Advisory Committee on Fishery Management

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REPORT OF THE

Study Group on Precautionary Reference Points For Advice on Fishery Management

ICES Headquarters
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International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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1.2 Terms of reference

The study group was given the following terms of reference (Council resolution 2ACFM23):

A **Study Group on Precautionary Reference Points for Advice on Fishery Management [**SGPRP] (Chair: Poul Degnbol, Denmark) will be established and will meet at ICES Headquarters from 24–26 February 2003 to:

a) review the proposal prepared by the ICES Secretariat on Reference Points for the stocks dealt with by HAWG, WGBFAS, AFWG, NWWG, WGNPBW WGNSSK, WGHMM, WGNSDS, WGSSDS, WGMHSA. The proposal will be built on the framework developed and agreed by SGPA in December and the outcome of SGBRP;

b) propose revisions of the Reference points used by ACFM in formulating advice on fishery management for consideration by the assessment working groups and with a view for adoption and use by ACFM in its May and October 2003 meetings.

SGPRP will report by 5 March 2003 for the attention of Assessment Working Groups and ACFM.

1.3 Background

1.3.1 The Precautionary Approach Background

The principal international agreements specifying the introduction of the precautionary approach to fisheries are the FAO Code of Conduct for Responsible Fisheries (FAO, 1995b), and the UN Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (Doulman, 1995). Their aim is to 'apply the precautionary approach to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment' and to 'avoid serious and irreversible harm to fisheries' by ensuring 'long-term sustainability of fishery resources at levels which promote the objective of their optimum utilisation and maintain their availability for present and future generations'. The word 'serious' is most likely to apply to fisheries, and the word 'irreversible' to the effect of contaminants. Technical Guidance on the application of the Precautionary Approach in fisheries was provided by FAO 1995. In pursuit of these objectives, ICES has advised on the state of stocks relative to predefined limits that should be avoided to ensure that stocks remain within safe biological limits. The concept of safe limits is explicitly referred to in the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks, but was in fact first introduced into ICES advice in 1981 and further developed in 1986 (Serchuk and Grainger, 1992).

1.3.2 The Precautionary Approach in ICES

The application of the Precautionary Approach in ICES was undertaken at two meetings of the ICES Study Group on the Precautionary Approach to Fisheries Management, the 1997 Study Group [SGPA 97, which reported as Anon 1997] and the 1998 Study Group [SGPA 98, which reported as Anon 1998].

SGPA 97 outlined the legal requirements, described how reference points should be defined and calculated, and proposed to maintain or restore stocks to within safe biological limits by using, respectively, pre-agreed harvest control rules or recovery plans (Anon 1997).

SGPA 98 estimated for as many stocks as possible the first set of reference point values, and these were adopted by ACFM in giving advice. In some cases these values have been amended, but the majority are still in use (Anon 1998).

The status of the Precautionary Approach in ICES was subsequently reviewed and developed by the ICES Study Group on the Further Development of the Precautionary Approach to Fisheries Management, SGPA 01(which reported as Anon 2001) and the SGPA 02a (which reported as Anon 2002).

1.3.3 ICES reference points – what they are and how they are used in advice

Based on SGPA 97 and SGPA 98, the ICES approach is that for stocks and fisheries to be within safe biological limits, there should be a high probability that spawning stock biomass (SSB) is above a limit $\mathbf{B}_{lim}$ below which recruitment becomes impaired or 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 limit. The word 'impaired' is synonymous with the concept that on average recruitment becomes systematically reduced as biomass declines below a certain point. Because of uncertainty in the annual estimation of F and SSB, ICES defines the more conservative operational reference points, $\mathbf{B}_{pa}$ (higher than $\mathbf{B}_{lim}$), and $\mathbf{F}_{pa}$ (lower than $\mathbf{F}_{lim}$), where the subscript PA stands for precautionary approach. When a stock is estimated to be at $\mathbf{B}_{pa}$ there should be a high probability that it will be above $\mathbf{B}_{lim}$ and similarly if F is estimated to be at $\mathbf{F}_{pa}$ there should be a low probability that F is higher than $\mathbf{F}_{lim}$. The reference values $\mathbf{B}_{lim}$ and $\mathbf{F}_{lim}$ are therefore estimated in order to arrive at $\mathbf{B}_{pa}$ and $\mathbf{F}_{pa}$, the operational values that should have a high probability of ensuring that exploitation is sustainable based on the history of the fishery.

This concept of LIMIT and PA reference points implies that LIMIT and PA reference points have a very different status and should be revised according to different principles. $\mathbf{B}_{lim}$ and $\mathbf{F}_{lim}$ may be considered estimates of properties of nature (namely the reproductive capacity of a fish stock and its ability to sustain fishing) whereas the distance between LIMIT points and PA point (the distance between $\mathbf{B}_{lim}$ and $\mathbf{B}_{pa}$ and between $\mathbf{F}_{lim}$ and $\mathbf{F}_{pa}$ respectively) relate to our ability to measure the present spawning stock biomass and fishing mortality and are thus related to data quality and estimation methodology. Better data and improved estimation methods would therefore lead to more precise estimates of $\mathbf{B}_{lim}$ and $\mathbf{F}_{lim}$ (which may be unchanged, larger or lower) but a smaller interval between LIMIT and PA reference points, that is lower $\mathbf{B}_{pa}$ and higher $\mathbf{F}_{pa}$ values. $\mathbf{B}_{pa}$ and $\mathbf{F}_{pa}$ are also dependent on the acceptable probability that LIMIT points have been passed. The decision on the acceptable risk is not a science issue but should be decided by managers and stakeholders.

The LIMIT reference points will thus be constant as long as the overall natural regime is unchanged (but the estimates of these reference point may change as improved estimation methods and data are used) whereas the PA reference points and their estimates will change and should be revised whenever the assessment methodology, the quality of data or the perception of acceptable risk change. These changes in PA reference points can be in either direction. If the data available for the annual stock assessments deteriorate the interval between LIMIT and PA reference points will increase. The interval between LIMIT and PA reference points can conversely be reduced by investments and measures which ensure an improved data quality and thus an improvement in the precision of the annual stock assessments.

When a fishery is at or above $\mathbf{F}_{pa}$, ICES will advise that F should be reduced, and when a stock is estimated to be at or below $\mathbf{B}_{pa}$ ICES will advise that F should be reduced. When a stock is estimated to be above $\mathbf{B}_{pa}$, but is subject to an F that is at or higher than $\mathbf{F}_{pa}$, ICES will again advise that F should be reduced. Stocks that are both above $\mathbf{B}_{pa}$ and below $\mathbf{F}_{pa}$ are considered to be inside safe biological limits. Stocks that are below $\mathbf{B}_{pa}$ are considered to be outside safe biological limits, and stocks that are above $\mathbf{B}_{pa}$ but also above $\mathbf{F}_{pa}$ are considered to be harvested outside safe biological limits. ICES intends that the reference points $\mathbf{F}_{pa}$ and $\mathbf{B}_{pa}$ are boundaries to the safe limits domain, and not targets.

ACFM previously defined and used the Minimum Biologically Acceptable Level (**MBAL**) of biomass for a number of stocks. **MBAL** was originally chosen as the SSB below which the probability of poor recruitment increased, and is therefore comparable to the current usage of $\mathbf{B}_{lim}$, but in some cases **MBAL** was more simply the biomass below which concerns were raised, and was therefore set as $\mathbf{B}_{pa}$, the level where management action to improve stock status should be taken. In some cases, where biomass estimates are not available, ICES uses the indices $\mathbf{U}_{pa}$ and $\mathbf{U}_{lim}$ based on LPUE (landings per unit effort) series, as biomass reference points.

Target reference points represent long-term management objectives. Target reference points are constrained by the precautionary reference points, so that a target fishing mortality should be below $\mathbf{F}_{pa}$ and a target SSB should be above $\mathbf{B}_{pa}$. Target reference points have not yet been defined for most stocks by clients of ICES advice nor used by ICES in the provision of advice.

1.3.4 The need to review ICES reference points

When the precautionary reference points were introduced it was envisaged that they should be reviewed and revised on basis of new data and information every 3-5 years. The SGPA 2002a (Anon 2002) reviewed the need for revisions and recommended that a revision process be initiated. The rationale for a revision is:

> *'The precautionary approach reference points were established in 1998 using the best assessment data then available, and although it was envisaged that they would be re-evaluated after some time, no specific time was set for this to take place. The following factors now suggest that it is time to undertake a thorough review of all the current reference point values, and to augment them:*
>
> *i) it appears that some original reference point values are not in conformity with the precautionary approach definitions, e.g. it would have been more correct if some previous $\boldsymbol{B}_{pa}$ values had been designated as $\boldsymbol{B}_{lim}$.*
>
> *ii) the reference point values for several stocks, particularly those based on $\boldsymbol{B}_{loss}$, have been overtaken by various changes, as discussed in earlier sections of the present report e.g.,*
>
> - *stock abundance has declined below $\boldsymbol{B}_{loss}$,*
> - *a change in assessment output has occurred due to the choice of a different structure for the assessment model,*
> - *trends in recruitment may be due to fluctuations in carrying capacity or some other key environmental parameter,*
> - *account should be taken of trends or fluctuations in weight-at-age, maturity-at-age, and age diversity of the spawning stock, that may be causing trends in reproductive potential*
> - *irregular changes to stocks dependent on episodic large year classes*
>
> *iii) it is important to validate as objectively as possible the estimates of the change point where recruitment becomes impaired, whether by fitting a conventional stock-recruit curve, or fitting a segmented regression, which has been suggested as a promising tool for this purpose*
>
> *iv) it should be considered whether it is appropriate to overcome the problem of assessment model structure uncertainty by using relative rather than absolute values*
>
> *v) the implementation of recovery plans for several EU stocks has led to the introduction of technical measures to change the pattern of exploitation, which will therefore change the basis for reference point calculation'*

As a result a SGPA meeting was arranged in December 2002 (SGPA 02b, reporting as Anon 2003a) to define the technical guidelines for a revision of the reference points.

The technical guidelines from SGPA 02b were then to be the basis for an evaluation of possible revisions to be undertaken by the present study group and specifically for North East Arctic cod by the Study Group on Biological Reference Points for Northeast Arctic cod (SGBRP, reporting as Anon 2003b).

1.3.5 Status of the present report

Following SGPA meetings in 2001 (SGPA 01) and early 2002 (SGPA 02a), SGPA met in December 2002 (SGPA 02b) to prepare the framework and procedures for revising reference point values, prior to their application at meetings of the Study Group on Biological Reference Points for Northeast Arctic Cod (SGBRP, 13-17 January 2003), and this Study Group on Precautionary Reference Points for Advice on Fishery Management (SGPRP, 24-26 February 2003).

This Study Group is based on the reports from the SGPA 02b which developed the general technical framework for reference point estimation. This framework was subsequently implemented for Northeast Arctic cod by SGBRP. The Northeast Arctic cod case is the only stock for which a full implementation of the framework was available prior to the meeting. This study group has investigated the validity of present LIMIT reference points for the stocks concerned in the terms of reference on basis of the framework proposed by SGPA 02a. It has however not been possible to extend this evaluation to PA reference points for other stocks than the Norteheast Arctic cod according to the framework proposed by the SGPA 02b. The method proposed by SGPA 02b includes retrospective assessments and predictions based on the models presently used and the tools to implement this method are not available in ICES presently. Alternative approaches based on historical predictions were discussed and explored but the group did not feel that these were sufficiently evaluated to be implemented.

This report therefore contains an evaluation of LIMIT reference points with proposals for stocks for which revisions may be justified. These proposals will be reviewed by the working groups and ACFM and should thus be considered preliminary evaluations which are only one step in the process of revising reference points. Proposals for further reviews and possible revisions presented in this report do therefore not represent any commitment to actual revisions and the actual values mentioned will in any case be subject to revisions during the subsequent review process.

Proposals for updates of LIMIT reference points in this report may be based on most of the reasons listed above. An important reason for revision for some stocks, notably cod stocks, is that the extra years added to the time-series since the SGPA 98 represent years with low spawning stock and low recruitment and thus provides a better possibility to estimate a change point below which recruitment has been impaired. But revisions in assessment methods, biological data and the methodology used to estimate change points are also reasons for proposals to revise LIMIT reference points for some stocks.

2 FRAMEWORK FOR REVISION OF REFERENCE POINTS

2.1 The framework and methodology used by SGPRP

This Study Group has inspected and analysed stock-recruitment plots of 65 stocks covering a wide variety of stock types in the ICES area. The segmented regression analysis presented by SGPA 02b was applied to all these stocks and was found to perform well for many stocks, but these total less than half of the stocks analysed, mainly those for which there is an apparent stock recruitment signal with points both below and above a change point. The Group therefore developed an approach which would cover all the stock types involved. This approach is based on a stock typology which has developed iteratively by a process where biologists who are well acquainted with the stocks concerned have discussed the problems for each stock and where these problems have then been generalised. This leads to a framework which is composed of the following steps:

- Compile data and inspect data and stock-recruitment plots. Identify cases where SSB has declined below the previous estimate of $\mathbf{B}_{loss}$, or cases where an estimate of $\mathbf{B}_{lim}$ has been overtaken by a change in the SSB-R values due to a change in the structure of the assessment model, a change in biological data or a different perception of the stock recruitment relationship emerging from the addition of recent data years.

- Identify stock type based on explorations of models assuming a change point and knowledge about the stock and fisheries (see overview of stock types below).
- Estimate LIMIT reference points according to methodology applicable to the stock type.

- Derive PA reference points from LIMIT points (not evaluated by this study group)

Dependent on the characteristics of the stocks and the data available it is proposed to distinguish between data poor situations (both short and long lived species), short lived species, and long lived species. Long lived species includes stocks for which a stock-recruitment relationship is apparent in the historical data, stocks for which this is not the case and a group of stocks with a special reproduction biology producing occasional large year classes. Some of these categories are then subdivided further.

A summary of the revised framework for the estimation of reference point values is given in the table below and in Annex 1.

The intention is to apply the revised framwork to the ICES reference points in order to identify whether there is a strong case for changing from the present values. On basis of the revised approach it is identified whether the current (old) reference points suffer from inconsistency, model structure, regime issues, changes in biological data or assessment method or addition of new data years which changes the perception of the stock-recruitment relationship. For example, has an old estimate of $\mathbf{B}_{\mathrm{loss}}$ been overtaken by further decline in SSB, or has there been a material change in the R-SSB plot from the assessment due to changes in biological data, the new data years added since the last estimation of reference points or a change in the conditioning (formulation) of the assessment model ? If any of these is the case it is identified what remedial action is needed. If the suggested change in reference point is marginal a change may not be justified.

The definition of the reference points assumes that information is available that allows the establishment of a SSB level ($\mathbf{B}_{\mathrm{lim}}$) below which recruitment is impaired, i.e. that the medium-term average recruitment is lower than has been observed at higher levels of SSB. Therefore, the definition requires implicitly that a Stock-Recruitment relationship exists and that there are observations available that shows where this lower limit of undisturbed recruitment occurs. Also, this concept is developed on the assumption that an assessment and a projection procedure (e.g. an analytical assessment) is available and that this assessment includes an estimate of the precision of the assessment. The buffer considerations also require that a method is available to enable the calculation of the buffer zones for F and SSB such as a medium-term projection or another evaluation of the risks associated with assessment and prediction error.

SGPRP has evaluated the results of applying a model which assumes a change point in the stock recruitment relationship (the segmented regression model as described in section 3) to 65 ICES stocks with stock and recruitment data derived from an analytical assessment, in order to investigate the suitability of the method for calculating $\mathbf{B}_{\mathrm{lim}}$ or $\mathbf{B}_{\mathrm{loss}}$ for those stocks, and to assess whether there are grounds for recommending changes. Because of both the provisional status of the proposed new methodology for calculating $\mathbf{F}_{\mathrm{pa}}$ and $\mathbf{B}_{\mathrm{pa}}$, however, and the lack of tools to implement the proposed methodology for many stocks within limited time, SGPRP was unable to proceed with the re-calculation and evaluation of $\mathbf{F}_{\mathrm{pa}}$ and $\mathbf{B}_{\mathrm{pa}}$. The basis for the evaluation carried out by SGPRP is outlined below. The possibilities and procedures for estimating reference points depend on the characteristics of the stock and the data available. This was discussed by SGPA 02a and in Lassen, O'Brien and Sparholt (2002).

The relation between stock and recruitment (and thus $\mathbf{B}_{\mathrm{lim}}$) may change if the natural regime changes. This has been demonstrated to be the case in the Baltic (Köster et al 2001a, 2001b). In such cases it could be relevant to limit the analysis to data representing the present regime. Such a procedure should however be implemented with caution because it will be difficult to identify the extent of a regime period and because a precautionary approach should include a consideration that the regime may have changed recently or may do so in the near future. An alternative approach could be to focus on reference points based on fishing mortality rather than biomass. This would require a specific framework to be developed because the F reference points in that case might need to be dependent on the state of the biomass. The FAO Code of Conduct states that: " *If a natural phenomenon has a significant adverse impact on the status of living aquatic resources, States should adopt conservation and management measures on an emergency basis to ensure that fishing activity does not exacerbate such adverse impacts*". So, even if it is considered that the environment will drive a stock to collapse (which we probably will never know because environmental conditions are as difficult to predict as climate) it is not "allowed" to continue fishing on it. Furthermore, if we do not have a biomass limit or another mechanisms for reducing exploitation for such stocks but can continue fishing on them with an unchanged F on their way down, we may preclude or seriously delay the possibility of recovery if the environment changes to be more supportive to recruitment in the process. However, for most stocks it is not possible to substantiate hypothesis about regime shifts and this discussion is only relevant for few stocks at this point in time.

2.2 Stock types and reference points

The analysis of stock-recruitment relationships is dependent both of the biological characteristics of the stock concerned and the availability of data. It is therefore not possible to apply one uniform approach across all stocks. This Study

Group has developed an approach which attempts to combine consistency with sensitivity to stock characteristics. This is based on a typology which has been developed through an iterative process of exploring models and discussing stock-recruitment by biologists with experience about the stocks concerned.

2.2.1 (1) Data Poor situations

There are numerous stocks for which no analytical assessment is available. Annex II of the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks states: …"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…". Due to the limited amount of data for defining the Precautionary Approach reference points this means that a pragmatic approach and expert judgement often will be an important part of the process although ICES strives to be objective and consistent.

For a number of stocks there are little data except landings. These cases are not dealt with in this round of revisions. ICES does presently not define Precautionary Reference points for these stocks.

2.2.2 (2) Short-lived species

These are species with a life-span restricted to 4-6 years old; high level of natural mortality (mean around 1.0 or even greater) that can vary because a large proportion is caused by predation and environmental conditions that also vary; recruitment is highly variable and the age of first capture is low; fishing mortality is generally much smaller than natural mortality. For short lived species such as sprat in the North Sea, capelin and anchovy, medium-term projections are not possible. The ICES advisory procedure is normally based on short-term (1-2 years) projection and such projections are usually not possible for the short lived species.

Short-lived species can be split into those that die after spawning like capelin, salmon (marine phase) and maybe Norway pout and those that do not. This distinction has bearings on the projection model.

An example of an approach for short lived species that die after spawning is the approach taken for capelin. The advice for capelin catches in the Barents Sea and in Iceland is based on acoustic estimates of the stock biomass shortly before spawning. The approach is to let an amount of spawners survive the fishery to secure reproduction at a level, which is not impaired by a too low SSB. This minimum SSB serves as a $\mathbf{B}_{\mathrm{lim}}$ value. Because the uncertainty in the acoustic estimate is proportional to the estimated size of the stock, a fixed $\mathbf{B}_{\mathrm{pa}}$ would not give the same probability in all years for maintaining SSB above $\mathbf{B}_{\mathrm{lim}}$. Therefore, a fixed $\mathbf{B}_{\mathrm{pa}}$ is not relevant for these stocks. Furthermore, $\mathbf{F}_{\mathrm{lim}}$ and $\mathbf{F}_{\mathrm{pa}}$ is neither relevant because there is no point in having more spawners survive the fishery than needed to secure a non-impaired recruitment because most capelin die after spawning and these fish will thus be a lost for the fishery. The advised TAC, using a 5% level for SSB dropping below $\mathbf{B}_{\mathrm{lim}}$, is in each year calculated based on the estimated biomass together with the associated uncertainties. The simulations required for these calculations can be done using bootstrapping of the survey results (directly or of the residuals around means) or by fitting a parametric error distribution to the survey results. In each specific case the procedure used should be described.

For short-lived stocks, which do not die after spawning F reference points can be used in management in addition to SSB reference points. In principle these points can be set in a similar way as for long-lived stocks

2.2.3 Long-lived species

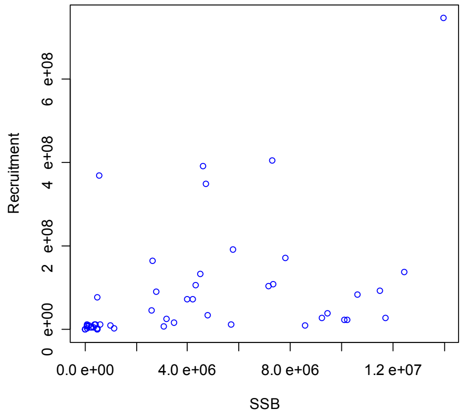
Long lived species are fish with M (adult phase) in the range of 0.1-0.3 per year and without any appreciable mortality due to spawning.

ICES stocks with analytical assessments and a time-series of paired SSB-R values can be grouped into categories as follows (modified from SGPA 1998 and SGPA 2002a and b). The basic distinction is whether a stock-recruitment relation is apparent. One type of stocks is dealt with as a separate group due to their unique biological characteristics.

2.2.3.1 (3) Stocks with occasional very strong year classes (spasmodic stocks).

This group of stocks have unique biological characteristics, which justifies a specific approach. They exhibit some points well above the cloud of points in a stock-recruitment scatter plot. However, the time-series are usually too sort to establish with any accuracy the frequency of such rare events. Examples of such stocks are most haddock stocks and Norwegian spring spawning herring. Establishing biomass reference points for such stocks is often difficult. For several of these stocks their entire population dynamics depend crucially on that these strong year classes actually occur. The analysis should therefore focus on establishing the minimum SSB above which strong year classes have been observed. However, when simulating the corresponding $\mathbf{B}_{pa}$, $\mathbf{F}_{lim}$ and $\mathbf{F}_{pa}$ these reference levels should be based on a S-R relationship based on data from periods where the very strong year class had no influence, i.e. before the year that produced the strong year class and period after starting from the year when the strong year class has little contribution to SSB.

Example (Norwegian Spring Spawning Herring)



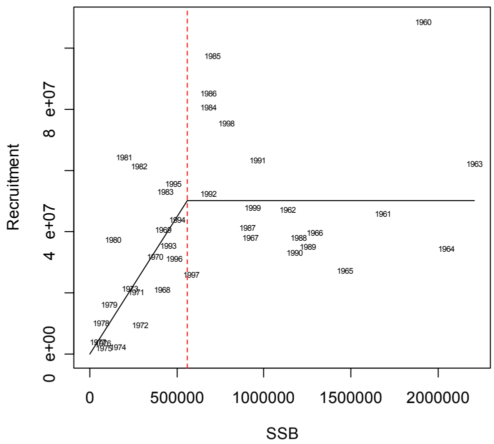
2.2.3.2 Stocks for which a relationship between stock and recruitment is apparent. (S/R signal apparent)

When a stock-recruitment signal is apparent this may be interpreted as either a change point, a monotonic increase of recruitment over the historic data or an inverse relationship. Ths gives bases for three stock types, each with a different interpretation of reference points.

a. Stocks with a wide dynamic range of SSB, and evidence that recruitment is or has been impaired.

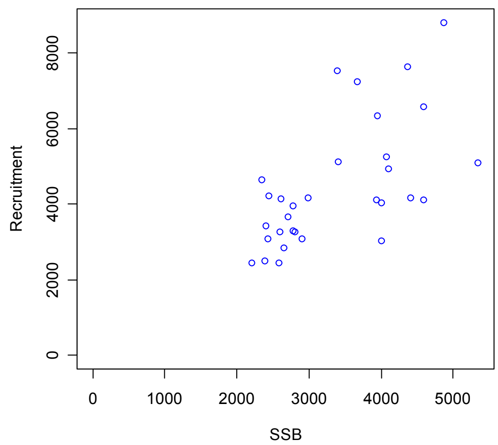
i. (4) Change point. Stocks for which there is a distinct change point in the S/R scatterplot, the scatterplot can be divided into a slope and a plateau region. A change point should be estimated and the change point is identified as an estimate of $\mathbf{B}_{lim}$. For these stocks the procedures described by SGPA 02b can be followed by performing a segmented regression and evaluate the diagnostics. If the estimation procedure is found to perform well a $\mathbf{B}_{lim}$ value can be established on this basis. If the performance of the segmented regression analysis is found to be unsatisfactory or if there are specific reasons for a modified approach alternative approaches for estimating $\mathbf{B}_{lim}$ should be investigated.

Example (Herring in the North Sea)



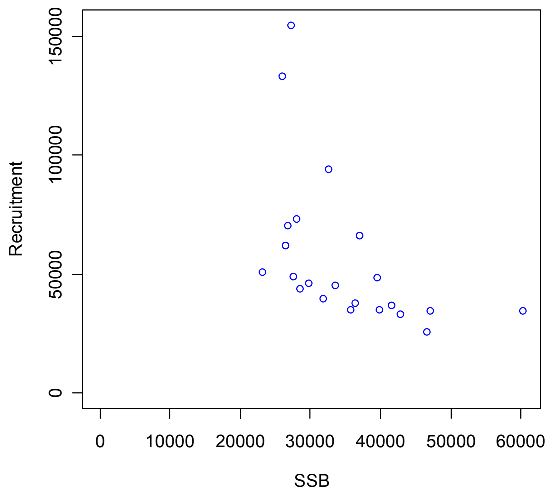
ii. (5) Positive proportionality without change point. These are stocks for which there is no distinct plateau in the scatterplot but for which R seem to be reduced with reduced SSB for the range of historical observations. In this case it may be suspected that fisheries mortality has been high before the historical time-series started and that all historical data are within the range of impaired recruitment. $\mathbf{B}_{\text{lim}}$ may be at higher SSB values than any observed. This decision should be based on evaluations of other data, especially the historical data on fishing mortality.

Example (Sole western Channel)



b. (6) Inverse relationship. Stocks where R increases as SSB decreases. For this inverse S/R relationship it is not possible to estimate limit reference points. $\mathbf{B}_{\text{loss}}$ may be estimated as a candidate value of $\mathbf{B}_{\text{pa}}$

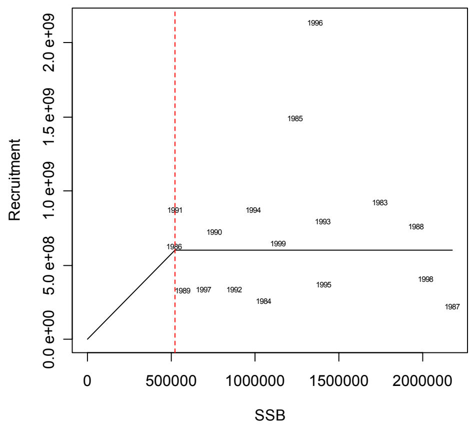
Example (Plaice in Kattegat-Skagerrak)



2.2.3.3 Stocks with no evidence that recruitment has been impaired or relation between stock and recruitment (no S/R signal apparent)

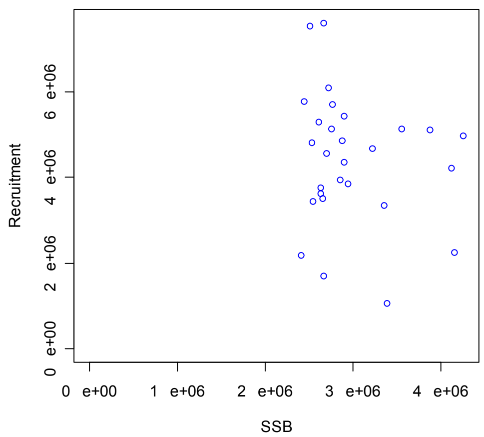
c. (7) Stocks with a clear plateau in the S/R scatterplot (a wide dynamic range of SSB, but no evidence that recruitment is impaired). Identify $\mathbf{B}_{\text{loss}}$ as a candidate value of $\mathbf{B}_{\text{lim}}$, below which the dynamics of the stock are unknown.

Example (Sandeel North Sea)



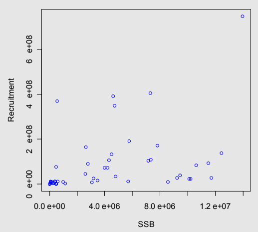
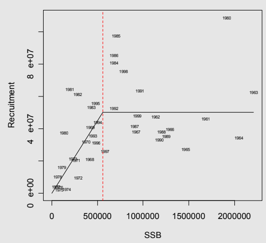
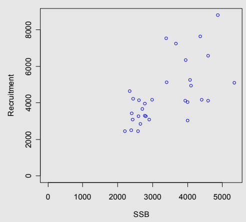
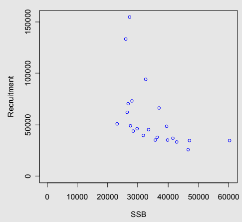
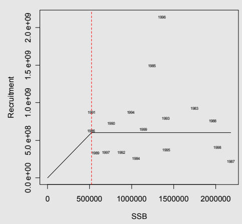
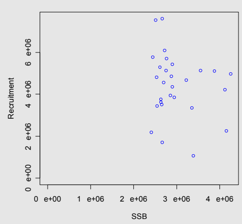
d. (8) Stocks for which the S/R scatterplot contains no information about neither plateau or impaired recruitment – a shotgun plot or stocks with a narrow dynamic range of SSB. If this is combined with a history of low exploitation $\mathbf{B}_{loss}$ can be used as a candidate value of $\mathbf{B}_{pa}$. Some stocks have little dynamic range in SSB, which makes it difficult to determine the SSB-R relationship and hence the biomass reference points. This is because, in reality, we have only one "point" to determine the SSB-R curve, namely a cloud of points in one particular spot on the SSB-R curve. ICES need to deal with these cases individually. If the stock is exploited at a high fishing mortality above what seems reasonable based on other reference points, e.g. $\mathbf{F}_{max}$ and $\mathbf{F}_{0.1}$ or experience with similar stocks and if this has been the prevailing situation for most or all of the time-series for which data are available then the stock should be considered as depleted and the SSB representing a stock that may not reproduce to its fullest potential. In this case a reasonable $\mathbf{B}_{pa}$ will need to be defined based on an $\mathbf{F}_{pa}$ consideration and is likely to be above the SSB forwhich ICES has experience with this stock. If, on the other hand, the fishing mortality is low judged by conventional reference points and experience with similar stocks then this may actually be a stable stock for which the $\mathbf{B}_{pa}$ should be defined as the $\mathbf{B}_{loss}$ value.

