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Investigation of some management scenario's for North Sea sole and plaice in 2006 and beyond

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Summary

This report deals with 4 issues regarding the management of North Sea plaice and sole: an evaluation of a management plan advised by the North Sea RAC in 2005, the relation between fishing effort and fishing mortality, the effects of TAC size on fishing mortality and biomass and the TACs needed to ensure stock sizes above Bpa.

The evaluated management plan as it was formulated was supplemented by measures and objectives by the fisheries department of the Dutch Ministry of Agriculture, Nature Conservation and Food Quality. The current evaluation of the NSRAC management plan has been restricted to the effects of effort measures. Limitations owing to TACs and the 15% limit in annual TAC changes have not (yet) been used in this evaluation.

The management plan as it formulated by the NSRAC is does not always clearly state the objectives and measures. This leaves room for interpretation, and results from analyses evaluating this plan are dependent on this interpretation.

The evaluation has been carried by using the FLR simulation toolbox that is under development in a number of EU funded research projects (e.g. EFIMAS, COMMIT, FISBOAT). The simulation consists of an operating model and a management procedure. The operating model is expected to mimic the true stock and fishery dynamics. The management procedure consists of the process of acquiring data, doing stock assessments and implementing a harvest control rule.

The operating model consists of two species (plaice, sole), two areas (north, south) and two fleets ("NL-type", "UK-type"). All the relevant processes in the stocks and the fishery have been modelled but at different levels of detail. The operating model has been conditioned on the data from the ICES Working Group on demersal stocks in the North Sea and Skagerak (WGNSSK). The operating model has been "fitted" using a very simple iterative process to estimate catchability, distribution over areas and recruitment levels. The final operating model generates approximately equal stock sizes in both observed and fitted SSB but the predicted landings for sole and plaice appear to be lower than the observed landings. This study shows that the parameterisation of simulation models to evaluate management plans is an area that requires more methodological development.

The probability of achieving the plaice B_{pa} target in 2010 is between 98% and 62% depending on the type of stock-recruitment relationships and whether or not additional measures are taken when a stock is below B_{lim}. The probability of reaching the sole B_{pa} in 2010 is between 82% and 48%. Owing to the low recruitment in 2003 and 2004 that has been measured in the surveys, the SSB in all runs is expected to fall below B_{pa} in the first years after the implementation of the management plan. The assumption on the shape of the stock recruitment relation has a strong impact on the expected success of the plan. The Ricker curve can be interpreted as a favourable environmental scenario and the Beverton-Holt as an unfavourable scenario.

For plaice, the expected landings associated with the management plan remain stable between 65 000 and 75 000 tonnes. For sole, the landings initially decrease in all runs. When a favourable environmental regime is assumed (Ricker curve) the landings are expected to increase again after the initial decline.

The success of effort management is dependent on a clear relation between fishing effort and fishing mortality. At present that relationship is poorly known, and surrounded by a large amount of variance, especially for North Sea plaice. Observed changes in the relation between fishing effort and fishing mortality may be the result of shifts in the spatial distribution of fishing effort. Such shifts are observed during the last 10 years, with fishing effort being allocated closer to the coastal areas. The model used to evaluate the effects of the NSRAC management

plan assumes a much more “responsive” effort-F relationship than observed in recent history, which could give the impression that changing effort will be directly detectable whereas in practice these changes in effort have often not lead to changes in fishing mortality.

The analysis of the effect of the size of the TACs on the spawning stock biomass of North Sea sole and plaice on the short-term indicates that a reduction of the plaice TAC to 55 000 tonnes is needed In 2006 or 2007 to ensure SSB exceeds Bpa. For North Sea sole, reductions of the TACs to levels below 15 000 tonnes are needed in both 2006 and 2007 to ensure spawning stock biomass does not fall below Bpa in 2008.

1 General introduction

This report was written to answer questions related to the management of North Sea sole and plaice by the Dutch Ministry of Agriculture, Nature Conservation and Food Quality. It is centred on 4 questions, which will be dealt with in the subsequent 4 sections of the report.

2 Effects of the NSRAC management plan on sole

2.1 Question

"Het RAC advies voor een schol beheerplan (…) is een uitwerking van de quick scan van deze lente. In hoeverre profiteert tong van de voorgestelde ontwikkelingen? Kunnen hiervoor schattingen van F reductie worden gedaan? " [1]

2.2 Background and approach

The North Sea plaice and sole stocks are managed by TACs, days at sea restrictions and technical measures. Both species are taken in a mixed fishery with by-catches of other species (e.g. cod, whiting, other flatfish species). The plaice stock has shown a decline in SSB after the early 1990s and has been at a relatively low level since the mid 1990s. The Nort Sea sole stock has fluctuated with trends mainly determined by incidental strong year-classes. SSB for sole in 2005 is estimated above B_{pa}. The two most recent sole year-classes are estimated to be very poor, which has a strong negative impact on the outlook for this stock.

Two approaches have been used to answer this question. Section 2.3.1 presents a simulation approach of the management plan proposed by the North Sea Regional Advisory Committee. The approach and results have been presented to the ICES Study Group on Management Strategies (SGMAS).

In Section 2.3.2 we present a summary of the study of fishing effort of the Dutch beamtrawl fleet (Rijnsdorp et al. 2005). In that study they used the partial fishing mortality per unit of effort (FPUE) as an indicator of fishing effort. Their results will here be interpreted with reference to the question about the effects of effort reduction.

2.3 Simulation approach of the NSRAC management plan

2.3.1 Objectives

In 2005, The North Sea RAC advised a management plan for the flatfish fishery in the North Sea to recover the plaice stock. The objective of the plan is formulated as follows:
"The NSRAC advises that a multi-annual management plan should be adopted for plaice in the North Sea with an initial target of reaching an SSB at the B_{pa} level within 3 – 5 years with a re-evaluation after 3 years and with the long term aim of exceeding B_{pa}. The plan should be implemented as of the 1st of January 2006. The management plan is aimed at reducing pressure on juvenile plaice and would comprise structural effort reductions accompanied by stability in the TAC for plaice. The multi-annual plan should be accompanied by a monitoring and evaluation scheme, which would also include the monitoring of social and economic impact."
The operational objective is to recover the plaice stock above B_{pa} within a defined timeframe of 3 - 5 years. Bpa for plaice has been proposed at 230,000 tonnes by ICES. There is no explicit objective for sole.

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[1] *"The RAC advice for a plaice management plan (…) is an elaboration of the quick scan that was carried out in the spring. To what extend will sole profit from the proposed measures? Could estimates of reduction In fishing mortality be made? "*

2.3.2 Measures

North Sea flatfish are currently managed by a combination of TACs, days at sea limitations and technical measures.

The management measures proposed in the NSRAC management plan are:

"To reach the target of the multi-annual management plan, the NSRAC advises a structural effort reduction of 15% of enforced licensed capacity limits in the international 80 mm flatfish fishery over 2006 and effort to be maintained at the new level for a further two years. The German fishing industry believed that there should be an exemption for German shrimpers in the 80 mm category, which target sole in the coastal waters during part of the year. The NSRAC is willing to consider an exemption for the shrimper fleet if scientific evidence supports the claim that plaice are not discarded in significant quantities in their targeted 80 mm sole fishery".

"The manner in which different Member States achieve this reduction should be at their own discretion through a national flatfish management plan (NFMP). The following conditions should apply:

1. *the NFMP needs to be verifiable and enforceable;*
2. *the NFMP needs to be submitted to the Commission for approval*
3. *the NFMP should consist of any or a combination of the following instruments for effort reduction (as measured in kW/days):*
    - *a. decommissioning, and/or*
    - *b. days-at-sea restrictions*
4. *in the case where decommissioning is part of the NFMP, the Member State will refrain from taking its decommissioning days under Annex Iva;*
5. *seasonal tie-ups during the spawning season may contribute to the effort reduction but should be managed by the fleets, not the Commission, in order to keep a flow of fish to the market.*

To allow for the management target to be achieved, the management regime should operate throughout the entire multi-annual plan period, i.e., the effort reduction level will be sustained. A re-evaluation will be carried out after three years. Intermediate changes to the management regime as a whole would only be permitted if unforeseen developments took place. In the event of the plaice stock falling below B_{lim} new measures would be applied. In the event of the plaice stock going above Bpa during the multi-annual management period, the harvest control rule will be that no amendments are made.

The management measures in the plan consist mainly of an effort reduction. However, the implementation of the effort reduction in the proposed plan is formulated as a capacity reduction. Studies show that capacity reductions do not necessarily results in effort reductions in situations of under-utilisation of capacity.

Intermediate changes to the regime are only allowed when the plaice stock fall below B_{lim}. This rule is problematic to interpret. B_{lim} is currently defined as the SSB below which recruitment is impaired. However, as fisheries management only has a perception of the stock status, generated by stock assessments, the true B_{lim} cannot be know to managers. In the model, we will therefore interpret these words as: "In the event of the plaice stock falling below the **perceived** B_{lim} new measures would be applied". Furthermore, we have assumed that the clause would apply to both plaice and sole.

The measures that would be taken when a stock is perceived to be below B_{lim} are not formulated in the plan, and thus open to interpretation. We have interpreted this measure as a further decrease of nominal fishing effort by 15% each year until SSB has returned to above

B_{lim}. This reduction shall subsequently not be reversed. However, because this implementation in the plan is not clearly defined, we have run models with and without this additional interpretation.

In the NSRAC management plan there is an implicit reference to stability in TACs. The objective of stability of the TACs is not quantified in the original text. The Dutch Ministry of Agriculture, Nature Conservation and Food Quality has requested to include a maximum annual change in TACs of 15%. However, in the present simulation model this has not yet been included as part of the evaluation.

2.3.3 HCR simulation: processes included

Biological operating model

The simulation model consists of "true" underlying plaice and sole stocks (operating model), representing the population dynamics of these stocks. The model is spatially structured, with two areas. The distribution of the species between the areas is estimated from the BTS survey, taking into account different distributions for each of the age classes. In general, sole is distributed mainly in the southern area, throughout its entire life-span, while plaice distribution shifts from south to north during their lifetime.

Data on the development of the stock is available from 1957 to 2004 by XSA assessments, the recruitment in the last 4 years estimated by the last assessment is still uncertain so has been omitted from the study.

