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REPORT OF THE STUDY GROUP ON MANAGEMENT STRATEGIES (SGMAS)

22 – 26 JANUARY 2007

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Contents

1 Introduction

1.1 Terms of reference

Council resolution 2006/2/ACFM22 stated that:

The **Study Group on Management Strategies [SGMAS]** (Chair: D. Skagen, Norway) will meet from 22 to 26 January 2007 at ICES HQ to:

a) Review and further develop specific evaluations of harvest control rules or management strategies that have been carried in working groups in 2006;

b) Review ongoing work on design and evaluation of management strategies;

c) Review and further develop methods;

- for estimating potential target references points for fish stocks taking into account the possible effects of species interactions and regime shifts
- for incorporating fleet-dynamics into management strategy evaluations, including mixed fisheries dynamics
- for data poor situations
- using other management instruments than TACs derived from annual estimates of stock abundance, like indicator based management, closed areas and direct effort regulation

d) Suggest processes for developing management strategies and harvest control rules in interactions between managers, stakeholders and scientists;

e) Update the framework and operational guidelines for the evaluation of fisheries management strategies with the findings from above.

The group met as planned. The list of participants is provided in Appendix 1.

This year, the meeting was open to participation from stakeholders and managers. One representative from the Pelagic RAC and one from NEAFC took part in the meeting. Rather than acting as observers, these participants were urged to take active part in the meeting in line with other participants. The group agreed that this arrangement was successful and very helpful in the discussions.

1.2 Background

The SGMAS was established in 2005 to provide ICES with guidelines for the evaluation of management strategies in general and harvest control rules in particular. It met previously in 2005 and 2006 The report from 2006 provides guidelines as requested, reflecting the state of the art at the time. However, some important fields were only superficially covered, such as ecosystem aspects of fisheries management, management of mixed fisheries and multispecies interactions.

At the 2006 ASC, a process was outlined where the ecosystem aspects in particular, but also other aspects of management strategies were allocated to separate expert groups to allow more specific, in-depth considerations of these items, with the ambition to merge the insight at a later stage. The view was that the SGMAS in the meantime should continue with a revised mandate, to keep track of the developments in the field and update the guidelines if necessary. The council endorsed this process, as reflected in the current terms of reference. Accordingly, the SGMAS this year revisited some management plans that have been developed, aiming to learn from experience, and reported on new developments in the field. Therefore, the present report is not a revision, but a supplement to the guidelines provided in 2006.

1.3 Overview of the report

The Terms of Reference were addressed as follows:

ToR a is covered in Section 2. A selection of stocks was considered, both stocks where management plans have been evaluated previously, and stocks where management plans are under development. The selection of stocks was largely restricted to those that were familiar to members of the group. Main emphasis was on experience gained and lessons learned, and feedback to the process as relevant. Both stocks inside and outside the EU were considered, and both successes and failures.

ToR b seemed to overlap with ToR a to some extent. In addition, the group made an inventory of current projects in EU related to management strategies (Section 5), noting the relevance of these projects to the development of management strategies, but without attempting to evaluate quality or progress.

Under ToR c the group mainly concentrated on the use of indicators as guidance for tactical decisions. Such indicators are increasingly being discussed in relation to ecosystem management, but may also be considered for fish stock management, in particular in cases where the information about the stock and the fishery is insufficient to follow the usual procedure of deriving management actions from estimates of fishing mortality and biomass through analytic stock assessments. The SGMAS found this to be a promising approach, but also recognised that the insight in how such management arrangements may work is sparse, and that proper evaluation of such arrangements still has many unsolved problems.

The group was only able to cover the other aspects of ToR c in a fragmentary way. The conceptual difference between –pa reference points and target reference points was noted. The group did not come up with specific guidelines for deriving targets.

A main theme for the SGMAS this year was the process of developing management plans. The interaction between managers, stakeholders and scientists (ToR d) is discussed in Section 6. An outline of the scientist's role in various stages of the process is given in Section 2.4. The experience from previous and current development processes is reflected under the individual stocks in Section 2, and summarised in Section 2.4. Section 2.4 also contains some advise on interpreting formal management plans, following up work initiated by WGMG in 2006.

This year, a number of ICES expert groups deal with items that are relevant for the future development of management strategies, to some extent supplementing aspects that were insufficiently covered by the previous SGMAS. The workshop WKEFA on the 'Integration of Environmental Information onto Fisheries Management Strategies' has been established, to deal with environmental aspects of management strategies, recognising the need to consider these aspects more in depth. The SGMIXMAN is progressing on modelling of mixed fisheries dynamics. WGSAM (Working Group on Multispecies Assessment Methods) will address multispecies issues. The Methods WG has methodological issues relating to our work on the agenda. A Workshop on Limit and Target Reference points (WKREF) will meet just after our group. SGMAS regards the role of all these groups in development and evaluation of management strategies as complementary to what SGMAS itself does. Rather than duplicating the work by these groups, SGMAS assumes that the insight gained by them can be synthesized by SGMAS in due time.

2 Review of management plans

2.1 Plans recently reviewed

2.1.1 North Sea haddock

In April 2006 ICES received a request for evaluation of the management plan for North Sea haddock, sent by the European Commission and Norway. The evaluation of the management plan was subsequently presented and discussed in a number of ICES groups, the first of which was WGMG, followed by WGNSSK and the ACFM meeting in October 2006. The text of the management proposal was first translated into a structured decision diagram, serving as a basis to set up simulations, but also revealing holes and ambiguities in the managers' proposals. The decision diagram was put into a simulation framework, together with the assumptions on the dynamics of the system in which the management plan is meant to operate. Indeed the above procedure showed that the original text was not clear on the entire management procedure. As a result of this, a set of simpler Harvest Control Rules that encapsulate the main features of the management plans were considered, as was clearly stated in the evaluation of the plan. The three HCRs that were simulated included: a target F, a fixed TAC, and a target F with a limit in the amount of inter-annual change possible in TACs. Additionally, intended F could only vary by 25% from current F.

The assumptions about the system used in the simulations (also known as Operating Model) are well described. Several of the components in the system are modelled in a stochastic way to reflect the uncertainty about these components, or the imprecision in information flow between the fishery and the management procedure. Particularly, these are the recruitment of the stock and the estimation of landings and discards in the simulation model. The unpredictably sporadic nature of the recruitment of the stock has been modelled using increasingly advanced methods.

The effect of the stock assessment method on the performance of the Harvest Control Rules is estimated directly by explicitly using a stock assessment procedure in the simulations. However, no comparisons were made to simulations where the knowledge about the stock in the management procedure is perfect.

The results of study summarize the probabilities of SSB or F passing the reference levels for each of the HCRs. Because these results are dependent on for instance the assumptions of the future recruitment, the different reports give different probabilities for the individual HCRs. However, the HCR with a target F of 0.3 with a constrained TAC change of 15% has a low (<12%) probability of SSB falling below B_{lim} in both studies. The authors further conclude that the evaluation is sensitive to the acceptable risk level (assumed to be 10%), the particular reference points used for testing, and assumptions about recruitment, growth, and so on. However, no explicit conclusions are drawn on the relative sensitivity of these results to the individual assumptions. Such sensitivity analysis might be helpful in the dialogue between the stakeholders and fisheries science to prioritize future effort in the evaluation of the management plan.

Throughout the description of the evaluation, much attention has been drawn to the fact that it does not constitute a formal review of the complete management plan, as this could not be done because of the ambiguities in the rules. Specifically, the evaluation is only really appropriate when biomass is greater than Bpa. As a result, it is concluded that evaluations must be done in collaboration with managers and stakeholders in order to avoid the problems caused by ambiguous interpretation of the management plan. It is stressed that negotiations cannot be simulated in a numerical framework.

In conclusion: The evaluation request was followed by a series of descriptions of the evaluation in different ICES fora, but no formal final document has been presented yet. Because of ambiguities in the management plan as it was proposed in the request, a derived set of HCRs was evaluated. The simulation model used to evaluate the management plan encompasses the some of the major stochastic processes, in particular the recruitment. Much effort has been put to model this in increasing detail. The general sensitivity of the outcomes of the results to the assumptions in the model has been highlighted, but no further sensitivity analysis has been presented on this. Lack of dialogue between the stakeholders and ICES has prevented a further clarification of the management plan after the description of the ambiguities in the original plan.

2.1.2 Northeast Arctic haddock

At the 31st session of The Joint Norwegian-Russian Fishery Commission in autumn 2002, the Parties agreed on a new harvest control rule for Northeast Arctic cod and haddock. The rule for cod and haddock was somewhat amended at the 33rd session of The Joint Norwegian-Russian Fishery Commission in autumn 2004. The harvest control rule for cod and haddock is described in the section on Northeast Arctic cod (2.2.4). Reference points for this stock used by AFWG in the HCR so far for haddock: B_{pa}=80 000 tonnes, F_{pa}=0.35, Reference F: $F_{4\text{-}7}$, arithmetic average.

It took some years from the HCR for haddock was established until it was evaluated. The reason for this was partly that one awaited the evaluation of a similar rule for Northeast Arctic cod (see section 2.2.4). Also, there was a need for revising the time series used in the assessment. The revision of the time series was carried out during the WKHAD meeting in March 2006 (ICES, 2006d), when also the reference points and HCR for this stock were evaluated. The evaluation of the HCR was completed during the ICES AFWG in 2006 (ICES, 2006e), and submitted to ACFM. On request from ACFM, additional evaluation work was done by an IMR sub-group of AFWG after the ACFM meeting in May 2006. (Anon. 2006). This evaluation was submitted to ACFM in June 2006. The response to request from ACFM is given below:

"The result that was presented by the NEA Haddock management plan evaluation group was found by the review group to be lacking in particular with respect to the influence of the recruitment pattern. It was argued that the recruitment pattern is rather abnormal and that the standard model that was used did not fully include the special features that pertain to haddock. As the request from Norway and Russia in particular mentions the recruitment pattern we find that this should be addressed explicitly and with a model that include the special features of the haddock recruitment. It has been proposed that this should be done using the PROST model but also that this might involve some additional programming.

The other issue is the implementation error and the management plan needs to be checked against (the evaluation report only includes 0% and 27% implementation error. we would like to see a more continuous range of values e.g. 0, 10, 20, 30 and 40%).

I hope that it will be possible for IMR to provide this background calculations within say 2 weeks to enable an advice before the end of June."

In the June 2006 evaluation, a 7-year recruitment cycle was assumed, see the text table below.

YEAR	1	2	3	4	5	6	7
Recruitment	Low	Low	Low	Low	Good	Outstanding (p=0.3) or Good (p=0.7)	Good

The "low" and "good" recruitment functions are Ricker functions with a stochastic term, while the "outstanding" recruitment function uses a 'hockey-stick' function with a stochastic term.

This pattern will be similar to the conditions observed in the 1980's and early 1990's. The simulation is slightly on the conservative side in that respect relative to the current recruitment conditions, but longer periods of low recruitment have been observed previous to 1980. An advantage of using this recruitment model is that it is tested how the HCR performs when a series of several weak year classes occurs.

The main conclusion of the new evaluations was that the rule was precautionary, provided that the 3-year rule was replaced by a 1-year rule (i.e. not making a 3-year average for setting the TAC, but calculating it based on the stock size in the prediction year). Evaluations of the HCR were carried out for different trigger points.

ACFM did not accept the AFWG assessment of haddock for 2006 and ICES recommended keeping the catches at or below recent levels (<130 000 tonnes). The Commission chose to set the TAC on an ad hoc basis for 2007 (TAC=150 000 tonnes). This corresponds to a 25% increase from the 2006 TAC. For later years, the '3-year' HCR rule will be used until new evaluations are available. The Commission did, however, ask the scientists to make a new evaluation of the haddock HCR so that a possible change to a 1-year rule could be considered at the 2007 Commission meeting. As a 1-year rule was actually evaluated by ICES in 2006, it is not yet clear how this request will be handled. The actual use of the rule in management advice in the recent years is described in the text table below.

YEAR	TAC ACCORDING TO HCR	AGREED TAC	REPORTED CATCHES	CATCHES USED BY AFWG
2004	------	130	125	155
2005	117	117	114	154
2006	120	120		
2007	150*	150		

---: TAC according to HCR not given in report.

*: Assessment not accepted by ACFM

Target reference points for haddock have not been investigated in detail, but the evaluations included simulations with fishing mortalities both higher and lower than F_{pa} (chosen as F_{target} in the HCR). These simulations indicated that the chosen F_{target} gave slightly higher long-term yield than lower or higher fishing mortalities.

The evaluation of the HCR for Northeast Arctic haddock is very similar to the evaluation of the HCR for Northeast Arctic cod. Comments to the cod evaluation and to whether it followed the SGMAS guidelines are given in Section 2.2.4.3. Most of these comments apply also to Northeast Arctic haddock. However, the sensitivity of the performance of the haddock HCR to the choice of recruitment function would be worthwhile to investigate in more detail.

From this evaluation we have learned that the "3-year" rule may not be appropriate for a stock with large recruitment variations. Concerning the stock/recruitment relationship for this stock, there is a need for further research. A comparative study with other stocks with spasmodic recruitment would be useful, in order to model recruitment of such stocks satisfactory in a HCR evaluation context.

2.1.3 Sandeel in the North Sea

2.1.3.1 Background

Management of North Sea sandeel is particularly problematic due to the fishery being principally on the 1-group whilst there is no reliable assessment estimate of this year class at the time of the December council to assist TAC setting.

The total landings of sandeel from the North Sea were at a historic low level in 2003. Due to the scarcity of the 2002 year-class the strength of the 2003 year-class was particularly important to the state of the stock in 2004. For this reason the EU adopted the following ad hoc harvest control rule for the 2004 fishery for sandeel in the North Sea at the Council meeting in December 2003:

where STECF estimates the size of the 2003 year class of North Sea sandeel to be at or above 500 000 million individuals at age 0, no restrictions in kilowatt-days shall apply;

where STECF estimates the size of the 2003 year class of North Sea sandeel to be between 300 000 and 500 000 million individuals at age 0, the number of kilowatt-days shall not exceed the level in 2003 as calculated in total kilowatt-days;

where STECF estimates the size of the 2003 year class of North Sea sandeel to be below 300 000 million individuals at age 0, fishing with demersal trawl, seine or similar towed gears with a mesh size of less than 16mm shall be prohibited for the remaining of 2004.

In order to facilitate the estimation of the 2003 year-class an *ad hoc* WG (STECF, 2004) under STECF was established with the specific purpose to assess the strength of the 2003 year class. The sandeel fishery in the EU-zone of the North Sea is mainly Danish, and the necessary data for assessing year class strength is based on Danish data obtained from the commercial fishery. The basic assessment methodology was a regression of recruitment indices against XSA estimated figures for the corresponding 1-groups, which are the youngest fish caught in the beginning of the fishery season. From the CPUE of 1-group, the historical relation between CPUE and stock size of 1-groups, and an assumed mortality of 0-groups, the observed 1-group CPUE index was translated into the recruitment strength at age 0. The ad hoc WG concluded that a reasonable precision of the recruitment could be obtained from the fishery using data for the period including April (10–30% of the annual catches).

The 2003 year class

The ad hoc WG provided a final estimate of the size of the 2003 year class in May 2004. The available CPUE data up to week 17 gave an estimate of more than 600 billion individuals at age 0 of the 2003 year class and concluded that, according to the HCR set up by the Commission, there should be no restrictions on effort for the 2004 fishery. This observation was then evaluated by STECF and the group concluded that when year-classes are from average to weak, the ability of the method used to classify year-class strength is highly unreliable. STECF recommended that in keeping with the precautionary approach, fishing effort for North Sea sandeel in 2004 be restricted to a maximum level no greater than that deployed in the fishery for North Sea sandeel in 2003 (level b in the HCR).

As a response to the critique from STECF the precision of the method was improved during a new ad hoc WG in Feb 2005 (STECF, 2005). This improvement was obtained simply by excluding very strong year-classes from the stock-number - CPUE regression.

The 2004 year class

The fishery in 2005 had an extremely low CPUE in the beginning of the season and both the *ad hoc* WG and STCEF concluded that the fishery should be closed for the rest of 2005 (level c in the HCR).

The 2005 year class

For 2006 the fishery had late start but relatively high catch rates later on. The ad hoc WG fisheries estimated the size of the 2005 year class to 507 billion using data up to and including week 17 (level a in the HCR).

Based on the report of the ad Hoc WG, STECF recommended:

- "… *they*" (the year class estimates) "*should not be accepted as a true reflection of the size of the 2005 year class and hence should not be used to automatically invoke the harvest rule agreed in Annex IID of Council Regulation (EC) 51/2006 of 22 December 2005*".
- "*… catches in 2006 should be restricted to a level that is predicted to result in the SSB being above Bpa (600 000 t) in 2007, under the assumption that the 2005 year-class strength at age 0 was less than 507 billion*".
- "*... alternative management and assessment methods for North Sea sandeel are evaluated, including the utility of alternative harvest control rules and closed areas taking into account ecosystem-orientated management aims*".

STECF concluded "… *it is reasonable to assume that the 2005 year-class strength at age 0 was at least as strong as the preceding 2003 and 2004 year-classes, which were estimated at 345 billion and 324 billion respectively and notes that this conclusion implies automatic implementation of option b) of the harvest rule. However STECF notes that implementation of option b) of the harvest rule could result in catches up to 300 000 t, which would offer no assurance that SSB in 2007 will be above Bpa*".

STECF noted "… *that there is a real possibility that SSB will be above Bpa in 2007 if effort and catches in 2006 are limited to the levels observed in 2005. This implies that catches in 2006 should be limited to about 170 000 t*".

Following the advice from STECF the fishery for the rest of the 2006 fishing season was managed through a TAC on 300 000 t and a maximum limit on effort on 40% of the effort applied in 2003.

Lesson learned from the 2004–2006 real time monitoring

<u>Do not use a step function to derive a TAC</u>. One of the problems with the HCR applied was the three distinct values of TACs. For example, a year-class of 299 billion the fishery should be closed, while a year-class of 301 billion would allow a TAC of 300 000 t. The estimate of the 2004 year-class was close to 300 billion and the 2005 year-class close to 500 billion, such that a relative small increase or decrease in CPUE from week to week had a very big impact on the resulting TAC, This gave a very intense debate between scientist and the fishing industry about the timing of the final result from the monitoring, which probably could have been avoided if the HCR had used a smooth function to derive the TAC from the real time estimate.

<u>The scientific evaluation is done relatively fast</u>. The final evaluations done by STECF on the basis of the results from the *ad hoc* WG on sandeel have been done relatively fast. For the 2004 year-class, where the advice was a closure, the evaluation took just a day without any discussion of the methodology. It took however almost a week to evaluate and give advice on the 2005 year-class where the estimate from the *ad hoc* WG was around 500 billion individuals. As it can be seen from the sections above, no clear advice was given by STECF in that case.

