The Role of BRP in the Fish Stock Assessment – Lessons from the History of ICES

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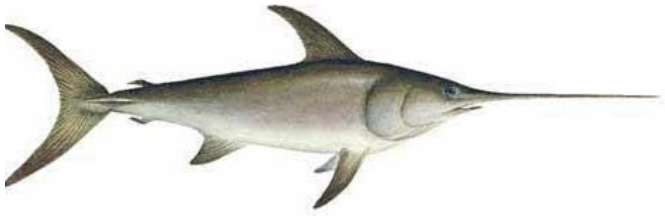

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The role of BRP in the fish stock assessment
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Introduction

ISC is currently developed as a scientific body of the northern committee of WCPFC. The northern committee is now requesting ISC to prepare information about the biological reference points (BRP). BRP is the one of basic idea coming from the history of the fish stock management. The fish stock management is the one of largest activity for human to control the population of wild organisms, but it usually faces with the grate hardness as the monitoring of fish population and fishing activities are rather difficult. Thus the managers and fishery scientists have been learning many things from the history of the fish stock management, and as a result of this, they developed variety of rules and basic ideas through their experiments. Though the prices they paid seem quite larger, but we can learn many things from their stories. Within RFMO, International Council for the exploration of the Sea (ICES) has longest history, and has been developed many basic ideas on the fish stock managements as well as fish stock assessments. This document reviews the past history of ICES fish stock management laying stress on the issue of BRP.

This is not a document but a kind of “Memo” which authors were used to grab an idea of the role of BRPs in the fish stock management. Almost of all parts below are the just a “copy and paste” of the series of reports and documents in ICES. The parts of “ICES AFCM” and “Development of the Basis and form of ICES Fisheries Management Advice” were referred from Serchuk and Grainger (1992), the part of “Revision of form of ACFM Advice” was refereed from Serchuk and Grainger (1992) and ICES (1992), and the part of “AFCM in recent years” refereed from ICES (2005) and ICES (2008). Though the manuscript in appeared in these parts are copies faithful to the original articles, the underlines and block letters were given by authors.

ICES AFCM

Since its founding in 1902, the ICES has been the most prominent intergovernmental organization in the world concerned with marine and fisheries science. Throughout its history, the mission of ICES with respect to provision of fisheries management advice has been very much in accord with the proposed by D'Arcy Thompson in June 1899 at the first International Conference for the Exploration of the Sea (cited in Went 1972), viz.

'it be recognized as a primary object to estimate the quantity of fish available for the use of man, to record the variations in its amount from place to place and from time to time, to ascribe natural variations to their natural causes, and to determine whether or how far variations in the available stock are caused by the operations of man, and, if so, whether, when, or how measures of restriction and protection should be applied.'

During the 1st half of the twenties century, scientific advices provided by ICES on fisheries management was restricted to "technical" measures involving minimum mesh sizes, minimum fish sizes and closed area regulations. In 1963, when NEAFC (North-East Atlantic Fisheries Commission) is established, catch control measures (TACs) could be used to limit exploitation rates. As a result, the ICES Liaison Committee, which had been established in 1953 to provide management advice on behalf of the Council, began to provide advice in relation to TACs.

In the mid-1970s, marked changes occurred in fishery management responsibilities as many countries implemented extended fisheries jurisdiction. In 1977, the Commission of the European Communities (EC) assumed responsibility for management of fishery resources within EC waters. In response to the changed management regimen, the ICES Liaison Committee was replaced in 1978 by the ICES Advisory Committee on Fishery Management (ACFM). ACFM membership consists of a Chairman, the Chairman of the Demersal, Pelagic, and Baltic Fish Committees and one scientific expert from each of the ICES member countries. So, ACFM is roughly corresponding to the plenary meeting of ISC. In formulating its advice, ACFM reviews and utilizes the results of stock assessment analysis conducted by about 20 ICES assessment working groups, established to provide information on the status of stocks.

