Potential approaches to use the range of values for Fmsy in mixed fisheries management

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IMARES WAGENINGEN UR

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Illustration of the consequences for the Dutch demersal fleets and potential issues under the EU landings obligation

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Contents

Summary

The new Common Fisheries Policy marks a number of key changes to European fisheries management, including (a) the introduction of multi-annual management plans aimed at achieving the Maximum Sustainable Yield (MSY) for all stocks and (b) the gradual introduction of a landings obligation to encourage more selective fishing practices. Their implementation cannot be seen in isolation from each other as strategies aimed at one objective may have consequences for achieving the other. To support the (inter)national discussion on management strategies in relation to these changes, the Ministry of Economic Affairs (EZ) asked IMARES to:

- investigate potential benefits or losses per fleet for different management scenarios for F_{MSY}, including the identification of which species might act as choke species under these scenarios;
- identify potential issues resulting from combination of the implementation of mixed fisheries management under a landings obligation.

The report presents mixed fisheries forecasts of the catches expected for the year 2016 for a range of management options representing different ways of using the F_{MSY} ranges. The forecasts are based on a mixed fisheries model developed by the ICES Working Group on mixed fisheries and values for F_{MSY} approved by its Advisory Committee. The forecasts are all conditional to behavioural scenarios on how the fleets will react to management constraints. The two extreme scenarios represent situations where the activity of each fleet stops as soon as the fleet's quota for one of the species is exhausted ("min" scenario), or, on the opposite, continues as long as the fleet has quota available ("max" scenario). The forecasts also include intermediate scenarios such as a status quo effort situation or a scenario where the effort corresponds to maximal economic yield.

Without clear indication on the most likely behavioural scenario, it is difficult to clearly identify which of them is performing best. Nonetheless, general observations can be made:

- the management option in which the TAC for all stocks is based on a target fishing mortality equal to the higher bound of the F_{MSY} ranges will produce the highest yields in the short term, but will increase the magnitude of TAC overshooting (in the "max" scenario) or undershooting (in the "min" scenario);
- using an optimization procedure, it is possible to find the optimal fishing mortality values within the FMSY range of each stock, so that the TACs set would result in overshoot (in a "max" scenario) or undershoot ("min" scenario) being as small as possible. This situation of 'minimal tension in the system' is achieved by lowering the target fishing mortality on the stocks with the largest TACs towards the lower bound of the F_{MSY} range, and increasing the target on the stocks with limiting TACs towards the upper bound of the ranges. In a situation where the fleets stop fishing when they reach their first quota, the catches resulting from setting the TAC based on the optimisation procedure are as high as when the TACs are set based on the upper bound of the F_{MSY} range. However, if the fleets have the possibility to overshoot, this "optim" management option will not allow for yields as high compared to the situation when the upper bound of the ranges is used for all stocks.

The implementation of the landing obligation is expected to result in changes in operational fishing practices due to discards obtaining a value, either through direct sales or through opportunities caused by quota uplifts; in a worst case scenario a 'race to fish' could become reality. This could lead to fishing mortality levels for individual species that are not optimal from a mixed fishery perspective or go outside F_{MSY} ranges. These dynamics have not (yet) been taken into account in the model and the short term forecasts in this report.

While this report presents the results of a first exercise in developing short term optimisation forecasts for mixed fisheries scenarios and is based on a model that is still in development, the approach taken in this project has strong potential in facilitating an informed policy discussion on the potential issues and risks associated with choosing different management scenarios for different fleets and Member States. A request to ICES to assess its current mixed fisheries advice and include optimisation scenarios for F-values would be useful in view of the policy discussion on the new multiannual mixed fisheries plan for the North Sea.

1 Background

The new Common Fisheries Policy (CFP) marks a number of key changes to European fisheries management, including (a) the introduction of multi-annual management plans aimed at achieving the Maximum Sustainable Yield (MSY) for all stocks and (b) the gradual introduction of a landings obligation to encourage more selective fishing practices. The implementation of these management objectives cannot be seen in isolation from each other as management strategies aimed at one objective may have consequences for achieving the other.

To support the national and international discussion on management strategies in relation to the introduction of multi-annual management plans for mixed fisheries and the landing obligation, the Ministry of Economic Affairs (EZ) asked IMARES to:

- investigate potential benefits or losses per fleet for different management scenarios for F_{MSY}, including the identification of which species might act as choke species under these scenarios;
- identify potential issues resulting from combination of the implementation of mixed fisheries management under a landings obligation.

The study was carried out within the EZ-programme *Beleidsondersteunend Onderzoek* (BO).

Under the new CFP, fisheries in each large maritime ecoregion in the EU should be managed based on Multi-annual plans (MAP), defining objectives, targets, and management rules for the relevant commercial stocks. Amongst others, the EU is currently preparing a multi-annual plan for the North Sea demersal stocks. The specificity of this plan is that mixed fisheries interactions should be taken into account. In mixed fisheries, different species are caught together by a same fleet, and therefore management actions aimed at one particular species may also have impact on other species. One of the challenges in developing the North Sea MAP is therefore to define management targets that are compatible between species caught in mixed fisheries.

One of the key objectives defined by the new CFP is achieving an exploitation rate (fishing mortality, F) consistent with MSY by 2015 and at the latest by 2020 for all stocks. In a mixed fisheries context, where exploitation levels of different species may be linked together, achieving simultaneously exploitation at F_{MSY} for all species might not be feasible: reaching F_{MSY} for some more productive species may imply exceeding F_{MSY} for other less productive species (and vice versa) caught at the same time in a mixed fishery. In order to introduce more flexibility, the European commission considers extending the definition of MSY by using ranges of values for F_{MSY}. ICES (2014) produced on the request of the commission F_{MSY} range values for a list of Baltic Sea and North Sea stocks. These F_{MSY} ranges are calculated so that a fishing mortality level taken within the range would lead, if applied consistently in the long term, to landings that are at least 95% of the MSY.

The European Commission requested STECF to carry out an evaluation of a proposal for the North Sea MAP (STECF, 2015). However, in absence of concrete instructions on how to use the F_{MSY} ranges in this evaluation, STECF only compared the management strategies in which either F_{MSY}, or the upper or lower bounds of the ranges were used as single fixed management target for all stocks. The latest ICES methods working group for mixed fisheries (ICES 2015a) then proposed a method based one a minimization of the incompatibilities between the single species TACs (i.e. risk of over-quota discarding, or loss of fishing opportunities) to find the most parsimonious F value within the F_{MSY} range of each species.

Borrowing the methodological framework developed by ICES to formulate its mixed fisheries advice (ICES, 2015b), this report revisits the work from both STECF and ICES and presents the TACs and expected corresponding landings for the 6 main fish stocks in the North Sea, resulting from different potential implementation of the F_{MSY} range concept in management strategies. Quota shares, landings and effort are also given for each of the Dutch demersal fleets.

