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Report of the Ad Hoc Group on Real Time Management and Harvest Control Rules for Norway Pout in the North Sea and Skagerrak (AGNOP)

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Contents

1 Executive summary

Harvest Control Rule Evaluations of Norway pout based on EU Request:

On basis of an request from the EU Commission to ICES harvest control rules for Norway pout in the North Sea and Skagerrak have been evaluated during the ICES WKNOP Meeting in the ICES Headquarters, Copenhagen, 1-2 March in order to i) allow the Maximum Sustainable Yields (MSY) to be obtained and are consistent with the precautionary approach, and ii) to take into account the function of Norway pout in the ecosystem. The request included that in the evaluation it may be expected that the management of the Norway pout fishery will include the setting of preliminary catch and/or fishing effort limits at the beginning of the year until scientific information is available in spring allowing for the final maximum fishing effort and/or catch levels to be fixed. The harvest rules should therefore include rules for setting preliminary and final fishing effort levels (expressed as a percentage of the reference level in kW-days) and/or catch levels. Furthermore, the monitoring systems and assessment methodologies required to implement the advised harvest control rules should be adviced..

Methods used in the management strategy evaluations and simulations:

The methods and model used in the management strategy evaluations is based on the SMS (**S**tochastic **M**ulti **S**pecies model) described in Lewy and Vinther (2004). Basically the method mimics that decisions on e.g. TAC are taken on the basis of imperfect knowledge (equivalent to stock numbers estimated from stock assessment or survey index). The 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 and estimation of a TAC. The true stock size is assumed known in the first projection year and is later updated annually by recruitment and true catches derived from application of HCR on the “perceived” stock.

Further methodological description of the SMS projections, using Harvest Control Rules is given in section 4 and 5 of this report.

Information used in the simulations:

The Input data used in the SMS simulations of management strategies for Norway pout are taken from the most recent full SXSA stock assessment accepted by ICES ACFM in autumn 2006.

Harvest Control Rule scenarios evaluated through simulations:

The simulations performed suggest a cycle with two annual decisions, in March-April and November-December, and two management periods, e.g. first and second half year. Two options are then possible:

1) A preliminary TAC (valid for the whole year) is set at one of the decision times, and a final TAC is set the second decision time.

2) A TAC for the next time period is set at each occasion.

The difference is that preliminary TAC set e.g. late in the year will apply for the whole next year. An unknown fraction of it will be taken in the first period. Then, a new TAC will be set for the second half year. The timing of the fishery matters for this stock, both because of its rapid growth and high mortality, and because the selection at age seems to vary between quarters. With the second alternative, the seasonal distribution of the fishery is decided directly. The TAC for the first half of the year will necessarily have to be conservative, because the information, in particular on the incoming year class, is sparse at that time.

The second alternative is assumed. In the simulations, fishing mortalities assumed for each quarter are the historical quarterly fishing mortalities, scaled by the same factor to obtain the required annual fishing mortality.

Scenarios were made to illustrate pros and cons with different management objectives:

1) An escapement strategy, aiming at maintaining an SSB at a target level which would imply a low risk to Blim. With the rapid turnover in the stock, this is likely to produce a near maximum long term average yield.
2) A fixed F strategy (MSY from constant F): Under the condition, fishing mortality is assumed proportional to effort. This is in principle equivalent to a constant effort management. Previous simulations have indicated that a rather low fixed F is needed to ensure a low risk of SSB falling below Blim.
3) Stabilising catches. For this short lived species with highly variable recruitment, stabilising catches is likely to imply a substantial loss in long term yield compared to other strategies, if the risk to Blim shall be acceptable.

Sensitivity tests performed in relation to the management strategy evaluations:

In relation to the escapement strategy sensitivity tests in relation to the base case run were performed with respect to variation in the conditions by changing those parameters stated in the following list:

The escapement strategy outlined in section 5 is sensitive to several assumptions:

4) Cap F, the maximum F the fleet can exert for with a given effort level;
5) Uncertainties in the stock assessment result;
6) The rules to derive the TAC for the fist half-year;
7) Changes in recruitment level;
8) And probably several other factors

Conclusions from management strategy evaluations and simulations:

Escapement Strategy:

The target of obtaining a true SSB above Blim with a high probability appears to be obtained when realistic values of uncertainties in assessment and survey are applied. This conclusion depends on the use of a Cap F in the order of 0.8, such that the HCR in practice becomes an escapement strategy with an additional maximum effort HCR. The cap F applied is relatively high compared to the historical fishing pressure. The equilibrium median yield is around 110 kt. There is a 50% risk closure of the fishery in the first half-year and a 20-25% risk of closure in the second half-year. The effect of allowing a higher proportion of the annual TAC in the first half-year is limited, even though it was not possible to fully-simulate the effect. The robustness of the HCR to uncertainties on stock-size (*i.e.* assessment) indicates that annual assessment might not be necessary for this species; the annual survey index might be sufficient.

The robustness to uncertainties might seem optimistic. There are, however, three important characteristics for this stock, that contribute to this robustness:

1) a very high natural mortality (M=1.6);
2) an early sexual maturation with 10% of age 1 mature and 100% mature for age 2 and older (which probably vary indicated from preliminary scientific investigation of maturity levels within the Norway pout stock (Larsen *et al*., 2001);
3) an exploitation pattern with almost no fishing mortality on the 0-group, and a much lower relative F at age 1 compared to F at the older ages. Mean F is defined

as the average of F for age 1 and 2, such that a mean F at 1.0 give a F at age 1=0.53 and F at age 2=1.46.

Due to the very high natural mortality and early maturation (as used in the SXSA assessment), most of the SSB will consist of age 1 and 2. With no fishing, 73% of SSB will come from age 1 (11%) and age 2 (62%). With mean F=1, 94% comes from the same ages (23% and 71% from age 1 and 2). This means that the outcome of an “escapement strategy approach” (the SSB after fishing) is mainly driven by F at age 1, as the 1-group will contribute most to SSB at their “two-years birthday” January 1st. In addition, the exploitation level of the 0-group is very low such that the SSB contribution from the 0-group (1-group January 1st) is practically independent of fishing.

As F of the 1-group is just half of the mean F value the scenarios seems more robust to uncertainties than normally seen for other species. The cap F (0.8) used as default becomes actually just around 0.4 for the 1.group which is just 25% of the natural mortality.

Overall the harvest of this stock is very dependent on recruitment levels.

Effort control strategy:

A scenario with fixed effort is rather robust to implementation uncertainties. The implementation of the approach will require a target F below 0.35, which will produce a long term yield at around 85 kt. The method is independent of an assessment, and will as such not require an annual assessment. A regime shift towards a lower recruitment level will not be detected by this approach and there is a severe risk of overfishing in such a situation with a fixed effort approach. However, the historical development in the fleet effort shows clearly a decreasing effort with decreasing stock, indicating some degree of self-regulating effort.

TAC stabilising strategy:

It was not possible fully to simulate the two-step TAC setting with additional TAC constraints. Instead the fishery was closed permanently in the first half-year and the TAC was estimated in a similar manner as for the escapement strategy1 With a scenario with a 50% inter-annual constraint (*i.e.* the TAC can vary within the 50-150% range of the previous year’s TAC) it takes longer before the equilibrium F is reached, due to the constraints and low SSB in the start of the period. The probability of F reaching cap F is small. A very constrained TAC (±10%) gives a much lower long-term yield and a much higher risk of SSB<Blim compared to the unconstrained scenario. The constraints must allow at least a ±50% variation in TAC to keep the risk of SSB<Blim smaller than 5%.

General:

The probability of below-average recruitment appears to have increased in recent years; however, the long term recruitment level is used as default in the scenarios. Given the assumed recruitment model is reduced to give only 70% of the historical recruitments, the probability of observing a SSB below Blim is greater than 5% in a system without any fishing activety. If, however, fishing is allowed and F is derived from the escapement strategy, the probability of SSB<Blim is higher than 5% for recruitment factors lower than 0.75. This small difference indicates that an unconditional closure of the fishery will have limited effect on maintaining SSB higher than Blim (*i.e.* 90 kt).

It should be noted that the simulations deals with observation error and implementation error of the management strategies, but does, however, not take into account process error in relation to especially variation in natural mortality, maturity at age, and mean weight at age in the stock which probably has a significant impact.

Whether to do a full assessment each time or not depends on how precise the surveys are and how consistent they are and whether new catch information exist or not. The fact that there is some mis-match between the information of the incoming year class in the Q3 survey and in the subsequent Q1 survey (R^2=0.59) indicate that at least for the decision in March, a full assessment may be necessary. However, simulations under the escapement strategy (base case) indicated that the robustness of the system to assessment uncertainties, due to the application of a modest cap-F, that an annual assessment is not strictly needed and might be replaced by a survey index evaluation. The IBTS Q1-index for the 1-group estimates the stock with a standard deviation of 0.48 which might be within the acceptable range (*i.e*. gives a probability less than 5% of having the SSB below Blim).

Overall it is suggested that an escapement strategy is used as harvest control rule for Norway pout where:

A TAC is set for Q1 and Q2. The TAC for Q1-2 is set based on the 3rd quarter IBTS survey result for the age 0 as:

If $I_{0\_q3} > C$, then

$TAC_{Q1\text{-}2} = A * I_{0\_q3}/\text{Average } I_{0\_q3}$, but not greater than B.

else

$TAC_{Q1\text{-}2} = 0$

Here I_{0_q3} is the index of age 0 in the 3rd quarter IBTS survey, and A, B and C are parameters for the rule. Conservative values for parameters were chosen as default. There will be no fishing for recruitment lower than the long term (geometric) mean, and a maximum TAC of 50 kt will be set for a recruitment 3 times higher than the long term GM recruitment.

For quarters 3-4, a TAC is set based on a full assessment in April-May (or a second survey information evaluation), including the results from the 1st quarter IBTS for the present year. The TAC is set so that the SSB at the start of next year is estimated at a target spawning biomass (i.e. the traditional used B_{pa}) – the escapement strategy.

2 Introduction and Terms of Reference

2.1 Introduction and TOR (Terms of Reference)

In 2006 the EC Commission and Norway requested ICES for advice on the management of Norway pout.

The request to ICES concerning Norway pout was as follows:

> *Harvest control rules for Norway pout in the North Sea and Skagerrak that:*
>
> *Allow the Maximum Sustainable Yields to be obtained and are consistent with the precautionary approach; and*
>
> *Take into account the function of Norway pout in the ecosystem*
>
> *It may be expected that the management of the Norway pout fishery will include the setting of preliminary catch and/or fishing effort limits at the beginning of the year until scientific information is available in spring allowing for the final maximum fishing effort and/or catch levels to be fixed. The harvest rules should therefore include rules for setting preliminary and final fishing effort levels (expressed as a percentage of the reference level in kW-days) and/or catch levels.*
>
> *The monitoring systems and assessment methodologies required to implement the advised harvest control rules.*
>
> *Level of by-catches in Norway pout fisheries separated for Division IIIa and Sub-area IV; and*
>
> *Appropriate technical measures, including possible closed areas, to reduce by-catches, in particular, of cod, haddock, saithe, whiting and herring.*

Part of the request was responded to by ICES in the autumn of 2006, but further analysis was required in addition to availability of key experts to be able to respond to parts of the request. This response was postponed until 2007.

With the purpose of dealing with the remaining of the request and to establish harvest control rules and a real time monitoring system for Norway pout in the North Sea and Skagerrak a special group, chaired by Rasmus Nielsen DIFRES, is scheduled to meet at ICES Headquarters 1–2 March 2007 with the following Terms of References:

- a) Advice on harvest control rules for Norway pout in the North Sea and Skagerrak
    - i) It may be expected that the management of the Norway pout fishery will include the setting of preliminary catch and/or fishing effort limits at the beginning of the year until scientific information is available in spring allowing for the final maximum fishing effort and/or catch levels to be fixed. The harvest rules should therefore include rules for setting preliminary and final fishing effort levels (expressed as a percentage of the reference level in kW-days) and/or catch levels.
    - ii) On basis of the harvest control rule for Norway pout adviced by ACFM in autumn 2006 simulations of precision in the assessment and forecast should be made according to scenarios for real time monitoring and management of the stock.
- b) Advice on the monitoring systems and assessment methodologies required to implement the advised harvest control rules.

2.2 Participants

The following participants attended the meeting:

Are Salthaug	IMR, Bergen, Norway
Dankert Skagen	IMR, Bergen, Norway
J. Rasmus Nielsen,	DIFRES, Charlottenlund, Denmark (chair)
Mark Payne,	DIFRES, Charlottenlund, Denmark
Morten Vinther,	DIFRES, Charlottenlund, Denmark

3 Data sources and data availability

3.1 Input data in the SMS simulations of management strategies for Norway pout

Input data used in the SMS simulations are taken from the input data used in the most recent full SXSA stock assessment accepted by ICES ACFM in autumn 2006.

Initial stock size

The simulation start for data by the 1st of January 2006 derived from the SXSA assessment.

Exploitation pattern

The average exploitation pattern for 1991-2004 was used for the simulation:

	AGE 0	AGE 1	AGE 2	AGE 3	AGE 4
	0.000	0.052	0.211	0.269	0.269
Q2	0.000	0.043	.176	0.615	0.615
Q3	0.009	0.163	0.407	0.597	.597
Q4	0.038	0.277	0.668	0.507	0.507

Exploitation pattern, scaled to mean $F_{(1,2)} = 1$.

The exploitation pattern has a very small F-level at age 0, and a much lower relative F at age 1 compared to F at the older ages. Mean F is defined as the mean of F for age 1 and 2, such that a mean F at 1.0 give a F at age 1=0.53 and F at age 2=1.46.

Natural mortality, proportion mature

Similarly to the SXSA assessment for Norway pout an assumed constant quarterly M at 0.4 is used for all ages. Furthermore, 10% of the 1-goup and 100% of older ages are assumed mature and that the stock spawning is 1st of January.

Recruitment

Recruitment in this species is highly variable but has a significant impact on both the SSB and the total stock biomass (TSB) due to the short average lifespan of the individuals. A plot of SSB against recruitment is shown in Figure 3.1. No relationship between the SSB and recruitment for the Norway pout stock is apparent and the distribution of the data appears similar to white noise. The recruitment process is, thus, dominated by factors other than the size of the SSB but the identity of these contributions is currently unknown. The approach taken in the SMS simulations to deal with this large source of uncertainty is to treat the SSB – recruitment relationship using a "hockey-stick" relationship and a log-normal distributed error term. Blim was chosen as inflection point which gave a (geometric) mean recruitment of exp(18.06)=698E9 above this point. The standard deviation was estimated to 0.66 on the basis of the data points with SSB higher than the inflection point.

Figure 3.1 The relationship between the spawning stock biomass (SSB) and the number of recruits to the fishery for Norwegian Pout (from ACFM advice 2006).

3.2 Process error in the simulations in relation to input parameters from assessment

Many factors contribute to the uncertainty inherent in the Norway pout stock assessment. In relation to process error, which is not taken into account in the simulations, the variation in factors such as natural mortality (M at age and season), stock growth patterns (mean weight at age in stock), and spawning maturity (maturity ogive), are important. The population dynamics of the Norway pout stock are mainly driven by changes caused by variation in those factors compared to mortality due to fishing. The variation in those factors is difficult to characterise precisely but can have a significant impact on the quality of an assessment. Here is described some of the most significant contributions to uncertainty in the assessment of the Norway Pout stock in the North Sea and Skagerrak, which is not dealt with in the evaluations of HCR, i.e. in the simulations.

Natural mortality: A major source of variability in the stock dynamics is the rate of natural mortality (M). Norway Pout in the North Sea is an important food source for many other species, especially cod, whiting, saithe and haddock. The stock dynamics of the Norway pout is to a higher degree driven by the natural mortality compared to fishing mortality (Sparholt *et al*., 2002a,b). During the benchmark assessment of Norway pout in 2006 it was concluded that naturally mortality vary between age classes (year 2-3 individuals have a higher mortality than those of year 1), and between different periods (years). The mortality also varies within a year, with the greatest rate occurring between the first and second quarters. No new information on variability in natural mortality is available since the benchmark assessment, and thus natural mortality has simply been treated here as being constant for all year classes and times at the value of M= 0.4/ quarter in the simulations like in the SXSA assessment. Accordingly, this process error is neither dealt with in the simulations.

Spawning maturity: Maturity of the year classes is an important source of uncertainty in the estimation of SSB in the assessment. The short lifespan of the species means that the population is dominated by the 0, 1 and 2 year classes. In the assessment it is assumed that 10% of the individuals are sexually mature at age 1, and all individuals are mature at age 2, of both sexes. There is evidence of differences in maturation rates between sexes and between age-groups as well as between years (Larsen *et al.*,. 2000). Initial information indicate that maturity for age 1 for both sexes probably is higher than 10 %. However, as this topic has only been initially investigated and no new information compared to previous years assessments on this issue is available then we adopt the simple approach described above also used in the

SXSA assessment. Consequently, this process error will neither be considered in the simulations.

