REPORT OF THE 2010
ICCAT WORKING GROUP ON STOCK ASSESSMENT METHODS
(Madrid, April 21-23, 2010)

1. Opening, adoption of Agenda and meeting arrangements

Mr. Driss Meski, ICCAT Executive Secretary, opened the meeting and welcomed participants. The Executive Secretariat made reference to the Working Group on the Future of ICCAT and the Joint Tuna RFMOs Workshops that will meet this year emphasizing the relevance of the work of the Stock Assessment Methods Working Group in relation to these important meetings.

The meeting was chaired by Dr. Victor Restrepo. Dr. Restrepo welcomed the Working Group participants, reviewed the objectives of the meeting and proceeded to review the Agenda which was adopted without (**Appendix 1**).

The List of Participants is attached as **Appendix 2**.

The List of Documents presented at the meeting is attached as **Appendix 3**.

The following participants served as Rapporteurs for various sections of the report:

Section	*Rapporteurs*
1, 5	P. Pallarés
2.1	S. Cass-Calay and P. De Bruyn
2.2	M. Ortiz, J. Walters and S. Cass-Calay
2.3	G. Scott and V. Restrepo
3	L. Kell
4	G. Díaz

2. Issues related to the Precautionary Approach:

In 1998 and 1999, the SCRS convened an ad Hoc Working Group on the Precautionary Approach to review the then-current thinking about how to apply the Approach in practice and to make appropriate recommendations to the Commission in case it wished to adopt the Approach. Practically all of what was discussed by the ad Hoc WG then is still valid today. The WG recommends that ICCAT scientists and managers read the reports, especially the 1999 report of the meeting that took place in Dublin (ICCAT 2000, Col. Vol. Sci. Pap. 51:1941-2056). That report covers some issues such as data collection and environmental considerations that are important but were not thoroughly discussed in this meeting.

Both the ICCAT Convention and much of the PA literature make references to MSY benchmarks (as targets or limits, respectively). **Table 1** shows a stock-by-stock status with respect to Bmsy and Fmsy, in 1999 (from the Dublin meeting report) and as of today (from the 2009 SCRS report).

2.1 Review of relevant documents:

The working group reviewed previous literature on precautionary approaches, and the current precautionary management practices of other Nations and RFMOs. What follows is a description of the contents of the available literature. Relevant excerpts from these documents are contained in **Appendix 4**.

2.1.1 Summary of the ICCAT convention

The ICCAT convention does not explicitly mention the precautionary approach. This is largely due to the fact that the ICCAT convention predates the formal concept of the precautionary approach as outlined in the 1995 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. Texts referring to the aim of fisheries management related to stocks status include the following:

Article IV, paragraph 2b. - *The carrying out of the provisions in paragraph 1 of this Article shall include: studying and appraising information concerning measures and methods to ensure maintenance of the populations of tuna and tuna-like fishes in the Convention area at levels which will permit the maximum sustainable catch and which will ensure the effective exploitation of these fishes in a manner consistent with this catch;*

Article VIII paragraph 1a - *The Commission may, on the basis of scientific evidence, make recommendations designed to maintain the populations of tuna and tuna-like fishes that may be taken in the Convention area at levels which will permit the maximum sustainable catch.*

These texts have resulted in the conclusion that ICCAT does not follow the precautionary approach strictly, because the ICCAT Convention can be interpreted to imply MSY as a target, while the precautionary approach as defined by the UN fish stocks agreement implies that MSY should be considered as an upper limit, which should, therefore, be avoided.

2.1.2 1999 ad hoc Working Group on the Precautionary Approach

The 1999 meeting reviewed management concepts for the implementation of the Precautionary Approach including targets, limits and harvest control rules. (Appendix 4),

2.1.3 The precautionary approach as applied by other tuna RFMOs (SCRS/2010/023)

The document (see Appendix 4) listed some recommendations for ICCAT based on these case studies taking into consideration several of the key suggestions by Mooney-Seus and Rosenberg (2007) would include:

- The development of formal MSE for main target species based on predetermined/consulted harvest control rules and possibly adopting a formal management procedure (MP) approach.
- Considering MSY as a limit or alternatively a target provided that uncertainty is taken into account. In other words, MSY related reference points can be considered targets if the probability of achieving those reference points is included. Then, managers should decide the limit probability for achieving the target reference points to achieve convention objectives.
- Continue to develop alternative forms of management when TACs or TAEs have not been reliably quantified or implemented.
- Include formal mention of the Precautionary approach either in an amendment to the convention, or in a binding recommendation.

2.1.4 1995 United Nations Fish Stocks Agreement (UNFSA)

The UNFSA describes principles for the conservation and management of Straddling Fish Stocks and Highly Migratory Fish Stocks and establishes that such management must be based on the precautionary approach and the best available scientific information. The Agreement also describes the objective of such management; that States should cooperate to ensure conservation and promote the objective of the optimum utilization of fisheries resources both within and beyond the exclusive economic zone.

Article 6 of the Agreement describes the application of the precautionary approach as follows:

States shall apply the precautionary approach widely to conservation, management and exploitation of straddling fish stocks and highly migratory fish stocks in order to protect the living marine resources and preserve the marine environment.

1. *States shall be more cautious when information is uncertain, unreliable or inadequate. The absence of adequate scientific information shall not be used as a reason for postponing or failing to take conservation and management measures.*
2. *In implementing the precautionary approach, States shall:*
   - *(a) improve decision-making for fishery resource conservation and management by obtaining and sharing the best scientific information available and implementing improved techniques for dealing with risk and uncertainty;*
   - *(b) apply the guidelines set out in Annex II and determine, on the basis of the best scientific information available, stock-specific reference points and the action to be taken if they are exceeded;*

(c) take into account, inter alia, uncertainties relating to the size and productivity of the stocks, reference points, stock condition in relation to such reference points, levels and distribution of fishing mortality and the impact of fishing activities on non-target and associated or dependent species, as well as existing and predicted oceanic, environmental and socio-economic conditions; and

(d) develop data collection and research programmes to assess the impact of fishing on non-target and associated or dependent species and their environment, and adopt plans which are necessary to ensure the conservation of such species and to protect habitats of special concern.

3. *States shall take measures to ensure that, when reference points are approached, they will not be exceeded. In the event that they are exceeded, States shall, without delay, take the action determined under paragraph 3 (b) to restore the stocks.*
4. *Where the status of target stocks or non-target or associated or dependent species is of concern, States shall subject such stocks and species to enhanced monitoring in order to review their status and the efficacy of conservation and management measures. They shall revise those measures regularly in the light of new information.*
5. *For new or exploratory fisheries, States shall adopt as soon as possible cautious conservation and management measures, including, inter alia, catch limits and effort limits. Such measures shall remain in force until there are sufficient data to allow assessment of the impact of the fisheries on the long-term sustainability of the stocks, whereupon conservation and management measures based on that assessment shall be implemented. The latter measures shall, if appropriate, allow for the gradual development of the fisheries.*
6. *If a natural phenomenon has a significant adverse impact on the status of straddling fish stocks or highly migratory fish stocks, States shall adopt conservation and management measures on an emergency basis to ensure that fishing activity does not exacerbate such adverse impact. States shall also adopt such measures on an emergency basis where fishing activity presents a serious threat to the sustainability of such stocks. Measures taken on an emergency basis shall be temporary and shall be based on the best scientific evidence available.*

Annex II of UNFSA further describes the precautionary approach by outlining the following guidelines:

1. *A precautionary reference point is an estimated value derived through an agreed scientific procedure, which corresponds to the state of the resource and of the fishery, and which can be used as a guide for fisheries management.*
2. *Two types of precautionary reference points should be used: conservation, or limit, reference points and management, or target, reference points. Limit reference points set boundaries which are intended to constrain harvesting within safe biological limits within which the stocks can produce maximum sustainable yield. Target reference points are intended to meet management objectives.*
3. *Precautionary reference points should be stock-specific to account, inter alia, for the reproductive capacity, the resilience of each stock and the characteristics of fisheries exploiting the stock, as well as other sources of mortality and major sources of uncertainty.*
4. *Management strategies shall seek to maintain or restore populations of harvested stocks, and where necessary associated or dependent species, at levels consistent with previously agreed precautionary reference points. Such reference points shall be used to trigger pre-agreed conservation and management action. Management strategies shall include measures which can be implemented when precautionary reference points are approached.*
5. *Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low. If a stock falls below a limit reference point or is at risk of falling below such a reference point, conservation and management action should be initiated to facilitate stock recovery. Fishery management strategies shall ensure that target reference points are not exceeded on average.*
6. *When information for determining reference points for a fishery is poor or absent, provisional reference points shall be set. Provisional reference points may be established by analogy to similar and better-known stocks. In such situations, the fishery shall be subject to enhanced monitoring so as to enable revision of provisional reference points as improved information becomes available.*
7. *The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points. For stocks which are not 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.*

The group noted that UNFSA is not necessarily binding to ICCAT Contracting Parties that are not Parties to UNFSA (26 of 48 CPs are currently UNFSA Parties). Nevertheless, the group felt that most of the items in

Article 6 and Annex II of UNFSA offer useful text for potential application to ICCAT stocks. The group generally agreed that a precautionary approach should use two types of reference points, targets and limits, but noted that the language about Fmsy as a limit contained in UNFSA Annex II(2) is potentially in conflict with ICCAT's Convention.

The group also discussed Article 6(5) some members felt that there was little need for such a measure in the ICCAT context since ICCAT fisheries tend to have a long history of exploitation, with few new or exploratory fisheries.

2.1.5 United States: Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA) of 2006

The United States precautionary management methods are described in the MSRA (Public Law 109–479) and in the National Standard Guidelines (74 FR[1] 3178 (2009-01-16). The objective of the MSRA can be summarized as follows: *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. Section 301(a)(1)*
To that end, the MSRA defined "overfishing" as the level of fishing above that which would produce the maximum sustainable yield (F_{MSY}, or a proxy thereof). It also specifies four reference catch levels described in Appendix 4

The working group considered this approach and agreed with the general concept of a precautionary target that considers scientific uncertainty, and an overfishing limit not to be exceeded.

The working group also examined a document (SCRS/2010/025) that illustrated a simple precautionary management approach used by the U.S. Pacific Fisheries Management Council. To demonstrate the procedure, the method was applied to Atlantic bigeye tuna to determine an acceptable level of catch that incorporated two dominant sources of scientific uncertainty.

2.1.6 Proceedings of the 2008 Joint Canada-ICCAT Workshop on the Precautionary Approach for Western Bluefin Tuna (ICCAT, 2009).

A joint Canada-ICCAT Workshop was convened in Halifax, Canada during March 17-20, 2008. (Appendix 4) It dealt with the development of a precautionary approach for western bluefin tuna. The objectives were to characterize production dynamics, review generic harvest strategies consistent with the ICCAT convention and the Precautionary Approach, develop candidate fishing mortality and biomass references and outline advantages of the Precautionary Approach. Among the main conclusions was that the F_{MAX} based fishery management strategy for western bluefin tuna was not consistent with the rebuilding intention of the Precautionary Approach. Alternative F proxies, such as $F_{0.1}$ or $F_{95\%MSY}$, which result in only slightly lower yields, would provide higher odds of rebuilding western bluefin tuna and could be considered consistent with the Precautionary Approach.

The working group considered this document and found that the conclusions were consistent with the precautionary approaches used by other nations and RFMOs.

2.1.7 A Fishery Decision-Making Framework Incorporating The Precautionary Approach. Dept. of Fisheries and Oceans, Canada[2]

This policy document describes a general fishery decision-making framework for implementing a harvest strategy that incorporates the Precautionary Approach (PA). In applying the framework, all removals of these stocks from all types of fishing must be taken into account. While application of this framework to key harvested stocks is the minimum requirement, it may be applied more broadly to other stocks where necessary and as circumstances warrant (Appendix 4).