Example (Mackerel in the North East Atlantic)



2.2.4 Reference points and stock types - summary

The evaluation of LIMIT reference points in relation to stock type is summarised in the table below. For some stock types a standard default procedure can be described. For other stock types the decision on a LIMIT reference point must depend on a consideration of stock-specific issues such as the history of fishing mortality, the history of the points in various parts of the S/R scatterdiagram, biological information on growth, natural mortality or fecundity changes etc. The management regime within which reference points is applied should always be considered and there may for some stock types such as short-lived stocks (for instance capelin) or spasmodic stocks (for instance Norwegian spring-spawning herring) be management regimes in operation which are based on a specific approach to reference points. Estimation of LIMIT reference points may not be possible or relevant for some stocks such as stocks exhibiting an inverse S/R relationship or where the S/R scatterplot does not exhibit a plateau or a slope, but only appears to be a shotgun cloud. If data are insufficient or specific considerations need to be taken into account it may be necessary to deviate from the standard approach for that stock type and move right in the diagram below.

Stock characteristics			Limit point estimation options dependent on data and specific stock information		
Stock type	**S/R plot characteristics**	**Sample S/R plot**	**B_{lim} estimation possible according to standard method**	**B_{lim} estimation possible on basis of stock-specific method or judgement**	**B_{lim} estimation not possible**
1 Data poor situation	Not available				Present alternative basis for advice
2 Short-lived 1-time spawners				(**B_{loss}**)	
3 Spasmodic stocks – occasional large year classes				Mortality based reference points such as **F_{loss}** based on normal recruitment situation.	
S/R signal	4 Clear change point (slope line and plateau)		**B_{lim}** = Segmented regression change point		
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			**B_{lim}** may be close to highest SSB observed. Decision dependent on evaluation of historical fishing mortality	
	6 Inverse S/R relation (there seems to be a negative slope)		No LIMIT point, only PA point. (**B_{loss}** candidate for PA point)		
No S/R signal,	7 Distinct plateau (wide range of SSB)		**B_{lim} = B_{loss}**		
	8 No apparent plateau (narrow range of SSB)			No LIMIT point, only PA point (**B_{loss}** is candidate for PA point dependent on considerations involving historical fishing mortality)	

2.3 Criteria for revisions

Reference points should only be revised if there is strong evidence against the present reference points (i.e. a well defined new and different reference point), if the methodology used is considered robust and if the change proposed is significant.

3 ESTIMATION METHODOLOGY

The general framework outlined above requires an analytic estimation method to be used for exploration, discrimination between types and to estimate reference points in those cases where this is appropriate.

As summarised below, SGPA 02b proposed the following:

a) a revised framework for estimating reference points, starting with $\mathbf{B}_{\mathrm{lim}}$, and leading on to the estimation of $\mathbf{F}_{\mathrm{lim}}$, $\mathbf{F}_{\mathrm{pa}}$, and $\mathbf{B}_{\mathrm{pa}}$.
b) the methodology for estimating $\mathbf{B}_{\mathrm{lim}}$, using segmented regression
c) a methodology for estimating $\mathbf{F}_{\mathrm{lim}}$ from $\mathbf{B}_{\mathrm{lim}}$ deterministically
d) a proposed new methodology for estimating $\mathbf{F}_{\mathrm{pa}}$ and $\mathbf{B}_{\mathrm{pa}}$ in order to take into account assessment uncertainty
e) clarification of the risks to be accounted for in this framework

The relationship between the reference points, and the risks to be taken into account when calculating them, are depicted in Figure 1, taken from SGPA 02b (Anon 2003a).

3.1 The framework

The implementation of the precautionary approach by ICES emphasises the aim of preventing stocks from being seriously harmed due to recruitment overfishing. SGPA 02a and SGPA 02b therefore proposed that the cornerstone of the reference point framework is to identify $\mathbf{B}_{\mathrm{lim}}$ as the SSB below which recruitment becomes impaired in a stock-recruitment scatter plot, since this point has an intrinsic biological meaning.

$\mathbf{B}_{\mathrm{lim}}$ should then be used as the basis for deriving the other reference points. Thus $\mathbf{F}_{\mathrm{lim}}$ should be estimated as the fishing mortality corresponding to $\mathbf{B}_{\mathrm{lim}}$, whilst to be sure that a stock is above $\mathbf{B}_{\mathrm{lim}}$ or that fishing mortality is below $\mathbf{F}_{\mathrm{lim}}$, the operational reference points $\mathbf{F}_{\mathrm{pa}}$ and $\mathbf{B}_{\mathrm{pa}}$ must be estimated in a way that takes into account assessment uncertainty. In this context, SGPA 02a used the term assessment uncertainty to mean the combination of measurement error, model error and estimation error as used by Rosenberg and Restrepo (1994), who described the various sources of error in stock assessment as follows:

- *natural variation* in dynamic processes (e.g. recruitment, somatic growth, natural mortality), also termed process error.

- *measurement error*, generated when collecting observations from a population

- *model error*, mis-specification of a model parameter (e.g. natural mortality), or the model structure

- *estimation error*, arises from any of the above errors and is the inaccuracy and imprecision in the parameters estimated by the model during the assessment process,

- *implementation error*, arising because management actions are never implemented perfectly, whether because the management plan does not correspond to the advice fully, or because compliance with the intent of the management plan is imperfect.

SGPA 02b felt that in practice it is not easy to distinguish between measurement error, model error and estimation error, and therefore used the single term *assessment uncertainty* for their combined effect. Implementation error was not considered in this framework.

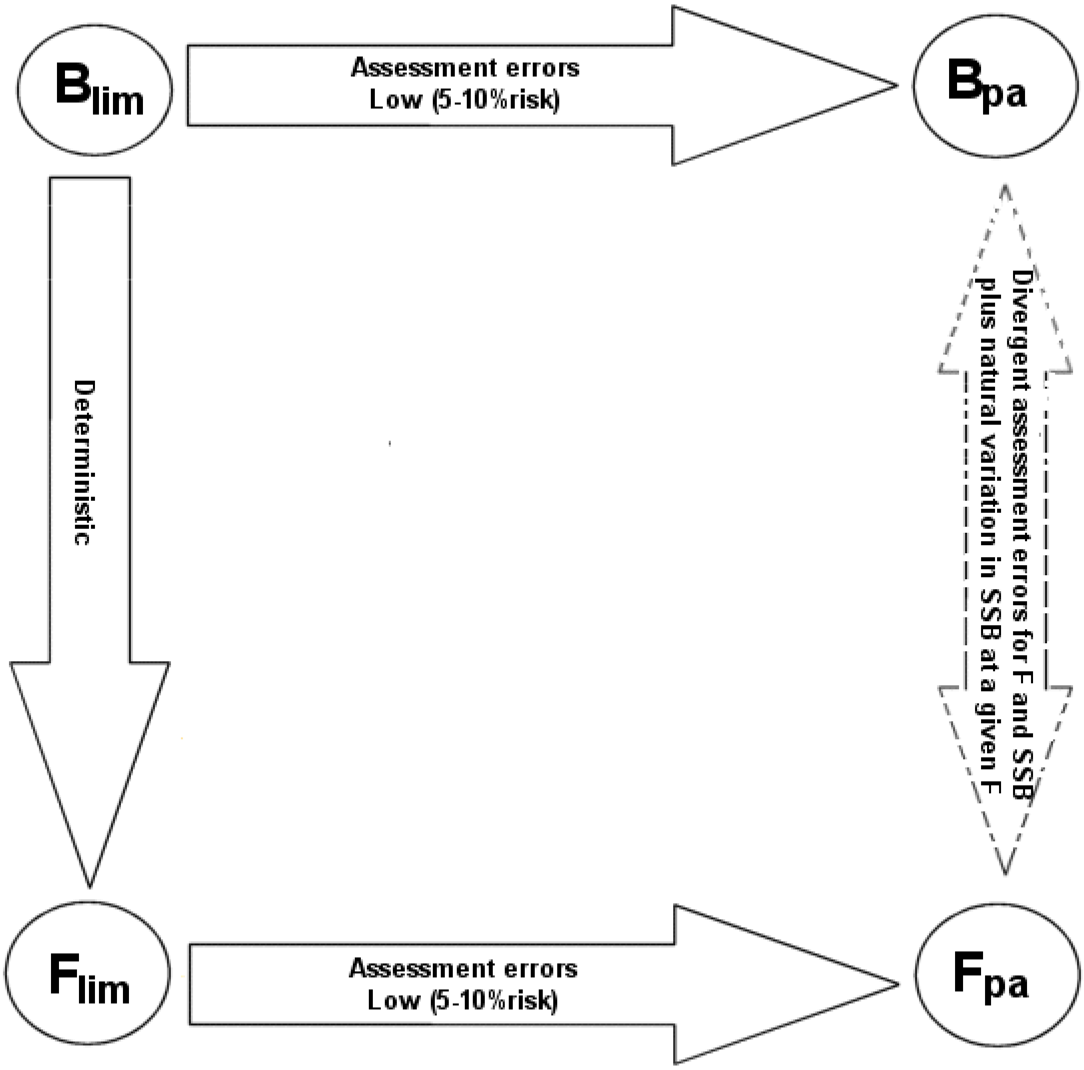


Figure 1. The links between reference points, and the related sources of uncertainty and risk.

3.2 Estimating $\mathbf{B}_{lim}$

SGPA 02a proposed that $\mathbf{B}_{lim}$ should be the SSB below which there is a substantial increase in the probability of obtaining reduced (or 'impaired') recruitment i.e. the estimate of $\mathbf{B}_{lim}$ should be risk averse, so that when the stock is at $\mathbf{B}_{lim}$ the probability that recruitment is substantially impaired is still small, but below $\mathbf{B}_{lim}$ that probability increases. Since the aim is to prevent impaired recruitment due to low SSB, then for those stocks where the stock-recruitment diagram is dome-shaped (i.e. recruitment is reduced at both low and high SSB) it is the left-hand part of the stock-recruitment curve that is being considered.

3.2.1 Segmented regression

For stocks where data on SSB and R are available from a full analytical assessment, SGPA 02a and SGPA 02b proposed that a segmented regression is a statistically objective tool for estimating $\mathbf{B}_{lim}$ (O'Brien and Maxwell 2002a and 2002b). The method assumes that recruitment is independent of SSB above some change point, below which recruitment declines linearly towards the origin at lower values of SSB. The method identifies the value of SSB at this change point (**S***), which is therefore a candidate value for $\mathbf{B}_{lim}$. Segmented regression is therefore estimating $\mathbf{B}_{lim}$ by fitting a 'hockey-stick' stock and recruitment relationship to the data. (The comparison between this and other stock-recruit relationships was discussed in Section 3.1.1. of SGPA 02b). O'Brien and Maxwell (2002a) described statistical tests for the significance of the change point, plus a log-likelihood method for estimating confidence limits for the change point. The diagnostics also incorporated the facility to identify how the fit depends on the influence of data for individual years.

It is important to consider how the uncertainty in the estimate of $\mathbf{B}_{lim}$ relates to risk averseness and the concept of a PA reference point. In the practical use of reference points two sources of uncertainty are involved: one is the uncertainty in the estimate of $\mathbf{B}_{lim}$, another is the uncertainty in the most recent assessment of stock biomass and fishing mortality. The first relates to the robustness of the statistical fit of the estimation model based on historical stock-recruitment data while the latter relates to assessment uncertainty. It is considered that the estimate (S*) of $\mathbf{B}_{lim}$ is risk-adverse by being an estimate of the biomass for which there is not yet an increased probability of impaired recruitment and that the operational problem in the precautionary approach primarily relates to the uncertainty in estimating whether the present biomass is above $\mathbf{B}_{lim}$ [1]. It has therefore been considered that the use of the central estimate of $\mathbf{B}_{lim}$ (S*) in combination with a PA reference point derived from an estimate of assessment uncertainty best represents risk averseness within the operational use of LIMIT and PA reference points.

There is a full description of the segmented regression method in O'Brien and Maxwell 2002a and a detailed account of its application to an example stock, the North East Arctic Saithe, in O'Brien and Maxwell 2002b. O'Brien and Maxwell also contributed a number of working papers to SGPA 02a, in which they applied the segmented regression to a range of stocks in order to illustrate the performance of the model and its diagnostics with different data sets (Working Documents 10-21 in Anon 2002).

The segmented regression determines the SSB below which the expected recruitment ceases to be best estimated by the average recruitment at higher biomass. Although the expected recruitment below the change point is lower than above it, the initial difference in R when the stock first enters the domain of reduced recruitment may be very small, causing doubt as to whether the resulting recruitment actually constitutes "impaired productivity". In some cases, the segmented regression fit may also be affected by the presence of individual large year classes that seem to exert undue influence. In such circumstances SGPA 02b proposed that an alternative procedure is to estimate directly the probability of recruitment being impaired as a function of SSB, using a non-parametric method such as that described by Rice and Mashal 2002. That method is based on Evans and Rice (1988) and Rice and Evans, (1988). It uses a locally weighted smoother to estimate the probability density function of a recruitment as being either poor or poorer than some specified "poor" value, or as good or better than some specified "good" value. This method could not be tested by SGPA 02b, however as sufficiently developed software implementations were not available and the method has therefore not been applied by SGPRP either.

3.2.2 $\mathbf{B}_{loss}$

In many cases the historic stock–recruit data indicate that the point of poor recruitment has either not yet been reached, or is very close to the left hand edge of the stock and recruit plot. In these cases a fit of a model with a change point (such as segmented regression) is not informative as the change point estimate will not be based on actual information from reduced recruitment. In such cases the most useful information which can be extracted is an estimate of the lowest SSB for which information is available on the population dynamics of the stock i.e. the lowest observed spawning stock biomass, $\mathbf{B}_{loss}$. Bringing the stock to a lower SSB is entering a domain where the risk cannot be assessed using the available data.

The B_{loss} value is defined as $\min\{SSB | Available\, time\, series\} = B_{loss}$

In cases where the stock is heavily exploited, and it appears that the stock-recruitment plot covers a wide dynamic range, SGPA 97 and 98 adopted the rationale that it is not precautionary to allow the stock to enter the domain where the stock dynamics and the risks are unknown, and $\mathbf{B}_{loss}$ was therefore proposed and used as a proxy for $\mathbf{B}_{lim}$. This is equivalent to stock type (7) above.

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[1] The confidence limits of the estimate of B_{lim} (S*) was discussed by SGPA 02a as a possible basis for defining limit and PA reference points. That is, $\mathbf{B}_{lim}$ should be at $\mathbf{S^*}(\alpha)$, where α is chosen depending on an agreed risk strategy for $\mathbf{B}_{lim}$. The revised risk framework developed by SGPA 02b proposed that $\mathbf{B}_{lim}$ should be risk averse, so there should be a low probability that at S* recruitment is actually impaired. Assessment scientists therefore need to decide whether the point estimate of S* is sufficiently risk averse, or whether $\mathbf{B}_{lim}$ should be estimated using a value at the top end of the range for α. In SGPA 02a it was suggested that a lower percentile of the confidence interval of S*, say 10%, could be used as $\mathbf{B}_{lim}$, and that an upper percentile, say 90%, could be used as $\mathbf{B}_{pa}$. This approach does not correspond to the revised framework, however, where it is proposed that the difference between $\mathbf{B}_{pa}$ and $\mathbf{B}_{lim}$ depends on assessment uncertainty, not simply the robustness of the statistical fit to the stock-recruit data.

In cases where the stock is lightly exploited, or where the range of data in the stock-recruit plot is limited, and in particular where R appears to be increasing as SSB decreases, SGPA 97 and 98 proposed and used $\mathbf{B}_{loss}$ as a proxy for $\mathbf{B}_{pa}$. This is equivalent to stock type (8) above.

SGPA 02b proposed to continue the use of this rationale but did not provide clear rules as to what constitutes a 'narrow' or 'wide' range of stock-recruit data, and except in the case where the R-SSB relation is inverse, it may therefore be difficult to decide whether $\mathbf{B}_{loss}$ should be $\mathbf{B}_{lim}$ or $\mathbf{B}_{pa}$. The rationale adopted in each case should therefore be specified individually.

It is proposed here that the distinction between a 'narrow' and a 'wide' range of stock-recruit data should relate to the information which is considered available in the data – whether the data indicate a stock recruitment signal in the form of a plateau of recruitment over a range of biomass values or whether the data do not indicate any relationship at all, when the stock-recruitment scatterplot basically appears to be a shotgun shot. If there is a plateau $\mathbf{B}_{loss}$ should be used as $\mathbf{B}_{lim}$, when there is no signal or an inverse relationship $\mathbf{B}_{loss}$ should be used as $\mathbf{B}_{pa}$.

$\mathbf{B}_{loss}$ may also be relevant in relation to stocks where the historical data exhibits an inverse relationship between stock and recruitment (type 6 above). In this case there is no basis for estimation of a LIMIT reference point and it is suggested that $\mathbf{B}_{loss}$ is used as $\mathbf{B}_{pa}$.

3.3 Estimating $\mathbf{F}_{lim}$

Although $\mathbf{F}_{lim}$ could be derived from some a priori considerations about population biology, SGPA 02b proposed that in practice $\mathbf{F}_{lim}$ should be estimated as the fishing mortality that corresponds to $\mathbf{B}_{lim}$. Since it is intended that $\mathbf{B}_{lim}$ should be estimated as risk averse (i.e the lowest biomass where there is still a low risk of impaired recruitment), it is proposed that to avoid double counting of the risk, $\mathbf{F}_{lim}$ should be risk neutral to $\mathbf{B}_{lim}$ i.e $\mathbf{F}_{lim}$ should be estimated from $\mathbf{B}_{lim}$ deterministically. When fishing mortality is at $\mathbf{F}_{lim}$, the probability that SSB is at $\mathbf{B}_{lim}$ is 50%.

$\mathbf{F}_{lim}$ should be estimated by obtaining a value for the expected recruitment at $\mathbf{B}_{lim}$. The method is to measure the slope of the replacement line at $\mathbf{B}_{lim}$ i.e R/$\mathbf{B}_{lim}$, and calculate the inverse, $\mathbf{B}_{lim}$/R. The equivalent fishing mortality derived from a curve of SSB/R against F will therefore be $\mathbf{F}_{lim}$.

If $\mathbf{B_{loss}}$ is used as the $\mathbf{B_{lim}}$ the $\mathbf{F_{loss}}$ is used as $\mathbf{F_{lim}}$.

$\mathbf{F_{loss}}$ is defined from the G_{loss} concept defined in Annex 1 in the report of SGPA (1997). The procedure depends on whether a stock-recruitment relationship can be identified or not.

1) A Stock-Recruitment Relationship Can Be Identified

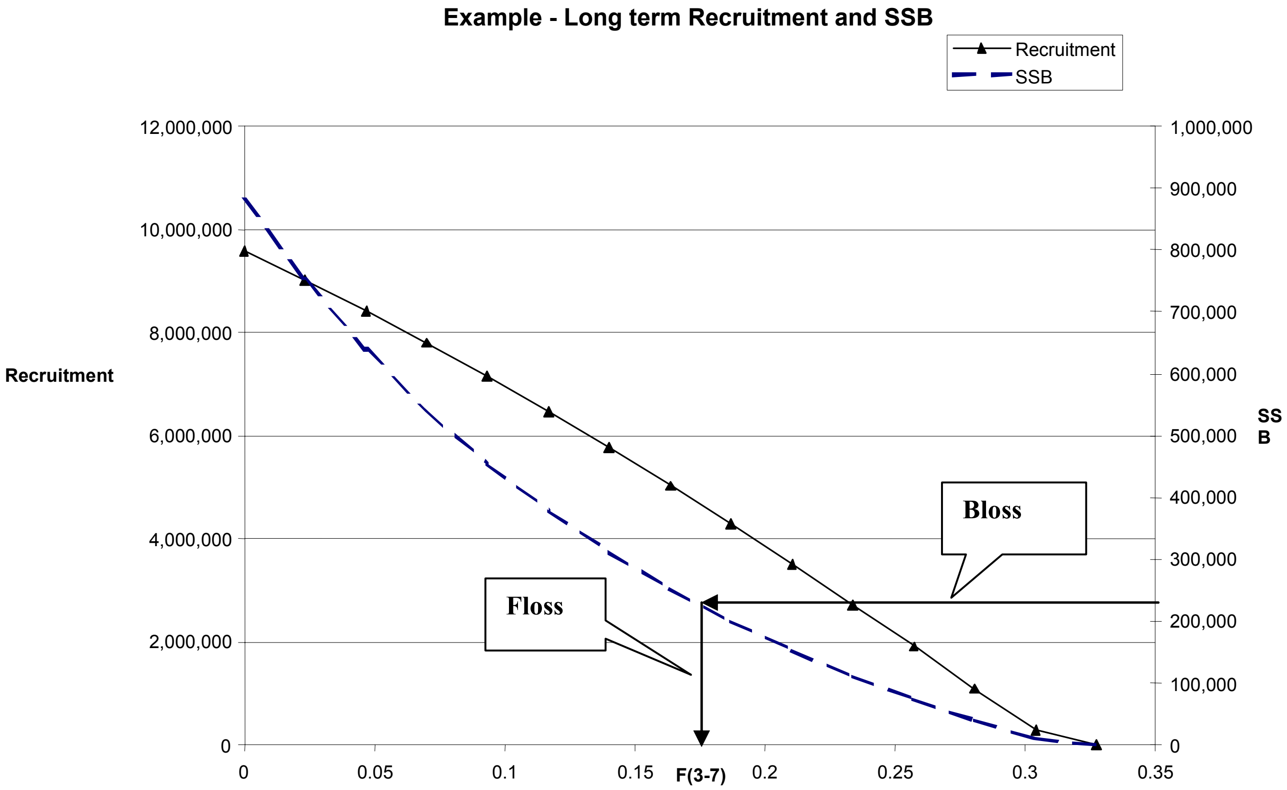
This concept is defined from the relationship R = f(SSB); the stock-recruitment relationship and the equilibrium d SSB = R*g(F,R,....). For a set of parameters (mean-weight-at-age for spawners, Maturity ogive, ...) the relationship is depicted below as function of the fishing mortality. In this example the f() is the Beverton&Holt stock-recruitment relationship R = A*SSB/(B+SSB) and the g() is the equilibrium SSB/R function.

This definition has two elements

- Equilibrium recruitment (R) and SBB for a given fishing mortality (F)
- Definition of the stock recruitment relationship

$$R = SSB\left(F, R \middle| Exploitation\ pattern, WeSt, M, Maturity, F_{prop}, M_{prop}\right)\ or\ \ short\ R = SSB(F, R)$$

The graph below illustrates the R= R(F) and SSB = SSB(F) relationships. The solution to the R= SSB(F,R) defines F_{loss}.



2) No Stock-Recruitment Relationship can be Defined

We are particularly interested in F_{loss} when we cannot define the stock-recruitment relationship, e.g. when the segmented regression approach cannot find a candidate to B_{lim}. Therefore introducing the S-R relationship was not considered a useful way forward in this case. Instead F_{loss} is calculated assuming that the stock recruitment relation cannot be seen in the data and therefore the arithmetic average of the recruitment for the time series available is a candidate for the recruitment to be expected from the B_{loss} spawning biomass. This implies that B_{loss} normally would be a candidate for B_{lim} as the lowest SSB for which recruitment seems unimpaired.

Therefore, the associated F_{loss} values are defined as the solution to

$$B_{loss} = SSB(\overline{R}, F_{loss}) = \overline{R} * [SSB / R](F_{loss})$$
$$where$$
$$\overline{R} = \sum_{yc} R_{yc} / no\ of\ yc$$

3.4 Estimating $\mathbf{F}_{pa}$ and $\mathbf{B}_{pa}$

In order to avoid $\mathbf{F}_{lim}$ and $\mathbf{B}_{lim}$ with high probability, $\mathbf{F}_{pa}$ should have a low probability of being above $\mathbf{F}_{lim}$ and $\mathbf{B}_{pa}$ should have a low probability of being below $\mathbf{B}_{lim}$, taking the uncertainty of the assessment of the present situation into account. These derivations specifically exclude taking into account implementation error, which cannot be quantified at present. In the revised framework SGPA 02b proposed that $\mathbf{F}_{pa}$ and $\mathbf{B}_{pa}$ should be derived independently, $\mathbf{F}_{pa}$ being derived from $\mathbf{F}_{lim}$, and $\mathbf{B}_{pa}$ from $\mathbf{B}_{lim}$. SGPA 97 and 98 determined the PA values from the LIMIT values using an estimate of uncertainty by assuming a variance that was used as a fixed multiplier of $\mathbf{F}_{lim}$ or $\mathbf{B}_{lim}$, but it has since been shown (Bertelsen and Sparholt 2002) that this approach is likely to represent a serious underestimate of the uncertainty in the assessments and the forecasts. Consequently, SGPA 02b proposed an alternative way of estimating $\mathbf{F}_{pa}$ and $\mathbf{B}_{pa}$ based on estimating the assessment uncertainty using retrospective analysis.

3.4.1 Estimating F_{pa}

The aim is that when $\mathbf{F}_{pa}$ is the intended or prescribed F in a TAC year, the forecast TAC should generate a realised F that has a very low probability of being above $\mathbf{F}_{lim}$. In any TAC year, the intended F is applied to the forecast SSB to give an equivalent TAC. Because of uncertainty, it is proposed that the realised F by that TAC needs to be calculated from the 'true' SSB in the TAC year, which can only be estimated retrospectively using the most reliable recent assessment. SGPA 02b therefore proposed that the assessment uncertainty should be estimated from the observed difference between the intended F and the realised F, determined for each individual stock by this form of retrospective analysis, where the 'true' SSB is estimated by the assessment whose SSB-R pairs are used to estimate $\mathbf{B}_{lim}$ and hence $\mathbf{F}_{lim}$. The comparison is made for a series of terminal years in the converged part of the most recent reliable assessment. The method is summarised more fully in Section 3.1.1 of the report of SGPA 02b (Anon 2003). Error in implementing F in the TAC year is not included in this approach, since the realised F is calculated using the actual advised TAC.

3.4.2 Estimating B_{pa}

It is proposed to derive $\mathbf{B}_{pa}$ from $\mathbf{B}_{lim}$ in a similar manner to the above, by comparing the SSB observed (SSB_{obs})in previous assessments to the 'true' SSB (SSB_{true})measured retrospectively by the most recent reliable assessment.

SGPA 02b noted that the comparison between the observed SSB and the true SSB can be made in either the assessment year, or in the forecast year, and concluded that the assessment year should be used since that was the value that was used to compare with the reference point value in giving the advice. However, at the present meeting SGPRP concluded that to be consistent with the estimation of assessment uncertainty, the observed SSB should be that forecast for the end of the TAC year.

Over the range of terminal years, retrospective analysis will give a set of $\{SSB_{assm},SSB_{true}\}$ pairs. Values of the ratio SSB_{assm}/SSB_{true} are plotted against SSB_{true} as the independent variable. A line is drawn through the origin so that α% of the points are above and (100-α)% are below the line, where α is the acceptable risk. This may be 10% or less, depending on the availability of the data. If the number of pairs is small, the highest line passing through a point should probably be used, unless this is a clear outlier. The slope β of the line is the ratio between $\mathbf{B}_{pa}$ and $\mathbf{B}_{lim}$, thus $\mathbf{B}_{pa} = \beta * \mathbf{B}_{lim}$.

3.4.3 Testing the estimation of PA points

It has to be stressed that SGPA 02b proposed a method for estimating assessment uncertainty that has not been peer reviewed and was not tested. The only test to date is that performed by SGBRP, whose report (Anon 2003b) was presented at this meeting. In the SGBRP report it should be noted that 'intended F' is called F_{pred}, whilst realised F is called $F_{obs,}$ whilst SSB_{assm} was called SSB_{pred}, and SSB_{true} was called SSB_{obs}. Even allowing for the work done by SGBRP, it has to be accepted that the proposed estimation procedures for $\mathbf{F}_{pa}$ and $\mathbf{B}_{pa}$ are virtually untested. There is thus a need to investigate the outcomes and performance of the proposed estimation procedures on a diverse range of stocks.

3.4.4 The middle year

The evaluation of assessment uncertainty is based on a retrospective analysis of forecasts. In this context an important point has arisen in relation to the so-called 'middle year' in the forecast i.e the year between the assessment year and the TAC year. SGBRP noted that in the Arctic Fisheries Working Group, it was for many years customary to use a catch constraint in the middle year, whereas more recently the forecast has been made using F status quo in the middle year.

SGBRP estimated PA values using both assumptions. Assuming a TAC constraint in the assessment year resulted in larger difference between intended and realised F and SSB, but SGBRP proposed that the values based on F = $\mathbf{F}_{sq}$ should be used, in spite of management by TAC for NEA cod. This is justified by the observation that due to some unknown factors, $\mathbf{F}_{sq}$ leads to more stable forecasts for the assessment year.

Looking back at the problem, the assessment done in this year is used to set quotas for the next year and will therefore affect the fishing mortality next year and the SSB by the end of next year. Therefore intended and realised F for next year should be compared as well as intended and realised SSB by the end of that year, based on TAC constraint next year, where the fishery is managed by TAC. This translation by one year will lead to an increased difference between intended and realised fishing mortality and SSB.

Where the fishing effort is limited by number of days or other effort limitation the predictions for the assessment year and next year will have to be based on specified F with random deviations reflecting changes in availability of the fishes, age composition of the stock as well as increase in efficiency of the fleet which will lead to bias if not accounted for in the management.

According to Jakobsen and Sparholt (2002) unless there is some prior indication of the error in the assessment, if the change in F implied by the TAC constraint exceeds ~0.2 the TAC would give the most precise TAC forecast.

There is, however, a link between the direction of the error in the assessment and the error in the forecast. The most common situation would be that F is underestimated in the assessment and is expected to decrease by applying a TAC constraint a status quo forecast will cause the smallest error, even when the change in F is as large as 0.4.

The main conclusion is that there needs to be strong evidence that the F in the assessment is not underestimated before a TAC constraint should be preferred.

3.4.5 The relationship between $\mathbf{F}_{pa}$ and $\mathbf{B}_{pa}$

Although $\mathbf{F}_{pa}$ and $\mathbf{B}_{pa}$ should both take into account assessment uncertainty, they do so independently, and individual assessment inputs will not affect F and SSB in identical ways so that the distances $\mathbf{F}_{pa}$-$\mathbf{F}_{lim}$ and $\mathbf{B}_{pa}$-$\mathbf{B}_{lim}$ will not necessarily be the same. Consequently there can be no guarantee that when advice is given according to $\mathbf{F}_{pa}$, SSB will necessarily be at or above $\mathbf{B}_{pa}$ all of the time. As a result, even if the stock is harvested at $\mathbf{F}_{pa}$, the estimated and real SSB may still be below $\mathbf{B}_{pa}$ in some years, and the stock is therefore 'outside safe biological limits'. ICES will then advise a further reduction in fishing mortality to below $\mathbf{F}_{pa}$ if this is needed to keep the estimated SSB at or above $\mathbf{B}_{pa}$. Although one could envisage choosing an $\mathbf{F}_{pa}$ that has a lower probability of the stock being below $\mathbf{B}_{pa}$, this would result in advice that is more restrictive on harvests in the short-term, even when SSB rises above $\mathbf{B}_{pa}$.

For these reasons SGPA 02a stressed that ICES should continue to emphasise that $\mathbf{F}_{pa}$ and $\mathbf{B}_{pa}$ are intended to be <u>boundaries</u> (as clearly implied in the formal EU-Norway agreements) and <u>not targets</u>. ICES should advise that action is taken at $\mathbf{F}_{pa}$ in order to reduce F <u>below</u> $\mathbf{F}_{pa}$, or should advise that action is taken at $\mathbf{B}_{pa}$ in order to raise stock <u>above</u> $\mathbf{B}_{pa}$. It is not intended that stocks should be fished continually at $\mathbf{F}_{pa}$, or should remain continually at $\mathbf{B}_{pa}$.

