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REPORT OF AD-HOC WORKING GROUP ON SANDEEL FISHERIES (ADHOC-05-03) OF THE SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF)

Charlottenlund, 7-9 November 2005

This report has been evaluated and endorsed by the Scientific, Technical and Economic Committee for Fisheries (STECF) in its plenary session of 7-11 November 2005

1 STECF evaluation and endorsement. Harvest control rule for sand eel in North Sea and Skagerrak and actions for 2006

STECF was asked the following:

To deliver an opinion based on the outcome of the ad hoc working group ADHOC-05-03 which aimed to (a) evaluate whether the current HCR for sand eel in the North Sea and Skagerrak are suitable or need to be changed (b) determine what actions shall be envisaged for 2006 on the basis of the ACFM advice and considering that Council Regulation n.1147/2005 of July 2005 has prohibited sand eel fishing until the end of 2005 on the basis of the agreed HCR; (c) assess what level of monitoring fishing (sentinel fishing) shall be allowed in 2006 with a view of monitoring the 2005 recruitment strength in case that a 0 TAC or a very low level of fishing effort need to be established for 2006.

1.1 Harvest control rule for sand eel in North Sea and Skagerrak and actions for 2006

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1.2 Review of ad hoc sand eel WG

STECF reviewed the report of the ad-hoc working group on sand eel, which met at short notice for 3 days running concurrently with the STECF plenary meeting. STECF acknowledges that the timing in relation to the STECF plenary meeting has prevented the report from undergoing the usual process of self-review and that the short notice reduced the ability of the group to do justice to the ToRs

The ad-hoc group met principally to evaluate a range of potential harvest control rules (HCRs) including the Commission's current HCR. The group was also tasked with compiling information regarding the ecosystem requirements for sand eel as a food source. The only analytical assessment of sand eel consumption available to the group was from the ICES study group on multi-species assessment in the North Sea (SGMSNS) which, using MSVPA, estimates average consumption of at least 1.7 million tonnes. This estimate does not include consumption by seals, cetaceans and most non-commercial fish species.

For the purpose of HCR evaluation, the group used new software, which is an extension of the SMS (Stochastic Multi-Species) model. The projection framework follows the STPR3 approach, which has previously been used by ICES (AGLTA). The SMS HCR implementation makes use of half-annual time steps, which is applied for the sand eel assessment. Essentially the HCR is applied to "observed" or "perceived" stock numbers and translated into a TAC, which is subsequently taken from the true population. Uncertainty enters the system as observation noise, recruitment variation and implementation error. The HCR evaluation framework has further options to further refine HCRs in terms of limiting inter-annual change in TAC or F, which were not explored by the group but are potentially useful options for managers to consider.

Management of North Sea sand eel is particularly problematic due to the fishery being principally on the 1-group whilst there is no reliable assessment estimate of this year-class at the time of the December Council to assist TAC setting. Currently the Commission uses an in-year monitoring system in the first 17 weeks of the year to estimate the size of the 1-group and subsequently enact management. Within the HCR evaluation model it was assumed that the fishery in the part year before a management decision is reached operates with a fixed F of 0.1. Historical performance of the in-year estimation of the 1-group indicates a CV of 35%, whilst the observation uncertainty from the assessment of other age groups is assumed to be 25%. Recruitment was generated from a hockey-stick stock-recruit relationship parameterised from historical assessments and a fixed inflexion point of 430kt (B_{lim}). One of the group's ToRs was to investigate whether there were grounds for changing the value of B_{lim} . However there was no new information to suggest that changes were warranted.

A range of HCRs was evaluated, including the Commission's current HCR as well as use of a fixed TAC and target SSBs.

The use of a fixed TAC as a management tool would do away with the need for the in-year estimation of the 1-group. In the long term (10 years) a TAC of around 200-300kt would ensure that SSB would be below B_{lim} with a <5% probability. The probability of being below B_{lim} in 2007 is around 65% due to the current poor state of the sand eel stock.

The in-year estimation of the 1-group permits the fishery to take, around 500kt (long term average) whilst complying with the SSB<B_{lim}<5% condition. The HCR currently employed by the Commission implies frequent closure of the fishery immediately after the in-year estimation. Another HCR, using B_{pa} (600kt) as a target SSB for the following year results in a lower probability of closure whilst still complying with the SSB<B_{lim}< 5% condition. However, use of B_{pa} as a target implies that true SSB is <B_{pa} about 35% of the time. The use of an HCR based on an SSB target results in a lower probability of being below B_{lim} in 2007 compared to the Commission's current HCR.

In order to investigate the performance of HCRs in the event of lowered recruitment, scenarios were run where mean recruitment was 50% of the historical value. Under this scenario the F=0.1 inflicted by the monitoring fishery is such that the probability of being below B_{lim} is well in excess of the 5% limit. Another scenario, with a hockey stick SSB/R relation and an inflection point at the 25 percentile of the historical values, showed a probability that true SSB is <B_{pa} at less than 5% of the time. Long-term yield for this scenario was about 500kt.

All of the HCRs evaluated by the group give a high probability of SSB in 2007 being less than B_{pa}, even with a minimal F of 0.1 as inflicted by the monitoring fishery. WGNSSK, using a short-term deterministic forecast with 25th percentile recruitment suggested that and F of 0.2 would permit the stock to be over B_{pa} in 2007. The difference between these results are due to the model used, SMS being more pessimistic regarding the current stock status than the seasonal XSA adopted by WGNSSK. In addition, the SMS simulation uses the hockey stick SSB/R relation, which with the present low SSB produces a low recruitment.

The minimum escapement implied by the use of a target SSB rule does not directly address the in-year ecosystem requirements for 0 and 1-group sand eel. Resolving this issue is not a straightforward exercise and requires further work.

The group were asked to comment on the level of monitoring fishery required for reliable estimation of the incoming year-class. The group has previously reported that a minimum of 100 biological samples, covering the main sand eel fishing grounds is required. The monitoring fishery is currently market driven in terms of effort and location, subject to a maximum effort cap of KW days for the North Sea as a whole.

There was no information available to determine appropriate effort levels at finer spatial subdivisions. The group recommends that the current effort cap remains in force as a means of preventing excessive F before the strength of the incoming year-class can be evaluated.

1.3 STECF comments and recommendations.

1.3.1 Long-term considerations

The ad-hoc group presented a number of HCRs and scenarios most of which perform similarly in terms of probability of being above B_{lim} and long-term yield. The main difference between the scenarios is the inter-annual variability in yield. Without further guidance from managers regarding long-term objectives for the stock and fishery, STECF cannot recommend any one HCR over another. The signal from the Danish fishing industry is however a preference for a more stable yield and capacity reduction. In the long-term, an HCR based upon a target SSB *may* perform better in terms of stability of yield than the Commission's current HCR, however the outcome is highly sensitive to the target SSB chosen. Furthermore, ecosystem considerations, including predator requirements for sandeel, need to be taken into account in determining an appropriate target SSB.

1.3.2 Options for 2006

The short-term prognosis for the sandeel stock is uncertain and highly dependent upon the strength of the incoming year-class. ICES advice for 2006 is to achieve Bpa by 2007. STECF notes that there is a real possibility that even in the absence of fishing in 2006, SSB in 2007 will not reach Bpa.

There is currently no alternative to the use of fishery data for either assessment of North Sea sandeel or the estimation of the incoming year-class strength. Unless managers are willing to enter a phase of total uncertainty regarding North Sea sandeel stock status, a monitoring fishery at the start of the 2006 is a prerequisite despite the risk of preventing the stock reaching B_{pa} in 2007. However STECF notes that in the longer term, exploiting sandeel at F= 0.1, (estimated mortality of the monitoring fishery) poses little risk to the stock.

STECF therefore **recommends** that the in-year estimation of the 1-group continues in 2006.

STECF further **recommends** the maintenance of the current cap on effort (40% of the total effort deployed in 2004) at least until the decision on a HCR for 2006 is agreed and implemented by managers.

STECF **recommends** that managers decide on an appropriate target SSB for 2007 that is not less than Bpa (600,000 t). Pending the estimated size of the 2005 year-class following the monitoring fishery, the total catch for 2006 should not result in a predicted SSB in 2007 that is below the agreed target.

STECF stress that all of the above recommendations are conditional on management action being taken immediately following the evaluation of the monitoring fishery and implementation of the HCR.

2 Executive Summary

The group convened at short notice for a 3 day meeting which ran concurrently with the STECF plenary and a report was made to STECF plenary immediately after the conclusion of the meeting. This precluded the usual checking procedures, and since the end of the meeting some errors have been detected and fixed. The report made to STECF plenary remains sound and the conclusions are unaffected by these changes.

The group met to evaluate the Commission's current harvest control rule (HCR) and to make recommendations regarding a potential sandeel fishery next year and what requirements there may be for a monitoring fishery. The group also commented on the current knowledge of ecosystem requirements for sandeel as a resource.

The commission's current HCR will perform adequately in the long term with respect to maintaining the population above $B_{lim,}$ with 95% probability. There are, however, alternatives which enable the fishery to be more stable whilst simultaneously achieving the B_{lim} criterion, in particular the setting of a TAC such that SSB in the following year achieves a target (e.g. B_{pa}).

HCR performance is highly dependent upon the recruitment scenario assumed. A long-term shift to a lower productivity regime would prevent the achievement of the current B_{lim} criterion, although in that situation a revision of the biological reference points may be desirable.

Further examination of HCRs requires more guidance from Managers as to what they require of the system. The use of B_{pa} as a target is only a suggestion and it may well be that given further ecosystem requirements the target requires redefinition. The only analytical assessment of ecosystem requirements for sandeels available to the group was the results of the ICES Study Group on Multispecies Assessment in the North Sea (SGMSNS) which indicates that around 1.7 million tonnes of sandeels are consumed annually by commercial fish species and seabirds.

3 Terms of Reference

At its April 2005 plenary session the STECF expressed an urgent need to improve the basis for North Sea sandeel management. Such a change would result in a proposal for a new HCR that will probably require agreement at the December Council. It is therefore suggested that an additional meeting of the ad-hoc sandeel meeting take place before the plenary session in order to:

1. assemble information on the eco-system requirements for minimum abundance levels for sandeel in the North Sea to better inform a suitable Blim for sandeel management under the eco-system approach and if appropriate advise on a change in Blim.

2. establish through stochastic simulation a HCR or range of HCRs. Selecting suitable long term F and trigger biomasses to replace the values in the current HCR. The simulation should include the following:

    a. the accuracy of the estimate of 1 group yearclass by week 17 in the fishery

    b. the implementation error between catch and TAC in the fishery, including delays in implementation of management.

c. inclusion of total mortality at age 2+ group between 1 January and spawning time for the target year +1.

d. the mortality implied by the fishery to week 17.

e. the precautionary approach which unless otherwise advised for the purposes of the simulation may be based on a probability of SSB being below Blim less than 5% of the time in any year of a 10 year period

f. Blim should be taken to be 430,000 t unless a higher level is deemed more appropriate under eco-system approach for the North Sea (see TOR 1) or due to a stock recruit relationship.

g. stochastic recruitment conforming to the variability observed, including stock recruit relationship and any autocorrelation in annual variability.

The Commissions wishes the STECF to:

- evaluate whether the current HCR, as established in paragraph 6 of Annex V of the Council Regulation n. 27/2005 that establishes fishing effort provisions for vessels fishing for sandeel in the North Sea and the Skagerrak, are still suitable or need to be changed and what actions shall be envisaged for 2006 on the basis of the ACFM advice and considering that Council Regulation n.1147/2005 of July 2005 has prohibited sandeel fishing until the end of 2005 on the basis of the agreed HCR.

- advise on what level of monitoring fishing (sentinel fishing) shall be allowed in 2006 with a view of monitoring the 2005 recruitment strength in case that a 0 TAC or a very low level of fishing effort need to be established for 2006. STECF should be particularly requested to advise on the likely fishing effort for monitoring that can be authorized in order to have reliable estimates on the consistency of the stock while avoiding the depletion of possible local residual aggregations of sub stock fractions.

4 Participants

Ewen Bell (UK, Chair)

Beatriz Roel (UK)

Peter Wright (UK)

Morten Vinther (DK)

Henrik Jensen (DK)

Henrik Mosegaard (DK)

Hendrik Doerner (EU Commission).

5 Ecosystem Requirements

Sandeels are preyed upon by a wide variety of commercially important fish species, including cod, haddock, whiting, mackerel and plaice as well as non-commercial species such as gurnards and weaver fish. They also form an important portion of diet for some species of seabird including kittiwake , puffin and razorbill as well as seals (both grey and harbour seal) and cetaceans such as minke whale and harbour porpoise. Dietary studies have shown varying levels of seasonality in the utilisation of sandeels as a food resource depending upon the method of capture. Some species of seabird (e.g. Black-legged kittiwake) are particularly dependent upon sandeels during the bird's breeding season thus making sandeel abundance in proximity to the colony critical and highlighting the need for management to avoid local depletion. All ages of sandeels are preyed upon.

There is currently no quantitative estimate for the ecosystem requirements in terms of sandeel numbers/biomass. MSVPA is currently the only tool parameterised for the North Sea to address multispecies issues. The ICES study group on multispecies assessment in the North Sea (SGMSNS) most recently estimated average consumption of 1.7 million tonnes of sandeel. This figure excluded the consumption by seals which may be considerable and takes no account of consumption by cetaceans and non-commercial fish species. The mortality on sandeel from species not included in the model is taken into account by a fixed mortality, however this mortality is guessed with a very high uncertainty.

More holistic ecosystem models such as Ecopath may give a more complete picture of sandeel utilisation and a complex model of the North Sea is currently under construction and will (hopefully) be presented to the ICES SGMSNS in its 2006 meeting. It should be noted, however, that the consumption estimates for non-commercial fish species are likely to be based on little data and therefore highly uncertain.

The depleted state of most finfish stocks means that the current ecosystem requirement for sandeels is below what might be expected in a "fully recovered" scenario. The forecasting equivalent of MSVPA assumes a fixed growth pattern for predators and therefore takes no account of the potential for food availability to affect predator populations. This makes MSVPA/MSFOR unsuitable for estimating the required level of sandeel abundance.

Both MSVPA and Ecopath are heavily reliant upon stomach contents analysis for dietary composition, the majority of the data coming from the ICES Year of the Stomach exercises undertaken in 1981 and 1991, with additional data from intervening years. Given the considerable change in fish stock abundance since these exercises were undertaken, the assumption of constant suitability (the preference of a predator for a particular type of prey) is unlikely to hold. The most immediate means of addressing this issue is to undertake another large scale stomach sampling programme.

6 Harvest Control Rule Evaluation

6.1 Methodology

New software for the evaluation of HCRs was developed for the meeting to take into account the real-time monitoring and the highly seasonal sandeel fishery Essentially this was an extension of the SMS package (Lewy and Vinther, 2004) , a separable multispecies model. A full description of the implementation of HCR is given in Annex 1.

Starting values for population size and F were obtained from a historical analyses performed using SMS and a summary of the results are given in table 2.1.1 and figure 2.1.1. This assessment was also presented to the WGNSSK in 2005 (ICES 2006/ACFM:09) This is slightly different to the results generated by final assessment by ICES where the SXSA model was used. The SMS model being slightly more pessimistic in the terminal year regarding stock status. The SMS assessment includes data from 1975, where SXSA uses data from 1983. Recruitment in the period before 1983 was on average slightly lower, such that the average recruitment becomes lower in the SMS assessment compared to the SXSA assessment. The group's decision to use the SMS results was so that a full MCMC evaluation could be made of the historical assessment and projection period in one go – hardwiring the forecast to the ICES results (made using Seasonal XSA) would have precluded this.

The SMS assessment includes catches from the first half-year of 2005. It is assumed that the Fishing mortality in the second half of 2005 can be calculated from the 2005 year effect estimated by the separable F-model and the season and age selections estimated from previous years. By doing this, F in the second half of 2005 become an overestimate, as the fishery was closed the 19th July, which is very early compared to previous years. The estimated F for the second half-year is however quite small due to the overall minor F year-effect for 2005. The stock was projected forward to the 1st Jan 2006 on the basis of the assessment and the estimated F for the second half-year of 2005.

Sandeel

Year	Recruits 1000	SSB (tonnes)	TSB (tonnes)	SOP (tonnes)	mean-F age 1-2
1975	271144011	751038	1669434	359749	0.307
1976	493895588	978050	1552564	426756	0.373
1977	552979870	800320	1843292	588315	0.629
1978	424386972	830707	1983216	800702	0.495
1979	395622899	1024682	1915276	684435	0.767
1980	217909131	722417	1541154	724491	0.595
1981	692026535	710482	1165429	528537	0.621
1982	189667815	465185	1709296	595924	1.086
1983	881903749	650489	1055942	530640	0.572
1984	381936269	440342	2018237	750040	0.812
1985	1106101755	981172	1670981	707105	1.549
1986	478710086	325559	2244067	685950	0.449
1987	281098365	1444954	2433008	791050	0.388
1988	532361019	1314377	1859223	1007304	0.914
1989	327046242	534164	1538527	826835	0.793
1990	502140029	661751	1262861	584912	0.815
1991	506713556	484664	1413043	898959	0.620
1992	338192537	716362	1616313	820140	0.418
1993	489855263	922376	1591748	576932	0.476
1994	680115787	729078	2073829	770747	0.616
1995	355776769	920926	3032229	915043	0.457
1996	1469245810	927131	1981302	776126	0.583
1997	337975110	588951	4196605	1114044	0.441
1998	337460171	1456914	2200803	1000375	0.621
1999	486757724	819086	1640211	718668	0.747
2000	467928458	463189	1812049	692498	0.814
2001	705748339	404838	1295366	858619	1.116
2002	105236456	324647	2166593	806921	0.617
2003	377740859	549923	791159	309725	1.079
2004	237836722	193380	1097433	359361	0.812
2005	367021411	283219	880639	158080	0.220
AM	483630171	723238	1782317	689322	0.671
GM	424720099				

Table 2.1.1 Summary statistics from the SMS assessment of North Sea sandeel. Note that this is not the same as the final assessment accepted by ACFM.

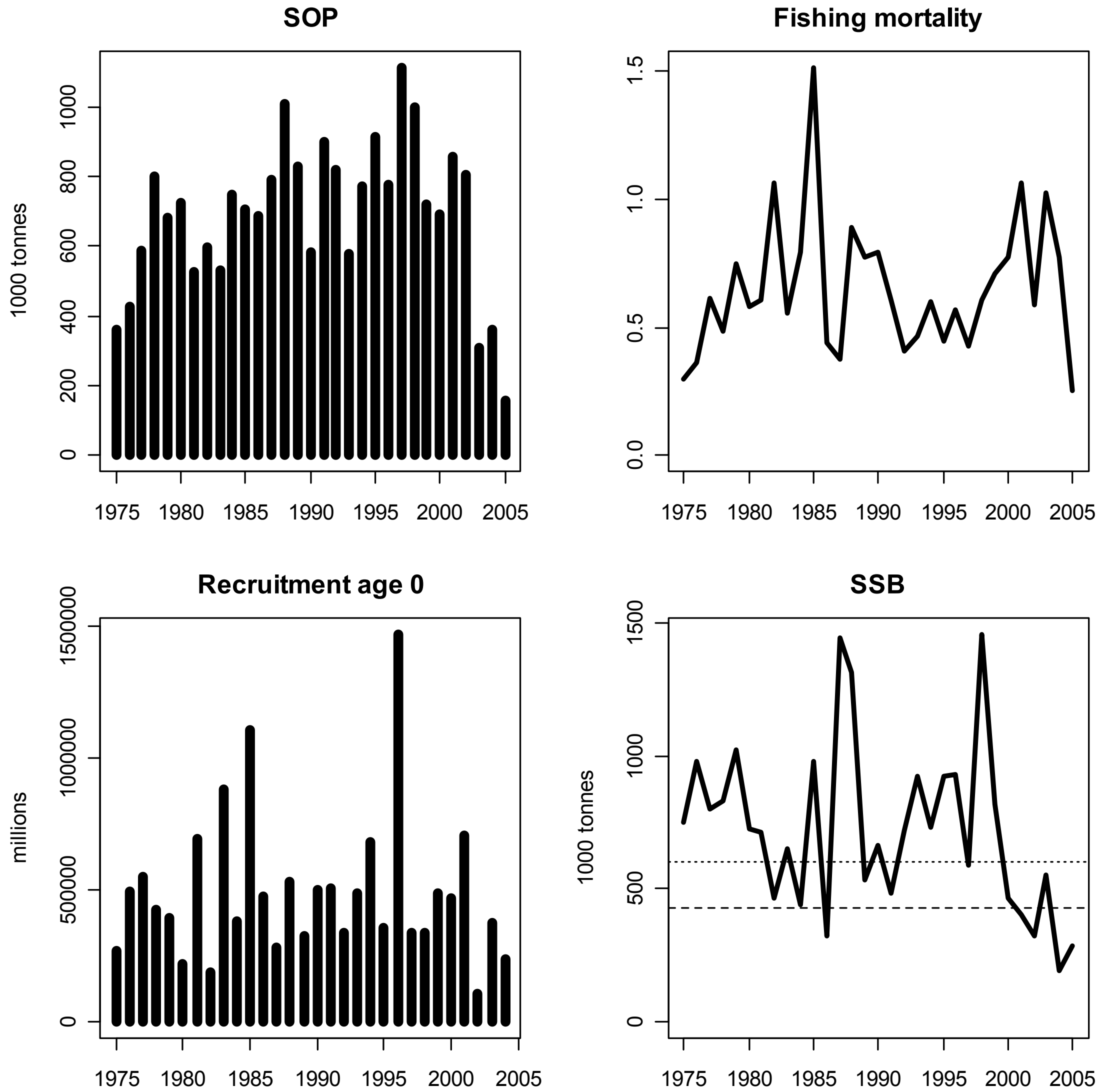

Figure 2.1.1 Summary statistics from the SMS assessment of North Sea sandeel.

Recruitment modelling.

Current management operates at the scale of the entire North Sea encompassing several sub-stock units thought to exist. The lack of obvious stock-recruit relationship discussed below may be an artefact of pooling several stock units with different dynamics which will not be resolved until it is possible to perform stock assessments on finer spatial scales.

The historical estimates from the SMS model range from approximately 100 billion to 1,450 billion and bears no obvious relationship with the SSB (fig 2.1.2) although there is a suggestion of reduced recruitment at very low stock size. A hockey-stick stock-recruitment model has been used to project recruitment in the future, with an inflexion point at 430kt (B_{lim}) and a log-normal error distribution has been used to generate variation around this relationship. Figure 2.1.2 shows the historical values along with the recruitment estimates from 1000 simulations of a 15 year period. Figure 2.1.3 shows the cumulative distribution of recruitment estimates from the SMS assessment and subsequent projections where SSB was above the inflexion point (SSB>430kt). The lines following closely with some deviation at the upper range of estimates where the projected estimates appear to be underestimated compared to the observed values. This makes the projections slightly conservative in terms of recruitment estimation although this bias appears to be minor.

There is some evidence from the historical recruitment series for autocorrelation. From 1980 to the late 1990's recruitment fluctuated with a 2 or sometimes 3 year pattern of high-low values. This was been suggested to originate from competitive exclusion by 1-group sandeels (Arnott & Ruxton, 2002) although the pattern appears to have disappeared in recent years and the last 3 recruitments are estimated to be low, a hitherto unseen pattern.

Most of the HCR scenarios use the hockey-stick recruitment relationship with parameters estimated from the historical assessment data. Alternative stock-recruit relationships were considered, a) a shift to a lower system productivity and b) negative autocorrelation in recruitment patterns.

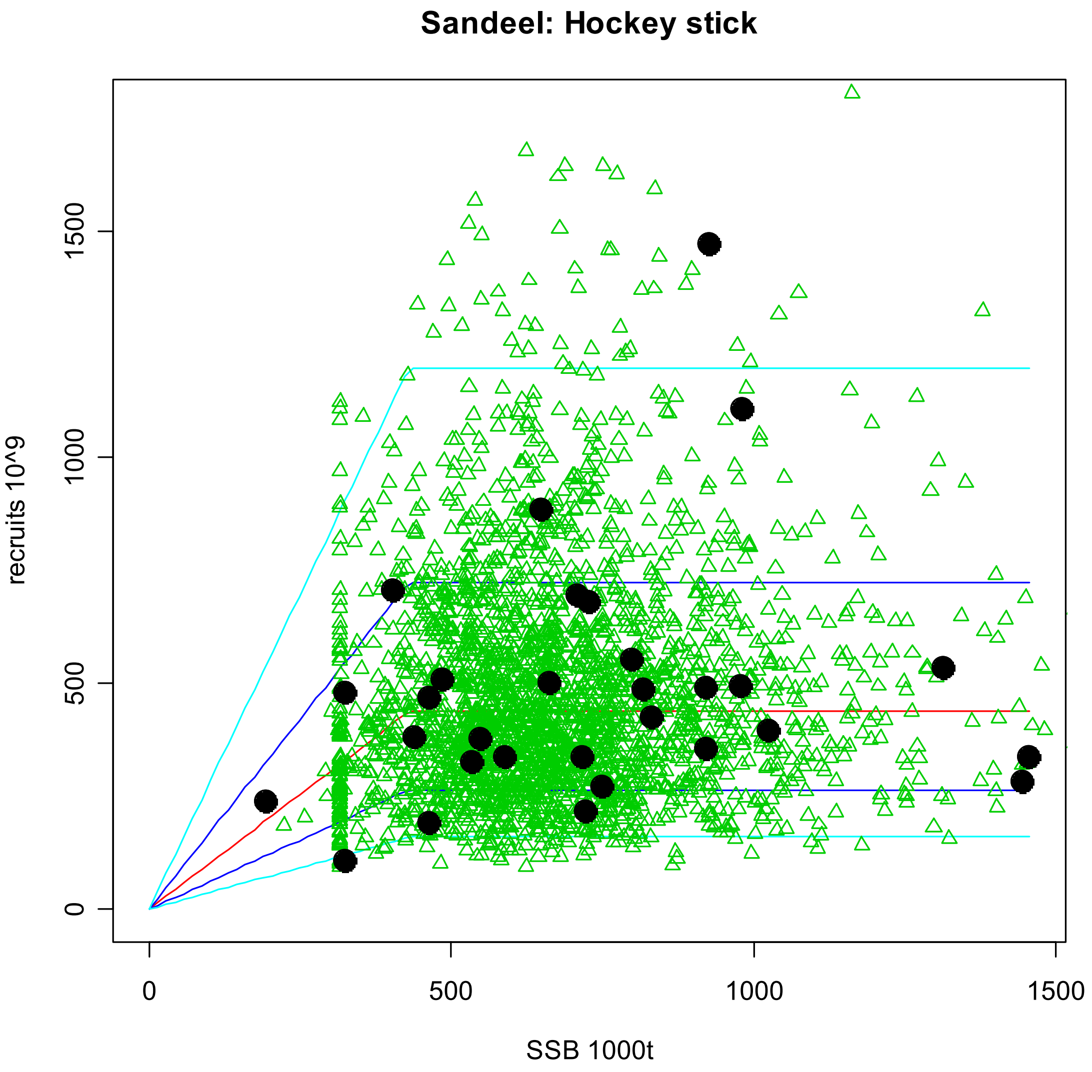

Figure 2.1.2 Stock-recruit relationship used in HCR evaluation. Black spots are the values from the SMS assessment, green triangles are the values from 1000 simulations. The red line is the median recruitment, dark blue lines are the 75th percentiles and the light blue lines the 95th percentile.