Mixed fisheries are typically fisheries in which unwanted bycatch occurs due to species and fisheries interactions. More selective fisheries practices could result in less unwanted by-catch and potentially further reduce fishing mortality. To encourage increased selectivity, a landing obligation (LO) is gradually being introduced as part of the new CFP. In North Sea fisheries, all catches of commercial target species will need to be landed by the end of 2019. To manage the transition from a fisheries management system which is effectively based on landings to a management system that is based on actual catches, a system of quota uplifts will be introduced. This report also discusses potential issues resulting from a combination of a LO and mixed fisheries management. Finding solutions for such issues are not within scope of this report.

2 Methods

2.1 Data used

The data used in the analyses presented here are the same data that were used to produce the 2015 ICES mixed fisheries advice for the North Sea (ICES 2015b):

- Catch and effort data for 39 North Sea fishing fleets for the year 2014,
- Stock assessment output for the 6 main commercial demersal stocks in the North Sea (cod, haddock, whiting, saithe, sole and plaice), giving estimates for abundance and fishing mortality at age for these stocks until the year 2014,
- ICES single stock TAC advice for these 6 stocks, giving the catch for 2016 resulting from the implementation of the management rule in place for each of the stocks.

An overview of these data can be found in the 2015 report of the ICES mixed-fisheries advice working group[1].

In addition, the values of the F_{MSY} ranges for the stocks were taken from the relevant ICES advice[2]. Note that no range values were calculated for whiting.

2.2 Mixed fisheries forecasts

The aim of the ICES mixed fisheries advice is to give an estimate of the likely catches for the most important North Sea demersal stocks corresponding to the TACs set for these stocks, when the mixed fisheries interactions are taken into account. The forecasts presented in this report are produced using the same methodology and data as used for the 2015 ICES mixed fisheries advice, based on the Fcube program (Ulrich et al., 2011).

In this framework, fishing activity is modelled at the scale of the fleet, which represents a group of vessels from a single country, with the same physical characteristics and predominant fishing gear during the year. The model has 39 fleets in the North Sea, of which 4 are from the Netherlands. There is no representation of the individual behaviour of each fishing vessel within each fleet. The assumption is that all vessels in a fleet behave in the same manner. The methodology can be summarized as follows (figure 1):

- Single stock TAC advice for 2016 is formulated based on stock assessments carried out in 2015.
- Quotas per species for 2016 are calculated for each fleet assuming “relative stability” (share of 2016 TAC = proportion of the 2014 landings).
- The effort (kw.day) required by each fleet to catch their quota for each species is calculated assuming constant catchability (relationship between fishing effort and fishing mortality)
- Different scenarios on the realized effort deployment for each fleet are the applied:
    - Scenario “max”: the realized effort of each fleet is calculated so that the fleets use up all their fishing quotas.
    - Scenario “min”: the realized effort of each fleet is calculated so that each fleet stops fishing as soon as one of its quota is exhausted.
    - Scenario “sq” (status quo): the effort of each fleet in 2016 is the same as in 2014.
- The catches in 2016 are forecasted on the basis of this realized effort.

1 http://ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2015/WGMIXFISH/01_WGMIXFISH-ADVICE%20Report%202015.pdf

2 http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2015/Special_Requests/EU_FMSY_ranges_for_selected_NS_and_BS_stocks.pdf

The “max” scenario is presented to illustrate the incentive for the fishermen to overshoot quotas in order not to lose any fishing opportunity. This scenario results in the largest efforts and substantial overshoot of the TAC of many species, and was considered unlikely. Under the LO however, marketable sized fish caught without quota will have to be landed and sold, which may result - and may even create an incentive for – quota overshoot. Unless some mechanism is put in place to prevent this from happening, there is a risk that the scenario “max” becomes more likely

The “min” scenario is the most precautionary situation, causing underutilization of the single-stock advice possibilities of other stocks. It is an unlikely scenario as long as discarding is allowed, this scenario reflects the constraints that result from a strictly implemented discard ban. The stock limiting the effort in this scenario can be considered as likely choke species, to which particular attention should be given.

Since 2015, the mixed fisheries advice uses catch limits instead of landings limits to reflect the implementation of the LO. The single stock TACs used in the input of the forecast correspond to the catch advice from ICES, including both landings and discards. While the model still computes landings and (former) discards separately, the forecasted catches, and the amount of over or undershoot now also represent the sum of marketable size fish and undersized fish. The assumption is made that discarding rates in 2016 are the same as in 2014. *In the remainder of the report, the term TAC is used to refer to the total catch limits.*

