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The Precautionary approach to fisheries management: How this is taken into account by Tuna regional fisheries management organisations (RFMOs)

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ABSTRACT

For several decades it has been acknowledged that there is an urgent need for new approaches to fisheries management, embracing conservation and environmental considerations. The voluntary Code of Conduct on Responsible Fishing and the United Nations Fish Stocks Agreement provide the formal basis for the Precautionary Approach to fisheries management. Some tuna Regional Fisheries Management Organisations such as the WCPFC and IATTC make explicit mention of these codes in their conventions, whilst others, whose conventions do not explicitly address the Precautionary Approach, are searching for ways in which to take these codes into consideration. In practical terms, the scientific obligations to Precautionary Approaches are to determine the status of the stock(s) relative to limit and target reference points, to predict outcomes of management alternatives for reaching the targets and avoiding the limits, and to characterise the uncertainty in both cases. A convenient framework to conduct management evaluations is through the use of harvest control rules, for which managers agree on specific management actions under their control which are evoked according to levels of stock status relative to predefined reference points. These pre-agreed management actions are then simulated for a range of scenarios. This paper presents the ways in which tuna RFMOs are currently incorporating the precautionary approach in their fisheries management as well as suggestions for possible best practice.

1. Introduction

For several decades, world fisheries have become a market-driven, dynamically developing sector of the food industry with large investments in modern fishing fleets and processing factories in order to meet the international demand for fish and fishery products. Since the 1980s it has become apparent that fisheries resources could no longer sustain such rapid and often uncontrolled increases in exploitation and development, and therefore new approaches to fisheries management embracing conservation and environmental considerations were urgently needed [1]. The situation was aggravated by the realisation that unregulated fisheries on the high seas, in some cases involving straddling and highly migratory fish species, which occur within and outside exclusive economic zones (EEZs), were impeding sound resource management.

The Committee on Fisheries (COFI) of the Food and Agriculture Organisation of the United Nations (FAO), at its Nineteenth Session in March 1991, called for the development of new concepts which would lead to responsible and sustainable fisheries. Subsequently, the International Conference on Responsible Fishing, held in 1992 in Cancun (Mexico) further requested the FAO to prepare an international Code of Conduct to address the concerns of uncontrolled exploitation. Although the Code of Conduct is a voluntary non-binding agreement, it contains sections regarding precautionary management that are similar to those in 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 which is a binding agreement (the UN Fish Stocks Agreement; UNFSA). These two agreements provide the formal basis for the PA to fisheries management.

These agreements are being incorporated into the conventions of Regional Fisheries Management Organisations (RFMOs). However, RFMOs may not be legally obliged to apply the PA, either because their convention pre-dates the UNFSA, or because many of their members are not signatories to the UNFSA. As a result, few RFMO conventions make explicit reference to the application of the PA. Of 12 RFMOs examined in 2007, the conventions of only four (Western Central Pacific Fisheries Commission; WCPFC, South East Atlantic Fisheries Organisations; SEAFO, General Fisheries Commission for the Mediterranean; GFCM and the Antigua Convention of the Inter American Tropical Tuna Commission; IATTC) refer to the application of the PA [2]. It is important to note that reference to the PA in the convention of an RFMO does not

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necessarily mean the PA has been effectively applied [3]. In order to be effective, any legislation/wording regarding the PA needs to be enforced or actively applied.

The objective of this paper is, therefore, to review the ideology of the Precautionary Approach and its current and future recommended application in the Tuna-RFMOs. In order to achieve this, we first provide a review of the approach, its current application in the tuna RFMOs as well as examples of good practice from other RFMOs, and conclude with several recommendations for future work and initiatives needed for making the approach operational.

2. Applying the precautionary approach

In practical terms, the scientific obligations to precautionary approaches are to determine the status of the stock(s) relative to limit and target reference points, to predict outcomes of management alternatives for reaching the targets while avoiding the limits, and to characterise the uncertainty in both of the cases. In addition, the approach advocates that the greater the uncertainty of the management advice, the more the precaution needed in its management [4]. These criterias impose some specific needs for fishery monitoring and research for stock assessments. On this matter, both the UN Fish Stocks Agreement and Code of Conduct have similar wording with regards to the PA and its principles. The two Agreements incorporate the principle of reference points as important instruments for the application of the Precautionary Approach to fisheries management. Annex II of the UN Fish Stocks Agreement provides guidelines for the application of precautionary reference points. For example:

- Paragraph 2 states, *"Two types of precautionary reference points should be used: conservation, or limit, reference points and management, or target, reference points."*
- Paragraph 5 stipulates, *"Fishery management strategies shall ensure that the risk of exceeding limit reference points is very low,"* and imposes the further constraint that target reference points should not be exceeded on average.
- Paragraph 7 states that *"The fishing mortality rate which generates maximum sustainable yield should be regarded as a minimum standard for limit reference points."*