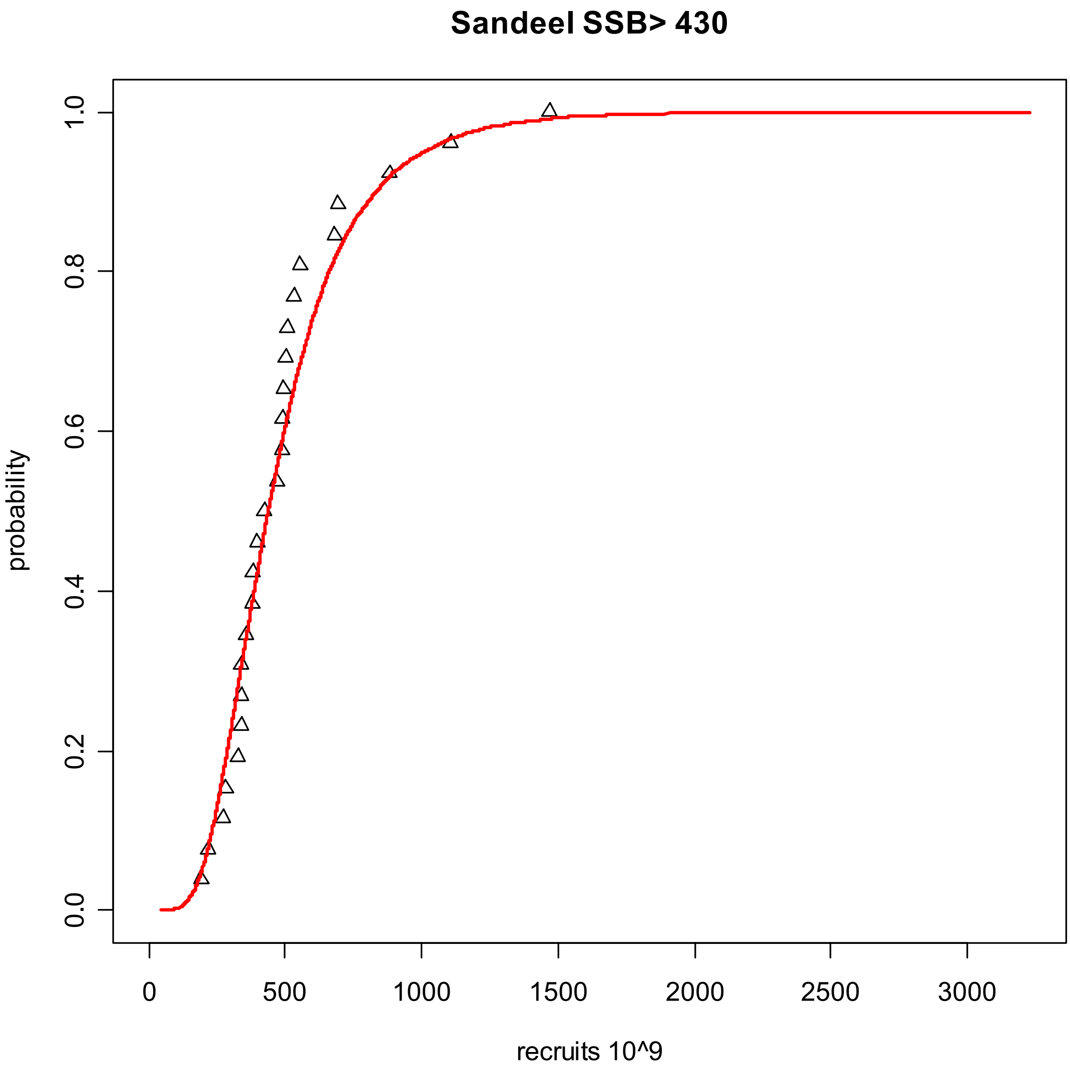

Figure 2.1.3 Cumulative distribution of sandeel recruitment values from the assessment (triangles) and the simulations (solid line) where SSB>430kt.

Uncertainties in stock assessment and real-time monitoring

The SMS assessment estimates uncertainties on the stock numbers from the Hessian matrix. This uncertainty is used as the "observation" noise when the projected stock numbers are estimated from an assessment. The CV of stock numbers in the beginning of the last assessment year and after the first half year of 2005 are calculated to be around 25% (Figure 2.1.4) for the most abundant ages, and this number was used as the assessment uncertainty in the simulations.

The precision of the estimate of 1-groups from real time monitoring depends on how early in the fishery season the estimate is given (Figure 2.1.5). The *ad hoc* sandeel group (STECF 2004 and 2005) concluded that a stock estimate could be given with an acceptable uncertainty after week 17. The regression statistics from the log(stock number) ~log(CPUE) regression (Figure 2.1.6) give a standard deviation of the observations of around 0.3, which was used in the HCR simulations.

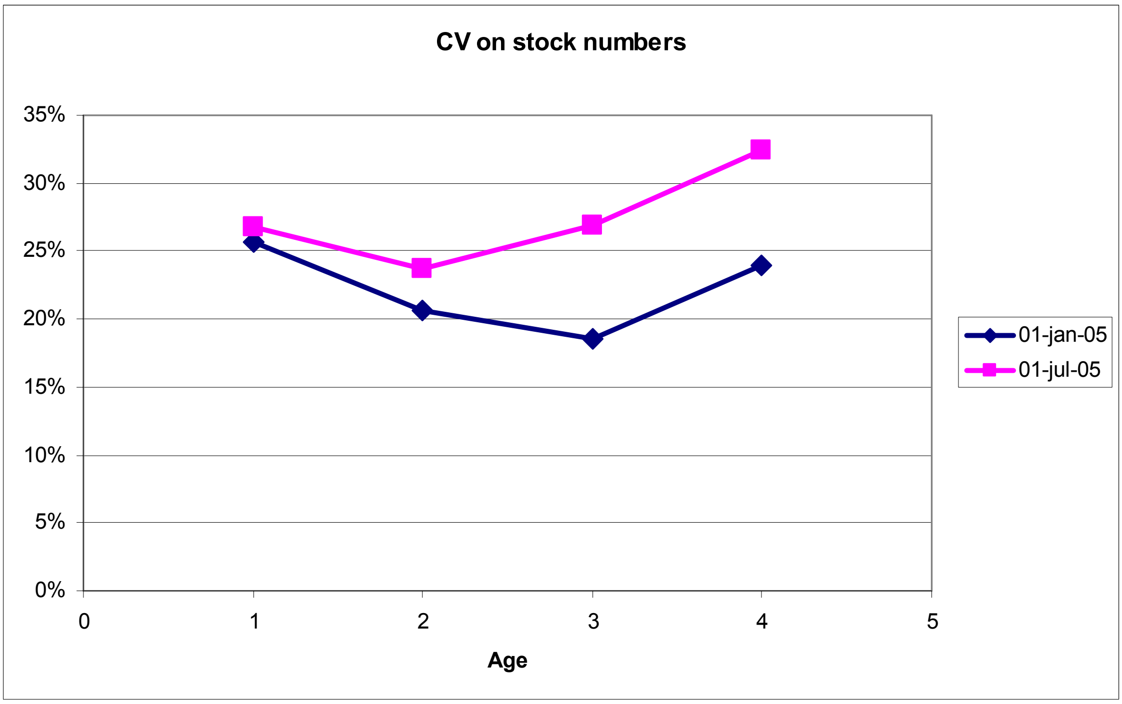

Figure 2.1.4. Uncertainties on stock numbers estimated by SMS assessment for the period 1975-2005 firs half year.

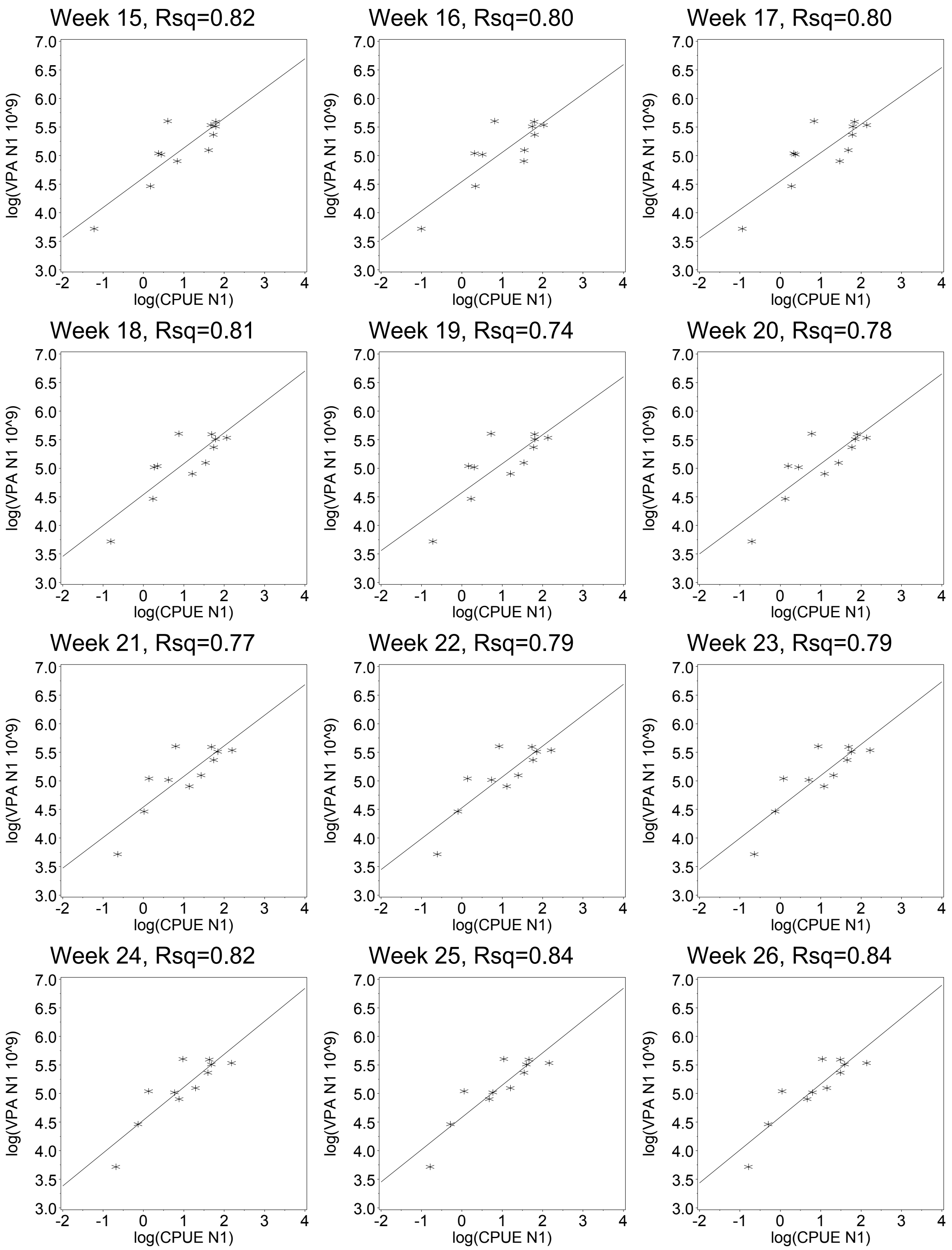

Figure 2.1.5. Relation between observed CPUE and stock estimate from VPA (from STECF 2005)

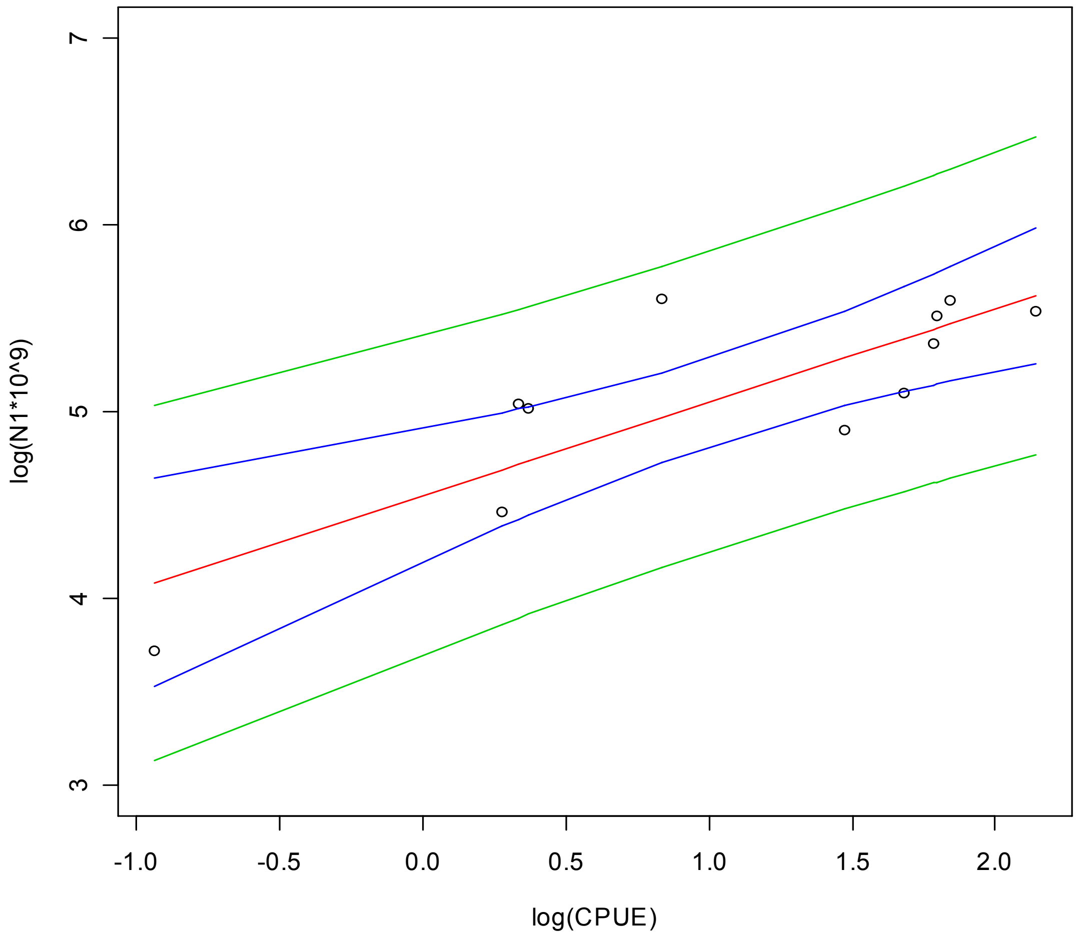

Figure 2.1.6 Observation from week 17 (redrawn from figure 2.1.5). Observed value of log (CPUE) and assessment stock numbers, predicted mean and 95% confidence interval for predicted mean and for observations.

6.2 HCRs evaluated

The following basic harvest control rules (HCR) were applied by the group. The primary objective of each HCR was to retain the SSB above B_{lim} with a probability of >95% in the long term (TOR **e**).

6.2.1 Constant F

This situation represents a simple forecast using a fixed F with perfect implementation and a direct link between F and effort. This situation therefore represents the utopia of sandeel fishery management and is therefore the benchmark against which all other scenarios are to be measured.

6.2.2 Constant TAC

One simple way to manage the sandeel fishery would be to have a fixed TAC thus offering a measure of stability to the industry, although this would come at the expense of stability in the population and fishing mortality.

When stock size is low, a fixed TAC may imply a fishing mortality way in excess of that which the fleet is able to inflict (assuming of course a link between F and effort, see section 3). An overall maximum F (Fcap) was therefore imposed to reflect the fact that fishery fleet behaviour which will be limited by it's capacity.

6.2.3 Existing HCR as determined by the Commission.

The existing HCR as determined by the Commission was evaluated. This involves two trigger values of 131 and 218 billions measured as 1-group (equivalent to 300 and 500 billion 0-groups) as estimated by the real-time monitoring exercise and a TAC of 660,960t. When the 1-group estimate is below 131 billion the fishery is closed (although an F=0.1 is inflicted by the monitoring fishery). Between 131 and 218 billion the F is 0.4* F2003 and above 218 billion the F=F2003 subject to the TAC limit.

An alternative was investigated where the TAC was set to the 2004 value of 826200t.

6.2.4 F from target SSB in the beginning of the year after the TAC year. (also termed "minimum escapement")

The Commission's current HCR involves a step function in effort rather than a smooth transition from closure upwards and involves arbitrarily determined trigger values. An HCR was constructed such that fishing opportunity was a smooth function of availability with a single target of achieving a particular SSB in the following year. The target SSB of 600kt (B_{pa}) was chosen as it represents an existing precautionary objective and should mean the stock is above B_{lim} with a probability of 95%.

Scenarios

A range of scenarios were explored and the results were compared by a number of standard graphs (Figures 2.3.4.1-2.3.4.20) and performance statistics (Table 2.3.1). Two sets of graphs are shown for each scenario: the first set shows median and 25th and 75th percentiles in 1000 simulations for annual SSB, yield, mean F and recruits for the period of the predictions (2005-2020). The probability of fishery closure and of SSB being below 600 kt (continuous line) and below 430 kt (dotted line) are also shown. The second set of graphs shows the cumulative probability distribution and the frequency distribution of SSB, yield and F in the final 6 years of the projections, the period when the stock is assumed to be at equilibrium. For the same parameters, the distribution of the change from one year to the next in a given trajectory (expressed as a ratio so that 1 equates to no change) is also shown.

We refer to the first scenario described below as the base case. Sensitivities to variation in the conditions of the base case are tested by changing only those parameters stated in the following list i.e. unless mentioned, parameters are re-set to the base case for each scenario.

a. Base case: target SSB in the TAC year+1 is B_{pa} (600kt). Fishing mortality is also limited so that it does not exceed 0.5 (F), this is to prevent F taking values above an assumed maximum capacity in the fishery based on recent and suggested reductions in fleet capacity. The number of 1-groups is simulated as estimated from the real-time monitoring. Older age groups were simulated as estimates from stock assessment (which suggests a 25% CV). . No bias in real-time estimates and assessment were applied. In order to facilitate the comparison between the various scenarios no implementation error was simulated in the base case. Stock and recruitment relationship is hockey-stick with parameters that define the slope (α = 1018) and threshold SSB where the inflection point takes place (β = 430 kt, which corresponds to Blim).

b. Sensitivity to the assumed value of Fcap was tested by running the simulations for Fcap = 0.6 and

c. Fcap = 0.4.

d. Implementation bias is introduced by allowing the TAC to be exceeded by 25%.

e. Low recruitment. The slope in the hockey-stick stock and recruitment relationship is = 0.5 α, inflection point remains unchanged. This corresponds to a 50% reduction in mean recruitment.

f. The slope as in a). The inflection point (β) is reduced so that the mean of the generated recruitment corresponds to the 1st quartile of the historic recruitments (330E6).

g. The same as f) but now the target SSB is reduced to 470 kt. This value corresponds to Bpa if Blim was changed to the new inflection point as in f).

h. In this scenario negative autocorrelation in recruitment residuals = -0.5 was introduced.

i. The target SSB was increased to 900kt to ensure a higher escapement taking into account ecosystem considerations.

j. All parameters used in the projections were drawn from the corresponding posterior distributions as estimated by MCMC. The exception is the inflection point used in the stock-recruitment relationship, which is a point estimate.

6.3 Results

6.3.1 Effects of constant F

The effects of a range of constant F's (F=0.0 to F=0.8) in steps of 0.1 were explored on the equilibrium stock status. Future recruitment was assumed to follow the long term historical pattern and implementation was assumed perfect. The results are summarised in figure 2.3.1.1. Landings peak at around 500kt and F of 0.5 although the probability of being below B_{lim} is around 20% and the probability of being below B_{pa} is around 55%. Maintaining the stock above B_{lim} with 95% probability involves an F of about 0.4 resulting in mean landings of around 450kt and a mean SSB of around 750kt

Figure 2.3.1.2 shows the mean stock trajectories for fishing at F=0.4 along with the 25th and 75th percentiles. The probability of being below B_{lim} remains relatively high until 2010 after which it declines to a low level.

Figure 2.3.1.3 shows the distribution of various metrics in the final 5 years of the projections, the period assumed to be at equilibrium. The distributions of yield and yield change demonstrates there is some considerable variation in the interannual yields.

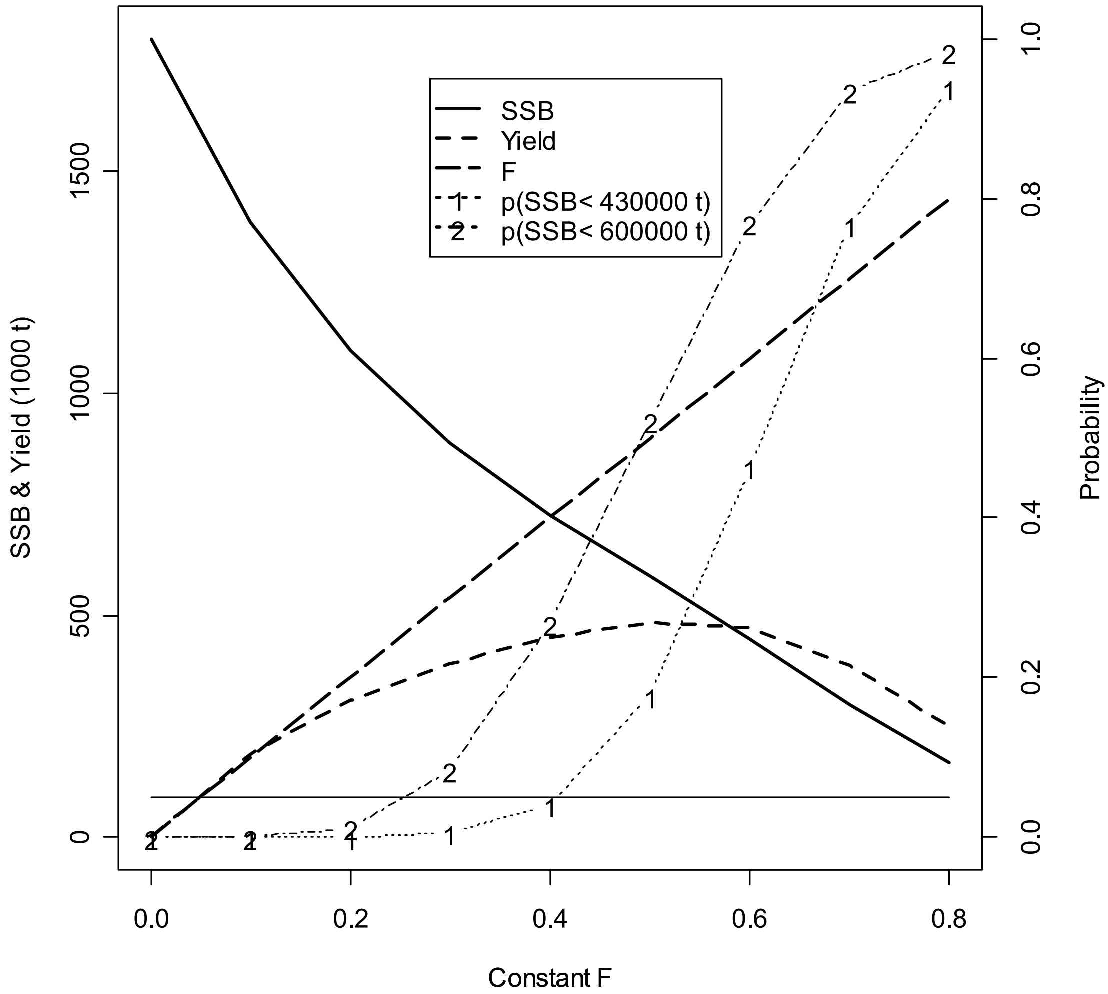

Fig 2.3.1.1 Effect of managing North Sea sandeels with a range of fixed F values. Metrics presented for population at equilibrium.

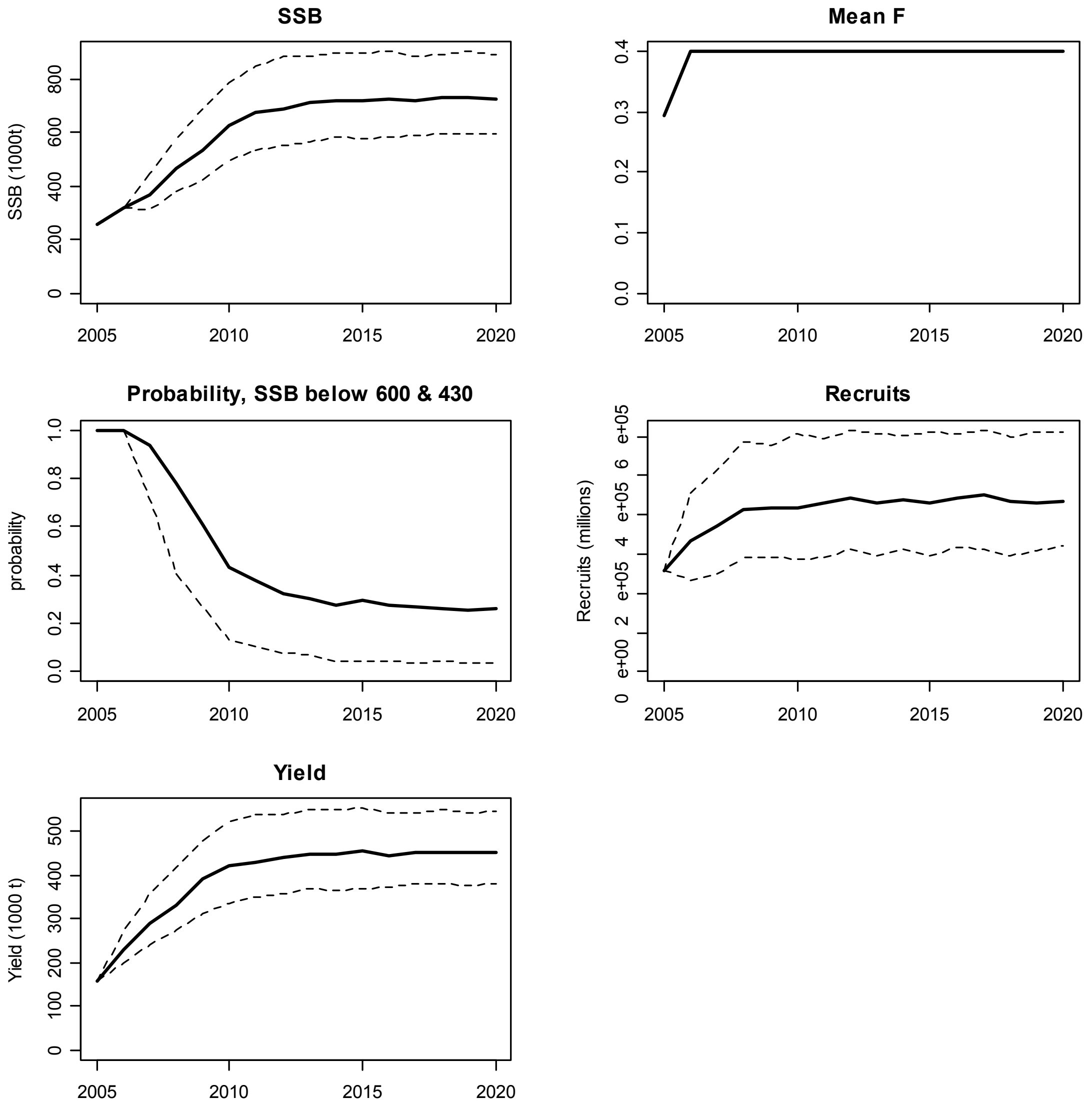

Fig 2.3.1.2 Mean trajectories for North Sea sandeels (with 25th and 75th percentiles) when managing using a fixed F=0.4

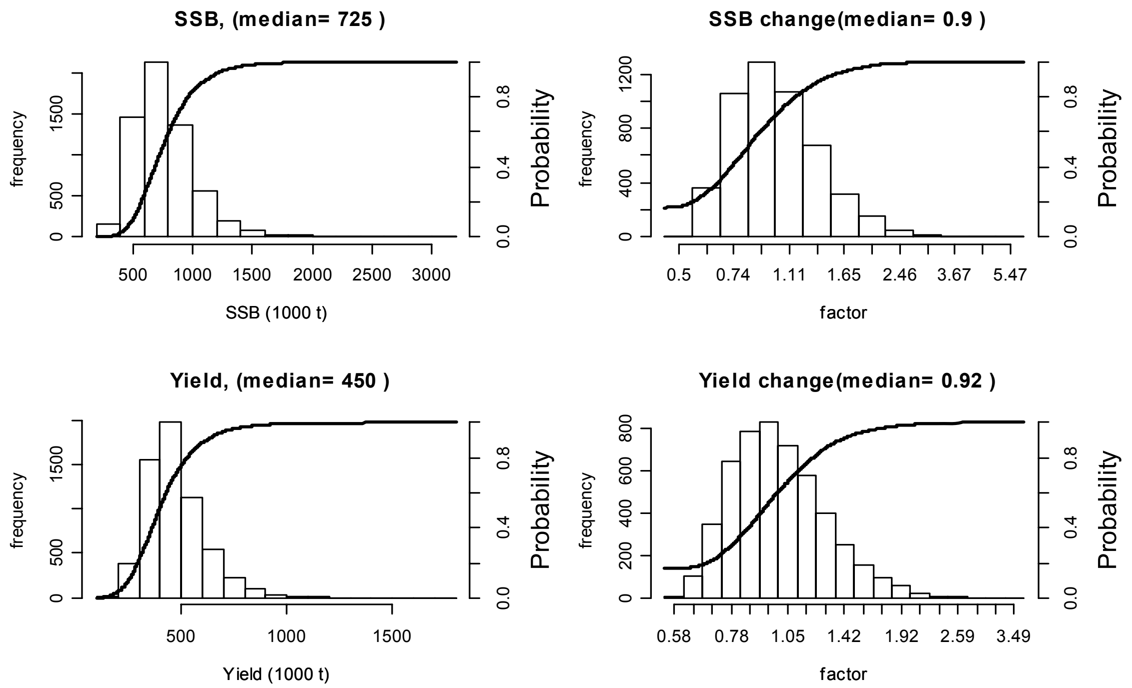

Fig 2.3.1.3 Distribution of population metrics at equilibrium (last 5 years of simulations) when managing with a fixed F=0.4.