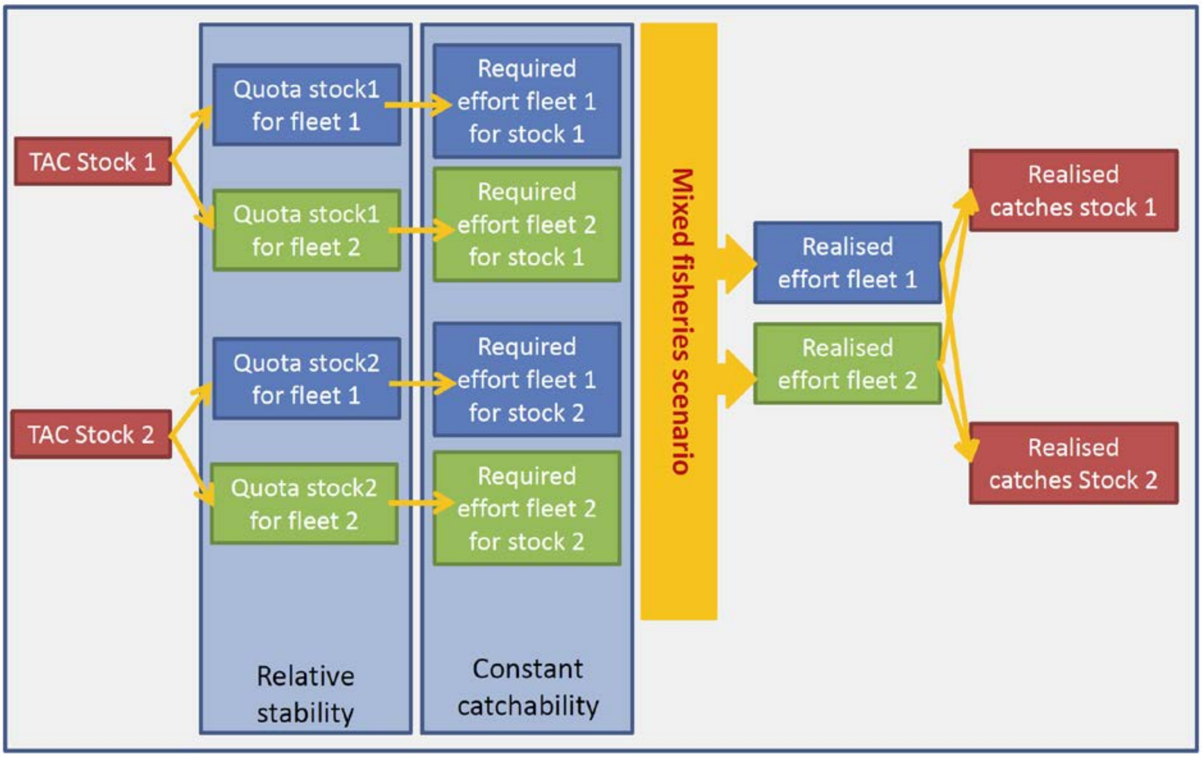


Figure 1: *Summary of the ICES mixed fisheries advice methodology. Forecast for the catches resulting from the single species TAC are made using information on the recent activity of the fleets, and formulating assumptions on individual fleet effort deployment (i.e. “max”, “min”, “status quo” scenarios, see text).*

2.3 Management options investigated

Four different management options, each using the F_{MSY} ranges in different ways, were investigated. For each of these four options, the corresponding 2016 TACs for the 6 species were calculated, and the mixed fisheries methodology was used to make projections of the resulting catches for each for the 3 mixed fisheries scenarios (“max”, “min” and “sq”), resulting in a total of 12 different forecasts.

The management options were as follows:

- MSY: The current ICES MSY approach, in which TAC for 2016 are calculated on the basis of the F_{MSY} for each stock.
- MSY high and MSY low: 2 extreme strategies, in which the TAC for 2016 are based for all stocks either on the upper bound of the F_{MSY} range or on the lower bound.
- Optim: A strategy in which an optimization procedure (ICES 2015a) is used to find, for each species, the fishing mortality within the F_{MSY} range to apply in 2016, resulting in the smallest incompatibilities between single stock TACs (i.e. minimum risk of over/under shooting quotas).

3 Results

3.1 Forecasted landings at the stock level

The optimization procedure finds, for each species, the fishing mortality within the F_{MSY} range (2016) that results in the smallest incompatibilities in relation to single stock TACs (i.e. minimum risk of over/under shooting quotas). In practice, the optimization looks for the set for F values for which the difference between the catches achieved in the mixed fisheries scenario “max” and the scenario “min” is the smallest.

Figure 2 shows for each species the upper and lower bounds of the ranges of F_{MSY}, the fixed point F_{MSY} and the F level that corresponds to the optimum for setting the TAC within a mixed fishery scenario. The optimization resulted in using a target fishing mortality close to the lower bound of the F_{MSY} range for plaice (PLE-NS) and haddock (HAD), close to the F_{MSY} point for cod (COD-NS), and in the upper part of the range for saithe (POK) and sole (SOL-NS). Since no range values are defined for whiting (WHG-NS), this species was not included in the optimization.

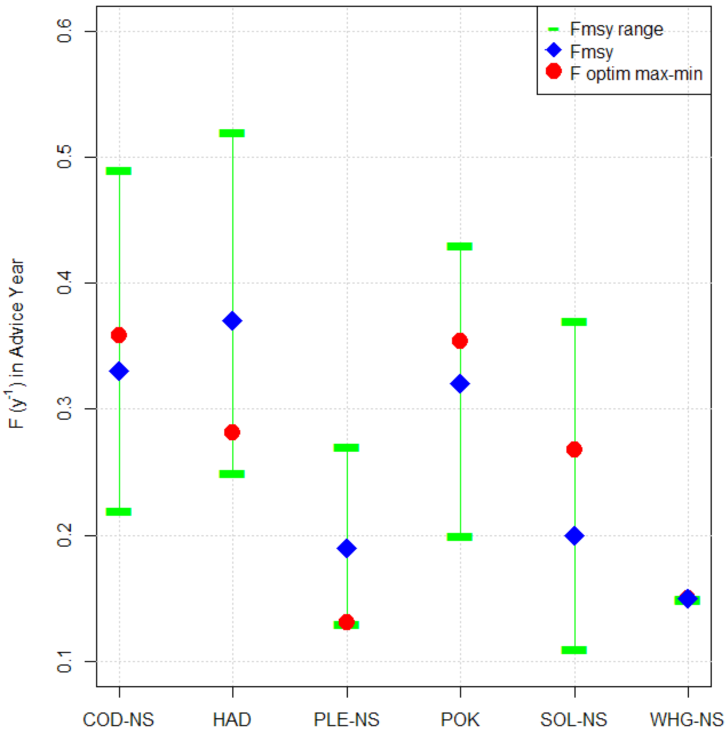


Figure 2: *F_{MSY} values and F_{MSY} ranges for the 6 main North Sea demersal stocks and fishing mortality (“optim”) minimizing the difference between the “max” and “min” scenarios (i.e. lower risk for quota over/under shoot).*