In order to address these important guidelines, the use of harvest control rules (HCRs) has been proposed as a framework to conduct management evaluations. These allow managers to agree on specific management actions under their control which are then evoked when stock status reaches agreed levels relative to predefined reference points (Fig. 1). Along this line, the FAO Technical Consultation on the Precautionary Approach to Capture Fisheries [5] recommended the use of HCRs to specify in advance what actions should be taken when limits are reached. However, although HCRs may include several precautionary elements, it does not necessarily follow that they will be precautionary in practice [6]. This is due to the fact that many HCRs are not evaluated formally to determine the extent to which they achieve the goals for which they were designed, given the uncertainty inherent in the system being managed [7]. Therefore Management Strategy Evaluation (MSE) based on simulation modelling has increasingly been used to evaluate the impact of the main sources of uncertainty inherent in the system being managed [6,8–10]. It is recognised that this involves continuous periodic feedback between managers and scientists with monitoring, re-evaluation, testing, and adjustment of management strategies [4]. This kind of framework is instrumental in guiding the appropriate division of responsibilities between science and management [11].

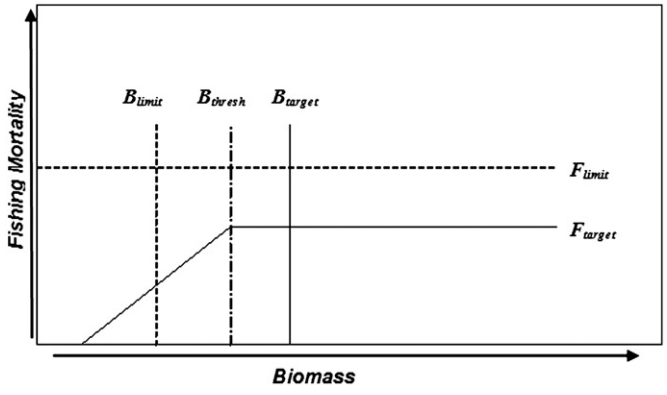

Fig. 1. Example of a simple harvest control rule incorporating targets and limits.

The PA is not without flaws. The above mentioned framework focuses only on 'risks to fish stocks' without considering risk to society [12]. Also, the precautionary approach as described by the FAO [1] does not help managers to make risk exposure decisions when there are chances of adverse consequences associated with both enacting and forgoing a proposed programme [13]. While the PA focuses on outlining the risk associated with enacting a programme, indeed, forgoing a programme that carries risk also means foregoing the associated potential benefits or even windfalls. Moreover, the precautionary approach fails to value the opportunity to reduce uncertainty by acquiring information [14]. When ad hoc safety margins are used as an approach to precaution, no value can be assigned to new information because such safety margins are not derived from a quantitative attribute of the uncertainty [14]. These drawbacks can be largely mitigated by the use of quantitative control rules [13] and associated formal decision analysis [15–17].

When embracing the PA, precautionary measures are expected to be applied in all steps of the management process including data collection, assessment, decision-making, monitoring, control and surveillance. Meaningful input is expected from the stakeholders not only through participation in the management process but also by "reversing the burden of proof" [5]. This means that stakeholders either have to show that their activities will not negatively affect fish stocks and the environment or that they will take action when it is assumed that further activities will damage the resources or the environment. An example of the latter will be the development and use of more selective fishing gear. The reversal of the burden of proof also means that managers will no longer wait to realise and prove negative outcomes prior to taking corrective management measures.

A useful step towards making the PA applicable to fisheries management and in this case tuna fisheries specifically, is to obtain a clear picture as to the definition of the approach, to understand and address the complexities involved, and to devise ways in which the approach can be applied under a given set of circumstances [5]. To aid this process, it is useful to examine how management bodies have thus far taken steps towards applying the PA and identify aspects of best practice.

3. The PA as applied by the tuna RFMOs

3.1. Inter-American Tropical Tuna Commission (IATTC)

As stated previously few RFMO conventions make explicit reference to the PA [2]. The Antigua Convention of the IATTC does specifically refer to the application of the PA in Part II, Article IV

1. *The members of the Commission, directly and through the Commission, shall apply the precautionary approach, as described*

in the relevant provisions of the Code of Conduct and/or the 1995 UN Fish Stocks Agreement, for the conservation, management and sustainable use of fish stocks covered by this Convention.

2. *In particular, the members of the Commission 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.*
3. *Where the status of target stocks or non-target or associated or dependent species is of concern, the members of the Commission 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 scientific information available.*

It must be noted, however, that the Antigua convention which explicitly mentions the PA, was only formally adopted in 2010. The renegotiation of the 1949 IATTC convention is a clear example of an RFMO revising its basic texts to include the latest trends in international fisheries management. With the adoption of the new convention the IATTC is taking strides towards applying the PA; however, it must now ensure its operationalization.

Prior to the adoption of the Antigua convention, the IATTC attempted to take a precautionary approach towards fisheries management. Since the 1980s, it has included precaution in the absence of information; and, an adaptive management approach when assessing impacts of expanded fisheries on stocks [3]. Although they have been suggested by the working group on reference points, the IATTC has not formally adopted specific target or limit reference points for management. This working group was established to suggest precautionary limits and targets [18] and the suggested limits which have been incorporated into stock assessments and reports [19] include

1. S_{MSY}, the spawning biomass corresponding to the maximum sustainable yield (MSY) as a target reference point;
2. F_{MSY}, the fishing mortality corresponding to the MSY as a limit reference point;
3. S_{min}, the minimum spawning biomass seen in the modelling period as a limit reference point.

