Best Practice II

Effect of discard survival on North Sea sole and plaice

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Wageningen University &
Research rapport C075/18A

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Publication: October 2018

This research project was carried out by Wageningen Marine Research

Wageningen Marine Research
IJmuiden

CONFIDENTIAL NO

Wageningen Marine Research report C075/18A

Verkempynck, R. Batsleer, J., Brunel, T., Poos JJ. 2018. *Best Practice II: Effect of discard survival on North Sea sole and plaice*. Wageningen, Wageningen Marine Research (University & Research centre), Wageningen Marine Research report. C075/18A. 48 pp.;

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Wageningen Marine Research is ISO 9001:2008 certified.

European Union, European Maritime and Fisheries Fund (EMFF)

This report can be downloaded for free from https://doi.org/10.18174/462554
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Summary

This report investigates the effects of discard survival on the current stock assessment and perception of the North Sea sole and plaice stocks. By recalculating the discard fraction of the catches and rerunning the assessment model, the stock assessment of sole and plaice is corrected for discard survivability. Secondly, all discard survival corrected assessments of both stocks are forecasted over 50 years under a landing obligation and discarding (business as usual) scenario. This simulation shows the effect of discard survival under a landing obligation and under the discarding scenario.

The trend and perception of both stocks do not change when discard survivability is taken into account. But the fishing mortality, stock biomass, and recruitment are overestimated. The effect of taking into account discard survivability is a scaling depending on the characteristics of the stock (such as maturity at age) and the extent to which the part of the stock is being discarded. The effect of discard survival is greater in North Sea plaice than in North Sea sole, since the plaice is discarded more.

The Fmsy reference points increase with increasing discard survivability. However, the “F-targets”, the F corresponding to the maximal yield under the landing obligation, that are calculated to simulate the “landing obligation-scenario” do not show the same trend with increasing discard survivability.

The forecast simulation of North Sea sole and plaice was performed by projecting the stocks with targets for fishing mortality that maximise the yield of both stocks. This method gives insight in the effects of the discarding and landing obligation scenario on the catches, recruitment, spawning stock biomass, and fishing mortality. Differences between scenarios increase with increasing discard survivability, although differences are marginal in the simulation of sole (compared to the differences between scenarios in plaice). Mainly the catches are effected by discard survivability under the landing obligation scenario.

1 Introduction

In July 2016 Wageningen Marine Research was granted several tasks and activities in work packages 1 to 5 of the Best Practice II project by its client VisNed. Wageningen Marine Research (WMR) will carry this project out together with ILVO and Wageningen Economic Research. The project is part of an overall Best Practice II project that is managed and executed by VisNed. The project is financed by the European Maritime and Fisheries Fund (EMFF).

This report details the research carried out in the work package on the effects of discard survival on the North Sea sole and plaice stocks.

1.1 Research questions

This report will deal with two questions:

- What is the effect of discard survival on the stock assessment and current perception of the North sea plaice and sole stock?
- What happens when you take discard survival into account and project the stock forward for 50 years under the current situation and under the landing obligation?

1.2 Discard survival and landing obligation effect on stock

Since 2015, the European Union (EU) has incorporated a landing obligation (LO) as part of the Common Fisheries Policy (CFP). Under the LO species subject to a TAC may not be discarded at sea anymore but must be landed. This implies 100% mortality for all caught fish. If all other factors remain the same (i.e. fishing behaviour and selectivity), this would mean an increase in overall mortality in comparison with a similar fishery allowing discards, since some discarded fish may survive but no landed fish will.

The impact of discards in a fishery depends however on the survival rate that is linked to the species and the fishing gear, and the selectivity of the fisheries (Guillen et al., 2014). The Dutch demersal fisheries are very mixed, and are typically characterised by high discarding rates, particularly from the 80mm beam trawl fleet targeting sole (Verkempynck et al., 2018). Survival trials on board commercial fishing vessels do suggest that there is survival of at least part of the discarded fish (van der Reijden et al. 2017).

Likewise, it is difficult to predict how much selectivity could be improved under a landings obligation. WMR is currently evaluating the impact of the change to pulse trawl gears on selectivity of flatfish (mainly sole and plaice), but selectivity is impacted by more factors than gear changes alone (e.g. timing and location of fishing, haul duration, fishing speed etc.).This study is a continuation of the simulation study conducted in 2015 under the demersal discard processing project (Verkempynck and Machiels, 2015). The study is combined with a previous study analysing the sensitivity of the North Sea plaice assessment to the zero discard survival assumption (Miller and Verkempynck, in prep), thus adding a baseline for the simulation study. The focus in this project is on the North Sea sole and plaice stocks.

The relation between survival and the effect on the stock is a much debated and highly relevant topic under the landing obligation. In the current assessments of North Sea sole and plaice any possible discard survival is not accounted for. This means that these assessment models assume that all caught fish (discards and landings) die and thus amount to the total fishing mortality. In other words, discards survival is equal to zero.

From survival studies on board commercial fishing vessels survival of North Sea sole and plaice has been inferred (van der Reijden et al. 2017). Without discard survival taken into account, stock assessment models are likely to be biased in their estimates of SSB, total stock size, fishing mortality, and recruitment. As a result, biological reference points derived from these biased assessments may also be different from assessments including discard survival.

The bias in stock assessments that do not account for discard survival can be graphically explained through the following figures:

1. In the current assessments landings and discards from any year and age, combined with an assumption of natural mortality, are used to calculate stock sizes in the previous year and the previous age (Figure 1.1).

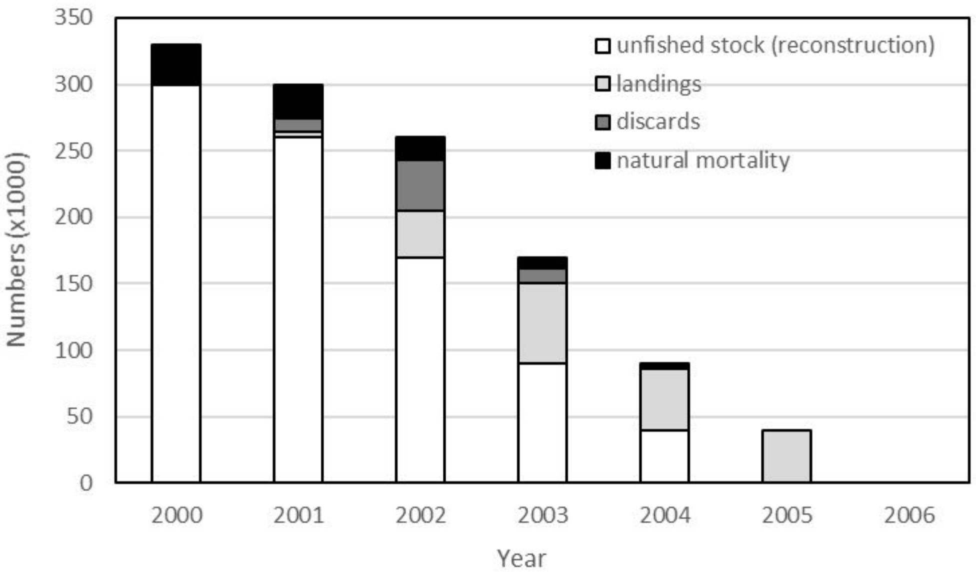

Figure 1.1: Graphical representation of the reconstruction of a single cohort (2000) in a stock assessment based on discards, landings and natural mortality. The total height of the bars is the size of the cohort (2000) at the start of the year. **Remark: Read the graph from right to left.**

2. When we consider discard survival (e.g. 50% survival), 50% of discards survive and thus the discard fraction and resulting catches are lower than without discard survival (0% survival) (figure 2). This difference between both situations is represented by the differences in the reconstruction of a single cohort, depicted as the difference in Figure 1.1 and Figure 1.2. Note that the bars for figure 3.2 are lower. For example, the estimate for this cohort in 2000 decreases from 330 thousand in figure 3.1 to 293 thousand in Figure 1.2.

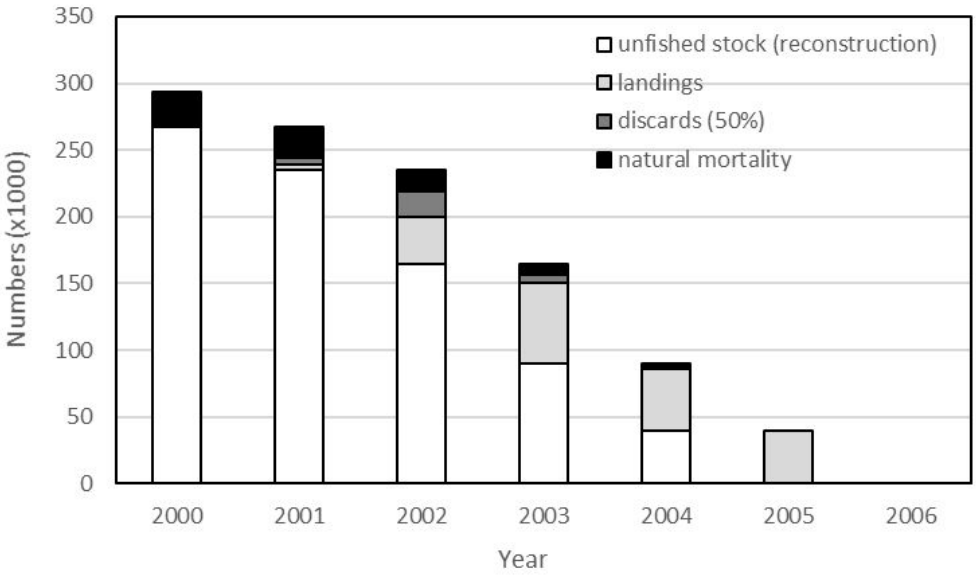

Figure 1.2: Graphical representation of the reconstruction of the same single cohort (2000) as in figure 3.1, but now assuming 50% discard survival. The total height of the bars is the size of the cohort (2000) at the start of the year. Remark: Read the graph from right to left.

1.3 North Sea sole

North Sea sole is a single stock in the North Sea, ICES area 27.4.

North Sea sole is taken mainly in a mixed flatfish fishery by beam trawlers in the southern and south-eastern North Sea (see Figure 1.3). Directed fisheries are also carried out with seines, gillnets, and twin trawls, and by beam trawlers in the central North Sea. The minimum mesh sizes enforced in these fisheries (80 mm in the mixed beam-trawl fishery) are chosen such that they correspond to the Minimum Landing Size for sole.

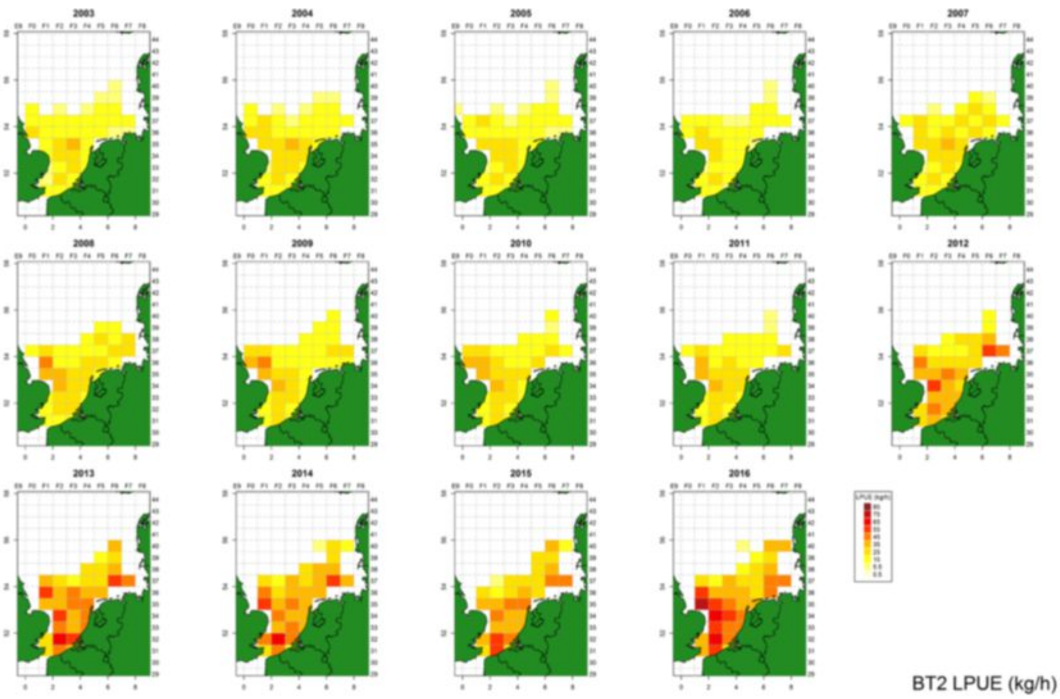

Figure 1.3: LPUEs (kg/h) by Dutch flagged BT2 (beam trawlers working 80 mm mesh).

Discards form a minor part of total sole catches, and discard rates have stabilised in the last years. The assessment at present includes 16 years of discards data obtained from discard sampling programs in several countries and is considered to be robust and consistent between years.

North Sea sole is the main species of commercial interest in the Dutch demersal fleet and subsequently most of the discards originate from the Netherlands. Observed discard quantities are shown on Figure 1.4. Strong cohorts are distinguishable when recruitment was high.

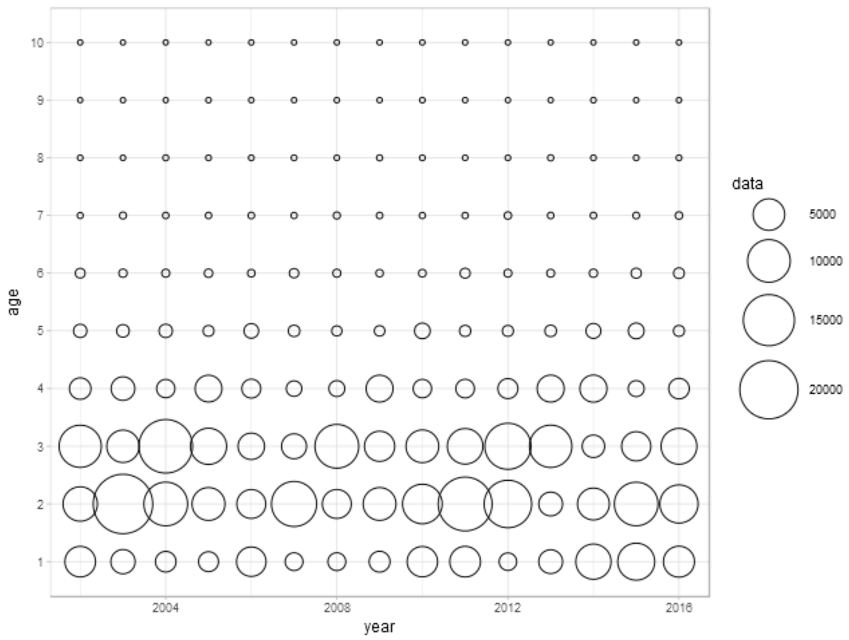

Figure 1.4: Observed discard numbers per age of North Sea sole for 2002 – 2016.

North Sea sole is assumed to be fully mature at age 3 (Figure 1.5). Age 1 and 2 are subsequently not part of the SSB. Since discards consist of mainly ages 1 and 2 and to a lesser extent age 3, the effect of discard survival on the SSB will be only slight.

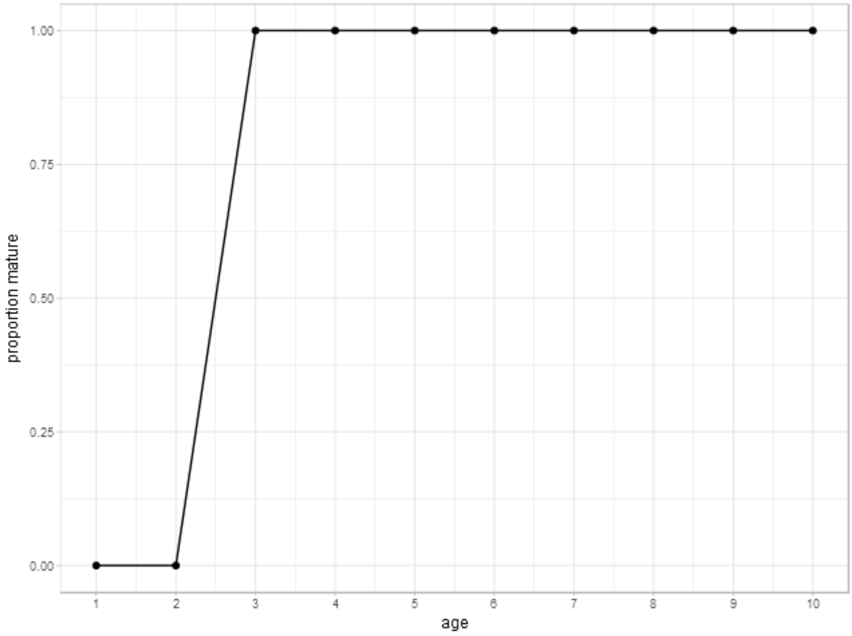

Figure 1.5: Assumed maturity ogive of North Sea sole.

