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Evaluation of a management plan as proposed by the European Commission in 2006 for fisheries exploiting stocks of plaice and sole in the North Sea

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Summary

According to the EC and scientific advisers the stocks of plaice and sole in the North Sea are fished at unsustainable levels. The Commission of the European Community has therefore proposed a long-term management plan for the fisheries exploiting these stocks, which is designed to gradually adjust the level of fishing activity so as to achieve greater catches, larger and more stable stocks and more profitable fisheries (COM/2005/0714 final - CNS 2006/0002). The plan defines target levels of annual fishing mortality of 0.3 for plaice and 0.2 for sole. These are values which, according to scientific advice, will allow higher yields for a given level of recruitment, reduce discarding, and allow a reduced biological risk to the fish stocks. The tools to achieve these objectives are the same as those in a number of other long-term management plans already in place. Fishing mortality will be reduced by 10% year-on-year based on the most recent stock assessment until the target levels have been reached, while annual variations in Total Allowable Catches (TAC's) will be kept within limits (15% up or down). Other measures will involve the regulation of fishing effort via fishing days at sea. The change in the number of fishing days is aimed to be proportional with the change in sole fishing mortality.

This paper results from a request by the Dutch Ministry of Agriculture, Nature Conservation and Food Quality to evaluate the management plan as proposed by the EC. For that purpose a simulation model was developed, which contains several modules. The operating module simulates the true stock and dynamics of the fishing fleet. An observation module mimics the indices generated by fisheries-independent surveys and the observed catches and catch at age composition from the commercial catches. Based on this information a stock assessment using the XSA procedure is executed, which results in perceived stock numbers at age and fishery mortality rates per age group. The assessment results are inputs to calculate the TAC's and the maximum number of days at sea following the rules in the management plan.

Spatial and seasonal differentiation in stock abundance and fleet effort allocation were not included. Also the fleet structure was simplified, the two stocks are exploited by a beam trawl fleet, which consists of the combined Dutch and UK fleet. In practice these fleets contribute most to the international catch. The operating model has been conditioned using data from the ICES Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), by calibrating catchability and recruitment levels from the historical data. The behaviour of the fishing fleet was simulated using a number of options on the fisher's response to the annual management measures. This fleet behaviour is uncertain and therefore several scenarios were formulated.

Results show that through the plan proposed by the EC, F target levels have been reached in 2015. At the same time the effort allowed (maximum number of days at sea) reduces to about 50% of its current (=2006) level. SSB of both species are expected on average to increase and the risk that SSB is below B_{pa} in 2012 is less then 20%. Under the assumption of a Ricker type stock recruitment relationship, average recruitment until 2015 shows no trend. Assuming a Beverton and Holt stock recruitment function results in a positive trend for the recruitment. Average TAC's and landings vary depending on the scenario used for a run. TAC's and landings for sole seem to level of at 14000-15000 tons. For plaice TAC and landings increase on average with 4000 tons per year at the end of the simulation period (2014).

Introduction

This report evaluates a management plan for North Sea sole and plaice stocks proposed by the European Commission in 2006 (COM/2005/0714 final - CNS 2006/0002). This management plan contains arguments for reducing the fishing mortalities to levels as low as 0.2 per year for sole and 0.3 for plaice, together with a Harvest Control Rule (HCR) describing the establishment of the annual TAC's and allowable maximum number of days at sea in the beam trawl fishery. Although not specifically stated in the management plan, it aims to reduce fishing mortality over time to values around F_{MSY} for both stocks. The Community and its Member States have subscribed to an international political commitment at the World Summit on Sustainable Development in Johannesburg (September 2002) to maintain or restore stocks to levels that can produce the maximum sustainable yield, with the aim of achieving these goals for depleted stocks on an urgent basis, and where possible not later than 2015.

The North Sea plaice and sole stocks are currently managed by TAC's, days at sea restrictions and technical measures. The stocks are exploited by several fisheries as but most of the catch is taken by the mixed beam trawl fisheries.
Fishing mortality (F per year) for plaice increased, with considerable variation in the annual estimates, from circa 0.4-0.5 per year around 1970 to circa 0.7 to 0.8 per year in the period from 2000 to 2005 (Figure 1a). The fishing mortality for sole increased with large variation as well, from circa 0.4-0.5 per year around 1970 to 0.5 to 0.6 per year.

The spawning stock biomass (SSB) of plaice declined from 1970 onwards but showed a temporal increase in the 1980s when both recruitment and growth rate were higher (Figure 1b). The spawning stock biomass of sole varied around the B_{pa} level. A series of strong year-classes made the spawning stock biomass of sole to increase for around five years in the early 1990s. Recruitment estimates for both plaice and sole for the year-classes 2002 and 2003 are low, negatively impacting outlook of the North Sea sole stock in the years thereafter.

The aim of the evaluation presented in this report was to find out whether measures would achieve the objective stated in the management plan, whether this could be achieved for both species simultaneously in the same time frame and to get an indication of consequences in this time frame in terms of development of TAC's, landings and permitted effort. The evaluation was carried out on request of the Dutch Ministry of Agriculture, Nature Conservation and Food Quality.

The Management plan

Objectives

On 10 January 2006 the European Commission adopted a proposal for a Council Regulation establishing a management plan for fisheries exploiting stocks of plaice and sole in the North Sea. This draft proposal is an application of article 6 of the Council Framework Regulation adopted under the reform of the Common Fisheries Policy (Council Regulation (EC) no 2371/2002, OJ L 358, 31.12. 2002, p. 59–80)

The objective of the proposal is to manage the fisheries exploiting the stocks of plaice and sole such that the stocks of plaice and sole in the North Sea are rebuilt to within safe biological limits, and that the stocks of sole and plaice are exploited sustainable thereafter.

Advice on long-term management from ICES indicates that at low target fishing mortalities (considerably lower than the present level), low risk to reproduction and high long-term yields are achieved simultaneously. The general pattern is that there is no conflict between the two objectives. A low fishing mortality will lead to high yield simultaneously with a low risk to reproduction that is lower than the 5-10% risk which has generally been considered acceptable by managers. Target fishing mortalities in the range 0.3 to 0.4 are considered appropriate. The operational objectives are target levels of fishing mortality of 0.3 for plaice and 0.2 for sole. Fishing mortality will be reduced by 10% year-on-year until the target levels have been reached, while annual variations in TAC's will be kept within a 15% change up or down.

Measures

The management measures proposed by the Commission are (see also the flowchart of figure 2):

Article 4 (Procedure for setting the TAC for plaice)

1. The Council shall set the TAC for plaice at that level which, according to a scientific evaluation carried out by Scientific Technical and Economic Committee for Fisheries (STECF), is the higher of the following:

    (a) that TAC whose application would result in a 10% reduction in the fishing mortality rate in its year of application compared to the fishing mortality rate estimated for the preceding year;

    (b) that TAC whose application would result in a fishing mortality rate of 0.3 on ages 2 to 4 in its year of application.

2. Where the application of paragraph 1 would result in a TAC which exceeds the TAC of the preceding year by more than 15%, the Council shall set a TAC which is 15% greater than the TAC of that year.

3. Where the application of paragraph 1 would result in a TAC which is more than 15% less than the TAC of the preceding year, the Council shall set a TAC which is 15% less than the TAC of that year.

Article 5 (Procedure for setting the TAC for sole)

1. The Council shall set a TAC for sole at that level which, according to a scientific evaluation carried out by STECF, is the higher of the following:

(a) that TAC whose application would result in the same proportionate change in the fishing mortality rate on sole as is generated by the application of Article 4(1) concerning plaice;

(b) that TAC whose application would result in a fishing mortality rate of 0.2 in its year of application;

(c) that TAC whose application would result in a 10% reduction in the fishing mortality rate in its year of application compared to the fishing mortality rate estimated for the preceding year.

2. Where the application of paragraph 1 would result in a TAC which exceeds the TAC of the preceding year by more than 15%, the Council shall set a TAC which is 15% greater than the TAC of that year.

3. Where the application of paragraph 1 would result in a TAC which is more than 15% less than the TAC of the preceding year, the Council shall set a TAC which is 15% less than the TAC of that year.

The implementation of the effort limitation is formulated as a days at sea reduction. In article 6[3] an effort reduction in terms of days at sea is proposed in accordance with the adjustment resulting from implementing the rule of article 5[1]:

Article 6 (Fishing effort limitation)

1. The TAC's referred to in Chapter II of the present Regulation shall be complemented by a system of fishing effort limitation based on the geographical areas and groupings of fishing gear, and the associated conditions for the use of the fishing opportunities set out in Annex IVa to Council Regulation (EC) No 27/2005 (OJ L 12, 14.1.2005).

2. Each year, the Council shall decide by a qualified majority, on the basis of a proposal from the Commission, on the maximum number of days at sea available for Community fishing vessels deploying beam trawl gear of mesh size equal to or greater than 80 mm and subject to the system of fishing effort limitation referred to in paragraph 1.

3. The annual adjustment of the maximum number of days referred to in paragraph 2 of this Article shall be in the same proportion as the annual adjustment in fishing mortality rate provided for in accordance with Article 5(1).

Evaluation

The evaluation is carried out using a numerical simulation model for the interplay between the biological dynamics of the stocks, and the economic dynamics of the fleet. A relational diagram of the -full feedback- model is given in figure 4.

Biological operating model

The biological operating model consists of the age structured population state of the 'real' plaice and sole stocks in the North Sea, including the population dynamics of these stocks. The spawning stock biomass (SBB), the biomass of the sexually mature part of the population determines the number of recruits of the next year class. Two commonly used relations can be chosen: (1) Ricker and (2) Beverton & Holt. The stock numbers are affected by natural mortality, assumed to be 0.1 for every age class, and fishing mortality that is calculated in the fleets module. The Ricker and Beverton & Holt types of stock recruitment relationships were estimated using assessment results from 1957 to 2004. Also the stock numbers at age in the initial year where taken from this assessment. The simulation was initiated in 1995. Landings, discards and survivors of the two stocks were calculated for the successive years given the (natural & fishing) mortality rates. From 2006 onwards the simulation continues with recruits, estimated from the stock-recruitment relationship, given the stock sizes. Natural mortality is assumed to be equal to 0.1 (ICES WGNSSK, 2005). Growth of individual fish is simulated via the Von Bertalanffy growth curves fitted to observed lengths at ages from the BTS survey. L_∞ for plaice was 41 cm and for sole 33 cm. K was 0.3 and 0.54 for plaice and sole respectively and t_0 was -0.5 for plaice and -0.2 for sole. A CV of 0.1 for plaice and 0.17 for sole was included for the estimated length at age to account for process errors in the model (since this variation in the size at age caused a systematic difference between observed and perceived landings the variation was reduced to a CV of almost zero). The length-weight relationship combined with length at age gives a weight at age relationship. The mature fraction is assumed to be 1 from age 4 onwards (0 0.5 0.5 [1]) for plaice and from age 3 for sole (0 0 [1]), so all plaice age 4 and sole age 3 are mature.

