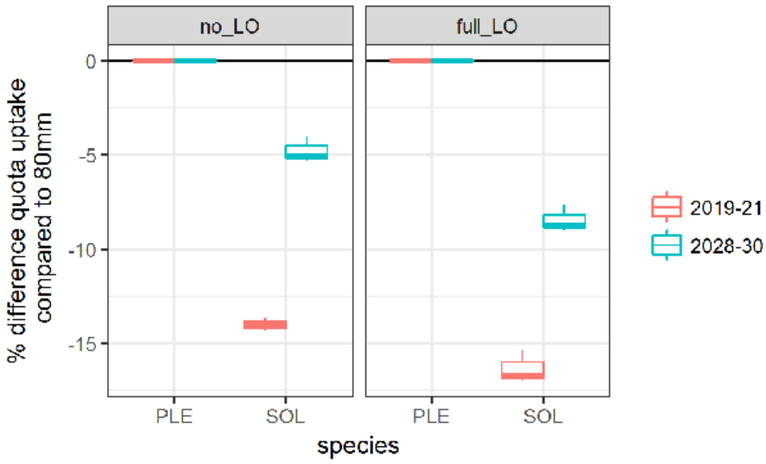

Figure 4.22 *Effect of the change to 90mm mesh size nets on the quota uptake of plaice (PLE) and sole (SOL) in the short (2019-2021) and medium (2028-2030) terms in case of no LO implementation (left) or full implementation (right)*

Economic impact

To compensate the loss of catchability and try to maintain their level of landings (Figure 4.23), all fleets increase their effort (Figure 4.24) but especially the fleet of larger beam trawlers that would spend 50 to 70% more time at sea.

The performances of the different fleets are described below:

- TBB 12-24m: The initial decrease of landings of sole is compensated by the increased landings of shrimp and plaice (Figure 4.23) leading to a slight increase in revenue (5% Figure 4.25). Despite the effort and fuel costs increase by 15%-20% (Figure 4.24 & Figure 4.26), the growth cash flow improves with the 90mm nets (Figure 4.27) and the NPV of profit increases by 7% (in case of LO) to 11% (without LO Figure 4.28).

- TBB 24-40m: effort & fuel costs increase by 15% and 30-40% respectively (Figure 4.24 and Figure 4.26). A slight increase of plaice landings (Figure 4.23), leads to higher revenues (Figure 4.25). Those do not compensate the higher fuel costs (Figure 4.26), leading to 10-50% lower GCF (Figure 4.27) and 10 to 15% lower NPV of profit (Figure 4.28). The economic situation is initially worse with LO implementation and 90mm for this fleet, leading to 7% less vessels after 10 years (Figure 4.30). The economic performances of the remaining vessels improve as they can increase their individual landings of sole and while the impact of introducing 90mm mesh sizes is still negative, the average remaining vessel fares better than without LO.
- TBB 40-XXm: to compensate the lower catchability, the effort is increased by 40 to 70% per vessel (Figure 4.24) leading to higher fuel costs (Figure 4.26) and lower crew compensation (-10 to -15% Figure 4.29). The increase in plaice landings compensates the decrease in sole landings (Figure 4.23) and leads to up to 10% increase in revenue (Figure 4.25). But even though the revenue is higher, the profitability of the fleet is reduced by 30% (Figure 4.28) but remains positive. The combination of 90mm and LO leads to less vessels exiting the fleet (Figure 4.30) because of the effort needed and quota availability.

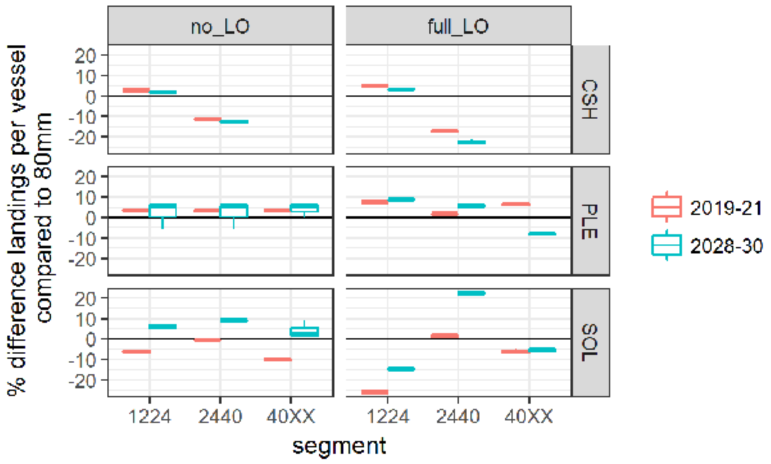

Figure 4.23 *Effect of the change to 90mm mesh size nets on the landings of marketable fish of shrimp (CSH), plaice (PLE) and sole (SOL) per fleet segment in the short (2019-2021) and medium (2028-2030) terms in case of no LO implementation (left) or full implementation (right)*