3.5 Method specifications and software

A WG Doc on "Revision of Reference Points: Calculations of $\mathbf{B}_{lim}$ and $\mathbf{F}_{lim}$ using segmented regression analysis" was presented by the ICES Secretariat. This paper contained calculations of the new $\mathbf{B}_{lim}$ and $\mathbf{F}_{lim}$ points following the guidelines from SGPA 02b (Anon 2003). These new reference points are given an ANNEX 2 of the present report. The following is a description of how this was done.

The segmented regression method (O'Brien and Maxwell 2002a and 2002b) was used to explore the significance of a change point model and estimate $\mathbf{B}_{lim}$ for stocks where there is an analytical assessment, and a sufficiently long time-series (more than 10 years) of data for SSB and recruitment to allow a proper analysis. The software was re-written in the R language from the original S-PLUS script used to produce the results given in the WDs presented by O'Brien and Maxwell at the SGPA 02a. The R language program was developed by participants in the SGPA meeting in December 2002. It has been tested on many stocks and produce identical results as the S-PLUS program. However, there is a need to rectify minor problems which were identified one of which relates to how replacement is handled. There is also a need to improve the diagnostics so that they demonstrate the discrimination of a change point model against two alternative hypothesis of stock recruitment relationships over the observed data which do not include a change point: 1) constant recruitment (a horizontal line without change point over the observed data) and 2) proportionality (a linear increase in recruitment over the observed data). The latter has proven important when assessing stocks of type 5 above.

Short lived stocks, like anchovy, Norway pout, (sardine) and capelin, have been omitted from the analysis.

The data used were SSB and recruitment values taken from the ACFM agreed assessments in 2002. Data from 2000 and 2001 were omitted in the analysis due to convergence problems with most XSAs, VPAs, etc.

Also presented is a risk neutral conversion of $\mathbf{B}_{lim}$ (using Y/R data) to $\mathbf{F}_{lim}$. The slope of the replacement line at $\mathbf{B}_{lim}$ is R/$\mathbf{B}_{lim}$, and so the inverse, $\mathbf{B}_{lim}$/R, will be equivalent to a particular fishing mortality on a curve of SSB/R against F. This F will be $\mathbf{F}_{lim}$.

4 REFERENCE POINTS FOR STOCKS IN THE ICES AREA

4.1 Introduction

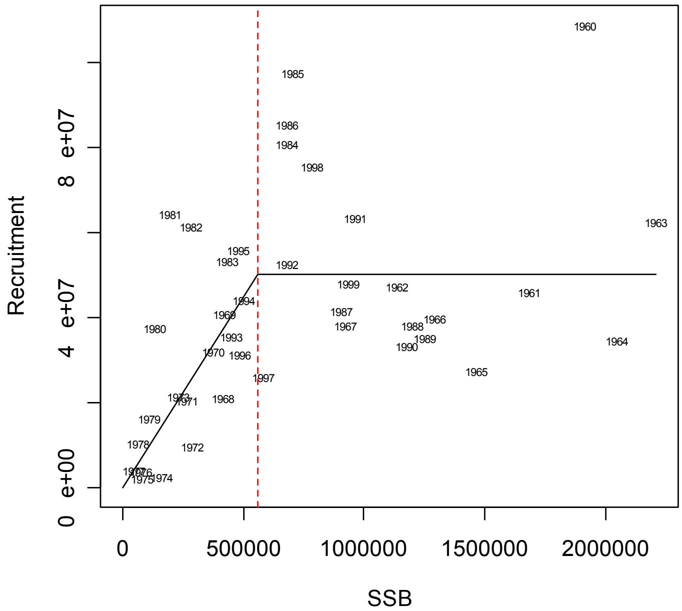
The stock-recruitment relationships for 65 stocks for which analytical assessments exist have been analysed by groups consisting of the Working Group chair and other members of the study group with knowledge about the stocks concerned. The analysis was based on stock recruitment plots and preliminary runs of a model assuming a change point (data and software described in section 3.5 above). The groups went through the procedures described in sections 2 and 3 above. The initial fit of a change point model was used as an exploratory basis to ascertain the relevance of revising present reference points. These initial fits are presented for each stock irrespective of whether the segmented model was subsequently used as the basis for reference point estimation.

4.2 HAWG - Herring Assessment Working Group for the Area South of 62°N

Stock type	S/R plot characteristics	B_{lim} estimation possible according to standard method	B_{lim} estimation possible on basis of stock-specific method or judgement	B_{lim} estimation not possible
1 Data poor situation				Herring Div IIIa -22 (Western Baltic Spring Spawners)
2 Short-lived 1-time spawners				
3 Spasmodic stocks – occasional large year classes				
S/R signal	4 Clear change point (slope line and plateau)	North Sea Herring	Celtic Sea Herring?	
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			
	6 Inverse S/R relation (there seems to be a negative slope)			
No S/R signal,	7 Distinct plateau (wide range of SSB)			
	8 No apparent plateau (narrow range of SSB)		Herring VIa(S) & VIIbc Herring VIa(N) Irsih Sea Herring	

4.2.1 North Sea Herring

The Segmented-regression on the 2002-data gave a change point at 558096. The previous $\mathbf{B}_{lim}$=800000 (1999) was based on the consideration that there would be increased risk of low R below that. O'Brien et al estimated a S* for North Sea herring to be 510 000, based on the 2001-assessment. In the 2002 assessment there was a change in the VPA-calibration (inverse variance weighting and downweighting of 0-1 catch) compared to previous year. Revision of $\mathbf{B}_{lim}$ should be considered by the HAWG.



4.2.2 Herring west of Scotland (VIa(N))

The Segmented-regression gives no change point for this stock. The current $\mathbf{B}_{\text{lim}}$ is not defined. Using the whole time-series, $\mathbf{B}_{\text{loss}}$ is considered a good candidate for $\mathbf{B}_{\text{loss}}$=$\mathbf{B}_{\text{lim}}$=50 000 t.

4.2.3 Irish Sea Herring

The Segmented-regression gives no change point for this stock. $\mathbf{B}_{\text{lim}}$ is thus recommended to be $\mathbf{B}_{\text{lim}}$=$\mathbf{B}_{\text{loss}}$= 5 452.t The present value is 6 000 and there is thus no reasons for changes.

4.2.4 Celtic Sea Herring

The current $\mathbf{B}_{\text{lim}}$=26000 t (1999), was based on $\mathbf{B}_{\text{loss}}$. The Segmented-regression gives a change point of 61 306 t. There is a relatively dense concentration of annual points above the estimated change point with SSB in the range of 60 000-100 000 t. The estimated $\mathbf{B}_{\text{lim}}$ may therefore probably be more related to $\mathbf{B}_{\text{pa}}$ than $\mathbf{B}_{\text{lim}}$.

Although the Segmented-Regression gives a significant fit, further analysis is recommended since temporal autocorrelation seems to be important. A change of $\mathbf{B}_{\text{lim}}$ is thus not recommended at this moment.

4.2.5 Herring in VIa(S) and VIIbc (Ireland West)

The Segmented-Regression gives no well defined change point for this stock The dynamics of the SSB shows two occasional high recruitment years, 1982 and 1986. The previous $\mathbf{B}_{\text{lim}}$=81000 was based on the lowest reliable estimated SSB (1999). From the current understanding of the stock, there is no reason to make a revision at the present stage.

4.2.6 Western Baltic spring spawning herring (Division IIIa and SD 22-24)

The time-series for this stock was less than 10 years. Therefore no revisions were presented.

4.3 WGBFAS – Baltic Fisheries Assessment Working Group

Stock type	S/R plot characteristics	B_{lim} estimation possible according to standard method	B_{lim} estimation possible on basis of stock-specific method or judgement	B_{lim} estimation not possible
1 Data poor situation				Herring 31 Flounder 24-25
2 Short-lived 1-time spawners				
3 Spasmodic stocks – occasional large year classes			Sprat 22-32	
S/R signal	4 Clear change point (slope line and plateau)		Cod 22--24	
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)		Cod in Kattegat Herring 25-32 (Herring Riga) Herring 30	
	6 Inverse S/R relation (there seems to be a negative slope)			
No S/R signal,	7 Distinct plateau (wide range of SSB)	Sole IIIa	Cod 25-32	
	8 No apparent plateau (narrow range of SSB)			

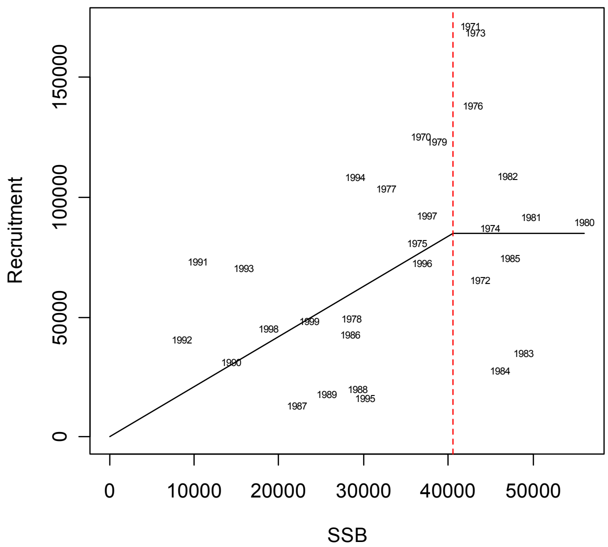
4.3.1 General comments

Analyses of new segmented regression in case of Baltic stocks in general show that at present it is worthwhile to maintain the previously defined reference points. The reason for this mainly is that the S-R relationships have time-series effects and the recruitment for many stocks has been demonstrated to be driven by environmental factors. Taking this into account it is considered that the method described above should be implemented taking a stock-specific approach regarding environmental changes into account. The problems with regime shifts were discussed in section 2.1 above.

It seems that the segmented regression of most of the Baltic stocks gives very high change points. This is the case for both of the cod stocks and for all the herring stocks. For sprat the change point is more in line with the present $\mathbf{B}_{lim}$ values. Species interactions in the Baltic Sea have in the recent 2 decades been intensively studied and it is now established that there are significant effect from 1) cod predation on sprat, herring and juvenile cod, 2) sprat and herring predating on cod eggs, 3) reproductive volume influencing cod recruitment, 4) (with less certainty) sprat and herring interactions with its zooplankton food items and 5) (with even less certainty – close to speculation) an inverse relationship between herring and sprat. There seems to be two semi-stable ecosystem states: one dominated by sprat and one dominated by cod (see for instance Köster et al. 2001a and 2001b). It is striking that only for sprat are these interactions reasonable well incorporated into the analysis used for getting the SSB-R values used in the present context and only for sprat are the revised $\mathbf{B}_{lim}$ in line with the old value. The revised PA reference points for the Baltic stocks would probably benefit from being analysed in a multispecies context taking into account reproductive volume and maybe other environmental conditions.

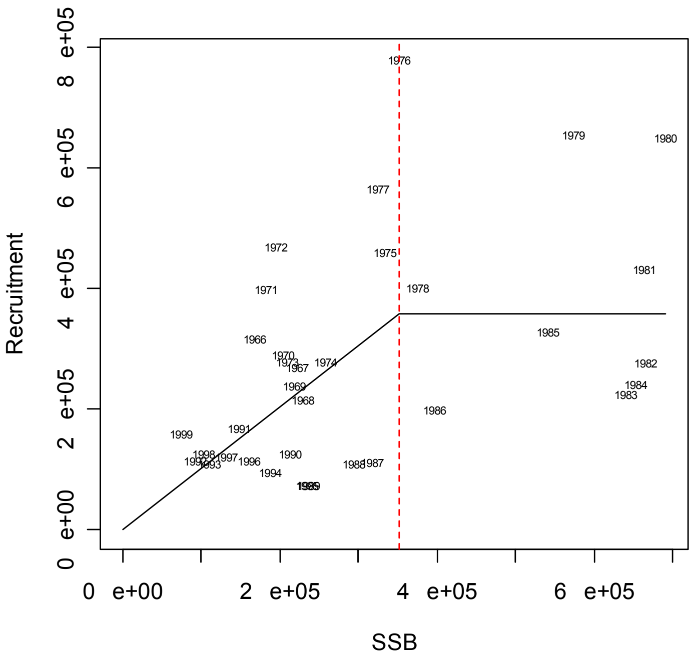
4.3.2 Cod in SD 22-24

The segmented regression is not significant. The S-R reveals time-series effects e. g high recruitment during 1970's compared to more recent decades. This presumably reflects environmental influences on recruitment, although these have not been described for this stock. $\mathbf{B}_{lim}$ obtained with segmented regression is 40000 t that is substantially higher then the existing $\mathbf{B}_{pa}$ =23000 t. This stock indicates some S-R signal, but further evaluation of an appropriate method to define PA points is required.



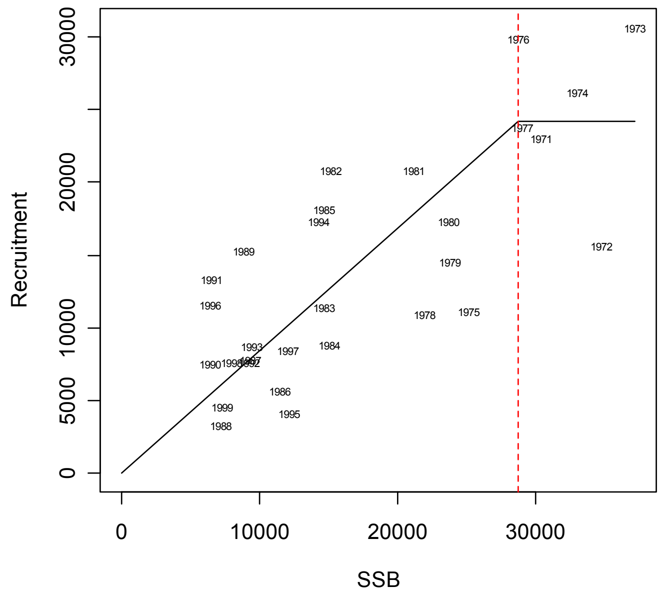
4.3.3 Cod SD 25-32

The segmented regression is highly significant. The S-R data reveals time-series effects which are linked to well-studied environmental regime changes in the Baltic. As a result, the stock-recruitment data are not informative about the form of the relationship between stock-size and recruitment. The estimate of the change point (345,000 t) is far above the existing $\mathbf{B}_{pa}$ (240,000.t), and reflects a period of high stock productivity due to favourable environmental conditions, and not a reduction in recruitment due to reduced stock size. Due to this it would be appropriate to investigate the possibility of F-based LIMIT points, because of the documented strong influence of environmental effects on recruitment, but this would require development of a new framework to deal with regime shift situations as discussed in section 2.1.



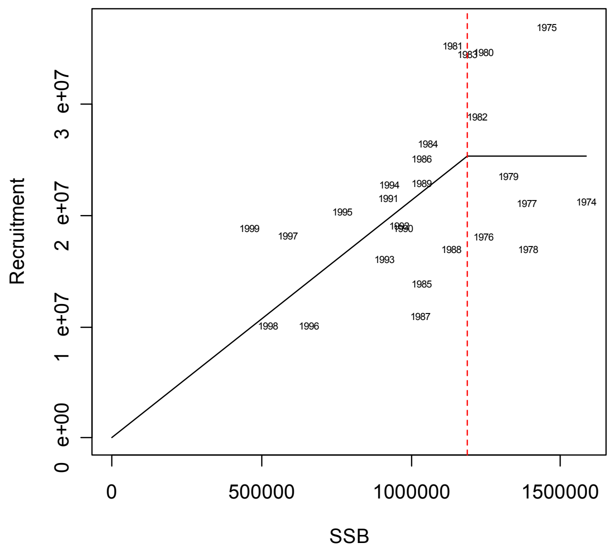
4.3.4 Cod in Kattegat

The segmented regression is highly significant. The S-R data reveal a linear pattern and it is not very informative about the placement of a change point. The regression is significant and there is a clear S-R signal but the change point estimate (28,700 t) is not realistic, because it is close to the highest observed biomass and thus poorly estimated. The exploitation level has been high for most of the historical records of this stock and it may thus be considered that the biomass reference points have been bypassed before the start of historical data. There is thus a need to revaluate the reference points for this stock.



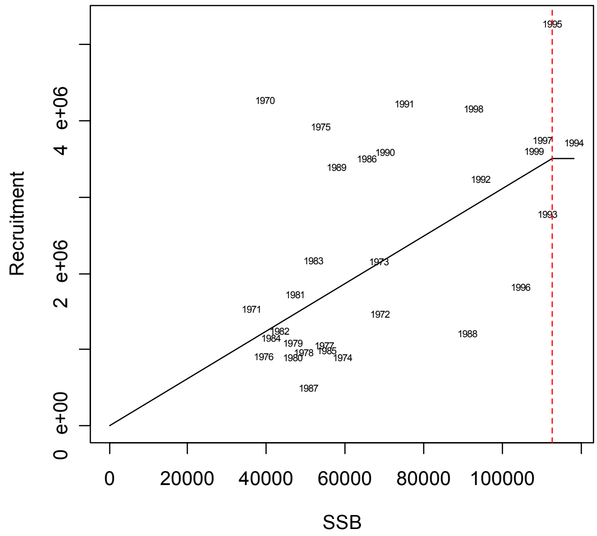
4.3.5 Herring in SD 25-29+32 without Gulf of Riga

Biomass reference points have not been defined for this stock. The segmented regression is highly significant but results reveal similar patterns as for some other stocks in the region: 1) there is a time-series effect in the S-R relationship, 2) the change point is close to maximal observed recruitment and thus poorly estimated. For estimation of $\mathbf{B}_{\mathrm{lim}}$ a stock-specific approach may be appropriate.



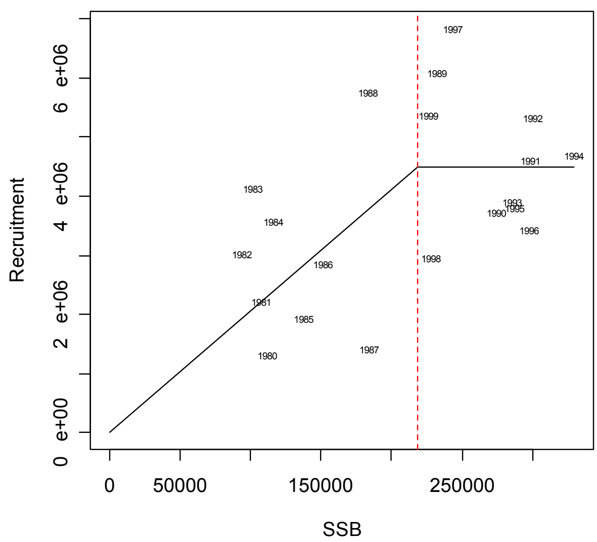
4.3.6 Herring in the Gulf of Riga

The recruitment it mainly driven by environment, revealing strong time-series effect and weak S-R relationship. The change point estimate (113,000.t) from the standard method is far above the previous $\mathbf{B}_{\text{lim}}$ (36,500 t) and is very close to maximum observed SSB and highest recruitment and is thus poorly estimated. It is not clear whether there is a signal in the S-R relationship. The historical data includes several years with low exploitation and there is therefore no reason to expect a situation where the change point should be at the far right or outside the range of the plot. Taking the weak S-R relationship, the low exploitation for a large part of the data period and the environmental influence into consideration there is no basis for changing the reference points.



4.3.7 Herring in SD 30 (Bothnian Sea)

The segmented regression is significant. The S-R relationship has strong time-series effect. The obtained change point value (218,000 t) substantially exceeds the existing $\mathbf{B}_{\text{lim}}$ (145,000 t) and is close to the present $\mathbf{B}_{\text{pa}}$ (200,000 t). The change point value is only a short distance from the observed maximum SSB values and near to maximum recruitment and is poorly estimated. Due to this it is necessary to find an adequate new method for defining reference points for this stock.

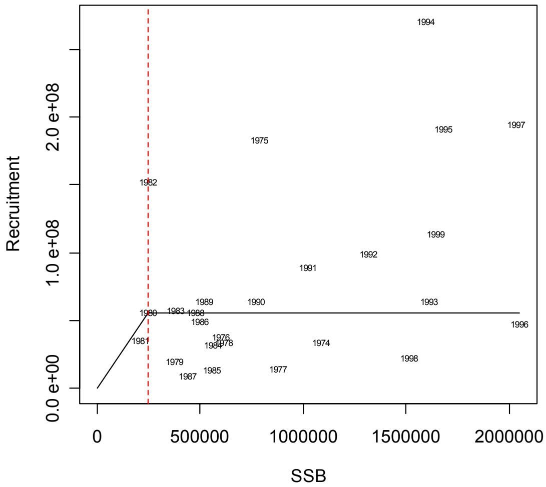


4.3.8 Herring in SD 31 (Bothnian Bay)

The segmented regression is insignificant (P=0.75). There is no S-R relationship mainly because recruitment is driven by environment. As the present assessment with XSA is very unstable the $\mathbf{B}_{\mathrm{lim}}$ estimation for this stock is not possible.

4.3.9 Sprat in SD 22-32

The segmented regression is insignificant (P=0.45). Recruitment has extreme year classes dependent from environment (temperature) and the S-R relationship is poorly determined. Although segmental regression analyses reveal slightly higher $\mathbf{B}_{\mathrm{lim}}$ (246 000 t) value which are on range of present $\mathbf{B}_{\mathrm{pa}}$ (250 000 t) and because $\mathbf{B}_{\mathrm{loss}}$ (209 000 t) is close to previous $\mathbf{B}_{\mathrm{lim}}$ (200 000 t), it is suggested to maintain the previously defined reference points.



4.3.10 Sole Division IIIA

Segmented regression is insignificant (P=0.38). There is no S-R relationship for this stock and $\mathbf{B}_{\mathrm{lim}}$ could be set equal to $\mathbf{B}_{\mathrm{loss}}$. The values obtained from segmented regression analyses of $\mathbf{B}_{\mathrm{lim}}$ and $\mathbf{B}_{\mathrm{loss}}$ is very similar, 922,000 and 909,000 t respectively. Taking into account insignificance of segmental regression analyses there are no reasons for changing previously defined $\mathbf{B}_{\mathrm{lim}}$ (770,000 t).

4.3.11 Flounder in Sd 24-25

Segmented regression is insignificant (P=0.42). There is no S-R relationship for this stock. Taking into account that the present XSA assessment very unstable the $\mathbf{B}_{\mathrm{lim}}$ estimation is not possible.

4.4 AFWG – Arctic Fisheries Working Group

Stock type	S/R plot characteristics	$\mathbf{B}_{\mathrm{lim}}$ estimation possible according to standard method	$\mathbf{B}_{\mathrm{lim}}$ estimation possible on basis of stock-specific method or judgement	$\mathbf{B}_{\mathrm{lim}}$ estimation not possible
1 Data poor situation				
2 Short-lived 1-time spawners				
3 Spasmodic stocks – occasional large year classes			NEA haddock	
S/R signal	4 Clear change point (slope line and plateau)	NEA cod	NEA Gr. halibut	
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			

	6 Inverse S/R relation (there seems to be a negative slope)			
No S/R signal,	7 Distinct plateau (wide range of SSB)	NEA saithe		
	8 No apparent plateau (narrow range of SSB)		Norw. coastal cod	

4.4.1 Northeast Arctic cod

The Noetheast Arctic cod is the only stock dealt with in this report which has been analysed in detail in a dedicated study group (Anon 2003b). Due to the better analysis available it is dealt with in some detail here.

The State Committee for Fisheries of the Russian Federation August 2000 requested that ICES reviewed the MBAL of 500 thousand tonnes. A revision of historic data on maturity and weights-at-age was ready during the first part of the 2001 WG, and the new data were applied in the assessment (ICES 2001/ACFM:19). The long-term mean SSB to decrease from 577,425 t to 372,934 t. This affected the historic stock-recruitment relationship, and spawning biomasses associated with some historic recruitment were estimated to be lower, suggesting that the current biomass reference points could be too high. The WG proposed a $\mathbf{B}_{\mathrm{lim}}$ at 140,000 tons, since SSBs below that value had produced only poor year classes. It was further argued that the safety margin between $\mathbf{B}_{\mathrm{lim}}$ and $\mathbf{B}_{\mathrm{pa}}$ should take due account of the consistent pattern of overestimating the stock seen for many years. $\mathbf{B}_{\mathrm{pa}}$ was therefore estimated by the formulae: $\mathbf{B}_{\mathrm{pa}} = \mathbf{B}_{\mathrm{lim}}\ e^{1.645\,\sigma} \times 1.4$ where 1.4 is a bias correction factor reflecting the degree to which the converged SSB values had deviated from the non-converged values on average. σ represents the fractional coefficient of variation of the assessment. By assuming a value of 0.4 for σ the estimated value of $\mathbf{B}_{\mathrm{pa}}$ was 378,000 tonnes. On this basis a $\mathbf{B}_{\mathrm{pa}}$ of 375,000 tons was proposed.

ACFM at its May 2001 meeting (ICES 2001/ACFM:19), however, pointed out that the new data appeared better to separate the strong environmental impact on recruitment from the biological productivity of the stock, and that the pattern suggested that the biological productivity of the stock at low SSB may be lower than previously thought, and this way may affect the selection of the reference points. ACFM therefore decided that rather than revising the reference points that year and again next year when new analysis would further separate environmental and biological contributions to stock productivity, ICES would continue to advise using the previous reference points.

A scientific peer review of the 2001 assessment for NEA cod (Beckett and Serra 2001), requested by The Norwegian Ministry of Fisheries, commented that “there appear to have been signified changes in growth and maturation rates during this period. In consequence, if these changes are real, it would seem questionable as to whether the full time-series of SSB values should be used, at least until more is known of the biological and physical processes”. They also illustrated that the SSB/R plot for the period after 1980 differed from the earlier period. However, “The reviewers would endorse ACFM’s advice to delay adopting a new value for $\mathbf{B}_{\mathrm{pa}}$ until further analyses have been undertaken.”

In December 2001 The State Committee for Fisheries of the Russian Federation requested a revision of $\mathbf{F}_{\mathrm{pa}}$ for NEA cod. It was referred to the proposed new $\mathbf{B}_{\mathrm{pa}}$ of 375,000 tons and argued that since $\mathbf{B}_{\mathrm{pa}}$ and $\mathbf{F}_{\mathrm{pa}}$ are interrelated mathematically it is natural to “specify $\mathbf{F}_{\mathrm{pa}}$ with reference to the adjusted $\mathbf{B}_{\mathrm{pa}}$”. The present values of $\mathbf{B}_{\mathrm{pa}}$ and $\mathbf{F}_{\mathrm{pa}}$ for NEA cod are, however, not interrelated mathematically, as is the case for a number of stocks. Neither is it straightforward to make them mathematically interrelated.

During the March 2002 meeting of the Study Group on the Further Development of the Precautionary Approach to Fishery Management (ICES 2002/ACFM:10) both reference points and environmental effects were on the agenda. A new objective method for identifying the value of SSB below which recruitment is impaired (change-point) was presented (O’Brien and Maxwell, WD to SGPA March 2002), and the method was applied to NEA cod for both the whole time-series of stock-recruitment data (1946-1997) and the first and second part separately, split in 1975. The splitting of the time-series had a considerable effect on the value of the estimated change-points, the one for the last period was about the double the first one. Splitting of a time-series, however, requires a good justification, i.e. plausible hypotheses for mechanisms or best some evidence for the hypotheses.

In ToR b) the 2002 AFWG (ICES 2002/ACFM:18). was asked to evaluate the agreed management strategy for cod, with special attention to the reference points for spawning stock biomass and fishing mortality. A group of scientists and managers, nominated by the Russian-Norwegian Fishery Commission, was at that time dealing with the management strategy and the WG did not address that issue.

The WG agreed that there was a need to evaluate the current values of reference points in light of the revised SSB time-series and improved knowledge about stock dynamics. The WG was, however, unable to develop and evaluate candidate values of reference points at this years meeting in addition to its normal assessment responsibilities. Instead, it was decided that a dedicated study group that would meet before the next AFWG meeting in 2003 should undertake this work.

Thus, the AFWG recommended that a study group on biological reference points for Northeast Arctic cod (Chair: Yuri A. Kovalev, PINRO) should meet in Svanhovd, Norway from January 13 2003 to January 17 2003. The terms of reference were:

a) determine the most appropriate time period for estimating biomass and fishing mortality reference points;
b) specify the technical basis for the reference point calculations;
c) establish reference points based on a) and b). In the event that agreement is not reached on points a) and b) different alternatives will be formulated and compared.

ICES agreed to establish such a study group. The study group, SGBRP (ICES CM 2003/ACFM:11), agreed on the use of the full time-series and the numbers-at-age 5 as the recruitment index until more accurate estimates of the number-at-age 3 are available. Although several good biological and environmental arguments were raised concerning a shift in the stock around 1980, the SG did not find the evidence strong enough to support the use of the shortened time-series at the present time. The discarding problem alone is a strong enough reason for not using the full time-series for recruitment at age 3. The SG therefore agreed on the use of number-at-age 5 as the recruitment index in order to minimise the problems introduced by discarding and cannibalism. The reference points determined here are therefore considered to be provisional until the effect of discarding on stock dynamics can be fully resolved or further analysis shows that recruitment at age 5 is as appropriate as age 3 for estimation of the $\boldsymbol{B}_{lim}$.