Fleet characteristics and the fishery

Exploitation of the North Sea plaice and sole stocks is mainly done by the beam trawl fleet. This fleet is considered being the combination of the English and the Dutch beam trawl fleet, using a mixture of mesh size between 80 and 100 mm. Selectivity at age is estimated by combining selectivity at length of the gear and an age-length key (ALK). The 80 mm mesh size causes considerable discarding of juvenile plaice. The efficiency increase of the fleets has not been taken into account in the current model. The fleet operating model affects the number at age in the biols objects via the fishing mortality rate (F). F per year, for each age group is calculated as the product of fishing effort (f) and catchability (q). The fishing mortality reduces stock numbers per age group in the biological operating model module. This results in a simulated dataset with 'true' catch values for the two species, which can then be differentiated into landings and discards for a species and an age group using minimum landing sizes of the species.

Assessment and forecast

The information or perception on the stocks status is generated through the explicit inclusion of a stock assessment in the simulation. Catches and landings of the fleet are recorded and a survey fleet samples the stocks by fishing with a constant fishing effort and a catchability that is linearly related to stock abundance, resulting in survey indices on the state of the stocks. The assessment method is XSA based on the landings (sole) or landings and discards (plaice). The implementation of the XSA stock assessment to the knowledge process explicitly takes into account the error generated by the stock assessment. To simulate this error, the assessment input data (simulated landings, discards and survey catches) were generated with an error of 10%. Biological parameters of the stocks in the assessment process are assumed to be equal to the biological parameters set in the operating model.

Conditioning the operating model means reflecting the states and dynamics of the operating model on our current understanding of the underlying biological and economical processes. The model was constrained to generate the observed variation of plaice and sole stock characteristics in terms of fishing mortality, landings, discards and SSB. the catchability of the fleet for the two species in relation to the range in fishing mortality for the different age groups of the species was used to match the stock characteristics and model predictions.

In order to set a management measure for year y, assessment data will be available up to year y-2 and the assessment itself is carried out in year y-1. The stock assessment process results in survivor and fishing mortalities estimates until year y-2 and a spawning stock biomass, SSB, estimate for year y-1. The assessment output data might deviate from the true population characteristics as modelled in the biological operating model module because of the introduction of observation errors.

In the management part of the model, estimated fishing mortality (F) and MSY characteristics are used as input measure for setting the TAC's, formulate advice and simulate a harvest control rule (HCR). The results of the HCR procedure in terms of TAC or F-level affect the state and behaviour of the fleet during the year in which the HCR is implemented. Management changes in F-levels will result in a different effort of the fleet by using a multiplication factor, which is proportional to the change in F.

Simulation runs

The simulations are run with 50-500 Monte Carlo realizations (figure 5), where the two sources of error are: (1) process error in the biology part, via random noise around the stock-recruitment relationship and (2) observation error in the management part, by including a random sampling error around the observed fleet and survey catches. In reality there are probably more sources of random noise, like for instance mortality rates.

In the simulation model a number of simplifications and assumptions were made:

- The fishery for all flatfish in the North Sea is a mixed fishery;
- All catches are made by one fleet (beam trawl fleet). Although this is the major fleet exploiting flatfish (about 70% of the plaice and 90% of the sole landings in the North Sea originates from beam trawlers), plaice and sole are also caught by other fleets which are not subject to the effort restrictions in the proposed regulation;
- Fishing mortality rate was taken from age 2-6 as in the working group in contrast with article 4[1] sub a of the regulation where an F of age 2 to 4 was proposed for plaice
- Catchability for plaice and sole by this fleet was estimated from the historical relationship between fishing mortality and effort and was assumed to remain constant over years;
- Future recruitment is related to stock size in the model by a stock-recruitment relationship. The standard choice was for the Ricker type of function. The Ricker curve starts in the origin, has a maximum and is asymptotic to zero (fig 2).
- It is assumed that information is available of overquota catches and discards (plaice) on an annual basis to be incorporated in the assessments for these species on which the calculations for the TAC's and the allowed days at sea are based;
- The fishing behaviour of the fleet as the response to the annual management measures was formulated as some alternative scenarios (see above);

Fleet behaviour assumptions

In order to simulate the fishing behaviour of the fleet, assumptions had to be made about the fleet's response to the annual management measures. Since there is uncertainty about the fleet's behaviour, several possible scenarios were formulated.

1. Within the restriction of the allowed number of days at sea, the fleet will go on fishing until the last of the two TAC's is fished up while discarding (or misreporting) the overquota catch of the other species.
2. Within the restriction of the allowed number of days at sea, the fleet will fish up both TAC's while avoiding catching overquota fish.
3. Within the restriction of the allowed number of days at sea, the fleet will stop fishing as soon as the first of the two TAC's is fished up.
4. The same assumption holds as in scenario 3, but for the stock dynamics a Beverton & Holt stock-recruitment relation is assumed, whereas in all other scenarios a Ricker relation is assumed. The two stock recruitment relationships are shown in figure 3.

- The fleet will ignore the TAC's and continue fishing until the allowed number of days at sea restricts further fishing activities.

Scenarios 1 and 2 both assume fishermen will aim to fish as long as possible and avoid a premature exhaustion of the TAC either by misreporting or discarding (scenario 1) or by avoiding catches of the most restrictive TAC (through spatio-temporal effort allocation or directive fishing). From these extreme assumption, the 'true' behaviour is thought to be somewhere in between.

The scenarios 3 (4) and 5 are considered to be less corresponding with daily practices. In scenario 3 (and 4 for other stock-recruitment assumption) fishing will stop when the first TAC is exhausted. This assumption is in line with the intention of the regulation. In scenario 5 the fleets ignores the TAC's and is only restricted by days at sea.

Simulation of the management plan

The Harvest Control Rule that was implemented for the scenario that fishers stop fishing after the second quota is finished (scenario 1 and 2) looks step-wise as follows

1. The F status quo (age 2-6) in the running year is assumed for plaice and equals the F estimate in the preceding year
2. Calculate multiplication factor for a F reduction of 10% ex. Article 4[1] sub a (=0.9)
3. Calculate multiplication factor to reach F_{msy} ex. Article 4[1] sub b (F_{msy}/F_{sq})
4. Take the maximum result of step 2 and 3 and estimate the stock size and TAC given the resulting effort multiplication factor. (Article 4[1])
5. Compare the resulting plaice TAC with the current TAC and if the difference exceeds 15%, estimate a new multiplication factor so that the resulting TAC is within these 15% bounds (Articles 4[2] & 4[3]).
6. The F status quo (age 2-6) in the running year is assumed for sole and equals the F estimate in the preceding year
7. Calculate multiplication factor for applying Article 5[1] sub a (= result from step 4)
8. Calculate multiplication factor to reach Fmsy ex. Article 51 sub b (F_{msy}/F_{sq}).
9. Calculate multiplication factor for a F reduction of 10% ex. Article 5[1] sub c (=0.9).
10. Take the maximum result of step 7 to 9 and estimate the stock size and TAC given the resulting effort multiplication factor (Article 5[1]).
11. Compare the resulting sole TAC with the current TAC and if the difference exceeds 15%, estimate a new multiplication factor so that the resulting TAC is within these 15% bounds (Articles 5[2] & 5[3]).
12. The effort (days at sea) limitation is calculated by multiplying the effort of the previous year with the multiplication factor resulting from the rules in Article 5[1] (step 10).
13. Estimating the effort needed to yield the plaice TAC and the sole TAC. Compare the two estimates so constrains in exploiting both fish stocks become clear. Under

scenario 1 it is assumed that fishing continues until the last TAC is caught, so the maximum effort estimate is selected.

14. The estimated effort from step 13 is compared with step the result of step 12 and the minimum is taken. This estimate is the effort used in the simulated year.
15. Sometimes depending on the selected management procedure and scenario, a TAC for a species is lower then the simulated catch or landing using the effort estimate from step 14. Under scenario 1 the surplus is to be regarded as overquota catch. As an alternative in scenario 2 the surplus catch is avoided and the estimated overquota are added to the stocks.

The management measure in the plan is a reduction of fishing mortality, which is partly implemented as a TAC reduction. The effort reduction is reached via the implementation of art 6 of the proposal. According to this rule, the change in effort (days at sea) is proportional to the outcome of article 5[1] (step 10).

The simulated landings for both plaice and sole show similar patterns as the observed landings before 2005. It means that the fit for selectivity and catchability mimics the perception in the real world. In case of plaice the simulated values were systematically below the observations (figure 6).

The simulation model is developed using the FLR package (FLR Team 2006), a collection of data types and methods written in the R language (R Development Core Team 2005) as part of the EU EFIMAS-COMMIT-FISBOAT project cluster. FLR is an OpenSource project meaning that the source code is available to the users. It is put on the FLR wiki (http://www.flr-project.org/doku.php?id=appl:flat2) together with data and additional sources for checking/validating/evaluation.

Results

The simulation was done for the proposed regulation under 5 scenario's. The stochastic model was run for 500 iterations with generated recruitment of 8 successive assessment years (2006- 2014). Figures 7 to 15 show time series of TAC's, landings, discards, perceived and implied fishery mortality, SSB and recruitment for scenario 1 and 2 as plots showing the distributions of results by the 5th, 25th, 50th, 75th, and 95th percentile.

A summary of the result of all scenarios' is given in Table 1.

Figure 16 shows landings, discards, TAC and overquota for both species under the various scenario's for comparison. Direct comparison of the scenarios is presented in figure 17 to 19.

<u>Scenario 1 and 2</u>

(sole)

For scenario 1 and 2 the (average) TAC of sole decreases initially with 15 % per year and stabilizes thereafter around 14 500 tonnes with 25 and 75 percentile results being 2 500 and 3 000 tonnes lower and higher respectively. Landings show a similar but slightly lower pattern. On average 500 tons of quota allowed are not fished (figure 7).

In some of the 500 realizations (those which generate large year classes) large amounts of overquota fish will be caught and under scenario 1 removed from the stock. On average the quantity of overquota sole that will be caught is low (median equals 0 tons, figure 8).

No temporal trend could be detected in the average recruitment of sole, which varies between 80 to 110 millions. The expected increase of SSB to around 50 000 tons has no effect on recruitment because according to the Ricker function for sole, recruitment is fairly stable in case the stock size varies between 30 and 60 thousand tons SSB (figure 9).