Maintaining tuna stocks at levels that will permit the MSY is the management objective specified by the IATTC Convention. If catches for target species reach the agreed limit, management measures are imposed. In addition, fleet capacity was constrained by Resolution (C-02–03).

The application of the precautionary approach is also reflected in the various International Plans of Action (IPOAs) developed by the FAO [20] in order to promote the sustainability of marine resources. In this regard the IATTC follows several IPOAs. For example, the IATTC has taken significant steps to adhere to IPOAs for Illegal Unreported and Unregulated fishing (IUU), Sharks, Seabirds and Fishing Capacity. These are detailed in a variety of resolutions adopted by the Commission. It has also, through the Agreement on the International Dolphin Conservation Plan (AIDCP), taken into account the broader impacts of fishing on the ecosystem. The AIDCP (AIDCP 2009 amended) states in article IV that contracting parties must"Take measures to ensure the conservation of ecosystems as well as conservation and management measures to ensure the long-term sustainability of tuna stocks and other stocks of living marine resources associated with the tuna purse-seine fishery in the Agreement Area, based on the best scientific evidence available, and apply the precautionary approach, consistent with the relevant provisions of the FAO Code of Conduct for Responsible Fisheries and the United Nations Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks. Such measures shall be designed to maintain or restore the biomass of harvested stocks at or above levels capable of producing maximum sustainable yield, and with the goal of maintaining or restoring the biomass of associated stocks at or above levels capable of producing maximum sustainable yield."

3.2. Commission for the Conservation of Southern Bluefin Tuna (CCSBT)

The CCSBT has not formally embraced the PA. There is no reference to the PA in the Convention (which entered into force pre-UNFSA). Nonetheless, the CCSBT has decided to implement the PA in its management of the Southern Bluefin Tuna (SBT) resource through the CCSBT Management Procedure (MP). However, uncertainties in data sets used to assess historic catch rates and the inability to reach agreement on stock recovery projections delayed the implementation of the proposed MP [21]. The former problem reflects a real challenge in implementing the PA – what to do if data are not lacking, but rather are inaccurate [3]. Prior to the development of the MP, the Commission had also been criticised for not paying attention to scientific advice, and in particular not reducing TACs until 2006/2007 despite increasingly pessimistic stock assessment results and evidence that the rebuilding objective initiated in 1995 could not possibly be met without serious catch reductions [2].

To address this issue, an Operating Model (OM; as defined in [22]) was used in MSE analyses to evaluate a range of possible past under-reported catch scenarios and to investigate the potential effect of these scenarios on current understanding of the state of the southern buefin tuna stock [23]. The latter problem arises from the fact that historically only one specific reference point was proposed for management purposes. This was the management objective of returning the spawning stock biomass to the 1980 level by 2020. On a number of occasions the CCSBT discussed the relevance of this objective in the light of scientific advice on stock status but it has not been formally rescinded. The objective is acknowledged as being unachievable and is no longer used by the CCSBT as a reference point and instead the CCSBT looked at adopting a more generalised objective of preventing further decline in the spawning stock biomass [21]. This was further modified in the new management procedure.

The CCSBT tested a variety of candidate MPs with the aid of the OM. The candidate MPs were tested against a range of uncertainties so that a robust procedure could be identified. The final MP, known as the "Bali Procedure", was recommended by the CCSBT's Scientific Committee in July 2011. Parameters of the recommended decision rule can be adjusted to set different time horizons for rebuilding, and to constrain the maximum TAC changes allowed every time the TAC is updated (see CCSBT Resolution on the adoption of a management procedure).

The parameters of the MP are as follows:

1. To rebuild the status of stock to an interim building target reference point of 20% of the original spawning stock biomass by 2035;
2. The MP shall be tuned to a 70% probability of achieving the interim rebuilding target;
3. The minimum increase or decrease TAC change shall be 100 t;
4. The maximum increase or decrease TAC change shall be 3000 t;
5. The TAC shall be set for three-year periods; and
6. The national allocation of the TAC within each three-year period will be apportioned according to the Resolution on the Allocation of the Global Total Allowable Catch.

The measures and criteria included in the adopted MP are considered precautionary in nature and thus conform to the principles of the PA [24].

In parallel, the CCSBT has made progress on the implementation of FAO IPOAs for seabirds, sharks and fishing capacity. The

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Commission has also established a Working Group on Ecologically Related Species (ERSWG) and has taken measures to reduce the impact of SBT fishing on ecologically related species and by-catch. It has not, however, developed full-scale plans relative to the IPOAs [25] although it has initiated efforts to monitor impacts of its respective fisheries on seabirds and sharks, developed educational material to help fishermen identify sharks when they are taken in fishing gear, and instituted technical measures (e.g. use of tori poles) to mitigate seabird entanglements (http://www.ccsbt.org/site/bycatch_mitigation.php).

