Best Practices II

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Wageningen University & Research report C016/19

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Summary

This study investigates the consequence for future development of stock size, catches, landings and discards of sole and plaice of changing the mesh size of the cod-end from 80mm to 90mm for the Dutch beam trawlers in theTBB 70-99 fleet currently fishing with 80 mm.
The question is addressed by means of long term stochastic simulations. Using the simulation framework developed to test the effect of implementing the landing obligation, the future fishery selection pattern (how the fishing mortality is distributed across ages) is modified based on the results of the selectivity experiment to represent the consequence of changing mesh size. Simulations were then run for the next 50 years for different assumptions on the survival rate for both stocks: a 0% survival rate, and the lower and upper bounds of the current estimates of survival for each species.
The differences in the effect on sole and plaice of using a 90mm net are related to both the direct effect of exploiting the stock with a different selection pattern and of applying different Fmsy values. The effects of changing mesh size are larger for sole than for plaice, because the share of the landings taken by the Dutch beam trawlers currently fishing with 80 mm is much larger for sole than for plaice.
For sole, fishing with the 90mm net results in lower discards (10 to 16%). Landings are also lower (up to 4%) in the short term, but the situation reverses and landings become higher in the medium and long term (up to 3% after 5 years). These results are explained by the fact that when the 90mm net is used, the cohorts are exploited at a slightly later age combined with a stronger targeting of the older ages. This exploitation patterns leads in the medium and long term to a larger stock (by 3 to 13%), which explains the higher landings. Those benefits (in the medium and long term) of using the 90mm net are largest for the 0% and 10% survival assumptions, but are smaller (especially for the landings) for the assumption with 30% survival: the higher the chance for a discarded fish to survive, the less it pays to increase the selectivity of the gear because fish caught and discarded have still a chance to join the stock and further grow and reproduce.
For plaice, in the scenarios with 0% and 10% survival, the Fmsy value for the 90mm net is higher than for the 80mm net. As a result, stock size is lower and catches, landings and (despite the improved selectivity of the net) discards are higher if the 90mm net is used. For the scenario with 20% survival rate, Fmsy values are similar for the 80mm and 90mm mesh size and the improved selectivity of the 90mm net indeed results in slightly lower discards, which in the medium and long term result in a slightly larger stock with slightly higher landings.
One important assumption in these simulations is that the stocks are exploited at Fmsy in the future. However, if the beam trawl fleet switches to the 90mm net, its catchability (at least for sole) will decrease, meaning that a higher fishing effort will be necessary to achieve a same fishing mortality on the stock. The present study does not model explicitly catchability and effort, and therefore cannot quantify the change in effort implied if the stocks were to be exploited at Fmsy with the 90mm net.

1 Introduction

This study investigates the consequence in term of future development of stock size, catches, landings and discards of sole and plaice, of changing the mesh size of the cod-end from 80mm to 90mm. To do so, this study combines the outcome of the work by Molenaar and Chen (2018) on the comparison of the selectivity of the 80mm and 90mm nets, with the simulation framework developed by Verkempynck et al (2018) to test the effect of implementing the landing obligation. First, the raw data from the selectivity experiments are combined with information on the length-age relationship to derive selectivity curves with respect to age (Molenaar and Chen, 2018 delivered selectivity curves with respect to size). The simulation model represents the biology of the stocks (weight and maturity at age, stock-recruitment relationships) and the fishery on the basis of the stock assessment output. In the present case, different assessments using different assumption on survival rate are used in separate simulations, corresponding to different characteristics in stock biology. The simulation are run independently for each stock. Simulations are conducted by bringing the stocks forward by step of one year, representing at each time step the different demographic processes in the population. As some processes, such as recruitment, are modelled in a random way, a large number of simulations (2000) are run in parallel for each scenario in order to define the complete envelop of the possible variations. To implement the change of mesh size, selectivity-at-age derived from the experiments is used to modify the fishery selection pattern (i.e how fishing mortality is distributed across ages) used in the future year in the simulation model. New values of Fmsy, corresponding to these new selection patterns are calculated and used as management target in the simulations.
Simulations are conducted for different assumptions on the survival rate for both stocks: a 0% survival rate, and the lower and upper bounds of the current estimates of survival for each species.

2 Methods

2.1 Implementing mesh size change in the simulation tools

2.1.1 Selectivity curves

The simulations for North Sea plaice and sole are based on an age-structured population model. The data collected during the selectivity experiments (Molenaar and Chen, 2018) are structured by length-class (no age information was collected), and the estimated selectivity curves calculated present the retention rate by the cod-end as a function of fish length. The first step to simulate the effect of changing the mesh size from 80mm to 90mm on the plaice and sole populations consisted in calculating selectivity curves as a function of age.

Two experiments were carried out to compare the selectivity of the 80mm and 90mm mesh size, with contrasting results (see Molenaar and Chen, 2018). For the present study, the decision was made to use only the data collected during the second experiment because the difference in mesh size in the two nets used in the first experiment was too small resulting in hardly any difference in the retention rate found for sole in the two cod-end.

In order to convert the results of the selectivity experiment from retention-at-length to retention-at-age, age-length keys were built for both stocks. The available biological sampling data for sole and plaice was extracted from WMR data bases: the data for fish above the minimum landing size (24cm for sole and 27cm for plaice) were extracted from the market sampling program, while the data for fish below the minimum size were extracted from the discards sampling programs (observers and self-sampling). The data was extracted for the 3rd quarter of the year 2017, for areas IVb-c, in order to match with the period and area in which the second selectivity experiment was conducted. The resulting age-length keys for sole and plaice are presented on figure 1.

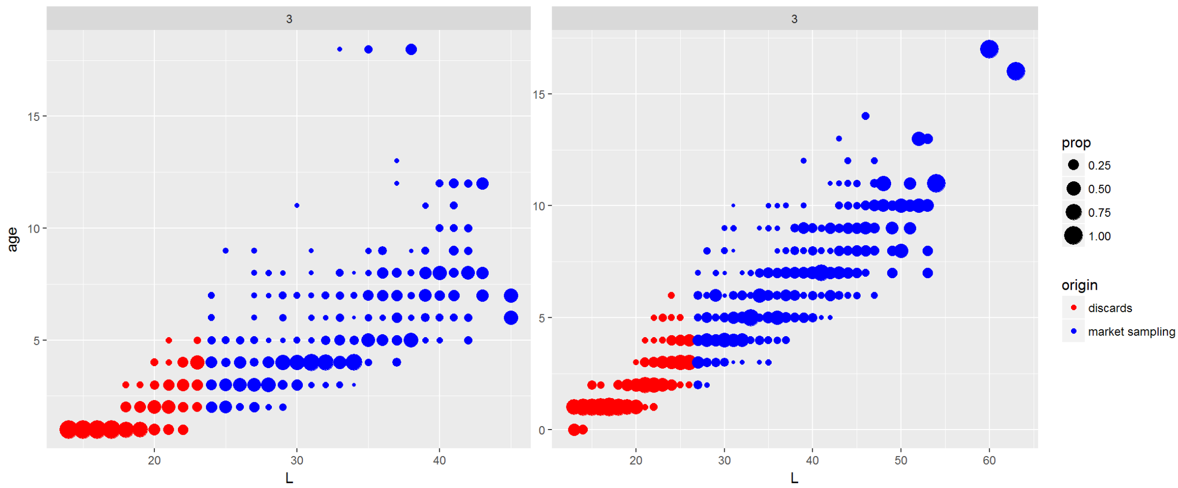


Figure 1 Age length keys for sole (left) and plaice (right) in the central and southern North Sea (ICES IVb and IVc) for the 3rd quarter for 2017.

The age-length keys were then applied to the raw data from the second selectivity experiment. The data are collected by trawl haul and give, for each mesh size (80mm and 90mm trawls used in parallel) and by 1cm length class, the number of fish retained in the cod-end and the number of fish escaping through the cod-end (and caught in the net covering the cod-end). These numbers of fish by length-class were then multiplied by the proportion of the different age-classes for the corresponding length-class in the age-length key to obtain the numbers of fish at age.

A binomial GLM model was then applied (as done in Molenaar and Chen (2018),) to fit a logistic model :

$Ret_i \sim binomial(\pi_i)$

With Ret_i is 1 for fish *i* retained by the net and 0 for fish retained in the net cover.
and

$E(Ret_i) = \pi_i$

$log\left(\frac{\pi_i}{1-\pi_i}\right) = I + age_i + mesh\ size_i$

The resulting selectivity curves are shown in figures 2 and 3. Changing the mesh size from 80mm to 90mm has a marked effect on the estimated selectivity curve of sole, with proportion of individuals retained lower for all age-classes, the difference being much larger for younger ages. For plaice, a lower selectivity is observed only for young fish (age 0 to 2).

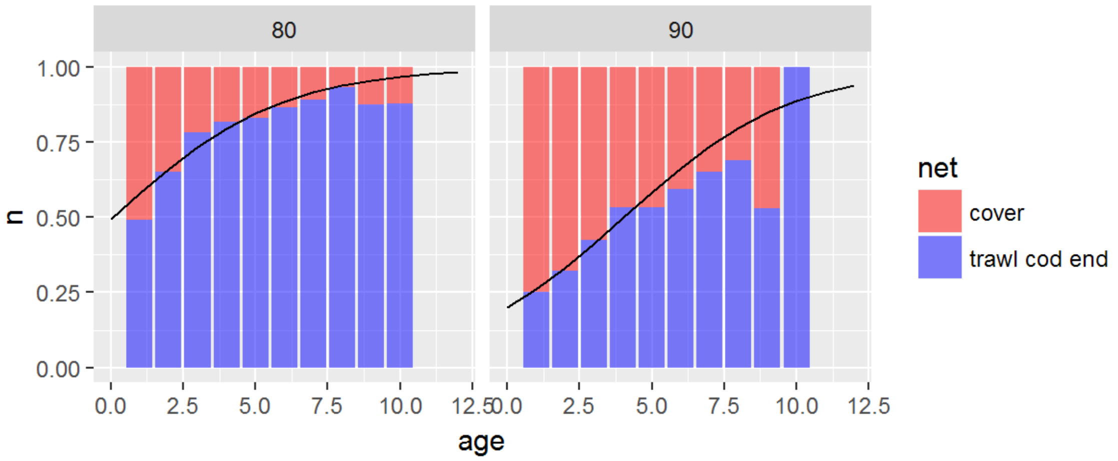


Figure 2 :proportion of sole retained in the cod-end per age-class (bar plots) and modelled selectivity curve for North Sea sole for the 80mm (right) and the 90mm (left) mesh sizes (black solid line).

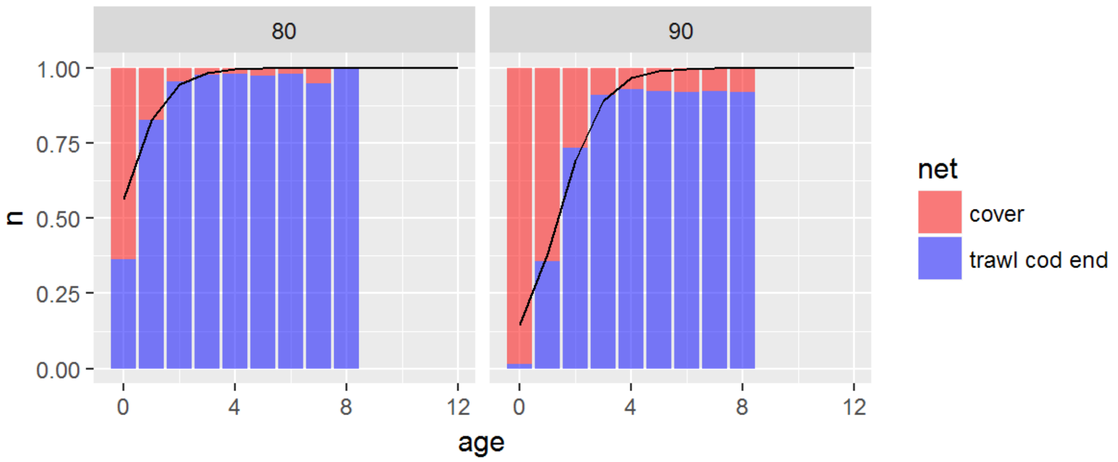


Figure 3 : proportion of plaice retained in the cod-end per age-class (bar plots) and modelled selectivity curve for North Sea plaice for the 80mm (right) and the 90mm (left) mesh sizes (black solid line).