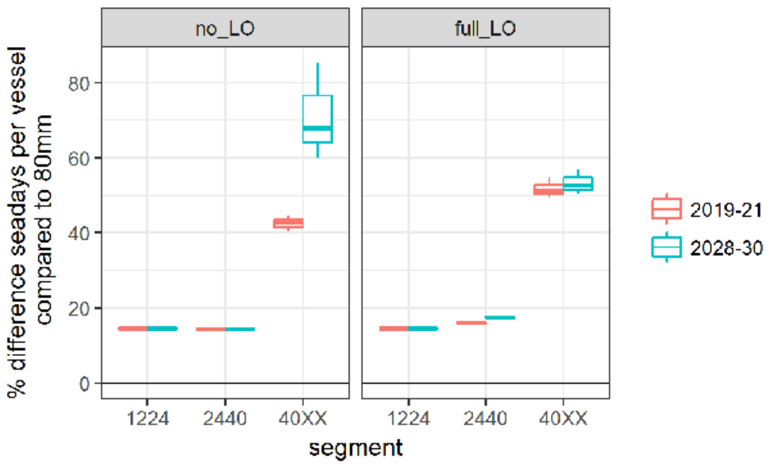

Figure 4.24 *Effect of the change to 90mm mesh size nets on the seadays per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms in case of no LO implementation (left) or full implementation (right)*

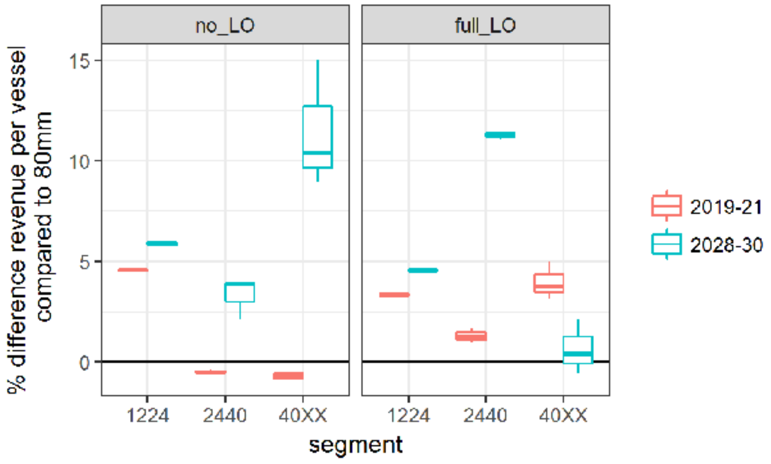

Figure 4.25 *Effect of the change to 90mm mesh size nets on the revenue per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms in case of no LO implementation (left) or full implementation (right)*

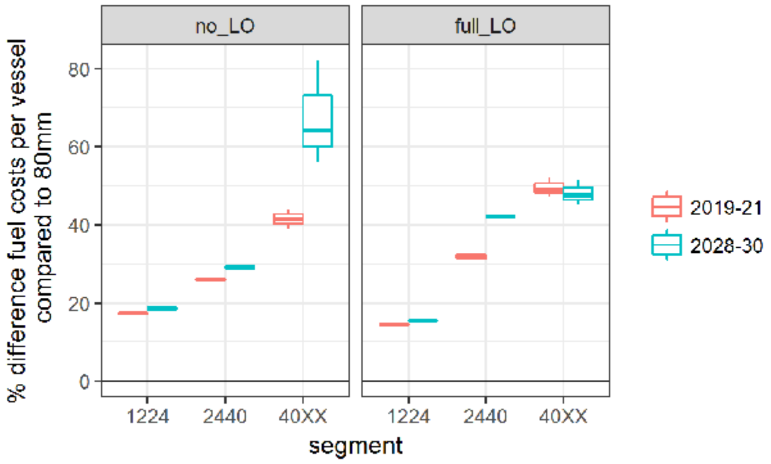

Figure 4.26 *Effect of the change to 90mm mesh size nets on the fuel costs per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms in case of no LO implementation (left) or full implementation (right)*