Mean weight at age in the stock: The same mean weight at age in the stock is used for all years. The reason for mean weight at age in catch is not used as estimator of weight in the stock is mainly because of the smallest fish in the population (notably the 0-group fish) are not fully recruited to the fishery in 3rd quarter of the year because of likely strong effects of selectivity in the fishery. Possible variation in the mean weight at age in the stock has not been considered in the simulations being an additional process error.

In conclusion, the above sources of uncertainty arise due to gaps in our knowledge of the population dynamics of the Norway pout stock, and in this respect it is difficult to characterise their impact. In the assessment these parameters have been assumed constant over years, ages and seasons. In relation to this study group no new documentation is available on the dynamics of these variables and the variability in these parameters. Accordingly, also in the harvest scenario evaluations and SMS simulations performed in the present workshop the dynamics of those and the resulting parameter uncertainty is not included in relation to process error of the simulations. Due to the above situation of assumption of constancy of those parameters the process error in relation to the simulations can very well be quite high inflicting the results.

3.3 Observation error in the simulations

The observation error in the simulations has been estimated to be around 25-30 % by SMS (30 % used as baseline in the simulations). Different levels of observation error arise from use of different information and data input in the assessment and simulations, either only survey information or full assessment information with use of a commercial fishery tuning fleet as well. In the simulations two levels of observation error have been applied, one level arising from using only survey information, and another level arising from using full assessment information.

3.4 Consistency between surveys

The consistency between the IBTS quarter 3 index and the IBTS quarter 1 index the following year (for a given year class) gives important information about the need to do a full Norway pout stock assessment once or twice each year. This is especially important for the incoming year class (measured as 0 group in quarter 3 and 1 group in quarter 1) since the projected landings typically are dominated by 1-group. The consistency between the surveys is not high (R^2 = 0.59), and the residuals for the fits between age 0-1 and age 1-2 also show a decreasing trend during the last part of the time series (Fig. 3.2). Part of the inconsistency and time trend in residuals may be due to large between-year variation and time trends in natural mortality.

Table 3.1. Standard deviation of log-catchability residuals (sd(log-q)) for each relevant age and survey. The quarterly VPA stock numbers used to estimate catchabilites are taken from the SXSA assessment accepted by ACFM in autumn 2006.

Survey	Period	Age	Sd(log-q)
IBTS q1	1983-2005	1	0.48
IBTS q1	1983-2005	2	0.42
IBTS q1	1983-2005	3	0.55
IBTS q3	1998-2005	0	0.42
IBTS q3	1998-2005	1	0.31
IBTS q3	1998-2005	2	0.44
IBTS q3	1998-2005	3	0.61

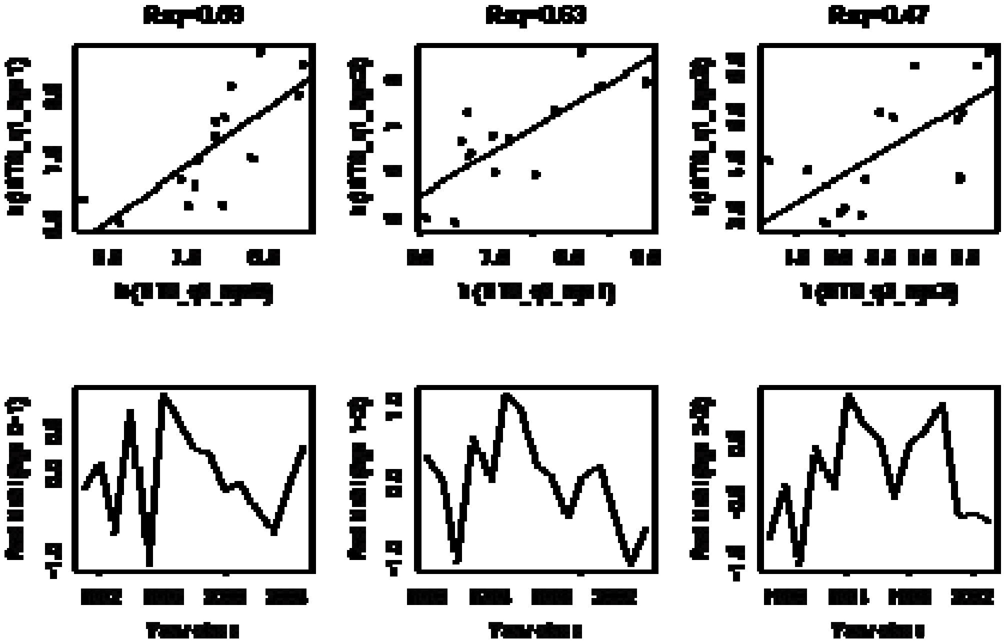


Figure 3.2. Consistency between the IBTS quarter 3 indices and IBTS quarter 1 indices the following year for the same year class of Norway pout. The time series of residuals are shown under each regression plot.

4 Methodological 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. When used 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 has a "traditional" forward running self-contained population model defined through its parameters. As such, it can also be used for prediction with given parameters. The present text discusses details in this use of SMS as a tool to simulate harvest rules.

For the Norway pout simulations, SMS is run using quarterly time steps. The expected catch in each time step 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

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

The estimated model parameters in an assessment include stock numbers the first assessment 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. Alternatively, maximum likelihood estimates can be substituted with input values. This option is used for the Norway pout simulations where the initial stock numbers and selections at age are taken from the most recent SXSA assessment of Norway pout accepted by ACFM in autumn 2006 (representing the stock at the start of 2006), and assumed known without error. Recruits are produced from the stock/recruitment relation with the input parameters from the same SXSA assessment. The season and age effects from the exploitation pattern are kept constant as estimated while the year factor is derived dynamically from a Harvest Control Rule. Weights at age and maturities at age are kept constant.

For a stochastic projection, the number of recruits derived from the stock recruit relation are multiplied with a random factor drawn from a truncated normal distribution with a known standard deviation. Mean and variance of future stock numbers, SSB yield etc., are calculated from a large number of replicate runs of the prediction.

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 implementation 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 ICES 2006/ACFM:15) The SMS implementation of HCRs is in gross terms similar to the HCR evaluation program STPR3 (Skagen, 2005).

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 then projected forward in time using a HCR so 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 known in the first projection year and is later updated 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 log-normal distribution with known standard deviation (std. dev.).

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 perceived stock. Another error function can be used to mimic the uncertainties of the stock size derived from real-time monitoring or from a survey index.

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 applied to the fishing mortality derived from the decision rule. This fishing mortality is expressed relative to the Fsq. Hence, with log-normal distributed noise, the realised fishing mortality becomes:

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

Stock recruitment relationship

A range of stock-recruitment-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.

The actual recruitments are derived from the stock-recruit function with a random noise term. Hence, for e.g. the Ricker relationship, the recruits (at age 0) , assuming a log-normal error distribution are obtained as:

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

where alpha and beta are 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 on the log scale.

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

HCRs 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 constraints in year-to-year variation in F or TAC, and an additional overall maximum F or TAC.

The proposed HCRs do in some cases operates with a specific TAC for the two half-years. This is taken into account by using a scaling factor for each half year on the quarterly exploitation pattern to calculate the quarterly F values. In cases of closure of e.g. the first half year, the scaling factor is zero leading to a zero F.

Constant F

A simple HCR is to apply a constant F irrespective of state of the stock.

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 furthermore prevent attempting to apply the TAC if it exceeds the stock biomass.

F from target SSB in the beginning of the year after the TAC year (Escapement strategy)

The basis for these HCRs is in most cases the stock size estimated from the traditional ICES assessment. In SMS projections, no new assessments are simulated. Rather, this stock estimate is simulated from the true stock size and an assessment “observation” error function.

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 assumed as a point estimate from the observed SSB and the SSB-recruitment relationship

Survey based HCR

The stock size in the beginning of the TAC year can be estimated from a survey index of the stock. This is simulated from N_{true} and a survey “observation” error function.

TAC is calculated from the 0-group abundance (survey index times a known constant) and stock number trigger values (T1 and T2)

If N0<T1   TAC=a1 + b1 * N0

else if N0>=T1 and N0<T2   TAC=a2 + b2 * (N0-T1)

else if N0>=T2   TAC=a3 + b3 * (N0-T2)

Trigger values T1 and T2 and intercepts and slopes are given as input

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

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 is assumed that a given fleet capacity will only be able to impose a maximum F.

Overview. Steps involved in applying HCR

This section gives and overview of data manipulations done for each year of a projection. Within the year specific actions are taken for each half-year or quarter, if necessary. Figure 4.1 illustrates the steps taken.

1) Obtain starting values of N at age at the start of the projection from an assessment. These stock numbers represent 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) Derive 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 assumed 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.

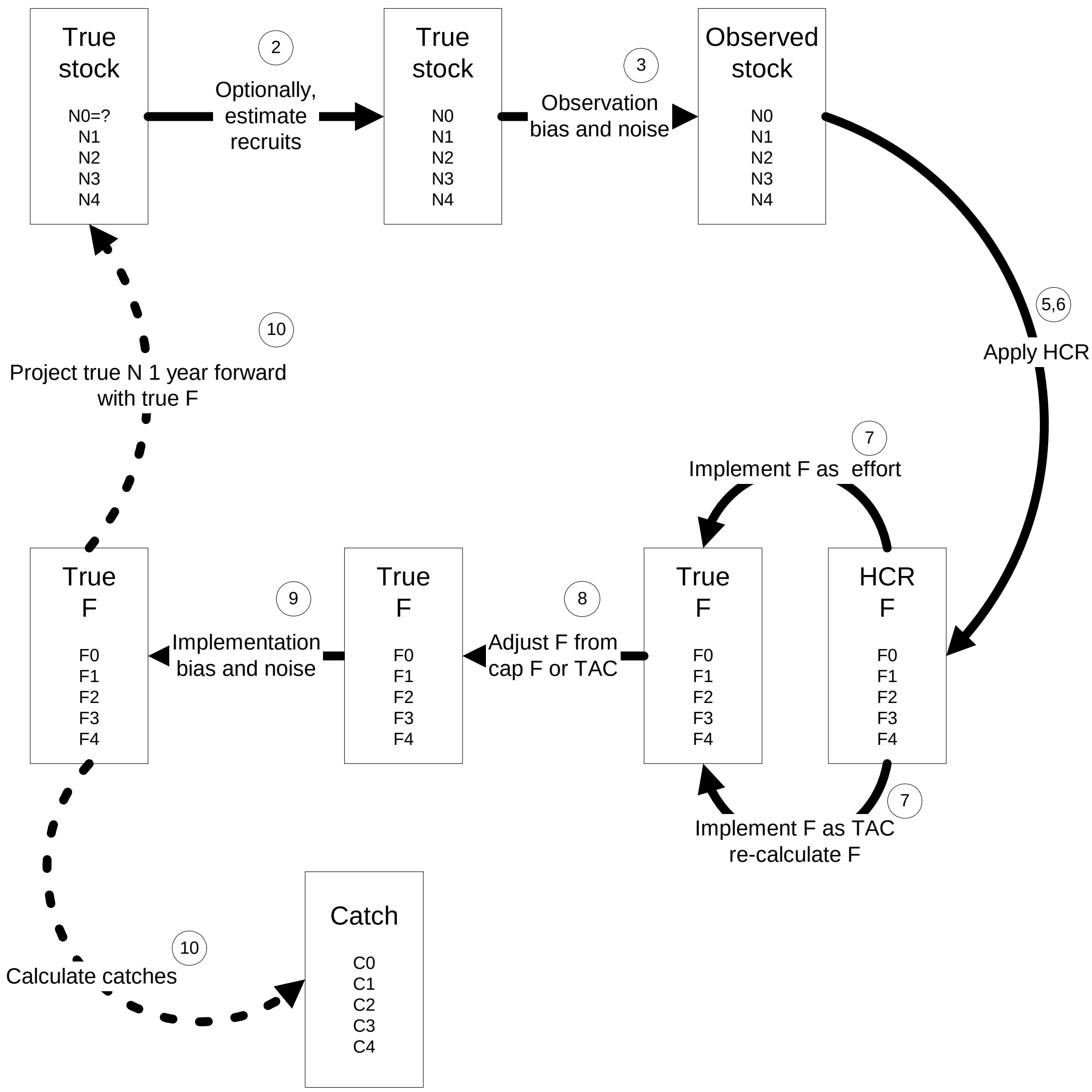


Figure 4.1. Overview of data manipulations done by SMS-HCR. Numbers in circles refer to steps in the overview text.

5 Scenarios of harvest rules: HCR scenario evaluations

5.1 Annual cycle

The starting point is that information about the state of the stock can be updated twice yearly, as survey information becomes available. Catch information is in principle available at any time when fishery is open, and can be used up to the previous quarter in assessments, since the assessment is on a quarterly time scale. Hence, at each point in time where new information is available, it may be used as input to an updated assessment, or used directly.

Whether to do a full assessment each time or not depends on how precise the surveys are and how consistent they are and whether new catch information exist or not. The fact that there is some mis-match between the information of the incoming year class in the Q3 survey and in the subsequent Q1 survey (see Fig. 3.2) indicate that at least for the decision in March, a full assessment may be necessary.

The simulations below suggest a cycle with two annual decisions, in March-April and November-December, and two management periods, e.g. first and second half year. Two options are then possible:

1) A preliminary TAC (valid for the whole year) is set at one of the decision times, and a final TAC is set the second decision time.

2) A TAC for the next time period is set at each occasion.

The difference is that preliminary TAC set e.g. late in the year will apply for the whole next year. An unknown fraction of it will be taken in the first period. Then, a new TAC will be set for the second half year. The timing of the fishery matters for this stock, both because of its rapid growth and high mortality, and because the selection at age seems to vary between quarters. With the second alternative, the seasonal distribution of the fishery is decided directly. The TAC for the first half of the year will necessarily have to be conservative, because the information, in particular on the incoming year class, is sparse at that time.

In the following, the second alternative is assumed. In the simulations, fishing mortalities assumed for each quarter are the historical quarterly fishing mortalities, scaled by the same factor to obtain the required annual fishing mortality (exploitation pattern).

5.2 Trade-off between objectives

Scenarios were made to illustrate pros and cons with different management objectives:

1) An escapement strategy, aiming at maintaining an SSB at a target level which would imply a low risk to Blim. With the rapid turnover in the stock, this is likely to produce a near maximum long term average yield.

2) A fixed F strategy: Under the condition, fishing mortality is proportional to effort. This is in principle equivalent to a constant effort management. Previous simulations have indicated that a rather low fixed F is needed to ensure a low risk of SSB falling below Blim.

3) Stabilising catches. For this short lived species with highly variable recruitment, stabilising catches is likely to imply a substantial loss in long term yield compared to other strategies, if the risk to Blim shall be acceptable.

For each of these scenarios, some more detail is added to reduce risk and make the strategy more feasible. The simulated harvest rules then become:

1. Escapement type

A TAC is set for Q1 and Q2. The TAC for Q1-2 is set based on the 3rd quarter IBTS survey result for the age 0 as:

If $I_{0\_q3} > C$, then

$TAC_{Q1\text{-}2} = A * I_{0\_q3} / \text{Average } I_{0\_q3}$, but not greater than B.

else

$TAC_{Q1\text{-}2} = 0$

Here I_{0_q3} is the index of age 0 in the 3rd quarter IBTS survey, and A, B and C are parameters for the rule. Conservative values for parameters were chosen as default. There will be no fishing for recruitment lower than the long term (geometric) mean, and a maximum TAC of 50 kt will be set for a recruitment 3 times higher than the long term GM recruitment.

For quarters 3-4, a TAC is set based on a full assessment in April-May (or a second survey information evaluation), including the results from the 1st quarter IBTS for the present year. The TAC is set so that the SSB at the start of next year is estimated at a target spawning biomass (i.e. the traditional used B_{pa}) – the escapement strategy.

The scenario simulations include a range of assessment and implementation uncertainties.

The first decision in this rule is made on the survey estimate of the incoming year class only from 3rd quarter IBTS, and is a quite conservative one. A full assessment in the autumn might have been done at the time, but would probably not reduce the uncertainty in the basis for decisions substantially, and would delay the decision process. The decision for the harvest in the second half of the year is based on a full assessment. The TAC under an escapement strategy is sensitive to the noise in the assessment, and at this time, the best information for an assessment is available.

2. Effort control

For the Norway pout, there seems to be a rather strong relationship between standardised effort and fishing mortality (Fig. 5.1) (even though it should be noted that F estimated in the SXSA assessment is not totally independently estimated of standardized effort). Therefore, it may be considered to regulate fishing mortality by regulating effort, leading to an effort strategy. Under such a strategy, no TACs will be needed, but regular assessments are needed to monitor the actual fishing mortality, and to adjust the effort if needed, i.e. if it leads to a realised fishing mortality that deviates from what is intended.