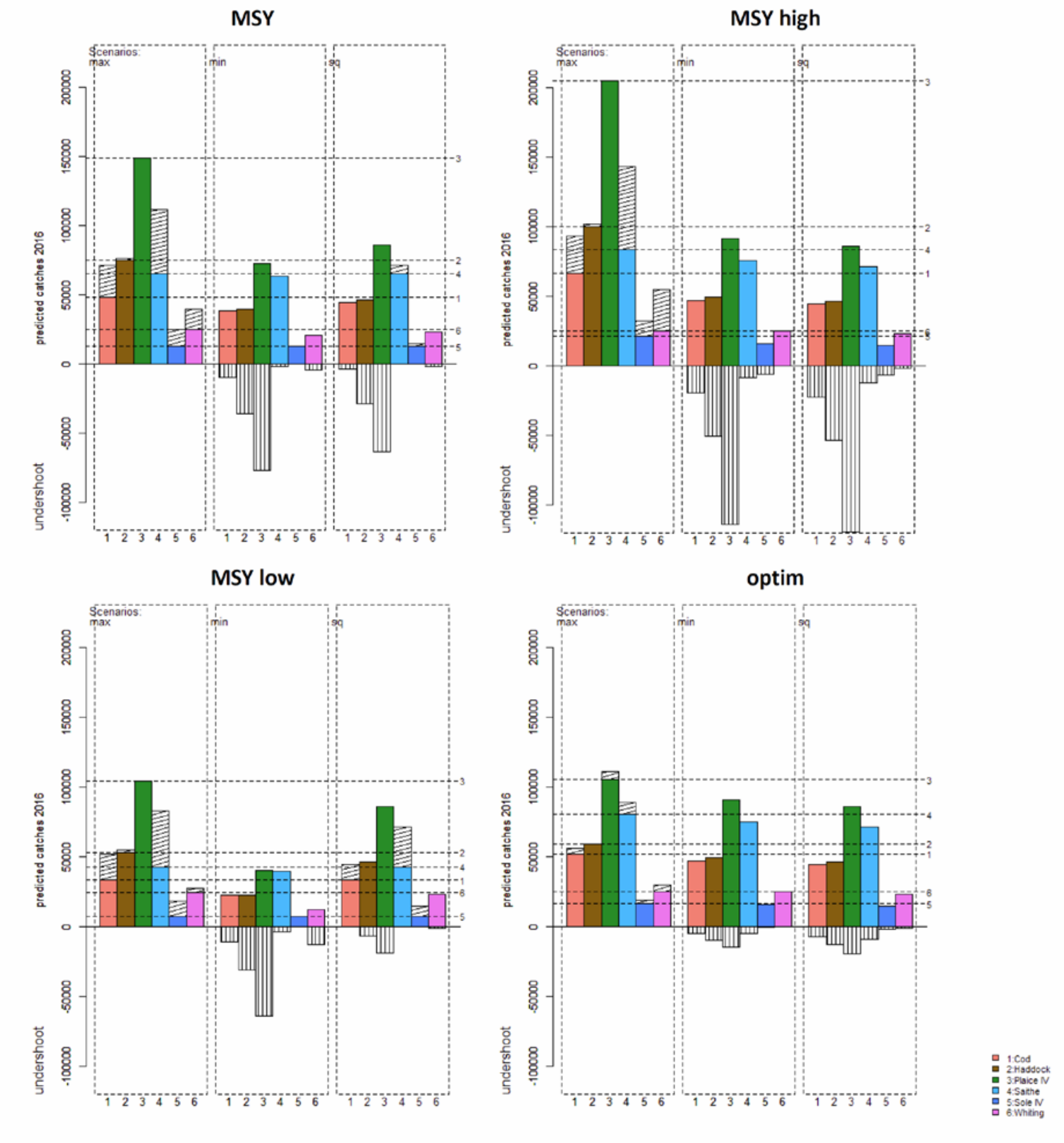
For the four management options (MSY, MSY high, MSY low and optim.), the TAC (total catch limits) for each of the species were calculated, and the ICES mixed fisheries framework was used to forecast the resulting catches, for the scenarios “max”, “min” and “status quo”. Figure 3 shows the predicted catches (sum of landings and discards) for each stock in all the scenarios (coloured bars). For the cases for which the catches exceed the TAC (indicated by the horizontal dashed lines with the number corresponding to each species), the part of the catches corresponding to the overshoot of the TAC is shown as a shaded area. Likewise, for cases for which the catches do not reach the TAC, the undershoot is represented by a bar with a negative value.

The performance of a management option can be judged on the basis of two criteria:

- the total amount of the catches, which should be maximized, and
- the magnitude of the incompatibility between single species TACs which should be minimized.

It can then be visualized by the overall amount of over/undershoot for each of the management options.

Figure 3: *Forecasted catches in 2016 for the 6 main North Sea demersal stocks, for the mixed*



fisheries scenario "max, "min" and "status quo" (see text for definition) calculated for TAC for 2016 based on four different management options (MSY, MSY high, MSY low nad optim). Horizontal dashed lines indicate the single stock TACs (defined as: sum of landings plus discards), vertical bars indicate the forecasted catches (coloured bars), with the shaded parts corresponding to quota overshoot (positive values) or undershoot (negative values).

The TACs resulting from the different management options (horizontal lines on figure 3) are, as expected, highest for all stocks (except whiting) when the upper bound of the F_{MSY} range is used, average when F_{MSY} is used, and lower when the lower bound of the range is used. As expected also, the TACs for the management option based on the optimization are lower for plaice and haddock (similar to when the lower bound of the range is used), slightly higher than when the F_{MSY} value is used for cod, and much higher than when the F_{MSY} value is used for saithe and sole. The TAC for whiting is the same in all cases, because there is no range defined for this stock.

In the first 3 management options, plaice and haddock are the two stocks requesting the largest effort for a full utilization of all the TACs. Catching entirely the TAC of these two stocks implies overshooting by a large percentage the TAC of the 4 other stocks ("max" scenario), except when the TAC are based on the lower bound of F_{MSY} range, where the overshoot for whiting is small.

In the "min" scenario, where each fleet stops fishing as soon as its smallest quota is reached, sole is the most limiting species in the management options using F_{MSY} and the lower bound the F_{MSY} range, and whiting is most limiting when the upper bound is used. In the three cases, there is a massive undershoot of the TAC for plaice and haddock and to a lesser extent for cod.

The results are contrasted across management options for the "status quo" scenario: if the TACs are set based on the upper bound of F_{MSY}, the TAC can be reached for none of the species, given the "status quo" effort level. When based on the F_{MSY} value, most TACs are reached, with only small over/under shoot, except for plaice and haddock for which the undershoot is large. If the lower bound of the F_{MSY} range is used, the undershoot is smaller for haddock and plaice, but the TAC is overshoot for cod and saithe.

For the management option using the optimization to set the target fishing mortality, the objective of minimizing the risk of TAC overshooting (in the "max" scenario) and undershooting (in the "min" scenario) is achieved. Catching entirely the TAC requesting the highest effort (haddock) only results in a marginal overshooting of the other stocks, whereas stopping fishing when the first TAC is reached (sole) causes only a small loss of fishing opportunity of the other stocks.

3.2 Forecasted landings and effort for the Dutch fleets

The mixed fisheries forecast can be broken down to the fleet level. The results specific to the 4 Dutch fleets, as identified by the ICES mixed fisheries working group, are given in this section.

3.2.1 Beam trawlers under 24m (figure 4)

The main species landed (among the 6 included in the forecast) are plaice and sole, with sole representing a slightly larger part of the landings than plaice.

Considering a "max" scenario, plaice is the species for which the TAC corresponds to the highest effort for the first 3 management options, and sole quota is exceeded. The highest landings are obtained for the management options based on the upper bound of the F_{MSY} range. The management option based on the optimization results in smaller quota for plaice and a larger quota for sole, with landings for those 2 stocks corresponding to the quotas. In this case cod is the stock requiring the largest effort.