1.4 North Sea plaice

North Sea plaice is mainly taken in a mixed flatfish fishery by beam trawlers in the southern and south-eastern North Sea. Directed fisheries are also carried out with seines, gillnets, and twin trawls, and by beam trawlers in the central North Sea. Due to the minimum mesh size enforced (80 mm in the mixed beam trawl fishery), large numbers of (undersized) plaice are discarded.

Discards make up a considerable part of the catches of North Sea plaice. The recent average discard rate (over years 2007 – 2016) of North Sea plaice is 38%. Discard sampling programmes started in the late 1990s to obtain discard estimates from several fleets fishing for flatfish. These sampling programmes give information on discards from 2000. For the period prior to 2000, a reconstructed discard time-series for 1957 – 1999 exists, based on a reconstructed population and selection and distribution ogives (Figure 1.6).

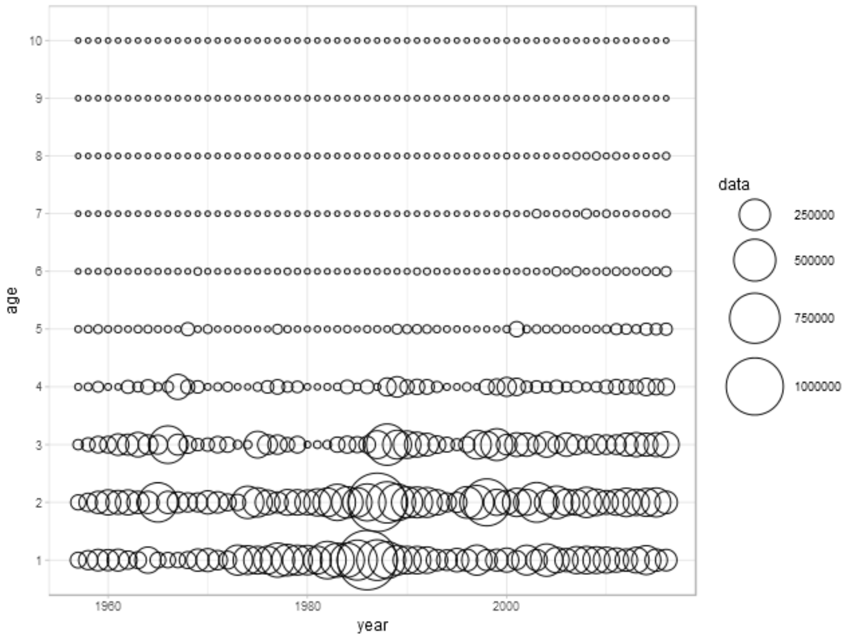

Figure 1.6: Observed discard numbers per age of North Sea plaice. Note: from 1957 – 2001 discards are reconstructed (where is this reference? Pastoors/Rijnsdorp/van Keeken?)

Age one is assumed to be fully immature, but both ages 2 and 3 are 50% mature (Figure 1.7). From age 4 onwards, it is assumed that all fish are fully mature and hence contribute to the SSB. Since up to age 3 fish are discarded, there is a substantial impact to be expected in the SSB.

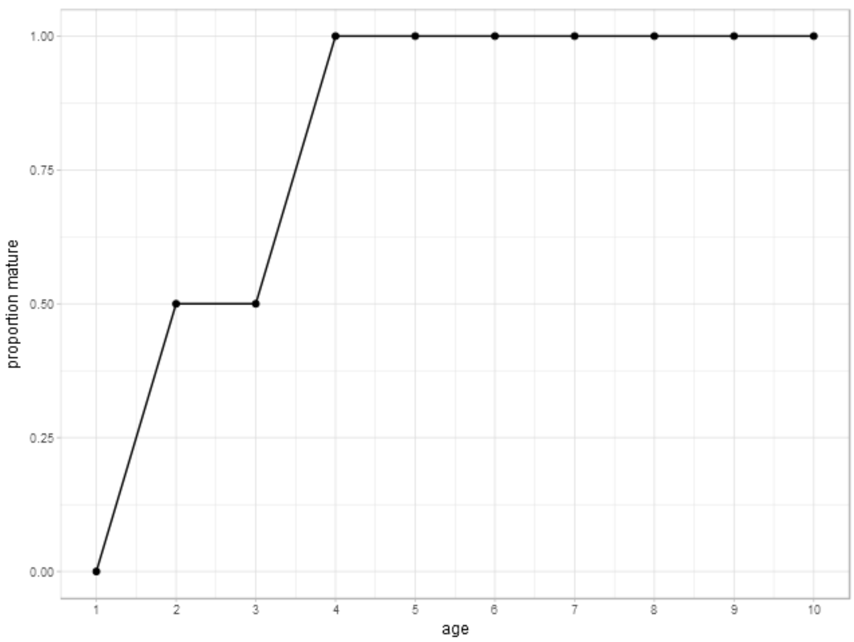

Figure 1.7: Assumed maturity ogive of North Sea sole.

2 Methodology

The assumption on discard survivability will effect both the current perception of the stock (i.e. the stock assessment model) and our prediction of future stock development (i.e. the forecast model). In addition, management reference points (e.g. FMSY) will also be affected.

2.1 Correcting stock assessment for discard survival

First, the stock assessment of North Sea sole and of North Sea plaice was recalculated according to different discard survival levels. Discard survival ranged from 0% to 100%. The 0% discard survival is basically the same assumption as under the current stock assessment.

Both the assessment of North Sea sole and of North Sea plaice was configured according to the settings of the most recent benchmark of those species (North Sea sole: ICES, 2015, North Sea plaice: ICES, 2017). Both assessments are based on a statistical catch-at-age model with flexible selectivity functions to reconstruct historical catches and estimate stock abundance (Aarts and Poos, 2009).

The assessment model was run for 11 discard survival scenarios, resulting in a recalculated stock assessment for sole and plaice for each run. Before each run the observed discard matrix (i.e. discards numbers and weights obtained for discard monitoring programmes) was multiplied by a survival rate (0% to 100%) (Figure 2.1-2), these discards thus represent the dead part of the caught discards in the assessment.

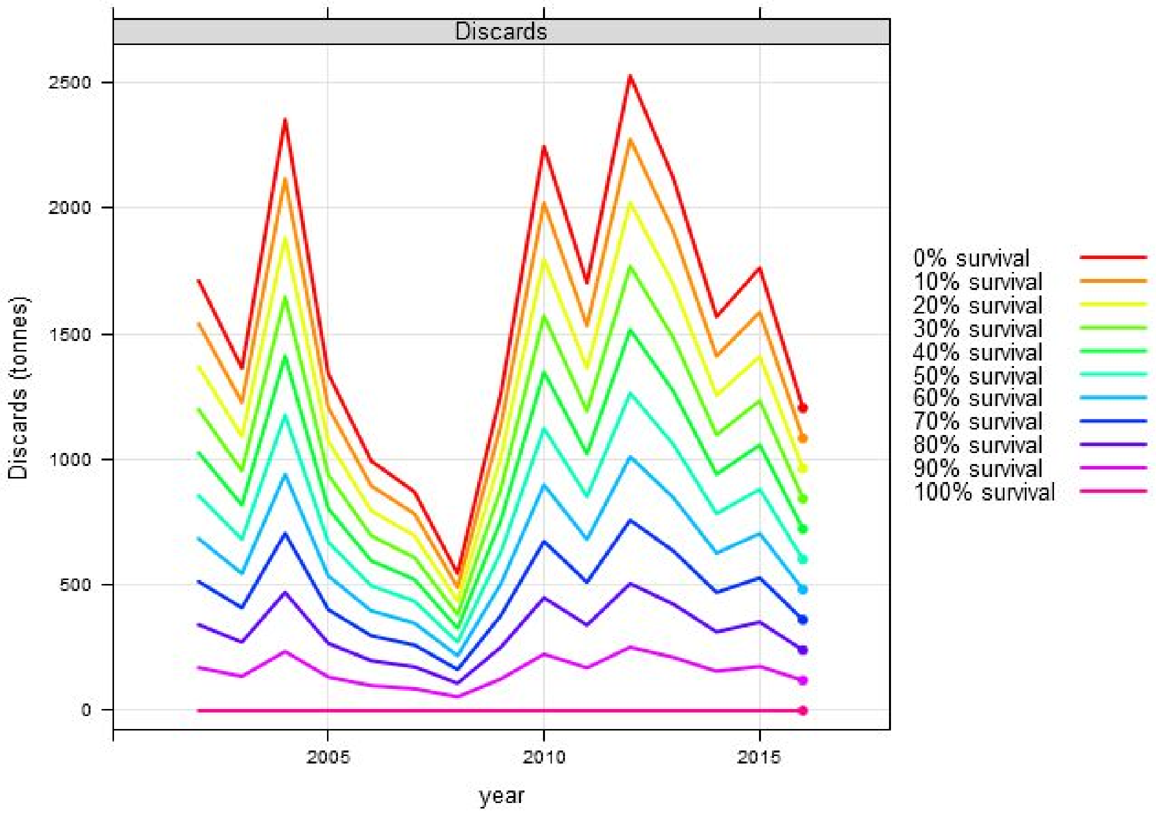

Figure 2.1: Total weight (tonnes) of dead discards as input for recalculations of the North Sea sole assessment according to different levels of discard survival.

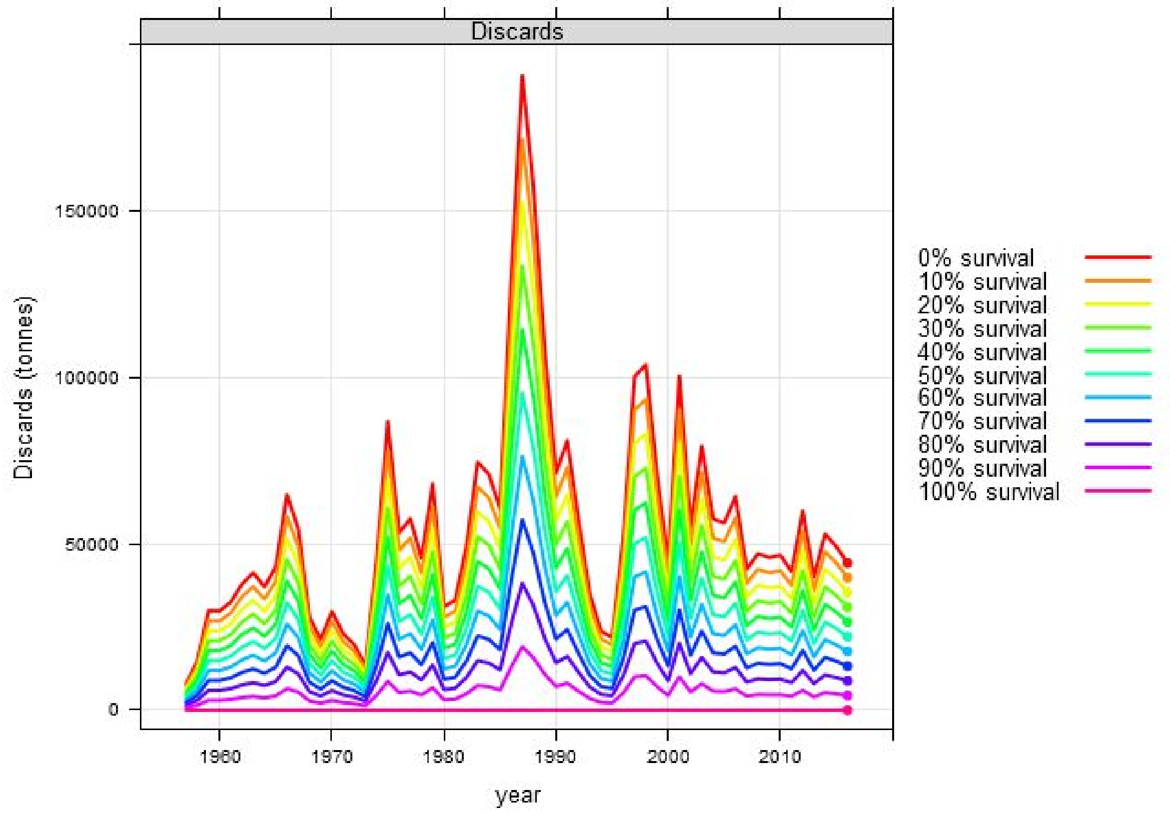

Figure 2.2: Total weight (tonnes) of dead discards as input for recalculations of the North Sea plaice assessment according to different levels of discard survival.

2.2 Reference point calculation under discard survival

Based on the stock assessment of North Sea sole and of North Sea plaice corrected for discard survival, reference points (Fmsy) were estimated. Each stock assessment run, corrected for discard survival, has a different estimated fishing mortality-at-age (selectivity). This discard survival-corrected selectivity and the corrected results for spawning stock biomass and recruitment form the basis for the calculation of the reference points under discard survival.

The EQsim software was configured and used according to the settings as described in the most recent benchmark of North Sea sole and North Sea plaice (North Sea sole: ICES, 2015, North Sea plaice: ICES, 2017). For North Sea sole, a segmented regression stock recruitment relationship is used (Figure 2.3), for North Sea plaice a combination of the Ricker, segmented regression, and Beverton and Holt stock recruitment relationship is used (Figure 2.4). The number of runs used for the EQsim analysis was 5000.

The reference points derived from the discard survival-corrected assessments are used in the forecast simulation (see Chapter 2.3).

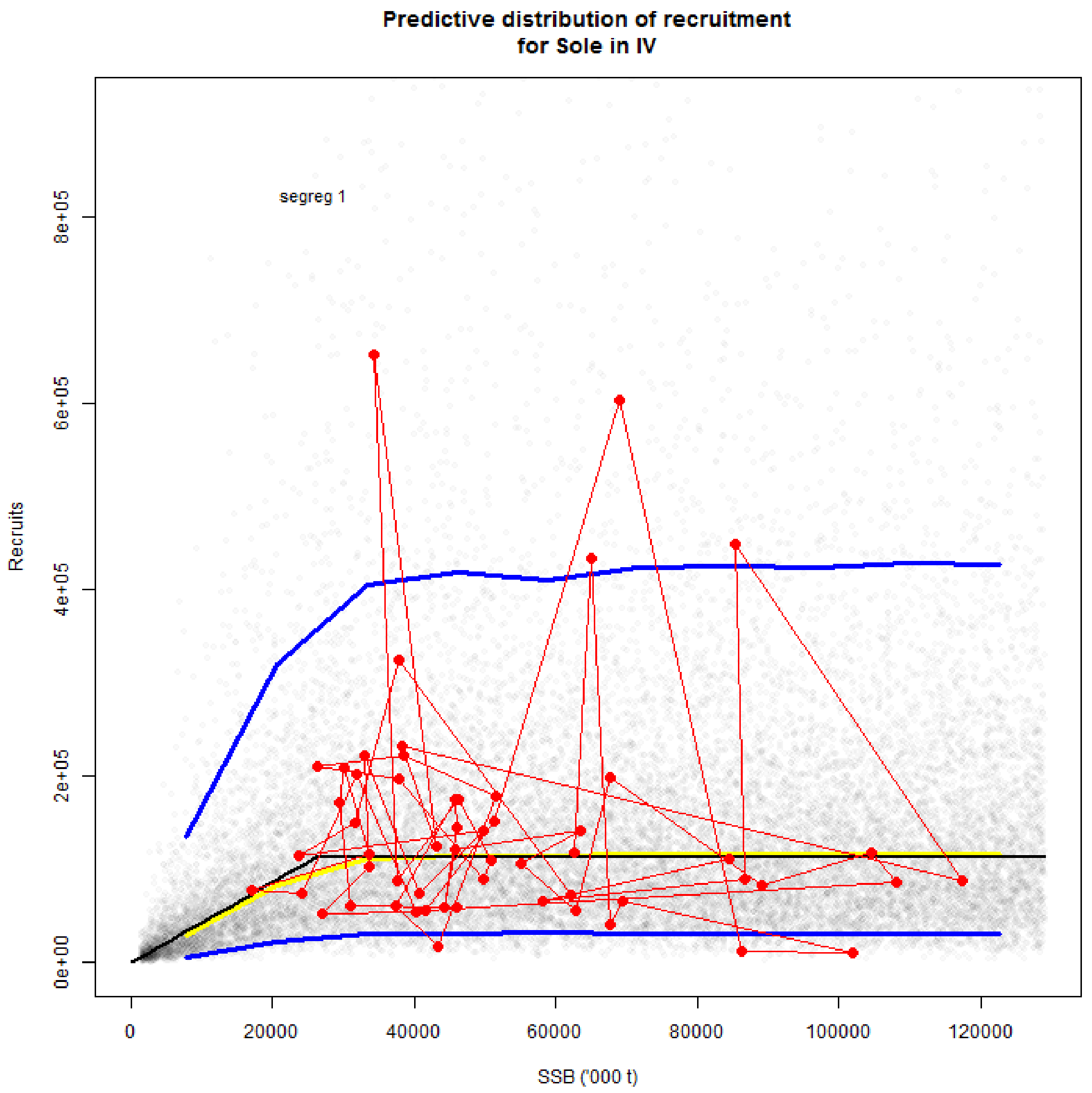

Figure 2.3: Stock-Recruitment relationship used for North Sea sole Fmsy reference point estimation during the most recent benchmark of North Sea sole (ICES, 2015).