6.3.2 Effects of constant TAC

In a similar way to the above scenario, the effect of maintaining a constant TAC was investigated using TACs of 0-800kt in steps of 100kt. Under this scenario it is possible to inflict impossibly high values of F and therefore F was constrained to be "reasonable". Values of 1.0 and 0.5 were used to represent historical maxima and the potential of recent fleet reductions and the results are summarised in figures 2.3.2.1 and 2.3.2.2 respectively.

With an F cap of 1.0, landings peak at around 300kt and a median F of 0.2. The main difference here is in the probability of driving the stock below the precautionary biomass reference points. The trends in the probabilities of being above B_{lim} / B_{pa} are closely linked, although the probability of being below B_{lim} is significantly increased. This is due to the insensitivity of the management to low recruitment episodes. Using the constant TAC rule and maintaining the stock above B_{lim} 95% of the time involves a TAC of around 200kt.

Under the assumption that the fleet has reduced its capacity to the point where it can not inflict an F of greater than 0.5, the TAC which corresponds to the maintenance of B_{lim} for at least 95% of the time is increased to around 300kt.

The trajectories and distributions for various stock metrics are given in figures 2.3.2.3 and 2.3.2.4 for the scenario where F is capped at 0.5. There are several differences between the fixed F=0.4 and fixed TAC=300kt; under a fixed TAC the probability of being below B_{lim} decreases more slowly and mean terminal yield is lower but the mean terminal SSB is higher

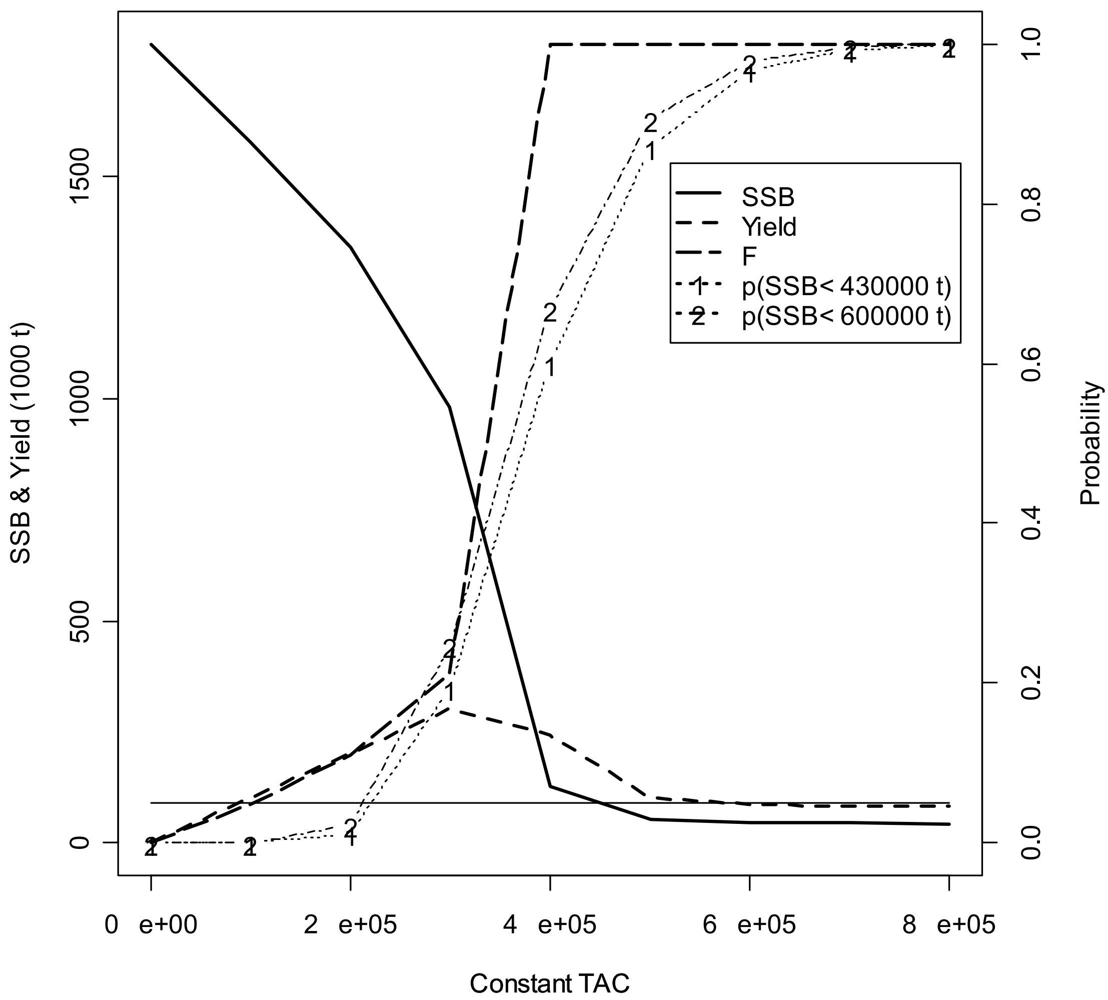

Figure 2.3.2.1 Effect of managing North Sea sandeels with a range of fixed TAC values and a cap on maximum F of 1.0 Metrics presented for population at equilibrium.

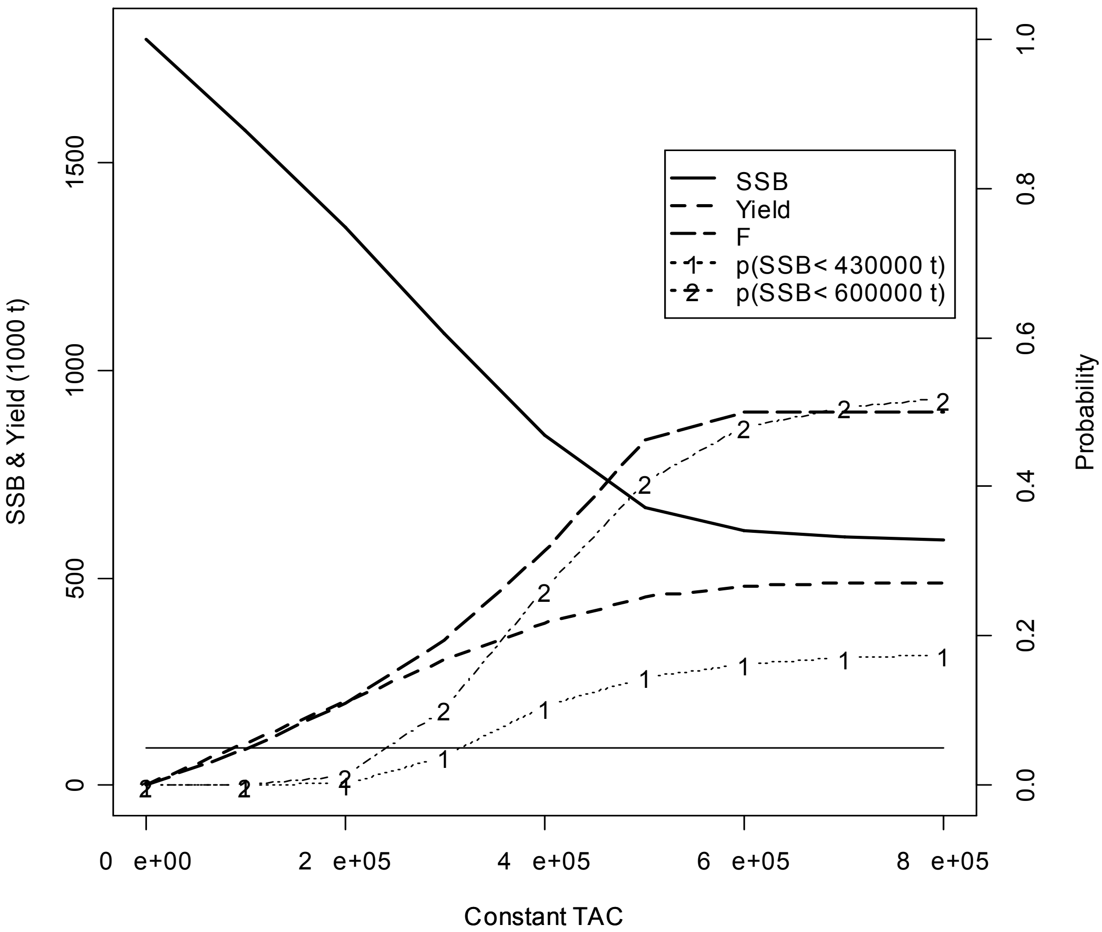

Figure 2.3.2.2 Effect of managing North Sea sandeels with a range of fixed TAC values and a cap on maximum F of 0.5. Metrics presented for population at equilibrium.

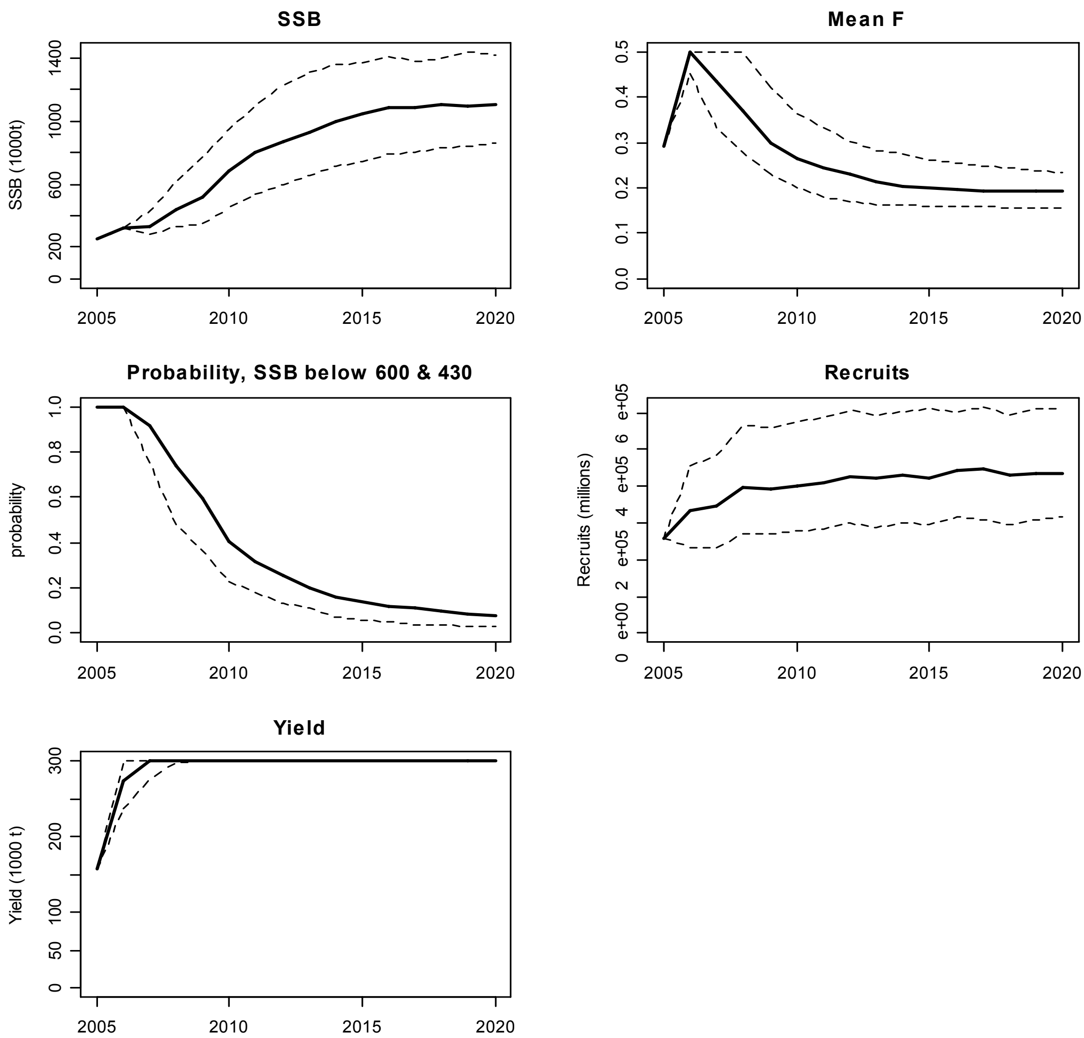

Figure 2.3.2.3 Mean trajectories for North Sea sandeels (with 25th and 75th percentiles) when managing using a fixed TAC of 300kt and a cap on F of 0.5.

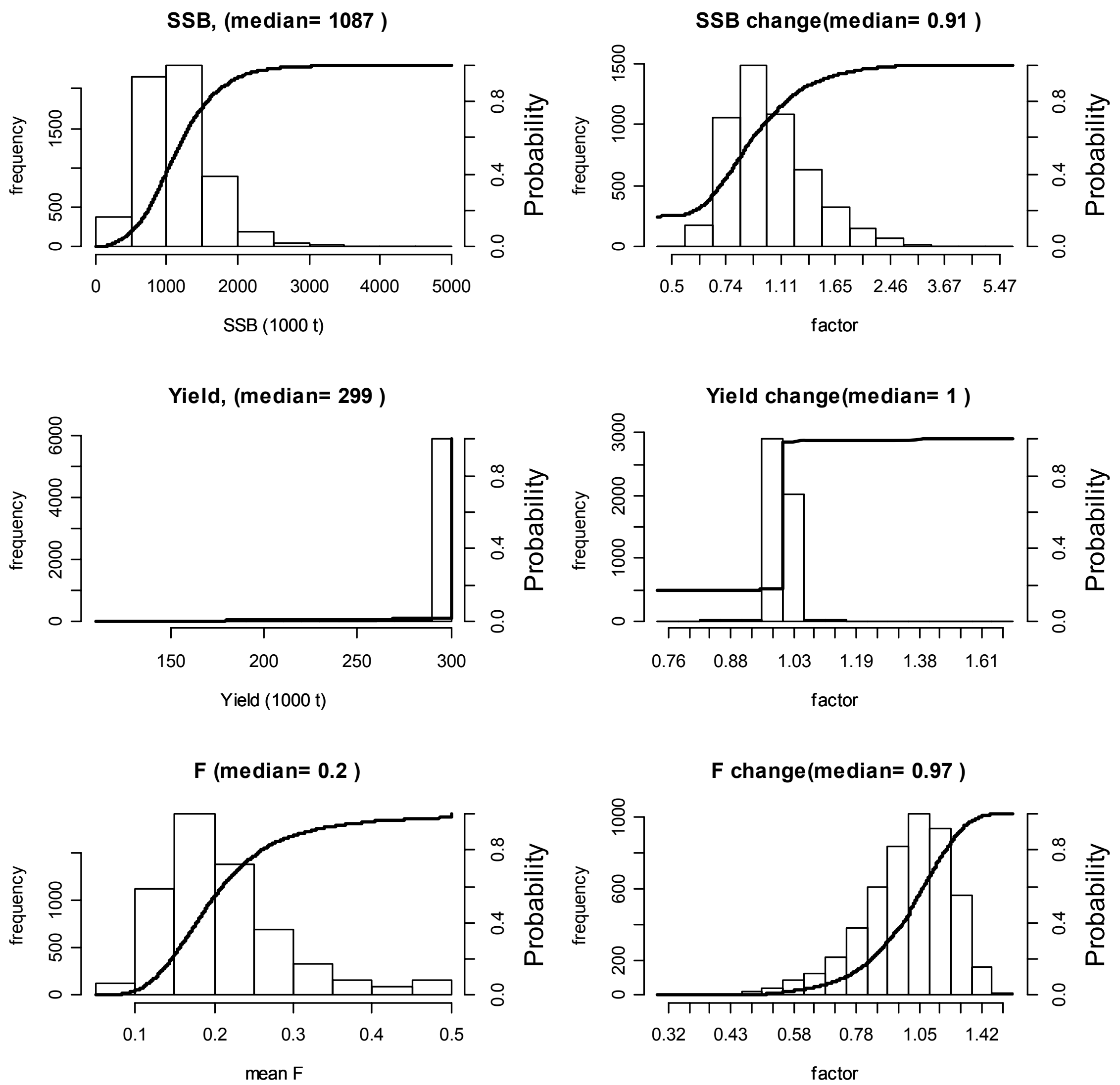

Figure 2.3.2.4 Distribution of population metrics at equilibrium (last 5 years of simulations) when managing with a fixed TAC of 300kt and a cap on F of 0.5.

6.3.3 Existing HCR

The assumption regarding Fcap, that is the maximum F the fishery is able to inflict, has relatively little effect upon the outcome of the Commission's existing HCR (figures 2.3.3.1 - 2.3.3.4). The probability of fishery closure remains the same as does the median yield and the median SSB. If F is genuinely capped at 0.5 then the yield at "equilibrium" is more stable than if the Fleet's capacity to inflict F is closer to 1.0. There is also a slightly higher probability of being below B_{pa} if the Fcap is 1.0.

If the TAC was raised to the 2004 value then the effectiveness of the HCR is lower, especially where Fcap=1.0 (figures 2.3.3.5 - 2.3.3.8). Yields are more variable and the probability of being below B_{lim} is greater.

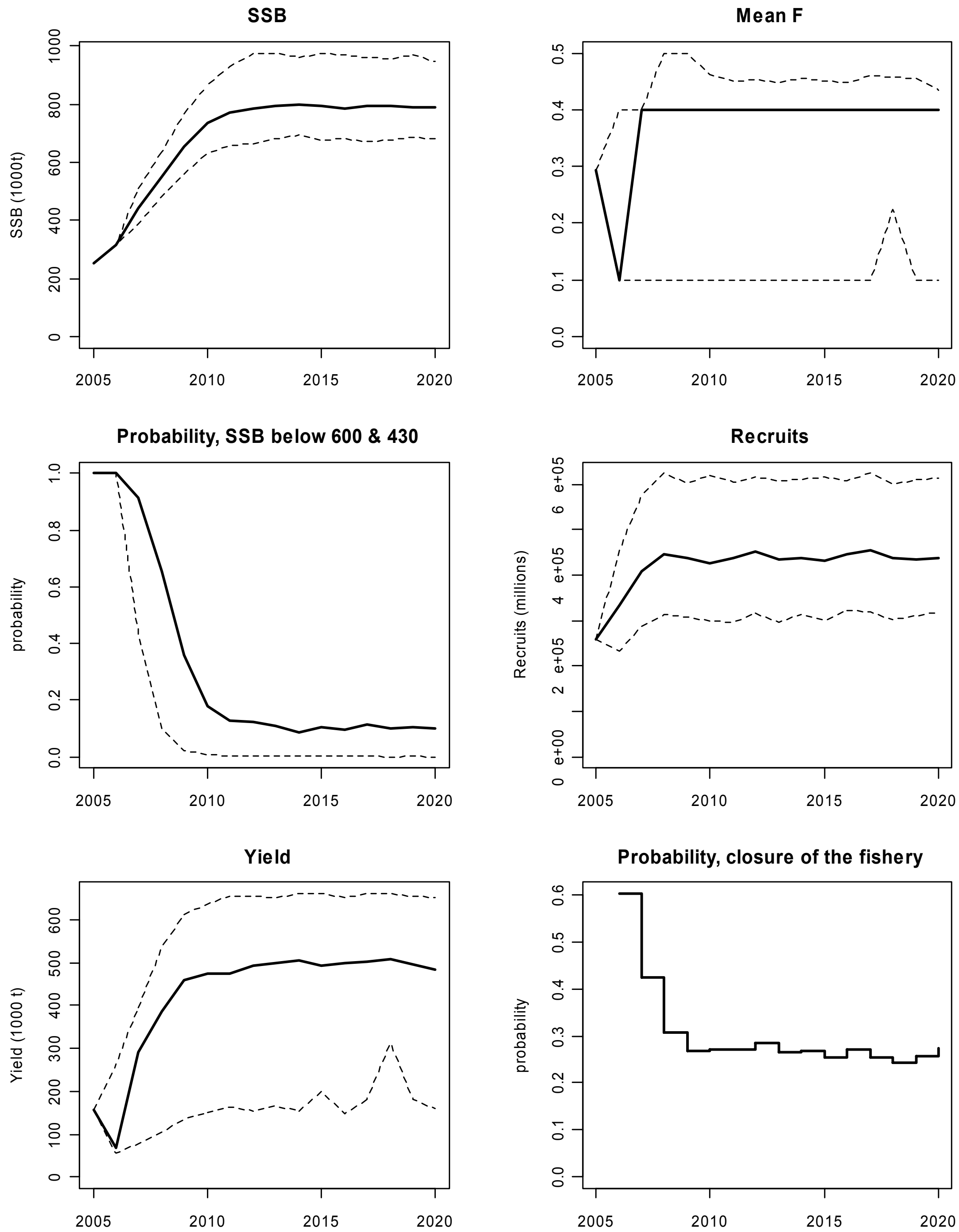

Fig 2.3.3.1 Time series for Commission's current HCR, Fcap=0.5 and TAC=660,960. The graphs show the median value and the 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

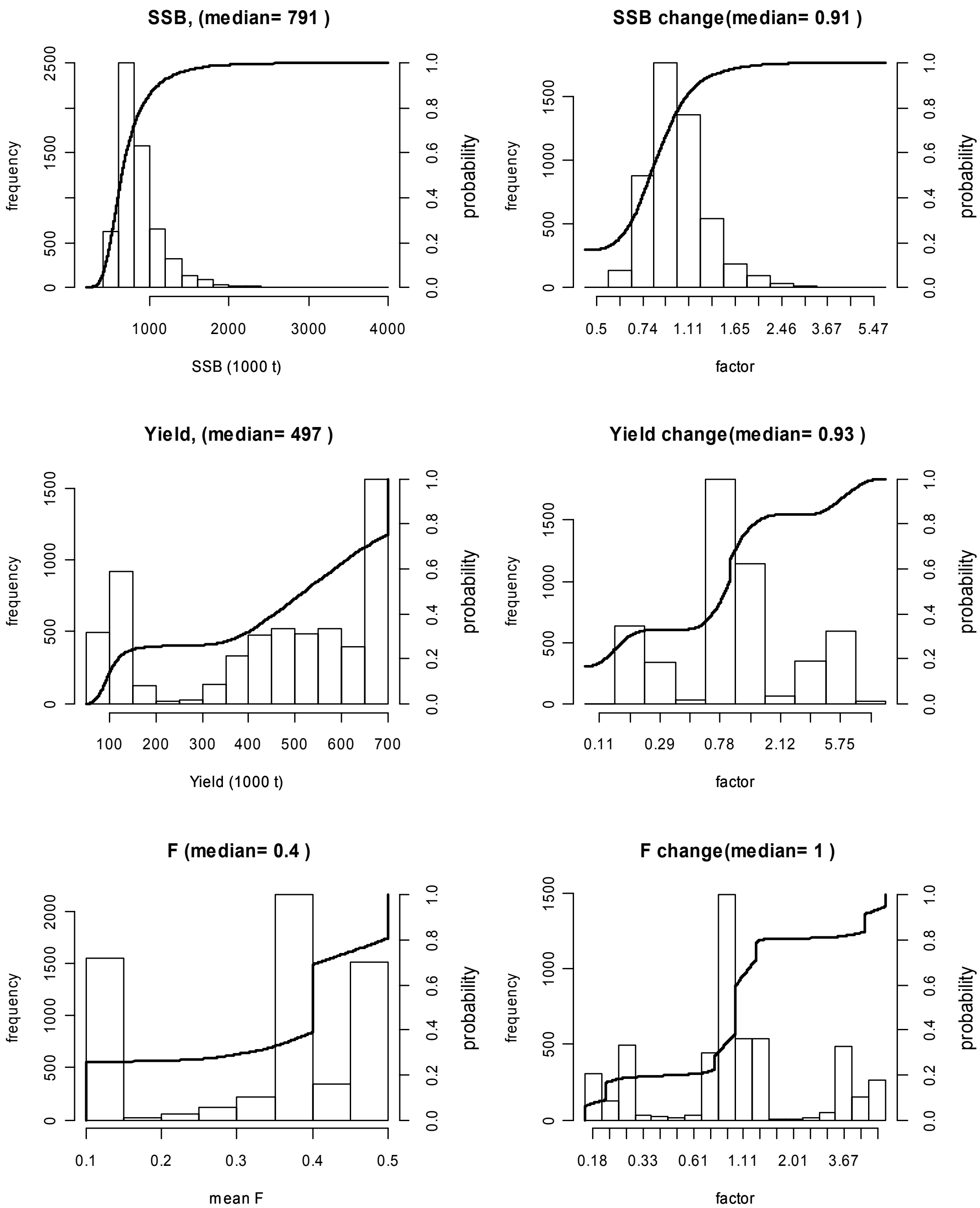

Fig 2.3.3.2 Distribution at equilibrium for Commission's current HCR, Fcap=0.5 & TAC = 660,960t.