During the time when the application of the HCR is simulated, the observed F (as estimated by XSA, two years later) is always higher than the intended or implied F (two years earlier). The implied F does not reach the target of 0.2 by the end of the simulation period in 2014 (figure 10).

plaice

For scenario 1 and 2 the TAC of plaice increases from 2008 onwards to around 70 000-75 000 tonnes in 2014. Landings show a similar but slightly lower pattern. (figure 11). Scenario 1 shows on average 3 000 tonnes lower TAC and landings compared to the result of scenario 2 where the over quota fish are avoided.

Discards of plaice decrease on average with 20 000 tons from approximately 65 000 in 2005 to 45 000 in 2014. Because the average weight of the plaice stock increases the discarded fraction of the catch will decrease considerable. Similar as for sole, for sole, on average no over quota fish are caught. Occasionally in some realization large amounts of over quota fish (up to 10 000 tons) are caught under scenario 1 (figure 12).

The SSB of plaice is expected to increase to around 350 000 tonnes. This implies that SSB will reach a level well above B_{pa}, which secures a good buffer against bad year classes. Plaice recruitment is variable around 0.9 to 1 billion. Note that in case SSB is above 300 000 tonnes, average recruitment decreases according to the Ricker model (figure 13).

The observed F (as estimated by XSA, two years later), gradually falls slightly below the implied F (two years earlier). The implied F reaches the target of 0.3 by the end of the simulation period (figure 14).

The relative effort reduces by approximately 50% in 7 years time. According to the HCR the effort can increase again after the F_{msy} targets are met (figure 15).

Scenario 3, 4 & 5

The results of the different scenarios (figure 17, 18, 19) show for sole similar results for those where the Ricker stock recruitment relationship was used. The Beverton and Holt SR relationship results initially, at lower SSB's, in lower recruitment levels and reduced catches. SSB of sole will on average increase and the risk that SSB is below B_{pa} in 2012 is low.

For plaice scenario 1 and 5 (overquota discarded and fishing until days at sea limit) showed similar average TAC and landings results. Scenario 2 and 3 results, on average, in higher TAC and landings, while scenario 4, similar as with sole, shows lower TAC and landings due to the Beverton and Holt stock recruitment function. SSB of plaice will on average increase and the risk that SSB is below B_{pa} in 2012 is low. Under the assumption of a Ricker type stock recruitment relationship, average recruitment until 2015 shows no trend. A Beverton and Holt stock recruitment relationship shows a positive trend. On average recruitment until 2011 is lower and higher thereafter (figure 19).

Discussion

The implementation of the management plan implies a change in management strategy from a risk avoidance strategy (to stay within safe biological limits) to a strategy of optimal harvesting of the resource. This new strategy is in accordance with the commitments made at the World Summit on Sustainable Development at Johannesburg (2002). It can be envisaged that management of other stocks in EU waters will follow and be adjusted using similar management approach as proposed for plaice and sole. The proposed management means a change from conservation or limit reference points to target reference point that are intended to meet management objectives. The concept of using a precautionary biomass threshold (B_{pa}) as a trigger for management action in the present management has disappeared. In fact, in the proposed procedure, the biomass of the stock is irrelevant to the management procedure and all management action is conditional to the fishing mortalities estimates by the fishery scientists based on stock assessments. The assumptions made in the assessment procedure should be clear, together with the methods used to monitor the status of the stocks. In the current model spatial variation in fish abundance and fishing effort is not included. Conditioning of a model with aerial differentiation is complicated (Pastoors et al. 2006; Poos et al. 2006) and the (XSA) observation model to which the results are compared don't include spatial variation either.

The realisation of the aim of the proposal (reaching and proxy for F_{msy}) was not completely achieved. Median intended F for sole in 2014 was 0.25 and the median intended F of plaice was 0.31. Simulations, which were run for an extended period (2006-2025), show that on average the target F's were reached in 2020, a time frame of stock rebuilding of 15 years. Apart from showing how the exploited species will respond to harvest control rules and management measures, the effects should be evaluated in a broader perspective. According to the proposed plan the allowed effort is reduced proportional to the F reduction. The social and economic impacts of the proposed management measures, over both the short and the long term using performance indicators like precaution/safety, employment, profitability and administrative costs is a next step in assessing its consequences on the fishers, society and environment.

This evaluation does not aim to predict what happens if the Regulation is implemented. The evaluation aims to indicate the changes and magnitude and range of the changes which may be expected under certain assumptions. The evaluation includes a simulation of the future under different assumed scenario's, each scenario repeated 500 times taking account for expected variation in biological parameters, such as recruitment. The results are presented as 'averages' of the 500 realisations and as percentiles defining the range in which most realisations occurred. The individual runs in each scenario indicate that results vary mainly pending the occurrence of exceptional good or poor year classes. The probability of one situation happening may be very different from the probability of another thing happening. Here the risk associated with the harvest control rule and the other stochastic processes should be kept in mind. Communicating the risks associated with all these processes are a challenge to both scientists, managers and administrators.

When evaluating the model, assumptions had to be made at different levels in the process. If these assumptions are very different from the true situation, the effect of the measures may be different than indicated by the evaluation. In some cases it may be possible to demonstrate that making one or another assumption does have little effect on the final outcome of the evaluation. In that case we can conclude that the measure is robust to this assumption. From the result and comparison of the 5 scenarios we can conclude that the measure is robust to the various scenario options chosen. As shown in the results the variation of the outcome between individual runs is to a large extent related to the stochastic recruitment pattern and related year class strengths. Still the underlying stock-recruitment relationship affects the results because, depending on the function chosen, on average more or less recruits are generated given a certain amount of biomass. The Ricker function generates more recruits compared with the

Beverton and Holt function in case the SSB is less than 50 000 and 320 000 tons for sole and plaice respectively. When SSB is larger the Ricker function generates less recruits. Given the large uncertainty in the choice of stock-recruitment relationships, additional runs should be executed using a constant recruitment equal to 25th, 50th and 75th percentiles of the long year recruitment observations imposed with stochasticity and thus simulate low, average and high recruitment patterns

Some examples of assumptions made in the current evaluation are given here. For both plaice and sole stocks it has been assumed that productivity of the marine ecosystem in the projected period will remain within the same range as has been observed in the past 50 years. This assumption may not be true. Observations of changes in the species composition in the North Sea towards more southern species and observation on changes in stock dynamics of some other stocks may indicate that external factors, such as climate change, do also affect the ecosystem. In the evaluation, it has also been assumed that annual decisions will be made using a certain assessment method (the present assessment procedure) with its associated uncertainties. It can be envisaged that other methods may be used in the future and this may affect (improve or deteriorate) the effect of the measures. It has also been assumed that all catches (landings and discards) are known with an assumed error of 10%. In practice this may not be true. In particular estimates of discards are much more variable and can have a large influence on the reference F which is used in the management procedure. Most important are the assumptions on the behaviour of fishers in respond to the measures. It is noted that the Regulation aims to control landings and not catch. Fishermen have the choice either to stop fishing when their quotas are depleted, or to discard over quota fish. This behaviour is not illegal in waters under Community legislation. To some extent, it may be possible to avoid catches of a target species, by selecting different fishing grounds or periods, or by modification to the gear but it is doubtful whether full avoidance, as assumed in some of the scenario's, is possible.

Another assumption made was that all plaice and sole were caught by beam trawls. This is not true. About 30% of the plaice is caught with other gears such as otter trawl, twin trawl and gill nets while 10% of the sole is caught by gill nets. It is noted that the annual adjustment (reductions) in fishing mortality, following from the proposed management plan apply to the entire stock, while the adjustment of fishing effort only applies to the beam trawl fleet. Pending the implementation of the effort reduction in practice (by ship or by fleet) this may lead to different developments which are mainly triggered by different associated economics. In the worst case, restriction in fishing days may lead to a decision to fish the quota using other gears which are not restricted by the effort measure. In that case fishing mortality would not reduce and the penalty at the end of the year would be a further reduction of the beam trawl effort. The extreme continuation of this behaviour would lead to disappearance of the beam trawl fleet.

The implied fishing mortalities for sole and plaice are linked in the management plan through connecting multipliers ex art 5.1 of the Regulation. The effect of the linkage has not been investigated in this study. In particular, it would be interesting to investigate how errors in one assessment may affect the performance of the HCR for the other species. This becomes more important in case the observed F (F_{sq}) is close to the target F (F_{MSY}), and the ratio F_{msy}/F_{sq} determines the F and f multiplier. In case the observed F is lower than the target F of any of the two species, the F (and effort) multipliers become larger then 1 and allowed number of days at sea increase ex art 6[3] of the proposed regulation.

Acknowledgement

This study was partly supported by the Commission of the European Communities Directorate General for Fisheries (DG XIV) under contracts COMMIT (Creation of Multiannual Management Plans for Commitment) and EFIMAS (Operational evaluation tools for fisheries management options).

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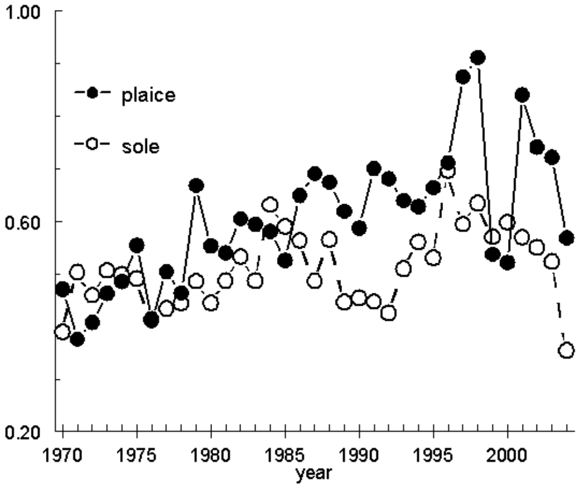
Figure 1: Fishery mortality rate (left) and SSB for sole and plaice. Observations are represented by black dots (plaice: closed ; sole: open). The red line in the SSB graph shows the precautionary biomass (B_{pa})



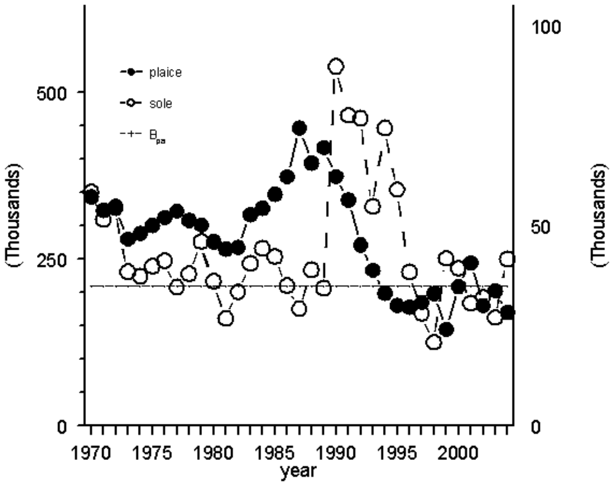


Figure 2. A schematic overview of the management types and harvest control rules extracted from the proposal and translated in the HCR algorithm.