Development of the Basis and form of ICES Fisheries Management Advice

At the beginning, ICES Liaison Committee refereed the $F_{0.1}$ as it would avoid some of

the inherent risks in a MSY-based strategy and would generate other benefits. This approach should also take into account the exploitation pattern, the spawning stock, a buffer stock (which implies that the stock size should be maintained at a sufficiently high level so that its variation due to recruitment is reduced), and catch per effort (which implies that fishable stock densities should be maintained at high enough levels to ensure harvesting without excessive costs).

The application of this new approach would require that for each stock there would be a need to:

a) Define an optimal range of spawning stock size. This should be assessed either on the basis of a stock/recruitment analysis or chosen more arbitrarily on the basis of historical reviews of periods of "normal" recruitment;
b) Define an agreed minimum fishable biomass level; this may, or many not, differ from the minimum spawning stock level;
c) Assess the characteristics of the fishing pattern in relation to an optimized pattern.

A TAC based pm yields corresponding to $F_{0.1}$ will often be found to meet the objectives of maintaining the spawning stock at the desired level. If used with a reasonably favorable exploitation pattern. This TAC should then be modified against the objectives for "optimum fishing", i.e. (a) maintain the spawning stock size within the defined range, and (b) keep the fishable biomass above the agreed minimum level. Objective (a) must be considered more important than (b).

Where the spawning stock biomass is substantially lower than the acceptable range, or the fishable biomass lower than the agreed minimum level, a scheme of rebuilding the stock in annual steps should be designed. Use should be made in such schemes of recruitment variations when strong year classes enter the stock.

When ACFM replaced the Liaison Committee in 1978, the underlying principles on which ICES management advice was based remained unchanged. ACFM was aware, however, that most stocks were being fished far above $F_{0.1}$, and that exploitation patterns were far from optimal. Since reaching these goals in one step would inevitably create major short-term economic and social hardships to the fishing industries, ACFM adopted a policy of recommending gradual reductions in fishing mortality (i.e., 10%/year) and phased improvements to exploitations patterns. ACFM also noted that there were biological and ecological reasons for advising on a gradual approach in reducing fishing mortality to $F_{0.1}$ (ICES 1981a). By 1980, however, ACFM recognized that little progress was being made in reducing fishing mortality on most of the heavily

exploited stocks. Consequently, ACFM modified its initial policy and began to recommend somewhat larger annual cutbacks in F, particularly in those cases where greater F reductions would not results in very large changes in yields (ICES 1981b).

ICES Dialogue Meetings were established in 1980 to provide a forum for regular communication between scientists, managers, and the fishing industry on issues related to management objectives, and advice.

The 1981 ACFM report defined five categories of stocks for the purpose of providing management advice:

1. Stocks which are depleted and suffering from recruitment failure. In these cases, ACFM shall not calculate options but shall recommend a single figure.
2. Stocks which are fished at levels largely in excess of the levels indicated by biological reference points. In these cases, ACFM shall give options inside safe biological limits, and shall recommend one of these options, according to the general principles of aiming at more stable levels.
3. Stocks which are fished at levels not very different from the biological reference points. In these cases, ACFM shall give options inside safe biological limits, but shall not recommend any particular one of these. It shall only indicate a preference, which is in line with the general principles mentioned above.
4. Stocks where at present it is not possible to carry out any analytical assessment with an acceptable reliability. In these cases, ACFM shall indicate precautionary TACs reduce the danger of excessive effort being exerted on these stocks.
5. In cases where fisheries on a stock are not subject to TAC regulation, there may be a danger of catches taken from stocks of the same species in adjacent areas being misreported as having been taken in areas of unregulated fisheries. To reduce the risk of this happening, ACFM, on occasion at the request of management bodies, has advised the implementation of TACs, and their levels on this basis. As in the majority of cases, the data on these stocks are inadequate for analytical assessment, they too will generally be recommended as precautionary TACs based on historical catch levels.

The introduction of catch options and categorization of advice by ACFM in 1981 was regarded as a change from 'normative' advice (i.e., advice based upon clearly identified management objectives or targets and the rates at which these should be approached) to

'exploratory' advice (i.e., advice given where management objectives have not been set (or are ill-defined) and stock conditions are such that a range of catch options are possible all within safe biological limits).