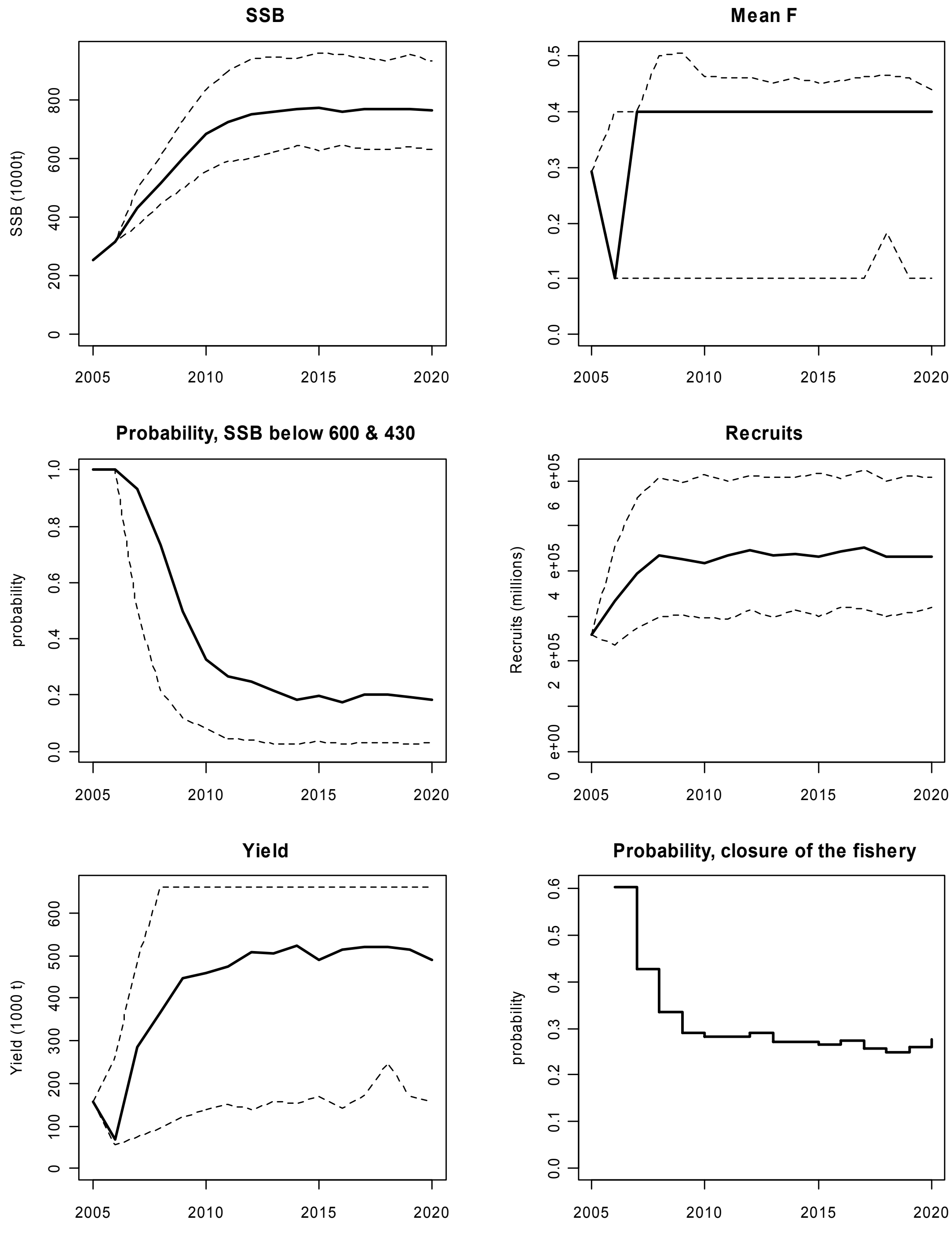

Fig 2.3.3.3 Time series for Commission's current HCR, Fcap=1.0 and TAC=660,960. The graphs show the median value and the 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

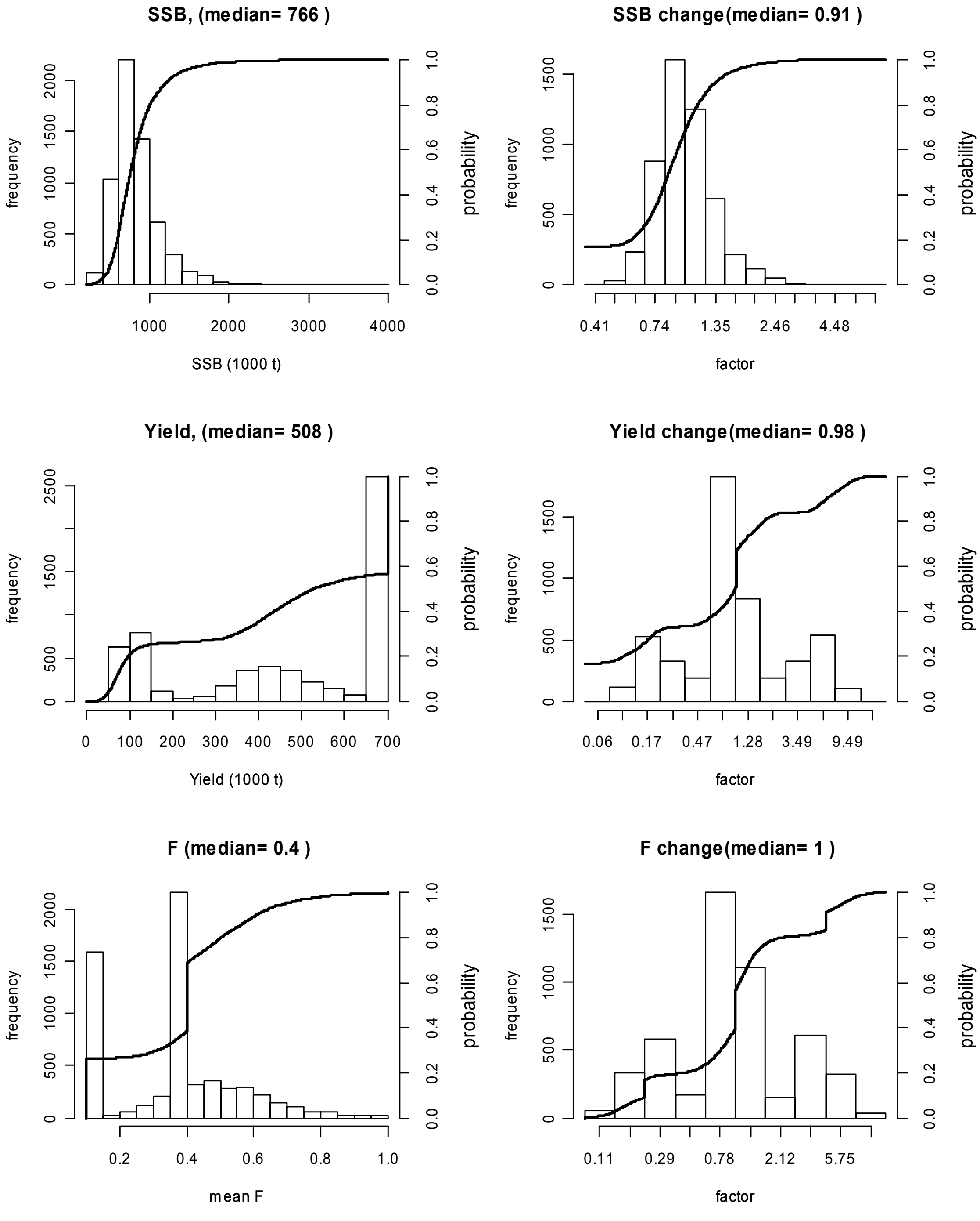

Fig 2.3.3.4 Distribution at equilibrium for Commission's current HCR, Fcap=1.0 & TAC = 660,960t.

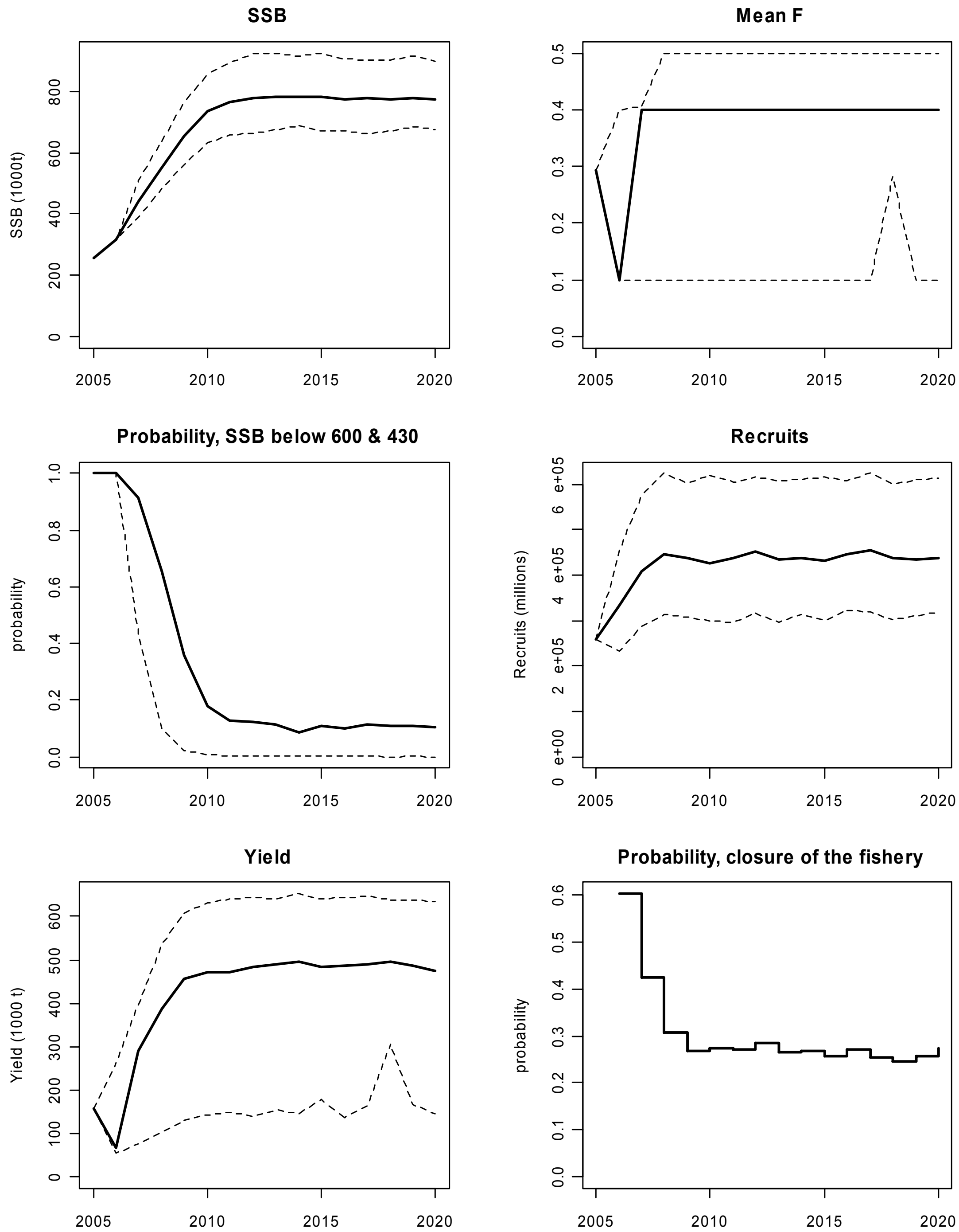

Fig 2.3.3.5 Time series for Commission's current HCR, Fcap=0.5 and TAC=826,200t. The graphs show the median value and the 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

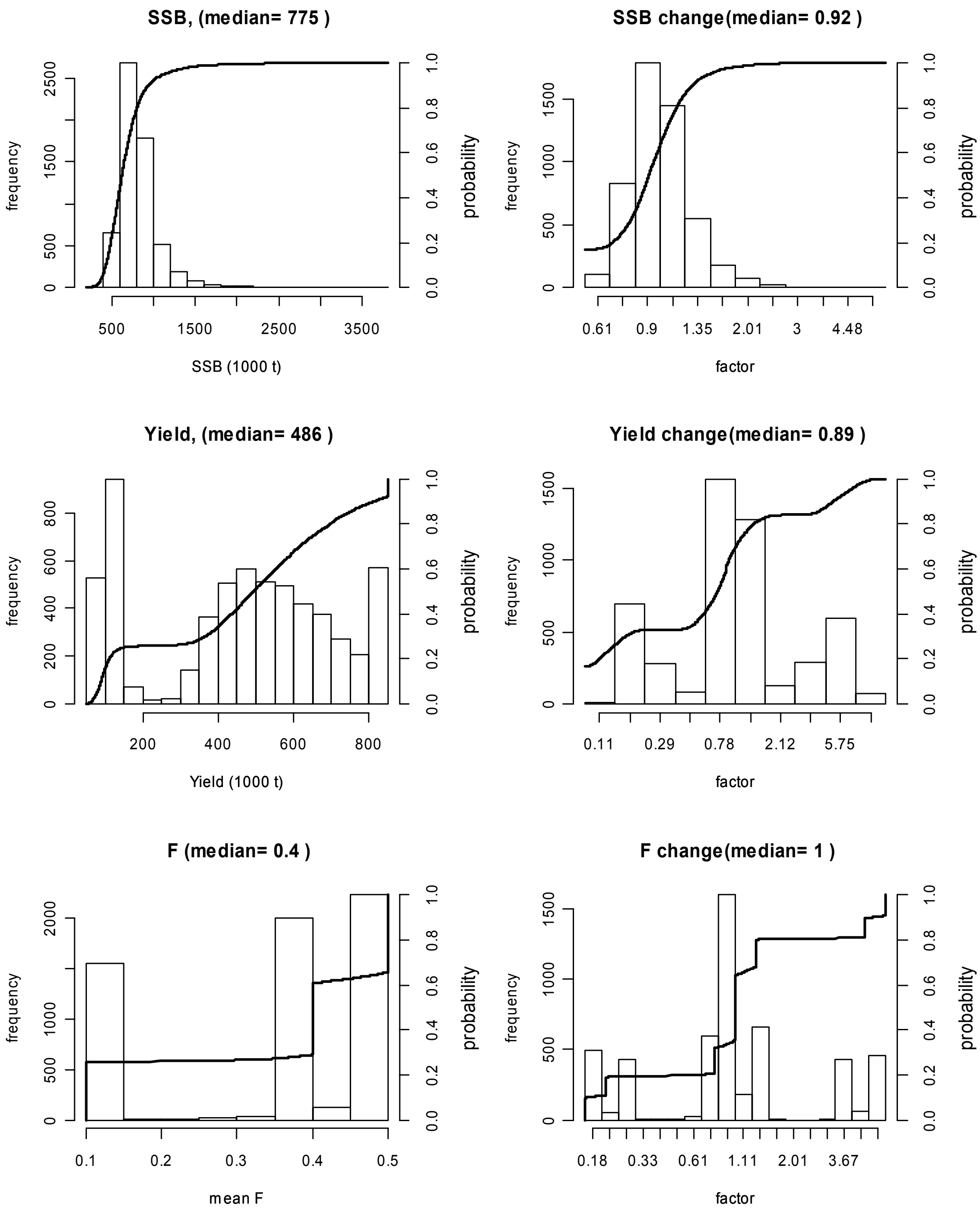

Fig 2.3.3.6 Distribution at equilibrium for Commission's current HCR, Fcap=0.5 & TAC = 826,200t.

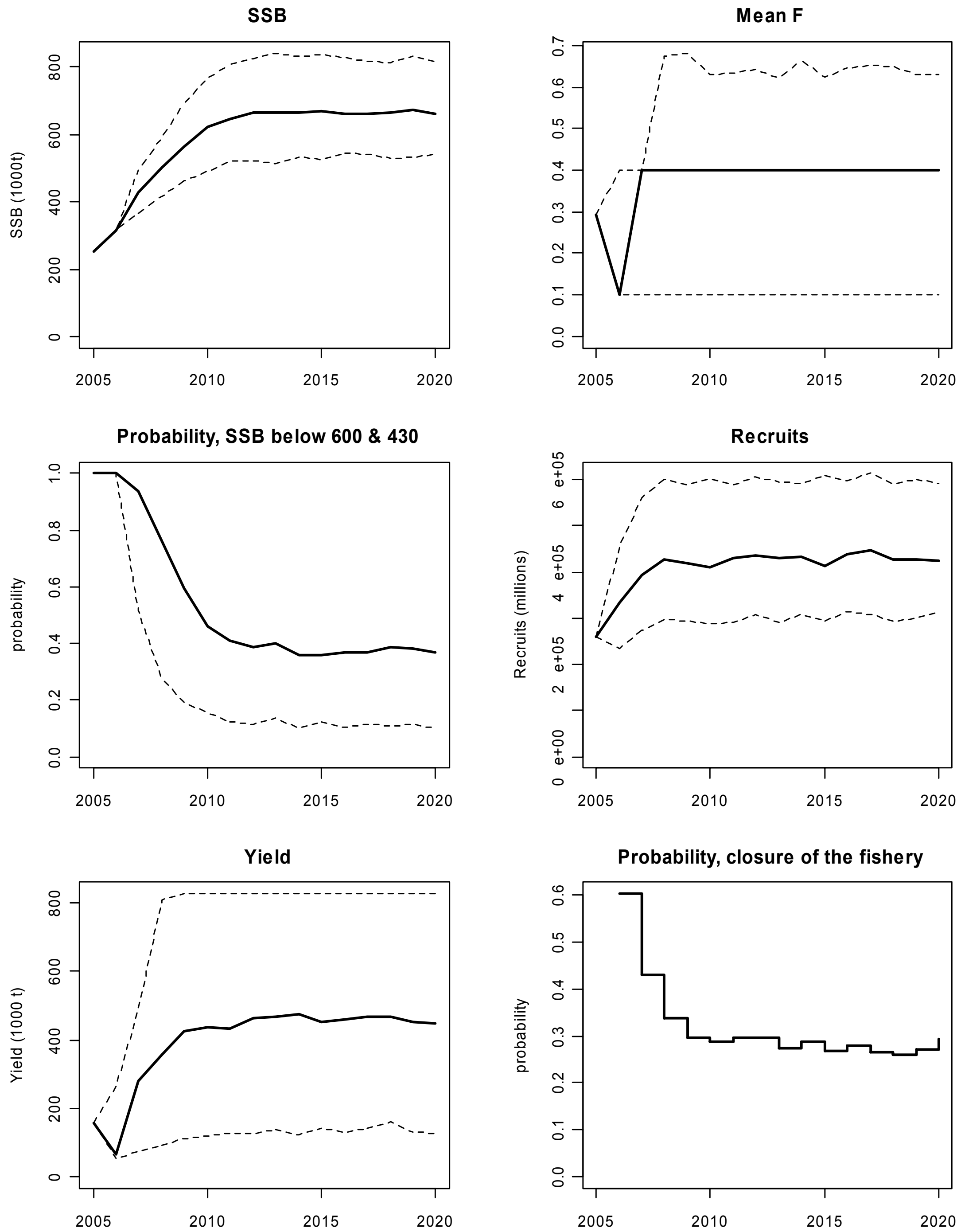

Fig 2.3.3.7 Time series for Commission's current HCR, Fcap=1.0 and TAC=826,200t. The graphs show the median value and the 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

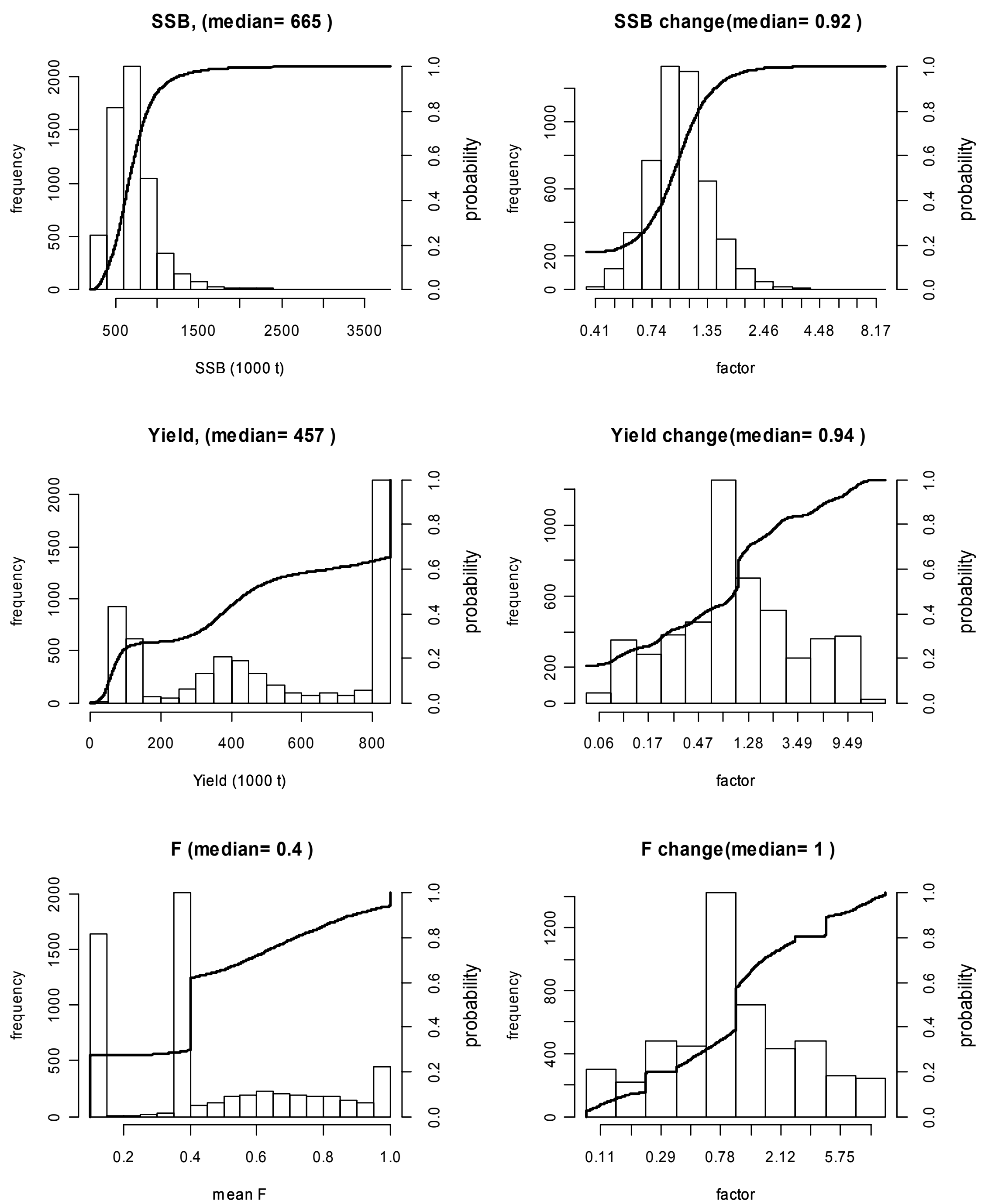

Fig 2.3.3.8 Distribution at equilibrium for Commission's current HCR, Fcap=1.0 & TAC = 826,200t.

6.3.4 F from target SSB in the beginning of the year after the TAC year.

a) *Base case*. The results from implementing the base case (scenario a) are shown in Figures 2.3.4.1 and 2.3.4.2. The target SSB of 600 kt is reached relatively quickly by 2009 and the stock stabilises well above the target. The probability of closure (an F corresponding to 0.1) is very low after the stock recovered. The distribution of F shows relative higher frequency for F = 0.1 corresponding to the effort on the monitoring fishery in years of closure and a mode at 0.5 suggesting that for the given conditions the fishery would be limited by F=0.5 rather than the target SSB. Comparison of the results with the constant F strategy (Fig. 2.3.1.1 & 2.3.1.2) suggests that in scenario a) although the mean F stabilises at Fcap= 0.5, the target of maintaining SSB> 600 kt results in lower F in the years 2006 – 8 when the stock is low. As a result, the stock reaches an equilibrium above 600 kt before it does in the constant F strategy as shown by the probability of the stock being below reference points which is much lower for the scenario a).

b) Results reflect the relaxation regarding Fcap which is now 0.6 and is summarised in figures 2.3.4.3 and 2.3.4.4. The fishery is less bound by the cap in fishing mortality as shown in the time-series plot of mean F. The yield and SSB trajectories are similar to scenario a) with a median yield marginally higher than in a) (the opposite applies to SSB). The probability of being below Blim is still very low and the probability of closure does not appear to change substantially from scenario a) therefore scenario b) is likely to be a better approach if maximising yields was a management objective.

c) Reducing Fcap to 0.4 certainly results in the fishery being limited by F rather than by the target SSB as illustrated by the mean F time-series (figures 2.3.4.5 and 2.3.4.6). Yields are low (median = 464 kt) compared to the previous scenarios but stability in F and yield is comparatively high. The stock recovers faster than it does when implementing a constant F = 0.4 strategy (Fig. 2.3.1.1).

d) The introduction of a 25% bias in the implementation (figure 2.3.4.7 and 2.3.4.8) results in increased risk of falling below Bpa and Blim and less stability in terms of F as suggested by the yield and F-change diagrams.

i) A target SSB of 900 kt results in frequent fishery closures, reduces mean yields and gives a much wider variation in potential yields (figures 2.3.4.17 and 2.3.4.18) but obviously holds the stock at a much higher level.

j) The results are almost identical to the base case. The range of SSB starting values from the MCMC posterior distribution is relatively narrow so, taking into account the uncertainty from this assessment has little impact on variability during the projection period. (figures 2.3.4.19 and 2.3.4.20) For the historical assessment period, the probability of being below SSB is high in some years before 2000, and in all years after 2000.

6.3.5 Sensitivity to low recruitment and autocorrelation in recruitment (scenarios e – h)

e) The reduction of the slope reflects in an immediate decline in recruitment (Fig. 2.3.4.9) which then stabilises at about half the level compared to the base case. SSB find an equilibrium just above 500000 therefore the probability of falling below reference points is very high. Given the target SSB the fishery is closed with high probability and F is at the monitoring fishery level = 0.1 most of the time (Fig 2.3.4.10).

f) The stock and recruitment slope does not change in this case therefore recruitment increases slightly as the stock recovers and then stabilises at a lower level compared to the base case (figures 2.3.4.11 and 2.3.4.12). As in scenario e) SSB stabilises at values lower than the base case but it reaches that equilibrium faster than scenario e) does. Reference points have been modified to reflect the new inflection point. However, the target SSB has not been modified accordingly and the fishery is closed often at the beginning of the projections period and Fcap is not limiting. SSB recovers quickly above 600 kt as a result of fishery closures.

g) The target SSB was brought down to a more realistic level therefore SSB stabilises at a lower level (Fig. 2.3.4.13 and 2.3.4.14) and yield is higher on average than in f). Fcap is limiting once the stock stabilises. This scenario illustrates the importance for optimal utilisation of having targets that are consistent with the dynamics of the stock. Also, interannual variability in yields is lower compared to f) as it results in a constant proportion strategy rather than constant escapement as in f).

h) The auto-correlation modelled seems to cause a mild increase in recruitment variability (Fig. 2.3.4.15 and 2.3.4.16). As the fishery is limited by F that does not reflect on an increase in yields variability. The stock recovers quickly and yields are optimised but not at the expense of stability so it can be concluded that the strategy is robust to this level of autocorrelation.

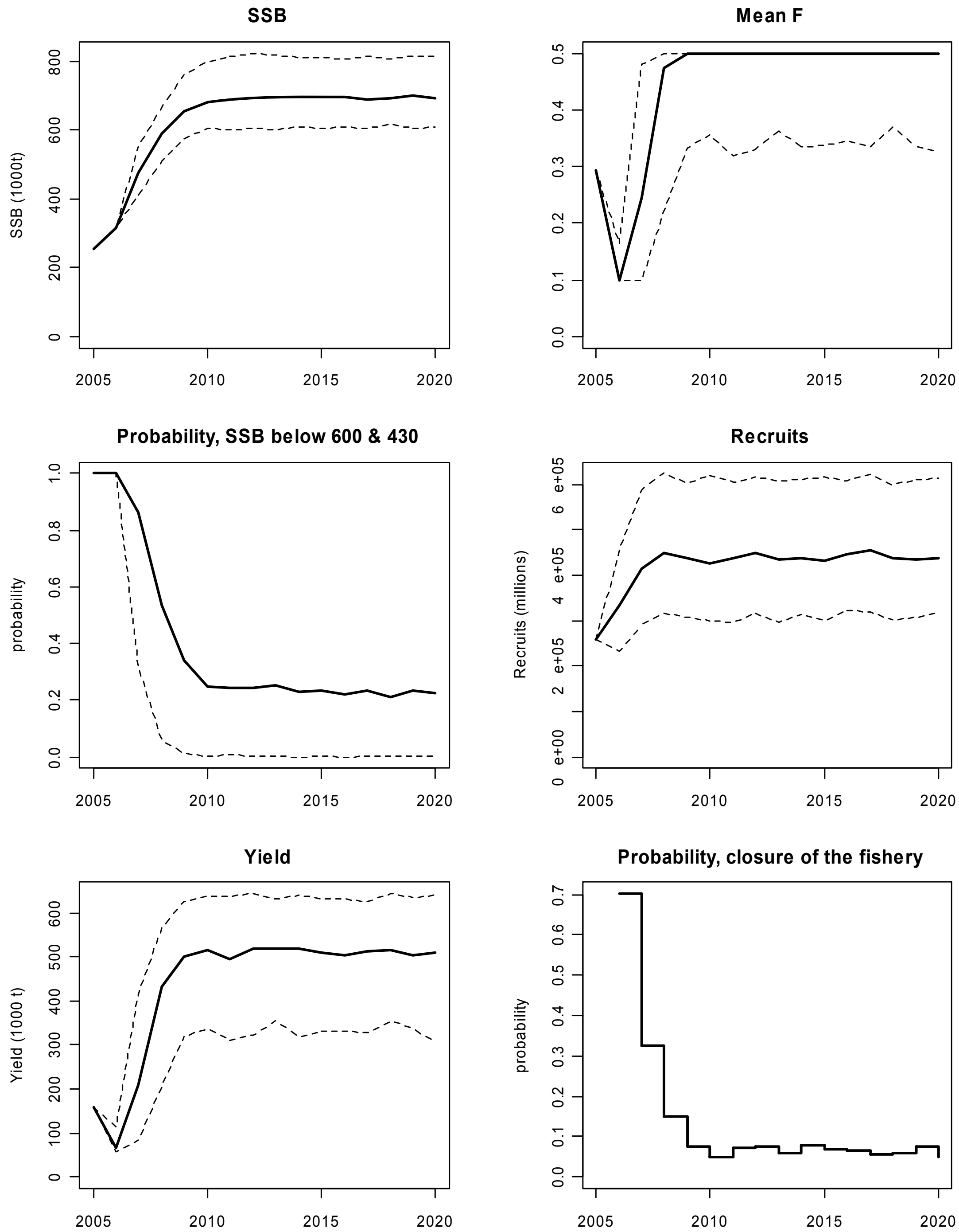

Figure 2.3.4.1 Time series for SCENARIO A: Target SSB=600000, overall maximum F=0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. The graphs show the median value and the 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

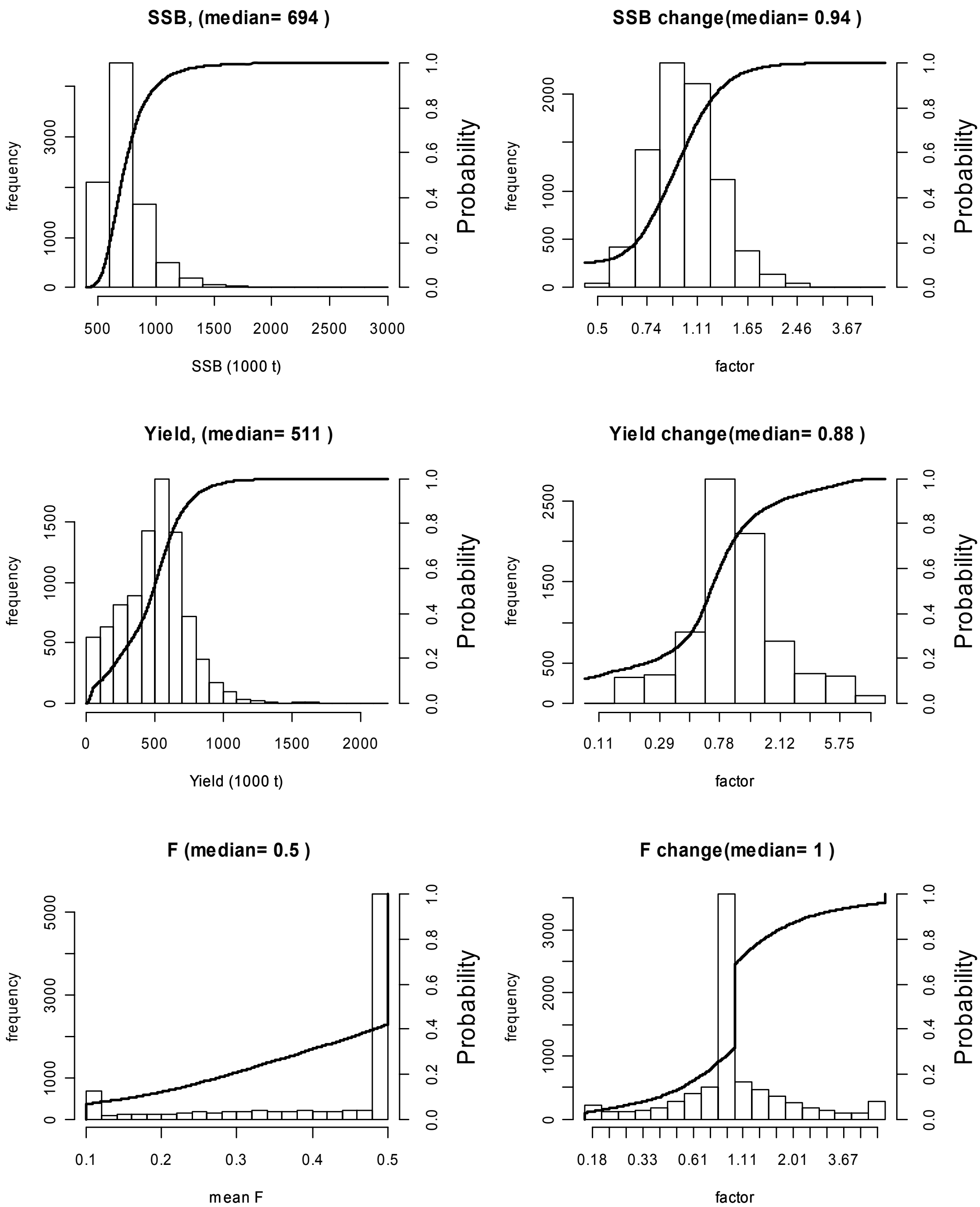

Figure 2.3.4.2 Distribution of metrics at equilibrium. SCENARIO A: Target SSB=600000, overall maximum F=0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%.