2.1.2 Selection pattern to be applied in the simulations

In the simulations, the effect of changing mesh size is implemented by changing the selection pattern (i.e. the age profile of the fishing mortality) used in the future years. The assumption made on the

future selection pattern in the analyses carried out by Verkempynck et al (2018) is that future selection is equal to the average of selection pattern over the last 3 years of the assessment period. We assumed here that this selection pattern is representative of a situation in which all vessels in the métier TBB_DEF_70-99_0_0_all use a 80mm net, corresponding to our base case. The selectivity-at-age curves are then used to compute the selection pattern that would correspond to switching to a 90mm net for all the TBB_DEF_70-99_0_0_all vessels.
Since the change in mesh size does not apply to all the vessels fishing sole in the North Sea, but only to the Dutch beam trawlers fishing with a 80mm mesh size, belonging to the métier TBB_DEF_70-99_0_0_all, the partial fishing morality for this métier was first calculated for the year 2017 (year in which the selectivity experiments were conducted). This was done by taking the landings and discards at age submitted by WMR to ICES for the stock assessment working group (WGNSSK 2018) for the TBB_DEF_70-99_0_0_all métier. The partial fishing mortality was then calculated

$$pF_{TBB\,XX\ \ a,2017} = F_{a,2017} \times \frac{C_{TBB\,XX\ \ a,2017}}{C_{a,2017}}$$

Then the decomposition of fishing mortality into catchability q and effort f was used :

$$pF_{TBB\,XX\ \ a,2017} = q_{TBB\,XX\ \ a} \times f_{TBB\,XX\ \ 2017}$$

The catchability coefficient $q_{TBB\,XX\ \ a}$ represents the probability for a fish of age a to be caught by one unit of effort of the TBB_DEF_70-99_0_0_all métier. According to Laurec and Le Guen (1981), catchability is the combination of a number of components, some of which related to fish and effort distribution, to fish and fishermen behavior, all conditioning the probability of a fish to enter the gear (all summarized in the coefficient Q_a in the equation below), and a component representing specifically the chance of escaping thought the net : the selectivity $S_{80\ a}$:

$$q_{TBB\,XX\ \ a} = S_{80\ a} \times Q_a$$

Changing the mesh size modifies the selectivity as describe on figure 2 and 3, but is not expected to have any effect on the others components of the catchability, Q_a . Therefore, the partial fishing mortality for the métier TBB_DEF_70-99_0_0_all TBB with a mesh size of 90mm can be expressed :

$$pF'_{TBB\,XX\ \ a,2017} = S_{90\ a} \times Q_a \times f_{TBB\,XX\ \ 2017}$$

And $$= pF_{TBB\,XX\ \ a,2017} \times S_{90\ a} \,/\, S_{80\ a}$$

And therefore the total fishing mortality can be obtained by:

$$F'_a = pF'_{TBB\,XX\ \ a,2017} + (F_{a,2017} - pF_{TBB\,XX\ \ a,2017})$$

Finally, the selection pattern to be use for the future years in the simulations for the 90mm net is calculated as :

$Sel'_a = \frac{1}{3}\sum_{y=2014}^{2017} Sel'_{a,y}$ with $Sel'_{a,y} = {F'_{a,y}}\big/{F'bar_{2-6,y}}$

2.2 Simulation scenarios

The effect of changing mesh size from 80mm to 90mm for the métier TBB_DEF_70-99_0_0_all was investigated for different scenarios summarised on the figure 4.
For both stocks, simulations were run for 3 scenarios on the survival rate: the lower and upper limits of the confidence bounds of the available estimates of survival rate, and a 0% survival. The limits of the confidence bounds for sole and for plaice are 13% and 28%, and 11% and 18% respectively (Schram and Molenaar, 2018). These percentages were rounded to 10% and 30%, and 10% and 20% so that the stock assessments, developed with these percentages by Verkempynck et al. (2018) can be used as a basis for these simulations, without having to set up new assessments.

As for the work done by Verkempynck et al. (2018), each of these survival scenarios were run twice, once in a scenario where discarding is allowed, and one in a scenario where the landing obligation is strictly implemented.
Simulations were run only for the modified selection patterns (representing the effect of changing to 90mm mesh size). The results for the base-case (80mm) are taken from the work carried out by Verkempynck et al. (2018). As the selection pattern applied in the new simulations is different, a new set of Fmsy values had to be calculated (one for each assumption on survival rate).
The same R scripts as developed by Verkempynck et al. (2018) for reference point estimation and for running the simulations were used here.

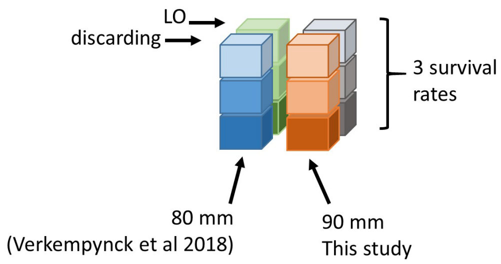


Figure 4 : representation of the 12 simulations scenarios compared in this study (2 LO scenarios X 2 mesh sizes X 3 survival rates). Simulations for the 80mm net were taken from Verkempynck et al (2018); simulations for the 90mm net were run for this study.

3 Results

3.1 Selection pattern

The figures 4 and 5 show the selection pattern for North Sea sole and plaice, corresponding to the mesh size 80mm and 90mm for the métier TBB_DEF_70-99_0_0_all calculated for a scenario where discarding is allowed, and for a scenario with the landing obligation implemented. The selection pattern represents how the fishing morality in the simulation is distributed across age-groups.

For sole, there was very little difference in the selection patterns estimated for the 3 survival rates in the base case (between vertical panels on figure 5). This comes from the fact that the stock assessment conducted with these 3 survival rates (Verkempynck et al. 2018) had similar output regarding the age profile of the fishing mortality. Since the 3 survival rates considered here are low, the selection patterns for a given survival rate is not markedly affected by whether discards are landed or not (little differences between horizontal panels on figure 5). More differences were observed for the effect of mesh size on the selection pattern (color of the curves on figure 5). For sole, the TBB_DEF_70-99_0_0_all métier represents a large proportion of the catches of the stock (70% on average across age-classes). The difference in retention rate by the cod-end between 80mm and 90mm mesh size is visible for all ages but is particularly large for younger fish (figure 2). As a result, the fishing mortality-at-age corresponding to the 90mm mesh is lower for all ages than for the 80mm mesh, but the difference is larger for younger ages, than older age. In terms of selection pattern, using the net with a 90mm cod-end results in applying a higher fishing mortality to older ages (5 and older) and lower fishing mortality for young fish (2 and 3 years old) for a same Fbar value.

In the case of plaice, there was also little influence of the assumed survival rate on the selection pattern (comparison across vertical panels on figure 6). As discard rates are high for young age-groups in plaice, discarding or landing the unwanted catch did have an effect on the selection pattern (differences in age 2 and 3 between horizontal panels on figure 6), but since the survival rates considered here are low, these differences in the selection patterns were small. The catches of the TBB_DEF_70-99_0_0_all métier represent 38% (on average across age-classes) of the total 2017 catches. The difference in selectivity-at-age between the 80mm and 90mm mesh size is mainly found for age 1 and 2. As a result, the fishing mortality-at-age corresponding to the 90mm mesh is lower only for young ages, and the magnitude of the difference is markedly smaller than for sole. In terms of selection pattern, this means that using the 90mm net results is targeting less ages 1 and 2, and targeting only slightly more older ages (4 and 5 year olds).

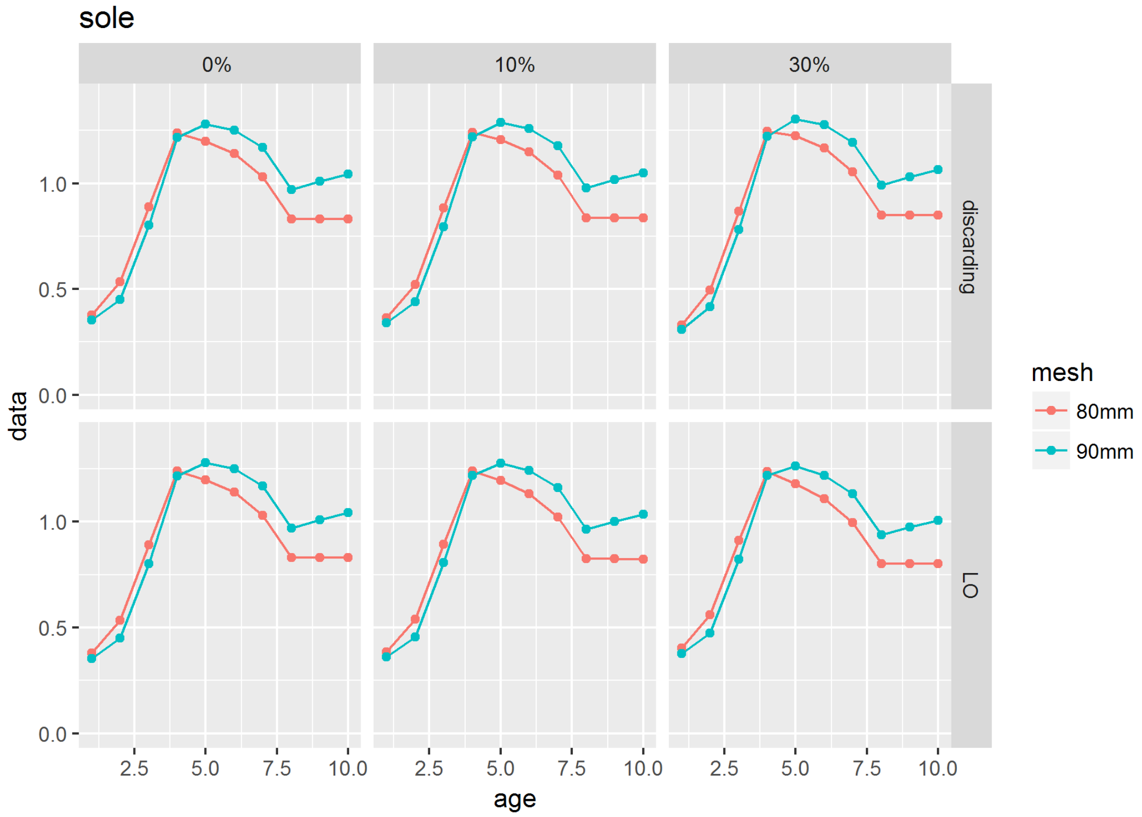


Figure 5 : Sole selection pattern for mesh size 80mm and 90mm based on stock assessment assuming 0%, 10% and 30% survival.

