REPORT OF THE

STUDY GROUP ON THE FURTHER DEVELOPMENT OF THE PRECAUTIONARY APPROACH TO FISHERY MANAGEMENT

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International Council for the Exploration of the Sea

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TABLE OF CONTENTS

Section **Page**

1 INTRODUCTION

1.1 Participants

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1.2 Terms of Reference

The Study Group on the Further Development of the Precautionary Approach to Fishery Management [SGPA] (Chair, Dr Colin Bannister, UK) was established at the 2000 Annual Science Conference (88th Statutory Meeting) by Council Resolution 2000/2ACFM02. It met from 2-5 April 2001 at ICES Headquarters to:

1. review the current status of the Precautionary Approach (PA) as implemented by ICES

2. develop a framework for formulating advice by defining protocols for the establishment of

a) advice in data poor situations specifically when advising on the exploitation of deep water species

b) advice in data rich situations

c) recovery plans

3. investigate the use of MSY ($\mathbf{F}_{MSY}$ and $\mathbf{B}_{MSY}$) as a biological reference point

4. the Group should work to provide specific guidance to ACFM

and report to ACFM in May 2001 and to the Resources Management Committee at the 2001 Annual Science Conference.

1.3 Executive Summary

1. The methodology for estimating reference points was reviewed (Annex 1).

2. ICES has implemented conservation reference points for 63 stocks, and the technical basis for the current reference point values is listed (Annex II). A range of comments on their use and interpretation was discussed and summarised (section 3). Ideally the current values need to be further reviewed for consistency, and a policy is required on the frequency and reasons for updating them routinely.

3. ICES has not yet determined target reference points routinely and so has not yet completed this part of the precautionary agenda.

4. ACFM has adopted a standard approach to the presentation of advice on both the status of the stocks relative to the reference points, and their likely future evolution under short term and medium term management scenarios.

SGPA has drawn attention to presentational improvements that would allow managers to make better use of the advice. It has also identified additional assessment results and predictions that, if feasible, could improve the advice (Section 4.).

5. Using the current reference points and advice, ACFM in 1999 identified 10 stocks that are seriously depleted and have recommendations for rebuilding plans, 9 stocks that are depleted but have no recommended rebuilding plans, and a further 41 stocks that are less seriously depleted and have no recommended rebuilding plan. These stocks are tabulated in section 4.2.

6. SGPA considered that formulation of the advice could be more consistent if a criterion key is used to diagnose the state of the stocks relative to the reference points, and then used to identify the need and time scale for rebuilding plans. This approach was tested in section 4.3.

7. SGPA reviewed historical examples of crisis management of fish stocks in the ICES area, leading up to the adoption of pre-agreed management agreements between EU and Norway (section 5.2). The recent emergency negotiation of recovery plans for seriously depleted stocks in the EU was discussed at length. Numerous observations and suggestions were made about the character of the process, and the need for additional scientific knowledge. In particular there is scope to develop the process to give better information on the time scale and trajectory of recovery under different scenarios of fishing mortality, size at first capture, and recruitment. SGPA also discussed the lack of detailed knowledge about technical and biological interactions, as well as the efficacy of enforcement and control measures (sections 5.3 to 5.5).

8. SGPA identified a range of estimation and forecasting issues in relation to the length of life cycles, uncertainty, medium term predictions, multispecies considerations, and multiannual TACs (section 6).

9. SGPA reviewed ICES views on the possible use of MSY as a reference point, but remains sceptical about this (section 7).

10. SGPA reviewed the possible use of biomass and spawning biomass per recruit at $\mathbf{F}_{0.1}$ as a robust estimator that could be used as a reference point across a range of species and life history types (section 8) and suggested this could be explored further.

11. SGPA had insufficient time to study the problem of data poor situations generally, but looked at the problem for two examples, the deep-water species (section 9.1) and *Nephrops* stocks (section 9.2). For deep-water species it was suggested that the priority is not so much to determine reference points, as to make use of existing knowledge and advice, however limited, and ACFM was urged to pursue this.

12. SGPA raised the issue of communication throughout the meeting. ICES is urged to substantially review the scope for improved dialogue, written communication, and practical cooperation between scientists, managers and catchers on the topics of assessment, advice, management strategy, and management methodology.

1.4 References and Working Papers

The Study Group made use of the following reference documents and working papers.

Anon. 1997a. Report of the Study Group on the Precautionary Approach to Fisheries Management. Feb 1997. ICES CM 1997/Assess:7.

Anon. 1997b. *__Section 6__* of the Report of the Working Group on *Nephrops* stocks. ICES CM 1997/Assess 9.

Anon.1998a. Report of the Study Group on the Precautionary Approach to Fisheries Management. Feb 1998. ICES CM 1998/ACFM:10.

Anon. 1999a Report of the ICES Advisory Committee on Fishery Management, 1998 . ICES Cooperative Research Report No 229.

Anon. 1999b. *__Section 8__* of the Report of the Working Group on *Nephrops* stocks. ICES CM 1999/ACFM 13.

Anon. 2000a. Report of the ICES Advisory Committee on Fishery Management, 1999 . ICES Cooperative Research Report No 336.

Anon.2000b. Application of the precautionary principle and multiannual arrangements for setting TAC's. COM(2000) 803. Brussels.

Anon 2000c. Report of the Study Group on the Biology and Assessment of Deep-sea Fisheries Resources. ICES CM 2000/ACFM: 8, 205 pp.

Anon. 2001a. Report of the ICES Advisory Committee on Fishery Management, 2000. ICES Cooperative Research Report No 242Anon. 2001b. Report of the CWP Intersessional Meeting. ICES CM 2000/ACFM:17.

Anon. 2001c Letter from the European Commission DGXIV to ICES on the nature of ICES advice.

Anon. 2001d Extract from WGCOOP .

Anon. 2001e Evaluation and Comparison of Methods for Estimating Uncertainty in Harvesting Fish from Natural Populations. Draft of Final Consolidated Report EU Concerted Action FAIR PL98-4231.

Anon. 2001f. Report of the Working Group on the Assessment of Southern Shelf Demersal Stocks. ICES CM 2001/ACFM:05: 89-567.

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Hammer, C. & Forest, A. 2000, in Anon 2000. Report from the ACFM ad hoc working group on developing interim and long term measures for deep sea fish stocks.

Lassen, H & H Sparholt, 2000. ICES Framework for the Implementation of the Precautionary Approach in Fisheries Management Advice. Precautionary Approach Reference Points. ACFM Practice 1998-1999. Working Paper for ACFM May 2000.

Lassen, H & H Sparholt, 2001a. ICES Framework for the Implementation of the Precautionary Approach in Fisheries Management Advice. Precautionary Approach Reference Points:Estimation Procedures. Working Paper for SGPA April 2001.

Lassen, H & H Sparholt, 2001b. ICES Framework for the Implementation of the Precautionary Approach in Fisheries Management Advice. Guidance to advice formulation. Working Paper for SGPA April 2001.

Lassen, H & H Sparholt, 2001c. The use of MSY in the Precautionary Approach in Fisheries Management. Working Paper for SGPA April 2001.

Mace, P. M. (1994). Relationships between common biological reference points used as thresholds and targets of fisheries management strategies. Can. J.
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Symes, D. 1998. The integration of fisheries management and marine wildlife conservation. Joint Nature Conservation Committee, JNCC Report No. 287.

2 THE PRECAUTIONARY APPROACH IN ICES

2.1 Background

The framework of the precautionary approach is outlined in the following quotes from Annex II of the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks:

Reference points

- *A precautionary reference point is an estimated value derived through an agreed scientific procedure, which corresponds to the state of the resource and of the fishery, and which can be used as a guide for fisheries management.*

- *Two types of precautionary reference points should be used: conservation, or limit, reference points and management, or target, reference points. Limit reference points set boundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield. Target reference points are intended to meet management objectives.*

- *Precautionary reference points should be stock-specific to account, inter alia, for the reproductive capacity, the resilience of each stock and the characteristics of fisheries exploiting the stock, as well as other sources of mortality and major sources of uncertainty.*

- *When information for determining reference points for a fishery is poor or absent, provisional reference points shall be set. Provisional reference points may be established by analogy to similar and better-known stocks. In such situations, the fishery shall be subject to enhanced monitoring so as to enable revision of provisional reference points as improved information becomes available.*

Management actions

- *Management strategies shall seek to maintain or restore populations of harvested stocks, and where necessary associated or dependent species, at levels consistent with previously agreed precautionary reference points. Such reference points shall be used to trigger pre-agreed conservation and management action. Management strategies shall include measures, which can be implemented when precautionary reference points are approached.*

- *Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low. If a stock falls below a limit reference point or is at risk of falling below such a reference point, conservation and management action should be initiated to facilitate stock recovery. Fishery management strategies shall ensure that target reference points are not exceeded on average.*

Maximum sustainable yield

- *The fishing mortality rate, which generates maximum sustainable yield, should be regarded as a minimum standard for limit reference points. For stocks which are not over-fished, fishery management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a pre-defined threshold. For over-fished stocks, the biomass, which would produce maximum sustainable yield, can serve as a rebuilding target.*

2.2 Development of the PA in ICES

ICES approach to the PA has concentrated on the development of conservation reference points. As outlined in the Introduction to the Report of the ICES Advisory Committee on Fishery Management, 1998 (Anon., 1999a), ICES adopted biological reference points in 1998 in order to advise on the status of stocks relative to predefined limits that should be avoided to ensure that stocks remain within what are termed safe biological limits. The concept of safe limits, explicitly referred to in the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks, was first introduced into ICES advice in 1981 and further developed in 1986 (Serchuk and Grainger, 1992). It was subsequently incorporated into the ICES implementation of the PA based on Anon. 1997a and Anon. 1998a .

The first ICES Study Group on the Precautionary Approach to Fisheries Management (Anon., 1997a, hereafter called 'the 1997 Study Group') provided a comprehensive introduction to the PA. It outlined the legal requirements; described the definition and calculation of reference points, including some of the likely problems of estimation; and proposed the use of harvest control rules and recovery plans to maintain or restore stocks within safe biological limits.

Under section 4.1 (Objectives and Tasks), the 1997 Study Group noted that the tasks of the Advisory Committee on Fishery Management (ACFM) are to:

1. assess the stock/fishery

2. compare the status of the resources/fishery with reference points in order to evaluate if conservation and sustainability criteria are met, if the resource is within safe biological limits, and if the fishery is sustainable

3. evaluate the effects of management actions on the stocks and on the fisheries, taking into account possible future states of nature

4. formulate advice-specific recommendations on management actions, which may be taken relative to the status of the resource and management objectives, including what must/could be done to improve the situation, and/or what may be done without detrimental consequences.

Also, "ACFM/ICES will attempt in its advice to:

5. explicitly consider and incorporate uncertainty about the state of stocks into management scenarios; explain clearly and usefully the implications of uncertainty to fisheries management agencies

6. propose precautionary reference points which ensure that limit reference points are not exceeded, taking into account existing knowledge and uncertainties

7. encourage and assist fishery management agencies in formulating fisheries management and recovery plans

8. quantify the effects of fisheries on target as well as non-target species, and on structural and functional aspects of the ecosystem

9. incorporate information on fishing fleets and multispecies fisheries systems as appropriate

10. evaluate fisheries management systems incorporating biological, social and economic factors as appropriate"

ACFM/ICES will advise and comment on how well aspects of management conform to the precautionary approach with respect to:

11. the existence, compatibility and measurability of objectives which could influence advice and the choice of targets

12. the existence and choice of limit and target reference points and management plans

13. the existence, appropriateness and effectiveness of recovery plans

14. the effectiveness of measures taken to monitor and regulate exploitation

15. the effectiveness of measures explicitly taken to protect non-target species, biodiversity and habitats."

These points represent the actions that ICES intended to follow in fulfilling the Precautionary Approach. To date, ICES has developed and implemented biological reference points for the principal stocks. ACFM formulates advice on the state of the stocks relative to these reference points, and presents management options in a standard format. Managers (for example EU, NEAFC, IBSFC) use ICES advice to formulate management actions including, in recent years, recovery plans. These aspects of the ICES approach are summarised and evaluated in the following sections.

3 BIOLOGICAL REFERENCE POINTS

3.1 Limit and precautionary reference points

To meet conservation objectives, ICES has adopted the approach that for stocks and fisheries to be within safe biological limits, there should be a high probability that spawning stock biomass (**SSB**) is above the limit $\mathbf{B}_{lim}$ where recruitment is impaired or where the dynamics of the stock are unknown, and that fishing mortality is below a value $\mathbf{F}_{lim}$ that will drive the spawning stock to that biomass threshold. Because of the error of estimation, however, management action should be taken before the limits are approached if the limit is to be avoided with high probability. ICES has therefore defined $\mathbf{B}_{pa}$ and $\mathbf{F}_{pa}$ ($_{pa}$ stands for precautionary approach) as the thresholds below or above which management action should be taken, $\mathbf{B}_{pa}$ being higher than $\mathbf{B}_{lim}$ and $\mathbf{F}_{pa}$ being lower than $\mathbf{F}_{lim}$. Thus $\mathbf{B}_{pa}$ is defined to have a high probability that SSB is above $\mathbf{B}_{lim,}$ whilst $\mathbf{F}_{pa}$ is defined to have a high probability that fishing mortality will be below $\mathbf{F}_{lim}$ In principle the distance between the limit and the threshold points depends on the risks that managers will accept, but in practice it depends on the risks that managers will accept, and on the reliability of the assessment.

ICES sees its responsibility as being to identify limit reference points, and to propose precautionary reference points for management use. In practice, although in the past some stocks in the ICES area have definitely collapsed when fishing mortality exceeded the values now defined as $\mathbf{F}_{lim}$ there are few stocks for which $\mathbf{F}_{lim}$ is accurately known. $\mathbf{F}_{pa}$ must therefore have a high probability of being sustainable based on the history of the fishery. $\mathbf{F}_{pa}$ is therefore the upper bound on the fishing mortality rate used by ICES in providing advice, and fishing mortality rates in excess of $\mathbf{F}_{pa}$ are regarded as “overfishing”.

Biomass reference points are important because even if fishing mortality is successfully maintained at or below $\mathbf{F}_{pa}$, stocks may still become depleted due to reduced recruitment, or because efforts to restrain fishing below $\mathbf{F}_{pa}$ may not be successful, and as a result biomass may decline. In the same way that $\mathbf{F}_{pa}$ defines an “overfishing threshold”, $\mathbf{B}_{pa}$ defines when the stock is regarded as being depleted or overfished having regard to all the uncertainties. It needs to ensure a high probability of preventing the stock falling to $\mathbf{B}_{lim}$, below which recruitment is impaired or the dynamics of the stock are unknown. In ICES, $\mathbf{B}_{lim}$ is in general equal to the Minimum Biological Acceptable Level (MBAL), calculated previously for stocks where stock-recruitment data were available. In cases where biomass estimates are not available, ICES uses the indices U_{pa} and U_{lim} as biomass reference points.

3.2 Target reference points.

The identification of target reference points, representing long term management objectives defined by a fishing mortality below $\mathbf{F}_{pa}$ or an SSB above $\mathbf{B}_{pa}$. has so far not been carried out by ICES. This is discussed at greater length in section 3. 4.

3.3 Reference Points Values

The methods and options available for estimating reference points in ICES have been reviewed by Lassen & Sparholt (2001a), and are summarised in Annex I. The current reference point values used by ICES were adopted by ACFM in 1999 following the 1998 Study Group (Anon., 1998a), and their technical basis is summarised in Table 1 below, derived from the full species-stock listing given in Annex II.

The summary shows that:

- $\mathbf{B}_{lim}$ was mostly based on $\mathbf{B}_{loss}$ and in only a few cases on S-R plots, previous MBAL values, or $\mathbf{B}_{pa}$. $\mathbf{B}_{lim}$ remains undefined for 11 of the 63 stocks with other defined reference points.

- $\mathbf{B}_{pa}$ was mainly based on $\mathbf{B}_{lim}$, but $\mathbf{B}_{loss}$ was also frequently used. S-R plots were used in only 7 cases. $\mathbf{B}_{pa}$ remained undefined in 8 cases.

- $\mathbf{F}_{lim}$ was mainly based on $\mathbf{F}_{loss}$ (21 cases) but remained undefined in 30 cases.

- $\mathbf{F}_{pa}$ was based on $\mathbf{F}_{lim}$ in 15 cases. $\mathbf{F}_{med}$ was used for 14 stocks, and medium-term projections were used in 15 cases. $\mathbf{F}_{0.1}$ was used in one case. $\mathbf{F}_{pa}$ remained undefined in 13 cases.

Table 1, summarising the basis for the precautionary reference points defined by the 1999 ACFM in Anon. 2000a

Reference point	Technical basis	Number of stocks
B_{lim}	B_{pa}	2
	B_{loss}	36
	S-R plots	6
	MBAL	5
	Lowest SSB producing an outstanding year class	1
	20% U_{max}	2
	Not defined	11
	Total	63
B_{pa}	B_{lim}	28
	B_{loss}	13
	S-R plots	7
	MBAL	6
	Lowest SSB producing an outstanding year class	1
	Not defined	8
	Total	63
F_{lim}	F_{loss}	21
	F_{pa}	3
	F leading to stock decline	5
	F_{med}	3
	B_{lim}	1
	Not defined	30
	Total	63
F_{pa}	F_{lim}	15
	F_{med}	14
	Medium term projections	15
	Historical experience	1
	Analogous to other stocks	2
	SSB/R in absence of fishing	1
	F_{lpg}	1
	$F_{0.1}$	1
	Not defined	13
	Total	63

3.4 Discussion

- The present reference points and values, largely calculated three years ago, represent the first approach by ICES to comply with the objectives of the Precautionary Approach. Very few of these were based on SSB-R plots and there is a considerable dependence on $\mathbf{B}_{loss}$ and $\mathbf{F}_{loss}$. In a substantial number of cases not all the reference points were defined. The EU has noted (Anon., 2000b, page 7, section 1.2.2) that " the arguments used to define $\mathbf{B}_{lim}$ and $\mathbf{F}_{lim}$ vary from stock to stock, with the result that there is little uniformity as to the dangers associated with overshooting the thresholds" and that "the procedures used to define $\mathbf{B}_{pa}$ and $\mathbf{F}_{pa}$ are not always clear". Table 1 and Annex II do indeed show heterogeneity, and it would be useful to extend the review of current values to distinguish between those that reflect differences in the population dynamics of stocks, those that are due to inadequacies in the data, or that are due to inconsistencies in the use of the criteria. The review could be guided by Annex I, and should include the suggested reality checks for consistency between fishing mortality and biomass reference points, and consistency with the historical behaviour of the stocks. It could be helpful to compare the values obtained from using a variety of different reference points as carried out by the Working Group on *Nephrops* stocks (see section 9.2).

- The choice of $\mathbf{B}_{pa}$ and $\mathbf{F}_{pa}$, and their distance from $\mathbf{B}_{lim}$ or $\mathbf{F}_{lim}$ have been determined by ICES scientists. It would be helpful to discuss with managers the significance of the choice of precautionary threshold, and the degree of risk that is inherent in the current values, and in the formulation defining the distance between the threshold and limit reference points. The EU has recently stressed (Anon. , 2000c) that reference points should "ensure sustainability by maintaining a low risk (5-10%) of recruitment decline and collapse, and should avoid entering an area where recruitment is expected to be low, or where knowledge of recruitment is poor, or where risk increases without any increase in yield" . It seems incumbent on ICES to review the current values in the light of these views.

