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A Proposal for a More Flexible Framework for Implementing the Precautionary Approach on NAFO Stocks

by

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Abstract

Precautionary approach frameworks incorporating biological reference points, harvest control rules, assessment of risk and rebuilding plans have been implemented and developed within a number of international fisheries agencies and national government organizations over the last decade. Although the precautionary approach tenets embodied in these frameworks have been widely accepted by scientists and decision makers, in most cases there has been only limited implementation. This has led to the current process of revision and modification, with the objectives of increasing the transparency of the methods underlying the frameworks and increasing the negotiation space defined within the frameworks. The NAFO Scientific Council framework created in 1997 is reviewed in the context of other frameworks and the revisions that they are going through, and a proposal is developed for a revised, more transparent and more flexible framework.

Key words: precautionary approach framework, biological reference points, fisheries management

Introduction

The term, "precautionary approach" was introduced into the fisheries lexicon primarily as a result of three major initiatives by FAO, conducted around 1991-1996. The first of these is the FAO Code of Conduct for Responsible Fisheries which was developed as a result of a request by FAO's Committee on Fisheries (COFI) in 1991 and elaborated on at the International Conference on Responsible Fishing held in Cancun, Mexico in May 1992, and the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in June 1992. The Code of Conduct for Responsible Fisheries was completed in 1995 (FAO 1995a). It addresses six key themes: 1) fisheries management, 2) fishing operations, 3) aquaculture development, 4) integration of fisheries into coastal area management, 5) post-harvest practices and trade, and 6) fisheries research. The Code asserts that "States should apply the precautionary approach widely to conservation, management, and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment", and emphasizes "The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures".

While the Code of Conduct is a voluntary, non-binding agreement, the second major initiative is a binding international instrument that has recently gained sufficient signatures to come into effect. The Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNFA; UN 1995) was negotiated over a similar period as the FAO Code of Conduct and contains nearly identical language as the Code on many issues, including the precautionary approach and general principles for the conservation and management of living marine resources. Even before the Straddling Stocks Agreement came into effect, one section in particular was being used extensively as an explicit statement of the application of the precautionary approach in fisheries management. This short section (Annex II of the Straddling Stocks Agreement) includes the following statements: “Two types of precautionary reference points should be used: conservation or limit reference points, and management or target reference points”, “Such reference points shall be used to trigger pre-agreed conservation and management action”, “Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low”, and “The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points”. Use of the concepts and definitions in Annex II has been extended to a wide variety of fisheries, not just straddling and highly migratory stocks.

The third initiative, FAO’s Technical Guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions (FAO 1995b), was essentially an elaboration of the two outlined above, plus others. It groups the elements of the precautionary approach into three categories (excluding sections on species introductions): 1) fisheries management, 2) fisheries research, and 3) fisheries technology, covering a wide diversity of issues in 103 paragraphs. For example, the paragraphs on fisheries management address overfishing, restoration of overfished stocks, management objectives, uncertainty, harvesting overcapacity, controlled access to fisheries, data reporting requirements, management planning processes, and effective systems for monitoring and enforcement.

Recent developments

Subsequent to completion of these initiatives, application of the precautionary approach has taken two divergent paths. The first is that some management authorities now label almost any and every management action as an application of the precautionary approach, even retrospectively. In cases where risk-averse management was or is being practiced, this may be reasonable because the precautionary approach embodies risk-averse management. However, if everyone jumps on the bandwagon, claiming they have already being practising precautionary management, just not calling it that, and claiming every management action to be a sound example of application of the precautionary approach, then the term loses its meaning. The term needs to apply to more specific situations, not just the set of all possible management actions.

Another way in which the term has been used very loosely is in the extension to fisheries science. The FAO Guidelines themselves suggest using the term even more broadly than simply applying to fisheries management. In particular, they include an extensive section on the Precautionary Approach to Fisheries Research, even defining a “precautionary assessment”. Examination of this section shows that all that is meant by these terms is that scientific analyses should be based on the best possible data, should be as comprehensive as possible, and should incorporate uncertainty. It is probably a misnomer to apply the word, “precautionary” to fisheries science or stock assessments. In fact, use of the term in this context has backfired on stock assessment scientists in many arenas. “Precautionary assessments” are perceived by many others to be “assessments deliberately biased to be overly conservative”, and scientists have had to defend the fact that they themselves want assessments to be as unbiased as possible, and that in most organizations there are checks and balances in place for quality control of assessments. Many scientists and scientific organizations (e.g., NAFO, ICES and ICCAT) advocate restricting the term “precautionary” to be an adjective of fisheries management, but not fisheries science.

At the opposite extreme to (a perhaps overly-) broad use of the term, assessment scientists have mostly focused on very narrow aspects of the precautionary approach; namely, the development and application of biological reference points, formulation of harvest control rules, and incorporation of uncertainty into assessment results. This has certainly been the focus at NAFO, ICES, ICCAT, NASCO, and in many individual countries. NAFO, ICES and ICCAT have all developed default harvest control rules and associated reference points. In the United States, NMFS and the eight regional fishery management councils have developed and applied definitions of “overfishing” (F too high) and “overfished” (B too low), often overlain with a harvest control rule, for more than 200 fish stocks.

Although a default harvest control rule was suggested for use in the United States by Restrepo *et al*. (1998), numerous variations of control rules have been adopted. There have been few studies comparing the performance of alternative control rules. One exception is a recent report by Breen *et al*. (2003) who compared the performance of 14 alternative rules in terms of their application to a New Zealand rock lobster fishery.

Overall, there is no shortage of alternative control rules that have been developed, but there is a shortage of cases where such rules have actually been applied. The primary reason for the latter seems to be a combination of two factors: 1) the fact that a large number of key target species throughout the world are currently overfished, thus requiring some very tough compromises to be made between the need to rebuild stocks and short-term socio-economic considerations, and 2) the resistance to control rules that essentially mandate pre-defined management actions depending on the current state of the resource or fishery. Obviously, these go hand in hand. The mechanistic approach of control rules to implementation of precautionary management may be hindering agreement on conservation restrictions, simply because it leaves so little room for negotiation and political considerations (Rosenberg, 2002). This situation is exacerbated when stock status dictates the need for extremely restrictive management actions.

Developing and implementing PA frameworks

There is a long history of devising biological reference points and incorporating them into management advice on allowable harvests of marine fish stocks; such history precedes the advent of the precautionary approach in the 1990s. However, the precautionary approach embodies at least five concepts not previously brought together in fisheries management. The first is "reversal of burden of proof". Under a precautionary approach it should be demonstrated that a particular fishing activity will not result in unacceptable harm to the resource, rather than waiting until the damage occurs and then trying to repair it. In practise, reversal of burden of proof has to be judiciously applied and will be most relevant to situations where ovefishing is occurring. It does not imply that no fishing can take place until all potential impacts have been assessed and found to be negligible (FAO 1995b). The second represents a major conceptual shift - the notion of F_{msy} as a minimum standard for a limit reference point. This is a profound and significant departure from past fisheries management practice, where F_{msy} was considered a target, rather than a limit, and consequently frequently exceeded (Mace and Gabriel 1999). The third is the need to be risk-averse in decision-making. This is generally interpreted to mean that decisions should be taken such that there is a low risk (10% or less) of serious harm resulting. How to define serious harm and to adequately capture risk is an active area of current fisheries research. The fourth is the development of havest control rules that predetermine the management actions to be taken to achieve risk-averse decisions. These most commonly take the form of feedback control rules whereby fishing mortality is adjusted through TAC setting or other measures based on perceived current state or projected future state of the resource. The fifth is the need to develop recovery plans for depleted or collapsed stocks that ensure a very low fishing mortality, facilitating recovery of stocks to a predetermined size over a specified time period. This is currently particularly relevant given that many groundfish stocks have been reduced to low levels through overfishing.

In their review of the application of the precautionary approach, Mace and Gabriel (1999) found that a number of international fisheries organizations have adopted the precautionary approach and have actively developed biological reference points and harvest control rules. However, operational procedures for implementation of the PA have lagged. International fisheries agencies and national governments have often shied away from implementation. Where fish stocks have not collapsed, this may often be attributed to "precautionary" management practices, whereas in many instances it may simply be fortuitous (e.g. in a developing fishery where effort and capacity have not yet increased to the point that the removals are unsustainable). Where fisheries have been closed, this is generally because harvesting the remaining fish is no longer commercially profitable and can no longer be justified in any circumstances. Although *post facto* such closures may be described as precautionary, the real test will be what happens if and when the stock recovers. Reopening a fishery at the first sign of commercial quantities of fish, rather than recovery to the point that there is a small probability that the resource is below a sensibly defined B_{lim}, would weaken the argument that a precautionary approach is being implemented. To its credit, NAFO is one of the few international fisheries organisations that has had the political will to close directed fisheries on several severely depleted stocks.

A big impediment to the implementation of the precautionary approach is gross overcapacity in most fisheries. The lack of political will, both in national governments and in international fishery agencies, to tackle overcapacity and reduce TAC sufficiently is the major issue in preventing overfishing (Mace 1996, Mace and Gabriel 1999), and this has not changed with the advent of the precautionary approach. The change from F_{msy} as a target to F_{msy} as a limit requires a change in the mindset of fisheries managers and resource users - not just a subtle change, but a fundamental shift towards long-term sustainable fishing practices, including accurate reporting of removals, elimination of illegal effort, minimisation of bycatch, adherence to mesh size regulations and respecting closed area and season regulations. The scale may only tip towards the implementation of sustainable fisheries practices when the number of disasters (collapses and non-recoveries) outweighs the optimism and denial of many resource users and political systems, and when the general public, concerned with the environmental and resource degradation that has occurred, decides to lean in favour of practices such as those embodied under the precautionary approach.

The Scientific Council of NAFO, through its ad hoc Working Group on the Precautionary Approach, developed a provisional framework for implementing the Precautionary Approach with particular attention to Annex II of the UN Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (Serchuk et al. 1997). Thus far, the Fisheries Commission of NAFO (FC) has not formally adopted the framework and has voiced a number of concerns that are preventing implementation. These concerns are not unique. There are few good examples where a comprehensive precautionary approach has been developed, accepted and is routinely implemented in the management of fish stocks. Reasons may in part stem from the adoption by fisheries scientists of a rigid formulaic approach to the development of control rules, leaving little room for negotiation and political consideration (Rosenberg 2002). In NAFO, FC reaches decisions by consensus, so the ability to negotiate a compromise is key.