The Canadian approach also includes advice for the construction of harvest controls for species lacking sufficient scientific information to formulate the reference points and stock status zones.

The working group considered this document and found that the conclusions were consistent with the precautionary approaches used by other Nations and RMFOs.

[1] Federal Register
[2] http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/precaution-eng.htm

2.2 Consideration of stock assessment issues that SCRS should consider, including:

2.2.1 Guidelines for the application of the Kobe II Strategy Matrix

The WG felt strongly that the Kobe II strategy matrix (K2SM) provides a concise and interpretable communication of assessment results and guidance for management decisions by the Commission. The K2SM presents a decision table summarizing the probabilities of achieving biomass or fishing mortality rate targets under different management actions. The Kobe K2SM strategy has been promoted by different RFMOs and its construction for inclusion in Executive Summaries should be a primary consideration of the assessment working groups. This expands the mandate of the assessment group from simply determining current stock status to providing probabilistic management advice.

The Commission also recognizes the value of the K2SM. Resolution [09-12] provides specifications regarding the information that should be provided in the matrix. Here, the WG provides additional recommendations to facilitate K2SM construction and interpretation:

- Matrices should be presented in both tabular and graphical form (e.g., **Table 2** and **Figure 1**)
- The model(s), model runs and methodologies used for construction should be clearly documented.
- Matrices should be constructed from the assessment models used to determine stock status.
- Matrices should clearly outline assumptions and uncertainties.
- Methodologies for model averaging, model harmonization and generation of probabilistic statements regarding harvest control rules should be employed (see Section 2.2.3).
- Multiple matrices may be necessary to provide advice spanning alternative hypotheses.

2.2.2 Specifications regarding projection methods

As projections form the basis of the construction of the Kobe matrix development, it will be critical that assessment working groups determine and fully document projection specifications including:

- projection software(s)
- recruitment model/recruitment replacement/error structure specifications
- selectivity/partial F specifications
- age "plus-group" calculations
- projection time period
- any management implementation assumptions

2.2.3 Recommendations for development of Kobe matrices

Construction of the Kobe matrices requires use of assessment models and projection methodologies with stochastic features that reflect the major sources of uncertainty in the assessment. Stochasticity is critical to developing the probabilistic statements. Stochasticity can be generated, for example, using bootstrapping methodology, Markov-Chain Monte Carlo methods and through the use of multiple model specifications.

Often, assessment working groups provide stock status results and stock projections from multiple models or multiple model runs. When it is impossible to combine models over several hypotheses or over different states of nature, it may be necessary to provide multiple K2SMs. However, it may be desirable to capture uncertainty by constructing K2SMs from combined stochastic results from multiple models or model runs.

Practical and statistical assumptions for model-averaging should be carefully considered. A practical consideration is that assessment working groups should ensure that model averaging maintains balance and avoids *implicitly* weighting one scenario over another. Weighting should be made as *explicit* as possible and be based upon either empirical considerations or expert opinion. When specification of external weights for a set of hypotheses (and also for specifying informative priors for a Bayesian approach) is required, expert judgment and consensus amongst experts should be sought. One approach to this is a Delphi-like protocol where expert opinion is used to evaluate alternative hypotheses for a given factor to allocate weighting factors derived by consensus.

Model averaging based upon an information-theoretic approach provides a means of empirical integration of multiple models. For example, the ICES report of the study group on risk assessment and management advice

(SGRAMA) considered Bayesian methodology to weight alternative hypotheses on the basis of the extent to which they are supported by the available data. Within a single model structure, this can be achieved by integrating over prior distributions for parameters, multiplied by the likelihood of the observed data. The assessment WG recommends that assessment groups consider information-theoretic and other alternative weighting schemes for development of scientific advice and for construction of Kobe matrices, particularly when there may be scientific support for certain models over others. Regardless of the weighting method used, it is very important that clear documentation be provided in the detailed report as to how model results were combined.

Document SRCR/2010/024 presents an example of Bayesian model-averaging to integrate alternative stock recruitment model formulations, weighted by the evidence in favor of each model. That document describes a proposed protocol for estimating evaluating stock recruitment relationships incorporating biological and expert knowledge into stock-recruitment models in a Bayesian framework. Because stock recruitment assumptions have a major influence on short-term projection results and biological long term reference points, and, as they are often poorly determined by available data, relying exclusively on statistical model fitting criteria is not advisable. The Methods WG recommends using alternative models, including prior scientific knowledge and basic demographic information to produce robust reference points and population projections.

The K2SM column labeled "Data Rich/Data Poor" provides an opportunity to comment on the quality of the information used to generate the probability statements. Data-rich scenarios would include those where assessments and projections are based upon long time series, well-fit assessment models and a high level of confidence that the probability statements capture most of the assessment uncertainty. Data poor scenarios would represent situations with poor model fits, poorly determined probabilities and a high percentage of unquantified uncertainty. The rationale for these statements is to provide guidance in setting harvest levels. When data quality is poor, harvest levels with a higher probability of achieving targets may be necessary.

2.2.4 Recommendations for harvest control rules

2.2.4.1 Example Harvest Control Rules for ICCAT

Under the current ICCAT Convention, fish stocks are managed with the objective of "maintaining the populations of these fishes at levels which will permit the maximum sustainable catch (MSY) for food and other purposes". This language is interpreted as a definition of a "target" objective for each stock unit. However, there are no provisions or guidelines for what acceptable level of variability around this "target" should be allowed. Thus, if a stock is found to be below the biomass level that allows the harvest of MSY (B_{MSY} reference), then a management action(s) should be implemented to restore the stock to levels at or above B_{MSY}.

The 1999 *ad hoc* Working Group on the Precautionary Approach reviewed several applications of the precautionary approach including ICES, NAFO, Multilateral High-Level Conference (MHLC, which preceded WCPFC), FAO expert consultations and national and regional approaches. That meeting discussed how a precautionary approach could be applied to the ICCAT situation and made several recommendations. In particular, they discussed the application of targets, limits and thresholds, and defined the following:

1. A ***limit*** is a conservation reference point based on a level of biomass (B_{limit}) or a fishing mortality rate (F_{limit}) that should be avoided with high probability because it is believed that the stock may be in danger of recruitment overfishing or depensatory effects if the limit reference points are violated.
2. A ***target*** is a management objective based on a level of biomass (B_{target}) or a fishing mortality rate (F_{target}) that should be achieved with high probability, on average. This generally means that the probability of exceeding the target reference point should be at least 50%. Targets should be set sufficiently far away from limits such that they result in only a low probability that the limits will be exceeded.
3. A ***threshold*** is a level of biomass (B_{thresh}) or a fishing mortality rate (F_{thresh}) between the limit and target reference points that serves as a "red flag" and may trigger particular management actions designed to reduce fishing mortality

An example of a potential harvest control from the 1999 ad hoc WG is shown in **Figure 2**.

The 2010 Methods working agreed with much of the advice of the 1999 *ad hoc* WG meeting. In particular, the working group strongly supports the use of targets, limits and thresholds for harvests control rules. The group recommended the following definitions for a control rule that would be consistent with UNFSA Annex 2. A control rule that would be consistent with UNFSA is illustrated in **Figure 3**. Note that:

1. The overfishing limit (F_{LIM}) should be set equal to F_{MSY} (or an appropriate proxy). This level would, by definition, correspond to a 50% probability of overfishing. F_{LIM} should be treated as a limit that should rarely be exceeded (managers should define the risk tolerance for exceeding the limit) .
2. The target fishing level (F_{TARGET}) should be set sufficiently below F_{LIM} by an amount that corresponds to an acceptable risk (probability) of overfishing so that there is a low probability of exceeding F_{LIM}.. Managers should choose a precautionary risk of overfishing that is unlikely to result in exceeding the F_{LIM}.
3. The biomass target (B_{TARGET}) will should remain $\geq B_{MSY}$ (or a proxy), which is consistent with the current ICCAT convention.
4. The biomass threshold ($B_{THRESHOLD}$) is a measure to allow some natural variation in abundance around B_{MSY} without triggering stronger management measures (e.g. lower F). This threshold should be set to a value that corresponds to the expected variance in equilibrium biomass at F_{MSY}. This value should be defined by Species Groups based on the species' life history characteristics and selectivity pattern[3].
5. The biomass limit (B_{LIM}) is a low level of biomass below which removals by all human sources should be eliminated or kept as low as feasible. A stock size below B_{LIM} is expected to have severe adverse effects on the stock, and possibly also the ecosystem and associated species. The working group discussed several measures for B_{LIM} including 5% or 10% of B_{MSY} (or a proxy thereof). Management Strategy Evaluations (MSE) could help identify an adequate value.

2.2.5 MSE evaluation of reference points

Management strategy evaluation can be used to develop general formulations for harvest control rules. The ICCAT convention requires stocks to be managed by strategies based on maximum sustainable yield (MSY); however, there is concern whether this will actually ensure sustainability with sufficiently high probability consistent with the principles of the precautionary approach. Kell at al. (2003) used MSE to evaluate the performance of MSY management strategies. The study elucidated guidelines about assessment and management that are general enough to be applied to all tunas in the Atlantic Ocean. Management performance was found to be especially sensitive to the carrying capacity of the stock (i.e. B_{MSY}) while the type of proxy used for MSY was found to be more important than the frequency of assessment or uncertainty in the indices of abundance used in the assessment. Proxies examined for F_{MSY} were $F_{40\%SPR}$, $F_{30\%SPR}$ and $F_{0.1}$; the actual choice of an adequate proxy for F_{MSY} was, however, stock-dependent.

Kell and Fromentin (2006), evaluated HCRs for Mediterranean bluefin tuna and found that F-based reference points performed better than yield or biomass-based ones when there was uncertainty about the true dynamics of the stock,. They also found that $F_{0.1}$ was the best proxy for F_{MSY}.

2.2.6 Exploration of Proxy reference points

Given that stock-recruitment relationships are often difficult to determine with precision, the group explored the performance of alternative reference points that could serve as proxies for F_{msy}. This was done by using VPA outputs projected to equilibrium, where recruitments were re-sampled from observed values. Commonly-employed proxies include F_{max}, defined as the fishing mortality rate at maximum yield per recruit, $F_{0.1}$ or the fishing mortality rate where the slope of the yield per recruit curve is 10% of the slope at the origin, and $F_{35\%}$ or the fishing mortality rate which gives a spawning potential ratio equal to 35%.

Explorations of the equilibrium performance of these alternative reference points indicated that, for most of the selected species, the yield per recruit curves did not have a well-defined maximum (**Figure 4**). Moreover, substantial increases in spawning biomass per-recruit could be achieved with minimal reductions in yield if more precautionary F targets were applied (**Table 3**). Given the uncertainties in stock recruitment relationships for most tuna species, these proxies may be useful for future consideration as management targets.

However these results should be interpreted with some caution, since they were calculated assuming constant

[3] e.g., SCRS/2009/029

recruitment, i.e. independent of a stock recruitment model. However, their performance as reference points is dependent upon the functional form of the underlying stock recruitment relationship, even if that relationship is not well known. An example based on Mediterranean swordfish was used to evaluate the performance of several proxy F reference points when the actual stock recruitment was either constant recruitment, Beverton-Holt or Ricker.