From this data, Ricker and Beverton-Holt type *stock-recruitment* relationships were estimated (Figure 2.3.1). For plaice, this relation is estimated directly from the WGNSSK2005 assessment data. For sole, the stock recruitment relation is estimated from WGNSSK2005 that is corrected for the absence of discards in the historic period. This correction factor was estimated by minimizing the sum of squares of the (observed – predicted) landings. In the forward simulation, recruitment estimates are taken from the stock recruitment relation, taking into account the variance estimate from the historic relationship.

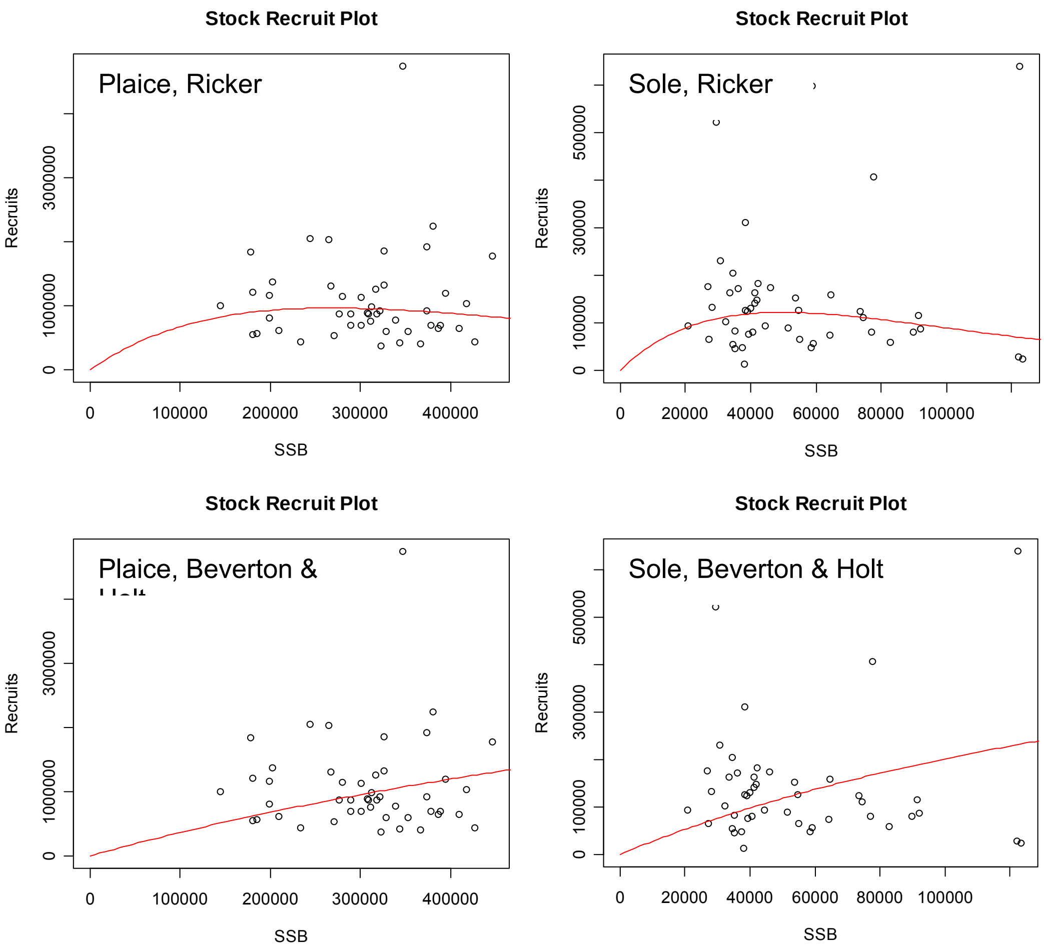
Figure 2.3.1: Stock/recruitment observations (dots) and fitted relations (red lines) of plaice (left) and sole (right), using either a Ricker (top) or Beverton and Holt (bottom) model.

Stock numbers at age were taken from the WGNSSK assessments. The simulations were initiated in 1995 with the observed stock numbers at age and with all estimated recruitments. Landings, discards and survivors were then calculated from the calculated fishing mortality. From 2006 onwards the simulations would use the estimated stock-recruitment relationship to generate recruitment, survivors and catches.

Natural mortality used in the simulation is assumed equal to the WGNSSK2005 estimates, being equal to 0.1 for all ages in both stocks.

Growth in the simulation model is implemented as a Von Bertalanffy growth curve fitted to observed lengths from the BTS survey (Figure 2.3.2). A CV of 0.1 surrounds the length-at-age for all ages for plaice, and 0.17 for sole. The weights-at-age are estimated from a length-weight relation estimated from the BTS survey.

Maturity is assumed equal to the WGNSSK2005 estimates for both stocks.



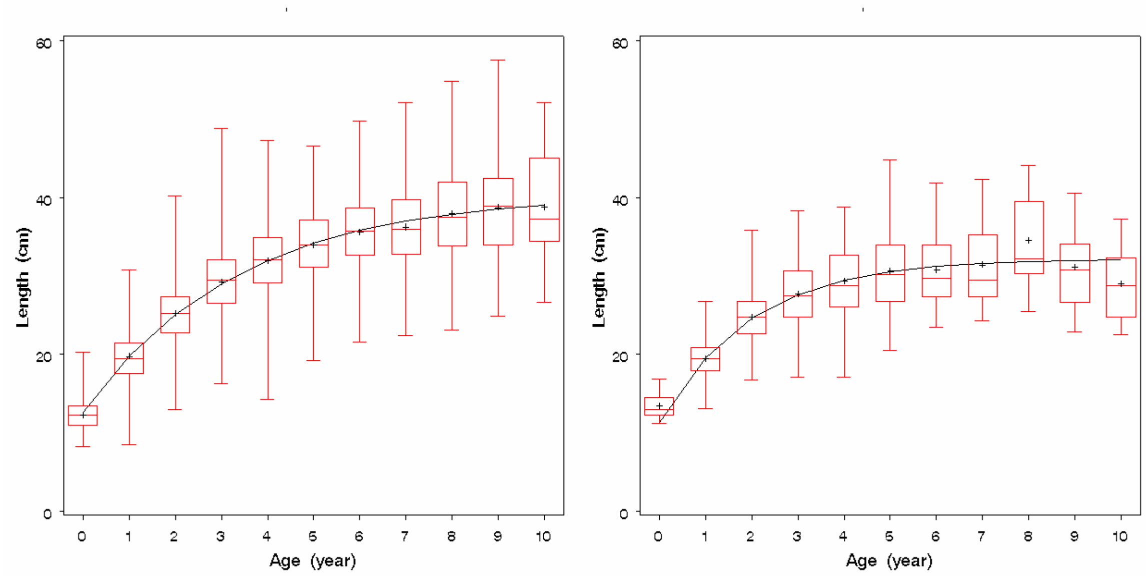


Figure 2.3.2: age/length observations from BTS surves (boxplots) and fitted relations (black lines) of plaice (left) and sole (right), using a Von Bertalanffy growth equation.

The fishery

Exploitation of the fish stocks under consideration mainly takes place by a multi-species demersal fishery, targeting mainly flatfish species sole and plaice. For the purpose of the evaluation the structure of the fishery has been simplified to the two major fleets that take the majority of the catches and it has been assumed that these fleets take all catches. These fleets are the English beam trawl fleet and the Dutch beam trawl fleet. These fleets allocate effort in both areas, with the Dutch beam trawl fleet allocation most of its effort in the southern area, while the English beam trawl fleet allocates effort equally over both areas (Figure 2.3.3). The fishery is allowed to use 80 mm mesh size in the southern area, and 100 mm mesh in the northern area. The 80 mm mesh size in the southern area combined with the minimum landing size of 27 centimetres for plaice causes considerable discarding of juvenile plaice.

During the last 10 years, the nominal fishing effort of the fleets has decreased substantially. However, a recent study has shown that the efficiency of the Dutch beam trawl fleet, one of the major operators in this fishery, has increased between 1.5% (plaice) and 3% (sole) per year. The efficiency increases have been used in the fitting of the operating model and in the future predictions of effective effort, partially counterbalancing the decrease in nominal fishing effort.

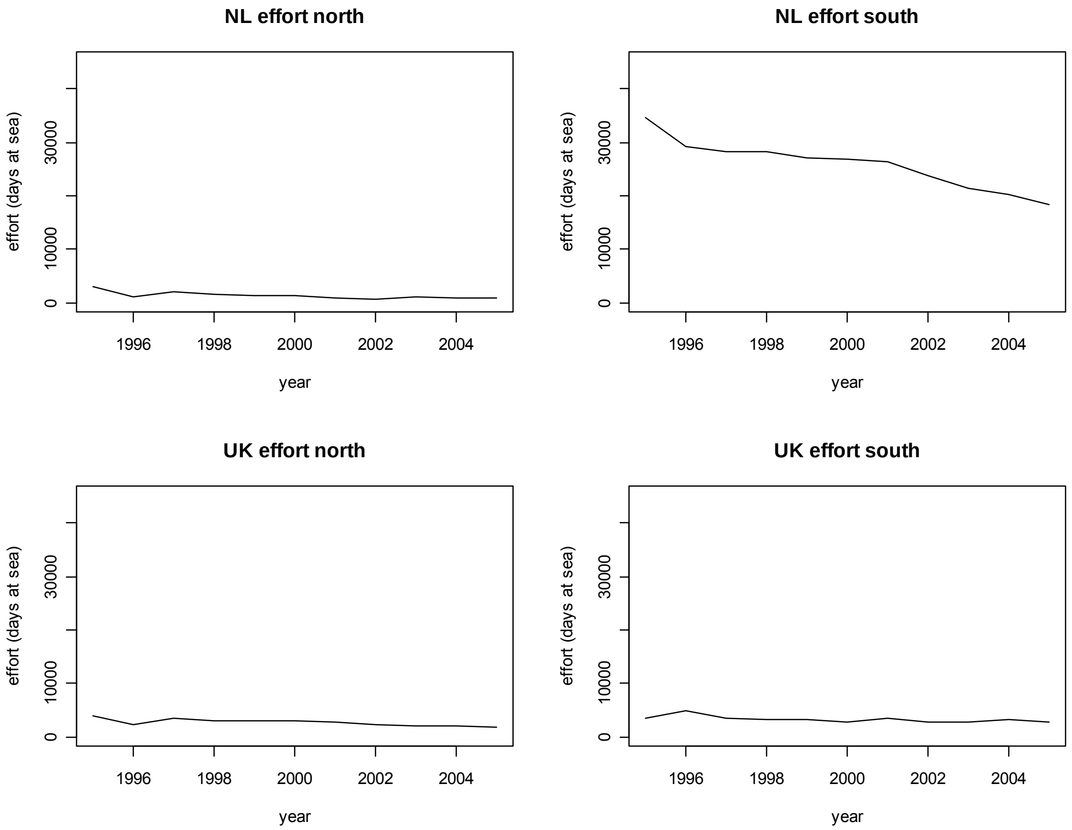


Figure 2.3.3: estimates of historic fishing effort, expressed in days at sea, for the two fleets in the two areas.