TAC_y: TAC for the next management year.
TAC_{y-1}: TAC for the assessment year
F_{sq}: F, assumed for the assessment year (=F_{y-1} estimate)
F_{msy}: F, assumed to result in a maximum catch.
mult: multiplication factors for F and f in the assessment year.

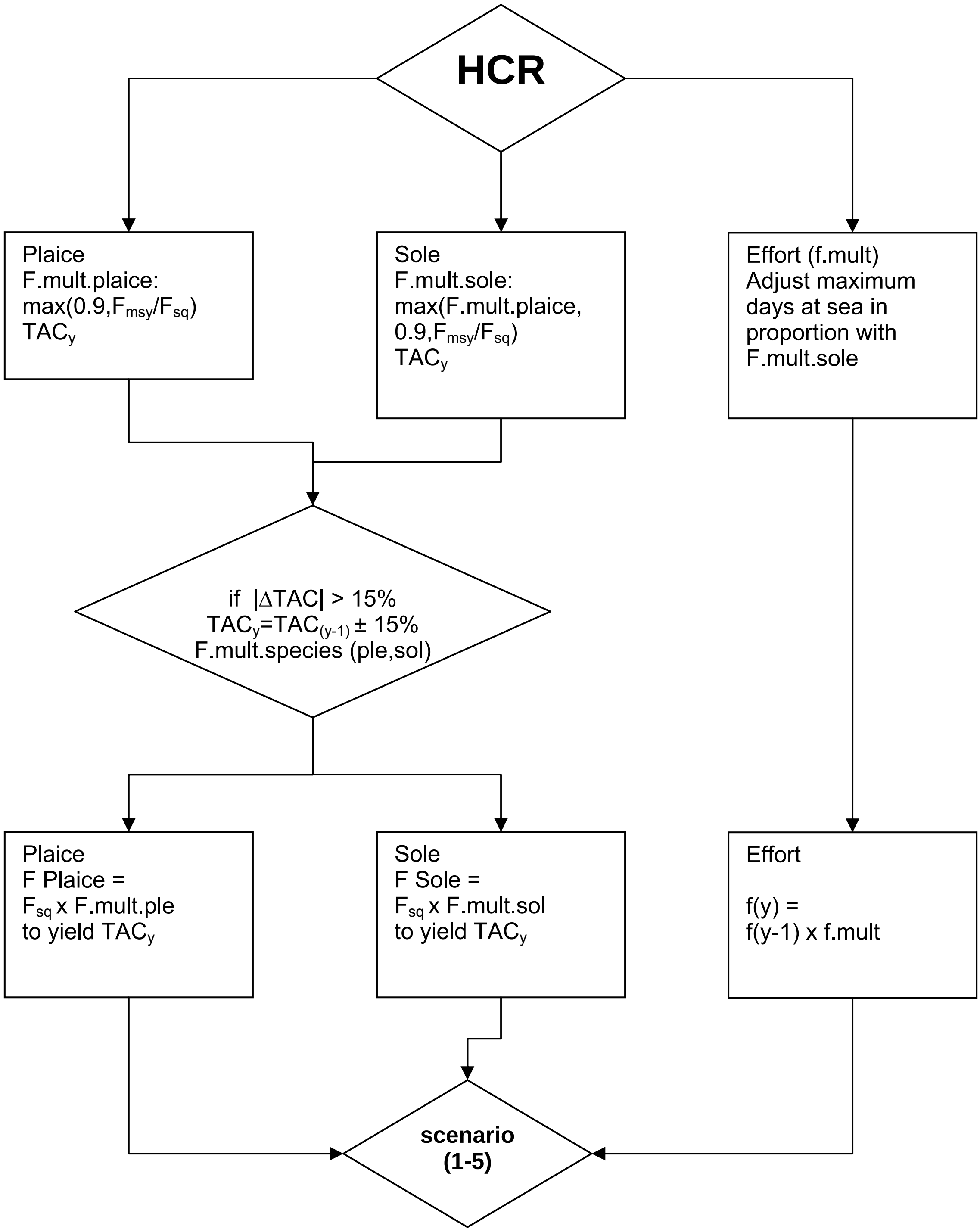


Figure 3. Stock recruitment relationship for sole (left) and plaice (right). Estimates are represented by black dots and predictions according to the Ricker or Beverton and Holt models are shown by lines (Ricker, solid line & B&H, dotted line). Note that on average more recruits are generated when the SSB is above 50000 ton and 320000 ton for sole and plaice respectively and a B&H stock-recruitment relationship is used. In case the SSB is lower the Ricker function results in a higher number of recruits given a similar SSB of the stocks.

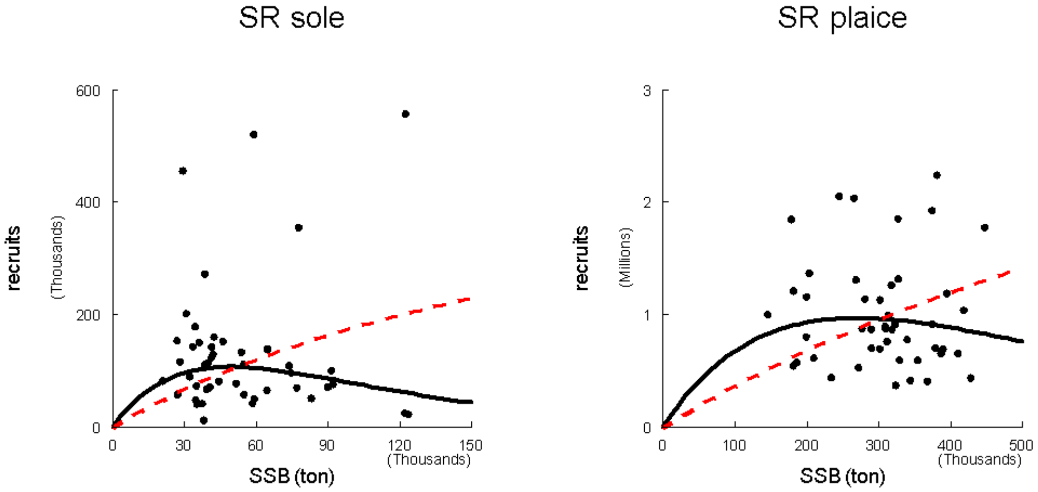


Figure 4. Relational diagram of the simulation model with 4 main modules. Boils and fleets represent the operating model while stocks and manage represent the observation model (the perception of the true state)

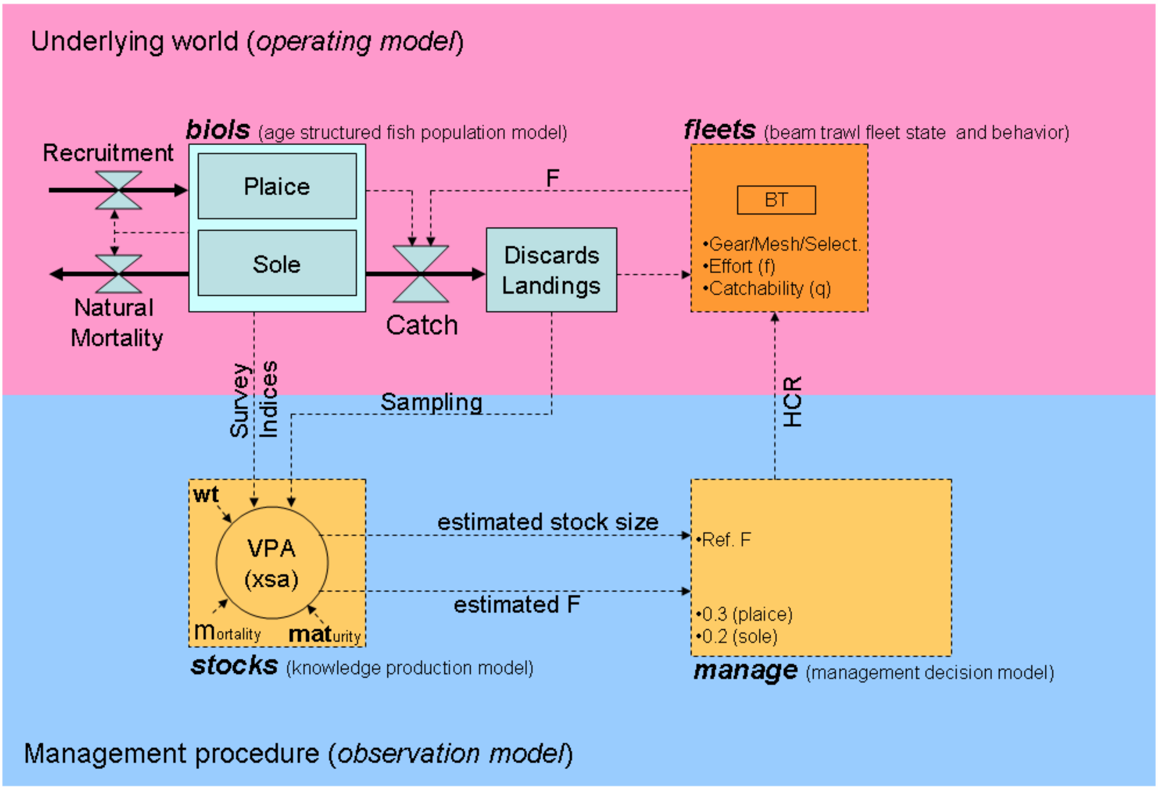


Figure 5. Results of 50 individual simulation runs (TAC plaice) from 2006 to 2014. The median per year is shown as dotted line.

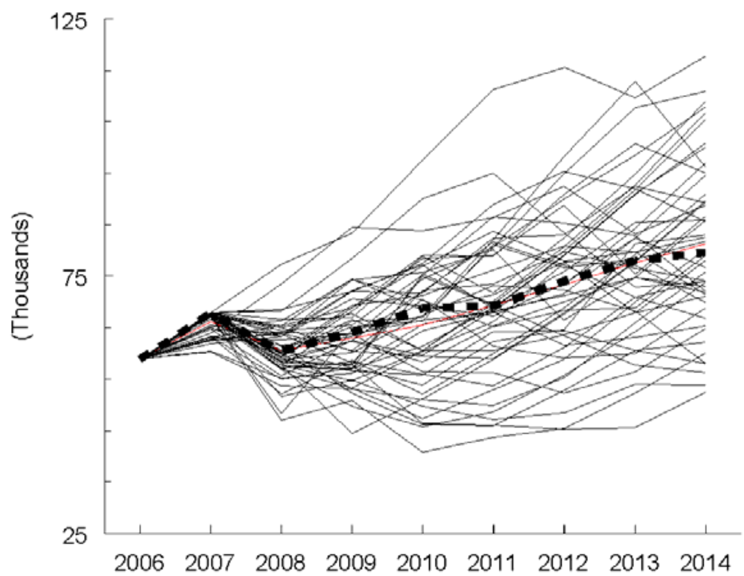


Figure 6. Comparison of the simulated historic WG estimates of North sea sole and plaice landings over the period 1995-2004 and simulated results over the similar period.