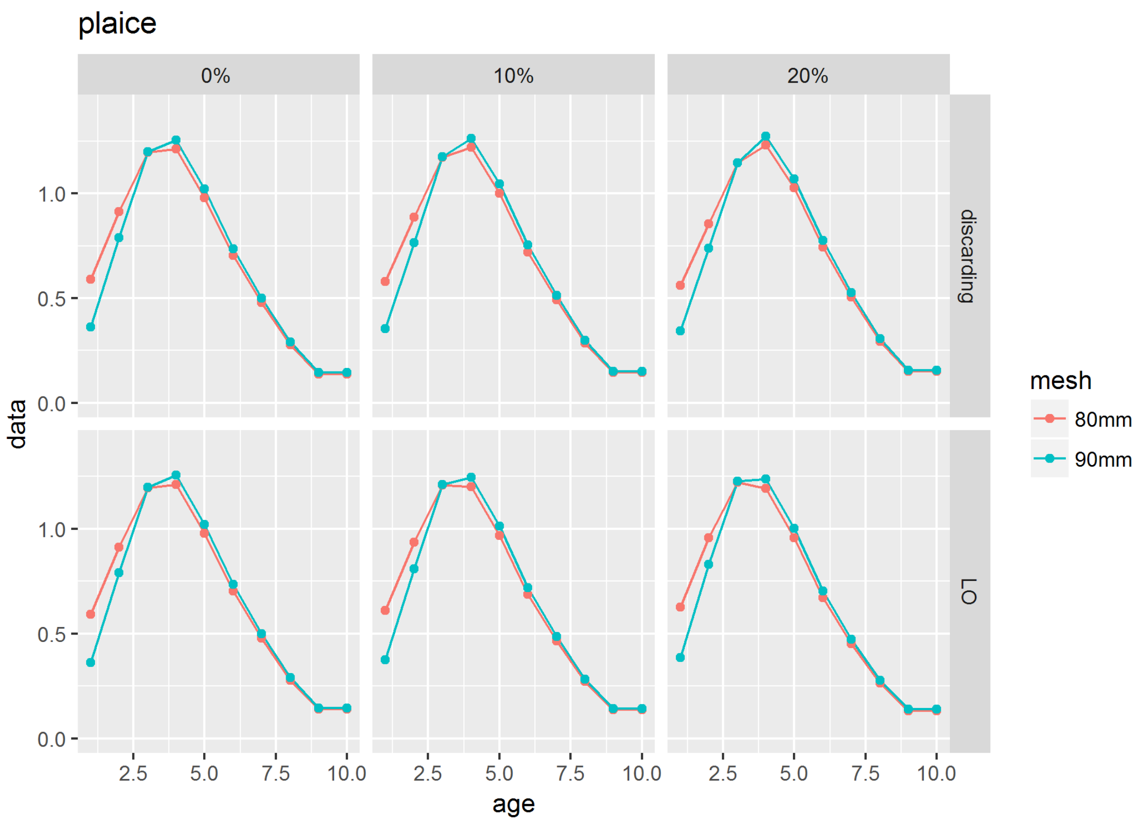


Figure 6 : Plaice selection pattern for mesh size 80mm and 90mm based on stock assessment assuming 0%, 10% and 20% survival.

3.2 Reference points

Reference points were calculated for each scenario to be implemented for the future years in the simulations on discarding (i.e. landed or thrown back at sea) and for the 90 mm mesh size. Values for the 80mm mesh size were taken from Verkempynck et al. (2018). Those reference points were used in the simulations to calculate future TACs in an MSE. By doing so, it was therefore assumed that managers are aware that changes from the current situation – using 80mm nets and discards not landed - to any other situation would require an update of the reference points.
The Fmsy values used in the different scenarios of the simulations are given in table 1. As observed in Verkempynck et al (2018), in cases where discarding is allowed, Fmsy values are larger for higher assumed survival rates. However, these differences disappear when discards are landed.
An almost systematic difference is observed in Fmsy between the 80mm and 90mm mesh sizes. Fmsy for the 90mm is roughly 0.03 lower for sole and 0.02 higher for plaice than for the 80mm gear. This contrast between sole and plaice comes from the difference in how the respective selection patterns of the 2 species is affected by the change in mesh size (i.e. mainly reduced targeting of young fish on plaice, and mainly increased targeting on older fish for sole).
One can also note that some differences in Fmsy values can be found between the non-LO and LO situation for the scenario with 0% survival, when there should not in principle be any (if all fish die, it makes no difference if they are landed or released). These differences (no larger than 2%) reflect the uncertainty in the estimation of Fmsy by the stochastic simulation tool used here.

Table 1 : Fmsy values estimated for the different simulation scenarios presented in figure 4

	Sole			Plaice		
	Survival rate	80mm	90mm	Survival rate	80mm	90mm
With discarding	0%	0.270	0.237	0%	0.202	0.222
	10%	0.275	0.244	10%	0.205	0.223
	30%	0.287	0.276	20%	0.222	0.223
Landing obligation	0%	0.269	0.232	0%	0.205	0.226
	10%	0.268	0.237	10%	0.201	0.220
	30%	0.269	0.233	20%	0.201	0.220

3.3 Simulation output

3.3.1 Sole

Future stock trajectories are show in appendix 1. The recent trend in fishing mortality is a decrease from high values (Fbar2-6>0.40) around 2010, to lower values in the last assessment year. Applying Fmsy in the first year of the simulation (2017) results in an increase in fishing mortality. This increase is of a larger magnitude for scenarios with a higher survival rate assumption (reflecting the differences in Fmsy values, table 1). The SSB has been on an ascending trend in the recent past. As a result of increasing the fishing mortality to apply Fmsy at the start of the simulation, SSB decreases slightly at the start of the simulation and quickly reaches a stochastic equilibrium. The increase in fishing mortality at the start of the simulation results in a jump in the catches and the landings, which then follow a similar trajectory as the SSB. The discards have been generally decreasing over the recent period and decrease further in the first year of the simulation until a stochastic equilibrium is reached. In none of the scenario tested the probability p(SSB<Blim) exceed 5%, implying that the stock always remained within safe biological limits.
Comparison of the mean stock size, landings and discard values in the short (2017-2021), medium (2022-2032) and long term (2033-2067) are given in table 2 and on figure 7. In the short term, using a 90mm mesh size results in a small loss in the landings (between 4.3% and 0% depending on survival rate assumed). The discards are also reduced by a higher percentage (from 10 to 16%). The resulting SSB is larger with the 90mm mesh size (by 0.5 to 5%). In the medium term, the difference in stock

size becomes larger (3 to 13% larger SSB if the 90mm mesh size is used). As a result of this larger stock, landings are also higher if the 90mm mesh size is used (by 2 to 3%) while the discards remain lower (by between 9 to 14%). Differences in the longer term between 80mm and 90mm mesh size remain similar to those described for the medium term.

The benefit of using a larger mesh size (reduction of discards, slightly higher landings) is largest for lower survival rate(e.g. upper row vs. lower row on figure 7).Assuming a survival rate of 0%, stock size in the medium and long term is around 12% higher (medium and long term) with the 90mm mesh size net than with the 80mm, the landings are 3% higher, and the discards are around 16% lower. Assuming a 30% survival rate, the SSB is 3% higher for the 90mm mesh size, landings are 2% higher and discards 9% lower. With low survival rate, improving selectivity to avoid catching small fish effectively results in a lower mortality at a young age, hence letting more time for cohorts to growth and contribute to reproduction before being targeted by the fishery. In a scenario with high the survival rate, small fish thrown overboard have a high chance to return in the population anyway, so there is less benefit in avoiding catching them. In a situation where the landing obligation is applied, the effect of using a 90mm mesh size net is similar to when discarding is allowed: small loss in the landings in the short term and a small gain thereafter, larger SSB, lower discards. There is however, no contrast between the different assumptions on survival rate: the differences between 90mm v.s 80mm net are similar for the 3 scenarios on survival rate (figure 7), close to the differences found for the 0% survival scenario in a situation where discarding is allowed.

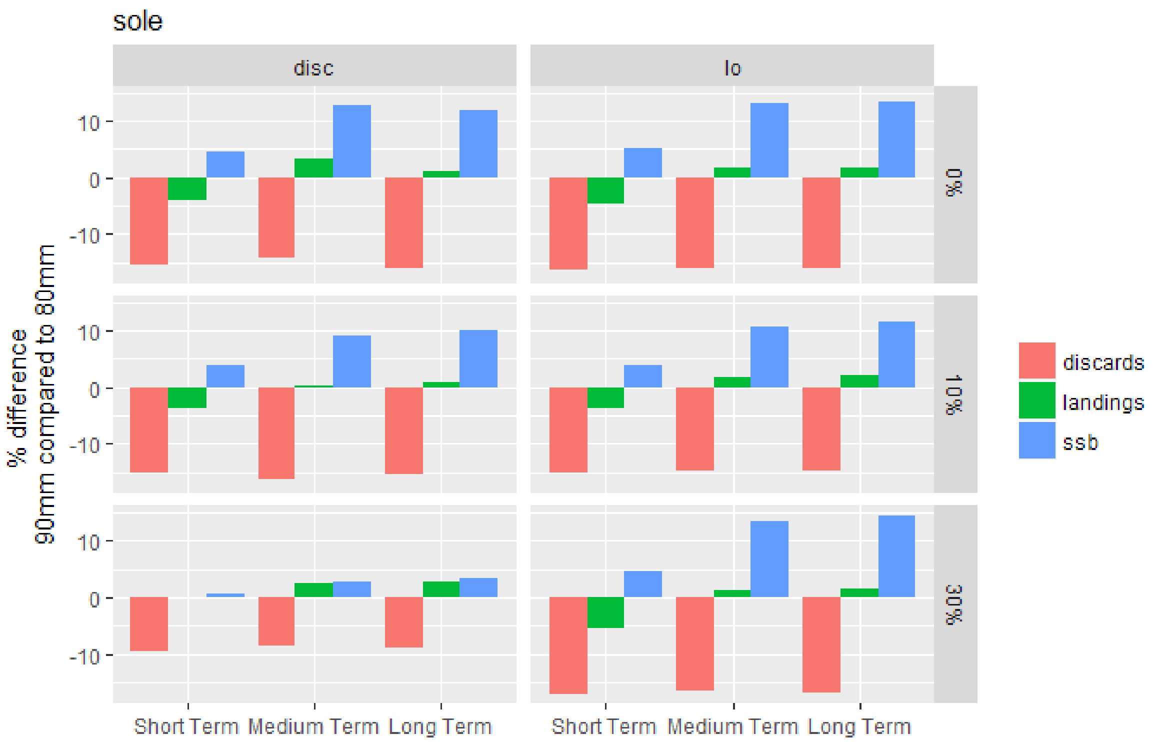


Figure 7 : percentage difference in the discards, landings and SSB for sole between the 90mm and 80mm nets. Differences are shown in the short, medium and long term, for the 3 scenarios on survival and the 2 scenarios on discarding

3.3.2 plaice

Future stock trajectories are shown in appendix 2. The recent trend in fishing morality is a steep decrease from high levels in 2007 (close to 0.30) to lower levels since 2010 (around 0.20). Applying Fmsy at the start of the simulations has different implications in each scenario. It results in a steep increase in fishing mortality for all scenarios with the 90mm mesh size and scenarios for the 80mm mesh size with discarding for an assumed survival rates of 10% and 20%. For the scenario with the

80mm net, the LO and 0% survival it causes a decrease in fishing mortality. Finally, it makes no change in fishing mortality for the other scenarios. The SSB has been increasing in the recent past and this increase continues, by a magnitude varying across simulation scenarios, until a stochastic equilibrium is reached in around 2040. Historical landing have been increasing since 2007 and reach a maximum in the first year of the simulation and decrease substantially the year after. The trend afterwards is similar to the increase in the SSB, until around 2040 when a stable level is reached. The discards have been varying with no specific trend in the recent past and decrease sharply for most scenarios at the start of the simulation and stabilize quickly to their long term level. As for sole, the risk of p(SSB<Blim) never exceeded 5%.

Comparison of the mean stock size, landings and discards values in the short (2017-2021), medium (2022-2032) and long term (2033-2067) is given on table 3. Contrasting results are observed between, on one hand, simulations for assumed survival rate of 0% and 10% and, on the other hand, assumed survival rate of 20%. For the assumed survival rates of 0% and 10%, using the 90mm mesh size results in a smaller SSB (by 2 to 7%) in the short, medium and long term. Landing and discards are higher in the short, medium and short term (by around 10% and 2% to 5% respectively). For the assumed survival rate of 20%, SSB is slightly larger for the simulations with a 90mm mesh size net (up to 4%), and landings are higher (by 4% to 9%) and discards are slightly lower (1 to 4%).

In a situation where the landing obligation is applied, as for sole, results are similar for the 3 assumptions used for survival rate, and similar to the results with discarding for the survival rate of 0%, but with larger differences between the 90mm and 80mm scenarios (8 to 10% smaller SSB, 3% to 15% higher landings, 6% to 8% higher discards).