- The EU has commented (Anon., 2000d) that the application of the precautionary approach to short lived species such as anchovy should be reconsidered, and this point is later revisited briefly in Section 6.1. It commented that it also sees a difference between a $\mathbf{B}_{lim}$ based on observed stock and recruit data that signal when recruitment is impaired, and a $\mathbf{B}_{lim}$ based on $\mathbf{B}_{loss}$ implying that there is a different inference when a stock enters a range where its dynamics are unknown. ICES needs to discuss whether this view is appropriate, given that the precautionary approach should strictly require action at $\mathbf{B}_{pa}$.

- It would be helpful to develop clear guidance on the factors that determine when management decisions should be driven by fishing mortality reference points rather than biomass reference points. Intuitively, managers and stakeholders may be more comfortable with biomass reference points , since biomass is more easily understood, and if biomass is low action must be taken immediately. Where fishing mortality is too high, but spawning biomass is still adequate, it may be possible to develop a response over a longer time scale. On the other hand, fishing mortality reference points may be particularly useful when there are difficulties over catch reporting, especially during a rebuilding programme, , or if it is perceived that biomass estimates could be affected by the impact of technical interactions, multispecies considerations, or regime shifts. Since F and B reference points are generally derived independently, SGPA recommends that the question of their compatibility should be examined to ensure that management of F will achieve the corresponding biomass objective.

- Each year, assessments may produce new sets of biomass, recruitment and fishing mortality values, new S-R plots, and hence, potentially, new values of $\mathbf{F}_{med}$ etc. If or when multispecies interactions are taken into account, these will lead to other potential reference point changes. SGPA appreciates that it may be easier for managers if the chosen reference points and their values are stable from year to year, so ICES needs to make a clear decision about when or if it is appropriate to upgrade them. This could be based on a time span, say every 3-5 years, depending on the life history characteristics of the stock; on the degree of change to key inputs such as maturity, natural mortality or weight at age; or when outputs exceed a certain relative value. Fishing mortality reference points may have to be changed whenever management measures substantially change the exploitation pattern, however. SGPA recommends that ACFM should develop a policy for these aspects.

- In ICES the current emphasis is on the use of limits, coupled with the thresholds designed to deal with uncertainty. The additional aim of the precautionary approach, to set target reference points, has not yet been fulfilled. As a result, managers and stakeholders, who are at present most strongly influenced by the depleted state of many stocks, are in effect viewing $\mathbf{B}_{pa}$ or $\mathbf{F}_{pa}$ as the target. Within ICES the absence of target reference points also reflects the difficulty of clarifying and identifying long-term management objectives or the actual values that represent them. The EU has commented in writing to ICES, however, that the "precautionary framework should normally allow long-term fishing mortalities consistent with target fishing mortalities e.g. $\mathbf{F}_{0.1}$, $\mathbf{F}_{max}$ or other sustainable levels, unless doing so would incur unacceptable risks" (From the stock viewpoint, the attraction of adopting a target reference point above $\mathbf{B}_{pa}$ is that as biomass and the range of age groups increase, stocks and landings should become more stable, being better buffered against the effect of year-class fluctuations and environmental change. This reduces the impact of uncertainties. Whereas the limit and threshold reference points are predominantly set on the basis of single species criteria, setting target reference points could require greater consideration of technical interactions, multispecies considerations, and socio-economic factors. ACFM needs to decide what priority to give to setting target reference points in order to complete the precautionary framework is a priority, and to develop a work plan accordingly. This would require a substantial dialogue between ICES, managers and stakeholders.

- Based on the above, SGPA **recommends** that ACFM should decide on a specific policy for evaluating and revising the current reference points, and for developing target reference points. An action plan should be developed to

  - examine the existing values for consistency between species and stocks, and for compatibility between F and B values

  - evaluate whether they meet such criteria as have been expressed by the EU

  - complete the enumeration of missing values where possible

- ♦ evaluate whether precautionary reference points are appropriate for short lived species such as anchovy

- ♦ develop the criteria and steps required to set target reference points, taking into account technical interactions, multispecies considerations, and socio-economic aspects. The attributes of $\mathbf{F}_{msy}$ and $\mathbf{F}_{0.1}$ have also been considered later in sections 7 and 8.

❖ The evaluation of ICES reference points has probably suffered from the demise of WGCOMFIE, and therefore requires the assistance either of the existing assessment working groups, or a dedicated study group along the lines of the 1998 PA Study Group (Anon.,1998a). Reference point revisions should be based on the standard estimation procedures outlined earlier, coupled with assessment of the risks that are acceptable to managers. This may require the development of additional software. The process should preferably involve an effective dialogue with managers and stakeholders, particularly before any changes are recommended in practice.

❖ SGPA draws attention to the question of communication. It is widely felt outside ICES that the precautionary reference points and the associated advice were implemented very suddenly and without proper preparation, explanation or discussion, whether of the criteria, risks, uncertainties, or the implications for catchers. Special attention needs to be given to this aspect in any future revisions or developments.

4 MANAGEMENT ADVICE

4.1 Presentation of the advice

"Advice from ICES will be constrained by $\boldsymbol{F}_{pa}$ *and* $\boldsymbol{B}_{pa}$*. If fishery management decisions lead to* $\boldsymbol{F}_{pa}$ *being exceeded, then this would be regarded as overfishing, and management would not be regarded as consistent with a precautionary approach. The development of a management plan to reduce fishing mortality to no greater than* $\boldsymbol{F}_{pa}$ *would be advised. If no such plan were developed, ICES would generally advise that management was not consistent with a precautionary approach"* (ACFM 1998 in Anon., 1999a and Anon, 2000a).

The standard format for presenting advice in the ACFM report compares the current estimates of SSB and F with the precautionary reference points, and describes the future expectations for SSB in an options table showing a two-year projection of SSB and landings for various multiples of $\mathbf{F}_{sq}$. Where feasible the table shows the probability of SSB being below or above $\mathbf{B}_{pa}$ after 10 years, the so-called medium term projection. Shading identifies the options where **F** exceeds $\mathbf{F}_{pa}$, which are therefore inconsistent with the precautionary approach. Where possible the presentation is supported by time-series plots of landings, F_{bar}, SSB and R, and the precautionary approach plot showing the time track of F and SSB relative to the precautionary reference points.

This format has become familiar to managers and catchers, and is successful, but the following issues were raised , some of them also reflecting comments likely to be incorporated in the Report of the Management Committee on the Advisory Processes.

❖ Managers, stakeholders, and advisors make particular use of the options table as a practical tool during negotiations. They readily identify changes from previous years, and ACFM should ensure that the reasons for such changes are clearly explained.

❖ The fine detail of the options table needs to be more carefully controlled. For example:

- ♦ F_{sq} should be calculated and stated in words in a consistent way between stocks, and decisions taken about F in the middle year should be reasoned and explained

- ♦ It is preferable, where possible, for the range and interval of F options to be consistent between years and between stocks, with the multiplier of F_{sq} shown for all F options, including $\mathbf{F}_{pa}$.

- ♦ It is worth considering whether it would help managers to have a second options table presenting the F values corresponding to a range of TAC intervals.

- ♦ Medium term projections should always be shown when available, and not left out simply because they were in previous reports. Specific problems with these projections should be explained in language that managers will understand.

- ♦ Some managers consider that the precautionary shading unduly limits their options. ACFM may wish to consider whether it is appropriate to remove the shading from all but the $\mathbf{F}_{pa}$ level itself.

❖ The current advice only considers the implication of changing F at the current exploitation pattern. It does not consider the effects of changing size or age of first capture, yet such changes are a significant management option that features specifically in some recent recommendations and recovery plans.

❖ The advice does not clearly show the short-term losses that arise from each option, and it does not illustrate the trajectory of stock change associated with the probability of a stock reaching $\mathbf{B}_{pa}$ in the medium term for each F option. This information would be particularly useful to stakeholders participating in discussions with managers, or attempting to come to terms with managers decisions.

❖ The EU (Anon. 2001c) has commented on the seeming lack of information on

- ♦ the risks incurred in crossing reference points
- ♦ the risks of stock collapse in the short, medium and long term
- ♦ the risks created by not taking remedial action or no action
- ♦ the absence of Y/R information for some stocks

❖ Thought should be given to terminology. ACFM has already clarified the meaning of the words "stock collapse" , and there are other terms that are likely to be misunderstood by users of the advice, for example "uncertainty" as applied to assessments and statistical criteria.

❖ **SGPA recommends** that ACFM quickly assesses the advisability, feasibility, and likely time scale of responding to these comments and criticisms, perhaps after a suitable dialogue with managers and stakeholders.

4.2 Formulation of the advice

"Management strategies shall seek to maintain or restore populations of harvested stocks, and where necessary associated or dependent species, at levels consistent with previously-agreed reference points. Such reference points shall be used to trigger pre-agreed conservation and management action. Management strategies shall include measures which can be implemented when precautionary reference points are approached." BODIL, the next line should start here(Section 4, Annex II of the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stock).

"… $\boldsymbol{F}_{pa}$ and $\boldsymbol{B}_{pa}$ are the thresholds which constrain advice or which likely trigger advice for the implementation of management/recovery plans. If a stock is regarded as depleted, or if overfishing is taking place, the development and effective implementation of a rebuilding plan to reduce fishing mortality to no higher than $\boldsymbol{F}_{pa}$ and to rebuild SSB to above $\boldsymbol{B}_{pa}$, within a "reasonable" period, would satisfy the condition that management is consistent with a precautionary approach.

If the development of plans were proposed, fishery management agencies, scientists and perhaps other parties would need to work together on their development. Such plans might involve explicit harvest control rules or sets of decision rules. If the development of plans were recommended but not taken up ICES would have to advise that management was not consistent with a precautionary approach. If plans were developed and not effectively implemented, again the advice would be that management was not consistent with a precautionary approach." (Anon., 2001a)

Lassen and Sparholt (2001b) analysed the 1999 ACFM report (Anon., 2000a) to show how ACFM has formulated advice on the basis of the current reference points. Stocks fall into three categories

a) depleted, and rebuilding plan recommended (summarised in Table 2)

b) depleted, but no rebuilding plan recommended (summarised in Table 3)

c) not depleted, and F advice generally $\mathbf{F}_{pa}$ (summarised in Table 4).

Stocks were designated as depleted when SSB (2,$\mathbf{F}_{pa}$) ,defined as the SSB *at the end of the TAC year* resulting from F(TAC year) equivalent to $\mathbf{F}_{pa}$, is predicted to be <<$\mathbf{B}_{pa}$, or when $F_{status\ quo}$ >> $\mathbf{F}_{pa}$. This contrasts with the case where SSB(2,$\mathbf{F}_{pa}$)>=$\mathbf{B}_{pa}$ resulting in F(advice)= $\mathbf{F}_{pa}$.

When SSB(2,$\mathbf{F}_{pa}$)<<$\mathbf{B}_{pa}$ the operational difficulty is to decide on a cut in F(advice) that is consistent and acceptable, given that fishers will obviously dislike large changes in the TAC from one year to the next. Catch (advice year 1) has therefore been assessed as a percentage of the previous year's TAC (year 0), or, where there is no such TAC, as a percentage of Catch (year 0). Since ACFM advice also takes into account changes in F, at least implicitly, F(advice) is also compared to $\mathbf{F}_{sq}$.

4.2.1 Depleted stocks with recommended rebuilding plan (Table 2)

In 8 out of 10 stocks in this category the concern was low values of SSB(2,$\mathbf{F}_{pa}$) falling into the range 34% - 77% (**average 63%)** of $\mathbf{B}_{pa}$. The advised catch (advice year 1) was 0%-67% of the previous TAC(year 0). The suggested rebuilding plans predicted that SSB will increase above $\mathbf{B}_{pa}$ in less than 5 years, except for the Irish Sea cod, where no time span was given.

For the remaining 2 stocks, $\mathbf{F}_{sq}$ was 92% and 170% of $\mathbf{F}_{pa}$. In one case (Herring ViaS and VIIb,c) the advice was to reduce F to $\mathbf{F}_{pa}$ or, if this cut is too large for one year, to agree a multi-annual recovery plan to reduce F as rapidly as possible, in only a few years. In this case even if fishing is reduced to $\mathbf{F}_{pa}$, SSB(2) will still be below $\mathbf{B}_{pa}$. In the second case (Sprat 22-32)F was high, but SSB was still well above $\mathbf{B}_{pa}$. ACFM recommended that F should either be reduced to $\mathbf{F}_{pa}$ right away, or, if such a large reduction in F could not be achieved in one year, then over a few years. The scenario allowed 2 to 4 years to reach $\mathbf{F}_{pa}$ or below, with 50% confidence.

Summarising, in these examples, a rebuilding plan was proposed when SSB(2,$\mathbf{F}_{pa}$) was less than 77% of $\mathbf{B}_{pa}$ or when $\mathbf{F}_{sq}$ was roughly twice $\mathbf{F}_{pa,}$ and the objective was to reach SSB >= $\mathbf{B}_{pa}$ in less than 5 years.

4.2.2 Depleted stocks but no rebuilding plan recommended (Table 3)

In this set anchovy is unusual because F (advice) = 0 achieves SSB (2,$\mathbf{F}_{advice}$**)** well above $\mathbf{B}_{pa.}$ In all other 8 stocks SSB values were low. In two cases (Plaice VIIe, Sole VIIe) depletion was minor, (SSB (2,$\mathbf{F}_{pa}$) being 96 % and 97 % of $\mathbf{B}_{pa}$ and the proposed catch was not reduced. For the other 6 stocks SSB(2,$\mathbf{F}_{pa}$) was 64% - 95% (**average 80%**) of $\mathbf{B}_{pa}$. Recommended Catch(advice in year 1) was 59% -110% of TAC(year 0). Compared to Table 1, the mean SSB was closer to $\mathbf{B}_{pa}$ and the mean catch reduction smaller. . In three cases, however, SSB(2,$\mathbf{F}_{pa}$) was in the same range as stocks in Table 1, but ACFM nevertheless recommended F values leading to SSB(2, F advice) << $\mathbf{B}_{pa}$, so that recovery is permitted to occupy a longer time scale than one year. The maximum reduction in F was 55% of $\mathbf{F}_{sq}$.

4.2.3 Stocks not classified as depleted and no rebuilding plan proposed (Table 4)

For 8 of the 41 stocks in this set $\mathbf{F}_{pa}$ was not defined. For 2 stocks SSB(2,$\mathbf{F}_{pa}$) was very slightly lower than $\mathbf{B}_{pa.}$ For 28 stocks F(advice) was $\mathbf{F}_{pa}$, or only a small percentage below $\mathbf{F}_{pa}$, and in no case was F(advice) higher than $\mathbf{F}_{pa}$.

For some stocks F(advice) was significantly below $\mathbf{F}_{pa}$. For NE Arctic haddock, F(advice) was only 54% of $\mathbf{F}_{pa}$ and 40% of $\mathbf{F}_{sq}$, because haddock is taken as a by-catch in the cod fishery. For Faroe Plateau cod, F(advice) was 84% of $\mathbf{F}_{pa}$, but was $\mathbf{F}_{sq}$. For N. Sea herring F (advice) was 51% of $\mathbf{F}_{sq}$, and 80% of $\mathbf{F}_{pa}$, but Catch (advice year 1) was only 7% below TAC (year 0). For megrim (*L. boscii*) in VIIIc and IXa F(advice) was 80% of $\mathbf{F}_{pa}$ giving Catch (year 1)15% below Catch (year 0), but SSB(2,$\mathbf{F}_{pa}$) >> $\mathbf{B}_{pa}$. For herring in the Gulf of Riga, F (advice) was 88% of $\mathbf{F}_{pa}$, but equal to $\mathbf{F}_{sq}$.

Although much of the advice was for F at $\mathbf{F}_{pa}$ the resulting catch changes were significant relative to TAC(0) , e.g. 1 at 36% of the recent year's TAC, 2 less than 50%, 2 from 50-60%, 4 from 60-70%, 6 cases from 70-80%, 9 cases from 80-90%, 9 from 90-100%, and 9 from 100% to 121%. Recommending $\mathbf{F}_{pa}$ such that SSB (2, $\mathbf{F}_{pa}$) > $\mathbf{B}_{pa}$, therefore significantly affected catch opportunity, even though no rebuilding plans were proposed.

4.2.4 Inconsistency in advice

For some depleted stocks (e.g. Faroe saithe, herring VIaS+VIIb,c, North Sea cod, Baltic cod 25-23) ACFM recommended only small reductions in catch (year 1) compared to TAC (year 0) but larger reductions were recommended for stocks not considered to be depleted stocks (NE arctic saithe, N.Sea haddock, VIId plaice, VIIa haddock, VIIa whiting, blue whiting). In other cases, the catch of NE haddock was recommended to be 47% of TAC(0) because it is a by-catch of the NE cod fishery, but the advised reduction in cod catch was to either 23% or 54% of TAC(0). The equivalent reductions in F(advice) were to 14% and 35% of $\mathbf{F}_{sq}$ for cod, and to only 40% of $\mathbf{F}_{sq}$ for haddock. There was inconsistency in the absolute reductions of F, and in the number of choices. There were also differences in the time scale over which stocks were expected to regain $\mathbf{B}_{pa}$. Tables 2-4 therefore confirm that, as pointed out in dialogue meetings, ICES advice has not been fully consistent. This probably partly reflects the combined effect of time pressures at the ACFM meeting, and the absence of specific quality control for this aspect.

SGPA also noted that uncertainty in the assessments, or variations in year-class strength, can cause estimates of SSB to fluctuate around a reference point value from one year to the next, so that a stock can move in and out of biological safe limits. This may cause operational problems if fishers who 'bank' quotas in 'safe' years are unable to use them in 'unsafe' years... This has been criticised as confusing by stakeholders, especially when the reference point is based on $\mathbf{B}_{loss}$**.** It was suggested that this problem requires a decision rule allowing either the exercise of judgement by advisors and managers, or incorporating a clearer statistical tolerance to be attached to the reference point or to the SSB estimate. This might be based on bootstrapping, or by expressing SSB values on a relative rather than an absolute scale, although it was noted that the distance between $\mathbf{B}_{pa}$ and $\mathbf{B}_{lim}$ is already meant to take uncertainty into account. This problem would obviously become less relevant once a stock moves towards a target reference point above the PA points. The point is reconsidered later in connection with Multiannual TACs in section 6.7.