A more flexible PA framework within NAFO will provide more room for negotiation by FC in reaching agreement on management measures. However, the cornerstone to the PA is the concept of a limit, which, by definition, is an inflexible construct. Annex II requires that management actions result in only a low probability of a stock falling outside safe biological limits. This leaves little room for negotiation when a stock is at a low level. If the stock is already outside safe biological limits, then, under Annex II, management actions need to be taken to facilitate recovery to within safe biological limits. However, within the area defined as being "biologically safe", Annex II provides considerable latitude for decision-makers. In this paper we explore this latitude in the context of NAFO. To provide a broader context, we contrast the NAFO situation with recent developments in ICES and the EU with respect to North Sea cod, in Canada and the USA with respect to Atlantic cod stocks, and the thinking on the PA, biological reference points and control rules expressed in the recent peer-reviewed scientific literature. This paper builds on the work on a revised PA Framework carried out at the recent NAFO Scientific Council Workshop on the Precautionary Approach to Fisheries Management (St John's March/April 2003, NAFO SCS Doc. 03/05).

A note on standardization of terminology

Early in the development of harvest control rules and associated reference points, it was recognized that each separate body of scientists had tended to develop their own sets of nomenclature. This was of particular concern for NAFO, ICES and ICCAT, and led to a Coordinated Working Party meeting in February 2000. While the CWP noted the differences in terminology and approaches, it was also evident that the various approaches evaluated had much in common. The CWP concluded that it was premature to harmonize the terminology and methodology because the approaches were still under development. Unfortunately, it may already be too late to develop a common terminology, because the terms developed by each assessment or management body have become ingrained within that body. For example, in the United States, the National Marine Fisheries Service's guidelines for implementation of National Standard 1 of the Magnuson Act use the term "threshold" to denote quantities that NAFO and ICES would refer to as "limits". This discrepancy was noted before the guidelines became final, but it was not fixed at the time and, in recent discussions concerning possible revisions to the guidelines, many scientists and managers are of the opinion that a change to make the U.S. definitions more consistent with international usage would add more confusion than the change is worth.

Examples of the development and implementation of PA frameworks

ICES

As a precursor to the precautionary approach, ICES introduced the concept of "safe biological limits" in 1981 and expanded on the idea in 1986 and 1987 in terms of historical experience of recruitment, stock size and fishing mortality (Serchuk and Grainger 1992). Biological reference points were adopted in 1998 in order to advise on the status of stocks relative to predefined limits that should be avoided to ensure that they remain within safe biological limits (ICES 2001). In 1991, the ICES Advisory Committee on Fishery Management (ACFM) decided that management recommendations would only be made in cases where stocks are exploited outside safe biological limits, which was interpreted to mean when they were below a "minimum biologically acceptable level" or MBAL, or were expected to fall below this level in the near future at present rates of exploitation (Serchuk and Grainger 1992). Under this approach options, consequences and risks would be evaluated for stocks within safe biological limits, but the choice of measures to be taken would be left to managers. ICES defined MBAL as the level of spawning stock size below which the probability of poor recruitment increases as spawning stock size decreases, a concept

common to many PA frameworks. Operationally, where this level cannot be defined based on SR data, the lowest observed level from which there has been a recovery may be applied, i.e. MBAL = B_{loss}.

The first ICES Study Group on the Precautionary Approach to Fisheries Management met in 1997. The SG provided definitions and methods for calculating reference points and proposed the use of harvest control rules and recovery plans to maintain or restore stocks within safe biological limits. The notion of "precautionary reference points" was developed. These attempt to ensure that limit reference points are not exceeded, taking into account existing knowledge and uncertainties. To date, ICES has developed and implemented biological reference points for the principal stocks under their jurisdiction and ACFM routinely formulates advice to the EU, NEAFC and IBSFC on the state of these stocks relative to their reference points. However, there is little evidence thus far of the precautionary approach being implemented in the actual management of fish stocks based on ICES advice. The recent developments with respect to North Sea cod, provides examples of the kinds of problems involved in going from the scientific framework to actual implementation. In principle the recent Recovery Plans for Northern Hake and North Sea Cod developed by the EU, although considered inadequate for North Sea cod by ICES (see below), suggest some movement towards implementing a precautionary approach.

The ICES PA framework divides SSB - F space into areas which are within safe biological limits, outside safe biological limits and in risk of stock collapse (Fig. 1). To be within safe biological limits, there should be a high probability that spawning stock biomass (SSB) is above B_{lim}, the point below which recruitment is impaired or where the dynamics of the stock are unknown, and that fishing mortality is below a value F_{lim} that will drive the spawning stock to that biomass level. Because of estimation error, management action should be taken before the limits are approached if the limit is to be avoided with high probability. ICES has therefore defined B_{pa} and F_{pa} as the thresholds below or above which management action should be taken. B_{pa} is defined to have a high probability that SSB is above B_{lim} while F_{pa} is defined to have a high probability that fishing mortality will be below F_{lim}. In practice, the distance between the limit and the threshold depends on the risks that managers will accept and on the reliability of the assessments. The responsibility for identifying the limit reference points rests with ICES. They also propose precautionary reference points for managers to consider. $F > F_{\text{pa}}$ is considered to be overfishing. B_{pa} defines when the stock is regarded as being depleted or overfished. In ICES the PA needs to ensure a high probability of preventing the stock falling to B_{lim}, below which recruitment is impaired or the dynamics of the stock are unknown. B_{lim} is in general equal to MBAL calculated previously for stocks where the stock-recruit data were available. Target reference points representing long-term management objectives within the "safe biological limits" space have not yet been defined for ICES stocks.

The approach used at ICES until most recently for calculating B_{lim}, or alternatively B_{pa}, for stocks with SSB and recruitment data, depends on the scatter of the stock-recruit data (ICES 2001). If recruitment decreased below some SSB level, then this level of SSB can be defined as B_{lim} – it is the point at which recruitment overfishing commences. If there is no evidence of a descending limb at low SSB and the range of SSB is large, then lowest observed SSB has been selected as B_{lim}. If R decreases with increasing SSB (i.e. as in a Ricker model), then the point corresponding to the lowest SSB has been selected as B_{pa}. If only a narrow range of SSB has been explored and there is no indication of a trend, then the lowest SSB has been selected as B_{pa}. If the stock has infrequent, very large year classes, then other procedures may be explored, e.g. setting B_{lim} as the lowest SSB that has produced outstanding year classes. If either B_{lim} or B_{pa} can be determined from the available SSB-R data, then the other reference point has been derived by $B_{\lim} = B_{pa} \exp^{(-1.645\sigma)}$, where σ is the measure of the coefficient of variation in the estimated SSB of the surviving fish in the quota year for which advice is to be given (i.e. after the quota is taken). B_{lim} thus corresponds to the lower 95% confidence interval of B_{pa}. F reference point estimates have not been derived following any one specific procedure. Most F_{lim} estimates have been based on of F_{loss} or F_{med}. F_{pa} could be also based on F_{med} in some cases where no F_{lim} is estimated. When F_{lim} is estimated, F_{pa} could be derived by applying the same rational as for B_{pa}.

Recent meetings of the Study Group on Precautionary Approach (ICES 2002a, 2003) concluded, based on experience in the practical application of the existing PA framework, that there was a need for a revision of the guidelines for estimating reference points. This new approach is shown schematically in Fig. 2 and can be outlined as:

(i) estimate B_{lim} on the basis of either the segmented regression method or the non-parametric kernel method;
(ii) calculate F_{lim} from B_{lim} deterministically;
(iii) calculate F_{pa} using a new methodology that accounts for assessment uncertainty by comparing intended F with realised F retrospectively, so that when F_{pa} is advised, there will be a low probability that realised F is above F_{lim};
(iv) calculate B_{pa} by comparing the yearly estimates of SSB with the realised SSB retrospectively, so that when observed SSB is at B_{pa}, there will be a low probability of SSB being below B_{lim}.

In the revised ICES framework, B_{lim} is the cornerstone reference point, defined as the SSB below which there is a substantial increase in the probability of obtaining reduced (or 'impaired') recruitment. Its estimate should be risk averse. F_{lim} is set on the basis of B_{lim} and should be risk neutral to B_{lim} i.e. F_{lim} should be the fishing mortality at which the deterministic equilibrium SSB is B_{lim}. F_{pa}, derived from F_{lim}, is the value not to be exceeded such that the fishing mortality actually realised by an advised catch derived from F_{pa} should have a very low probability of being above F_{lim}. F_{pa} should therefore be estimated by a method that takes assessment uncertainty into account. Similarly, if B_{pa} is derived from B_{lim} taking assessment uncertainty into account, there should be a very low probability that a stock currently estimated to be at B_{pa} is actually at B_{lim}. In the revised framework, F_{lim} is linked to B_{lim} and there is no consideration of F_{msy} as a minimum standard for F_{lim}.

Implementation on North Sea Cod

The Fall 2002 report of ACFM notes that in the past 10 years the state of most roundfish and flatfish stocks in the North Sea has deteriorated, one of the major causes being the continuous very high levels of exploitation (ICES 2002b). For cod, whiting and plaice, recruitment had been found to be lower than in previous decades while at the same time cod, haddock, whiting, sole and plaice body growth rates have been simultaneously low. ACFM considers that these conditions could seriously impair the ability of a stock to replace itself, but does not believe that these changes can be related solely to the effects of fishing - changes in the environment may also have played a role. For North Sea cod, the stock is outside safe biological limits. The spawning stock is estimated to have been below *B*pa since 1984 and in the region of B_{lim} since 1990. SSB in 2001 is estimated at a new historic low at about 30 000 t and is now estimated 50% lower than in the previous assessment. The SSB in 2002 is estimated around 38 000 t. Fishing mortality has remained at about the historic high and above *F*pa since the early 1980s and F in 2001 is estimated to be above *F*lim. Except for the 1996 year class, recruitment has been below average in all years since 1987. The 1997 and 2000 year classes are estimated to be the poorest on record.