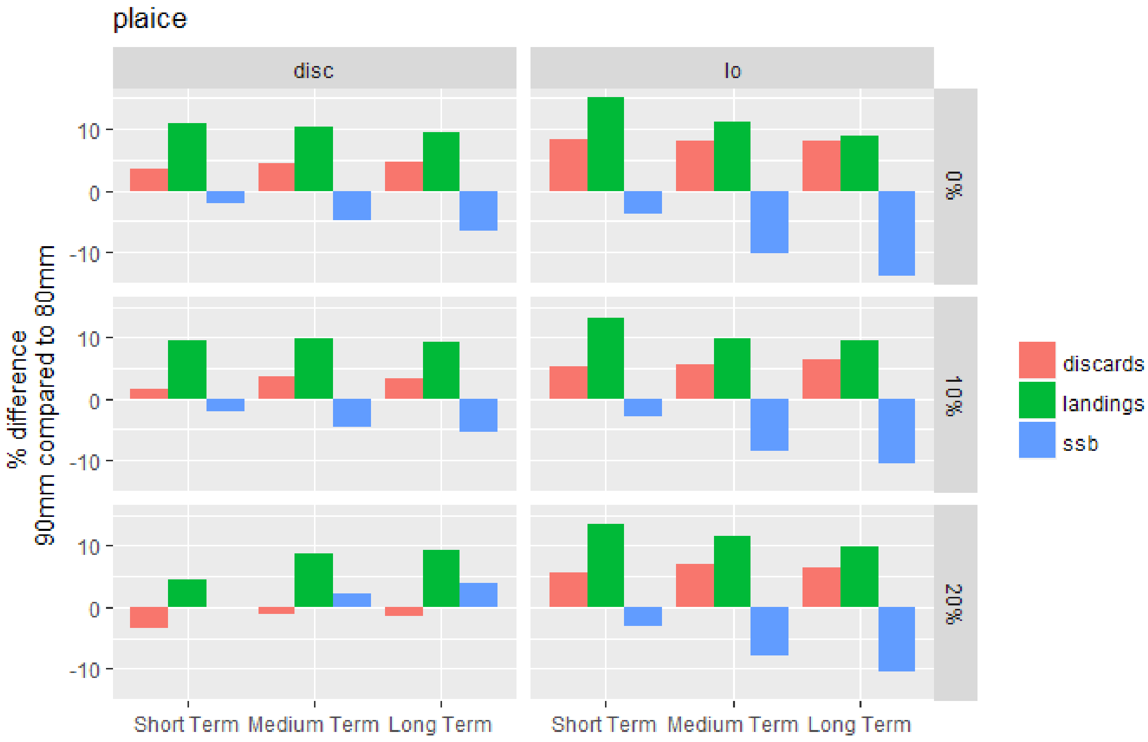


Figure 8 : percentage difference in the discards, landings and SSB for plaice between the 90mm and 80mm nets. Differences are shown in the short, medium and long term, for the 3 scenarios on survival and the 2 scenarios on discarding

*Table2 : simulations results for **sole** in the short (2017-2021) medium (2022-2032) and long (2033-2067) term. Median across the 2000 replicates of the stock (average over the time period) and percentage difference between 80mm and 90mm mesh size. For each combination of survival rate and mesh size, results are presented for scenarios with discarding and with the landing obligation implemented.*

Sole summary of the results for scenario with discarding

		Short Term			Medium Term			Long Term		
survival rate		80mm	90mm	percentage difference	80mm	90mm	percentage difference	80mm	90mm	percentage difference
0%	catch	18057	17114	-5.2	17409	17733	1.9	17716	17691	-0.1
0%	discards	1362	1151	-15.5	1416	1215	-14.2	1431	1202	-16.0
0%	fbar	0.27	0.24	-12.4	0.27	0.24	-12.4	0.27	0.24	-12.4
0%	landings	16668	15958	-4.3	15918	16428	3.2	16215	16415	1.2
0%	ssb	58654	61325	4.6	57164	64528	12.9	58026	64899	11.8
10%	catch	18071	17259	-4.5	17507	17324	-1.0	17575	17518	-0.3
10%	discards	1245	1059	-15.0	1322	1106	-16.3	1314	1110	-15.5
10%	fbar	0.28	0.24	-11.4	0.28	0.24	-11.4	0.28	0.24	-11.4
10%	landings	16807	16196	-3.6	16124	16144	0.1	16192	16335	0.9
10%	ssb	57475	59758	4.0	55725	60811	9.1	55999	61653	10.1
30%	catch	18212	18124	-0.5	17195	17476	1.6	17315	17660	2.0
30%	discards	1019	921	-9.6	1063	972	-8.6	1069	975	-8.8
30%	fbar	0.29	0.28	-3.8	0.29	0.28	-3.8	0.29	0.28	-3.8
30%	landings	17183	17197	0.1	16059	16432	2.3	16190	16607	2.6
30%	ssb	54967	55224	0.5	51432	52838	2.7	51682	53425	3.4

Sole summary of the results for scenario with landing obligation

		Short Term			Medium Term			Long Term		
survival rate		80mm	90mm	percentage difference	80mm	90mm	percentage difference	80mm	90mm	percentage difference
0%	catch	18062	17025	-5.7	17620	17619	0.0	17698	17770	0.4
0%	discards	1368	1143	-16.4	1417	1191	-15.9	1418	1189	-16.1
0%	fbar	0.27	0.23	-13.5	0.27	0.23	-13.5	0.27	0.23	-13.5
0%	landings	16671	15864	-4.8	16089	16345	1.6	16204	16500	1.8
0%	ssb	59117	62123	5.1	58062	65626	13.0	58704	66621	13.5
10%	catch	17834	17019	-4.6	17263	17271	0.1	17376	17494	0.7
10%	discards	1335	1134	-15.1	1392	1185	-14.9	1394	1186	-14.9
10%	fbar	0.27	0.24	-11.7	0.27	0.24	-11.7	0.27	0.24	-11.7
10%	landings	16338	15738	-3.7	15633	15882	1.6	15753	16087	2.1
10%	ssb	58255	60500	3.9	56517	62449	10.5	57104	63669	11.5
30%	catch	17686	16522	-6.6	16746	16642	-0.6	16958	16906	-0.3
30%	discards	1319	1092	-17.2	1365	1140	-16.5	1373	1141	-16.9
30%	fbar	0.27	0.23	-14.2	0.27	0.23	-14.2	0.27	0.23	-14.2
30%	landings	15910	15033	-5.5	14840	15024	1.2	15037	15280	1.6
30%	ssb	56428	59022	4.6	53373	60562	13.5	53996	61801	14.5

*Table3 : simulations results for **plaice** in the short (2017-2021) medium (2022-2032) and long (2033-2067) term. Median across the 2000 replicates of the stock (average over the time period) and percentage difference between 80mm and 90mm mesh size. For each combination of survival rate and mesh size, results are presented for scenarios with discarding and with the landing obligation implemented.*

plaice summary of the results for scenario with discarding

		Short Term			Medium Term			Long Term		
survival rate		80mm	90mm	percentage difference	80mm	90mm	percentage difference	80mm	90mm	percentage difference
0%	catch	130433	141580	8.55	130283	141593	8.68	134253	145094	8.07
0%	discards	39457	40858	3.55	39419	41151	4.39	39591	41451	4.7
0%	fbar	0.20	0.22	10.12	0.20	0.22	10.12	0.20	0.22	10.12
0%	landings	90690	100556	10.88	90205	99635	10.45	93855	102827	9.56
0%	ssb	986382	965078	-2.16	1111446	1055727	-5.01	1205636	1126559	-6.56
10%	catch	131062	140516	7.21	128894	139077	7.9	131392	141377	7.6
10%	discards	37025	37613	1.59	36671	38033	3.71	36812	38083	3.45
10%	fbar	0.21	0.22	8.77	0.21	0.22	8.77	0.21	0.22	8.77
10%	landings	93807	102740	9.52	91332	100162	9.67	93726	102502	9.36
10%	ssb	968039	948299	-2.04	1062000	1014503	-4.47	1124233	1062410	-5.5
20%	catch	136604	139855	2.38	127984	135551	5.91	128836	136969	6.31
20%	discards	35767	34493	-3.56	34784	34354	-1.23	34964	34468	-1.42
20%	fbar	0.22	0.22	0.54	0.22	0.22	0.54	0.22	0.22	0.54
20%	landings	100535	105089	4.53	92385	100485	8.77	93150	101839	9.33
20%	ssb	933677	934096	0.04	953477	974344	2.19	964989	1001476	3.78

Plaice summary of the results for scenario with landing obligation

		Short Term			Medium Term			Long Term		
survival rate		80mm	90mm	percentage difference	80mm	90mm	percentage difference	80mm	90mm	percentage difference
0%	catch	126645	143043	12.95	129255	142540	10.28	133156	144609	8.6
0%	discards	38287	41450	8.26	38467	41601	8.15	38516	41571	7.93
0%	fbar	0.19	0.23	17.53	0.19	0.23	17.53	0.19	0.23	17.53
0%	landings	88169	101422	15.03	89960	100091	11.26	93820	102161	8.89
0%	ssb	998540	960445	-3.82	1161613	1043399	-10.18	1274251	1096945	-13.91
10%	catch	123810	137289	10.89	124379	134796	8.38	127014	137907	8.58
10%	discards	37134	39098	5.29	37064	39165	5.67	37041	39414	6.41
10%	fbar	0.19	0.22	13.94	0.19	0.22	13.94	0.19	0.22	13.94
10%	landings	85325	96555	13.16	85376	93698	9.75	87990	96362	9.52
10%	ssb	984264	954576	-3.02	1122345	1025422	-8.64	1210635	1082200	-10.61
20%	catch	119864	133036	10.99	116821	129020	10.44	119864	130575	8.94
20%	discards	35510	37520	5.66	34879	37305	6.95	35124	37408	6.5
20%	fbar	0.19	0.22	14.24	0.19	0.22	14.24	0.19	0.22	14.24
20%	landings	81779	92727	13.39	79115	88314	11.63	81747	89767	9.81
20%	ssb	972062	942327	-3.06	1081567	996283	-7.89	1153500	1033498	-10.4

4 Discussion - Conclusions

Overall, the effect of using a 90mm mesh size is rather limited: most of the time the differences in SSB, landings or discards are smaller than 10%, which, given the large magnitude of stochastic fluctuations (width of the envelop around the median in the annexes) would probably not be detectable. The largest differences observed (>10%) is the larger stock size and lower discards for the 90mm mesh size of sole, and the higher landings for plaice.

The differences in the effect on sole and plaice of using a 90mm net are related to both the direct effect of exploiting the stock with a different selection pattern and of applying different Fmsy values. The effects of changing mesh size are larger for sole than for plaice, because the share of the landings taken by the Dutch beam trawlers currently fishing with 80 mm is much larger for sole than for plaice.

For sole, the results seem to be counter-intuitive: the net with 90mm mesh catches less fish for all age-classes (figure 2), but simulations indicate that landings are not dramatically impacted (even slightly larger), while discards are substantially reduced and stock size is larger. This is because, in the simulations, the change in gear selectivity is transposed into a change in selection pattern to be used in future years. Although gear selectivity is lower for all ages, the selection pattern has no dimension (scales so that average across age 2 to 6 is 1). It is therefore only the age-profile of the fishing mortality which has changed, not its overall level. The difference in shape of the selection pattern for sole implies that there is slightly less pressure on the young fish, and higher pressure on older fish. Exploited with the selection pattern corresponding to the 90mm mesh size, young fish survive slightly more and get exploited at an age where they are heavier. This explains the lower discards and the slightly higher SSB. Although the immediate effect of changing mesh size is to have slightly lower landings than if the current net is used, this negative effect is counter-balanced already after 5 years by the fact that there is a larger stock for simulations with the 90mm mesh size.

For plaice , the difference in selection pattern resulting from the use of the 90mm net is maximal for age 1 and 2 fish. Despite of this seemingly small difference, the Fmsy values corresponding to this new selection pattern are notably higher (around 10%) than for the current selection pattern (except for an assumed survival rate of 20%). This higher Fmsy to be implemented if the 90mm mesh size is used (for survival rate of 0 and 10%) explains the lower stock size and higher catch, landings and (despite the improved selectivity of the net) discards. For the scenario assuming a survival rate of 20%, Fmsy is similar for the 80mm and 90mm mesh size. For this scenario, the improved selectivity of the 90mm net indeed results in slightly lower discards, which in the medium and long term result in a slightly larger stock with slightly higher landings.

One important assumption in these simulations is that the stocks are exploited at Fmsy in the future. However, if the beam trawl fleet switches to the 90mm net, its catchability (at least for sole) will decrease, meaning that a higher fishing effort will be necessary to achieve a same fishing mortality on the stock. It is not sure if that is technically possible, and economically or ecologically sustainable. The present study does not model explicitly catchability and effort, and therefore cannot quantify the change in effort implied if the stocks were to be exploited at Fmsy with the 90mm net.