Table 2. Depleted stocks (defined as SSB(2, $\mathbf{F}_{pa}$)<<$\mathbf{B}_{pa}$), with rebuilding plans recommended (at least as an alternative) by ACFM

	Stock		F(advice) compared to $\mathbf{F}_{sq}$	F(advice) compared to $\mathbf{F}_{pa}$	SSB(2, $\mathbf{F}_{pa}$) in % of $\mathbf{B}_{pa}$	SSB(2, Fadvice) in % of $\mathbf{B}_{pa}$	Catch (advice year 1) in % of TAC (year 0)	Rationale
Rebuilding plan recommended	NE Arctic cod	Alternative 1	14%	31%	77%	100%	23%	Reach $\mathbf{B}_{pa}$ in 2001
		Alternative 2	35%	76%	77%	84%	54%	Reach $\mathbf{B}_{pa}$ in 2003
	Saithe Faroe		Well below 70%	Well below 100%	50%	Well above 50%	63% of catch(0)]	Rebuilding cannot be achieved in short-term
	Whiting N.Sea		0% (Lowest possible)	0% (Lowest possible)	58%	77%	0%	To give the greatest chance of recovery
	Cod VIa		40%	53%	70%	87%	36% (47% catch(1) of catch(0))	If advised F is maintained for 5 years ⇒ high prob. for SSB>$\mathbf{B}_{pa}$
	Cod VIIa		0% (Lowest possible)	0% (Lowest possible)	34%	64%	0%	Rebuild SSB as soon as possible
	Herring VIaS+VIIb,c	Alternative 1	37%	100%	92%	92%	67%	Reduce F to $\mathbf{F}_{pa}$
		Alternative 2	Multiannual plan to reduce F as rapidly as possible					If a 63% reduction in F is not possible in 1 year
	Hake (northern)		50%	65%	75%	81%	36%	50% prob. of SSB>$\mathbf{B}_{pa}$ in 5 years
	Herring 25-29+32		46%	100%	73%	73%	45%(advice compared to expected catch year 0, “paperfish” problem)	To ensure SSB increase towards $\mathbf{B}_{pa}$
	Sprat 22-32	Alternative 1	52%	100%	220%	220%	41%	
		Alternative 2	a plan to reduce F to $\mathbf{F}_{pa}$ in steps				If this 48% reduction in F cannot be achieved in a single year	
	Cod 25-32		60%	92%	68%	70%	67% (advice compared to expected catch year 0, because the TAC includes 22-24)	Increase SSB above $\mathbf{B}_{lim}$ in short-term

Table 3. Depleted stocks (defined as SSB(2, $\mathbf{F}_{pa}$)<$\mathbf{B}_{pa}$) where no rebuilding plan was recommended

	Stock	F(advice) compared to $\mathbf{F}_{sq}$	F(advice) compared to $\mathbf{F}_{pa}$	SSB(2, $\mathbf{F}_{pa}$) in % of $\mathbf{B}_{pa}$	SSB(2, Fadvice) in % of $\mathbf{B}_{pa}$	Catch (advice year 1) in % of TAC (year 0)	Rationale
No rebuilding plan recommended	Saithe Iceland	60%	73%	64%	68%	80%	Ensure stock increases in short-term
	Greenland halibut	45%	41%	76%	86%	110%	Not stated but this will ensure a stock increase in the short -term
	Cod N.Sea	80%	85%	80%	88%	61%	To prevent further decline of SSB in the short-term
	Saithe N.Sea	70%	80%	77%	85%	68%	Prevent further decline
	Herring VIIa	90%	86%	95%	103%	59%	Bring SSB above $\mathbf{B}_{pa}$ in the short-term
	Plaice VIIf and g	70%	78%	84%	91%	78%	Increase SSB above $\mathbf{B}_{pa}$ in 10 years and consistent with sole advice
	Plaice VIIe	68%	100%	96%	96%	96%	No rationale proposed
	Sole VIIe	80%	100%	97%	97%	100%	To increase SSB above $\mathbf{B}_{pa}$ in 10 years
	Anchovy	0%	0%	86%	141%	0%	No fishing until evidence of good R which will bring SSB>$\mathbf{B}_{pa}$ (the most recent two y.c. estimated to be very poor)

Table 4. Stocks not depleted (defined as SSB(2, $\mathbf{F}_{pa}$)>$\mathbf{B}_{pa}$), where generally $\mathbf{F}_{pa}$ has been recommended

	Stock	F(advice) compared to $\mathbf{F}_{sq}$	F(advice) compared to $\mathbf{F}_{pa}$	SSB(2, $\mathbf{F}_{pa}$) in % of $\mathbf{B}_{pa}$	SSB(2, Fadvice) in % of $\mathbf{B}_{pa}$	Catch (advice year 1) in % of TAC (year 0)	Rationale
1	Haddock N E arctic	40%	54%	111%	131%	47%	High prob. of maintaining SSB>$\mathbf{B}_{pa}$. Consistent with cod.
2	Saithe N E arctic	65%	100%	124%	124%	62%	
3	Herring NS Spawners	132%	97%	153%	154%	115%	Agreed harvest rule
4	Cod Iceland	-	-	-	-	99%	Agreed harvest rule
5	Haddock Iceland	-	-	-	-	100%	Further work on PA points pending
6	Herring Iceland	122%	100%	170%	170%	113%	
7	Cod Faroe Plateau	100%	100%	190%	190%	102% of catch(0)	
8	Haddock Faroe	100%	84%	151%	158%	88% of catch(0)	y.c. 95-97 below average and SSB(+2) expected to decline
9	Cod Kattegat	56%	100%	147%	147%	102%	
10	Plaice IIIa	95%	100%	146%	146%	84%	
11	Pandalus IIIa	100%	-	-	114%	86%	
12	Haddock N.Sea	90%	100%	142%	142%	57%	
13	Plaice N.Sea	67%	100%	102%	102%	93%	
14	Sole N.Sea	70%	100%	123%	123%	90%	
15	Herring N.Sea	51%	80%	100%	104%	93%	Roll over 1999 measures
16	Sole VIId	93%	100%	138%	138%	83%	
17	Plaice VIId	70%	100%	111%	111%	66%	
18	Haddock VIa	89%	100%	138%	138%	78% (84% catch(1) of catch(0) the TAC covers also VIb and if that is subtracted ~100%).	
19	Haddock VIb	83%	100%	114%	114%	89% [of catch(0)]	
20	Whiting	64%	100%	108%	108%	68%	
21	Haddock VIIa	45%	100%	-	-	56%	
22	Whiting VIIa	40%	100%	101%	101%	36%	
23	Plaice VIIa	107%	100%	148%	148%	96%	
24	Sole VIIa	73%	100%	111%	111%	120%	
25	Cod VIIe-k	83%	100%	111%	111%	72% [of catch(0)]	
26	Whiting VIIe-k	83%	-	-	224%	86% [) of catch(0)]	
27	Sole VIIf and g	71%	100%	142%	142%	121%	
28	Plaice VIIe	68%	100%	96%	96%	72% [of catch(0)]	
29	Sole VIIIa,b	102%	100%	123%	123%	107%	
30	Herring Celtic Sea	94%	-	-	200%	96%	
31	Megrim VII and VIIIa,b,d,e	94%	100%	115%	115%	94% [of catch(0)]	
32	Anglerfish (L pisc.) VIIb-k and VIIIab	80%	100%	99%	99%	70% [of catch(0)]	
33	Anglerfish (L budeg.) VIIb-k VIIIab	80%	100%	318%	318%	78% [of catch(0)]	
34	Megrim (L boscii)VIIIc IXa	80%	80%!!!	105%	109%	84% of catch(0)]	

35	Megrim (L whiff.) VIIIc IXa	80%	-	-	107%	89% [of catch(0)]	
36	Horse mackerel Southern	94%	100%	117%	117%	98% [of catch(0)]	
37	Mackerel combined	82%	100%	169%	169%	114%	
38	Horse mackerel Western	-	-	-	218%	75%	
39	Blue whiting	62%	100%	116%	116%	65%	
40	Herring Gulf of Riga	100%	88%	214%	224%	97%	
41	Cod 22-24	80%	-	-	133%	85%	

4.3 Guidelines for Formulating ACFM Advice

To improve consistency in the formulation of advice, SGPA explored the use of a key proposed by Lassen and Sparholt (20001b). for comparing SSB (2, $\mathbf{F}_{pa}$) against $\mathbf{B}_{pa}$, and $\mathbf{F}_{sq}$ against $\mathbf{F}_{pa}$, leading to a standard decision about the advice. One such key is shown below for a single species approach. (Table 5). The key does not consider multispecies or technical interactions, or very short-lived species such as capelin.

Table 5: A key for formulating management advice based on stock criteria

	Evaluation	Action	Comments
1	If SSB(2,$\mathbf{F}_{pa}$)>=$\mathbf{B}_{pa}$*0.95	Go to 2	
	If SSB(2,$\mathbf{F}_{pa}$)<$\mathbf{B}_{pa}$*0.95	Go to 3	
2	If $\mathbf{F}_{sq} > 2*\mathbf{F}_{pa}$	Advise recovery plan to reduce F to $\mathbf{F}_{pa}$ in 2-4 years	(For advice given in year y, $\mathbf{F}_{pa}$ should be reached in year y+2 to y+4)
	If $\mathbf{F}_{sq} < 2*\mathbf{F}_{pa}$	Advise $\mathbf{F}_{pa}$	
3	If SSB(2,**F**=0)>=$\mathbf{B}_{pa}$*0.95	Go to 4	
	If SSB(2, **F**=0)<$\mathbf{B}_{pa}$*0.95	Go to 6	
4 Find F' corresponding to SSB(2,F') = $\mathbf{B}_{pa}$	If Catch(1,F')> X% of TAC(0) (X to be decide by ACFM and managers; 75% would be consistent with current ACFM practice)	Advise F'	F' always < $\mathbf{F}_{pa}$
	If Catch(1,F')< X% of TAC(0)	Go to 5	
5 Find F" corresponding to Catch(1,F") = X% of TAC(0)	If SSB(3,F")>= $\mathbf{B}_{pa}$	Advise F"	F" always > F'. The stock will be rebuilt in the year after the advice year.
	If SSB(3,F")< $\mathbf{B}_{pa}$	Advise recovery plan to rebuild stock in 3-4 years	The stock will be rebuilt in the 2-3 years after the advice year.
6 Advise a plan to rebuild stocks rapidly	If SSB(7,F=0)>=$\mathbf{B}_{pa}$*0.95	Advise recovery plan to rebuild the stock in 2-5 years	The number of years should be related to stock dynamics
	If SSB(7,F=0)<$\mathbf{B}_{pa}$*0.95	Advise recovery plan to rebuild the stock in 6-15 years	The number of years should be related to stock dynamics

Using as an example the 1999 Faroe saithe assessment, the results of each step are:

1. SSB (2,$\mathbf{F}_{pa}$)(= 55 000t) is <$\mathbf{B}_{pa}$*0.95 (=104 500t).

2. SSB (2,F=0) (=69 300t) is < $\mathbf{B}_{pa}$*0.95

3. SSB (7,F=0) (=160 300t) is => $\mathbf{B}_{pa}$*0.95

so the key identifies a recovery plan that rebuilds the stock in 3-5 years time. As the generation time of Faroe saithe is 6 years (maturity at age 6 is 65%) and thus quite long, a 5-year rebuilding scenario is most relevant. The F needed to rebuild the stock by 1st Jan 2006 is 0.2*$\mathbf{F}_{sq}$.

Using the stock and F values in the 1999 ACFM advice, SGPA tested the key on a range of stocks and compared the resultsagainst the ACFM 2000 advice. For simplicity the 0.95 values in the Key were replaced by 1.00, although in practice ACFM uses 0.95 as a ' bagatel' limit to avoid designating a stock as outside safe biological limits when it is close to $\mathbf{B}_{pa}$ and $\mathbf{F}_{pa}$.

The results are shown in Table 6 located at the back of this report. For stocks within safe biological limits the Key produced the same results as the ACFM advice. For stocks outside safe biological limits the Key gave in general very similar advice to the ACFM advice, with two interesting exceptions for saithe. For Icelandic saithe, the Key recommended a rebuilding plan, while the actual ACFM advice was F<<$\mathbf{F}_{pa}$. For saithe in area 4+6, the Key gave F=0.25 compared to the ACFM advice of F=0.36. Smaller deviations were mainly due to use of the 75% criterion as the acceptable catch reduction limit, although in some cases ACFM 2000 accepted larger reductions than this.

Results from the Key were encouraging, but the following weak points were identified:

- ....F' and F'' were sometimes estimated to be higher than $\mathbf{F}_{pa}$, which should not happen.
- ....Under point 2 (overfished stocks that are above $\mathbf{B}_{pa}$) the factor 2 should be reduced to say 1.5 or 1.33.
- ....SSB (3,F'') may not be available for many stocks.
- ....Alternatives to the 75 % catch reduction rule could be discussed
- ....The Key does not cover the situation where a rebuilding plan is already in place.
- ....Point 5) and 6), dealing with rebuilding plans, should be revisited when ACFM discusses standards for such advice..

SGPA recommends that this approach should be explored further as a contribution to developing the PA in data rich situations.

4.3.1 Generation time

SGPA discussed whether rebuilding time could be based on **generation time**. Anon., (1997a) noted that generation time (T) could be estimated as the average age of the spawning stock in a stable age distribution where only natural mortality is acting, and that it can be approximated by T = 3/M, where M is natural mortality. For cod in the North Sea, the North East Arctic, and the Baltic this would give generation times as high as 15 years. To be useful in determining recovery plans, generation time should be closely connected to the population dynamics of a given stock, but for most stocks where the progeny from successive spawnings overlap it is not easy to define generation time. For cod in the Baltic Sea, for example, as many as five generations could contribute significantly to spawning in years when the stock is unexploited. It might be more appropriate to consider generation time as the age when more than 50% are mature. For North Sea and Baltic cod this will be 4 years, and for North East Arctic cod 7 years.

The formula suggested by the 1997 Study Group (Anon., 1997a) is :

$$\textit{Rebuilding time} = \frac{SSB - SS\boldsymbol{B}_{pa}}{SSBlimit - SS\boldsymbol{B}_{pa}} * T$$

If this formula is applied to Faroe saithe, for example, rebuilding time is defined as 36 years!BODIL take out the next line space.SGPA therefore considers that this formula for rebuilding time requires further consideration.

5 IMPLEMENTING THE ADVICE

"*in all three agencies (NAFO, ICCAT and ICES), it is presupposed that if a stock falls outside the "safe" or "target" area of its precautionary framework, action should be taken to decrease fishing mortality below the threshold value to allow biomass to increase towards a rebuilding target"* (page 13, ICES 2001b) .

Stocks described as outside safe limits are above $\mathbf{F}_{pa}$ or below $\mathbf{B}_{pa}$. They have entered the region where there is an increased risk of reduced recruitment, potentially leading to stock collapse in the sense that such stocks will not be able to sustain a viable fishery, rather than that they will become biologically extinct. Stocks should then become subject to management action to return them to safe limits.

The precautionary approach intends that managers should adopt a pre-agreed strategy in the form of a harvest control rule, or a rebuilding plan (Anon., 1997a). Where the advice requires a modest reduction in F or catch in order to restore a stock to safe limits, it may be reasonable to achieve this in one year. Where a substantial reduction in F or catch is required, greater than some limit to be agreed with managers and preferably also stakeholders, a rebuilding plan will be needed for some agreed longer time frame. The word *rebuilding* appears to be more appropriate than *recovery,* as it implies that management action is being taken, whereas a recovery could stem from natural causes irrespective of any remedial action. In certain jurisdictions, "recovery" plans refer to actions undertaken in response to species-at-risk issues.

5.1 Historical Practice

The following examples were discussed to illustrate the context of stock rebuilding programmes to date.

Norwegian Spring Spawning herring became depleted at the end of the 1960s, and in the 1970s SSB was extremely low. Fishing was banned and a rebuilding target set of at least 2.5 million t. Following the large 1983 year class the target was reached in the mid-1980s and the fishery was reopened.

The *North Sea mackerel* stock collapsed in the late 1970's. A zero TAC was recommended by ACFM and implemented in 1982. There is no specific rebuilding target, but despite the zero TAC no improvement in stock size has yet been observed. Directed fishing for mackerel in the southern North Sea and IIIa therefore remains closed in order to protect this component of the stock.

For *Arctic cod* it was recognised in May 1988 that the TAC was much too high and that the stock was even lower than estimated the previous year. A within-year revision of the 1988 TAC was advised by ICES and agreed by managers (mainly Norway at that time). Managers later accepted the low F recommended by ICES, and F fell from 0.9 prior to 1988 to 0.3 in 1990. F subsequently increased by about 0.1 per year and again reached 0.9 in the late 1990s. In 1999, ICES recommended a reduction in F (2001) to F=0.13 and the implementation of a rebuilding plan.

For *capelin* stocks at Iceland-East Greenland - Jan Mayen and in the Barents Sea the fishery is stopped when stocks fall below a threshold size, until there are clear signs that SSB will remain above the threshold after fishing a pre-specified quantity.

The *North Sea herring* stock collapsed in 1967, and the EU banned directed fishing until SSB should reach 0.8 million tonnes, above the level where the SSB-R data show that recruitment declines, or until one of the stock components showed a significant and sustainable increase. In 1981 fishing was allowed on the increasing Downs stock component only. The fishery was opened fully in 1983 following forecasts showing that with the advent of the 1981 and 1982 year classes fishing at $\mathbf{F}_{0.1}$ in 1983-1985 would allow SSB to increase from 0.5 million t in 1983 to over 1.3 million t in 1985.

In these examples management action was not taken until stocks were either very low or had collapsed, and the management response was draconian, including fishery closures. This represents crisis management that the precautionary approach seeks to avoid.

5.2 Pre-agreed plans

For *Icelandic cod*, a formal harvest control rule was implemented in 1995. The TAC for a fishing year is set as a fraction (25%) of the "available biomass" computed as the biomass of age 4 and older fishaveraged over the two adjacent calendar years. In the long term, this corresponds to a fishing mortality of about 0.4. This harvest control rule is considered to accord with the precautionary approach, simulations having shown that under this rule there is only a very low probability of the stock declining to very low levels. If, however, unfavourable environmental conditions for recruitment prevail for a number of years the stock might decline to low levels and a recovery plan might be needed. As the harvest control rule dictates a low F, this should prevent the stock from becoming very low.

The International Baltic Sea Fisheries Commission has recently agreed a *Baltic Salmon Action Plan* for the period 1997-2010, and long term management strategies for *Baltic cod* in sub-divisions 22-24 and 24-32, and for *Baltic sprat* in sub-divisions 22-32. The *salmon plan* aims to increase the natural production of wild Baltic salmon to at least 50% of the natural capacity of each river by 2010, while retaining as high a catch level as possible. There are no pre-agreed harvests control rules, but long term projections made by ICES are being used to evaluate which catch options will both maximise yield and attain the productivity goal. For *gadoids*, the strategy has defined a minimum acceptable SSB, and a higher precautionary biomass $\mathbf{B}_{pa}$, below which F will be adjusted "to ensure safe and rapid recovery of SSB". These plans and strategies embrace the intention to manage stocks when they pass designated thresholds, but the precise time scale and formula for recovery has not been specified.

5.2.1 The EU-Norway Management Agreement

By agreement between EU and Norway, the precautionary approach has now been brought into the long-term management of the North Sea stock of herring (as agreed in 1997) and the North Sea stocks of cod, haddock, saithe, and plaice (as agreed in 1999).

For *North Sea herring*, the agreement specifies that SSB should be maintained above $\mathbf{B}_{lim}$ (0.8Kt). A $\mathbf{B}_{pa}$ of 1.3 million t has also been set, above which the TAC will be based on F = 0.25 for adult herring and F = 0.12 for juveniles. If SSB falls below 1.3 million t, it is agreed that other measures will be implemented taking account of scientific advice. The specific form of these measures has not been formally pre-agreed, but since 1997 managers have agreed that F values of 0.2 (adult) and < 0.1 (juvenile) will continue until SSB reaches 1.3 million t.