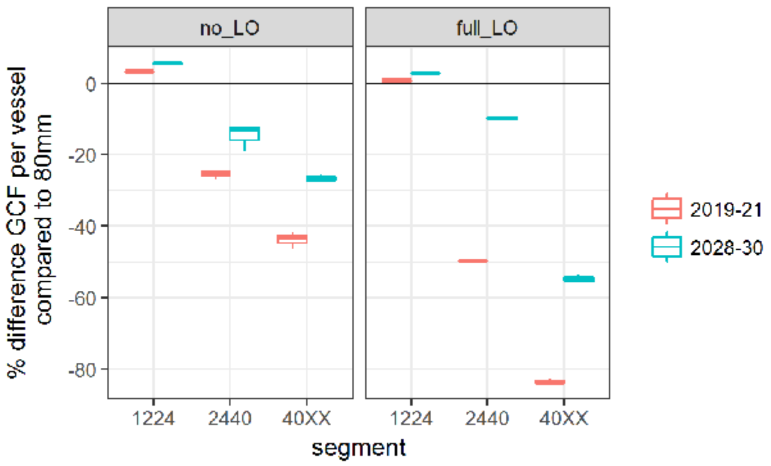

Figure 4.27 *Effect of the change to 90mm mesh size nets on the gross cash flow per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms in case of no LO implementation (left) or full implementation (right)*

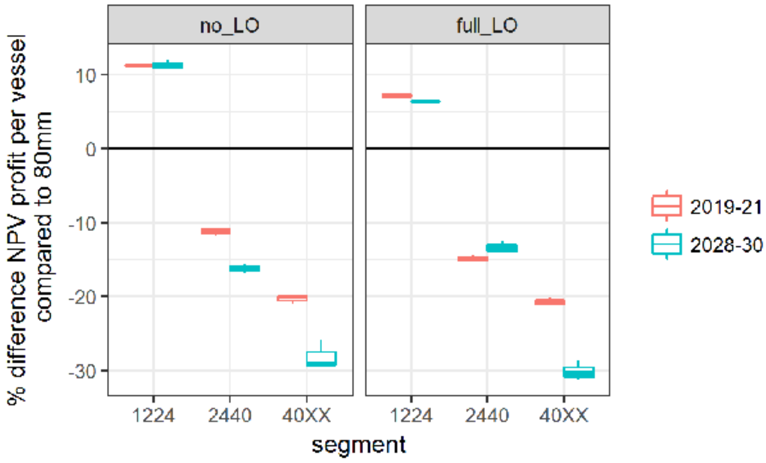

Figure 4.28 *Effect of the change to 90mm mesh size nets on the net present value (NPV) of profit per vessel per fleet segment in the short (2019-2021) and medium (2028-2030) terms in case of no LO implementation (left) or full implementation (right)*

Social impact

Crew costs tend to follow the trend of the GCF and an improvement is seen in the remaining vessels of the 24-40m fleet because of the exit of vessels in the LO scenario. Switching to 90mm nets would mean extra seadays for vessels in all fleets (Figure 4.24), having a serious impact on their work-life balance by limiting the amount of time spent on land.

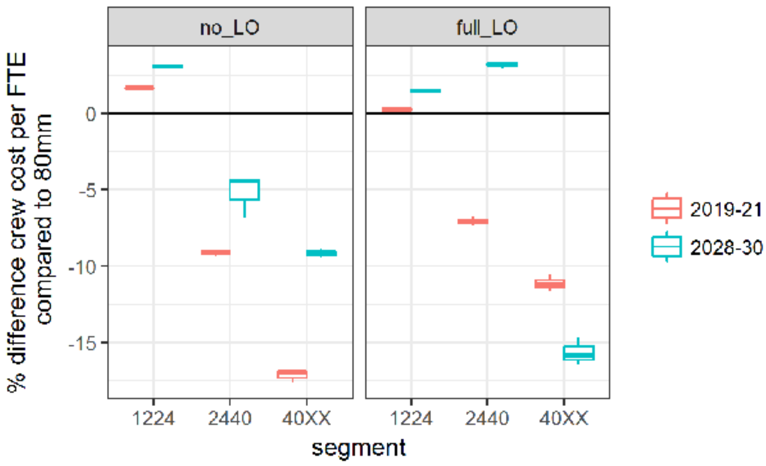

Figure 4.29 *Effect of the change to 90mm mesh size nets on the crew cost per FTE per fleet segment in the short (2019-2021) and medium (2028-2030) terms in case of no LO implementation (left) or full implementation (right)*