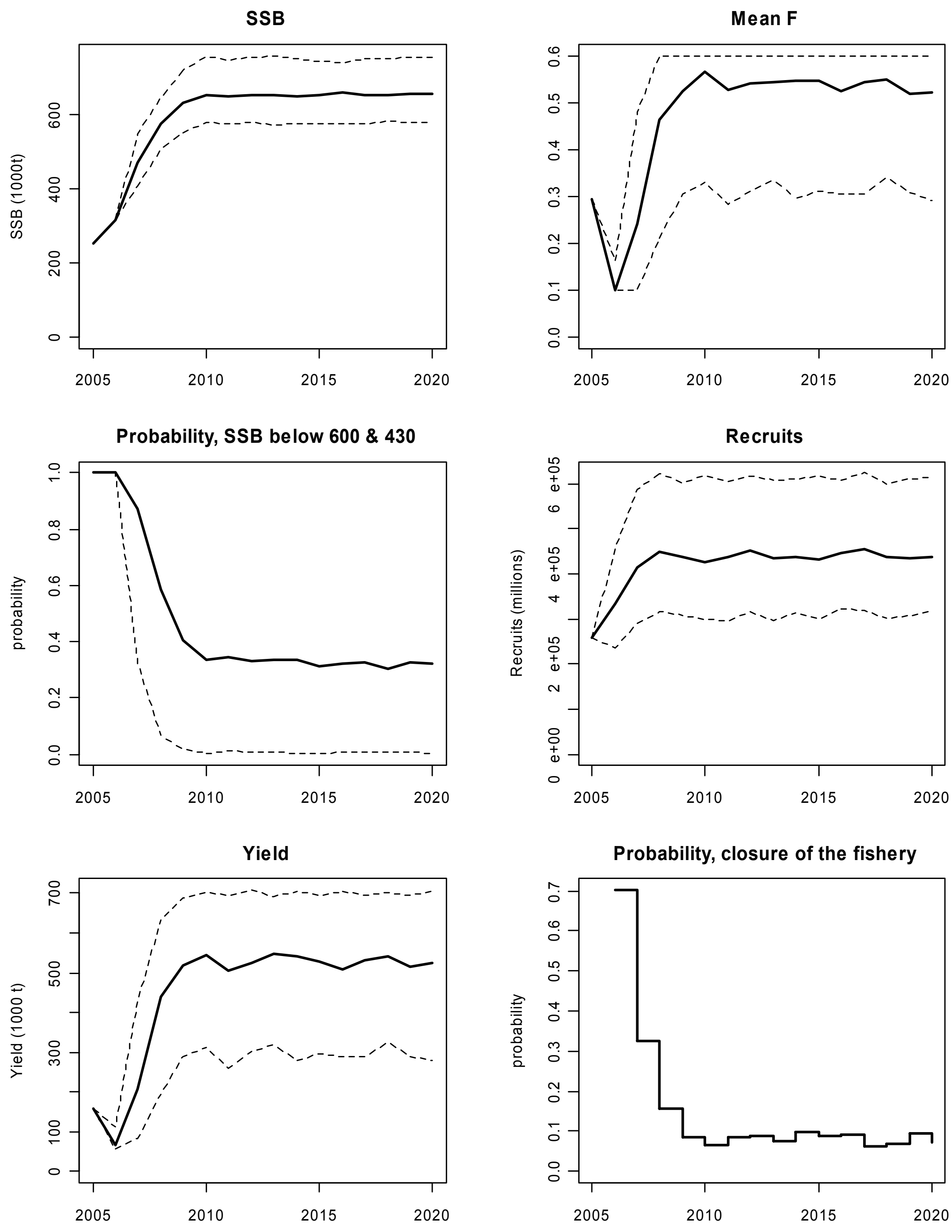

Figure 2.3.4.3 Time series for Scenario B. Target SSB=600000, overall maximum F=0.6, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25% The graphs show the median value and the 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

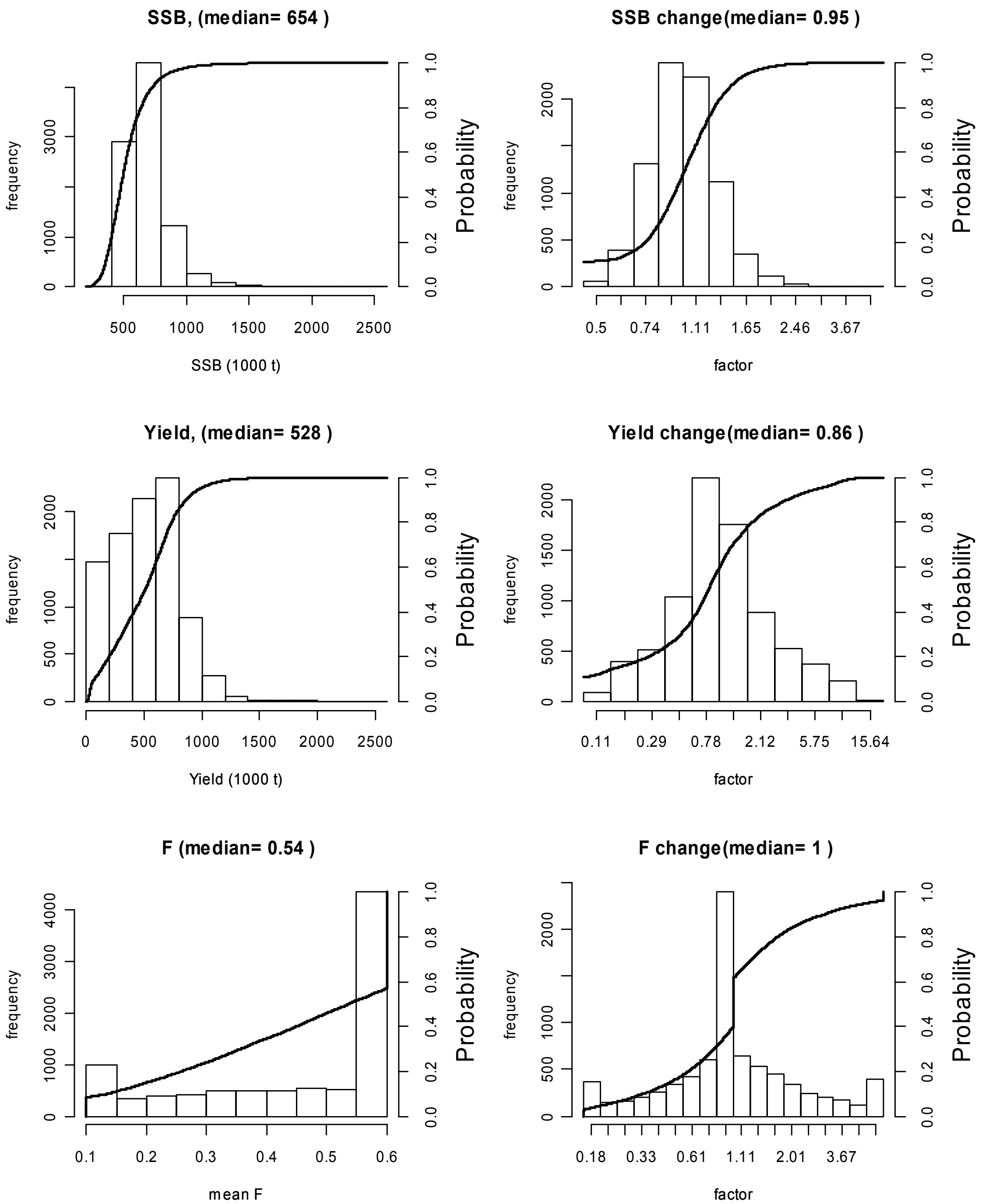

Figure 2.3.4.4 Distribution of metrics at equilibrium. SCENARIO B: Target SSB=600000, overall maximum F=0.6, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%

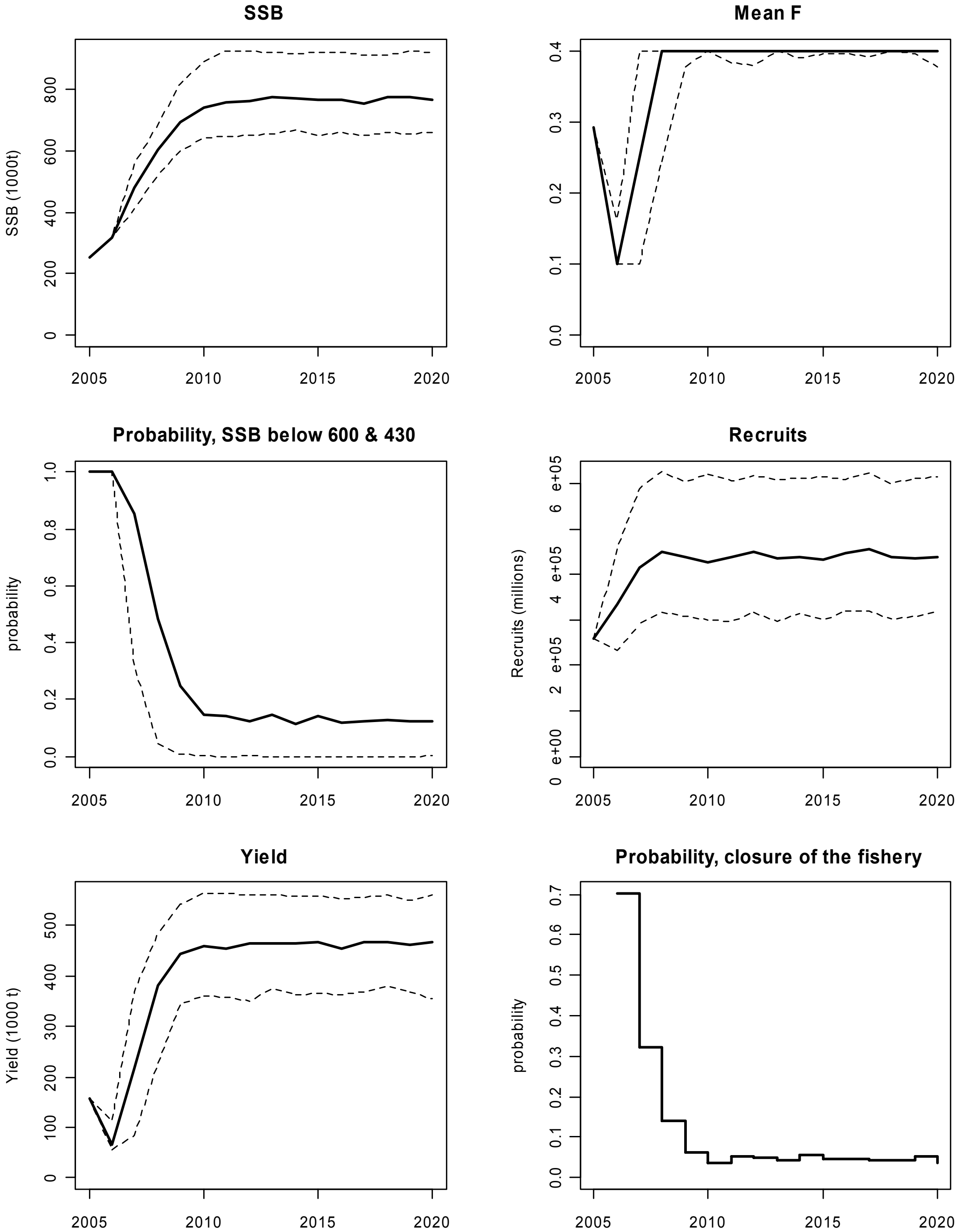

Figure 2.3.4.5 Time series for Scenario C. Target SSB=600000, overall maximum F =0.4, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. The graphs show the median value and the 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

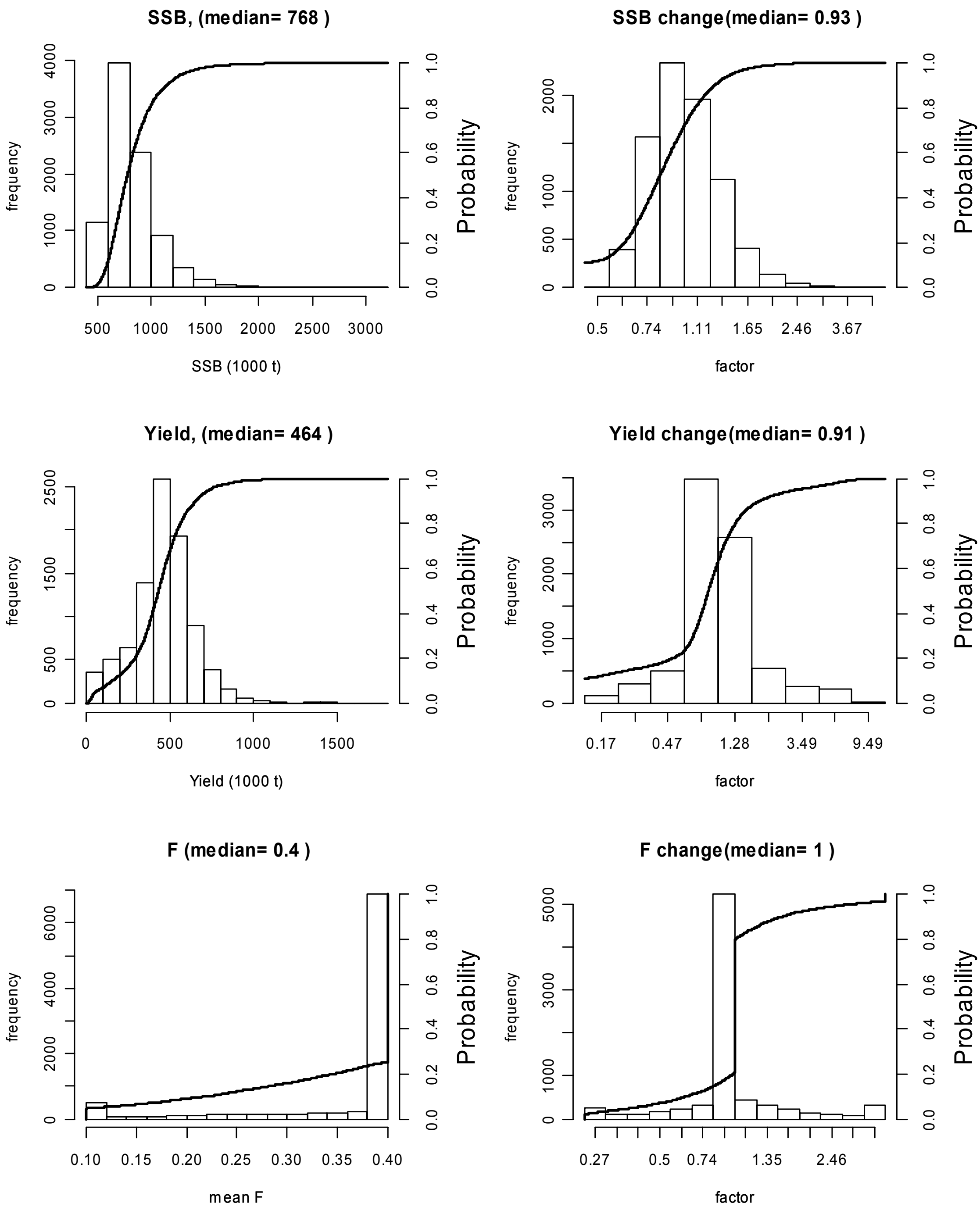

Figure 2.3.4.6 Distribution of metrics at equilibrium. SCENARIO C: Target SSB=600000, overall maximum F =0.4, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%.

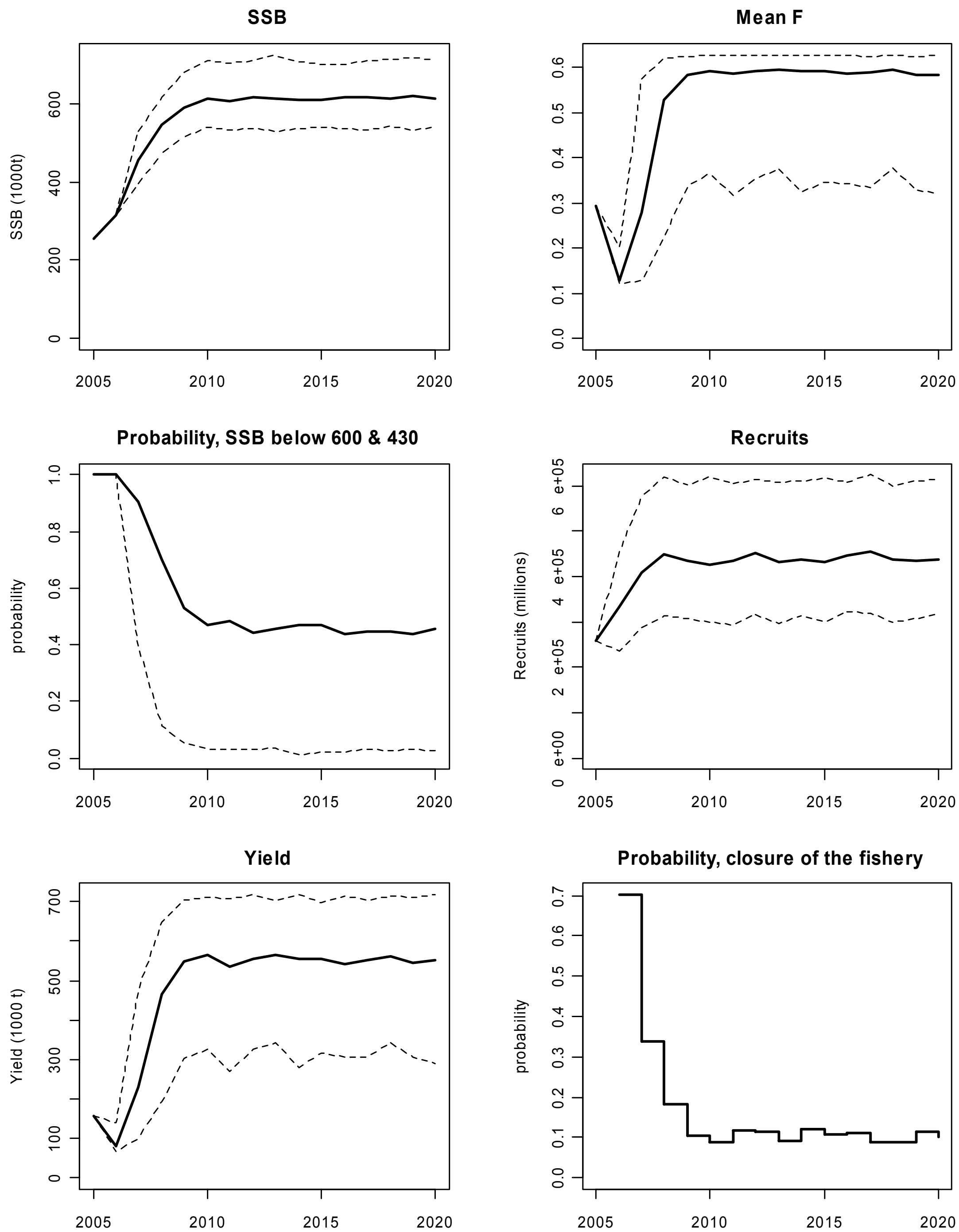

Figure 2.3.4.7 Time series for Scenario D. Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Implementation bias at 1.25 and a CV at 5%.. The graphs show the median value and the 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

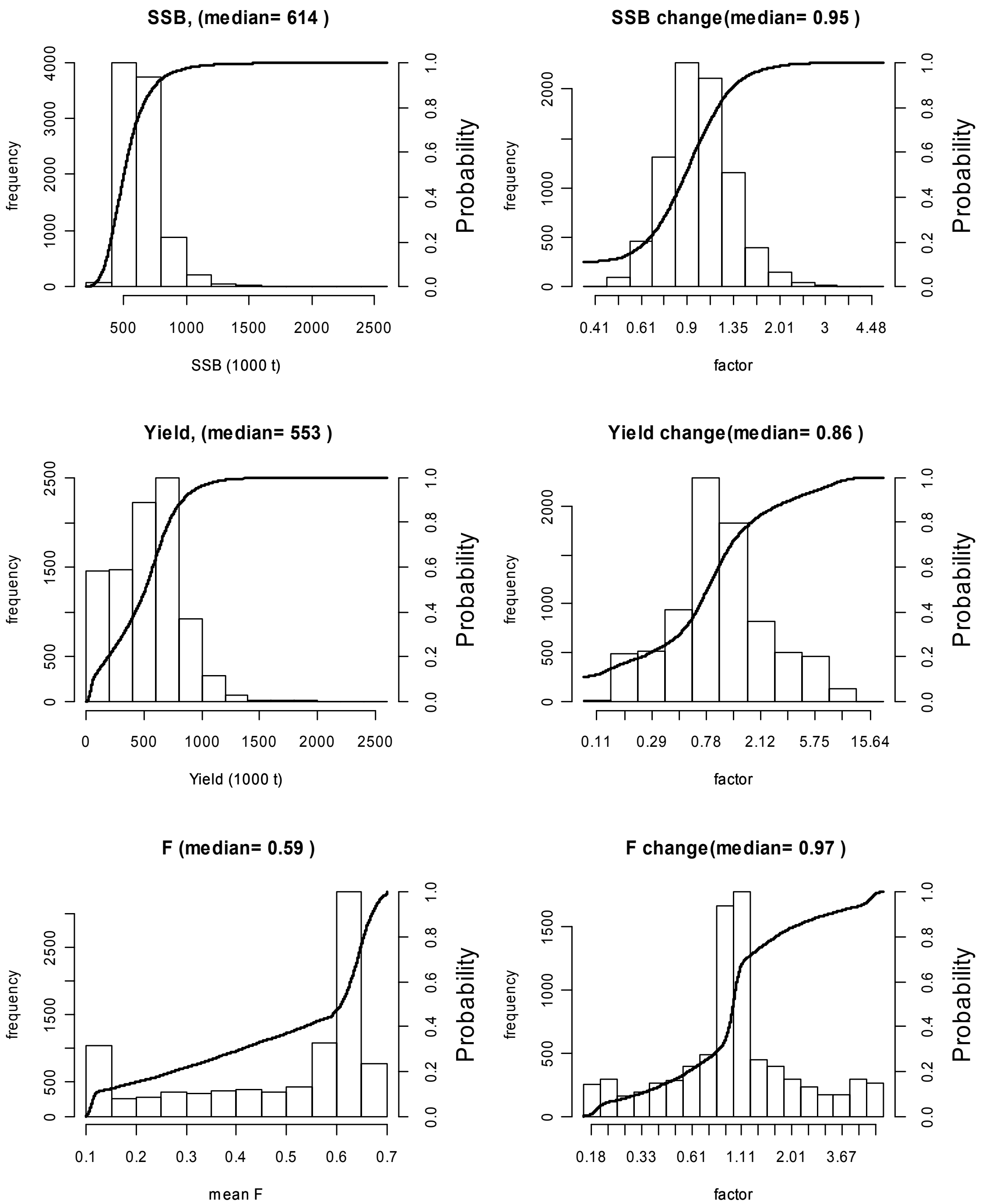

Figure 2.3.4.8 Distribution of metrics at equilibrium. SCENARIO D: . Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Implementation bias at 1.25 and a CV at 5%