<u>Structural changes in the fishery happen quickly and may violate the assumptions for the method.</u> There has been a substantial reduction in the fleet capacity in the last 3 years due to the low sandeel catches and decommissioning. Total international effort has decreased by more than 50% over the period 2002–2006. The number of Danish fishing vessels participating in the sandeel fishery has been reduced by almost 50% and the Norwegian vessels by much more in the same period. The real time monitoring is based on the assumption that there is a fixed relation between CPUE and stock size, but this assumption might be violated with the much smaller fishing fleet. With a smaller fleet the competition for the best

fishing banks is reduced, such that the average CPUE can remain high even though the stock size has decreased.

In 2006 it was observed that the fishery was concentrated on a fewer banks than normal, which might simply be the result of a smaller fleet or a smaller stock – we don't know yet.

2.1.3.2 Management measures for 2007

Most of the work with developing sandeel HCR was done by STECF working groups outside ICES. In 2006 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*".

The request for ICES advice on management measures concerning sandeel is quoted below:

> *a. Harvest control rules for sandeel in the North Sea and Skagerrak that:*
>
> *i. Allow the Maximum Sustainable Yields to be obtained and are consistent with the precautionary approach.*
>
> *ii. Prevent any local depletion of sandeel aggregations, and*
>
> *iii. Take into account the function of sandeel in the ecosystem.*
>
> *It may be expected that the management of the sandeel fishery will include the setting of preliminary catch and/or fishing effort limits at beginning of the year until scientific information is available allowing for the fixing of the final maximum fishing effort and/or catch levels. 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.*

Points b) - d) of the request are not shown.

The request was handled by WGNSSK and ACFM in the autumn 2006. ICES recognized the need for a HCR that takes the spatial structure of the population (request a ii) and ecosystem considerations (request a iii) into account, however it was concluded that the scientific knowledge was not sufficient to take these topics into account in the new HCR.

ICES formulated a revised version of the HCR based on real-time monitoring, based on the experience from 2004–2006 system. The suggested HCR is based on the escapement strategy, where the target is to maintain a minimum SSB after the fishery has taken place. The HCR used for 2004–2006 determined TAC purely from the abundance of the 1-group, but with the present triggers and TAC this HCR was not precautionary in some cases.

The simulation was done using the SMS software and followed the guidelines from SGMAS. The complex spatial structure of the population was taken into account. The proposed HCR requires an estimate of the abundance of the 1-group from real time monitoring and an estimate of older sandeel from the stock assessment, which makes the HCR sensitive to uncertainties in both estimates. Both noise and bias (up to 50% overestimate of the 1-group) in the stock estimate from both real time monitoring and stock assessment have been large and are included in the simulation.

Comments to the ICES evaluation

Due to the very large bias in both real-time monitoring and assessment the, it was necessary to include maximum values (cap values) for both effort and TAC to reach the objective of having a SSB above Blim. The upper limit for effort was set to justify an upper limit on the "true F" used in the simulation. The choice of maximum effort and the corresponding F seems well justified, even though the absolute value of cap F (implemented as an absolute effort) cannot be estimated without large uncertainties.

Simulations so far have indicated that both the cap on F and a maximum catch are necessary to maintain a low risk of reaching Blim. Therefore, this harvest rule may in practise act as a constant-F rule with a maximum catch or a fixed catch rule with an F-limitation, both supplemented with additional measures to reduce the TAC if there are indications form the early fishery that incoming year classes are poor. Previously, this fishery has been self-regulating to a large extent, and the option to manage it primarily by constraining the fleet capacity, but with some extra precaution may still be relevant, in particular because the basis for setting TACs is uncertain due to the rapid turn-over in the stock.

Future effort

Bias on the assessment seems to have a major influence on the performance of the HCR. The 2004–2006 HCR is purely based on real time monitoring of the 1-group, so assessment does not influence the performance for this approach.

With the present low stock size the major contribution to the SSB in the year after the fishery has taken place is coming from the 1-group which abundance are estimated by real time monitoring. It might have been useful to investigate an adjusted version of the 2004-2006 HCR as this HCR is purely based on real time monitoring of the 1-group and does not rely on the stock assessment.

2.1.4 Blue Whiting

2.1.4.1 The process of establishing the management plan

From 1993, NEAFC managed the stock of blue whiting in the northeast Atlantic by an unallocated TAC of 650 000 tonnes. Of the relevant coastal states, only EU adopted comprehensive conservation measures with catch restrictions covering both Community and international waters. The absence of similar restrictions on the part of the other coastal States caused no major problems until 1997 as the overall catches had stayed well within the TAC.

From that time, catches increased dramatically so that by 1998 they were already at about 1 100 000 tonnes.

NEAFC recognised the need for fully-fledged regulatory measures at the 1998 Annual Meeting and so a Working Group on Blue Whiting was established, meeting for the first time in May 1999. The Working Group presented its report in early 2000. In February 2000, the five relevant coastal States of NEAFC (EU, The Faroe Islands, Greenland, Iceland and Norway) met for the first time to consult on regulatory measures for the blue whiting stock.

During the course of the next 5 years, more than 15 meetings between the coastal States were held – without significant results.

In 2005, the catching sector in EU took the initiative for representatives from the catching sectors from EU, Iceland, Norway, The Faroe Islands and Russia to meet. The European catching sector felt threatened by the fact that they – as the only of the different parties – were limited in their fishing opportunities, since only the EU had catch restrictions.

In the course of the summer and autumn of 2005 representatives from the catching sectors from EU, Iceland, Norway, The Faroe Islands and Russia met a number of times. The goal of the meetings was to try and break the deadlock between the coastal states in trying to find an agreement on the sharing of the fishing opportunities and the creation of a robust management plan. The parties soon realised that only by tying rules for setting the TAC, rules for sharing the fishing opportunities and the long-term management plan together would it be possible to reach an agreement.

In mid September 2005, the catching sectors from EU, Norway and Iceland managed to reach agreement on all items, and the agreed Management Plan for blue whiting was presented to the coastal states on a meeting in Reykjavik in late September.

The plan read:

Management Plan for Blue Whiting

The following organisations:

The Norwegian Fishing Vessel Owners Association (Norway)

Northern Pelagic Working Group (EU)

The Federation of Icelandic Fishing Vessel Owners (Iceland)

recommend to the respective authorities the following Management Plan for the Blue Whiting fisheries in the Northeast Atlantic Ocean:

1. *The management plan is for the five-year period 2006-2010. The plan shall be reviewed before the end of this five-year period.*
2. *The TAC for Blue whiting in the first year, 2006, shall be 2 million tonnes.*
3. *For each succeeding year the TAC shall be reduced by 100,000 tonnes annually, unless this results in the SSB falling below 2,25 mio tonnes. However, should a fishing mortality of F=0,32 result in a higher TAC, then this should be implemented.*
4. *The objective is to attain a fishing mortality of F=0.32 within five years.*
5. *Spawning stock biomass (SSB) shall be maintained at values exceeding 2.25 million tonnes.*
6. *Special measures should be adopted to protect juvenile Blue Whiting.*
7. *Percentage shares of the Blue Whiting TAC should be allocated as follows:*

EU and Norway:	*57%*
Faroe Islands and Russia	*25%*
Iceland	*18%*

8. *The coastal states are granted access to each other EEZ's to catch blue whiting, only if this element is included in any bilateral agreement between the coastal states concerned.*
9. *Iceland and Norway recognise that the EU has to resolve the internal management areas arrangements*
10. *A +/- 10 % year to year flexibility should be allowed, provided the coastal state accepts such an arrangement for itself.*

The coastal states took the proposal onboard as a starting point for their continued discussions.

With the momentum from this proposal the coastal states managed to reach a technical agreement at a meeting in Copenhagen on November 2nd. The final coastal state agreement was signed in Oslo on December 16th 2005 and included as Annex II a management plan:

ANNEX II

ARRANGEMENT FOR THE MULTI-ANNUAL MANAGEMENT OF THE BLUE WHITING STOCK

1. *The Parties agree to implement a multi-annual management arrangement for the fisheries on the Blue Whiting stock which is consistent with the precautionary approach, aiming at constraining harvest within safe biological limits, protecting juveniles, and designed to provide for sustainable fisheries and a greater potential yield, in accordance with advice from ICES.*

2. *The management targets are to maintain the Spawning Stock Biomass (SSB) of the Blue Whiting stock at levels above 1.5 million tonnes (Blim) and the fishing mortality rates at levels of no more than 0.32 (Fpa) for appropriate age groups as defined by ICES.*

3. *For 2006, the Parties agree to limit their fisheries of Blue Whiting to a total allowable catch of no more than 2 million tonnes.*

4. *The Parties recognise that a total outtake by the Parties of 2 million tonnes in 2006 will result in a fishing mortality rate above the target level as defined in paragraph 2. Until the fishing mortality has reached a level of no more than 0.32, the Parties agree to reduce their total allowable catch of Blue Whiting by at least 100,000 tonnes annually.*

5. *When the target fishing mortality rate has been reached, the Parties shall limit their allowable catches to levels consistent with a fishing mortality rate of no more than 0.32 for appropriate age groups as defined by ICES.*

6. *Should the SSB fall below a reference point of 2.25 million tonnes (Bpa), either the fishing mortality rate referred to in paragraph 5 or the tonnage referred to in paragraph 4 shall be adapted in the light of scientific estimates of the conditions then prevailing. Such adaptation shall ensure a safe and rapid recovery of the SSB to a level in excess of 2.25 million tonnes.*

7. *This multi-annual management arrangement shall be reviewed by the Parties on the basis of ICES advice.*

The following table presents the changes made from the sections of the catching sector's proposal that relate to the management of the stock to the actual plan adopted by the coastal States (NB Russia is not a coastal State)

CATCHING SECTOR'S PROPOSAL	COASTAL STATE AGREEMENT
Five-year-agreement with a reviewing clause before end of period	An open-ended agreement with an immediate review by ICES
An initial TAC of 2 mio tonnes that should cover the catches by all parties – including Russia	A TAC of 2 mio tonnes that does not include the catches by Russia. In NEAFC, Russia is given a separate TAC on top of the 2 mio tonnes.
An annual reduction of 100.000 tonnes until the target F (0,32) is reached	Expanded the reduction to 'at least' 100.000 tonnes
The target F should be reached within five years	No dead-line for reaching target F
SSB should be maintained at values exceeding 2,25 mio tonnes	SSB should be maintained at levels above 1,5 mio tonnes (B_{lim})

Special measures to protect juveniles are specifically called for	'Protecting juveniles' is reduced to being mentioned in the preamble
A +/- 10% year-to-year flexibility should be allowed to the individual parties	Provision is made for transfer of unutilised quantities from one year to the next
No specifications on measures to be taken to avoid SSB falling below target	If SSB falls below trigger value (2,25 mio tonnes = B_{pa}) mortality rate shall be reduced

The coastal states decided to ask ICES to evaluate whether this multi-annual management arrangement is in accordance with the precautionary approach.

ICES did this evaluation in 2006, and an answer was submitted from ACFM in October – but the coastal states had scheduled their meeting for discussions about 2007 in early November, so there was no time for processing the response given by ICES.

The catching sector from EU has discussed the evaluation and has now undertaken to propose changes to the plan that will make it precautionary. The EU-industry expects to be able to present the proposals in the Pelagic RAC during one of the spring-meetings, and conditioning approval by the RAC, the proposals can be submitted to the coastal states well in advance of the annual consultations for 2008. If adopted by the coastal states, the new amended management plan will be sent to ICES for a new evaluation.

What are the lessons learned?

- The catching sector has developed long-term interests that in this case paved the ground for an international agreement that seemed almost impossible to reach.
- The catching sector wants sustainability and precaution.
- Managers can be less cautious than stakeholders.
- A usable management plan can be drafted by laymen.
- Had science been involved at an earlier stage, some of the pitfalls could have been avoided and a precautionary management plan could have been achieved much faster. However, one should not disregard the advantages of giving the catching sector the time to accept the new situation. So what could have been saved in terms of time might have been lost in terms of acceptance by stakeholders.
- An iterative process in an interaction between stakeholders, managers and science is likely to lead to a management plan that has the support of all parties.

2.1.4.2 ICES evaluation of the management plan

ICES evaluated the management in autumn 2006.

Interpretation of management plan

The proposed management plan includes some ambiguities such that it cannot be transposed directly into a numerical evaluation. ICES made the following assumptions:

- Paragraph 4 in the agreed record includes a rule for the intermediate phase between the 2006 TAC and the year when reference F reach a target at 0.32. This paragraph is interpreted as the TAC should be decreased by 100 000 t until reference F is at or below F_{pa} for the first time.
- Paragraph 5 is interpreted as F_{pa} is used as a target F, such that F should be set at Fpa when possible.
- Paragraph 6 uses a target SSB at Bpa. The target is interpreted as the SSB to be reached after the TAC is taken. "Rapid recovery" is interpreted as within one year, such that the TAC should be set to allow a SSB after the implementation at

B_{pa}. It is interpreted that paragraph 6 overrules the initial condition defined by paragraph 4 if SSB drops below B_{pa} in any year.

Methodology and result

The HCR was evaluated using the Stochastic Multi-Species model, the same model that is at present used for blue whiting stock assessment. When evaluating the plan, the following uncertainties were taken into account: uncertainty in stock assessment (including bias), uncertainty in stock-recruitment relationship, and uncertainty in implementation of the TAC. The simulations followed the guidelines from SGMAS.

The simulations were carried out with respect to two recruitment scenarios. Prior to 1996, recruitment was generally low – the average recruitment was approximately 9.5 billion individuals per year. From 1996 onwards, recruitment averaged approximately 35 billion individuals per year. Given the substantial differences between these two periods, ICES considered that it was not appropriate to carry out the evaluations using the long-term mean recruitment (20 billion approx. individuals per year). The evaluation was thus done separately for the two observed recruitment periods. No external explanations have been found for the change around 1996 and a return to the situation prior to 1996 should be considered possible.

The simulations show that, given the high recruitment level observed for the period 1996–2005, the management plan is robust to uncertainties in both assessment and implementation. For low recruitment scenarios, the management plan is not robust to these uncertainties, unless there are unrealistically low levels of noise and bias in both stock assessment estimates and implementation of the TAC.

Comments to the evaluation

The outcome of the evaluation shows that the safety margin between the limit reference point and the precautionary reference point is not wide enough to take realistic values of uncertainties and bias into account. In addition the corresponding values of F and SSB reference points may not be consistent. A target F at F_{pa} as suggested by the HCR has shown a risk of bringing SSB below B_{lim}, even though it by definition should maintain SSB at B_{pa}.

The blue whiting case also illustrates some of the problems with management of stocks with a clear shift in productivity, a so-called regime shift. Reference points are in the case of blue whiting defined from the full time series including the low productivity period. This leads to a conservative estimate of the F reference points for a stock in the high productivity stage. The evaluation showed that in such case fishing at F_{pa} gave a SSB consistently higher than Bpa and that the defined F_{pa} might be lower than F_{max}.

The Study Group on the Precautionary Approach (ICES 2001) discussed the reference points for stocks subjected to regime shift. They concluded that management plans based on F reference points were the most suitable in such situation. The topic will part of the TOR for WKREF in 2007.

One of the problems in management of fish stocks during a period with a regime shift is to detect when the regime shift has actually taken place, such that the HCR can, if necessary, be adapted to the new regime. The SMS simulations did not present output to illustrate the performance of the present HCR in such a transition zone; it just presented the long-term equilibrium. A simulation could be done to investigate how quickly a sequence of low recruitments actually is detected by the assessment procedure. This could be used to guide the formulation of an additional paragraph in the HCR, specifying the criteria and conditions in case of a consistent shift in recruitment.

2.1.5 Irish sea (Division VIIa) Cod Management Plan

SGMAS considered the Irish Sea recovery plan which implemented regulations given by the European Commission in Council Regulation EC No. 423/2004. The HCR in this plan states the following:

"*For stocks above* $\mathbf{B}_{lim}$ *the harvest control rule (HCR) requires:*

6. *setting a TAC that achieves a 30% increase in the SSB from one year to the next,*
7. *limiting annual changes in TAC to* $^{+}_{-}$ *15% (except in the first year of application), and,*
8. *a rate of fishing mortality that does not exceed* F_{pa}*.*

For stocks below $\mathbf{B}_{lim}$ *the Regulation specifies that:*

9. *conditions 1-3 will apply when they are expected to result in an increase in SSB above* $\mathbf{B}_{lim}$ *in the year of application,*
10. *a TAC will be set lower than that calculated under conditions 1-3 when the application of conditions 1-3 is not expected to result in an increase in SSB above* $\mathbf{B}_{lim}$ *in the year of application.*"

The TAC applies two years after the last year of assessment data.

The discussions reflected in the SGMAS 2006 report (ICES 2006c) included results from a partial evaluation undertaken using F-PRESS as a simulation tool. Since then the Northern Shelf Working Group (WGNSDS) undertook a full evaluation of the HCRs using FLR as a simulation tool to investigate whether the management plan was consistent with the precautionary approach.

The main findings resulting from the FLR evaluation were the following:

- The simulated stock was found to recover and there was a high probability that SSB would exceed $\mathbf{B}_{pa}$ by 2011 for all three uncertainty schedules.
- To allow the stock to recover, it is likely that the fisheries will need to be closed for 1 year (in 2007). Future simulations could investigate the effect of applying the change in catch constraint when SSB is also below $\mathbf{B}_{lim}$.

Subsequently ICES reviewed the work. The ACFM sub-group Review of the Working group on the Assessment of Northern Shelf Demersal Stocks [RGNSDS]. RGNSDS considered that the approach adopted by the WG to evaluate the management plan followed the guidelines of SGMAS and was appropriate. RGNSDS stated that the simulations indicated that VIIa cod would recover to spawning biomass levels above Bpa by about 2011. However, the results of the evaluation were conditional on a large number of assumptions and it was important to stress numerous caveats when considering the output of the simulations.

Specific concerns about the evaluation are with regard to:

- Assumptions about the biology of the stock
- Assumptions about the behaviour of the fleet
- Assumptions regarding the implementation of the HCR
- Assumptions regarding noise and implementation bias.

Assumptions about the biology of the stock

Environmental drivers of stock productivity and a potential relationship between cod recruitment and sea surface temperatures in the Irish Sea, indicates that recruitment levels may be reduced at higher sea temperatures (WGNSDS - ICES 2006g). Recent sea surface temperatures are higher than historic levels yet the stock and recruitment relationship used in evaluating the plan for both stocks uses the full time series of data and takes no account of the potential decline in recruitment due to environmental effects. This is an important consideration and should be investigated further before making firm conclusions about performance of the management plan.

A log-normal error term has been assumed for estimates of recruitment but no temporal correlation in the recruitment values has been implemented. The VIIa cod stock has experienced 3 successive years of reduced recruitment. Successive years of low recruitment can lead to drastically reduced SSB.