In the "min" scenario, sole is limiting the effort of the fleet in the management option based on the F_{MSY} value and the option based on the lower bound of the range, while whiting is limiting in the 2 other options. The highest landings for both species are obtained for the two options for which whiting and not sole is limiting the effort (using the upper bound of the range and using the optimization).
In the "status quo" scenario, the landings are identical for all management options (same effort), but the sole quota is overshoot for the options using the F_{MSY} value and the one using the lower bound of the range.

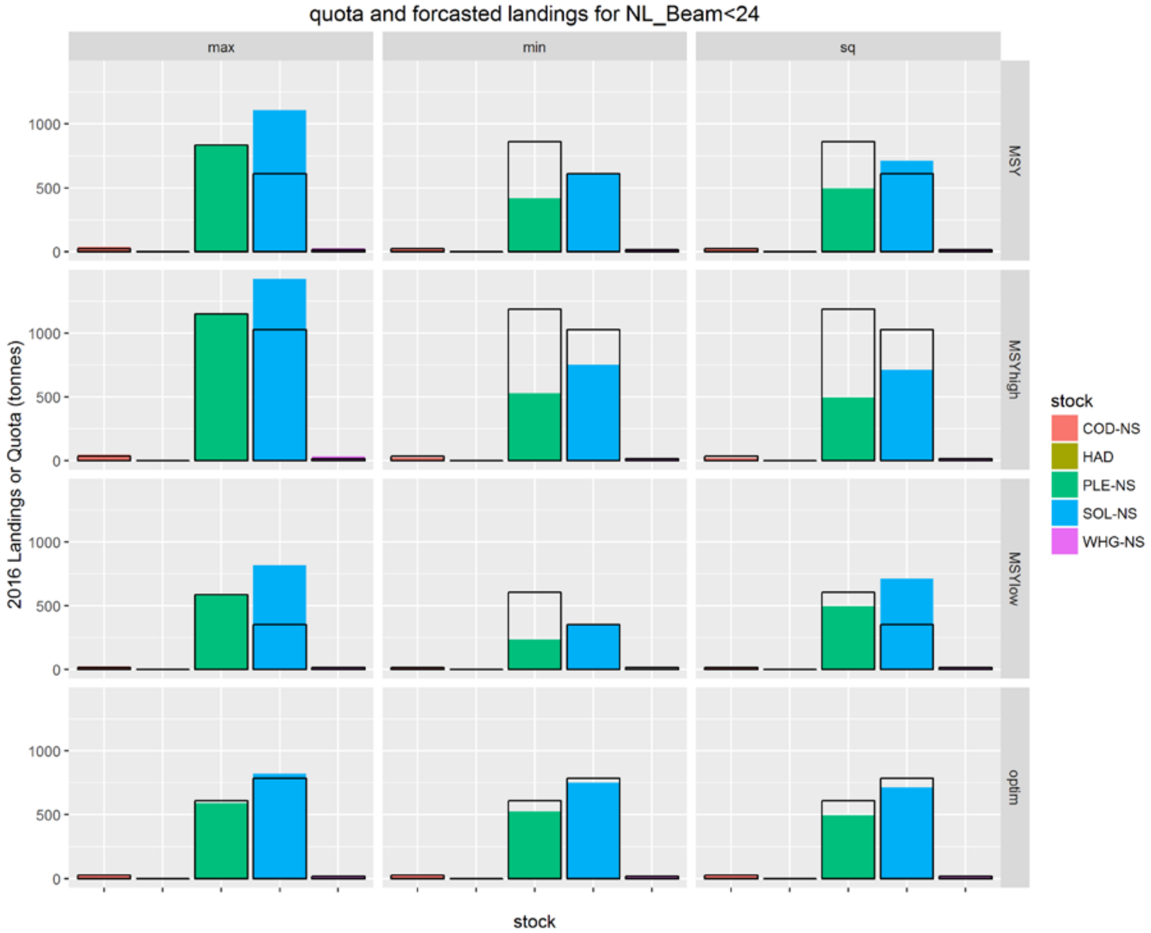


Figure 4: *Forecast of the landing (colored bars) and quota share (black transparent bars) for the Dutch beam trawlers under 24m for the 4 management options and the 3 mixed fisheries scenarios.*

3.2.2 Beam trawlers 24-40m (figure 5)

This fleet also catches mainly sole and plaice, with slightly higher plaice landings. The results for these fleet are quite similar to the results for the beam trawlers under 24m.