The precautionary approach reference points for North Sea cod have not changed since 1999. The B_{lim} for North Sea cod is the rounded value for the lowest observed biomass, B_{loss} and is 70,000 t. B_{pa} is set at 150,000 t - the previously agreed MBAL, set to afford a high probability of maintaining SSB above B_{lim} taking into account uncertainty in the assessments. Below this value the probability of below-average recruitment increases. F_{lim} is set at F_{loss} and is 0.86. F_{pa} is the 5th percentile of F_{loss} and is 0.65. F_{pa} is considered to have a 95% probability of avoiding F_{lim} taking into account the uncertainty in the assessments. The stock is currently well below B_{lim} and F is above F_{lim}. ICES Scientific advice in 2001 and 2002 was "lowest possible catch" whereas in 2003 it was "closure". A rebuilding plan for the cod stock in the North Sea has recently been proposed by the European Commission. Although ICES advises a closure and not a rebuilding plan with lowered fishing on cod, it did conduct a review of the proposed plan. The proposal consists of a set of measures that aim at increasing the spawning stock biomass by 30% per year. This is to be achieved by reduction in fishing mortality and changes in maximum allowed TAC's. The reduction in fishing mortality is to be accompanied by reductions in fishing effort. According to the ICES PA framework, the stock is in the red zone – "Risk of stock collapse". Consequently ICES has reported that any proposed rebuilding scenario, other than $F = 0$ is inconsistent with the precautionary approach.

United States of America

United States domestic law does not explicitly recognise the Precautionary Approach to fisheries management. However, recent amendments to the Magnuson Act (the act which governs U.S. marine fisheries activities) have introduced many elements of the precautionary approach into the management of marine resources. Thomson and Mace (1997) and Restrepo *et al*. (1998) have provided technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. The amended Act, renamed the Magnuson-Stevens Act, includes new definitions of overfishing, overfished, and optimum yield. It states that "Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry". It requires the establishment of objective and measurable criteria for determining the status of a stock or stock complex. The Act also mandates specific remedial action in the event that overfishing is occurring, or if a stock or stock complex is overfished. The management objective in terms of the Act is optimum yield (OY), which is defined as MSY reduced by relevant factors. Thus MSY, or an MSY control rule such as $F = F_{msy}$, should represent an upper limit on fishing activity. In the case of an overfished fishery, the new Act requires rebuilding to the MSY level. "Overfishing" is defined as a fishing mortality rate that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis. The Magnuson-Stevens framework is illustrated in Fig. 3. NMFS guidelines for implementing the Magnuson-Stevens Act treat MSY related reference points in a dynamic context which takes fluctuations into account. As a consequence, F_{msy} may be treated as an upper limit on fishing mortality, but B_{msy} is not treated as a lower limit on biomass. Rather, the minimum stock size threshold (MSST) is defined either as a biomass that is less than B_{msy} from which it is possible to build back to the average B_{msy} within 10 years, or ½ B_{msy}, whichever is greater. The maximum fishing mortality threshold (MFMT) is defined by an MSY control rule. Exceeding MFMT constitutes "overfishing" whereas falling below MSST denotes an "overfished" stock. Overfishing requires the reduction of fishing mortality to below MFMT while an overfished stock requires the development of a formal rebuilding plan to restore the stock at least back to the level of the average B_{msy} within a specified period of time, often as short as 10 years. MSST is not associated with closure of a fishery and is therefore not equivalent to limit reference points used in some other PA frameworks. The MSY control rule defining MFMT should result in a low probability of the stock falling below MSST. The requirement to define overfishing in an operational manner (primarily in terms of appropriate biological reference points) has been instrumental in eliminating overfishing and rebuilding depleted fish stocks. Before such requirements were mandated (by law), maintenance of the status quo was the norm in terms of management objectives, regardless of the state of the status quo.

Implementation on Georges Bank Cod

Georges Bank Cod was assessed in April 2001 (Northeast Fisheries Science Center Reference Document 02-16- Assessment of 20 Northeast Groundfish Stocks through 2001 – A Report of the Groundfish Assessment Review Meeting (GARM) http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0216/) . Fully recruited fishing mortality (age 4-8) was estimated at 0.38 in 2001. Spawning stock biomass in 2001 was estimated at 29,170 t, a 12% increase from 2000 and a 53% increase from the record low in 1994. Biological reference points were established for Georges Bank Cod based on a Beverton-Holt stock-recruit model as: MSY = 35, 236 t, SSB_{msy} = 216,780 t and F_{msy} = 0.175. Based on the assessment results, Georges Bank cod was placed into the "overfishing" category, joining 65 other stocks (NOAA 2002). In terms of SSB, it moved from the "rebuilding" category to the "overfished" category, joining 85 other stocks. The provisional catch for 2001 is reported in the GARM Assessment as 12,769 t. Under the rebuilding plan, in order to achieve biomass targets by appropriate dates, $F_{rebuild}$ was computed using stochastic medium-term projections. The F reductions required to achieve the biomass goals by the target dates are greater than the F reductions required to achieve F_{msy}. In theses calculations it is assumed that the F in 2002 = 0.85*F in 2001. Time to rebuild is 2019. F in 2001 was estimated to be 0.38, %F reduction to achieve F_{msy} is 53%, F to rebuild is 0.15 and the %F reduction to achieve $F_{rebuild}$ is 61%. B_{msy} is 216,800 t and B_{2001} is 29,200 t, 14% of B_{msy}.

Two fundamental problems relating to the implementation of the precautionary approach in the rebuilding plans developed for U.S. fisheries outlined by Rosenberg (2002) appears to apply to Georges Bank Cod. Firstly, rebuilding timeframes are usually set at or near the maximum limit allowed by law (10 years or within one generation time of the minimum rebuilding period if life-history constraints indicate a 10-yr time frame cannot be met). Secondly, the difficulty in maintaining conservation restrictions on fishing as stocks rebuild.

Canada

Through the Oceans Act of 1996 Canada undertakes to promote the wide application of the precautionary approach to the conservation, management and exploitation of marine resources in order to protect these resources and preserve the marine environment. Further, Canada ratified the United Nations Fisheries Agreement (UNFA) on 3 August 1999. Canada therefore subscribes to the application of the precautionary approach both in terms of national legislation and international agreement. At a more general level, a discussion paper by the Privy Council Office (PCO) of the Canadian Federal Government entitled "A Canadian Perspective on the Precautionary Approach/Principle" (http://www.pco-bcp.gc.ca/raoics-srdc/docs/precaution/Discussion/discussion_e.pdf) has had a substantial impact on the development of a Canadian precautionary approach framework in many areas of governmental decision making, including fisheries (Shelton and Rice 2002). The Canadian precautionary approach framework with respect to cod stocks off Atlantic Canada was developed in workshops in 2001 and 2002 (Rice and Rivard 2002, Rivard and Rice 2003; see also Shelton and Rice 2002, Shelton et al. 2003, Shelton and Rivard 2003). It focuses on evaluating the risk of serious or irreversible harm. Serious harm is interpreted in terms of "impaired productivity" and the conservation limits are related to definitions of what constitutes impaired productivity for each stock as determined by scientific experts applying "best science practice". While limits are determined by science, the framework allows for societal input regarding risk tolerances relative to these limits. This framework has recently been applied in the provision of advice on three Atlantic cod stocks. Application of similar approaches to setting limits for other cod stocks and other species is being considered within DFO. Although the current framework is minimalistic (Fig. 4), there is considerable interest in developing harvest control rules to structure the space above B_{lim} and, for stocks below B_{lim}, to evaluate alternative recovery plans taking into account such issues as bycatch through a process of simulation testing, with input from fisheries managers on risk levels, recovery times and management objectives.

The Canadian framework defines impaired productivity in terms of impaired ability of the stock to reproduce itself. Impaired stock productivity could be linked to combinations of reduced body growth rates, decreased maturation rates, increased mortality rates or decreased recruitment rates. In terms of recruitment, impaired productivity is consistent with the notion of "recruitment overfishing" and this has been the initial emphasis in the implementation of the Canadian PA. To define recruitment overfishing, one needs to find the *SSB* level consistent with a marked decrease in recruitment. However, most *S-R* models have only two parameters and recruitment is a smooth continuous function of SSB. If the limit reference point is expressed in terms of the depletion of the spawner biomass to a level so low that the probability that the stock will produce good recruitment is diminished, or the probability that the stock will produce poor recruitment is increased, then the non-parametric kernel smoother approach applied to modeling stock-recruit data by Rice and Evans (1988) is particularly suitable. Having determined what constitutes good recruitment (for example the 90^{th} percentile), and/or poor recruitment (for example the 10^{th} percentile), the probability that recruitment will fall into the good recruitment range or into the poor recruitment range can be computed directly from the *S-R* data and the kernel smoother fit to the data. These probability profiles generally show a marked decrease or increase over a narrow range of SSB which can be used to determine B_{lim} . Alternatively, B_{lim} could be defined as the point along the decreasing SSB axis at which the probability of good recruitment falls below a predetermined probability level, or the probability of poor recruitment rises above a predetermined level, for example 0.5. This approach is being evaluated further in the context of Canadian Atlantic cod stocks.

Implementation on 3 Canadian cod stocks

Concerns about unsustainable fisheries on three reopened cod stocks, Northern Cod (Div. 2J+3KL), Northern Gulf Cod (Div. 4Rs3Pn) and Southern Gulf Cod (Div. 4TVn), prompted special attention to be given by DFO to these stocks in 2002 and early 2003. A DFO workshop in November 2002 (Rivard and Rice 2003) selected $B_{50\%\text{Rmax}}$, Serebryakov's $B_{50\%\text{R}90\%\text{surv}}$ and the SSB level from which the stock has previously sustained a rapid recovery as SSB limit reference points. Three variations of $B_{50\%\text{Rmax}}$, were considered: BH50 based on the fit of a Berverton-Holt stock-recruit model, RK50 based on the fit of a Ricker stock-recruit model, and NP50 based on a nonparametric smoother. Where the estimates of B_{lim} appeared to be sensible, and particularly where they appeared to be clustered at roughly the same SSB level, it was considered that a reasonably strong case could be made for defending the associated SSB level as a limit reference point. Where the estimates covered a wide range, it was considered that, although B_{lim} was poorly defined, an argument could be made for keeping the SSB above all "plausible" candidate

B_{lim} values until better estimates have been obtained. The B_{lim}'s from the various methods were relatively consistent for Southern Gulf Cod, but covered a wide range for Northern Gulf Cod and Northern Cod. For Northern Gulf Cod and Northern Cod, the $B_{50\%Rmax}$ was found to be very sensitive to the computational method used for the stock-recruit relation. Typically, large variances were associated with parameter estimates and therefore maximum recruitment was poorly defined. Northern Cod results were strongly influenced by high recruitment levels in the early part of the time series. Serebryakov's method was found to be robust (not too strongly influenced by only one or two data points) and scaled well across the three stocks considered, in the sense that it gave reasonable estimates relative to historical *SSB* and stock productivity levels.