Although not stated in the report, it is understood that the underlying population has been based on the results of the most recent (2006) assessment. The underlying population therefore bears very close relationship to the assessed stock.

Assumptions about the behaviour of the fleet

A scenario incorporating an implementation bias of 25% has been considered in order to investigate the effect of over-capacity in the fishing fleet. The 25% value appears to be arbitrarily chosen. Either an effort implementation bias that can be shown to be appropriate for the fishery should be used or else the simulations should be run with a range of implementation biases in order to show the sensitivity of the results to different assumptions.

It is noted that the used implementation bias cannot be applied when fishing effort is set to zero. RGNSDS considers this to be an unrealistic assumption as it is likely that there will always be some level of catch. A more appropriate method of applying implementation bias in the context of mixed fishery considerations should be considered.

Assumptions regarding the implementation of the HCR

A constant recruitment value was assumed in the short term forecast. This assumption leads to reduced yield being taken from the modelled fish stock when recruitment is assumed low and that may result in faster increases in SSB at high stock levels than may be realised in practice.

Assumptions regarding noise and implementation bias

A limited set of noise and bias scenarios have been investigated here and in many cases the values assumed appear to be arbitrarily determined. The variability in recruitment is derived from the stock and recruit relationship and is considered to be appropriate. However, the justification for the level of “noise” associated with the assessment is not clear. As stated above, a value that can be shown to be appropriate for this stock should be used or else a range of values should be considered to investigate sensitivity of the results to this assumption. Bias in the perceived state of the stock may also be investigated.

Recommendations from the Review Group

Based on the work from WGNSDS, RGNSDS considered that they could not fully evaluate the management plan. More work should be done to resolve the concerns listed above and to allow for mixed fishery considerations that will impact on any proposed measures to reduce fishing mortality of cod.

Comments from SGMAS

The group agreed that the comments from the Review Group were appropriate and addressed the key technical weaknesses in the evaluation undertaken by the WGNSDS. SGMAS noted that given the low quality of the data the review group concluded that the assessment was only indicative of trends and thus, its use in the FLR simulation may lead to conclusions on stock development, which may not be robust to the underlying uncertainty. Therefore, SGMAS took a step back from the technical evaluation of the Management Plan to consider the plan in a broader perspective. Given that both precision and accuracy of the assessment were poor, it appeared unrealistic to set the TAC on the basis of percentage increases in SSB (condition 1 in the MP) that were unlikely to be detected by the assessment. SGMAS suggests that the limitations in the knowledge base should be made explicit to managers and stakeholders. This includes uncertainty in the stock dynamics, in the state of the stock and in the magnitude of the removals from the fishery. Therefore, the future development of the Management Plan should consider objectives that are both measurable and that take into account the uncertainty in the indicators.

2.2 Existing plans revisited

2.2.1 The North Sea flatfish management plan evaluation in a broader context

Following the evaluation of the management plan put forward by the North Sea RAC, both the European Commission and DEFRA have put forward alternative strategies for evaluation. These plans are being used as case studies for evaluation in different EU funded research projects. The DEFRA plan is a slight variation from the EU plan, which contains arguments for reducing the fishing mortalities to levels as low as 0.2 per year for sole and 0.3 for plaice, together with a Harvest Control Rule (HCR) describing the establishment of the annual TACs and allowable maximum number of days at sea in the beam trawl fishery. Although not specifically stated in the management plan, it aims to reduce fishing mortality over time to values around F_{MSY} for both stocks. The plan follows the international political commitment at the World Summit on Sustainable Development in Johannesburg (September 2002) to maintain or restore stocks to levels that can produce the maximum sustainable yield, with the aim of achieving these goals for depleted stocks on an urgent basis, and where possible not later than 2015. The EU plan aims for a gradual reduction in F, similar to the RAC plan, while the DEFRA version discusses a stepwise reduction in F.

The measures to reach the objectives in the EU management plan include both a effort reduction and TAC measures, which are set in a mixed fisheries context. The objectives and measures in this plan have been described in greater detail by the EU at the onset of the evaluation, reducing the amount of assumptions that were to be made by the institutes involved in the evaluations. However, the simulations increased in complexity because of the implementation of both effort restrictions and TACs in the management procedures. With respect to the implementation of TACs in the management plan, several scenarios were run with different assumptions about the possibility to avoid overshooting of quota by the fisheries, and the discarding behaviour in the case of quota overshooting.

Also, economic dynamics of the fleets were included in yet another evaluation of the EU management plan, which was performed in the context of STECF. This inclusion of economic processes increased the complexity and the number of assumptions in the operating models. Preliminary results of these studies indicate that differences in the assumptions about the economics of the fleets may have a substantial impact on the conclusions that are drawn about the effects of the management plans.

To conclude, an increasing number of different management strategies plans for the mixed demersal fisheries in the North Sea have been put forward for evaluation without ICES involvement. These evaluations deal with slightly different Harvest Control Rules, and different level of complexities in the assumptions of the operating models. The assumptions about the economic dynamics in these operating models have differed, which has been shown to lead to different conclusions about the effects of the management strategies.

2.2.2 Northern hake

2.2.2.1 Context and recovery plan implementation

Following concerns in the late 1990s about the low level of the stock biomass and the possibility of recruitment failure a range of technical measures were introduced (Council Regulations N°1162/2001, 2602/2001 and 494/2002) aimed at improving the selection pattern and protecting juveniles. Subsequently a recovery plan was introduced (Council regulation EC Reg. No 811/2004).

The technical measures comprise a 100 mm minimum mesh size for otter-trawlers when hake comprises more than 20% of the total amount of marine organisms retained onboard, with a dispensation for those vessels less than 12 m in length and which return to port within 24 hours of their most recent departure. Further, two areas have been defined, one in Sub area VII and the other in Sub area VIII, where a 100 mm minimum mesh size is required for all otter-trawlers, irrespective of the proportion of hake caught.

The recovery plan consists of setting a TAC equivalent to a target F of 0.25 (Fpa), or a lower F to prevent decline in SSB, and with the constraint that annual change in TAC should not exceed 15%.

2.2.2.2 Evaluations of the technical measures and of the recovery plan which have been carried out.

An STECF “Hake Technical Measures meeting” (Lisbon, 2003) was requested to evaluate the impact of the technical measures in 2003. No simulations were conducted during that meeting and the group concluded that, with the information available, it was not able to measure any impact. WGHMM has also been asked previously to evaluate the measures, but considers that the scarcity of detailed spatially structured information and natural variations in the system preclude attributing improvements in the stock situation as the direct consequence of the technical measures.

Two evaluations of the recovery plan were conducted following suggestions of SGMAS (ICES, 2005a) for the evaluation of management plans:

- A first review of the plan was carried out by SGMAS (ICES, 2006c). The uncertainties represented in the simulation were recruitment variability and variance in the observation of population abundance at age, at the start of the year in which management measures are to be applied. A series of values of F and Biomass constraints were tested. Almost all scenarios tested lead to a high probability of recovery in the 10 years period. For none of them the maximum 15% variation in yield was found to be a constraint.
- During last year WGHMM (ICES, 2006f), further simulations were carried out to evaluate the management plans in place for northern hake using the program CS5, supplemented by some additional simulations carried out using MS Excel and Visual Basic. The simple projections carried out suggested that given the dynamics assumed and if perfectly implemented then the recovery plan would be successful in meeting its aims with a high probability (>95%) and is in accordance with the precautionary principle. The results were reasonably robust to a range of plausible stock recruitment relationships.

In none of the simulation implementation failures were taken into account. Furthermore, several sources of uncertainty for this stock and their impact were not evaluated. This concerns mainly growth, discards estimation, and CPUE indices in the earlier years. The CPUE series and surveys do not cover the whole area. Northern hake is a wide-ranging stock where the stock definition is considered to be problematic. There are concerns about the accuracy of aging data and the calculation of historic catch-at-age data.

2.2.2.3 Where are we now? How has the existing plan worked?

The current assessment indicates that the spawning biomass of the northern hake stock has been increasing recently and is currently around Bpa (140kt), the rebuilding target, while F is just below Fpa. The increase appears to be due to a combination of good recruitment and moderate fishing mortality.

Although the regulations may have contributed to the recovery of the stock, the extent of the effect of the measures cannot be quantified (ICES, 2006f). This is an important issue which makes any evaluation of the plan difficult. When a plan is implemented, it is important to define some measurable “performance criteria” in order to evaluate the efficacy of any conservation measures implemented.

As planned in the regulation, the targeted SSB being attained for two consecutive years, the current plan should be replaced by a management plan in 2007. As the estimated absolute values of biomass and fishing mortality are questionable due to the uncertainties mentioned above, the use of trends instead of absolute values could be envisaged in future management plan for this stock . The implementation of management plan based on adaptative approaches, less dependent on quantitative assessment, could also be investigated.

2.2.3 Barents Sea capelin

2.2.3.1 Stock dynamics and fishery

Capelin (*Mallotus villosus*) is a short-lived pelagic fish found in Arctic/boreal waters. There are two capelin stocks in the ICES area: Barents Sea capelin and Capelin in the Iceland-East Greenland-Jan Mayen area. There are many similarities between these stocks, both in population dynamics, fishery and assessment/management methods. We will here consider only Barents Sea capelin. Assessment and management of Capelin in the Iceland-East Greenland-Jan Mayen have been described by Gudmundsdottir and Vilhjalmsson (2002).

The spawning stock of Barents Sea capelin has in recent years mainly consisted of age 3 and 4 fish, but in the 1970s, age 5 spawners were also common. Almost all capelin die after spawning. We consider this a short-lived species, although it’s life history does not quite comply with the definition of short-lived species given in the 2006 SGMAS report: ‘Short-lived species are usually considered as those that have high natural mortality at all ages and because of that the main part of the catch and the population are 1 or 2 years old’. Natural mortality of capelin is high at all ages. Cod (*Gadus morhua*) is the main predator on age 1 and older capelin, and capelin is the most important prey item for cod.

The recruitment failures for capelin, which has led to three stock collapses (see Fig. 2), have to a large extent been attributed to predation by young Norwegian Spring-Spawning herring (*Clupea harengus*) on capelin larvae (Gjøsæter and Bogstad, 1998). Only young herring (mainly ages 0-3) are found in the Barents Sea, and the herring abundance in this area is very variable due to the strong fluctuations in the year class strength of that stock.

The capelin stock in the Barents Sea is surveyed by an annual acoustic survey in September/October (Gjøsæter *et al*., 1998). This survey is considered to give an absolute estimate of the abundance of age 1+ capelin. The capelin stock, as well as the capelin catches, has fluctuated strongly (ICES 2006e, Fig. 2.1). The stock abundance has varied between 0.1 and 7 million tonnes. The maximum annual catch recorded is close to 3 million tonnes, but the fishery has been closed in several periods (1987–1990, 1994–1998, 2004-present).

The fishery takes place on mature capelin in the period January-March, but minor catches of a mixture of immature and mature capelin are also taken in autumn. In the 1970s and 1980s, autumn catches were a considerable proportion of the total catch.

50 000–100 000 tonnes of the annual catch can be used for human consumption, while the remaining catches are used for meal and oil. Capelin is fished in a single-species fishery, and by-catches are negligible.

2.2.3.2 Assessment and management

The capelin stock has been managed by a target escapement strategy since the first TACs were set in the 1970s. This strategy has developed over time. The current methodology for assessment of the Barents Sea capelin stock, using a combination of the multispecies model Bifrost (Tjelmeland, 2002) and the spreadsheet model CapTool (Gjøsæter *et al.*, 2002) run in the @RISK add-in to MS Excel, has been applied since 1997. Bifrost is a multispecies model used for estimating e.g. maturation and mortality of capelin, based on capelin survey and catch data, cod abundance and cod stomach content data. It estimates predation and maturation parameters used in half-year prediction of spawning stock size made in CapTool (see below), and is also used for long-term simulations investigating limit and target reference points.

At present, the quota (TAC) is calculated based on a half-year prediction of spawning stock size at 1 April (spawning time) the year after (Fig. 2.2). This prediction, run in CapTool, assumes maturation to be length-dependent and takes into account the uncertainty in the acoustic survey estimate as well as in the predation by cod on capelin. Half-year predictions are then run in CapTool for different quota levels, and the quota is set so that there is a 95% probability for the SSB to be above 200 000 tonnes (ICES, 2006e). 200 000 t is thus used as a B_{lim}. This value is somewhat above the smallest spawning stock, which has given a strong year class (the 1989 year class, 1989 SSB estimated to 84 000 tonnes). It should be considered to make the capelin B_{lim} dependent on herring abundance, as the survival of capelin larvae is strongly affect by herring abundance.

2.2.3.3 Adoption and implementation of harvest control rule

The Joint Norwegian-Russian Fishery Commission adopted the current harvest control rule in 2003. The managers have followed the TAC advice, and the catches have been close to the agreed TAC. The catch statistics are assumed to be reliable.

2.2.3.4 Evaluation of the work done so far

A target escapement strategy (and thus a ‘HCR’) has been used for this stock for many years, but the methodology has been under continuous development. The scientists have developed the strategy; there has been little or no dialogue with the managers about the formulation of the HCR.

Management criteria have not been explicitly formulated for this stock, but the management objective for Barents Sea capelin seems to be to maximize the long-term yield, while also ensuring that there is enough capelin available as food for cod.

A socio-economic objective sometimes stated by Norwegian fishermen is that they would like to always have a small fishery for human consumption. It has become accepted also by fishermen and industry that the large variations in stock abundance means that the fishery of capelin for meal and oil has to be closed for some periods.

Stock collapses have occurred, but it is reason to believe that fishing has had a negligible effect on the second and third collapse.

2.2.3.5 How should the HCR be evaluated?

The rule has not been evaluated by ICES. We will here try to outline how an evaluation could be carried out.

We suggest using Bifrost as a scenario model. The methodology for half–year predictions as well as for long-term simulations, should be evaluated.

The following components of the biological sub-models as well as the observation models should be evaluated:

- Sub-models for recruitment, natural mortality, growth and maturity, taking species interactions into account.
- The way the uncertainty in the spawning stock estimate is calculated (probabilistic models for acoustic abundance, age/length distribution, proportion mature and mortality due to predation by cod)
- The use of the acoustic estimate as an absolute estimate, the spatial coverage of the survey (entire distribution area covered, small amount of capelin found in bottom trawl catches) should also be evaluated. The species identification during the acoustic survey is generally reliable, but capelin can be mixed with polar cod in some cases.

The two ‘parameters’ in the HCR which could be varied, are: B_{lim} and the probability for falling below B_{lim}. It should also be considered to make B_{lim} a function of herring abundance.

The criterion for evaluating the capelin HCR cannot be how often SSB falls below B_{lim}, since this in nature sometimes happens anyway. A reasonable criterion for a HCR to be precautionary would be that the probability for a fishery to *cause* the SSB to fall below B_{lim} is very low, e.g. less than e.g. 5%.

The herring and cod population dynamics should be given, but the HCRs for those species should be varied in order to study the effect on capelin and see how robust the management of capelin is to changes in the HCRs for cod and herring. To simplify matters, effects of capelin abundance on the population dynamics of cod and herring should be neglected in the initial analysis, although effects of capelin abundance on cod growth and maturation have been observed (Mehl and Sunnanå, 1991).

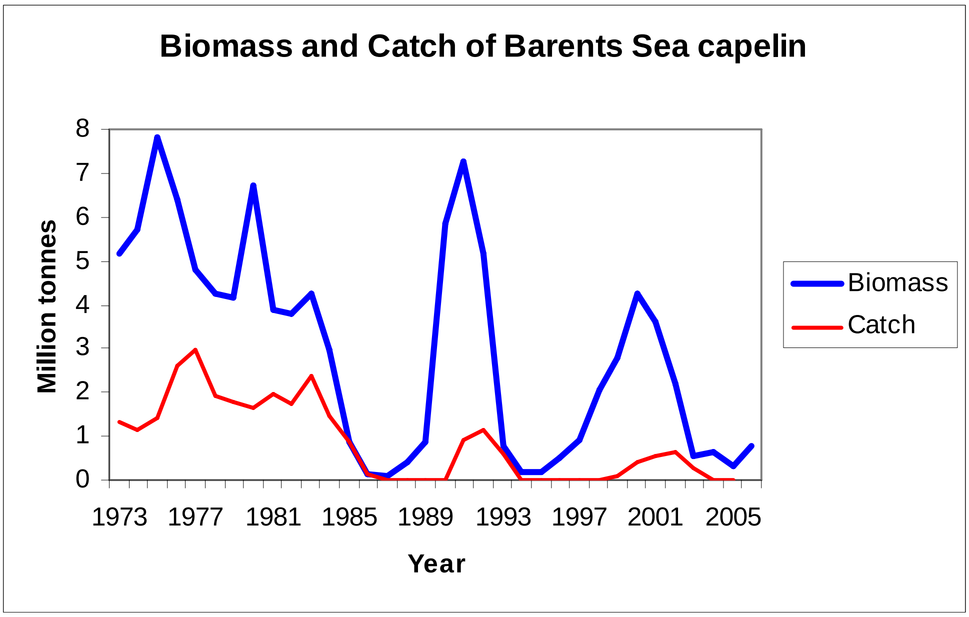


Figure 2.1. Biomass and catch of Barents Sea capelin. From (ICES, 2006e)

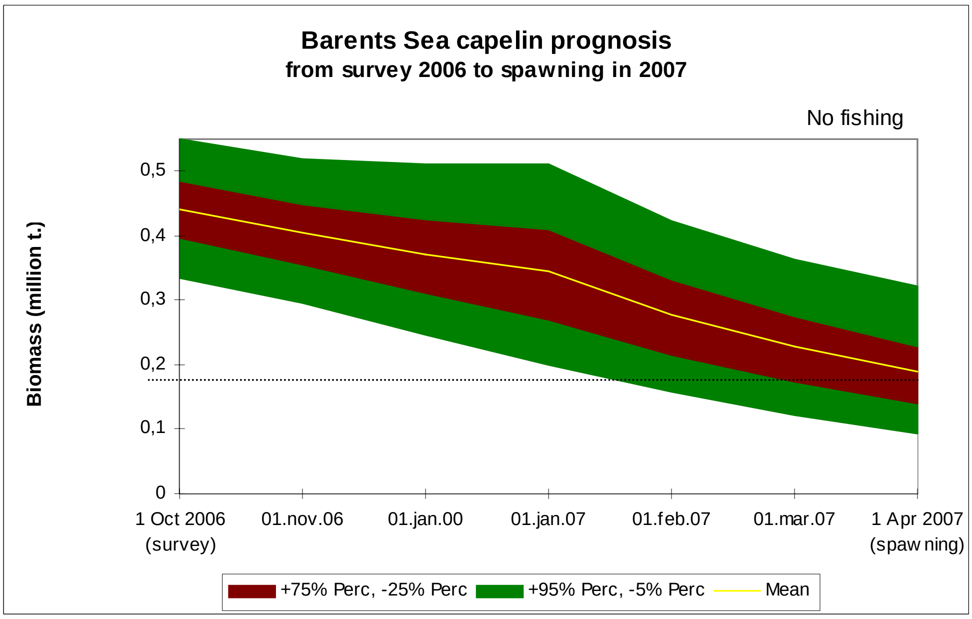


Figure 2.2. Half-year prediction of Barents Sea capelin, used in assessment.