3.3. Western Central Pacific Fisheries Commission (WCPFC)

During the last two decades, implementation of the PA in the Western Central Pacific Ocean (WCPO) has been discussed and some actions have been carried out. Following the Rio Summit in 1992, the Forum Fisheries Agency (FFA) members together with distant water fishing nations held Multilateral High Level Conferences (MHLCs) to address concerns on management and conservation of stocks in the high seas. At the fourth MHLC in 1999 a resolution was taken to limit the expansion of fishing effort and capacity and to further apply the PA [26]. In 2004, the WCPFC Convention entered into force, including provisions for the application of the PA. Specifically, part II article 5 (c) of the Convention text states the PA is to be used in accordance with the Convention and any other international agreed standards and recommended practices and procedures. Article 6 of the Convention text provides detailed guidelines on the application of the PA in the Convention area. It also specifies that the guidelines for the implementation of reference points to be utilised when implementing the PA are those provided in Annex II of the UNFSA. In addition, Article 6 provides the principles for the application of the PA in fisheries management with special focus on the inclusion of uncertainty, the development of reference points and the monitoring of resource status in relation to these reference points. The need to avoid delays in implementing conservation actions when facing a lack of information and the need to develop data collection and research actions to evaluate the impact of fisheries on non-target and associated species are also stated.

Regarding scenario modelling, the use of MSE as a tool to make the PA operational in the region is being considered. For that purpose, in 2009 the Commission's Scientific Committee commissioned a study by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) with the aim of discussing reference points and MSE for the WCPO region. This study suggested tentative steps to implement them in the region [27]. A workshop on reference points and MSE was also held in 2009. Some scientists believe that MSE will be difficult to implement as there is no operating model developed for the region and technical capacity to capture the whole range of uncertainty is lacking (SPC-OFP, pers. comm.). In addition, a final agreement on appropriate reference points for exploited stocks has yet to be reached [28] although stocks assessment outputs are usually given in relation the spawning biomass corresponding to the MSY (S_{MSY}) and the fishing mortality corresponding to the MSY (F_{MSY}).

Although the PA has not been officially implemented in the WCPFC Convention area, some general principles of the PA are being taken into consideration, especially with regard to the conservation and management measures (CMMs) to reduce mortality of non-target species such as seabirds, marine turtles and sharks. The WCPFC has taken action to implement IPOAs for sharks, IUU fishing, seabirds, and fishing capacity [29].

3.4. Indian Ocean Tuna Commission (IOTC)

The IOTC has not formally embraced the PA. There is no reference to the PA in the Convention, which entered into force pre-UNFSA, and thus the objectives of the IOTC Agreement do not make specific reference to the PA. On the contrary, the Agreement refers to optimum utilisation of stocks, specifically stating "to ensure the conservation of the stocks covered by this Agreement and to promote the objective of their optimum utilisation throughout the Area". This is considered to be an outmoded goal for fisheries management following the developments at the World Summit on Sustainable Development (WSSD) in 2002 [30].

Although the IOTC has not formally adopted specific target or limit reference points for management, the objectives of the IOTC as understood by the scientific committee (SC) are to ensure keeping the tuna stocks at sustainable levels while maximising catch (i.e. ensuring populations remain at levels sufficient to facilitate taking the MSY). Therefore, the scientific advice for fishery management for most of the populations are given in relation to biological reference points such as the spawning biomass corresponding to the MSY (S_{MSY}) and the fishing mortality corresponding to the MSY (F_{MSY}). The IOTC scientific committee and IOTC Commission has also encouraged the development of HCRs to be evaluated using MSE [31]. It is intended that MSE be developed and presented at the Scientific Committee over the next few years.

On the other hand, some general principles of the PA are being taken into consideration, especially with regard to the conservation and management measures to reduce mortality of non-target species such as seabirds, marine turtles and sharks. The IOTC follows several IPOAs such as IPOAs IUU, Sharks, Seabirds, and Capacity. These are detailed in a variety of resolutions adopted by the Commission. In fact, in 2008, the SC started to present the management advice on sharks, sea turtles, and seabirds which are not species considered under IOTC agreement based on the management advice given by the Working Party on Ecosystems and Bycatch [32].

Thus, the SC is striving to take into account the issues regarding the ecosystem approach to fisheries management and the protection of biodiversity and, more importantly, the scientific advice for fisheries management is considering biological reference points as well as the precautionary approach.

3.5. International Commission for the Conservation of Atlantic Tuna (ICCAT)

Although ICCAT has not formally adopted the PA, in practical terms it can be considered that it has adopted many of the principles of the precautionary approach. In 1997, the ICCAT Standing Committee on Research and Statistics (SCRS) created an Ad Hoc Working Group on the PA although this group has met very sporadically since. The probability of achieving management targets given uncertainty in stock assessments is also considered, e.g. structural uncertainty where alternative model assumptions are considered and implementation error where alternative assumptions about total catch are made. ICCAT has also recently investigated the possibility of conducting MSEs for several fisheries. Guidelines for developing HCRs and possible applications of the PA were discussed and recommended during the 2010 Working Group on Stock Assessment Methods [33]. The 2011 meeting of the same group recommended the formulation of HCRs and application of MSE for exploited species [34].