Assessment and forecast

Knowledge on the status of the stocks is generated through the explicit inclusion of a stock assessment and forecast model in the simulation. This process encompasses recording the catches and landings of both fleets in the model, and having a survey that covers both areas. The assessment method is XSA based on the landings (sole) or catches (plaice). The implementation of the XSA stock assessment to in the knowledge process explicitly takes into account the assessment error generated by the stock assessment, including potential biases that are dependent on the stock developments. The implementation of a two-year catch prognosis explicitly takes into account potential errors in the advisory process by assuming stable exploitation rates in the intermediate year.

The WGNSSK assessments are tuned with multiple research surveys (plaice) or a combination of surveys and commercial CPUE data (sole). The assessment data are rather noisy, especially the discards estimates of plaice which make up a considerable part of the catch-at-age data. This lack of precision in the assessment has not been fully taken into account in the simulations so far. At present an error of only 10% has been applied to the simulated landings, discards and survey catches. The sensitivity of the results to the assumed error still has to be investigated.

Biological parameters of the stocks in the assessment process are assumed to be equal to the “true” biological parameters set in the operating model. No observation error on growth and maturity are included in the simulation model.

2.3.4 Simulation of the management plan

In the evaluation, nominal fishing effort was reduced by 15% in 2006 compared to 2005. The level of effort was maintained in the following years.

With regards to the Blim trigger, we have interpreted the management plan as: "In the event of **a stock** falling below the **perceived** B_{lim} new measures would be applied".
The measures that would be taken when a stock is perceived to be below B_{lim} are not formulated in the plan, and thus open to interpretation. We have interpreted this measure as a further decrease of nominal fishing effort by 15% each year until SSB has returned to above B_{lim}. This reduction shall subsequently not be reversed. We have run the models both with and without the extra 15% interpretation.

In the NSRAC management plan there is an implicit reference to stability in TACs. The Dutch Ministry of Agriculture, Nature Conservation and Food Quality has requested to include a maximum annual change in TACs of 15%. However, in the present simulation models the TACs are not constraining the fishery. We have not yet implemented the behaviour of fishermen when a TAC is reached but the effort quota is not yet reached. This needs to be done in a future version of the model.

The decision process in each year is based on the prognosis of the remaining spawning stock after the year to which the management action applies. This prognosis is compared to the B_{lim} trigger points from the management plan.

No systematic implementation error with respect to misreporting or unreported landings is included in the simulation.

2.3.5 Conditioning of the operating model

Conditioning of the operating model refers to the way in which the dynamics in the operating model reflect the current understanding of the biological and economic dynamics. The simulation model has been set up with two fleets, two areas and two species. The operating model was constrain to generate the observed dynamics of plaice and sole in terms of landings, discards, SSB and fishing mortality. Given the multiple dimensions in the model (fleet, area and species) it was difficult to choose process parameters that gave a close match between the model estimated landings, discards, SSB and F and the values taken from WGNSSK for the period 1995-2005. This is because the parameter values, functional forms and the area-fleet divisions in the operating model may be different from the true processes which are taken here as the WGNSSK realization. The mean F values in the historic part of the simulation and the WGNSSK estimates are given in figure 2.3.4.

2.3.6 Robustness testing

Robustness testing is the process whereby the robustness of the management strategy is tested to the variability in the operating model (nature, fleet dynamics) and the uncertainty in the knowledge generation process (stock assessment, forecasts).

The management evaluation has not been finalized yet. Therefore, the results are still preliminary, and not all robustness testing has been carried out. The robustness of the evaluation to two different hypothesis have so far been tested in several runs (Table 2.3.1), each with 50 iterations:

- sensitivity to the implementation of the 15% effort reduction when the stock falls below the B_{lim}. The implementation of this rule has a large effect on the risk of failing the objective, because the present poor state of the sole stock results in further effort reduction, reducing fishing mortality for both sole and plaice.
- sensitivity to the stock recruitment curve (either "Ricker" or "Beverton and Holt"). The median recruitment is higher using the Ricker stock-recruitment curve compared to the

Beverton-Holt curve (Figure 6), so that the Ricker curve can be interpreted as a favourable environmental scenario and the Beverton-Holt as an unfavourable scenario.

Table 2.3.1: Model hypothesis used in robustness testing of management plan

Run	Stock recruitment relation	Rule
1	Beverton & Holt	• 15% effort reduction in 2006
2	Beverton & Holt	• 15% effort reduction in 2006 • Additional 15% effort reduction if stock falls below perceived Blim
3	Ricker	• 15% effort reduction in 2006
4	Ricker	• 15% effort reduction in 2006 • Additional 15% effort reduction if stock falls below perceived Blim

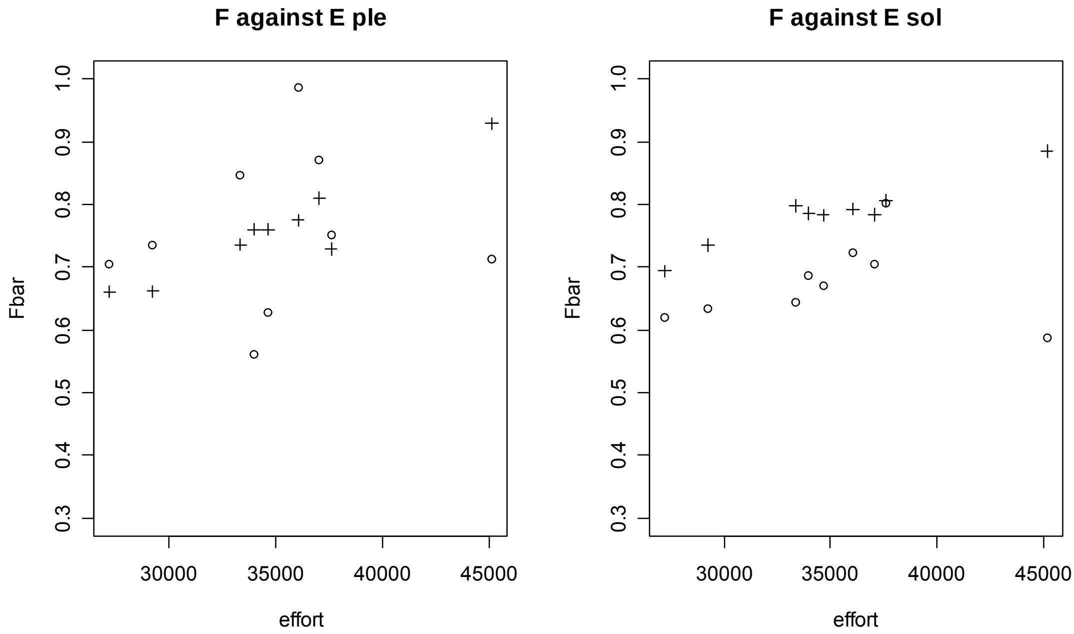


Figure 2.3.4: Effort / mean F (ages 3:6) relation observed from the model (+) and from the WGNSSK2005 assessment data (○) for plaice (left panel) and sole (right panel)

2.3.7 Results

The simulation model of the management plan proposed by NSRAC Indicate that:

1. The fitted landings for both plaice and sole are lower than the observed landings in the historic period (Figure 2.3.5). This result indicates that it is difficult to get a good fit of the selectivity and catchability parameters in the model and that in general it is difficult to mimic the perception from the WGNSSK, which is due to one historic realisation. The issue of fitting operating models to data requires much more attention in the process of developing simulation models. The dynamics in the operating model determine the outcome of the simulations to a large extend and a lack of fit to the historic data reduces the communication value of the evaluation, because clients will want to refer to fixed reference levels.

2. The probability of achieving the plaice B_{pa} target in 2010 is between 98% and 62% depending on the type of stock-recruitment relationships and whether or not additional measures are taken when a stock is below B_{lim} (Table 2.3.2) The probability of SSB being below B_{lim} is less than 2% in all runs.

3. The probability of reaching the sole B_{pa} in 2010 is between 82% and 48% (Table 2.3.3). Due to the low recruitment in 2003 and 2004 that has been measured in the surveys, the SSB in all runs is expected to fall below B_{pa} in the first years after the implementation of the management plan (Figure 2.3.6). Only when additional effort reductions are applied when perceived SSB is below B_{lim}, there is a high probability (82%) of that SSB will be above Bpa in 2010. This scenario is consistent with overall effort reductions in the order of 40% (Beverton-Holt stock-recruitment curve) or 30% (Ricker curve). See table 2.3.4 for details.

4. The recruitment trajectories for future predictions show variances that are equal to the observed variances for both species in the past. The median recruitment in the prediction is higher using the Ricker Stock recruitment curve compared to the Beverton-Holt curve (Figure 2.3.7), so that the Ricker curve can be interpreted as a favourable environmental scenario and the Beverton-Holt as an unfavourable scenario.

5. For plaice, the expected landings associated with the management plan remain stable between 65 000 and 75 000 tonnes. For sole, the landings initially decrease in all runs. When a favourable environmental regime is assumed (Ricker curve) the landings are expected to increase again after the initial decline. The 95% confidence intervals of the predicted sole landings vary between 4-28 thousand tonnes with a mean around 9 and 13 thousand tonnes. This is much lower than in the historical period.

2.3.8 The process of evaluation

The process of evaluation of the North Sea RAC management plan has been started in November 2005, when RIVO was requested to carry out such an evaluation by the Dutch Ministry of Agriculture, Nature Conservation and Food Quality (LNV). There were three major actors involved in the evaluation: the ministry LNV, the NSRAC through the chairperson of the NSRAC flatfish group and the research group at RIVO.