Despite some of the difficulties encountered, the November 2002 Workshop reached consensus on B_{lim} values of 80,000 t for Southern Gulf Cod, 200,000 t for Northern Gulf Cod and a bench-mark *SSB* 150,000 t for Northern Cod. For Northern Gulf Cod it was noted that the 200,000 t B_{lim} was not definitive because there were few data in the 100,000 – 200,000 t range of *SSB* and that the B_{lim} may be revised downward when more data become available. For Northern Cod, maximum recruitment was poorly defined, but it was agreed that B_{lim} would likely be greater than 300,000 t, the *SSB* level for B_{lim} from the Serebryakov's method. It was considered that when the *SSB* approaches the bench-mark *SSB* level of 150,000 t (corresponding to $B_{recovery}$), the *S-R* data would be reviewed to see if there was more information for defining B_{lim}.

These limit reference points were applied to the most recent data at a special DFO Zonal Cod Assessment held in Halifax in February 2003. All three stocks were assessed to be below B_{lim}. Medium-term deterministic projections were carried out under *status quo F* and $F = 0$. At status quo *F*, all three stocks were predicted to decline further. At $F = 0$, only marginal increases at best were predicted (Southern Gulf Cod was predicted to decline further over the next 5 years and Northern Cod was predicted to decline over 10 years, even in the absence of fishing) at current stock productivity conditions with recovery above B_{lim} not occurring with 5 years. The results of the DFO scientific assessments were made available to the Fisheries Resource Conservation Council (FRCC) which is tasked with advising the Minister on appropriate conservation measures for domestic groundfish stocks in Atlantic Canada. For northern cod, the FRCC did not support reduction of removals to a minimum possible level - instead it suggested, as a guideline, that a bycatch cap of 1,000-1,500 t be allowed in the inshore each year in the next 5 years (inclusive of the $\pm$200 t sentinel survey fishery). This substantially exceeds recent reported bycatch levels and was interpreted by fishermen and their organizations as a small allocation to be shared out among license holders to "keep them on the water". For Southern Gulf Cod the FRCC recommended that removals not exceed 3,000 t each year for the next 5 years, half the TAC in the precious year. Similarly, the FRCC recommended that the total removals for Northern Gulf Cod should not exceed 3,500 t each year for the next 5 years, half the TAC in the previous year. The Minister of Fisheries and Oceans rejected the FRCC recommendations for TAC reductions and instead announced closures of all three cod fisheries on April 24, 2003, based on DFO scientific assessments. An energetic campaign of lobbying and protest by fishermen, their organisations, and in the case of Newfoundland and Labrador, the Provincial Government, followed the announcement, but the decision remained in place. Scientists involved in the assessments of these stocks considered the decision to be an endorsement of the application of the precautionary approach in the management of Canadian fisheries and are optimistic regarding extending the application to include harvest control rules for stocks above B_{lim}, and applying the precautionary approach to other groundfish and shellfish stocks. For Atlantic salmon and marine mammal populations, forms of the precautionary approach are also under consideration and are at various stages of development and implementation.

NAFO

Background

The process of developing a precautionary approach to the management of stocks under NAFO jurisdiction has been underway for about seven years, beginning with the Fisheries Commission (FC) request to Scientific Council (SC) in 1996 (see Appendix 1 for details). In each year from 1998 to 2000, fishery managers from FC and scientists from SC met in a joint Working Group on the PA. Although some progress was made at each of these three sessions, it was clear by the end of the 2000 meeting that many issues remained to be resolved. By then, the Joint WGs, as they were constituted, had run their course and accomplished what they could. A smaller group of scientists and managers met in 2002 to try and re-establish some dialogue and get the process moving again. The report from this meeting noted major concerns with the NAFO PA framework and made some recommendations to FC, but no action was taken when the report was discussed at the 2002 meeting of FC.

Once the roles of scientists and managers had been defined by NAFO in 1998 (Table 1), a major concern appeared to be the lack of harmonisation in the precautionary approaches of different organizations, primarily ICES and NAFO. This remained a contentious issue, despite a comprehensive report in early 2000 that noted many similarities in the approaches, and which stated that harmonisation was probably premature. Another concern that was expressed was how to manage by-catch in a PA Framework, given the present situation with many NAFO stocks under moratorium but subjected to increasing by-catch in fisheries for other stocks.

FC never did formally adopt the PA framework proposed by SC in 1997 (this framework is described in detail in the next section), but did resolve in 1999 to apply a precautionary approach for all stocks under its purview (Table 2). Implementation plans were developed for some stocks by the Joint WG in 2000 (e.g. 3LNO yellowtail; Table 3), and although these were never approved by FC, some of the management measures contained therein have been implemented. FC did continue to ask SC to provide its advice in terms of a PA, and SC provided information in this context, including information on reference points, for stocks where this was possible.

At the SC level, progress in establishing reference points was slow for many stocks, mainly due to data deficiencies. Various methodologies were explored for defining reference points, and some PA reference points were indeed proposed by SC, and in a few cases, used by FC to manage the stocks (one example is the 2/3 F_{msy} reference point used for advice on 3LNO yellowtail flounder). Recognizing the importance of defining B_{lim} in a scientifically defensible manner, SC recommended at its 2003 WS that a study group be formed to review strengths and weaknesses of alternative approaches to defining B_{lim}, and to recommend to SC the most appropriate approach for each stock.

The existing Scientific Council PA framework

In September 1996, the Fisheries commission, in response to UNFA, requested Scientific Council to provide information on Fisheries Commission managed stocks that included recommendations on limit and target reference points. Scientific Council, through an Ad hoc Working Group, developed a precautionary approach framework (Serchuk et al. 1997; Fig. 5). The framework uses, as it's basis, Paragraph 7 of Annex II of the UNFA: "*The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points. For fish stocks which are not overfished, fishery management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a predefined threshold. For overfished stocks, the biomass which would produce maximum sustainable yield can serve as a rebuilding target*."

NAFO defined limit, buffer and target reference points in terms of both SSB and *F*. The notion of a buffer reference point is similar to that of precautionary reference points in ICES. B_{lim} is not given any specific definition other than the SSB below which the stock should not be allowed to fall, although a number of examples are explored under different data availability and quality conditions. B_{buf} is set to ensure that there is a high probability that B_{lim} is not reached. The more uncertain the estimate of B_{lim} is, the higher the value of B_{buf}. In a data rich environment, B_{target} is defined as B_{msy}. F_{lim} cannot be higher than F_{msy}; F_{buf} is set to ensure a high probability that F_{lim} is not reached and is dependent on the uncertainty in the estimate of F_{lim}. F_{target} depends on management objectives, but is below or equal to F_{buf}. It is not shown in the schematic.

The ramping down of F_{buf} and F_{lim} below B_{target} appears to be unique among existing PA frameworks. Further, the fishery is closed below B_{buf}, a more severe rule than found in either the ICES or the US framework. In the ICES framework, if the stock falls on the wrong side of B_{pa} and F_{pa} it is considered to be outside safe biological limits and management action must be taken, not necessarily closure of the fishery. In the US framework, when the stock is below MSST a formal rebuilding plan must be developed, not necessarily resulting in the fishery being closed. In the Canadian framework, fisheries on stocks that are below B_{lim} may be closed. The NAFO framework makes reference to recovery over a predetermined time horizon, a property it shares with the US framework. If the stock is at or above B_{target}, but *F* is above F_{buf}, it should be reduced to F_{buf} or below over a predetermined time horizon. If the stock is below B_{target} but above B_{buf}, and *F* is above F_{buf}, then the *F* should be reduced towards F_{buf} or below so that *B* increases towards B_{target} over a predetermined time horizon.

Although the NAFO framework provides some sensible guidelines for implementing the PA, it has not yet permeated very far into the stock assessment and decision making process. Some of the reasons for this are explored below.

Why has progress been slow in developing a comprehensive PA for NAFO stocks?

Almost all groundfish stocks regulated by NAFO collapsed and the directed fisheries have closed; exceptions are Div. 3LNO yellowtail, Div. 2+3KLMNO Greenland halibut and Div. 3M redfish. Implementing a sound precautionary approach in the management of these remaining stocks is of paramount importance. In the case of the other stocks, the emphasis is on rebuilding and recovery to levels above B_{lim} and B_{buf} by keeping fishing mortality as low as possible. The real test will be whether or not bycatch mortality can be controlled to sufficiently low levels to allow recovery within reasonable time scales, and whether or not directed fisheries will remain closed or fished at suitably low levels, as stocks begin to recover. Within NAFO, there is not a single stock for which a complete PA framework has been defined. Elements exist for some stocks, but a full framework consisting of limit, buffer and target reference points specified in terms of both SSB and *F*, together with associated harvest control rules, is not yet in place. What has prevented this from happening?

Initial discussion between SC and FC concerning roles and responsibilities in developing a PA framework produced some differences of opinion, although these were ironed out quickly. Scientists have a number of responsibilities to provide advice on stock status and reference points, but it is managers who specify the objectives, courses of action, time horizons, and acceptable levels of risk (Table 1). However, it is fair to say that, within NAFO, some grey areas remain in terms of responsibility for developing different parts of the framework.

Harmonization of terminology and concepts (mainly between NAFO and ICES), long regarded as a stumbling block to development of the PA within NAFO, no longer appears to be an issue. How serious an obstacle this actually represented in the first place can be debated, given the many different management bodies, coastal state practices, bilateral agreements, etc. with which managers of NAFO CP's such as Canada, Russia, and the EU have experience. The Coordinated Working Party detailed report compiled in early 2000 presented a very good summary of the various precautionary approaches (ICES, NAFO, ICCAT), with advice on pros and cons of these approaches and this issue should no longer be seen as a major stumbling block.

Sometimes a lack of communication between FC and SC has been apparent. For example, there was little or no feedback from FC on SCs traffic light summary for 3M shrimp in its 1999 report. Consequently, this method was not used again by SC, and SC did not advance any other PA methods or advice on this stock for FC consideration. Although the three joint WG meetings on PA resulted in much discussion and some progress, the formal delegation-based structure of these WGs was often not conducive to making progress on key issues. Also, it was clear that not all NAFO CP's at these joint FC/SC WG meetings shared the same views on development of the PA, both in terms of substance and timelines.