2.2.4 Northeast Arctic cod

2.2.4.1 Description of harvest control rule

At the 31st session of The Joint Norwegian-Russian Fishery Commission (JNRFC) in autumn 2002, the Parties agreed on a new harvest control rule for Northeast Arctic cod. This rule was applied for the first time when setting quotas for 2004. The rule was somewhat amended at the 33rd session of JNRFC in autumn 2004. The amended rule was evaluated by ICES in 2005 and found to be precautionary. The rule is as follows:

"The Parties agreed that the management strategies for cod and haddock should take into account the following:

- *conditions for high long-term yield from the stocks*
- *achievement of year-to-year stability in TACs*
- *full utilization of all available information on stock development*
-

On this basis, the Parties determined the following decision rules for setting the annual fishing quota (TAC) for Northeast Arctic cod (NEA cod):

- *estimate the average TAC level for the coming 3 years based on F_{pa}. TAC for the next year will be set to this level as a starting value for the 3-year period.*
- *the year after, the TAC calculation for the next 3 years is repeated based on the updated information about the stock development, however the TAC should not be changed by more than +/- 10% compared with the previous year's TAC.*
- *if the spawning stock falls below B_{pa}, the procedure for establishing TAC should be based on a fishing mortality that is linearly reduced from F_{pa} at B_{pa}, to F= 0 at SSB equal to zero. At SSB-levels below B_{pa} in any of the operational years (current year, the year before and 3 years of prediction) there should be no limitations on the year-to-year variations in TAC.*

The Parties agreed on similar decision rules for haddock, based on F_{pa} and B_{pa} for haddock, and with a fluctuation in TAC from year to year of no more than +/-25% (due to larger stock fluctuations).

(The wording of the last bullet point is confusing; the rule tested and used can be accurately described by replacing the text inside the parentheses by "intermediate year and 3 years of prediction")

Reference points for this stock:

B_{pa}=460 000 tonnes, F_{pa}=0.40, Reference F: F_{5-10}, arithmetic average.

2.2.4.2 Evaluation and use of rule

The HCR for NEA cod was evaluated by ICES AFWG, and was finalized in 2005 (ICES, 2005b, see also SGMAS report (ICES 2006c). The HCR was found to be precautionary.

The SGMAS 2006 report only refers to the evaluation made by AFWG in 2004. It should be noted that the 2005 evaluation tested the HCR for different levels of implementation error. Note also that the line on the F vs. SSB plot on the top of p. 43 in the 2006 SGMAS report, which describes the HCR, should go through the origin (F=0 when SSB=0).

The quota for the years 2004, 2005 and 2006 was set based on the HCR. For 2007, the quota was also set based on the HCR, but using an alternative assessment with lower figures for the unreported catches in 2005, given in brackets in the table below.

The text table below shows TAC advice based on the HCR, agreed quota and reported catches for the years 2004-2007. Figures in thousand tonnes.

Year	TAC according to HCR	Agreed TAC	Reported catches	Catches used by AFWG
2004	486	486	489	606
2005	485	485	475	641 (589)
2006	471	471		
2007	366	424		

The advice given and quota set in 2006 – summary:

Assessment by AFWG, based on estimated total catch of 641 000 tonnes in 2005 and assuming F_{sq} (=F_{2005}) for 2006: **366 000 tonnes**, corresponding to using the 3-year rule with F=0.383 (0.40*441/460). The 10% constraint on year-to-year variations was suspended because SSB in 2007 is below B_{pa} (441 000 tonnes). It should also be noted that the F_{sq} catch in 2006 (551 000 tonnes) is less than the 2006 TAC+ the level of unreported catches estimated for 2005 (471 000+166 000 = 637 000 tonnes). This fact was noted by AFWG, who also gave alternative predictions based on catch levels in 2006 above the F_{sq} catch.

ACFM Spring 2006: "ICES has evaluated these decision rules for cod and a management plan based upon them is in accordance with the precautionary approach when the SSB is above $\mathbf{B}_{lim}$. The agreed management plan was not evaluated with an implementation error as large as the one currently occurring in the fishery. The agreed management plan has been evaluated to be consistent with the precautionary approach when the SSB is above $\mathbf{B}_{lim}$ and there is a low level of implementation error. However, the management plan is not fully enforced, resulting in non-reported landings and exploitation above what was intended in the management plan. Total catches in 2007 consistent with the Precautionary Approach reference points are below **309 000** t." (F=0.40 in 2007 gives 309 000 tonnes). ACFM did not comment on whether it would be more appropriate to use a value above F_{sq} for F_{2006} in the predictions.

The JNRFC considered the estimate of unreported catches in 2005 made by the Norwegian Directorate of Fisheries (114 000 tonnes) to be the appropriate figure to use in the assessment. An assessment using this figure was also given in the AFWG report for 2006. A short-term prediction based on this assessment gave an SSB in 2007 (and later years) above B_{pa} (460 000 tonnes), and thus the 10% constraint on year-to-year variations in HCR was not suspended. The HCR then resulted in a TAC advice of 424 000 tonnes for 2007, a 10% reduction from the 2006 value of 471 000 tonnes. Accordingly, the JNRFC set the TAC for 2007 to **424 000** tonnes.

2.2.4.3 Unexpected/undesired consequences of the HCR

The HCR does not take into consideration possible assessment revisions from year to year. This may lead to unexpected results, as illustrated by the following example: This year, the predicted SSB in 2007 (441 000 t) is < B_{pa}, and thus the limit of 10% year-to-year-change is suspended when setting the TAC for 2007. The prediction also gives an increase of more than 10% in the TAC from 2007 to 2008 (from 366 to 425 thousand tonnes), which will be allowed because SSB < B_{pa} in 2007. However, if next year's assessment should show that the SSB in 2007 and following years all are > B_{pa}, this means that the TAC for 2008 then will be limited by the 10% year-to-year change, and thus may not increase by more than 10%. One of the intentions of the rule was that the 10% limit should not apply in the situation when the SSB increases from below B_{pa} in one year to above B_{pa} in next year, so that the TAC can be increased by more than 10% in such situations. This intention will thus not always be fulfilled.

One could imagine some kind of ‘smoothing’ of the rule for SSB values just below B_{pa} to avoid this problem.

Medium-term prognosis shows that the new strategy will not always keep F at below $\mathbf{F}_{pa}$. (AFWG 2003). The reason is that when F=$\mathbf{F}_{pa}$ is applied for a three-year period, the stock will in many cases increase, so that the catch corresponding to F=$\mathbf{F}_{pa}$ will also increase during the period. When applying the 3-year averaging method to find the TAC in the first year, this will thus be higher than the TAC corresponding to F= $\mathbf{F}_{pa}$ in the first year.

Two stabilizing elements are included in the rule:

- 10% limit to year-to-year changes in TAC
- The 3-year averaging procedure.

The first part may be sufficient to ensure stability.

The TAC will not be a continuous function of the stock size in the prediction year, as illustrated in the description of the advice for 2006. It could be considered to ‘smooth’ the rule for values of SSBs close to B_{pa} in order to avoid this problem.

2.2.4.4 Comments to the evaluation and the use of the HCR

Nearly all the work on evaluation of this rule took place before the guidelines from SGMAS were in place. Thus, it seems appropriate to consider to what extent the guidelines developed by SGMAS were followed during the evaluation process.

Interaction with management and interested parties (cf. ICES 2006c, section 4.2)

In 2001 the JNRFC set up a working group of Norwegian and Russian scientists and economists, called the Basic Document Working group (BDWG), to develop a "Basic document regarding the main principles and criteria for long term, sustainable management of living marine resources in the Barents and Norwegian Seas". This document, which was presented to the JNFRC in 2002, outlined consequences of relevant possible management objectives for the Northeast Arctic Cod. On the basis of the chosen management objectives by JNFRC the HCR for cod, that has been accepted by ICES to be in compliance with the Precautionary Approach, was developed and adopted. The actual wording of the HCR was, however, developed without a formal dialogue with the scientists.

Later, the mandate for the BDWG has been prolonged and extended, including the haddock HCR as well as issues related to the joint Norwegian-Russian project “Evaluation of maximum sustainable yield from the Barents Sea” (see below). The BDWG annually presents a report to the JNRFC. It is also a forum for the scientists to provide input to the JNRFC, and the BDWG has thus developed to be an important forum for the dialogue between the JNRFC and the scientists.

The dialogue between scientists and managers during the evaluation process thus seems to have been fairly adequate.

Management objectives (cf ICES 2006c, section 4.4.2)

Objectives in HCR evaluation: Precautionarity, stability

Kovalev and Bogstad (2005) evaluated the long-term yield for NEA cod for different harvesting strategies, using the same biologically detailed model as in the evaluation of the HCR done by ICES. They found that the agreed HCR gives a long-term yield close to the optimal one, as fishing mortalities in the range 0.25–0.5 will lead to the highest long-term yields. Further work on studying the long-term yield will be carried out within a 10-year

(2005–2014) research project “Evaluation of maximum sustainable yield from the Barents Sea”, initiated by the JNRFC in 2003. The goal of this project is:

“To make a scientific assessment of optimal harvest (maximum sustainable yield) from the most important commercial species in the Barents Sea, based on existing knowledge. This includes an evaluation of:

- *the size of maximum sustainable yield and corresponding fishing mortality*

- *effects of establishing relatively stable quotas*

This work should be based on an analysis of the population dynamics of Northeast Arctic cod and take into account this species interaction with other species which influence the yield from the cod. Later, this work should be broadened by assessing other species following this order of priority: capelin, herring, harp seal, minke whale, shrimp, haddock etcetera. The assessment shall include all ecosystem elements available for evaluation, i.a. natural and man-made effects on reproduction, growth and survival. The work shall contain a verification that the models used in the assessments provides reliable results which are compatible with the known history of the stocks. The assessment shall also specify further scientific work necessary to provide more precise answers to these questions.”

Conformity of a HCR to the management strategy

The HCR seems to be of a type suited to this stock, which is a ‘mainstream’ stock.

Implementation error is a major problem (in 2005, unreported catches were estimated to be about 1/3 of the TAC), and there is so far no sign that this problem will be reduced.

HCR simulation parameterization

Biological model:

- Weight at age in stock function of total stock biomass
- Weight at age in catch and maturity at age function of weight at age in stock
- Segmented regression stock/recruit relationship, with uncertainty
- No uncertainty in weight at age (stock/catch), maturity at age and mortality at age
- Exploitation pattern: Fixed (average of recent years)

A reality check of the biological model has been carried out.

Management measures

Not particularly relevant

Robustness of management strategy

Assessment error/bias:

Derived from historical data, implemented as cv and bias.

Age dependent, no correlation between age groups

Implementation error:

This is modeled with an overall cv and bias for all age groups. The performance of the HCR has been investigated for various levels of implementation error.

Constructing full feedback models (cf. ICES 2006c section 7.5.1) and utilizing those to evaluate the HCR could be a long-term goal.

2.2.4.5 Summary

The biological model seems to be reasonable, although there is certainly room for improvement.

The development of the HCR has given new insight in how a HCR should be formulated when the SSB is below or close to the trigger point.

The stock has not developed as intended, mainly because of implementation error, which has increased in recent years.

The HCR has been followed, although the 2006 situation casts some doubt on whether the HCR always will be followed when it results in TAC reductions of more than 10% from one year to the next.

2.3 Plans under development

2.3.1 Norway Pout

Norway pout is a small, short-lived gadoid species with a high natural mortality. The fishery is mainly performed by Danish and Norwegian vessels in a directed fishery using small mesh trawls. Main fishing seasons are 3rd and 4th quarters of the year with also high catches in 1st quarter of the year especially prior to 1999. Some by-catch of Norway pout is also taken in the fishery for blue whiting.

Total landings have been low since 2001, and the 2003-2004 landings were on the lowest level ever recorded since 1961. The fishery towards Norway pout as one of the target species has been closed in 2005 and in the first half year of 2006. The fishery was opened on 24 August 2006 with an EC quota of 95 000 t and unrestricted Norwegian fishery in the Norwegian zone for the rest of the year. Less than half of the EU-quota was taken.

Stock assessment is done using the SXSA with quarterly time step, tuned with catch rates from the commercial fishery and survey index from the first and third quarter IBTS. Analysis with the SMS model indicates a highly uncertain estimate of SSB and F.

ICES advices that the fishery should be closed until information, which assures that the stock will be above $\mathbf{B}_{pa}$ at the beginning of 2008 is available.

2.3.1.1 Management plan

Request for HCR

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

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 dealt with the request during WGNSSK (ICES 2006h) but no final HCR was suggested. An EU-Norway meeting is suggested for February 2007 to propose and evaluate HCR.

Plans for setting up and evaluation of HCR

Recruitment of Norway pout is highly variable and influences catch opportunities and SSB rapidly due to the short life span of the species. The stock will be assessed in May during the WGNSSK where there is no indication available about the recruitment (0-group) such that no reliable forecast of the catch opportunities for the next year can be given. This might lead to a very conservative TAC, or alternatively, the use of real time information to adjust or set the TAC.

The first and third quarter IBTS give a rather good indication of recruitment and abundance of the 1-group and can be used in a real-time management of the stock. For establishment of a HCR the quality of the IBTS index will be evaluated. HCR which use one or both surveys will be suggested and evaluated. Doing this, the timing of both the decision making process and the implementation will be taking into account. Further, the benefits of the analytical assessment versus an assessment based entirely on survey indices will be evaluated.

2.3.2 Celtic sea herring: Some lessons learned in the early stages of developing a management plan

The motivation to develop a management plan based on some sort of harvest rule came on foot of the May 2006 ICES advice which stated "..*no fishing should be allowed until a management plan is in place*.." The timing of the development of such a plan was that nothing was done over the summer when the fishery was closed but as soon as it reopened in late August there was an expression of interest from FPO's (Fish Producers Organisations) that such a plan be developed. This was endorsed by the Pelagic RAC.

There was no real dialogue about the elements of such a plan, so the scientists decided to start the work based on the stated aims of the industry with regard to the management of the stock "*To build the stock to a level whereby it can sustain annual catches of around 20,000 t. In the event of the stock falling below the level at which these catches can be sustained the Committee will take appropriate rebuilding measures*." Thus Scientists began to explore constant harvest strategies,.(details of the simulation set up are given in (Kelly, Working Document). The main elements of this were;

- Recruitment was modelled as hockey stick which gave an estimate of recruitment impairment at about 44kt, this was used as a trigger point.
- HCR was a (constant) target yield which was scaled according to the ratio between the assessed SSB and Btrig. i.e. when SSB<Btrig, target yield decreased by the scalar SSB/Btrig, but by corollary the TAC would be allowed to increase when SSB>Btrig. In all cases the TAC was subject to an annual +-15% TAC change limit.
- CV and bias put on assessment based on retrospective performance
- Risk calculated relative to SSB<Bpa and Blim

A number of problems related to the objective and process quickly arose affecting the development of the plan

- The recruitment impairment point turned out to be coincidentally almost equal to Bpa, and erroneously this was used as a trigger point. To account for assessment uncertainty & bias the trigger point should have been set far enough above this level. With the stability rule and the trigger point at the recruitment impairment, this means that by the time the stock has achieved full reproductive potential the TAC is allowed to increase, and this can quickly drive the stock into recruitment impairment. When you couple this with a 15% TAC change limit it is difficult to prevent stock depletion.
- Managers considered the stock to be currently in a depleted state and in need of rebuilding rather than a long term constant yield plan. Thus managers were still looking for 2007 options, and wrongly the scientists tried to shoe horn these out of FPRESS which is not an appropriate tool for the job.
- There was no dialogue with industry and the simulations weren't even presented to either them or managers. In the absence of effective communication managers went ahead and applied their own solution for the 2007 fishing opportunities

The short term outcome of this is that a TAC for 2007 was agreed which was 15% lower than 2006. Subsequent to this calls for urgent development of a management plan have somewhat dissipated. Managers and industry are still some way apart in their thinking, managers considering that the stock needs rebuilding before a long term plan can be considered. However if the process is reinitiated scientists are now aware that due to the uncertainty in the assessment the approach of using it in the HCR will give very conservative yields as the trigger point needs to be well above the point of recruitment impairment.

Even though a plan has not been developed a number of lessons can be learned from the process so far;

- There should be some dialogue between managers, scientists and industry/stakeholders before any simulations are done.
- These plans require several iterations of dialogue which can take a considerable time
- If the recruitment model implies impairment at a point which is at or above the value previously used for Bpa and the stock has been managed according to this then the stock will require further building before a constant yield harvest strategy (especially with a stability rule) can be applied.
- An extremely noisy assessment is almost useless as a basis to manage a stock where you want to be risk averse and stabilise yields

2.3.3 Western horse-mackerel. Feed-back to process.

Work on harvest control rules (HCRs) given paucity of fishery-independent information was first presented to SGMAS in 2006 (ICES 2006c). That contained simple harvest control rules applied on a 3-year basis. Some of the rules were based on the results from the assessment and others on the slope of the most recent three egg survey estimates. The egg surveys are performed every three years and provide an estimate of annual egg production. Estimates of the biological parameters that would allow translation of egg abundance into SSB are not available.

The evaluation of the HCRs, subsequently peer-reviewed (Roel and De Oliveira, 2007), was presented for further discussion considering that the results will be contributing to the formulation of a management plan for the stock to be discussed in the February Pelagic RAC where stake-holders and scientists will be present.

Main objectives addressed in the study are the following:

- To evaluate simple multi-annual 3-year TAC harvest control rules (HCRs) based on the existing information;

- To investigate the effect of increasing fishing pressure in the juvenile area;
- To analyse the impact of implementation error in the strategies considered.

The HCRs tested are the following:

1) Slope Strategy 1: The TAC is last year's TAC adjusted by a function of the trend in the last 3 egg survey data, $f(slope)$, but subject to a minimum:

$$TAC_y = \max\left\lfloor \beta\, TAC_{y-1} f(slope)\, ; TAC_{\min} \right\rfloor \quad \textbf{[1]}$$

This formulation ensures a minimum TAC of TAC_{min}, unless the stock is depleted and is unable to support this minimum. The function of the slope takes values between 0 and 1.4. This function caps the TAC upwards so that it cannot increase from one TAC year to the next by more than 40% but it can be decreased to zero where no minimum is imposed. Only two slope functions were considered: *f(slope) 1*, the TAC is decreased fast when the value of the slope < 0 and is increased slowly when the slope > 0 and *f(slope) 2*, the opposite applies, the TAC is reduced slowly for slope < 0 and is increased fast for slope > 0.