For *North Sea cod*, EU and Norway agreed to "implement a long term management plan consistent with the precautionary approach and intended to constrain harvesting within safe-biological limits and designed to provide for sustainable fisheries and greater potential yield." The plan is to:

- maintain SSB above 70Kt ($\mathbf{B}_{lim}$)
- set a TAC consistent with F = 0.65 ($\mathbf{F}_{pa}$)
- but if SSB falls below 150Kt ($\mathbf{B}_{pa}$), F shall be adapted to ensure a safe and rapid recovery of SSB to above 150kt
- improve the exploitation pattern to reduce discards, taking account of the mixed gadoid fishery
- review and revise the measures in the light of any new advice from ICES

Similar wording and concepts have been agreed for North Sea haddock, whiting and plaice.

These agreements for the North Sea represent a further step forward in the application of the precautionary approach. They specify that management action will be triggered when F or SSB passes the precautionary reference points, and they define the objectives of such action in terms of $\mathbf{B}_{pa}$ or $\mathbf{F}_{pa}$. As for the Baltic stocks the agreement prescribes that management action should ensure *a safe and rapid recovery*, but without specifying exactly what this means, or what measures are to be used to achieve it. No target reference points have been set, so these agreements are in effect using the precautionary threshold as a target.

5.3 Recovery plans in the EU

The EU-Norway management agreement has been implemented at a time when stocks such as the cod, haddock and whiting round Britain, and hake in western waters, are seriously depleted. Over the last two decades the SSB of these stocks has fallen rapidly towards or below what is now $\mathbf{B}_{\mathrm{lim}}$, and in some cases recruitment has been reduced. The priority for managers is now to rebuild these stocks, and the required remedial changes in F are so large that they require the implementation of recovery or rebuilding plans. The first such plan was developed for Irish Sea cod in 2000 and 2001, and plans are currently being negotiated for hake, North Sea cod, and West of Scotland cod.

The proposed management actions comprise

- substantial reductions in TACs
- the adoption of seasonal closures to protect spawning and juvenile areas
- by-catch restrictions in the smaller meshed fisheries
- methods to reduce discarding and improve size of first capture by increasing mesh sizes and selectivity in the principal fisheries.

For institutional reasons the initial actions for some stocks will be taken as ‘emergency measures’ followed later by longer term measures probably lasting up to five years. These plans are being negotiated between the European Commission, EU Member States, and third countries, with the involvement of catchers. The negotiations are conducted outside ICES, and have involved meetings of expert groups to make additional assessments and calculations.

5.4 Discussion of recovery plans

The development of recovery plans represents a significant step by managers toward achieving precautionary objectives for seriously depleted stocks, and has in general generated a greater recognition by catchers of the need for serious management action. It has also highlighted a considerable number of examples and issues where improvements in either the advice or the basic knowledge of stocks and fisheries are necessary, as outlined below. Although these comments relate more to the implementation of the PA than to its development, they relate to the credibility of the current PA process, and need to be noted and where necessary addressed.

❖ The assessments or the advice could provide more comprehensive information on:

- .... the uncertainty of present assessments
- .... the quantitative options available for achieving recovery over different time scales
- .... estimates of the risks associated with these options
- .... likely trajectories of short-term losses and long-term gains
- .... solving the problem of technical interactions in mixed fisheries

❖ Stakeholders express concern that ICES assessments and advice make little or no reference to whether stocks are affected by non-fishery factors such as temperature change, industrial fishing, or the effect of seal predation, as discussed at, for example, the North Sea Commission.

❖ There appears at present to be a disconnection between giving advice and providing the tools available for its implementation. For example, current ICES advice only predicts the outcome of changes in F and the TAC. For cod and hake, however, ICES advice recommended not only a reduction in F but also reduced discarding and an improved exploitation pattern. These recommendations were in effect left to the managers, yet neither the advice nor the assessments illustrate the combined effect of reducing F and increasing size of first capture, nor the range of time scales over which different combinations of these might achieve recovery plan objectives. Although there may be numerous options here, presenting at least a selection of them would guide discussion, particularly between managers and catchers.

- The EU cod and hake recovery plans have required additional investigations and calculations by expert groups convened outside ICES. These have shown that in order to discuss the benefits of closures, more biological knowledge is required on the time-space distribution of spawning and juvenile fish, whilst data needs to be more readily available on the distribution of effort and catch by fleet by statistical rectangle. In order to discuss the scope and effect of changes in mesh size and other technical measures, more data are also required at the fleet level on all aspects of gear selectivity, and on the pattern and quantity of by-catches and discarding.

- When managers and catchers discuss options and time-scales it is natural to ask about the likely time-trend in losses and gains, but scientists are lukewarm about the reliability of such scenario modelling. This reflects their lack of confidence in long term projections due to basic uncertainties in the assessments, inadequate fleet data, the difficulty of forecasting recruitment, and uncertainty over the effects of technical, multispecies and ecosystem interactions. These aspects require attention and are discussed again later.

- Recovery plans that introduce significant changes to the TAC and to mesh sizes could seriously influence the assessment of stocks in succeeding years. Decisions will be required on how to take into account the TAC constraint and changes in the exploitation pattern in the upcoming middle year, for example, and disruption to the fisheries could also disrupt the utility of tuning fleets. BODIL Next sentence BOLD It is important that ICES working groups and ACFM respond in a uniform and credible way to these problems.

- Even if accurate predictions are difficult, there are obvious qualitative biological benefits in stabilising stock structure by increasing the number of age groups and reducing dependence on the incoming recruitment. Even in the absence of precise forecasts, therefore, some form of stock structure target based on life history considerations could still be considered.

- For managers in the ICES area the current priorities are stocks that are close to or below $\mathbf{B}_{lim}$, and therefore require rebuilding to prevent recruit failure. Management of stocks that are close to $\mathbf{B}_{pa}$ has therefore taken a lower priority. In fact at present stakeholders and managers are tending to treat $\mathbf{F}_{pa}$ and $\mathbf{B}_{pa}$ as targets rather than as thresholds, and there appears to have been no clear policy on whether or how to implement appropriate harvest control rules as stocks fall below the threshold point. In the interests of avoiding future collapses, it is important that there is a clear recognition by managers and fishers of the management obligations at $\mathbf{B}_{pa}$ and $\mathbf{F}_{pa}$. This could be one benefit from formulating the advice using the Key described in the previous section. There is a linkage here to the setting of target reference points, and the possible development of longer-term management strategies based on, for example, multiannual TACs.

The intention of the precautionary approach is that decisions and actions should be *pre-agreed*. So far managers have agreed *when* to take action, and have pre-agreed certain management objectives, but in general they have not pre-agreed what action to take, or over what time scale. The latter depends on the perception of risk, and the availability of data and forecasts not routinely part of current advice. It also depends on previewing all the likely causes of stock decline, implying that in the case of the North Sea and Irish Sea gadoids, for example, the combination of high F and reduced recruitment could have been anticipated. The question of pre-agreement could be addressed if ICES and managers develop an appropriate dialogue on recovery plans following current experience.

5.5 Enforcement and control

The negotiation of recovery plans has brought managers, catchers and scientists into closer contact, but conflicts continue to arise over the likely short-term effects of management measures on catchers, and between the interests of different groups of catchers targeting different species or areas with different gears. Under these circumstances there is inevitably concern about the efficacy of TAC’s (which may control landings but not necessarily catches), and scepticism as to whether technical measures targeted at a variety of different gears and target species can be enforced properly. Although these issues have been fundamental to the credibility of assessments and fisheries management throughout the past, the public profile of recovery plans means that they are even more important for the credibility of implementing the precautionary approach. At the most practical level, these issues will affect the assumptions made during upcoming assessments.

6 ESTIMATION AND FORECASTING ISSUES

The present review highlights several issues where there is pressure to support or enhance the advice using techniques or information that are still imprecise or undeveloped. This section amplifies some of these issues, and identifies some scientific and technical requirements that should be dealt with as a matter of urgency.

6.1 Forecasts for short lived species or heavily fished species

Stock prediction will be particularly unreliable for short-lived species whose stocks have a very rapid turnover. Stock size in the prediction year will comprise year classes that have just entered the stock and whose abundance is either poorly estimated, or has to be assumed, so that forecasts could be particularly unreliable.

Similar considerations apply when a high fishing mortality reduces the effective life span of longer- lived species. As a result, when a target fishing mortality is applied to a predicted stock estimate to produce a TAC, quite small errors in the predicted stock will cause that TAC to generate a very different fishing mortality from what was intended. In such cases, a TAC may be unsuitable, especially if there is a tendency to overestimate stock size, since the TAC may be unattainable and the harvest mainly determined by the available effort. In such cases attempts to improve the stock by relatively small adjustments to the fishing mortality cannot be expected to be successful.. It was suggested that the expression 1/Z could be used to indicate of the life span of the stock for comparison with the time frame of the advisory process. For several cod stocks, where Z is about 1, this would indicate an effective life span of around one year.

Recovery or rebuilding plans are implemented by management restrictions that aim to reduce the direct and indirect mortality on depleted stocks. At low stock size, increased stochastic noise will be associated with surveys that are sampling spatially heterogeneous distributions, and there could be degradation of commercial CPUE and total catch data. These effects will increase the uncertainty in stock assessments and projections, so unless sampling is adjusted to compensate for this, data quality will deteriorate at the very time when there is an increased risk of stock collapse.

6.2 Overestimation of stock size

It is increasingly clear that assessments tend to overestimate stock abundance in the last year (Patterson et al, 2000). In principle $\mathbf{F}_{pa}$ should be set relative to $\mathbf{F}_{lim}$ in order to take this uncertainty into account, but quite often this is not the case. If stock is seriously overestimated, realised fishing mortality may be consistently beyond the acceptable upper bound of $\mathbf{F}_{pa}$, and the advised fishing mortality may not be sustainable. This problem becomes more prominent when the stock is heavily exploited and fishing mortality becomes more sensitive to the stock overestimate. In such cases, ICES advice will become less accurate even if the loss of accuracy cannot be fully measured. This should be taken into account when the advice is formulated. .

6.3 Medium term predictions and uncertainty

Managers naturally seek guidance on which catch options are most likely to bring SSB above $\mathbf{B}_{pa}$ with a high probability. Where possible this is done using medium term predictions. Such predictions are also desirable for evaluating recovery plan options, and will become a necessity if managers and ICES agree to developmultiannual TACs (see Section 6.7).

Single species medium term analyses attempt to look beyond the 1-2 year time horizon typical of short-term forecasts. The time period considered is related to the longevity of the species and for many fish stocks this tends to be in the range 5-10 years. In general, the population at the start of the analysis, which has been estimated by an assessment model, is completely replaced by simulated recruitment by the end of the projection period. These analyses afford an opportunity to investigate the progression of a population from an initial state towards another under different management regimes and states of nature, and to investigate the associated gains and costs of moving to different states.

Until recently, medium term prediction methods have been used somewhat uncritically, as little testing has been done to validate them, but they are certainly subject to bias and error in the prediction process due to uncertainty. Patterson *et. al.* (2000) recently evaluated the performance of medium term methods in current use at ICES. For a large number of age based assessment data sets, medium term predictions derived retrospectively from shortened data series were compared with eventual outcomes derived from the full assessment time series. The tests examined the consistency with which uncertainty is estimated, but did not investigate the overall performance of the methods. Issues such as the accuracy of predicting stock size or catch are also important, and need to be considered in future.

The results are that in the majority of projections current methods appear to underestimate uncertainty. The reasons are diverse and could not be fully explored within the time allocated to the project. Further work is needed to identify the components of stochastic noise or bias that are present in the true data but missing from the assessment and projection models. Patterson *et. al.* (op cit) concluded that, until this problem is solved, probability statements derived from medium term projections should be presented as providing a relative measure of the risks associated with different harvesting strategies, rather than representing the actual probability of eventual outcomes.

Despite these weaknesses the authors concluded that the provision of uncertainty estimates has led to management decisions that are better informed than if only deterministic projections had been provided.

6.4 Medium term predictions and biological change

A further problem with medium and long-term forecasts is their dependence on biological data that only reflect the current status of the stock, or the current status of the ecosystem and the environment. In a rebuilding period, for example, stocks consist primarily of young individuals whose spawning potential is not considered to be equivalent to that of the historic stock component containing a mixture of older more experienced individuals. Rates of recovery determined from historic data sets may be over-estimated, therefore. (SGPRISM). Furthermore, inputs on natural mortality, growth and recruitment may only be truly valid for the life expectancy of the current stock, which may be no more than 0 to 3 years for heavily exploited stocks in the ICES area (Brander, pers. comm). Beyond that limited time horizon it becomes increasingly likely that the level and variability of stocks will be determined by factors that are not included in the traditional models, such as the effects of temperature, or other forcing factors related to, for example, the North Atlantic Oscillation.

6.5 Multispecies considerations

Multispecies interactions could cause problems for the use of precautionary reference points at both the lower and upper end of the biomass scale. At low biomass, for example, predation by another species on some stage in the life history of the target species could add uncertainty to the determination of $\mathbf{B}_{\mathrm{lim}}$, the relation between $\mathbf{B}_{\mathrm{lim}}$ and $\mathbf{F}_{\mathrm{lim}}$, and the annual estimation of biomass and recruitment. For example, as the stock of predator *y* increases, the SSB required for reasonable recruitment of prey *x* will also increase, as when herring eat cod larvae. Interactions of this type could also influence the evolution of stock during a recovery programme. At the upper end of the biomass scale, interactions could also affect the selection and determination of target reference points and values such as $\mathbf{F}_{\mathrm{MSY}}$ $\mathbf{B}_{\mathrm{MSY}}$. Although these are not so far being calculated by ICES it is obvious that not all species can be optimised simultaneously, and that trade-offs will be required depending on the species chosen for optimisation.

The effect of multispecies interactions on reference points has been considered by several ICES groups (Anon. 1997a & 1998a, COMFIE 1999, Anon 2001g). A principal conclusion is that reference points are less well defined when viewed in a multispecies context, since biomass and yield curves for each stock merge to become multidimensional surfaces with the potential for multiple maxima. Under such conditions, effective and achievable reference points will depend upon particular management and environmental scenarios. This is not to say that some reference points will not be broadly applicable over a range of scenarios, but the potential need to adjust the reference points to reflect prevailing biotic conditions increases. The choice of reference point stability or reference point attainability needs to be discussed with managers.

Although we may not be able to provide multispecies reference points *per se*, we may still be able to identify which interactions will cause most problems for limit reference points, and which choices and options for optimisation are most likely to be reasonable and robust.

6.6 Scientific and technical requirements

SGPA discussed the necessary scientific developments required within the fields of stock assessment, short-term prediction, and medium-term projections in order to advance the precautionary approach. The quantification of uncertainty in relation to stock assessment outputs and the PA reference points *per se*, and the validity of the medium-term projection methodology were highlighted as of major importance and must be investigated with some urgency. It is proposed that they are considered by upcoming meetings of the ICES Working Group on Methods on Fish Stock Assessments.

Specifically, five topics were discussed.

6.6.1 Sources and quality of data

Stock assessments depend upon a variety of data and factors (effort, landings, discards, mis-reporting, research vessel surveys). The quality of the basic sampled data requires further investigation. Problems identified include:

- assessment noise resulting from a country taking only a small part of the annual quota but adopting a poor sampling regime can be disproportionately large

- tuning the VPA using fleet catch-at-age data that also forms a major part of the total catch-at-age data

- age dis-aggregated acoustic data may be of limited use if poor additional sampling leads to inaccurate age discrimination.

6.6.2 Quality of stock assessments

Many sources of data are available for stock assessment but these are not all equally used within any particular model. When coupled with structural uncertainty within each assessment model this can lead to different inferences about the status of the stock, and hence uncertainty in the quality of the assessment. As a priority, further research is required to quantify the quality of stock assessments and subsequent sensitivity of advice. A useful tool to aid this might be the inclusion of probability profiles of F for a range of TAC. This will also be dependent upon the validity of the short-term projection model adopted.

Retrospective studies have established that the application of assessment methodologies to fish stock data can produce patterns of consistent under- or over-estimation bias in estimates of F and population numbers-at-age (Sinclair et al., 1990; Anon., 2001e}This could result in incorrect advice being given to managers. Such cases need to be examined, and resolved, or the results of the assessment and its subsequent predictions set aside. At the simplest level, it could be helpful to managers if assessments were labelled as ‘good’, ‘moderate’ or ‘poor’ using some appropriate qualitative criteria.

6.6.3 Uncertainty

Perceptions about uncertainty depend upon the viewpoint: scientists view uncertainty as the variance of stock estimates, whilst managers are more concerned by the implications for inter-annual yields. PA reference points are currently set with an arbitrary uncertainty assigned to them and the basis for these calculations needs to be reassessed. There is also a need to assess the uncertainty of the current F and stock size relative to the PA point. This is of particular concern to catchers.

6.6.4 Medium-term projection

Medium-term projections are not forecasts but are easily mis-interpreted as such by managers. Problems with medium-term projections have been highlighted above, and must be rectified before they can confidently be used in the formulation of annual management advice and in the initiation of stock rebuilding plans. Problems identified with the medium-term projection methodology implemented by ICES are:

- specification of an appropriate stock-recruitment model, the estimation of its parameters, their variance and autocorrelation of residuals (distribution);

- incorrect initial starting values and statistical structure;

- future trends in maturity, growth and selection patterns

6.6.5 Stock rebuilding and recovery

In addition to using reference points to identify when management advice is not consistent with the PA approach, ICES is committed to recommend when a stock rebuilding plan is needed. This requires proposing an F with a strong probability that a stock does not further decline, based on medium-term projections. . ICES should prepare case studies on the likely combination of measures, including technical measures that might be relevant in the specification of a rebuilding plan. The time-scale for stock rebuilding must be agreed by the managers taking into account the chosen target,, the scientific advice, unforeseen events, and the likely efficacy of the management actions chosen. This requires an effective dialogue between scientists, managers and catchers.

6.7 Multiannual TACs

The prevailing character of fisheries management in the ICES area has been the calculation of annual TACs that vary considerably from year to year due to the effects of changes in year class strength, especially when stocks are depleted and depend principally on the incoming recruitment. When such variations cause stocks to fluctuate around $\mathbf{B}_{pa}$ or $\mathbf{B}_{lim}$ they also change the conservation and management status of the stocks from year to year. This variability increases instability in the fishing industry, and inhibits long term planning, including the effective management of fishing capacity.

The EU has therefore proposed that it would benefit both the fishing industry and the stocks if it could develop a longer term management strategy, based on decision rules coupled to multiannual TACs that are less variable than annual TACs (Anon 2000b). This will require a fishing mortality strategy that reduces the harvest rate, and allows the size and age structure of stocks to increase, so that stocks are well buffered, and changes in spawning biomass relative to reference points become less important. As before the questions of technical and biological interactions will also need to be considered.

The EU is commissioning simulation studies to explore the feasibility and conservation implications of such an approach, which could conceivably be integrated with the evolution of current recovery plans, and the development of target reference points. Achieving this will require considerable discussion between scientists, managers and catchers. SGPA proposes that ICES should support the exploration of such a strategy and should seek ways to integrate it into the ongoing implementation of the precautionary approach.