Figures 5-7 show the expected or equilibrium values of SSB, yield and profit versus fishing mortality rate and the equilibrium recruits, yield and profit versus SSB with plotted reference points for F_{MSY}, F_{Ma}, $F_{0.1}$, and F_{MEY} for the three recruitment scenarios. F_{MEY} is the fishing mortality rate that would give maximum economic yield. Points and lines plotted outside the yield or profit curve reflect that these quantities have been reduced to zero, indicating that these reference points would not be sustainable under the assumed stock recruitment relationships. Proxy reference points $F_{0.1}$, and F_{MEY} were sustainable proxies for F_{MSY} under constant and Beverton-Holt stock recruitment, however F_{Max} was not sustainable with Beverton-Holt recruitment. For Ricker recruitment, neither $F_{0.1}$ or F_{Max} were safe proxies for long-term sustainability. These results reflect the findings of Kell at al. (2003) that adequate proxies for F_{MSY} are likely to be stock dependent and to critically depend upon the functional form of the underlying stock recruitment relationship.

2.3 Draft Recommendations to the Commission

2.3.1 Recommendations for applying the Precautionary Approach

The Precautionary Approach, as understood by the WG, is a general practice. It is a way of making consistent management decisions that are unlikely to result in overfishing or would have severely adverse or irreversible impacts on the target and non-target stocks. The PA is not necessarily a very rigid framework that managers are bound by, unless they decide to make it so. But, at the same time, the PA should not be mistakenly equated with any isolated management decision that helps improve stock status. Throughout its existence, ICCAT has adopted multiple conservation and management measures, such as TACs intended to reduce fishing mortality to F_{MSY} in a given time horizon. These measures contain elements of the precautionary approach, but they are not necessarily the result of following the Approach as a general management practice.

As the report of the 1999 meeting of the ad Hoc WG on the PA noted, the implementation of the PA to fisheries management requires two-way communication between scientists and managers. For example, reference points should be calculated by scientists while managers should be responsible for choosing between alternative reference points and the degree of risk avoidance. **Table 4** summarizes the respective roles of the scientists and the managers within ICCAT, as envisioned by the SCRS in 1999. The WG recommends that, should the Commission intend to implement the PA, then a two-way dialogue on these matters needs to take place, perhaps through one or more workshops.

The WG also recognizes that there are a number of useful steps that can be taken to make progress before a two-way dialogue takes place. For example, the WG recommends that the SCRS include in its Executive Summary tables various quantities that will help further inform the Commission. One of these quantities is the catch that would occur in the short term if fishing mortality equaled F_{MSY} as well as the catch that would result from fishing at (usually conservative) proxies for F_{MSY} such as $F_{0.1}$.

If the Commission wishes to embrace the Precautionary Approach, the WG recommends that Commission endeavor to establish management measures which result in a low probability of exceeding F_{MSY} (or an appropriate proxy) in cases of stocks for which status is consistent with the Convention Objective. For stocks below the level consistent with the convention objective, the Commission should endeavor to establish management measures which result in rebuilding of biomass to levels consistent with the Convention Objective within as short a time period as biologically feasible and practicable and which have a high probability of success.

The WG also recommends that the Commission mandate the SCRS to assess the stocks with sufficient frequency such that conservation and management measures can be modified as needed. For the major tunas, billfishes, swordfish and pelagic sharks that are currently monitored by ICCAT, an adequate frequency could be every four or five years. For stocks that are depleted and are under a rebuilding plan, more frequent assessments and intense monitoring may be necessary in order to follow a Precautionary Approach.

In addition, the WG hopes that the presentation of decision tables such as the Kobe II Strategy Matrix will improve the way in which the SCRS communicates potential risks and consequences of alternative management actions to the Commission. The WG recommends that SCRS produce such tables in all quantitative assessments, specifically addressing the probability that future catches will result in F_{MSY}. In order to follow the Precautionary Approach, the Commission should take such tables into consideration when adopting conservation and management measures, with the aim of having a low probability of exceeding F_{MSY}.

2.3.2 Recommendations for potential changes to the Convention text

The meeting did not count with participants who are experts in policy and legal texts, so its ability to offer advice on this topic is limited. Nevertheless, it would seem that Article VIII of the ICCAT Convention would be an adequate place for such changes. For example (underlined text is a new addition):

> Article VIII. 1.(a) The Commission may, on the basis of scientific evidence, make recommendations designed to maintain the populations of tuna and tuna-like fishes that may be taken in the Convention area at levels which will permit the maximum sustainable catch. In making these recommendations, the Commission shall apply the precautionary approach, as described in the relevant provisions of the 1995 United Nations Fish Stocks Agreement[4]. These recommendations shall be applicable to the Contracting Parties under the conditions laid down in paragraphs 2 and 3 of this Article.

Other alternatives the WG noted, would involve adopting language that has been agreed in the IATTC Antigua Convention Article 4 by appending that language into ICCAT's Article VIII, or attempting to integrate the concepts laid out in the WCPFC Convention Text Articles 5 and 6, which encompass broader elements of a Precautionary Approach and more explicitly considers ecosystem, data collection, and scientific research issues.

3. Other Methodological issues

3.1 CPUE Standardization

Gear selectivity and targeting are important components influencing stock status evaluations. In the 2009 methods meeting (ICCAT, 2010) it was noted that appropriate methods to account for such effects are not fully developed, especially for cases wherein detailed information on gear, time/area/ and other features pertinent to the issue are unavailable. Methodological approaches using proxies such as proportion of different species in the catch have been implemented, but not rigorously tested. Simulation testing of the different methods implemented should be fully tested using simulated data sets such as available through the LLSIM model, presented at the meeting, seems to be able to use most of these variables, at least for some stocks where sufficient information is available. However, work in this area still needs to be carried out.

3.2 Meta-analyses

Meta-analysis of multi-stock data sets are a potentially an important tool for improving estimates of model parameters compared with those derived through single-stock analyses (Peterman, 2004).

For example stock recruitment relationships are important for completing the life cycle in population models and when assessing and projecting stocks and for calculating reference points such as maximum sustainable yield (MSY). However, there is often insufficient information in stock assessment data to choose the appropriate functional form for a stock recruitment relationship or to estimate parameters of interest. Meta-analysis of stock recruit relationships from several stocks by including more existing information for example on growth, maturation and adult natural mortality can be used to model and reduce uncertainty in the relationship between the biomass of reproductively mature individuals (spawning stock) and the resulting offspring added to the population recruitment Mangel et al (2009). Making such data freely available will be important in encouraging collaboration across RFMOs and with scientists from different regions.

3.3 Biological studies

The adoption of the precautionary approach (FAO 1996) to fisheries management requires a formal consideration of uncertainty based upon limit and target reference points and control rules. However, uncertainty is mainly based on estimates from statistical models using non-biologically based estimates of spawning potential and there is often insufficient information to determine the correct functional form of the stock recruitment relationship or important parameters such as steepness. Ecology studies can provide information for use in reducing uncertainty. While value-of-information analysis can be used to identifying key scientific

[4] 1995 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

uncertainties in the stock recruitment relationship that affect decisions and to quantify how better science can reduce those uncertainties and the benefit for managers e.g. in terms of increased yield and reduced risk of stock collapse.

3.4 Bio-economic studies

If two policies have same biological but differing economic impacts, then there might be a preferred economic option. For example, seasonal or area closures may reduce fishing mortality by the same amount, but have different economic consequences on a fleet by fleet basis. Therefore bio-economic analysis will be a useful adjunct to biological assessments when evaluating recovery and management plans.

4. Recommendations

The WG recommended that all Species Groups construct a Kobe II Strategy Matrix (K2SM). In the construction of the matrices the Species Groups should clearly document how the matrix was constructed with regards to the models used, methods used to average among models, the hypothesis, etc. In addition, the K2SM should only be constructed using the output of the model(s) used to provide advice.

The WG recommended that the SCRS evaluates techniques to weight assessment models for those cases where the outputs of more than one model are combined to provide advice. This recommendation applies to all assessments and not just to those that prepare a K2SM.

In an effort to facilitate meta-analysis, the WG also recommended to make available, for example by posting in the ICCAT web page, results of stock assessments such as YPR and SPR vectors and extend this recommendation to other Tuna RFMOs.

The WG noticed that the quality of the assessment reports, with regards to providing detailed information of the work produced during the assessment meetings, has degraded in the past few years. The lack of detailed information on assumptions, hypothesis, models used to provide advice, averaging of models outputs, model weighting schemes, etc. have created difficulties in those cases where additional analyses, such as preparation of the K2SM, were needed after assessment meetings. The SCRS should also consider revising and updating the current structures of the detail reports.

The WG reiterates that the Species Groups should increase the effort to better document and provide more detailed information on the analyses performed during assessment meetings. In addition, the Species Groups should also increase their effort to better provide the Secretariat with the model inputs and outputs, assumptions used for base cases and sensitivity runs, backup of the software used, etc.

The WG also noticed that the Summary Tables provided by the Species Groups suffer from a lack of standardization. Although the WG recognized the need for certain flexibility in preparing those tables, it also indicated that the summary tables should include at a minimum estimates of MSY, B_{MSY}, F_{MSY} (or proxies), relative B, relative F, replacement yield, catch corresponding to F_{MSY}, current TAC, current yield, stock status (e.g., overfished, overfishing), and a summary of management measures in place as shown in **Table 5**.

Regarding standardizing practices among Tuna RFMO's, the WG concluded that harmonization should be encouraged between RFMOs for data inputs, data structure and data formats, but not necessarily for assessment methods. The WG encourages making data available on the web, that can be used in meta-analysis type research for highly migratory species. These studies can provide basis for better understanding the biological features of tuna and tuna-like species when specific data is missing for some regional stocks. For example, analysis of extensive tagging programs in the Indian Ocean could help to model natural mortality by age for tropical tunas in the Atlantic. To facilitate this harmonization process, the WG recommends to hold joint meetings with scientists from other Tuna RFMOs.

Stock Synthesis is a statistical framework for the calibration of a population dynamics model based on ADMB using a diversity of fishery and survey data. It is designed to accommodate both age and size structure and with multiple stock sub-areas and include projections for different management scenarios. The structure of Stock Synthesis allows for building of simple to complex models depending upon the data available. Other generic frameworks exist, i.e. Coleraine, MULTIFAN-CL, CASAL, A-SCALA and FLR and are in use by various tuna RFMOs. Recently SS3 has been submitted for validation as part of the ICCAT software catalogue. The aim of the catalogue is to document the procedures taken to validate some of the stock assessment programs that are commonly used by the various ICCAT working groups. Inclusion in the catalog is simply a way of documenting what steps, if any, the programmer has taken to ensure that the program does what it purports to do. However, the validation of software framework such as SS3 is not a trivial task. Therefore as part of the validation of SS3 it would be useful to consider how to validate generic frameworks in the future both for ICCAT and other tuna RFMOs.

5. Adoption of the report and closure

The report was adopted during the meeting.

The Chairman thanked the participants for their hard work.

The meeting was adjourned.

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Table 1a. Status of ICCAT stocks relative to biomass at MSY (from 2009 SCRS). These classifications are based on the point estimates of biomass and BMSY (or a proxy) from the most recent assessment. They should not be considered definitive, but rather they provide an indication of exploitation as related to the stated objectives of the ICCAT Convention.

Stock	$B_{Current}$: B_{MSY}	$F_{Current}$: F_{MSY}	***Comments***
ALB-N	0.62 (0.45-0.79)	1.045 (0.85-1.23)	
ALB-S	0.91 (0.71-1.16)	0.63 (0.47-0.9)	
ALB-Med			
BFT-W	0.14 (0.08-0.21)	2.18 (1.74-2.64)	High Recruitment
	0.57 (0.46-0.70)	1.27 (1.04-1.53)	Low Recruitment
BFT-E	0.14	3.04	High Recruitment & Reported catches
	0.35	3.42	Low Recruitment & Adjusted catches
BET	0.92 (0.85-1.07)	0.87 (0.70-1.24)	
SKJ-W	most likely>1	most likely<1	
SKJ-E	most likely>1	most likely<1	
YFT	0.96 (0.72-1.22)	0.86 (0.71-1.05)	
SWO-N	1.05 (0.94 - 1.24)	0.76 (0.67 - 0.96)	
SWO-S	Likely >1	Likely <1	
SWO-Med	0.26-0.87	1.3 (0.6-2.5)	Range & 80% CI
BUM	< 1.0	Possibly > 1.0	Potential to rebuild under current management plan but needs verification.
SAI-W	Possibly < 1.0	Possibly > 1.0	
SAI-E	Likely < 1.0	Likely > 1.0	

Table 1b. Status of ICCAT stocks relative to biomass at MSY at the time of the *ad hoc* Precautionary Approach meeting (1999) and currently. The current classifications are based on estimates of biomass and Bmsy from the most recent assessment. They should not be considered definitive, but rather they provide an indication of abundance as related to the stated objectives of the ICCAT Convention.