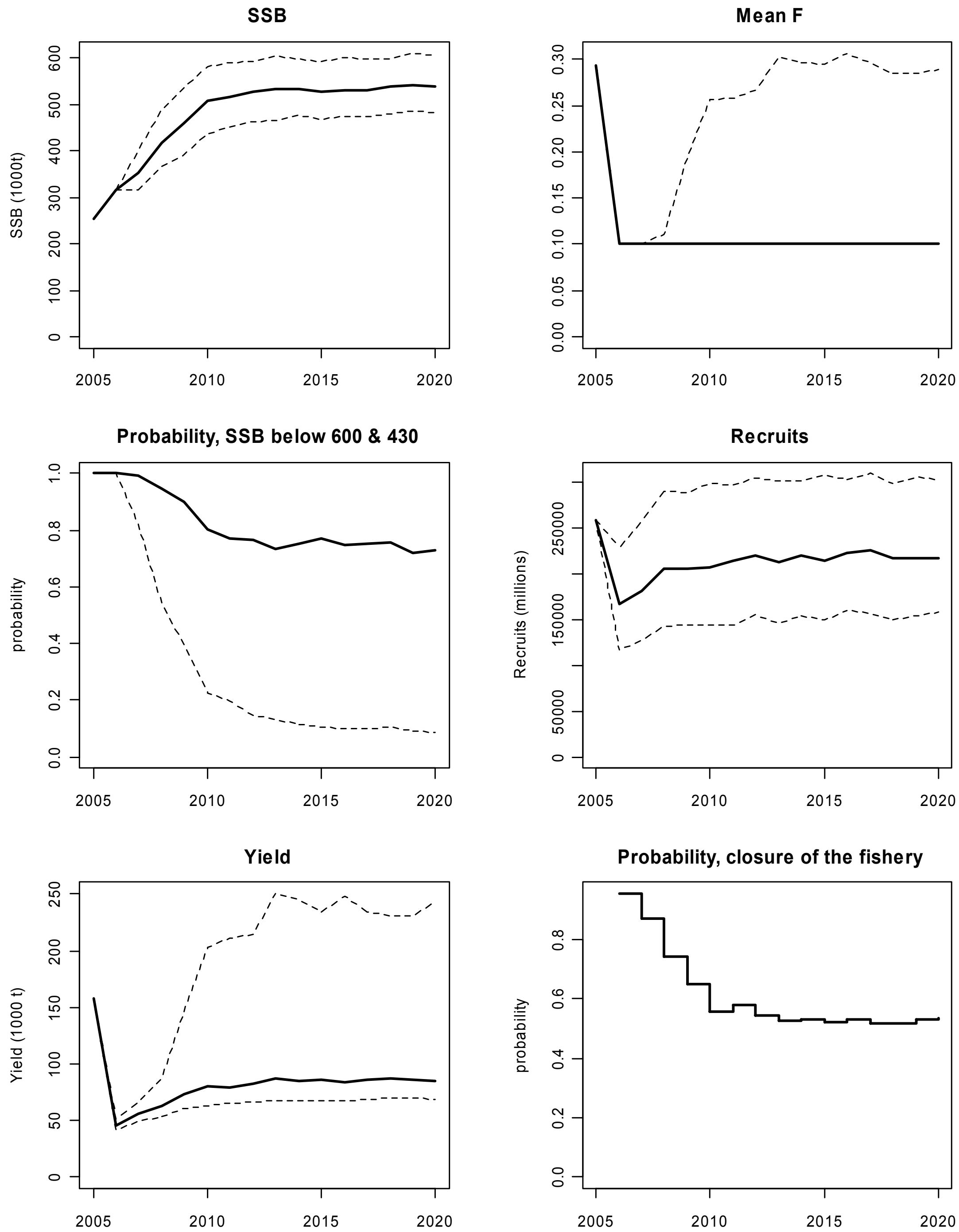

Figure 2.3.4.9 Time series for Scenario E. Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Stock recruitment relation with 50% reduction of the slope in the hockey-stick model. The graphs show the median value and the 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

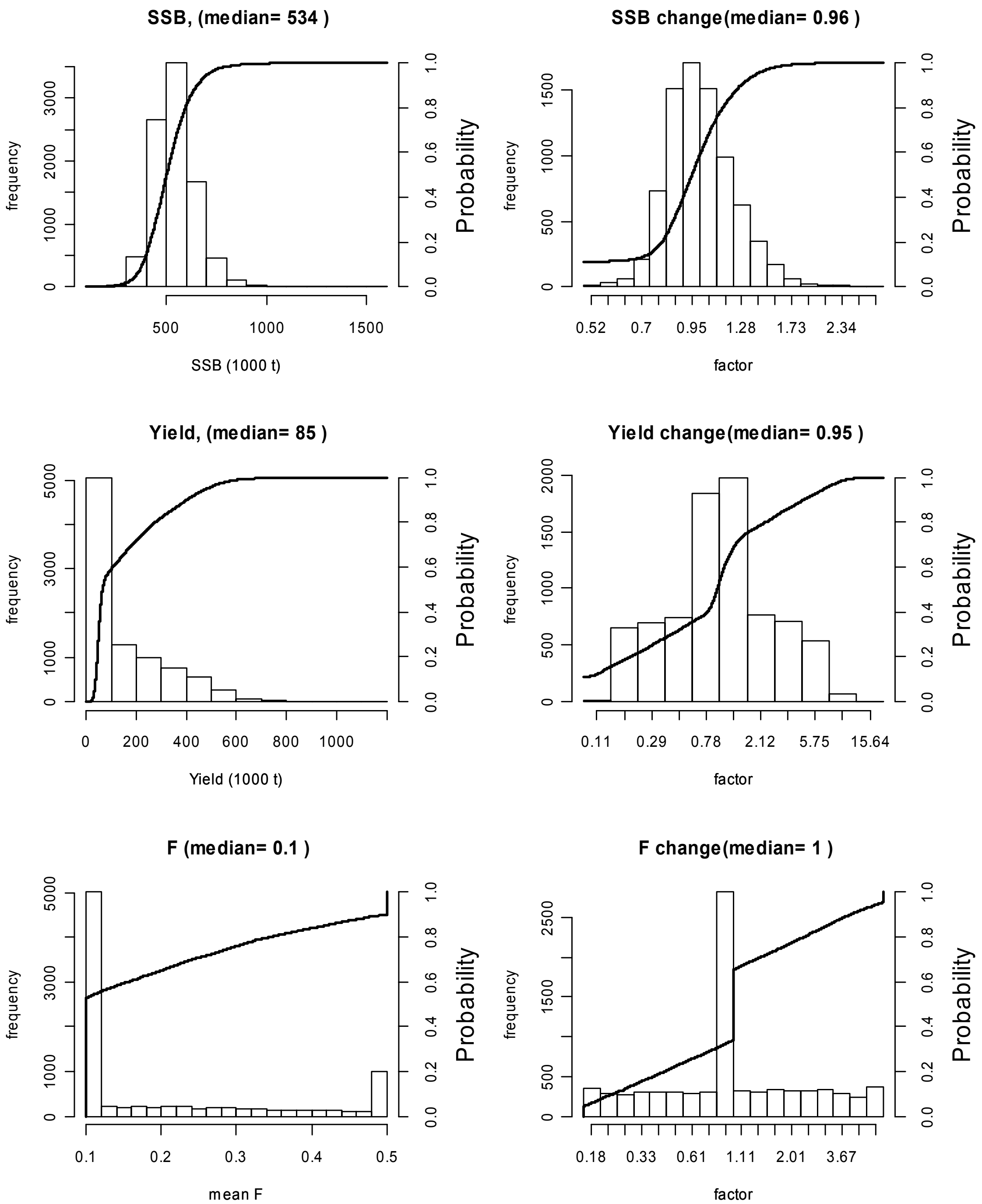

Figure 2.3.4.10 Distribution of metrics at equilibrium. SCENARIO E: . Scenario E. Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Stock recruitment relation with 50% reduction of the slope in the hockey-stick model.

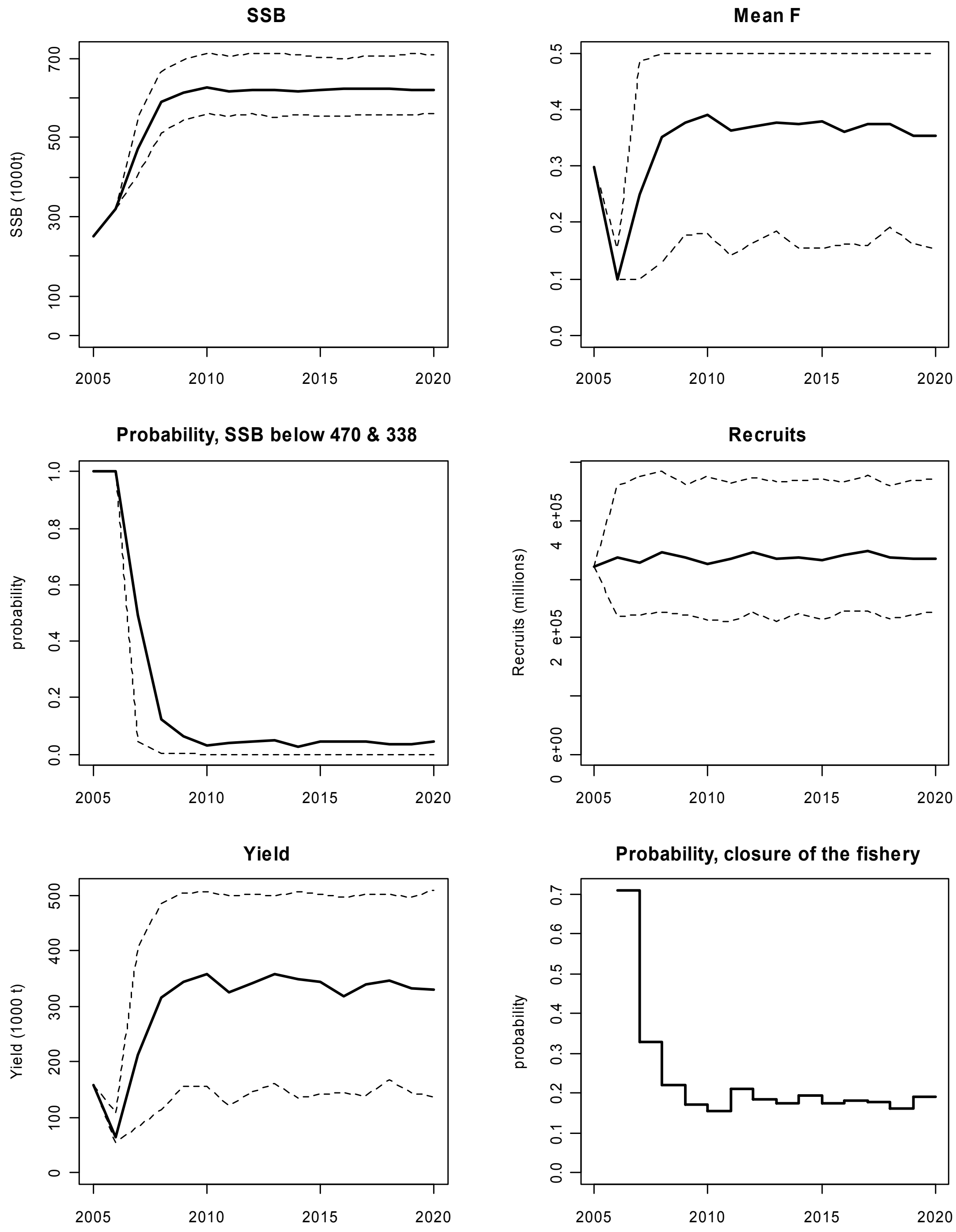

Figure 2.3.4.11 Time series for Scenario F. Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Stock recruitment relation with the historical value for the slope in the hockey-stick model, and a new inflection point 330000 tonnes (derived from the 25 percentiles of historical recruitment) . The graphs show the median value and 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

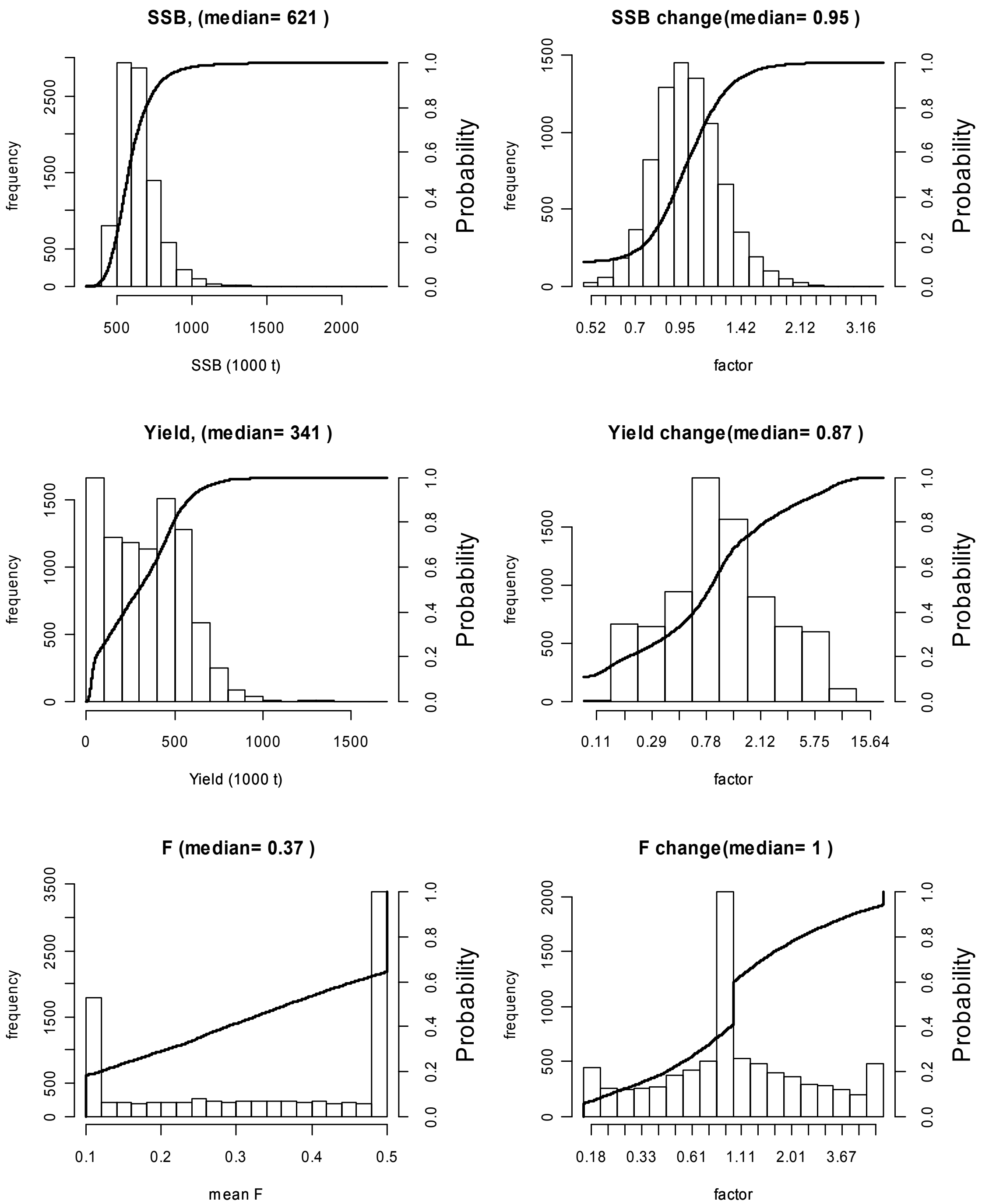

Figure 2.3.4.12 Distribution of metrics at equilibrium. SCENARIO F Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Stock recruitment relation with the historical value for the slope in the hockey-stick model, and a new inflection point 330000 tonnes (derived from the 25 percentiles of historical recruitment) .

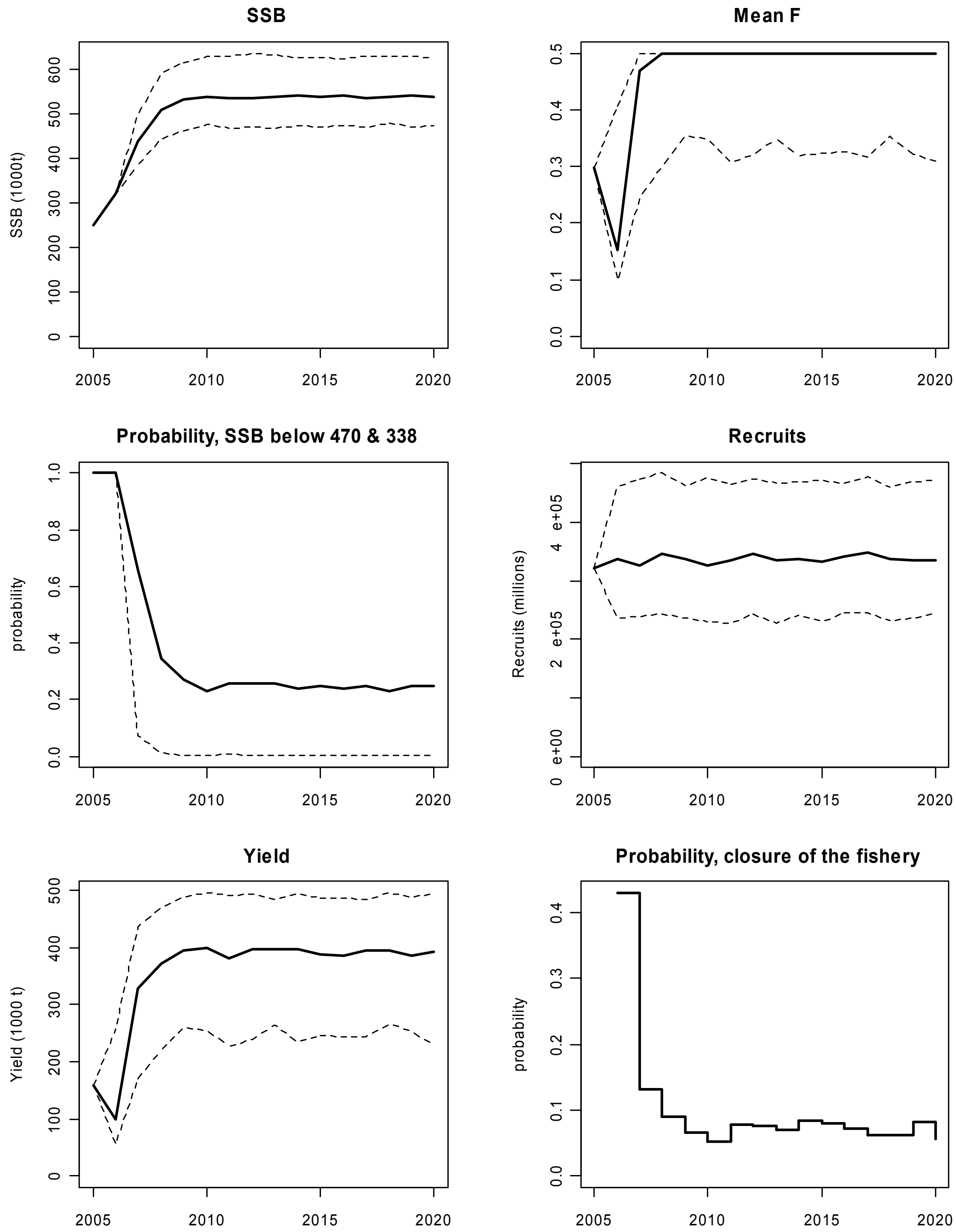

Figure 2.3.4.13 Time series for Scenario G. Target SSB=470000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Stock recruitment relation with the historical value for the slope in the hockey-stick model, and a new inflection point 330000 tonnes (derived from the 25 percentiles of historical recruitment). The graphs show the median value and 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

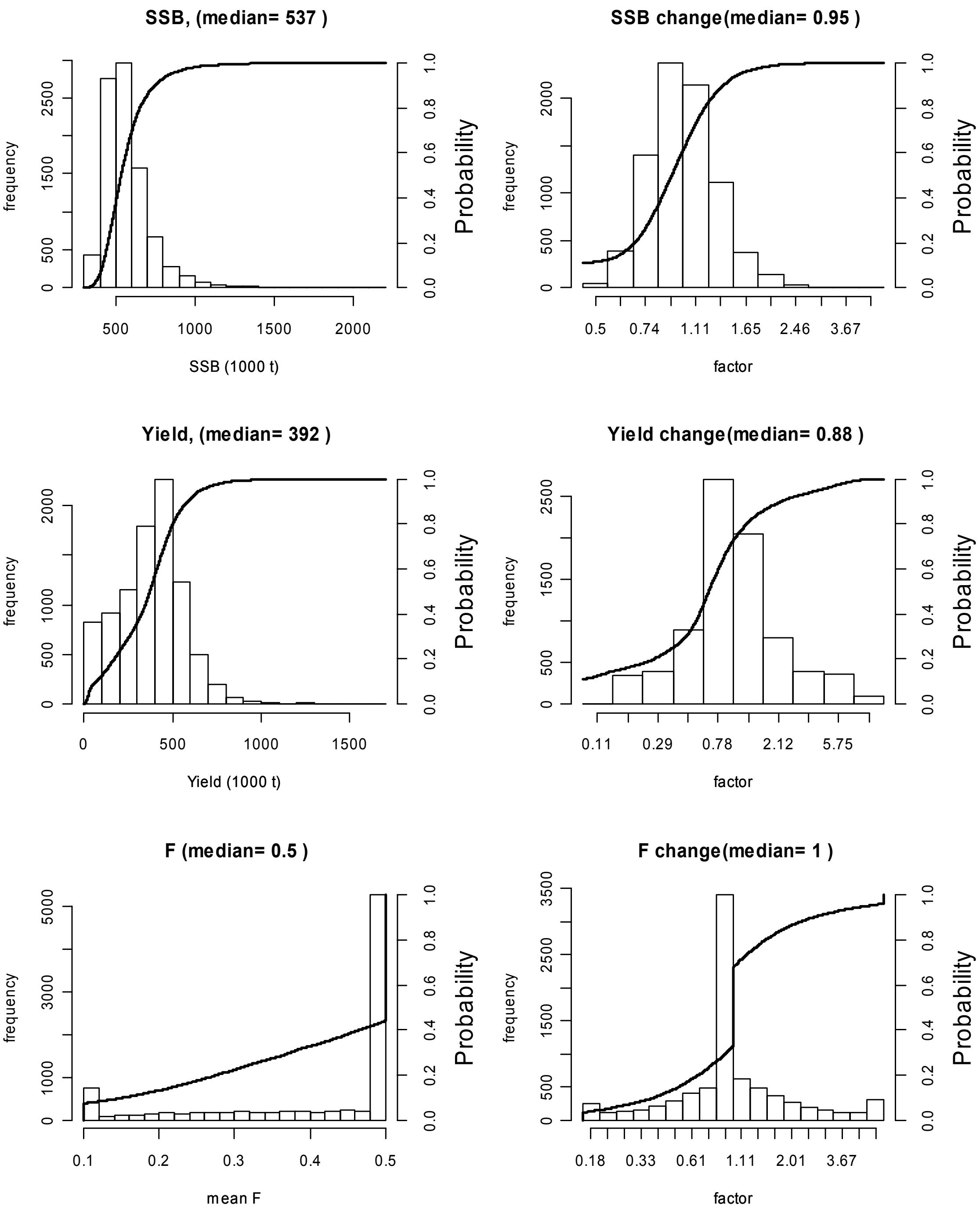

Figure 2.3.4.14 Distribution of metrics at equilibrium. Scenario G. Target SSB=470000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Stock recruitment relation with the historical value for the slope in the hockey-stick model, and a new inflection point 330000 tonnes (derived from the 25 percentiles of historical recruitment).

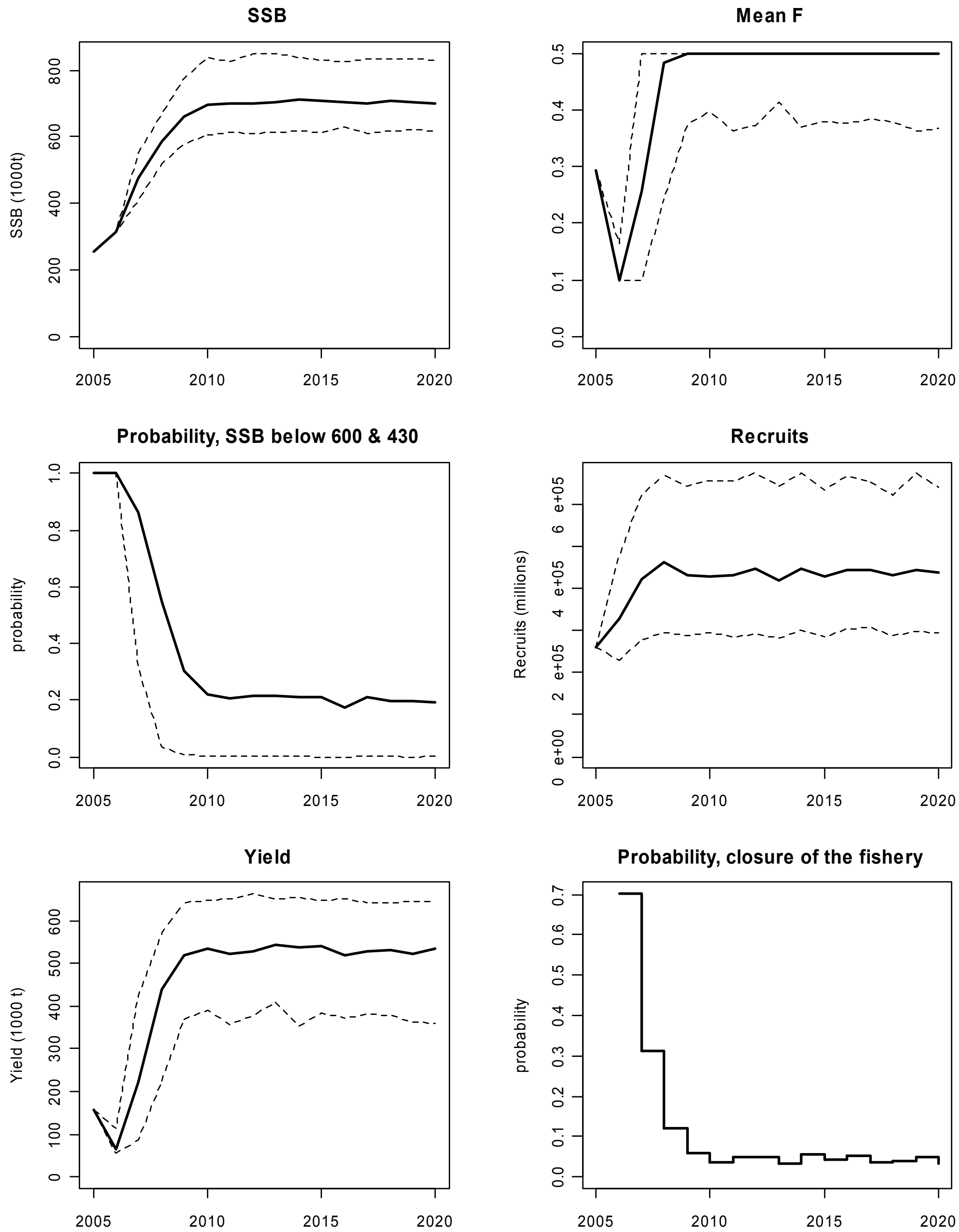

Figure 2.3.4.15 Time series for Scenario H. Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Negative autocorrelation (-0.5) in the SSB/R residuals. The graphs show the median value and 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

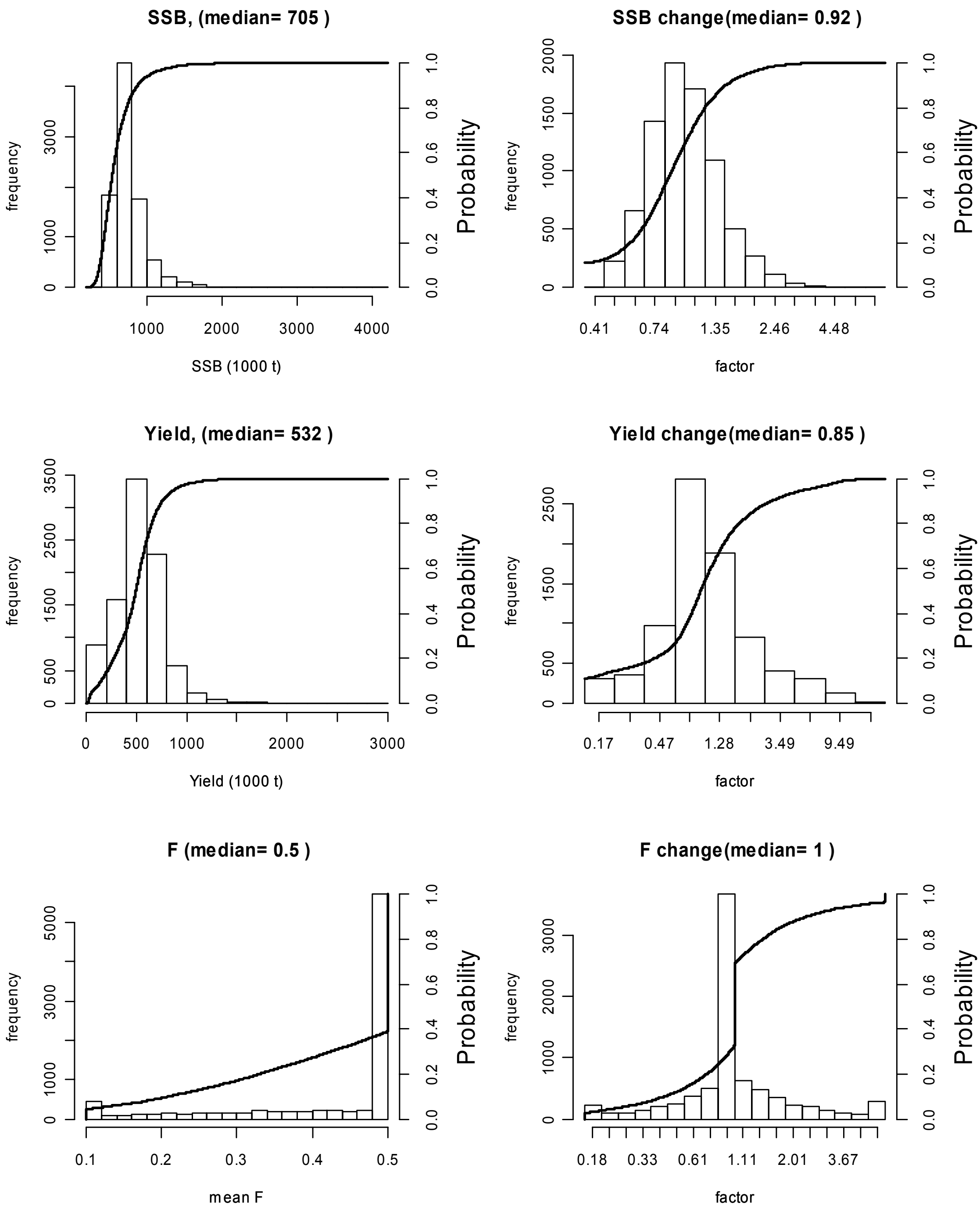

Figure 2.3.4.16 Distribution of metrics at equilibrium for Scenario H. Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. Negative autocorrelation (-0.5) in the SSB/R residuals.