7 MSY AS A REFERENCE POINT

..… Limit reference points set boundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield…

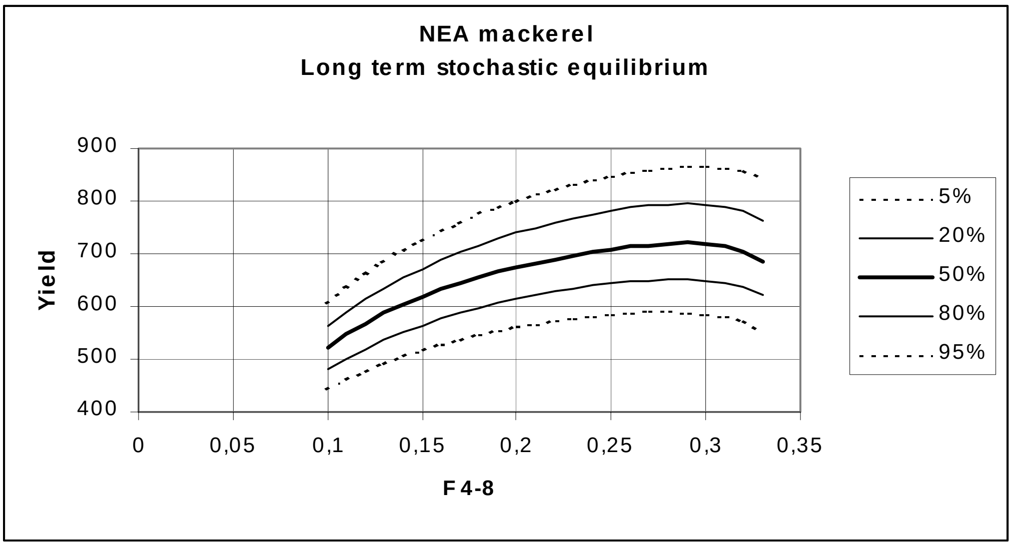
….The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points" (Annex II of the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks)

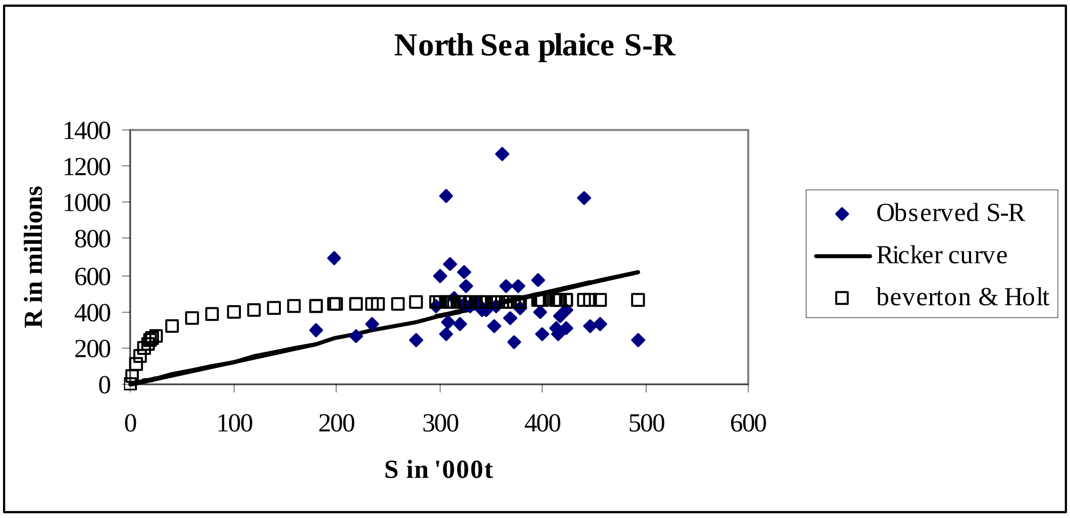
SGPA discussed the potential role of MSY in reference point estimation from analytical assessments, drawing on views expressed by Lassen and Sparholt (2001c) and Skagen (2001).

Traditionally, MSY is linked to the concept of an optimal harvest beyond which yield deteriorates and instability increases, whereas $\mathbf{F}_{MSY}$ has been proposed by NAFO and ICCAT as the maximum value for the limit fishing mortality (Anon 2001a). So far, ICES has yet to use $\mathbf{F}_{MSY}$ as a reference point. This is because the estimation of $\mathbf{F}_{MSY}$ is unreliable due to density dependent and multispecies effects, whilst experience shows that for decades numerous stocks in the ICES area have sustained relatively high exploitation rates , well above the level corresponding to $\mathbf{F}_{MSY}$. Whether the long-term yield of these stocks would have been higher at a lower fishing mortality is not clear, but it seems problematic to advise a strong reduction from a level that historically has appeared to be sustainable. This suggests that for these stocks $\mathbf{F}_{MSY}$ is not a suitable limit point. On the other hand there are some stocks with moderate exploitation rates where the current reference points based on other criteria are in practice close to what would be derived using $\mathbf{F}_{MSY}$ or its proxy. This includes stocks that are managed according to a $F_{0.1}$ regime or at fishing mortalities close to $F_{0.1}$, such as Icelandic summer spawning herring, and North-East Atlantic mackerel.

Technically, MSY is derived by combining a stock-recruitment relation and yield or biomass per recruit, in either a deterministic equilibrium or stochastic framework. The yield and biomass per recruit element should take into account density dependence, and both MSY and $\mathbf{F}_{MSY}$ will also be sensitive to the assumption about natural mortality. These calculations are not carried out routinely by the current software, and in any case $\mathbf{F}_{MSY}$ may be difficult to implement because in practice the response of the stock to lower mortality and hence higher stocks may be poorly known. $\mathbf{F}_{MSY}$ also depends on the selection pattern and the ages over which it is computed. In cases where consideration is being given to the trade off between fisheries for juveniles and for adults it may be necessary to consider the maximum long term yield for combinations of juvenile and adult mortality, and to estimate MSY as the eumetric point using the isolines of a 2-dimensional plot of yield against F and age at first capture.

There is concern that the uncritical use of stock-recruitment relations could lead to problematical results. For example, the figure below shows the best fit for two different functions applied to North Sea Plaice data from WGNSSK (ICES 2001/ACFM:7). The issue is not the difference between the stock-recruitment functions, but rather the problem of estimating more parameters than allowed for by the data when the signal to noise ratio is low. This is a very common problem that could have a strong impact on the estimation of reference points based on $\mathbf{F}_{MSY}$. Problems will also arise if the historical series of stock-recruit pairs is uncertain due to poor data. The estimation of reference points then becomes heavily influenced by differing perceptions about the past development of the stock, and MSY could be more vulnerable to this problem than are other F-related reference points. Other ways of obtaining a relation between stock and recruitment may therefore have to be considered.

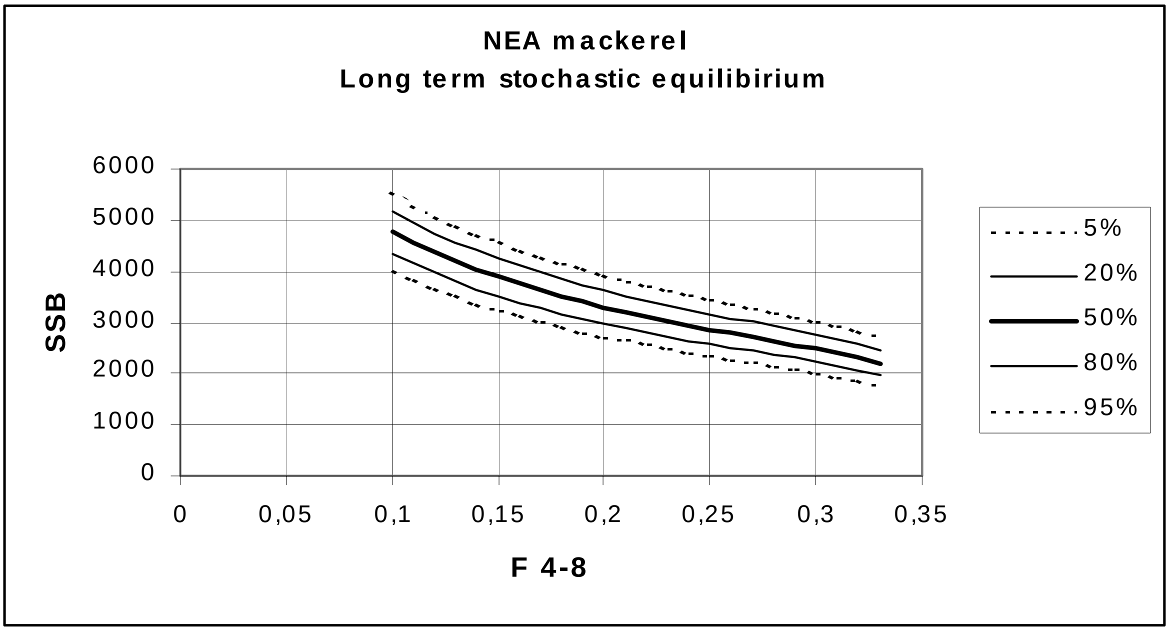




Inferences outside the range of the data are also not advisable, although this may not be necessary when the MSY equilibrium point corresponds to the part of the curve where recruitment is largely independent of SSB. If however MSY is obtained at an SSB where recruitment becomes impaired, $\mathbf{F}_{MSY}$ becomes the level of exploitation that should be avoided with high probability.

The equilibrium yield as a function of fishing mortality is most often a flat-topped curve where the maximum is poorly defined. Proxies for $\mathbf{F}_{MSY}$ could then be considered, in particular reference points of the $F_{0.1}$ type. The argument for such reference points is that there is little to gain in terms of increased long-term yield by increasing the fishing mortality further, especially as this increase the risk of excessive stock depletion coupled with increased year to year variability.

The figure below, which shows the distributions of catches and biomasses for mackerel in a long-term stochastic equilibrium illustrates these points. $F_{0.1}$ is approximately 0.19 with the data used here.



SGPA discussed alternatives to F $_{0.1}$, such as biomass per recruit measures.. These have the advantage that they represent direct measures of the overall survival irrespective of the selection at age. This may be useful when changes in exploitation pattern are to be evaluated. They can also be computed directly from growth, natural mortality and selection at length in situations where age structured models cannot be used (Azevedo & Cadima, 2001, see Section 8).

MSY is traditionally defined in a single species context, but many stocks in the ICES area belong to ecosystems with strong multispecies interactions. The optimal yield in a multispecies framework will generally be at a higher fishing mortality than estimated in a single species framework, and what is optimal for one species will not necessarily be optimal for another. If a stock of predators becomes very large, for example, prey stocks will suffer, perhaps even depriving the predator stock of its main food supply. Modelling the combined effect of changes in fishing mortality in a multispecies system is complicated. Although it may perhaps be possible for relatively simple systems such as the Baltic, the reliability of the results for advisory , may still be problematic, particularly if they are extended to a scenario outside the range of historical experience. Given the limitations of our knowledge it may therefore be naïve or dangerous to advise on the trade off between stocks and fisheries in a system where strong multispecies interactions are likely.

The forgoing suggests that MSY is still too problematical to be used by ICES for the calculation of reference points. To overcome the problems that have made ICES abstain from using MSY in it's the advisory framework requires better knowledge, better use of existing knowledge, or proxies for MSY that are more robust to these difficulties. On the other hand, one would expect that management agencies are interested not only in the risks associated with recruitment overfishing, but also in the potential yields to be obtained. At present ICES restricts its precautionary framework to providing advice on acceptable risks and provides advice on yield within the acceptable risk boundaries so defined. If the demand for evaluation of optimal harvest strategies increases, , ICES may therefore have to revisit concepts like MSY (and possibly other optimality criteria).

8 F $_{0.1}$ AS A REFERENCE POINT

For 30 ICES stocks, Cadima & Azevedo (1998) showed that the ratio of spawning biomass per recruit (SPR) at $\mathbf{F}_{0.1}$ to that at F=0 is close to 40% , with a variation between 30% and 50%. This approach was evaluated further by Azevedo and Cadima (pers. comm) and the results discussed by SGPA. The percentage biomass per recruit (BPR) at $\mathbf{F}_{0.1}$ was computed for a wide range of simulated stocks and a wide range of exploitation patterns using the simplified Beverton and Holt model (Beverton and Holt, 1957, 1966). This describes stocks using the parameter M/K (natural mortality coefficient/growth coefficient) and the parameter c, which expresses length of first capture as L_c/L_{inf} or 1-exp(-K.(t_c-t_o)). Results show that %BPR at $\mathbf{F}_{0.1}$ has a small range of variation, from 32% to 42%. In comparison, %BPR at $\mathbf{F}_{0.1}$ is fixed at 46%BPR for the Fox production model (Fox, 1970) and at 55%BPR for the Schaefer model (Schaefer, 1954). The variation observed by Azevedo and Cadima is due to differences in the exploitation pattern (parameter c), since %BPR decreases as c increases, whereas when exploitation pattern does not change, %BPR is almost unchanged for different M/K values. The values of %BPR and %SPR at $\mathbf{F}_{0.1}$ are above most of those corresponding to the ICES precautionary reference points.

In addition to providing a robust estimate and high %SPR, $\mathbf{F}_{0.1}$ has the following advantages for protecting reproductive potential in order to avoid stock collapse:

- $\mathbf{F}_{0.1}$ can always be determined, which is not the case for $\mathbf{F}_{max}$ when Y/R curve is flat topped

- $\mathbf{F}_{0.1}$ is the least variabile of all reference points (Smith et al 1998)

- computation does not rely on a stock-recruit relationship which is often difficult to estimate

- more year classes contribute to spawning biomass, thus improving the chance of a good recruitment and reducing the effects of year-class variation (May, 1981)

- the higher stock level associated with low fishing mortality improves the "safety margin" by allowing more time for identifying the effects of uncertainties in stock assessments, and for developing management recommendations.

- yield-per-recruit at $\mathbf{F}_{0.1}$ is likely to be close to the maximum net economic yield .

Previously, $\mathbf{F}_{0.1}$ has been suggested as a target reference point (see for instance Rivard & Maguire, 1993, Mace, 1994), but the various characteristics identified above suggest that $\mathbf{F}_{0.1}$ could be used as a valid substitute for $\mathbf{F}_{pa}$. The Table below (Azevedo & Cadima, pers. comm) shows that at $\mathbf{F}_{0.1}$ %SPR ranges from 30-50%, whereas at $\mathbf{F}_{pa}$ %SPR ranges between 8-23%, including values low enough to suggest that reproductive potential is compromised.

Stock	%SPR $\mathbf{F}_{0.1}$	%SPR $\mathbf{F}_{pa}$
North-East Arctic cod	41	10
North-East Arctic saithe	40	14
Faroe Plateau cod	44	23
Cod in Kattegat	41	11
Sole in Div. IIIa	32	22
Cod in West of Scotland	43	10
Cod in the Irish Sea	44	9
Plaice in the Irish Sea	41	12
Cod in Div. VIIe-k	39	8
Sole in Celtic Sea	36	12
Plaice in Western Channel	39	10
Northern white anglerfish	43	10
Sole Bay Biscay	39	9
Northern hake	30	23
Southern hake	35	23

These results suggest that further consideration should be given to the possible role of biomass per recruit and spawning biomass per recruit at $\mathbf{F}_{0.1}$ as conservation or target reference points. As noted in the next section for deep-water species, it may also be a possible estimator for stocks where other reference points cannot be evaluated. It was noted that in Canada, however, attempts to manage stocks using $\mathbf{F}_{0.1}$ have still resulted in a fishing mortality that is too high and insufficient to arrest a rapid decline in many groundfish stocks (Rivard, pers comm)

9 DATA POOR SITUATIONS

"*The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation or management measures"* Article 7.5 of the FAO Code of Conduct …

The 1997 Study Group proposed that when the available data are poor , a first working estimate of a limit reference point for F could be a fishing mortality corresponding to , say, 35% of the virgin SSB/R (F=0). (Anon., 1997a). For biomass limits, it advocated as a reference point using a pre-agreed value of a biomass index.. For example, $\mathbf{B}_{lim}$, which should be set at a value corresponding to considerable depletion, could be say 30% of the maximum observed index. $\mathbf{B}_{pa}$ should then be set to trigger management action at a biomass index representing a high probability of avoiding $\mathbf{B}_{lim}$. Such an approach is only feasible when a biomass index or a time series of survey data are available.

Information on longevity, maturation or gonadosomatic indices could be used to derive estimates of natural mortality (M) using empirical methods. Then if catch data are available catch curve methodology could be used to estimate total mortality (Z) and hence derive approximations for the level of fishing mortality (F) that could be used to provide advice.

SGPA noted that, following section 8, further work could also be done to explore the use of $\mathbf{F}_{0.1}$ as a reference point for data poor stocks, based on the use of the Beverton and Holt model

Where no analytical or index data are available, SGPA discussed the "traffic light" approach of Caddy (1998) This uses whatever observations are available on the state of the stock, together with qualitative information on biology, life history, and environmental signals. These factors are weighted to produce a green, yellow or red signal as a guideline to the need for pre-agreed action. The approach has been used by NAFO for shrimp fisheries and for some Canadian domestic stocks, and research has been directed to improving the technique. The views of fishermen could be incorporated into such a model, and it may also be possible to incorporate ecosystem considerations.. Such a method could combine and synthesise quantitative and qualitative data, and provides a powerful presentational tool Since the output signal is qualitative, however, the links between the assessment and the resulting management actions may need strengthening. SGPA felt that it would be useful to investigate this approach further. For example a study group could evaluate its suitability for applying the precautionary approach to deep-water stocks, or where ecosystem factors need to be given further consideration. Deep-sea resources

In the last few years, the management of deep-water species has become a priority issue for NEAFC and the EU, and has been evaluated by ACFM (2001a). The issue arises because deep-water species inhabit a stable environment, grow slowly, mature relatively late in life, and have a low fecundity. They are therefore considered to be very vulnerable to exploitation. A sub-group of SGPA briefly reviewed the current situation.

Deep-water species are those that spend most of their life cycle at depths below 400m. In the ICES area they comprise some 20 or more finfish species, and a further 10 species of shark. At present ACFM only provides advice within a precautionary framework for *Reinhardtius hippoglossoides* - Greenland halibut, and *Sebastes spp.* – Redfish.

Other deep-water species include:

Alepocephalus bairdii -Baird's smoothhead
Aphanopus carbo - Black scabbardfish
Argentina silus - Argentine, great silver smelt
Beryx splendens - Golden eye perch
Beryx decadactylus -Red bream, alfonso
Brosme brosme - Tusk
Chimaera monstrosa - Rabbitfish
Coryphaenoides rupestris - Roundnose grenadier
Epigonus telescopus -Big eye, deep-water cardinal fish
Helicolenus dactylopterus - Bluemouth
Hoplostethus atlanticus - Orange roughy
Hoplostethus mediterraneus - Silver roughy
Lepidopopus caudatus - Silver scababardfish
Macrourus berglax - Roughhead grenadier
Molva molva - Ling
Molva dypterygia - Blue ling
Mora mora - Mora
Pagellus bogareveo - Red (=blackspot) seabream
Phycis blennoides - Greater forkbeard
Polyprion americanus - Wreckfish
Trachyrhynchus trachyrhynchus - Roughnose grenadier
Chaecon (Geryon) affinis - Deep-water red crab
Aristeomorpha foliacea - Giant red shrimp

The main shark species caught in deep water are:

Centrophorus granulosus - Gulper shark
Centrophorus squamosus - Leafscale gulper shark
Centroscillium fabricii - Black dogfish
Centroscymnus coelolepis - Portuguese dogfish

Centroscymnus crepidater - Longnose velvet dogfish
Dalatius licha - Kitefin shark
Deania calcea - Birdbeak dogfish
Etmopterus princeps - Great lantern shark
Etmopterus spinax - Velvetbelly
Scymnodon ringens - Knifetooth dogfish

Although aome fisheries are recent and developing, fisheries for species such as black scabbard, red (=blackspot) sea bream off Portugal, redfish, Greenland halibut, ling & tusk have existed for many decades. Unfortunately there has been no legal requirement for developing fisheries to report more than landings, so that commercial catch rates at the start of exploitation have not necessarily been recorded. For the more established fisheries catch rates, though relatively stable, have gradually declined over time, and the available data invariably refer to stocks that are already reduced from the pristine state. Although biomass in such low productivity stocks may be difficult to sustain long term, there is pressure to increase effort in these fisheries as a result of relocation from over-exploited shelf stocks, which increases the difficulty of implementing management measures.