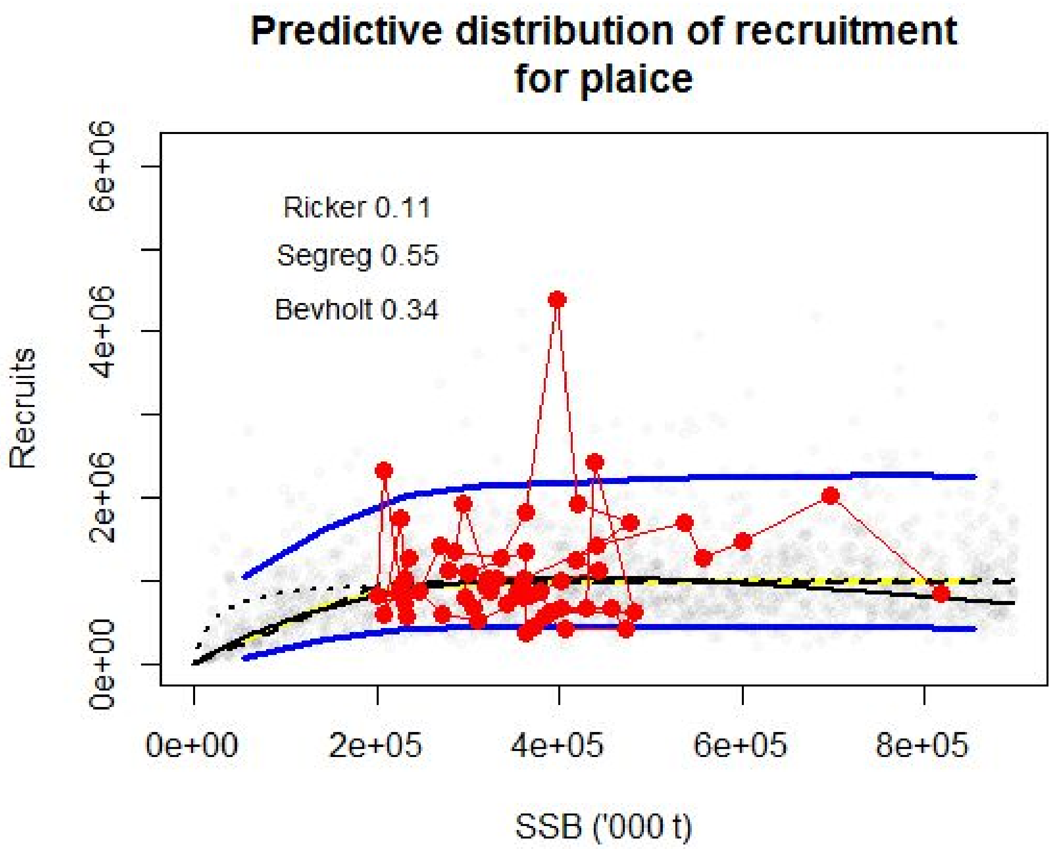

Figure 2.4: Stock-Recruitment relationship used for North Sea plaice Fmsy reference point estimation during the most recent benchmark of North Sea plaice (ICES, 2017).

2.3 Forecast simulation under current discarding practice and landing obligation

To assess the impact of discard survival under the landing obligation a 50-year forecast (2017 – 2066) was simulated starting from each discard survival-corrected assessment. Two scenarios were defined:

1. Discarding continues: the stock is projected with the Fmsy reference point from each discard survival-corrected assessment as F-target.

This scenario corresponds with the objectives of the EU common fisheries policy (Council Regulation No. 676/2007).The Fmsy reference points recalculation is described above (2.2 Reference point calculation under discard survival).

2. Landing obligation is implemented: for all discards of each stock from 2017 onwards, the stock is projected with an F-target optimized for maximum landings under a landing obligation (see below).

The F-target points that maximize the landings for forecasting the discard survival-corrected assessments under the landing obligation are derived from a second EQsim analysis. The procedure for this EQsim analysis follows the same configuration and settings as performed for the Fmsy reference point calculation (2.2 Reference point calculation under discard survival), but since all discards caught are landed under the landing obligation, the discards in each EQsim run are reset to the total observed discards corresponding to the total gear selectivity of both stocks (which are the discards observed in the stock assessment with 0% discard survival).

$$discards.n(stock) = discards.n(stock\_0\%)$$
$$discards(stock) = discards(stock\_0\%)$$

Doing this, the catch matrix and consequently the selectivity pattern for each discard survival-corrected assessment is changed so that the total dead discards are set to what can be maximally observed (discard estimates come from catch monitoring programmes).

After defining the F-target values each discard survival-corrected assessment under both scenarios the stock is forecasted 50-years using the FLR software (www.flr-project.org). A Beverton and Holt stock recruitment relationship is taken for defining the recruitment for each projected year. To account for uncertainty in recruitment the stock is projected forward with 500 iterations including stochasticity in recruitment. The results from the forecast simulation are then derived by taking the median over the iterations.

The historic part of the time-series of each stock (from 1957 to 2016) is identical for both scenarios. Both stocks have been corrected for potential survivability of discards for the historic part of the time series in the first part of this project (see Chapter 2.1). The scenarios differ for the future years. Under scenario 1 the stock is projected having the same discard survival as the survival rate with what it was corrected for in the historic part of the time-series. Following scenario 2, the stock is projected without discard survival (all discards of North Sea sole and plaice are landed).

3 Results

3.1 Discard survival-corrected stock assessment

3.1.1 North Sea sole

The assessment of North Sea sole was corrected for discard survivability, and the resulting stock development over time, including total dead catch, spawning stock biomass (ssb), total stock biomass (tsb), recruitment, and fishing mortality (fbar) for discard survival levels from 0% to 100% are shown in Figure 3.1 (a - e).

For discards, results vary according to their survival. As we assume the same survival over all ages in the discards, the discards are scaled by the corresponding survival rate (Figure 2.1). For catches, the effect of discard survival on the recalculated catches is less obvious (figure 3.1a). This can be explained by the fact that North Sea sole is not commonly discarded (current discard rate is ~ 11%) as it is a commercially important target species.

Results show that the ssb and tsb of North Sea sole is slightly overestimated in the current assessment (0% survival) if North Sea sole discards survive the catch process (Figure 3.1 b and c). However, the effect of discard survival is only slightly noticeable. Recruitment (Figure 3.1d) on the other hand, defined here as age 1, is mainly driven by discard survival and is scaled to the same extent as the discards.

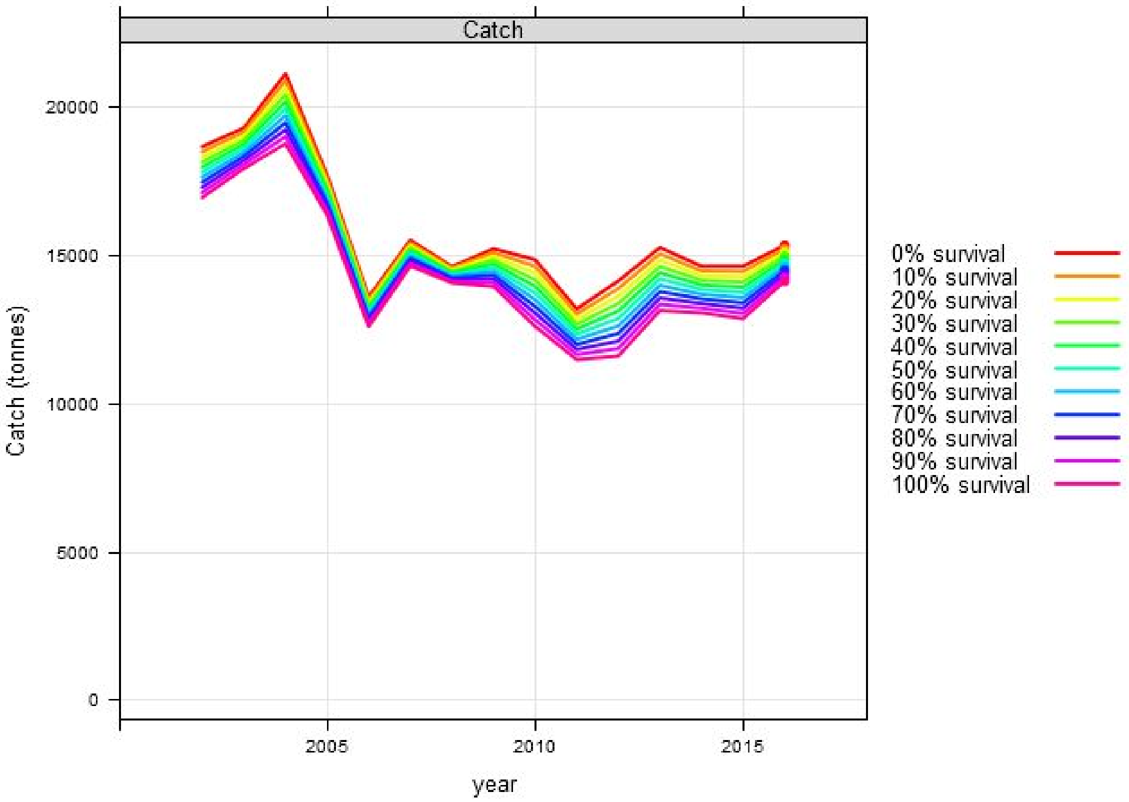

Figure 3.1a: Total weight (tonnes) of dead catches (landings + dead discards) as input for recalculations of the North Sea sole assessment according to different levels of discard survival.

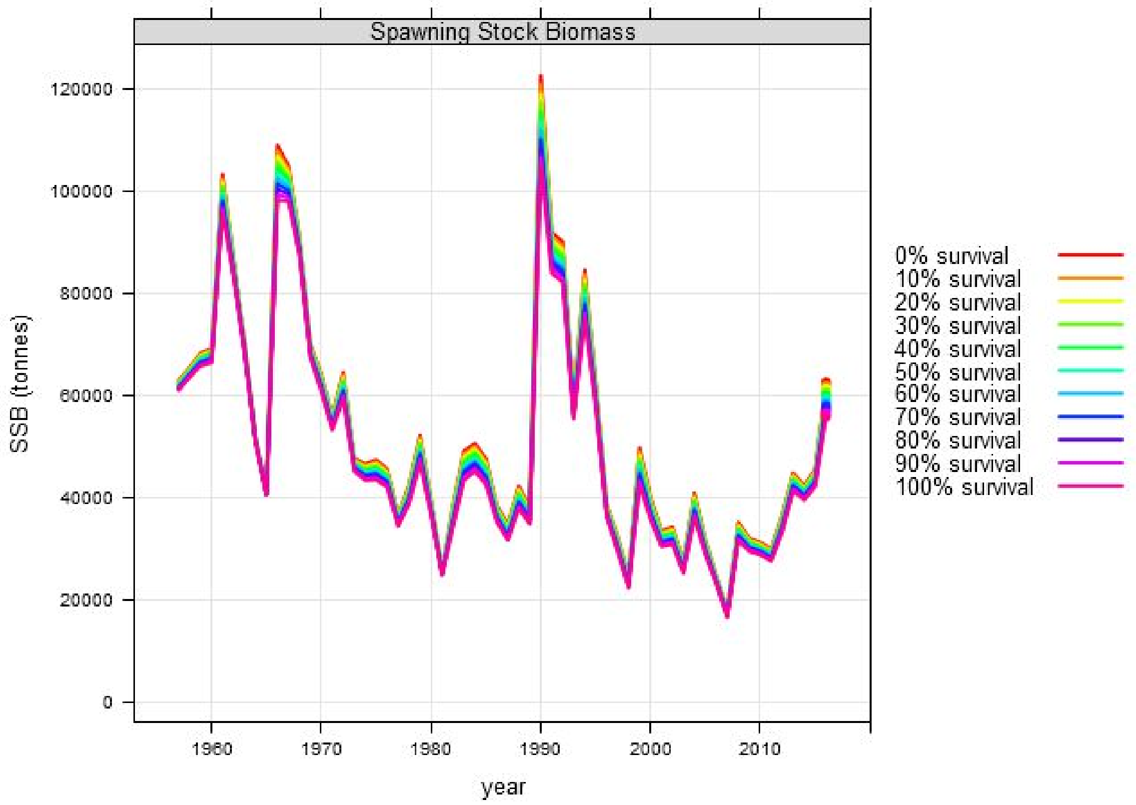

Figure 3.1b: Spawning stock biomass (1957-2016) of North Sea sole assessment under different scenarios of discard survival (0 to 100% discard survival).

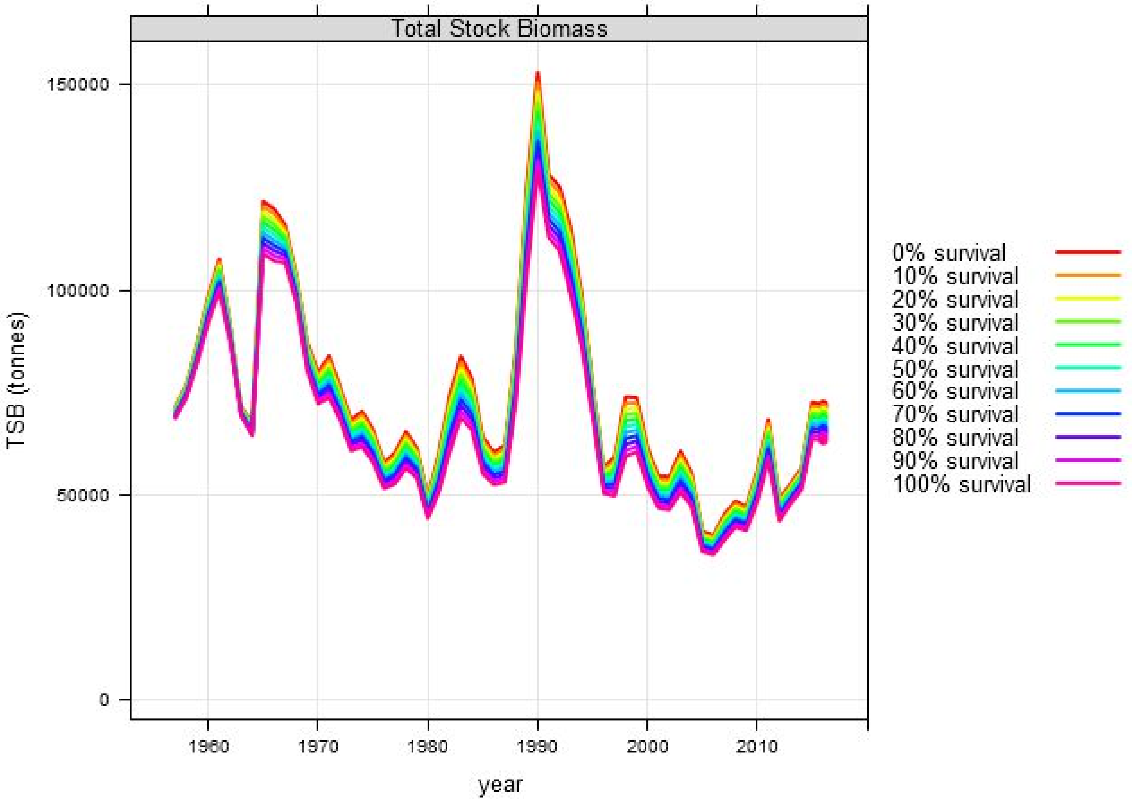

Figure 3.1c: Total stock biomass (1957-2016) of North Sea sole assessment under different scenarios of discard survival (0 to 100% discard survival).