The development of decision rules and MSE simulations are only starting to be considered for species evaluations, and HCRs have not been explicitly discussed/consulted or agreed yet. ICCAT considers the MSY reference points (MSY, F_{MSY}, and SSB_{MSY}) as targets. Although projections of stock status and reference point determination has been done for several species, incorporating certain key uncertainties, reference points which consider MSY as a target and not a limit may not be precautionary due to the fact

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that target reference points, by definition, need only not be exceeded on average i.e. they may be exceeded up to 50% of the time [5]. To this end, discussions regarding the development of limit reference points are being conducted but are far from being agreed upon [34]. If it is considered undesirable to establish MSY as a limit, MSY calculated as a target should be estimated with its full associated probabilities and uncertainties, which will allow managers to define the uncertainty/probability thresholds that are acceptable to achieve the convention objectives at the same time as being precautionary.

In addition, ICCAT addresses bycatch and ecosystem issues through a dedicated working group and subscribes to several codes of conduct and IPOAs for responsible fishing (namely IPOA for Reducing Incidental Catch of Seabirds in Longline Fisheries, IPOA for the Conservation and Management of Sharks IPOA for the Management of Fishing Capacity IPOA to Prevent, Deter and Eliminate IUU Fishing).

3.6. The PA in other RFMOs

Examples of good practice regarding the PA can be obtained from non-tuna RFMOs. In terms of reference point identification and HCR development, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) states target and limit reference points are implicit in the criteria of the agreed management procedures that are used for determining catch limits in the directed fisheries for finfish and for determining the precautionary catch limit for krill. The criteria are designed to ensure that there is a low probability of violating the limit reference point, and the management procedures recommend zero catches if the limit reference point is exceeded. For finfish management, procedures are applied to ongoing determination of catch limits and these procedures result in catches being reduced as a limit reference point is approached [35].

The International Pacific Halibut Commission (IPHC) has a clearly defined harvest policy based on both target and limit reference points [36]. In summary, the policy has a target harvest rate on the exploitable biomass, threshold and limit reference points established for the female spawning biomass, which is defined by the maturity schedule and a "Slow Up Fast Down" (SUFD) annual commercial catch quota adjustment which is employed to limit annual variance in quotas due to both biological and methodological changes [37]. In the Northwest Atlantic Fisheries Organisation (NAFO), precise definitions for target and limit reference points (as well as buffer zones) have been adopted by the Scientific Council, although the PA framework (effectively a HCR) was not formally adopted due to several concerns expressed by managers. The framework has, however, been applied to certain selected species, (eg. yellowtail flounder) and the outcomes from the evaluation of these selected stocks will be used to guide the Fisheries Commission regarding the most appropriate application of the framework to all NAFO stocks [38]. Of additional interest, the International Whaling Commission has a clearly defined precautionary management strategy for sustainably fishing whale populations worldwide, however, this strategy has not been fully implemented for any of the whale stocks, and management is still based on a moratorium [3].

In terms of the adverse effect of fishing on non-target species, CCAMLR management has established the prohibition of directed fishing on sharks, lantern fish and whiptails, the prohibition of deep-sea gillnets and the limitations on gears that impact the seabed. Most of the by-catch limits and spatial zoning of catches are taken as measures in response to a perceived threat, despite limited scientific information [35].

4. Discussion

4.1. Commonalities between tuna RFMOs on implementation of the precautionary approach to fisheries management

Table 1 shows some of the characteristics and commonalities between the implementation of the PA in the different Tuna RFMOs studied. Only the IATTC and WCPFC have explicitly included statements to implement the PA in their Convention's text. The former is in the process of implementing the PA since 2010. Even though CCSBT does not have the PA as a component of its Convention's text, it has acknowledged the PA and is attempting to make this operational in the form of Management Procedures (MP). Operational PA in the form of MSE is under consideration in the WCPFC, ICCAT and IOTC. A common objective for all tuna RFMOs is to maintain a catch at the maximum level that can, on average, be sustained over time, or the MSY and its associated fishing mortality rate F_{MSY} [39]. As has been pointed out, whether these reference points are treated as targets or limits varies between RFMOs.

General measures that can be considered precautionary are widely applied in all Tuna RFMOs and precautionary steps towards management of target and non-target species are also taken. A variety of IPOAs are now key components of management in the diverse regions and address ecosystem considerations. The WCPFC, IATTC, ICCAT and IOTC are carrying out studies and workshops to discuss and develop reference points. However, this may prove to be difficult due to the diverse interests of the various parties involved. This may require the inclusion of political considerations as is the case of the WCPFC (see WCPFC case study).

4.2. Problems identified with applying precautionary approach

The main generic impediment to implementing the PA and risk management is the inertia in the fishery management process itself and the fact that most fisheries are either overcapitalised or overharvested. Excess capacity to harvest the available resource undermines diversification of fishing effort to manage risk, particularly because of the absence of entry and exit mechanisms. For overfished stocks where severe declines are likely to occur or already have, the risk could be already out of control and it might be difficult to effectively manage it [12]. In other words, for many Tuna RFMOs the majority of their regulated fish stocks are either fully fished or overfished. This leaves little room to allocate shares to new members including developing countries. Another major issue when finalising management options for PAs are that many Tuna RFMOs have opt out procedures whereby Contracting Parties within a set period of time may choose not to abide by agreed upon fishing regulations, without penalty, thereby undermining the effectiveness of management efforts. This is exacerbated by the fact that most Tuna RFMOs do not explicitly mention the PA in their conventions.