9.1.1 Empirical methods and reference point proxies

The 1998 Study Group on the Precautionary Approach to Fisheries Management pointed out that deep-water fisheries could deplete stocks before there are sufficient data to provide management advice based on standard assessment methodology. It could not calculate the common biological reference points (Anon, 1998a), but following a working paper by Bell & Stefansson, (1998) it proposed the following harvest rule based on biomass (B) estimated from survey or appropriate commercial CPUE data:

$$Y_t = Y_{t+1}*(1+g[(B_{t-1}-B_{t-2})/B_{t-2}])$$

Y is catch, t is the year for which a TAC is to be set, and g (‘feedback gain’) is a proportionality factor determining how rapidly the TAC will be adjusted to compensate for a change in biomass. The performance of this function was evaluated by the 1998 Study Group. It simulated the application of a range of feedback strategies for 27 ICES stocks that had been modelled using status quo fishing mortality during a run-in period. Even with quite severe feedback gain (from g =1 to g =2), however, this rule produced low probabilities of stock recovery.

The ICES Study Group on the Biology and Assessment of Deep-Sea Fisheries Resources (Anon., 2000c) proposed that the following reference points were appropriate for deep-sea stocks:

$\mathbf{F}_{lim} = F_{35\%SPR}$; $\mathbf{F}_{pa} = M$

$U_{lim} = 0.2* U_{max}$; $U_{pa} =0.5*U_{max}$.

U is an index of exploitable biomass, rather than the spawning biomass, since the latter is not readily available for deep-water stocks. It is arguable that 50% of the maximum biomass is too restrictive for U_{pa}, and that a more appropriate figure could be:

$U_{pa} =0.3*U_{max}$

SGPA was unable to offer an alternative to these proposals as a first approach to setting precautionary reference points when appropriate data are available. An example is for *Sebastes marinus* and *Sebastes mentella*, where precautionary thresholds can be set as a percentage of maximum catch per unit effort (CPUE). .

It was noted that the proposed harvest control rule is a reactive method that is aimed at maintaining current stock status, rather than moving to a precautionary region. The calculations may also be susceptible to noisy data, and the approach requires confidence that management by TAC will be effective.

Where data are available for production models, but fits are poor, constraining one or more parameter(s) using values from similar stocks might allow better estimation of the remaining parameter(s).

SGPA had insufficient time and knowledge of the deep-sea resources to find immediate alternatives to these reference points, or to the harvest control rule based on Bell and Stefansson (1998). Instead it proposes that the most immediate priority is to apply what is known now, as discussed below.

9.1.2 Management background

The state of a number of deep-water stocks was summarised by the Study Group on Deep-Sea Fisheries (Anon., 2000c, Table 5. 1) and by the Advisory Committee for Fisheries Management (Anon. 1999a 2001a). ACFM stated that sustainable yield might be no more than 1-2% of virgin or initial biomass per year, and that the rate of stock rebuilding, even assuming no fishing, could be very slow. A working paper on developing management measures for deep-sea fish stocks was presented at ACFM in October 2000, and listed 13 points describing management objectives and the pros and cons of various management measures. This noted that there are doubts about the benefit of closed areas for species whose distribution is very widespread, or for species whose distribution is restricted to seamounts. ACFM also noted that regulating the deep-sea fishery by TAC *as the primary tool* is likely to be difficult because of the mixed-fishery character of some deep-sea fisheries in Europe, especially as most species are easily damaged and are likely to suffer serious mortality if discarded.

The advice is that " *most exploited deep water stocks are considered to be harvested outside safe biological limits and that an immediate reduction in these fisheries is recommended unless they can be shown to be sustainable. New fisheries should be permitted only when they expand very slowly and are accompanied by programs to collect data that allow the evaluation of stock status*" (Anon, 2001a).

Using the biomass reference points discussed previously, the priorities should be to cap or to reduce effort or landings in order to either maintain or restore stock biomass to above 30% of B_o, the virgin or initial level. If recovery is required it is recommended that SSB should reach B_o in a period of ten years. A fishery that falls below 20% B_o would require strict action, such as closure.

On the basis of life history criteria, and the above ACFM advice, SGPA endorses the need for timely and effective management action. It suggests that the further development of the precautionary approach for deep-sea resources is less a question of developing reference points, than of proposing specific management actions for individual species, areas or fishing fleets, utilising current knowledge, however limited. ACFM should either amplify its previous advice with specific reference to the findings of WGDEEP, or should convene a meeting of experts in order to do so. Because of jurisdictional questions, effective management may require EU and NEAFC to act together.

9.1.3 Data collection

Because basic statistics are generally poor or lacking, and there are generally few long time series of data, SGPA reiterates previous views about the urgent need to rectify this. Management measures introduced to cap or reduce effort in existing fisheries should not compromise data collection, but should be accompanied by additional measures to improve the collection of data for assessing stock status. This requires an international database of catch and effort data collected by statistical rectangle and by depth strata, rather than by ICES areas, which are too large in the deep-water areas. This will require collaboration and co-operation between countries to ensure that the data and sampling scales are calibrated and capable of integration in the database. By-catch species should be monitored. Stock surveys and or sentinel fisheries could also be established on a formal basis. Biological information, including data on growth, age and maturity, should be collected and collated routinely to agreed protocols. Information is also urgently required on stock structure and stock discrimination. In the NAFO area vessels entering a developing fishery may be required to carry observers, provide detailed information and conduct surveys in addition to fishing under strict limits. Similar schemes might have application in the NEAFC area.

9.2 Reference points for *Nephrops* stocks

Nephrops norvegicus is a burrow-dwelling crustacean that is captured when the animals forage outside their burrows. The exploitation rate on males is often much higher than for females, because the latter do not leave the shelter of their burrows when carrying eggs. *Nephrops* stocks are assessed using analytical methods (length-based analysis, or XSA based on age-sliced length frequencies), supplemented by trends in LPUE, mean size, or camera-based biomass estimates. . In 1997, the ICES *Nephrops* Working Group compared the observed fishing mortality against a variety of fishing mortality reference points, using male data for six stocks, and female data for one stock (Anon., 1997b). The observed F for males, which ranged from 0.60 to 0.85, was less than $\mathbf{F}_{high}$ (0.41-1.39), was similar to $\mathbf{F}_{med}$ (0.24-1.01), but substantially exceeded $\mathbf{F}_{low}$ (0.12-0.61), $\mathbf{F}_{max}$ (0.38-0.55), and $\mathbf{F}_{0.1}$ (0.2-0.24). For females, observed F (0.49) was less than $\mathbf{F}_{high}$ (0.65) and $\mathbf{F}_{med}$ (0.58), was similar to $\mathbf{F}_{low}$ (0.44) and exceeded both $\mathbf{F}_{max}$ (0.34) and $\mathbf{F}_{0.1}$ (0.17). The observed range of F was equivalent to a Spawning Stock Per Recruit ranging from 11 to 30% of the virgin value. Given that there are as yet no signs of recruitment failure in *Nephrops* stocks the results suggest that stocks are not compromised by exploitation above $\mathbf{F}_{max}$, which, if it were to be selected as a limit reference point, would require considerable reductions in fishing effort. The Nephrops working group therefore suggested that $\mathbf{F}_{max}$ might be suitable as a target reference point.

Biological reference points for *Nephrops* stocks were re-examined by the 1999 Nephrops Working Group using the results of age-based assessment (XSA) output to examine SSB/R, Y/R, and stock-recruit plots (Anon.,1998b). Results showed that there was very little difference between the values of $\mathbf{F}_{high}$, F_{med} and $\mathbf{F}_{low}$, and that because in many cases the stock-recruitment plots were linear, it was difficult to determine when the stocks became vulnerable to recruitment overfishing. The problem of adopting biological reference points for Nephrops based on the results of analytical assessments has therefore still not been resolved.

SGPA had insufficient time and expertise to investigate this issue, which means that at present *Nephrops* stocks are, strictly speaking, managed outside the precautionary framework.

10 COMMUNICATION

The sudden implementation of precautionary reference points by ICES in 1998, with little warning or consideration of the consequences to the outside world, is seen outside ICES as an illustration that communication needs a practical review. As the Open Forum indicated at the ASC 2000, ICES also needs to make a significant response to fishing industry requests for more involvement in the scientific and advisory process. There are frequent references throughout this document to the need for ICES scientists, managers, and catchers to discuss risks and strategies during the reappraisal and development of the precautionary approach, as well as the development of the recovery plan issues. These are therefore avenues and issues that could be explored during any review of communications strategy. There is a similar need for increased communication within ICES between modellers, assessment scientists and the advisory process. SGPA has in mind communication at the working level in addition to the discussions that take place at formal set-piece dialogue meetings and client request meetings. Finally, ICES needs to reassess the quality and consistency of its presentation of advice in the ACFM report, as discussed in Section 4.1 of this report.

ANNEX 1

FRAMEWORK FOR SELECTION OF PA REFERENCE POINTS

Text adapted from Lassen, H & H Sparholt, 2001a. ICES Framework for the Implementation of the Precautionary Approach in Fisheries Management Advice. Precautionary Approach Reference Points: Estimation Procedures. Working Paper for SGPA April 2001.

Annex Table 1. Some commonly used reference points

(Extract from: Updated Draft Report of the ICES Study Group on the Precautionary Approach to Fisheries Management, ICES CM 1997/Assess:7)

RP	Definition	Data Required
$\mathbf{F}_{0.1}$	F at which the slope of the Y/R curve is 10% of its value near the origin	Weight at age, natural mortality, exploitation pattern
$\mathbf{F}_{max}$	F giving the maximum yield on a Y/R curve	Weight at age, natural mortality, exploitation pattern
$\mathbf{F}_{low}$	F corresponding to a SSB/R equal to the inverse of the 10% percentile of the observed R/SSB	Data series of spawning stock size and recruitment, weight and maturity at age, natural mortality, exploitation pattern.
$\mathbf{F}_{med}$	F corresponding to a SSB/R equal to the inverse of the 50% percentile of the observed R/SSB	Data series of spawning stock size and recruitment, weight and maturity at age, natural mortality, exploitation pattern.
$\mathbf{F}_{high}$	F corresponding to a SSB/R equal to the inverse of the 90% percentile of the observed R/SSB	Data series of spawning stock size and recruitment, weight and maturity at age, natural mortality, exploitation pattern.
$\mathbf{F}_{MSY}$	F corresponding to Maximum Sustainable Yield from a production model or from an age-based analysis using a stock recruitment model	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship or general production models
2/3 $\mathbf{F}_{MSY}$	2/3 of $\mathbf{F}_{MSY}$	as above
$\mathbf{F}_{20\%\ SPR}$	F corresponding to a level of SSB/R which is 20% of the SSB/R obtained when F=0	Weight and maturity at age, natural mortality, exploitation pattern.
$\mathbf{F}_{crash}$	F corresponding to the higher intersection of the equilibrium yield with the F axis as estimated by a production model; could also be expressed as the tangent through the origin of a Stock-Recruitment relationship.	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship
$\mathbf{F}_{lpg}$	F corresponding to a 10% probability of giving a replacement line above G_{loss}	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship
$\mathbf{F}_{loss}$	F corresponding to a SSB/R equal to the inverse of R/SSB at the Lowest Observed Spawning Stock $\mathbf{B}_{loss}$	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship
$\mathbf{F}_{comfie}$	F corresponding to the minimum of $\mathbf{F}_{med}$, $\mathbf{F}_{MSY}$ and $\mathbf{F}_{crash}$	
F >= M	Empirical (for top predators)	M and sustainable F:s for similar resources
F < M	As above (for small pelagic species)	M and sustainable F:s for similar resources
$\mathbf{Z}_{mbp}$	Level of total mortality at which the maximum biological production is obtained from the stock	Annual data series of standard catch rate and total mortality
$\mathbf{B}_{MSY}$	biomass corresponding to Maximum Sustainable Yield from a production model or from an age-based analysis using a stock recruitment model	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship or general production models
MBAL	A value of SSB below which the probability of reduced recruitment increases	Data series of spawning stock size and recruitment (not necessarily from an VPA)
$\mathbf{B}_{50\%\ R}$	The level of spawning stock at which average recruitment is one half of the maximum of the underlying stock-recruitment relationship.	Stock recruitment relationship (not necessarily from an VPA)
$\mathbf{B}_{90\%\ R,\ 90\%\ Surv}$	Level of spawning stock corresponding to the intersection of the 90th percentile of observed survival rate (R/S) and the 90th percentile of the recruitment observations	Data series of spawning stock size and recruitment
$\mathbf{B}_{20\%\ B\text{-}virg}$	Level of spawning stock corresponding to a fraction (here 20%) of the unexploited biomass. Virgin biomass is estimated as the point where the replacement line for F=0 intersects the stock-recruitment relationship or as the biomass from a spawning stock per recruit curve when F=0 and average recruitment is assumed	Weight at age, natural mortality, exploitation pattern and a stock recruitment relationship
$\mathbf{B}_{loss}$	Lowest observed spawning stock size	Data series of spawning stock size

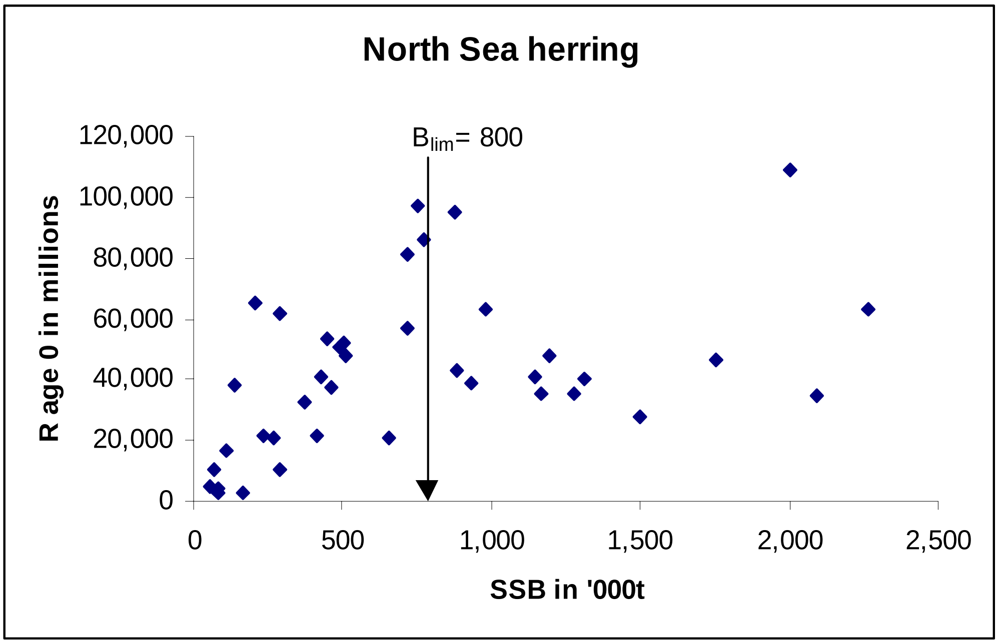
Not all limit reference points are intrinsically equal, and their interpretation depends on the specifics of each particular case they are applied to. For example, $\mathbf{F}_{max}$ can in some cases be considered as a target, when it is well defined and corresponds to a sustainable fishing mortality, while it would be a limit when it is ill defined and/or corresponds to unsustainable fishing mortality. Similarly $\mathbf{F}_{MSY}$, that is suggested as a minimal international standard for a limit reference point in the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks, could in some particular cases be considered a target. $\mathbf{F}_{crash}$ on the other hand is an extremely dangerous level of fishing mortality at which the probability of stock collapse is high. The probability of exceeding $\mathbf{F}_{crash}$ should therefore be very low.

BIOMASS REFERENCE POINTS

The preferred procedure is to use the SSB-R relationship.

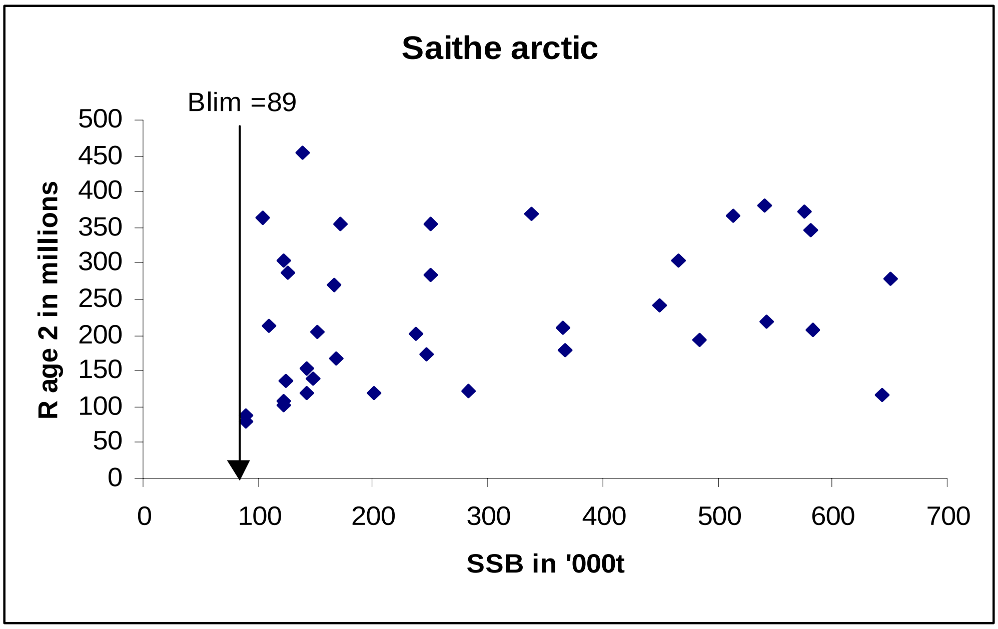
a) If the SSB-R plot clearly indicates that R is impaired at low SSB, select $\mathbf{B}_{lim}$ as the SSB value above which R is not impaired.

The example below is from the North Sea herring assessment, where $\mathbf{B}_{lim}$ was selected as 800 000t.