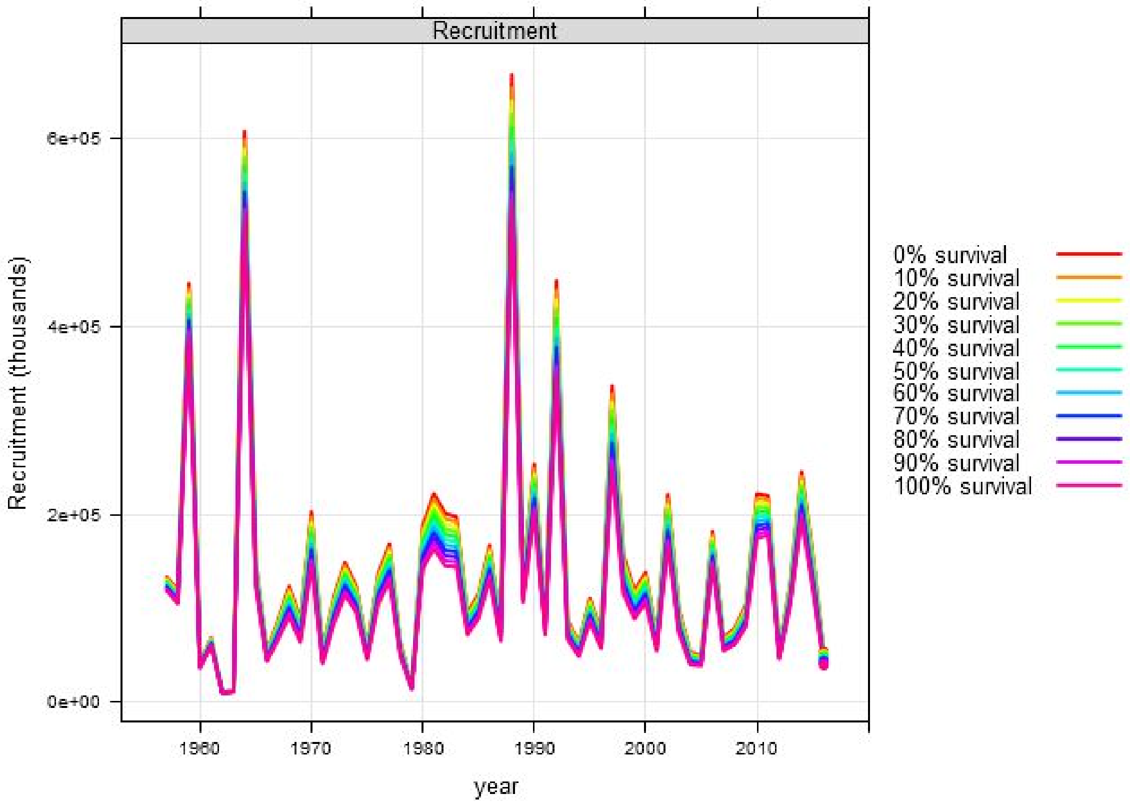

Figure 3.1d: Recruitment (1957-2016) of North Sea sole assessment under different scenarios of discard survival (0 to 100% discard survival).

The current assessment (0% discard survival) is overestimating the fishing mortality. When discard survival is taken into account the fishing mortality decreases with increasing discard survival levels (Figure 3.1e).

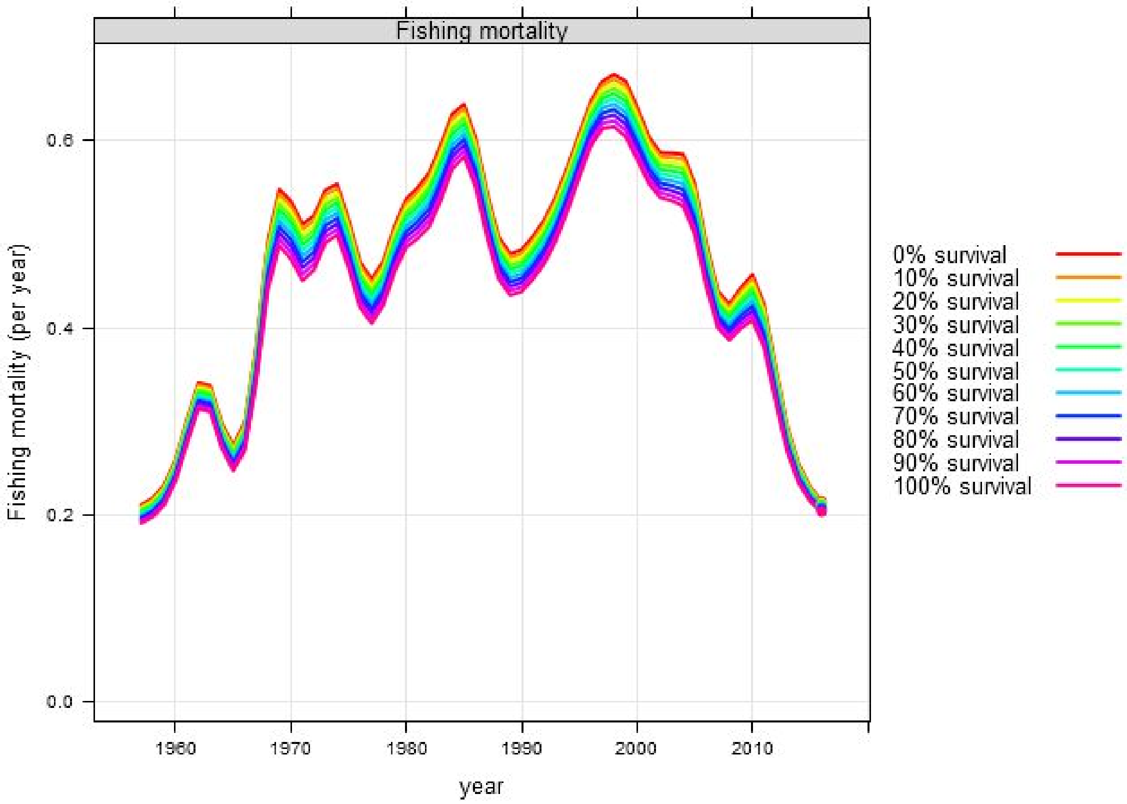

Figure 3.1e: Fishing mortality (1957-2016) of North Sea sole assessment under different scenarios of discard survival (0 to 100% discard survival).

The selectivity of the assessment (exploitation pattern over the ages in the population) changes with discard survival. There is a clear shift in fishing mortality from younger ages to older ages (figure 3.2) with increasing discard survival levels. Fishing mortality is lower under higher discard survival levels (Figure 3.1e) but the fishing mortality shifts to older individuals in the stock because there are less younger fish in the population that die because of fishing with higher discard survival rates.

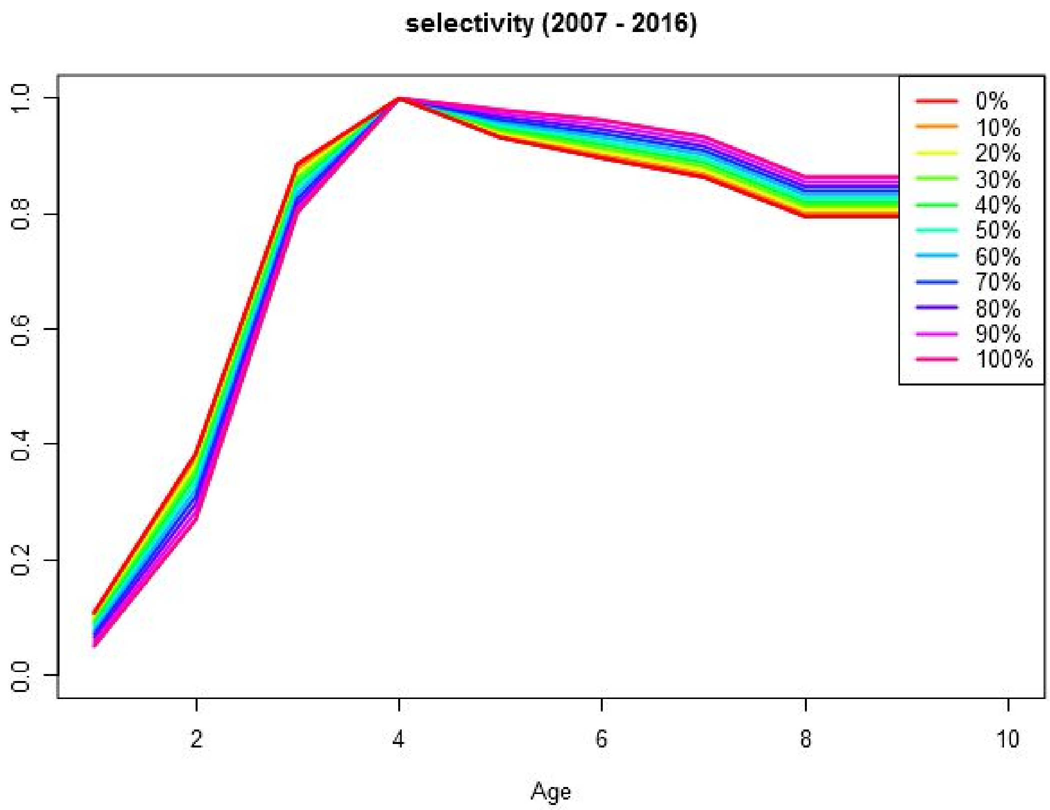

Figure 3.2: Selectivity's (fishing mortality-at-age scaled to maximum fishing mortality) for the period 2007-2016 under different scenarios of discard survival (0 to 100% discard survival).

3.1.2 North Sea plaice

The assessment of North Sea plaice was corrected for a range of discard survival levels (0% to 100%). The resulting stock development over time, including total dead catch, spawning stock biomass (ssb), total stock biomass (tsb), recruitment, and fishing mortality (fbar) are shown in Figure 3.3 (a to e).

For discards, results vary according to their survival, as we assume the same survival over all ages in the discards, the recalculated discards are scaled by the corresponding survival rate (Figure 2.2). For catches of North Sea plaice, the effects of discard survival on the recalculated catches is obvious (Figure 2.3a) as discards observed in the catches are considerable (currently a discard rate of ~ 36%).

Results show that the spawning stock biomass and total stock biomass of North Sea plaice is overestimated in the current assessment (0% survival) if North Sea plaice discards survive the catch process (Figure 3.3b - c). Recruitment on the other hand, defined here as age 1, is mainly driven by discard survival and is scaled in the same way as discards and catches (Figure 3.3d).

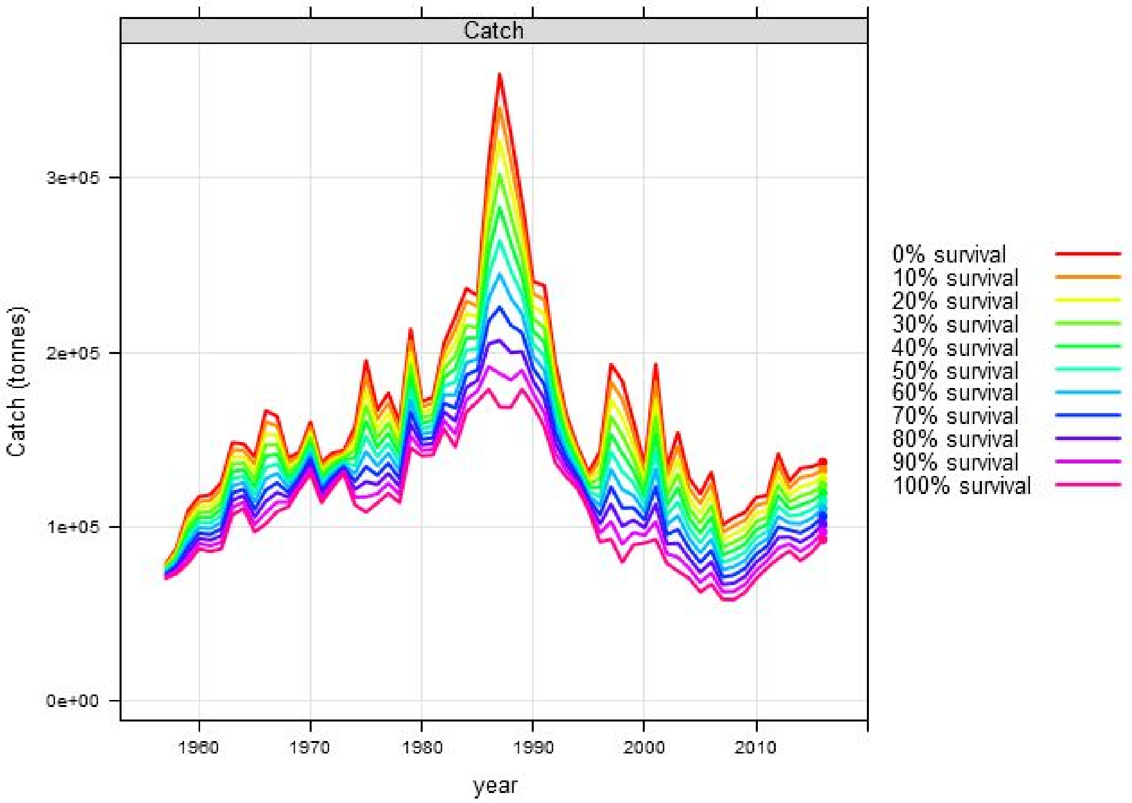

Figure 3.3a: Total weight (tonnes) of dead catches (landings + discards) as input for recalculations of the North Sea plaice assessment according to different levels of discard survival.

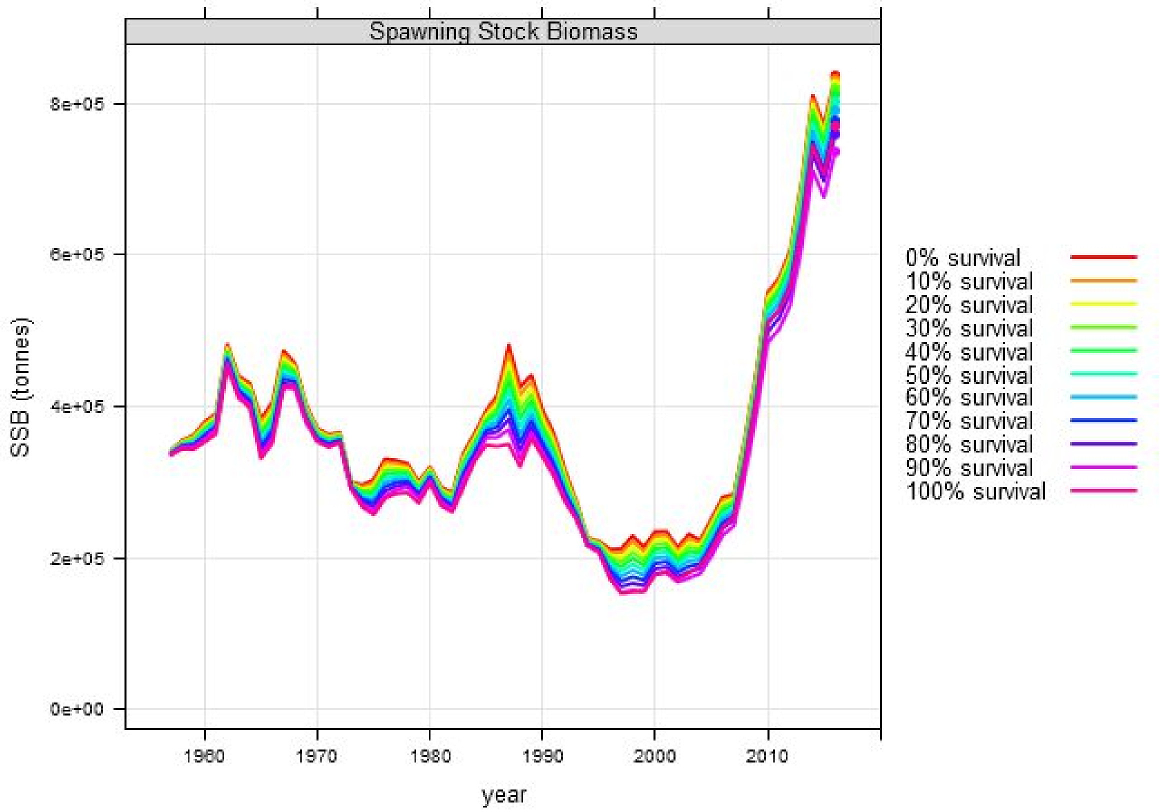

Figure 3.3b: Spawning stock biomass (1957-2016) of North Sea plaice assessment under different scenarios of discard survival (0 to 100% discard survival).