The research plan was to develop a simulation model in the FLR[1] framework as this was a way to combine the development of a practical application in FLR with a very directed request from the clients, which could not be addressed with standard software.
It was very clear from the beginning of the process, that the management plan of the NSRAC was not specific enough for a simulation approach. Simulating management plans, requires that all eventualities be covered in the plan and that no ambiguities are left. However, in order to lift those ambiguities, a close connection between the different parties would have been required. Yet, the rush of the December Council of ministers where both the ministry and the NSRAC were involved prevented such a connection.

Only in January 2006, it has been possible to establish a discussion on how the contents of the management plan should be interpreted. We noted that it is not obviously clear to the clients what the evaluation software can and cannot do. Sometimes the expectations with regards to details of the plan and the precision of the outcome were much higher than can be warranted from a tool that is mainly designed to explore the overall effect of different strategies.

The lesson learnt from this process, it that there needs to be a frequent dialogue between scientists and clients/stakeholders on how the evaluation should be set up, what kind of results to expect and how to digest the results.

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1 www.flr-project.org

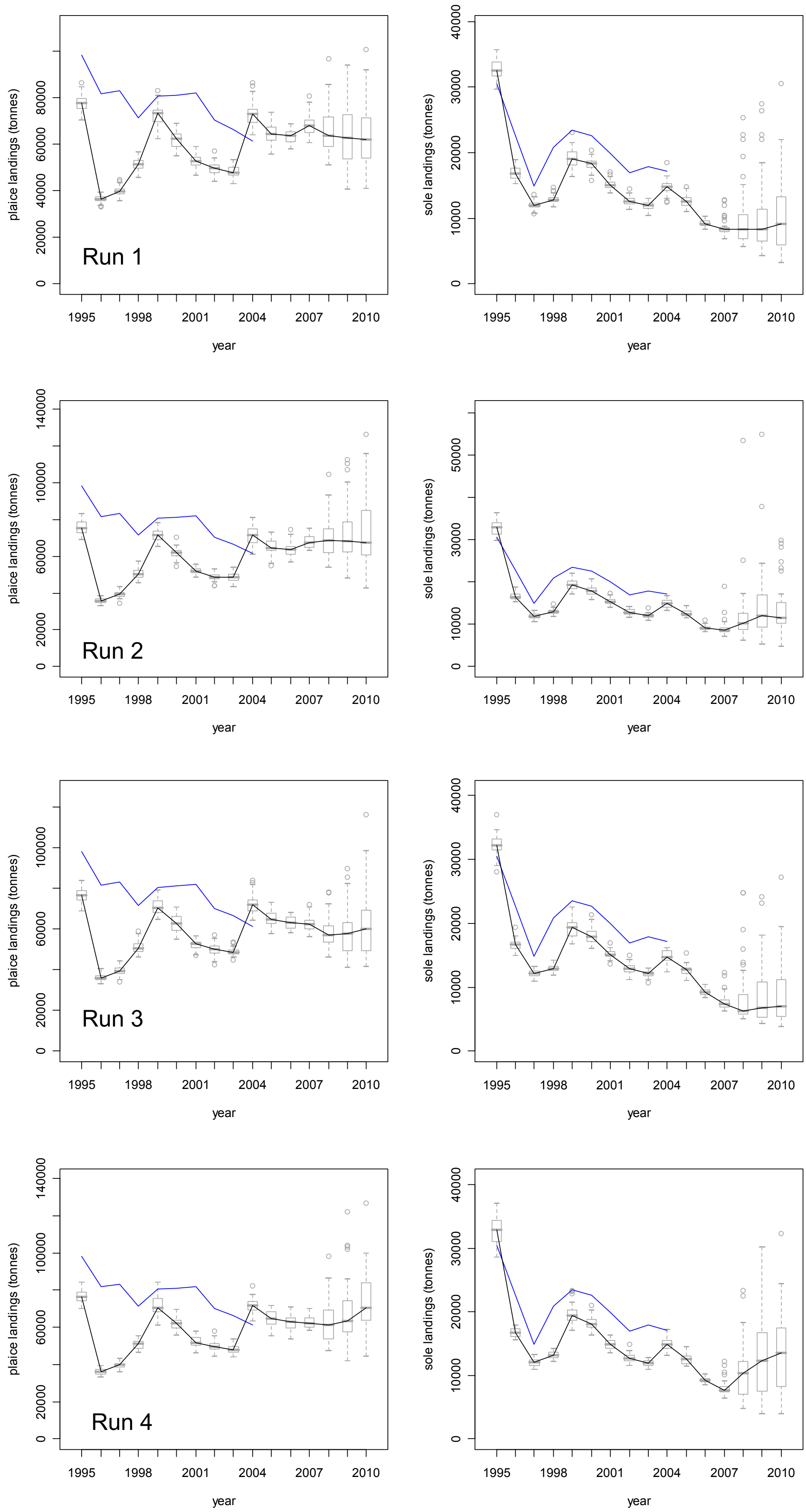

Figure 2.3.5: Landings of plaice (left) and sole (right), for the 4 different runs (see panels, table 1). Boxplots connected through median by black line indicate model fit and prediction. Blue line indicates historic observations.

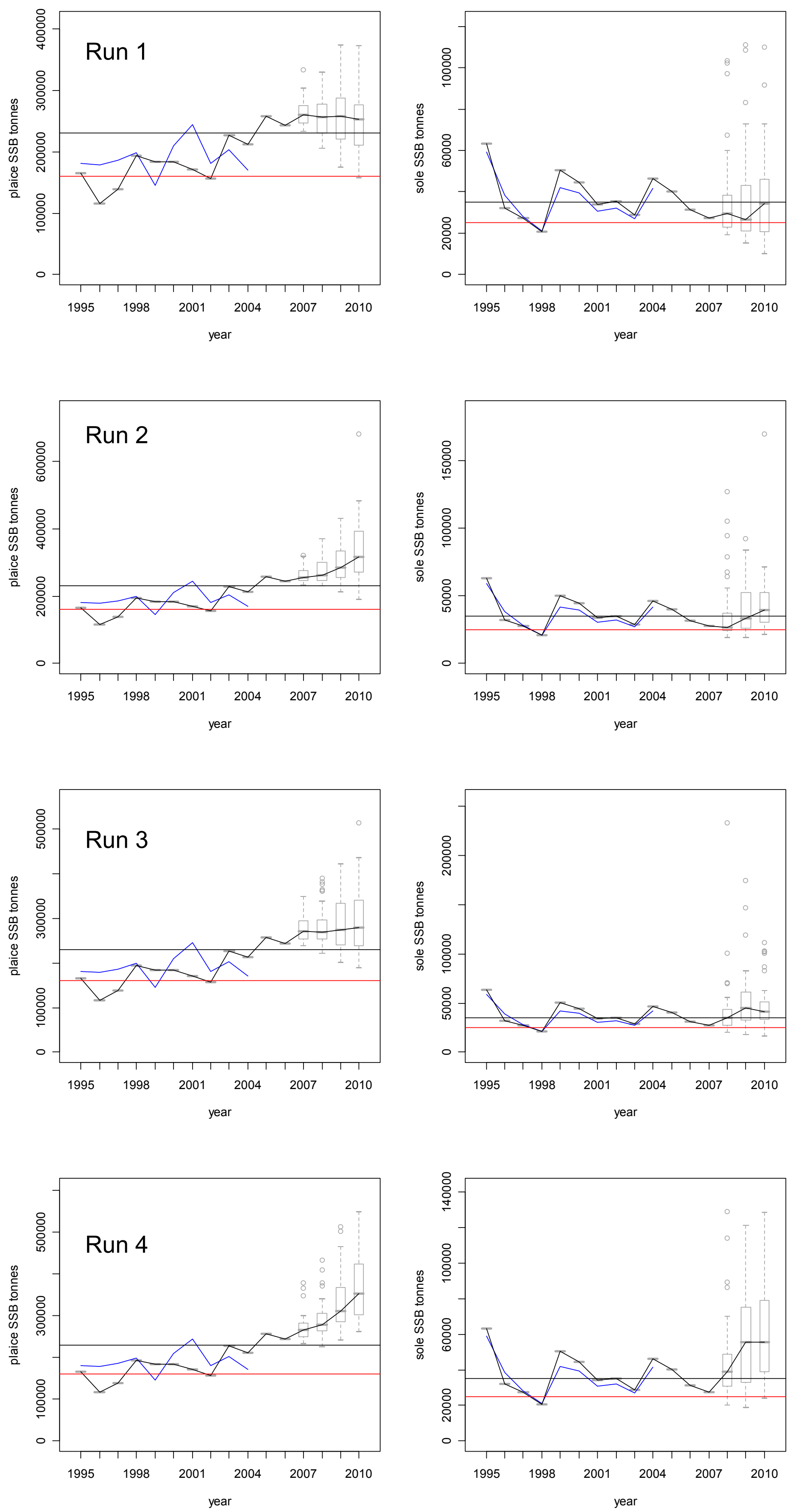

Figure 2.3.6: SSB of plaice (left) and sole (right), for the 4 different runs (see panels, table 1). Boxplots connected through median by black line indicate model fit and prediction. Blue line indicates XSA estimates of SSB from WGNSSK 2005. Horizontal lines indicate Bpa (black) and Blim (red).