Lacking from most Tuna RFMOs is adequate enforcement and compliance by Contracting Parties with agreed upon management measures. Furthermore, when catch limits have been established and are exceeded, only a few of these organisations have well-articulated, pre-negotiated management responses [3]. IUU fishing further complicates the ability to ensure that precautionary management is being adopted. In addition, the balancing of tradeoffs between short-term economic gains of fishing under the status quo and the costs associated with imposing immediate and stricter management measures, which contribute to long-term conservation of fish stocks and economic benefits, need to be considered. This, in turn, will increase the level of consultation and complexity of risk assessment modelling.

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Table 1
Commonalities and characteristics of PA implementation between RFMOs.

Criteria	IATTC	ICCAT	IOTC	CCSBT	WCPFC
Precautionary approach in convention text	Yes (in new Antigua convention)	No	No	No	Yes
Decision rules	Currently under development.	Currently under development.	The importance of decision rules has been acknowledged.	An MP has been developed, and was formally implemented in 2011.	Currently under development.
Reference points MSY, B/B_{MSY}, S/S_{MSY}, F/F_{MSY}	Limit and target.	Target only.	Target only.	Target only.	Limit only.
Uncertainty quantified and presented to management	Uncertainty included in quantitative assessments, and Kobe plots with confidence intervals are developed for most target species.	Uncertainty included in quantitative assessments and Kobe plots with confidence intervals and matrices (taking into account their limitations) developed for most target species.	Uncertainty included in quantitative assessments and Kobe plots with confidence intervals and matrices (taking into account their limitations) developed for most target species.	Uncertainty included in quantitative assessments and investigated under the MP framework.	Uncertainty included in quantitative assessments, and Kobe plots with confidence intervals are developed for most target species.
Management based on scientific advice	Yes	Yes (although in the case of Bluefin tuna, the advice has been ignored in the past).	Yes	Yes although management advice is not always followed.	Yes although management advice is not always followed.
Input controls (capacity and effort control)	Yes	Yes	Yes	Yes	Yes
Output controls (TACs)	Yes for the majority of key target species.	Yes for some key species, not for others.	No	Yes	Yes for some key species, not for others.
Bycatch monitoring and reduction	Yes, extensive bycatch monitoring and management predominantly through the AIDCP.	Yes, bycatch reduction measures in place, IPOAs are followed and bycatch issues are discussed and recommendations made by the subcommittee on ecosystems.	Yes, bycatch reduction measures in place, IPOAs are followed and bycatch issues are discussed and recommendations made by the working party on ecosystems and bycatch.	Yes, bycatch reduction measures in place and bycatch issues are discussed and recommendations made by the ecologically related species working group.	Yes, Bycatch reduction measures in place, IPOAs are followed and bycatch issues are discussed and recommendations made by the working group on ecosystems and Bycatch.
Recovery plans	No	Yes	No	No, although once adopted, the MP will address this issue.	No
Rapid response to unexpected effects of fishing, or natural catastrophes.	The commission may hold extraordinary meetings when deemed necessary and at the request of at least two members, provided that a majority of the members support the request.	In cases of special necessity, where a decision cannot be deferred until the next meeting of the commission, a matter may be decided during the period between meetings of the commission by intersessional vote, either electronically via the Internet (e.g. e-mail, secure web site) or other means of written communication.	The Commission may hold urgent meetings when deemed necessary at request of at least one-third of members. With commission approval the scientific committee may convene and initiate work through correspondence. Rapid response does not require a physical meeting of parties. At the initiative or with the support of a Member, a plan of action may be approved by correspondence in a rapid time frame.	Response requires input by all members. small membership may facilitate rapid response.	Secretariat can coordinate remotely with members, but response requires input by all. Members are asked to respond within three weeks for administrative issues, but emergency issues are not clearly dealt with.
Voluntary code of conduct	IPOAs and IUU lists.	IPOAs and IUU lists.	IPOAs and IUU lists.	IUU lists.	IPOAs and IUU lists.
Monitors compliance	Tuna tracking and verification system, comprehensive observer programme on large PS vessels, transhipment restrictions, monthly reporting for large catches of bigeye tuna.	Tuna tracking and verification for certain species, national observer programmes, transhipment restrictions, IUU identification, VMS on large vessels, capacity building schemes for CPCs to meet minimum reporting obligations.	National VMS programmes for several states, observer programmes for several member states, transhipment restrictions.	Monthly catch reporting by CPCs, observer programme, VMS, trade information scheme, transhipment monitoring and IUU identification.	Observer programmes, VMS, development of a full trade/catch documentation scheme and transhipment verification.
Penalties for non-compliance	Trade restrictions.	Sanctions on trade when unavoidable.	None.	Trade restrictions.	Potential to reduce catch or effort limits.