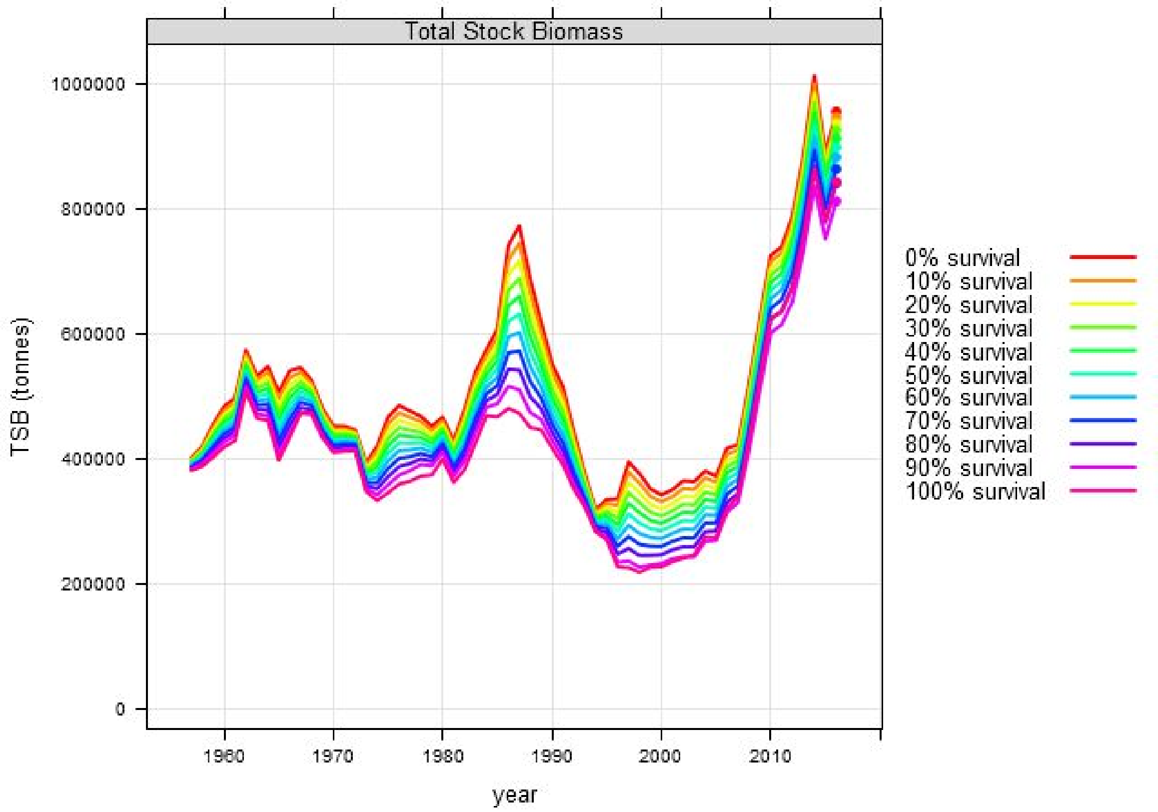

Figure 3.3c: Total stock biomass (1957-2016) of North Sea plaice assessment under different scenarios of discard survival (0 to 100% discard survival).

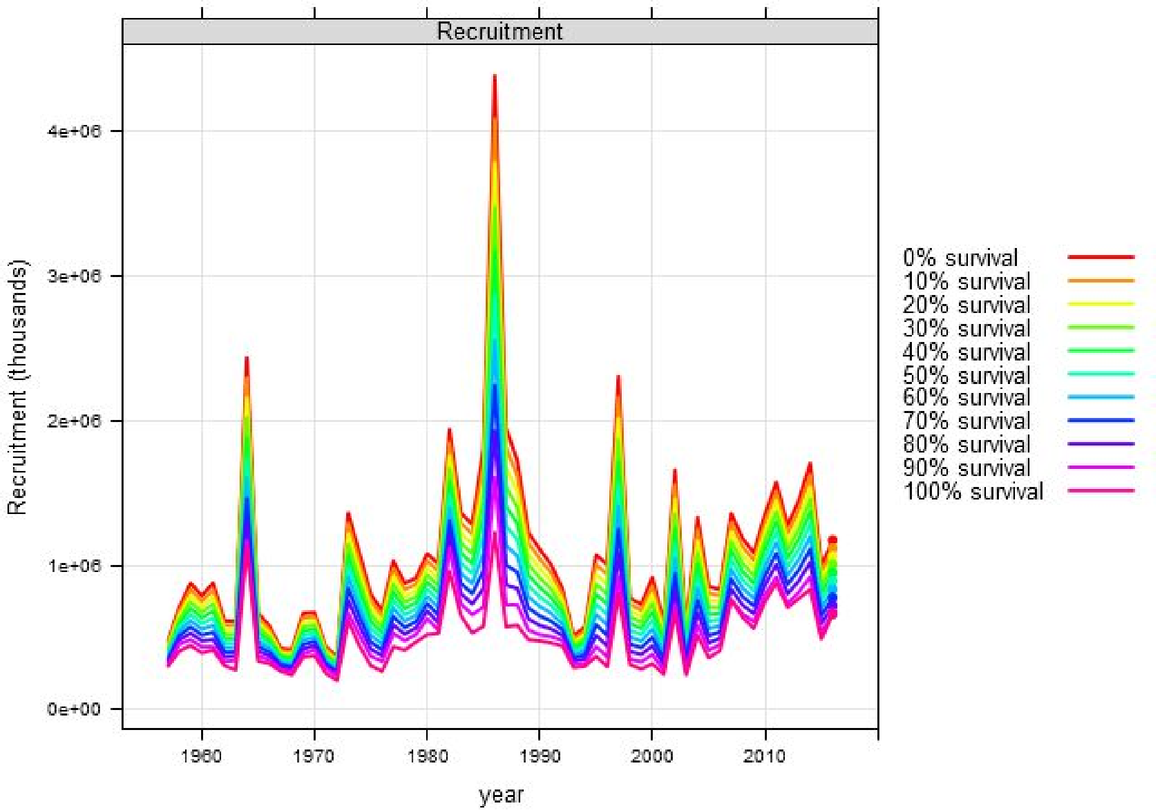

Figure 3.3d: Recruitment (1957-2016) of North Sea plaice assessment under different scenarios of discard survival (0 to 100% discard survival).

Also, when discards survive the catch process, subsequently the total fishing mortality is less than under the scenario where all discards die (Figure 3.3e). This is because part of the total fishing mortality caused by catching discards that die is less when discards survive.

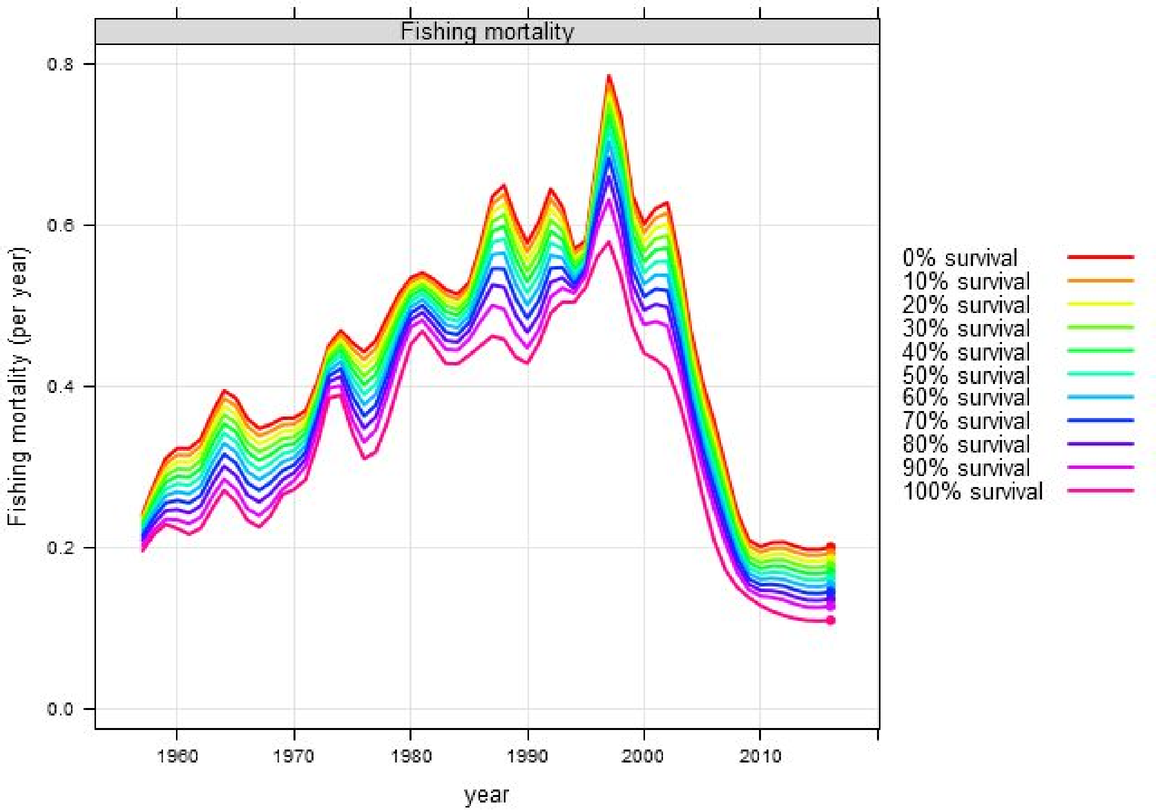

Figure 3.3e: Fishing mortality (1957-2016) of North Sea plaice assessment under different scenarios of discard survival (0 to 100% discard survival).

Selectivity of the North Sea plaice assessment changes with different discard survival levels. There is a clear shift from fishing mortality on younger ages of the population to older ages in the population (Figure 3.4) with increasing discard survival levels. Overall, fishing mortality is lower under higher discard survival rates (figure 3.3e) but at the same time the fishing mortality shifts to older ages in the population as the younger fish die less because of fishing under higher discard survival rates.

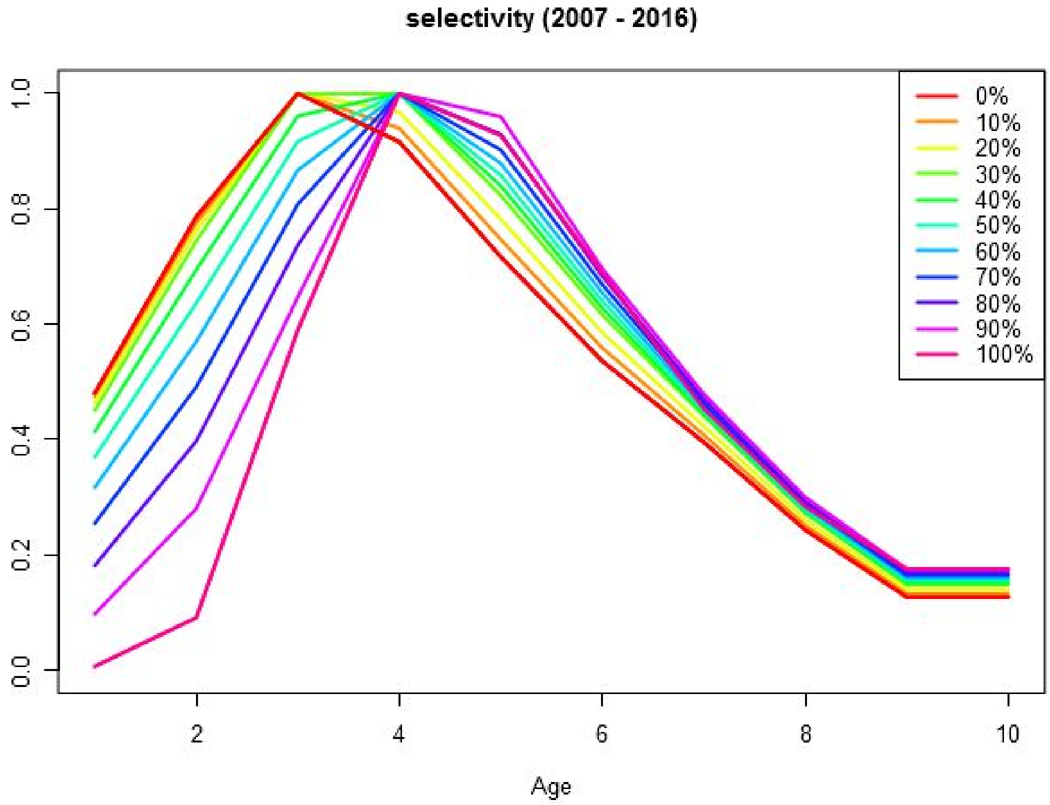

Figure 3.4: Fishing mortality (1957-2016) of North Sea plaice assessment under different scenarios of discard survival (0 to 100% discard survival).

3.2 Reference point recalculation under discard survival

3.2.1 North Sea sole

Fmsy reference points of North Sea sole were estimated for different levels of discard survival (0 to 100% discard survival). Fmsy reference points are higher with increasing discard survival. The Fmsy reference points for the different levels of discard survival are presented in Table 3.1 and in Figure 3.5.

The current Fmsy reference point of North Sea sole is (0.202). This value was calculated at the most recent benchmark of North Sea sole (ICES, 2015) using catch data and stock weights from 1957 to 2013 (available at that time). The reference points calculated from the discard survival-corrected stock assessments (Table 3.1) are calculated with the most recent catch data and stock weights (1957 – 2016).

Table 3.1: Fmsy reference points of North Sea sole for different levels of discard survival (0 to 100% discard survival).

Discard survival	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Fmsy	0.270	0.275	0.276	0.287	0.291	0.297	0.304	0.309	0.312	0.316	0.322

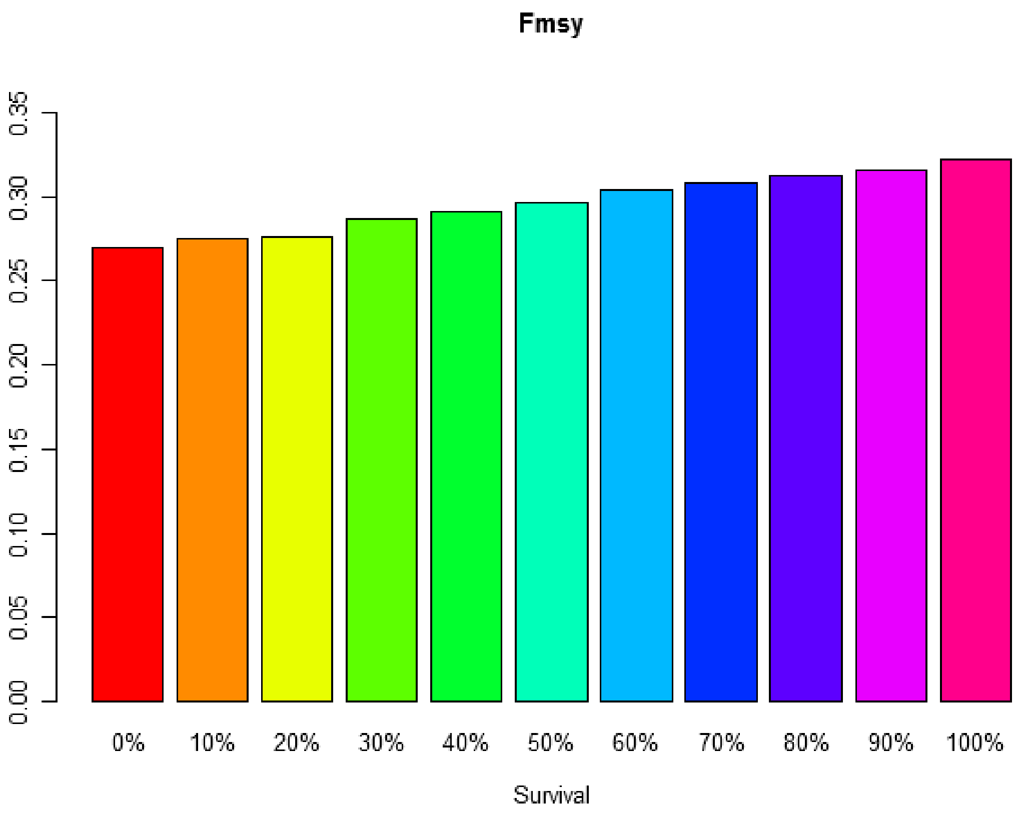

Figure 3.5: Reference points (Fmsy) of North Sea sole for different levels of discard survival (0% to 100% discard survival).