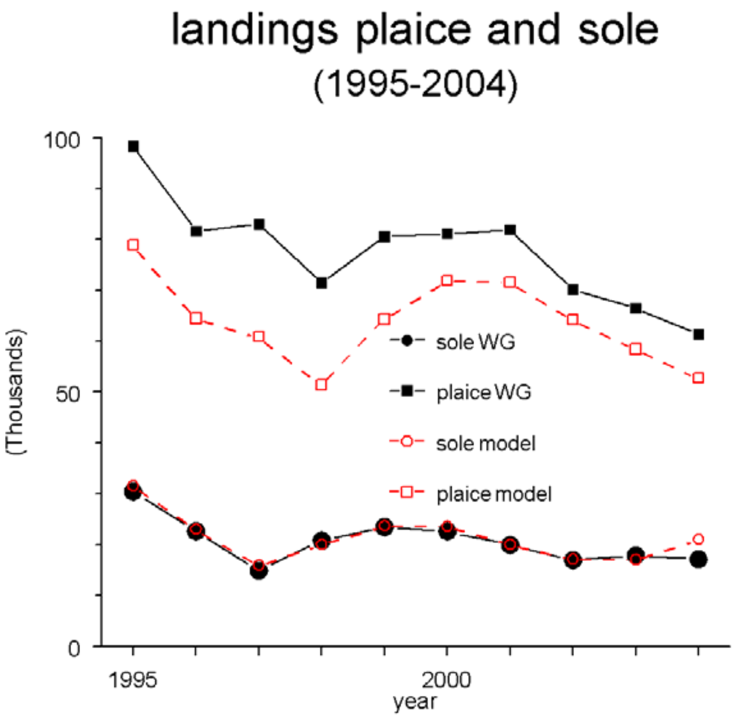


Figure 7. The sole TAC and landings (in thousand tonnes) over time. Red: scenario 1 (overquota catch discarded or misreported). Black: scenario 2 (overquota catch avoided). Triangles: medians. Thick lines end at the 25th (red) and the 75th (black) percentile respectively. Thin lines end at the 5th (red) and 95th (black) percentile respectively. For scenario 1 only the downward variation and for scenario 2 only the upward variation are shown, but the variability is expected to be similar between the scenarios.

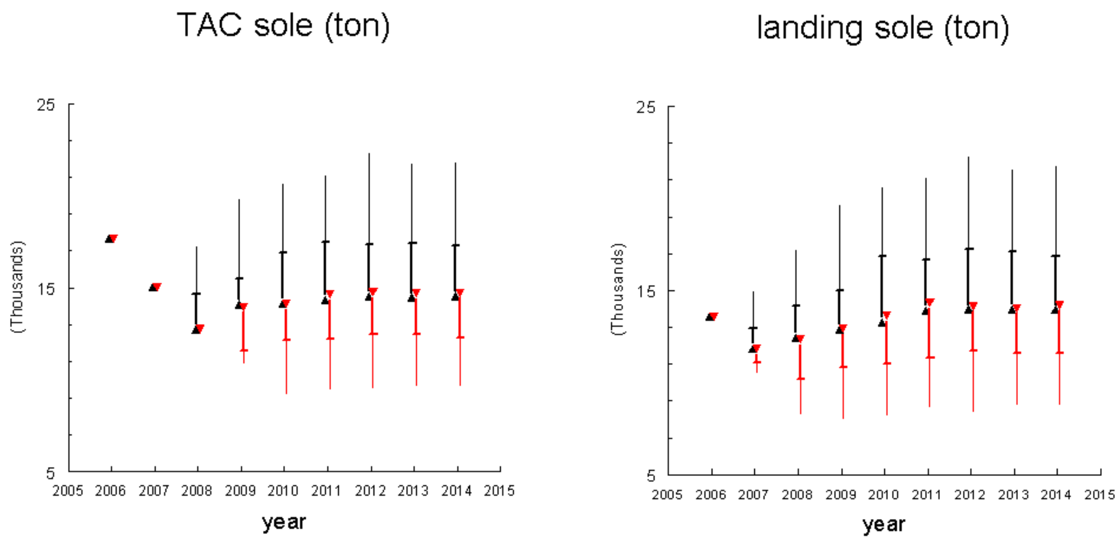


Figure 8. The overquota catches (in thousand tonnes) over time. Only scenario 1 is shown, because in scenario 2 overquota catches are avoided. Symbols and lines, see Figure 6. Note that the 50% quantiles for all tables amount 0 (see summary table).

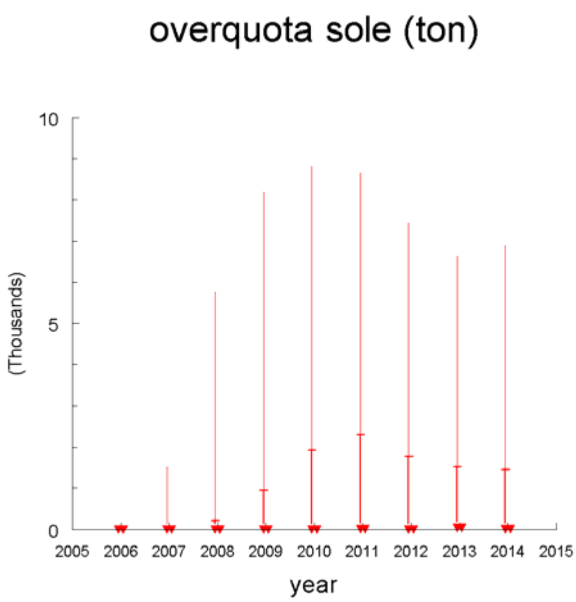
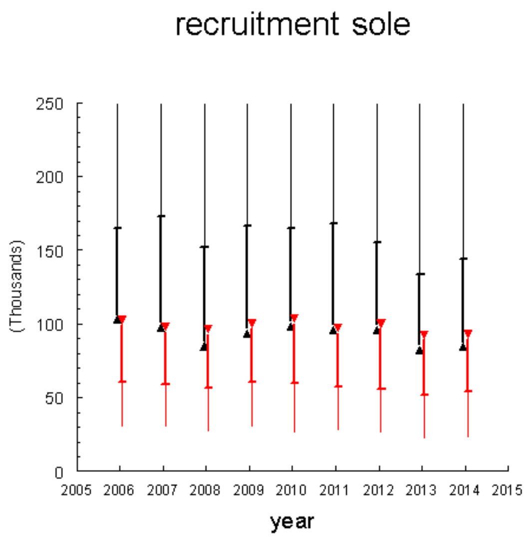


Figure 9. The number of sole recruits (in thousands over time) and SSB (in thousand ton). Red: scenario 1 (overquota catch discarded or landed illegally). Black: scenario 2 (overquota catch avoided). Symbols and lines, see Figure 6.



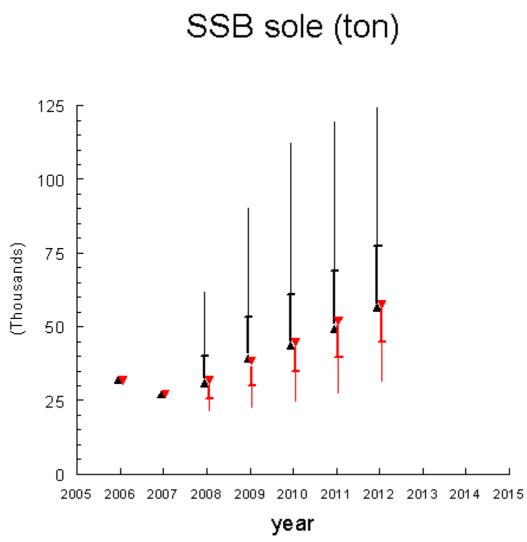


Figure 10. The sole fishing mortality (F) over time. Red: scenario 1. Black: scenario 2. The circles and squares connected by broken lines represent the implied or expected F under the HCR-measure. The triangles connected by thick lines represent the F as estimated two years later by XSA. Vertical lines, see Figure 6.

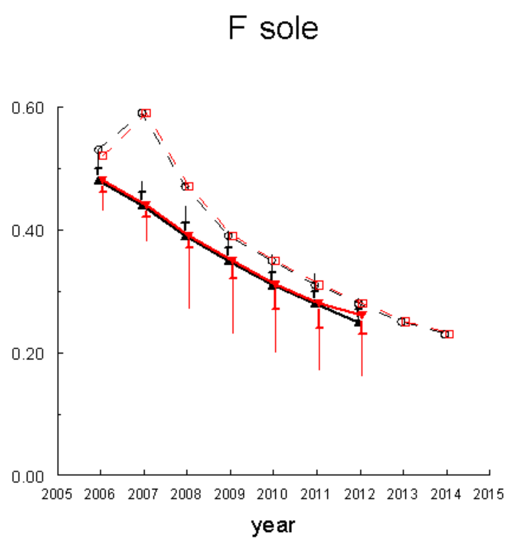


Figure 11. The plaice TAC and landings (in thousand tonnes) over time. Red: scenario 1 . Black: scenario 2. Triangles: medians. Thick lines end at the 25th (red) and the 75th (black) percentile respectively. Thin lines end at the 5th (red) and 95th (black) percentile respectively. For scenario 1 only the downward variation and for scenario 2 only the upward variation are shown, but the uncertainty is expected to be similar between the scenarios