F***Stock***	***Over B_{MSY}***		***Near B_{MSY}***		***Under B_{MSY}***		***Unknown***	
	1999	***2010***	***1999***	***2010***	***1999***	***2010***	***1999***	***2010***
ALB-N					X	X		
ALB-S			X	X				
ALB-Med							X	X
BFT-W					X	X		
BFT-E						X	X	
BET				X	X			
SKJ-W		X					X	
SKJ-E		X					X	
YFT			X	X				
SWO-N				X	X			
SWO-S				X	X			
SWO-Med			X			X		
BUM					X	X		
SAI-W					X	X		
SAI-E					X	X		

Table 1c. Status of ICCAT stocks relative to fishing mortality at MSY at the time of the *ad hoc* Precautionary Approach meeting (1999) and currently. The current classifications are based on estimates of F and F_{MSY} from the most recent assessment. They should not be considered definitive, but rather they provide an indication of exploitation as related to the stated objectives of the ICCAT Convention.

F***Stock***	***Under F_{MSY}***		***Near F_{MSY}***		***Over F_{MSY}***		***Unknown***	
	1999	***2010***	***1999***	***2010***	***1999***	***2010***	***1999***	***2010***
ALB-N				X	X			
ALB-S		X	X					
ALB-Med							X	X
BFT-W					X	X		
BFT-E					X	X		
BET				X	X			
SKJ-W		X					X	
SKJ-E		X					X	
YFT			X	X				
SWO-N		X			X			
SWO-S		X			X			
SWO-Med						X	X	
BUM					X	X		
SAI-W					X	X		
SAI-E					X	X		

Table 2 Strategy Matrix for Setting Management Measures (ICCAT Res[09-12]

Management Target	Time Frame*	Probability of Meeting Target				Data Rich/Data Poor
		50%	60%	75%	90%	
F_{MSY}	In 1 year					
	In 3 years					
	In 5 years					

Management Target	Time Frame*	Probability of Meeting Target				Data Rich/Data Poor
		50%	60%	75%	90%	
B_{MSY}	In 5 year					
	In 10 years					
	In 15 years					

* In cases where a rebuilding timeframe has already been agreed, the SCRS should base its advice on that time frame.

Table 3. Yield and spawning biomass for selected species, based on the most recent assessment. The table compares the relative yield or SSB for different reference points, indicating that, compared to F_{max}, $F_{0.1}$ and $F_{35\%SPR}$ result in relatively small losses in yield per recruit but large gains in SSB per recruit.

Species	ref. pt.	YPR/YPR_{MAX}	SPR/SPR_{MAX}	% decrease in yield	% increase in SPR
BET	F_{MAX}	1.00	1.00		
	$F_{0.1}$	0.94	2.32	6%	132%
	$F_{35\%SPR}$	0.88	2.96	6%	196%
ALB	F_{MAX}	1.00	1.00		
	$F_{0.1}$	0.92	2.83	8%	183%
	$F_{35\%SPR}$	0.84	3.91	9%	291%
YFT	F_{MAX}	1.00	1.00		
	$F_{0.1}$	0.95	1.61	5%	61%
	$F_{35\%SPR}$	0.95	1.65	1%	65%
WBFT	F_{MAX}	1.00	1.00		
	$F_{0.1}$	0.94	1.65	6%	65%
	$F_{35\%SPR}$	0.95	1.61	1%	61%
NSWO	F_{MAX}	1.00	1.00		
	$F_{0.1}$	0.93	2.31	7%	131%
	$F_{35\%SPR}$	0.86	2.94	7%	194%
EBFT	F_{MAX}	1.00	1.00		
	$F_{0.1}$	0.93	1.54	7%	54%
	$F_{35\%SPR}$	0.98	1.27	5%	27%

Table 4. The roles of scientists and managers within ICCAT, as envisioned by the SCRS (from the 1999 ad Hoc WG report).

Scientists	**Managers**
1. Collect, collate and evaluate statistical databases.	1. Provide procedures for maintaining data reporting and for conducting research, including the infrastructure to collect data from developing countries.
2. Determine the status of stocks.	2. Specify management objectives, select target reference points, and set limit reference points.
3. Calculate limit reference points and/or empirical measures that might be used for proxies, associated probabilities, and performance indicators under selected management strategies.	3. Specify management strategies (courses of action) for biomass/fishing mortality zones.
4. Describe and characterize uncertainty associated with current and projected stock status with respect to reference points or their proxies. Provide constraints for recovery time horizons.	4. Specify time horizons for stock rebuilding and for fishing mortality adjustments to ensure stock recovery and/or avoid stock collapse.
5. Scientific evaluation of management options proposed by the Commission.	5. Specify acceptable levels of risk to be used in evaluating possible consequences of management actions.

Table 5 Example of Executive Summary Table Format .

Species stock unit	
Maximum Sustainable Yield[1]	
Current TAC	
Current Yield[2]	
Yield in last year used in assessment	
B_{MSY}	
F_{MSY}	
Relative Biomass (B/B_{MSY}) last year assessment	
Relative Fishing Mortality (F/F_{MSY}[1]) last year assessment	
Replacement Yield (at current year / year +1)	
Catch at Fmsy (year +1)	
Catch at Fmsy (year +2)	
Catch at Fmsy (year +3)	
Catch at Fref points (i.e F0.1, F%SPR,)	
Stock Status	Overfished: YES/NO Overfishing: YES/NO
Management Measures in Effect:	

[1] Description of the MSY estimate or proxy for	Base Case production model (Logistic) results based on catch data 1950-2008.
[2]	Provisional and subject to revision.
[3] Information of the level of confidence bounds provided	80% bias corrected confidence intervals are shown.
[4]	Provisional and preliminary, based on production model results which included catch data from 1970-2008.

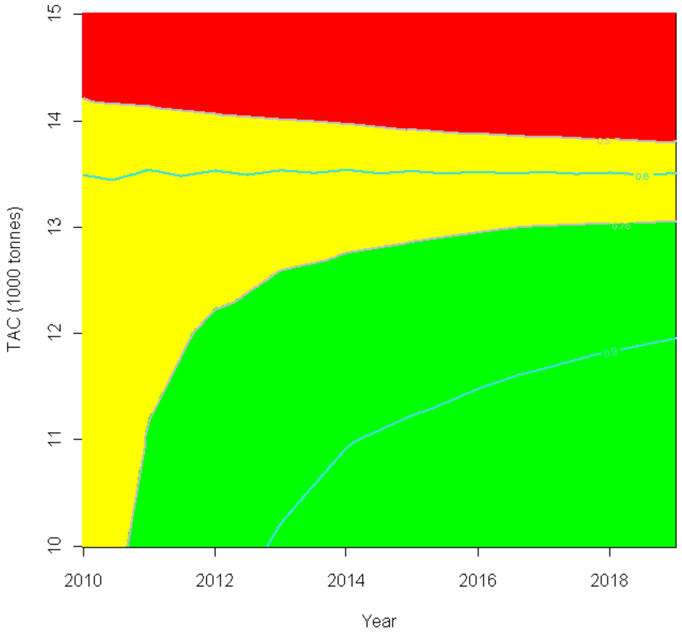

Figure 1 Example graphical illustration of the applying the Kone II Strategy Matrix. The isolines are probability contours of $B \geq B_{MSY}$ and $F \leq F_{MSY}$ for the constant catch scenarios indicated over time. Red areas represent probabilities less than 50%, yellow from 50-75%, and green above 75%. The 90th, 75th, 60th, and 50th probability contours are also depicted.

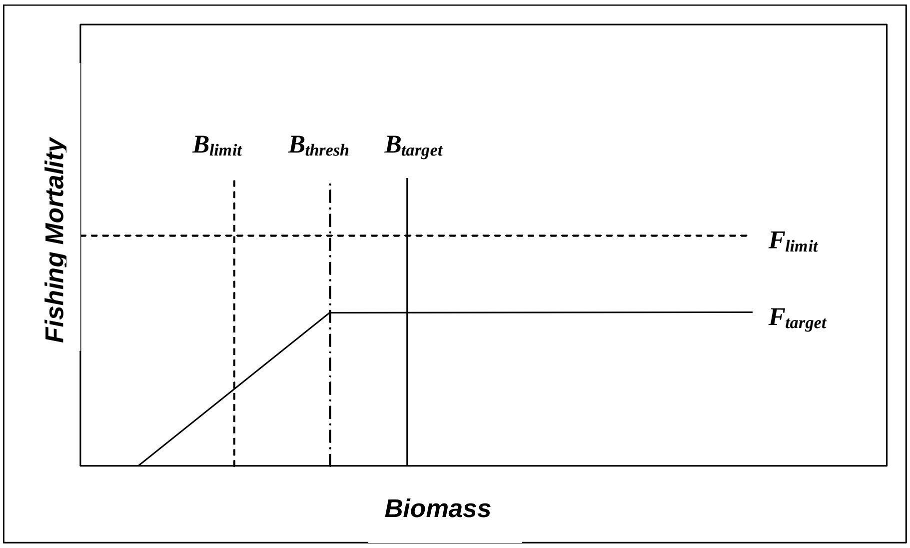

Figure 2 An example of the harvest control rule proposed by the 1999 meeting of the ad hoc WG on the Precautionary Approach.

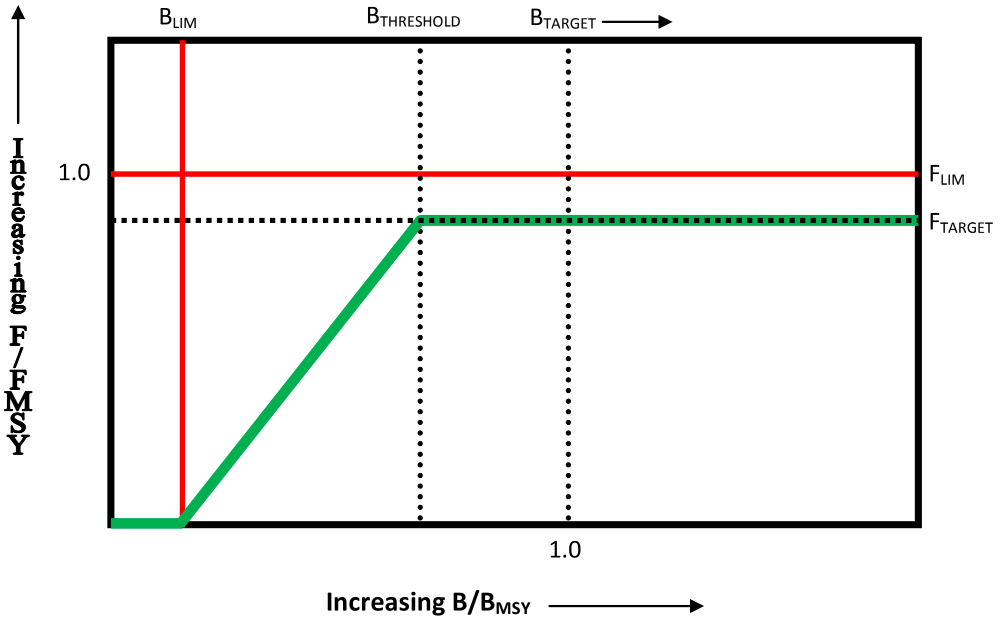

Figure 3 A harvest control rule hat would be consistent with UNFSA. Green, red and dashed lines represent targets, limits and thresholds, respectively. The reduction between F_{LIM} and F_{TARGET} should be based on the acceptable risk of overfishing, and should result in a very low probability of exceeding F_{LIM}. The reduction between F_{TARGET} and $F_{THRESHOLD}$ should be related to the variability in equilibrium biomass at F_{MSY}.