3.2.2 North Sea plaice

Fmsy reference points of North Sea plaice were also estimated for different levels of discard survival (0 to 100% discard survival). Fmsy reference points are higher with increasing discard survival. The current Fmsy reference point of North Sea plaice is (0.20). The Fmsy reference points for the different levels of discard survival are presented in Table 3.2 and in Figure 3.6.

Table 3.2: Fmsy reference points of North Sea plaice for different levels of discard survival (0 to 100% discard survival).

Discard survival	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Fmsy	0.202	0.205	0.222	0.223	0.225	0.226	0.228	0.232	0.239	0.263	0.262

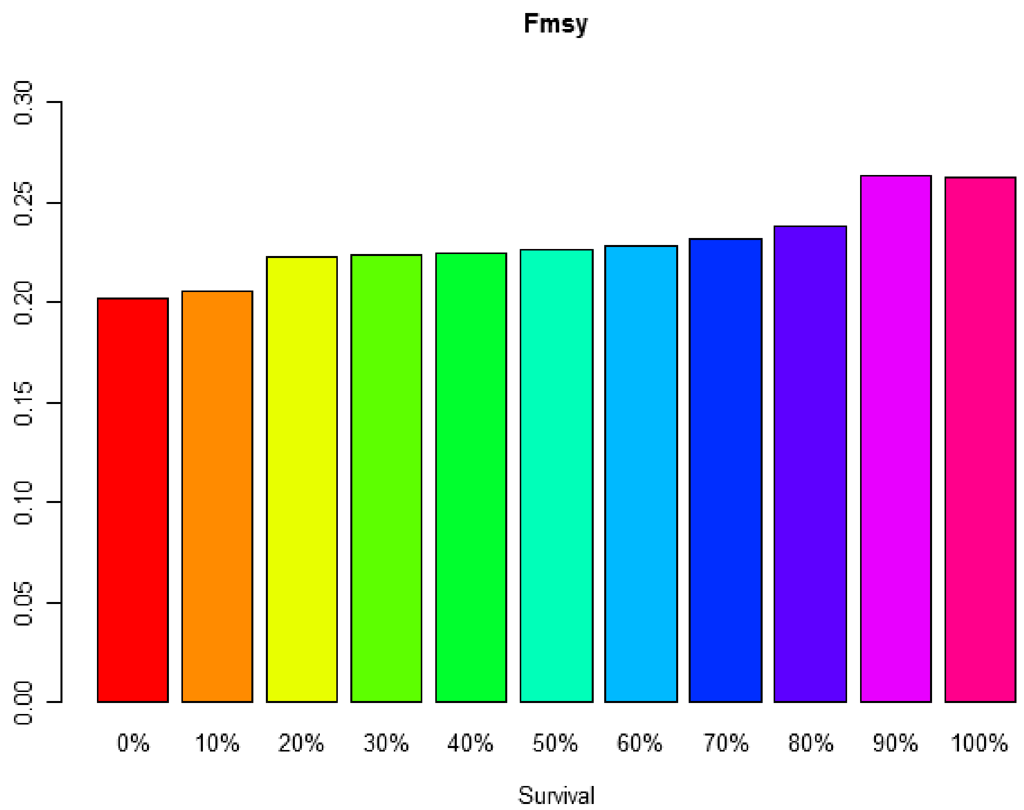

Figure 3.6: Reference points (Fmsy) of North Sea plaice assessment for different levels of discard survival (0% to 100% discard survival).

3.3 Forecast simulation under current discarding practice and landing obligation

3.3.1 North Sea sole

3.3.1.1 F-targets

First F-targets for the landing obligation scenario were calculated by resetting the discards to the total observed discards (which are the discards observed in the stock assessment with 0% discard survival), thus assuming the current gear selectivity. These F-targets are presented in Figure 3.7. These F-targets are approximately constant for different levels of discard survival.

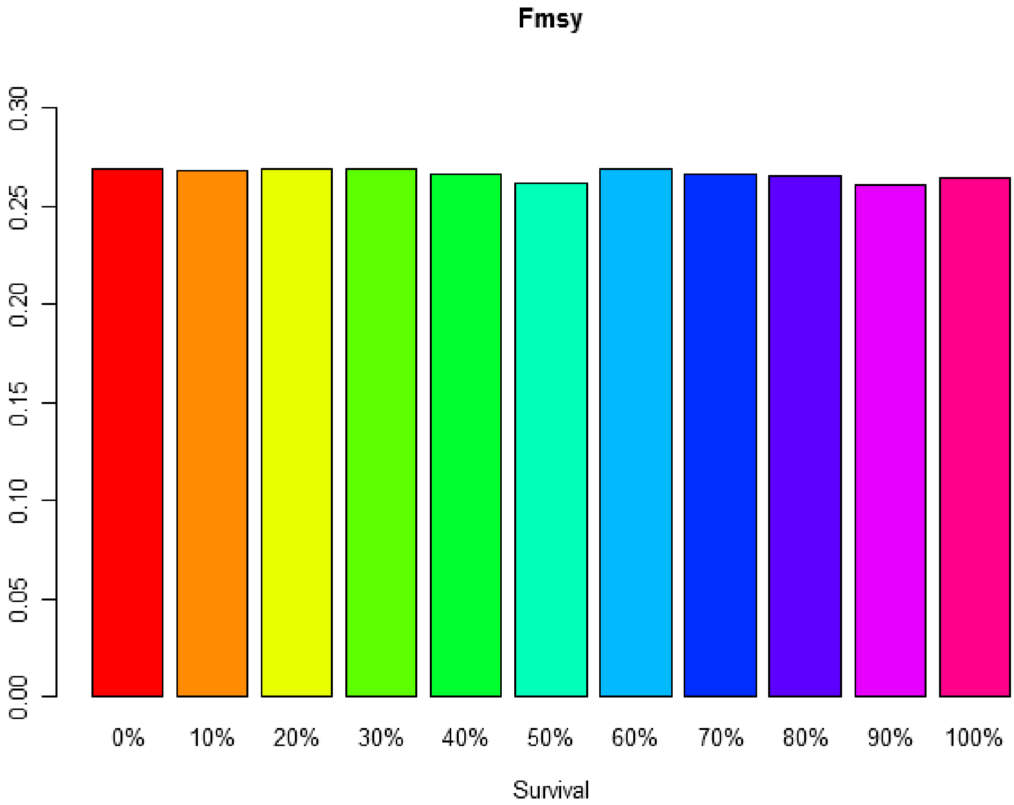

Figure 3.7: F-targets of North Sea sole for the landing obligation scenario of forecast simulation for different levels of discard survival (0% to 100% discard survival).

3.3.1.2 Forecast simulation

The forecast simulation of North Sea sole under the discarding scenario is shown for 0%, 20%, 40%, 60%, 80%, and 100% discard survival on Figure 3.8.

The forecast simulation of North Sea sole under the landing obligation scenario is shown for 0%, 20%, 40%, 60%, 80%, and 100% discard survival on Figure 3.9.

The graphical representation without the confidence bounds (only median values) of the forecast simulation of both scenarios is shown on Figure 3.10.

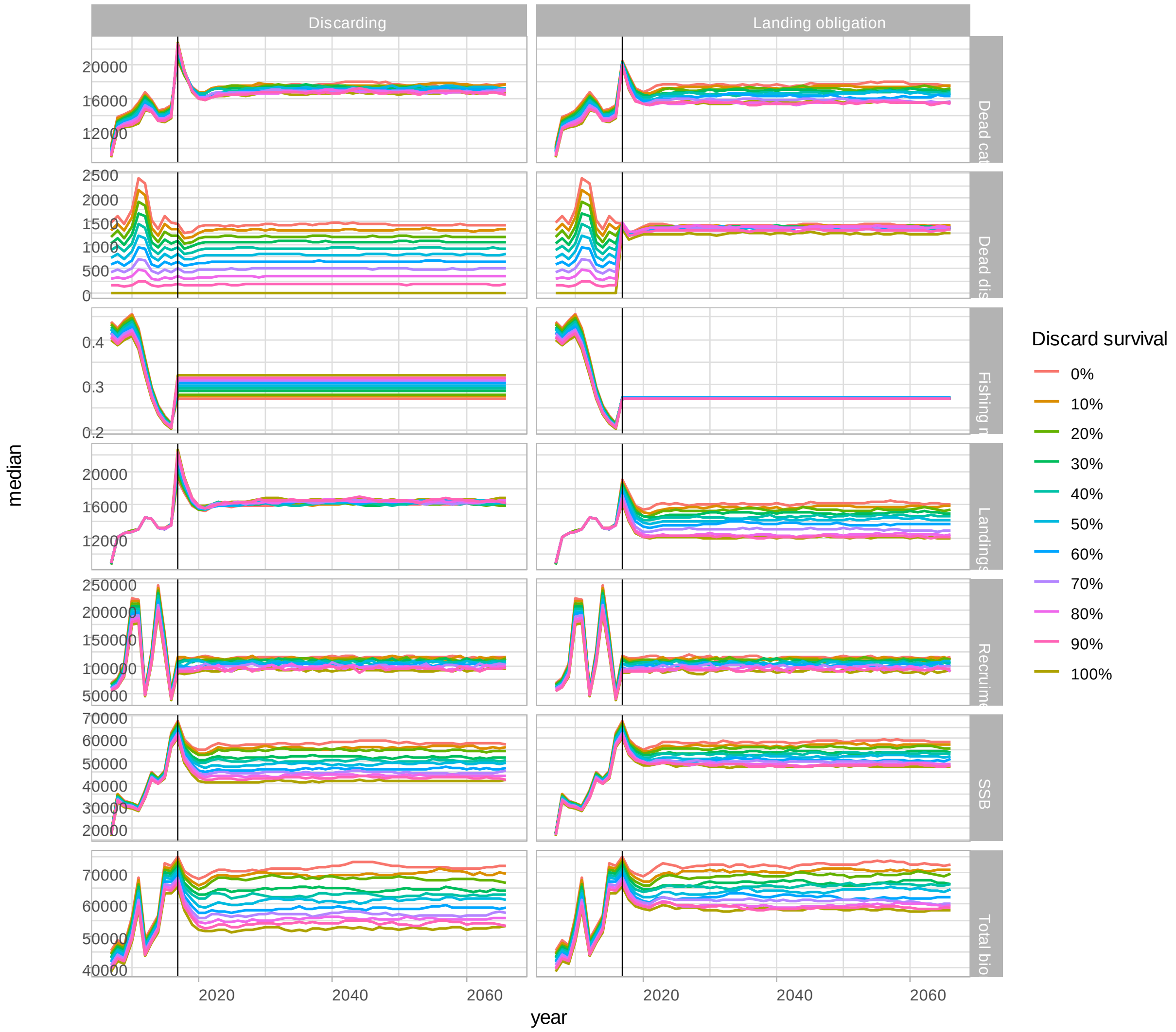

Figure 3.10: Forecast simulation of North Sea sole under two scenarios (only median values).

3.3.1.3 Comparing discarding and landing obligation scenario

The median results of the forecast simulation of North Sea sole for both the discarding as the landing obligation scenario for different levels of discard survival (0% to 100%) are shown on Figure 3.10. Only the results for the years 2021, 2031 and 2066 are shown for practical reasons.

The results clearly show less landings of North Sea sole under the landing obligation scenario than under the discarding scenario for the same discard survival levels. Also dead discards are greater under the landing obligation scenario than under the discarding scenario, since with discarding the fish that is set overboard will have a chance to survive. Under the discarding scenario, the fishing mortality can be higher than under the landing obligation for the same discard levels.

Median results of forecast simulation of North Sea sole under the discarding and landing obligation scenarios for different levels of discard survival and for the years 2021, 2031, and 2066.

The median results for landings, dead discards, ssb, and stock per 5-year step and the percentage change after the forecast simulation period between both scenarios are presented in Table 3.3.

Table 3.3: Median results for 2016 and 2066 and percentage change after forecast of North Sea sole.

Scenario	Indicator	Discard survival	2016	2066	Percentage change
disc	catch	0%	15150	17729	
lo	catch	0%	15150	17551	-1.00%
disc	catch	10%	14992	17622	
lo	catch	10%	14992	17474	-0.84%
disc	catch	20%	14833	17148	
lo	catch	20%	14833	17193	0.26%
disc	catch	30%	14675	17188	
lo	catch	30%	14675	16833	-2.07%
disc	catch	40%	14517	17224	
lo	catch	40%	14517	16755	-2.72%
disc	catch	50%	14359	17183	
lo	catch	50%	14359	16550	-3.68%
disc	catch	60%	14202	17074	
lo	catch	60%	14202	16225	-4.97%
disc	catch	70%	14047	17044	
lo	catch	70%	14047	15677	-8.02%
disc	catch	80%	13896	16880	
lo	catch	80%	13896	15336	-9.15%
disc	catch	90%	13753	16384	
lo	catch	90%	13753	15504	-5.37%
disc	catch	100%	13629	16778	
lo	catch	100%	13629	15556	-7.28%
disc	discards	0%	1484	1423	
lo	discards	0%	1484	1401	-1.55%
disc	discards	10%	1335	1339	
lo	discards	10%	1335	1408	5.15%
disc	discards	20%	1185	1172	
lo	discards	20%	1185	1375	17.32%
disc	discards	30%	1036	1049	
lo	discards	30%	1036	1344	28.12%
disc	discards	40%	887	936	
lo	discards	40%	887	1342	43.38%
disc	discards	50%	738	800	
lo	discards	50%	738	1351	68.88%
disc	discards	60%	590	656	
lo	discards	60%	590	1359	107.17%
disc	discards	70%	441	505	
lo	discards	70%	441	1346	166.54%
disc	discards	80%	293	344	
lo	discards	80%	293	1367	297.38%
disc	discards	90%	146	173	
lo	discards	90%	146	1324	665.32%

Scenario	Indicator	Discard survival	2016	2066	Percentage change
disc	discards	100%	0	0	
lo	discards	100%	0	1246.13	Inf%
disc	fbar	0%	0.22	0.27	
lo	fbar	0%	0.22	0.27	0%
disc	fbar	10%	0.21	0.28	
lo	fbar	10%	0.21	0.27	-3.57%
disc	fbar	20%	0.21	0.28	
lo	fbar	20%	0.21	0.27	-3.57%
disc	fbar	30%	0.21	0.29	
lo	fbar	30%	0.21	0.27	-6.90%
disc	fbar	40%	0.21	0.29	
lo	fbar	40%	0.21	0.27	-6.90%
disc	fbar	50%	0.21	0.3	
lo	fbar	50%	0.21	0.27	-10%
disc	fbar	60%	0.21	0.3	
lo	fbar	60%	0.21	0.27	-10%
disc	fbar	70%	0.21	0.31	
lo	fbar	70%	0.21	0.27	-12.90%
disc	fbar	80%	0.21	0.31	
lo	fbar	80%	0.21	0.27	-12.90%
disc	fbar	90%	0.2	0.32	
lo	fbar	90%	0.2	0.27	-15.63%
disc	fbar	100%	0.2	0.32	
lo	fbar	100%	0.2	0.27	-15.63%
disc	landings	0%	13665.95	16194.11	
lo	landings	0%	13665.95	16092.82	-0.63%
disc	landings	10%	13657.14	16270.71	
lo	landings	10%	13657.14	15852.15	-2.57%
disc	landings	20%	13648.04	15944.89	
lo	landings	20%	13648.04	15361.83	-3.66%
disc	landings	30%	13638.79	16081.36	
lo	landings	30%	13638.79	14958.18	-6.98%
disc	landings	40%	13629.46	16241.87	
lo	landings	40%	13629.46	14604.57	-10.08%
disc	landings	50%	13620.35	16322.01	
lo	landings	50%	13620.35	14232.76	-12.80%
disc	landings	60%	13611.97	16355.95	
lo	landings	60%	13611.97	13674.93	-16.39%
disc	landings	70%	13605.33	16522.93	
lo	landings	70%	13605.33	12882.29	-22.03%
disc	landings	80%	13602.51	16552.38	
lo	landings	80%	13602.51	12365.96	-25.29%
disc	landings	90%	13607.63	16216.36	
lo	landings	90%	13607.63	12169.76	-24.95%