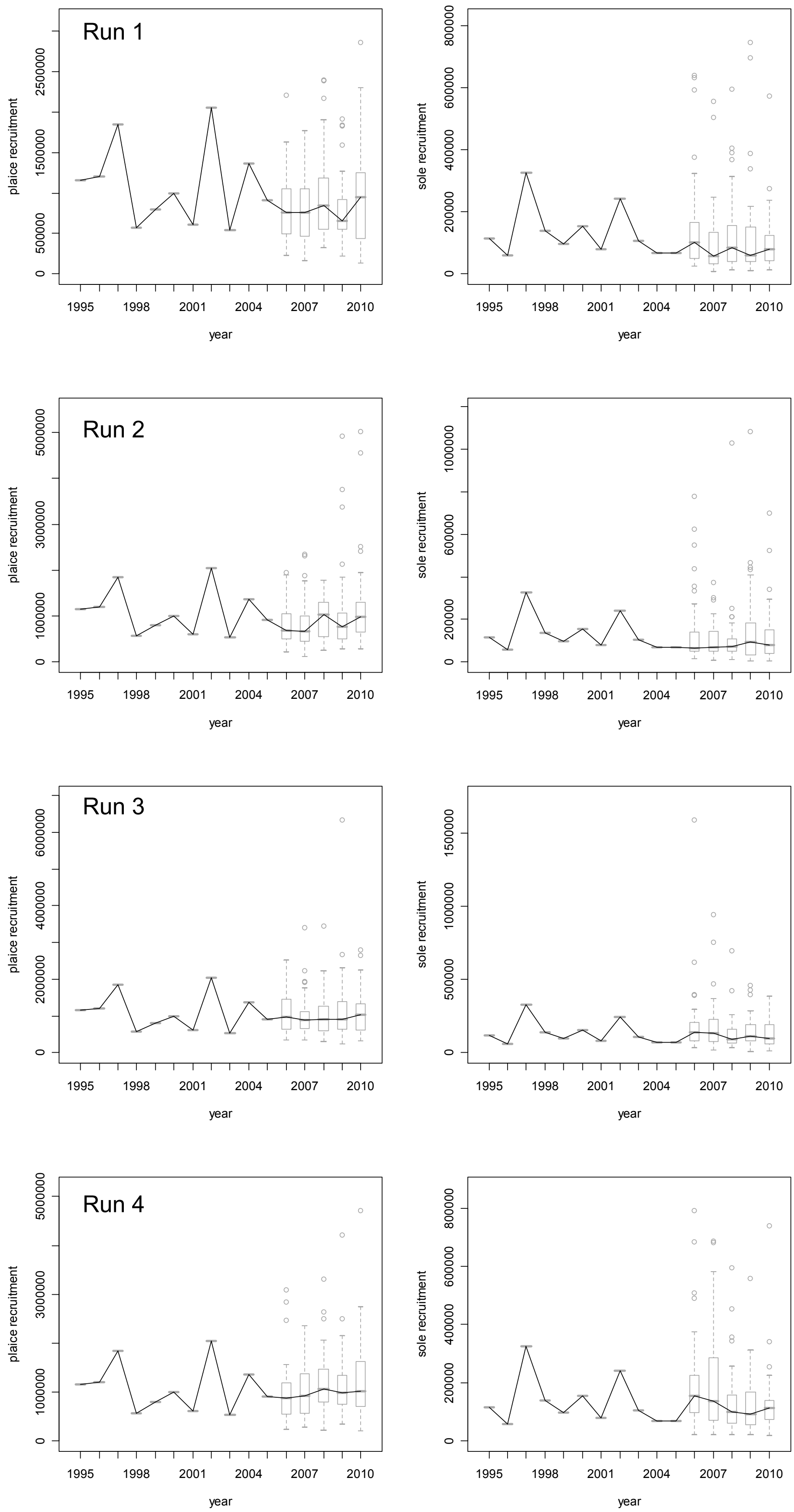

Figure 2.3.7: Recruitment of plaice (left) and sole (right), for the 4 different runs (see panels, table 1). Boxplots connected through median by black line indicate model fit and prediction.

Table 2.3.2: Summary of model runs for plaice

Run	True SSB < Blim (any year)	Perceived SSB < Blim (any year)	Perceived SSB < Bpa (any year)	True SSB < Blim (2010)	True SSB < Bpa (2010)	Median recruitment simulated period and 95% percentiles	Median true ssb and 95% percentiles (2010)	Median landings and 95% percentiles (2010)
						100 000 000	**100 000 tonnes**	**10 000 tonnes**
1	<2%	8%	>98%	< 2%	38%	7.83 (3.60 19.0)	2.48 (1.96 3.85)	6.22 (4.73 9.90)
2	<2%	10%	>98%	< 2%	8%	8.02 (3.11 21.1)	3.27 (2.35 5.50)	6.53 (4.11 10.7)
3	<2%	6%	>98%	< 2%	8%	8.71 (3.72 22.4)	2.88 (2.19 4.37)	7.64 (5.25 11.6)
4	<2%	<2%	>98%	< 2%	<2%	9.29 (4.14 24.3)	3.63 (2.70 6.04)	7.38 (5.56 13.7)

Table 2.3.3: Summary of model runs for sole

Run	True SSB < Blim (any year)	Perceived SSB < Blim (any year)	Perceived SSB < Bpa (any year)	True SSB < Blim (2010)	True SSB < Bpa (2010)	Median recruitment simulated period and 95% percentiles	Median true ssb and 95% percentiles (2010)	Median landings and 95% percentiles (2010)
						10 000 000	**10 000 tonnes**	**1 000 tonnes**
1	55%	>98%	>98%	30%	52%	7.48 (1.96 39.1)	3.42 (1.37 7.38)	9.09 (4.08 21.2)
2	42%	>98%	>98%	10%	46%	7.63 (2.37 43.4)	3.96 (2.38 6.34)	7.07 (4.27 18.9)
3	18%	>98%	>98%	6%	30%	11.5 (3.52 39.3)	4.13 (2.61 10.2)	11.4 (7.90 28.2)
4	10%	>98%	>98%	2%	18%	11.8 (2.82 49.0)	5.58 (2.90 9.14)	13.5 (4.58 22.2)

Table 2.3.4: Summary of model runs for fishing effort

Run	Median effort and 95% percentiles (2010)
	10 000 Days at sea
1	2.02*
2	1.24 (1.06 1.72)
3	2.02*
4	1.46 (1.06 1.72)

*percentiles equal to median

2.4 Review of the report on partial fishing mortality in the Dutch beamtrawl fleet

Rijnsdorp et al (2005) showed that fishing mortality per unit of effort (FPUE) can be standardized to a 2000 HP vessel and that this standardized FPUE fluctuated in time and space according to a predictable pattern. The average seasonal patterns in FPUE showed a peak in autumn and a low in summer in most areas (Figure 2.4.1). Only in the eastern central North Sea, FPUE peaks in late autumn and reaches a low in early spring.

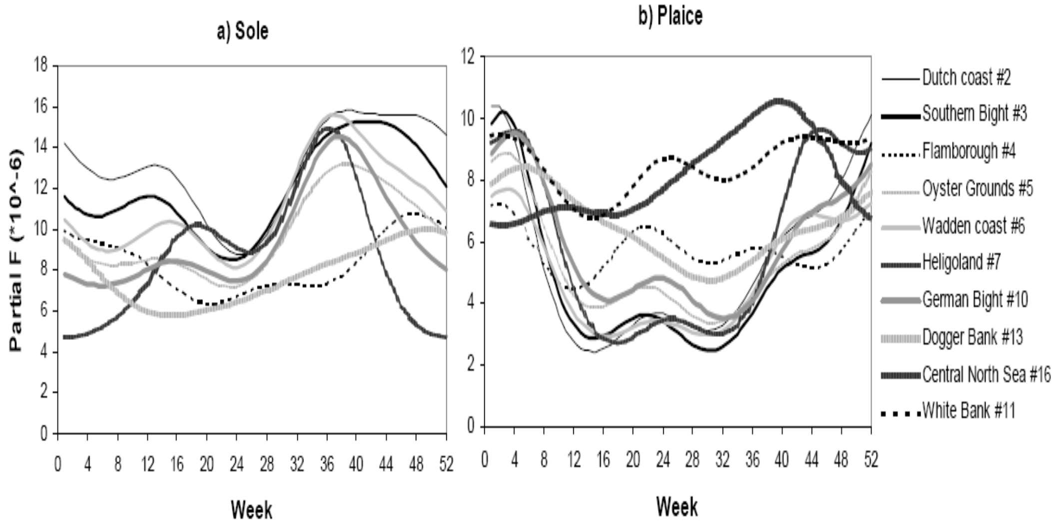

Figure 2.4.1: Model estimated seasonal patterns in partial FPUE for sole (a) and plaice (b) for a vessel of 2000 hp.

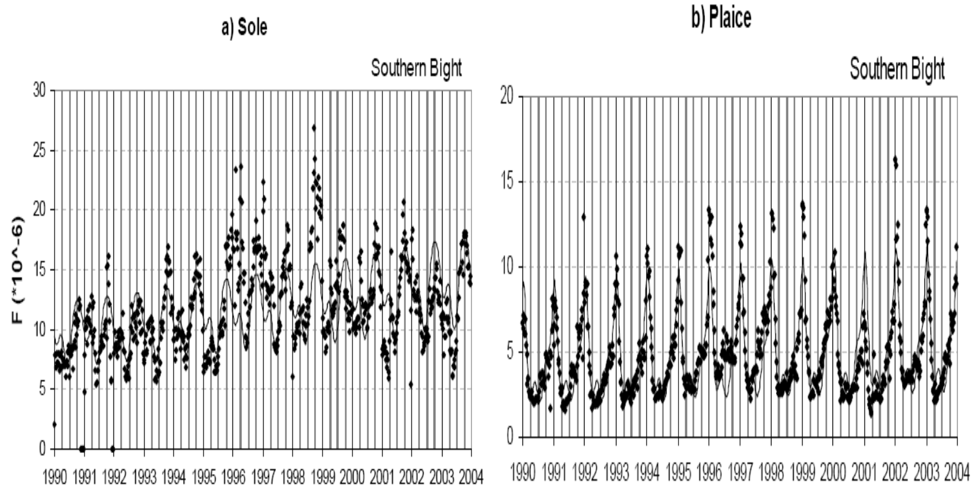

Figure 2.4.2: Seasonal pattern in partial fishing mortality for a 2000 hp trawler in the Southern Bight.

The longer term trends in FPUE are shown in figure 2.4.2. The model showed a significant positive trend in FPUE Indicating that the FPUE increased by around 3% per year in sole and 1.5% in plaice. This can be interpreted as an increase in efficiency.

2.5 Discussion and Conclusions

In the evaluation of the NSRAC management plan, a simulation model has been developed in FLR that consists of an operating model and a management procedure (data sampling, assessment and harvest control rule). The FLR toolbox is still under development but at present it already allows the development of custom made simulation models for specific situations and harvest rules.

The conditioning of the operating model on the observations from WGNSSK 2005 has been proven difficult. The operating model has been “fitted” using a very simple iterative process to estimate catchability, distribution over areas and recruitment levels. The selectivity of the fleet is assumed the result of the distribution of the fleet over the two areas, each with different mesh sizes. Combining the mesh size in each of the areas with the growth curves of the species results in the selectivity. This assumption is different from the assumptions made in XSA to which these data are compared. The final operating model generates approximately equal stock sizes in both observed and fitted SSB but the predicted landings for sole and plaice appear to be lower than the observed landings. It should be noted that all the results are conditional on the current fit. This study shows that the parameterisation of simulation models to evaluate management plans is an area that requires more methodological development.