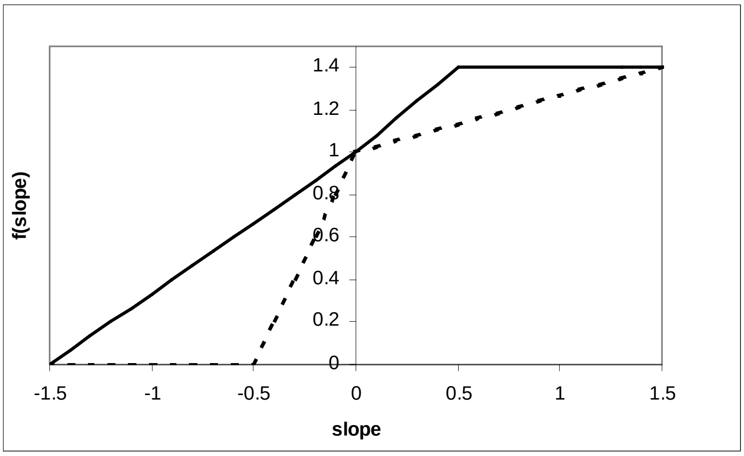


Figure 2.3.5. Diagram showing the values taken by the function of the slope (f(slope)) for given estimates of the slope of the most recent three estimates of annual egg production from the triennial Egg Surveys. The dotted line corresponds to f(slope) 1 and the solid line to f(slope)2.

2) Slope Strategy 2: The TAC is a weighted average between a reference TAC, TAC_{ref}, and last year's TAC, which is adjusted by a function of the trend in the last 3 egg survey data, $f(slope)$:

$$TAC_y = \beta\left\lfloor wTAC_{ref} + (1-w)TAC_{y-1} f(slope) \right\rfloor \quad \textbf{[2]}$$

where w is a weighting factor and β is a control parameter that allows scaling the TACs. Once agreed β is fixed.

In the two slope strategies considered, both the TAC_{min} and the term that includes TAC_{ref} ensure that fishery closures are kept to a minimum.

3) Constant Proportion Strategy: The TAC is computed as a fraction, α, of the estimated SSB.

$$TAC_y = \alpha\ SSB_y$$

The evaluation of the proposed HCRs was performed by means of a simulation framework.

- The slope function that results in a rapid increase when the slope is positive and slow decrease when the slope is negative is less risky than the reverse function.
- If stability in the catch is a management objective, slope strategy b) which has a fixed component should be preferred to the a) strategy which has a minimum TAC (Roel and De Oliveira, 2007).
- The constant proportion strategy based on an assessment results in a higher SSB at the end of the projections than the slope b) (weight = 0.5, Roel and De Oliveira, 2007) and is less risky at low and moderate levels of exploitation.
- If the assessment is biased that would have a negative effect on the performance of the constant proportion strategy, particularly when exploitation level is high.
- At moderate levels of exploitation a strategy close to constant catch performs well compared to the more variable options considered.
- For slope strategies, if spasmodic recruitment is switched off in the stock dynamics, the risk associated with a given fishing pressure which results in a mean annual catch, increases rapidly when the mean annual catch exceeds ± 120 thousand tonnes.
- An increase in the proportion of the catch taken in the juvenile area (from 30% to 70%) results in a slight increase in the risk associated with a level of catch.
- The mis-match between the TAC area and the area where the stock is caught has resulted in catches for the entire stock area exceeding the TAC set for a subset of the stock area. This is referred to as overshooting of the TAC. Overshooting, at the levels seen historically will practically double the risk associated with a given strategy.

Technical details related to the operating model were provided and discussed by the group. Comparison between the cumulative frequency distribution of the simulated recruitment, resulting from a Ricker model, and the observed suggested that simulated recruitment was close to the observed and slightly under-estimating it putting the framework on the conservative side and that was considered appropriate. In addition, the group suggested testing sensitivity of the results to additional recruitment scenarios, i.e. generated by a hockey-stick model.

The group expressed some concerns in relation to the fact that the starting numbers at age in the simulations were based on results from an assessment that had not been accepted by ICES. The possibility of a biased assessment does not invalidate the conclusions from the comparison between the HCRs proposed but it may alter the estimates of risk associated with catch levels examined. However, the assessment model used in the simulations is the one providing the more pessimistic scenario regarding numbers at age in the stock and is therefore more precautionary. Stakeholders involved in discussion of HCRs should be made aware of the uncertainty regarding the state of the stock. The group suggested the evaluation of a HCR that used the results from the assessment in a similar way the slope strategies made use of the egg estimates. The group also suggested considering a 2-stage HCR which included a different management action or sets of actions depending on whether the stock was above or below a limit point. The group suggested that a 10% flexibility in the uptake of the TAC is considered in further simulation work.

2.4 Further guidelines for developing management strategies.

In previous reports from SGMAS, detailed guidelines for evaluating management strategies were provided. These guidelines have to a variable degree influenced the development and evaluation of the plans revisited in the above sections, mostly depending on when the work was done. Some generic aspects of the experience gained is summarised here. This summary can be regarded as an extension of previous guidelines, and are not supposed to substitute them. Most of the attention this time was directed towards the process of developing management strategies, rather than towards the evaluations as such. This summary also reflect points made in discussions about communication with managers and stakeholders (Section 6)

2.4.1 Guidelines for the process of developing management strategies.

The points below outline steps in the process and in particular the role and requirements of science in the process. SGMAS has always regarded dialogue and communication as essential in the process, and some indications to how that should work are outlined.

The process leading to a management strategy can be triggered in various ways, and will take place in a variety of fora depending on administrative structures, interests and driving forces. Some plans discussed above were triggered by a strong advise from ICES, because the stocks have been depleted. Others, for example for the Blue whiting (Section 2.1.4), were developed to obtain a compromise between the interests of various stakeholders and political priorities, brining science in at a late stage.

The SGMAS recommends that scientific insight is brought into the process of developing management strategies at an early stage. For science, this will lead to an incremental process, starting with being a partner in discussions and ending with the evaluation that will be the basis for approving the plan as precautionary.

1. At the early stage, science should be open-minded, working together with managers and stakeholders to get some understanding of needs and preferences, and communicate possibilities, limitations and trade-offs. Also, one should get an overview of problems that may complicate the process or the development and implementation of the plan. It should be realised that to be agreed, a rule for the exploitation often has to be part of a broader agreement, which for example includes the sharing of the resource between parties (see e.g. Section 2.1.4). The science contribution at this early stage should be to get an overview of opportunities and limitations, rather than coming up with detailed proposals.

2. At this early stage, concentrate on communicating essentials. Simple calculations can show important properties of various alternative management arrangements. At this stage, science should assist in outlining the range of feasible alternatives of management strategies, rather than attempting to promote a single construction. One should avoid diverting the communication by highlighting technical simulation problems. Important things to consider from a science point of view is the implications of biological properties of the stock like the life-span, i.e. the turnover in the stock, variability in recruitment, limitations in the stock and fishery related knowledge base, i.e. the possibility of obtaining reliable assessments, the possibility of getting good measures of recruitment, possible regime shifts, and the current state of the stock, and how these influence the performance of management strategies. Likewise, limitations in the insight in the properties of various management strategies should be recognised. The properties of some management strategies are better known than others. For example, the standard 3-stage harvest control rule is quite well known in ICES, while the experience with fixed TAC strategies is quite limited. Scientific background work, sometimes on a quite theoretical and conceptual level may be required, but that should not preclude considering a broad range of possible strategies.

3. Do not expect managers to come with clear objectives at the early stage. Rather, once alternatives are beginning to emerge, demonstrating trade-offs between objectives, gains and losses should be a key task for science.

4. As more specific alternatives are emerging, science should be prepared to provide quite realistic simulations. That implies that technical problems around simulations,

like recruitment models, variances for stochastic elements etc. should have been settled by now.

5. When a final management plan is proposed, it should be scrutinised for ambiguities and unclear formulations. A good exercise is to make flow-charts as described in WGMG (ICES 2006a). A good guideline is that the rule should be possible to program for a computer (and at some stage, it will actually have to be programmed). Ambiguities may have a variety of causes, from people simply not being aware of the problem, to deliberate unclear formulations to reach a political compromise or to give managers some space to manoeuvre in the future.
6. If ambiguities are found, it is better to communicate with managers than to just assume one interpretation. If ambiguities have to remain, aim at showing the consequence of a reasonable range of interpretations. Likewise, if unwanted side effects are spotted, communicate that to managers and help in amending the rule.
7. Try to avoid overly complex rules. Usually, quite simple decision rules cover the important issues. For example, in a rebuilding situation, the main question at the end of the day is to get the fishing mortality low enough to allow the stock to increase, and to preserve good year classes if they appear.

2.4.2 Interpreting management plans:

2.4.2.1 Timing

Very often, agreed plans are unclear with respect to the exact timing. In the tactical advisory context where the basis for decisions is regular analytical assessments, we typically relate to the following terminology:

Last assessment year – last year for which there are measurements.

Intermediate year – when the assessment and decisions are made

Prediction year (TAC year) – year for which the advised measures apply.

Suppose we are in 2007.

- 2006 is the last assessment year. Our data go up to and including 2006, so we can analyse real data up to the end of 2006.
- 2007 is the intermediate year. The decisions for 2007 should be in place, so we have a formal basis for projecting the stock through 2007. We may assume that catches will be taken according to these decisions, or – more often – we assume that the fishing mortality remains at the recent level.
- The advice on management that is produced applies to 2008, which is the prediction year.

2.4.2.2 Spawning stock biomass (SSB)

SSB values are typically used as landmarks for applying different options: ‘if SSB is below xxx, then the fishing mortality shall be reduced .....’.

SSB is not a constant, it varies from year to year. So, a crucial question is ‘SSB at which time’? The formulation in the legal texts typically is ‘When SSB **is** ......’ The naive interpretation of this present tense expression would be SSB at the time when the decision is made, which normally would be in the intermediate year. For a large number of stocks, spawning is assumed to take place early in the year, so it would be SSB at the start of the intermediate year. However, it is not obvious that this is what actually is meant, and it may not necessarily be the best basis for decisions. A further problem is that the SSB at a certain time is not settled once and for all, it is estimated, and the estimate changes as new data are included, and if new methods are applied.

If nothing else is specified, one likely interpretation of the term 'the SSB is' would be the *SSB in the intermediate year (at the start of the intermediate year if spawning takes place at the start of the year), as estimated at the assessment made in the intermediate year with data up to and including the last assessment year.* In most cases, it is tacitly assumed that the estimate is the one adopted as the basis for the ICES advise (or approved by STECF in the case of the EU). This interpretation is also in line with how ICES classifies a stock relative to the PA reference points where the phrase is 'Based on the most recent estimate....'. Another interpretation may be 'SSB in any of the years', and a third interpretation may be 'SSB after the prediction year', i.e. after the TAC has been taken.

In a harvest rule, one alternative might be to use the resulting SSB to decide on removals from the stock. One would then look at the SSB at the first spawning after the prediction year. Some simulation programs actually use this interpretation (e.g. STPR). Some harvest rules have elements of this, for example 'If SSB < Blim, TAC shall be set so that SSB will increase with 30% from one year to the next'. It becomes confusing when a management plan apparently uses SSB at both times in the decision process, without specifying the timing clearer. One may interpret the formulation (assuming spawning at the start of the year) as: 'If SSB at the start of the intermediate year is estimated to be below Blim, the catch in the prediction year shall be set so that the predicted SSB at the start of the year after the prediction year is 30% higher than the predicted SSB at the start of the prediction year'. But it is by no means clear that this is what is actually meant.

2.4.2.3 The role of precautionary reference points.

Trigger points in a harvest rule are conceptually different from the precautionary reference points. The –pa reference points are established to take the uncertainty in the estimates of the current stock situation into account. They are intended as landmarks to indicate that there is some probability that the stock or mortality actually is at the limits. Lacking other guidelines, this should be an incentive to take action to improve the situation. A harvest rule, on the other hand, should have elements that ensure a low risk that the real stock or mortality reaches the limits. Such elements can be trigger points where special action is taken, but should primarily be chosen to provide a feasible functionality of the rule, in addition to a low risk.

Since the –pa points indicate a risk to the real stock, a rule where action is taken only when the –pa points are reached would in principle not be risk adverse. The only justification for using these points as triggers would be to provide an extra protection to a rule that in itself should keep the stock estimate well away from the –pa points. Hence, the Bpa is only relevant as a trigger point if the rule implies a fishing mortality low enough to keep the stock estimate well above Bpa. By definition, this should require a lower fishing mortality than Fpa.

The use Blim as a trigger for further action is problematic because Blim refers to the true state of the stock, which is not known. Hence, by definition, we do not know where the stock is relative to Blim. Bpa refers to estimate of the stock, and should be the adequate basis for action. The current ICES advisory practise recommends one kind of action when the estimate is at Bpa and another when the estimate is at Blim, which is not quite logical in this perspective.

In a simulation framework, where the operating model represents the 'true' stock, it is possible to demonstrate the probability that Blim is reached, and a core criterion for accepting the rule as precautionary is that this probability is low. Hence, the relevant measure of performance is the risk to Blim in the operating model. However, to tell the performance from a mangers perspective, the risk to Bpa as seen by the decision model (i.e. with assessment uncertainty included) is a more adequate measure of performance, since that relates to when managers are warned that the stock may be at risk.

2.4.2.4 Fishing mortalities

These are usually less problematic if they are just parameters in the rule, i.e. if so and so, a TAC shall be set according to an F = xx. There are some pitfalls, though:

One is what the fishing mortality shall cover: Does it include discards, and perhaps even illegal landings? Sometimes, attempts are made to account for these, either by adding to the catches that go into the assessment, or to operate with a separate discard fleet. If additional catch is included in the assessment, then the predicted catch will be consistent with the total assumed removal.

There may be two ways of handling removals in excess of recorded landings:

1. Include all removal in the assessment. The, the assessment reflects the real world to the best of our knowledge. Two problems can arise:
    a) The additional removal may be disputed by the managers, in particular if some of it is estimated using evidence that cannot be confirmed in a legal context, but relies on informal sources, mismatch between signals in catch and survey information etc. North-East arctic cod is one recent example where this was a problem.
    b) The predicted total removal is interpreted as a TAC advise. If the TAC is overfished as before, the total removal will be higher, leading to a higher fishing mortality than intended. One may get around the problem by developing a partial F for the 'official' fishery, and set TAC accordingly. The reference F may still be the total F, although that may not be acceptable for the managers.
2. Assess the stock with the official landings as the only catch data. That will give an assessment relating to the virtual stock that is required to account for the reported landings, but if the underreporting has been consistent and stable, this is mostly a scaling problem. The managers will get a quota advise relating to their virtual world. NEA mackerel is one example of this approach. If the discrepancy between reported and total removals varies, however, the TAC will not be efficient in controlling the exploitation (ICES, 2006a)

Another pitfall is how the fishing mortality is defined. It is typically the arithmetic mean over some ages. If the reference age span changes, the F-values in the rule have to be revised. Doing so is not quite straight forward, it may not be a simple ratio. Problems may also be encountered if the selection at age varies over time, or if the estimate of F at some ages becomes unreliable, for example at older age as the stock becomes overexploited. In simulations we are used to regard the F as a scaling of a fixed selection pattern, but the real world may be more complex than that.

2.4.2.5 Step responses

It is common to see rules where different options apply according to the state of the stock. For example, a rule to restrict the year to year variation in TAC is only valid if the stock is above Bpa

In such cases, a small change in the stock estimate may imply a great change in fishing opportunities. Although this may be adequate from a conservation point of view, smooth transitions may be more acceptable to managers and stakeholders. It may be useful for managers to have simulations showing how the rule will work if the stock appears to be close to the landmark, and to assist in improving the rule if necessary.

The assessment uncertainty may lead to further surprising results. The following example is taken from Section 3.8.2 in the report of the AFWG 2006 (ICES 2006,e):

> Concerning the HCR, it should also be noted that it does not take into consideration possible assessment revisions from year to year. This may lead to unexpected results, as illustrated by the following example: This year, the predicted SSB in 2007 (441 000 t) is < B_{pa}, and thus the limit of 10% year-to-year-change is suspended when setting the TAC for 2007. The prediction also gives an increase of more than 10% in the TAC from 2007 to 2008 (from 366 to 425 thousand tonnes), which will be allowed because SSB < B_{pa} in 2007. However, if next year's assessment should show that the SSB in 2007 and following years all are > B_{pa}, this means that the TAC for 2008 then will be limited by the 10% year-to-year change, and thus may not increase by more than 10%. One of the intentions of the rule was that the 10% limit should not apply in the situation when the SSB increases from below B_{pa} in one year to above B_{pa} in next year, so that the TAC can be increased by more than 10% in such situations. This intention will thus not always be fulfilled.

In conclusion, some problems with interpreting the legal text of management strategies have been highlighted. Most of these problems have been uncovered during the processes of evaluating such strategies, and typically, when the rule has to be programmed in a simulation framework. A good way of discovering ambiguities is to write flow-charts for the decision process as recommended by the WGMG (ICES 2006a).

Each alternative interpretation may be perfectly adequate, but it is recommended that the right interpretation is identified through communication with managers at an early stage of the evaluation process, rather than just assuming one interpretation. In that process, it may be relevant to assiste managers by demonstrating the implications of alternative interpretations. In the final evaluation, naturally the exact interpretation assumed should be clearly documented.

2.4.3 Additional points on evaluation

1. When evaluating a management strategy, simulations should be done according to the guidelines previously outlined by SGMAS. The exact choice of software for simulations depends on availability and experience, but it is essential that the software covers the options that are included in the plan – limitations to the software should not preclude a proper evaluation of relevant options. If necessary, the software has to be extended. The software should be quality controlled as outlined by the WGMG (ICES 2006a). Simulations should show both the risk to precautionary reference points and the performance in relation to management objectives.

2. In simulations, one should avoid more assumptions than necessary. If assumptions have to be made and it is uncertain what they should be, it is often better to outline the sensitivity to these assumptions by screening over a range, rather than just fixing a value. This applies for example to error in implementation. When the implementation error is uncertain, the range in which the risk to for example SSB is acceptable should be outlined, rather than just calculating the risk for a certain mean value of the implementation error. However, such screenings have to be limited to where it is really relevant, there is no point in simulating everything. The final step will then be to consider if the implementation error that leads to a low risk is realistic, or can be achieved. The required level of compliance can then be presented as a necessary condition for the rule to be compatible with the precautionary approach.

2.4.4 Some points relating to design of management strategies.

The purpose of this section is to highlight some points that have emerged during the development and evaluations of management strategies.