The framework implemented for establishing new reference points was mainly the one proposed by SGPA at its December 2002 meeting (Anon 2003a); namely:

- To identify whether the existing reference points suffer from inconsistency, uncertainty, model structure, or regime issues, and identify what remedial action is needed.
- To fit a segmented regression to estimate $\boldsymbol{B}_{lim}$.
- To estimate $\boldsymbol{F}_{lim}$ from $\boldsymbol{B}_{lim}$.
- To estimate $\boldsymbol{F}_{pa}$ from $\boldsymbol{F}_{lim}$.
- To estimate $\boldsymbol{B}_{pa}$ from $\boldsymbol{B}_{lim}$ and $\boldsymbol{F}_{pa}$

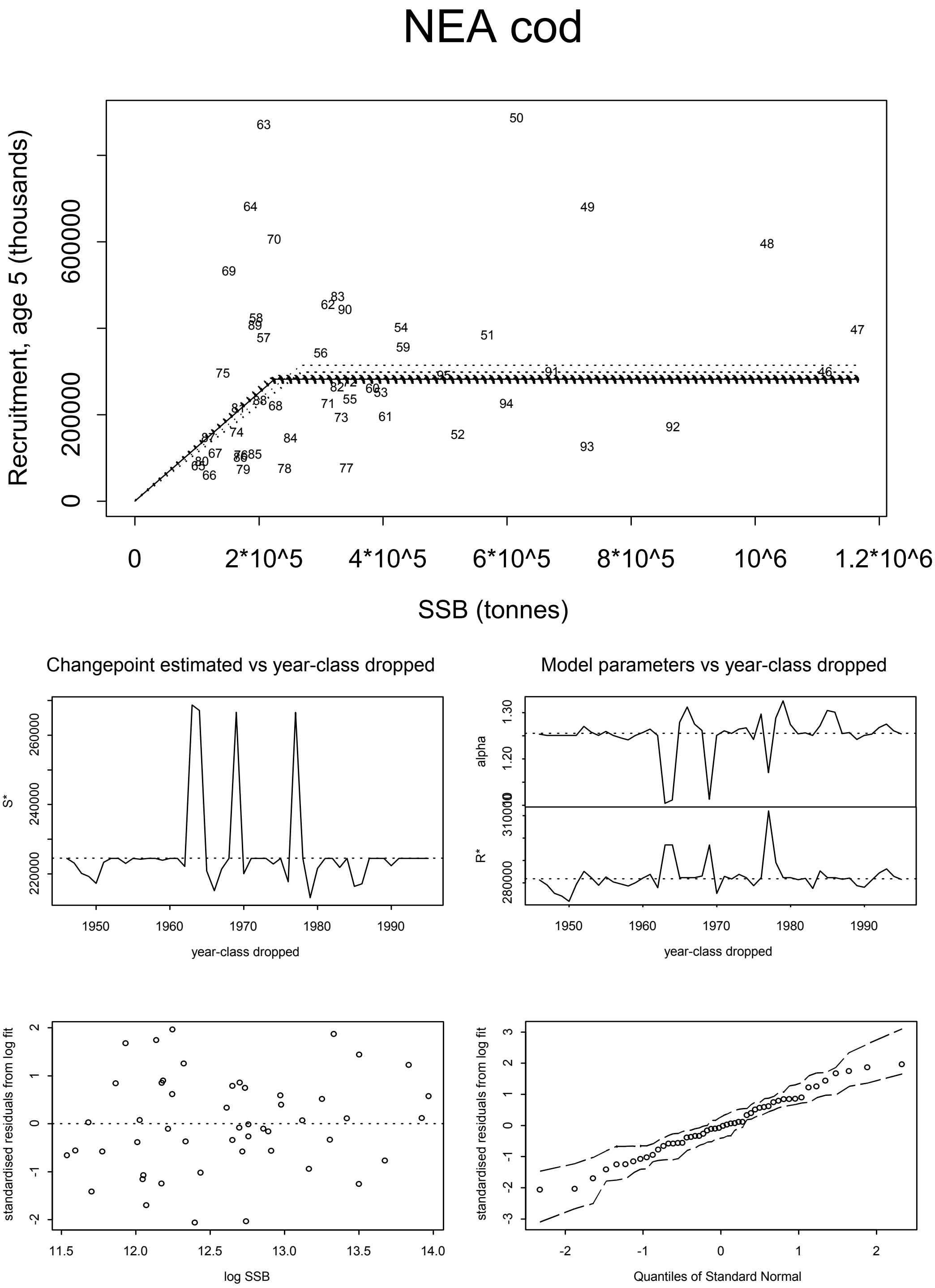
The results of the segmented regression was statistically significant at p=0.01 and implied a substantial revision to $\mathbf{B}_{\mathrm{lim}}$.

a)

From algorithm in Julious (2001)				From search on 500x500 grid		
S*	$\hat{\alpha}$	R*		S*(10)	S*	S*(90)
224482	1.26	281832		190219	224252	306051

b)

Model	Resid df	RSS	Test df	Sum of sq	F value	Bootstrap
mean	49	22.36				p-value
changepoint	48	18.10	1	4.26	11.29	< 0.001



It is proposed that F_{lim} is derived from B_{lim} as a deterministic equilibrium value (ICES 2003b). The functional relationship between spawner-per-recruit and F will then give the F associated with the R/SSB slope derived from the B_{lim} estimate obtained from the segmented regression. Due to high variability, arithmetic means of proportion mature, weight in stock, weight in catch and exploitation pattern over the whole observation period (1946-2001) were used for calculating the spawner-per-recruit function.

For setting $\mathbf{B}_{pa}$ relative to $\mathbf{B}_{lim}$ the recommended procedure is (section 3.2.3 of ICES SGPA 02b):

… When the procedure in Section 3.2.2 is followed, SSB values in each terminal year (Bassm) are estimated as part of the assessment, and can be compared with the SSB estimated for that year using the reference data set (Btrue). To derive $\mathbf{B}_{pa}$, a ratio B_{assm}/B_{true} can be obtained in a way that is analogous to the usual procedure for deriving $\mathbf{F}_{high}$ from a stock-recruit plot: plot pairs of values of Bassm and Btrue pairs with Btrue as the independent variable. Draw a line through the origin so that □% of the points are above and (100-□) are below the line. Here □ is the acceptable risk,

which may be 10% or less, depending on the availability of the data. If the number of pairs is small, the highest line passing through a point should probably be used, unless this is a clear outlier. The slope □ of the line is the ratio between $\boldsymbol{B_{pa}}$ *and* $\boldsymbol{B_{lim}}$*, thus* $\boldsymbol{B_{pa}}$ *= □ **$\boldsymbol{B_{lim}}$*.*

Since the retrospective predictions also gives pairs of SSBs (Bpred and Bobs, as described in section 3.4.2), this could be used to get similar ratios for the predictions, thereby including the effect of prediction errors. With 12 points the highest observed Bpred/Bobs ratio would be a reasonable candidate for $\mathbf{B}_{pa}/\mathbf{B}_{lim}$ ratio. These ratios are quite dependent on the intended F and a fitting of max ratios was needed to able to estimate the max ratio corresponding to a given F. Since the standard ICES advice is restricted to Fs at or below $\mathbf{F}_{pa}$, the max Bpred/Bobs ratio at $\boldsymbol{F_{pa}}$ seems most relevant for establishing $\mathbf{B}_{pa}$.

The current reference points used by ICES are:

Reference points (1998)
source: ICES CM 2001/ACFM:19

ICES considers that:	**ICES proposes that:**
$\mathbf{B}_{lim}$ is 112 000 t, the SSB below which no above-average year classes have been observed	$\mathbf{B}_{pa}$ is set at 500 000 t, the value below which the probability of below-average year classes increases
$\mathbf{F}_{lim}$ is 0.70	$\mathbf{F}_{pa}$ be set at 0.42. This value is considered to have a 95% probability of avoiding the $\mathbf{F}_{lim}$

Technical basis:

$\mathbf{B}_{lim} = \mathbf{B}_{loss}$	$\mathbf{B}_{pa}$ = examination of stock-recruit plot
$\mathbf{F}_{lim}$ = Median value of $\mathbf{F}_{loss}$	$\mathbf{F}_{pa} = 5^{th}$ percentile of $\mathbf{F}_{loss} = \mathbf{F}_{lim} * 0.6$ from $\mathbf{F}_{pa} = \mathbf{F}_{lim}\, e^{-1.645\sigma}$ with $\sigma = 0.3$

At the meeting of the SGBRP, provisional revised estimates were calculated and these estimates are presented in the following table:

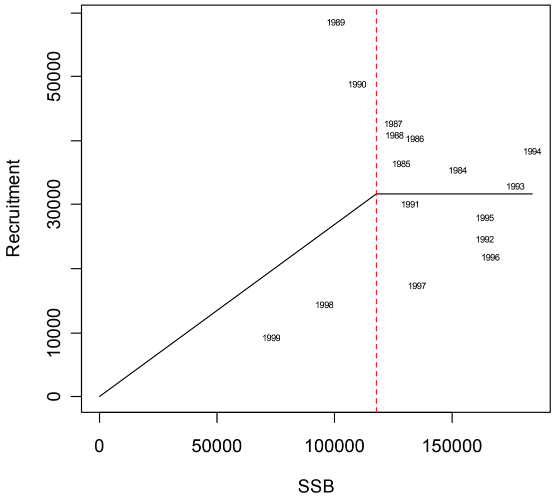
Reference points proposed at the meeting of SGBRP (2003)
source: provisional

SGBRP considers that:	**SGBRP proposes that:**
$\mathbf{B}_{lim}$ is 220 000 t	$\mathbf{F}_{sq}$: $\mathbf{B}_{pa}$ is set at 460 000 t TAC-constraint: $\mathbf{B}_{pa}$ is set at 550 000 t
$\mathbf{F}_{lim}$ is 0.74	$\mathbf{F}_{sq}$: $\mathbf{F}_{pa}$ be set at 0.40 TAC-constraint: $\mathbf{F}_{pa}$ be set at 0.35

The SGPRP recommends that the LIMIT revised reference points be adopted for NEA cod, while the appropriate PA-reference points be adopted upon clarification of the acceptable method for calculation.

4.4.2 Norwegian Coastal cod

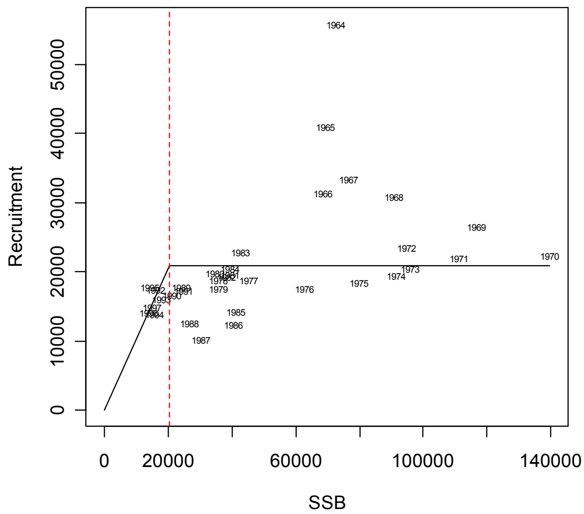
The result of the segmented regression is not statistically significant. The most recent recruitment values are very influential in the segmented regression, since recruitment is at age 2, the analysis should not include the final 2 data pairs since the assessment is still unstable. This would result in a completely different pattern in any potential S-R relationships.



4.4.3 Northeast Arctic Greenland Halibut

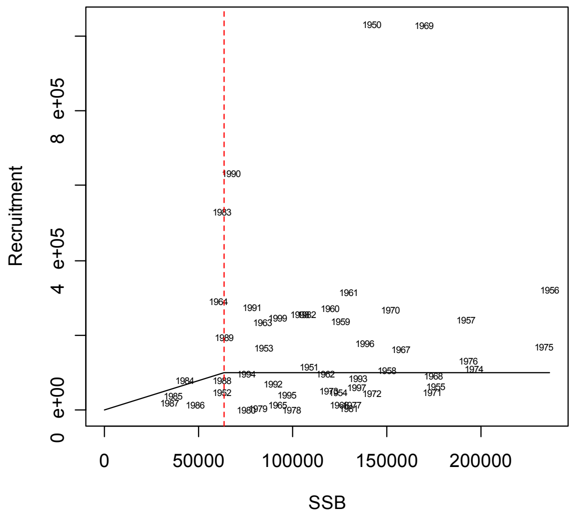
The result of the segmented regression is statistically significant. Recruitment is measured at age 5. Change point is above the most recent data points. Recruitment in 2002 is the mean of recruitment from 1990-1998, and the analysis should be done with the final 3 data pairs removed since the assessment is still unstable. While there is a clear S-R signal, the removal of these points would change the potential reference points considerably.

The basis is unclear but a $\mathbf{B}_{lim}$ should be established since there is a S/R signal. AFWG should review this, but it is largely an investigation to seek for adequate methodologies.



4.4.4 Northeast Arctic Haddock

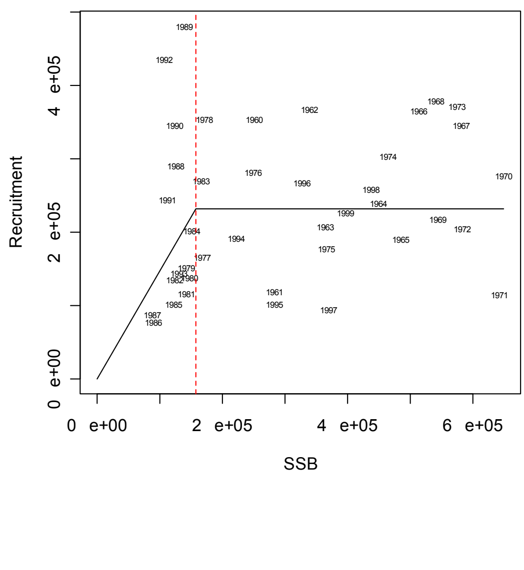
The result of the segmented regression is not statistically significant. There are very high recruitment variations and four extremely high year classes. Category: spasmodic stocks, special consideration.



4.4.5 Northeast Arctic Saithe

While the result of the segmented regression is statistically significant, there is not a very strong stock-recruitment relationship. Also, the two highest historical recruitment values are observed below the change point. There are strong retrospective trends in both the assessment and the change point estimation and the analysis is sensitive to individual data points. The retrospective trend in the assessment has also changed over the years from overestimation to underestimation of the stock in the assessment year. The tuning series applied today are too short to cover this period, and it is therefore not straight forward to estimate robust reference points using the proposed framework.

There may be basis for changing PA reference points given recent change in minimum landing size. AFWG should look into this, but given the state of the stock there is no urgent need to change any reference point.



4.5 NWWG – North Western Working Group

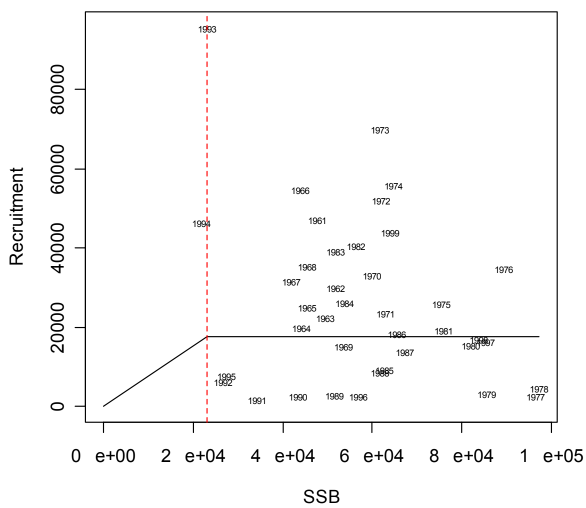
Stock type	S/R plot characteristics	B_{lim} estimation possible according to standard method	B_{lim} estimation possible on basis of stock-specific method or judgement	B_{lim} estimation not possible
1 Data poor situation				
2 Short-lived 1-time spawners				
3 Spasmodic stocks – occasional large year classes				
S/R signal	4 Clear change point (slope line and plateau)	Icelandic cod stock		
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			
	6 Inverse S/R relation (there seems to be a negative slope)			
No S/R signal,	7 Distinct plateau (wide range of SSB)	Faroe cod Faroe haddock Icelandic saithe		
	8 No apparent plateau (narrow range of SSB)		Faroe saithe Icelandic haddock	

4.5.1 Faroe cod

The segmented regression method gives no change point for this stock. The $\mathbf{B}_{loss}$ is estimated to be 22,000 t. ICES has previously defined $\mathbf{B}_{lim}$=$\mathbf{B}_{loss}$=21,000 t. There is thus no reason to change the basis of $\mathbf{B}_{lim}$.

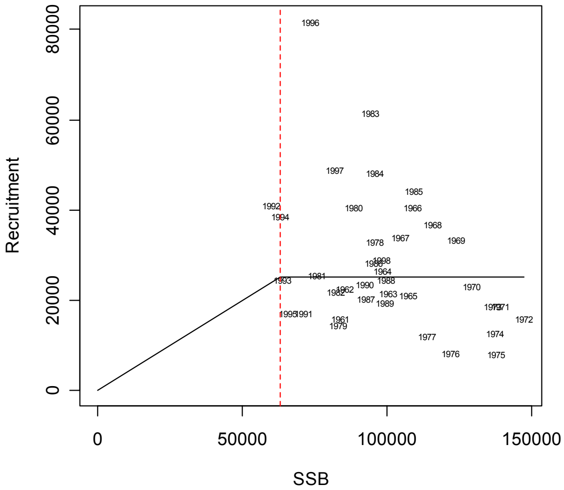
4.5.2 Faroe haddock

The segmented regression method gives no change point for this stock. The $\mathbf{B}_{loss}$ is estimated to be 22,000 t. ICES has defined $\mathbf{B}_{lim}$ = MBAL = 40,000 t. It is likely that the MBAL was established prior to the observations of the large 1993 and 1994 year classes [xxx COULD THIS BE CHECKED]. Given the dynamics of recruitment patterns observed, including the observation that two large year classes were established at the $\mathbf{B}_{loss}$, it is suggested that the derivation of $\mathbf{B}_{lim}$ should be revisited. According to the "standard method" $\mathbf{B}_{loss}$ could be a candidate for $\mathbf{B}_{lim}$. Revision of the $\mathbf{B}_{lim}$ reference point should thus be addressed by the working group.



4.5.3 Faroe saithe

The segmented regression method gives no change point for this stock. The $\mathbf{B}_{loss}$ is estimated to be 60,000 t. ICES has previously defined $\mathbf{B}_{lim}$=$\mathbf{B}_{loss}$=60,000 t. In the light of the relatively narrow range of SSB it was proposed that the $\mathbf{B}_{loss}$ estimates could be a candidate for $\mathbf{B}_{pa}$. This should also be checked against alternative derivations of reference points, such as SSB at FX%SPR values [xxx explain this]. Revision of the $\mathbf{B}_{lim}$ reference point should thus be addressed by the working group.



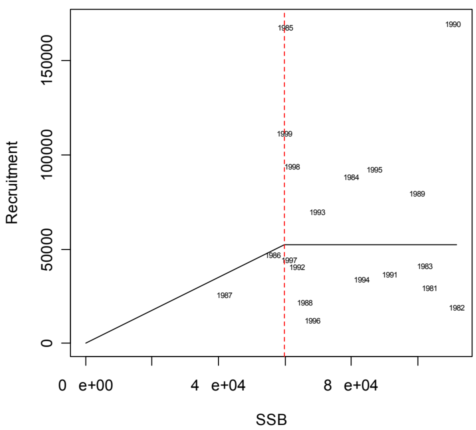
4.5.4 Icelandic cod

The SSB/R data on the Icelandic cod are one of the clearest examples of reduced recruitment below a certain spawning stock biomass. Number of methods, visual as well as more objective ones, indicate that the $\mathbf{B}_{lim}$ is somewhere in the range of 400kt.

Change point regression analysis gives a point estimate at 414,000 t with a high p-value. There are however strong negative time trends in the R-residuals. Although change in environmental regime cannot be excluded, preliminary analysis indicate that by using a different (and more realistic) definition of the SSB the time trend in the residuals decrease. Setting of $\mathbf{B}_{lim}$ reference point should be addressed by the working group.

4.5.5 Icelandic haddock

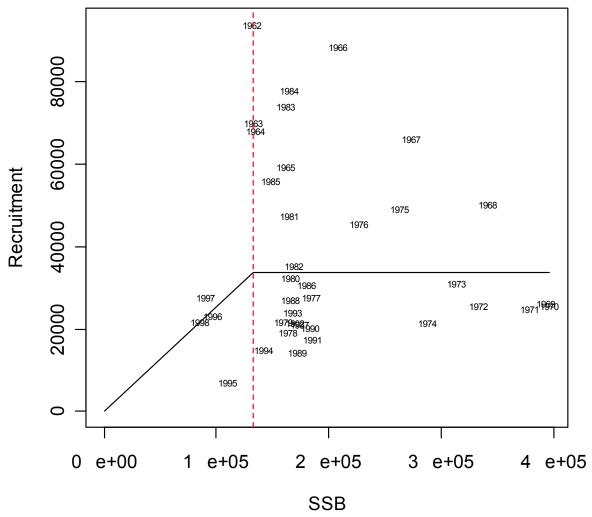
The segmented regression analysis indicate that the change point (S*=69,000 t) for this stock is poorly defined and only two data points are below the change point. $\mathbf{B}_{loss}$ is 42,000 t. The dynamic range of SSB is relatively narrow and SSB is calculated based on survey maturity and weight-at-age, which in combination may suggest that the $\mathbf{B}_{loss}$ may be a candidate for $\mathbf{B}_{pa}$. This should also be checked against alternative derivations of reference points, such as SSB at FX%SPR values. Setting of $\mathbf{B}_{lim}$ reference point should be addressed by the working group.

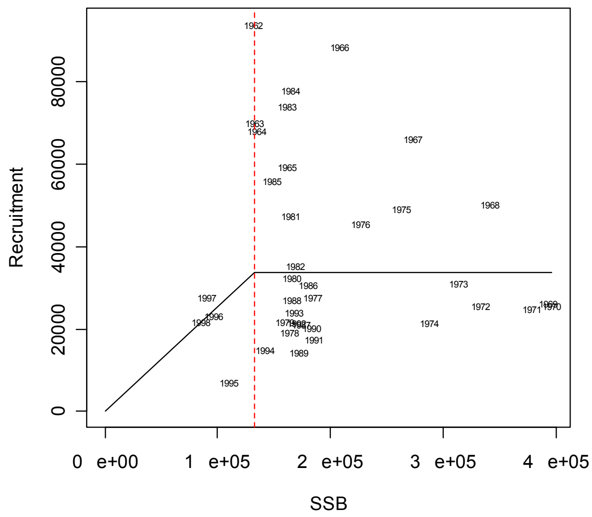


4.5.6 Icelandic saithe

The segmented regression for Icelandic saithe was run on two similar datasets both extending from 1962 to 1998 (WD #6: Sigurður Jónsson). One incorporated migration estimates restricted to the latter part of the period while in the other all migrations were ignored. The estimated values of the change point were 133,000 t for the first data set but 103,000 T for the second data set, neither significantly different from $\mathbf{B}_{loss}$. The saithe data show extended periods of high and low recruitment so serial correlation in residuals from the SSB-R relationship was also included. The serial correlation was highly significant in both datasets and the estimated change point was at $\mathbf{B}_{loss}$ for both data sets but with wider error margin. $\mathbf{B}_{loss}$ is estimated to be 84,000 t. ICES defined $\mathbf{B}_{lim}$=$\mathbf{B}_{loss}$=90,000 t. Revision of the $\mathbf{B}_{lim}$ reference point should thus be addressed by the working group, especially in light of migrations only being estimated for the latter part of the time-series.

Xxx the two plots below (from the two sets in total file) seem to be from the same run and do not correspond to the text. xxx



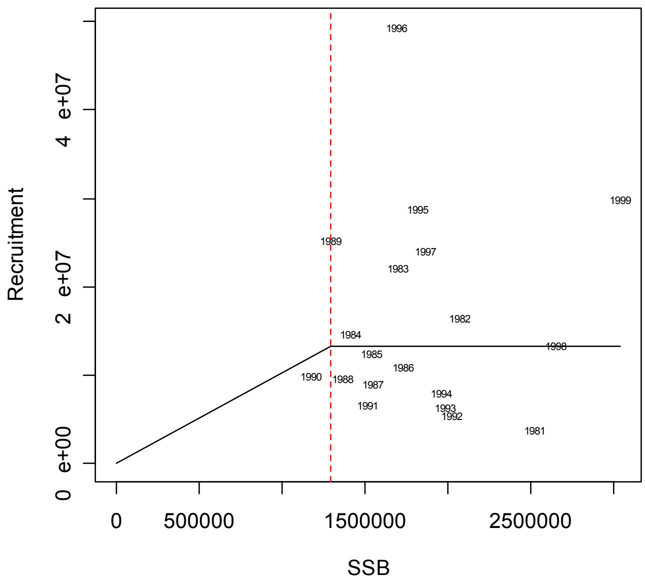


4.6 WGNPBW - Northern Pelagic and Blue Whiting Fisheries Working Group

Stock type	S/R plot characteristics	$\mathbf{B}_{lim}$ estimation possible according to standard method	$\mathbf{B}_{lim}$ estimation possible on basis of stock-specific method or judgement	$\mathbf{B}_{lim}$ estimation not possible
1 Data poor situation				
2 Short-lived 1-time spawners				
3 Spasmodic stocks – occasional large year classes			Norwegian spring spawning herring	
S/R signal	4 Clear change point (slope line and plateau)		Icelandic herring	
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			
	6 Inverse S/R relation (there seems to be a negative slope)			
No S/R signal,	7 Distinct plateau (wide range of SSB)		Blue whiting	
	8 No apparent plateau (narrow range of SSB)			

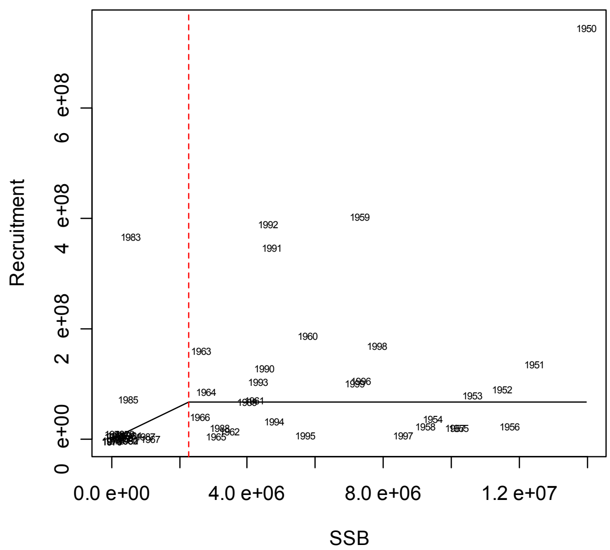
4.6.1 Blue whiting

The current $\mathbf{B}_{lim}$ a value of 1.5 million t is based on $\mathbf{B}_{loss}$. As the segmented regression was not significant, a $\mathbf{B}_{loss}$ was computed. It has the value of 1.2 mill. t. This value does not deviate very much from the old $\mathbf{B}_{lim}$ (1.5 million t) and as the assessments of the blue whiting are unstable, both current and historical, especially for the older years, there is no need to change the value of $\mathbf{B}_{lim}$.



4.6.2 Norwegian spring-spawning herring

The current $\mathbf{B}_{lim}$ a value of 2.5 million t is based on MBAL. The segmented regression was significant on a 5% level and gave a change point of 2.3 million t. As these numbers are close to each other and as this stock is managed to an agreed harvest control rule, there is no need to change the $\mathbf{B}_{lim}$ value.



4.6.3 Icelandic summer-spawning herring

The current $\mathbf{B}_{lim}$ has a value of 200,000 t (based on decline in recruitment). The recalculations available were based on data for only the 1982 to 1999 year classes. These year classes don't show any stock recruitment relationship. However, data exists for the icelandic summer-spawning herring back to 1947. A working document (WD3) was presented which repeated the segmented regression using the full time-series of data. This regression was significant at the 5% level, giving a change point of about 300,000 t, which is the current $\mathbf{B}_{pa.}$ The Icelandic summer-spawning herring is harvested at or close to $\mathbf{F}_{0.1}$. It can be argued that management by this low fishing mortality makes biomass reference points less appropriate and that it is therefore not considered relevant to change the $\mathbf{B}_{lim}$ from 200,000 t. However, in the past fishing mortality was very high and there is a case for closer inspection of PA reference points to safeguard against that situation again.

4.7 WGNSSK – Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak

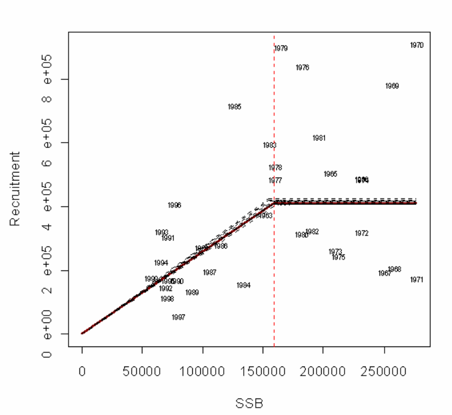
Segmented regression analysis were carried out for all the stocks for which analytical assessments are provided by the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK). The interpretation on the results is focussed on the estimation of change points from retrospective analysis. For each of the stocks a graph is supplied that shows the segmented regression line with different ending years for the assessment data. A comparison is made between the two different ways of calculating the change point (Julious method and grid-search method). More detailed output of the segmented regression analysis can be found in WD 1.

Results of the analysis are summarized in table 4.7.1 and in the text table below.

Stock type	S/R plot characteristics	$\mathbf{B}_{lim}$ estimation possible according to standard method	$\mathbf{B}_{lim}$ estimation possible on basis of stock-specific method or judgement	$\mathbf{B}_{lim}$ estimation not possible
1 Data poor situation				
2 Short-lived 1-time spawners				
3 Spasmodic stocks – occasional large year classes			Had-34	
S/R signal	4 Clear change point (slope line and plateau)	Cod-347d, Whg-47d		
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			
	6 Inverse S/R relation (there seems to be a negative slope)	Ple-IIIa		
No S/R signal,	7 Distinct plateau (wide range of SSB)	Ple-IV, San-IV, Sol-IV		For Sai-346 the analysis was considered invalid, to be updated by WG
	8 No apparent plateau (narrow range of SSB)		Sol-VIId Nop-IV, Ple-VIId,	

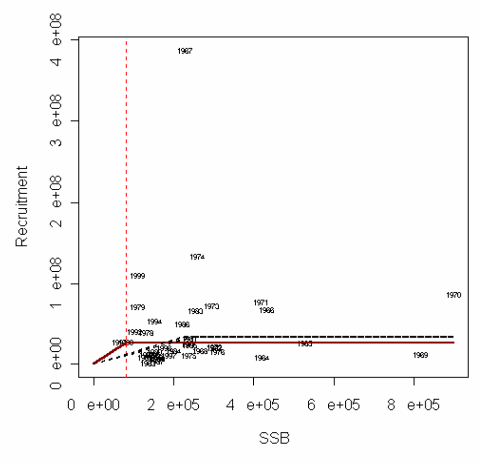
4.7.1 Cod in the North Sea, VIId and Skagerrak (cod-347d)

For cod in the North Sea, the segmented regression was significant ($p<0.01$). The change point was around 160 thousand tonnes and was not very sensitive to the addition of years in the retrospective analysis. See the conclusions sections for a more detailed discussion of the results for North Sea cod. The WG is requested to evaluate a change in reference points for North Sea cod. It should be noted that the change point indicated by the segmented regression – which is a $\mathbf{B}_{\text{lim}}$ candidate - is slightly above the present $\mathbf{B}_{\text{pa}}$.



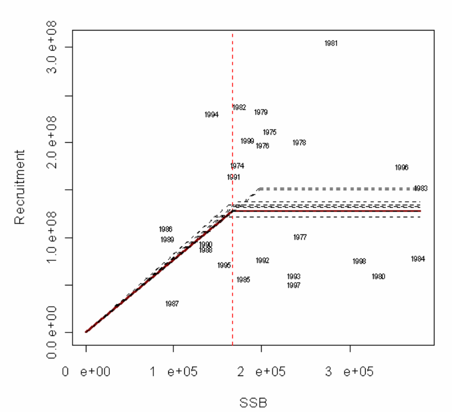
4.7.2 North Sea Haddock (had-34)

This stock shows a very high recruitment variation. There is one exceptional and two extremely high year classes. The segmented regression is not significant. There appear to be two different states of the change point which is dependent on the number of years included in the analysis. This stock is categorized as a spasmodic stock that merits special consideration for the estimation of $\mathbf{F}_{\text{loss}}$ rather than biomass reference points directly. The WG is requested to evaluate a change in reference points for North Sea haddock based on F reference points primarily.