The discarding of juvenile sole below the minimum landing size is estimated to be between 10-20%, but has not been included in the WG assessments (WGNSSK2005). Therefore, the stock-recruitment relationship for sole has been derived from a landings-based assessment that underestimates the “true” recruitment. In the simulation model we have implemented the process of fishing as a combination of effort, selectivity and catchability, which does generate discards due to the combination of the distribution of the stock and the fishery. Therefore, the recruitment estimates had to be corrected for the inclusion of discards in the simulation. This could be a generic issue for operating models that are conditioned on stock assessments that are based on landings only.

The management plan as it formulated by the NSRAC is does not always clearly state the objectives and measures. This leaves room for interpretation, and results are dependent on this interpretation. One of the interpretations is that the 15% effort reduction is formulated as a reduction in nominal effort rather than a reduction in capacity. This is especially important in the case of capacity under-utilization, where capacity reduction generally does not lead to effort reduction.

The observed sole SSB has a high probability of falling below B_{lim} in the prediction. This is largely driven by the series of low recruitments at the end of the observed time series. These observed recruitment have been used directly in the operating model. The expected low sole stock implies that management actions to implement the additional effort reduction rule are mainly triggered by sole. If further effort reductions are implemented when a stock is below Blim, this is expected to lead to higher SSB and catches of plaice despite the lower effort.

The success of effort management is dependent on a clear relation between fishing effort and fishing mortality. At present that relationship is poorly known. Figure 2.3.4 indicates that the relationship between effort and F in the WGNSSK data is much more noisy that the relationship that is generated from the operating model. This suggests a much more “responsive” effort-F relationship in the simulation model which could give the impression that changing effort will be directly detectable whereas in practice these changes in effort have often not lead to detectable changes in fishing mortality. We also noted that the inclusion of technical efficiency creep was a very important aspect to take into account in the simulation model. In the absence of technical creep and given the observed decreases in nominal effort, any model result would indicate a very strong decrease in fishing mortality and hence a quick increase of the stocks.

The current evaluation of the NSRAC management plan has been restricted to the effects of effort measures. The limitations due to TACs and the 15% limit in annual TAC changes have not (yet) been used in this evaluation.

The seasonal and spatial patterns in FPUE indicate that an overall reduction in fishing effort may have different effects on the overall fishing mortality depending on where the effort reduction is actually achieved and whether it is applied uniformly over the year.

3 Relationship between F and effort for plaice and sole

3.1 Question

"In het schol advies wordt een verband gelegd tussen de zeedagen restricties (en olieprijzen) en de verdeling van de vloot over kustwateren en centrale Noordzee. Is er een dergelijk verband met tong te leggen? Is er een kwantitatieve relatie tussen F (tong en schol) en de visserij-inspanningsreductie (zeedagen/motorvermogen) te leggen?"[1]

3.2 Approach

This question asks for a detailed study on the relation between the fishing effort by the two main beam trawl fleets (NL and UK) and the fishing mortality of sole and plaice. The relation between fishing effort and fishing mortality is dependent on the areas in which the fishing effort is excerted. It is therefor important to take the spatial distribution of fishing effort Into account.

3.3 Results

The nominal fishing effort expressed in horsepower days for the main beam trawl fleet has increased to reach peak levels in the mid '90s. (Fig. 3.3.1). Since then, a decrease has been observed. However, the efficiency of the fishing fleet for sole has increased in this period by up to 2.5 % (Rijnsdorp 2005). The efficiency increase affects the effective fishing effort. The effective effort for sole appears to have decreased, but to a lesser extend than the nominal fishing effort. For plaice, the efficiency increase is smaller than for sole, and estimated to be approximately 1.5%.

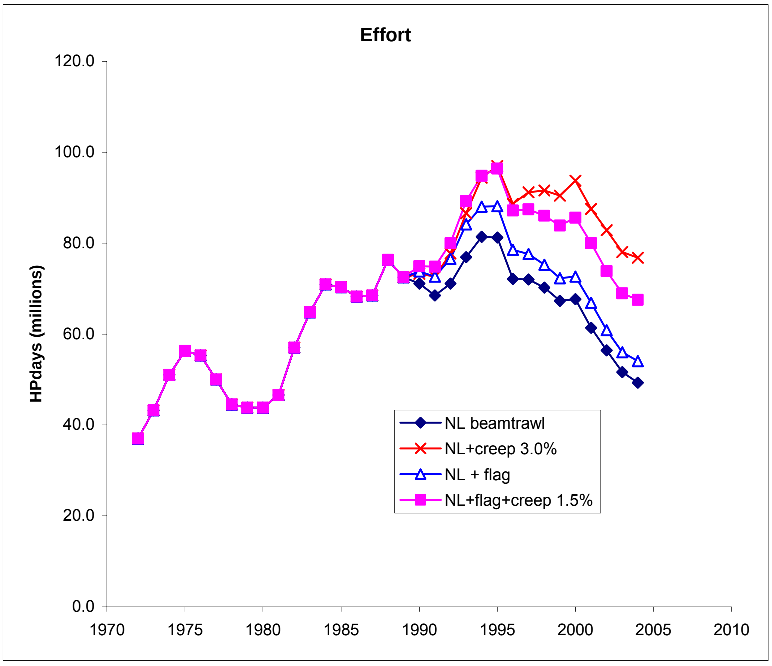

Figure 3.3.1: Trends in Dutch nominal fishing effort (HPdays at sea) by area

[1] *"In the plaice advice, there is linkage between the restrictions in days at sea (and oilprices) and the spatial distribution of the fleet In the coastal waters and the central North Sea. Can such a linkage be assumed for sole as well? Is there a quantitive relationship between F (sole and plaice) and the reduction in fishing effort (days at sea/engine power)?*

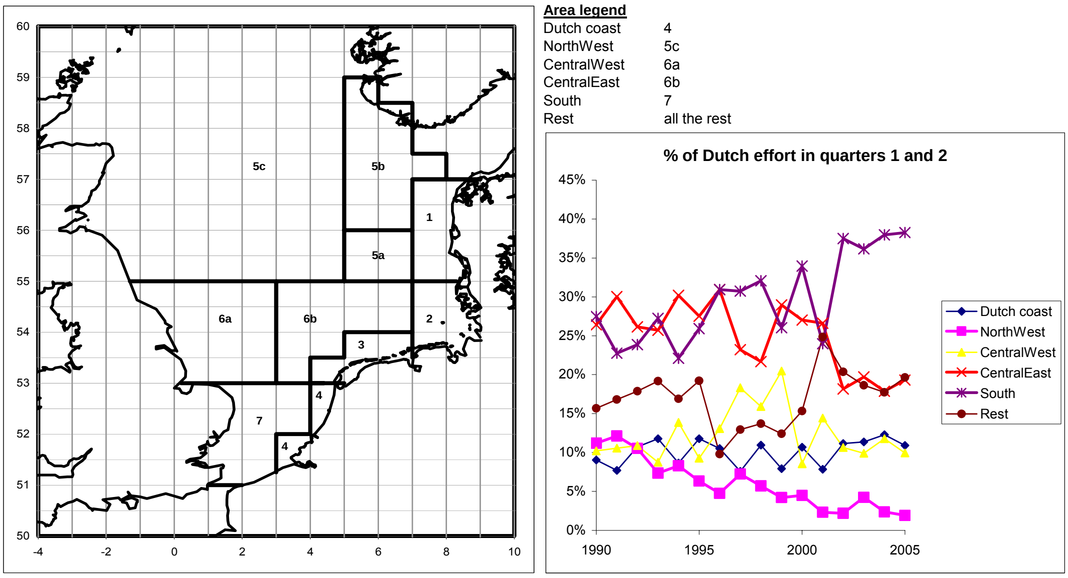

Figure 3.3.2: Time series of the spatial distribution of Dutch nominal fishing effort

The spatial distribution of the Dutch beam trawl fleet has shifted considerably (figure 3.3.2). From the early 1990s, the fishing effort has shown a gradual shift from the Northern areas to the southern areas. In the early 1990s, up to 12% of fishing effort was allocated In the Northwest area, decreasing to less than 3% in 2005. On the other hand, fishing effort In the the Southern area Increased from approximately 27% to almost 40%.

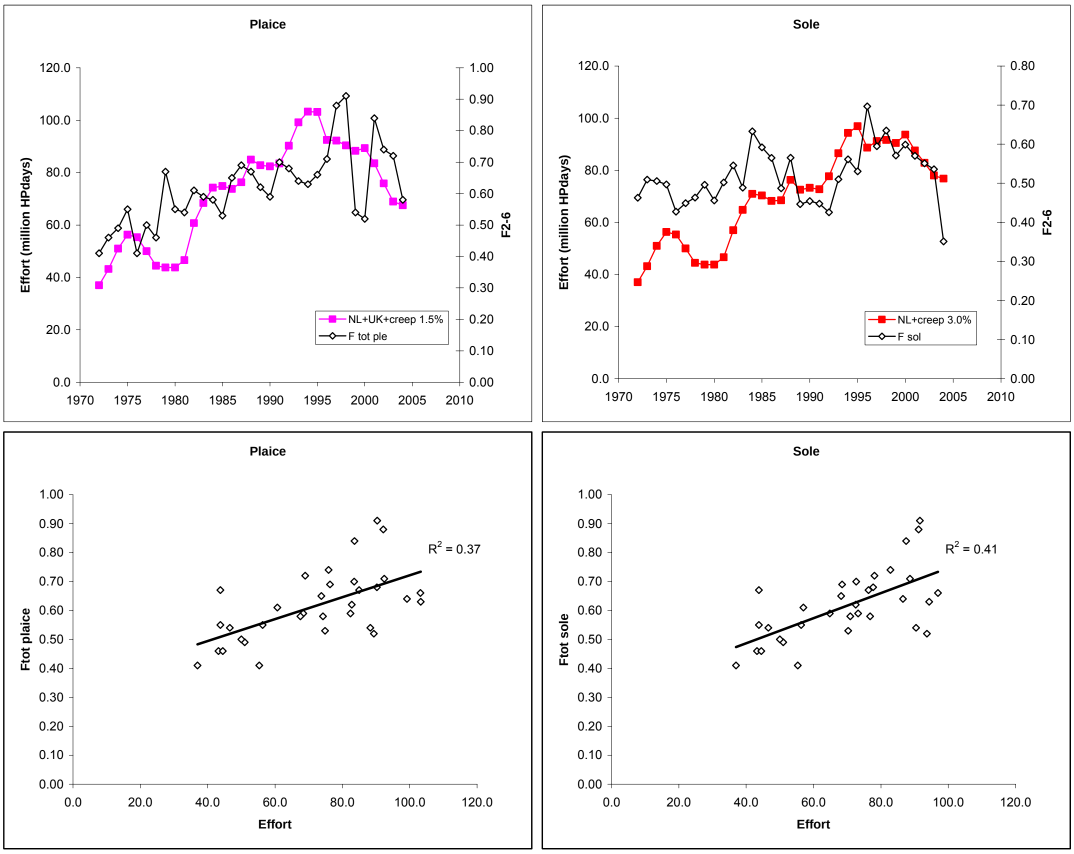

Figure 3.3.3: Historic trends in effective fishing effort and fishing mortality for sole and plaice (upper panels), and regression plot of fishing mortality versus fishing effort (lower panels)