2.4.4.1 Protective measures

Management strategies do not always work as intended, for many reasons. Implementation may fail, unforeseen side-effects may emerge or the natural conditions may change to outside the bounds that were assumed when the plan was developed. Therefore, any rule should include some option to take action if the rule does not work properly. It may not be possible, and even not relevant, so specify exactly what action should be taken. More important is probably that the conditions that should trigger action are clearly stated, with clauses to ensure that the action is strong and timely enough. Taking proper action in time is likely to be facilitated if there is a legal basis for doing so in the agreement formalising the strategy. Likewise, a clause to ensure that the plan is revised at regular intervals, for example every 5 years, should be in place.

2.4.4.2 Monitoring the effect.

Monitoring the effect of the measures included in the rule is desirable, and sometimes necessary to adapt to the development of the stock, and to strengthen measures if they seem insufficient. This is not always achievable, however, because the effects on e.g. fishing mortality may be blurred by assessment uncertainty. If monitoring the detailed effects of e.g. rebuilding measures is problematic, it may be worth concentrating on whether the objectives are reached. As an example, in the case of the Northern hake it is likely that the stock now is close to the rebuilding target, but it is less clear why the stock has improved.

2.4.4.3 The term ‘rapid recovery’.

The term is often used, and its interpretation is unclear. There are several examples in the part where the term has been interpreted as ‘bring the SSB above Bpa in one year’, which has sometimes led to quite draconian advise. Such advise is both counter-productive and detrimental to credibility. If possible, some indications of the trade-off between strength of measures and efficiency of recovery should be indicated.

In a rebuilding situation, setting as an objective that the stock shall reach a certain magnitude by a certain year may be unrealistic. In practise, recovery will often depend on how well incoming year classes are allowed to contribute to the recovery. Hence, the important point is to establish the conditions, e.g. by sufficient reduction of fishing mortality. The exact timing of the recovery then will depend mostly on the strength of the future year classes, which normally cannot be predicted.

2.4.4.4 Multiple rules

Many of the rules presented to ICES recently have multiple elements: Increase in SSB, stabilisation of catch and constraints on fishing mortality. The priorities between such elements are crucial for the performance of the rule, and have to be stated clearly. Depending on the priorities, one component may dominate in practice, leading to a performance according to that type of rule. For example, if a rule to increase the SSB with a certain amount every year in a rebuilding situation is combined with a constraint on variation in TAC, the SSB increase will commonly be overruled by the constraint in TAC variation, because the stated increase in SSB will require a drastic reduction in the catch. Hence, such a rule will largely have the performance properties of a catch stabilising rule, including the increased risk of stock depletion associated with catch stabilising rules. Highlighting these features can be useful even in the early stages of the development process to understand how the rule can be expected to work, and can often be done on a generic level with simple computational tools (Skagen, Working Document).

Multiple measures will often improve the rule. For example, a catch stabilizing rule should be safer if supplemented with an upper limit to the fishing mortality. With a stock in a good shape, the catch stabilizing rule will be in effect most of the time, while the F-constraint will act as an extra protection.

2.4.4.5 Effort management.

Most management plans that have been presented to ICES mainly concentrate on rules for setting TACs. TACs are not the only instruments that can be used for managing stocks and fisheries. Alternative instruments were not extensively discussed at this year's SGMAS, but some points were noted.

- Management by constraining effort needs to take into account that effective effort may increase even when nominal effort is kept constant or decreased, due to improvement in technology and skills. Therefore, a constant effort regime must have instruments to reduce the nominal effort (number of vessels, number of fishing days etc.) in line with improvements in effective effort.
- For stocks where reliable predictions for setting TACs cannot be provided, effort regulation may be the most feasible alternative. Some such fisheries, like the industrial fisheries in the North Sea, have in practice been self-regulating in the past. This may still be an adequate alternative, if the effort can be limited to what the stock can sustain, and there are supplementary measures in place as an additional security if the stock productivity changes. As one example, the suggested management regime for sandeel in the North Sea (Section 2.1.2) may function that way in practise.
- In other data poor situations, using effort limitations as part of an indicator-based management may be worth exploring (see Section 3.1)
- Constraining effort in one fishery may result in reallocation of effort, the effect of which has to be taken into account (see Section 3.2 and SGMIXMAN (2007))

2.4.4.6 Complexity vs. simplicity.

In several of the case studies it has been noted a tendency to increase complexity both of the rules themselves and the simulations. Although there may be good reasons to do so, there is some concern that this creates more problems that it solves. One common problem is that complex rules often require more precise assessments than it is possible to obtain. Also, too much complexity may hamper good communication and dialogue, both because it is hard to fully understand all implications, and because it easily becomes open to multiple interpretations. Finally, multiple rules with associated priorities may sometimes lead to contradictions, situations that are not covered or unwanted results, which may be difficult to discover in advance if the rule is complex.

So far, most of the attention with respect to evaluations has been concentrated on risks in relation to the precautionary approach. The upcoming emphasis on MSY considerations will require more attention in that direction in the future, for example with respect to the interpretation of MSY in relation to management strategies and the trade-off between short term loss and long term gain. This has not been extensively discussed by the SGMAS this time.

3 Options for management strategies

This section deals with recent developments in the design of management strategies, in particular for 'non-standard' situations. It should be regarded as a continuation of Section 3 in the 2006 SGMAS report (ICES 2006c).

This year attention was concentrated on the use of indicators in managing stocks, in particular in data-poor situations. Also, the progress made on management of mixed fisheries by the SGMIXMAN was considered.

3.1 Indicator-based advice

3.1.1 Introduction

SGMAS 2006 examined the case of managing "data poor stocks". In that report it was concluded that in situations where data is lacking or critical data is uncertain or biased, there might be considerable potential for the use of empirical indicators. A list of potential indicators is given in last year's report, along with some very elementary steps in how they could be used operationally. This year SGMAS provides some information from previous studies of how indicators have been employed in fisheries science, following a development of their use from informing "soft advice" (i.e. to provide directions or qualitative management advice) to "hard advice" (i.e. actual prescriptive advice). Indicator use in "hard advice" may be developed further using signal detection methods, which could then be incorporated in HCR simulations to develop management plans. This section concludes with some ideas on the testing and evaluation of such an approach.

A management plan based on simple indicators is fundamentally suited to a strategy that can prioritize stability in yield over optimization of exploitation. In this respect indicator-based management may be considered an unsuitable approach for a management plan with the objective of optimizing long term yield. Conversely, it should also be considered that strategies that are based on optimizing exploitation might be unsuitable for data poor situations.

3.1.2 Previous studies

Some theoretical as well as practical uses of empirical indicators in fisheries management have been published in the literature in recent years. First, we briefly review some general work on using indicators in informing management and then some case studies exploring the validity of candidate indicators applied to actual decision rules.

The most widespread use of empirical indicators in the literature is to inform "soft advice" (e.g. Rochet and Trenkel 2003, Rice and Rochet 2003, Rochet and Rice 2003). Rochet and Trenkel (2003) review some community indicators to measure fishing impacts on an ecosystem. They conclude with the scientific need for more validation studies of indicators in fisheries science as an objective way to avoid subjective processes in assessment.

Rice and Rochet (2005) developed a framework of eight steps for the selection of indicators as an objective aid to a formal screening of indicator performance. This step-by-step framework is also aimed at creating a structure for the dialogue between scientists, stakeholders and managers when choosing the proper suite of indicators and avoiding common pit-falls. Rochet & Rice (2005) then test this proposed framework in selecting indicators for use in ecosystem-based fisheries management.

Rochet and Trenkel (2003) evaluated the performance of empirical indicators for abundance estimators to test the effect of fishing on a fish community. For their case study of Celtic Sea groundfish, they found that mean length of catch (L_{bar}) was a very good indicator (consistently large statistical powers) but requires both landing and discard information for the populations at hand.

Empirical indicators can also be used in lieu of decision rules to give “hard advice”. In the most elementary case “hard advice” is simply expert judgment applied to indicators such as CPUE. The common practice, for example, of recommending a TAC based on a rational that is qualitative for data poor stocks occurs in ACFM.

An increased level of complexity in the use of empirical indicators for “hard advice” is to base decision rules directly on the quantitative level of empirical indicators In Punt et al. (2001), fisheries management using indicators was explored in lieu of decision rules due to paucity of data. In this study, the empirical indicators that performed best for management decisions were mean individual length and weight frequencies. For some stocks catch rate is not a good indicator of stock abundance (Punt et al. 2001, Scandol 2005) but is still often used. Yet, for the broadbill swordfish fishery off Eastern Australia, Punt et al. (2001) showed that catch rates were a poor empirical indicator of the stock. This was partly due to the fact that the fishery fished the swordfish opportunistically, and not regularly, which skewed catch as an abundance indicator.

A simulation in Codling and Kelly (2006a) looks at an empirical indicator (proportion of the stock above a certain age) as a proxy for exploitation and applies a simple harvest control rule (HCR) based on trigger levels for this indicator. The performance of this empirical indicator is compared to a HCR based on traditional estimated indicators (SSB and F). This simulation was carried out on a virtual stock with the qualitative dynamics of Irish Sea cod (but not in a depleted state), and used the simulation tool F-PRESS (Codling and Kelly 2006b). Among the scenarios tested were those with bias on the traditional observation model. The results showed that the traditional estimated indicators performed better than the empirical indicators (as you might expect), but also that the empirical indicators could be still used to manage the stock with a low risk to recruitment impairment. In addition it was shown that if there is a bias in the output of the observation model, (i.e. the assessment, - as can arise when the catch data are underreported) the risk to the stock from an HCR based on the assessment was significantly greater than an HCR based on the empirical indicator.

By shifting the paradigm from estimating stock productivity to maintaining stability, a more advanced application of indicators can be made using a statistical framework (process control). In the traditional paradigm process and error is modelled and management action is taken which relates to the process (thus it can be directly modelled). In a different paradigm employing process control theory, the process and error is not directly modelled. Rather the indicator is used to monitor if the process is “in control” and management action is initiated when the process is determined to be “out of control”. Because the process is not modelled, the effect of management actions is simply measured by the success of returning the system to a state of control. In this respect the management strategy would have to be adaptive.

The utility of the statistical process control approach is using the signal from empirical indicators to detect real changes in system state There may be some potential in exploring different kinds of strategies in this paradigm, where management actions are initiated by an out of control signal in the system rather than a direct response to the resource productivity.

3.1.3 The case of the Northern Gulf of St Lawrence cod

In Canada an indicator-based approach is under development to determine quotas based on changes in a composite indicator’s value for Northern Gulf of St. Lawrence cod. This approach has also previously been described by SGMAS (ICES 2005a, ICES 2006c). The indicator is termed the overall adult stock biomass (OASB), which is calculated as an average of several standardized fishery dependent and independent indices of adult stock abundance multiplied by a reference biomass. The indicator-based advice is given by the following procedure: the percentage change in the current OASB value compared to the value of the OASB two years prior drives an absolute quota increment either up, down or retains the status quo quota. Primarily, government managers and the fishing industry have developed this framework for quota decision. Government scientists have recently begun evaluating the framework for compliance with the precautionary approach (PA).

Duplisea, Fréchet and Castonguay (Working Document) conducted a simulation to test the OASB quota decision rules using a cohort model as the underlying operating model. Biological parameters and errors in composite indicators form distributions to simulate uncertainty. Then quotas were determined from the rule set and fed back into the operating model. Time for the stock to reach limit and target reference points at a 15% risk level were determined.

There were some lessons learned from this experience in Canada using an indicator index in the development of decision rules in fisheries management. The development process should have included more assessment scientists working on the stock. The decision rules also had non-compliant precautionary approach (PA) aspects from the start (large initial TAC when stock was 50% below Blim); a modest starting quota must be determined at the start of the process and this should be deemed PA compliant. Also, there was a scientifically accepted cohort model assessment already for the stock so by-passing that for a poorly defined indicator system would be difficult to define as best practice. Finally, risk levels need to be agreed upon by stakeholders before the start of simulations and a commitment by all stakeholders to abide by the rules for a specified period of time needs to be agreed before the process begins and consequences of not abiding should be clearly specified.

3.1.4 Testing and evaluation

SGMAS sees potential for using empirical indicators in developing management strategies for data poor situations. By applying signal detection methods of statistical process control, empirical indicators could be used to develop a HCR by simulation. Such a development would require testing and we give some outline of what needs to be considered here.

A basic requirement for any harvest rule should be that it is testable, i.e. that it possible to evaluate it in the context of the precautionary approach, and management objectives. The field of testing indicator-based regimes is far less developed than testing harvest rules based on analytic assessments, and the experience with indicator-based rules with respect to both testing and performance is at present very limited. Clearly, testing indicator-based harvest rules requires different ways of thinking. Some ideas and suggestions are put forward here. These are not meant to be prescriptive, but may hopefully be of some help in promoting the further development in the field.

Basically, a simulation would require and operating model and a decision rule, as usual. The operating model can still be a population model with the appropriate complexity, but since indicator-based management typically will apply to data-poor situations, it is more problematic to relate the operating model to the real stock under consideration. Furthermore, when indicators are used for decisions, a critical issue will be the link between the indicators and the state of the stock. Some suggestions that may be helpful are further discussed below:

- Even if the stock in question is poorly known, some information about its biology should be available, if necessary by referring to other stocks of the same species.
- The dynamic properties of some types of management strategy can sometimes be inferred a generic basis with artificial data. This applies for example to the risk of depletion in catch-stabilising regimes
- Simulation studies can be conducted, but elements in the operating model that normally would be taken from analytic assessments, like the initial stock numbers and selection at age, may have to be assumed. In such cases, they may be

introduced as stochastic variables, and the robustness to assumptions about these elements may have to be tested. At the end, some common sense considerations may be necessary to decide whether the robustness is sufficient for the purpose.

Indicator-based harvest rules will often imply rules for change in regulations (e.g. TACs, effort etc.) rather than explicit levels. These rules will most often be quite conservative in the sense that the current regulations are kept unchanged unless there is good reason to change them. Indicators are probably not a good basis for micro-management. Therefore, some inferences can be made from studying catch-stabilising rules on a generic basis.

With fixed catches, or slowly varying catches, there is the risk that maintaining catches while the stock is declining can lead to a vicious circle with escalating mortality and stock collapse. (Murawski and Idoine, 1989) It appears that the variation in recruitment and the state of the stock when the regime is introduced are the most important factors determining the risk, while growth rate and life span have less influence, at least within a range that is reasonable given even sparse knowledge of the stock. (Skagen, 2007). Furthermore, some protection rule needs to be in place, which enables strong reduction in the exploitation if the stock develops unfavourably.

In that perspective, the use of indicators will be two-fold.

1. To decide on adjustment of management actions, for example to respond to trends in indicators relating to abundance of the stock.

2. To trigger a protection measure if necessary.

For the former point, the performance of the rule will depend on how strongly the stock responds to the rate of change in TACs, versus the degree of change of TACs resulting from the rule. For example, if the stock abundance is highly sensitive to a small change in the catch, a rule that allows for large changes in the catch may induce large fluctuations in the stock. If there is a delay between change in the stock and response to the indicator signal, this delayed feedback may amplify the fluctuations.

For protective measures, the trigger level and the strength and timing of the response are the important parameters. Both can to some extent be evaluated on generic grounds. Then the robustness of the rule depends on whether the indicators are sufficiently linked to the stock dynamics to provide the necessary response.

A major problem is that the link between the state of the stock and the indicators may be poorly known. (Punt et al. 2001) One may argue that rules have to be designed in such a way that they are robust to the expected uncertainty of this link. However, that will easily lead to a rule that is overly conservative. Depending on the indicator, some assumptions may realistically be made about the sensitivity of the indicator to fluctuations in the stock abundance. For example, with relatively wide assumptions about the biology of the stock, it should be possible to quantify the link between change in stock abundance and indicators like age distribution or length distribution in catches or surveys, catch rates or changes in catch rates.

An additional problem with indicators is that they may be influenced by regulations, sometimes in a quite intricate way that may be difficult to foresee. For example, for North Sea flatfish, due to lower TACs, fishermen wanted to save fuel. Therefore, the fishery was drawn closer to shore to the juvenile areas for the stock and fished more on the juvenile fish. If mean length was used as an indicator here, this change in the fleet behaviour will change the mean length indicator.

3.2 Mixed fisheries and fleet dynamics

SGMIXMAN (originally WKMIXMAN) was established with the short-term requirement of defining a framework for simple models of mixed fisheries which could be used to obtain consistency between management (TAC and/or effort) advice for species caught together. The original context for this was the requirement for advice for the demersal stocks of the North Sea, which are caught together to varying extents but have different conservation needs. This situation became particularly problematic in 2003 when ICES first advised closure of all cod fisheries in the North Sea. This led to the development of the MTAC approach (Vinther *et al*, 2004) and the requirement of the MIXMAN group was to define a replacement for MTAC. The result of the first MIXMAN meeting was the Fleet and Fishery Forecast approach (F^3 or Fcube).

The basic structure of Fcube, and the key way in which it differs from MTAC, is the separation of fleets (i.e. the vessels) and their activity (the fisheries or métiers). Fleets (i.e. homogeneous groups of vessels) have a certain amount of effort each year which is allocated between different métiers. The fishing mortality that each fleet exerts on each of its target species is then derived from its total effort, the proportion of that effort allocated to each métier, and the catchability of each species within each métier. In this way the approach allows the impact of different fleet efforts and allocations to be modelled. For instance by assuming that all fleets will fish until all of their quotas are exhausted (the scenario of max. effort), the approach can be used to show the misreported or discarded catches implied by this scenario, and thus illustrate the extent to which the single species TACs are mis-matched.

After the initial adoption of the FCube approach by WKMIXMAN (ICES 2006b), exploratory runs were made at WGHMM and WGNSSK. These identified a number of issues for further testing and development and these were investigated further by SGMIXMAN (2007). Further development and testing will be required before Fcube can be used in an advisory context. Part of this work will be done within the EU-funded Aframe project due to start on 1 April 2007.

In its initial form, Fcube was developed for short-term advice across multiple stocks within the same area/fishery. As such it is a rather different tool to the fisheries management strategies simuolation tools considered elsewhere by SGMAS, which typically address single stocks on a longer time scale. One exception is the analyses that have been done in relation to proposals for a management plan for the North Sea flatfish fisheries. These simulations have considered the fishery as having two target species (Sole and Plaice) and have considered some simple fleet scenarios along the lines of the ‘max. effort’ scenario used in Fcube.

Fcube is a deliberately simple model, and while there may be scope for developing its fleet dynamic components for use in multi-year simulations, e.g. by developing fisher behaviour models using economic and other data, it will first be essential to ensure that it works effectively in its intended, short-term role. This will require further hind-cast testing and in particular, compilation and analysis of suitable data. While Fcube is a simple model, the data required to provide an adequate representation of e.g. the demersal fisheries of the North Sea are necessarily extensive, and their compilation is a non-trivial task. It is possible that some of the problems so far encountered with the approach, relate more to the need to use data compiled for other purposes than to the approach itself.