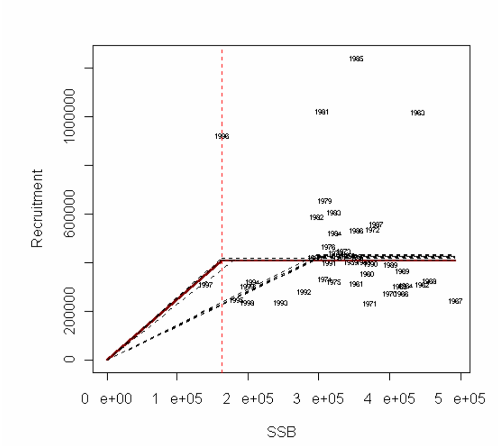
4.7.3 Norway pout

The segmented regression is not significant. The regression is sensitive to individual years being removed. There exists a trend in SSQ in the retrospective analysis. Classification: no S/R relationship and no indication of a plateau in the relationship. Given the exploitation history which includes a long range of recent years with low exploitation $\mathbf{B}_{\text{loss}}$ could be used as a proxy for $\mathbf{B}_{\text{pa}}$.. $\mathbf{B}_{\text{loss}}$ is close to the current $\mathbf{B}_{\text{lim}}$. The working group should review the situation.



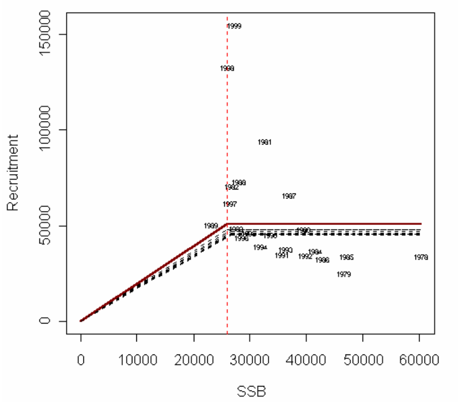
4.7.4 Plaice North Sea

The segmented regression is not significant. There appear to be two different states of the change point which is dependent on the number of years included in the analysis. The regression is sensitive to the addition of the 1996 data and onwards in the retrospective analysis. Classification: no S/R relationship and relatively large spread in SSB (use $\mathbf{B}_{\text{loss}}$ as proxy for $\mathbf{B}_{\text{lim}}$). Assessment has been substantially revised compared to the assessment that gave rise to the original estimate of $\mathbf{B}_{\text{lim}}$ (as $\mathbf{B}_{\text{loss}}$). The WG is requested to evaluate a change in reference points for North Sea plaice based on an updated value of $\mathbf{B}_{\text{loss}}$.



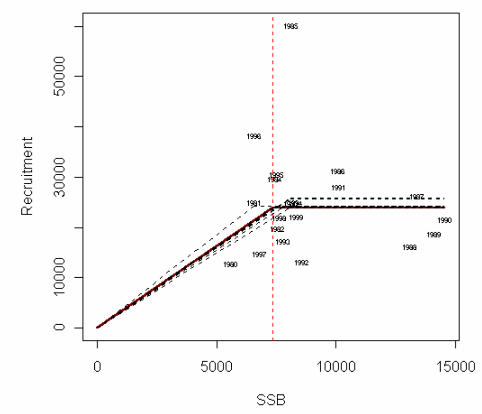
4.7.5 Plaice Skagerrak

The segmented regression is not significant. The regression is sensitive to the addition of the 1998 data and onwards in the retrospective analysis. Classification: Inverse relationship between SSB and R (use $\mathbf{B}_{\text{loss}}$ as proxy for $\mathbf{B}_{\text{pa}}$). The WG is requested to evaluate the $\mathbf{B}_{\text{loss}}$ as a potential $\mathbf{B}_{\text{pa}}$ for this stock.



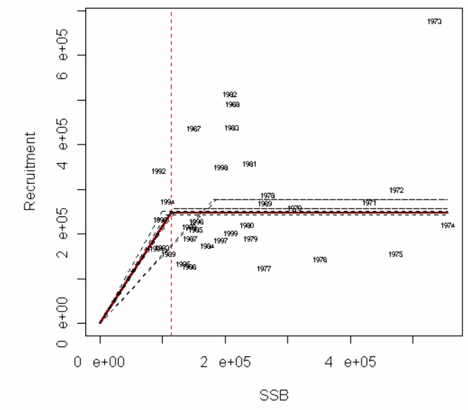
4.7.6 Plaice VIId

The segmented regression is not significant. Classification: no S/R relationship and no indication of a plateau in the relationship. Given the exploitation history which includes a long range of recent years with low exploitation $\mathbf{B}_{\text{loss}}$ could be used as a proxy for $\mathbf{B}_{\text{pa}}$.. $\mathbf{B}_{\text{loss}}$ is close to the current $\mathbf{B}_{\text{lim}}$. The working group should review the situation.



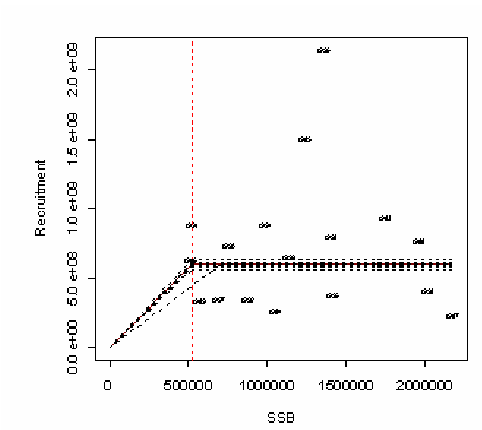
4.7.7 Saithe North Sea and VIa

The segmented regression is not significant. The analysis is also considered invalid because recruitment has been included up to the 1999 year class which is taken as a mean recruitment in the assessment. The analysis was sensitive to the addition of 1992 data and onwards in the retrospective analysis. There appear to be two different states of the change point which is dependent on the number of years included in the analysis. Classification: no S/R relationship and relatively large spread in SSB (use $\mathbf{B}_{loss}$ as proxy for $\mathbf{B}_{lim}$). However, because of the problems in the analysis mentioned above, a new analysis should be carried out with fewer years included. The WG is requested to carry out a new segmented regression analysis with the appropriate number of years included. The WG is requested to analyse a potential update of the $\mathbf{B}_{lim}$ reference point based on the $\mathbf{B}_{loss}$.



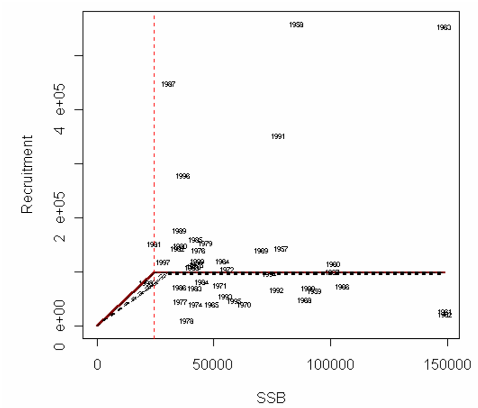
4.7.8 Sandeel

The segmented regression is not significant. The regression is sensitive to two individual years being removed; for all other years the change point appears to be constant. There is a clear upward trend in the residual SSQ in the retrospective analysis. Classification: no S/R relationship and relatively large spread in SSB (use $\mathbf{B}_{loss}$ as proxy for $\mathbf{B}_{lim}$). The WG is requested to evaluate a change in reference points for North Sea sandeel based on an updated value of $\mathbf{B}_{loss}$.



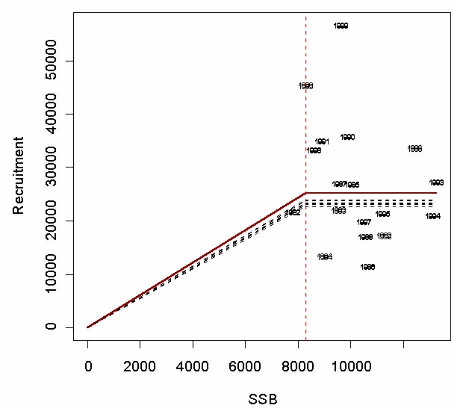
4.7.9 Sole North Sea

The segmented regression is not significant. There appear to be two different states of the change point which is dependent on the number of years included in the analysis. The regression is sensitive to the addition of the 1997 data and onwards in the retrospective analysis. Classification: no S/R relationship and relatively large spread in SSB (use $\mathbf{B}_{loss}$ as proxy for $\mathbf{B}_{lim}$). Given that the new $\mathbf{B}_{loss}$ is close to the old $\mathbf{B}_{lim}$, the current reference points can be maintained.



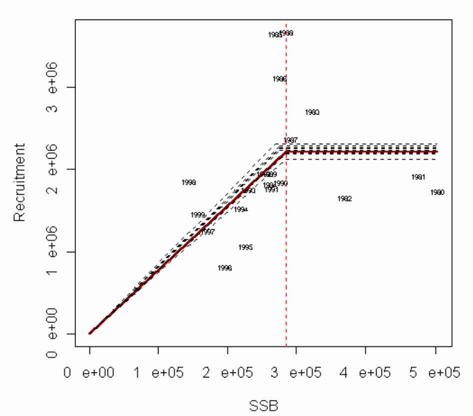
4.7.10 Sole Eastern Channel

The segmented regression is not significant. There appears to be only one state of the change point but with different slopes dependent on the number of years included in the analysis. The regression is insensitive to the addition of the data in the retrospective analysis. Classification: no S/R relationship and relatively narrow spread in SSB (use $\mathbf{B}_{loss}$ as proxy for $\mathbf{B}_{pa}$). The WG is requested to evaluate the $\mathbf{B}_{loss}$ as a potential $\mathbf{B}_{pa}$ for this stock.



4.7.11 Whiting North Sea

The segmented regression was considered significant ($p<0.01$). The change point was around 285 thousand tonnes. There is a clear upward trend in the residual SSQ in the retrospective analysis. If the change point would be interpreted as a $\mathbf{B}_{lim}$ point, this would imply a substantial revision of the reference point from 225,000 to 285,000 tonnes. The WG is requested to evaluate a change in reference points for North Sea whiting.



4.7.12 Conclusions

The segmented regression approach has not proven to be very successful for the stocks considered by this WG. For only two out of the eleven stocks, a significant regression could be shown. This indicates that the stock recruitment signal in the other stocks is not strong enough to be picked up by the segmented regression. This corroborates the general finding that it has been difficult to fit stock recruitment curves to these stocks.

The general finding that no significant regressions could be found for many of the stocks casts doubts about the applicability of medium-term projections for these stocks.

The two significant regressions that have been found are for North Sea cod and North Sea whiting. North Sea cod has received a substantial amount of scrutiny over the most recent years because of the rapid decline of the stock to well below the current $\mathbf{B}_{lim}$. The existing reference points for North Sea cod were established in 1998. $\mathbf{B}_{lim}$ (70,000t) was determined using a rounded $\mathbf{B}_{loss}$ (from the method of Cook) while $\mathbf{B}_{pa}$ (150,000t) was taken as the MBAL current at that time. These figures have provided a workable scale against which to judge the ongoing stock development.

In the period since setting these reference points, recruitments for cod have stayed low and the SSB has continued to decline; the most recent estimate suggests that SSB is around 38,000t. It is clear that for some time recruitment has been impaired and that this becomes increasingly evident in the structure of the stock and recruitment plot which shows a more or less steady decline to the origin.

An examination of the stock-recruitment plot shows that recruitment impairment has been occurring some way above the existing $\mathbf{B}_{lim}$. Whereas within the ICES precautionary approach framework, $\mathbf{B}_{lim}$ is by definition taken to indicate a point below which impairment occurs. There is clearly an issue to address here and the current $\mathbf{B}_{lim}$ is inappropriate. On basis of new evidence in the data which have been added since the 1998 the WG should consider the change point of 160,000 tonnes as a potential candidate for $\mathbf{B}_{lim}$ and investigate the consequences in terms of PA points for this stock.

Table 4.7.1 Summary of segmented regression analysis for stocks in the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK).

Stock	Blim	Julious			Gridmethod		Bloss	Remark	Revision	Data category	Blim category	Bloss/ Bseg	Bseg/ Blim	Julious/ grid
		Changepoint	slope	**P value**	Changepoint	slope								
Cod N. Sea	70000	159354	2.58	**<0.01**	159444	2.58		***	substantial	3	1		2.3	0%
Haddock N. Sea	100000	81400	320.27	0.56	**63837**	**405.71**	63500	not significant	lower	6	2	0.78	0.8	**28%**
N.pout N. Sea	90000	167172	767.57	**0.05**	166959	768.28	89435	**	Use Bloss	5	1	0.53	1.9	0%
Plaice IIIa	Not defined	26021	1.96	0.65	**23242**	**2.18**	23198	not significant	Use Bloss	7	1	0.89		**12%**
Plaice N. Sea	210000	162560	2.53	0.33	162531	2.53	140553	not significant	Use Bloss	4	1	0.86	0.8	0%
Plaice VIId	5600	7354	3.26	0.23	7353	3.26	5584	not significant	Use Bloss	5	1	0.76	**1.3**	0%
Saithe N. Sea	106000	115254	2.15	0.54	115213	2.15	91900	analysis invalid	not applicable	8	1	0.80	**1.1**	0%
Sandeel IV	**430000**	522139	1154.82	0.52	521237	1156.70	519749	not significant	Use Bloss	4	1	1.00	**1.2**	0%
Sole N. Sea	25000	24712	3.98	0.53	24709	3.98	21053	not significant	Use Bloss	4	1	0.85	1.0	0%
Sole VIId	Not defined	8289	3.03	0.56	8284	3.03	7779	not significant	Use Bloss	5	1	0.94		0%
Whiting N. Sea	225000	285180	7.74	**0.01**	284827	7.75		***	Use Seg Reg	3	1		**1.3**	0%

Data categories: (1) Data poor situation, (2) Short-lived 1-time spawners, (3) S/R signal, (4) No S/R signal, wide range of SSB, (5) No S/R signal, narrow range of SSB, (6) Spasmodic stocks – occasional large ycl, (7) Inverse S/R relation, (8) Invalid analysis.

$\mathbf{B}_{lim}$ categories: (1) $\mathbf{B}_{lim}$ estimation possible according to standard method, (2) $\mathbf{B}_{lim}$ estimation possible on basis of stock-specific method or judgement, (3) $\mathbf{B}_{lim}$ estimation not possible

4.8 WGHMM - Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim

Stock type	S/R plot characteristics	B_{lim} estimation possible according to standard method	B_{lim} estimation possible on basis of stock-specific method or judgement	B_{lim} estimation not possible
1 Data poor situation				
2 Short-lived 1-time spawners				
3 Spasmodic stocks – occasional large year classes				
S/R signal	4 Clear change point (slope line and plateau)		Northern hake Southern hake	
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			
	6 Inverse S/R relation (there seems to be a negative slope)	Angler7&8ab(*L.pisca*)		
No S/R signal,	7 Distinct plateau (wide range of SSB)			
	8 No apparent plateau (narrow range of SSB)		Angler7&8ab(*L.bude*) Megrim7&8ab Four S.Megrim8c&9a	

4.8.1 Northern hake (IIIa, IV, VI, VII and VIIIab)

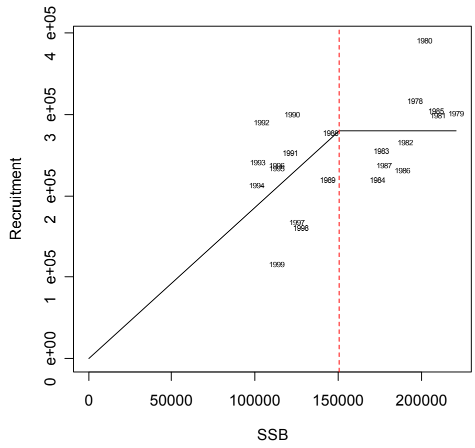
The time-series for this stock was over twenty years however there is a relatively narrow range of spawning stock biomass (the minimum SSB is around half the maximum. Spawning stock biomass has been high in the early part of the time-series but declined in the late 1980s before stabilising at a lower level on the 1990s. Recruitment in the late nineties has been poor. Recent recruitment is estimated to have increased.

The segmented regression outputs indicate the change point is very sensitive to adding and dropping years and the segmented regression fit is not highly significant. In addition fitting of the segmented regression is sensitive to the number of iterations used in the fitting procedure.

There have been many updates of the input data used in this assessment in recent years and this does in itself justify a revision of reference points (both $\mathbf{B}_{lim}$ and $\mathbf{B}_{pa}$) which were based on other biological data. In relative terms the SSB trends are similar and a revision of the reference points for this stock in line with the changes in the assessment setup is required. The new $\mathbf{B}_{loss}$ (1994) estimate is 101,000 t, which is around half the maximum SSB.

Considering visual inspections, it seems that there is a S/R signal but is not possible to apply the standard method proposed for this type of stocks. The working group should investigate the specific approach to be used for a revision of $\mathbf{B}_{lim}$ and propose a revision. As a minimum requirement a revision should be made which reflects the changes in input data and assessment setup.

The changes in biological data have resulted in the present $\mathbf{B}_{pa}$ value being grossly inconsistent even within the approach used to derive it originally. On the short-term a preliminary revision of $\mathbf{B}_{pa}$ should be produced, based on the same approach as the existing value but on basis of the biological data presently used in the assessments.

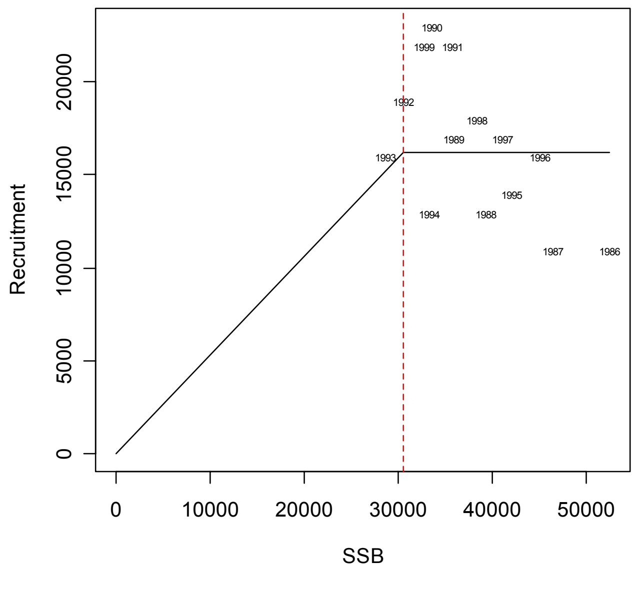


4.8.2 Anglerfish (L. piscatorius) (VII and VIIIab)

There is a narrow range of SSB and short time-series of data for this stock. Inspection of the stock recruit data indicates an inverse relationship.

The segmented regression outputs indicated that the fit is not significant.

$\mathbf{B}_{\mathrm{lim}}$ for this stock was remains undefined. Where such a stock recruit relationship exits it maybe appropriate to consider $\mathbf{B}_{\mathrm{loss}}$ as $\mathbf{B}_{\mathrm{pa}}$.



4.8.3 Anglerfish (L. budegassa) (VII and VIIIab)

There is a narrow range of SSB and short time-series of data for this stock. There has been a recent strong year class in this stock.

The segmented regression outputs indicated that the fit is not significant. The change point estimate is in line with the recent strong year class.

$\mathbf{B}_{\mathrm{lim}}$ for this stock was remains undefined and there is no compelling reason to revise the current $\mathbf{B}_{\mathrm{pa}}$.

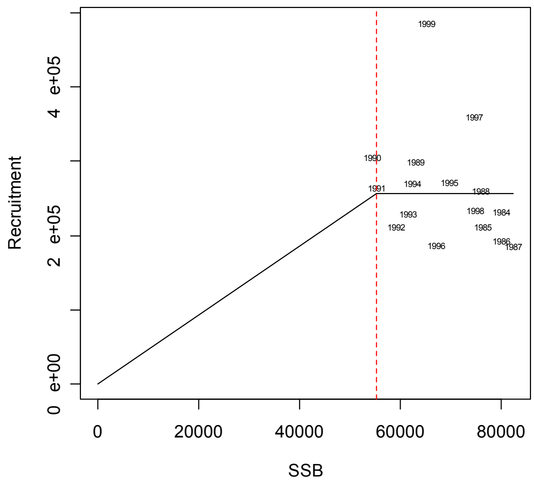
Any recommendation to this stock should be coupled with the implications to the other angler due to both are managed together.

4.8.4 Megrim (VII and VIIIab)

There is a narrow range of SSB and short time-series of data for this stock. Recruitment and SSB appears to have been relatively stable in this stock.

The segmented regression outputs indicated that the fit is not significant and there are problems in estimating the change point.

$\mathbf{B}_{lim}$ for this stock remains undefined. The current $\mathbf{B}_{loss}$ is estimated to be close to $\mathbf{B}_{pa}$.



4.8.5 Southern Hake (VIIIc and IXa)

The assessment for this stock has been revised significantly in recent years and there have been concerns about the quality of input data. Recruitment in the early part of the time-series was relatively high since the early 1990s recruitment has been stable at a relatively lower level. Spawning stock biomass has declined until the mid 1990s. There is a wide dynamic range of SSB.

The segmented regression outputs indicated that the fit is highly significant. The change point is well defined and not sensitive to adding years. However there are only three points (all from the start of the time-series) above the change point estimate. In addition there are limited number of data points around this change point.

The estimated change point is close to the current $\mathbf{B}_{pa}$ and well above the current $\mathbf{B}_{lim}$. The change point is three times greater than $\mathbf{B}_{loss}$ (1998).

Taking into account the estimates obtained by WGHMM, there are indications of S/R signals for this stock. Therefore, it should be necessary update a new $\mathbf{B}_{lim}$ with more appropriate methodologies after checking the quality of input data and uncertainty of the assessment.

4.8.6 Four Spot Megrim (L. boscii) (VIIIc and IXa)

There is a narrow range of SSB and short time-series of data for this stock. Recruitment has been variable and SSB has been very stable.

The segmented regression outputs indicated that the fit is not significant and there are problems in estimating the change point.

No reference points have been proposed for this stock. There appears to be no new information to define reference points for this stock.

4.9 WGNSDS - Working Group on the Assessment of Northern Shelf Demersal Stocks

Stock type	S/R plot characteristics	B_{lim} estimation possible according to standard method	B_{lim} estimation possible on basis of stock-specific method or judgement	B_{lim} estimation not possible
1 Data poor situation				Anglerfish IIIa, IV & VI, Haddock VIIa, Megrim VIa & VIb, Whiting VIIa
2 Short-lived 1-time spawners				
3 Spasmodic stocks – occasional large year classes			Haddock VIa, Whiting VIa	
S/R signal	4 Clear change point (slope line and plateau)	Cod VIIa, Cod VIa?		
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			
	6 Inverse S/R relation (there seems to be a negative slope)			
No S/R signal,	7 Distinct plateau (wide range of SSB)	Haddock VIb, Plaice VIIa, Sole VIIa		
	8 No apparent plateau (narrow range of SSB)			

4.9.1 Anglerfish (combined IIIa, IV & VI)

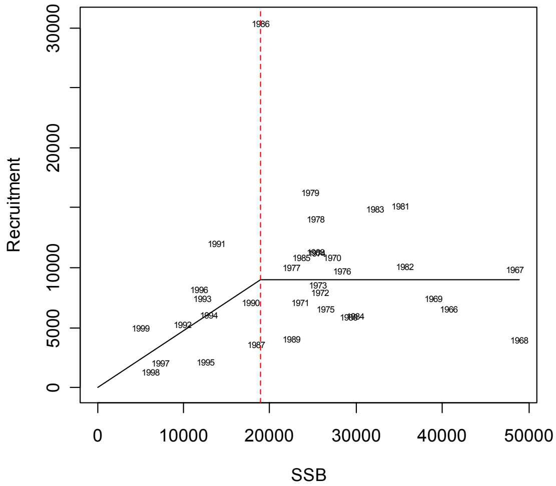
The assessment time-series is short and assessment data is poor. The assessment is likely to remain unstable for some years. F reference points (35% SPR) appear most practical but their application is complicated by an inability to estimate F in absolute terms and uncertainty in the exploitation pattern at length.

4.9.2 Cod VIa (West of Scotland)

The fit of the segmented regression is relatively insensitive to the inclusion or exclusion of particular years and there are no strong time trends in the residuals. However, some sensitivity to values in recent years was indicated in retrospective segmented regression fits. The range in SSB and Recruitment values is wide and indicates a relatively strong S/R relationship. The assessment and the trend in recent recruitment is very dependent on whether discarding has increased in recent years. To date discard data, although available, have not been used in the assessment of this stock. This was because discards were thought to have been low. However, recent WG reports have stated that there has been a substantial increase in the mean discarding percentage from 1995-1999. In 2001ACFM asked for discards data to be included in the 2002 WG assessment. Inclusion of these data resulted in a substantial increase in estimates of some year classes, and the WG decided that further evaluation of the quality of these data is required before changing the assessment procedure to include discards.

Revision of $\mathbf{B}_{lim}$ according to the segmented regression method should be considered by the WGNSDS. However, any revision of the biomass reference point should consider the following issues:

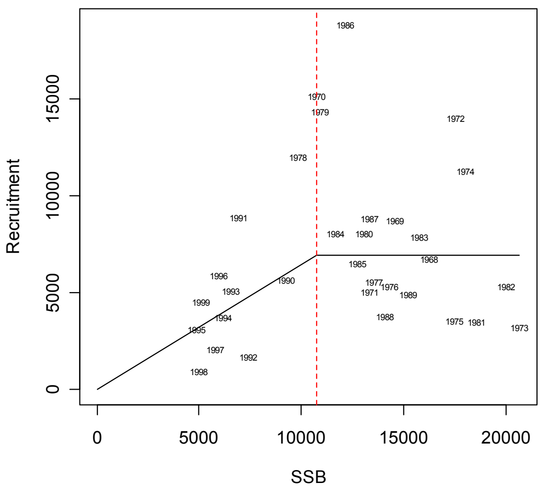
- The coincidence of the change point with the SSB in the year where the highest recorded recruitment was observed is a cause for concern.
- The impact on the assessment of any changes in discarding levels has not been evaluated. It is noted that data and assessment model implementations exist to enable such an evaluation.



4.9.3 Cod VIIa (Irish Sea)

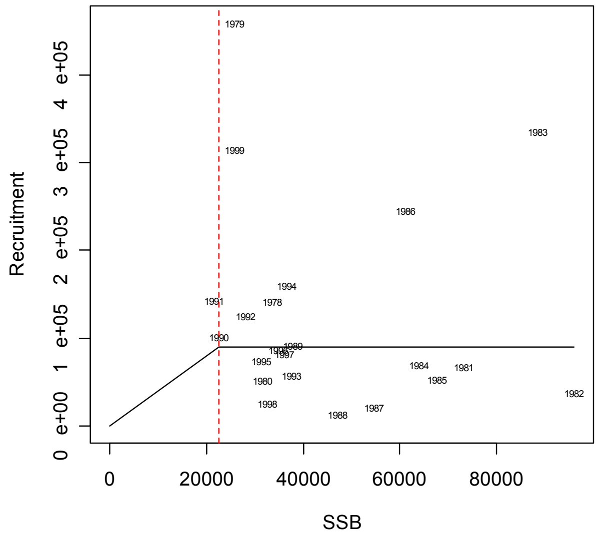
There has been a strong declining trend in SSB and R in recent years. The fit of the segmented regression is relatively insensitive to the inclusion or exclusion of particular years and there are no strong time trends in the residuals. The range in SSB and Recruitment values is wide and indicates a relatively strong S/R relationship. At SSB levels below the change point there is evidence for impaired recruitment in recent years. It was noted that in recent years there has been low recruitment at low SSB which could indicate that the stock is now at a level where recruitment is impaired.

Revision of $\mathbf{B}_{\mathrm{lim}}$ according to the segmented regression method should be considered by the WGNSDS.



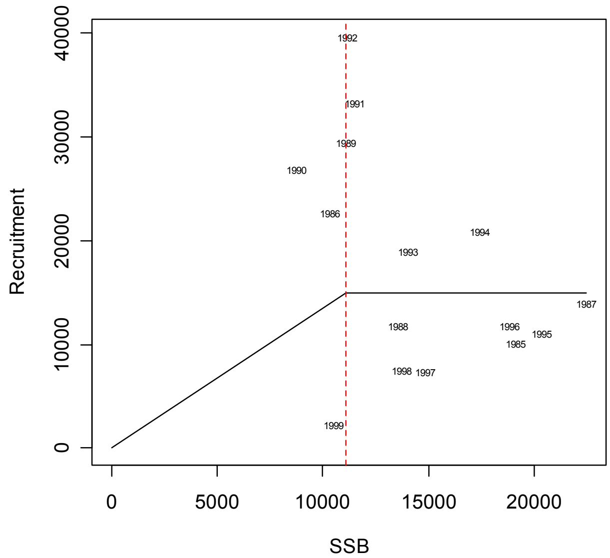
4.9.4 Haddock VIa (West of Scotland)

Large year classes as well as ordinary year classes do not seem to be related to the SSB. Segmented regression gives a change point at a value near $\mathbf{B}_{\mathrm{loss}}$. $\mathbf{B}_{\mathrm{lim}}$ should be maintained as $\mathbf{B}_{\mathrm{loss}}$.



4.9.5 Haddock VIb (Rockall)

Large year classes as well as ordinary year classes do not seem to be related to the SSB. Segmented regression gives a change point at a value near $\mathbf{B}_{loss}$. $\mathbf{B}_{lim}$ should be maintained as $\mathbf{B}_{loss}$.



4.9.6 Haddock VIIa (Irish Sea)

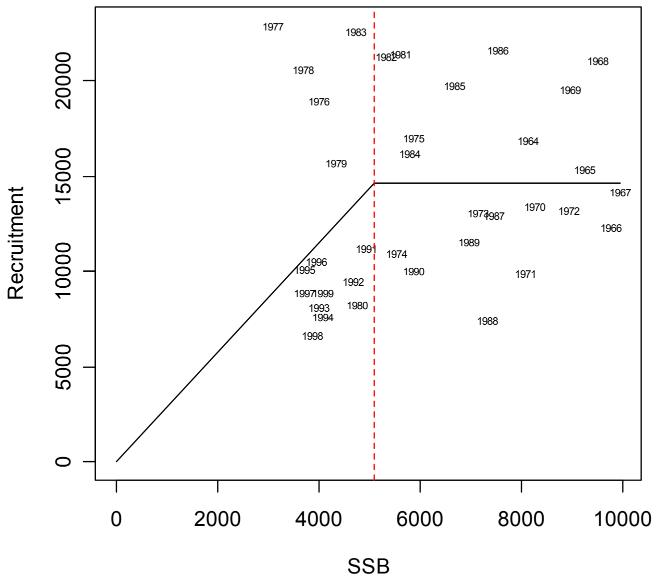
No accepted assessment.

4.9.7 Megrim VIa & VIb (West of Scotland & Rockall)

No accepted assessment.