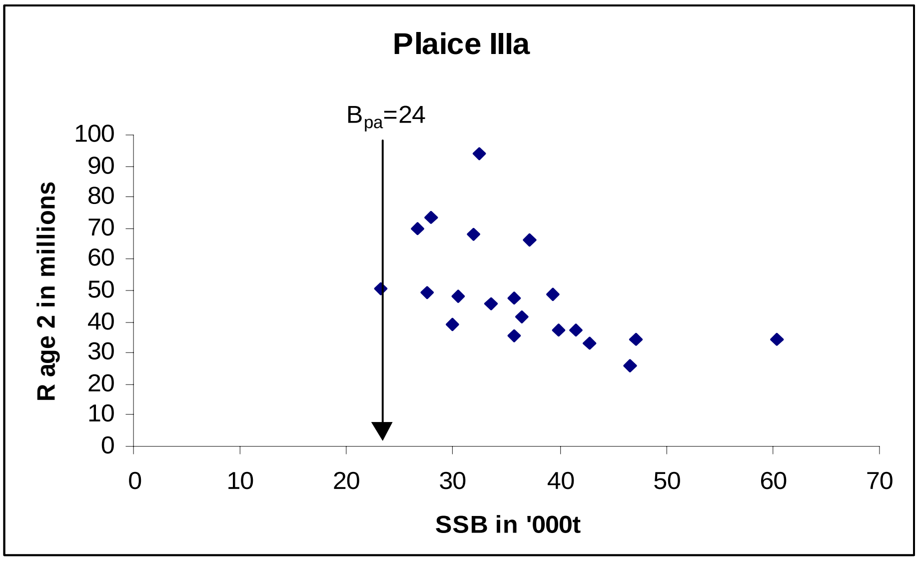
b) If the SSB-R plot indicates no impairment in R at low SSB but the range of SSB values is large then the lowest observed SSB is selected as $\mathbf{B}_{lim}$.

The example below is from the Arctic Saithe assessment where $\mathbf{B}_{lim}$ is selected as 89 000t.



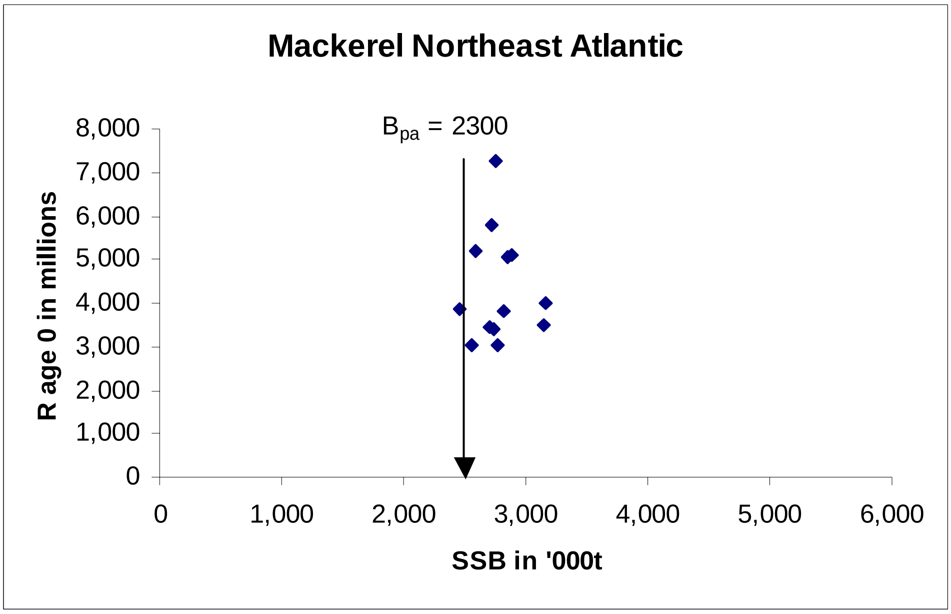
c) If the SSB-R plot indicates that R decreases with increasing SSB, then select the lowest SSB as $\mathbf{B}_{pa}$.

The example below is from the Skagerrak-Kattegat plaice assessment where $\mathbf{B}_{pa}$ is selected as 24 000t.



d) If the SSB-R plot has a narrow SSB range and indicates no trend then select the lowest SSB as $\mathbf{B}_{pa}$.

The example below is from the Northeast Atlantic mackerel assessment where $\mathbf{B}_{pa}$ is selected as 2.3 million t.



If a stock has infrequent very large year classes, such as haddock stocks, horse mackerel, Norwegian Spring Spawner herring, and capelin, various other procedures may be advisable. For example, setting $\mathbf{B}_{lim}$ to the lowest SSB that has produced outstanding year classes has been used for the two capelin stocks and for western horse mackerel.

If it has been possible to apply the above procedures then either $\mathbf{B}_{lim}$ or $\mathbf{B}_{pa}$ has been selected, from which the other reference point can then be derived, based on $\exp(1.645*\sigma)$, where 1.645 corresponds to the 5% one-sided percentile, and σ measures the uncertainty on SSB. If $\mathbf{B}_{lim}$ has been selected, then $\mathbf{B}_{pa}$ can be estimated as $\mathbf{B}_{lim} \exp(1.645*\sigma)$. If $\mathbf{B}_{pa}$ has been selected then $\mathbf{B}_{lim}$ can be estimated as $\mathbf{B}_{pa} \exp(-1.645*\sigma)$. Strictly speaking, σ is a measure of the coefficient of variation in the estimated SSB value of the surviving fish in the quota year for which advice is given (i.e. if advice is given for the fishery in 2001, then the relevant SSB value is normally that of 1 January 2002).

Where either $\mathbf{B}_{lim}$ or $\mathbf{B}_{pa}$ derived as above are close to an already established MBAL value, it may be regarded as preferable to keep the MBAL value (but not the term MBAL) to avoid introducing a new value which is only slightly different.

When the time series of data used in an assessment are changed (e.g. the maturity ogive, natural mortality or mean weight) or there is a change in the configuration of the SSB-R relationship, $\mathbf{B}_{lim}$ and $\mathbf{B}_{pa}$ may need to be re-estimated (See section 3.4).

Long time series of observations of SSB and R are not available for all stocks. If CPUE data are available it may be possible to use them as an index for stock size, and to set $\mathbf{U}_{lim}$ and $\mathbf{U}_{pa}$ as particular percentages of $\mathbf{U}_{virgin}$ or $\mathbf{U}_{max}$. Typically, $\mathbf{U}_{lim}$ could be set at 20% and $\mathbf{U}_{pa}$ at 60%, or less, depending on the life history of the species.

FISHING MORTALITY REFERENCE POINTS

If $\mathbf{B}_{lim}$ or $\mathbf{B}_{pa}$ are reliably estimated by the above procedures then $\mathbf{F}_{lim}$ or $\mathbf{F}_{pa}$ could be obtained as the F values that correspond to these biomass values in long-term projections. $\mathbf{F}_{pa}$ should be set so that the lower 10-25% percentile is equal to $\mathbf{B}_{pa}$ in order to be above $\mathbf{B}_{pa}$ most of the time. However, given doubts about the utility of medium term projections (see Section) the estimation of F reference points may have to be made independently.

The limit reference point $\mathbf{F}_{lim}$

$\mathbf{F}_{lim}$ may be based on:

1. $\mathbf{F}_{loss}$
2. $\mathbf{F}_{med}$
3. $\mathbf{F}_{crash}$
4. $\mathbf{F}_{pa}$
5. $\mathbf{F}_{lpg}$
6. $\mathbf{F}_{MSY}$
7. on medium-term simulations
8. F corresponding to $\mathbf{B}_{lim}$
9. By analogy with other similar stocks
10. On F values historically observed to lead to stock decline

The order of the above points does not indicate priority

If $\mathbf{F}_{loss}$ and $\mathbf{F}_{crash}$ appear to give reliable estimates of a collapse fishing mortality, the smallest can be selected as $\mathbf{F}_{lim}$. If neither is available and there is any doubt as to whether $\mathbf{F}_{med}$ is sustainable then $\mathbf{F}_{med}$ can be taken as $\mathbf{F}_{lim}$.

If $\mathbf{F}_{pa}$ is available (see below) then $\mathbf{F}_{lim}$ can be obtained by $\mathbf{F}_{lim} = \mathbf{F}_{pa}*\exp(1.645*\sigma)$, where σ is a measure of the uncertainty of F estimates.

$\mathbf{F}_{lim}$ is not always very useful for management. For example, the Norwegian Spring Spawning herring stock, capelin in the Barents Sea, capelin at Iceland, and Western horse mackerel, normally comprises one or a few occasional very strong year classes, causing large fluctuations in biomass independently of the fishing rate. However, according to the UN agreements limit reference points have to be calculated and set.

The precautionary reference point $\mathbf{F}_{pa}$

1. If $\mathbf{F}_{lim}$ is defined, $\mathbf{F}_{pa}$ can be obtained by $\mathbf{F}_{pa}=\mathbf{F}_{lim}*\exp(-1.645*\sigma)$, where σ is a measure of the uncertainty of F estimates.

2. If there is no $\mathbf{F}_{lim}$, use the following in the given order:

2.1 If $\mathbf{F}_{med}$ goes through a cloud of points that appears to come mostly from the right hand side of the S-R plot then $\mathbf{F}_{pa}=\mathbf{F}_{med}$.

2.2 If $\mathbf{B}_{pa}$ is defined as $\mathbf{B}_{loss}$ then $\mathbf{F}_{pa}$ should be below $\mathbf{F}_{loss}$ in order to give a higher than 50% probability that the corresponding B is higher than $\mathbf{B}_{pa}$. The 10-25% percentiles are usually appropriate. If $\mathbf{B}_{loss}$ is used as $\mathbf{B}_{lim}$ the $\mathbf{F}_{loss}$ cannot be used as $\mathbf{F}_{pa}$.!!

2.3 If medium-term projections are available then $\mathbf{F}_{pa}$ can be set to the level that gives a 90% confidence that B>$\mathbf{B}_{pa}$.

2.4 Set $\mathbf{F}_{pa}$ based on historical experience.

2.5 Choose $\mathbf{F}_{pa}$ by analogy with other similar stocks.

REALITY CHECKS

Time series of data on Catch, F, R and SSB could be used to verify the selected values of $\mathbf{F}_{lim}$ and $\mathbf{F}_{pa}$. For example, if the stock has obviously sustained an F equal to or larger than the selected $\mathbf{F}_{lim}$ *for a long period*, then $\mathbf{F}_{lim}$ is set too low. If there are indications (it does not have to be very clear - the PA says that one should be precautionary in case of uncertain information) that the stock has not been able to sustain an F equal to or lower than the selected $\mathbf{F}_{pa}$ then $\mathbf{F}_{pa}$ is set too high

CONSISTENCY BETWEEN F AND B REFERENCE POINTS

In principle, long-term projections should be used to check and obtain consistency between $\mathbf{B}_{lim}$ and $\mathbf{F}_{lim}$ and between $\mathbf{B}_{pa}$ and $\mathbf{F}_{pa}$. By definition $\mathbf{F}_{lim}$ will in the long-term lead to stock collapse or to SSBs lower than ever experienced. If long-term projections do not lead to SSBs lower than $\mathbf{B}_{lim}$ then $\mathbf{F}_{lim}$ is set too low.

If a long-term projection using $\mathbf{F}_{pa}$ does not lead to SSB values that are above $\mathbf{B}_{pa}$ then $\mathbf{F}_{pa}$ is set too high. An appropriate $\mathbf{F}_{pa}$ value should lead to SSB values with 10-25% lower percentile at $\mathbf{B}_{pa}$.

Medium-term projections (x years) could be used instead of long-term projections (y years) only if the starting stock size is close to $\mathbf{B}_{pa}$.

ANNEX II

THE TECHNICAL BASIS FOR CURRENT ICES REFERENCE POINTS

Results from Lassen, H & H Sparholt, 2000. ICES Framework for the Implementation of the Precautionary Approach in Fisheries Management Advice. Precautionary Approach Reference Points. ACFM Practice 1998-1999. Working Paper for ACFM May 2000.

PA reference points (sorted by type) as defined by ACFM in 1999.

PA point	Technical basis	Stock
$\mathbf{B}_{lim}$	0.71*$\mathbf{B}_{pa}$	Herring Gulf of Riga
$\mathbf{B}_{lim}$	0.72*$\mathbf{B}_{pa}$	Sole IIIa
$\mathbf{B}_{lim}$	400000t surviving for spawning	Capelin, Iceland
$\mathbf{B}_{lim}$	Agreed by managers	Plaice N.Sea
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	NEA cod
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	NEA saithe
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Whiting N.Sea
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Saithe N.Sea
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Sole N.Sea
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	N.pout N. Sea
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Plaice VIId
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Haddock VIa
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Haddock VIb
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Cod VIIa
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Whiting VIIa
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Sole VIIa
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Cod VIIe-k
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Whiting VIIe-k
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Plaice VIIf+g
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Plaice VIIe
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Sole VIIe
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Megrim VIIIc and IXa (L. boscii)
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Megrim VIIIc and IXa (L. whiffiagonis)
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Horse mackerel VIIIc+IXa
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Anchovy VIII
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Hake, Northern stock
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Cod Faroe Plateau
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Blue whiting
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Saithe Iceland
$\mathbf{B}_{lim}$	$\mathbf{B}_{loss}$	Greenland halibut V+XIV
$\mathbf{B}_{lim}$	Close' to lowest observed	Herring 25-29+32
$\mathbf{B}_{lim}$	From S-R plot. "Only poor R has been observed from 4 years of SSB < 50,000t and all moderate or large year classes have been produced at higher SSB."	NEA Haddock
$\mathbf{B}_{lim}$	ICES CM 1998/ACFM:10	Herring Icelandic
$\mathbf{B}_{lim}$	Increased risk of low R	Herring N.Sea
$\mathbf{B}_{lim}$	Lowest observed	Sandeel IV
$\mathbf{B}_{lim}$	Lowest observed	Cod Kattegat
$\mathbf{B}_{lim}$	Lowest observed	Herring Irish Sea
$\mathbf{B}_{lim}$	Lowest observed	Herring Celtic Sea
$\mathbf{B}_{lim}$	Lowest reliable estimated SSB	Herring VIa(N)+VIIb.c
$\mathbf{B}_{lim}$	Lowest SSB estimated in previous assessments	Whiting VIa
$\mathbf{B}_{lim}$	MBAL	Sprat 22-32
$\mathbf{B}_{lim}$	MBAL	Cod 22-24
$\mathbf{B}_{lim}$	MBAL	Haddock Faroe
$\mathbf{B}_{lim}$	MBAL	Herring Norwegian Spring

PA point	Technical basis	Stock
		Spawners
B_{lim}	MBAL, R lower below this	Saithe Faroe
B_{lim}	No biological basis for defining B_{lim}	Mackerel, combined stock
B_{lim}	Not defined	Anglerfish IV and VI
B_{lim}	Not defined	Haddock VIIa
B_{lim}	Not defined	Sole VIIf+g
B_{lim}	Not defined	Sole VIIIab
B_{lim}	Not defined	Megrim VII and VIIIabde
B_{lim}	Not defined	Anglerfish VIIb-k VIIIab (L. piscatorius)
B_{lim}	Not defined	Anglerfish VIIb-k VIIIab (L. budegassa)
B_{lim}	Not defined	Horse mackerel, western
B_{lim}	Not defined. S-R data uninformative	Plaice VIIa
B_{lim}	Poor biological basis for definition	Sole VIId
B_{lim}	Rounded B_{loss}	Cod N.Sea
B_{lim}	Smooth B_{loss}	Cod VIa
B_{lim}	Smoothed B_{loss}	Haddock N. Sea
B_{lim}	SSB below which R is impaired	Cod 25-32
B_{lim}	The lowest SSB that has produced an outstanding rich year class	Barents Sea capelin
B_{lim}	Ulim 20% of highest survey index	S. marinus V,VI,XII +XIV
B_{lim}	Ulim = Umax/5	S. mentella Deep Sea V,VI+XIV
B_{pa}	-	Capelin, Iceland
B_{pa}	~1.4*B_{lim}	Herring VIa(N)+VIIb.c
B_{pa}	1.33*B_{lim}	Herring 25-29+32
B_{pa}	1.38*B_{lim}	Sprat 22-32
B_{pa}	1.4*B_{lim}	Haddock N. Sea
B_{pa}	1.4*B_{lim}	Whiting N.Sea
B_{pa}	1.4*B_{lim}	Sole N.Sea
B_{pa}	1.4*B_{lim}	Sandeel IV
B_{pa}	1.4*B_{lim}	Plaice VIId
B_{pa}	1.4*B_{lim}	Whiting VIa
B_{pa}	1.4*B_{lim}	Sole VIIa
B_{pa}	1.4*B_{lim}	Whiting VIIe-k
B_{pa}	1.4*B_{lim}	Sole VIIe
B_{pa}	1.4*B_{lim}	Megrim VIIIc and IXa (L. boscii)
B_{pa}	1.4*B_{lim}	Hake, Northern stock
B_{pa}	1.4*B_{loss}	Haddock VIa
B_{pa}	1.4*B_{loss}	Haddock VIb
B_{pa}	1.4*B_{loss}	Whiting VIIa
B_{pa}	1.5*B_{loss}	Horse mackerel VIIIc+IXa
B_{pa}	1.51*B_{lim}	Blue whiting
B_{pa}	1.51*B_{lim}	Herring Icelandic
B_{pa}	1.6*B_{lim}	Herring Irish Sea
B_{pa}	1.63*B_{lim}	Cod Kattegat
B_{pa}	1.634*B_{lim}	Herring N.Sea
B_{pa}	1.64*B_{lim}	Plaice VIIf+g
B_{pa}	1.64*B_{lim}	Megrim VIIIc and IXa (L. whiffiagonis)
B_{pa}	1.64*B_{lim}	Greenland halibut V+XIV
B_{pa}	1.93*B_{lim}	Cod Faroe Plateau
B_{pa}	1.93*B_{lim}	Herring Norwegian Spring Spawners
B_{pa}	2 std above B_{lim}	Saithe Faroe
B_{pa}	2 std above B_{lim} but reduced based on S-R plot	Haddock Faroe
B_{pa}	Agreed by managers	Plaice N.Sea