Finally, the selectivity trials were done on a pulse trawler and the selectivity curves derived in this study are therefore representative of this specific gear. For lack of similar data, the assumption had to be made that those selectivity curves also applied to the part of the fleet using the conventional gear equipped with tickler chains.

5 Quality Assurance

Wageningen Marine Research utilises an ISO 9001:2015 certified quality management system. This certificate is valid until 15 December 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV GL.

Furthermore, the chemical laboratory at IJmuiden has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2021 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation. The chemical laboratory at IJmuiden has thus demonstrated its ability to provide valid results according a technically competent manner and to work according to the ISO 17025 standard. The scope (L097) of de accredited analytical methods can be found at the website of the Council for Accreditation (www.rva.nl).

On the basis of this accreditation, the quality characteristic Q is awarded to the results of those components which are incorporated in the scope, provided they comply with all quality requirements. The quality characteristic Q is stated in the tables with the results. If, the quality characteristic Q is not mentioned, the reason why is explained.

The quality of the test methods is ensured in various ways. The accuracy of the analysis is regularly assessed by participation in inter-laboratory performance studies including those organized by QUASIMEME. If no inter-laboratory study is available, a second-level control is performed. In addition, a first-level control is performed for each series of measurements.
In addition to the line controls the following general quality controls are carried out:

- Blank research.
- Recovery.
- Internal standard
- Injection standard.
- Sensitivity.

The above controls are described in Wageningen Marine Research working instruction ISW 2.10.2.105. If desired, information regarding the performance characteristics of the analytical methods is available at the chemical laboratory at IJmuiden.

If the quality cannot be guaranteed, appropriate measures are taken.

References

Laurec, A. and Le Guen, J.-C. 1981. Dynamique des populations marines exploitées. Tome 1. Concepts et Modeles. Rapports scientifiques et techniques N^{0}45. CNEXO.

Molenaar, P. and Chen, C. 2018. Cod-end selectivity for sole (*Solea solea*) and plaice (*Pleuronectes platessa*) in North Sea pulse-trawl fisheries. Best Practices II – WP4 selectivity. Wageningen Marine Research report C049/18. 30 pp.

Schram E., and Molenaar P. 2018. Discards survival probabilities of flatfish and rays in North Sea pulse-trawl fisheries. Wageningen, Wageningen Marine Research (University & Research centre), Wageningen Marine Research report C037/18. 39 pp.

Verkempynck, R., Brunel, T. Poos, J.J. and Batsleer, J. 2018. Effect of discard survival on North Sea sole and plaice. Best Practices II – WP2 survival. Wageningen Marine Research report C075/18. 50 pp.l

Justification

Report C016/19
Project Number: 4311400005

The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of Wageningen Marine Research

Approved: Ir. N.T. Hintzen
Research scientist

Signature:

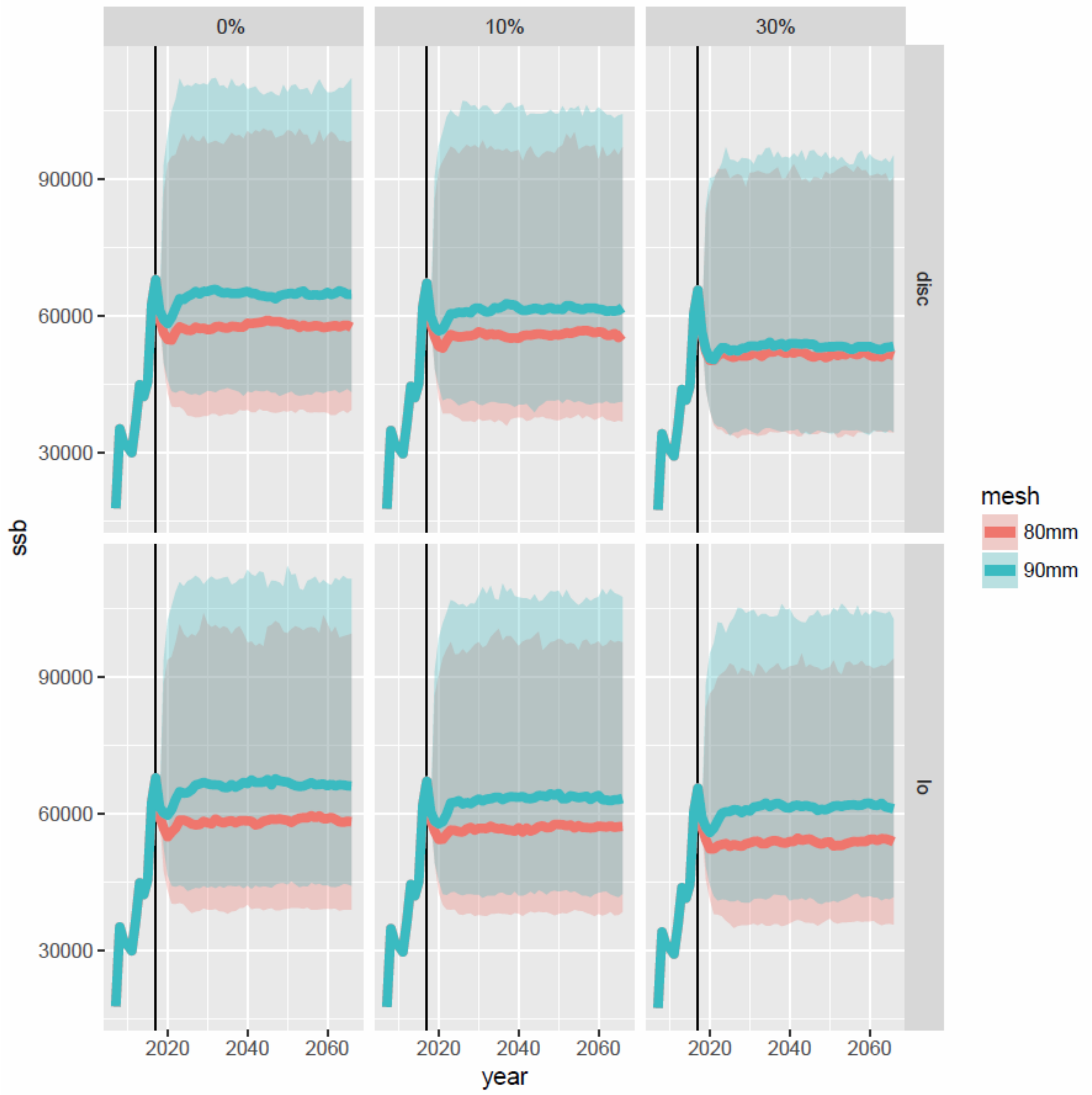
Date: 14 February 2019

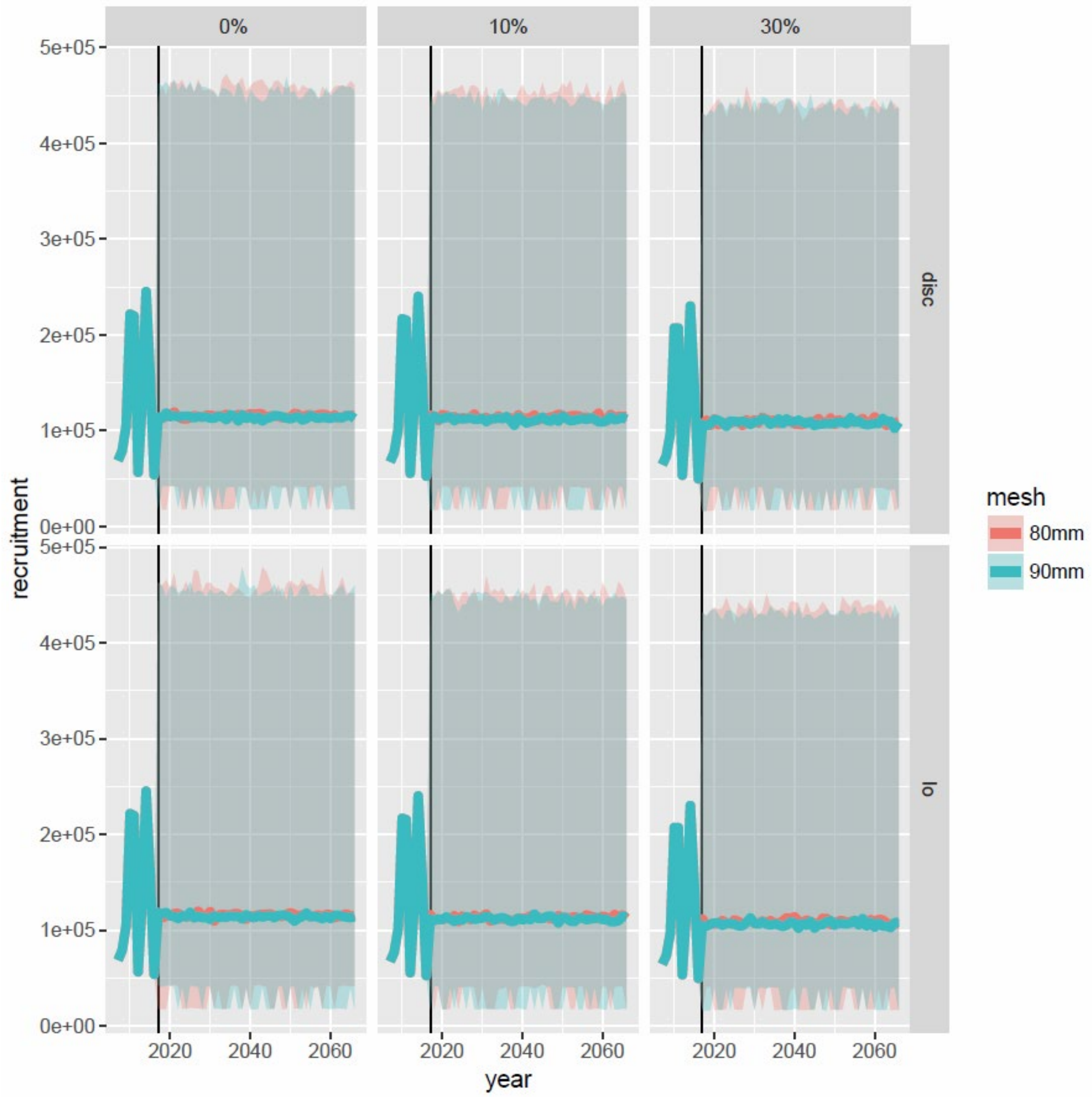
Approved: Dr.ir. T.P. Bult
Director

Signature:

Date: 14 February 2019

Appendix 1 : detailed stock trajectories for all simulations for sole (vertical panels represent different assumption on survival rate, horizontal panels represent