In practical management, a target fishing mortality could be translated into an initial effort according to effort is translated into fishing mortality according to the historical relation

$$\text{Effort} = 7.8384 * F_{(1\text{-}2)} - 0.0123$$

where effort is standardised total fishing days in thousands by the Danish and Norwegian fleets. This relation is shown in Figure 5.1 below:

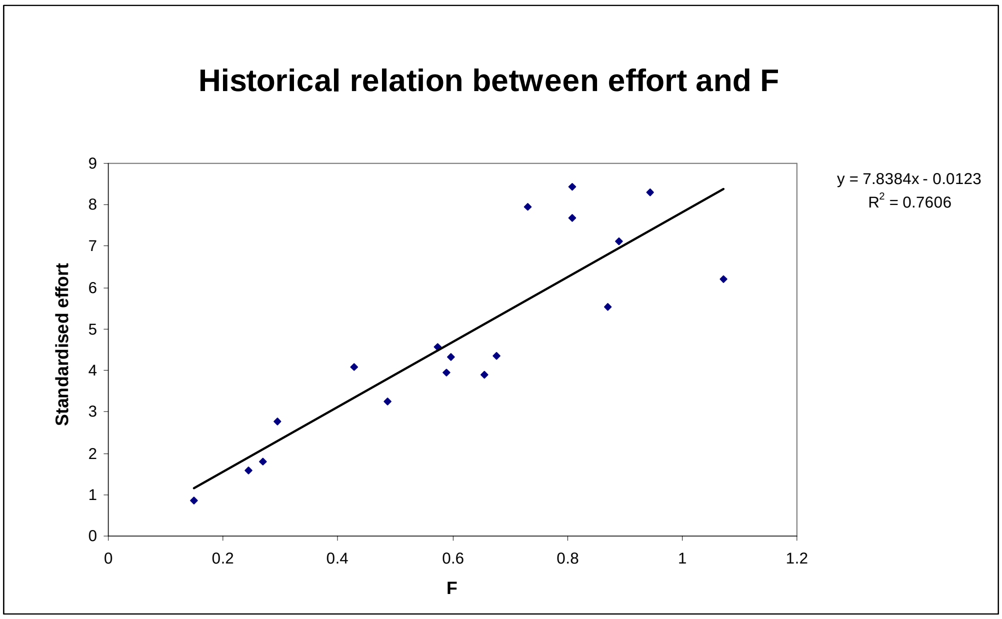


Figure 5.1 Historical relationship between yearly standardized effort and fishing mortality as estimated in the accepted SXSA assessment from autumn 2006 (ICES, 2007).

When designing a rule for adjusting effort, its consequences for the dynamic properties of the system need to be considered. If the rule is too weak, it will allow the fishing mortality to move far away from what is intended. If it is too strong, it may amplify the noise in the estimates of fishing mortality. The management system will then act as a feed-back amplifier with delays, which is known to lead to oscillatory behaviour.

On this background, it would have been preferable to explore the following rule:

A possibility is that each year in April-May, an effort, defined as standardised days at sea for the 3rd and 4th quarter and the 1st and 2nd quarters next year, is set as:

$$\text{Effort this year} = \text{Effort last year}^* \left(1+a^*(F_{target}/F_{realised}-1)\right)$$

where a is a gain factor, $F_{realised}$ is the F last year according to the assessment and F_{target} is the target fishing mortality. The gain factor determines the strength of the response to a deviation fishing mortality, and by scaling this factor, the dynamic response to this effort control rule can be explored.

The purpose of this rule is to adjust the effort if there are signs of effort creeping. Hence, it is dynamically different from a fixed F rule, since it has a feed-back that adjusts the effort if it does not lead to the intended fishing mortality.

The simulation software does not however, explicitly model the full management cycle including an assessment. Therefore it is not possible to obtain $F_{realised}$ - the only available value in the simulations is the true F, which might differ from the F “observed” via the assessment. The proposed dynamic adjustment of effort was therefore not simulated.

Instead a more traditional approach was taken. A given effort level is translated into F, which are implemented with some noise, to reflect the precision of the effort-F relation. (Figure 5.1).

3. TAC stabilising.

For this stock, stabilising catches is probably not a good idea because of the short life span of the species and the highly variable recruitment (and also possible variation in natural mortality). Hence, these simulations are largely made to demonstrate the limitations of this approach.

It was not possible, with the available software, to fully simulate a TAC stabilised version of the escapement strategy given in example 1. Instead it was assumed that the fishery is closed in the first half-year and the TAC in the second half-year is determined as in example 1.

In all simulations, an upper value for F has to be assumed, to cover the cases where a TAC has been decided that cannot be reached. This was set at 0.8, which is considered to be the highest F that the present fleet is able to induce (given the fishing pressure in more recent times). Previous studies have indicated that a lower upper bound on the F can come into effect quite often. This implies that if the effective effort is sufficiently limited, the harvest rule is turned into an effort rule.

6 Results and discussion

This section gives the results of the stochastic simulations for each of the strategies presented in section 5.

6.1 Overview scenario, MSY from Constant F

A scenario using a constant F was made to get an overview of sustainable F levels and yield. No observation or implementation errors were assumed. The long term equilibrium values for various F-levels are shown in Figure 6.1. This style of figure is used for several scenarios: it shows the values of yield and SSB on the left y-axis and the values of F and the probability of the true SSB falling below Blim or Bpa on the right y-axis. The solid horizontal line denotes the 0.05 probability value and is used to highlight the region where there is a 5% (or less) probability of SSB being below Blim. The parameter of interest is plotted on the x-axis. The step-size between individual model evaluations can be determined from the density of the labels “1” and “2” shown in the plot.

Figure 6.1 shows the long-term equilibrium values for a constant F varied between 0.05 and 0.75 in steps of 0.05. It can be seen that the yield peaks at F levels higher than 0.45 shown at the figure. However, F values above 0.4 will lead to probability of SSB<Blim being greater than 5%. Fishing mortality at 0.4 gives a yield of around 95 kt.

6.2 Escapement strategy scenarios

6.2.1 Escapement strategy

The outline of the baseline-escapement strategy is described in sec 5.

Recruitment index, IBTS Q3

For the fishery in the first half-year, based on the Q3 IBTS 0-group index, the default TAC rather conservative can be given by:

TAC = 0 for recruitment lower than the long term geometric mean (70E9) and

TAC = Max((SSB-Blim)* 3.57E-4, 50000) for recruitment higher than the geometric mean (GM), equivalent to a maximum TAC at 50000 t obtained for a recruitment 3 times the mean.

The recruitment index is assumed observed from a log-normal distribution with a standard deviation of 0.42 (Table 3.1, 0-group Q3)

Assessment estimate

The TAC for the second half of the year is based an escapement strategy of leaving the SSB above Bpa after the fishery has taken place (*i.e.* on January 1st the following year). The basis for the TAC is the stock estimate from an assessment (which includes the catches from the previous year - if fishery has taken place) and the IBTS Q1 index from the current year. The true stock is assumed to be “observed” (using the assessment) from a log-normal distribution with a standard deviation of 0.3.

Cap F

Cap F, the maximum F the fleet can exert with a given effort level, is set to 0.8 (see section 5.2, point 3), which is high compared to the historical F level: mean F is been estimated below 0.8 for the period since 1995 and with average 0.95 before that year.

Results

Two sets of graphs are shown for each scenario: the first set (*e.g.* Figure 6.2) shows the median and 25th and 75th percentiles obtained from 1000 simulations for annual SSB, yield, mean F and recruits for the period of the predictions (2005-2030). The probability of fishery closure in the first and second half of the year is also shown. The probabilities of SSB being below 150 kt (continuous line) and below 90 kt (dotted line) are also shown.

The second set of graphs (*e.g.* Figure 6.3) shows the cumulative probability distribution and the frequency distribution of SSB, yield and F in the final 20 years of the projections, during which period when the stock is assumed to be at equilibrium. For the same parameters, the distribution of the interannual change ratio (*i.e*. the ratio of parameters between subsequent years) on a given trajectory is also shown. The frequency and cumulative distribution of the number of consecutive years of a closure is also shown.

The trajectories in Figure 6.2 show that equilibrium is obtained quickly, reflecting the short life-span of the species. The long-term median-SSB is slightly above the target (Bpa), but for the individual trajectories there is a probability of around 40% that the "true" SSB will fall below Bpa. The probability of SSB being below Blim is less than 5%. For the second half-year there is a probability of 22% of a closure, and a 75% probability that the closure will only last for one year (Figure 6.3). For the first half-year, the fishery will be closed in 50% of the years, equivalent to the probability of recruitment being below the GM. The long-term median-SSB is above the target of Bpa. This is due to the use of the Cap F restriction, which is reached in around 35% of the years. The most frequent F values are around 0 (a closure) and close to or at the cap F value.

Sensitivity tests

We refer to the scenario described above 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.

The escapement strategy outlined in section 5 is sensitive to several assumptions:

1. Cap F, the maximum F the fleet can exert for with a given effort level;
2. Uncertainties in the stock assessment result;
3. The rules to derive the TAC for the fist half-year;
4. Changes in recruitment level;
5. - And probably several other factors

These effects of these assumptions are explored further in this section.

6.2.1.1 Escapement strategy, Cap F

The strong correlation between historical effort and F (Figure 5.1) indicates that F can be controlled with some confidence from the fishing effort allowed in the fishery. To test the robustness of the choice of the upper F-value the fleet can exert (Cap F), scenarios with varying levels of Cap-F were examined.

The equilibrium plot for Cap-F at 2.0 is shown in Figure 6.4. There is around a 10% probability of reaching the Cap F at 2.0 in this scenario.

The effect of varying the Cap F value (Figure 6.5) is an increase in mean F for a cap F of up to 0.5 and decreasing mean F with higher cap F values. The maximum yield of around 110 kt is obtained with a cap F of around 0.7 but this maxima is broad and yields above 100 kt are observed for cap F in the range 0.5-0.9. The probability of SSB being below Blim is less than 5% for values of Cap F up to 1.5.

6.2.1.2 Escapement strategy, assessment uncertainty

The effect of an increase in the uncertainty in the assessment is presented in Figure 6.6. For uncertainties (*i.e.* the standard deviation of assessment) up to 0.5, the probability of a SSB below Blim is less than 5%. Increasing uncertainty gives a slightly increasing median F, but the median yield (110 kt) is almost independent of the uncertainty level.

For uncertainties above 0.5, the probability of having a SSB below Blim is above 5% but the risk only increases modestly with increasing uncertainty due to the value of Cap F used (0.8). For a high uncertainty (1.0) the fishery is mainly regulated by the Cap F restriction (Figure 6.7), which is reached in almost 45% of the years.

The robustness of the system to assessment uncertainties, due to the application of a modest cap-F, indicates that an annual assessment is not strictly needed and might be replaced by a survey index evaluation. The IBTS Q1-index for the 1-group estimates the stock with a standard deviation of 0.48 which, from Figure 6.6, might be within the acceptable range (*i.e*. gives a probability less than 5% of having the SSB below Blim).

6.2.1.3 Escapement strategy, levels of first half-year fishery

The baseline strategy allows a maximum TAC in the first half-year at 50000 kt when recruitment is three times higher than GM recruitment. To evaluate the effect of this maximum TAC, various values were tried (Figure 6.8). It is clear, that the maximum TAC does not change very much with respect to (annual) yield or the probability of SSB<Blim. If no fishing is allowed in the first half-year, the annual yield will be less than 10% lower than for the maximum first half-year scenario.

The HCR is implemented by first calculating the F values for the first half-year from the TAC derived from the recruitment index. The fishery for the remaining year is then calculated from the assessment. However, in case of an annual-mean F greater than the cap F value, the quarterly F are all downscaled to get an annual F at cap F. This means that the simulation does not handle relatively high TAC values correctly in some cases.

6.2.1.4 Escapement strategy, recruitment level

The probability of below-average recruitment appears to have increased in recent years; however, this is not taken into account in the baseline scenario. The impact of reduced recruitment-levels was evaluated with scenarios based on the “hockey-stick” recruitment relationship with an inflection point at Blim, but with the mean value of recruitment above Blim lowered by a factor.

Figure 6.9 presents the SSB for various levels of recruitment in a system without fishing (F=0). Given the assumed recruitment model, the probability of observing a SSB below Blim is greater than 5% for recruitment factors lower than 0.70. If, however, F is derived from the escapement strategy, the probability of SSB<Blim is higher than 5% for recruitment factors lower than 0.75 (Figure 6.10). This small difference indicates that an unconditional closure of the fishery will have limited effect on maintaining SSB higher than Blim (*i.e*. 90 kt).

6.2.2 Conclusion, escapement strategy

The target of obtaining a true SSB above Blim with a high probability appears to be obtained when realistic values of uncertainties in assessment and survey are applied. This conclusion depends on the use of a Cap F in the order of 0.8, such that the HCR in practice becomes an escapement strategy with an additional maximum effort HCR. The cap F applied is relatively high compared to the historical fishing pressure. The equilibrium median yield is around 110 kt. There is a 50% risk closure of the fishery in the first half-year and a 20-25% risk of closure in the second half-year. The effect of allowing a higher proportion of the annual TAC in the first half-year is limited, even though it was not possible to fully-simulate the effect. The robustness of the HCR to uncertainties on stock-size (*i.e.* assessment) indicates that annual assessment might not be necessary for this species; the annual survey index might be sufficient.

The robustness to uncertainties might seem optimistic. There are, however, three important characteristics for this stock, that contribute to this robustness:

1) a very high natural mortality (M=1.6);

2) an early sexual maturation with 10% of age 1 mature and 100% mature for age 2 and older (which probably vary indicated from preliminary scientific investigation of maturity levels within the Norway pout stock (Larsen *et al*., 2001);

3) an exploitation pattern (see section 3.1) with almost no fishing mortality on the 0-group, and a much lower relative F at age 1 compared to F at the older ages. Mean F is defined as the average of F for age 1 and 2, such that a mean F at 1.0 give a F at age 1=0.53 and F at age 2=1.46.

Due to the very high natural mortality and early maturation (as used in the SXSA assessment), most of the SSB will consist of age 1 and 2. With no fishing, 73% of SSB will come from age 1 (11%) and age 2 (62%). With mean F=1, 94% comes from the same ages (23% and 71% from age 1 and 2). This means that the outcome of an "escapement strategy approach" (the SSB after fishing) is mainly driven by F at age 1, as the 1-group will contribute most to SSB at their "two-years birthday" January 1st. In addition, the exploitation level of the 0-group is very low such that the SSB contribution from the 0-group (1-group January 1st) is practically independent of fishing.

As F of the 1-group is just half of the mean F value the scenarios seems more robust to uncertainties than normally seen for other species. The cap F (0.8) used as default becomes actually just around 0.4 for the 1.group which is just 25% of the natural mortality.

Overall the harvest of this stock is very dependent on recruitment levels.

6.3 Effort control strategy

The constant-F strategy in Figure 6.1 indicates that a constant F of 0.35 gives a probability of SSB<Blim of just below 5%. This F value was chosen as default F value, which can be translated into effort from the effort-F relation (Figure 5.1).

However, this strategy does not take into account uncertainties. The implementation error (*i.e.* the translation of effort into F) is assumed to follow a log-normal distribution. This is a more conservative distribution compared to a normally-distributed error, as the log-normal distribution will produce a higher spread of F values above mean F than below mean F, and thereby a higher risk of overfishing.

Figure 6.11 presents the equilibrium values using a target F of 0.35 with implementation noise. This figure shows that the HCR is robust to this type of uncertainty and the probability of SSB<Blim is 5% with implantation noise at 0.3 (*i.e*. a standard deviation of 0.3 in a log-normal distribution). Median yield is around 90 kt and almost unaffected by the level of noise.

The distribution of metrics using an unrealistically high implementation-noise of 0.8 is presented in Figure 6.12. The distribution of F values is log-normal (as intended) but as the simulation does not account for a possible link between stock size and F, the risk of overfishing is probably underestimated.

6.3.1 Conclusion, fixed effort control

This scenario is rather robust to implementation uncertainties. The implementation of the approach will require a target F below 0.35, which will produce a long term yield at around

85 kt. The method is independent of an assessment and will as such not require an annual assessment. A regime shift towards a lower recruitment level will not be detected by this approach and there is a severe risk of overfishing in such a situation with a fixed effort approach. However, the historical development in the fleet effort shows clearly a decreasing effort with decreasing stock, indicating some degree of self-regulating effort.

6.4 TAC stabilising strategy

It was not possible to simulate the two-step TAC setting as used in section 6.1. Instead the fishery was closed permanently in the first half-year and the TAC was estimated in a similar manner as for the escapement strategy in section 6.1. In addition, constraints were put on the year to year variation of TAC.