Moreover, the ability to conduct resource projection modelling with control rules along with other MSE evaluations requires an increase in scientific capacity in most instances. This can be expensive to address. This is a burden that must be carried either by the RFMO or by contracting party scientists. It is not always clear that each RFMO has the scientific capacity either within their Secretariats or contracting party scientists to fully realise these additional modelling scenarios.

Lastly and more importantly, for the PA to be effective, clear management objectives need to be set up by managers; which will allow a better definition of the target and limit reference points. However, in most of the cases the management objectives are not clearly defined. For example, the World Submit in Johannesburg defined that all fisheries worldwide should be restored to their MSY level by 2020 without clearly defining whether MSY should be a target or limit reference point. For Tuna RFMOs, convention objectives are generally linked to "maintaining tuna stocks at levels that will permit the MSY"; however, it is not clear if those levels are related to limit or target reference points and this is something that should be discussed by managers prior to formal PA application.

4.3. Precautionary approach best practice

Many of the newer tuna RFMOs which intend adopting the PA have specifically included reference to the approach in their conventions. This ensures all contracting parties clearly understand the aims and requirements of the approach and are legally obliged to fulfil them. For older RFMOs, the renegotiation of new conventions may be a costly and time consuming process and thus undesirable. In these cases, the PA 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.

A potential list of ideal practices for RFMOs is provided in Table 2. This table is based on advice provided in a more general review of many different RFMOs [3], supplemented with advice received from key stakeholders and invited experts to a workshop held under the auspices of the EU 7th framework project, TXOTX (http://www.txotx.net). From a scientific perspective, the establishment of decision or HCRs based on perceived stock status, including future stock status projections and the possible use of MSE techniques to evaluate these rules is essential. The perceived stock status in turn 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, the consequences of management actions (or HCRs) can be evaluated and long-term management and/or rebuilding plans can be developed depending on stock status. 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. This is not trivial and requires substantial additional data and analysis. These socio-economic considerations may most easily be incorporated 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 [40]. Moreover, the reduction of IUU fishing is very important as the IUU can diminish the benefits of any management plan incorporating PA, limit reference points and HCRs. To this end, tuna RFMOs are working together to reduce the occurrence of IUU fishing and IUU lists are already often shared between them. 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 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.

5. Future recommendations

For tuna-RFMOs, a major priority for implementing the PA, is to improve the commitment to the approach from a management perspective. This would include specific reference to the code either in updated conventions or in agreed recommendations and resolutions. This would strengthen the contracting parties' obligations to apply and adhere to the PA. From a scientific point of view, the adoption of science-based limit and target reference points related to management objectives is necessary to integrate the science and management perspectives. In most tuna RFMOs F_{MSY} has been considered a target reference point in the past, however, fishing at F_{MSY} will mean that 50% of the time biomass will be below B_{MSY} [5]. Therefore it would be more precautionary to use F_{MSY} as a limit and to define the fishing mortality target based upon a multiplier (or proportion) of F_{MSY} [33]. However, if stock assessments and reference points are highly uncertain, using a point estimate or expected value as a single target or limit, will not necessarily link information quality to risk (i.e. uncertainty around the estimation of the value will not be carried forward into the provision of management advice). Thus when using a point estimate, it would be necessary for managers to agree on and specify the acceptable risk or probability of exceeding the limit.

It is thus strongly recommended that MSE technique be used to evaluate and provide advice on suitable reference points for management purposes. A benefit of this framework is that a greater range of sources of uncertainty are considered than within traditional stock assessment. The traditional assessment mainly considers only uncertainty in observations and process (e.g. recruitment). However, uncertainty about the actual dynamics (i.e. model uncertainty) has a larger impact on achieving management objectives [7]. Therefore when providing management advice it is important to consider appropriate sources of uncertainty. The MSE process will require the definition of a HCR that incorporates the targets and limits such as demonstrated in Fig. 1. Moreover, MSE approaches will allow not only to test the robustness of the agreed HCR but also to identify research priorities (i.e. what is important to investigate) as they can identify the sources of uncertainty (growth, reproduction, control and monitoring) which most affect the agreed HCR [41]. In addition, MSE can be used as a tool to evaluate and identify a robust HCR, incorporating uncertainty into the management advice. This is preferable to a system which just maximises yield which may result in large interannual fluctuations in TAC and may not be responsive or provide the flexibility to take action under the changing conditions encountered by fish stocks [42]. Recognising that an MSE process needs to be widely implemented in the tuna-RFMOs in conjunction with the PA for tuna fisheries management, the participants at the 2011 Kobe III tuna-RFMO meeting recommended that a Joint MSE Technical Working Group be created [43]. This will allow the tuna RFMOs to work together to define and apply MSE practices based on the PA for use across RFMOs.

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Table 2
Practices of an ideal RFMO (modified from Mooney-Seus and Rosenberg [3]).