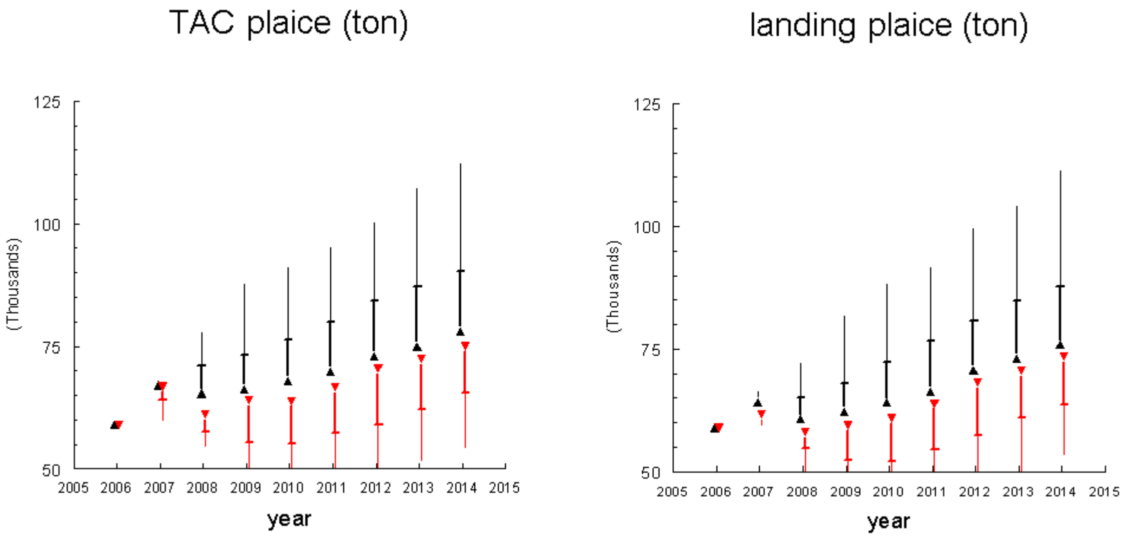


Figure 12. Plaice discards (in thousand tonnes) and the overquota catches (in thousand tonnes over time. Only scenario 1 is shown for overquota, because in scenario 2 overquota catches are avoided Symbols and lines, see Figure 11

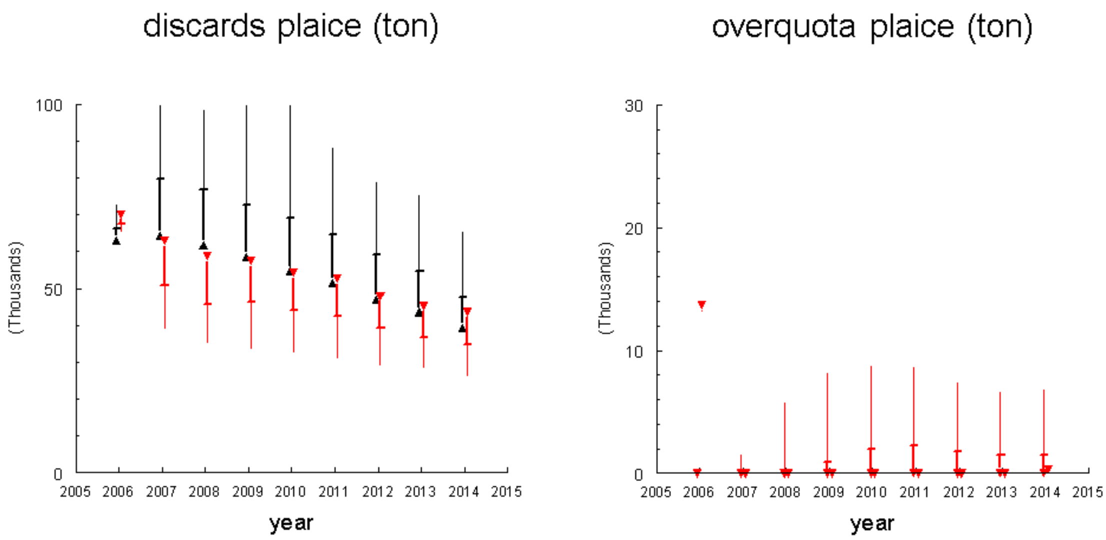


Figure 13. The number of plaice recruits (in million over time) and SSB (in thousand ton). Red: scenario 1 (overquota catch discarded or landed illegally). Black: scenario 2 (overquota catch avoided. Red: scenario 1. Black: scenario 2. Symbols and lines, see Figure 11.

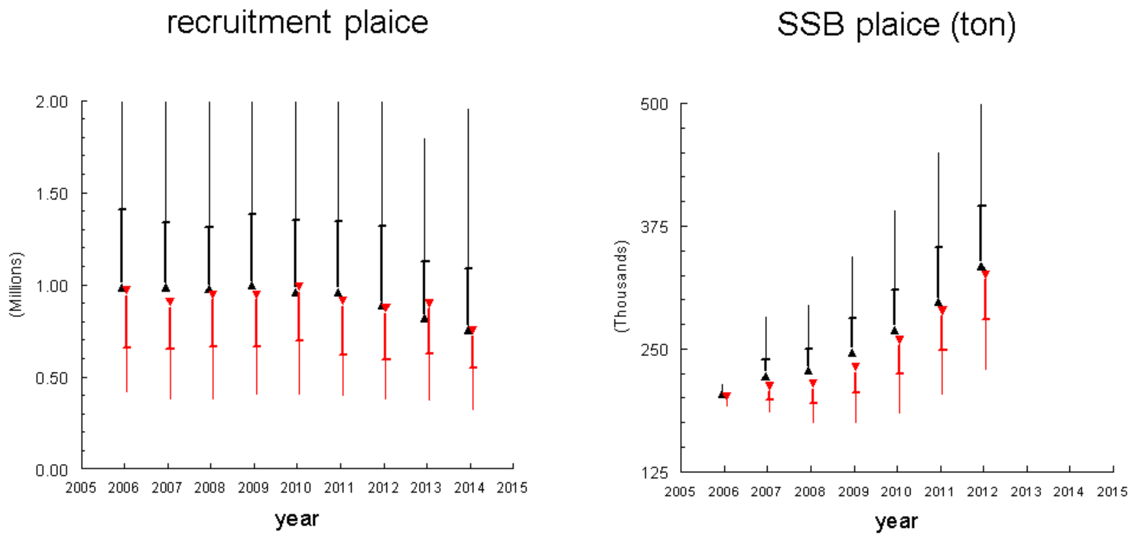


Figure 14. The plaice fishing mortality (F) over time. Red: scenario 1. Black: scenario 2. The circles and squares connected by broken lines represent the intended F by the HCR-measure. The triangles connected by thick lines represent the F as estimated two years later by XSA. Vertical lines, see Figure 11.

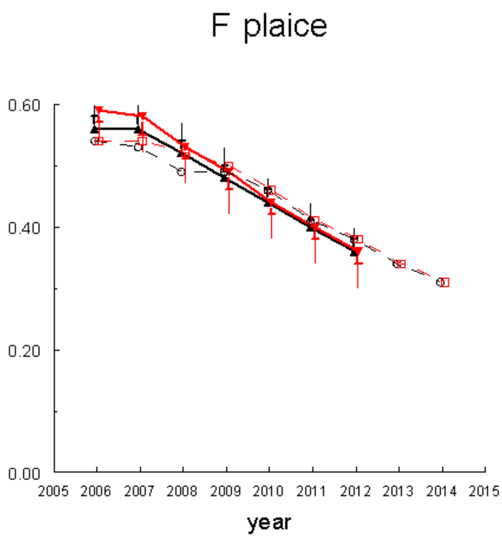


Figure 15. Relative Effort over time. Red: scenario 1 (overquota catch discarded or landed illegally). Black: scenario 2 (overquota catch avoided).
The allowed number of days at sea (2006=100 %). Closed circles represent the (median) allowed fishing effort and will restrict future fishing activities. The actual effort used (under the TAC constrains) is under these scenarios similar as the allowed effort.

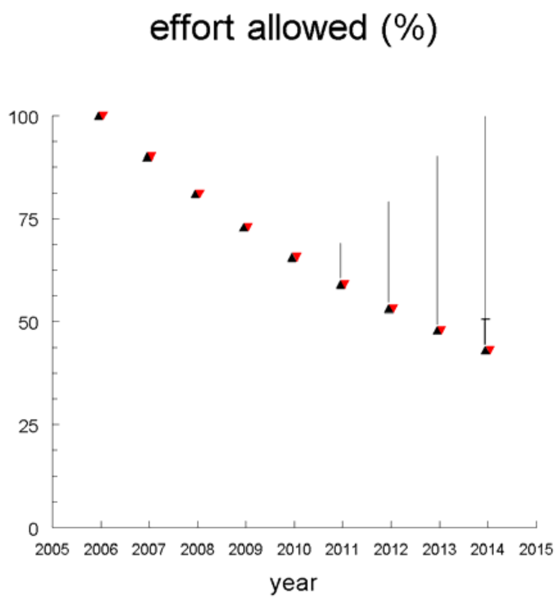


Fig 16. Results for sole and plaice according to the 5 different scenario's. Grey represents yearly landings. The black line represents the TAC and the red densely striped area represent the discards and widely striped area's are overquota which are discarded.

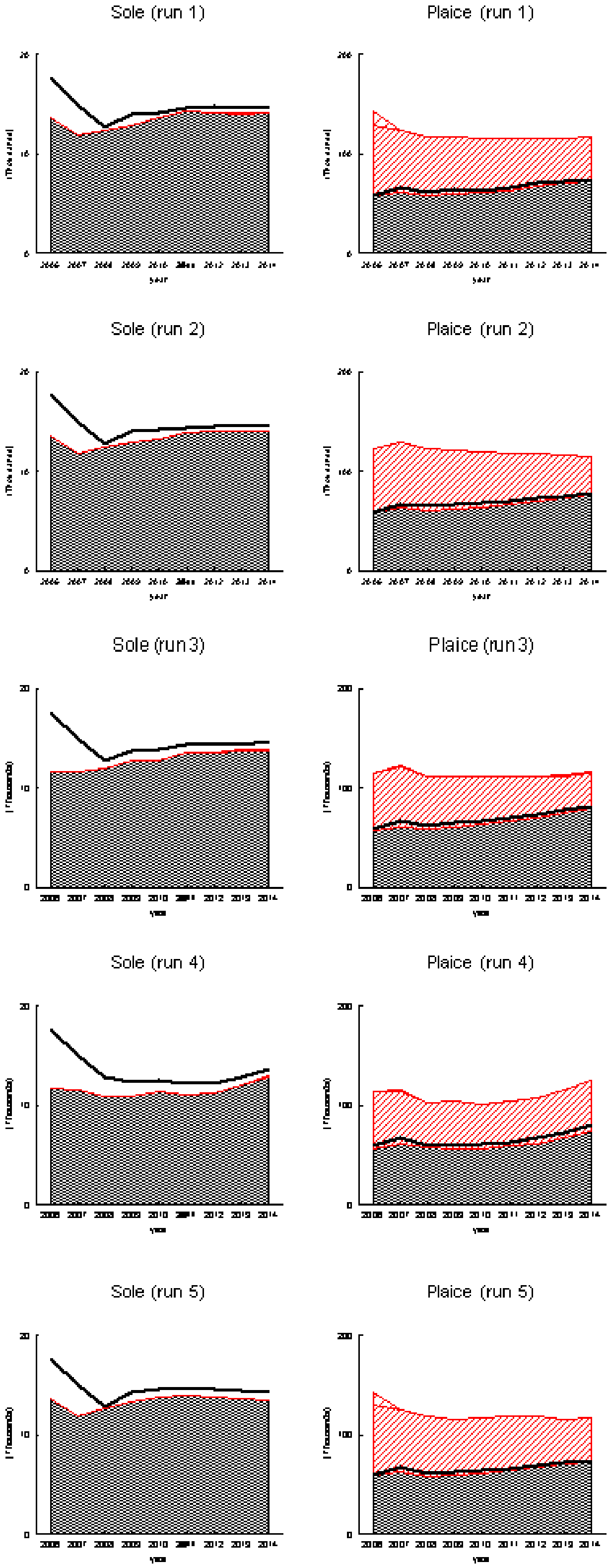


Fig 17. Average TAC and - landings for sole and plaice resulting from the 5 different scenario's. Scenario 1 and 2 are black lines, 2 and 3 red lines and 5 is represented by the green line.