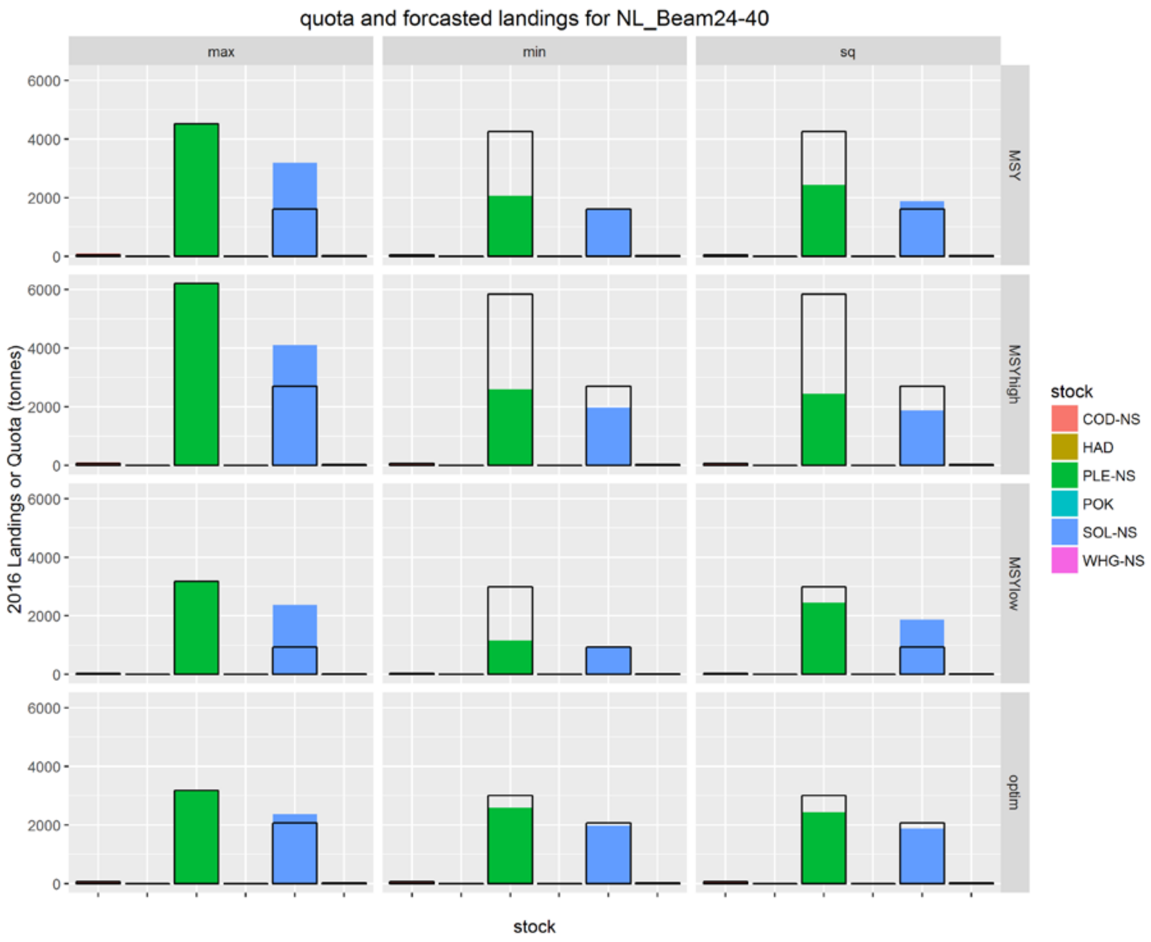


Figure 5: *Forecast of the landing (coloured bars) and quota share (black transparent bars) for the Dutch beam trawlers between 24m and 40m for the 4 management options and the 3 mixed fisheries scenarios.*

3.2.3 Beam trawlers larger than 40m (figure 6)

This fleet also catches mainly sole and plaice, with plaice being the most important species. Again, the results are broadly similar to the two other beam trawler fleets.

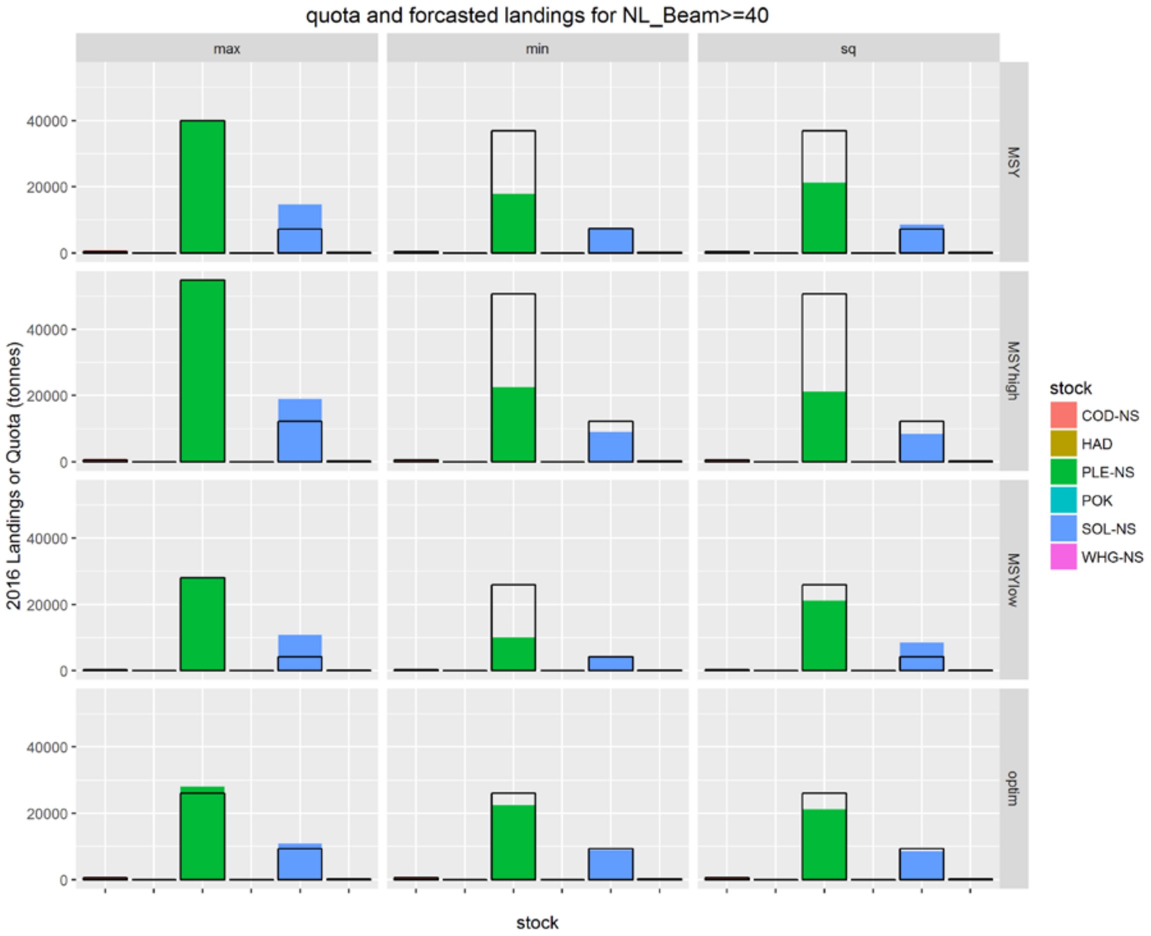


Figure 6: *Forecast of the landing (colored bars) and quota share (black transparent bars) for the Dutch beam trawlers larger than 40m for the 4 management options and the 3 mixed fisheries scenarios.*

3.2.4 Otter trawlers (figure 7)

The otter trawlers land mainly plaice, and to a smaller extent cod and whiting.

Considering a "max" situation, the haddock quota, although being small, is the one requiring the largest effort. For all management options, the landings are reasonably in line with the quotas, except for whiting when the upper bound of the F_{MSY} range is used.

In a "min" situation, again, sole is the limiting species if management is based on F_{MSY} value or the lower bound of the F_{MSY} range, and whiting is the limiting species for the two other options. The highest catches, especially for plaice, are obtained for these two options.

In the status quo scenario, the landings are identical for all management options (same effort), but the plaice quota is undershoot by a large percentage when the TAC is based on the F_{MSY} value and on the upper bound of the F_{MSY} range.