The concepts behind the approach, and in particular the need for routine incorporation of fleet and fisheries information in the assessment process, have a number of implications. By placing the focus on fisheries rather than on fish stocks, it becomes necessary to account for other components of the catches, and not just those species that are the subject of routine stock assessments. This might involve simpler models or indicator approaches, rather than the traditional age-based assessments. This in turns provides a natural link into the ecosystem approach to fisheries management. This link runs in two directions. Firstly issues with the impact of fisheries on other aspects of the ecosystem typically involve the use of specific gears in specific areas and thus involve fleet/fishery information. Secondly, indicator approaches designed for ecosystem considerations may also have applications within more fishery-related management contexts. Hence the routine incorporation of fleet and fishery information into the assessment and advice process would provide a way of bridging the gap between the traditional single species assessments and the ecosystem approach to fisheries management.

4 Updates on software

4.1 Development of F-PRESS since SGMAS 06

An introduction to F-PRESS is given in Section 8.2.5. of the SGMAS report (ICES 2006c). Some verification of the programme was completed by WGMG (ICES 2006a) and it was used for Horse mackerel and Celtic sea herring simulations during the year. Ver 2.0 is now complete and includes the developments given below

- Code Restructured
  - 20 fold improvement in performance
  - Modular code
- Development of supporting applications to support
  - Options file management (xml format)
  - Input data file management (from ICA)
- Automation
  - Batch operation (weekend/overnight)
  - Automatic loading of R libraries, options on startup
- FLR Outputs
  - FLQuant objects available as output, but “Area” dimension is used to hold information on the iteration number, until extra dimension added to FLQuant.
- Additional Graphics/Statistical Routines
- Code packaged as a library

The user and technical manual is now complete. It is intended to bring this development to WGMG in 2007 for appraisal. Code validation with test scripts is underway and following this it is hoped to release the package as an R library on the FLR site.

4.2 FLR

This platform consists of a set of libraries for management strategy evaluation in the R statistical environment (R Development Core Team 2005 http://r-project.org. It has been applied in various research projects to evaluate management strategies . The use of the R statistical environment has the important advantage of providing a powerful supporting system for data manipulation and a tested set of routines for statistical analysis and modelling capability, making use of the S language and several database interfaces. The code is open source and licensed under the GPL2 Free Software Licenses. It has been fully designed to deal with uncertainty estimates and variability in data and models, and allows for complete replicability of the analyses carried out for later inspection or audit in mind. The library is design in a modular system implemented as a set of R packages, building up from a central package, called FLCore. This core package provides a common interface on which secondary packages can be built through the use of standard classes and methods for storage and manipulation of input and output of fisheries models (Kell et al. 2007). Both FLCore and the secondary package for exploratory data analysis are accepted as official R packages and available through CRAN (http://cran.r-project.org). Development of secondary packages is greatly simplified by this emphasis on Object Oriented Programming (OOP). Currently 30 packages are available for a range of more specific purposes, and other packages are under development. These cover tasks ranging from: stock assessment, construction of Harvest Control rules, the construction of operating models, the evaluation of HCRs using simulation and the graphical exploration of inputs and outputs.

A wide variety of standard stock assessment methods are available in FLR as well as some more novel methods, including Bayesian estimators. Validation mechanisms follow standard R language procedures, and include not only the software behaviour, but also the existence of documentation. In addition, validation of model results will be conducted following a standard procedure. Finally, all source code is open for inspection and testing.

Program

- R interface – easy to edit and implement, built in statistical modeling capability and extensive data manipulation tools;
- Modular core structure: flexible mix and match use of functions as required; provision of extra functionality can be achieved through new C++, Fortran, R routines,
- User constructed implementation: high control of output detail and supplementary analyses

Operating model

- Currently various operating models have been developed on a case specific basis, for both mixed and single fisheries like Northern Hake, North Sea flatfish and roundfish.
- Both deterministic and stochastic implementation of operating models have been developed;
- Most applications single species, age structured annual time step, but design allows for development of multi-species, multi-fleet, alternative time scales;
- A variety of observation error models are being developed, and a variety of forms of uncertainty can be modeled including process errors that can be modeled using a parametric or non-parametric facility to include correlation

Management model

- Management model explicitly modeled: sampling errors, assessment methods, decisions and implementation errors may be all explicitly modeled

User considerations

- Ease of implementation depends on complexity required, but has been criticized as requiring a steep learning curve. However, full documentation, tutorials and course notes are available online (http://www.flr-project.org/doku.php?id=doc).
- Good selection of commonly used assessment is being made available (e.g. FLBRP, FLSTF, FLXSA for the calculation of biological reference points, performing short-term forecasts and performing VPA). Common data formats through classes simplify testing of various assessment models on a single dataset without extra work.
- Interface allows flexible implementation of HCRs

• Developed using Concurrent Versions System (CVS) to insure integrated development. All development and discussion carried out openly through website

• Documentation is available and can be updated, corrected or added to by users via the web-site. A mailing list is also available for users and developers.

Conclusions/Recommendations:

Highly flexible, with appropriate expertise it is suitable to carry out full evaluations of management strategies. The routines have been used to set up management strategy evaluation schemes for a range of management strategies, including Antarctic toothfish in CAMMLR, North Sea haddock in ICES, as well as simple OM explorations in ICCAT. Also, the individual stock assessment procedures have been used in ICES.

5 Ongoing projects related to management strategies

A large number of EU funded projects have some relation to the development and evaluation of management strategies. The SGMAS found that it might be informative to get an overview of ongoing projects, without attempting to evaluate the content or progress in the projects

The idea of this section is to give a comprehensive overview of relevant projects that are somehow related to improving management strategies and/or policies and that are ongoing as part of the EU framework programmes (FPs), specifically FP6. We have merely collected more general information about these projects, i.e. their research contexts, their concepts, scopes and foci, as well as their design implementations, to see what is done so far and how can we learn from them - specifically in the light that at this time no substantial outcome resulted from all of the projects being considered.

5.1 Overview

The best source of finding ongoing EU projects is the EU website itself. There are two important links that refer to EU projects sorted by themes and being linked to research in fisheries and aquaculture:

- http://ec.europa.eu/research/agriculture/projects/list_theme_13_en.htm
- http://ec.europa.eu/research/fp6/ssp/themes_en.htm#188

Under the first link about 50 fisheries related projects are listed in total of which 28 projects claim an improvement of management strategies; 13 of these are completed, 15 are in an ongoing stage. Under the second link 32 projects are listed of which 15 projects claim an improvement of management strategies. As this link exclusively refers to projects that are running under the 6th framework (FP6) and that are still in an ongoing stage, the following table summarizes all 15 projects by acronyms that claim an improvement of management strategies and that are attached to this link:

Acronym	Topic
BECAUSE	Improving multi-species fisheries assessment in five European regional seas
CAFÉ	Measurement of capacity, effort and fishing mortality
CEDER	Real-time monitoring of fishing activity
CEVIS	Evaluating alternative, participatory management models for EU fisheries
COMMIT	Committing to tailor-made long-term fishery management strategies
EFIMAS	Evaluating scientific advice and decision-making processes in fisheries management systems
EMPAFISH	Ecosystem conservation and fisheries management through Marine Protected Areas
FISBOAT	Taking reliable stock of fish numbers
IN EX FISH	Incorporating non-fishery influences into stock assessments
INDECO	Developing environment indicators for assessing fishery management
ISTAM	Improving fishery data acquisition, management and analysis
POORFISH	Developing probability model applications in data-poor fisheries
PRONE	Assessing risk in fishery advice and management decisions
PROTECT	Ecosystem conservation and fisheries management through Marine Protected Areas
UNCOVER	Developing more effective stock-recovery programmes

To give a structured and concise overview of topics, objectives and design of these projects, the EU web sites related to these projects are all organised in the same following way:

- Overview
- Contribution to policy development
- Project deliverables
- Dissemination

of which the point “Contribution to policy development” always contains a statement on whether and how the project will affect or improve the current EU management strategy.

To highlight features of three typical but quite different approaches that aim to improve management strategies or policies, it was decided to exemplarily focus on the three following projects:

- EFIMAS
- CAFÉ
- PROTECT

Based on a brief outline of the features of these three selected projects the scientific spectrum will cover

- the development of theoretical tools to evaluate fisheries management options
- the investigation of new possibilities of measuring capacity, effort and fishing mortality and their interrelationships and
- the investigation of the usefulness of MPAs as a management tool.

It should be noted at this point that in several of the projects listed above extensive use of FLR routines is or will be made, but that specifically in EFIMAS and CAFÉ also own FLR routines will be developed that will add to the scope of the FLR project.

5.2 Selected projects

5.2.1 EFIMAS

EFIMAS is an ongoing FP6 project and can be reached using the following two links

- http://ec.europa.eu/research/fp6/ssp/efimas_en.htm
- http://www.efimas.org/

where the first link gives a structured overview and the second provides more detailed information on the project and its status. The acronym EFIMAS means "Operational Evaluation Tools for Fisheries Management Options". EFIMAS is implemented in collaboration between 29 European research institutes in the fields of fish biology, fisheries and economics. Project Coordinator is J. Rasmus Nielsen from DIFRES, Denmark.

In short: EFIMAS is supposed to enable the EU adopting a proactive approach to fishery management that is readily accessible to all stakeholders. It will develop an operational evaluation framework (evaluation tools) to appraise the biological, social and economic effects of fisheries management measures in the EU. The evaluation framework (tools) are supposed to be generic in the sense that it will be able to evaluate most existing management systems and descriptive models and analysis tools used for production of management advice (fisheries/stocks evaluation models and tools), as well as systems not yet implemented, but which can be simulated. The evaluation framework can compare alternative management systems producing relative measures of performance applying output from either currently used or appropriate alternative descriptive models and analysis tools in question. The project aims to

- use models that will run stochastic simulations incorporating data from selected EU fisheries
- compare range of management options generated with the current management of the test fisheries
- compare the performance of a range of management options under alternative management systems and objectives

The framework will be applied to important EU fisheries and thus will concentrate on using data of the following 9 case studies:

- Flatfish, North Sea
- Round fish, North Sea
- Salmon, Baltic Sea
- Nephrops, East Atlantic
- Northern Hake
- Swordfish, Mediterranean
- Hake, Mediterranean
- Cod, Baltic Sea

The framework will be based on an understanding of the processes contributing to the overall performance and it will take account of uncertainties (parametric as well as structural uncertainty) and it will include risk assessments. The five main types of uncertainties to be evaluated are

- The dynamic processes (phenomena not fully understood, e.g. variation of recruitment)
- Measurement errors (error arising from sample-based estimation)
- Estimation errors (errors arising from incomplete or biased samples)

- Model mis-specification (inadequate model, e.g. use of single species model to describe mixed fisheries systems)
- Implementation errors (error arising from management measures not having the expected effect)

The project will also perform risk assessments by stochastic simulation of the errors listed above. The project's specific deliverables are expected to be

- A review of present management and decision-making processes (due by April 2005)
- The development of a preliminary software package of operational models to compare alternative fisheries management regimes (due by October 2006)
- The development of a final software package - aiming at a high level of user-friendliness - with documentation (due by June 2007)
- The installation of a Policy Implementation Plan detailing the application of the evaluation framework at the fishery management level (due by April 2008)

5.2.2 CAFÉ

The second project highlighted here is CAFÉ that is also running under the 6th EU framework (FP6) and can be reached using the following two links

- http://ec.europa.eu/research/fp6/ssp/cafe_en.htm
- http://fish.jrc.cec.eu.int/fisheries/cafe/cafe.php

where the first link gives a structured overview and the second provides more detailed information on the project and its status. The acronym CAFÉ is an abbreviation for "Capacity, F and Effort" and thus aims to investigate new possibilities of measuring capacity, effort and fishing mortality and their interrelationships. Café is implemented in collaboration between 15 European research institutes in the fields of fisheries and economics. Project Coordinator is Dr Anna Korre, Imperial College of Science Technology and Medicine, UK. The background for CAFÉ is that capacity reduction and effort limitation are seen as major tools in EU fisheries management. The objective of the Common Fisheries Policy (CFP) reform of the EU is to match European fleet capacity to resource availability. Connections are assumed between these and fishing mortality, but the scientific basis for these has not been fully established, particularly for pelagic fisheries.

In short: CAFÉ is supposed to examine the relationship between these factors for six case studies; North Sea, Biscay & East Mediterranean pelagic fisheries; and North Sea, western (Biscay & Celtic Sea) and north east Mediterranean demersal fisheries. It will review existing approaches to measuring capacity and effort and control measures derived from these. It will collate data on fleets (catch, vessel & gear metrics, costs & profits, and investment & capital values) and on fish stocks (abundance, distribution, fishing mortality). It will include analyses of fisher's behaviour from targeted fine scale studies. Statistical and mathematical modelling tools will be used to explore and quantify relationships between metrics for the three factors. Metrics will be selected that are suitable for capacity and effort and have good explanatory power in the model systems. Appropriate models and metrics will be developed to quantify the links between capacity, effort and species mortality, partitioned by fleet and area. A key element will be a study of capacity utilisation, i.e. the match between capacity and real effort, including a quantitative study of the factors controlling capacity change, i.e. investment strategy, control legislation and economic factors. Finally, the project will propose a series of new effort and capacity control measures and scenarios. These will be tested and compared to current measures using operational models. At all stages explicit measures will be taken to quantify structural and parametric uncertainty. The final outcome will be a comprehensive review of possible management measures and their likely effect in conserving fish stock resources.

The project's specific deliverables are expected to be:

- Report: measuring and assessing capacity in EU fisheries
- Report: capacity management options in place in European and other fisheries
- Report: analyses undertaken in each case study fishery
- Report: methodologies for analysing the information available on capacity adjustment and capacity utilisation
- An empirical analysis of the capacity adjustment in the EU/EEA states involved
- Evaluation of the performance and recommendations on which methods perform best for each of the case studies
- Final Report (December 2008)

5.2.3 PROTECT

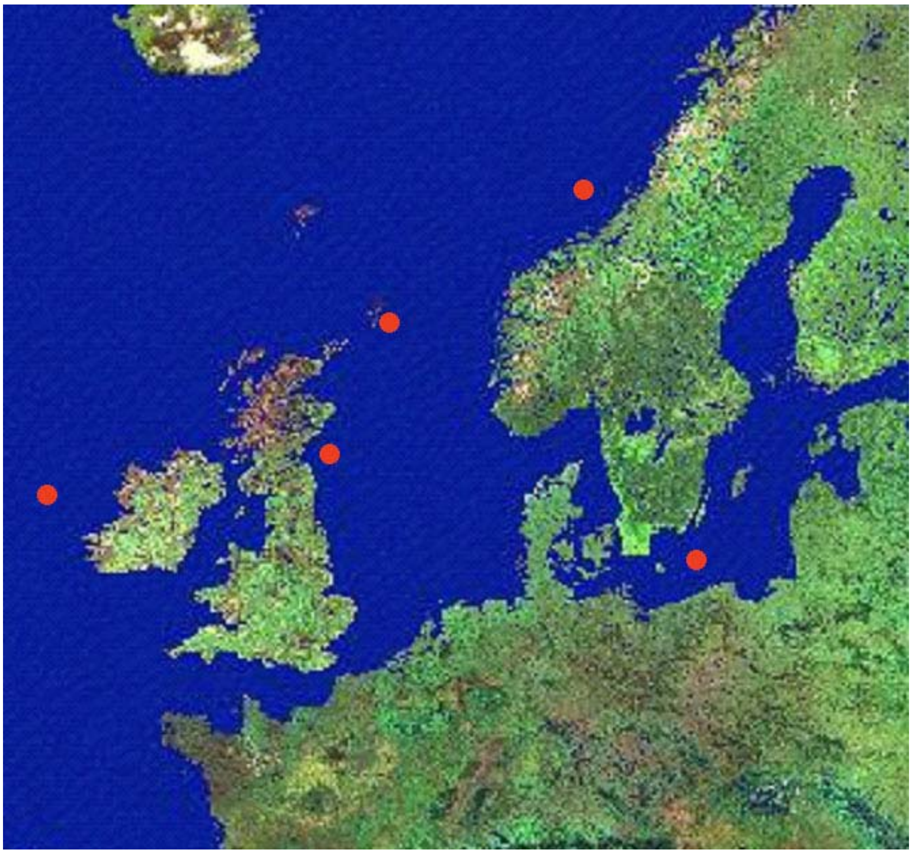
The third project highlighted here is PROTECT which is an ongoing EU FP6 project that can be reached using the following two links

- http://ec.europa.eu/research/fp6/ssp/protect_en.htm
- http://www.dfu.min.dk/dfu/dfuvis.asp?id=342

where the first link gives a structured overview and the second provides more detailed information on the project and its status. The acronym PROTECT is a short form for "Marine Protected areas as a tool for ecosystem conservation and fisheries management". Protect is implemented in collaboration between 17 European research institutes in the fields of fisheries and economics. The project coordinator is Erik Hoffmann from DIFRES, Denmark. The project is running from January 2005 to June 2008 with support from the EU 6th Framework Programme. The scientific background for PROTECT is that marine protected areas (MPAs) are seen as an instrument to manage fisheries and to protect marine environmental at the same time. Whilst many potential benefits of MPAs have been identified, little empirical evidence exists to demonstrate the full potential of MPAs in a temperate water setting. Part of the reason is that

- insufficient scientific knowledge and tools for MPA selection, design, implementation, monitoring and evaluation do exist
- little is known about the linkage of fisheries management and environmental protection.

In short: PROTECT seeks to strengthen the decision basis regarding potential use, selection, development and management of MPAs in Europe, as part of an ecosystem-based approach to fisheries management. To address a range of issues relating to development and management of MPAs in temperate waters, PROTECT undertakes three case studies covering a range of ecological, economic and fisheries management scenarios. The case studies will be undertaken in the Baltic Sea, the North Sea and the Northeast Atlantic. The case study areas are given by Fig. ???.



PROTECT has 4 objectives:

- to evaluate the potential of MPAs as a tool to protect sensitive species and habitats against the effect of fishing
- to develop scientific methods and information products to design and evaluate the effect of MPAs
- to co-operate with other EU-funded projects, such as EMPAFISH
- to organise a series of thematic workshops and compile reports that will draw from experience and lessons learnt from specific case studies

In particular, the modeling and evaluation work in WP 5 will seek to develop a suite of modelling tools for assessing the expected performance of planned and implemented MPAs, in the context of EU Fisheries and environmental priorities, using the performance measures developed in the success criteria work as well as monitoring strategies described and data availability carried out in the development of MPA monitoring strategies and databases. Modelling approaches will encompass:

- ecosystem indicators and community metrics
- stock specific spatial models
- multi species, multi fleet spatial models, and
- bio- and socioeconomic models.