In 1982, ACFM revised the type of recommendation it would provide for stocks in Category 2 indicated that its biological advice should not be considered entirely apart from economic aspects, viz.

In order to allow more flexibility to the management authorities, the type of recommendation for a Category 2 stocks is that fishing mortality should be reduced to one of the biological reference points as quickly as possible, or (in some cases) towards one of these points.
The ACFM considers that biological advice on fisheries management should not be considered entirely in isolation from economic considerations. Economic analysis would more clearly illustrate optimal management strategies within biological constraints. ACFM Would welcome advice from professional economic analysts on how to tailor its biological output to best suit the needs of economic analysis. It must be stressed, however, that it will be necessary for management to improve both the quality and the detail of much of the information available to ACFM and the ICES Working Groups, which at present is not adequate to carry out any kind of analytical biological assessment on several stocks and seriously impairs the precision of some of the assessments carried out on others.

In 1987, ACFM introduced the additional biological reference points F_{med} and F_{high} into its advice and noted that these were intended to provide guidelines for levels of fishing mortality at which it is probable (in the case of F_{med}) and doubtful (in the case of F_{high}) that recruitment will, in the long-term, be sufficient to sustain a stable stock. It was furthermore noted that:

ACFM found F_{med} in particular to be a useful quantity in providing guidance in preparing management options, and reference to it will be found in this report where appropriate. ACFM also stresses that biological reference points are intended to provide guidance concerning management options, and that no single reference point can possibly serve as a universal target for management. ACFM advice is, however, based on the evaluation of as many relevant factors as possible, including levels of F in relation to biological reference points, spawning stock size in relation to historic levels,

trends and recent levels of recruitment, and the precision of the assessment. Different factors dominate in different situations.

The issue of 'safe biological limits' was addressed by ACFM in both 1986 and 1987. ACFM requested that all ICES assessment working groups "try to define safe biological limits for the stocks which they assess and to indicate whether sufficient data exist on which to base a definition". Although working group responses varied, 'target' or 'minimum acceptable' spawning stock levels were identified for many stocks. ACFM informally adopted the approach taken by the Irish Sea and Bristol Channel Working Group in addressing 'safe biological limits'.
Biologically safe limits should be based on the historical experience of recruitment, stock size, and fishing mortality for each stock. Precise "safe limits" cannot be defined but indications of the current stock situation in relation to safe limits can be obtained by addressing the following questions;

1) Is there any evidence from the stock/recruit data that recruitment is reduced at the lowest levels of spawning stock which have been observed in the historic series?
2) Is the spawning stock currently at a level which is lower than any previously observed?
3) Does spawning biomass show a declining trend which, taken with available evidence on recruitment, might indicate that a historically low level will be reached in current year or next year?
4) What level of F in next year would be needed to reduce the spawning stock biomass to a historically low level in the following year and what would the corresponding catch be in next year?

In general, the basis and form of advice used by ACFM during 1981-1990 was accepted without major reservations. On more than one occasion, however, ACFM was criticized for assuming responsibilities for the selection of management objectives and for the time-scales (rates) at which objectives should be reached. Such responsibilities were deemed more appropriate (or solely appropriate) to management bodies. As well, dissatisfaction was expressed that the ACFM advice had occasionally made reference to socio-economic considerations, which were felt to be outside of ACFM's purview. At various times, ACFM was also criticized for not providing sufficient detail or justification for its recommendations.

Revision of form of ACFM Advice

1) Overview

In autumn 1991, ACFM adopted a new approach to formulating its advice. This new approach was the result of a year-long process wherein ACFM examined and evaluated the basis and criteria that had been used in developing its scientific advice since 1981. ACFM believes that this protocol is a significant improvement over its previous approach and will result in more objective, consistent, and credible management advice.