Comparing the trends in effective fishing effort and fishing mortality for sole and plaice, It appears that In recent history, the fishing mortality for sole follows more closely the observed fishing effort than the fishing mortality for plaice. However, the fishing mortality for sole in the most recent year is estimated to be far lower than expected from the fishing effort. The large inter-annual fishing mortality for plaice observed during the last 10 years may be the result of the incorporation of discards estimates in the stock assessment. These discard estimates are based on a low number of international samples, but make up a large fraction of the catch-at-age matrix upon which the sock assessment is based. The differences in the similarity between mortality and effort between the two species result in differences between the explained variance in figures 3.3.3.

3.4 Discussion and conclusions

After correction of nominal fishing effort for efficiency increase, the relation between fishing effort and fishing mortality appears better defined for sole than for plaice. The spatial redistribution of fishing effort during the last 15 years may contribute to these differences. Moreover, owing the considerable amount of plaice discards, the stock assessment used to estimate fishing mortality uses discards for plaice, but not for sole. The plaice discards are based on a small number of international discard samples, therefore adding uncertainty in the assessment. The low estimate of fishing mortality in the final year of the assessment is likely to increase in future assessments, as this is a general trend in the assessment of sole.

Poor relations between fishing mortality and fishing effort should cause for concern when In case of fisheries management by reduction in fishing effort, because changes in effort may not result in changes in mortality.

4 Stepwise approach based on TACs

4.1 question

"Wat zijn de gevolgen voor SSB in ’06 en ’07 als:

TAC	2006	2007		TAC	2006	2007
Plaice	60	60		Sole	18	18
Plaice	55	55		Sole	17	17
Plaice	50	50		Sole	16	16
				Sole	15	15

Voor tong gelden dan de 2 scenario’s: met na 2004 weer een gemiddeld recruitment óf met een blijvend laag recruitment." [1]

4.2 approach

This analysis estimates the effects of different TAC settings for the population size predictions of flatfish species sole and plaice. The approach uses an iterative process of calculating stock numbers-at-age in a year t+1 using natural mortality (M) and different levels of fishing mortality (F) from the previous year. The levels of fishing mortality-at-age are set using the observed average fishing pattern from 2002 to 2004 and the resulting landings that are assumed equal to the desired TACs (see text table above).

The initial population numbers at age needed in this analysis are derived from the ACFM. Recruitment into the population is generally assumed to be equal to the geometric mean of the time series of estimated recruitment. Age two is generally estimated using a regression technique on the surveys data for young fish, and older ages are generally assumed the survivors of the last year of the stock assessment using the “Baranov equation”. Mean weights were calculated as the averages between 2002 and 2004.

This analysis strongly leans on the assumption that future exploitation patterns are equal to those observed in the recent past, and may not be dependent on the level of the TAC. This assumption is questionable, as fishing fleets may adapt to changing situations like TAC constraints.

4.3 results

4.3.1 North Sea Plaice

The population numbers in 2005, that are used as a basis for this analysis are derived from three different sources (Table 1, annex). Age 1 population numbers are assumed equal to the geometric mean of recruitment, being equal to 913 747 million. Age 2 population numbers are estimated using callibrative regression analysis of surveys (RCT3), including the Beam Trawl Survey (BTS) survey conducted in 2005. RCT3 analysis estimates this age to be 598 million. All other ages are calculated as being the survivors from the 2004 ages, given the M and F estimates.

The mean fishing mortality between ages 2-6 in 2005 is assumed equal to 2004, resulting in the F-at-age in 2005 in table 1 (annex). In 2006, population numbers are derived from survivor analysis with the exception of the recruits, which are derived from geometric mean recruitment. The estimated Spawning Stock Biomass in 2006 is 191 145 tonnes.

Scenario for 2006

[1] *"What are the consequences for SSB in 2006 and 2007 for the presented TAC scenarios, assuming for sole 2 scenarios: average recruitment or below average recruitment after 2004?"*

The first year in which the TAC options are calculated is 2006. The mean F values in 2006 and SSB in 2007 associated with options are presented in table 4.3.1. None of these options result in a spawning stock biomass higher than Bpa (230 000 tonnes) in 2007.

Table 4.3.1. North Sea Plaice. Mean F values in 2006 and SSB in 2007 associated with the TAC options.

TAC 2006	F2-6 2006	SSB 2007
50	0.42	221 157
55	0.47	211 526
60	0.53	201 899

Scenarios for 2006 and 2007

The fishing mortality in 2007 and the SSB in 2008 resulting from the TAC options in 2007 depend on the TAC option in 2006. The F values resulting from the combination TAC2006/TAC2007 are presented in table 4.3.2. The SSB values resulting from the combination TAC2006/TAC2007 are presented in table 4.3.3 and figure 4.3.1. Several of the explored combinations of TACs in 2006 and 2007 are expected to result in SSB above 230 000 tonnes in 2008.

Table 4.3.2. North Sea Plaice. F estimates in 2007 resulting from TAC options in 2006 and 2007

		TAC 2007		
		50	**55**	**60**
TAC 2006	50	0.35	0.39	0.43
	55	0.37	0.41	0.46
	60	0.39	0.44	0.49

Table 4.3.3. North Sea Plaice. SSB estimates (tonnes) in 2008 resulting from TAC options in 2006 and 2007

		TAC 2007		
		50	**55**	**60**
TAC 2006	50	269 841	260 241	250 648
	55	255 123	245 453	235 789
	60	240 378	230 625	220 894

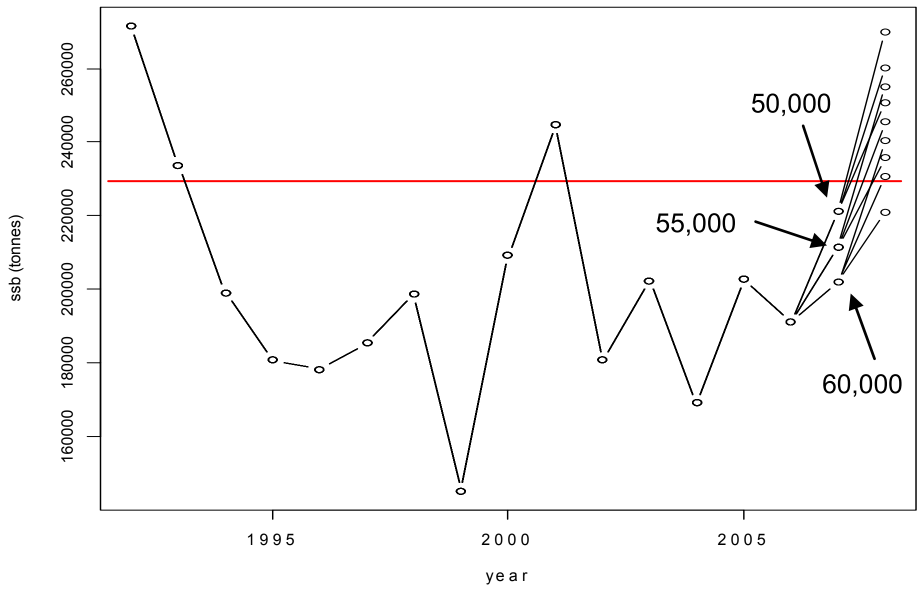

Figure 4.3.1: North Sea Plaice. Time series of spawning stock biomass for the TAC options. The horizontal red line Indicates Bpa for North Sea plaice. Arrows indicate TAC settings.

4.3.2 North Sea Sole: medium recruitment

The population numbers in 2005, that are used as a basis for this analysis are derived from two different sources (Table 2, annex). Age 1 and 2 population numbers are estimated from surveys using RCT3 regression analysis. The RCT3 analysis includes the 2005 BTS survey. The estimates of age 1 and 2 (year classes 2004 and 2003) are 56 and 55 million which is 35% and 42% below average. The population numbers of the older ages are the survivors in 2005 from the assessment as presented by ACFM. Average recruitment (97 million)) has been assumed from 2006 onwards. The fishing mortality in 2005 is assumed equal to 2004.
The resulting population in 2006 has a Spawning Stock Biomass of 41 393 tonnes.

Scenario for 2006

The first year in which the TAC options are calculated is 2006. The mean F values in 2006 and SSB in 2007 associated with options are presented in table 4.3.4. None of these options result in a spawning stock biomass higher than Bpa (35 000 tonnes) in 2007.

Table 4.3.4. North Sea Sole. Population parameter estimates

TAC 2006	**F2-6 2006**	**SSB 2007**
15	0.40	32 084
16	0.43	31 100
17	0.46	30 116
18	0.50	29 136

Scenarios for 2006 and 2007

The fishing mortality in 2007 and the SSB in 2008 resulting from the TAC options in 2007 depend on the TAC option in 2006. The F values resulting from the combination TAC2006/TAC2007 are presented in table 4.3.5. All F values are above Fpa in the scenarios considered.

The SSB values in 2008 resulting from the combination TAC2006/TAC2007 are presented in table 4.3.6 and figure 4.3.2. All scenarios indicate that SSB will be below Bpa in 2008.