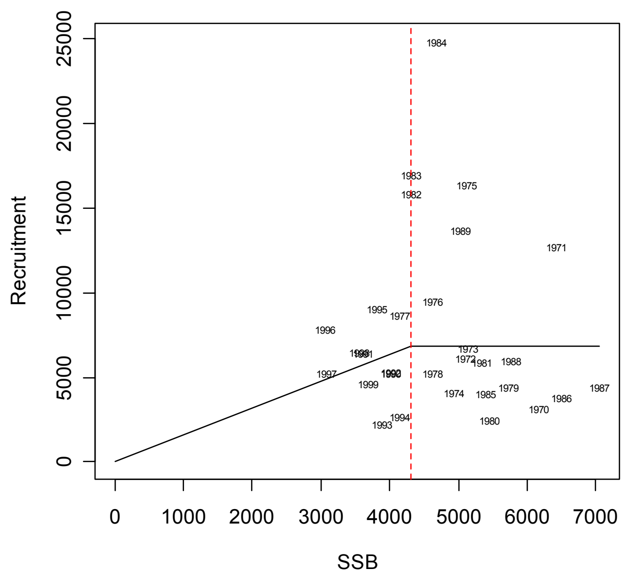
4.9.8 Plaice VIIa (Irish Sea)

No strong S/R signal, segmented regression is sensitive to individual years, has a poorly defined maximum likelihood. Biomass reference points should be established with respect to $\mathbf{B}_{loss}$. The WGNSDS should consider whether $\mathbf{B}_{loss}$ represents $\mathbf{B}_{lim}$ or $\mathbf{B}_{pa}$.



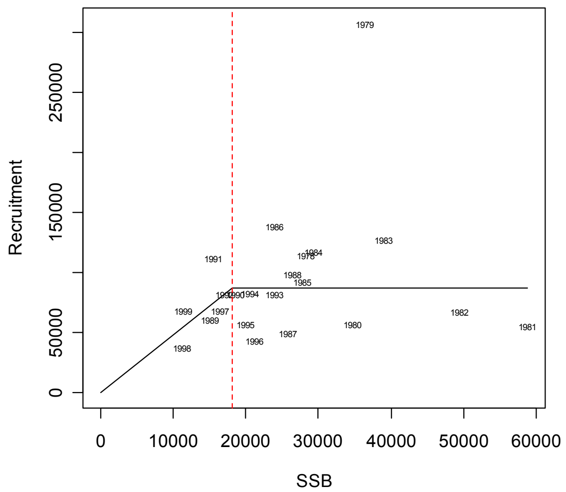
4.9.9 Sole VIIa (Irish Sea)

No strong S/R signal, segmented regression is sensitive to individual years, and has a very poorly defined maximum likelihood. $\mathbf{B}_{lim}$ should be maintained as $\mathbf{B}_{loss}$.



4.9.10 Whiting VIa (West of Scotland)

The stock history shows one exceptionally high year class. There has been a declining trend in SSB and R in recent years but there is no strong signal in the S/R plot. The maximum likelihood is poorly defined. At SSB levels below the change point there is no clear evidence for impaired recruitment. $\mathbf{B}_{lim}$ should be maintained as $\mathbf{B}_{loss}$.



4.9.11 Whiting VIIa (Irish Sea)

No accepted assessment. The converged part of the XSA assessment shows a strong declining trend in SSB and high F. A strong retrospective pattern for downwards revision of the SSB and upwards revision of F indicates that the stock is in a very poor state and needs rebuilding irrespective of current reference points. There is no basis for revision of reference points without an improvement in the quality of the assessment.

4.10 WGSSDS - Working Group on the Assessment of Southern Shelf Demersal

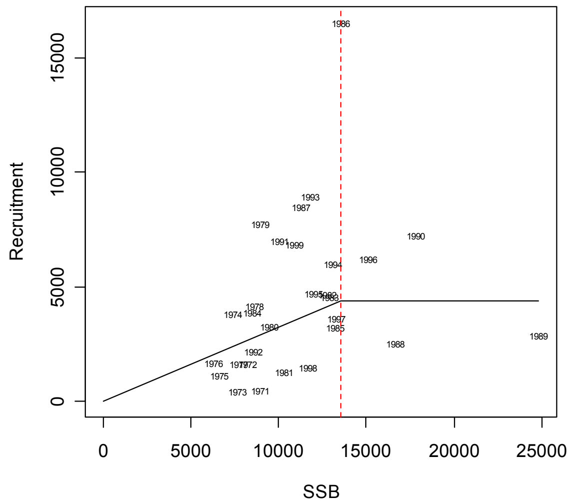
Stock type	S/R plot characteristics	$\mathbf{B}_{lim}$ estimation possible according to standard method	$\mathbf{B}_{lim}$ estimation possible on basis of stock-specific method or judgement	$\mathbf{B}_{lim}$ estimation not possible
1 Data poor situation				VIIb-k haddock VIIh-k plaice VIIh-k sole VIIb,c cod VIIb,c plaice VIIb,c sole VIIb,c whiting
2 Short-lived 1-time spawners				
3 Spasmodic stocks – occasional large year classes				
S/R signal	4 Clear change point (slope line and plateau)		VIIe-k cod	
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)		VIIe sole VIII sole	
	6 Inverse S/R relation (there seems to be a negative slope)			
No S/R signal,	7 Distinct plateau (wide range of SSB)	VIIe plaice VIIfg plaice VIIfg sole VIIe-k whiting		
	8 No apparent plateau (narrow range of SSB)			

4.10.1 Cod in VIIe-k

Wide range of SSB (4-5 times min.) apparent. One very strong year class (1986) in mid-series. Graph gives some evidence of stock-recruit relationship. Stock history shows that SSB increased from a low level in 1970s, following above-average recruitments, but has declined recently at high F levels despite some recent good recruitments.

Segmented regression output indicates a significant fit, not sensitive to adding or dropping years, no upper limit on likelihood plot but changepoint estimate appears robust; however most observations are below the estimated changepoint. But inspection of the S/R plot does not give compelling evidence for impaired recruitment below the change point, and no evidence of higher recruitment above this point. So this stock has been categorised in the second column. The WG should review the results of the analysis on this stock.

Use of the change point as $\mathbf{B}_{\mathrm{lim}}$ implies more than double present $\mathbf{B}_{\mathrm{lim}}$.

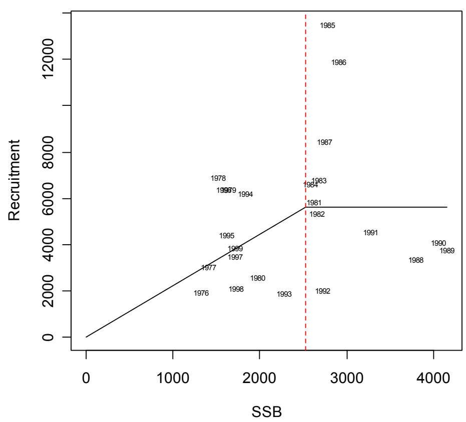


4.10.2 Plaice in VIIe

Wide range of SSB (3-4 times min.) apparent. Two strong year classes (1985, 1986) in mid-series. Graph gives some evidence of stock-recruit relationship. Stock history shows that SSB increased from a low level in the late 1970s, following above-average recruitments, but has declined recently at relatively high F levels and as a result of generally lower recruitment since 1989.

Segmented regression output does not indicate a significant fit; with some sensitivity to adding or dropping years, multiple maxima on likelihood plot and changepoint is not well-defined. Results are therefore not robust. So this stock has been categorised in the first column, no S/R signal and wide range of SSB.

No reason to change current $\mathbf{B}_{\mathrm{lim}}$.

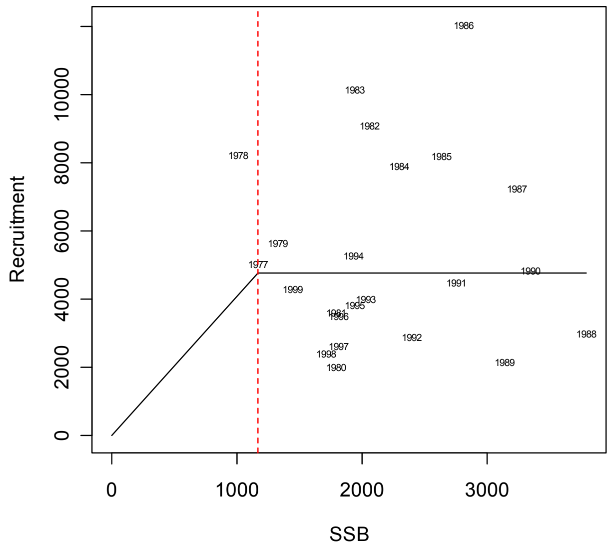


4.10.3 Plaice in VIIf,g

Wide range of SSB (3-4 times min.) apparent. No especially strong year classes are apparent. Graph gives no evidence of stock-recruit relationship. Stock history shows that SSB increased from a low level in 1970s, following above-average recruitments, but has declined recently following a generally lower level of recruitment since 1988.

Segmented regression output indicates no significant relationship. So this stock has been categorised in the first column, no S/R signal and wide range of SSB.

No reason to change current $\mathbf{B}_{\mathrm{lim}}$.

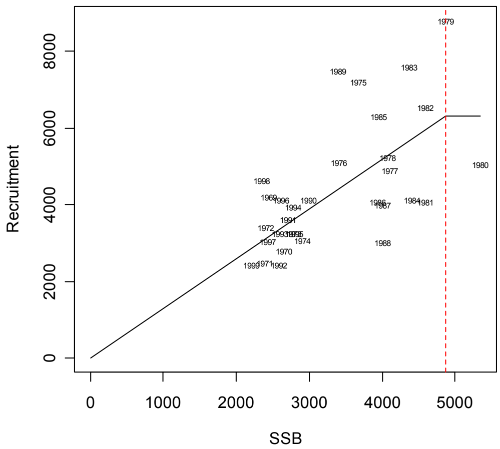


4.10.4 Sole in VIIe

Narrow range of SSB (2-3 times min.) apparent. No outstanding year classes are apparent. Graph gives some evidence of stock-recruit relationship. Stock history shows that SSB increased from a low level in 1970s, following above-average recruitments, but has declined recently at high F levels and as a result of average or below-average recruitments since 1991. Landings data recently revised (2002) to allow for misallocation of landings into VIId, but under-reporting is thought to have been significant in the 1990s.

Segmented regression output indicates a significant fit, not sensitive to adding or dropping years, and multiple maxima over a wide SSB range on the log likelihood plot. The change point estimate is therefore poorly-defined, although the fit appears good. But inspection of the S/R plot shows only one observation above the change point, which itself is coincident with the strongest year class. Given the stock history, in which the stock increased from a low level, but is now declining under the influence of high fishing mortality, the WG should attempt to validate whether this really represents the left-hand side of a stock-recruit relationship. This stock has been categorised in the second column.

N.B. Use of the change point as $\mathbf{B}_{\mathrm{lim}}$ implies more than double the present $\mathbf{B}_{\mathrm{lim}}$.

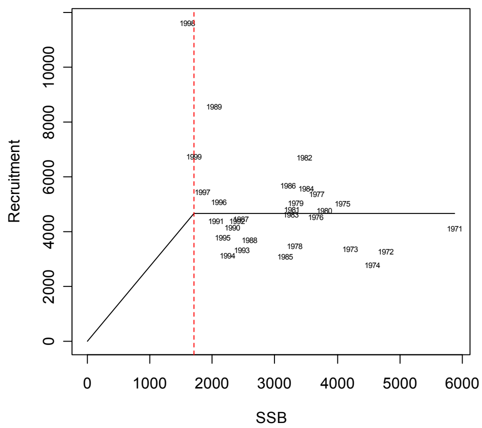


4.10.5 Sole in VIIf,g

Wide range of SSB (4 times min.) apparent. One very strong recent year class (1998). Graph gives no evidence of stock-recruit relationship, with the strongest year class at the lowest SSB. Stock history shows that SSB has continuously declined since 1971, with a recent upturn due to the strong 1998 year class.

Segmented regression output indicates no significant fit, some outliers observed, no maximum on log likelihood plot. (And F obs. = negative). So this stock has been categorised in the first column, with wide range of SSB. The possibility that this stock exhibits an inverse S/R relation was discussed and rejected.

Currently no $\mathbf{B}_{lim}$ defined; $\mathbf{B}_{pa} = \mathbf{B}_{loss}$. WG to review this stock, and to consider $\mathbf{B}_{loss}$ as a candidate for $\mathbf{B}_{lim}$, given the unknown dynamics below this level.

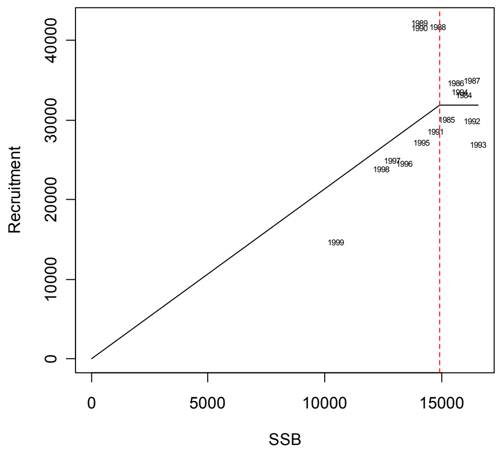


4.10.6 Sole in VIII

Narrow range of SSB (<2 times min.) apparent. There are no strong year classes in the series (which only includes data from 1984 onwards, due to quality of data prior to that), but the most recent year class is weak. Graph gives some evidence of stock-recruit relationship, with an apparent decline in recent years. Stock history shows that SSB has declined since 1993 at high F levels.

Segmented regression output indicates a significant fit, change point not too sensitive to adding or dropping years, but the model fit worsens with added years. There is a problem with the log-likelihood profile at high SSB levels, and the pattern of residuals gives some cause for concern. This stock has been categorised in the second column, with the recommendation for further work. The possibility of the stock being on the lower limb of a stock-recruit relationship was discussed, and the WG should attempt to clarify the real nature of the S/R relationship.

B_{lim} is currently not defined. Use of the changepoint as B_{lim} (15,000t) has implications for this stock: B_{pa} is currently 13,000t.

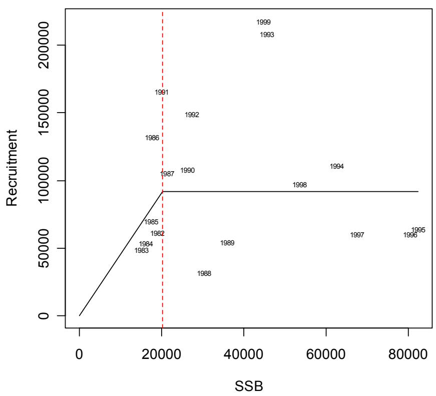


4.10.7 Whiting in VIIe-k

Wide range of SSB (5 times min.) apparent. Some strong year classes in mid-series, and one in 1999. Graph gives some evidence of stock-recruit relationship, although largely dependent on two strong year classes in mid-SSB range. Stock history shows that SSB increased from a low level in the 1980s, as a result of a series of above-average recruitments, and has fluctuated around a relatively high level following good and weak recruitments since 1992.

Segmented regression output indicates no significant fit, not sensitive to adding or dropping years, but changepoint difficult to estimate. No stock-recruit signal, so this stock has been categorised in the first column, with a wide range of SSB.

B_{lim} currently set as B_{loss}. No reason to recommend change.

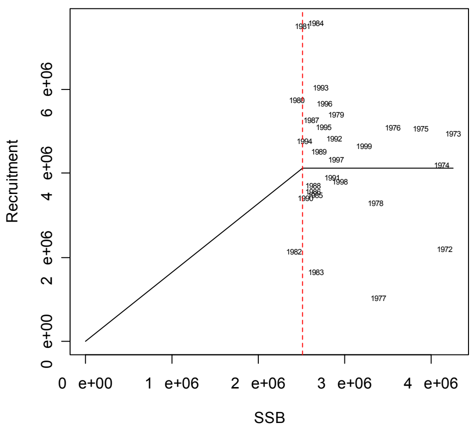


4.11 WGHMSA - Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine, and Anchovy

Stock type	S/R plot characteristics	B_{lim} estimation possible according to standard method	B_{lim} estimation possible on basis of stock-specific method or judgement	B_{lim} estimation not possible
1 Data poor situation				Horsemackerel VIIIc & IXa, North Sea Horsemackerel, Sardine VIIIc & IXa
2 Short-lived 1-time spawners			Anchovy Bay of Biscay	Anchovy IXa
3 Spasmodic stocks – occasional large year classes			Western Horsemackerel	
S/R signal	4 Clear change point (slope line and plateau)			
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			
	6 Inverse S/R relation (there seems to be a negative slope)			
No S/R signal,	7 Distinct plateau (wide range of SSB)			
	8 No apparent plateau (narrow range of SSB)		Mackerel NEA	

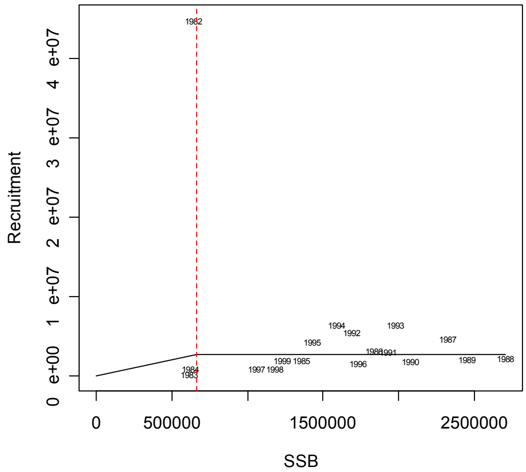
4.11.1 Mackerel NEA

The time-series of SSB and R was revised by the WG in 2002. The maximum likelihood given by the segmented regression is poorly defined. There is no clear S/R signal. At the lowest recorded SSB levels there is no evidence for impaired recruitment. SSB shows a relatively narrow range from 2.4 to 4.3 million tonnes. Fishing mortality has been maintained at about 0.2 in most years with few exceptions. Current basis for $\mathbf{B}_{pa}$ is $\mathbf{B}_{loss}$ for the Western component raised by 15% to account for the Southern and NS components. From last year on, the revision of the historic data allows a recalculation for the whole stock, and $\mathbf{B}_{loss}$ is now believed to be at around 2.4 mill. T – so the accepted $\mathbf{B}_{pa}$ (2.3 mill. t) is currently even lower than $\mathbf{B}_{loss}$. $\mathbf{B}_{pa}$ should be maintained on the same basis as previously but updated to reflect data revisions.



4.11.2 Western Horsemackerel

The 1982 recruitment was outstanding and arose from a very low SSB. The signal given by the S/R plot is uninformative. The maximum likelihood given by the segmented regression is poorly defined. If a biomass reference point is to be re-established $\mathbf{B}_{loss}$ is a candidate for $\mathbf{B}_{lim}$.



4.11.3 Horsemackerel VIIIc and IXa

No accepted assessment. No basis for revision of reference points without an improvement in the quality of the assessment.

4.11.4 North Sea Horsemackerel

No accepted assessment.

4.11.5 Anchovy, Bay of Biscay

This is a very short-lived species. The dynamic range in SSB and R has been relatively large but there is no clear signal in the S/R relationship. Furthermore the assessment time-series relatively short. $\mathbf{B}_{loss}$ should be maintained as $\mathbf{B}_{lim}$.

4.11.6 Anchovy, IXa

No accepted assessment.

4.11.7 Sardine, VIIIc & IXa

No accepted assessment. No basis for revision of reference points without an improvement in the quality of the assessment.

5 IMPLEMENTATION OF REFERENCE POINT REVISION

ICES developed in 1997-1998 a set of proposed reference points for about 65 stocks using various methods and the stock and fishery data then available. This was a provisional step in the implementation of the precautionary approach. Since then these reference points have been kept under constant review individually but now five years later a general review is required, comprising a review of the principles that were used to establish reference points, revisiting all proposed reference points and consideration of stocks for which reference points could not be proposed in 1998.

ICES considered that this should be done using a planned coordinated process to achieve the best possible consistency, so that different stock reference points only reflect ecological and population dynamic differences.

The original time scale for the intended process comprised the following elements

Task No	Task	Planned Timing (May 2002)
1	Establishment of a framework for deriving reference points	SGPA (December 2002)
2	Compilation of reference points based on the established framework	January-February 2003
3	ICES Internal Review of the compiled set of proposed reference points	Study Group on Precautionary Reference Points for Advice on Fishery Management (SGPRP) February 2003 and AWGs March-September 2003
4	Consultation of the reviewed reference points with stakeholders in particular the industry	May-September 2003
5	Adoption of revised reference points by ACFM	May 2003 and Oct 2003

5.1 Status February 2003

SGPA met in December 2002 in order to revise the framework for estimating reference points, and propose an associated methodology for estimating limit and precautionary reference values. The risk framework and the methodology for estimating limit reference values based on segmented regression with appropriate diagnostics were completed, and a new but untested method proposed for estimating the precautionary reference values, using retrospective analysis to take into account assessment uncertainty. The revised framework and methods were applied to the Northeast Arctic Cod assessment at the Study Group on Biological Reference Points for Northeast Arctic Cod (SGBRP).

Based on software available for the segmented regression approach, the ICES Secretariat provided SGPRP with a compilation of LIMIT reference points and diagnostics for the current stocks with available stock-recruit data. There was no compilation of PA reference points, largely because the method prescribed by SGPA 02b would require a very extensive rerun of assessments and predictions for all the stocks concerned which was not achievable in the short timeframe between the meetings.

SGPRP reviewed the trial LIMIT reference point values calculated by the Secretariat stock by stock, taking into account the typology of the stock-recruit data, the statistical goodness of fit of the segmented regression, and whether the estimate of the change point (S*) was sensible in the light of the time-series of points available, and other known biological or fishery features. In general, the change point estimates were more justifiable when there is an unambiguous stock and recruit signal in data sets with a wide dynamic range. Even when there is a good statistical fit to the data the change point was less acceptable in cases where the stock-recruit signal appears to be confounded by known biological, fishery or environmental factors, or when there is no clear stock and recruit signal, or when the data set is restricted. SGPRP has divided the list of stocks into stock types for which different approaches to reference point estimation is required and indicated whether the trial $\mathbf{B}_{\mathrm{lim}}$ values

a) imply that a revision is indicated

b) do not appear to be different from existing values

c) suggest further consideration needs to be given by the appropriate working group

d) suggest that the new method appears to be inappropriate for the data or for the stock. In these cases it was also considered whether other available methods (largely $\mathbf{B}_{\mathrm{loss}}$ estimates) were sensible in the specific context as a basis for $\mathbf{B}_{\mathrm{lim}}$ estimates.

This is summarised in a table in section 7.

SGPRP was unable to develop PA reference points at this meeting. It noted that the proposed method appeared to provide a satisfactory outcome for NEA cod, but to be able to compile the full set of PA reference points for all the stocks concerned integrated software is required which has not yet been developed. Furthermore, based on the experience of this meeting it is imperative that trial calculations are fully evaluated and compared across stocks by the assessment working group chairs in order to obtain consistency in the application and interpretation of the results.

It should be noted that many of the difficulties encountered at SGPRP reflect the nature of the stock-recruit data, rather than the methodology itself. Nevertheless, several technical and interpretational issues were raised that need further attention (Section 6).

It was also noted that at a later stage the discussion of individual data sets and revisions would benefit from the dialogue with stakeholders and managers, once the scientific evaluation of the results is completed.

For data poor and stocks without a clear S/R signal in the scatterplot no new methods have been proposed, or revisions attempted.

5.2 The future process

SGPRP noticed that the task is to review the set of reference points and change these points where required. This process has been started and is continuing. However, it is inevitable that the original time schedule needs to be modified. The Group identified the following steps

- Identification of those stocks for which a revision of the reference points should be considered. Further iteration required after this years assessment working groups, perhaps by correspondence. This needs to take into account whether there are any stocks where the new methods appear to be unsuitable, but revisions could take place on the basis of the previous methodology.

- Establishment of software that allows the calculation of PA reference points following the framework defined by SGPA December 2002. This software should link the XSA(retrospective) program to the prediction program followed by a statistical analysis of the results;

- Based on this software to compile PA reference points for the stocks under consideration;

- Consider what is to be done for data poor stocks, or those stocks for which reference points were not previously calculated.

- Present this compilation to the relevant assessment WG chairs at a further meeting of SGPRP and go through an evaluation process of both the approach for PA reference point estimation and the specific stocks similar to what have taken place for LIMIT points at this February 2003 meeting on SGPRP.

- Consult with management and the industry (and other stakeholders) on the proposed revisions

- Present proposal for revisions of reference points to ACFM in 2004

5.3 Consultations with Management and Industry

The consultation process could be split regionally, but only after the scientific review has been concluded globally. (Conducting the prior processes regionally would inevitably lead to inconsistencies).

a) NEA Cod (and other candidates relevant to the NRFC). This could be done through JNRFC

b) Iceland and Faeroe Islands consultations could be done through the national laboratories without direct involvement of ICES

c) Baltic Stocks. This would involve IBSFC and national laboratories.

d) North Sea Stocks. The North Sea Commission Fisheries Partnership could be a vehicle

e) The EC ACFA (Advisory Committee on Fisheries and Aquaculture) may be invited to take this onboard;

5.4 Time Schedule

The time scale required to complete this process properly is much more extended than originally realised, and it is not possible to complete it within 2003. SGRP suggests that the earliest data for completion is 2004.

6 DEVELOPING THE FUTURE FRAMEWORK

6.1 The need to develop a new approach and framework

The SGPRP regards the present round of revisions of reference points as a temporary measure to improve the advise for some stocks where the present values for the reference points do not appear to be appropriate for various reasons. For future development of advise, the SGPRP, like the SGPA, sees a need to broaden the advisory framework to include a wider range of harvest control rules and management plans than the present framework allows for. This includes management plans for optimal harvesting of stocks as well as rebuilding plans. Such management plans already have been or are being developed for a range of stocks. So far, ICES has been asked to evaluate some of these plans. For the future, one may foresee a need for ICES to be more proactive, and assist in developing such plans in close dialogue with managers and other stakeholders.

To be able to do so, there is a need to develop tools to evaluate management plans with respect to performance compared to proposed objectives and to the precautionary approach. Work in this field is ongoing in several institutes. Some suggestions for evaluation tools in terms of scenario simulation software are described below.

Furthermore, SGPRP, like SGPA, recognises that management strategies can only be developed in a close dialogue between stakeholders and science, where the role of science will be both to evaluate proposed strategies, but also to advise on which kinds of strategies can be worth considering.

If ICES shall adapt its advisory framework to such developments, ICES will need a home for this kind of work. SGPA proposed to establish a Working Group and suggested the following initial topics.

- Identify and review and HCR types and their properties
- Identify candidate long-term management objectives
- Identify and review tools to evaluate HCRs and establish quality criteria and guidelines for such tools.
- Consider the applicability of developing a default HCR/Rebuilding rule.

In relation to rebuilding plans, the SGPA noted that there was scope for work on the following areas :

- Summarise the management tools available for use within the context of rebuilding plans, with particular regard to the practical experience of their use, and the data requirements for monitoring their effectiveness
- Consider the features of potential rebuilding plans with particular regard to the need to achieve measurable effects in a limited time scale.

The SGPRP supports this proposal.

6.2 The need to validate the reference points by management scenario simulations

The present approach has been limited to an evaluation of reference points on basis of the statistical properties of stock-recruitment plots and knowledge about the stock and fisheries history. However, reference points are guidance for management and will be used within specific management frameworks such as year-to-year decisions based on point estimates or recovery plans taking a longer perspective on the development of stocks and fisheries. Specific reference points may prove inadequate within the specific management framework by being either not precautionary enough in practice - not ensuring that sustainability objectíves are met – or by being excessively conservative and thus lead to unnecessary losses to society. LIMIT reference points are supposed to reflect properties of the stock and could thus be evaluated independently of management regimes. But PA and TARGET reference points are meant to incorporate the uncertainties of assessments and to relate to specific objectives for management, both in relation to sustainability, acceptable risk and societal benefits. There is thus a need to evaluate PA and TARGET reference points in relation to the specific management context within which they are going to be used and to explore whether the practical use of proposed values can be expected to lead to outcomes of management that correspond to objectives. Reference points should be decided on basis of an exploration of their expected properties in the management context.

The first requirement for such explorations is that the objectives against which the performance is to be measured are known. There is thus a need to have a dialog with managers to develop the objective framework for reference point evaluation.

It is furthermore required that the management framework within which the reference points are going to be used is known. This will also require dialogue with managers.

The development of reference points should in the longer term be seen as an ongoing process within an advisory framework where there is close interaction between managers and scientists in exploring the properties of reference points in relation to management objectives and various options for management frameworks (recovery plans, harvest control rules etc).

An important tool in such explorations would be to use simulations to evaluate the relative merits of candidate management and assessment strategies before implementation. The benefit of such an approach is that it is able to evaluate the robustness of scientific management advice frameworks to a wider variety of uncertainty in the systems to be managed than is possible by current methods.

The real system dynamics are modelled within **a Operating Model** that represent the best available understanding of the actual system dynamics, both natural processes, operational characteristics of the fishery, assessment and management. It should also include alternative hypotheses about the dynamics, reflecting our uncertainty about the systems. Appropriate management and assessment strategies based upon simpler models that are developed through a rigorous testing procedure in which the performance of alternative "simple" are evaluated against the operating models.

Accounting, in the Operating Models, for the all the factors adding to our uncertainty about the system, is in many cases going to take long time, delaying urgently needed actions to be taken. Thus most of the simulations done will probably be based on Operating Models including a limited number of the factors that would be included in a complete model.

With regards to reference points, a requirement for candidate management strategies would be to have a low probability of the stock falling below $\mathbf{B}_{\mathrm{lim}}$, making PA points redundant where a management strategy has been evaluated through simulation testing. Some of the factors included in the scenario simulations will change the historical perception of the stock, affecting the value of $\mathbf{B}_{\mathrm{lim}}$, which should probably be based on some relative measure of the spawning stock.

Examples of where scenario simulations have been used to evaluate management strategies are.

- IWC (1992) used this approach to test the potential future performance of alternative proposals for new whaling management procedures.

- The approach was used to decide upon Harvest Control Rules for Iceland cod. The HCR for Icelandic cod is now being revised incorporating knowledge obtained from the implementation of the original HCR, for example changes in selection pattern when the TAC is limiting.

- Two studies commissioned by the EU evaluated multi-annual management strategies through simulation for seven major flatfish (MATACS) and eight major roundfish stocks (MATES) in the ICES area.

- A HCR for North Sea Herring was evaluated by (Patterson, Skagen, Pastoors and Lassen, Harvest Control Laws for North Sea Herring, Working Document to ACFM, 1997) and adopted in the agreement by Norway and the European Community in 1997.

For Norwegian Spring Spawning Herring, a harvest strategy was adopted in 1999, based on evaluations done by a study group appointed by the Coastal States in 1999 (see Bogstad, B, Røttingen, I, Sandberg, P and Tjelmeland, S. The use of Medium-Term Forecasts in advise and managemnt decisions for the stock of Norwegian spring spawning herring *(Clupea harengus L.)* ICES CM2000/V:01). The harvest strategy has since then been extended, based on simulations done by the Norhtern Pelagic and Blue Whiting WG (2001)

In the future management strategies for more stocks and fisheries will be evaluated this way. Already medium-term simulation including probability profiles are required from Stock Assessment Working group so Fishery scientists will be required to be more competent in scenario simulations. Evaluating management strategies is then only taking this work one step further.

7 CONCLUSIONS AND RECOMMENDATIONS

ICES developed in 1997-1998 a set of proposed reference points for about 65 stocks using various methods and the stock and fishery data then available. This was a provisional step in the implementation of the precautionary approach. Since then these reference points have been kept under constant review individually but now five years later a general review is required, comprising a review of the principles that were used to establish reference points, revisiting all proposed reference points and consideration of stocks for which reference points could not be proposed in 1998.