Scenario	Indicator	Discard survival	2016	2066	Percentage change
disc	landings	100%	13629.1	16778.06	
lo	landings	100%	13629.1	11985.64	-28.56%
disc	recruitment	0%	53947.3	116088.4	
lo	recruitment	0%	53947.3	115753.3	-0.29%
disc	recruitment	10%	52491	114765.6	
lo	recruitment	10%	52491	112227.9	-2.21%
disc	recruitment	20%	51034.8	112969.3	
lo	recruitment	20%	51034.8	110734.7	-1.98%
disc	recruitment	30%	49578.6	109525.3	
lo	recruitment	30%	49578.6	106384.6	-2.87%
disc	recruitment	40%	48122.4	107785	
lo	recruitment	40%	48122.4	104650.1	-2.91%
disc	recruitment	50%	46666.3	105610.6	
lo	recruitment	50%	46666.3	109483.4	3.67%
disc	recruitment	60%	45210.6	98166.76	
lo	recruitment	60%	45210.6	101311.8	3.20%
disc	recruitment	70%	43757.1	102195.4	
lo	recruitment	70%	43757.1	99533.6	-2.61%
disc	recruitment	80%	42310	99899.58	
lo	recruitment	80%	42310	91100.42	-8.81%
disc	recruitment	90%	40879.9	98137.06	
lo	recruitment	90%	40879.9	93822.83	-4.40%
disc	recruitment	100%	39492.7	95854.06	
lo	recruitment	100%	39492.7	92911.59	-3.07%
disc	ssb	0%	62636.45	57547.33	
lo	ssb	0%	62636.45	58370.15	1.43%
disc	ssb	10%	61989.54	56050.97	
lo	ssb	10%	61989.54	57340.69	2.30%
disc	ssb	20%	61338.52	54409.71	
lo	ssb	20%	61338.52	55743.25	2.45%
disc	ssb	30%	60683.16	51368.52	
lo	ssb	30%	60683.16	53978.31	5.08%
disc	ssb	40%	60022.9	50490.32	
lo	ssb	40%	60022.9	53272.63	5.51%
disc	ssb	50%	59357.18	49048.4	
lo	ssb	50%	59357.18	51989.64	6.00%
disc	ssb	60%	58685.35	46567.03	
lo	ssb	60%	58685.35	50759.38	9.00%
disc	ssb	70%	58006.79	45512.22	
lo	ssb	70%	58006.79	48679.09	6.96%
disc	ssb	80%	57320.5	43568.76	
lo	ssb	80%	57320.5	48330.28	10.93%
disc	ssb	90%	56627.14	41760.59	
lo	ssb	90%	56627.14	48048.03	15.06%

Scenario	Indicator	Discard survival	2016	2066	Percentage change
disc	ssb	100%	55930.06	41670.32	
lo	ssb	100%	55930.06	47216.53	13.31%
disc	stock	0%	72111.78	72073.57	
lo	stock	0%	72111.78	72373.28	0.42%
disc	stock	10%	71268.4	69820.81	
lo	stock	10%	71268.4	70717.7	1.29%
disc	stock	20%	70420.78	66730.08	
lo	stock	20%	70420.78	69586.79	4.28%
disc	stock	30%	69568.68	64244.42	
lo	stock	30%	69568.68	66407.63	3.37%
disc	stock	40%	68711.55	63213.02	
lo	stock	40%	68711.55	66287.91	4.86%
disc	stock	50%	67848.97	61425.85	
lo	stock	50%	67848.97	64506.35	5.02%
disc	stock	60%	66980.34	58787.9	
lo	stock	60%	66980.34	62229.21	5.85%
disc	stock	70%	66105.54	57382.56	
lo	stock	70%	66105.54	60269.45	5.03%
disc	stock	80%	65224.42	55716.43	
lo	stock	80%	65224.42	59640.99	7.04%
disc	stock	90%	64339.41	53023.19	
lo	stock	90%	64339.41	58957.58	11.19%
disc	stock	100%	63458.14	53104.45	
lo	stock	100%	63458.14	58202.76	9.60%

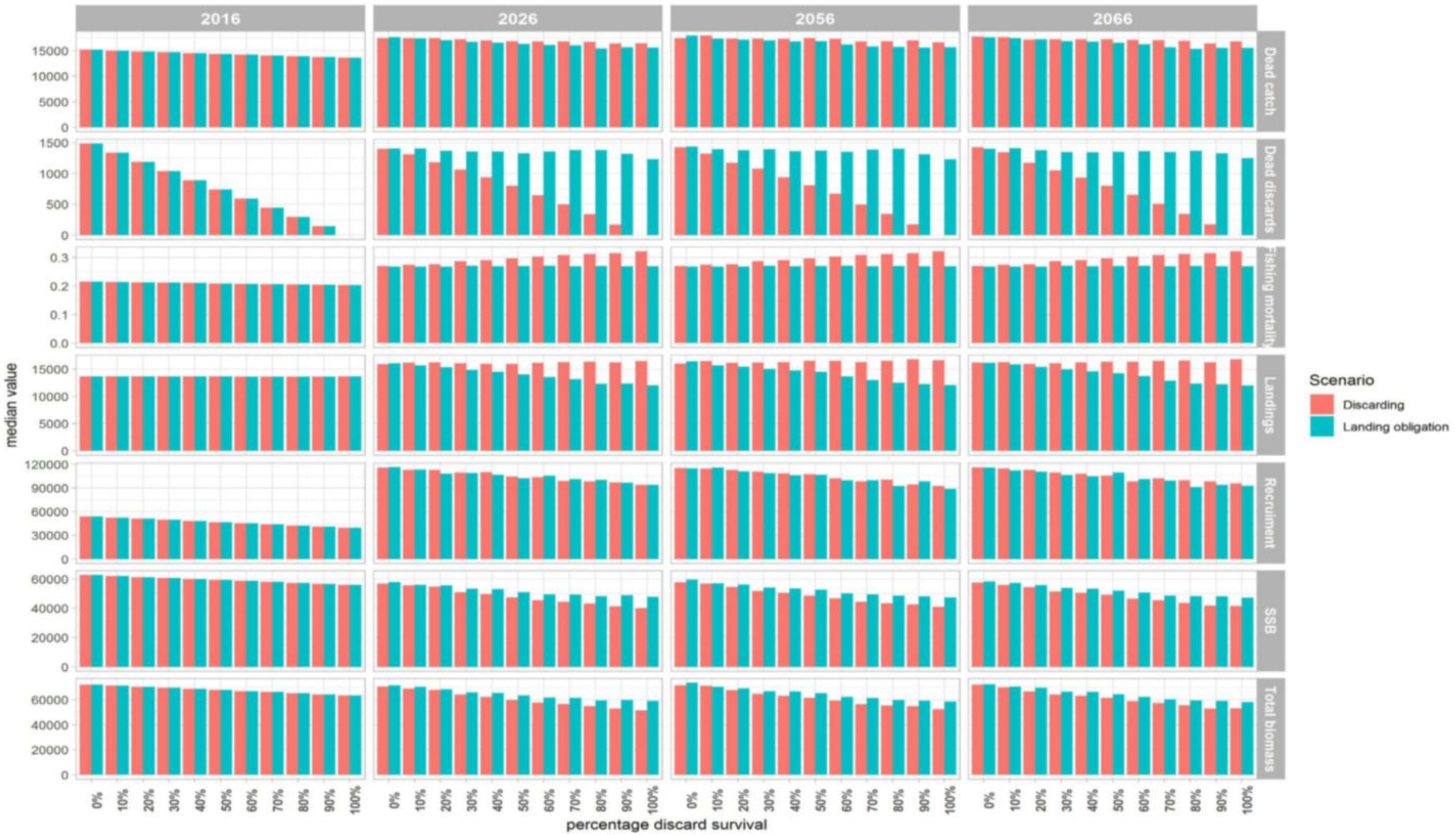

Figure 3.11: Median results of the forecast simulation of North Sea sole for different levels of discard survival and for the years 2016,2026, 2056, and 2066.

3.3.2 North Sea plaice

3.3.2.1 F-targets

First F-targets for the landing obligation scenario were calculated by resetting the discards to the total observed discards (which are the discards observed in the stock assessment with 0% discard survival), thus assuming the current gear selectivity. These F-targets are presented in Figure 3.12. These F-targets are approximately constant for different levels of discard survival.

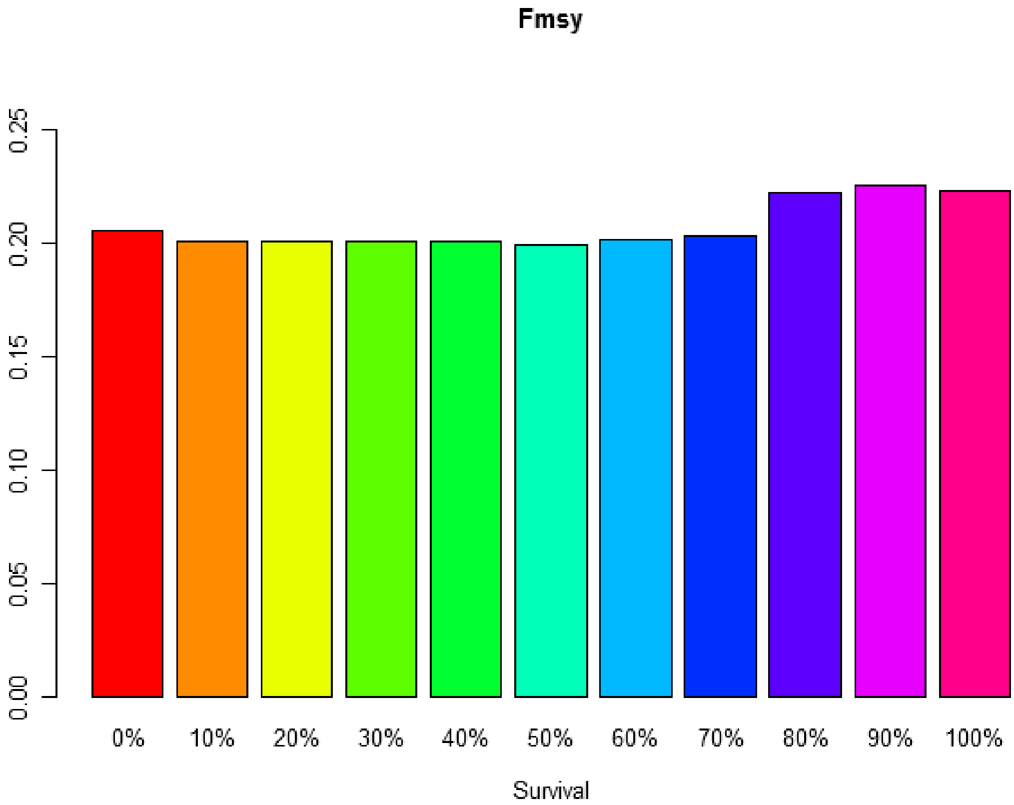

Figure 3.12: F-targets of North Sea plaice for the landing obligation scenario of forecast simulation for different levels of discard survival (0% to 100% discard survival).

3.3.2.2 Forecast simulation

The forecast simulation of North Sea plaice under the discarding scenario is shown for 0%, 20%, 40%, 60%, 80%, and 100% discard survival on Figure 3.13.

The forecast simulation of North Sea sole under the landing obligation scenario is shown for 0%, 20%, 40%, 60%, 80%, and 100% discard survival on Figure 3.14.

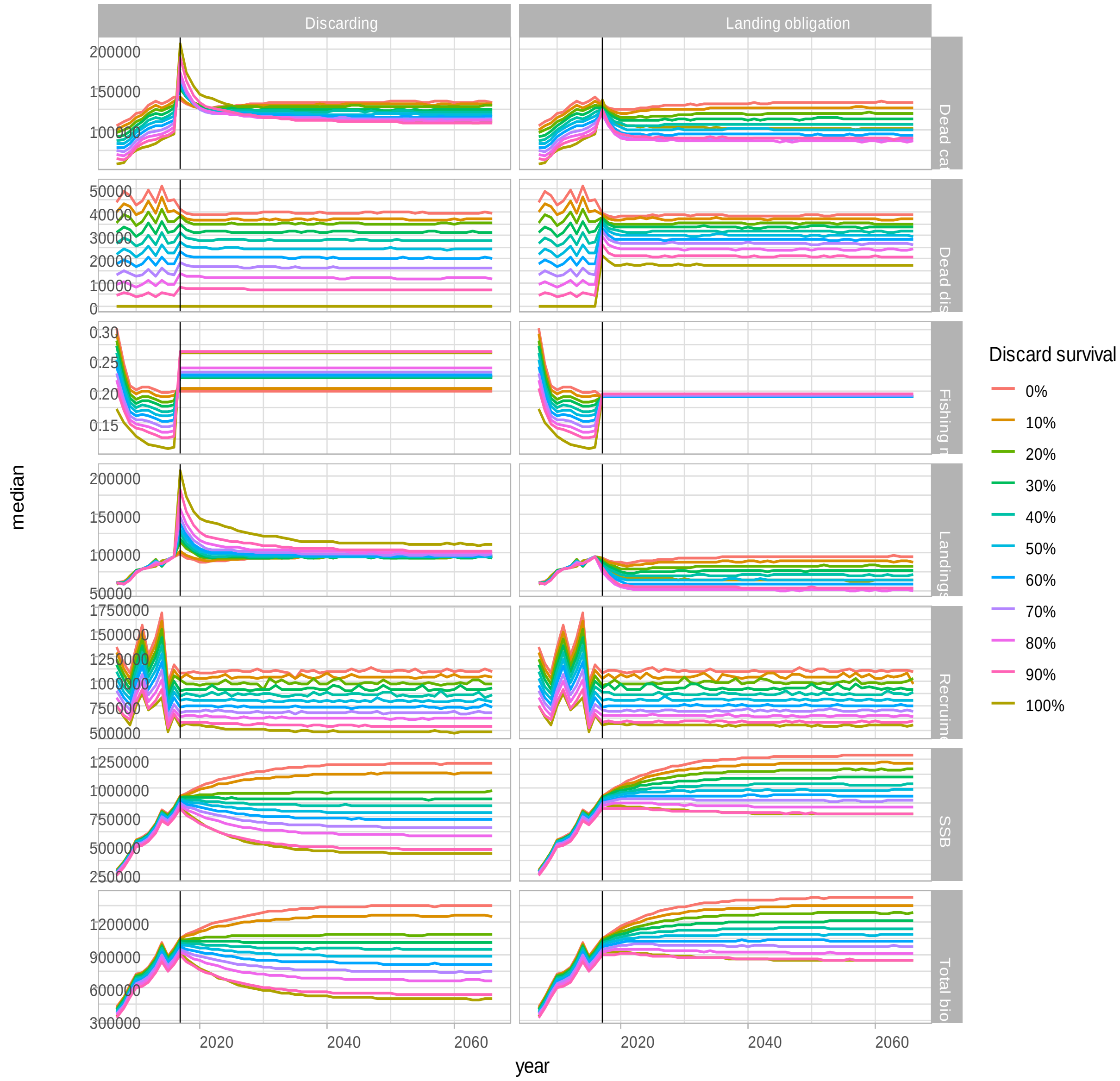

Figure 3.15: Forecast simulation of North Sea plaice under two scenarios (only median values).

3.3.2.3 Comparing discarding and landing obligation scenario

The median results of the forecast simulation of North Sea plaice for both the discarding as the landing obligation scenario for different levels of discard survival (0% to 100%) are shown on Figure 3.16. Only the results for the years 2021, 2031 and 2066 are shown for practical reasons.

The results clearly show less landings of North Sea plaice under the landing obligation scenario than under the discarding scenario for the same discard survival levels. Also dead discards are greater under the landing obligation scenario than under the discarding scenario, since with discarding the fish that is set overboard will have a chance to survive. Under the discarding scenario, the fishing mortality can be higher than under the landing obligation for the same discard levels.

Median results of forecast simulation of North Sea plaice under the discarding and landing obligation scenarios for different levels of discard survival and for the years 2021, 2031, and 2066.