Figure 6.13 shows with a scenario with a 50% interannual constraint (*i.e*. the TAC can vary within the 50-150% range of the previous year's TAC). Compared to Figure 6.2, it takes longer before the equilibrium F is reached, due to the constraints and low SSB in the start of the period. The probability of F reaching cap F is small (Figure 6.14) Figure 6.15 shows the equilibrium values, defined as values in the period 2020-2030. No constraints are marked as 0% on the x-axis, while the values 10% and higher defines the constraints on the TAC variation, *e.g*. 10% means than the TAC must be within the range 90-110% of last year's TAC. A very constrained TAC (±10%) gives a much lower long-term yield and a much higher risk of SSB<Blim compared to the unconstrained scenario. The constraints must allow at least a ±50% variation in TAC to keep the risk of SSB<Blim smaller than 5%.

6.5 Overall conclusion

Overall it is suggested that an escapement strategy is used as harvest control rule for Norway pout where:

A TAC is set for Q1 and Q2. The TAC for Q1-2 is set based on the 3rd quarter IBTS survey result for the age 0 as:

If $I_{0\_q3} > C$, then

$TAC_{Q1\text{-}2} = A * I_{0\_q3} / \text{Average } I_{0\_q3}$, but not greater than B.

else

$TAC_{Q1\text{-}2} = 0$

Here I_{0_q3} is the index of age 0 in the 3rd quarter IBTS survey, and A, B and C are parameters for the rule. Conservative values for parameters were chosen as default. There will be no fishing for recruitment lower than the long term (geometric) mean, and a maximum TAC of 50 kt will be set for a recruitment 3 times higher than the long term GM recruitment.

For quarters 3-4, a TAC is set based on a full assessment in April-May (or a second survey information evaluation), including the results from the 1st quarter IBTS for the present year. The TAC is set so that the SSB at the start of next year is estimated at a target spawning biomass (i.e. the traditional used B_{pa}) – the escapement strategy.

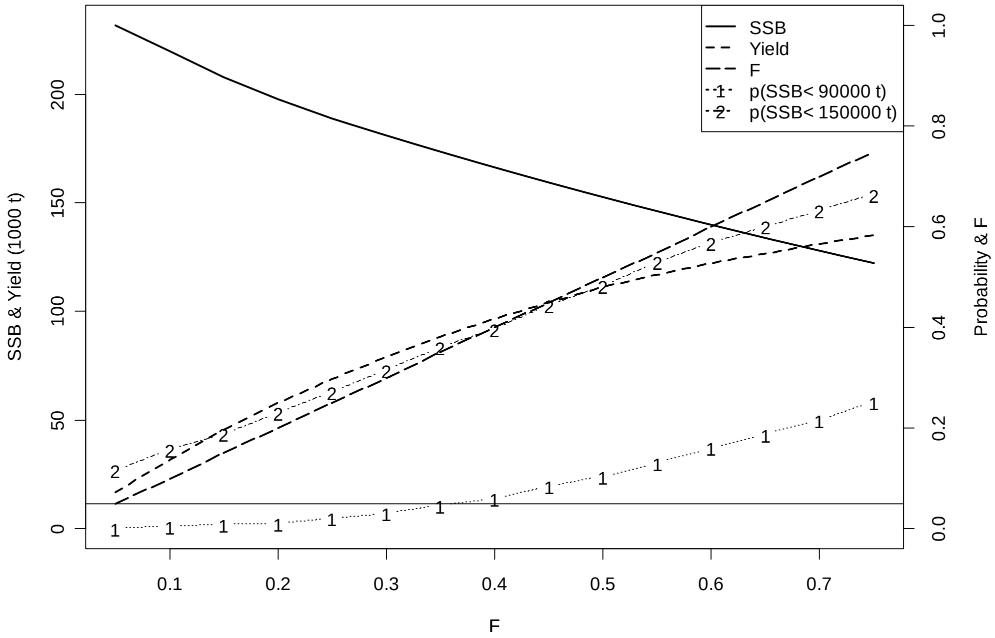
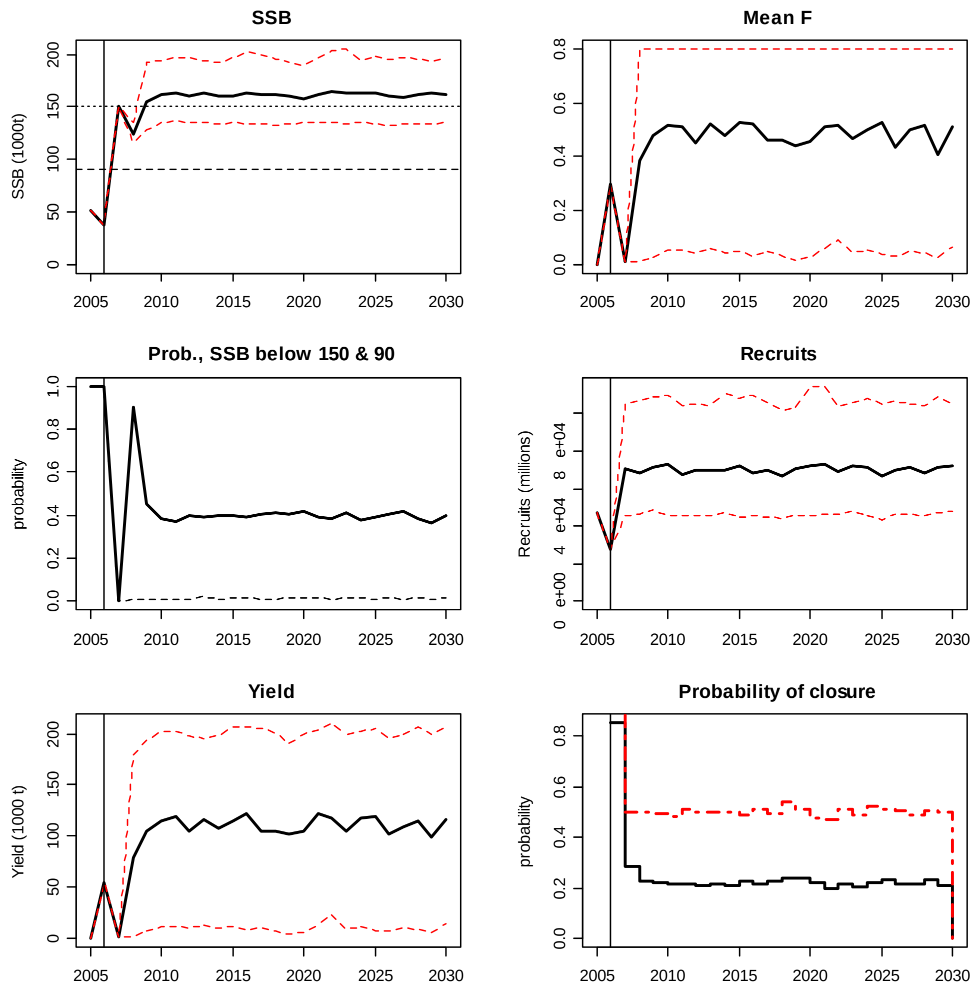


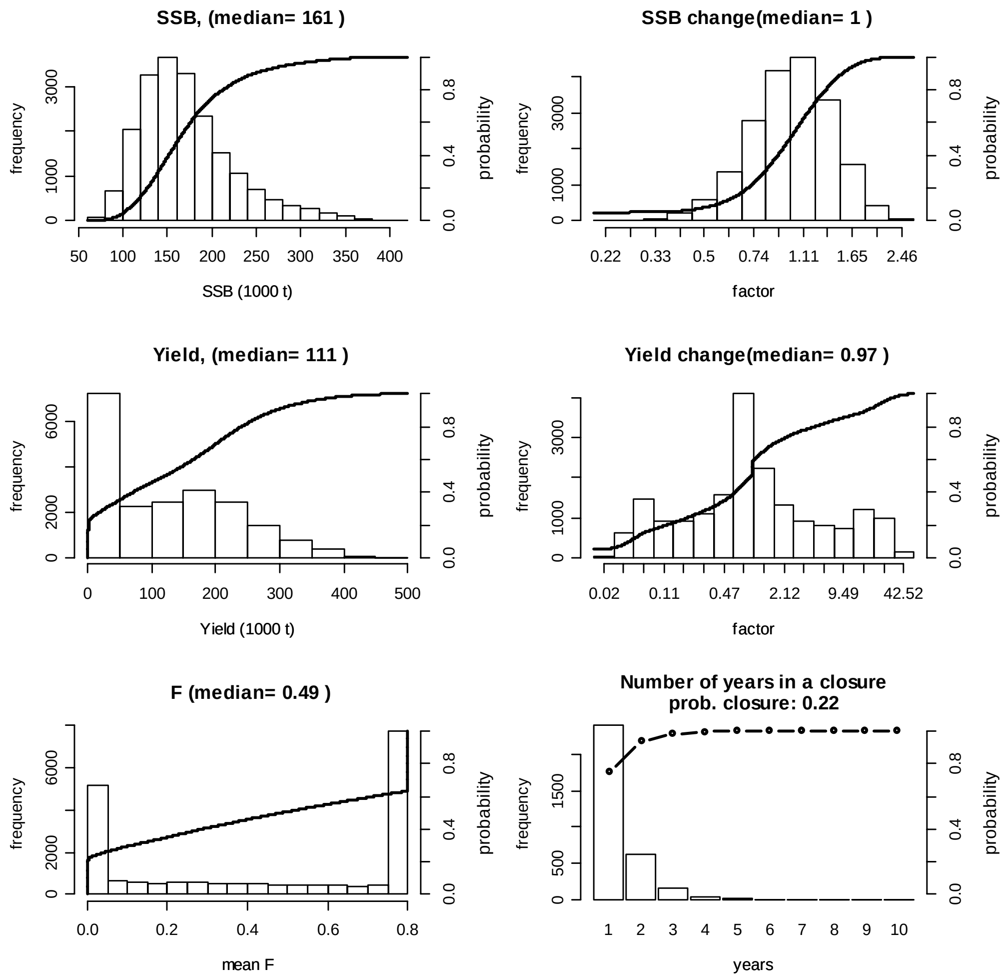
Figure 6.1. Long term equilibrium values for constant F.

Settings:	
Assessment uncertainty: no	SSB-R: Hockey stick, Stochastic
Survey uncertanty: no	Cap F: none
Cap TAC: none	Target SSB: none



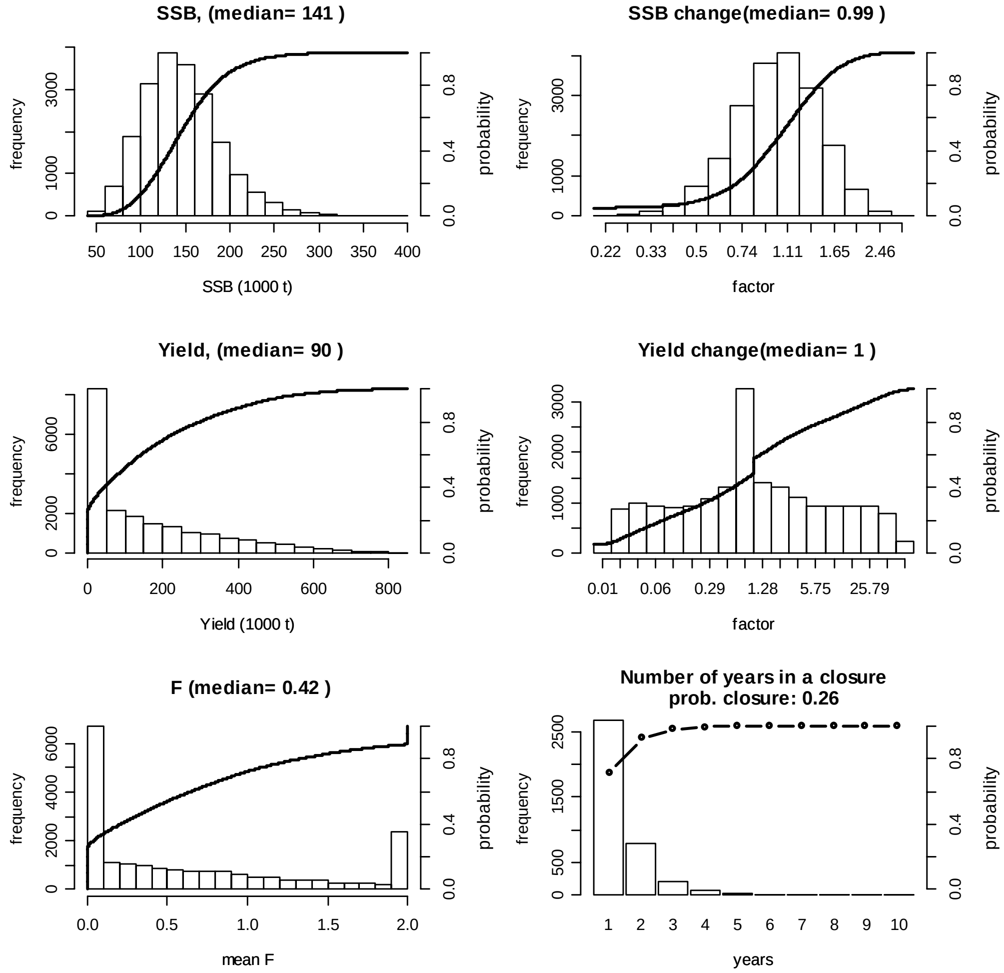
Settings:	
Assessment uncertainty: 0.3, log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: 0.42, log-normal, no bias	Cap F: 0.8
Cap TAC: none	Target SSB: 150 kt

Figure 6.2. Escapement strategy, Baseline. Mean trajectory of Norway pout SSB, yield, mean F and recruit (25, 50 and 75 percentiles), and probability of a fishery closure in 1 half-year (dashed, red line) and second half-year (solid black line), and the probability of the SSB being below Bpa (150 kt) and Blim (90 kt)



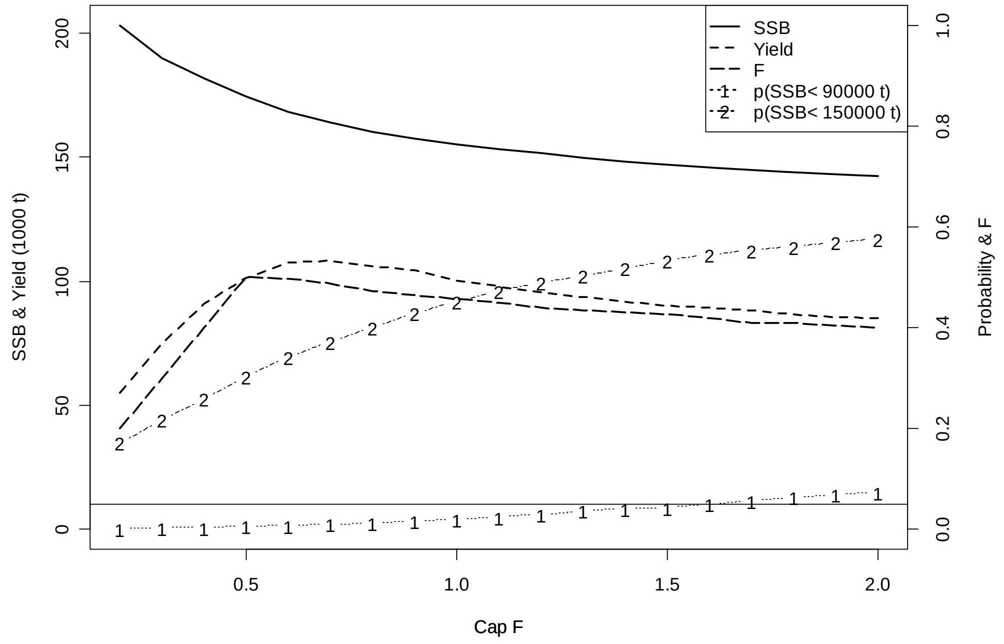
Settings:	
Assessment uncertainty: 0.3, log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: 0.42, log-normal, no bias	Cap F: 0.8
Cap TAC: none	Target SSB: 150 kt

Figure 6.3 Escapement strategy, Baseline. Distribution and cumulative probability of population metrics at long term equilibrium. For the yield change plot a minimum yield of 10kt has been applied for years with no or very limited yield.