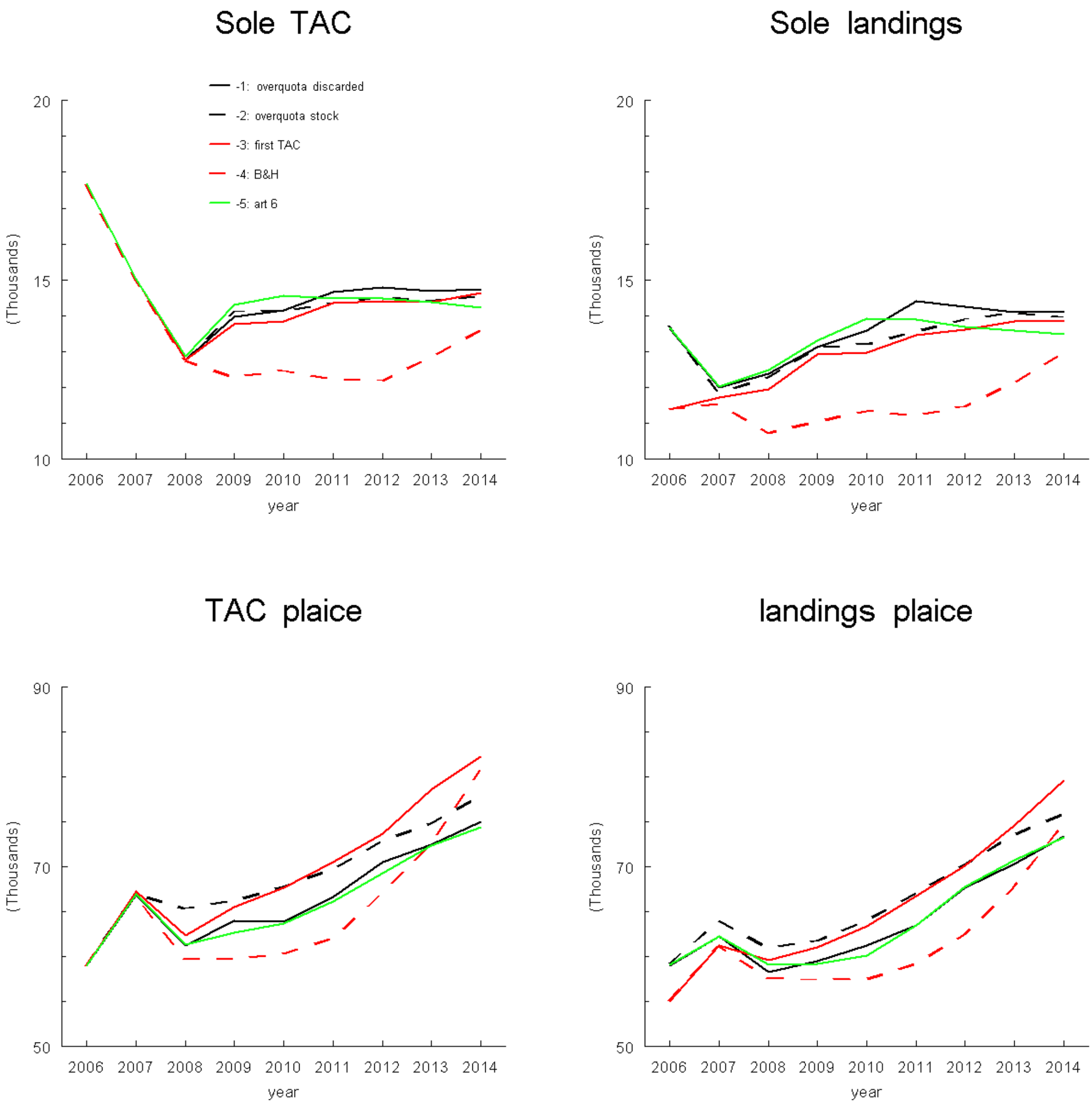


Fig 18. Average observed and intended fishery mortality for sole and plaice resulting from the 5 different scenario's. Scenario 1 and 2 are black lines, 2 and 3 red lines and 5 is represented by the green line.

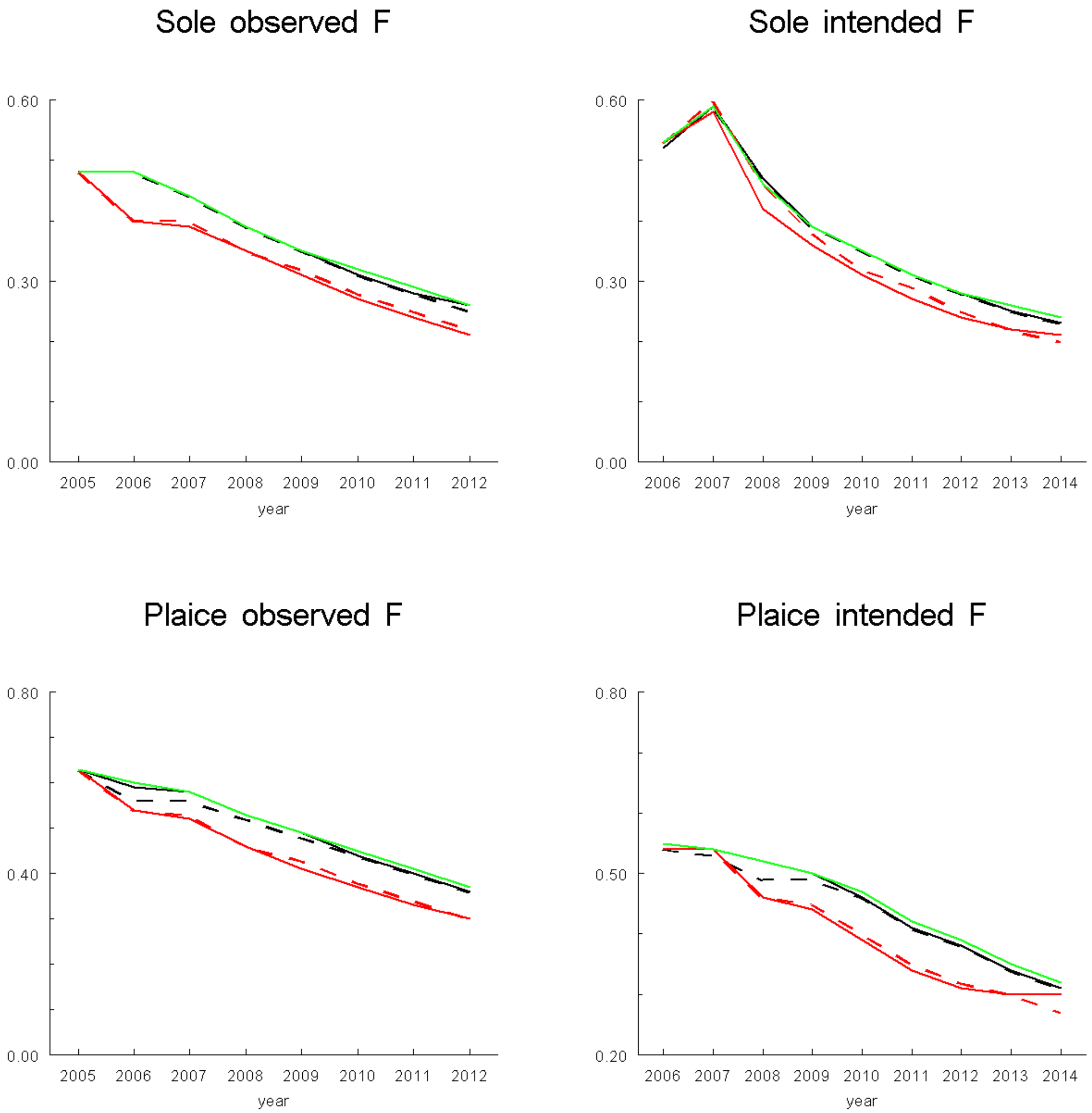
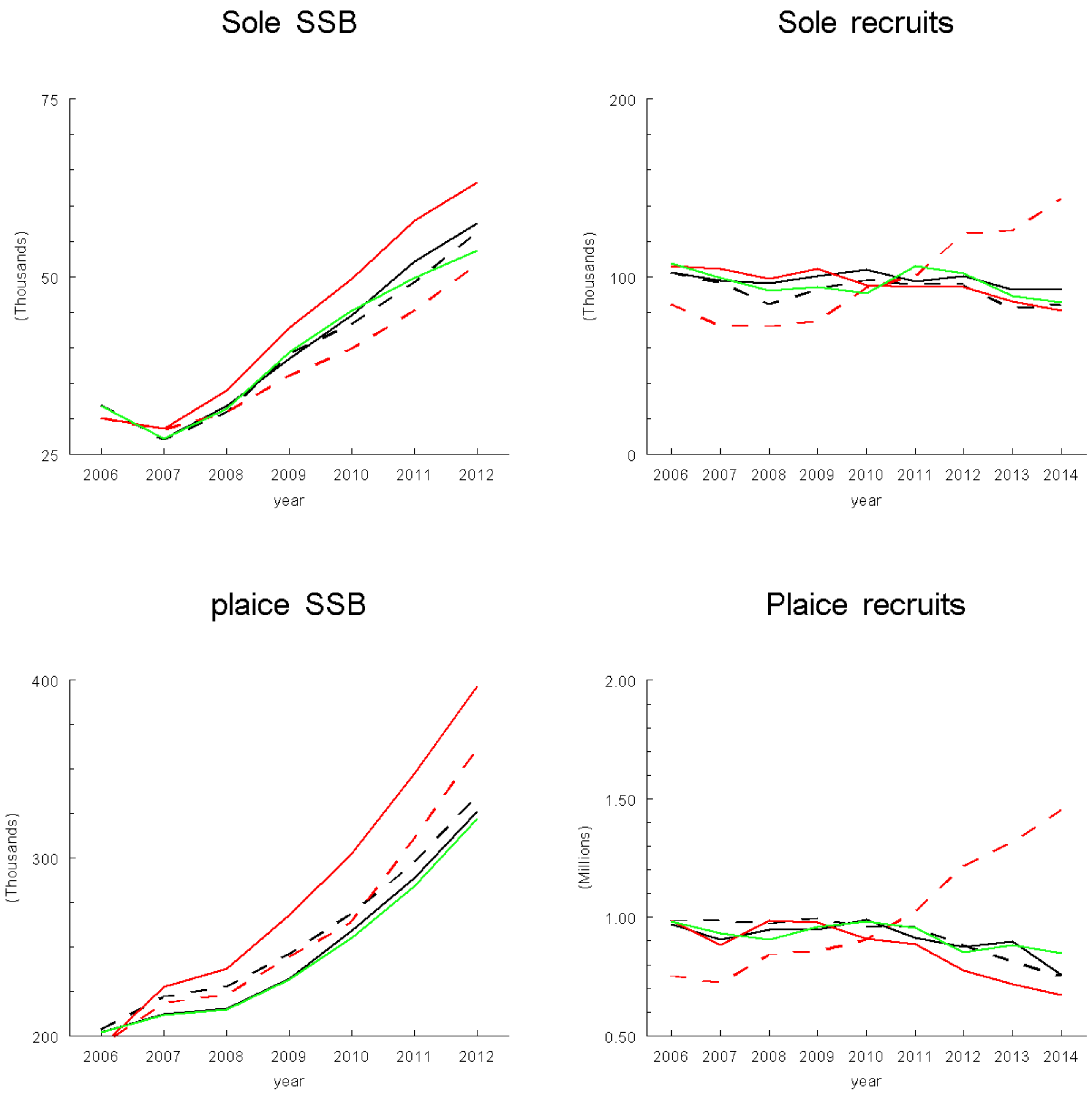