This Study Group on Precautionary Reference Points (SGPRP) has reviewed the approaches to reference point estimation presented by earlier study groups. SGPRP has, on basis of discussions of the reference points for 65 stocks, developed the proposed framework further as summarised in Annex 1.

This framework has been implemented to 65 stocks in the ICES area. The Study Group reviewed the LIMIT reference points for stocks within its terms of reference. Except for North East Arctic cod for which a separate study group has done the groundwork, the study group has not been in a position to evaluate PA reference points due to limitations in the software tools available. It is suggested that a similar process is adopted for PA reference points leading to revisions in 2004. For northern hake it is suggested that a preliminary revision of the PA reference point is made reflecting the changes in biological data used in the assessment.

The study group has noted that some issues regarding methodology and implementation tools still need to be resolved within the present approach. These issues are manageable. However, the present framework is limited to analysis of stock-recruitment data and analysis of uncertainties in stock assessments. In the longer term there is a need to expand the approach to include explorations of the performance of reference points in the management context within which they are to be used and to measure the performance against the multiple objectives of fisheries management. There is a need to expand the framework for PA reference point estimation to include such explorations on basis of close interaction with managers and simulations of performance.

In the shorter term, a procedure is proposed for evaluation of LIMIT reference points and to finalise the approach and evaluate PA reference points, leading to recommendations in 2004 (section 5).

The study group has proposed a review of reference points to be undertaken by working groups and evaluated by ACFM as summarized in the table below:

Stock	**Revision basis**	**Recommendation**	**Comments**
North Sea herring	$\mathbf{B}_{\text{lim}}$ estimated from segmented regression lower	HAWG will review possible change of $\mathbf{B}_{\text{lim}}$	
Cod Kattegat	Change point may be above historical biomasses.	WGBFAS to evaluate possible change of reference points	High exploitation over historic series, Biomass reference points may be bypassed before the start of records.
Cod 22-24	Unclear basis but update of $\mathbf{B}_{\text{lim}}$ necessary as there is a S/R signal	WGBFAS to review, but this is largely an investigation to seek for adequate methodologies	There is S/R signal, but unclear which method can be used to estimate change point
Cod 25-32	Limit point may be F-based – because of strong environment signal	WGBFAS to investigate options for F-based reference points	Environment influence need to be reviewed
Herring SD 25-32	Unclear basis but update of $\mathbf{B}_{\text{lim}}$ necessary as there is a S/R signal	WGBFAS to review, but this is largely an investigation to seek for adequate methodologies	There is S/R signal, but unclear which method can be used to estimate change point
Herring SD 30	Unclear basis but update of $\mathbf{B}_{\text{lim}}$ necessary as there is a S/R signal	WGBFAS to review, but this is largely an investigation to seek for adequate methodologies	There is S/R signal, but unclear which method can be used to estimate change point
NE Arctic cod	$\mathbf{B}_{\text{lim}}$ revision proposal based on segmented regression, $\mathbf{B}_{\text{pa}}$ ref points derived accordingly	Basis for PA to be resolved ($\mathbf{F}_{\text{sq}}$ or TAC constraint)	Need to develop process to clarify procedure for PA point estimation basis

Stock	Revision basis	Recommendation	Comments
NEA Green land halibut	Unclear basis but update of $\mathbf{B}_{lim}$ necessary as there is a S/R signal	AFWG to review, but this is largely an investigation to seek for adequate methodologies	There is S/R signal, but unclear which method can be used to estimate change point
NEA Saithe	There may be basis for changing PA points given recent change in exploitation pattern	AFWG to review change in exploitation pattern and implications for ref points	Given the state of this stock there is no urgency in changing reference points
Faroe haddock	$\mathbf{B}_{loss}$ can be candidate	NWWG to review need to use updated $\mathbf{B}_{loss}$ as $\mathbf{B}_{lim}$	Check timing of old MBAL and year classes
Faroe saithe	Check $\mathbf{B}_{loss}$ as candidate for $\mathbf{B}_{pa}$	NWWG to review	
Icelandic haddock	Check $\mathbf{B}_{loss}$ as candidate for $\mathbf{B}_{pa}$	NWWG to review	
Cod North Sea	$\mathbf{B}_{lim}$ to be revised but PA points still to be estimated	WGNSSK to review PA points derived from new $\mathbf{B}_{lim}$	Send message that $\mathbf{B}_{lim}$ will be revised but need to finalise work with PA points. S/R signal is now clear and justifies revision.
Whiting North Sea	$\mathbf{B}_{lim}$ to be revised but PA points still to be estimated	WGNSSK to review PA points derived from new $\mathbf{B}_{lim}$	Send message that $\mathbf{B}_{lim}$ will be revised but need to finalise work with PA points. S/R signal is now clear and justifies revision.
Plaice North Sea, Sole North Sea	$\mathbf{B}_{lim}$ continue to be $\mathbf{B}_{loss}$	WGNSSK to review the need to use updated $\mathbf{B}_{loss}$ as $\mathbf{B}_{lim}$	
Plaice Skagerrak, Sole Eastern Channel	$\mathbf{B}_{loss}$ may be used for $\mathbf{B}_{pa}$	WGNSSK to review the need to use updated $\mathbf{B}_{loss}$ as $\mathbf{B}_{pa}$	Inverse S/R relationship or short range of SSB
Norway Pout North Sea, Plaice VIId,	$\mathbf{B}_{loss}$ to be used as reference point dependent on stock type.	WGNSSK to review stock type and use of $\mathbf{B}_{loss}$	It is not clear whether $\mathbf{B}_{loss}$ should be used as a limit or pa point given the spread of observations and the exploitation history.
Northern hake	Unclear basis but update of $\mathbf{B}_{lim}$ necessary as there is a S/R signal	WGHMM to review, but this is largely an investigation to seek for adequate methodologies. PA reference point to be revised preliminarily to reflect update of biological data.	Revision due to changed assessment setup and input data. There is S/R signal, but unclear which method can be used to estimate change point
Angler (pisca) 7 and 8a	Updated $\mathbf{B}_{loss}$ candidate for $\mathbf{B}_{pa}$	WGHMM to review	May be coupled to L. Budegassa update as these are managed together
Southern hake	Unclear basis but update of $\mathbf{B}_{lim}$ necessary as there is a S/R signal	WGHMM to review, but this is largely an investigation to seek for adequate methodologies.	Revision due to changed assessment setup and input data. There is S/R signal, but unclear which method can be used to estimate change point
Cod Via	$\mathbf{B}_{lim}$ may be estimated from segmented regression	WGNSDS will review basis for $\mathbf{B}_{lim}$ change	Evaluation to include some data issues and properties of estimate.
Cod VIIa	$\mathbf{B}_{lim}$ may be estimated from segmented regression	WGNSDS will review basis for $\mathbf{B}_{lim}$ change	Evaluate robustness of new estimate.
Haddock VIb, Sole VIIa	$\mathbf{B}_{lim}$ continue to be $\mathbf{B}_{loss}$	WGNSDS to review the need to use updated $\mathbf{B}_{loss}$ as $\mathbf{B}_{lim}$	

Stock	Revision basis	Recommendation	Comments
Plaice VIIa	$\mathbf{B}_{loss}$ to be used as reference point dependent on stock type.	WGNSDS to review stock type and use of $\mathbf{B}_{loss}$	It is not clear whether $\mathbf{B}_{loss}$ should be used as a limit or pa point given the spread of observations and the exploitation history.
Cod VIIe-k	Unclear basis but update of $\mathbf{B}_{lim}$ necessary as there is a S/R signal	WGSSDS to review, but this is largely an investigation to seek for adequate methodologies	There is S/R signal, but unclear which method can be used to estimate change point
Sole VIIe	Unclear basis but update of $\mathbf{B}_{lim}$ necessary as there is a S/R signal.	WGSSDS to review. The lack of S/R plateau indicates need to use fishing mortality information in evaluation	There is S/R signal, but unclear which method can be used to estimate change point. Development of assessment may give a clearer pattern and be basis for review.
Sole VIII	Unclear basis but update of $\mathbf{B}_{lim}$ necessary as there is a S/R signal.	WGSSDS to review. The lack of S/R plateau indicates need to use fishing mortality information in evaluation	There is S/R signal, but unclear which method can be used to estimate change point. Development of assessment may give a clearer pattern and be basis for review.
Sole in VIIf,g	$\mathbf{B}_{loss}$ may be candidate for $\mathbf{B}_{lim}$	WGSSDS to review basis for revision	
Western horse mackerel	$\mathbf{B}_{loss}$ may be a candidate for $\mathbf{B}_{lim}$	WGHMSA to review	This is close to the value which was used earlier.

8 REFERENCES

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

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

Anon. 2001. Study Group on the Further Development of the Precautionary Approach to Fisheries Management (Copenhagen, 2-5 April 2001) ICES CM 2001/ACFM:11

Anon 2002. Study Group on the Further Development of the Precautionary Approach to Fisheries Management (Lisbon, 4-8 March 2002) ICES CM 2002/ACFM: 10

Anon 2003a. Study Group on the Further Development of the Precautionary Approach to Fisheries Management (Copenhagen, 2-6 December 2002) ICES CM 2003/ACFM: xx

Anon 2003b. Study Group on Biological Reference Points for Northeast Arctic Cod (Svanhovd, 13-17 January 2003). ICES CM 2003/ACFM:11

Evans G.T.,and J.C.Rice, 1988. Predicting recruitment from stock size without the mediation of a functional relation. .J. Cons. int. Explor. Mer. 44: 111-122

Doulman, D.J. 1995. Structure and Process of the 1993-1995 United Nations Conference on Straddling Fish Stocks and Highly Migratory Fish Stock. FAO Fisheries Circular. No 898. Rome, FAO. 1995. 81p

FAO 1995. Precautionary approach to fisheries. Part 1. Guidelines on the precautionary approach to capture fisheries and species introductions. Elaborated by the Technical Consultation on the Precautionary Approach to Capture Fisheries (including Species Introductions). Lyseksil, Sweden, 6-13 June 1995 (A scientific meeting organised by the Government of Sweden in cooperation with FAO). FAO Fisheries Technical Paper. No 350. Part 2. Rome, FAO. 1995. 52pp.

FAO 1995b Code of Conduct for Responsible Fisheries. 46 pp

Jakobsen, T. and H. Sparholt. 2002. SHORT-TERM FORECAST, Defining status quo F – The status quo F versus TAC constraint F advice versus SSB advice. WG Doc to SGWP and SGPA.

Köster, F., C. Mollmann, S. Neunfeldt, M.A.St John, M. Plikshs and R.Voass (2001a). Developing Baltic cod recruitment models I. resolving spatial and temporal dynamics of spawning stock and recruitment for cod, herring and sprat. Can. J. Fish. Aq. Sci. 58: 1516-1533.

Köster, F., H.H. Hinrichsen, M.A.St John, D. Schnack, B.R.MacKenzie, J. Tomkiewitz and M. Plikshs (2001b). Developing Baltic cod recruitment models II. Incorporation of environmental variability and species interaction. Can. J. Fish. Aq. Sci. 58: 1534-1556.

Lassen, H., C. M. O'Brien, and H. Sparholt (2002): DRAFT ICES' guidelines for calculating PA reference points for stocks with analytical assessments. Working Document 3 in Anon. 2003a, Study Group on the Further Development of the Precautionary Approach to Fisheries Management (Copenhagen, 2-6 December 2002) ICES CM 2003/ACFMxx

O'Brien, C.M. and Maxwell, D.L., 2002a. Towards an operational implementation of the Precautionary Approach within ICES - biomass reference points. Working Document 8 in Anon. 2001, Study Group on the Further Development of the Precautionary Approach to Fisheries Management (Copenhagen, 2-5 April 2001) ICES CM 2001/ACFM11

O'Brien, C.M. and Maxwell, D.L. 2002b. A segmented regression approach to the Precautionary Approach – the case of Northeast Arctic saithe (Sub areas I and II). Working Document 10 in Anon. 2001, Study Group on the Further Development of the Precautionary Approach to Fisheries Management (Copenhagen, 2-5 April 2001) ICES CM 2001/ACFM11

Rice. J.C. and O. Mashal 2002. Estimating Biomass Limit Reference Points For Canadian Cod with Non-Parametric Density Estimation methods. Working Document 4 in Anon. 2002, Study Group on the Further Development of the Precautionary Approach to Fisheries Management (Copenhagen, 2-6 December 2002) ICES CM 2003/ACFMxx

Rice, J.C. and G.T.Evans, 1988. Tools for embracing uncertainty in the management of the cod fishery in NAFO Division 2J+3KL. .J. Cons. int. Explor. Mer. 45: 73-81

Serchuk, F.M and J.R. Grainger, 1992. Development of the basis and form of ICES Fisheries Management Advice: Historical background (1976-1990) and the new form of ACFM Advice (1991-?). ICES CM 1992/Assess:20.

Sparholt, H and M Bertelsen. 2002. Quality of ACFM advice: How good have forecasts been since 1988 ? Working Document for ICES Advisory Committee on Fishery Management, May 2002.

9 WORKING DOCUMENTS

The following working documents were presented to the Study Group:

WD1 ICES Secretariat: Revision of reference points: Calculations of $\mathbf{B}_{lim}$ and $\mathbf{F}_{lim}$ using segmented regression analysis

WD2 Kell, L., C.M. O'Brien, G.M. Pilling and M.T. Smith. A comparison of limit reference points based upon segmented regression and Blosss.

WD3 Asta Gudmundsdootir. Revision of the reference points for the icelandic summer spawning herring

WD4 Höskuldur Björnsson. Estimation of Harvest Control Rules with regards to reference points.

WD5 Valentin Trujillo. Segemneted regression applied to WGHMM stocks.

WD6 Sigurdur Thor Jonsson. Some PA considerations for saithe in Icelandic waters.

WD7 ICES Secretariat: PA reference points on basis of historic assessments

10 ANNEX 1. GUIDELINES FOR REFERENCE POINT ESTIMATION

The proposed framework for reference point estimation includes the following steps:

- Compile data and inspect data and stock-recruitment plots. Identify cases where SSB has declined below the previous estimate of $\mathbf{B}_{loss}$, or cases where an estimate of $\mathbf{B}_{lim}$ has been overtaken by a change in the SSB-R values due to a change in the structure of the assessment model, a change in biological data or a different perception of the stock recruitment relationship emerging from the addition of recent data years.

- Identify stock type based on explorations of models assuming a change point and knowledge about the stock and fisheries (see overview of stock types below).
- Estimate LIMIT reference points according to methodology applicable to the stock type.

- Derive PA reference points from LIMIT points

10.1 Data compilation and inspection

For data poor situations (where a stock-recruitment plot cannot be produced due to the absence of analytical assessments) ICES does not define reference points.

For stocks where an analytical assessment exists:

Tabulate the current (old) PA and LIMIT reference points and their basis, as well as other conventional reference points ($\mathbf{F}_{0.1}$, $\mathbf{F}_{max}$.)

Identify the assessment, R-SSB data set, and time period to be used in the recalculation

Inspect the R-SSB data visually. Assess the pattern of the plot and classify the plot according to the pattern of the relationship and your knowledge about the history of the stock and the fishery. This assessment may be assisted by exploratory estimation of change points using segmented regression analysis and checking whether the segmented regression provides better fits to the data than either constant recruitment or constantly increasing recruitment.

10.2 Stock type identification

Dependent on the characteristics of the stocks and the data available it is proposed to distinguish between data poor situations (both short and long lived species), short lived species, and long lived species. Long lived species includes stocks for which a stock-recruitment relationship is apparent in the historical data, stocks for which this is not the case and a group of stocks with a special reproduction biology producing occasional large year classes. Some of these categories are then subdivided further.

10.2.1 (1) Data Poor situations

There are numerous stocks for which no analytical assessment is available. Due to the limited amount of data for defining the Precautionary Approach reference points this means that a pragmatic approach and expert judgement often will be an important part of the process although ICES strives to be objective and consistent.

For a number of stocks there are little data except landings. These cases are not dealt with in this round of revisions. ICES does presently not define Precautionary Reference points for these stocks.

10.2.2 (2) Short-lived species

These are species with a life-span restricted to 4-6 years old; high level of natural mortality (mean around 1.0 or even greater) that can vary because a large proportion is caused by predation and environmental conditions that also vary; recruitment is highly variable and the age of first capture is low; fishing mortality is generally much smaller than natural mortality. For short lived species such as sprat in the North Sea, capelin and anchovy, medium-term projections are not possible. The ICES advisory procedure is normally based on short-term (1-2 years) projection and such projections are usually not possible for the short lived species.

Short-lived species can be split into those that die after spawning like capelin, salmon (marine phase) and maybe Norway pout and those that do not. This distinction has bearings on the projection model.

An example of an approach for short lived species that die after spawning is the approach taken for capelin. The advice for capelin catches in the Barents Sea and in Iceland is based on acoustic estimates of the stock biomass shortly before spawning. The approach is to let an amount of spawners survive the fishery to secure reproduction at a level, which is not impaired by a too low SSB. This minimum SSB serves as a $\mathbf{B}_{lim}$ value. Because the uncertainty in the acoustic estimate is proportional to the estimated size of the stock, a fixed $\mathbf{B}_{pa}$ would not give the same probability in all years for maintaining SSB above $\mathbf{B}_{lim}$. Therefore, a fixed $\mathbf{B}_{pa}$ is not relevant for these stocks. Furthermore, $\mathbf{F}_{lim}$ and $\mathbf{F}_{pa}$ is neither relevant because there is no point in having more spawners survive the fishery than needed to secure a non-impaired recruitment because most capelin die after spawning and these fish will thus be a lost for the fishery. The advised TAC, using a 5% level for SSB dropping below $\mathbf{B}_{lim}$, is in each year calculated based on the estimated biomass together with the associated uncertainties. The simulations required for these calculations can be done using bootstrapping of the survey results (directly or of the residuals around means) or by fitting a parametric error distribution to the survey results. In each specific case the procedure used should be described.

For short-lived stocks, which do not die after spawning F reference points can be used in management in addition to SSB reference points. In principle these points can be set in a similar way as for long-lived stocks

10.2.3 Long-lived species

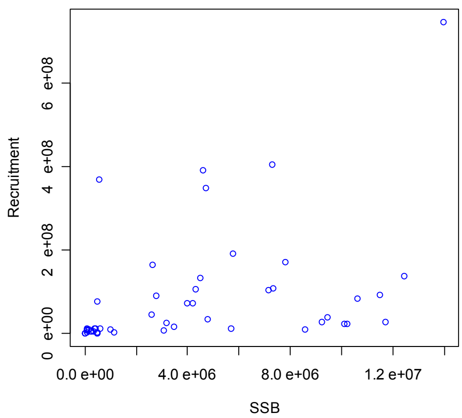
Long lived species are fish with M (adult phase) in the range of 0.1-0.3 per year and without any appreciable mortality due to spawning.

ICES stocks with analytical assessments and a time-series of paired SSB-R values can be grouped into categories as follows. The basic distinction is whether a stock-recruitment relation is apparent. One type of stocks is dealt with as a separate group due to their unique biological characteristics.

10.2.3.1 (3) Stocks with occasional very strong year classes (spasmodic stocks).

This group of stocks have unique biological characteristics which justifies a specific approach. They exhibitit some points well above the cloud of points in a stock-recruitment scatter plot. However, the time-series are usually too sort to establish with any accuracy the frequency of such rare events. Examples of such stocks are most haddock stocks and Norwegian spring spawning herring. Establishing biomass reference points for such stocks is often difficult. For several of these stocks their entire population dynamics depend crucially on that these strong year classes actually occur. The analysis should therefore focus on establishing the minimum SSB above which strong year classes have been observed. However, when simulating the corresponding $\mathbf{B}_{pa}$, $\mathbf{F}_{lim}$ and $\mathbf{F}_{pa}$ these reference levels should be based on a S-R relationship based on data from periods where the very strong year class had no influence, i.e. before the year that produced the strong year class and period after starting from the year when the strong year class has little contribution to SSB.

Example (Norwegian Spring Spawning Herring)



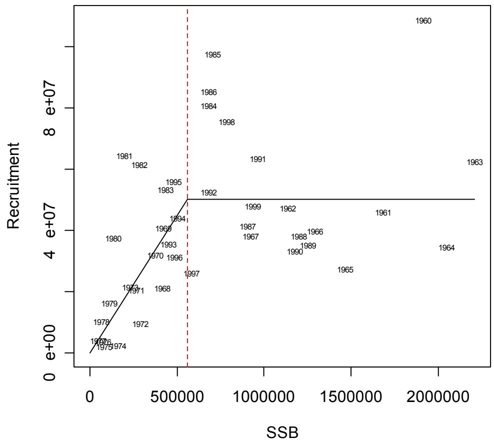
10.2.3.2 Stocks for which a relationship between stock and recruitment is apparent. (S/R signal apparent)

When a stock-recruitment signal is apparent this may be interpreted as either a change point, a monotonic increase of recruitment over the historic data or an inverse relationship. Ths gives bases for three stock types, each with a different interpretation of reference points.

e. Stocks with a wide dynamic range of SSB, and evidence that recruitment is or has been impaired.

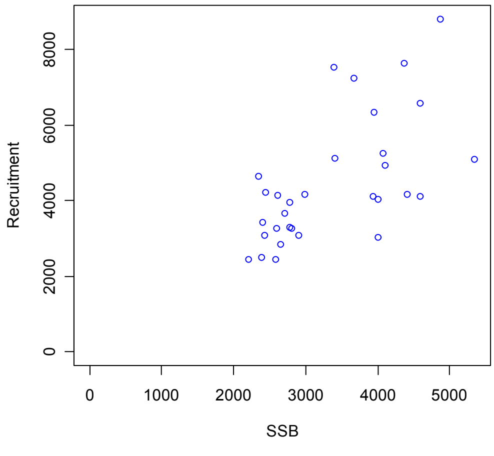
i. (4) Change point. Stocks for which there is a distinct change point in the S/R scatterplot, the scatterplot can be divided into a slope and a plateau region. A change point should be estimated and the change point is identified as an estimate of $\mathbf{B}_{\text{lim}}$. For these stocks the change point should be estimated on basis of a segmented regression and an evaluation of the diagnostics. If the estimation procedure is found to perform well a $\mathbf{B}_{\text{lim}}$ value can be established on this basis. If the performance of the segmented regression analysis is found to be unsatisfactory or if there are specific reasons for a modified approach alternative approaches for estimating $\mathbf{B}_{\text{lim}}$ should be investigated.

Example (Herring in the North Sea)



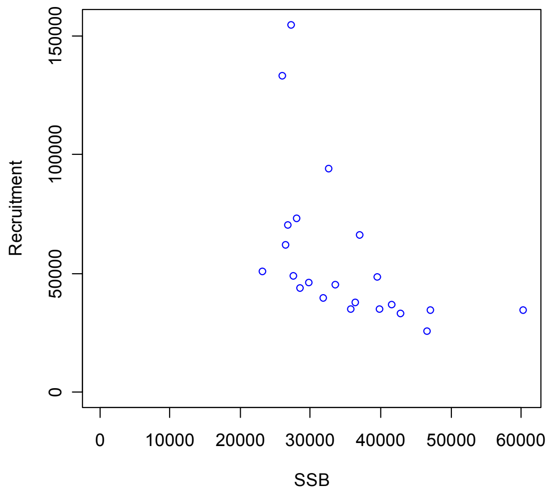
ii. (5) Positive proportionality without change point. These are stocks for which there is no distinct plateau in the scatterplot but for which R seem to be reduced with reduced SSB for the range of historical observations. In this case it may be suspected that fisheries mortality has been high before the historical time-series started and that all historical data are within the range of impaired recruitment. $\mathbf{B}_{\text{lim}}$ may be at higher SSB values than any observed. This decision should be based on evaluations of other data, especially the historical data on fishing mortality.

Example (Sole western Channel)



f. (6) Inverse relationship. Stocks where R increases as SSB decreases. For this inverse S/R relationship it is not possible to estimate limit reference points. $\mathbf{B}_{loss}$ may be estimated as a candidate value of $\mathbf{B}_{pa}$

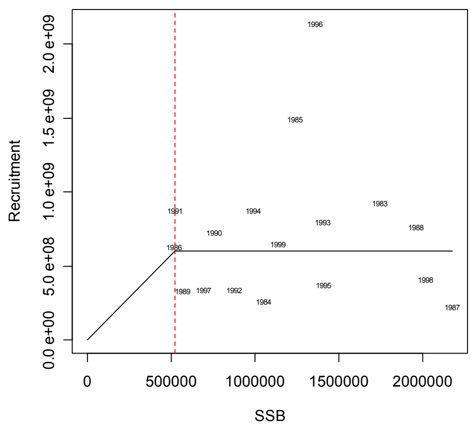
Example (Plaice in Kattegat-Skagerrak)



10.2.3.3 Stocks with no evidence that recruitment has been impaired or relation between stock and recruitment (no S/R signal apparent)

g. (7) Stocks with a clear plateau in the S/R scatterplot (a wide dynamic range of SSB, but no evidence that recruitment is impaired). Identify $\mathbf{B}_{loss}$ as a candidate value of $\mathbf{B}_{lim}$, below which the dynamics of the stock are unknown.

Example (Sandeel North Sea)



h. (8) Stocks for which the S/R scatterplot contains no information about neither plateau or impaired recruitment – a shotgun plot or stocks with a narrow dynamic range of SSB. If this is combined with a history of low exploitation $\mathbf{B}_{loss}$ can be used as a candidate value of $\mathbf{B}_{pa}$. Some stocks have little dynamic range in SSB, which makes it difficult to determine the SSB-R relationship and hence the biomass reference points. This is because, in reality, we have only one "point" to determine the SSB-R curve, namely a cloud of points in one particular spot on the SSB-R curve. ICES need to deal with these cases individually. If the stock is exploited at a high fishing mortality above what seems reasonable based on other reference points, e.g. $\mathbf{F}_{max}$ and $\mathbf{F}_{0.1}$ or experience with similar stocks and if this has been the prevailing situation for most or all of the time-series for which data are available then the stock should be considered as depleted and the SSB representing a stock that may not reproduce to its fullest potential. In this case a reasonable $\mathbf{B}_{pa}$ will need to be defined based on an $\mathbf{F}_{pa}$ consideration and is likely to be above the SSB forwhich ICES has experience with this stock. If, on the other hand, the fishing mortality is low judged by conventional reference points and experience with similar stocks then this may actually be a stable stock for which the $\mathbf{B}_{pa}$ should be defined as the $\mathbf{B}_{loss}$ value.

Example (Mackerel in the North East Atlantic)

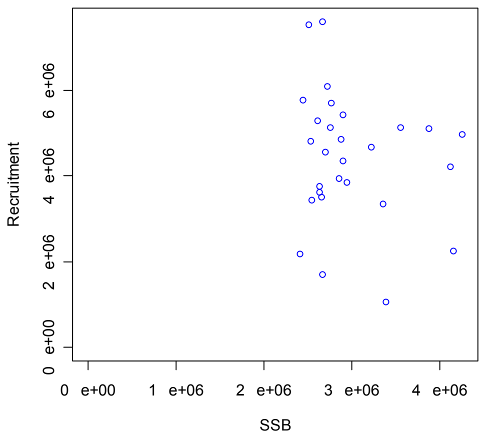
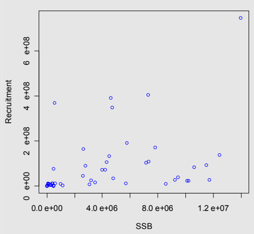
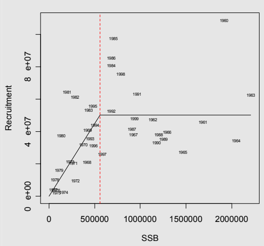
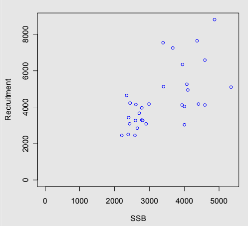
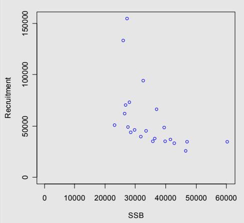
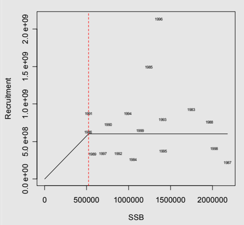
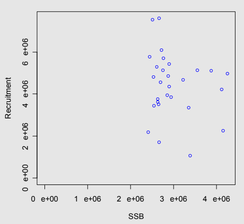


Table 1 Summary of stock types and reference point estimation

Stock characteristics			**Limit point estimation options dependent on data and specific stock information**		
Stock type	**S/R plot characteristics**	**Sample S/R plot**	**B_{lim} estimation possible according to standard method**	**B_{lim} estimation possible on basis of stock-specific method or judgement**	**B_{lim} estimation not possible**
1 Data poor situation					Present alternative basis for advice
2 Short-lived 1-time spawners				(**B_{loss}**)	
3 Spasmodic stocks – occasional large year classes				Mortality based reference points such as **F_{loss}** based on normal recruitment situation.	
S/R signal	4 Clear change point (slope line and plateau)		**B_{lim}** = Segmented regression change point		
	5 Relationship between S and R, no clear change point (there seems to be a positive slope but the plateau is not evident)			**B_{lim}** may be close to highest SSB observed. Decision dependent on evaluation of historical fishing mortality	
	6 Inverse S/R relation (there seems to be a negative slope)		No LIMIT point, only PA point. (**B_{loss}** candidate for PA point)		
No S/R signal,	7 Distinct plateau (wide range of SSB)		**B_{lim} = B_{loss}**		
	8 No apparent plateau (narrow range of SSB)			No LIMIT point, only PA point (**B_{loss}** is candidate for PA point dependent on considerations involving historical fishing mortality)	

10.3 Estimation and possible revision of B_{lim} and F_{lim}

On basis of this assessment, identify whether the current (old) reference points suffer from inconsistency, model structure, regime issues, changes in biological data or assessment method, addition of new data which changes the perception of the stock-recruitment relationship. For example, has an old estimate of $\mathbf{B}_{loss}$ been overtaken by further decline in SSB, or has there been a material change in the R-SSB plot from the assessment due to changes in biological data or a change in the conditioning (formulation) of the assessment model ? If any of these is the case identify what remedial action is needed. If the suggested change in reference point is marginal a change may not be justified.

LIMIT reference points are estimated as follows:

For stocks where a change point is evident (stock type 4 above) $\mathbf{B}_{lim}$ is estimated on basis of a segmented regression estimate of $\mathbf{B}_{lim}$: estimate the change point S* for the chosen set of R-SSB data. Examine the diagnostics for S* and decide if the fit is statistically robust. If this is the case S* is used as a $\mathbf{B}_{lim}$ estimate.

For other stocks $\mathbf{B}_{loss}$ may be used as a proxy of $\mathbf{B}_{lim}$ according to stock type and specific considerations including historical exploitation as described above.

$\mathbf{F}_{lim}$ is then derived from $\mathbf{B}_{lim}$ as follows:

- Calculate R/SSB at $\mathbf{B}_{lim}$, the slope of the replacement line at $\mathbf{B}_{lim}$.

- Invert to give SSB/R.

- Use this SSB/R to derive $\mathbf{F}_{lim}$ from the curve of SSB/R against F.