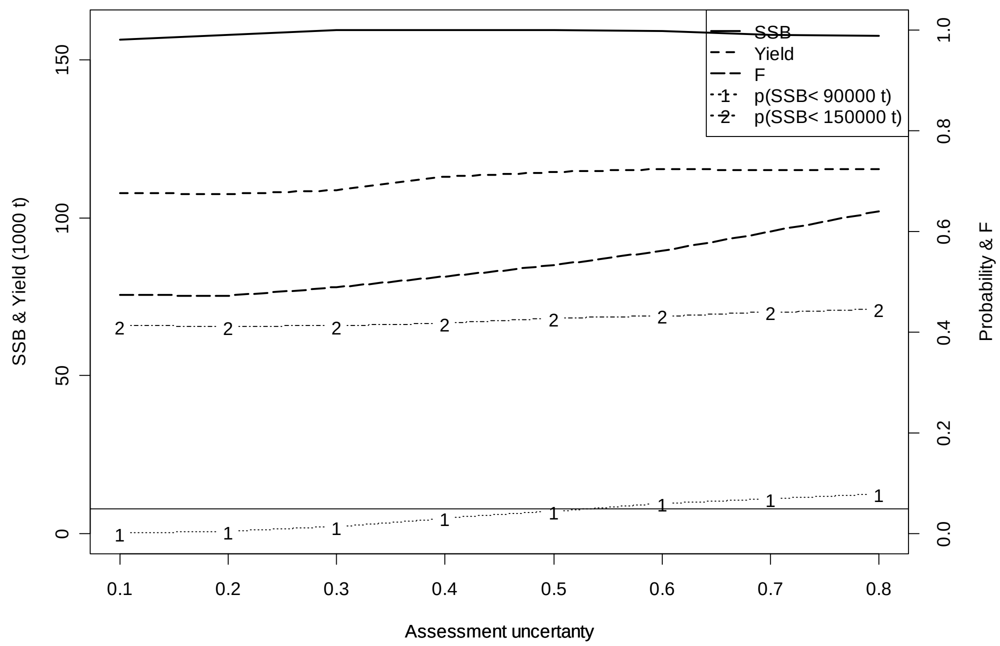
Settings:	
Assessment uncertainty: 0.3, log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: 0.42, log-normal, no bias	Cap F: 2.0
Cap TAC: none	Target SSB: 150 kt

Figure 6.4. Escapement strategy, Baseline. Distribution and cumulative probability of population metrics at long term equilibrium. For the yield change plot a minimum yield of 10kt has been applied for years with no or very limited yield.



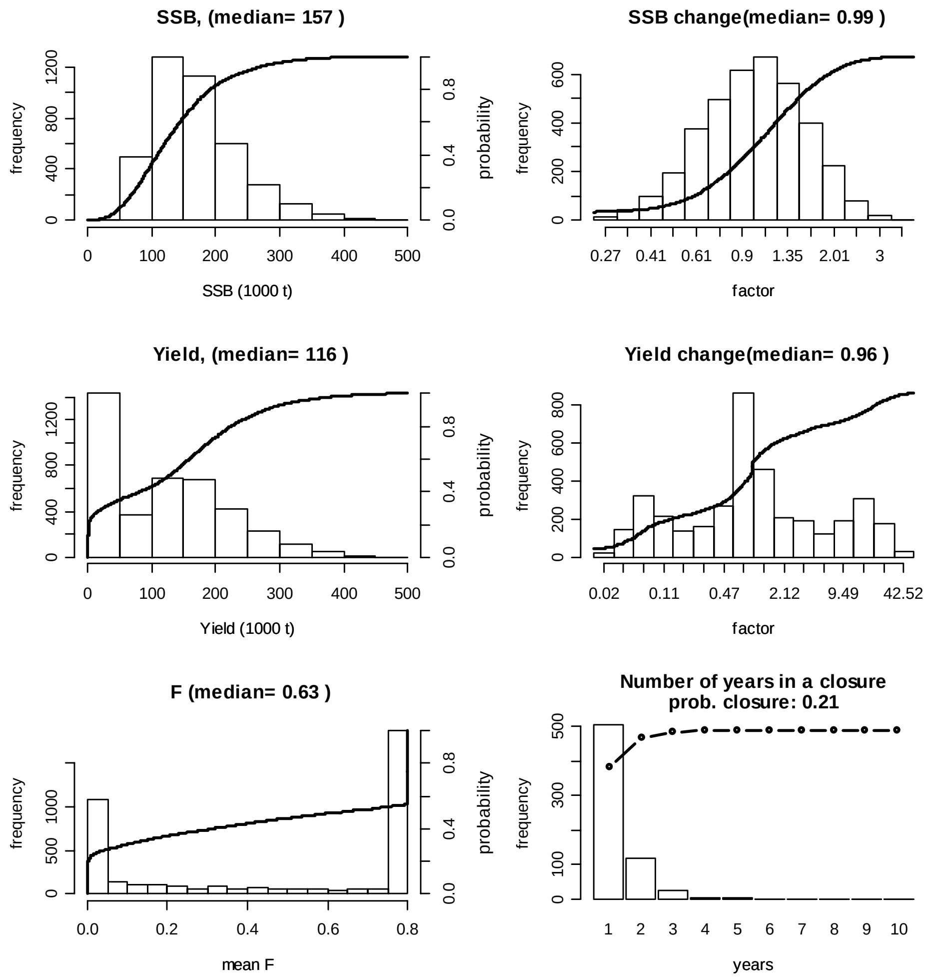
Settings:	
Assessment uncertainty: 0.3, log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: 0.42, log-normal, no bias	Cap F: 0.1 - 2.0
Cap TAC: none	Target SSB: 150 kt

Figure 6.5. Escapement strategy, Baseline Long term equilibrium values for varying Cap F.



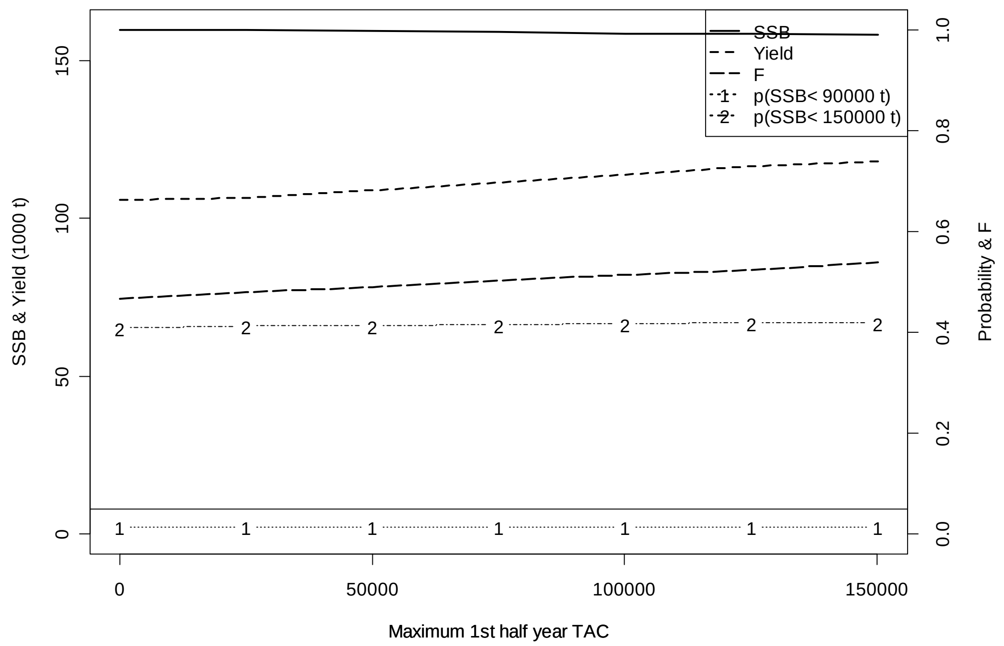
Settings:	
Assessment uncertainty: 0.1-08, log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: 0.42, log-normal, no bias	Cap F: 0.8
Cap TAC: none	Target SSB: 150 kt

Figure 6.6. Escapement strategy, Assessment uncertainty, , Long term equilibrium values for varying uncertainties un the assessment results.



Settings:	
Assessment uncertainty: 0.8 , log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: 0.42, log-normal, no bias	Cap F: 0.8
Cap TAC: none	Target SSB: 150 kt

Figure 6.7. Escapement strategy, Assessment uncertainty, Long term equilibrium values for varying uncertainties un the assessment results..



Settings:	
Assessment uncertainty: 0.3, log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: 0.42, log-normal, no bias	Cap F: 0.8
Cap TAC: none	Target SSB: 150 kt

Figure 6.8. Escapement strategy, first half-year TAC, , Long term equilibrium values for varying maximum TAC in the first-half year. Values on the X-axis gives the maximum TAC in the first half year with a recruitment 3 times higher than GM.

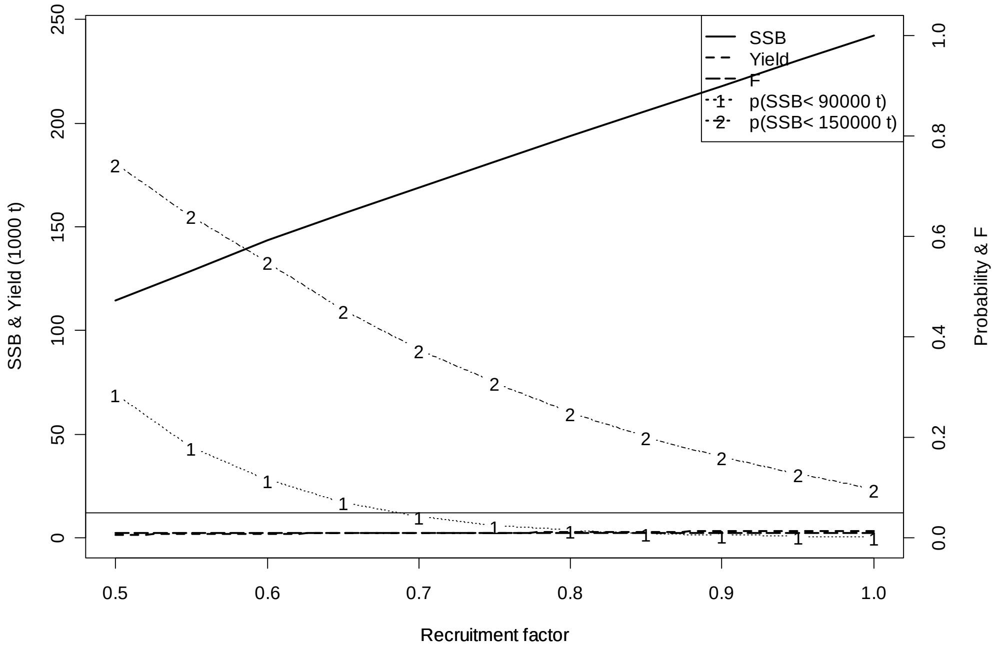
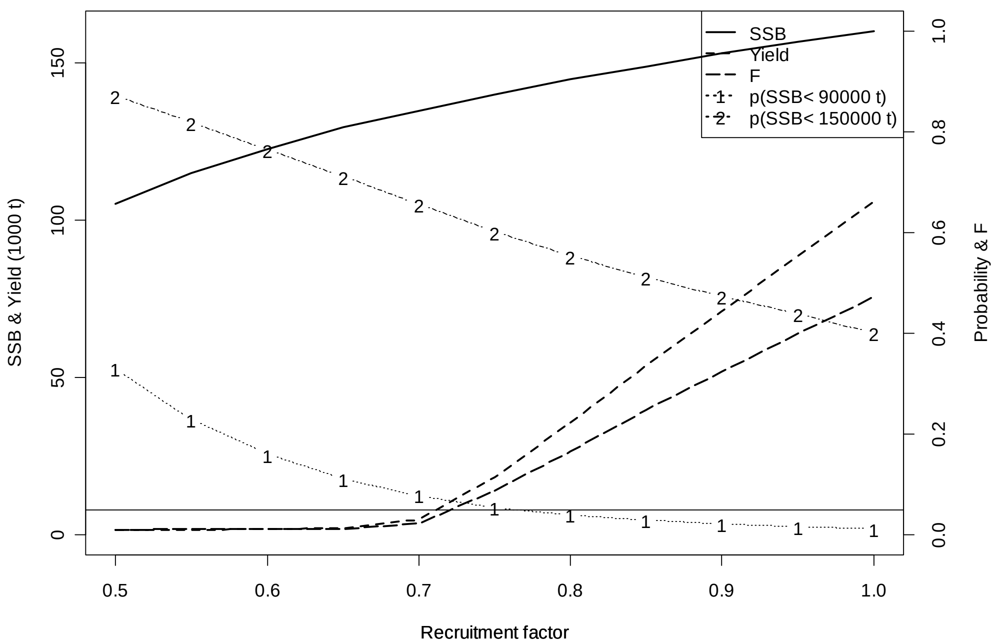
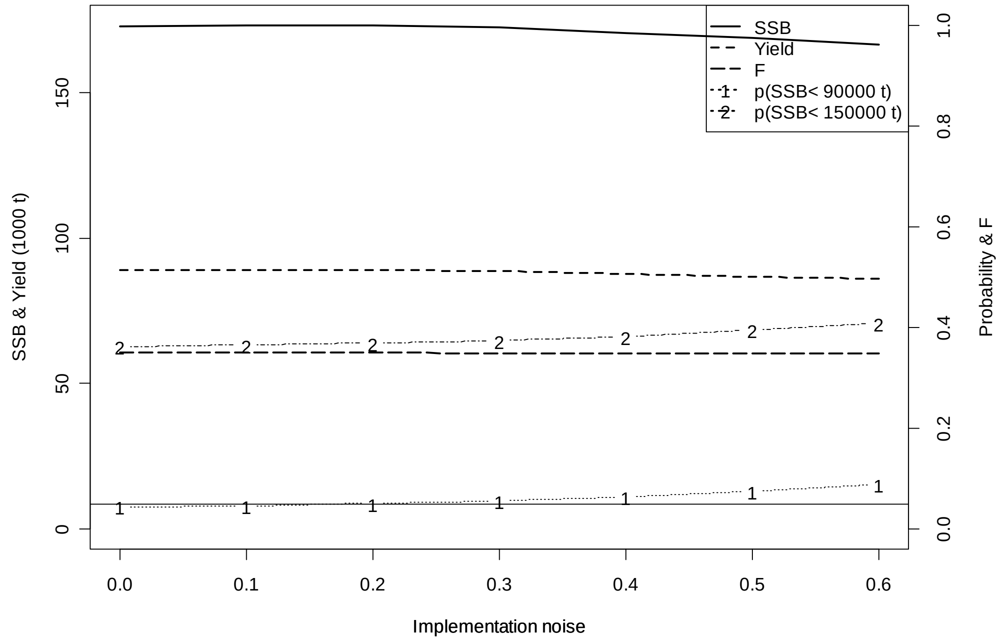


Figure 6.9. Long term equilibrium values for various levels of recruitment and no Fishing.



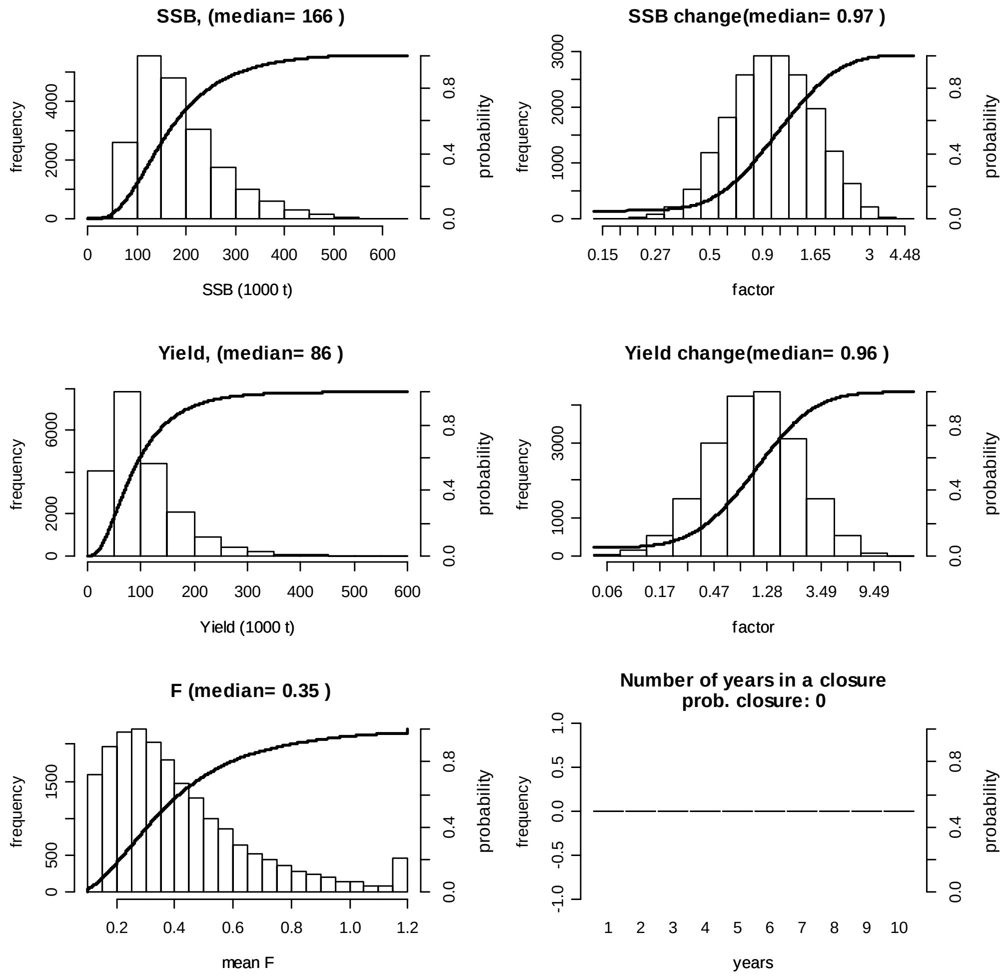
Settings:	
Assessment uncertainty: 0.3, log-normal, no bias	SSB-R: Variable. Hockey stick, Stochastic
Survey uncertanty: 0.42, log-normal, no bias	Cap F: 0.8
Cap TAC: none	Target SSB: 150 kt

Figure 6.10. Escapement strategy. Long term equilibrium values for various levels of recruitment.