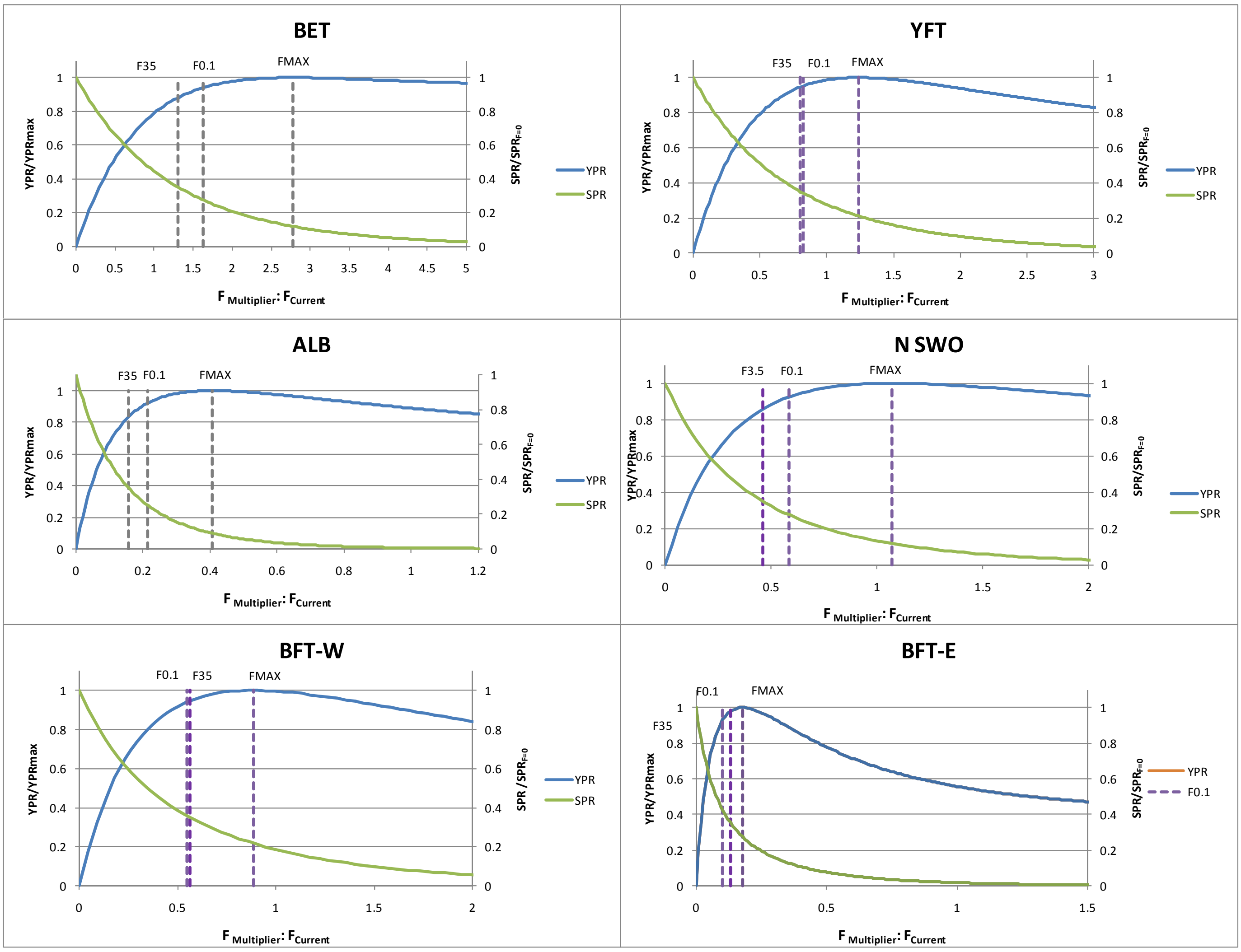

Figure 4 Yield (blue) and spawning biomass (green) per recruit plotted against fishing mortality for selected species, based on the most recent assessment. The vertical dashed lines show the values of three reference points (Fmax, F0.1 and F35% SPR) often used as proxies for Fmsy.

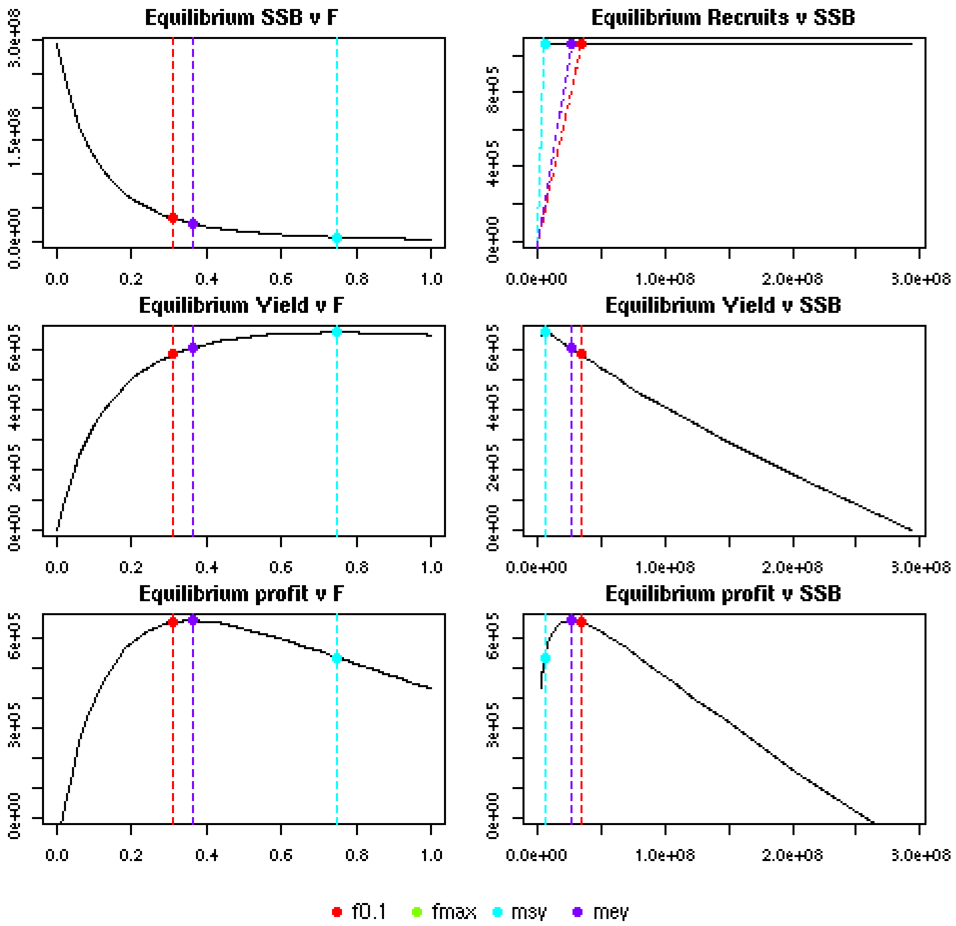

Figure 5 Equilibrium SSB, yield and profit versus fishing mortality rate and equilibrium recruits yield and profit versus SSB for an example based on Mediterranean swordfish assuming constant recruitment. Note that for constant recruitment, F_{Max} is equal to F_{MSY}.

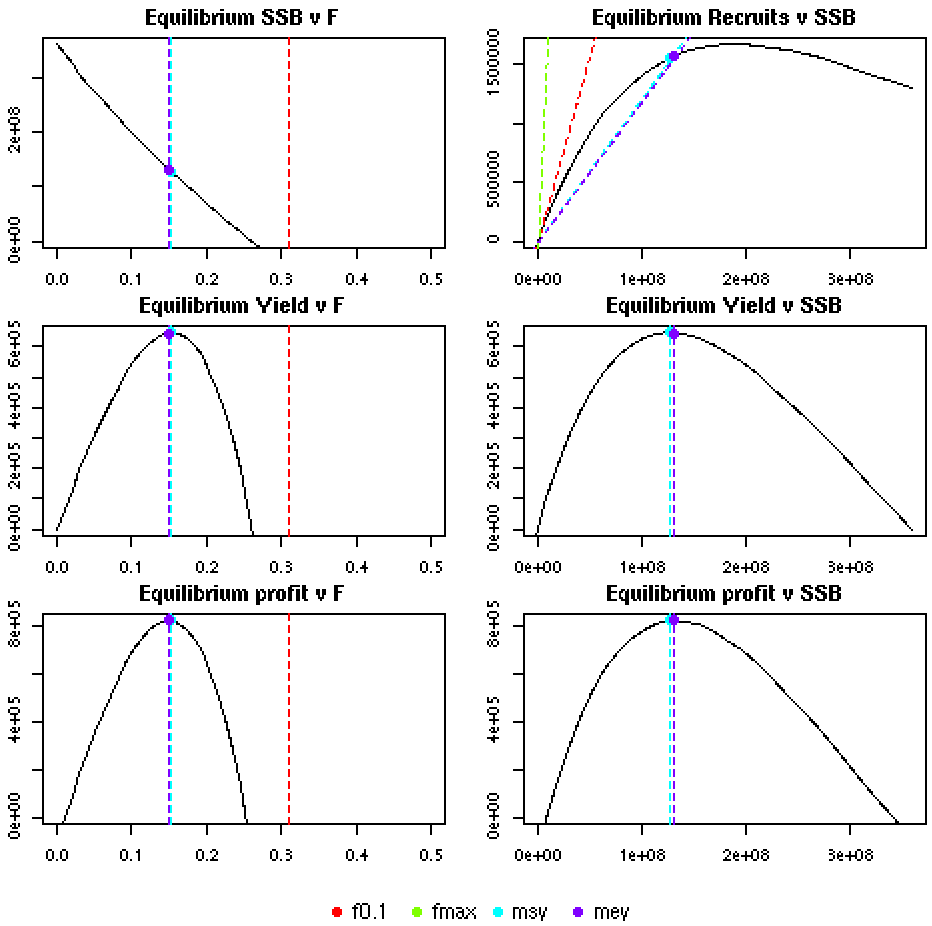

Figure 6 Equilibrium SSB, yield and profit versus fishing mortality rate and equilibrium recruits yield and profit versus SSB for an example based on Mediterranean swordfish assuming Beverton-Holt recruitment. Note that points and lines plotted outside the yield or profit curve reflect that these quantities have been reduced to zero indicating that these reference points are not adequate.