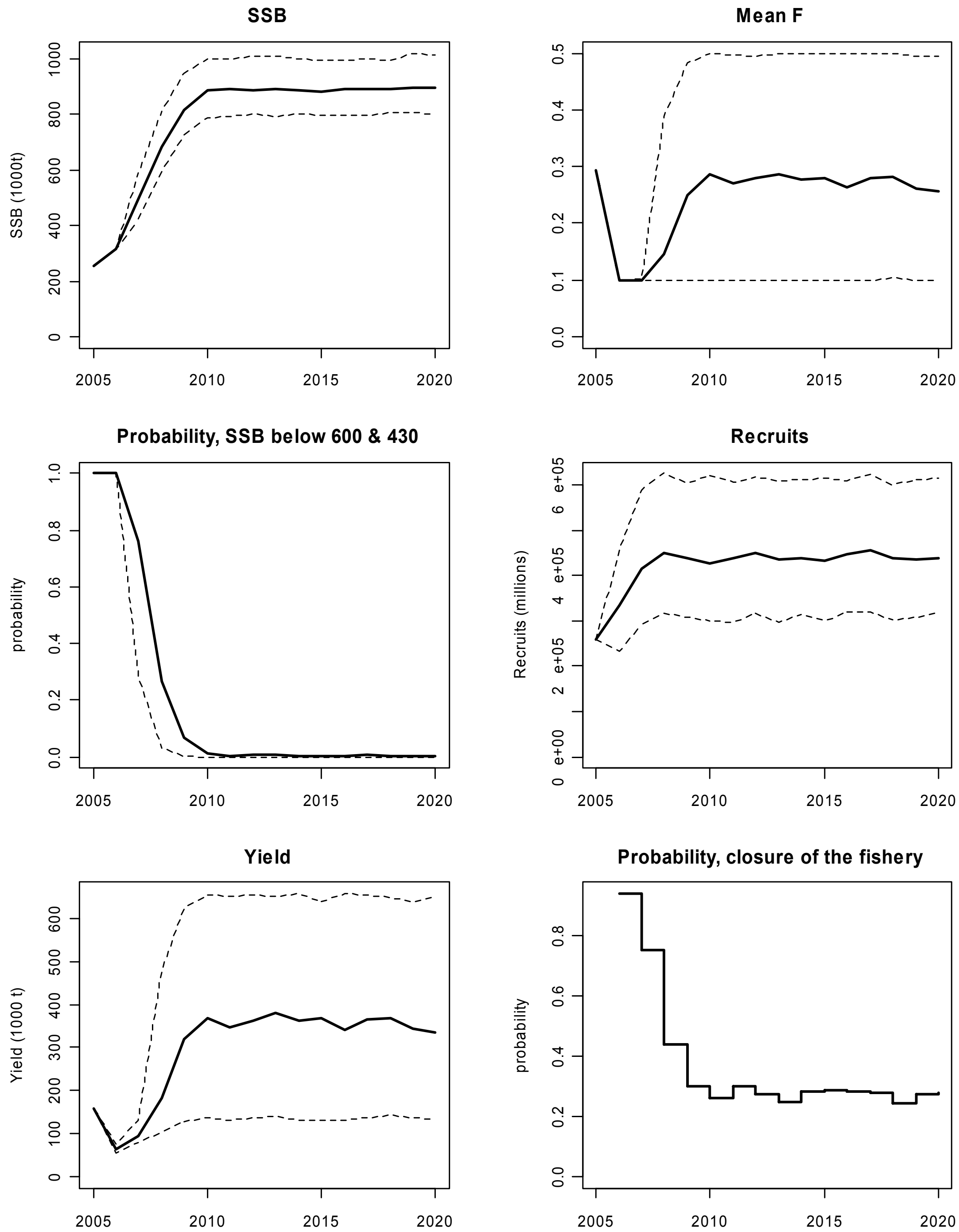

Figure 2.3.4.17 **Time series for Scenario I. Target SSB=900000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%.. The graphs show the median value and 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.**

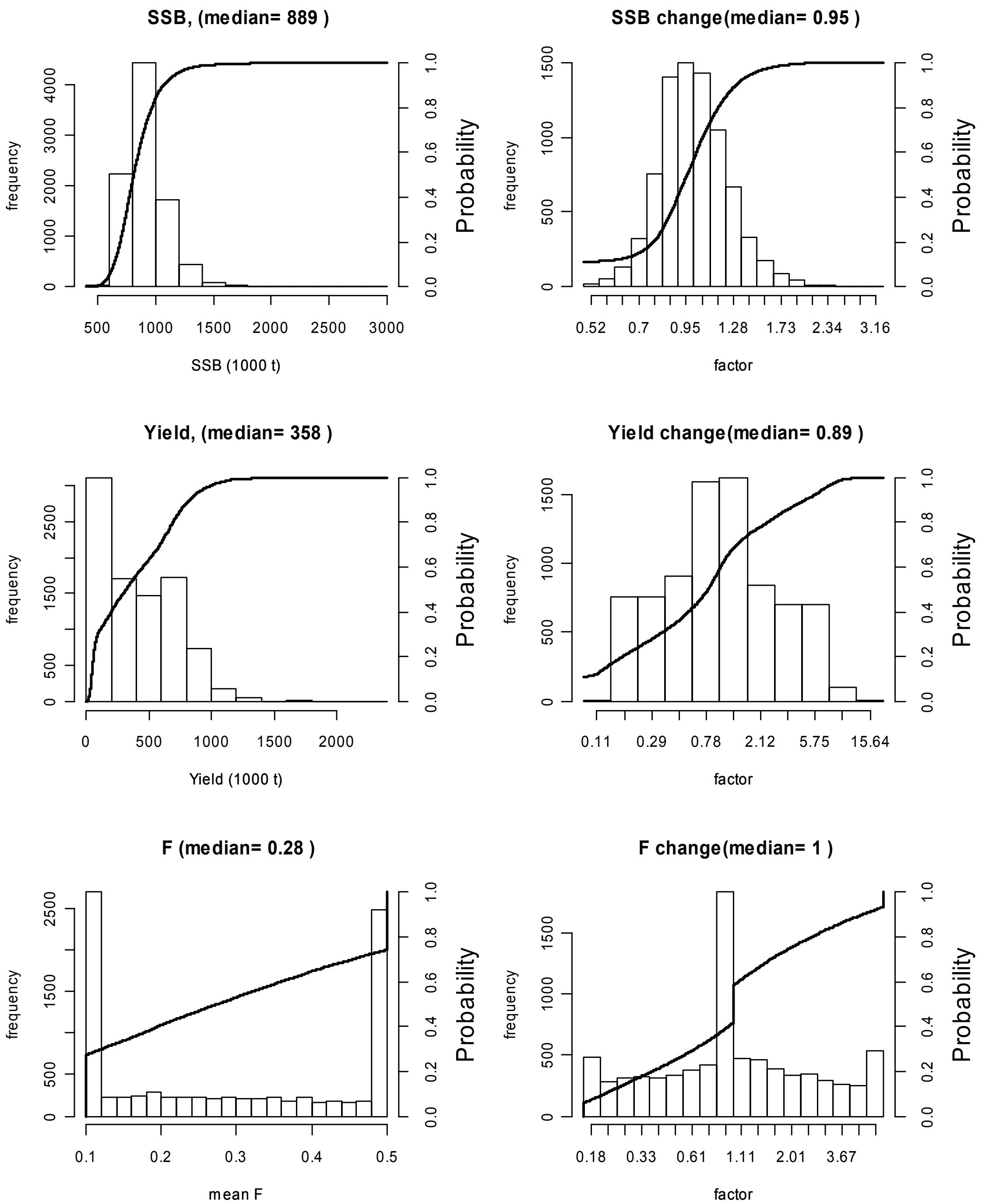

Figure 2.3.4.18 Distribution of metrics at equilibrium for scenario I. Target SSB=900000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%..

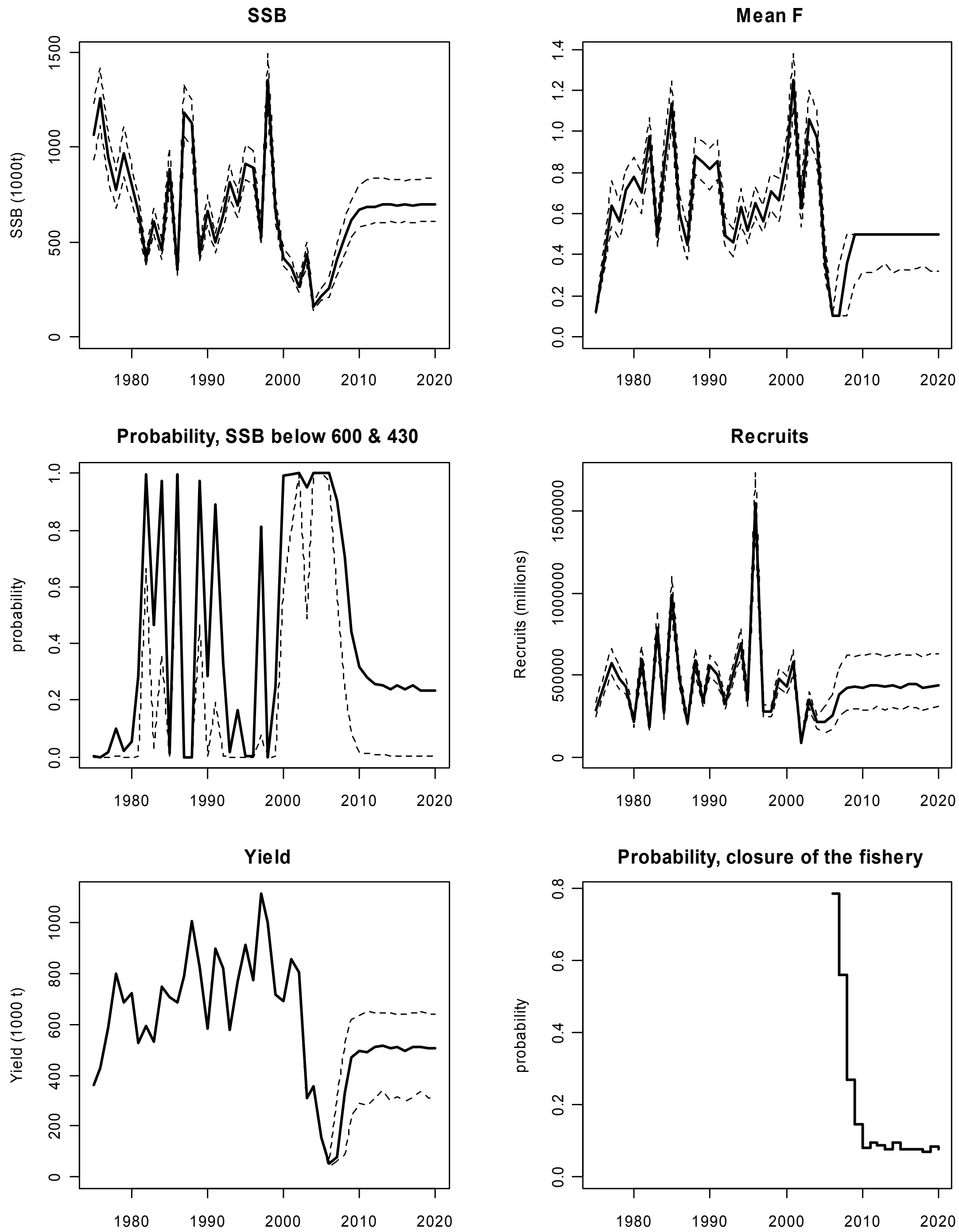

Figure 2.3.4.19 Time series for Scenario J. Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. MCMC posterior distribution. The graphs show the median value and 25 and 75 percentiles, except for the probability plot of SSB being below 430 000 and 600 000 tonnes.

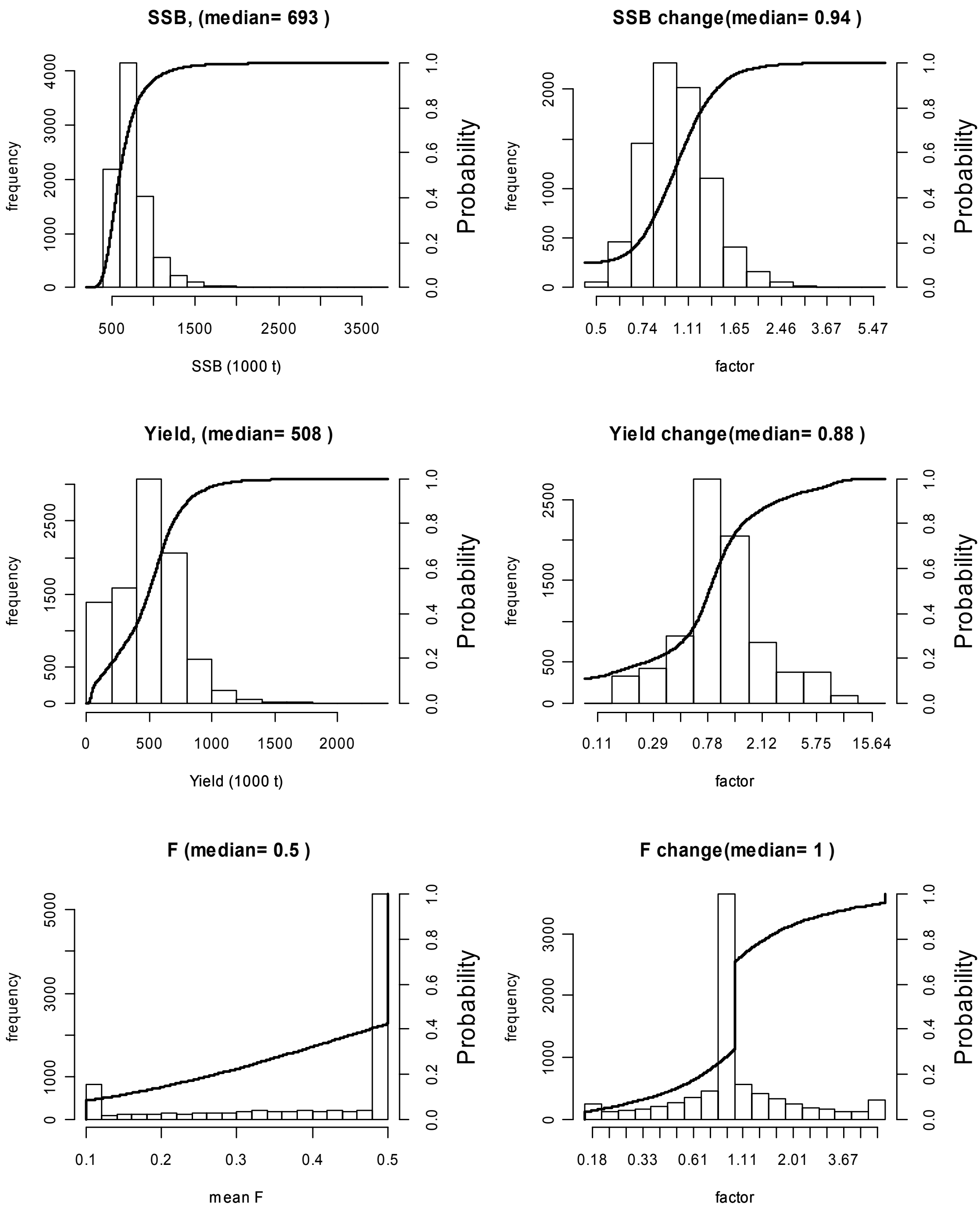

Figure 2.3.4.20 Distribution of metrics at equilibrium for Scenario J. Target SSB=600000, overall maximum F =0.5, N at age 1 observed with a std at 0.35 (log-normal distribution), N for age 2 and older observed with a CV at 25%. MCMC posterior distribution.

	Prob. SSB< Blim		Prob. SSB<Bpa		Yield			SSB
	2007	L.T.	2007	L.T.	25th q	median	75th q	median
A	**0.32**	0.00	0.86	0.23	331	511	636	694
B	**0.33**	0.01	0.87	0.32	296	529	700	655
C	**0.32**	0.00	0.85	0.13	366	465	559	768
D	**0.40**	0.03	0.91	0.45	313	554	709	615
E	**0.82**	**0.11**	0.99	0.75	68	85	237	534
F	**0.33**	0.01	0.87	0.42	144	342	502	621
G	**0.46**	**0.11**	0.94	0.68	246	393	489	538
H	**0.32**	0.00	0.86	0.20	374	533	650	706
I	**0.28**	0.00	0.76	0.00	136	359	650	889
J	**0.57**	0.00	0.90	0.24	315	509	644	694
Current, Fcap=0.5, TAC=660960	**0.44**	0.00	0.92	0.10	177	497	659	791
Current, Fcap=1.0, TAC=660960	**0.50**	0.03	0.93	0.19	166	508	661	767
Current, Fcap=0.5, TAC=826200	**0.44**	0.00	0.92	0.11	160	487	641	776
Current, Fcap=1.0, TAC=826200	**0.52**	**0.11**	0.94	0.37	135	458	826	666
Fixed TAC=300kt, Fcap=0.5	**0.75**	0.04	0.92	0.10	300	300	300	1088
Fixed TAC=225kt, Fcap=1.0	**0.65**	0.03	0.87	0.05	225	225	225	1272

Table 2.2 Summary results for the SSB target scenarios and the Commission's current HCR. For explanation regarding the scenario settings see section 2.2.4. Values for the probability of being below B_{lim} greater than 5% of the time are in bold

6.4 Conclusions.

All of the HCRs evaluated by the group give a high probability of SSB in 2007 being less than B_{pa}, even with a minimal F of 0.1 as inflicted by the monitoring fishery. This is different to the conclusion reached by ICES who, using a short term deterministic forecast with 25^{th} percentile recruitment, suggested that an F of 0.2 would permit the stock to be over B_{pa} in 2007. The difference between these results are due to the model used, SMS being more pessimistic regarding the current stock status than the seasonal XSA adopted by WGNSSK. . The initial very low SSB will produce fewer recruits following the SSB/R relationship than the 25^{th} percentile of the historical recruitment.

Management of the sandeel stock with a fixed TAC implies a greatly reduced mean yield if the management plan of being above B_{lim} 95% of the time is to be achieved when compared to alternative HCRs. This would give a low but stable input to the processing plants, but in plentiful years this would imply the season being very short indeed.

Under the scenarios of low recruitment (e-h), the probability of maintaining the stock above B_{lim} with 95% probability is not achievable with a 50% reduction in recruitment unless the precautionary reference points are changed. This is because the monitoring fishery, operating with an assumed F of 0.1 exceeds the optimal fishing rate. With a minor reduction in recruitment, the HCR seems to work properly with respect to having a SSB above the defined limit. The performance of the HCR is insensitive to the level of negative autocorrelation applied.

The value of Fcap assumed alters the perception of HCR performance, lower values of Fcap implying a more stable fishery and a minor reduction in yield For the range of applied Fcap, 0.4-0.6, the HCR manage to keep the SSB above Blim with more than 95% probability.

The use of a target SSB as a basis for an HCR gives a better chance of being above B_{lim} in 2007 compared to the current HCR .In the long run the target SSB HCR produces a slightly higher and more stable yield although the degree to which this holds is dependent upon the value assumed for Fcap.

In the long term it would appear that using the target SSB rule, the fleet would be fishing at capacity more often than under the current HCR which results in frequent fishery closures. Implementing the target SSB HCR follows the ICES advice of "the fishery should remain closed until information is available which assures that the stock can be rebuilt to Bpa by 2007"

Long-term yields are maximised when the target SSB based HCR is implemented under the assumption of Fcap = 0.6. Fcap is, however, a theoretical construct and may be violated by a fishery on a shoaling species. Where individuals are distributed randomly, then as the population becomes more scarce so the effort required to locate them becomes greater. Sandeels, on the other hand, are shoaling fish with highly specific habitat requirements, hence the fishery is able to target them with a high degree of accuracy. Any fishery operating in the next few years will, with the reduced capacity of the fleet, elucidate whether the concept of Fcap is valid for this fishery.

7 Linkage between stock numbers, fishing mortality and effort.

Management of a fishery through effort regulation assumes a direct linkage between F and effort. The relationship between fishing mortality (F), stock numbers (N) and total international standardised fishing effort (E) was explored by plotting these three measures against each other (Figure 3.1) using values from the final ICES assessment.

There was no relationship between F and E, for either age-1 or age-2 sandeels (Figure 3.1 a and b). Further, there was no relationship between N and E for either age-1 or age-2 sandeels (Figure 3.1 e and f). There was a indication (not statistically significant) for a positive relationship between F and N of age-1 sandeels (Figure 3.1 c and d) although the values for 1986 and 1997 are obvious outliers. The small F for age-1 sandeels in these two years may be explained by that age-1 sandeels in 1986 and 1997 come from the two largest year-classes (the 1985 and 1996 year-class respectively) in the time series 1983-2004, and suggests that supply of sandeel exceeded the capacity of the industrial fleet and/or the capacity of the fish meal factories reached an upper limit in 1986 and 1997 respectively.

The poor relationship between F and E implies that the management of North Sea sandeels by effort regulation alone would carry a significant risk of overexploitation, as a predefined level of E may result in a wide range of F's. During periods of low recruitment and hence stock size, there is a risk that the potential fishing capacity may be too high for the stock size. It should be noted however that there has been a substantial reduction in the fleet capacity in the last couple of years due to decommissioning and insolvency.

The poor relationship between E and N, and no tendency towards increasing effort in the North Sea sandeel fishery through the time period 1983 to 2005 (see ICES 2006), indicate that other factors than the sandeel stock size determine the effort used in the sandeel fishery. These factors could for example be fishing opportunities in other fisheries and variation in the economical conditions of the fishery, e.g. fuel and sandeel prices.

The tendency towards increasing F for increasing N of age-1 sandeels suggests that the selection pattern of sandeels in the targeted sandeel fishery varies with the abundance of the different age-classes of sandeels. The same tendency of increasing F for increasing N, that is seen for age-1 sandeels, is also indicated for age-2 sandeels, although not as strong as for age-1 sandeels. This may result for several reasons. One interpretation of this may be that the fishing mortality declines with a declining stock and that the suggested Fcap used in the simulations seems reasonable, especially after the reduction of the fleet capacity in the most recent years. Alternatively it may demonstrate that the fishermen target the areas with the highest abundances of sandeels.

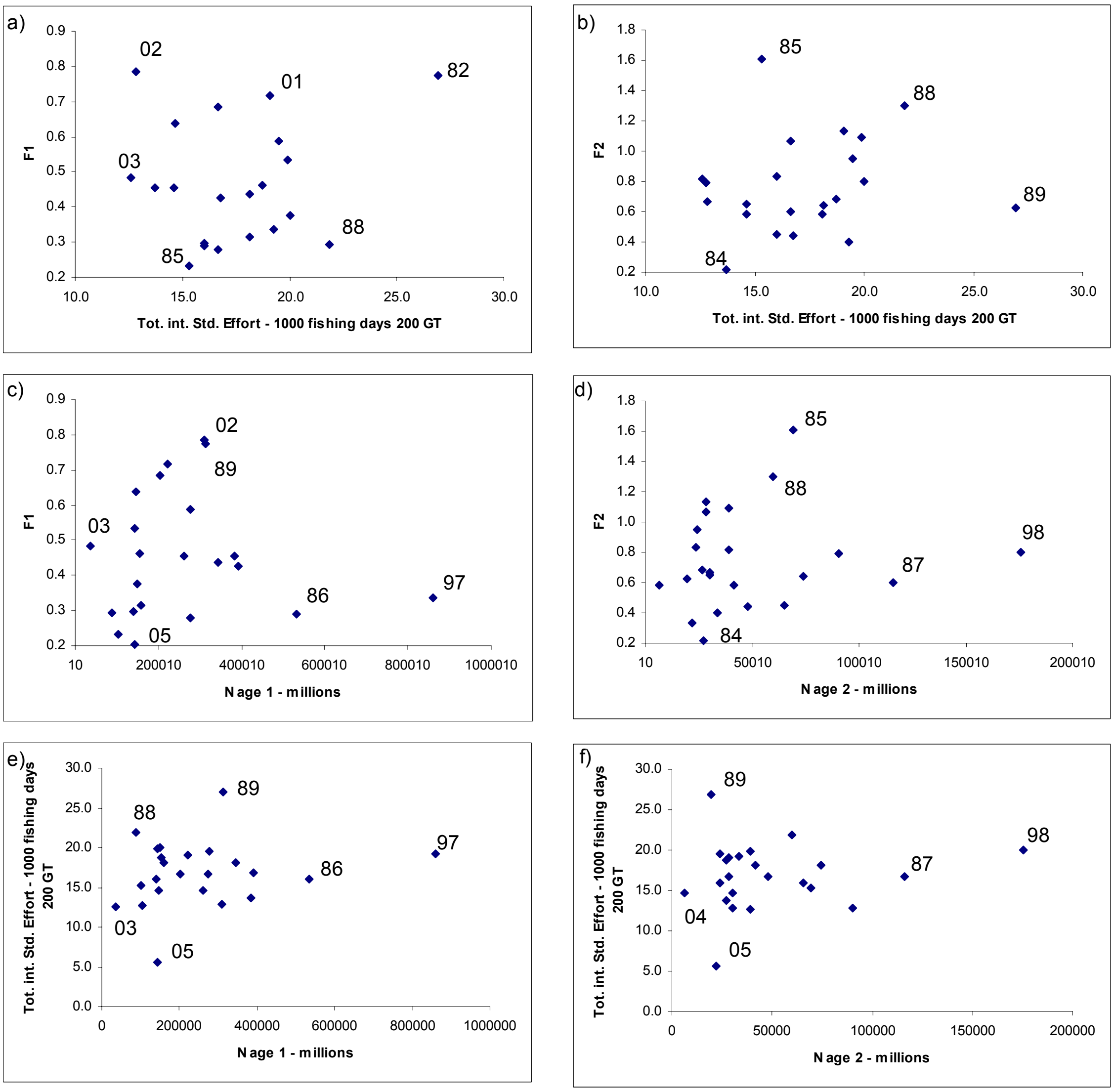

Figure 3.1 Plots of the relationship between fishing mortality, stock numbers and effort.

a & b: Fishing mortality of age 1 and age 2 sandeels plotted against total international standardised effort.

c & d: Fishing mortality of age 1 and 2 sandeels plotted against stock numbers of age 1 and 2 sandeels 1st of January.

e & f: Total international standardised effort plotted against stock numbers of age 1 and 2 sandeels 1st of January. Outliers are labelled with year. Estimates of fishing mortality, stock numbers and effort were taken from to final ICES assessment of sandeels in sub-area IV in 2005 (ICES 2006).

8 Monitoring Fishery Effort

As there is no routine survey undertaken which samples sandeels adequately for the determination of the size of the 1-group, a monitoring fishery is required during the first part of the year. The Commission has requested that STECF evaluates what is the minimum level of effort required for such an undertaking and how it might be undertaken such that local aggregations of sandeels are not fished with too much pressure during this period.