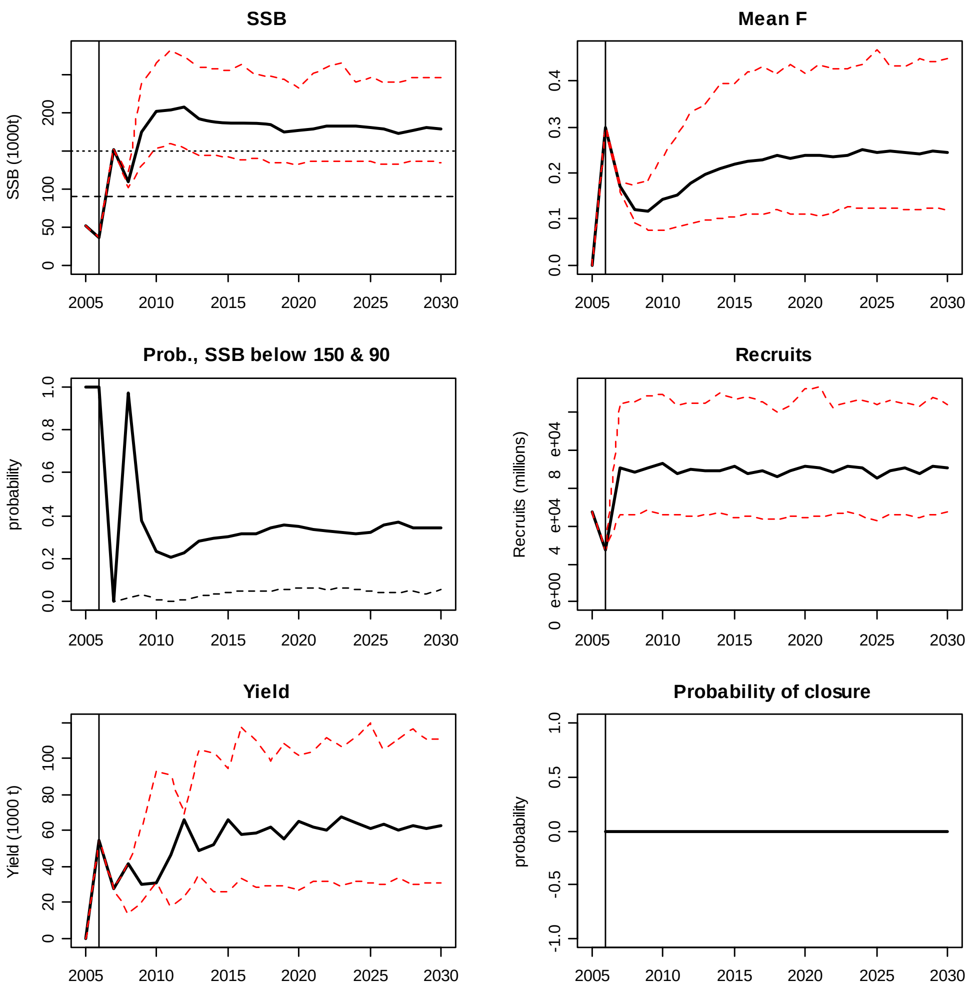
Settings:	
Assessment uncertainty: no	SSB-R: Variable. Hockey stick, Stochastic
Survey uncertanty: no	Cap F: no
Implentation uncertanty: log-normal dist, varying standard deviation	Target F: 0.35

Figure 6.11 Fixed effort strategy, Long term equilibrium values for various levels of implantation noise



Settings:	
Assessment uncertainty: no	SSB-R: Variable. Hockey stick, Stochastic
Survey uncertanty: no	Cap F: no
Implentation uncertanty: log-normal dist: std: 0.8, no bias	Target F: 0.35

Figure 6.12 Fixed effort strategy, Long term equilibrium values for various levels of implantation noise



Settings:	
Assessment uncertainty: 0.3, log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: not relevant	Cap F: 0.8
TAC constraints: +- 50% from year to year	Target SSB: 150 kt

Figure 6.13. TAC stabilising and Escapement strategy, Baseline. Mean trajectory of Norway pout SSB, yield, mean F and recruit (25, 50 and 75 percentiles), and probability of a fishery closure in 1 half-year (dashed, red line) and second half-year (solid black line), and the probability of the SSB being below Bpa (150 kt) and Blim (90 kt)

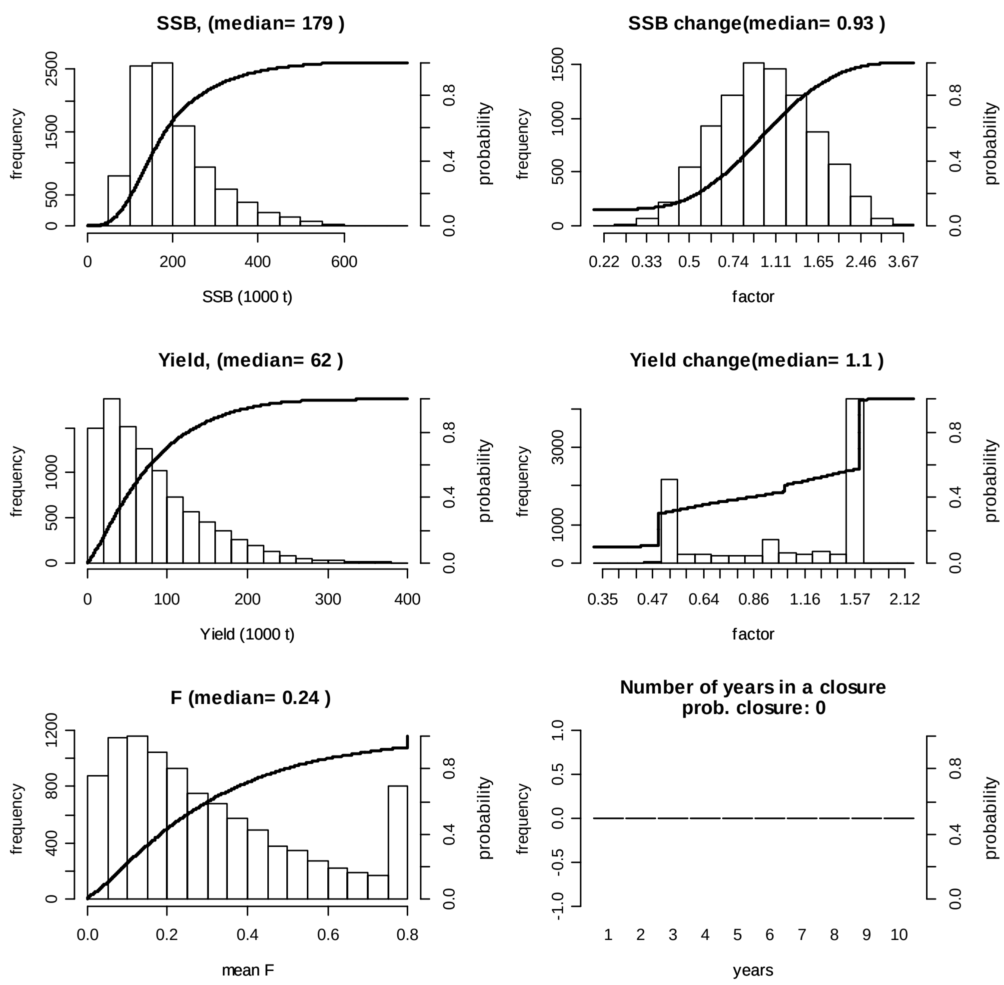
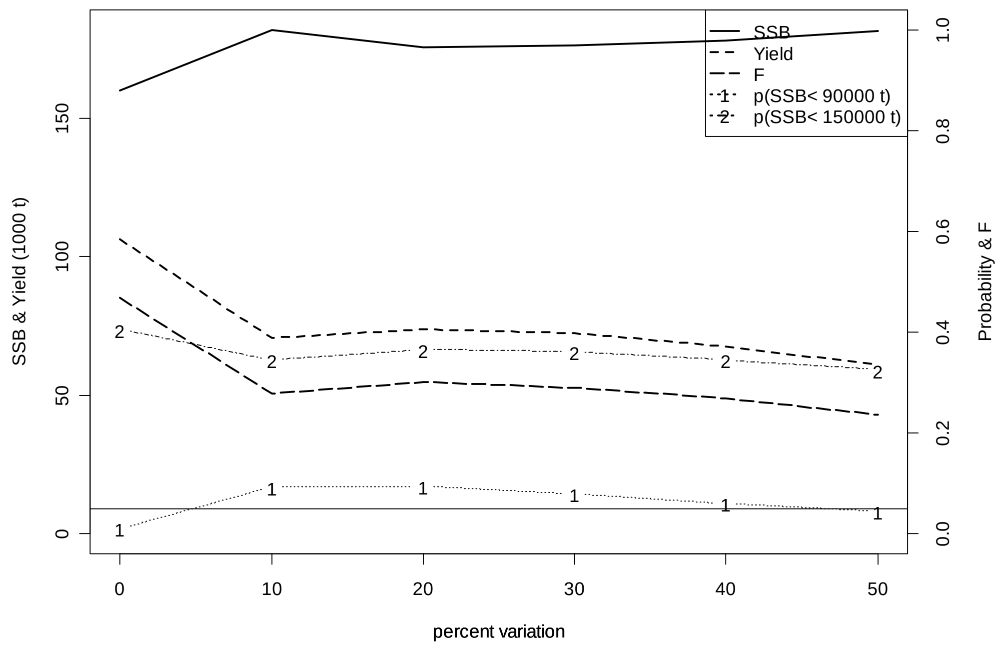


Figure 6.14. TAC stabilising and Escapement strategy, Long term equilibrium values for various levels of implantation noise

Settings:	
Assessment uncertainty: 0.3, log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: not relevant	Cap F: 0.8
TAC constraints: +- 50% from year to year	Target SSB: 150 kt



Settings:	
Assessment uncertainty: 0.3, log-normal, no bias	SSB-R: Hockey stick, Stochastic
Survey uncertanty: not relevant	Cap F: 0.8
TAC constraints: no constarints and 10-50%	Target SSB: 150 kt

Figure 6.15 TAC stabilising and Escapement strategy, Long term equilibrium values for various levels of year to year constraints in TAC. The value 0 shows no constraints. Value 10 and higher mean constrains, e.g. 10% means that the TAC must be within the range 90%-110% of last year TAC.

7 References (including the references in Annex 1)

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Annex 1: Recommendations by ICES ACFM Autumn 2006 focusing on by-catch reduction in the Norway pout fishery

6.3.3.5 Norway pout

The European Community and Norway have requested ICES for advice on management measures for the sandeel and Norway pout fisheries in the North Sea and Skagerrak in 2007.

This Section deals with the request for Norway pout. Sandeel are covered in Section 6.3.3.4.

The request to ICES concerning Norway pout was as follows:

Harvest control rules for Norway pout in the North Sea and Skagerrak that:

Allow the Maximum Sustainable Yields to be obtained and are consistent with the precautionary approach; and

Take into account the function of Norway pout in the ecosystem

It may be expected that the management of the Norway pout fishery will include the setting of preliminary catch and/or fishing effort limits at the beginning of the year until scientific information is available in spring allowing for the final maximum fishing effort and/or catch levels to be fixed. The harvest rules should therefore include rules for setting preliminary and final fishing effort levels (expressed as a percentage of the reference level in kW-days) and/or catch levels.

The monitoring systems and assessment methodologies required to implement the advised harvest control rules.

Level of by-catches in Norway pout fisheries separated for Division IIIa and Sub-area IV; and

Appropriate technical measures, including possible closed areas, to reduce by-catches, in particular, of cod, haddock, saithe, whiting and herring.

a) Harvest control rules for Norway pout

ICES is suggesting harvest control rules for Norway pout that are based on in-year monitoring similar to the recommendation for Sandeel. The suggested HCR for 2007 is:

1. *According to the ICES advice (Section 6.4.22) the preliminary TAC for 2007 should be zero*
2. *A final TAC for 2007 shall be set during the first half of 2007 on the basis of advice from ICES in spring 2007 based on:*
   a) *allowing for the spawning stock in the beginning of 2008 to be above Bpa,*
   b) *the most recent survey information (namely the0-group estimate for 2006 from the Q3 (2006) IBTS survey, and the 1-group estimate for 2007 from the Q1 (2007) IBTS survey),*
   c) *complete catch information from 2006 and*
   d) *an assumed recruitment of the 2007 year class of 25% of the long-term geometric mean*

Comments:

Norway pout is a short-lived species, and catches are dominated by 1-group fish. Significant amounts of 0-group fish may be caught towards the end of 2007. The only information in autumn 2006 about the number of 1-group in the start of 2007 is the 0-group index from the autumn of the previous year from the Q3 Scottish groundfish survey. The number of 0-group entering the stock in 2007 will have to be assumed, and a suitable candidate for this 25% of the long-term geometric mean. On this basis a preliminary TAC can be calculated such that the stock can be shown to exceed Bpa in 2008.

The in-year update cycle again refers to the rebuilding of the spawning stock in the beginning of 2008 to above Bpa and using the then-available information from the spring surveys and from the 2006 catches and from the assumed recruitment for the 2007 0-group. The most recent survey information refers to the IBTS quarter 3 indices from 2006 and the IBTS quarter 1 indices from 2007. The 1-group index from the IBTS quarter 1 survey is particularly important for the revised forecast. The reason for using the conservative assumption of 25% of the long-term mean is that the recruitment seems to have changed to a lower level in recent years.

Evaluation of the suggested HCR

EU and Norway have requested ICES to advice on harvest rules for Norway pout, primarily as a two-stage rule with an initial precautionary TAC and a mid-year revision. ICES has not been able to evaluate the suggested HCR for its performance in relation to the precautionary approach, due to lack of available experts.

ICES suggests that evaluation of the proposed HCR should occur in a separate process. Within the two-stage harvest rule there are a multitude of designs that should be explored, in order to find the best possible rule with respect to low risk, high yield and practical implementation. Hence, the evaluation should cover:

A range of annual decision cycles

Evaluation of feasible sources of information, including the use of survey data directly without full annual analytic assessments.

Evaluation of the uncertainty in the information underlying the decision at each stage in the annual cycle

Variability in recruitment, growth maturation and possibly in natural mortality

The trade-off between high long term yield and stable conditions for the industry.

The likely tool for simulations will be the SMS software, developed by DIFRES. Other existing software will require substantial work to adapt to the needs for Norway pout, where a quarterly time scale is mandatory. The delay in the response to the request is mostly caused by the limited capacity by people who have the necessary insight both in the stock and in the software that has to be used.

Scientists from DIFRES and IMR will in February 2007 outline a plan for simulations to be done and how to amend the software. The results will be considered in a short meeting in April 2007 shortly after which time the advice will be released.

b) monitoring systems and assessment methodologies required to implement the advised harvest control rules.

Because there is no final advised harvest control rule, ICES has not been able to address item b) of the request

c) By-catches in Norway pout fisheries

Demersal fisheries in the North Sea are mixed fisheries, with many stocks exploited together in various combinations in different fisheries. Small-mesh industrial fisheries for Norway pout and blue whiting take place in the northern and northeastern North Sea and have by-catches of haddock, whiting, herring and saithe. Some cod is also taken as a by-catch, predominantly at ages 0 and 1.

Existing by-catch regulations:

In the agreed EU Council and EU-Norway agreement, by-catch regulations in the small meshed fishery (16-31mm in mesh size) have been established (e.g. EU Regulation No 850/98, EU 1998). The catch retained on board must consist of:

- at least 90% of any mixture of two or more target species, or

- at least 60% of any one of the target species, and no more than 5% of any mixture of cod, haddock, saithe, and no more than 15% of any mixture of certain other by-catch species.

The EU TAC regulation prescribes that a maximum by-catch of 40% herring is allowed in the Norway pout fishery.

By-catch levels from landings statistics

Tables 6.3.2.1-6.3.2.2 presented recent (2002-2005) by-catch levels by species in Danish and Norwegian small meshed industrial trawl fishery in the North Sea and Skagerrak targeting Norway pout and Blue whiting. For Norway the landings used for human consumption purposes in the small meshed fishery can only be allocated to industrial fishery for the last two years. Due to low Norway pout landings in recent years the Norwegian by-catch estimates are uncertain.

Factors affecting by-catch levels in commercial fishing trials during 2005

Danish-Norwegian fishing trials were performed in autumn 2005 to explore by-catch- levels in the small meshed industrial trawl fishery in the North Sea targeting Norway pout. The trial fishery was performed by two Norwegian commercial trawlers and a Danish commercial trawler.