Many stocks within NAFO waters are under a moratorium on fishing. In many cases, these stocks are well below proposed B_{lim} values, with little or no sign of recovery (e.g. 3LNO A. plaice and 3NO cod), even after moratoria have been in place for more than eight years. Despite the ban on directed fishing, by-catches have increased steadily, and SC has expressed concerns that further declines are likely unless fishing mortality is reduced. As TAC's for other stocks have increased in recent years (e.g. 3LNO yellowtail and 2+3KLMNO Greenland halibut), and as fisheries for unregulated species developed (e.g. 3NO white hake, thorny skate), by-catches of species under moratorium have also increased. Various proposals to limit by-catch to lowest possible levels (e.g. through depth restrictions) have not been very successful, and this has presented managers with very difficult problems in managing the by-catch from increasing fisheries which overlap with many stocks still closed to directed fishing.

SC has not been able to define a B_{lim} value for all stocks it assesses. In many cases, the data are considered to be inadequate to allow calculation of limit reference points using accepted methodology. Attempts to define survey-based reference points have generally met with little success, but in many cases have not been thoroughly evaluated. The 2003 SC WS made significant progress in evaluating a number of methodologies, and recommended further study of the issue of defining B_{lim}. In cases where values for B_{lim} have been proposed by SC, there has been no formal recognition by FC of these reference points, and none have been specified in managing the stocks. There may be some apprehension on FC's part in setting a B_{lim} value for a particular stock, which may not be reached for many years given projected stock levels, thereby limiting future management options.

In September 2000 FC decided that a small group of technical experts would meet to promote further progress on implementing the PA (see Appendix 1 for details). This meeting took place in June 2002 and a number of concerns with either or both the NAFO and ICES PA Frameworks were identified:

- Prescribed harvest control rules (no fishing) below B_{lim} or B_{buf}
- A fishing mortality limit at F_{msy}
- The perception of a linear decrease in fishing mortality from the biomass target to the biomass buffer
- No consideration of the desirability for stable TAC's
- No consideration of multi-species situations

Proposed revised NAFO framework

A subgroup of the SC Workshop in 2003 attempted to address the main concerns identified by managers regarding the existing approach by developing a proposal for a revised framework (Fig. 6). The specific concerns reflect a more general reluctance to embrace a formulaic approach that reduces the space for negotiation. Within NAFO, negotiation is key to reaching consensus. Without consensus, a contracting party can file an objection and then fish with impunity, notwithstanding regulations that have been agreed to by the remaining contracting parties. The key issue therefore is to increase flexibility for management options so that fisheries managers and commissioners can negotiate and reach consensus, while still retaining the essential elements of a precautionary framework.

In the description of the revised framework that follows, probabilities and time horizons are provided as guidelines only, with the expectation that managers will choose appropriate values on a case by case basis. In the revised framework, F_{lim} should have a low probability of being exceeded ($\leq$20%). F_{lim} cannot be higher than F_{msy}. F_{buf} is a fishing mortality rate below F_{lim} that is only required in the absence of analyses of the probability that current or projected fishing mortality exceeds F_{lim}. F_{buf} should be specified by managers and should satisfy the requirement that there is a low probability that F_{target} exceeds F_{lim} ($\leq$20%). The more uncertain the stock assessment, the greater the buffer zone should be. F_{target} is a flexible mortality rate to be selected by managers from the shaded area in Fig. 5 to achieve desired management objectives, subject only to the constraints defined by the limit and buffer reference points. In particular, F_{target} must be chosen to ensure that there is a low probability that F_{target} exceeds F_{lim} ($\leq$20%) and a very low probability ($\leq$5-10%) that the biomass will decline below B_{lim} within the foreseeable future (5-10 years).

B_{lim} is a SSB level that should have a very low probability of being violated (<5-10%), defined to be a biomass level below which the stock productivity is likely to be seriously impaired. B_{buf} is SSB level above B_{lim}, specified by managers and satisfying the requirement that there is very low probability ($\leq$5-10%) that any biomass estimated to be above B_{buf} would actually be below B_{lim}. The more uncertain the stock assessment, the greater the buffer zone should be. Two further SSB reference points are specified in the revised framework – B_{msy}, the average biomass associated with fishing at F_{msy}, and B_{av}, average biomass associated with fishing at F_{buf}.

Different actions are prescribed in the revised framework, depending on which of 3 zones applies, given the current *SSB* and *F* levels. In Zone 1, the F_{target} Zone, F_{target} is selected so as to have low probability of exceeding F_{lim} and a very low probability of driving biomass below B_{lim} in the foreseeable future. Zone 1a is the Cautionary F_{target} Zone – the curved boundary to this area reflects that the closer the current or projected biomass is to B_{lim}, the lower F_{target} must be to ensure that the biomass remains above B_{lim}. Zone 2 defines the Overishing Zone – fishing mortality must be reduced into the F_{target} Zone. Zone 3 is the Collapse Zone – fishing mortality must be as close to zero as possible.

The proposed revised NAFO PA framework, in contrast to the original version, allows fishing below B_{buf}, subject to constraints such as ensuring a very low probability that biomass will fall below B_{lim} in the foreseeable future. However, below B_{lim} fishing mortality should be as close to zero as possible.

The proposed revised framework continues to consider F_{msy} as a minimum standard for an F_{limit} reference point. Compared to a F_{msy}-B_{msy} equilibrium situation, fishing somewhat below F_{msy} can be expected to result in relatively small loss in average catch, but a substantial increase in average biomass with concomitant decreased risk to the fish stock and increased benefits to fishing through higher catch rates. For example, one set of model results derived from an age-structured deterministic model showed that for 600 combinations of life history parameters and stock-recruit relationships, fishing at 75%F_{msy} resulted in an average yield of 94-98% MSY and a biomass of 125-131% B_{msy} (Restrepo et al. 1998).

The harvest control rule embodied in the revised framework still results in a decrease in fishing mortality as SSB decreases. However, instead of a linear decrease in fishing mortality from B_{target} to B_{buf}, the revised framework presents a range of options to managers. For example, no reduction in F is prescribed if stock biomass is above B_{buf}, and F is below F_{buf} . Managers also decide on the levels of B_{buf} and F_{buf} in those cases where the risk of biomass being below B_{lim} or the risk of fishing mortality being above F_{lim} cannot be provided.

FC requested that the PA framework take into account the desirability of stable TAC's. This is a difficult concept to capture in the simple revised framework schematic, however there is now considerable flexibility for managers in setting target F levels. Stable TAC's are easier to achieve if the fishery remains in Zone 1. In this zone, F_{target} is selected so as to have low probability of exceeding F_{lim} and a very low probability of driving biomass below B_{lim} in the foreseeable future. Provided these probabilities remain within an acceptable range, the TAC can remain stable and the F can fluctuate, buffering the fishery from small changes in stock size. This flexibility is reduced below B_{buf}.

FC noted that the framework did not address multi-species situations. Although the proposed revised framework is still focused on single species, ensuring that no individual species is fished harder than the single-species F_{msy} has frequently been suggested as a first step towards satisfying several important and common ecosystem objectives (NRC 1999; Mace 2001; Sissenwine and Mace 2003). In addition, two other aspects of multi-species management were considered in the proposed revised framework. First, in contrast to the original NAFO framework in which B_{target} was B_{msy}, there is no emphasis on B_{msy} in the proposed revised framework. This avoids the problem of the inability of simultaneously maintaining all stocks in the multi-species assemblage at their respective single-species B_{msy} levels. Second, by replacing the requirement that fishing mortality be zero when biomass is below B_{lim} with a requirement that fishing mortality be as close to zero as possible in this situation, there is now a recognition of the need for a certain amount of flexibility to account for technical interactions that result in unavoidable by-catch of depleted species, provided the bycatch levels of fishing mortality still allow recovery to above B_{buf}.

The proposed revised framework is simpler and should be more transparent to fisheries managers. It provides substantial room for negotiation by FC, not afforded in the original framework. To some degree it lowers the bar. Instead of a depleted stock having to recover to B_{buf} before a directed fishery reopens, under the proposed revised framework, if the stock has recovered to above B_{lim}, the fishery can reopen with the constraint that F_{target} must be chosen to ensure that there is a low probability that F_{target} exceeds F_{lim} ($\leq$ 20%) and a very low probability ($\leq$ 5-10) that the biomass will decline below B_{lim} within the foreseeable future (5-10 years). Even if the stock is below B_{lim}, there is some flexibility regarding the bycatch F that is allowed.

Discussion

The precautionary approach as applied to fisheries has been in existence in one form or another for about a decade. During this time it has gone through a cycle of technical analyses, mainly related to stock-recruit data, formulation of frameworks comprising reference points and harvest control rules, development of methods for quantifying uncertainties and communicating risk, and finally, initial application of the frameworks in the provision of scientific advice. In most cases the feedback from fisheries managers and decision makers from the initial implementation attempts have been only marginally encouraging. Although the general principles embodied in the precautionary approach have been broadly adopted, implementation has lagged. The reasons have been varied, including lack of transparency in the derivation of the reference points and the basis for the harvest control rules whereby F is reduced as SSB decreases, and unease in the general reduction in decision space leaving little room for negotiation in the fisheries management process. In most cases, including NAFO, this has resulted in a rethinking of the approach and the consideration of changes to the frameworks to make them more acceptable and useful tools for fisheries managers. To improve the chance of having any framework implemented, the message from scientists should be as simple as possible and focus primarily on keeping the resource within safe biological limits, leaving targets and rules of actions to managers. This has led to the second generation of precautionary approach frameworks which attempt to address the shortcomings of their predecessors.

Although the scientific community has generally embraced the precautionary approach and gotten on with the job of making it operational by developing reference points and control rules, support has not been unanimous. For example, Hilborn (2002) has suggested that our preoccupation with developing reference points has led us to neglect more important issues in fisheries management such as the evaluation of stock trajectories and alternative management strategies. However, examination of stock trajectories, including stock projections where it is possible to provide these, is the foundation of the scientific advice that scientists attempt to provide to managers. In addition, although examination of alternative management strategies may not always be part of a stock assessment *per se*, scientists are frequently involved in quantitative evaluations of the stock and fishery implications of actions proposed by managers, either as part of various follow-up exercises or, in the case of the U.S., as part of a Plan Development Team formed specifically to develop and evaluate alternative management strategies as a means of satisfying management objectives. Hilborn also argued that while reference points attempt to address the problem of overfishing, other problems may be more pressing such as the loss of economic yield due to overcapitalisation, loss of yield due to discarding, and the threat to nontarget species by bycatches. In response, we believe that all three of these areas are receiving considerable attention in various international and national fisheries arenas (e.g., FAO, the EU, the U.S., Canada, Australia and New Zealand). Finally, Hilborn claims that management by reference points is not transparent because of the large number of arbitrary decisions made in the process of deriving reference points. Here, we suggest that rather than "arbitrary", the appropriate term is actually "informed scientific judgement", and that usually the informed judgment of different scientists are actually quite similar, except perhaps in very data poor situations.