PA point	Technical basis	Stock
B_{pa}	Below average R below 150000t	N .pout N. Sea
B_{pa}	B_{lim}*1.67	NEA Haddock
B_{pa}	B_{lim}+5%perc. of predicted SSB	Capelin Barents Sea
B_{pa}	B_{loss}	Plaice VIIa
B_{pa}	B_{loss}	Sole VIIf+g
B_{pa}	B_{loss}	Sole VIIIab
B_{pa}	B_{loss}	Megrim VII and VIIIabde
B_{pa}	B_{loss}	Anglerfish VIIb-k VIIIab (L. piscatorius)
B_{pa}	B_{loss}	Anglerfish VIIb-k VIIIab (L. budegassa)
B_{pa}	B_{loss}	Mackerel, combined stock
B_{pa}	Examined from S-R plot	NEA cod
B_{pa}	Examined from S-R plot	NEA saithe
B_{pa}	From S-R plot	Saithe N.Sea
B_{pa}	Historical development of stock	Cod VIIe-k
B_{pa}	MBAL	Plaice VIIe
B_{pa}	MBAL	Herring Gulf of Riga
B_{pa}	MBAL	Cod 25-32
B_{pa}	MBAL	Sole IIIa
B_{pa}	MBAL and signs of impaired R below it.	Cod N.Sea
B_{pa}	MBAL and signs of reduced R	Cod VIIa
B_{pa}	Not defined	Anglerfish IV and VI
B_{pa}	Not defined	Haddock VIIa
B_{pa}	Observed low SSB values in 1978-1993	Saithe Iceland
B_{pa}	Previously set at 25000t at which good R is probable. Reduced to 22000t due to an extended period of stock decline	Cod VIa
B_{pa}	Reduced prob.of low R	Herring Celtic Sea
B_{pa}	Set at 36000t, the SSB which allows the stock to remain above B_{lim} in the year following an event of a weak R	Anchovy VIII
B_{pa}	Set at 500000t, the egg survey estimate of SSB that produced the exceptionally strong 1982 y.c.	Horse mackerel, western
B_{pa}	Slightly above lowest observed	Pandalus IIIa
B_{pa}	Smooth B_{loss}	Sole VIId
B_{pa}	Smoothed B_{loss}	Plaice IIIa
B_{pa}	Upa =Umax/2	S. mentella Deep Sea V,VI+XIV
B_{pa}	Upa 60% of highest survey index	S. marinus V,VI,XII +XIV
B_{pa}	Withdrawn	Cod 22-24
F_{lim}	-	S. marinus V,VI,XII +XIV
F_{lim}	-	S. mentella Deep Sea V,VI+XIV
F_{lim}	-	Herring Icelandic
F_{lim}	-	Capelin, Iceland
F_{lim}	1.4*F_{pa} which has historically led to decline	Haddock N. Sea
F_{lim}	1.93*F_{pa}	Cod Faroe Plateau
F_{lim}	2 std over F_{pa}	Haddock Faroe
F_{lim}	Agreed by managers	Plaice N.Sea
F_{lim}	Based on historical response of the stock	Cod VIIe-k
F_{lim}	Consistent with B_{lim}	Saithe Faroe
F_{lim}	F above 0.8 had led to stock decline in early 1980s	Cod VIa
F_{lim}	F_{loss}	Cod N.Sea
F_{lim}	F_{loss}	Whiting N.Sea

PA point	Technical basis	Stock
F_{lim}	F_{loss}	Saithe N.Sea
F_{lim}	F_{loss}	Plaice VIId
F_{lim}	F_{loss}	Whiting VIIa
F_{lim}	F_{loss}	Sole VIIf+g
F_{lim}	F_{loss}	Sole VIIe
F_{lim}	F_{loss}	Megrim VII and VIIIabde
F_{lim}	F_{loss}	Anglerfish VIIb-k VIIIab (L. piscatorius)
F_{lim}	F_{loss}	Megrim VIIIc and IXa (L. boscii)
F_{lim}	F_{loss}	Horse mackerel VIIIc+IXa
F_{lim}	F_{loss}	Hake, Northern stock
F_{lim}	F_{loss}	Mackerel, combined stock
F_{lim}	F_{loss}	Herring 25-29+32
F_{lim}	F_{loss}	Herring Gulf of Riga
F_{lim}	F_{loss}	Herring VIa(N)+VIIb.c
F_{lim}	F_{loss}	Blue whiting
F_{lim}	F_{loss} and historical considerations	Sole VIIa
F_{lim}	F_{loss}. Analog to N.Sea sole	Sole VIId
F_{lim}	F_{med}	Cod VIIa
F_{lim}	F_{med}	Cod 25-32
F_{lim}	F_{med}, excl. abnormal years around 1990	Sole IIIa
F_{lim}	Is 1.0 above which stock decline has been observed	Whiting VIa
F_{lim}	Median of F_{loss}	NEA cod
F_{lim}	Median of F_{loss}	NEA Haddock
F_{lim}	Median values of F_{loss}	NEA saithe
F_{lim}	None advised	N .pout N. Sea
F_{lim}	None advised	Sandeel IV
F_{lim}	Not considered relevant	Herring Norwegian Spring Spawners
F_{lim}	Not defined	Haddock VIa
F_{lim}	Not defined	Haddock VIb
F_{lim}	Not defined	Anglerfish IV and VI
F_{lim}	Not defined	Haddock VIIa
F_{lim}	Not defined	Plaice VIIa
F_{lim}	Not defined	Whiting VIIe-k
F_{lim}	Not defined	Plaice VIIf+g
F_{lim}	Not defined	Plaice VIIe
F_{lim}	Not defined	Sole VIIIab
F_{lim}	Not defined	Anglerfish VIIb-k VIIIab (L. budegassa)
F_{lim}	Not defined	Megrim VIIIc and IXa (L. whiffiagonis)
F_{lim}	Not defined	Anchovy VIII
F_{lim}	Not defined	Horse mackerel, western
F_{lim}	Not defined	Sprat 22-32
F_{lim}	Not defined	Cod 22-24
F_{lim}	Not defined	Herring N.Sea
F_{lim}	Not defined	Herring Irish Sea
F_{lim}	Not defined	Herring Celtic Sea
F_{lim}	Not defined	Capelin Barents Sea
F_{lim}	Not defined	Greenland halibut V+XIV
F_{lim}	Not yet defined	Saithe Iceland
F_{lim}	SSB has declined since early 1970s at F=1.0	Cod Kattegat
F_{lim}	Technical basis	Stock
F_{lim}	Undefined	Sole N.Sea
F_{pa}	-	S. marinus V,VI,XII +XIV
F_{pa}	-	S. mentella Deep Sea

PA point	Technical basis	Stock
		V,VI+XIV
$\mathbf{F}_{pa}$	-	Capelin, Iceland
$\mathbf{F}_{pa}$	0.3 considered having a high prob. of avoiding $\mathbf{F}_{lim}$	Sole VIIa
$\mathbf{F}_{pa}$	0.6 implies an equiv B of 10600t and a rel. low prob. of B<$\mathbf{B}_{pa}$, and is within the range of historic Fs	Whiting VIIa
$\mathbf{F}_{pa}$	0.6*$\mathbf{F}_{lim}$	Whiting VIa
$\mathbf{F}_{pa}$	0.63*$\mathbf{F}_{lim}$ (also =$\mathbf{F}_{max}$ and $\mathbf{F}_{med}$)	Horse mackerel VIIIc+IXa
$\mathbf{F}_{pa}$	0.65*$\mathbf{F}_{lim}$, (also=$\mathbf{F}_{0.1}$)	Mackerel, combined stock
$\mathbf{F}_{pa}$	0.7*$\mathbf{F}_{lim}$	Whiting N.Sea
$\mathbf{F}_{pa}$	0.72*$\mathbf{F}_{lim}$	Cod VIIa
$\mathbf{F}_{pa}$	0.72*$\mathbf{F}_{lim}$	Anglerfish VIIb-k VIIIab (L. piscatorius)
$\mathbf{F}_{pa}$	0.72*$\mathbf{F}_{lim}$, implies a less than 10% prob. that SSBmt<$\mathbf{B}_{pa}$	Hake, Northern stock
$\mathbf{F}_{pa}$	0.72*$\mathbf{F}_{lim}$: implies a less than 10% prob. of SSBmt<$\mathbf{B}_{pa}$	Sole VIIe
$\mathbf{F}_{pa}$	0.72*$\mathbf{F}_{lim}$; implies a less than 5% prob. of SSBmt<$\mathbf{B}_{pa}$	Sole VIIf+g
$\mathbf{F}_{pa}$	0.8*$\mathbf{F}_{lim}$	Megrim VIIIc and IXa (L. boscii)
$\mathbf{F}_{pa}$	1.638*$\mathbf{F}_{lim}$	Cod Kattegat
$\mathbf{F}_{pa}$	35% of the unfished S/R. It is considered to be an approximation of $\mathbf{F}_{MSY}$	Anglerfish IV and VI
$\mathbf{F}_{pa}$	5% percentile of $\mathbf{F}_{med}$	Cod 25-32
$\mathbf{F}_{pa}$	5th % of $\mathbf{F}_{loss}$; SSB*>$\mathbf{B}_{pa}$ and prob. (SSBmt<$\mathbf{B}_{pa}$) 10%	Plaice VIId
$\mathbf{F}_{pa}$	5th perc. of $\mathbf{F}_{loss}$ =0.49, F=0.4 implies an eq. SSB > $\mathbf{B}_{pa}$, and < 10% prob. that SSBMT<$\mathbf{B}_{pa}$	Sole N.Sea
$\mathbf{F}_{pa}$	5th perc. of $\mathbf{F}_{loss}$ which implies an eq. SSB>$\mathbf{B}_{pa}$ and a less than 10% prob. that SSBmt<$\mathbf{B}_{pa}$	Saithe N.Sea
$\mathbf{F}_{pa}$	5th perc. Of $\mathbf{F}_{loss}$, implies an eq. SSB > $\mathbf{B}_{pa}$ and a less than 10% pro. that SSBMT<$\mathbf{B}_{pa}$	Cod N.Sea
$\mathbf{F}_{pa}$	5th percentile of $\mathbf{F}_{loss}$=$\mathbf{F}_{lim}$*0.6	NEA cod
$\mathbf{F}_{pa}$	Adopted by analogy to other haddock stocks	Haddock VIb
$\mathbf{F}_{pa}$	Agreed by managers	Plaice N.Sea
$\mathbf{F}_{pa}$	Between $\mathbf{F}_{med}$ and 5th % of $\mathbf{F}_{loss}$; SSB>$\mathbf{B}_{pa}$ and prob. (SSB<$\mathbf{B}_{pa}$) 10%	Sole VIId
$\mathbf{F}_{pa}$	Close to $\mathbf{F}_{max}$ and $\mathbf{F}_{med}$	Cod Faroe Plateau
$\mathbf{F}_{pa}$	Consistent with $\mathbf{F}_{lim}$ and $\mathbf{F}_{med}$	Saithe Faroe
$\mathbf{F}_{pa}$	Consistent with long-term $\mathbf{B}_{pa}$	Cod VIa
$\mathbf{F}_{pa}$	F at which SSB/R is half what it would have been in the absence of fishing	Anchovy VIII
$\mathbf{F}_{pa}$	F sustained for 3 decades	Saithe Iceland
$\mathbf{F}_{pa}$	$\mathbf{F}_{0.1}$	Herring Icelandic
$\mathbf{F}_{pa}$	$\mathbf{F}_{lim}$*0.6	NEA saithe
$\mathbf{F}_{pa}$	Flpg, which implies an eq. SSB>$\mathbf{B}_{pa}$ and a less than 10% prob. that SSBmt<$\mathbf{B}_{pa}$	Haddock N. Sea
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$	NEA Haddock
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$	Plaice IIIa
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$	Herring 25-29+32
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$	Sprat 22-32
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$	Herring Irish Sea
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$	Herring VIa(N)+VIIb.c
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$	Haddock Faroe
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$	Blue whiting

PA point	Technical basis	Stock
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$	Greenland halibut V+XIV
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$ consistent with proposed $\mathbf{B}_{pa}$	Anglerfish VIIb-k VIIIab (L. budegassa)
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$ implies a less than 5% prob. SSBmt<$\mathbf{B}_{pa}$	Plaice VIIf+g
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$ in a previous assessment and long-term consideration	Plaice VIIa
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$: less than 5% prob. (SSBmt<$\mathbf{B}_{pa}$)	Sole VIIIab
$\mathbf{F}_{pa}$	$\mathbf{F}_{med}$: less than 5% prob. (SSBmt<$\mathbf{B}_{pa}$)	Megrim VII and VIIIabde
$\mathbf{F}_{pa}$	From m-t projections	Herring Gulf of Riga
$\mathbf{F}_{pa}$	From simulations low risk of SSB<$\mathbf{B}_{pa}$	Herring N.Sea
$\mathbf{F}_{pa}$	ICES Study Group 1998	Herring Norwegian Spring Spawners
$\mathbf{F}_{pa}$	Not defined	Herring Celtic Sea
$\mathbf{F}_{pa}$	No proposal	Megrim VIIIc and IXa (L. whiffiagonis)
$\mathbf{F}_{pa}$	None advised	N .pout N. Sea
$\mathbf{F}_{pa}$	None advised	Sandeel IV
$\mathbf{F}_{pa}$	Not defined	Horse mackerel, western
$\mathbf{F}_{pa}$	Not defined	Capelin Barents Sea
$\mathbf{F}_{pa}$	Not proposed	Whiting VIIe-k
$\mathbf{F}_{pa}$	Set at 0.5. This has a high prob of avoiding $\mathbf{B}_{pa}$ in the long-term	Haddock VIa
$\mathbf{F}_{pa}$	Set at an F which implies a less than 10% prob. of Bmt<$\mathbf{B}_{pa}$	Cod VIIe-k
$\mathbf{F}_{pa}$	Set by analogy with other haddock stocks.	Haddock VIIa
$\mathbf{F}_{pa}$	Set consistent with $\mathbf{F}_{lim}$	Sole IIIa
$\mathbf{F}_{pa}$	Set so that prob. (SSBmt<$\mathbf{B}_{pa}$) is low	Plaice VIIe
$\mathbf{F}_{pa}$	Technical basis	Stock
$\mathbf{F}_{pa}$	To be discussed with managers	Cod 22-24

Table 6. Application of the Key to Formulation of Management Advice (from Lassen and Sparholt, WG DOC SGPA 2001) to the ACFM based on a given stock status. Stock status data are taken from the ACFM advice given in 2000 (ICES 2001 CRR 242).

Stock	$\mathbf{B}_{pa}$	$\mathbf{F}_{pa}$	$\mathbf{F}_{sq}$	SSB(2,$\mathbf{F}_{pa}$)	SSB(2, F=0)	F’	TAC (0)	Catch (F’)	F’’	SSB(3,F’’)	Resulting advice	Actual advice by acfm
Greenland cod												No fishing Rec. plan
Iceland cod (Va)												Continued HCR
Iceland haddock (Va)		0.47 provisional										F<$\mathbf{F}_{pa}$
Iceland saithe (Va)	150	0.3		102	130						RP rebuild stock 2-5 or 6-15 (need SSB(7,F=0)	F<<$\mathbf{F}_{pa}$
Greenland halibut (V+XIV)	80	0.36										TAC<20 th t
Sebastes marinus (V+VI+XII+XIV)	Upa=166											f<=f99
Deep-sea Sebastes mentella	Upa=0.5											f01=0.25f98
Sebastes mentella Irminger sea												TAC01=85 th t
Iceland summer-spawning herring (Va)	300	0.22		620							<$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$ ($\mathbf{F}_{0.1}$)
Capelin (V+XIV+IIa)												HCR
Cod VIIe-k	10 000	0.68		7 700	~ 15 000	0.36	16 000 (VII-VIIa)	3 100	???	???	???	40% reduction in F
Whiting VIIe-k	21 000	NO (0.72?)		33 100							< $\mathbf{F}_{pa}$	$\mathbf{F}_{sq}$ (<$\mathbf{F}_{pa}$)
Plaice VIIfg	1 800	0.60		1 450	~2 200	0.28	800	420	0.42	???	???	40% reduction in F
Sole VIIfg	2 200	0.37		2 510							< $\mathbf{F}_{pa}$	< $\mathbf{F}_{pa}$
Plaice VIIe	2 500	0.45		2 060	~ 3 000	0.18	6 500 (VII d+e)	410	???	???	???	< $\mathbf{F}_{pa}$

Sole VIIe	2 500	0.26		2 220	~2 800	0.12	640	280	0.22	???	???	< $\mathbf{F}_{pa}$
Megrim VII+VIIIab	55 000	0.30		63 700							< $\mathbf{F}_{pa}$	< $\mathbf{F}_{pa}$
Anglerfish VIIb-k VIIIab L.piscatoriu	31 000	0.24		47 800							< $\mathbf{F}_{pa}$	< $\mathbf{F}_{pa}$
L. budegass	16 600	0.23		25 200							< $\mathbf{F}_{pa}$	< $\mathbf{F}_{pa}$
Southern Hake	33 600	0.27		37 600							< $\mathbf{F}_{pa}$	< $\mathbf{F}_{pa}$
Megrim VIIIc IXa (Lwhiff & boscii)	???	???									???	$\mathbf{F}_{sq}$
Anchovy VIII	36 000	1.0 – 1.2		30 000 (2001)								
NEA cod	500	.42		456	650	.30	390	250	.38	?	F" = 0.38(?)	F = 0.32
NEA haddock	80	.35		106							$\mathbf{F}_{pa}$=0.35 =36% red	$\mathbf{F}_{pa}$=0.35
NEA saithe	150	.26		257							$\mathbf{F}_{pa}$ = .26 =30% red	$\mathbf{F}_{pa}$ = .26
NSpSpHerr	5.0	0.15		6.1							$\mathbf{F}_{pa}$= 0.15 =4% red	F = 0.125 (managers decision)
S. mentella	Not defined	Not defined										
S. marinus	Not defined	Not defined										
Gr. halibut	Not defined	Not defined										
Capelin	Not defined	Not defined										
Cod 25-32	240,000	0.6		194,000	290,000	0.30	105,000	39,000	0.65	200,000	Recovery plan 3-4 yr F (0.4 or 0.5)	F=0.3 or Recovery plan
Cod 22-24	23,000	1.00		38,400							$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$
Sprat 22-32	275,000	0.4		868,000	-						$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$
Herring 30	200,000	0.21		185,000	226,000	0.13	85,000 (Catch=59000)	24,000	0.26	270,000	0.26	$\mathbf{F}_{pa}$ (ACFM accepted

												61% instead of 75% in catch(1) vs catch(0)
Herring 25-29	Not defined	0.17		452,000	554,000							
VIIa Cod (TAC constraint in year 0)	10,000	0.72	1.19	9860	17600	0.67	2100	4180			F=0.67	Recovery plan in place. Lowest possible F, continue rec. plan. Etc.
VIIa Cod ($\mathbf{F}_{sq}$ constraint in year 0)	10,000	0.72	1.19	8400	14600	0.48	2100	2800			F=0.48	
VIIa whiting	7,000	0.65	1.07	6086	12075(if discards in Nephrops fishery avoided) else 6764							
VIIa plaice	3,100	0.45	0.32	4800							$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$
VIIa sole	3800	0.3	0.43	4000							$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$
VIIa herring	9500	0.36	0.26	12,000							$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$
Cod VI	22,000	0.6	0.94	8200	13,200						Recovery plan 2-5 yr.	F lowest possible and recovery plan
Haddock VI	30,000	0.5	0.61	48,700	70,200						$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$
Haddock Rockall	9000	0.4	0.52	8800	11,500						$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$
Hake Northern	165,000	0.2	0.32	86,100	103,300						Recovery plan	Lowest possible F and recovery plan
Mackerel NEA	2,300,000	0.17	0.185	3,900,000							$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$
Blue whiting	2,250,000	0.32	0.43	2,170,000	3,000,000	0.28	1,136,000	628,000	0.38	$<\mathbf{B}_{pa}$	Recovery plan 3-4 years	F=0.28 which gets SSB>$\mathbf{B}_{pa}$

Cod N. Sea	150,000	0.65	0.90	72,000	135,000						Recovery plan 2-5 yr	Lowest possible F and recovery plan
Haddock N. Sea	140,000	0.70	0.78	241,000							$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$
Whiting N. Sea	315,000	0.65	0.61	271,000	350,000	0.25	~30,000	22,000			0.25	0.25
Saithe N. Sea +VI	200,000	0.40	0.45	149,000	250,000	0.18	85,000	47,000	0.25		0.25	0.36
Plaice N. Sea	300,000	0.30	0.32	273,000	360,0000.19	97,000	60,000	0.24			0.24	0.26
Sole N. Sea	35,000	0.40	0.47	40,600	~60,000						$\mathbf{F}_{pa}$	$\mathbf{F}_{pa}$