The median results for landings, dead discards, ssb, and stock per 5-year step and the percentage change after the forecast simulation period between both scenarios are presented in Table 3.3.

Table 3.4: Median results per 5-year step and percentage change after forecast of North Sea plaice.

Scenario	Indicator	Discard survival	2016	2066	Percentage change
disc	catch	0%	139769.3	134216.3	
lo	catch	0%	139769.3	134015.1	-0.15%
disc	catch	10%	135232.5	131603.6	
lo	catch	10%	135232.5	126644	-3.77%
disc	catch	20%	130684.4	130188.7	
lo	catch	20%	130684.4	119473.7	-8.23%
disc	catch	30%	126121.7	125105.1	
lo	catch	30%	126121.7	113475.7	-9.30%
disc	catch	40%	121539.4	122059	
lo	catch	40%	121539.4	106495.3	-12.75%
disc	catch	50%	116930.1	118336.9	
lo	catch	50%	116930.1	100107.5	-15.41%
disc	catch	60%	112281.8	116159.8	
lo	catch	60%	112281.8	93907.5	-19.16%
disc	catch	70%	107572	113267.1	
lo	catch	70%	107572	87662.51	-22.61%
disc	catch	80%	102753.2	111351.6	
lo	catch	80%	102753.2	85756.57	-22.99%
disc	catch	90%	97698.96	107656.2	
lo	catch	90%	97698.96	89474.28	-16.89%
disc	catch	100%	94343.45	110198.8	
lo	catch	100%	94343.45	101135.6	-8.22%
disc	discards	0%	45146.27	39555.22	
lo	discards	0%	45146.27	38525.51	-2.60%
disc	discards	10%	40605.37	36778.37	
lo	discards	10%	40605.37	36993.21	0.58%
disc	discards	20%	36068.43	35057.11	
lo	discards	20%	36068.43	34964.1	-0.27%
disc	discards	30%	31535.29	31324.59	
lo	discards	30%	31535.29	33336.17	6.42%
disc	discards	40%	27005.92	27604.28	
lo	discards	40%	27005.92	31544.65	14.27%
disc	discards	50%	22479.85	24386.07	
lo	discards	50%	22479.85	29757	22.03%
disc	discards	60%	17956.75	20445.1	
lo	discards	60%	17956.75	28294.66	38.39%
disc	discards	70%	13436.21	16313.27	
lo	discards	70%	13436.21	26260.61	60.98%
disc	discards	80%	8918.67	11745.86	
lo	discards	80%	8918.67	23996	104.29%
disc	discards	90%	4411.79	6775.23	
lo	discards	90%	4411.79	21027.53	210.36%

Scenario	Indicator	Discard survival	2016	2066	Percentage change
disc	discards	100%	0.01	0.02	
lo	discards	100%	0.01	17313.68	86568300%
disc	fbar	0%	0.2	0.2	
lo	fbar	0%	0.2	0.19	-5%
disc	fbar	10%	0.19	0.21	
lo	fbar	10%	0.19	0.19	-9.52%
disc	fbar	20%	0.19	0.22	
lo	fbar	20%	0.19	0.19	-13.64%
disc	fbar	30%	0.18	0.22	
lo	fbar	30%	0.18	0.19	-13.64%
disc	fbar	40%	0.17	0.22	
lo	fbar	40%	0.17	0.19	-13.64%
disc	fbar	50%	0.16	0.23	
lo	fbar	50%	0.16	0.19	-17.39%
disc	fbar	60%	0.15	0.23	
lo	fbar	60%	0.15	0.19	-17.39%
disc	fbar	70%	0.15	0.23	
lo	fbar	70%	0.15	0.19	-17.39%
disc	fbar	80%	0.14	0.24	
lo	fbar	80%	0.14	0.2	-16.67%
disc	fbar	90%	0.13	0.26	
lo	fbar	90%	0.13	0.2	-23.08%
disc	fbar	100%	0.11	0.26	
lo	fbar	100%	0.11	0.19	-26.92%
disc	landings	0%	94622.98	93969.88	
lo	landings	0%	94622.98	94559.15	0.63%
disc	landings	10%	94627.07	94175.14	
lo	landings	10%	94627.07	87579.9	-7.00%
disc	landings	20%	94615.93	93627.81	
lo	landings	20%	94615.93	81440.57	-13.02%
disc	landings	30%	94586.4	93014.18	
lo	landings	30%	94586.4	76240.48	-18.03%
disc	landings	40%	94533.46	93314.74	
lo	landings	40%	94533.46	69973.42	-25.01%
disc	landings	50%	94450.21	93665.89	
lo	landings	50%	94450.21	64187.63	-31.47%
disc	landings	60%	94325.02	95144.78	
lo	landings	60%	94325.02	58112.75	-38.92%
disc	landings	70%	94135.81	96647.93	
lo	landings	70%	94135.81	52294.74	-45.89%
disc	landings	80%	93834.48	99121.12	
lo	landings	80%	93834.48	50059.16	-49.50%
disc	landings	90%	93287.17	100709.1	
lo	landings	90%	93287.17	53160.07	-47.21%

Scenario	Indicator	Discard survival	2016	2066	Percentage change
disc	landings	100%	94343.44	110198.8	
lo	landings	100%	94343.44	63110.86	-42.73%
disc	recruitment	0%	1173720	1100396	
lo	recruitment	0%	1173720	1102484	0.19%
disc	recruitment	10%	1118150	1048717	
lo	recruitment	10%	1118150	984119.1	-6.16%
disc	recruitment	20%	1062200	981998.7	
lo	recruitment	20%	1062200	1033830	5.28%
disc	recruitment	30%	1005800	932353.9	
lo	recruitment	30%	1005800	928857.3	-0.38%
disc	recruitment	40%	948912	864004.8	
lo	recruitment	40%	948912	899689.8	4.13%
disc	recruitment	50%	891553	798234.5	
lo	recruitment	50%	891553	817715.2	2.44%
disc	recruitment	60%	833890	740056.3	
lo	recruitment	60%	833890	759118.7	2.58%
disc	recruitment	70%	776466	681236.5	
lo	recruitment	70%	776466	701900.1	3.03%
disc	recruitment	80%	720918	637663.5	
lo	recruitment	80%	720918	652396.3	2.31%
disc	recruitment	90%	672663	548191.6	
lo	recruitment	90%	672663	598203.9	9.12%
disc	recruitment	100%	661220	490220.8	
lo	recruitment	100%	661220	557327	13.69%
disc	ssb	0%	836066.4	1216275	
lo	ssb	0%	836066.4	1291648	6.20%
disc	ssb	10%	831259.1	1129829	
lo	ssb	10%	831259.1	1219823	7.97%
disc	ssb	20%	825634.1	972919.4	
lo	ssb	20%	825634.1	1164135	19.65%
disc	ssb	30%	819000.3	904485.1	
lo	ssb	30%	819000.3	1097761	21.37%
disc	ssb	40%	811122.1	846348.8	
lo	ssb	40%	811122.1	1033003	22.05%
disc	ssb	50%	801700.8	784446.7	
lo	ssb	50%	801700.8	984822.4	25.54%
disc	ssb	60%	790347.4	722752.4	
lo	ssb	60%	790347.4	933240.4	29.12%
disc	ssb	70%	776493.6	655446.5	
lo	ssb	70%	776493.6	892176.7	36.12%
disc	ssb	80%	759121.4	587074.9	
lo	ssb	80%	759121.4	832414.6	41.79%
disc	ssb	90%	735799.1	462703.8	
lo	ssb	90%	735799.1	776468.1	67.81%

Scenario	Indicator	Discard survival	2016	2066	Percentage change
disc	ssb	100%	769693.1	427375.1	
lo	ssb	100%	769693.1	772125.3	80.67%
disc	stock	0%	956572.2	1345163	
lo	stock	0%	956572.2	1423834	5.85%
disc	stock	10%	947344.2	1249819	
lo	stock	10%	947344.2	1342045	7.38%
disc	stock	20%	937249.4	1086469	
lo	stock	20%	937249.4	1278572	17.68%
disc	stock	30%	926083.6	1015132	
lo	stock	30%	926083.6	1208479	19.05%
disc	stock	40%	913595.9	945809.7	
lo	stock	40%	913595.9	1135667	20.07%
disc	stock	50%	899468.5	882312.9	
lo	stock	50%	899468.5	1079841	22.39%
disc	stock	60%	883288.7	814108.2	
lo	stock	60%	883288.7	1024518	25.85%
disc	stock	70%	864455	744007.3	
lo	stock	70%	864455	975765.5	31.15%
disc	stock	80%	841893.2	666914.3	
lo	stock	80%	841893.2	911479.4	36.67%
disc	stock	90%	813020.4	534322.8	
lo	stock	90%	813020.4	853109.6	59.66%
disc	stock	100%	843931.7	494111.2	
lo	stock	100%	843931.7	845866.9	71.19%

Figure 3.16: Median results of the forecast simulation of North Sea plaice for different levels of discard survival and for the years 2016, 2026, 2056, and 2066.

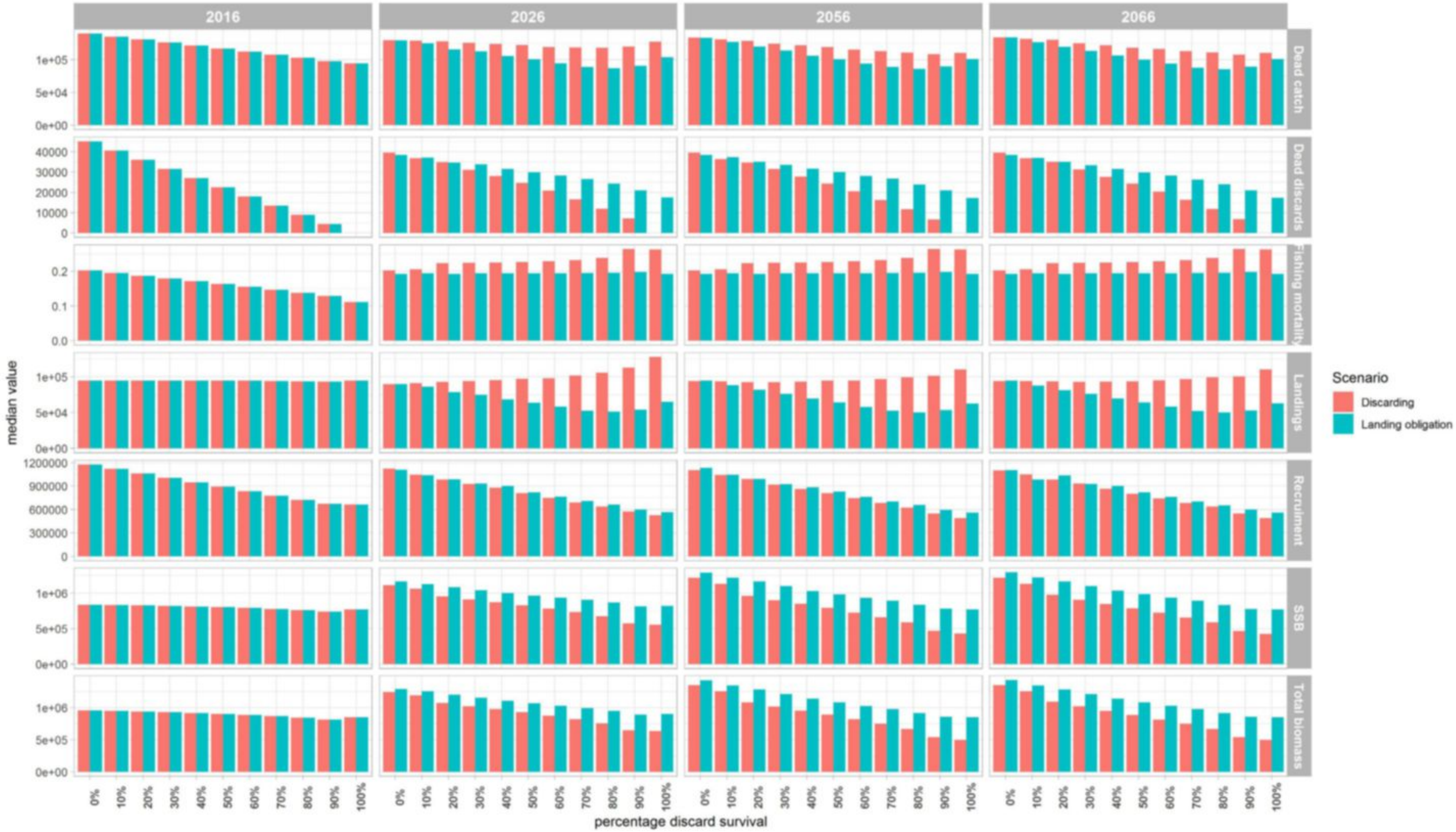

Figure 3.16: Median results of the forecast simulation of North Sea plaice for different levels of discard survival and for the years 2016, 2026, 2056, and 2066.

4 Discussion and conclusion

This study evaluated discard survival effect on the current assessment of North Sea sole and plaice. For both stocks experiments have shown that at least part of the discarded fish have potential to survive the catch process (van der Reijden et al. 2017). This would imply that the current assessments, assuming 0% discard survival, are biased.

The results shown in Chapter 3.1 show that when discard survivability is taken into account in the assessment of North Sea sole and plaice, the perception and trend of the stock does not change. But the fishing mortality, stock biomass, and recruitment are overestimated. The scale of the effect of the discard survival in the assessment is depending on the characteristics of the stock (such as maturity at age) and the extent to which the part of the stock is being discarded. The effect of discard survival is greater in North Sea plaice than in North Sea sole, since the plaice is discarded more.

Also reference points change when discard survivability is taken into account. The Fmsy reference points increase with increasing discard survivability (Chapter 3.2). However, the “F-targets”, the F corresponding to the maximal yield under the landing obligation, that are calculated to simulate the “landing obligation-scenario” do not show the same trend with increasing discard survivability (Chapter 3.3.2.1). This can be explained because that when the landing obligation is implemented fishing mortality is higher on the younger ages (all discards are landed, and discards consist mainly of younger ages).

In order to get the highest yield under the landing obligation, the individual fish need to be able to grow (a compromise between catching many small individuals or catching fewer but larger individuals). With a lower F, the individual growth in the stocks is ensured, and the yield can be higher.
On the opposite, if there isn’t any substantial fishing mortality on the younger ages and F only peaks at older ages (such as when discards are able to survive), the individual fish get to grow fully and can be exploited with a higher F.

The forecast simulation of North Sea sole and plaice was performed by projecting the stocks with targets for fishing mortality that maximise the yield of both stocks. Differences between scenarios increase with increasing discard survivability, although differences are marginal in the simulation of sole (compared to the differences between scenarios in plaice). Mainly the catches are effected by discard survivability under the landing obligation scenario.

The methodology used in the forecast simulation of North Sea sole and plaice gives insight in the effects of the discarding and landing obligation scenario on the catches, recruitment, spawning stock biomass, and fishing mortality. However, the most appropriate methodology to compare the effects of both scenarios would have been under a management strategy evaluation framework in which the assumption is made that the biological population has some degree of survival but that the assessment accounts for all discards and fishing mortality of those discards.

Finally, the discard survivability is assumed to be constant over all ages in the North Sea sole and plaice stocks in this study. However, there is evidence that discard survivability is not constant over all ages (Revill et al., 2013). The addition of age-specific discard rates would shed more light on the effect of discard survivability on the stocks of North Sea sole and plaice. But length-specific discard survivability estimates are not yet available (length-specific estimates can be converted to age-specific estimates with the von Bertalanffy growth equation) and were therefore not included in this study.

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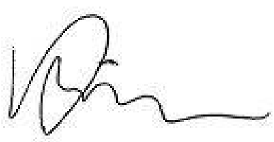
Justification

Report C075/18A
Project Number: 4311400005

Dit rapport is met grote zorgvuldigheid tot stand gekomen. De wetenschappelijke kwaliteit is intern getoetst door een collega-onderzoeker en het verantwoordelijk lid van het managementteam van Wageningen Marine Research

Approved: Ir. N.T. Hintzen
Research scientist



Signature:

Date: 22 October 2018

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Wageningen Marine Research levert met kennis, onafhankelijk wetenschappelijk onderzoek en advies een wezenlijke bijdrage aan een duurzamer, zorgvuldiger beheer, gebruik en bescherming van de natuurlijke rijkdommen in zee-, kust- en zoetwatergebieden.

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