Some authors have also argued that the reference point / control rule approach is inferior to the management procedures approach such as the Revised Management Procedure adopted by the International Whaling Commission (IWC) in 1994, a system for evaluating management strategies adopted by ICES in (1994), a management procedures simulation model approach adopted by ICCAT in 2000, a management strategy evaluation or MSE by Smith et al. (1996) and Polacheck et al. (1999), and an operational management procedure or OMP by Butterworth and Punt (1999), and should be replaced by it. Briefly, the management procedures approach involves constructing one or more operating models to simulate reality, generating data (with error) from these models, conducting stock assessments (with error) using these data, and implementing management strategies (with error) based on the assessment results. At each stage of the process, there are performance measures associated with the outcomes. In many respects, the management procedures approach is an extension of the control rule approach, with both using various reference points (mainly biological reference points for current control rule approaches, but both biological and socio-economic for management procedures approaches) to judge performance of the system and to suggest appropriate management actions. Thus, management procedures approaches may be superior in some respects, but they are generally much more complex to design and do not seem to have been any easier to implement than control rules.

Regardless of the problems associated with implementing control rules, the requirement to define overfishing in an operational manner (primarily in terms of appropriate biological reference points) has been instrumental in eliminating overfishing and rebuilding depleted fish stocks in most of the situations where it has been seriously applied. For example, before such requirements were mandated (by law) in the United States, maintenance of the status quo was the norm in terms of management objectives, regardless of the sustainability of the status quo.

There is little doubt that the outstanding problems of the early 2000's extend beyond the single species SSB-F precautionary frameworks that have been developed thus far and to some extent, the buzz-phrase "precautionary approach" has already been supplanted by "ecosystem-based management (EBM)" as the latest bandwagon to board. This term is even more nebulous, with more alternative interpretations than the precautionary approach. At least the term, "precautionary" has a single overall interpretation (tread carefully, don't overfish); EBM can mean anything from fishing only at very conservative levels to strategies that deliberately overharvest certain species for the sake of maximizing the production of key target species, or strategies that ensure exploitation takes place at all trophic levels. However, the most common interpretation is that ecosystem-based management will likely require even more conservative fishing mortality targets than "traditional" single species based management approaches. Ensuring that no major stock is fished harder that the single-species F_{msy} as is the case in most current single species PA frameworks, may be a good first step towards ecosystem-based management (Mace 2001) in the absence of more complicated models capable of usefully examining the tradeoffs of managing complex systems of interacting species.

Most current precautionary approach frameworks pay little attention to management objectives encompassing economic and social considerations in addition to conservation issues. Traditional bio-economic models indicate that the fishing mortality associated with maximum economic yield (F_{mey}) is usually considerably less than F_{msy}, so that the concept of F_{msy} as a minimum standard for F_{lim} in current frameworks may partially address issues related to economic yield. However, the economics associated with declining and collapsed stocks may be beyond the scope of standard bioeconomic models. Issues associated with a high level of social measures (unemployment insurance, subsidies, subsistence payments etc.) complicate the economics of fishing beyond traditional bioeconomics models. There are known cases of sustainable fisheries at $F > F_{msy}$ (e.g. Northern megrim in the NE Atlantic) and even in the long term, the gain in reducing F may not be sufficient to balance the financial effort from government needed to cover the reduction of fishing effort.

There is some evidence that implementation of aspects of precautionary approaches associated with recovery plans for depleted stocks and sustainable F for relatively healthy stocks is proceeding. We are cautiously optimistic that the revised precautionary approach frameworks, such as the proposed revised NAFO PA framework or future incarnations, will also become effective in influencing the difficult decisions related to overfished, declining and collapsing stocks.

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Table 1. Roles of Scientific Council and Fisheries Commission, as previously agreed. (from FC Doc 98/02)

Scientific Council	Fisheries Commission
1. Determine status of stocks. 2. Classify stock status with respect to biomass/fishing mortality zones. 3. Calculate limit reference points and security margins. 4. Describe and characterize uncertainty associated with current and projected stock status with respect to reference points 5. Conduct risk assessments.	1. Specify management objectives, select target reference points, and set limit reference points. 2. Specify management strategies (courses of actions) for biomass/fishing mortality zones. 3. Specify time horizons for stock rebuilding and for fishing mortality adjustments to ensure stock recovery and/or avoid stock collapse. 4. Specify acceptable levels of risk to be used in evaluating possible consequences of management actions.

Table 2. Text of FC Resolution on Implementation of the PA. (from FC WP 99/12 Revised)

Resolution to Guide Implementation of the Precautionary Approach within NAFO

The Fisheries Commission,

NOTING that considerable work and progress have occurred toward implementation of the precautionary approach within the NAFO context;

NOTING Article 6 and Annex II of the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks;

NOTING the provisions of Article 7.5 of the FAO Code of Conduct for Responsible Fisheries;

NOTING the Roles and Responsibilities of Scientists and Managers outlined in Annex 3 to the Report of the Working Group on Precautionary Approach (NAFO/FC Doc. 98/2);

DESIRING to further harmonize terminology and application of the precautionary approach within relevant fisheries organizations;

FURTHER DESIRING to be precautionary in its management of stocks within the NAFO Regulatory Area;

RESOLVES to apply a precautionary approach widely for stocks under NAFO purview and to achieve this goal agree:

1. To determine precautionary reference points for stocks where sufficient information exists.

2. For all other stocks, to determine provisional precautionary reference point, whenever possible, and a precautionary approach otherwise.

3. To provide mechanisms to fill in data gaps.

4. To implement precautionary management strategies (harvest control rules), consistent with 1. and 2. above.

5. To consider additional supportive management measures to complement the application of the precautionary approach.

6. To define and adopt precautionary strategies for the re-opening of fisheries and for new and developing fisheries.

7. To harmonize terminology and concepts for the application of the precautionary approach within relevant fisheries organizations.

Table 3. Implementation plan for PA, 3LNO yellowtail flounder (from FC Doc 00/2).

Objectives

The action plan for implementation of a Precautionary Approach should include the eight objectives discussed at the Joint Scientific Council/Fisheries Commission Working Group meeting in May 1999:

1. Maintain harvest levels that will continue to rebuild and maintain the stock biomass above the rebuilt biomass level.
2. Continue with a comprehensive suite of management measures.
3. Ensure a conduct of the fishery in a manner that will not jeopardize recovery of other stocks in the area which are currently under moratorium, specifically 3NO cod and 3LNO American plaice.
4. Performance measures of interest to the managers could be expressed in terms of biomass and its trajectory and where it is with respect to the reference level and catch levels. With respect to catch, the performance measure was: cumulated yield, yield trajectories and trends (in particular, to identify declining trends).
5. It was noted that production models do not permit determination of all reference points. It should be ensured that data are available for scientists to move toward using age-structured modelling.
6. Despite these limitations, production modelling is a tool that could be used to start to evaluate real F limits and could be used to provide insight in what will happen if there are lower or higher fishing mortality levels.
7. There is a need to develop "target" biomass levels that could be higher than the biological limits so as to take into account management objectives including economic considerations.
8. Endorse the work of the Scientific Council in its attempts to develop a better understanding of the stock-recruit relationship.

Management Strategies

1. As a management objective, Fisheries Commission should maintain SSB at a level that will continue the probability of good recruitment and maintain the stock at a level that will support a sustainable fishery.
2. Given that the present estimate of F_{buf} is in the same range as the 2/3 F_{msy} value used in past requests from Fisheries Commission, the value of 11% for exploitation rate could continue to be used by Fisheries Commission as a basis for establishing catch levels until such time as Scientific Council may recommend an alternative.
3. Fisheries Commission requests Scientific Council to give priority to work aimed at calculation of possible biological reference points as appropriate including age-based models and any other applicable stock evaluation methodologies.
4. Fisheries Commission shall, as appropriate, review and revise these management measures and strategies based on any new advice provided by Scientific Council.

Data Collection/Analyses

1. Scientific Council and Fisheries Commission should encourage continuation of multiple annual surveys in support of stock assessment.
2. Contracting Parties should ensure that appropriate data are collected and that scientists utilize stock evaluation techniques that allow for estimation of stock size and exploitation rates, risk assessment procedures, and a fuller evaluation of reference points.
3. Scientific Council continue efforts to develop a better understanding of the stock-recruit relationship.
4. Scientific Council and Contracting Parties continue to monitor expansion of the range into Div. 3L.
5. Scientific Council and Contracting Parties continue to monitor recruitment as well as trends in weight-at-age.
6. Scientific Council to review and update, as necessary, information on spawning locations and timing.
7. Scientific Council to provide updated information to the Fisheries Commission regarding the distribution of juvenile yellowtail flounder in relation to adult distribution.

Supportive Management Measures/Good Practises

1. Fisheries Commission should take steps to minimize the catch of juveniles, and ensure that the total catches of yellowtail flounder are in accordance with the target exploitation rate. Some measures that could be considered to achieve this objective are:
2.
    - Review of current directed fisheries for the determination of specific yellowtail flounder by-catch problems so that remedies can be applied.
    - A revision of conservation and technical measures that only permit by-catch that is truly incidental in nature.
    - Closure of specific areas for specific periods of time identified as: a) nursery areas, and b) areas where high concentrations of juveniles are found.

3. Fisheries Commission to explore the utility of closure periods to protect spawners as well as the utility of closures of areas identified as spawning locations.

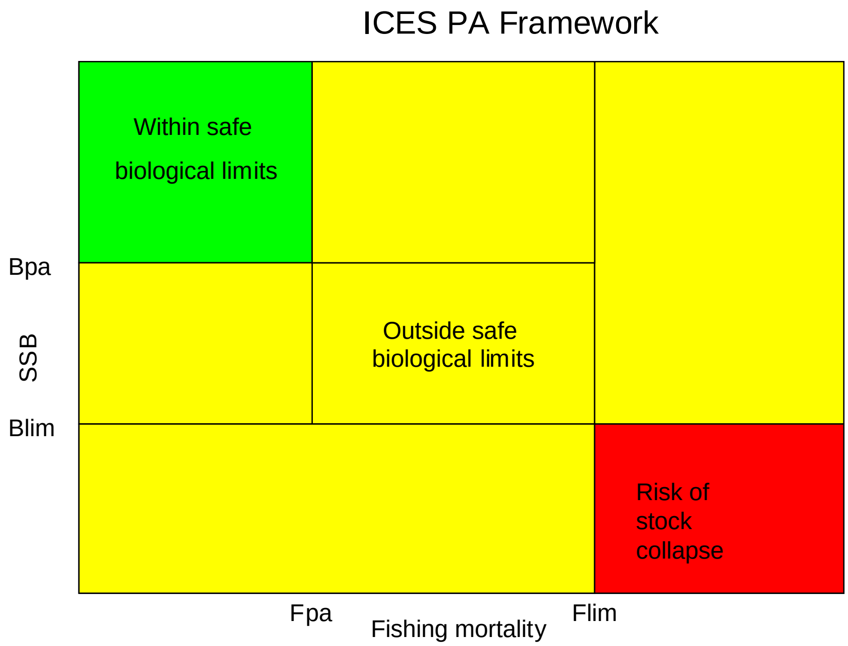

Fig. 1. Schematic describing the existing ICES precautionary approach framework.