10.4 PA reference points

SBPRP has not evaluated the derivation of PA reference points. SGPA 02b proposed the following procedure:

10.4.1 Estimate F_{pa} from F_{lim}

- Identify the most recent reliable assessment data set to be used as a reference data set (usually the one used to estimate $\mathbf{B}_{lim}$).
- Note the year of the reference assessment, full documentation of the data sources, the assessment method, and the configuration used for the derivation of the new biological reference points.
- Note the sensitivity of the reference assessment to assumptions (e.g. shrinkage, +group], and document and justify the exploitation pattern, weight and maturity-at-age for the reference assessment.
- Use the reference data to carry out a set of retrospective assessments within the converged part of the assessment.
- Tabulate and plot the distributions of realised F across assessment years generated by the TAC corresponding to each intended F.
- Compare the distributions between intended F values and identify the highest intended F that still carries a low risk that the realised F is above $\mathbf{F}_{lim}$

10.4.2 Estimate B_{pa} from B_{lim}

- Use the set of retrospective assessments to obtain the observed SSB in each TAC year and compare with the 'true' SSB estimated by the reference data set.

- Plot the pairs of SSBobs/SSBtrue against SSBtrue

- Draw through the origin the line that leaves α% (where α is the acceptable risk) of the points above the line, whose slope is β in $\mathbf{B}_{pa} = \beta * \mathbf{B}_{lim}$.

11 ANNEX 2. RECALCULATED B_{LIM} BASED ON SEGMENTED REGRESSION ANALYSIS AND CORRESPONDING F_{LIM}. BIOMASS IN T.

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)		New B_{loss}/ F_{loss}
B_{lim}	Not defined	Anglerfish VIIb-k VIIIab (*L. budegassa*)	Not defined	25673 α=0.6044775	P=0.12	22072
B_{lim}	Not defined	Anglerfish VIIb-k VIIIab (*L. piscatorius*)	Not defined	30600 α=0.5296454	P=0.51	27600
B_{lim}	B_{loss}	Blue whiting	1.5 mill	1293635 α=10.29598	P=0.55	1175685
B_{lim}	Not defined	Cod 22-24	Not defined	40611 α=2.089255	P=0.13	8525
B_{lim}	SSB below which R is impaired	Cod 25-32	160000	352442 α=1.017377	P=0.00	68201
B_{lim}	B_{loss}	Cod, Arctic	112000	282521 α=2.149658	P=0.00	102315
B_{lim}	Not defined	Cod Coas	Not defined	117705 α=0.2684854	P=0.04	53739
B_{lim}	B_{loss} (98)	Cod Faroe Plateau	21000	22358 α=0.6746609	P=1.00	21824
B_{lim}	Not defined	Cod Iceg	Not defined	414234 α=0.5223662	P=0.01	192470
B_{lim}	Lowest observed	Cod Kattegat	6400	28733 α=0.8424109	P=0.00	5705
B_{lim}	Rounded B_{loss}	Cod N. Sea	70000	159354 α=2.584308	P=0.00	30278
B_{lim}	Smoothed estimate of B_{loss} (as enumerated in 1998)	Cod VIa (West of Scotland)	14000	18858 α=0.4794685	P=0.00	3596
B_{lim}	B_{loss}	Cod VIIa (Irish)	6000	10719 α=0.6482971	P=0.00	2312
B_{lim}	B_{loss}	Cod VIIe-k	5400	13553 α=0.3262769	P=0.01	6304
B_{lim}	Not defined	Flounder 24-25	Not defined	20328 α=2.123884	P=0.57	18224
B_{lim}	Not defined	Arctic halibut	Not defined	20501 α=1.021276	P=0.04	14095
B_{lim}	Not defined	Greenland halibut V+XIV	Not defined	53608 α=0.6364023	P=1.00	45791
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."	Haddock, Arctic	50000	63620 α=1.577961	P=0.12	34976
B_{lim}	MBAL	Haddock Faroe	40000	23221 α=0.7614777	P=0.54	21972
B_{lim}	Not defined	Haddock, Icelandic	Not defined	59698 α=0.8781476	P=0.26	41677
B_{lim}	Smoothed B_{loss}	Haddock N. Sea	100000	81400 α=320.2692	P=1.00	63500
B_{lim}	B_{loss}	Haddock VIa (West of Scotland)	22000	22554 α=3.982247	P=1.00	18433
B_{lim}	B_{loss}	Haddock VIb (Rockall)	6000	11093 α=1.348668	P=0.56	2328

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New B_{loss}/ F_{loss}
B_{lim}	Not defined	Haddock VIIa (Irish)	Not defined	Time-series not long enough	1274
B_{lim}	B_{loss}	Hake, Northern stock	120000	150393 α=1.859640 P=0.09	101300
B_{lim}	B_{loss}	Hake, Southern stock	20500	34417 α=3.178300 P=0.01	11800
B_{lim}	Not defined	Herring 25-29+32 ex GoR	Not defined	1130397 α=19.73128 P=0.00	368023
B_{lim}	Spawning stock biomass, where probability of lower recruitment increases	Herring, Bothnian Sea (30)	145000	218815 α=20.54079 P=0.00	94268
B_{lim}	Not defined	Herring, Bothnian Bay (31)	Not defined	10066 α=27.59316 P=0.67	8514
B_{lim}	Lowest observed	Herring Celtic Sea	26000	46328 α=9.72095 P=0.02	27912
B_{lim}	Lowest reliable estimated SSB	Herring VIa & VIIb,c	81000	66684 α=11.67787 P=0.62	66487
B_{lim}	B_{pa}/exp (1.65*0.2)	Herring Gulf of Riga	36500	112681 α=31.08613 P=0.00	36328
B_{lim}	SSB with a high probability of impaired recruitment	Herring Icelandic	200000	219757 α=3.059119 P=0.39	193256
B_{lim}	Lowest observed	Herring Irish Sea	6000	5472 α=30.86224 P=1.00	5452
B_{lim}	Increased risk of low R	Herring N. Sea	800000	558096 α=89.72825 P=0.00	48797
B_{lim}	MBAL	Herring Norwegian Spring Spawners	2.5 million	2271752 α=30.34923 P=0.00	1854
B_{lim}	Not defined	Herring VIa(N) (West of Scotland)	Not defined	52988 α=17.85445 P=0.53	66487
B_{lim}	B_{loss}	Horse mackerel VIIIc+IXa	136000	164595 α=7.15394 P=1.00	146356
B_{lim}	Not defined	Horse mackerel, western	Not defined	666345 α=4.193263 P=0.35	615757
B_{lim}	No biological basis for defining B_{lim}	Mackerel, combined stock	Not defined	2508240 α=1.640164 P=0.57	2407086
B_{lim}	Not defined	Megrim VIIb,c,e-k and VIIIabd	Not defined	55300 α=4.631823 P=1.00	54500
B_{lim}	Not defined	Megrim VIIIc and IXa (*L. whiffiagonis and L. boscii*)	Not defined	4977 α=5.28879 P=0.61	953
B_{lim}	B_{loss}	N.pout N. Sea	90000	167172 α=767.569 P=0.14	89435
B_{lim}	Cannot be accurately defined	Plaice IIIa (Kattegat-Skagerrak)	Not defined	26021 α=1.958527 P=0.67	23198
B_{lim}	B_{loss}	Plaice N. Sea	210000	162560 α=2.527299 P=0.36	140553
B_{lim}	Not defined. S-R data uninformative	Plaice VIIa (Irish)	Not defined	3102 α=2.87669 P=1.00	3095
B_{lim}	B_{loss}	Plaice VIId (Eastern Channel)	5600	7354 α=3.257796 P=0.18	5584

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New B_{loss}/ F_{loss}
B_{lim}	B_{loss}	Plaice VIIe (Western Channel)	1300	2532 α=2.225335 P=0.15	1321
B_{lim}	B_{loss}	Plaice VIIf+g (Celtic)	1100	1170 α=4.092039 P=0.59	1010
B_{lim}	B_{loss}	Saithe Arctic	89000	158512 α=1.464357 P=0.04	88546
B_{lim}	Lowest observed SSB	Saithe Faroe	60000	63068 α=0.4008100 P=1.00	60085
B_{lim}	B_{loss} estimate in 1998	Saithe Iceland	90000	132811 α=0.2550103 P=0.08	83857
B_{lim}	B_{loss}	Saithe N. Sea	106000	115254 α=2.150196 P=0.47	91900
B_{lim}	B_{loss}	Sandeel IV	90000	522139 α=1154.822 P=1.00	519749
B_{lim}	B_{pa}*exp(-1.645*0.2)	Sole IIIa	770	922 α=3.906653 P=1.00	919
B_{lim}	B_{loss}	Sole N. Sea	25000	24712 α=3.978441 P=0.63	21053
B_{lim}	B_{loss}	Sole VIIa (Irish)	2800	4302 α=1.585350 P=0.52	3052
B_{lim}	No biological basis for definition	Sole VIId (Eastern Channel)	Not defined	8289 α=3.029171 P=0.51	7779
B_{lim}	B_{loss}	Sole VIIe (Western Channel)	2000	4869 α=1.295763 P=0.00	1814
B_{lim}	Not defined	Sole VIIf+g (Celtic)	Not defined	1712 α=2.735754 P=0.70	1599
B_{lim}	Not defined	Sole VIIIab Biscay	Not defined	14913 α=2.139374 P=0.01	6594
B_{lim}	MBAL	Sprat 22-32	200000	246146 α=227.9169 P=0.52	209428
B_{lim}	B_{loss}	Whiting N. Sea	225000	285180 α=7.744097 P=0.02	144700
B_{lim}	Lowest SSB estimated in previous assessments	Whiting VIa (West of Scotland)	16000	18069 α=4.842521 P=0.11	7208
B_{lim}	B_{loss}	Whiting VIIa (Irish)	5000	3263 α=30.64137 P=0.45	2090
B_{lim}	B_{loss}	Whiting VIIe-k	15000	20183 α= 4.57125 P=0.15	15100
B_{pa}	B_{loss}	Anglerfish VIIb-k VIIIab (*L. budegassa*)	22000		
B_{pa}	B_{loss}	Anglerfish VIIb-k VIIIab (*L. piscatorius*)	31000		
B_{pa}	B_{lim} exp(1.645*σ) σ=0.25	Blue whiting	2.25 mill.		
B_{pa}	Withdrawn - Previous MBAL	Cod 22-24	23000		
B_{pa}	MBAL	Cod 25-32	240000		
B_{pa}	Examination of stock-recruit plot	Cod, Arctic	500000		
B_{pa}	Not defined	Cod Coas	Not defined		

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New $\mathbf{B}_{loss}$/ $\mathbf{F}_{loss}$
$\mathbf{B}_{pa}$	Blime$1^{.645\sigma}$, assuming a of about 0.40 to account for the relatively large uncertainties in the assessment	Cod Faroe Plateau	40000		
$\mathbf{B}_{pa}$	Not defined	Cod Iceg	Not defined		
$\mathbf{B}_{pa}$	$\mathbf{B}_{lim}$*exp(1.645*0.3)	Cod Kattegat	10500		
$\mathbf{B}_{pa}$	Previous MBAL and signs of impaired recruitment below: 150 000 t	Cod N. Sea	150000		
$\mathbf{B}_{pa}$	Previously set at 25 000 t at which good recruitment is probable. Reduced to 22000 t due to an extended period of stock decline	Cod VIa (West of Scotland)	22000		
$\mathbf{B}_{pa}$	Previous MBAL with signs of reduced R	Cod VIIa (Irish)	10000		
$\mathbf{B}_{pa}$	Historical development of stock	Cod VIIe-k	10000		
$\mathbf{B}_{pa}$	Not defined	Flounder 24-25	Not defined		
$\mathbf{B}_{pa}$	Not defined	Greenland halibut V+XIV	Not defined		
$\mathbf{B}_{pa}$	$\mathbf{B}_{lim}$*1.67	Haddock, Arctic	80000		
$\mathbf{B}_{pa}$	2 std above $\mathbf{B}_{lim}$ but reduced based on S-R plot	Haddock Faroe	55000		
$\mathbf{B}_{pa}$	Not defined	Haddock, Icelandic	Not defined		
$\mathbf{B}_{pa}$	1.4*$\mathbf{B}_{lim}$	Haddock N. Sea	140000		
$\mathbf{B}_{pa}$	$\mathbf{B}_{lim}$*1.4	Haddock VIa (West of Scotland)	30000		
$\mathbf{B}_{pa}$	1.4*$\mathbf{B}_{loss}$	Haddock VIb (Rockall)	9000		
$\mathbf{B}_{pa}$	Not defined	Haddock VIIa (Irish)	Not defined		
$\mathbf{B}_{pa}$	1.4*$\mathbf{B}_{lim}$	Hake, Northern stock	165000		
$\mathbf{B}_{pa}$	$\mathbf{B}_{lim}$ x 1.64	Hake, Southern stock	33600		
$\mathbf{B}_{pa}$	Not defined	Herring 25-29+32 ex GoR	Not defined		
$\mathbf{B}_{pa}$	$\mathbf{B}_{lim}$ *exp(1.645*0.2)	Herring, Bothnian Sea (30)	200000		
$\mathbf{B}_{pa}$	Not defined	Herring, Bothnian Bay (31)	Not defined		
$\mathbf{B}_{pa}$	Low probability of low recruitment	Herring Celtic Sea	44000		
$\mathbf{B}_{pa}$	Approximately 1.4 $\mathbf{B}_{lim}$	Herring VIa & VIIb,c	110000		
$\mathbf{B}_{pa}$	MBAL	Herring Gulf of Riga	50000		
$\mathbf{B}_{pa}$	$\mathbf{B}_{lim}\, e^{1.645\,\sigma}$ $\sigma = 0.25$	Herring Icelandic	300000		
$\mathbf{B}_{pa}$	$\mathbf{B}_{lim}$ *1.58; still under consideration	Herring Irish Sea	9500		
$\mathbf{B}_{pa}$	Part of a harvest control rule based on simulations	Herring N. Sea	1.3 mill		

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New B_{loss}/ F_{loss}
B_{pa}	B_{lim} * exp(0.4*1.645)	Herring Norwegian Spring Spawners	5.0 million		
B_{pa}	Not defined	Herring VIa(N) (West of Scotland)	Not defined		
B_{pa}	1.5*B_{loss}	Horse mackerel VIIIc+IXa	205000		
B_{pa}	Not defined	Horse mackerel, western	Not defined		
B_{pa}	B_{loss}	Mackerel, combined stock	2.3 million		
B_{pa}	B_{loss}	Megrim VIIb,c,e-k and VIIIabd	55000		
B_{pa}	Not defined	Megrim VIIIc and IXa (*L. whiffiagonis and L. boscii*)	Not defined		
B_{pa}	Below average R below 150000t	N .pout N. Sea	150000		
B_{pa}	Smoothed B_{loss} (no sign of impairment)	Plaice IIIa (Kattegat-Skagerrak)	24000		
B_{pa}	Approximately 1.4 B_{lim}, previous MBAL	Plaice N. Sea	300000		
B_{pa}	B_{loss}	Plaice VIIa (Irish)	3100		
B_{pa}	1.4*B_{lim}	Plaice VIId (Eastern Channel)	8000		
B_{pa}	MBAL	Plaice VIIe (Western Channel)	2500		
B_{pa}	1.64*B_{lim}	Plaice VIIf+g (Celtic)	1800		
B_{pa}	Examination of stock-recruit plot	Saithe Arctic	150000		
B_{pa}	Former MBAL	Saithe Faroe	85000		
B_{pa}	Observed low SSB values in 1978-1993	Saithe Iceland	150000		
B_{pa}	Impaired recruitment at SSB less than 200 000 t. This affords a high probability of maintaining SSB above B_{lim}, taking into account the uncertainty of assessments. Below this value the probability of below-average recruitment increases.	Saithe N. Sea	200000		
B_{pa}	1.4*B_{lim}	Sandeel IV	600000		
B_{pa}	MBAL	Sole IIIa	1060		
B_{pa}	1.4*B_{lim}	Sole N. Sea	35000		
B_{pa}	1.4*B_{lim}	Sole VIIa (Irish)	3800		
B_{pa}	Smooth B_{loss}	Sole VIId (Eastern Channel)	8000		
B_{pa}	Historical development: Biomass below this has increased risk of reduced recruitment	Sole VIIe (Western Channel)	2800		

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New B_{loss}/ F_{loss}
B_{pa}	B_{loss}	Sole VIIf+g (Celtic)	2200		
B_{pa}	Historical development of the stock [lowest observed for the converged part of the VPA, i.e. the most recent years are not included]	Sole VIIIab Biscay	1300		
B_{pa}	1.38*B_{lim}	Sprat 22-32	275000		
B_{pa}	1.4*B_{lim}	Whiting N. Sea	315000		
B_{pa}	1.4*B_{lim}	Whiting VIa (West of Scotland)	22000		
B_{pa}	1.4*B_{loss}	Whiting VIIa (Irish)	7000		
B_{pa}	1.4*B_{lim}	Whiting VIIe-k	21000		
F_{lim}	Not defined	Anglerfish VIIb-k VIIIab (*L. budegassa*)	Not defined		0.280030483
F_{lim}	F_{loss}	Anglerfish VIIb-k VIIIab (*L. piscatorius*)	0.33		0.315799563
F_{lim}	F_{loss}	Blue whiting	0.51		9.52482E-08
F_{lim}	Not defined	Cod 22-24	Not defined	1.045398776	2.993120872
F_{lim}	F_{med} 98	Cod 25-32	0.96	0.707946194	2.901554839
F_{lim}	Median value of F_{loss}	Cod, Arctic	0.70	1.111489927	1.9117246
F_{lim}	Not defined	Cod Coas	Not defined	0.333525222	0.646781521
F_{lim}	Fpae$^{1.645\sigma}$, assuming a □ of about 0.40 to account for the relatively large uncertainties in the assessment	Cod Faroe Plateau	0.68	1.445197169	1.767577842
F_{lim}	Not defined	Cod Iceg	Not defined	0.66247447	1.151538463
F_{lim}	SSB has declined since early 1970s at F=1.0	Cod Kattegat	1.0	0.778282326	2.09045545
F_{lim}	F_{loss}	Cod N. Sea	0.86	0.849735886	2.024359937
F_{lim}	F above 0.8 had led to stock decline in early 1980s	Cod VIa (West of Scotland)	0.8	0.727668674	2.468901692
F_{lim}	F_{med}	Cod VIIa (Irish)	1.0	1.048869	3.890813239
F_{lim}	Based on historical response of the stock	Cod VIIe-k	0.9	0.65012062	1.026206232
F_{lim}	Not defined	Flounder 24-25	Not defined		7.77682E-07
F_{lim}	Not defined	Arctic halibut	Not defined	0.387508501	0.553025363
F_{lim}	Not defined	Greenland halibut V+XIV	Not defined		6.52671E-07
F_{lim}	Median of F_{loss}	Haddock, Arctic	0.49		1.583751578
F_{lim}	2 std over F_{pa}	Haddock Faroe	0.40		0.988273947
F_{lim}	Not defined	Haddock, Icelandic	Not defined		4.507573304
F_{lim}	1.4*F_{pa} which has historically led to decline	Haddock N. Sea	1.0		5.144598404
F_{lim}	Not defined	Haddock VIa (West of Scotland)	Not defined		1.383895617
F_{lim}	Could not be defined, due to uninformative stock recruitment data	Haddock VIb (Rockall)	Not defined		2.137512133

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New B_{loss}/ F_{loss}
F_{lim}	Not defined	Haddock VIIa (Irish)	Not defined		4.507573304
F_{lim}	F_{loss}	Hake, Northern stock	0.28	0.330003698	0.397968458
F_{lim}	F_{loss}	Hake, Southern stock	0.45	0.471063918	0.682967581
F_{lim}	F_{loss}	Herring 25-29+32 ex GoR	0.33	0.189186348	0.642786514
F_{lim}	F_{loss}	Herring, Bothnian Sea (30)	0.30	0.275550493	0.655732562
F_{lim}	Not defined	Herring, Bothnian Bay (31)	Not defined		1.039732939
F_{lim}	Not defined	Herring Celtic Sea	Not defined	0.425618288	2.374386131
F_{lim}	F_{loss}	Herring VIa & VIIb,c	0.33		2.79468E-07
F_{lim}	Not defined	Herring Gulf of Riga	Not defined	0.366816323	0.944956366
F_{lim}	Not defined	Herring Icelandic	Not defined		0.771581438
F_{lim}	Not defined	Herring Irish Sea	Not defined		0.850867179
F_{lim}	Not defined	Herring N. Sea	Not defined	0.811884456	-0.243252
F_{lim}	Not considered relevant	Herring Norwegian Spring Spawners	Not defined	No S-R	1.93162E-07
F_{lim}	Not defined	Herring VIa(N) (West of Scotland)	Not defined		0.74538078
F_{lim}	F_{loss}	Horse mackerel VIIIc+IXa	0.27		0.219502416
F_{lim}	Not defined	Horse mackerel, western	Not defined		0.272390755
F_{lim}	F_{loss}	Mackerel, combined stock	0.26		0.295056964
F_{lim}	F_{loss}	Megrim VIIb,c,e-k and VIIIabd	0.44		0.380221575
F_{lim}	Not defined	Megrim VIIIc and IXa (*L. whiffiagonis and L. boscii*)	Not defined		1.038173992
F_{lim}	None advised	N .pout N. Sea	Not defined	-0.185	-0.185
F_{lim}	Cannot be accurately defined	Plaice IIIa (Kattegat-Skagerrak)	Not defined		5.801733869
F_{lim}	F_{loss}	Plaice N. Sea	0.6		1.008159866
F_{lim}	Not defined	Plaice VIIa (Irish)	Not defined		0.978303373
F_{lim}	F_{loss}	Plaice VIId (Eastern Channel)	0.54		0.793599239
F_{lim}	Not defined	Plaice VIIe (Western Channel)	Not defined		0.990541924
F_{lim}	Not defined	Plaice VIIf+g (Celtic)	Not defined		1.258300488
F_{lim}	Median value of F_{loss}	Saithe Arctic	0.45	0.518613098	0.761120198
F_{lim}	Consistent with B_{lim} of 60 000 t	Saithe Faroe	0.40		0.598531084
F_{lim}	Not defined	Saithe Iceland	Not defined		0.33371755
F_{lim}	F_{loss}	Saithe N. Sea	0.6		0.785210349

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New B_{loss}/ F_{loss}
F_{lim}	None advised	Sandeel IV	Not defined		1.016460301
F_{lim}	F_{med}, excl. abnormal years around 1990	Sole IIIa	0.47		1.398251034
F_{lim}	Not defined	Sole N. Sea	Not defined		0.987904492
F_{lim}	F_{loss} and historical considerations	Sole VIIa (Irish)	0.4		0.614958686
F_{lim}	F_{lim} is set equal to F_{loss}, but poorly defined; analogy to North Sea and setting of 1.4 F_{pa} = 0.55.	Sole VIId (Eastern Channel)	0.55		0.632073325
F_{lim}	F_{loss}	Sole VIIe (Western Channel)	0.28	0.249717073	0.478904988
F_{lim}	F_{loss}	Sole VIIf+g (Celtic)	0.52		0.623997101
F_{lim}	Based on historical response of the stock	Sole VIIIab Biscay	0.5	0.436462484	1.016196269
F_{lim}	Not defined	Sprat 22-32	Not defined		1.913010856
F_{lim}	F_{loss}	Whiting N. Sea	0.9	0.736602432	2.74606147
F_{lim}	Is 1.0 above which stock decline has been observed	Whiting VIa (West of Scotland)	1.0	0.679905876	1.696748708
F_{lim}	F_{loss}	Whiting VIIa (Irish)	0.95		1.537600785
F_{lim}	Not defined	Whiting VIIe-k	Not defined		5.409868434
F_{pa}	F_{med} consistent with proposed B_{pa}	Anglerfish VIIb-k VIIIab (*L. budegassa*)	0.23		
F_{pa}	0.72*F_{lim}	Anglerfish VIIb-k VIIIab (*L. piscatorius*)	0.24		
F_{pa}	F_{med}	Blue whiting	0.32		
F_{pa}	To be discussed with managers	Cod 22-24	Not defined		
F_{pa}	5% percentile of F_{med}	Cod 25-32	0.6		
F_{pa}	5^{th} percentile of F_{loss} = F_{lim} x 0.6	Cod, Arctic	0.42		
F_{pa}	Not defined	Cod Coas	Not defined		
F_{pa}	Close to F_{max} (0.34) and F_{med} (0.38) values from 1998 assessment	Cod Faroe Plateau	0.35		
F_{pa}	Not defined	Cod Iceg	Not defined		
F_{pa}	F_{lim}*exp(-1.645*0.3)	Cod Kattegat	0.6		
F_{pa}	Approx. 5^{th} percentile of F_{loss}; implies an equilibrium biomass >B_{pa} and a less than 10% probability that (SSBMT<B_{pa})	Cod N. Sea	0.65		
F_{pa}	Consistent with long-term B_{pa}	Cod VIa (West of Scotland)	0.60		
F_{pa}	F_{med}* 0.72	Cod VIIa (Irish)	0.72		
F_{pa}	5^{th} percentile of F_{loss}	Cod VIIe-k	0.68		
F_{pa}	Not defined	Flounder 24-25	Not defined		
F_{pa}	Not defined	Greenland halibut V+XIV	Not defined		
F_{pa}	F_{med}	Haddock, Arctic	0.35		

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New B_{loss}/ F_{loss}
F_{pa}	F_{med} was provisionally proposed in 2000	Haddock, Icelandic	0.47		
F_{pa}	F_{med}	Haddock Faroe	0.25		
F_{pa}	Flpg, which implies an eq. SSB>B_{pa} and a less than 10% prob. that SSBmt<B_{pa}	Haddock N. Sea	0.7		
F_{pa}	Set at 0.5. This has a high prob of avoiding B_{pa} in the long-term	Haddock VIa (West of Scotland)	0.5		
F_{pa}	Adopted by analogy to other haddock stocks	Haddock VIb (Rockall)	0.4		
F_{pa}	Set by analogy with other haddock stocks.	Haddock VIIa (Irish)	0.5		
F_{pa}	0.72*F_{lim}, implies a less than 10% prob. that SSBmt<B_{pa}	Hake, Northern stock	0.20		
F_{pa}	F_{lim} x 0.61	Hake, Southern stock	33600		
F_{pa}	F_{med}	Herring 25-29+32 ex GoR	0.19		
F_{pa}	F_{med}	Herring, Bothnian Sea (30)	0.21		
F_{pa}	Not defined	Herring, Bothnian Bay (31)	Not defined		
F_{pa}	Not defined	Herring Celtic Sea	Not defined		
F_{pa}	F_{med}(98)	Herring VIa & VIIb,c	0.28		
F_{pa}	From m-t projections	Herring Gulf of Riga	0.4		
F_{pa}	$F_{0.1}$	Herring Icelandic	0.22		
F_{pa}	F_{med}	Herring Irish Sea	under review, proposed as 0.36 in 1999, not adopted		
F_{pa}	From simulations low risk of SSB<B_{pa}	Herring N. Sea	$F_{ages\ 0\text{-}1}$ = 0.12; at $F_{ages\ 2\text{-}6}$ = 0.25		
F_{pa}	ICES Study Group 1998	Herring Norwegian Spring Spawners	0.15		
F_{pa}	Not defined	Herring VIa(N) (West of Scotland)	Not defined		
F_{pa}	0.63*F_{lim}	Horse mackerel VIIIc+IXa	0.17		
F_{pa}	Not defined	Horse mackerel, western	Not defined		
F_{pa}	0.65*F_{lim}, (also=$F_{0.1}$)	Mackerel, combined stock	0.17		
F_{pa}	F_{med}: less than 5% prob. (SSBmt<B_{pa})	Megrim VIIb,c,e-k and VIIIabd	0.30		
F_{pa}	Not defined	Megrim VIIIc and IXa (*L. whiffiagonis and L. boscii*)	Not defined		
F_{pa}	None advised	N .pout N. Sea	Not defined		

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New B_{loss}/ F_{loss}
F_{pa}	F_{med}	Plaice IIIa (Kattegat-Skagerrak)	0.73		
F_{pa}	5th % of F_{loss} (0.6) is 0.36, which implies that $B_{eq} < B_{pa}$. Therefore a lower value is required. F = 0.3 implies $B_{eq} > B_{pa}$ and a less than 10 % probability that $SSB_{MT} < B_{pa}$.	Plaice N. Sea	0.30		
F_{pa}	F_{med} in a previous assessment and long-term consideration	Plaice VIIa (Irish)	0.45		
F_{pa}	5th % of F_{loss}; SSB*>B_{pa} and prob. (SSBmt<B_{pa}) 10%	Plaice VIId (Eastern Channel)	0.45		
F_{pa}	Set so that prob. (SSBmt<B_{pa}) is low	Plaice VIIe (Western Channel)	0.45		
F_{pa}	Not defined	Plaice VIIf+g (Celtic)	Not defined		
F_{pa}	F_{lim} * 0.6	Saithe Arctic	0.26		
F_{pa}	Consistent with F_{lim} and F_{med}	Saithe Faroe	0.28		
F_{pa}	F sustained for 3 decades	Saithe Iceland	0.3		
F_{pa}	5th perc. of F_{loss} which implies an eq. SSB>B_{pa} and a less than 10% prob. that SSBmt<B_{pa}	Saithe N. Sea	0.4		
F_{pa}	None advised	Sandeel IV	Not defined		
F_{pa}	Set consistent with F_{lim}	Sole IIIa	0.3		
F_{pa}	5th percentile (0.49) of F_{loss} implies $B_{eq} < \sim B_{pa}$, F = 0.4 implies $B_{eq} > B_{pa}$ and P($SSB_{MT} < B_{pa}$) < 10%.	Sole N. Sea	0.4		
F_{pa}	0.3 considered having a high prob. of avoiding F_{lim}	Sole VIIa (Irish)	0.3		
F_{pa}	Between F_{med} and 5th % of F_{loss}; SSB>B_{pa} and probability (SSB_{mt}<B_{pa}), 10%: 0.4.	Sole VIId (Eastern Channel)	0.4		
F_{pa}	0.72*F_{lim}: implies a less than 10% prob. of SSBmt<B_{pa}	Sole VIIe (Western Channel)	0.2		
F_{pa}	0.72*F_{lim}; implies a less than 5% prob. of SSBmt<B_{pa}	Sole VIIf+g (Celtic)	0.37		
F_{pa}	F_{lim} * 0.72	Sole VIIIab Biscay	0.36		
F_{pa}	Average F_{med} in recent years, allowing for variable natural mortality	Sprat 22-32	0.4		
F_{pa}	0.7*F_{lim}	Whiting N. Sea	0.65		
F_{pa}	0.6*F_{lim}	Whiting VIa (West of Scotland)	0.6		

PA point	Technical basis (2002 report)	Stock	Ref. point used in 2002 report	Seg reg. R-program (α=slope from origin to breakpoint)	New $\mathbf{B}_{loss}$/ $\mathbf{F}_{loss}$
$\mathbf{F}_{pa}$	0.65, implies an equilibrium SSB of 10.6 kt, and a relatively low probability of SSB < $\mathbf{B}_{pa}$ (= 7 kt), and is within the range of historic Fs	Whiting VIIa (Irish)	0.65		
$\mathbf{F}_{pa}$	Not proposed	Whiting VIIe-k	Not proposed		