Table 4.3.5. North Sea Sole. F estimates in 2007 resulting from TAC options in 2006 and 2007

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="4">TAC 2007</td></tr>
<tr><td>15</td><td>16</td><td>17</td><td>18</td></tr>
<tr><td rowspan="4">TAC 2006</td><td>15</td><td>0.43</td><td>0.46</td><td>0.50</td><td>0.53</td></tr>
<tr><td>16</td><td>0.44</td><td>0.48</td><td>0.52</td><td>0.56</td></tr>
<tr><td>17</td><td>0.45</td><td>0.49</td><td>0.53</td><td>0.58</td></tr>
<tr><td>18</td><td>0.47</td><td>0.51</td><td>0.55</td><td>0.60</td></tr>
</table>

Table 4.3.6. North Sea Sole. SSB estimates (tonnes) in 2008 resulting from TAC options in 2006 and 2007

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="4">TAC 2007</td></tr>
<tr><td>15</td><td>16</td><td>17</td><td>18</td></tr>
<tr><td rowspan="4">TAC 2006</td><td>15</td><td>33 379</td><td>32 394</td><td>31 404</td><td>30 418</td></tr>
<tr><td>16</td><td>32 373</td><td>31 391</td><td>30 401</td><td>29 413</td></tr>
<tr><td>17</td><td>31 377</td><td>30 386</td><td>29 401</td><td>28 413</td></tr>
<tr><td>18</td><td>30 373</td><td>29 383</td><td>28 399</td><td>27 415</td></tr>
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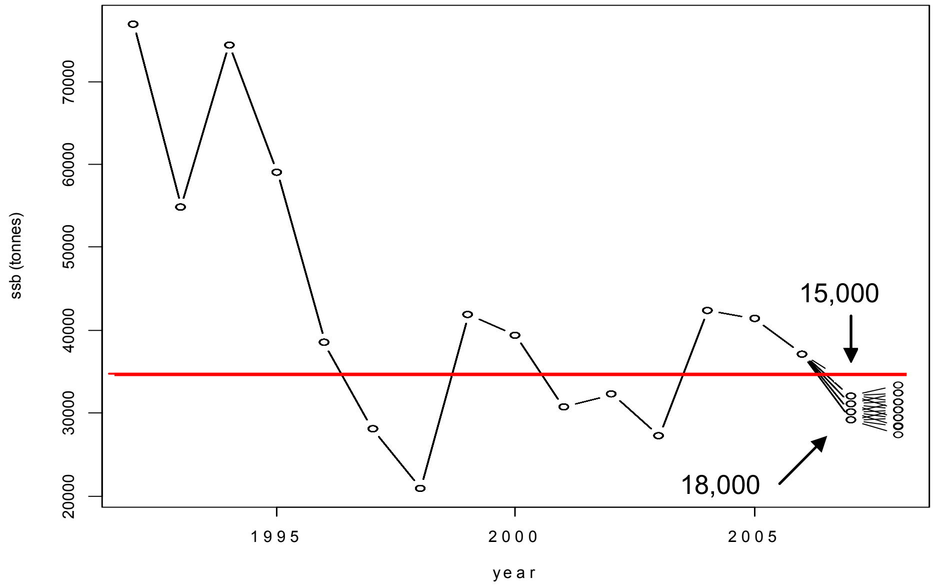

Figure 4.3.2: North Sea Sole. Time series of spawning stock biomass for the TAC options. The horizontal red line Indicates Bpa for North Sea sole. Arrows indicate TAC settings.

4.3.3 North Sea Sole: low recruitment

In the low recruitment scenario, the recruitment levels from 2006 onwards are set equal to the 2005 recruitment that is 42% below the historical average. This implies a recruitment of 56 488 thousand throughout the predictions. The population numbers in 2005 are equal to the analysis presented in the previous section.

Because the exploitation pattern for sole is high for ages 3 and older, the lower recruitment in these runs affect the SSB especially in 2008, when the recruits enter the fishery.

The fishing mortality in 2007 and the SSB in 2008 resulting from the TAC options in 2007 depend on the TAC option in 2006. The F values resulting from the combination TAC2006/TAC2007 are presented in table 4.3.7. All F values are above Fpa in the scenarios considered.

The SSB values in 2008 resulting from the combination TAC2006/TAC2007 are presented in table 4.3.8 and figure 4.3.3. All scenarios indicate that SSB will be below Bpa in 2008 and many scenarios indicate that SSB will be below Blim.

Table 4.3.7 North Sea Sole. F estimates in 2007 resulting from TAC options in 2006 and 2007

		TAC 2007			
		15	**16**	**17**	**18**
TAC 2006	**15**	0.471	0.512	0.554	0.599
	16	0.488	0.531	0.576	0.622
	17	0.507	0.551	0.598	0.648
	18	0.526	0.574	0.623	0.674

Table 4.3.8 North Sea Sole. SSB estimates in 2008 resulting from TAC options in 2006 and 2007. Underlined values Indicate SSB below Blim.

		TAC 2007			
		15	**16**	**17**	**18**
TAC	**15**	26 878	25 897	<u>24 915</u>	<u>23 922</u>

2006	**16**	25 874	24 887	23 898	22 916
	17	24 880	23 893	22 903	21 918
	18	23 887	22 888	21 896	20 926

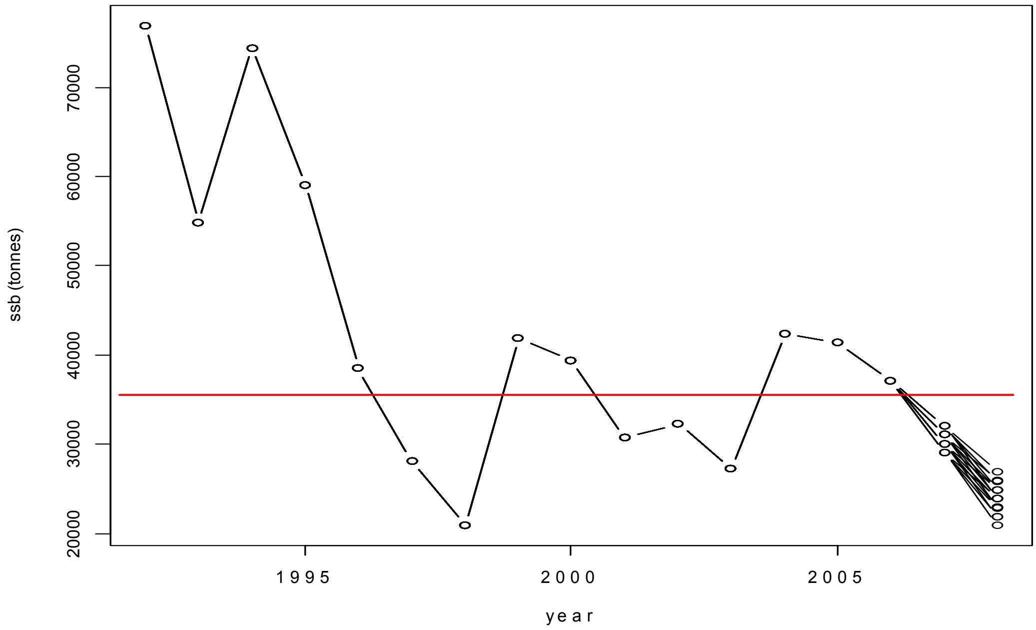

Figure 4.3.3 North Sea Sole. Time series of spawning stock biomass for the TAC options assuming low recruitment. The horizontal red line Indicates Bpa for North Sea sole. Arrows indicate TAC settings.

5 Stepwise approach based on Bpa in 1 or 2 years

5.1 Question

"Hoe hoog mag de tong TAC zijn (uitgaande van gelijkblijvende TACs de komende jaren) als we niet langer dan 1 of 2 jaar onder Bpa uit willen komen?" [1]

5.2 Approach

To answer this question, the results of chapter 4 are compared to the Bpa reference levels for sole and plaice.

5.3 Results

The Bpa for plaice is currently set at 230 000 tonnes. In order to obtain SSB values higher than Bpa in 2008, a reduction of the TAC to 55 000 tonnes is needed in 2006 or 2007.

The Bpa for sole is currently set at 35 000 tonnes. In the In order to obtain SSB values higher than Bpa in 2008, reductions of the TACs are needed to levels below 15 000 tonnes, irrespective of the recruitment scenario.

5.4 Discussion and conclusions

For plaice, a reduction of the TAC in 2006 or 2007 to 2007 is needed to rebuils SSB above Bpa In 2008. These reductions are small compared to the reductions in sole TACs that are needed to ensure SSB will remain above Bpa In 2008. The substantial decrease in TACs to levels < 15 000 tonnes is needed because of the poor recruitment of sole in 2003 and 2004. These year-classes will contribute to the SSB and landings from 2006 onwards.

[1] *"What is the maximum TAC (assuming contant TAC in future years) if we don't want to be longer than 1 or 2 years below B_{pa}?"*

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7 Annex: Input data for the NSRAC simulations

Table 1: North Sea Plaice. Population parameter estimates

Age	Numbers-at-age in 2005 (*10^6)	Stock weight-at-age (kg)	F-at-age 2005	M-at-age	Maturity-at-age
1	913747[1]	0.053	0.188	0.1	0.0
2	598000[2]	0.115	0.646	0.1	0.5
3	171629[3]	0.218	0.541	0.1	0.5
4	328565[3]	0.292	0.555	0.1	1.0
5	58279[3]	0.349	0.557	0.1	1.0
6	28608[3]	0.408	0.576	0.1	1.0
7	14816[3]	0.466	0.547	0.1	1.0
8	8523[3]	0.569	0.425	0.1	1.0
9	10256[3]	0.726	0.282	0.1	1.0
10	2787[3]	0.845	0.282	0.1	1.0

1. Geometric mean recruitment 1957-2002
2. RCT analysis including BTS 2005
3. XSA survivors

Table 2: North Sea Sole. Population parameter estimates

Age	Numbers-at-age in 2005 (*10^6)	Stock weight-at-age (kg)	F-at-age 2005	M-at-age	Maturity-at-age
1	56488[1]	0.050	0.005	0.1	0.0
2	54868[1]	0.143	0.151	0.1	0.0
3	59561[2]	0.195	0.380	0.1	1.0
4	77407[2]	0.242	0.388	0.1	1.0
5	14070[2]	0.256	0.419	0.1	1.0
6	12997[2]	0.287	0.399	0.1	1.0
7	3561[2]	0.315	0.285	0.1	1.0
8	2659[2]	0.356	0.381	0.1	1.0
9	3017[2]	0.433	0.288	0.1	1.0
10	702[2]	0.497	0.288	0.1	1.0

1. RCT analysis including BTS 2005
2. XSA survivors