Under the new system, ACFM defines its own objective to be: 'To provide the advice necessary to maintain viable fisheries within sustainable ecosystems.' The specification of objectives for fisheries management is recognized as a responsibility of management bodies, not ACFM. The role of ACFM will be to provide the biological information and advice necessary for managers to achieve the objectives they choose. In providing its advice, ACFM will present options as to how management objectives can be reached and will clearly describe the implications and consequences of these options and their associated risks. ACFM may comment, for example, that an increase in fishing mortality is not expected to produce any gain in long-term yield, or that reductions in fishing mortality would allow for a greater buffer spawning stock as a hedge against future recruitment fluctuations. However, recommendations will only be made in cases where stocks are exploited outside biological limits (i.e., where stocks are below a "minimum biologically acceptable level (MBAL)" or expected to fall below this level in the near future at present rates of exploitation). For stocks in this category, ACFM will give advice on what measures are needed to rectify the situation; the severity of this advice and the extent to which management options are possible, will normally depend on the degree of stock depletion. When stocks are exploited within safe biological limits, ACFM will provide options without indicating a preference – but ACFM will indicate the biological consequences and risks associated with each option. In this latter situation, the choice of a particular option is left to the managers. Advice on precautionary TACs will generally be provided only if specifically requested.

In providing its advice, ACFM will normally identify a number of BRPs. These represent a set of signposts to enable scientists and managers to judge the state of exploitation of the stocks. The BPRs refer to levels of fishing mortality on the yield-per-recruit curve, or to levels of fishing mortality that effect the sustainability of recruitment. The BRPs are not the same as management objectives; they simply serve as a guide to aid managers in choosing from the range of available options.

ACFM has long recognized the need to provide advice, wherever possible, within a multispecies context (ICES 1985). As scientific understanding of the nature of technical and biological interactions among fisheries and fish stocks has becomes known, ACFM has striven (and will continue to strive) to take these interactions into account in its advice.

2) Stock Categories and MBAL

In this revision of the advice, ACFM set its objective as "**To provide the advice necessary to maintain viable fisheries within sustainable ecosystems**". At the same time, ACFM considered that it is appropriate to redefine the stock categories.

There is likely to be a level of spawning stock size below which the probability of poor recruitment increases as spawning stock size decreases. Because of the inherent variability of recruitment at any given spawning stock size, this level is not known for certain in many stocks. Nevertheless, some idea of the bounds within it may lie can be obtained by examining the historic variation in recruitment at different levels of spawning stock. For present purpose, this level is named the "minimum biologically acceptable level" (MBAL). This level may be useful in providing managers with an indication of a lower level of spawning stock above which the stock should, in so far as possible, be maintained.

It should be noted that stocks below the MBAL are not necessarily in danger of imminent collapse, but simply that recruitment is expected to be lower than at higher levels of spawning stock size. Because of the fact that there must be a direct proportionality between recruitment and spawning stock at low levels of spawning stock, however, any further decreases in spawning stock size may result in an accelerating progression towards collapse.

In stocks for which information is limited, it is safest to assume that the MBAL is equal to the lowest level of spawning stock so far recorded. Stocks below this level are in "unknown territory", and, therefore, any action resulting in such a condition would be outside safe biological limits, even though the level of spawning stock biomass at which the probability of poor recruitment increases as spawning stock decreases is not known.

On the bases of the above considerations, ACFM recognizes two categories of stocks; those that are below the MBAL (or expected to become so in the near future at present

levels of exploitation) and those that are not in immediate danger of falling below this level.

In stocks in the category of below the MBAL, ACFM will in so far as possible give advice on what measures are needed to rectify the situation. The severity of this advice and the extent to which management options are possible, will normally depend on the degree of depletion of the stock and on what information is available on the historic series of stock and recruitment.

The category of not in immediate danger of falling below MBAL includes stocks that are currently being exploited over a wide range of fishing mortalities, either above or below the BRPs on the yield-per-recruit curve, but which are not thought to be in imminent danger of falling below the MBAL. In these stocks, ACFM normally provides a range of options together with impact statements for each option.