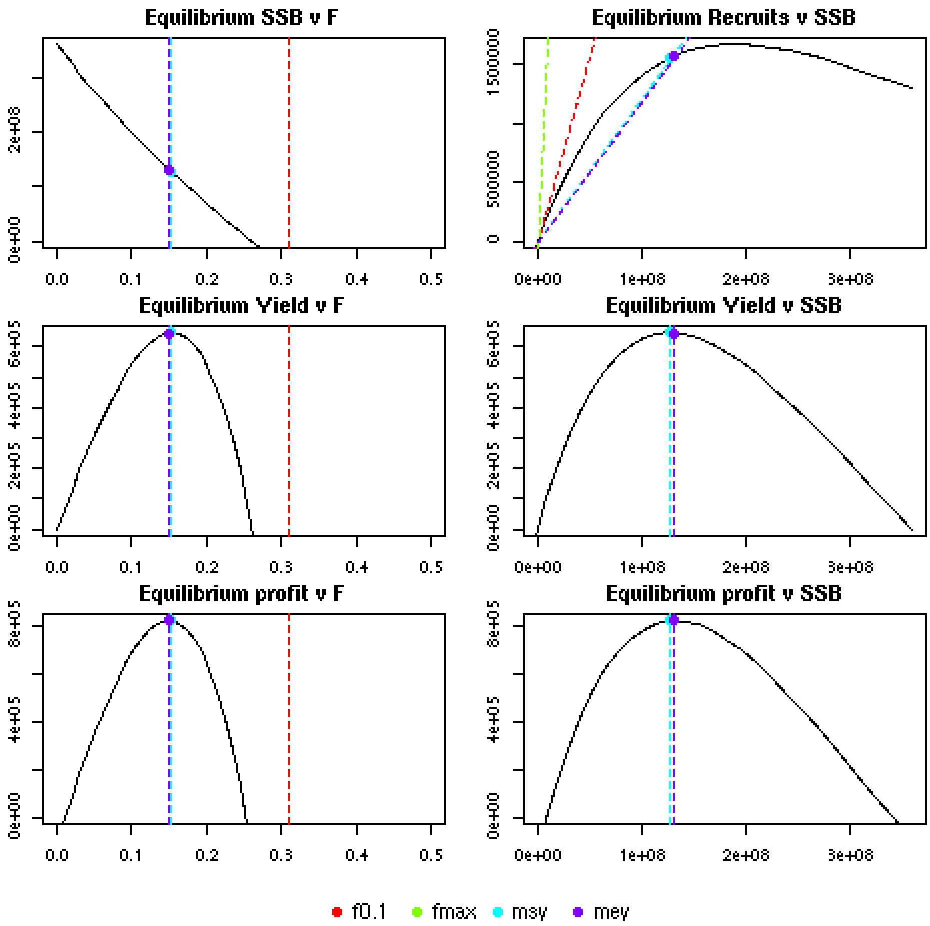

Figure 7 Equilibrium SSB, yield and profit versus fishing mortality rate and equilibrium recruits yield and profit versus SSB for an example based on Mediterranean swordfish assuming Ricker recruitment.

Appendix 1

AGENDA

1. Opening, adoption of the Agenda and meeting arrangements.
2. Issues related to the Precautionary Approach:

   2.1 Review of relevant documents, including:

   - The ICCAT Convention
   - Report of the 1999 ad hoc Working Group on the Precautionary Approach
   - 1995 UN Fish Stocks Agreement

   2.2 Consideration of stock assessment issues that SCRS should consider, including:

   - Harmonized estimation procedures (assessments, reference points, probability profiles, etc)
   - Guidelines for the application of the Kobe Strategy Matrix

   2.3 Draft recommendations for the Commission:

   - For applying the Precautionary Approach
   - For potential changes to the Convention text

   2.4 Other issues
3. Other Methodological issues
4. Recommendations
5. Adoption of the report and closure

Appendix 2

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Appendix 3

LIST OF DOCUMENTS

SCRS/2010/023	The Precautionary approach to fisheries management: How this is taken into account by Tuna regional fisheries management organisations (RFMOs) de Bruyn, P., Murua, H and Aranda, M.
SCRS/2010/024	Preliminary evaluation of alternative stock-recruitment models for estimating benchmarks of tuna-like species. Application to the eastern bluefin tuna (Thunnus thynnus) stock and recruitment data. Ortiz, M.
SCRS/2010/025	Incorporation of scientific uncertainty to define precautionary management targets: a case study of Altlanic bigeye tuna. Cass-Caley, S.

Appendix 4

Excerpts from Relevant Documents Discussed During the Meeting

A4.1 1999 Meeting of the ICCAT Ad Hoc Precautionary Approach Working Group

The 1999 ad hoc working group reviewed several applications and discussions of the precautionary approach in other fora, namely ICES, NAFO, Multilateral High-Level Conference (MHLC), FAO expert consultations and national and regional approaches. This led to discussion regarding how the precautionary approach could be applied to the ICCAT situation with ICES and NAFO in particular being highlighted. ICES had proposed a HCR based on limits for fishing mortality and biomass i.e. F_{lim}, $B_{lim}$and thresholds that are designed to trigger action before the limits are reached i.e. F_{pa} and B_{pa}, While NAFO proposed F_{lim}, B_{lim}, F_{buf} and B_{buf}. The buffers in NAFO are to act in the same was as B_{pa} and F_{pa} in ICES. Depending on the "level of precaution" chosen between F_{lim} and F_{pa} in ICES and between F_{lim} and F_{buf} in NAFO, the two frameworks are comparable. Subsequently ICES realised that an operational HCR also requires the definition of a target and are currently considering the use of F_{MSY} as a target. However, management of stocks is not the responsibility of ICES and MSE has been used by the EU to develop stock specific and generic management plans for many of teh stocks assessed by ICES. It was found that these plans and associated harvest control rules had to include many extra elements than originally proposed by ICES and NAFO. For example NAFO has been applying Management Strategy Evaluation to the task of testing alternative harvest control rules to ensure the precautionary approach is adopted in its management rules (Miller et al, 2008; Shelton & Miller, 2009). Seven candidate management strategies were evaluated under a wide range of biological scenarios. A Precautionary Approach strategy was defined based on the break point of a segmented regression stock-recruitment model, with values of fishing mortality being determined as different proportions of F0.1, used as implicit target mortality rate.

Different international and national organizations have used the terms "target", "limit", and "threshold" in different ways, resulting in confusion when trying to communicate these concepts (see Gabriel and Mace 1998). Here we define the terms as used by the Committee. All three terms can be used to refer to biological reference points based on either biomass or fishing mortality, or other related quantities.

A limit is a conservation reference point based on a level of biomass (B_{limit}) or a fishing mortality rate (F_{limit}) that should be avoided with high probability because it is believed that the stock may be in danger of recruitment overfishing or depensatory effects if the reference points are violated. However, if the stock falls below the limit biomass or if fishing mortality exceeds the limit F, this does not necessarily imply that the fishery must be shut down. If a stock exceeds the limit fishing mortality, reductions in fishing mortality are required as quickly as possible; if the stock falls below the limit biomass, a rebuilding plan with a specific time horizon may be required. In some other fora, limit biomass has been used in an absolute sense to imply the need to reduce fishing mortality to zero; more commonly, a gradual reduction towards F=0 at some lower biomass or even B=0 is employed. The level chosen to represent "high probability" depends on the severity of the consequences of the violation. The actual probability (risk) levels should be set by managers, in consultation with stock assessment scientists.

A target is a management objective based on a level of biomass (B_{target}) or a fishing mortality rate (F_{target}) that should be achieved with high probability on average. This generally means that the probability of exceeding the reference point should be around 50%. Targets should be set sufficiently far away from limits that they result in only a low probability that the limits will be exceeded. Fishing mortality-based targets have tended to assume more importance than biomass targets (except that the latter may be used as targets of rebuilding plans) because while fishing mortality rates can theoretically be controlled by setting quotas, it is expected that biomass will fluctuate around the corresponding biomass target.

A threshold is a level of biomass (B_{thresh}) or a fishing mortality rate (F_{thresh}) between the limit and target reference points that serves as a "red flag" and may trigger particular management actions designed to reduce fishing mortality. Biomass thresholds are used more commonly than fishing mortality thresholds. Of the four combinations of limit/ target and fishing mortality/ biomass-based reference points, the Committee believes that the most important reference points are targets based on fishing mortality rates (F_{target}) and limits based on biomass levels (B_{limit}).

A4.1.1 Potential candidates for target reference points

Based on language in the ICCAT Convention, F_{MSY} is probably the most appropriate fishing mortality-based target reference point. However, note that the corresponding B_{MSY} is only appropriate as a target in an average or equilibrium sense; i.e. in natural systems where F_{MSY} is the target, biomass should be expected to fluctuate around B_{MSY}, so there should be no unnecessary cause for alarm when biomass falls somewhat below B_{MSY}. Thus, it may make more sense to consider F-targets in conjunction with biomass limits, rather than biomass targets, *per se*. On the other hand, B_{MSY} may be a better rebuilding target than B_{limit}, because this will enhance the probability of rebuilding the age structure as well as the biomass of a previously-depleted stock.

Other potential candidates for target fishing mortality rates include biological reference points that have frequently been used as proxies for F_{MSY}. These include (i) reference points from yield per recruit analysis (e.g. $F_{0.1}$ and F_{max}), (ii) reference points from spawning biomass per recruit analysis (e.g. $F_{20\%}$, $F_{30\%}$, $F_{35\%}$, $F_{40\%}$), (iii) F=M, (iv) F_{med} calculated over a period where the fishery was believed to be in a sustainable mode, (v) empirical reference points (see, for example, Caddy 1998b, ref 10). Average or equilibrium biomass targets include the biomass levels associated with these fishing mortality reference points.

A4.1.2 Potential candidates for limit reference points

Based on paragraph 7 of Annex II of the Straddling Stocks Agreement, F_{MSY} is probably the most appropriate fishing mortality-based limit reference point.

Other potential candidates for limit fishing mortality rates include: (i) F_{crash} (equivalently, $F_{extinction}$), (ii) reference points from yield per recruit analysis (e.g. F_{max}), (iii) reference points from spawning biomass per recruit analysis (e.g. $F_{5\%}$, $F_{10\%}$, $F_{20\%}$), (iv) F_{med} calculated over a period when the fishery was believed to be in an overfished state, (v) empirical reference points (see, for example, Caddy 1998b, ref 10). Potential candidates for limit biomass levels include: B_{limit} = 20% B_0; (1-M)* B_{MSY}; MBAL (ICES 1997,1998); $B_{MSY} * e^{-1.645\sigma}$ (ICES 1998).

4.1.3 F_{MSY} as a target vs. a limit

Annex II of the Straddling Stocks Agreement states that F_{MSY} should be a minimum standard for a limit reference point. This is potentially in conflict with the objectives of the ICCAT Convention, which imply that F_{MSY} is the target. In fact, there are very few examples where fishing mortality has been limited to F_{MSY} over a significant period of time, even where MSY has been the stated management objective, and the Committee was not aware of any examples where stocks have collapsed despite fishing mortality being maintained near F_{MSY} over a substantial period.

Generally speaking, a target refers to a management objective (e.g. maximum sustainable catch, as stated in the ICCAT Convention), while a limit refers to conservation and sustainability considerations. From a theoretical viewpoint and with this general distinction in mind, F_{MSY} has been considered so far by fisheries biologists as an optimization reference point. However, depending on the quality and quantity of available information, a situation may exist where a stock managed at F_{MSY} could encounter sustainability problems: the true fishing mortality, while maintained around a perceived F_{MSY}, could exceed some sustainable limit due to the level of uncertainty in assessments. For tuna stocks, it is not clear whether the quality and quantity of information allows an F_{MSY} management strategy to avoid sustainability problems with sufficiently high probability. Therefore, the Committee decided to investigate this and related problems using a simulation model (specified below).

A4.1.4 Harvest Control rules

A harvest control rule incorporates limit and target (and possibly threshold) reference points into a simple schematic that shows the action to be taken in terms of defining and setting fishing mortality rates or yields (y-axis) depending on the estimated biomass level (x-axis) (**Figure 1**). In essence, a harvest control rule can be thought of as a pre-agreed course of management actions dependent on the status of the stock.