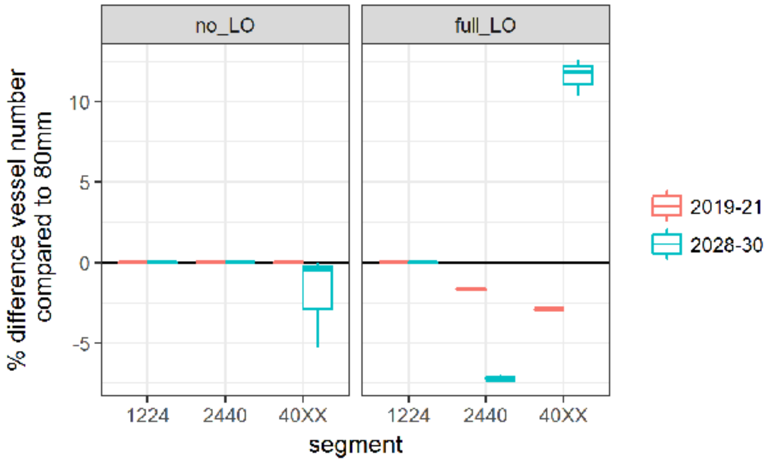

Figure 4.30 *Effect of the change to 90mm mesh size nets on the number of active vessels per fleet segment in the short (2019-2021) and medium (2028-2030) terms in case of no LO implementation (left) or full implementation (right)*

5 Discussion

In this study we were asked to evaluate the medium-term impact of the LO (after 10 years), and to look at the impact of a number of scenarios on survivability and change in selectivity. The results are discussed below, first on the LO in general and then looking at the survivability and selectivity change. The limitation of the current approach is discussed after.

The implementation of the LO without plaice exemptions will have a lasting effect on the Dutch flatfish fishery. In this study we looked at the effect of the LO on three fleets (defined based on their vessel length as in the EU DCF data) targeting sole and plaice with beam trawls.

The impact of the LO implementation on the stocks is quite limited for plaice (<1%) and variable for sole depending on the scenarios. The change of mesh size has a much larger impact on the sole stock than the LO because changing the relative catchability of sole and plaice makes the plaice quota even more limiting and reduces the uptake of sole quota.

The LO would be felt differently by the three fleets. Some of the extra effort allowed in the model for the smaller vessels (12-24m) so that they can steam to and from fishing grounds to compensate the limited onboard storage is used to target shrimp (not impacted by the LO). By decreasing slightly their effort towards flatfish, the fleet could allocate 130% of that freed effort towards the shrimp fishery (in our scenarios there are no limits on effort or landings for shrimps) leading to the improvement of its economic situation on short and medium term. The fleets fishing exclusively or semi-exclusively on flatfish and for which no extra effort is allowed show poor economic performance due to the introduction of the LO. So much so that the LO results in a substantial decrease of the fleets after 10 years, up to 7% for the 24-40 fleet and between 10 and 17% for the vessels larger than 40m (40XX).

While the smaller vessels benefit at the vessel level, the extra crew needed during flatfish trips means that on average, remuneration of the crew would immediately decrease by 20% and 22% in the long term. For the 24-40m fleet, the crew cost per FTE also decrease by about 18%, only the larger vessels seem to end up with better crew remuneration. However, those results are obtained based on estimates on extra labour at sea from the best practice 1 project (Baarssen et al. 2015). More recent trials done during this project indicate that for larger vessels 3.6 extra FTEs (compared to the 2 extra FTEs used in the model; or almost twice as much extra labour) are needed to sort out all the additional landings (VisNed, unpublished). Those results have not been taken in this task by lack of time, but should be included in a later study where scenarios should be investigated as to how this extra labour is compensated (e.g. by decreasing the individual remuneration or proportionally increasing labour costs, or a solution in between).

The real past survivability of plaice remains uncertain. With the estimated survivability, not only would the benefit of the LO to the stock decrease, it would also worsen the economic situation of the fleets, and the degradation of economic profitability only increases in time. If the estimates of Schram and Molenaar (2018) are accurate, the full implementation of the LO on plaice (currently still largely exempted) would have worse consequences than what has been expected and the need to adapt their selectivity to avoid unwanted catch would be stronger.