Where fishing mortality is above F_{max} and $F_{0.1}$, the question of whether it should be reduced may be primarily an economic one. ACFM will, if asked or where appropriate, give indications on how longer-term benefits can be obtained in these cases, e.g., by effort reductions.

Where the fishing mortality rate is below or close to F_{max} or $F_{0.1}$, managers may have a wide range of options to consider. In these cases, ACFM would simply point out that nothing is to be gained in terms of yield-per-recruit by allowing fishing mortality to increase above the F_{max} or $F_{0.1}$ levels.

ACFM also considers that growth overfishing represents a sub-optimal use of resources, but accepts that this is partly an economic judgment outside its present area of competence. Similarly, ACFM considers that it has a responsibility to indicate measures that prevent a waste of resources (e.g., through discarding) or that minimize any harmful side effects of fishing.

AFCM in recent years

The Precautionary Approach was summarized in the UN Straddling Fish Stocks Agreement (UN 1995) as follows:

" States shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason

for postponing or failing to take conservation and management measures."

In 1997, ICES was asked by its clients to suggest an approach for implementing the precautionary approach into fisheries management in the North East Atlantic. The precautionary approach suggested by ICES consists of a dual system of conservation limits (limit reference points) and a buffer to account for the uncertainty of the knowledge about the present and future states relative to the conservation limit (precautionary approach reference points). The reference points are expressed in terms of single-stock exploitation boundaries (limits on fishing mortality) and biomass boundaries (minimum biomass requirements).
In practice the precautionary approach suggested by ICES (ICES 1997; ICES 1998; ICES 1999) is based on the following reference points:

	Spawning stock biomass (SSB)	Fishing mortality (F)
Limit reference point	B_{lim}: minimum biomass. Below this value recruitment is expected to be 'impaired' or the stock dynamics are unknown.	F_{lim}: exploitation rate that is expected to be associated with stock 'collapse' if maintained over a longer time.
Precautionary reference point	B_{pa}: precautionary buffer to avoid that *true* SSB is at B_{lim} when the *perceived* SSB is at B_{pa}.	F_{pa}: precautionary buffer to avoid that *true* fishing mortality is at F_{lim} when the *perceived* fishing mortality is at F_{pa}.
	The buffer safeguards against natural variability and uncertainty in the assessment. The size of the buffer depends upon the accuracy of the projections (of SSB and F) and the risk society accepts that the true SSB is below B_{lim} and the true F is above F_{lim}. The accuracy of the projections depends on the magnitude of the variability in the natural system and of the accuracy of the population estimates.	

Limit reference points:
The minimum spawning stock reference point is described by the symbol B_{lim} (the biomass limit reference point). B_{lim} is set on the basis of historical data so that when a stock would be below B_{lim}, there is a high risk that recruitment will 'be impaired' (i.e. substantially lower than when the stock size is higher). Below B_{lim} there is a higher risk that the stock could "collapse". The meaning of "collapse" is that the stock has reached a level where it suffers from severely reduced productivity. "Collapse" does not mean that a stock is at high risk of biological extinction. However, recovery of the stock to an improved status is likely to be slow and will depend on effective conservation measures. When information about the relationship between recruitment and SSB is absent or inconclusive, **ICES has used the lowest observed biomass B_{loss} as a proxy for B_{lim}**. This interpretation of B_{lim} is as a boundary under which the stock would enter an area where the stock dynamics are unknown.
The limit reference point for fishing mortality F_{lim} is the fishing mortality that is

expected to drive the stock to the biomass limit when it is maintained over time.

Precautionary reference points;
Spawning stock biomass and fishing mortality can only be estimated with uncertainty. As long as the estimate of spawning biomass is at or above B_{pa}, the probability of actually being at or below B_{lim} should be small. Similarly for fishing mortality: when the estimate of fishing mortality is at or below F_{pa}, there should be a low probability of actually fishing at or above F_{lim}.
The precautionary reference points are a mechanism for managing the risk of the stock falling below B_{lim} or the fishing mortality exceeding F_{lim}. This buffer safeguards against natural variability and uncertainty in the assessment. The size of the buffer depends upon the accuracy of the projections (of SSB and F) and the risk society accepts that the true SSB is below B_{lim} and the true F is above F_{lim}. The accuracy of the projections depends on the magnitude of the variability in the natural system and of the accuracy of the population estimates. E.g. if the quality of catch data were to decline, for example, a higher B_{pa} would be needed for the same B_{lim}. The same applies when society would want to accept a lower risk that the true biomass was below B_{lim}.