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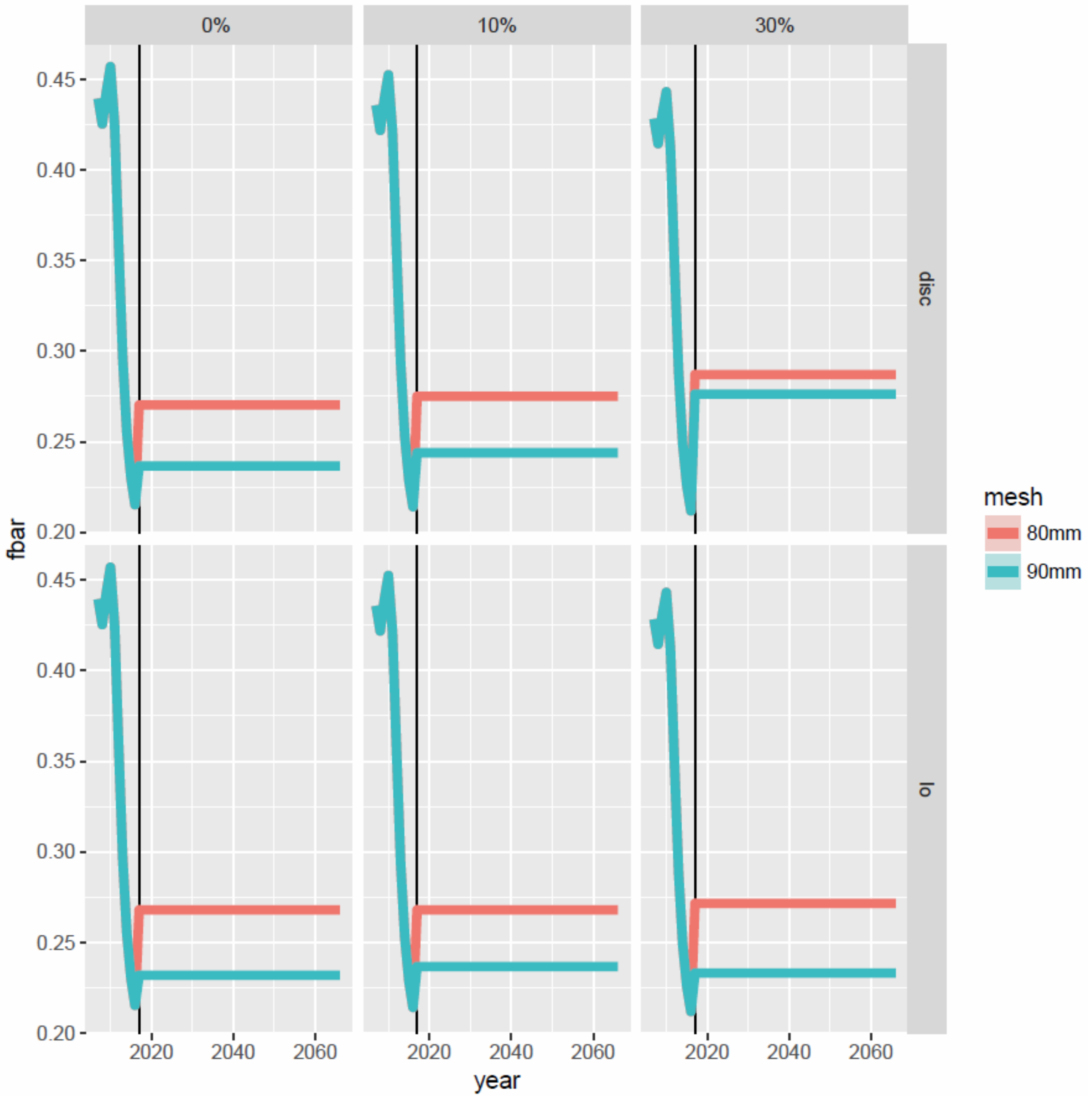
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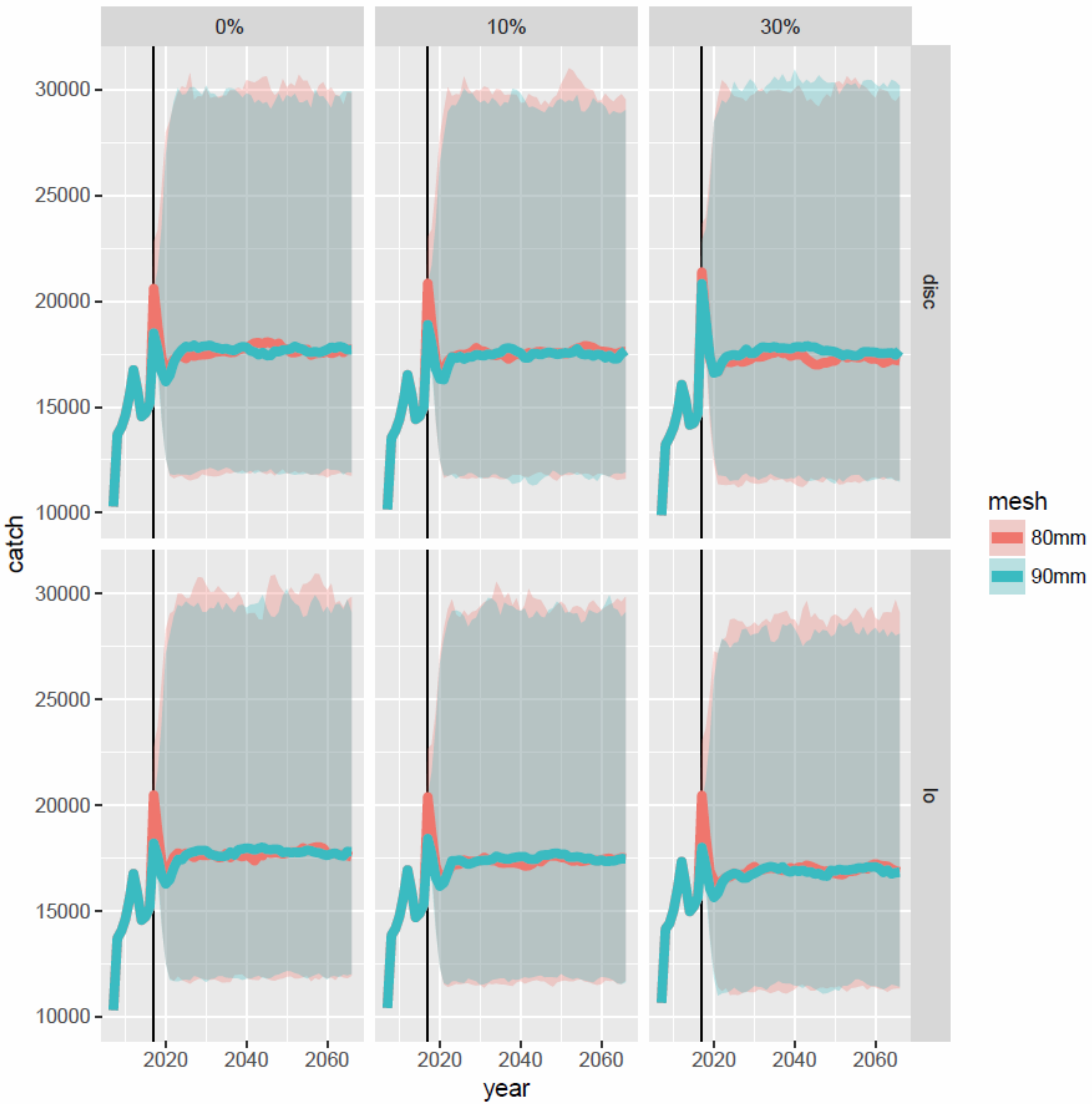
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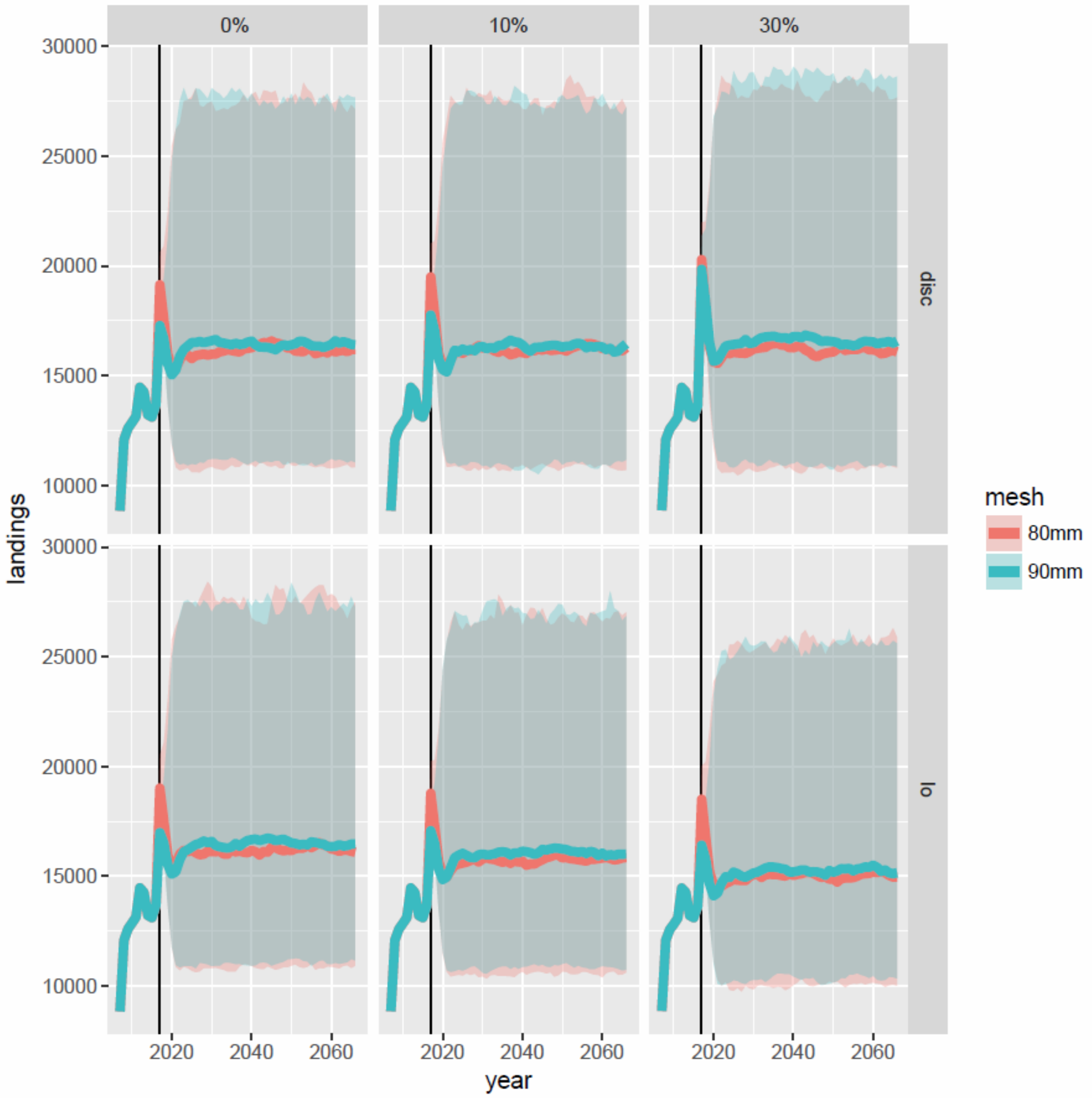
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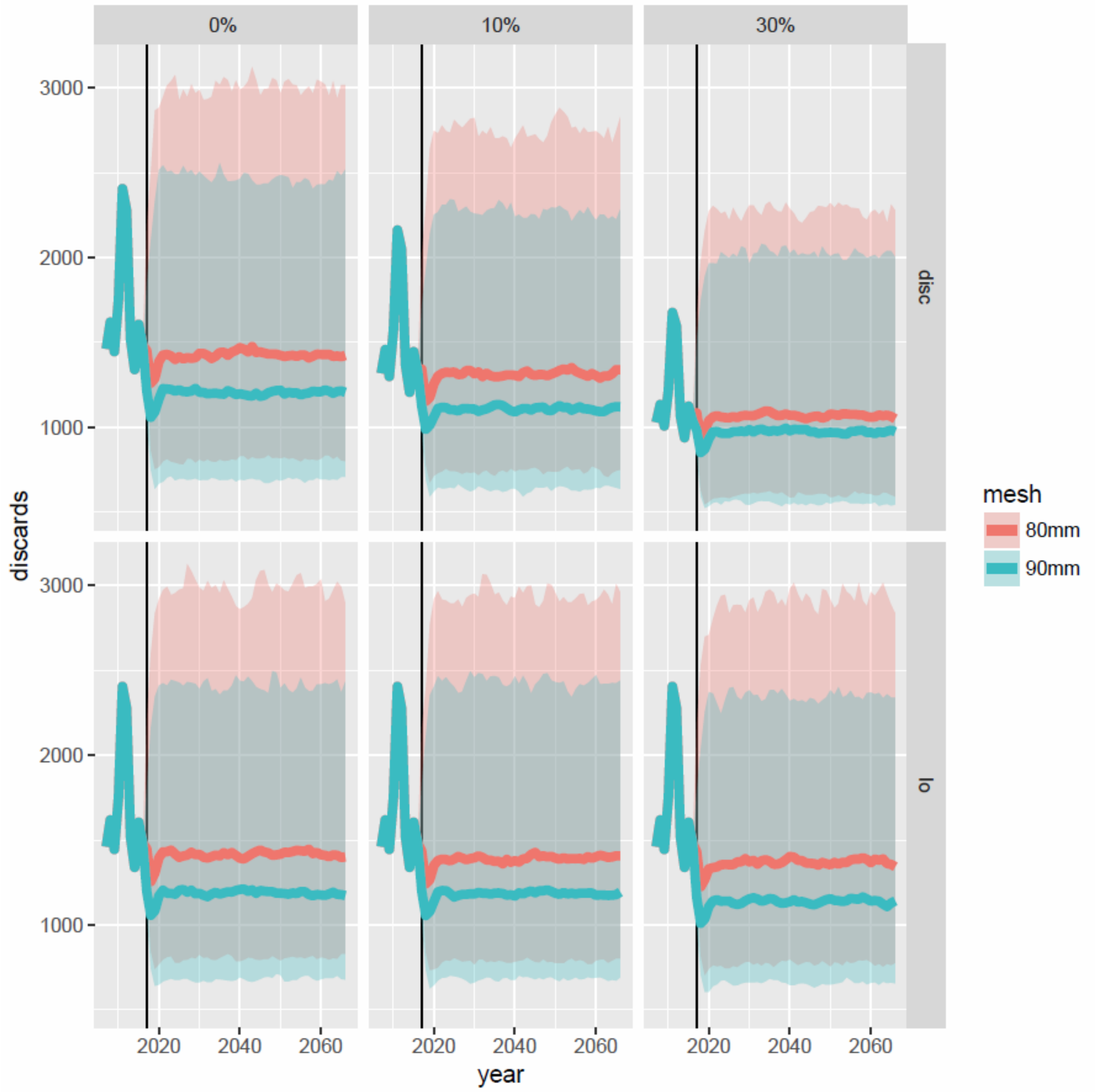