Fig 19. Average SSB and - recruitment for sole and plaice resulting from the 5 different scenario's. Scenario 1 and 2 are black lines, 2 and 3 red lines and 5 is represented by the green line.



Appendix A : Summary Table

Table 1. A summary of the results of the 5 scenario's.

Scen 1 — fishing until last TAC is used, **with** discarding after fishing first TAC, SR Ricker — code: EC yes 50 ricker last min disca — X

	Sole										Plaice								
	TAC	Landings	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc	Effort used	Effort allowed	TAC	Landings	Discards	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc
2006	17670	13649	0	0.48	0.52	0.43	102645	31801	26473	26473	59000	58975	70193	13677	0.59	0.54	0.57	970647	202105
2007	15020	11996	0	0.44	0.59	0.39	97910	27174	23826	23826	66864	62254	62939	0	0.58	0.54	0.51	906841	212139
2008	12767	12378	0	0.39	0.47	0.35	96372	31851	21443	21443	61176	58254	58831	0	0.53	0.52	0.46	948262	215137
2009	13966	13133	0	0.35	0.39	0.31	100181	38470	19299	19299	63978	59453	57538	0	0.49	0.5	0.41	947569	232028
2010	14145	13588	0	0.31	0.35	0.28	103908	44639	17369	17369	63877	61197	54321	0	0.44	0.46	0.37	991359	259062
2011	14663	14400	4	0.28	0.31	0.25	97292	52183	15632	15632	66679	63472	52722	0	0.4	0.41	0.34	914237	288974
2012	14792	14261	0	0.26	0.28	0.23	100185	57457	14069	14069	70574	67704	48052	0	0.36	0.38	0.3	875874	326022
2013	14696	14103	41		0.25	0.21	92831		12662	12662	72479	70272	45235	0		0.34	0.27	898304	
2014	14730	14126	5		0.23	0.18	93090		11396	11396	75018	73346	43616	324		0.31	0.24	754413	

Scen 2 — fishing until last TAC is used, **avoid** discarding after fishing first TAC, Ricker — code: EC yes 50 ricker last min stock — X

	Sole										Plaice								
	TAC	Landings	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc	Effort used	Effort allowed	TAC	Landings	Discards	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc
2006	17670	13730	0	0.48	0.53	0.43	102747	32018	26473	26473	59000	59270	63096	0	0.56	0.54	0.57	986458	203766
2007	15020	11890	0	0.44	0.59	0.39	97518	27220	23826	23826	67057	64067	64307	0	0.56	0.53	0.51	988349	222638
2008	12767	12308	0	0.39	0.47	0.35	84989	31002	21443	21443	65409	61043	61819	0	0.52	0.49	0.46	975885	227804
2009	14113	13142	0	0.35	0.39	0.31	93291	39261	19299	19299	66323	61851	58655	0	0.48	0.49	0.41	995668	246373
2010	14147	13222	0	0.31	0.35	0.28	98523	43514	17369	17369	67894	64128	54822	0	0.44	0.46	0.37	958952	269565
2011	14351	13582	0	0.28	0.31	0.25	96042	49326	15632	15632	69806	67200	51525	0	0.4	0.41	0.34	960224	297653
2012	14534	13912	0	0.25	0.28	0.23	95945	56395	14069	14069	72940	70320	47083	0	0.36	0.38	0.3	886702	334607
2013	14443	14106	0		0.25	0.21	82459		12662	12662	74971	73675	43631	0		0.34	0.27	815540	
2014	14552	13969	0		0.23	0.18	84454		11396	11396	78013	75989	39246	0		0.31	0.24	757155	

Scen 3 — fishing until first TAC is used, Ricker — code: EC yes 50 ricker first min disca — X

	Sole										Plaice								
	TAC	Landings	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc	Effort used	Effort allowed	TAC	Landings	Discards	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc
2006	17670	11399	0	0.4	0.53	0.36	106248	30179	22040	26473	59000	54989	58848	0	0.54	0.54	0.47	987144	194243
2007	15020	11713	0	0.39	0.58	0.34	104381	28623	21092	23826	67213	61201	60303	1405	0.52	0.54	0.45	883485	227679
2008	12767	11949	0	0.35	0.42	0.29	98740	34018	18021	21443	62343	59620	53275	0	0.46	0.46	0.39	987773	237559
2009	13773	12923	0	0.31	0.36	0.26	104487	42843	16028	19299	65519	61041	51919	0	0.41	0.44	0.34	977553	268082
2010	13856	12989	0	0.27	0.31	0.23	95323	49669	14097	17369	67648	63418	48247	0	0.37	0.39	0.3	910642	302628
2011	14351	13451	0	0.24	0.27	0.2	94215	57931	12474	15632	70544	66716	45025	0	0.33	0.34	0.27	888193	347469
2012	14417	13605	0	0.21	0.24	0.18	94482	63313	11365	14069	73706	70102	41257	0	0.3	0.31	0.24	775186	396636
2013	14372	13848	87		0.22	0.18	86061		10875	12818	78626	74652	37794	780		0.3	0.23	717505	
2014	14624	13857	165		0.21	0.17	80833		10485	13116	82237	79677	35421	2558		0.3	0.23	673430	

Table 1. A summary of the results of the 5 scenario's.

fishing until first TAC is used

Scen 4 code: EC yes 50 Bevholt first min disca X

Beverton & Holt

	Sole										Plaice								
	TAC	Landings	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc	Effort used	Effort allowed	TAC	Landings	Discards	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc
2006	17670	11418	0	0.4	0.53	0.36	84844	30235	22041	26473	59000	55068	57850	0	0.54	0.54	0.47	756503	194890
2007	15020	11560	0	0.4	0.6	0.35	72733	28658	21557	23826	66816	61199	52359	1931	0.53	0.54	0.46	726237	219015
2008	12767	10764	0	0.35	0.46	0.3	72062	31060	18218	21443	59683	57640	45588	0	0.46	0.46	0.39	843171	223184
2009	12306	11088	0	0.32	0.38	0.27	75428	36118	16631	19299	59733	57440	46656	0	0.43	0.45	0.36	858989	245060
2010	12479	11359	0	0.28	0.32	0.24	94355	39954	14735	17369	60406	57551	45230	0	0.38	0.4	0.32	908896	264411
2011	12243	11241	0	0.25	0.29	0.21	100815	45360	12799	15632	62177	59304	45698	0	0.34	0.35	0.27	1027527	310762
2012	12199	11493	0	0.22	0.25	0.18	124359	51939	11258	14069	67188	62566	46371	0	0.3	0.32	0.24	1219299	361447
2013	12870	12165	0		0.22	0.16	126293		10049	12662	72567	67740	49392	0		0.3	0.22	1321263	
2014	13612	13000	57		0.2	0.15	144285		9155	12537	80897	74845	51012	0		0.27	0.2	1455995	

continue fishing untill allowed effort is used

Scen 5 code: EC yes 50 Ricker last art disca X

Ricker

	Sole										Plaice								
	TAC	Landings	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc	Effort used	Effort allowed	TAC	Landings	Discards	Overquota	F perc (stq)	F pred	True F	Recr	SSB perc
2006	17670	13671	0	0.48	0.53	0.43	107392	31820	26473	26473	59000	59108	70282	13687	0.6	0.55	0.57	980654	201966
2007	15020	12031	0	0.44	0.59	0.39	99572	27222	23826	23826	66956	62263	63441	0	0.58	0.54	0.51	934078	211832
2008	12862	12478	0	0.39	0.46	0.35	92016	31474	21443	21443	61368	59041	59688	0	0.53	0.52	0.46	905994	214662
2009	14311	13319	0	0.35	0.39	0.31	94056	39363	19299	19299	62697	59192	57346	0	0.49	0.5	0.41	958749	231505
2010	14548	13915	0	0.32	0.35	0.28	90466	45209	17369	17369	63694	60070	56245	0	0.45	0.47	0.37	984197	254982
2011	14493	13908	0	0.29	0.31	0.25	105878	49783	15632	15632	66132	63454	54775	0	0.41	0.42	0.34	955621	284107
2012	14489	13694	0	0.26	0.28	0.23	101741	53668	14069	14069	69259	67820	51579	0	0.37	0.39	0.3	852393	322185
2013	14383	13601	0		0.26	0.21	89000		12662	12662	72316	70774	45213	99		0.35	0.27	881766	
2014	14239	13479	0		0.24	0.18	85428		11396	11396	74413	73305	43979	681		0.32	0.24	846343	

	Drs. E. Jagtman
Signature:	______________________
Date:	29 January 2007