Harvest control rules are not new to ICCAT or most other management organizations. They are simply a concise way of specifying how the current management process works conceptually. ICCAT's implicit control rule is that once biomass falls below B_{MSY} and/or fishing mortality substantially exceeds F_{MSY}, regulations (**Figure 2)** should be enacted to reduce fishing mortality (by reducing fishing effort or imposing quotas corresponding to reduced levels of fishing mortality and fishing effort). Thus, the Committee is not introducing a new concept; rather it is formalizing existing protocols and, more importantly, suggesting methods for evaluating the performance of these and alternative control rules (see following section on simulation models for evaluating alternative management strategies).

The simplest management strategies consist of fixing either a TAC or a fishing mortality rate for a given period. In the case of a fixed F strategy, the associated harvest control rule would consist of setting a TAC each year corresponding to the target F, based on the most recent estimate of fishing mortality. However, alternative strategies can be envisioned, in particular strategies utilizing a multi-annual basis. In a such strategies, gradual changes in fishing mortality can be envisioned, from a given current value of F to the target F. These kinds of strategies may achieve the desired target while, at the same time, avoiding abrupt changes in fishing mortality and therefore in successive TAC values. Thus, it may be particularly useful to examine rebuilding strategies on a multi-annual basis. The performance of harvest control rules can be evaluated through simulation models.

A4.2 ***The precautionary approach as applied by other tuna RFMOs (SCRS/2010/023)***

Some tuna RFMOs such as the WCPFC and IATTC make explicit mention of the precautionary approach in their conventions, whilst others, whose conventions either predate these codes or are whose conventions have not been recently revised, are searching for other ways in which to take these codes into consideration.

Based on the case studies presented, best practices for adopting the precautionary approach were identified. Tuna RFMOs with recently adopted conventions which intend adopting the precautionary approach have specifically included reference to the approach in their conventions. This ensures all contracting parties clearly understand the aims and requirements of the approach are legally obliged to fulfil them. For RFMOs with conventions that predate the UN fish stocks agreement, the renegotiation of new conventions may be a costly and time consuming process and thus undesirable. In these cases, the precautionary approach could be formally addressed through the adoption of binding resolutions or recommendations. Again this may not be completely achievable if "opt out" clauses are maintained.

In practical terms, the scientific obligations to Precautionary Approaches are to determine the status of the stock(s) relative to limits and targets, to predict outcomes of management alternatives for reaching the targets and avoiding the limits, and to characterize the uncertainty in both of these. A convenient framework to conduct management evaluations is through the use of control rules, for which managers specify variables under their control through some functions related to the status of the stock under a pre-agreed plan for adjusting management actions. The perceived stock status is reliant upon the development of reference points (either target or limit). The calculation of these reference points requires a suitable quantity and quality of data for the species of concern. With the inclusion of stock projections, rebuilding plans can be developed should a stock be determined as being overexploited. In addition to target species, the monitoring and management of bycatch species is also necessary as is the impact of fishing activities on marine ecosystems and the environment. Socio-economic factors should also be taken into consideration. These considerations may potentially be accommodated in the MSE framework.

From a management perspective, monitoring and compliance is crucial, the latter of which should carry penalties if disregarded. Access or effort controls are also necessary to ensure populations are not unsustainably exploited. If the fishery is perceived to be over capacitated, buy back or capacity reduction schemes should be considered. Of great importance too is the reduction of IUU fishing. The management scheme employed by the RFMO should also be flexible in order to address data poor issues. The management should be able to take action and provide management for species which are data deficient but which have a strong likelihood of being adversely impacted upon by fishing activities. Where TACs are not possible to calculate or implement alternative forms of management such as closed areas or seasons should be considered to reduce fishing pressure on potentially vulnerable stocks.

A4.3 United States: Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA) of 2006

The United States precautionary management methods are described in the MSRA (Public Law 109–479) and in the National Standard Guidelines (74 FR[1] 3178 (2009-01-16)). The objective of the MSRA can be summarized as follows: *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. Section 301(a)(1).*

To that end, the MSRA defined “overfishing” as the level of fishing above that which would produce the maximum sustainable yield (F_{MSY}, or a proxy thereof). It also specifies four reference catch levels (**Figure 3**):

- OFL: The overfishing limit is the level of annual catch expected when the best estimate of FMSY is applied to a stock’s abundance in any given year. The OFL will be less than MSY to the degree that stock abundance is less than BMSY
- ABC: The acceptable biological catch is a level of annual catch to be set at or below the OFL based on the level of scientific uncertainty.
- ACL: The annual catch limit is the level of annual catch of a stock that serves as the basis for invoking accountability measures (AMs), defined as management controls to prevent ACLs from being exceeded, and to correct or mitigate overages of the ACL when they occur. The NS Guidelines further state that if catch exceeds the ACL for a given stock or stock complex more than once in the last four years, the system of ACLs and AMs should be re-evaluated and/or modified to improve performance and effectiveness .
- ACT: The annual catch target is the most conservative level of catch. It is recommended in the system of accountability measures to avoid exceeding the ACL (essentially accounting for management uncertainty). The ACT is optional, but regarded as useful for fisheries lacking effective in-season management controls to prevent the ACL from being exceeded. For these fisheries, management plans are advised to set ACTs sufficiently below ACLs that catches are unlikely to exceed the ACL.

A provision of the MSRA is that OFL ≥ ABC ≥ ACL. However, it should be noted that while ACL may be legally set equal to OFL, the U.S. National Marine Fisheries Service has concluded that there are few fisheries for which setting OFL, ABC, and ACL equal to each other would be appropriate.

By law, ACLs must be determined for all stocks in U.S. fisheries management plans by 2011, with the exception of species/stocks identified as “ecosystem components”. To be considered for possible “ecosystem component” classification, species should, amongst other considerations:

1. Not be a target of directed fisheries
2. Not be identified as “subject to overfishing”, “approaching overfished”, or “overfished”;
3. Be unlikely to become subject to overfishing (or overfished) according to the best available information
4. Not generally be retained for sale or personal use.

Neither the MSRA not the National Standard Guidelines specify a particular methodology to quantify or incorporate uncertainty for the determination of precautionary catch levels (ABC, ACL, ACT). Instead, the eight U.S. Regional Fishery Management Councils are given broad authority to devise precautionary strategies consistent with MSRA objectives regarding the following:

1. Scientific Uncertainty (e.g. measurement error, model specification error, forecast error, environmental variability and uncertainty about overall stock productivity).
    a. ABC control rule: A specified approach to setting the ABC for a stock as a function of the scientific uncertainty in the estimate of OFL and any other scientific uncertainty.

[1] Federal Register

b. Risk policy is part of ABC control rule: The determination of ABC should be based, when possible, on the probability that an actual catch equal to the stock's ABC would result in overfishing.
c. This probability that overfishing will occur cannot exceed 50 percent and should be a lower value.

2. Management Uncertainty
   a. Address through a full range of accountability measures.
   b. For fisheries without effective in-season management controls to prevent the ACL from being exceeded, an accountability measure (ACT) should be utilized. ACT should be set sufficiently below ACL so that catches do not exceed the ACL.
3. Overfished stocks:
   a. For overfished stocks and stock complexes, a rebuilding ABC must be set to reflect the annual catch that is consistent with the schedule of fishing mortality rates in the rebuilding plan.
   b. Councils must prepare and implement management measures within 2 years of the notification of an overfished or "approaching overfished" condition
   c. If the stock is overfished and overfishing is occurring, the rebuilding plan must end overfishing immediately.
   d. The rebuilding time for an overfished stock must be "as short as possible," and may not exceed 10 years + one generation time.

A4.4 Proceedings of the 2008 Joint Canada-ICCAT Workshop on the Precautionary Approach for Western Bluefin Tuna (ICCAT, 2009).

The Canada-ICCAT working group also considered precautionary harvest strategies. The following conclusions were reported.

1. Although population dynamics theory suggests that harvesting at F_{MSY} should be sustainable and would maintain a population at around B_{MSY}, such a policy may not perform as expected because it affords little room for errors of assessment or environmentally driven fluctuations of productivity, particularly if these are correlated over time. Further, the rate of recovery for depleted populations may be slow. Therefore, strategies that reduce fishing mortality below F_{MSY} when the stock biomass is low generally perform better, in relation to both long term yield and conservation of the resource.
2. A practical approach to incorporate the considerations discussed above is to adopt a harvest strategy that specifies a non-constant F_{REF} that is a function of biomass. When biomass becomes low F_{REF} is reduced. Minimally, such a harvest strategy requires specification of an F_{REF} and a B_{REF} at which reduction of the F reference begins. Additionally, a lower B_{REF} below which harvesting should be reduced to the lowest possible level may also be specified. Some candidate forms of harvest strategies are illustrated (**Figure 4)**.
3. A precautionary approach requires that uncertainties should be taken into account. The form of the advice should facilitate incorporation of greater precaution for cases with more uncertainty. One alternative is to conduct simulation experiments to determine the value of F_{REF} that results in a low probability (specified by managers) of the biomass falling below B_{MSY}, given the level of uncertainty. Another alternative is for managers to incorporate greater risk adversity when biomass is low, in addition to reducing F_{REF}.
4. Plans for rebuilding biomass to B_{MSY} may specify the rebuilding period. The group recommended that the rebuilding F be periodically updated and warned that delaying updates when there is lack of progress will require an even larger subsequent adjustment.

A4.5 A Fishery Decision-Making Framework Incorporating The Precautionary Approach. Dept. of Fisheries and Oceans, Canada.

This document describes the fishery management policy developed by Canada based on the Precautionary Approach.

Components of the General Decision Framework:

1. Reference points and stock status zones (Healthy, Cautious and Critical).
2. Harvest strategy and harvest decision rules
3. The need to take into account uncertainty and risk when developing reference points and developing and implementing decision rules.

The three stock status zones are created by defining a Limit Reference Point (LRP), an Upper Stock Reference Point (USR) and the Removal Reference for each of the three zones (**Figure 5**). The LRP represents the stock status below which serious harm is occurring to the stock, and possibly also the ecosystem, associated species and fishing opportunities. The LRP is based on biological criteria and established by Science through a peer reviewed process. The Removal reference is the maximum acceptable removal rate for the stock. It is normally expressed in terms of fishing mortality (F) or harvest rate. The Removal reference includes all mortality from all types of fishing.

Table CALAY-1 provides generalized management actions to apply this decision framework to the management of key harvested stocks. Specific values for individual stock harvest strategies are to be provided through science assessments.

Both scientific uncertainty and uncertainty related to the implementation of a management approach must be explicitly considered for the PA. Uncertainty should be incorporated in the calculation of stock status and biological reference points. It is desirable that scientific uncertainty be quantified to the extent possible and used to assess the probability of achieving a target or of a stock falling to a certain level under a specific management approach.

Management decisions should be explicit about the risk of decline associated with a management action by deciding on a risk tolerance for a particular management decision. Management actions would then aim to be consistent with this level of risk tolerance.

When a stock is in the critical zone, management actions must promote stock growth, and removals by all human sources must be kept to the lowest possible level. There should be no tolerance for further preventable decline. When the stock is in the Cautious or Healthy zone, management actions could be differentially considered on the basis of both stock status (e.g. abundance) and trajectory or rate of change in status. For example, management actions might appropriately vary if a stock is in the Cautious zone but clearly improving in status.

When necessary, the development of a rebuilding plan should be initiated enough in advance to ensure the plan is ready to come into effect at the boundary of the Critical and Cautious zones if a stock has declined and reached the LRP. If a stock is already in the critical zone, a rebuilding plan must be developed and implemented on a priority basis.

Table 1. Three zone PA framework with criteria for management actions for key harvested stocks.