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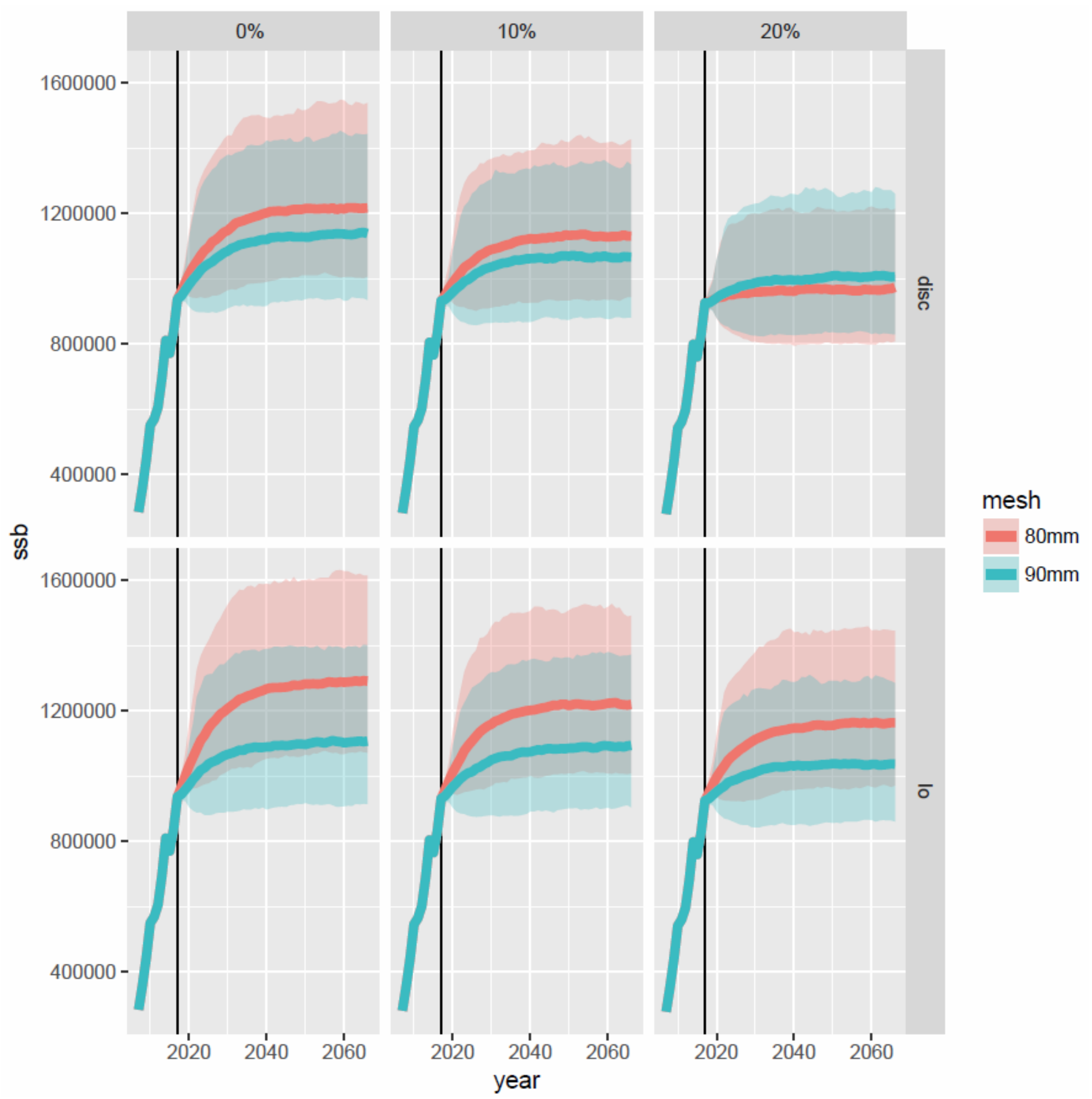
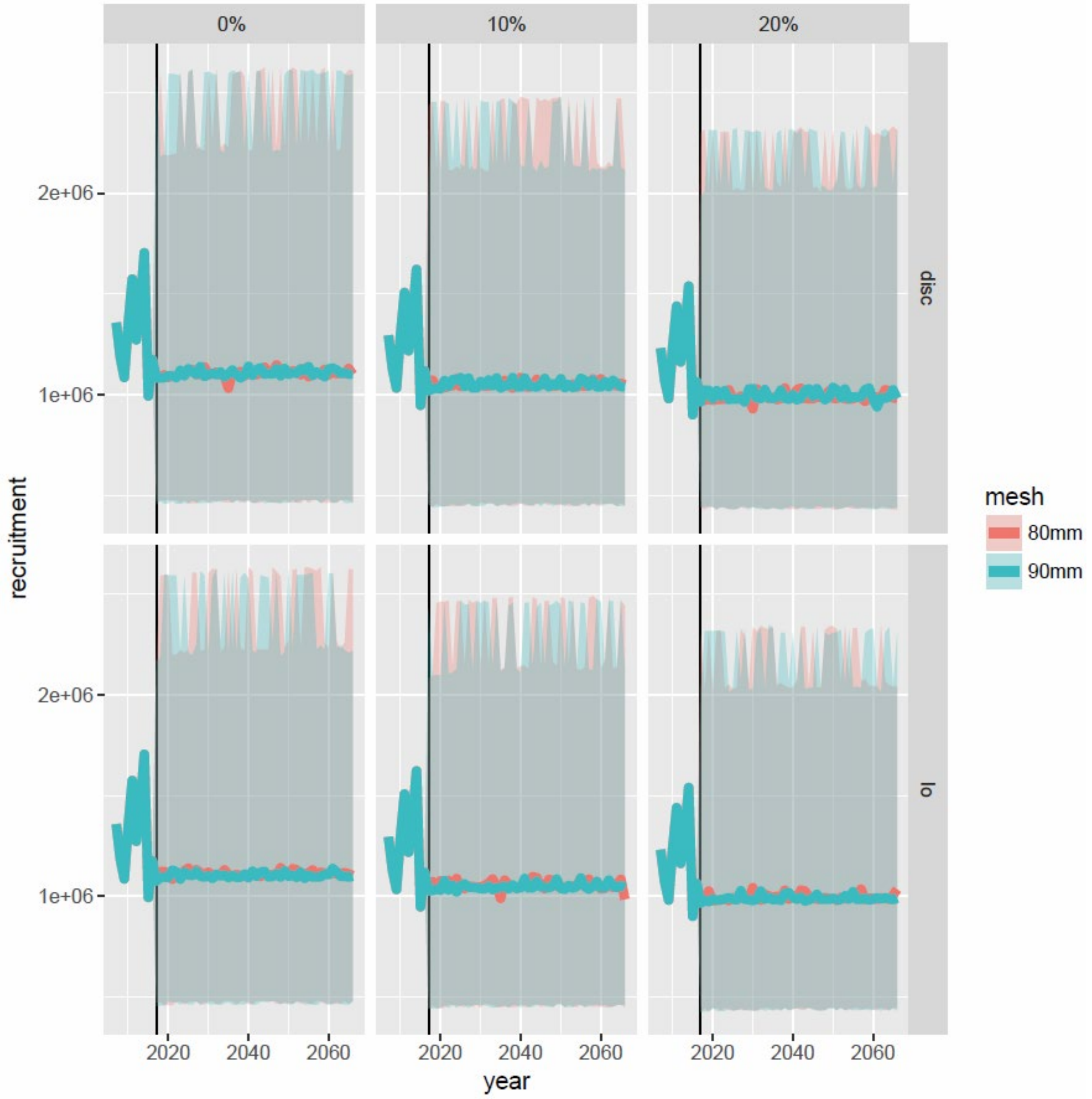
Appendix 2 : detailed stock trajectories for all simulations for plaice (vertical panels represent different assumption on survival rate, horizontal panels represent