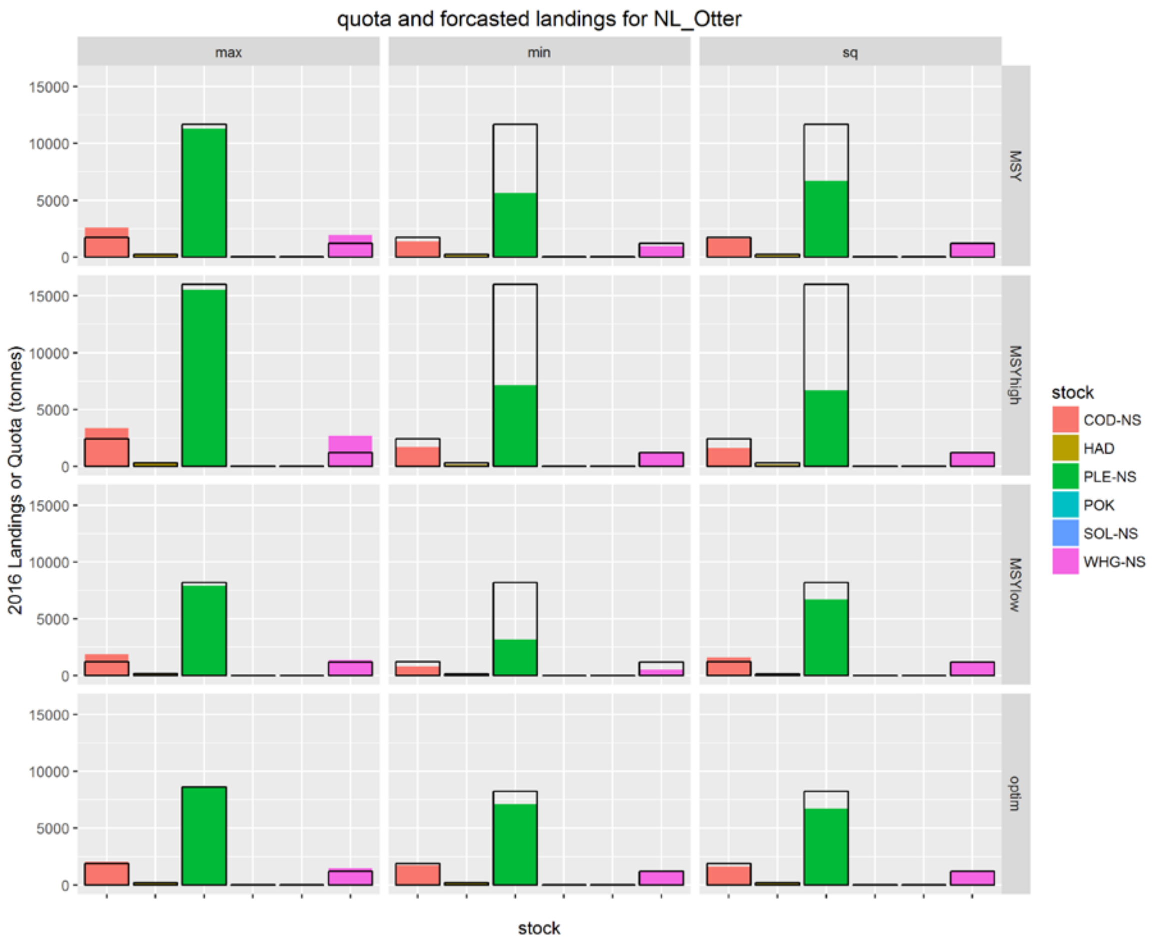


Figure 7: *Forecast of the landing (colored bars) and quota share (black transparent bars) for the Dutch otter trawlers for the 4 management options and the 3 mixed fisheries scenarios.*

4 Discussion

4.1 Management options

These forecasts give an illustration of consequences of applying different management options based on the use of the ranges for F_{MSY} in the mixed fisheries context.

A general observation from these results is that the highest yields in 2016, both when looking at the stock level, or at the scale of the Dutch fleets, are obtained when the TAC is based on the use of the upper bound of the F_{MSY} range for all species. However, in this case, there is a large unbalance between the TAC set (or the quota shares for the fleets) and the actual landings (large overshoot under the “max” scenario, large underutilization under the “min” scenario).

In a “min” situation, the yields obtained when TACs are set using the optimization procedure are as high as with the MSY high management option.

In both of these management options, the target fishing mortality for the limiting species (here sole) is increased compared to the default management option based on the F_{MSY} value. Considering a “min” situation, the effort of the different fleets can subsequently increase to the effort required to catch the quota of the second limiting species, whiting. This increased effort results in a higher catches for all species.

In addition to increasing the target fishing mortality of the limiting stocks, the optimization procedure also decreases the target for the stocks requiring the largest effort, thereby setting lower TACs. In a “min” situation, this has no consequence on the actual catches, since the TAC for e.g. plaice and haddock is not reached, but the magnitude of the TAC undershoot is smaller. There is therefore less interest for the fishermen to continue fishing to complete these quotas, which would also cause overshooting of the quotas of the more limiting species.

Finally, using only the lower bound of the F_{MSY} range also reduces the unbalanced between single species TACs (compared to the MSY option) but this option results in substantially smaller catches.

4.2 Limitations of the forecast

The ranges of value for F_{MSY} defined by ICES are in principle precautionary: applying consistently the upper bound of the range in the long term should result only in a low risk for the stock to be reduced to below safe biological limits. However, the ranges were estimated based on simulations not considering mixed fisheries interactions. Because of mixed fisheries interactions, exploiting one stock at the upper bound of the F_{MSY} range may result (in a “max” scenario) in exploiting other stocks with a fishing mortality higher than the upper bound of its range, and possibly at unsustainable levels. During its evaluation of the North Sea MAP, STECF (2015) noticed that when managing all stocks using the upper bound of the range, the biological risk for the period going to the year 2020 increased markedly for cod and sole.
Similarly, applying any fishing mortality value within the Fmsy ranges consistently in the long term (30-40 years) should bring the stock to an equilibrium situation where the yields are of at least 95% of the MSY. However, the results shown here are based on short-term forecast carried out over a period of time (2years) too short for the stock to reach an equilibrium. Therefore, in the results presented here, TAC based on the upper bound of the Fmsy range is higher than the TAC based on the lower bound.
It should also be noted that in a situation where the TACs are based on the output of the “optim” scenario, the fishing mortality applied to each stock can vary (within the F_{MSY} range) from one year to the next. Therefore, the long term equilibrium on which the MSY concept is based, may not be reached and consequently, the long term yields may not be as high as 95% of the MSY. A proper

evaluation of the performance of a management strategy based on the “optim” procedure is needed to quantify better the long term yields as well as the biological risk associated.
This study only includes the 6 largest demersal fish stocks and therefore presents a simplified perception of the mixed fisheries system in the North Sea. The results presented here can still be used to understand conceptually the differences between the 4 management options presented. However, in reality, it cannot be excluded that species not incorporated in this analyses play an important role, especially as choke species.

4.3 Mixed fisheries management considerations under a landings obligation

Due to species and fisheries interactions, there is a higher risk for unwanted by-catch in mixed fisheries and hence, discarding. There is a strong inverse relation between catch discarding and harvesting selectivity (Arnason, 2014). More selective fisheries could potentially further reduce fishing mortality. The LO, which will be introduced gradually as part of the new CFP, is seen as an incentive to encourage more selective fishing.