Variation in number of 1-group sandeels per kg sample is the most influential uncertainty going into the calculation of CPUE in numbers of 1-group sandeel per day absent, and the precision of the year-class estimation at a given week will largely depend on the number of samples attained until that week, except for unusual years with a very low proportion of 1-group sandeels. Based on bootstrap analysis of variation in number of age 1 sandeels per kg sample, made at by the Ad hoc Working group on Sandeel Fisheries (STECF, 2004a) it was estimated that a total of 100 samples until week 17 is sufficient to estimate the age group 1 abundance. A sampling period from week 12 until week 17 with an average of 20 samples per week appears to be necessary to stabilise CV of CPUE at a low level and thus produce an abundance estimate of group-1 sandeels with an acceptable precision.

To achieve the target of 20 biological samples per week between weeks 12 and 17, a minimum of 100 successful fishing trips (with a catch of sandeels) will have to be carried out within this period. In 2004 192 fishing trips were carried out from week 12 to 17. In 2005 the number of fishing trips were 41, due to a late start of the fishery and poor catch rates. Thus, limiting the monitoring fishery to 100 trips would have about halved the effort in 2004, whereas this would not have had any effect in 2005.

The total catch of sandeels from such a limited monitoring fishery will of course depend on the abundance of sandeels. A calculation of the expected yield in a monitoring fishery limited to 20 trips in each of the weeks 12 to 17 have been carried out. In this calculation the estimated standardised (to a 200 GT vessel) catch per fishing trip for 2004 (STECF 2004b) and 2005 (STECF 2005) were used, i.e. assuming the same low abundance levels of sandeels as seen in 2004 and 2005. This calculation predicts the yield to between 5000 (2005 conditions) and 13000 tons (2004 conditions).

Provided that the fishing trips were well distributed amongst the traditional fishing grounds, a monitoring programme limited to 100 fishing trips would achieve the minimum number of biological samples required for estimation of CPUE of 1-group sandeels.

It is however unclear if the precession of the estimate of the stock size of 1-goup sandeels would be acceptable if the fishing effort is reduced to less than 100 fishing trips, as this was not included in the simulation. To determine this, a more thorough simulation of the consequence of reducing the fishing effort to such a low level is required. The focus of such a simulation should be to determine the minimum effort level in a limited monitoring fishery that would produce estimates of sandeel abundance with an acceptable high precession. The results of the in year monitoring in 2005 indicate, that a much reduced fishing effort in a monitoring fishery will lead to a much higher uncertainty in the sandeel abundance estimates. An effort level higher than that seen in 2005 is probably required to attain population estimates with a sufficiently high precision.

The sandeel fishery is highly seasonal with the spatial distribution of fishing effort changing markedly through the season, responding to changes in the availability of sandeels to the fishery. At the start and end of the season the fishery traditionally targets grounds relatively close to the Danish coast whereas grounds in the western and central part of the North Sea tend to dominate in the middle of the fishing season. It is also during this central part of the season when the largest catches are taken. As the season progresses, the increasing oil content of sandeels permits the fishery to exploit grounds more distant from Denmark (i.e. western/central north sea) whilst maintaining profitability. The fishing pattern is thus subject to both biological and economical constraints. A limited monitoring fishery must be based on this fact, i.e. it will not be possible to force the fishing fleet to areas or seasons which will lead to a cost-ineffective fishery without economic compensation to the vessels participating in such a programme. This is exemplified by the 2005 fishing season, when a unusual small fishing effort was due to a combination of poor sandeel abundance and high fuel prices.

Although the change in fishing pattern during the season ensures some spatial dispersal of the fishing effort it is still uncertain if this is sufficient to prevent local overexploitation of sandeel populations. Such an analysis has not been carried out due to a lack of information about the population dynamics of sandeels on a more local scale. The quantification of the indirect effect of the sandeel fishery on sandeel predators is hampered by the lack of information about the distribution, abundance and diet composition of sandeel predators at more localised scales. It is therefore not possible to quantify the local requirements of sandeel by sandeel predators.

There are, however, some studies which are exploring the local impacts of sandeel dynamics and the fishery upon predator populations, notably in the Firth of Forth and on the south west Dogger bank. These studies have yet to complete but the results are likely to provide information to managers regarding the local scale dynamics and requirements of sandeel dominated ecosystems.

Annex 1: Technical description of SMS projection, using Harvest Control Rules

SMS (**S**tochastic **M**ulti **S**pecies model; Lewy and Vinther, 2004) is an age-structured multi-species assessment model that includes biological interactions. However, the model can be used with one species only. In "single species mode" the model can be fitted to observations of catch-at-age, survey CPUE at age, and SSB and recruitment. SMS uses the maximum likelihood technique to weight the various data sources assuming a log-normal error distribution for all data sources.

SMS is a "traditional" forward running assessment model using annual or shorter (e.g. half year or quarterly) time steps. The expected catch is calculated from the catch equation and *F*-at-age, which is assumed to be separable into an age selection, and a season and year effect. For annual time steps, the season effect is set to a constant of one.

$$F = F_1(age) \times F_2(year) \times F_3(age, season)$$

The estimated model parameters include stock numbers the first year, recruitment in the remaining years, age selection pattern, and the year and season effect for the separable *F* model, catchability at age for CPUE time series and parameters for a stock recruitment relation.

When SMS is used as a forecast program, the stock is projected forward in time using the maximum likelihood estimate of the model parameters and the population in the terminal year as initial stock size. The season and age effects from the F-model are kept constant and a year factor is derived dynamically from a Harvest Control Rule. Recruits are produced from the stock/recruitment relation and the estimated parameters. For a stochastic projection, the number of recruits calculated is altered by a factor drawn from a truncated normal distribution with a known standard deviation. By making a high numbers of projection, mean and variance of future stock numbers, SSB yield etc. can be calculated. Alternatively, mean and variance can be estimate using Markov Chain Monte Carlo simulations (Gilks et al. 1996), MCMC, to get the posterior distributions of the parameters. For each set of parameters, the initial stock size is estimated and projected forward in time using the set of parameters. Noise on recruitment is produces as for the method using the maximum likelihood estimate as starting value.

SMS is implemented using the Ad-model builder **(**Otter Research Ltd.), which is a software package to develop non-linear statistical models. Presentation of results are made using R-scripts.

The approach taken in this implementations of HCR is based on the framework for evaluation of management strategies as described by ICES study group on management strategies (ICES 2005/ACFM:09) and used for a range of stocks, e.g. presented in the report of the ICES *ad hoc* group on long term advice (ICES 2005/ACFM:25). The HCR evaluation program, STPR3 (Skagen, 2005), has been widely used for these evaluations and the SMS implementation of HCR is also inspired by the STPR3 approach.

Estimation of historic stock size and model parameters

The estimation of the model parameters for the historical assessment and initial stock size for the projection is done by a SMS assessment run (see e.g. an SMS assessment of sandeel in ICES 2006/ACFM:09). Assessment is normally done in the year following the last year included in the assessment. This means that the forecast and estimation of e.g. TAC made during the assessment-working group is for the next physical year. Therefore, it is necessary to make assumption for the fishery in the present year, the socalled intermediate year. The implementation of the intermediate year is described further later in this annex.

Harvest Control Rules

The state of the stock is a prerequisite for application of harvest control rules, however the true stock size is not known. The ICES procedure is to make an assessment each year to get an estimate of the true stock. This estimate is projected then forward in time using a HCR such that the TAC can be calculated. The SMS approach does not simulate the full annual cycle of assessment and projection. Instead, it is assumed that the true stock size can be "observed" with some bias and noise and it is this "perceived" stock that makes the basis for the use of HCR. The true stock size is assumed know in the first projection year and is later updated annually by recruitment and catches derived from application of HCR on the "perceived" stock.

Uncertainties in assessment, real-time monitoring and implementation

The "observation" error applied to the real stock to get the perceived stock is defined from a bias factor and observation noise. The observation noise can be specified as random number from a normal distribution with a known coefficient of variation (CV), or as a random number from a lognormal distribution with known standard deviation (std)

Example: "observed" stock numbers at age (N_{obs}) are derived from the "true" stock numbers (N_{true}):

normal distributed noise: $N_{obs} = N_{true} * (bias + CV * NORM(0,1))$

or log normal noise: $N_{obs} = N_{true} * bias * e^{(std * NORM(0,1))}$

Where NORM(0,1) is a random number drawn from a normal distribution with mean 0 and variance 1.

The perceived stock numbers can be obtained from the real stock in two ways. The first method is to replicate the uncertainties in the assessment, e.g. by using the estimated CV on the terminal stock numbers from a stochastic assessment model to derive the perceive stock. Another error function can be used to mimic the uncertainties of the stock size derived from real-time monitoring.

A similar error function as specified above, can be applied to the implementation of the outcome of the HCR (e.g. a TAC), such that the realised value differs from the defined. Implementations errors are always calculated on the basis of the F multiplier used to raise the F status quo (Fsq) by season and age to forecast F. Example using log-normal distributed noise

$$F_{y,q,a} = Fmult_y * bias * e^{std*NORM(0,1)}\ Fsq_{q,a}$$

Stock recruitment relationship

The stock recruitment relationship and its variability are essential for the results of the simulations done. A range of relationships (Ricker, Beverton & Holt, Geometric mean, Hockey stick with known inflection point) can be fitted in the SMS assessment and subsequently used in the projections. As default the parameters for the relationship and the standard deviation of the historical fit is used, however alternative parameters can be read in as well.

For e.g. the Ricker relationship, the recruits (at age 0) are produced in the standard way assuming a log-normal error distribution:

$$R_y = \alpha * SSB_y * e^{-\beta * SSB} * e^{\varepsilon_y}$$

where alpha and beta are estimated parameters, and epsilon is as default equal to the NORM(0,1) function times the standard deviation (std) of the historical SSB-recruitment model fit.

It is possible to add an autoregressive term to the default “noise” function, such that epsilon in relies on epsilon in the preceding years:

$$\varepsilon_y = std * NORM(0,1) + \sum_i \rho_i * \varepsilon_{y-i}$$

where ρ_i is given as input. As an example: a value of –0.5 for ρ and i equal to one will simulate a negative autocorrelation in recruitment.

Random numbers drawn from the NORM(0,1) distribution will in rare cases be “extreme”, such that the resulting recruit number is far outside the historical observed range. This can be avoided by using a truncated version of the function, where extreme values are discarded and replaced by a new random number within a specified range. As an example, the range of used numbers can be specified as –2.0 to 1.5, which is equivalent to excluding the lowest 2.28% and the highest 6.68% of the numbers drawn from a standardised normal distribution.

Harvest Control Rules

HCR are implemented by two steps. First step, the basic HCR, gives the harvesting level based on the state of the stock and defined decision rules. In a second step it is possible to adjust the harvesting level further according to constrains in year-to-year variation in F or TAC, and an additional overall maximum F or TAC.

Constant F

A simple HCR is to apply a constant F irrespective of state of the stock. Input is the absolute F value or a factor to be used with F *status quo* (F in the last assessment year).

Constant TAC

When a constant TAC is applied the underlying forecast F is calculated from the TAC and the true stock size. This HCR should be combined with an overall maximum F to reflect that the fishery fleets will be limited by its capacity. A cap F will further more prevent that the TAC exceeds the stock biomass.

HCR based purely on stock assessment estimate

The basis for these HCRs is in most cases the stock size estimated from the traditional ICES assessment. This stock estimate is simulated from the true stock size and an assessment “observation” error function.

F based on SSB in beginning of the TAC year

When this option is applied, F cannot exceed an F estimated on the basis of SSB, at the start of the TAC year. This F value is set from trigger values of “observed” SSB (based on N_{obs}) and a linear relation between F and SSB. The slope in this relation can be set to zero for a constant F within a trigger range:

If SSB<T1 F=a1 + b1 * SSB

else if SSB>=T1 and SSB<T2   F=a2 + b2 * (SSB-T1)

else if SSB>=T2   F=a3 + b3 * (SSB-T2)

Trigger values T1 and T2 (e.g. B_{lim} and B_{pa}) and intercepts and slopes are given as input

TAC based on SSB in beginning of the TAC year

This rules is similar to the one defined above, however it gives the result as a TAC instead of an F.

F from target SSB in the beginning of the year after the TAC year

F is calculated so that the "observed" SSB in the year following the TAC year is above a target SSB. SSB in the year following the TAC year is calculated from N_{obs} and F in the TAC year implemented without errors. The "observed" recruits in the TAC year (which may contribute to the yield or SSB) are estimated as a point estimate from the observed SSB and the SSB-recruitment relationship.

Real-time monitoring HCR

The stock size in the beginning of the TAC year can be estimated from real-time monitoring of the fishery. This is simulated from N_{true} and a real-time "observation" error function. It is assumed that the stock estimate is obtained by applying a constant fishing mortality in the beginning of the TAC year. Three variants of real-time HCRs are implemented:

F from stock numbers, age 1, and trigger values.

F is calculated from the 1-group abundance and stock number trigger values (T1 and T2) similarly to basic HCR based on SSB triggers.

F from TSB and trigger values.

F is calculated from the real-time estimate of the whole population (TSB) and trigger values.

F from target SSB in the beginning of the year after the TAC year.

F is calculated such that SSB will reach a target SSB in the start of the year that follows the TAC year. The 1-group is estimated from N_{true} and real-time observation errors. Remaining year classes are estimated from N_{true} and assessment observation errors.

Constraints on year-to-year variations

The basic HCR gives F or TAC, which can be limited by constraints on the year-to-year variation in F, TAC or SSB. The results of applying these constraints may be influenced by the sequence, and they are implemented in the order 1) F, 2) TAC and 3) SSB.

Input for each variable is minimum and maximum change between years, e.g. for TAC:

TAC >min * last year's TAC   and   TAC < max * last year's TAC

SSB constraints are implemented on the basis of "observed" SSB.

HCR implemented as TAC or effort

Some of the HCRs result in a fishing mortality, which in management can be transformed into an effort regulation or into a TAC. If an effort-based regulation is chosen, the resulting catch is calculated from the HCR F and N_{true}. With a TAC based system, the HCR F is used with N_{obs} to give a TAC. From this TAC the true F is afterwards calculated on the basis of N_{true}.

Overall maximum TAC and F

The result of the HCR and constraints can be modified so that the TAC or F cannot exceed a user-defined maximum value. When a cap TAC is set, the true F is downscaled, if necessary, such that the TAC is reached. This calculation is done on the basis of N_{true}.

The maximum F is compared with the true F (the F applied to N_{true} to give the TAC). If this true F exceeds the maximum F, the true F is downscaled appropriately. A real cap F cannot be managed and is as such, not applicable directly in the real world. It can however be used if it assumed that a given fleet capacity will only be able impose a maximum F.

F in the intermediate year

There are three options for fishing mortality in the intermediate year:

a. No intermediate year: TAC can be calculated on the basis of an assessment for the preceding year and the intermediate year is not relevant

b. F in the intermediate year is calculated from F *status quo* and an input factor.

c. F in the intermediate year is calculated from a TAC.

a) no intermediate year.

Some fisheries are highly seasonally and stop before the end of the year, such that the assessment and the projection needed for setting the TAC for the next year can be done without an intermediate year.

The ICES assessment of e.g. sandeel in the North Sea is done using data and time steps by half-year and due to the timing of the WGNSSK the assessment includes only data from the first half-year of the last assessment year. The sandeel fishery in the second half-year is only a minor fraction of the total fishery. In such cases, it can be assumed that the fishing mortality for the second half of the year can be estimated from the separable F model used by SMS and the year effect estimated from the available data in the beginning of the last assessment year.

Example: the assessment includes only the first half-year in the last assessment year. F for the remaining period is estimated from $F_{y=\text{last year},\ q=\text{second half},\ a} = F_{y=\text{last year}} * F_{q=\text{second half}} * F_a$ assuming that F_q and F_a are known (constant) from the separable model. An input factor can modify the F in the not assessed part of the year F. This might be useful if the fishery has been closed before the usual time.

b) F in the intermediate year from F *status quo*

F in the intermediate year is calculated from F *status quo* and an input factor. N_{obs} in the start of the intermediate year is derived from N_{true} end the assessment "observation" error function. Recruitment in the intermediate year (and in the following TAC year) is estimated as a point estimate from the SSB/R relation and a SSB based on N_{obs}. F is applied to the N_{obs} without implementation errors, to get an updated N_{obs} in the start of the year after the intermediate year. This N_{obs} is later used as basis for the HCR calculation.

c) F in the intermediate year from a TAC

The TAC in the intermediate year is transformed into F on the basis on N_{obs} and the observed stock is projected forward as described above.

Overview. Steps involved in applying HCR

This section gives and overview of data manipulations done for each year of a projection. Figure 1 illustrates the steps taken.

1. Make an assessment and estimate the "true" stock numbers, N_{true} the 1st January in the year after the last assessment year.

2. Calculate "true recruits" from a SSB derived from N_{true} (1st January) and a stochastic SSB/R relationship.

3. Estimate observed stock number, N_{obs} the 1st January from N_{true} and an observation error function. An option determines whether the recruits can be "observed" or have to be estimated from a point estimate of the SSB/R relation, using the observed SSB.

4. If relevant, project the observed stock through the intermediate year. Use N_{obs} from step 3 and a point estimate of the recruit numbers in the intermediate year estimated from SSB derived from N_{obs} and the SSB/R relation

5. Calculate TAC (or F, effort etc.) from the basic HCR using N_{obs} derived from step 3 (or step 4 if an intermediate year is relevant)

6. Adjust the result from step 5 by optionally constraints on year-to year variations

7. If the management system is based on TACs, calculate the true F from the TAC estimated by the HCR and N_{true}. If the management system is based on effort regulation, use the HCR F as true F.

8. Calculate a new true F from the results of step 7 and an optional overall maximum F or TAC.

9. Add implementation errors to the true F and calculate the true catch numbers from this implemented F.

10. Project N_{true} one year forward using the true catches from step 9 and natural mortality. Start again from step 2 for a new year.

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ICES 2006/ACFM:09. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). ICES CM 2006/ACFM:09

Lewy, P. and Vinther, M., 2004. A Stochastic age-length-structured multispecies model applied to North Sea stocks. ICES CM 2004/FF:20

Skagen, D. 2005. Programs for stochastic prediction and management stimulation (STPR3 – s3s and LTEQ). Program description and instructions for use (available from the author dankert@imr.no)

Figure 1. Overview of data manipulations done by SMS-HCR. Numbers in circles refer to steps in the overview text.

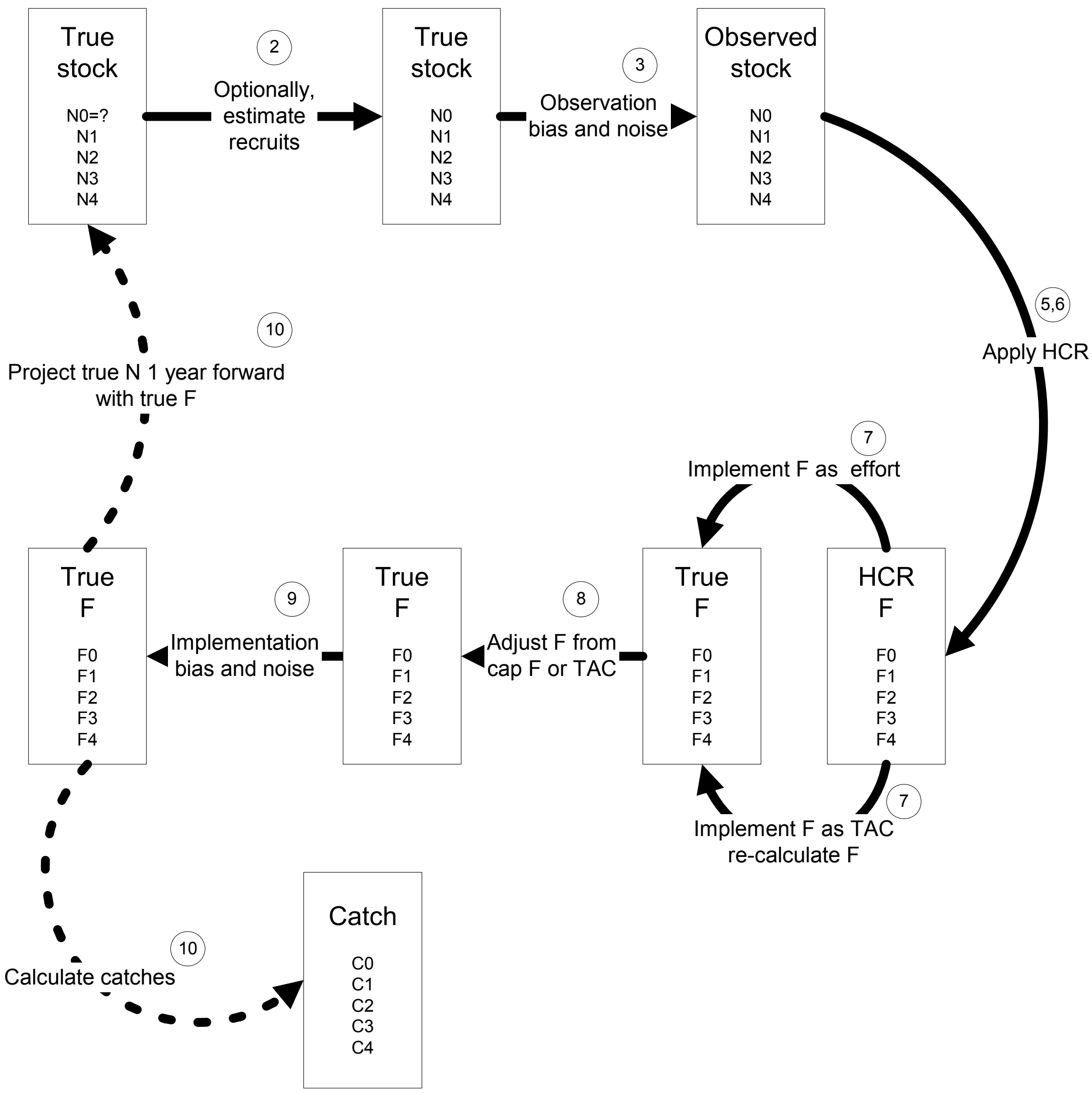

Table 1. Input file "HCR_options.dat"

The following present an annotated input file for the SMS-HCR program.

```
######################################################################
# option file for HCR
# text that follows the "#" character in a line is a comment and ignored by SMS
######################################################################
# 1. last year in prediction
2020
######################################################################
# 2. no. of repetitions.
# This is the number of times the projection is repeated
#    e.g. 1000 times when the maximum likelihood estimate of parameters is used
#    or 1 time for each MCMC set of parameters
1000
######################################################################
# 3-4. first and last year for calculation of mean weight in the sea
2001
2004
######################################################################
# 5-6. first and last year for calculation of mean weight in the catch
2001
2004
######################################################################
# 7. F-year adjustment factor  for "missing" seasons in the last assessment year
#  This option is relevant for a seasonal assessment where the terminal assessment year
#     does not include all seasons. The  stock is projected to the end of the year by using F
#    from the separable F-model (where the year, season and age effect are known) times this
#    factor for the missing seasons in the final year
  1.0
######################################################################
# 8-9. truncation of standardised normal distribution used to produce noise on recruitment
#  Lower and upper   values -10.0 and 10.0 give practically no truncation,
#     -2 and 2 give approximatly 95% of the distribution
 -10.0  10.0
######################################################################
# 10. Harvest control Rule
#          1=constant F
#          2= constant TAC
#         10=  F from trigger T1&T2 and SSB in the beginning of the TAC year
#         11=TAC from trigger T1&T2 and SSB in the beginning of the TAC year
#
#         15=  F from target SSB (targetSSB) in the beginning of the TAC year+1
#         16=TAC from target SSB (targetSSB) in the beginning of the TAC year+1
#
#         real time-monitoring
#         20=  F from trigger T1&T2 and N1 in the beginning of the TAC year
#         21=TAC from trigger T1&T2 and N1 in the beginning of the TAC year
#         22=  F from target SSB (option no. 22 ) in the beginning of the TAC year+1.
#                 SSB is derived from real time N (age 1) and assessment estimates for older ages
#         23=TAC from target SSB (option no. 22) in the beginning of the TAC year+1.
#                 SSB is derived from real time N (age 1) and assessment estimates for older ages
#         30=F from trigger T1&T2 and real-time estimate of TSB in the beginning of the TAC year
#         31=TAC from trigger T1&T2 and real-time estimate of TSB in the beginning of the TAC year
#
 22
######################################################################
#  11      T1. trigger 1 (SSB, TSB or stock N depending on HCR in use)
#  12      T2. trigger 1 (SSB,TSB  or stock N depending on HCR in use)
0  0
#  13-14.   a1 and b1: intercept and slope for regression to calc max F or TAC for observed values below T1.
#           e.g     F  =a1+b1 * SSB using HCR=10 and SSB in TAC year
0  0
#  15-16   a2 and b2: intercept and slope for regression to calc max F or TAC for observed values above T1 but
#   below T2.
#           e.g     F = a2+b2 *(SSB-T1) using HCR=10 and SSB in TAC year
0  0
#  17-18.   a3 and b3: intercept and slope for regression to calc max F or TAC for observed values above T2.
#          e.g     F  = a3+b3 *(SSB-T2) using HCR=10 and SSB in TAC year
0 0
```

```
########################################################################
# 19.     implement HCR-F as effort (option=0) or TAC (option=1)
# The F that is derived from the HCR can be applied as a it stands (e.g. by an effort regulation) or as a TAC.
# With an F implemntation the percieved F is used as the real F to project the true stock and to produce the
# yield
# When the TAC option is chosen, the TAC calculated from the percieved stock and F is is transformed into a
# a  true F, and  the true F is later used in the projection of the stock
1
########################################################################
# 20.    constant F
# For use with HCR option 1.  A value >0 gives absolute F,
#  a value<0 gives fraction of F status quo, e.g opiton=-0.5 gives F=0.5*Fsq
0
########################################################################
# 21.    constant TAC
# For use with HCR option 2.
0
########################################################################
# 22.    target SSB
# For use with HCR option 22 and 23
0
########################################################################
#  23.    mean F to obtain real time estimate
# For use with HCR based on real-time monitoring (HCR options 20-31)
0.1
########################################################################
#  24.    max true TAC irrespective of HCR and other constraints (0 is no max TAC)
0
########################################################################
#  25.    Maximum true F irrespective of HCR and other constraints (0 is no maximum F)
0
########################################################################
#  26-27. F constraints. Min and max variation in F between years
# F >min * last year's F   and     TAC < max * last year's F
# 0  is no constrains
0  5
########################################################################
#  28-29. TAC constraints. Min and max variation in YIELD between years
# TAC >min * last year's TAC   and     TAC < max * last year's TAC
# 0 is no constrains
0  5
########################################################################
#  30-31. SSB constraints. Min and max variation in SSB between years
# SSB >min * last year's SSB   and     SSB < max * last year's SSB
# 0 is no constrains
0.5  5
########################################################################
#  32-33. lower and upper value for truncation of standardised normal distribution used to produce noise on
# assessment and real-time observations, and implementation noise
#    values -10.0 and 10.0 give practically no truncation, -2 and 2 give approximatly 95% of the distribution
-2 2
########################################################################
#  34-36  real time monitoring observation uncertanties –
#  distribution model (-1=no uncertanties, 0=normal, 1=log normal distribution)
#  bias factor
#  standard deviation for log-normal dist, or CV for normal distributed error
1 1 0.35
########################################################################
#  37-39.  assessment observation uncertanties (on stock numbers at age) - model, mean and standard deviation
#  distribution model (-1=no uncertanties, 0=normal, 1=log normal distribution)
#  bias factor
#  standard deviation for log-normal dist, or CV for normal distributed error
0 1.1 0.25
########################################################################
#  39-41.  Implementation uncertanties on F at age
#  distribution model (-1=no uncertanties, 0=normal, 1=log normal distribution)
#  bias factor
# standard deviation for log-normal dist, or CV for normal distributed error
0 1 0.05
########################################################################
#  42.     TAC in the year after last assessment year
#  When an intermediate year is used, the F in that year is derived from a TAC
```

```
660900
#######################################################################
#  43.     Factor to change F status quo in the intermidiate year
# When an intermediate year is used, F in the can be derived from F staus quo by an input factor
1.0
#######################################################################
#  44.     F in intermidiate year
#    0=not relevant, no intermidiate year. Option no. 42 and 43 are ignored
#    1=use F status quo, (option no. 43)
#    2= calculate F from current TAC (option no. 42)
0
#######################################################################
#  45.      no. of years in recruitment noise atocorrelation
1
#  46.      autocorrelation term(s) used by year
-0.4
#######################################################################
#  47.     read SSB recruitment parameters, and initial stock numbers from file SSB_R.in
#  0=no use estimated parameters
# 1=yes, read in new parameters
0
#######################################################################
```