These modelling methods will be applied to the case studies mentioned above, considering as well other management measures implemented. The project's specific deliverables will be:

- Initial review of MPAs as management measures
- A series of scientific tools and knowledge products to design, monitor and evaluate MPAs, including:
    - Strategies to monitor and assess MPAs
    - Meta-database on MPA information
    - Ecosystem indicators
    - Stock specific spatial models; multi-species and multi-fleet models; bio- and socio-economic models
- Case specific information through studies on specific ecosystems (Baltic Sea, North Sea, North East Atlantic)
- Synthesised information for EU policy support, including:
    - Improved scientific advice on MPAs to achieve their objectives with respect to target species and ecosystems
    - Improved scientific advice on MPA impacts on fisheries and socioeconomic consequences
    - Recommendations on legal strategies to be adopted for establishing MPAs
    - Policy Implementation Plan

6 Interactions with managers and stakeholders

SGMAS 2007 discussed the interaction between science, stakeholders and managers in a session which included some participants from these three different categories. The stakeholders were represented in SGMAS by members of a number of Regional Advisory Councils (RAC). This section covers that discussion, as well as some further experience gained during the meeting.

There seems to be broad consensus that the development of management strategies requires dialogue between all interested parties at all stages of the process. A summary of the role of science in such a process is provided in Section 2.4. In the present section, the dialogue process is discussed in a broader context.

ICES does not presently have the instruments ready for taking part in a dialogue process as suggested. Some suggestions to how ICES can contribute are presented here.

6.1 Dialogue process

6.1.1 Basic guidelines

SGMAS (2006) has identified four guidelines to facilitate these dialogues:

1) Candidate HCRs should be identified by fishery managers and ICES in a dialogue process
2) Sufficient time and resources should be allocated to the dialogue
3) Standards for acceptable risk
4) Care in protecting the "Science Boundary"

Furthermore, the need for science to take part at all stages, including the early ones, has become increasingly apparent.

6.1.2 Outlining objectives

The objectives for fishery management vary, but often refer to attaining a healthy/productive fish stock, high and stable yield, and low probability of moving a fish stock down to low-productive states. Objectives like these could be the standards on which a HCR should be evaluated. The choice of HCR will often imply choices on three levels:

- trade-off between different objectives.
- performance criteria; how can be ascertained whether objectives are met,
- handling of risk and uncertainty; how much risk is society willing to take

6.1.3 Trends in preferences

Preferences cannot be expected to be static. As an example, the attitudes in the pelagic fleet have changed substantially over the last 3 to 5 years. Before, the pelagic fleet had the same objectives as the other fleets. Today pelagic fishermen are more interested in stability in fishing opportunities than in trying to squeeze the TAC to its highest possible level and more interested in their long-term interests than in possible short-term gains. The trigger has been the introduction of ITQ for the major pelagic stocks in more or less all the countries in the North East Atlantic. The change has further been accommodated – at least for the EU-part of the fleet – by the introduction of RACs – in this case the Pelagic RAC. This has given the pelagic fishermen the foundation for a better understanding of the scientific world – and of the importance of the science on the external conditions for their businesses.

Such changes in preferences naturally differ between stakeholders, but represent new challenges for science, since new types of management plans may require new kinds of scientific understanding.

6.1.4 Dialogue partners

Ideally, a dialogue should be between all interested parties. In practise, various fora have emerged as partners in dialogue about management strategies.

In the EU in particular, RACs have been actively engaged in the development of management plans and long term targets. The NSRAC and NWWRAC organized a successful workshop on MSY in March 2006 which included economics, governance, social and environmental dimensions. A general conclusion was that governance was the most important factor. Scientists of national research laboratories have played an important role in the RAC process by providing input into the discussions in the form of submitting specific research documents or by providing verbal input during meetings. There has been almost no formal ICES involvement in this process.

In other contexts, other partnerships have evolved, mostly between managers and scientists. In developing the management plans for Arctic cod and haddock a working group of Norwegian and Russian scientists and economists provided background material for the decision by the Joint Norwegian-Russian Fishery Commission, as described in Sections 2.2.4 and 2.1.2. STECF has provided background material for e.g. the management of sandeel in the North Sea (Section 2.1.3). In these cases, there apparently has been enough communication with managers to enable scientists to understand which material would be relevant. In contrast, Section 2.3.2 provides an example where the communication was insufficient.

In NEAFC, a Management Science Committee is under development, which could become a forum for interaction.

The role of the partners in a dialogue process needs to be further clarified. In the discussion, there were some doubts as to a possible double role of the RACs, being both fora for dialogue and decision making bodies, and the precise role of the RACs in development of management strategies still needs clarification. For science in general, and ICES in particular, the role must be to provide independent information about implications of objective, trade-off between objectives, risks and uncertainty, and to suggest alternative options for management if that is relevant. Science should not jump into the managers role, and not be used to give legitimacy to political preferences.

6.2 The role of ICES in developing management strategies.

So far, the main role of ICES has been to evaluate more or less final management plans, primarily to decide if they are in accordance with the precautionary approach. If so, ICES will normally advise according to the plan (ICES 2005d, Anon., 2004)

The evaluation process very briefly includes interpreting the plan, noting inconsistencies, ambiguities and possible unwanted effects, and simulations to estimate the risk to conservation reference points.

In some cases, members of assessment Working Groups have done the work associated with the evaluation, and presented that to the assessment WGs. In other cases, ad hoc meetings have been set up to do the work. ACFM review groups have reviewed the results and the final decision made by ACFM. When the result of the evaluation was unsatisfactory, the plan has been passed back to the managers with recommendations for improvement.

ICES has provided a forum for settling questions linked to the development of management plans where that has been expedient, for example when revising reference points for Arctic cod and haddock (ICES 2003, ICES 2006d), or for doing simulations requested by managers (AGLTA – ICES 2005b))

The future role of ICES in facilitating the development of management plans could be to provide a broad forum for discussion that could go beyond the RACs, by involving science - management - stakeholders (both RAC + non-RAC). A possible route would be to organize joint workshops between ICES and relevant parties where the overall aim is to enhance the exchange of view. The objective would not be to come with definitive answers to the questions but rather to stimulate the exchange of views and to discuss trade-offs between different objectives, performance criteria and ways of handling uncertainty. Such workshops will represent a new type of working environment in ICES.

One possible drawback of the dialogue-model for developing management plans, is that they involve substantial transaction costs. There needs to be a process of clear prioritization among stakeholders and fishery managers and science managers on where dialogue processes are needed and what form they should take. In that context, ICES also will need to consider the logistics of its involvement, the annual cycle of deciding on expert groups may not be practical for this purpose and the fast track route may be too *ad hoc* in its present form. ICES also needs to ensure that the scientific participation in workshops is adequate.

In order to assist the process of developing management plans in a workshop-type of environment, there is a need for tools that have an understandable front-end that allows meaningful and comprehensible comparisons. Presentation of results has already been addressed by SGMAS (ICES 2006c, section 7.3), but the development of tools for presenting results still needs further work. This could include interactive computer tools for simple expression of trade-offs and consequences. Decision trees could be one alternative. One example of that, applied to management of wild rhinoceros in African national parks given only qualitative expert knowledge, is shown in Annex 2.

ICES has recently received a number of requests for evaluations of management plans. These requests could be treated as case studies of an integrated dialogue process, by inviting stakeholders and managers to a workshop model rather than have scientists carrying out the work in isolation.

7 References

Anon 2004. Memorandum of Understanding between the North-East Atlantic Fisheries Commission and the International Council for the Exploration of the Sea; Agreement in the form of an Exchange of Letters between the European Community and the International Council for Exploration of the Sea . Links in: http://www.ices.dk/advice/request/requesttable.asp

Anon. 2006. Further evaluation of the HCR for Northeast Arctic Haddock. Report by a sub-group of AFWG. Bergen June 2006, 19 pp.

B. Bogstad, H. Gjøsæter, K. Korsbrekke, I.Røttingen, S.Tjelmeland, K.Drevetnyak, Y.Kovalev, Y. Lepesevich and A. Filin, 2006. Report of the Basic Document Working Group (BDWG) to the 35th Session of The Joint Norwegian-Russian Fishery Commission, 30 October- 03 November 2006, on Harvest Control Rule for Management of Fishery on North East Arctic Haddock and Optimal Long Term Harvest in the Barents Sea Ecosystem

Codling, E.A., and Kelly, C.J. (2006a) "Cheap and dirty" fisheries science part II: An example of fisheries management using simple indicators. 62-68pp, in Codling, E.A., and Kelly, C.J.(Eds), Reports from the FSS mini-symposia 2004-2005. Marine Institute, Rinville, Ireland. ISSN 0578-7476. (http://privatewww.essex.ac.uk/~ecodling/FSS%20Mini%20symposium%20report%20-%20Codling%20&%20Kelly%202006.pdf)

Codling, E.A., and Kelly, C.J. (2006b). F-PRESS: A stochastic simulation tool for developing fisheries management advice and evaluating management strategies. Irish Fisheries Investigation Series No. 17. Marine Institute, Rinville Ireland, ISSN 0578-7476. 34 pp

Gjøsæter, H. and Bogstad, B. 1998. Effects of the presence of herring (*Clupea harengus*) on the stock-recruitment relationship of Barents Sea capelin (*Mallotus villosus*). Fisheries Research, 38: 57–71.

Gjøsæter, H., Bogstad, B., and Tjelmeland, S. 2002. Assessment methodology for Barents Sea capelin (*Mallotus villosus* Müller). ICES J. mar. Sci. 59:1086-1095.

Gjøsæter, H., Dommasnes, A. and Røttingen, B. 1998. The Barents Sea capelin stock 1972-1997. A synthesis of results from acoustic surveys. Sarsia, 83: 497-510.

Gudmundsdottir, A. and H. Vilhjálmsson 2002. Predicting total allowable catches for Icelandic capelin, 1978-2001. ICES Journal of Marine Science, 59: 1105–1113.

ICES 2001 . Report of the Study Group on the Future Development of the Precautionary Approach for Fishery Management (SGPA). ICES CM 2001/ACFM:11

ICES 2003. Report of the Study Group on Biological Reference Points for Northeast Arctic Cod. ICES CM 2003/ACFM:11

ICES, 2005a. Report of the Study Group on Management Strategies (SGMAS). ICES CM 2005/ACFM:09

ICES. 2005b. Report of the Arctic Fisheries Working Group. ICES C.M. 2005/ACFM:2

ICES, 2005c . Report of the *ad hoc* Group on Long Term Advice (AGLTA). ICES CM 2005/ACFM:25

ICES 2005d. Report of the ICES Advisory Committee on Fishery Managment, Advisory Committee on the Marine Environment and Advisory Committee on Ecosystems 2005. ICES advise, Vol. 1.

ICES 2006a. Report of the Working Group on Methods of Fish Stock Assessments. ICES CM 2006/RMC:07

ICES 2006b. Report of the Working Group on Workshop on Simple Mixed Fisheries Management Models (WKMIXMAN) . ICES CM 2006/ACFM:14

ICES, 2006c. Report of the Study Group on Management Strategies (SGMAS), 23 - 27 January 2006, ICES Headquarters. ICES CM 2006/ACFM:15. 157 pp.

ICES 2006d. ICES Workshop on Biological Reference Points for North East Arctic Haddock (WKHAD). Svanhovd, Norway, 6-10 March 2006. ICES C.M. 2006/ACFM:19, 102 pp.

ICES. 2006e. Report of the Arctic Fisheries Working Group, Copenhagen 19-28 April 2006. ICES C.M. 2006/ACFM:25, 594 pp.

ICES, 2006f . Report of the Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim, 10 19 May 2006 (ICES CM 2006/ACFM:29)

ICES, 2006g . Report of the Working Group on the Assessment of Northern Shelf Demersal Stocks (ICES CM 2006/ACFM:30)

ICES, 2006h. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK) (ICES 2006/ACFM:35)

Kell, L.T., Mosqueira, I., Grosjean, P., Fromentin, J-M., Garcia, D., Hillary, R., Jardim, E., Mardle, S., Pastoors, M., Poos, J.J., Scott, F and Scott, R.D. 2007. FLR: an open soource framework for the evaluation and development of management strategies. ICES Journal of Marine Science, *in press 2007*

Kovalev, Y., and Bogstad, B. 2005. Evaluation of maximum long-term yield for Northeast Arctic cod. In Shibanov, V. (ed.): Proceedings of the 11th Joint Russian-Norwegian Symposium: Ecosystem dynamics and optimal long-term harvest in the Barents Sea fisheries. Murmansk, Russia 15-17 August 2005. IMR/PINRO Report series 2/2005, p. 138–157.

Mehl, S. and Sunnanå, K. 1991. Changes in growth of Northeast Arctic cod in relation to food consumption in 1984-1988. ICES Marine Science Symposia, 193:109–112.

Roel, B. A. and De Oliveira, J. A. 2007. Harvest Control Rules for Western horse mackerel (*Trachurus trachurus* L.) given paucity of fishery-independent data. ICES Journal of Marine Science *in press*.

Murawski, S. A., and Idoine, J. S. 1989. Yield Sustainability under Constant-Catch Policy and Stochastic Recruitment. Transactions of the American Fisheries Society, 118: 349-367.

Punt, AE; Campbell, R and Smith, ADM. 2001. Evaluating empirical indicators and reference points for fisheries management: Application to the broadbill swordfish fishery off Eastern Australia. Mar. Freshw. Res. 52: 819-832.

Rice, JC and Rochet, M-J. 2005. A framework for selecting a suite of indicators for fisheries management. ICES Journal of Marine Science, 62: 516-527.

Rochet, M-J and Trenkel, VM. 2003. Which community indicators can measure the impact of fishing? A review and proposals. Can. J. Fish. Aquat. Sci. 60: 86-99.

Rochet, M-J and Rice, JC. 2005. Do explicit criteria help in selecting indicators for ecosystem-based fisheries management? ICES Journal of Marine Science, 62: 528-539.

Scandol, J. (2005). Use of Quality Control Methods to Monitor the Status of Fish Stocks. Pp. 213-234 in GH Kruse, VF Gallucci, DE Hay, RI Perry, RM Peterman, TC Shirley, PD Spencer, B Wilson, D Woodby (eds), Fisheries Assessment in Data-Limited Situations. Alaska Sea Grant AK-SG-05-02. ISBN:156612-093-4.

Skagen, D. W. 2007. Management strategies for reducing variation in annual yield: when can they work? ICES Journal of Marine Science, *in press 2007*

STECF (2004). Report of the Ad hoc Working Group Sandeel Fisheries.

STECF (2005). Report of the Ad hoc Working Group Sandeel Fisheries

Tjelmeland, S. 2002. A model for the uncertainty around the yearly trawl-acoustic estimate of biomass of Barents Sea capelin, *Mallotus villosus* (Müller). ICES Journal of Marine Science 59: 1072–1080.

Vinther, M.,Stuart, A.R and Patterson, K.R. 2004. From Single-species advice to mixed species management; taking the next step. ICES Journal of Marine Science, 61: 1398-109.

8 Working documents:

Bjarte Bogstad
Harvest control rule for Barents Sea capelin

Bjarte Bogstad
Harvest control rule for Northeast Arctic cod

Bjarte Bogstad and Knut Korsbrekke
Harvest control rule for Northeast Arctic haddock

Daniel Duplisea, Alain Fréchet and Martin Castonguay
An evaluation of Northern Gulf of St. Lawrence cod TAC decision rules with simulation.
Draft Document, presented as WD to SGMAS.

Kjartan Hoydal.
A note on the advice provided by ICES seen from NEAFC

Ciaran Kelly
Stochastic simulations of Celtic sea herring

Dankert W. Skagen,
The anatomy of management and recovery plans, or how to interpret legal texts and to predict the outcome of simulations.

Annex 1: Participants

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22 - 26 January 2007

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Annex 2: An example of a decision tree

One possibility of presenting results in a concise way that is understandable to stakeholders including non-experts is to generate decision trees in order to show what the consequences will be when following a specific “track of combined management options”. This holds for “data rich” (quantitative approach) but also “data poor” (qualitative approach) situations. Whilst in data rich situations the knowledge base is supposed to be informative, in data poor situations where we have a lack of information even expert knowledge may be incorporated. The concept of decision trees has been developed in the field of decision making being less related to natural sciences than to economics and business administration. The underlying theory of decision making and thus decision trees originates from decision theory. As an illustration of a decision tree Fig. A2.1 presents an example on how to manage wild rhinoceros in African national parks given only qualitative expert knowledge. Here two sets of management options are combined in association with specific actions and specific risks to give the total risk of extinction when following a specific track.

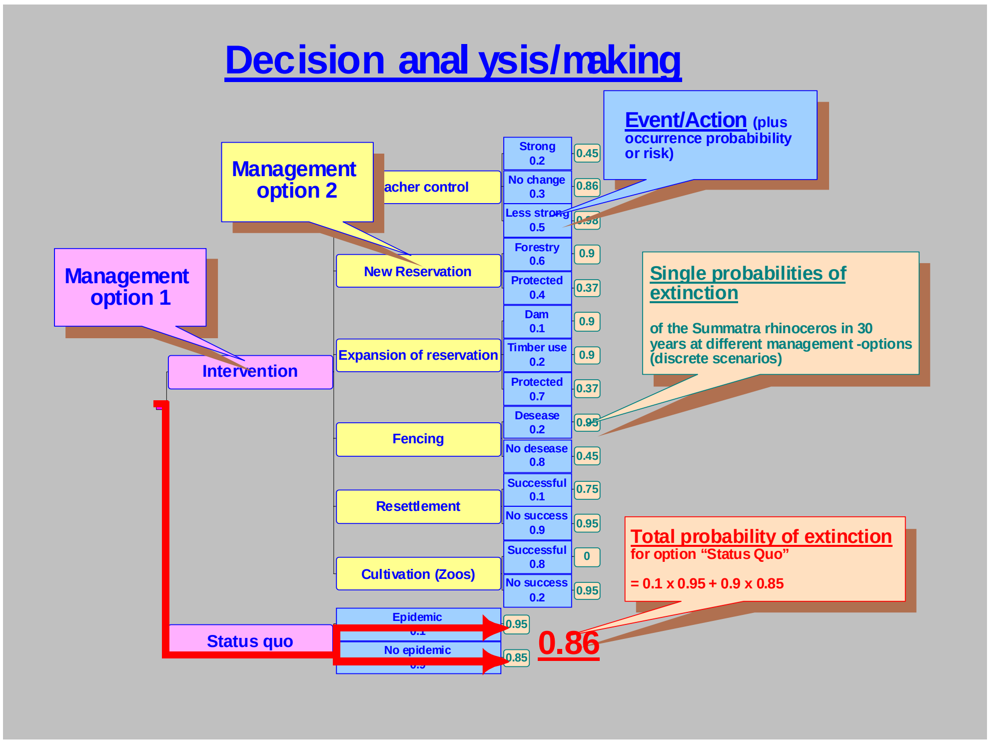

Figure A2.1