In North Sea fisheries, all catches of commercial target species must be landed by the end of 2019. Fishermen will be allowed to sell their ‘former discards’, implying that discards will get some market value. This could potentially create a perverse incentive to decreasing selectivity, for example if market prices for smaller fish are relatively high (e.g. Dover sole) or if the extra costs of landing the former discards are at or above the break-even point. Therefore, catches of fish under the minimum conservation reference size are not allowed to be sold for direct human consumption, and thus become a by-product having a much lower value than the marketable fish. As currently in most mixed fisheries, the benefits of selling the former discards seem to be well below the handling costs (Buisman *et al.,* 2013; Poelman *et al.*, 2015), there seems to be no immediate risk of substantial additional fishing pressure under the target species. There are, however, other issues that have to be taken into account. Combined, these could have implications for fishing pressure on individual stocks.

First, to facilitate the implementation of the LO, former discards that now must be landed will not be subtracted from the national TAC but there will be quota uplift. These uplifts are based on the information on total discards levels for each individual stock. Member States are responsible for managing the allocation of their national uplift, either by ‘banking’ the uplift using it to collectively manage the fisheries or by allocating ‘individual uplift quota’ to fishermen or vessels. Discards are well-known to vary per métier and in time and space (Quirijns *et al.*, 2014). In a mixed fishery scenario, each métier and even fishermen within a métier will have different incentives to optimize maximum net profit and will therefore have different needs for ‘uplift quota’. Therefore, the way the national uplift is going to be managed can have substantial consequences for ‘relative stability’ within the quota management system at fleet level; i.e., resulting in changing needs for quota swopping or leasing. Furthermore, if former discards get a market value or if fishermen ‘creatively’ use the quota uplift as a way to catch more marketable sized fish, this may lead to increases in fishing mortality for individual species.

Second, in a number of Member States around the North Sea, Individual Transferable Quota (ITQs) or other rights based quota allocation systems, such as vessel quota, have been introduced as part of the national fisheries management system (Symes *et al.*, 2003). In such systems, fishermen are only allowed to land those species for which they hold or lease a quota. In mixed fisheries in particular, ITQ systems have been criticised for creating additional incentives to discard fish when its market value is lower than its costs of catching and landing (OECD, 2011; Arnason, 2014; Batsleer *et al.*, 2015). On the other hand, in non-transferable quota systems, fishermen have no alternative but to discard all catches for which they have no quota so that they can keep fishing their remaining quota (OECD, 2011). Under a LO, however, these dynamics change, as fishermen must land all commercial species irrespective whether or not they have (individual) quota. Moreover, fishermen who hitherto did not have quota and were forced to discard, are now allowed to sell fish for which they have no quota entitlement under equal terms as the quota holders. This may result in a situation where fishermen who previously avoided targeting species for which they have no or insufficient quota, deliberately start fishing for these species. This free-rider behaviour would not only affect the value of the quota shares held by the quota holders, but could also lead to a ‘race to fish’ in cases where the fishery would be closed if its total quota is exhausted. There is evidence that particularly in fisheries managed under individual quota allocation systems increasing pressure on fish stocks through (illegal) overshoot of quota is the result (Langstraat, 1999, OECD, 2011, Symes *et al.*, 2003, Arnason, 2014). The likelihood of a ‘race to fish’ increases in mixed fisheries management, where potentially an entire fishery could be closed once the limiting quota is exhausted (choke species).

For future management of mixed fisheries under a LO, it is therefore key to consider additional management incentives to ensure more selective fishing. In New Zealand, Namibia, Iceland and Norway, where (partial) discards bans have already been introduced in both single and mixed stock management situation, additional management measures to encourage fishermen to land formerly unwanted by-catch while at the same time discouraging from targeting this catch are an essential part of the package (Buisman *et al.*, 2016, Arnason, 2014).

5 Conclusions

The European Commission requested ICES to develop ranges of values for F_{MSY} in order to allow for more flexibility in the management system, offering the possibility to set higher or lower TACs than the TAC corresponding to the point value of F_{MSY}. The rules specifying how the ranges should be used will form the basis for the future North Sea mixed-fisheries multiannual plan.

The mixed fisheries forecast presented here are all conditional to scenarios on how the fleets will react to management constraints. Without clear indication on the most likely behaviour, it is difficult to clearly identify which of the management scenario presented here is performing best. Nonetheless, general observations can be made:

- Using only the higher bound of the ranges will produce the highest yields in the short term, but it will result in a high chance of overshooting or undershooting TACs (depending on whether the fleets continue fishing to catch all their quotas, or stop when their first quota is reached).
- By lowering the target fishing mortality on the stock with the largest TACs, and increasing the target on the stocks with limiting TACs, the optimization procedure effectively reduces the risk of TAC overshoot or undershoot, and thereby represents a solution creating less tension in the system. The resulting yields can be as high as when only the upper bound of the range is used if the fleets are absolutely not allowed to over catch the quotas. But the fleets have the ability to overshoot, this management option will not allow for yield as high as when the upper bound of the ranges is used for all stocks.

The forecasts for the different scenarios for mixed fisheries management show that in theory it is possible to optimize the F values for the commercial species in the model in such a way, that the least overshoot of limiting catch quota is achieved. The forecasts also facilitate an informed discussion on the potential issues and risks associated with choosing different management scenarios for different fleets and Member States. A request to ICES to assess its current mixed fisheries advice and include optimisation scenarios for F-values would be useful in view of the policy discussion on the new multiannual mixed fisheries plan for the North Sea. Such a request can be done by a group of Member States or, preferably, the European Commission.

We emphasize that the mixed fishery model as it is operating now does not consider any potential change in the fishing behaviour resulting from the introduction of the landing obligation. The LO implies in effect a transition from a fisheries management system based on landings quota (*de facto* the ‘old TAC’) to a management system that is based on actual catches. The model now assumes that the national quota uplift for each stock will be allocated to each fleet using the same allocation key as for the landings, under the principle of ‘relative stability’. In reality, the LO will result in changing in operational fishing practice due to discards obtaining a value – either through direct sales or through opportunities caused by quota uplifts; in a worst case scenario a ‘race to fish’ could become reality. This could lead to fishing mortality levels for individual species that are not optimal from a mixed fishery perspective or go outside F_{MSY} ranges. These dynamics have not (yet) been taken into account in the model, but could be incorporated as part of future work by ICES.

6 Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 187378-2015-AQ-NLD-RvA). This certificate is valid until 15 September 2018. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V.

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 2017 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 IMARES 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.

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Justification

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The scientific quality of this report has been peer reviewed by a colleague scientist and a member of the Management Team of IMARES.

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