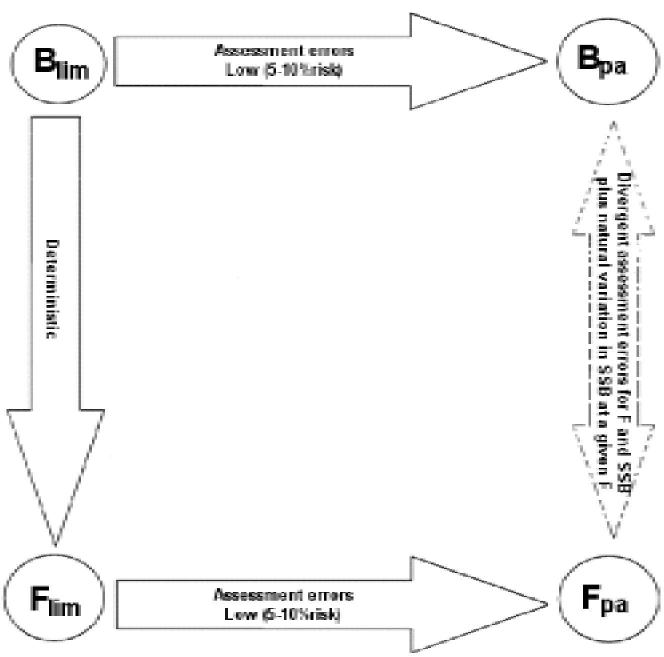

Fig 2. Schematic describing the revision of the guidelines for estimating reference points recently proposed by ICES (see text for details).

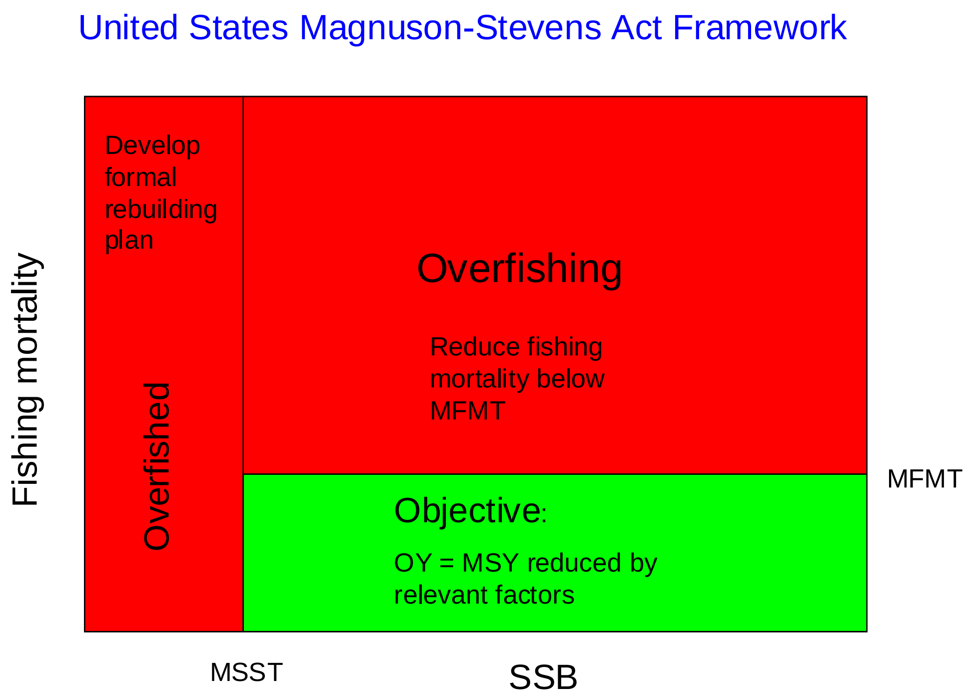

Fig. 3. Schematic of the Magnuson-Stevens Act framework developed in the USA.

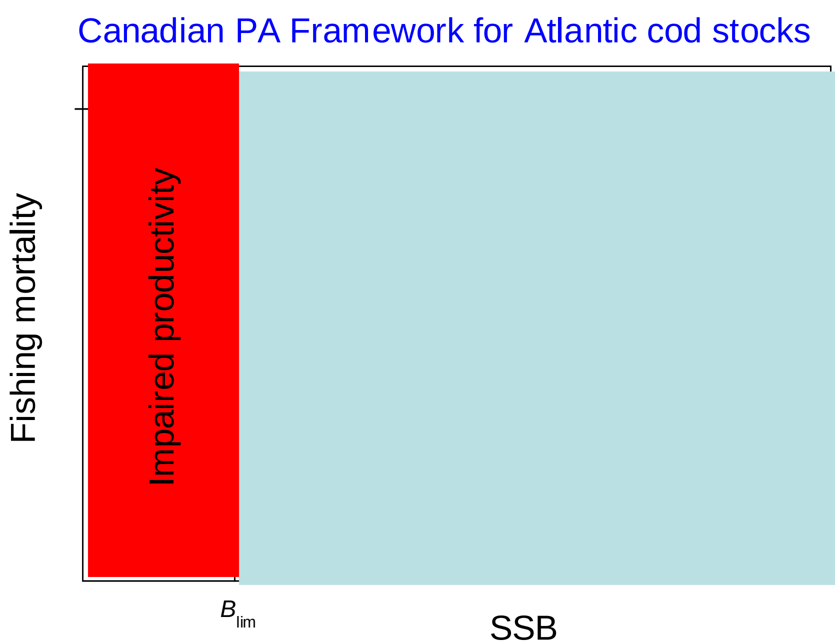

Fig. 4. Schematic of the Canadian Precautionary Approach framework as currently applied to three Atlantic cod stocks in a recent assessment leading to closure of the fisheries.

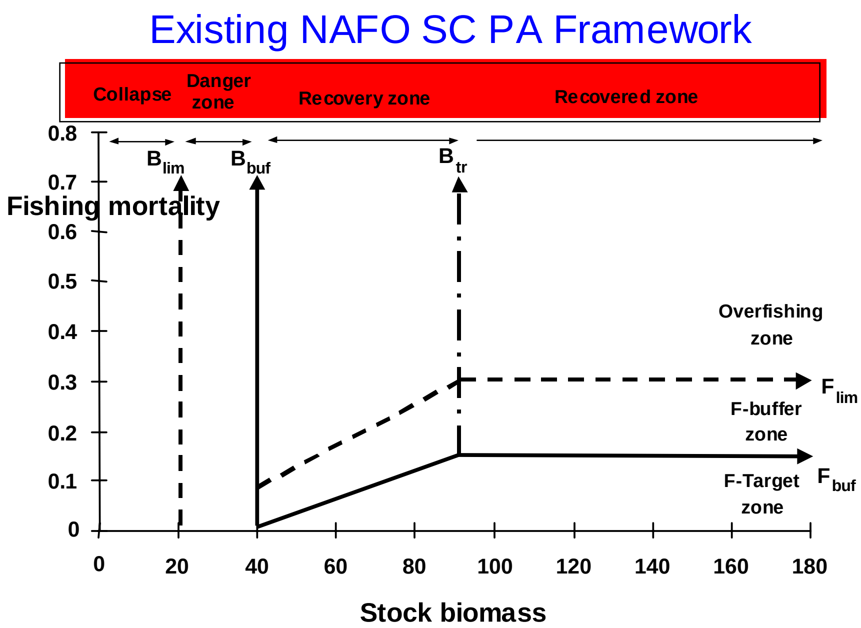

Fig. 5. The original PA framework developed by the Scientific Council of NAFO in 1996.

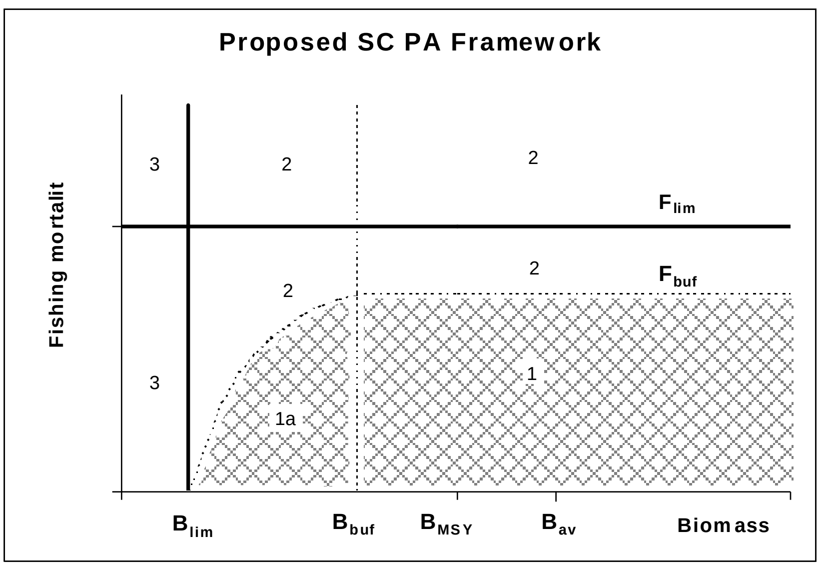

Fig. 6. The proposed revised NAFO PA framework developed at the NAFO Scientific Council Workshop in St John's in March/April 2003.