The trial fishery was carried out in autumn 2005 within traditional periods and areas for fishery on Norway pout. The Norwegian vessels conducted trials in the area vest of Egersund on the edge of the Norwegian Trench and the Danish vessel conducted trials at Fladen Ground. The Norwegian vessels conducted both day and night fishery while the Danish vessel only fished during daytime. The skipper at the Danish vessel decided the positions and fishing design on some of the hauls and the rest of the hauls were allocated in two selected ICES statistical squares. Because the trial fishery was conducted during a period when the fishery was closed and partly took place in areas normally closed to Norway pout fishing, the results may not be directly comparable to a “normal fishery” situation. Only daytime hauls were used in the interpretation of the results.

The general finding is that the by-catch ratio is high in the Norway pout fishery but the results also indicate that fishermen can minimize the by-catch ratio by targeting in the fishery (temporal-temporal targeting, way of fishing, etc.). The investigations show no general spatio-temporal patterns in the by-catch ratio although there are geographical and diurnal differences in the species composition of the by-catch.

With regard to diurnal differences in the catch rates of Norway pout and by-catches of other species, the few results at present indicate significant catches of Blue whiting during night hauls. The rest of the by-catch species show no diurnal differences

The relation between by-catch and depth could not be determined from the trial fishery.

d) Appropriate technical measures to reduce by-catches

Regulation of temporal-temporal effort allocation (closed seasons and areas):

The above investigations indicate some spatio-temporal differences in catch levels by species. However, these patterns are only based on results from pilot investigations. Knowledge about spatio-temporal patterns in catch rates of target and by-catch species in the fishery are not sufficient to implement management measures on spatio-temporal allocation of fishing effort with the aim to reduce by-catches.

During the 1960s a significant small meshed fishery developed for Norway pout in the northern North Sea. This fishery was characterized by relatively large by-catches, especially of haddock and whiting. In order to reduce by-catches of juvenile roundfish, the “Norway pout box” was introduced where fisheries with small meshed trawls were banned. The “Norway pout box” has been closed for industrial fishery for Norway pout since 1977 onwards (EC Regulation No 3094/86). The box includes roughly the area north of 56° N and west of 1° W. In the Norwegian economic zone, the Patch bank has been closed since 2002. It is not possible to quantify the effects of the Norway pout box on catch rates of target and by-catch species or on the effects on the stocks (EU 1985, 1987a, 1987b; ICES-NPS 1979).

Gear technological by-catch reduction devices:

Investigations of gear specific selective devices and gear modifications to reduce by-catch in the small meshed Norway pout fishery have been performed in a number of studies. Early Scottish and Danish attempts to separate haddock, whiting and herring from Norway pout by using separator panels, square mesh windows, and grids were all relatively unsuccessful. More recent Faeroese experiments with grid devices have been more successful. A 74 % reduction of haddock was estimated (Zachariassen and Hjalti, 1997) and 80% overall reduction of the by-catch (ICES-SGGSS 1998).

Eigaard and Holst (2004) found that trawl gears with a sorting grid with a 24 mm bar distance in combination with a 108 mm (nominal) square mesh window improved the selectivity of the trawl with catch weight reductions of haddock and whiting of 37 and 57% but also with a 7 % loss of Norway pout. The study showed that application of these reduction percents to the historical level of industrial by-catch in the North Sea lowered on average the yearly haddock by-catch from 4.3 to 2.7% of the equivalent spawning stock biomass. For whiting the theoretical reduction was from 4.8 to 2.1%. The purpose of the sorting grid was to remedy the by-catch of juvenile gadoids in the industrial fishery for Norway pout, while the purpose of square mesh window was to retain larger marketable consume fish species otherwise sorted out by the grid.

Kvalsvik *et al.* (2006) carried out experimental fishing during 1998-1999 on commercial vessels to evaluate grid systems and two different mesh sizes (10mm or 24mm) in the grid section. A grid with a bar space of 22mm and various bar thicknesses was used. They showed that in the 1998 trials, 95% (weight) of the by-catch species was sorted out with a 33% loss of the industrial target species. The loss of Norway pout was around 10%. With the 1999 trials they found that 62% of the by-catch species were sorted out and the loss of target species was 22% with a loss of Norway pout of 6%. The selectivity parameters for haddock showed a sharp size selection in the grid system.

In conclusion, recent experiments with grid devices indicate a substantial reduction in by-catch of saithe, whiting, cod, ling, hake, mackerel, herring, haddock and tusk. The reduction in haddock by-catch was lowered by the presence of many small individuals of the strong 1999 year class. The loss of Norway pout at around 10% or less when using a grid with a 22-24 mm bar distance. There was also a considerable loss of other industrial species: blue whiting, Argentine and horse mackerel. The Danish experiment indicates that it is possible to retain larger valuable consume fish species by using a square mesh panel in combination with a grid. Selectivity parameters have been estimated for haddock, whiting and Norway pout. These can be used for simulation scenarios including estimates of the effect of changing the bar distance in the grid.

A general problem for implementing sorting grids in industrial fisheries is the sheer size of the catches. Durability and strength of the grid devices used under full commercial conditions is very important and needs further attention.

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Table 6.3.2.1 Species composition in the Danish and Norwegian small-meshed fisheries in the North Sea of the catches landed for reduction (1000 tonnes). Data provided by WG members. The category "other" is subdivided by species in Table 6.3.2.2.

Year	Sandeel	Sprat	Herring	Norway pout	Blue whiting	Haddock	Whiting	Saithe	Other	Total
1974	525	314	-	736	62	48	130	42		1857
1975	428	641	-	560	42	41	86	38		1836
1976	488	622	12	435	36	48	150	67		1858
1977	786	304	10	390	38	35	106	6		1675
1978	787	378	8	270	100	11	55	3		1612
1979	578	380	15	320	64	16	59	2		1434
1980	729	323	7	471	76	22	46	-		1674
1981	569	209	84	236	62	17	67	1		1245
1982	611	153	153	360	118	19	33	5	24	1476
1983	537	88	155	423	118	13	24	1	42	1401
1984	669	77	35	355	79	10	19	6	48	1298
1985	622	50	63	197	73	6	15	8	66	1100
1986	848	16	40	174	37	3	18	1	33	1170
1987	825	33	47	147	30	4	16	4	73	1179
1988	893	87	179	102	28	4	49	1	45	1388
1989	1039	63	146	162	28	2	36	1	59	1536
1990	591	71	115	140	22	3	50	8	40	1040
1991	843	110	131	155	28	5	38	1	38	1349
1992	854	214	128	252	45	11	27	-	30	1561
1993	578	153	102	174	17	11	20	1	27	1083
1994	769	281	40	172	11	5	10	-	19	1307
1995	911	278	66	181	64	8	27	1	15	1551
1996	761	81	39	122	93	5	5	0	13	1119
1997	1091	99	15	126	46	7	7	3	21	1416
1998	956	131	16	72	72	5	3	3	24	1283
1999	678	166	23	97	89	4	5	2	40	1103
2000	655	191	24	176	98	8	8	6	21	1187
2001	810	156	21	59	76	6	7	3	14	1152
2002	804	142	26	73	107	4	8	8	15	1186
2003	303	175	16	18	139	1	3	8	18	681
2004	324	193	19	12	107	1	2	7	29	692
2005	172	207	23	1	101	0	1	6	13	524
Avg 75-05	694	196	59	207	66	11	32	7	32	1294

Year quarter	Sandeel	Sprat	Herring	Norway pout	Blue whiting	Haddock	Whiting	Saithe	Other	Total
1998 q1	37	7	7	13	11	1	0	0	5	80
1998 q2	754	1	2	8	12	2	1	0	4	784
1998 q3	153	60	4	29	38	2	1	2	9	298
1998 q4	12	63	4	23	12	0	0	0	6	121
1999 q1	14	14	4	8	23	1	1	1	8	74
1999 q2	507	2	4	22	30	1	2	1	8	577
1999 q3	139	129	10	41	18	1	2	0	7	347
1999 q4	17	21	6	25	17	1	1	0	18	106
2000 q1	10	42	1	9	13	1	0	0	5	82
2000 q2	581	2	4	17	32	3	2	0	4	646
2000 q3	63	133	10	30	39	2	3	6	5	291
2000 q4	0	15	8	119	14	2	3	0	8	169
2001 q1	12	40	2	20	15	1	1	0	3	94
2001 q2	462	1	2	10	32	3	1	2	4	517
2001 q3	314	44	4	4	12	1	2	0	5	386
2001 q4	22	72	13	24	16	1	2	0	2	152
2002 q1	11	5	6	8	18	0	0	0	2	50
2002q2	772	0	3	5	19	1	2	0	4	806
2002q3	21	71	8	31	46	1	3	5	4	189
2002q4	0	66	10	28	24	1	2	3	6	141
2003 q1	3	18	1	2	14	0	0	1	5	45
2003 q2	239	1	2	4	42	0	1	1	3	292
2003 q3	57	56	4	5	56	0	1	4	4	188
2003 q4	4	100	9	7	28	0	1	2	6	157
2004 q1	2	1	4	1	19	0	0	1	12	41
2004 q2	273	0	2	1	33	0	1	1	5	315
2004 q3	50	55	5	4	37	0	0	2	7	160
2004 q4	0	136	9	6	18	0	0	2	5	177

Table 6.3.2.2 Sum of Danish and Norwegian North Sea bycatch (tonnes) landed for industrial reduction in the small-meshed fisheries by year and species (excluding saithe, haddock, and whiting accounted for in Table 6.3.2.1).

Species	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**
Gadus morhu	544	710	1092	1404	2988	2948	570	1044	1052	876
Scomber scor	4	534	2663	6414	8013	5212	7466	4631	4386	3576
Trachurus tra	22789	16658	7391	18104	22723	14918	5704	6651	6169	4886
Trigla sp.	0	888[2]	45342[2]	5394[2]	9391[2]	2598[2]	5622[2]	4209	1593	1139
Limanda limar	187	3209	4632	3781	7743	4706	5578	3986	4871	528
Argentina spp	8714	5210	3033	1918	778	2801	3434	2024	2874	2209
Hippoglossoid	59	718	1173	946	2160	1673	1024	1694	1428	529
Pleuronectes	34	119	109	372	582	566	1305	218	128	143
Merluccius me	349	165	261	242	290	429	28	359	109	10
Trisopterus m	0	68[3]	0	5[2]	48[2]	121[2]	79[2]	111	36	0
Molva molva[3]	51	1	40	39	37	13	65	10	28	0
Glyptocephalu	236[3]	132	341	44	255[3]	251[3]	1439[3]	195[3]	246	40
Gadiculus arg	1210	729	3043	2494	741	476	801	0	0	0
Others	31715[1]	3853	3604	3670	3528	3154	4444	4553	4106	5141
Total	65892	32994	72724	44827	59277	39866	37559	29685	27026	19077

Species	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002[2]**	**2003**	**2004**
Gadus morhu	955	366	1688	1281	532	383	192	29	49	44
Scomber scor	2331	2019	3153	1934	2728	2443	1749	1260	2549	6515
Trachurus tra	2746	2369	3332	2576	5116	5312	1159	2338	5791	10272
Trigla sp.	2091	897	2618	1015	2566	1343	2293	1071	847	1101
Limanda limar	1028	1065	2662	6620	4317	441	1441	321	596	386
Argentina spp	292	3101	2604	5205	3580	333	397		1376	786
Hippoglossoid	617	339	1411	2229	1272	493	431	112	208	174
Pleuronectes	33	90	73	91	88	64	56	51	28	1
Merluccius me	0	3625	2364	33	211	231	167	6	301	423
Trisopterus m	9	30	181	261	922	518	0	196	5	91
Molva molva[3]	0	0	31	31	125	19	49	0	42	169
Glyptocephalu	0	97	394	860	437	154	246	58	437	286
Gadiculus arg	0	7	248	248	387	532	942	459	993	1550
Others	5158	50	749	5405	17931	8927	301	2226	4888	6953
Total	15260	14055	21508	27787	40211	21192	12523	8127	20115	28750

Species	**2005**
Gadus morhu	22
Scomber scor	2195
Trachurus tra	5226
Trigla sp.	597
Limanda limar	287
Argentina spp	1348
Hippoglossoid	61
Pleuronectes	38
Merluccius me	254
Trisopterus m	0
Molva molva[3]	34
Glyptocephalu	87
Gadiculus arg	909
Others	1964
Total	13022

[1]DK cod and mackerel included. [2]Only DK catches. [3]N catches. DK catches in "Others". [4]Until 1995 N catches only. DK catches in "Others".

Annex 2: Management Plan Evaluations for Norway Pout in 2007 by ICES WGNSSK September 2006 (ICES 2007 (ACFM:35))

16.5.2 Norway pout

The request to ICES concerning Norway pout:

a. Harvest control rules for Norway pout in the North Sea and Skagerrak that:

i. Allow the Maximum Sustainable Yields to be obtained and are consistent with the precautionary approach; and

ii. Take into account the function of Norway pout in the ecosystem

It may be expected that the management of the Norway pout fishery will include the setting of preliminary catch and/or fishing effort limits at the beginning of the year until scientific information is available in spring allowing for the final maximum fishing effort and/or catch levels to be fixed. The harvest rules should therefore include rules for setting preliminary and final fishing effort levels (expressed as a percentage of the reference level in kW-days) and/or catch levels.

b. The monitoring systems and assessment methodologies required to implement the advised harvest control rules.

c. Level of by-catches in Norway pout fisheries separated for Division IIIa and Subarea IV; and

d. Appropriate technical measures, including possible closed areas, to reduce bycatches, in particular, of cod, haddock, saithe, whiting and herring.

ICES is requested to submit its report on points a) to d). If point d) cannot be addressed at this time, ICES is requested to submit its advice to the Parties on the next possible occasion and in case no later than 2007.

16.5.2.1 Norway pout, ecosystem considerations

See Sections 5.1.1 and 16.5.1.3 for reviews on information regarding Norway pout as food for fish species.

16.5.2.2 By-catches in Norway pout fisheries

Demersal fisheries in the North Sea are mixed fisheries, with many stocks exploited together in various combinations in different fisheries. Small-mesh industrial fisheries for Norway pout takes place in the northern and northeastern North Sea and has by-catches of haddock, whiting, herring, saithe and blue whiting. Some cod is also taken as a by-catch, predominantly at ages 0 and 1 (ICES-ACFM 2005). With respect to un-intended by-catch in the commercial, small-meshed Norway pout trawl fishery in the North Sea and Skagerrak conducted by Denmark and Norway for reduction purposes, ICES-ACFM (2005) commented that management advice must consider both the state of individual stocks and their simultaneous exploitation. Stocks at reduced reproductive capacity should be the overriding concern for the management of mixed fisheries where these stocks are exploited either as a targeted species or as a by-catch (e.g. ICES-ACFM 2005).

Existing by-catch regulations:

In the agreed EU Council and EU-Norway Bilateral Regulation of Fisheries by-catch regulations in the Norway pout fishery have been established (e.g. EU Regulation No 850/98, EU 1998). The by-catch regulations in force at present for small meshed fishery (16-31mm in mesh size) in the North Sea is that catch retained on board must consist of i) at least 90% of any mixture of two or more target species, or ii) at least 60% of any one of the target species, and no more than 5% of any mixture of cod, haddock, saithe, and no more than 15% of any mixture of certain other by-catch species. Provisions regarding limitations on catches of herring which may be retained on board when taken with nets of 16 to 31 mm mesh size are stipulated in EU Community legislation fixing, for certain fish stocks and groups of fish stocks, total allowable catches and certain conditions under which they may be fished (EU 1998). Currently 40% herring is allowed in the Norway pout fishery.

Important by-catch species

By-catch of the following species in the commercial, small meshed Norway pout fishery has been a concern for fisheries management: Cod, Haddock, Saithe, Whiting, Monkfish, Herring, and Blue Whiting, where especially by-catch of juvenile haddock and cod as well as larger saithe has been in focus.

By-catch levels from landings statistics

In Tables 16.5.2.1-16.5.2.2 are presented recent (2002-2005) by-catch levels by species in Danish and Norwegian small meshed industrial trawl fishery in the North Sea and Skagerrak areas targeting Norway pout. For Norway the landings used for human consumption purposes in the small meshed fishery can only be allocated to industrial fishery for the last two years. Due to low Norway pout landings in recent years the Norwegian by-catch estimates are rather uncertain.