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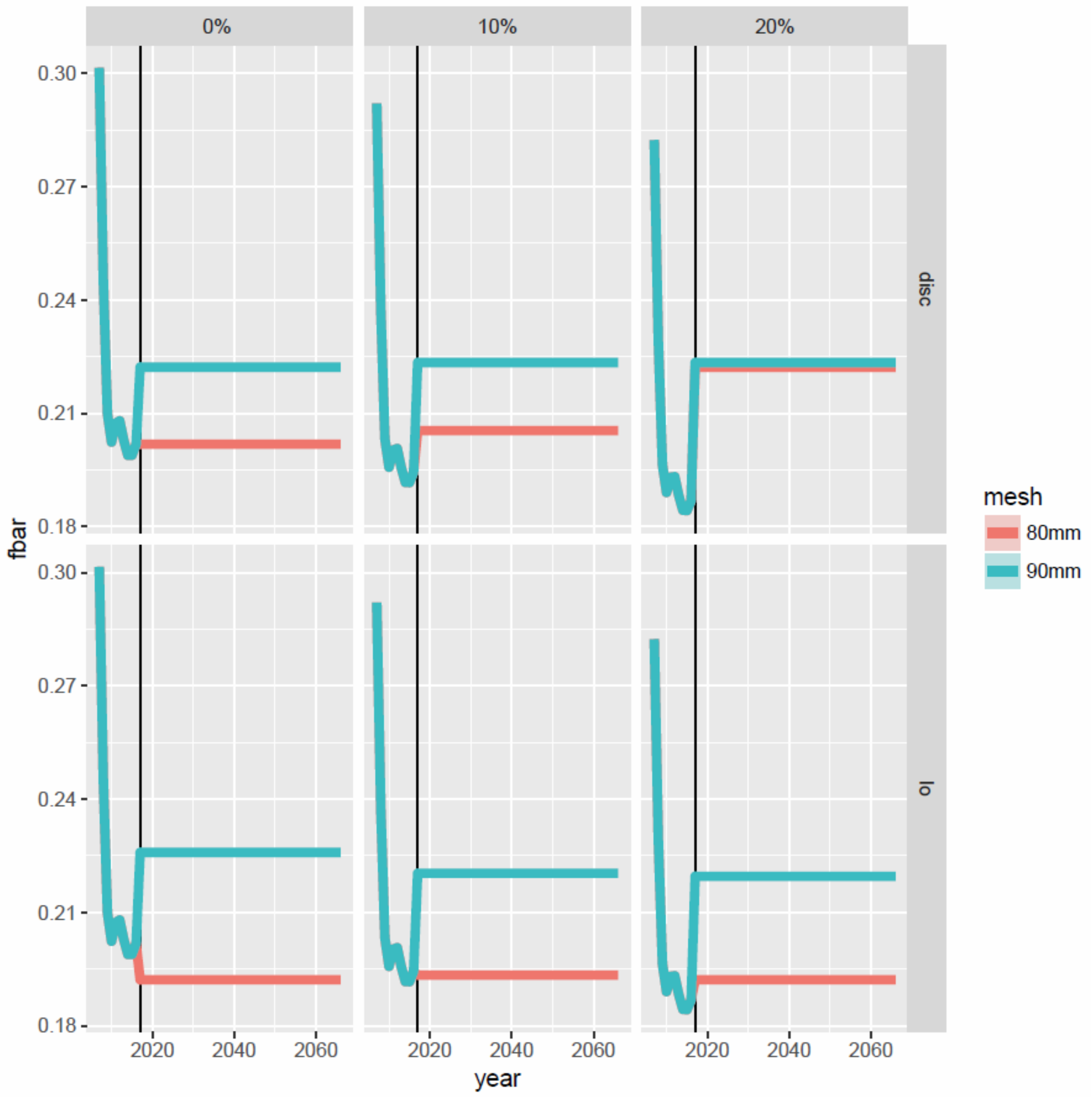
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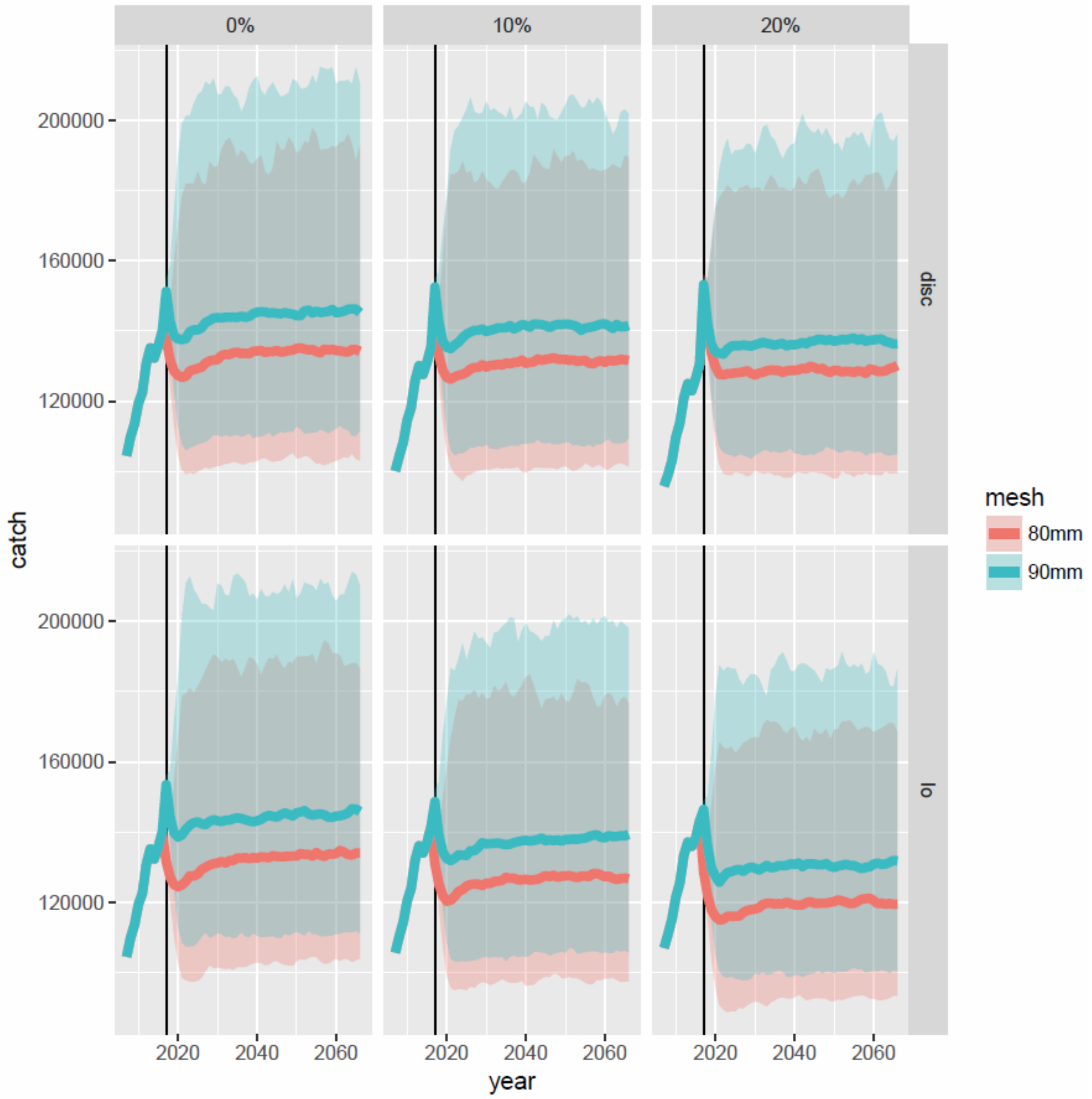
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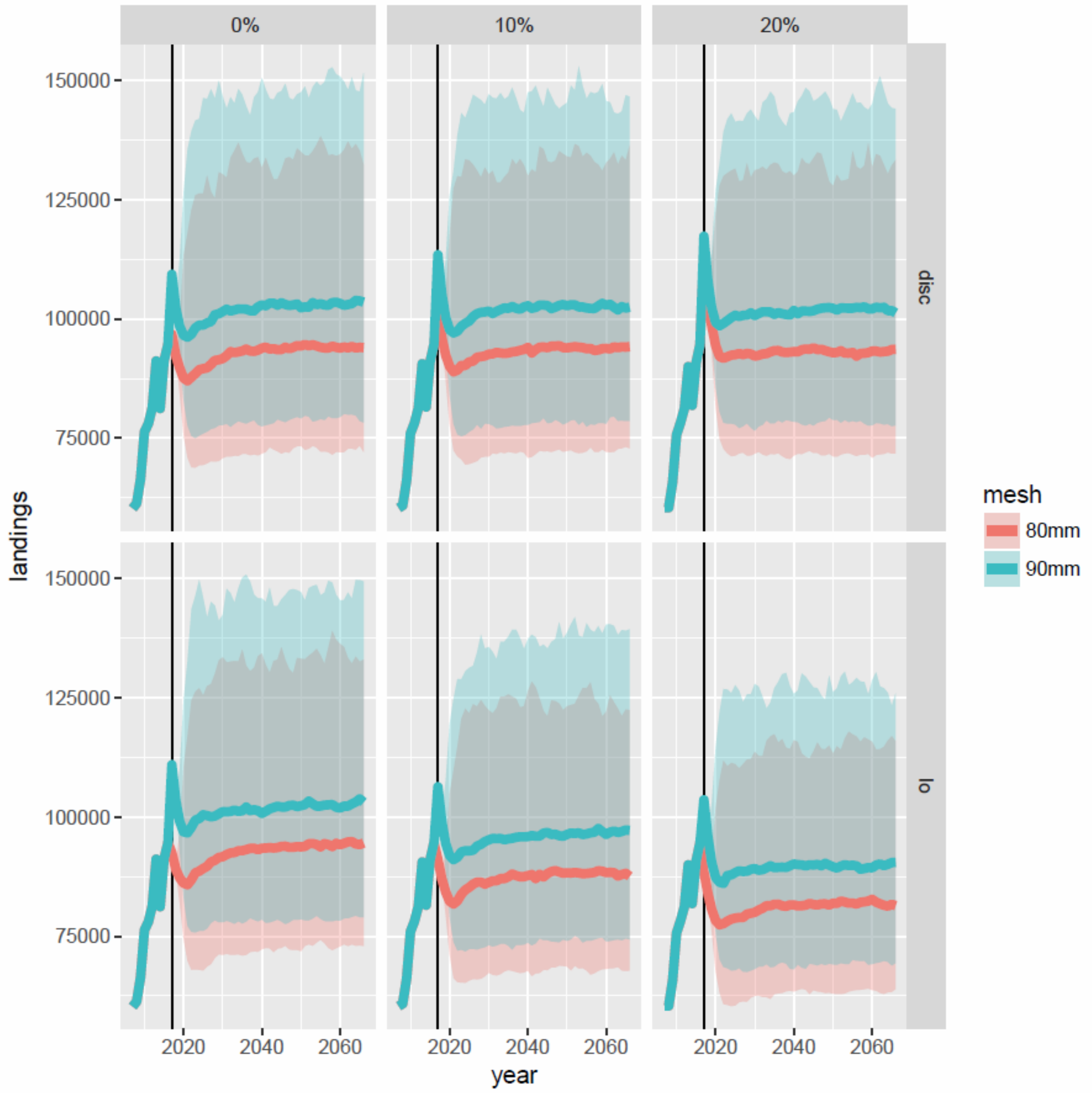
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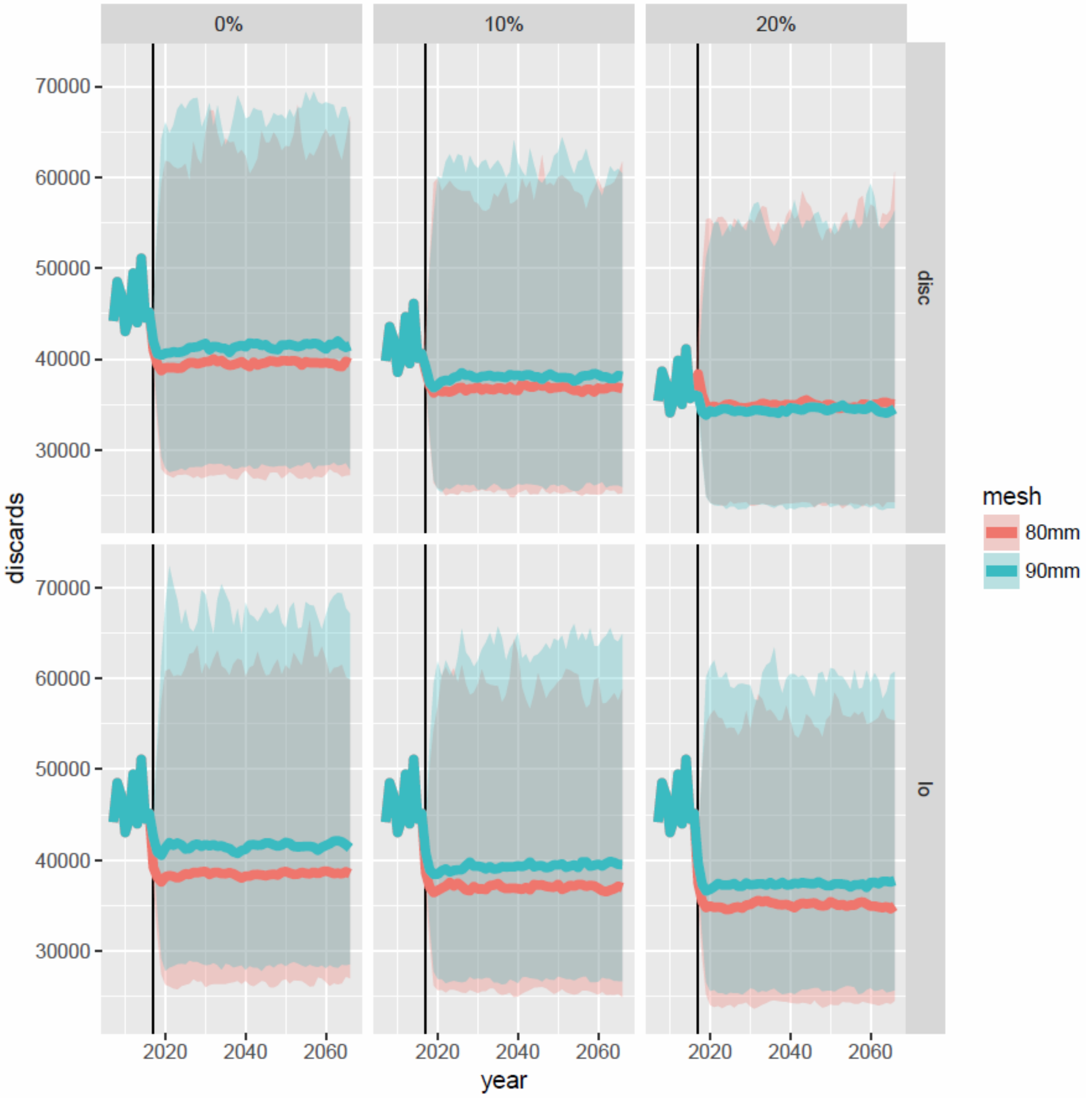

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