Appendix 1. History of the Precautionary Approach within NAFO – 1996-2003

1996-97

- The development of a PA framework in SC in 1997 (Serchuk et al 1997) was based on a request from FC in its 1996 meeting (NAFO 1997a). Included in SC's initial report on the PA was an Action Plan for implementation (NAFO 1997b). This plan called for the Chair to propose that FC adopt the draft PA framework in Sep 1997.
- FC endorsed the proposed Action Plan in 1997 (NAFO 1998). They also recognized that it was necessary for managers to study the implications of the PA to fisheries management decisions. They proposed a STACTIC WG in spring 98, with involvement of scientists to facilitate productive discussions. This was later amended to become a WG on PA, which met immediately prior to STACTIC in May 1998.
- Beginning in 1997, FC's requests for advice, given to SC, included specific requests for PA reference points for the FC stocks, as well as other PA-worded requests (NAFO 1998a). This despite not having formally adopted the PA framework proposed by SC.

1998

- SC held a two-week workshop in March 1998 on the Development of the Precautionary Approach to Fisheries Management (NAFO 1998b). The WS reviewed methods for defining reference points, uncertainties on the estimation of reference points, decision rules, criteria for reopening closed fisheries, and selected some stock specific cases to work on.
- The WG on PA met in May 98 (as noted above), consisting of managers and scientists. One agenda item, Discussion of the SC WS recommendations for their practical implementation, was changed to Discussion of the SC WS recommendations, "as it was seen to be premature to consider any 'practical implementation' at this meeting". Presentations were given by both chairs (SC and FC). Perhaps the key item to come from this meeting was a table outlining the respective roles of scientists and managers in relation to the PA (Table 1, NAFO 1998c). In addition, a number of recommendations were put forth to FC by the WG which were to assist SC in giving priority to a number of issues. These included standardization of PA nomenclature with ICES, estimation of limit reference points, calculation of security margins around the limit reference points, and continuation of the WG as "an instrument of dialogue" between FC and SC.
- At its June meeting in 1998, SC adopted the Workshop report and began to incorporate PA language into its advice where possible, although reference points were not available for most stocks. SC noted that analytical assessments were not possible for most stocks, and that establishing frameworks based on survey indices would be a crucial step in implementing the PA. SC also commented that in the case of diverging views on the basis for a framework, more than one framework could be put forward. For this to succeed, it would be important for scientists and managers to work closely together (NAFO 1998d).
- In its September 1998 Report (NAFO 1999a) FC noted that the WG discussions revealed that the perception of what the PA is and how it should be applied and implemented varied greatly among participants. The chair noted that the WG featured "scientists and managers sitting at the same table as two cultures trying to work together". Some other perspectives included one by Canada that the PA need not be limited to reference points, and it could include specific measures to protect juveniles and SSB, such as closed areas, gear restrictions, and bycatch protection. EU noted that a clear line should be drawn between the tasks of scientists and managers, and that reference points can be "overcautious". FC agreed that the joint WG should continue, and that it should develop PA for 3 model stocks (fishery closed – 3NO cod; fishery open – 3LNO yellowtail; data limited – 3M shrimp). This meeting was set for spring 1999 – SC was to meet first followed by the joint SC-FC WG meeting. The chair stressed that "no decisions are to be made at the meeting, it is to be a WG meeting for technical experts in the field of management". It was agreed that the meeting would develop simulations of a PA for the 3 model stocks for presentation to the 2 parent bodies (SC, FC). During its Sept. 1998 meeting, SC agreed to have a SC meeting immediately prior to the Joint WG meeting, and nominated a list of participants (NAFO 1998d).

1999

- At the SC meeting in April-May 99, work was carried out on the 3 model stocks, and recommendations on reference points prepared for the joint WG meeting. (NAFO 1999b). Various methodologies were explored, including SSB-recruit analyses, production modelling, and a qualitative "traffic light" approach. The SC recommendations were presented and discussed at the joint WG which followed immediately. The WG also considered a list of potential management tools to be considered by FC at its Sep 99 meeting. In the WG report (NAFO 1999c), it was pointed out that the scientific terminology related to the PA was difficult for managers and clients, and that differences in terminology between NAFO and ICES created some difficulty for managers working in both organisations. Some managers also expressed a need for a clear and simple presentation of results in order to understand the background. For each of the 3 stocks, the WG compiled a list of elements pertaining to a PA for management of each stock. There was not, however, any consensus on identification of options for decision rules or evaluation of appropriate management strategies for the 3 stocks.

- There was minimal discussion of the April-May meetings in the June 1999 SC meeting, although progress made at those meetings was reflected in the June report on the relevant stocks. At its September 1999 meeting, SC reviewed the earlier meeting reports and called for continued joint WG meetings to further understanding of the PA. Harmonization of PA terminology was again identified as an important concept.
- At the FC meeting in 1999, there was support for continuing the joint WG meeting, and an agenda was prepared for such a meeting in early 2000. Noting the progress that had been made thus far, along with the provisions of the various international agreements on PA and responsible fisheries, FC also adopted a resolution to guide the implementation of the PA within NAFO (NAFO 2000a). The main points, as tabled in a working document at that meeting, are listed in Table 2.

2000

- To address concerns with harmonization of PA terminology, arising within both ICES and NAFO, a coordinated working party (CWP) meeting was held in February 2000 (ICES 2000). Representatives attended from NAFO, ICES, ICCAT, and FAO, and presentations were given on the PA in each organisation. The CWP made detailed comparisons of the PA in each of the 3 scientific agencies (ICES, NAFO, ICCAT). It was noted that there were differences in interpreting the original UN guidelines for implementing the PA, but that the objectives of these scientific agencies shared a number of common elements. With regard to harmonization, the report stated that even if it were possible to recommend a common approach to the PA, it may be premature, as work on the PA was in the exploratory stage in many cases.
- The joint FC/SC WG on PA met in Feb-March 2000. On the issue of harmonisation of concepts and terminology, the WG agreed that there were "several broad similarities between the ICES and NAFO versions of the PA" (NAFO 2000b). The issue of F_{msy} as a maximum value for F_{lim} (as in the NAFO PA) was clearly an issue, as this is not the case in the ICES framework. Strong views were expressed on the appropriateness of F_{msy} as a reference point, and the WG could not agree on which formulation was more appropriate. On a more positive note, the WG defined steps for the implementation of a PA for 2 of the model stocks (3NO cod and 3LNO yellowtail – see Table 3). Additional technical management measures, as elements of a PA, were also specified, including protection of spawners and pre-recruits, and concerns with by-catch. The need to address harvest control rules in implementing the PA was noted. The WG also addressed changes to FC's request to SC to reflect the PA, although it was agreed that the term PA Framework would not be used as FC had not yet formally adopted the PA Framework proposed by SC. Although some progress was made at this meeting, it is clear from the report that many differences in opinion over the PA existed among the Contracting Parties of NAFO. The meeting also featured procedural wrangling over wording of the report, lack of consensus on some presentations, and considerable debate on what items should or should not be included in the report. The report indicated guidance was required from FC on some issues pertaining to preparation of WG reports.
- From the June 2000 SC meeting (NAFO 2000c): "Noting that Scientific Council has been working with the PA framework since 1997 while the Fisheries Commission has not adopted it, the Council recorded that the structure of the last three meetings of the Joint Scientific Council and Fisheries Commission Working Group was not optimal for discussion of the PA framework. The Council was of the view that less formal and smaller meetings in the form of dialogue between scientists and managers may see progress. It was also suggested that there may be more success if the Scientific Council presented applications of the PA to specific cases."
- In September of 2000, SC had development of the PA on its agenda, although there were no papers or specific items to discuss (NAFO 2000c). However, the SC Special Session at that meeting, a 3-day WS on assessment methods, dealt extensively with PA methodology and risk analysis software.
- At its September 2000 meeting, FC reviewed the results of the joint PA WG meeting, and received a summary presentation by the chair of SC (NAFO 2001a). The report was adopted, and considerable discussion occurred on whether the WG should continue or not. Some CP's strongly supported continuation, and proposed a 3 year pilot project to "operationalize" the work done on the model stocks. Other CP's held the view that more work

needed to be done before decisions could be taken to implement the PA. Inconsistencies between NAFO and NEAFC were noted, as was the lack of agreement on fundamental elements of the PA. To promote further progress on implementing the PA, it was agreed that a small group of technical experts should meet in the first half of 2001, and produce a recommendation on whether the joint WG should meet later in 2001.

<u>2001-02</u>

- During 2001, there was little discussion in SC on development of PA. In addition, the annual meeting of FC, scheduled for September 2001, did not occur due to the events of September 11 in the USA. In June 2002, SC discussed options for advancing development of PA methodology, and agreed that a WS be held in 2003 (NAFO 2002a).
- The meeting of technical experts, proposed in Sep 2000, occurred immediately after the SC meeting in June 2002 (NAFO 2002b). At that meeting, various presentations were given, including overviews of the work done in NAFO and ICES on the PA thus far. Management experience with the ICES PA Framework was also discussed. A number of concerns with either or both the NAFO and ICES PA Frameworks were identified:

  - Prescribed harvest control rules (no fishing) below B_{lim} or B_{buf}
  - A fishing mortality limit at F_{msy}
  - The perception of a linear decrease in fishing mortality from the biomass target to the biomass buffer
  - No consideration of the desirability for stable TAC's
  - No consideration of multi-species situations

  The group agreed that further progress as well as overall implementation of the PA would benefit by addressing specific cases and problems. The report also contained a recommendation that "FC determine appropriate examples then instruct the Joint FC/SC WG on PA to meet intersessionally to address the points as they apply to the examples". The Group also suggested that FC consider steps to develop proposals for long-term plans for management of different fleet sectors of the fisheries, and provided 5 characteristics to consider.

- The WG Report was presented at the FC meeting in Sept 2002 (NAFO 2002c), and the recommendations were tabled. The FC Report states "following discussions within the FC, no action was taken to initiate a joint FC/SC WG on the PA". No reasons were given and no further discussion of the PA occurred at that meeting.

- SC developed terms of reference for its PA Workshop at its September 2002 meeting (NAFO 2002a). SC also reviewed the data which would be available for each stock for use with various PA methodologies.

<u>2003</u>

- SC held its PA WS in March-April of 2003 (NAFO 2003). A wide range of methodologies for calculating PA reference points was reviewed, and applied to as many stocks as data allowed. In addition, the basis for the existing PA reference points was reviewed for stocks where they exist. Progress in other jurisdictions was also reviewed, including ICES, Canada, and USA. Finally, the existing NAFO PA framework was considered, in light of the concerns expressed above (from the 2002 meeting of technical experts). To address these concerns, a revised PA framework was proposed, as outlined in this document. SC also pointed out how the revised framework attempted to address specifically each concern, recognizing for example, the need for a certain amount of flexibility to account for technical interactions that result in unavoidable by-catch of depleted species.