By-catch levels and factors affecting them from commercial fishing trials 2005:

Danish-Norwegian fishing trials and pilot investigations were performed in autumn 2005 in order to explore by-catch- levels in the small meshed industrial trawl fishery in the North Sea targeting Norway pout. The results are given in Degal et al (WD 22). The trial fishery was performed by two Norwegian commercial trawlers and a Danish commercial trawler traditionally involved in the small meshed industrial trawl fishery in the North Sea and Skagerrak targeting Norway pout. The investigation was in cooperation between the fisheries research institutes DIFRES and IMR. The South Norwegian Trawl Association (SNTA) and the Danish Fishermen s Association (DF) provided the contact to the fishing vessels used. The fishery was carried out in autumn 2005 within periods and areas of conducting traditional fishery for Norway pout. It should be noted that the Norway pout fishery was closed in 2005 due to low stock size, which might bias the by-catch proportions. The Norwegian vessels conducted each a survey to the area vest of Egersund on the edge of the Norwegian Trench. The Danish vessel conducted two surveys at Fladen Ground in and around the closed box for

Norway pout fishery in the North Sea. Comparison fishery between one of the Norwegian vessels and the Danish vessel was performed on a patio-temporally overlapping scale at the Patch Bank, a closed box for Norway pout fishery in an area between the Egersund Bank and Fladen Ground. The Norwegian vessels conducted both day and night fishery while the Danish vessel only fished during daytime. Since the trial fishery was conducted in closed areas and during a period when the ordinary fishery was closed, the results will not be directly comparable to a normal fishery situation.

The results (except for the figure and table showing the diurnal variation in the fishery) comprise only hauls from daytime fishery conducted with standard trawl gears used in the commercial small meshed industrial fishery targeting Norway pout. The skipper at the Danish vessel decided the positions and fishing design on a smaller fraction of the conducted hauls based on his evaluation of optimizing the fishery economically, while the rest of the hauls were allocated and pre-distributed in two selected ICES statistical squares.

In general the ratio between the Norway pout target species and the sum of by-catch of certain selected species indicate that the by-catch ratio is high in the commercial Norway pout fishery. However, statistical analyses reveal that the fishermen can significantly minimize the by-catch ratio by targeting in the fishery (temporal-temporal targeting, way of fishing, etc.), i.e. when they determine the fishing stations and the fishery performed. The pilot investigations show no general significant temporal-temporal patterns in the by-catch ratio. However, there are from the results obvious geographical and diurnal differences in the species composition of the by-catch between areas and between day and night fishery. The length distributions of the catch rates by species indicate spatial patterns between some of the species caught. These fishing trials and pilot investigations are based on only very few observations, and data are obviously rather uncertain, variable and noisy. In addition, the trials were conducted in area, closed with the purpose to reduce by-catch, and during a period when the ordinary fishery was closed. In general, it can be concluded that relatively high by-catches can be reduced by specific targeting in the fishery, both with respect to allocation of the fishery in time and space but also in relation to fishermen knowledge about the fishery and resource availability. This demands though that the skippers/fishermen act accordingly when fishing, and a proper at-sea control. The conclusions above relate to using the Turbotrawl and the Expo1300. The few experiments with Jordfraeser and Kolmuletrål 1100 indicate a different species composition, with unchanged or higher by-catch rates of most species and general significant lover catch rates of Norway pout.

With regard to diurnal differences in the catch rates of Norway pout and by-catches of other species, the few results at present indicate significant lower by-catch of Blue whiting during night hauls. The rest of the by-catch species show no diurnal differences

With regard to possible depth differences in the catch rates of Norway pout and by-catches of other species, this matter relates primarily to the areas close to the Norwegian Deep, and more investigations are about to be carried out to document this better.

16.5.2.3 Technical measures to reduce by-catches

Regulation of temporal-temporal effort allocation (closed seasons and areas):

The above investigations indicate spatio-temporal differences in catch levels by species in the commercial small meshed fishery for Norway pout as well as an effect of targeting and use of fishing method on the by-catches. However, these patterns are only based on results from pilot investigations. Knowledge about spatio-temporal patterns in catch rates of target species and by-catch species in the fishery are at present not adequate to implement management measures with respect to regulations on spatio-temporal allocation of fishing effort to reduce by-catches. During the 1960s a significant small meshed fishery developed for Norway pout in the northern North Sea. This fishery was characterized by relatively large by-catches, especially of haddock and whiting. In order to reduce by-catches of juvenile roundfish, the Norway pout box was introduced where fisheries with small meshed trawls were banned. The Norway pout box has been closed for industrial fishery for Norway pout since 1977 onwards (EC Regulation No 3094/86). The box includes roughly the area north of 56 N and west of 1W. In the Norwegian economic zone, the Patch bank has been closed since 2002. It is not possible to fully quantify the effect of the closure of the fishery inside the Norway pout box both with respect to catch rates of target and by-catch species as well as effects on the stocks (EU 1985, 1987a, 1987b; ICES-NPS 1979). There has not been performed fully covering evaluation of

the effect of closed areas in relation to interacting effects of technological development in the fishery including changed selectivity and fishing behaviour over time in relation to by-catch rates. These effects cannot readily be distinguished.

Gear technological by-catch reduction devices:

Investigations of gear specific selective devices and gear modifications to reduce un-wanted by-catch in the small meshed Norway pout fishery in the North Sea and Skagerrak have been performed in a number of studies. It was recently investigated based on sea trials in year 2000 and reported through an EU Financed Project (EU, 2002), and the results from here have been followed up upon in a scientific paper from DIFRES and CONSTAT, DK (Eigaard and Holst, 2004). Previous investigations of size selective gear devices in the Norway pout trawl fishery in the North Sea was performed by IMR Norway during sea trials in 1997-1999 also published in a scientific paper (Kvalsvik *et al*., 2006), as well as in a number of other earlier studies on the issue. Main results of previous investigations have been reviewed and summarized in Nielsen and Madsen (WD 23).

Early Scottish and Danish attempts to divide haddock, whiting and herring from Norway pout by using separator panels, square mesh windows, and grids were all relatively unsuccessful. More recent Faeroese experiments with grid devices have been more successful. A 74 % reduction of haddock was estimated (Zachariassen and Hjalti, 1997) and 80% overall reduction of the by-catch (ICES-SGGSS 1998).

Eigaard and Holst (2004) and EU (2002) found that when testing a trawl gears with a sorting grid with a 24 mm bar distance in combination with a 108 mm (nominal) square mesh window through experimental, commercial fishery the results showed improved selectivity of the commercial trawl with catch weight reductions of haddock and whiting of 37 and 57%, but also a 7 % loss of Norway pout. The study showed that application of these reduction percents to the historical level of industrial by-catch in the North Sea lowered on average the yearly haddock by-catch from 4.3 to 2.7% of the equivalent spawning stock biomass. For whiting the theoretical reduction was from 4.8 to 2.1%. The purpose of the sorting grid was to remedy the by-catch of juvenile gadoids in the industrial fishery for Norway pout, while the purpose of square mesh window was to retain larger marketable consume fish species otherwise sorted out by the grid. By-catches in this study were mainly evaluated for haddock, whiting and cod, i.e. not for all above mentioned by-catch species of concern in the Norway pout fishery.

However, the experiments have shown that the by-catch of important human consumption species in the industrial fishery for Norway pout can be reduced substantially by inserting a grid system in front of the cod-end. The study also demonstrated that it is possible to retain a major part of the larger marketable fish species like whiting and haddock and at the same time maintain substantial reductions of juvenile fish of the same species. The study also gave clear indications that further improvement of the selectivity is possible. This can be obtained by adjusting the bar distance in the grid and the mesh size in the selective window, but further research would be necessary in order to establish the optimal selective design.

The results reported in Kvalsvik *et al*. (2006) include results for more species of concern in the Norway pout fishery. They carried out experimental fishing with commercial vessels first testing a prototype of a grid system with different mountings of guiding panel in front of the grid and with different spacing (25, 22 and 19 mm) between bars, and then, secondly, testing if the mesh size in the grid section and the thickness of the bars influenced the selectivity of the grid system. Two different mesh sizes and three different thicknesses of bars were tested.

Based on the first experiments, only a bar space of 22mm were used in the later experiments.

These showed respectively that a total of 94.6% (weight) of the by-catch species was sorted out with a 32.8% loss of the industrial target species, where the loss of Norway pout was around 10%, and respectively that 62.4% of the by-catch species were sorted out and the loss of target species was 22%, where the loss of Norway pout was around 6%. When testing selectivity parameters for haddock, the main by-catch species, the parameters indicated a sharp size selection in the grid system.

In conclusion, the older experiments indicate that there is no potential in using separator devices and square mesh panels. Recent and comprehensive experiments with grid devices indicate a loss of Norway pout at around 10% or less when using a grid with a 22-24 mm bar distance. It is also indicated that there is a considerable loss of other industrial species being blue whiting, Argentine and horse mackerel. A substantial by-catch reduction of saithe, whiting, cod, ling, hake, mackerel, herring, haddock and tusk have been observed. The reduction in haddock by-catch is, however, lowered by the presence of smaller individuals. The Danish experiment indicates that it is possible to retain larger valuable consume fish species by using a square mesh panel in combination with the grid. Selectivity parameters have been estimated for haddock, whiting and Norway pout. These can be used for simulation scenarios including estimates of the effect of changing the bar distance in the grid. Selectivity parameters for more by-catch species would be relevant. However, the grid devices have shown to work for main by-catch species.

A general problem by implementing sorting grids in industrial fisheries is the very large catches handled. Durability and strength of the grid devices used under fully commercial conditions are consequently very important and needs further attention. Furthermore, handling of heavy grid devices can be problematic from some vessels. Grid devices are, nevertheless, used in most Pandalus fisheries, where catches often are large.

Conclusions from section 16.5.2.2-16.5.2.3

In conclusion, the commercial, exploratory fishery and provision of recent by-catch information has shown by-catch-ratios to be significant in the fishery, however, spatio-temporal differences in catch levels by species has been observed and by-catches can be reduced through targeting and fishing method. Recent scientific research based on at sea trials in the commercial fishery has shown that use of gear technological by-catch devices can reduce by-catches of among other juvenile gadoids significantly. Accordingly, **the WG conclude that the use of these gear technological by-catch reduction devices (or modified forms of those) in the fishery may be beneficial**. Introduction of those should be followed up upon by adequate landings or at sea catch control measures to assure effective implementation of the existing by-catch measures.

16.5.2.4 Suggestion for a HCR for 2007

Suggested HCR for 2007

1) A preliminary TAC for 2007 shall be set such that the spawning stock in the beginning of 2008 is estimated above Bpa.
2) No more than 25 % of this preliminary TAC may be taken during the first half of 2007.
3) A final TAC for 2007 shall be set during the first half of 2007 on the basis of advice from ICES in spring 2007 based on:

a) the criterion mentioned in point 1,
b) the most recent survey information,
c) complete catch information from 2006 and
d) an assumed recruitment of the 2007 year class of 25 % of the long-term
e) geometric mean

Comments:

(Point 1) The reason for setting a preliminary TAC for 2007 is that this will be based on a veryuncertain forecast. Norway pout is a short-lived species, and catches are dominated by 1-group. In addition, significant amounts of 0-group may be caught towards the end of 2007.

The only information in autumn 2006 about the number of 1-group in the start of 2007 is the 0-group index from the most recent Scottish groundfish survey. The number of 0-group entering the stock in 2007 will have to be assumed, and a suitable candidate for this 25 % of the long-term geometric mean.

(Point 2) If the preliminary TAC is higher than the final TAC, the latter can be over-fished if the (entire) preliminary TAC is taken during the first half of 2007. To keep the probability lowthat this happens, a restriction for the first half of 2007 is introduced. The maximum proportion of 25 % corresponds approximately to the average proportion of the Norway pout landings taken during the first half of the year during 2002-2004.

(Point 3a) This refers to the spawning stock in the beginning of 2008 being above Bpa.

(Point 3b) The most recent survey information refers to the IBTS quarter 3 indices from 2006 and the IBTS quarter 1 indices from 2007. The 1-group index from the IBTS quarter 1 survey is particularly important for the revised forecast (that the final TAC will be based on).

(Point 3c) This refers to the catch at age and total landings for 2006.

(Point 3d) The reason for using the conservative assumption of 25 % of the long-term mean, and not the more common assumption of the geometric mean, is that the recruitment seems to have changed to a lower level in recent years compared to earlier.

Evaluation of the suggested HCR

The WG was not in the position to evaluate the suggested HCR for Norway pout.

Table 16.5.2.1 Landings (tons) per species in the Danish small meshed Norway pout fishery in the North Sea by year and quarter. Landings are divided into the part used for reduction purposes and the part used for human consumption purposes. The latter landings are included in catch in numbers of human consumption landings.

Year	Species	Purpose	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Blank	Total	% of total catch
2005	Norway pout	Reduction						0	0
2004		Reduction	504		1474	5877		7855	87.5
2003		Reduction		45	1556	6322		7923	87.8
2002		Reduction	2,576		6,803	26,667	6,508	43221	78.6
2005	Blue whiting	Reduction						0	0
2004		Reduction	66					66	0.73
2003		Reduction		10	23	8		50	0.55
2002		Reduction	1800		569	800	1171	4070	8.50
2005	Herring							0	0
2004			11		422	304		737	8.21
2003				1	113	222		336	3.73
2002					217	2337	580	3108	6.81
2005	Cod	Reduction						0	0
		Hum. Con.						0	0
2004		Reduction				1		1.3	0.01
		Hum. Con.	0.3		0.2	0.3		0.8	0.01
2003		Reduction				3		3	0.03
		Hum. Con.			0.5	0.8		1.3	0.01
2002		Reduction				3		3	0.01
		Hum. Con.	2		15.4	22.7		40.1	0.07
2005	Haddock	Reduction						0	0
		Hum. Con.						0	0
2004		Reduction	5		49	3		57	0.63
		Hum. Con.	0.2		0.2	0.5		0.9	0.01
2003		Reduction				16		16	0.18
		Hum. Con.			0.1	1.8		1.9	0.02
2002		Reduction			403	1137		1540	2.81
		Hum. Con.	0.7		4.3	6.8		11.8	0.03
2005	Whiting	Reduction						0	0
		Hum. Con.						0	0
2004		Reduction	32		59	141		232	2.58
		Hum. Con.	0.4		0.3	0.2		0.9	0.01
2003		Reduction			61	214		265	2.94
		Hum. Con.			0.3	2		2.3	0.03
2002		Reduction			239	1436		1675	3.06
		Hum. Con.			5.4	5.5		10.9	0.02
2005	Saithe	Reduction						0	0
		Hum. Con.						0	0
2004		Reduction						0	0
		Hum. Con.	0.7		5.8	4.2		10.7	0.12
2003		Reduction		0.4	4	22.0		27.2	0.30
		Hum. Con.						0	0
2002		Reduction			40	201		240	0.45
		Hum. Con.	30		84.3	66.3		180.6	0.33
2005	Other human	Hum. Con.						0	0
2004	Cons. Species	Hum. Con.	0.9		2.7	2.5		6.1	0.07
2003		Hum. Con.		0.8	2.2	6.2		9	0.10
2002		Hum. Con.						0	0
2005	All species	All						0	0
2004		All	626		2028	6321		8983	100
2003		All		60	2023	6929		9023	100
2002		All	4511		6815	31867	11767	54960	100

Table 16.5.2.2. Landings and by-catches in the Norwegian Norway pout fishery 2002-2004 (only for reduction). In 2005 Norway pout was only landed as by-catch in the blue whiting fishery

Year	Unit	Norway pout	Blue whiting	Herring	Cod	Haddock	Whiting	Saithe	Other	Sum
2002	%	72,6	12,2	3,3	0,0	1,8	3,0	5,3	1,8	100
	Tonnes	17151	2881	779	10	432	700	1257	428	23638
2003	%	52,9	6,7	6,6	0,0	5,9	5,1	18,8	3,9	100
	Tonnes	6027	764	755	0	675	576	2139	447	11383
2004	%	86,9	3,2	0,9	0,5	1,6	0,9	3,1	2,8	100
	Tonnes	4344	158	45	26	78	47	157	142	4998

Annex 3: List of Participants

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Annex 4: Meeting Agenda

Dear all, I will like to welcome you all to the AG NOP meeting during the 1-2 March at the ICES Headquarters.

1. I suggest that we start the meeting at 9.30 AM 1st of March 2007

2. You have all got access to the SG Sharepoint (below). I have under the working directory SG_NOP_Docs placed some relevant background information and preliminary input to be used in addressing the TORs. This will naturally be up-dated runningly.

3. I hope you agree that we start the meeting with the following agenda issues:

a. Welcome and practical details

b. Go through the TORs

c. Short presentation of some relevant background information:

i. 2006 Catches and By-catches (have not obtained the information from Norway yet)

ii. Up-dated survey indices

iii. Correlation plots of survey indices, commcercial tuning fleets, etc. from last benchmark assessment

iv. Correlation plots between E and F

v. Population dynamics driving the advice (with special reference to M) and assumptions on those (also issues of S-R-relationship, growth (in stock), spawning maturity, etc. is important here)

d. Short notice on management strategy used for 2006 (known in advance)

e. Presentation of preliminary thoughts in relation to simulations to be used to advice management strategies

f. Preliminary discussion on potential management strategies

g. Decision on further workplan and agenda as well as the report composition (see draft suggestion on sharepoint) and further details of this.

I look forward to see you, Best regards, Rasmus