How have reference points been estimated?
Most reference points that are currently used were estimated in a process whose results were endorsed by the Advisory Committee on Fishery Management in 1998 (ICES 1999).
The estimation process consisted of the identification of limit reference points based on risk of reduced reproductive capacity and fishing mortality which is expected to drive stocks to reduced reproductive capacity. Precautionary reference points reflect the combined effects of the uncertainties in the assessments and the level of risk society is willing to take. In practice neither of these two effects could be directly quantified. Uncertainties in the assessments were approximated with rules-of-thumb estimates of coefficients of variation in the order of 20%. The level of risk that measures the distance between the limit and precautionary reference points was set at 5-10%. If, for example, the quality of catch data were to decline or multi-year forecasts were required for catch advice, a higher B_{pa} would be needed for the same B_{lim}. The same is true if society will only accept a very low risk that the true biomass is below B_{lim}.

Fisheries managers and stakeholders shall define the level of risk they were willing to accept this is not a science question. Therefore, the limit reference points have been

proposals.

How are reference points used in the advice;
Precautionary and limit reference points are used in two ways in the fisheries advice: (1) to classify the state of the stocks and (2) to bind the advice for short term exploitation boundaries.
When the spawning biomass is estimated to be below B_{pa}, ICES advises that management action should be taken to increase the stock to above Bpa. Similarly, to be certain that fishing mortality is below F_{lim}, fishing mortality should in practice be kept below a lower level F_{pa}. When fishing mortality is estimated to be above F_{pa}, ICES advises management action to reduce it to F_{pa}. Such advice is given even if the spawning biomass is above B_{pa} because fishing mortalities above F_{pa} are considered unsustainable. If a management plan exists which ensures that the SSB will be kept above B_{pa}, F_{pa} may temporarily be above F_{pa} as long as there are mechanisms ensuring a downward adjustment before SSB approaches B_{pa}.
ICES stresses that these precautionary reference points should not be treated as management targets, but as lower bounds on spawning biomass and upper bounds on fishing mortality. Good management should strive to keep SSB well above B_{pa} and fishing mortality well below F_{pa}. If stocks are managed close to their precautionary reference points, then annual scientific advice will be altering conclusions on stock status and necessary management actions on the basis of assessment uncertainty as much as on the basis of true changes in stock status. Managing stocks to achieve targets well removed from the risk-based reference points would result in more stable scientific advice, as well as healthier stocks and more sustainable fisheries.

Fisheries managers and stakeholders shall define the level of risk they were willing to accept this is not a science question. Therefore, the limit reference points have been presented as considerations from ICES and the precautionary reference points as proposals.

Target reference points;
The ICES advice is primarily risk-averse, i.e. it aims at reducing the risk of something undesirable happening to the stocks. Biological target reference points are also part of the Precautionary Approach, but setting targets for fisheries management involves socio-economic considerations. Therefore, ICES does not propose values for Target

management targets based on socio-economic benefits. Hence Target Reference Points have not been used directly in the advice. This means that even if the ICES advice is followed and therefore the stock should be protected from impaired productivity, exploitation of most stocks is likely to be sub-optimal, i.e. the long-term yield is lower than it could be. When societal objectives or targets have been identified ICES can provide advice relating to these targets. ICES may advise on the likeliness of achieving targets under different management regimes and may propose parameters and values for target points if a basis for such choices has been defined in fisheries policies. Managers are invited to develop targets and associated management strategies. ICES will comment on these and consider if they are consistent with the precautionary approach. If they are, ICES will frame the advice to be consistent with the adopted management targets.

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