		Stock Status		
		Critical	**Cautious**	**Healthy**
General Approach		Conservation considerations prevail. Management actions cannot be inconsistent with secure recovery	Socio-economic and conservation considerations should be balanced in a manner that reflects location in zone and trajectory	Socio-economic considerations prevail. Conservation measures consistent with sustainable use apply.
Harvest rate strategy		Harvest rate (taking into account all sources of removals) kept to an absolute minimum.	Harvest rate (taking into account all sources of removals) should progressively decrease from the established maximum and should promote stock rebuilding to the Healthy Zone.	Harvest rate (taking into account all sources of removals) not to exceed established maximum.
Recent Stock Trajectory	**Increasing**	Management actions must promote stock growth. Removals from all sources must be kept to the lowest possible level until the stock has cleared the Critical Zone. A rebuilding plan must be in place with the aim of having a high probability of the stock growing out of the Critical zone within a reasonable timeframe[12]. This plan must be associated with appropriate monitoring and assessment of the condition of the stock to confirm the success of rebuilding. The plan must also include additional restrictions on catches, and a provision that application of the measures is mandatory if the evaluation fails to find clear evidence that rebuilding is occurring.	Management actions should promote stock growth to the Healthy Zone within a reasonable time frame. Risk tolerance for preventable decline – low to moderate (if high in zone)	Management actions should be tolerant of normal stock fluctuations. Risk tolerance for preventable decline – high
	Stable[11]		Management actions must encourage stock growth in the short term. Risk tolerance for preventable decline – low to moderate (if high in zone)	
	Declining		Management actions must arrest declines in the short term or immediately if low in the zone. Risk tolerance for preventable decline – very low / low. Development of a rebuilding plan is ready to come into effect if the stock declines further and reaches the critical zone.	Management actions should react to a declining trend that approaches the cautious boundary. Risk tolerance for preventable decline – moderate (if low in zone) to neutral

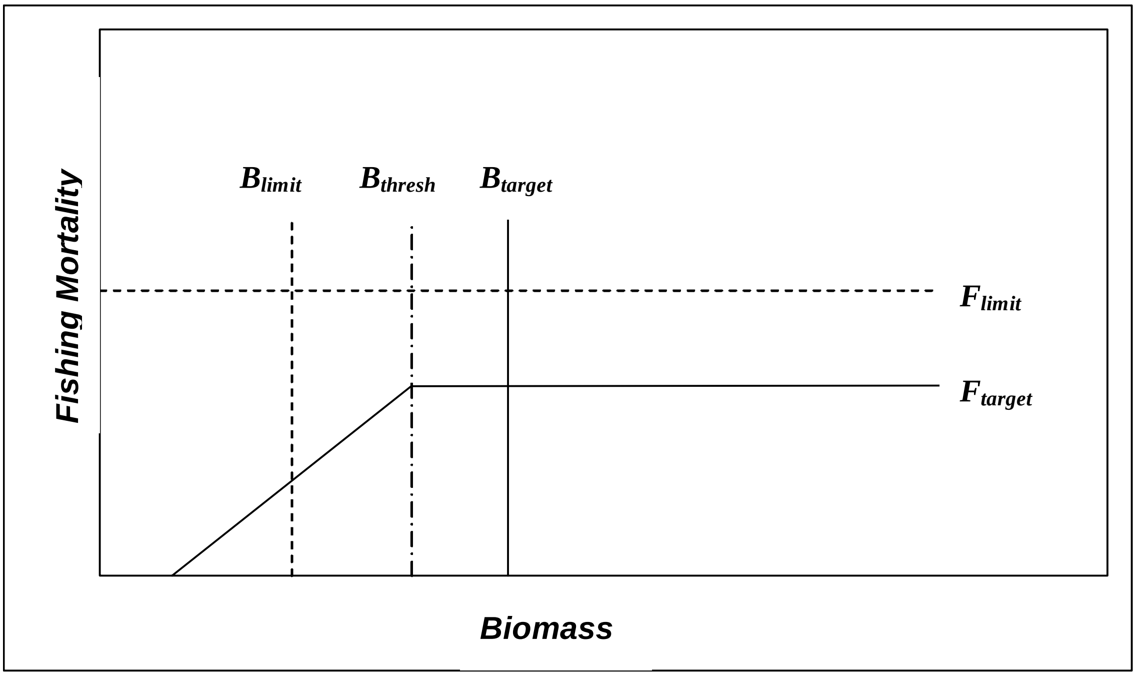

Figure 1 Simple example control rule based on the terminology used in this document.

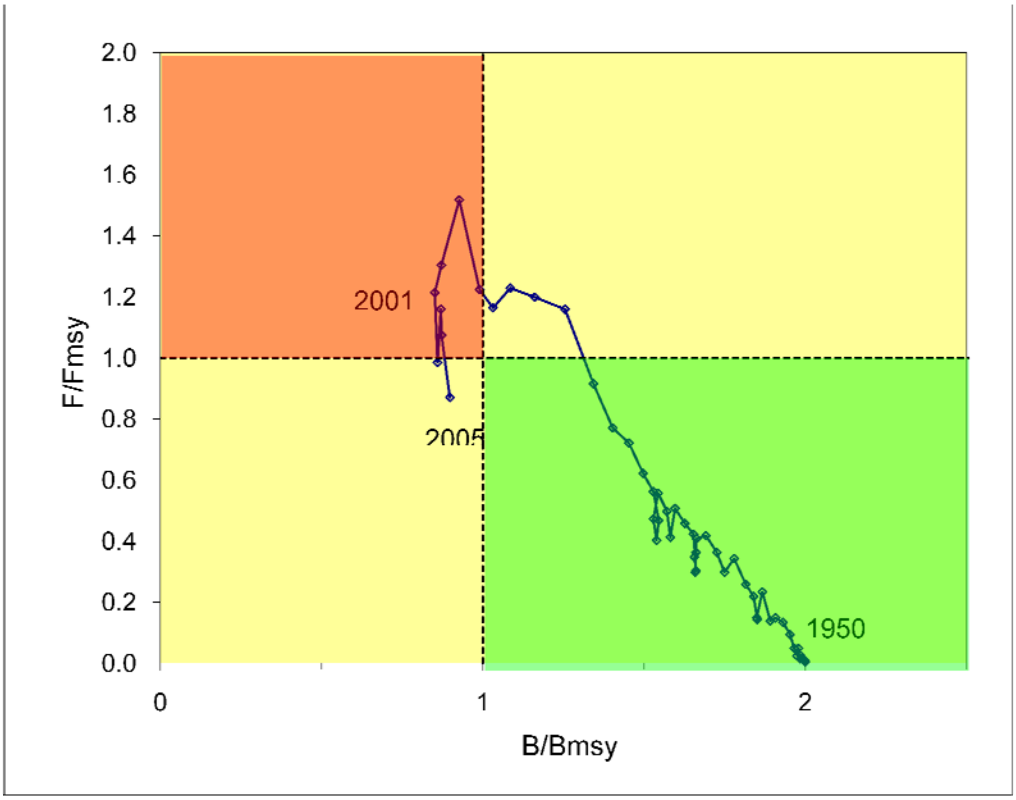

Figure 2 An example of the harvest control rule applied to ICCAT stocks (Bigeye Tuna, 2007). Values of F/Fmsy ≥ 1 indicate overfishing. Values of B/Bmsy < 1 indicate an overfished condition. The line shows the annual trajectory of stock status.

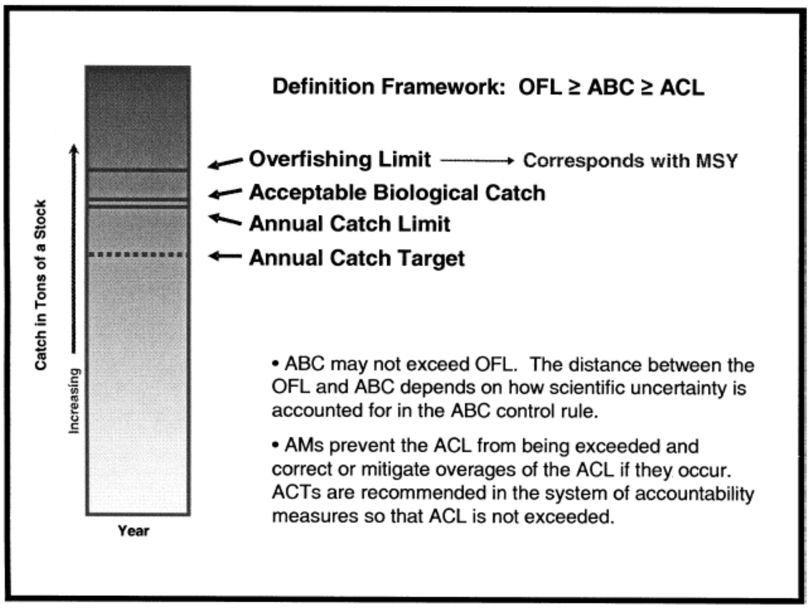

Figure 3 Description of revised MSRA management targets and limits. The annual catch target (ACT) is optional, but recommended when in-season controls/monitoring of fishing are insufficient to avoid exceeding the ACL.

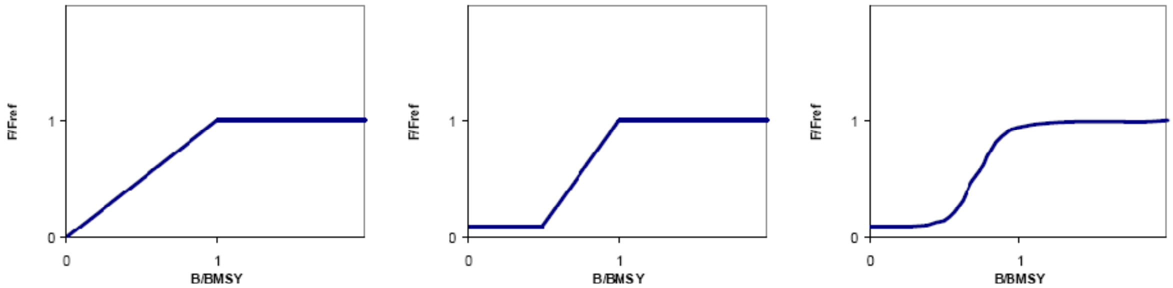

Figure 4 Schematics of various forms of harvest strategy that comply with reduction in Fref when biomass falls below BMSY.

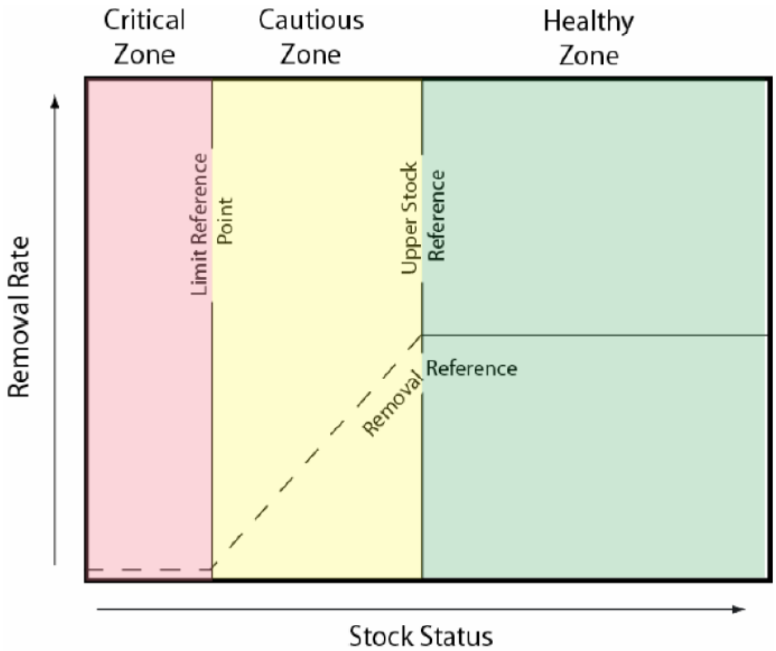

Figure 5 Canada's guidelines for a harvest strategy compliant with the Precautionary Approach.