The 90mm selectivity has a beneficial impact on the stock of sole because the quota cannot be caught anymore as the plaice quota becomes limiting but not on plaice as the fleets compensate by fishing more, reducing their profitability and the crew remuneration. Unfortunately, the 90mm nets reduce too much of the wanted part of the catch to become a viable gear, even after 10 years. The effort needed to catch (most of) the sole quota is much higher than what is needed with 80mm nets. This not only has an impact on bycatch species that still cannot escape 90mm nets but also on the habitat. Nets have to be dragged longer on a larger surface to catch the same amount of the target species sole. In a political environment where the space still available for fishing is threatened to be drastically reduced (PBL, 2018) and crowding effect is expected, spending more time at sea to catch the same amount of the target species would certainly be controversial.

Limitations to the approach

Modelling approaches are very data consuming and the quality of the data put in is reflected in the quality of the output. In this study we based most of the parameterisation on results from this project. However, large uncertainties on survivability and selectivity remain as the trials have been limited. In addition, all trials have been done with pulse trawls while these will not be allowed after 2021. Given the claims that pulse was more selective than the traditional beam-trawl, reverting back to the traditional gear will likely worsen the impact of the LO.

The model is very sensitive to the data put in and the constraints set on the behaviour of the fleets. The model optimises profit within a set of constraint, as long as fishing is profitable, the model is very much driven by those constraints. The total sea-days that are allowed for each fleet are one of those constraints that has been adjusted to allow extra fishing due to 1) larger steaming proportion for the fleet of 12-24m vessels and 2) lower catchability of the 90mm gear. Of course this extra time at sea comes at a cost, less time on land for repair or free, social time. This cost is not included in the dynamics of the model and how much would a vessel really increase their time at sea is probably fisher-specific. In this model we chose ad-hoc limits depending on the scenario (Table 2.5) those should be revisited based on data collection with fishers. And sensitivity analysis should be ran to check how those limits impact the results of the simulations.

6 Conclusions

Negative economic consequences for the flatfish exclusive fleets for little biomass improvement
Despite being implemented to reduce the bycatch and discarding of unwanted catch, the model projections suggest that the LO would have very little impact on the stock of plaice, which is the most discarded species under quotas of the North Sea flatfish fishery. This is due to the fact that the fishery is very much driven by the landings of high value sole and that the technical interactions between sole and plaice cannot yet be reduced by beam trawling. The stock of sole would benefit from lower catches as the quotas of plaice become limiting and the uptake of sole quotas would then be lower.

The fleets on the other hand would be severely impacted with on average 3 to 13% fewer vessels in the 24-40m and above 40m fleets leaving the fishery within 10 years of LO implementation. The remaining vessels also suffer from the LO and display 20 to 40% lower NPV of profit after 10 years.

The LO would lead to worse outcomes than expected if the current survivability is positive
The slight increase in plaice biomass gained through the implementation of the LO would be completely dissipated if the actual survivability of discards is non-null (as assumed by stock assessment). Indeed, given the importance of plaice discards, the survivability of 20% of those discards would have an importance at the population level. And while using the adjusted biomass to calculate the TAC leads to its reduction in the short term and to a worsened economic situation for the flatfish exclusive fleets, it avoids overexploiting the stock in the short term which would have even more dire consequences for those fleets in the medium term.

Switching to 90mm would lead to worse economic and ecological situation
The limited trials with 90mm mesh sized nets have not been encouraging, the loss of catchability of marketable sole can only be compensated by additional fishing effort at the cost of bycatch species, habitat and the economic performances of the fleet. While it would have a positive impact on the biomass of sole, biomass of plaice and probably other bycatch would decrease. Additional work is still needed to design a gear that would maintain the fishing capabilities of the target species sole while decreasing the bycatch of other less desired species.

The social costs of LO, changing work practices and social balance
The current implementation of the LO (with plaice exemption), has had little impact on the fleet as the volume of unwanted catch that must be landed remains low. For this reason, some aspects remain unclear and the parameterisation of the model reflects that. Recent results (VisNed, unpublished) indicate that the extra labour needed to process the catch on board could be twice as high as previously estimated (Buisman et al. 2013) or about double the number of crew on board (with the impact it would have on space on board). Beyond the quantitative assessment of the LO implementation, lifting the exemption on plaice and processing the unwanted catch on board will have deep impacts on the life on board. The extra work will completely transform the practice on board, potentially halving the level of remuneration.

The extra time at sea expected to catch the sole quota would profoundly alter the life of fishers and the organisation of the fishery, leaving less time for activities on land, connected to work such as vessel maintenance or meeting attendance or simply time to socialise, be part of a community and a family.

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