Criteria	Best practices
Overarching objectives	Contains ecosystem considerations, precautionary approaches and promotes use of best available science.
PA decision rules	• Portion of TAC allocated to foodweb considerations • Rebuilding targets for depleted stocks • Robust suite of indicators and metrics of ecosystem structure, function, productivity and services at multiple scales • Control rule includes estimated exploitable biomass thresholds where more conservative harvest rates apply—fishing ceases when limits reahced • Catch limits account for uncertainty
Limit reference points	• Minimum/average historical biomass • MSY a limit for fishing effort not a target • Fishing not allowed when stocks below a predetermined proportion of carrying capacity (e.g., IWC 54%,)
Target reference points	• Constant exploitation yield or fishing mortality targets • SSB rebuilding target (e.g., MSY)
Access control	Combination of measures including, but not limited to • Allocation schemes • Closed areas/season • Vessel/gear licensing • Moratoriums, etc.
Bycatch reduction	• Bycatch TACs • Shifting seasons/areas to avoid high incidence of bycaught species • Minimum size/corresponding to mesh/hook size requirements • Mesh length requirements • Innovative methods to reduce entanglement (e.g., nighttime fishing, pingers, limits on soak time, use of tori poles) • Safe handling technique training for released species • Measures to regulate bycatch in recreational and charter boat fisheries
Habitat protection	• Habitat mapping schemes • Closed areas for target, associated and dependent species • Pollution monitoring • Restriction on gear type in sensitive habitats
Interim measures/ recovery plans	• Conservative management procedure framework • Rebuilding plans (RBP)
Capacity reduction schemes	• Closed vessel registry • Fleet segmentation scheme (LOUs) • Quotas for contracting and non-contracting parties • IUU control measures
Evaluation	• Flexible management framework, accounts for uncertainty and new information (i.e. adaptive management) • Pre-specified rules when TAC deemed too risky
Code of conduct	• Education effort—disseminate code of conduct to contracting party fishing vessels. • FAO IPOAs: identification guides, gear/fishing method modifications to protect seabirds, turtles and sharks
Research programme	Ecosystem monitoring programme with data collection protocols including dataon socio-economic considerations, impacts of fishing on sensitive habitats and associated and dependent species, ecological relationships between species/habitat, population assessments for associated and dependent species and ecosystem models which incorporate cumulative impacts, climate change variables
Experimental fisheries	• Experimental/exploratory fishery monitoring and assessment requirements • Restrictions on number of new entrants
Monitors/improves compliance	• Real time 100% observer coverage • VMS • Catch/trade documentation schemes—exchange of trade data with other RFMOs • Minimum standards for data collection and submission of national reports to RFMO • Joint Inspection schemes (contracting parties and independent inspectors) • Fund for capacity building to meet data collection, quality assurance and reporting obligations (particularly for developing countries)
Penalties for non-compliance	• Black/white lists • Landings and transshipments from non-complying parties prohibited • Trade/quota restrictions/sanctions imposed

In order to make the PA operational and easily integrated into management advice, the participants at the Kobe III meeting recommended that the use of KOBE II Strategy matrices (K2SM) is continued provided that the uncertainties in the assessments can be properly quantified and indicated in the matrix [43]. An example of the matrix is provided in Table 3 with an example diagram in Fig. 2. The problems identified with incorporating uncertainty in the matrix have been evaluated and documented [44]. It is recommended that providing these issues can be overcome, this matrix remains a key tool in presenting uncertainty as well as the outcomes

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Table 3
Example Kobe II strategy matrix.

Management target	Time Frame	Probability of meeting target			Data rich/data poor
		A (%)	B (%)	C (%)	
< Fishing mortality target >	In x years	–	–	–	–
	In y years	–	–	–	–
	In z years	–	–	–	–
< Biomass target >	In x years	–	–	–	–
	In y years	–	–	–	–
	In z years	–	–	–	–

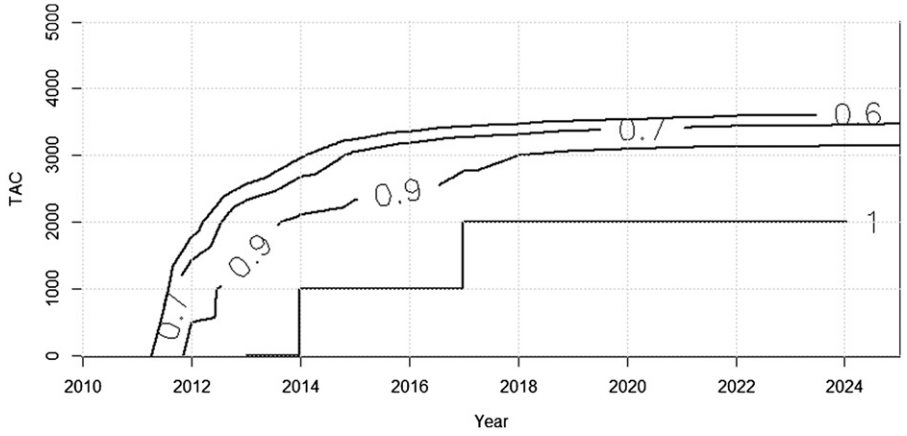

Fig. 2. An example of a Kobe II strategy matrix plot showing probabilities of the stock being above B_{MSY} while being fished at levels below F_{MSY}, (i.e. the green zone of the Kobe phase plot [45]) in a given year for projected TAC levels. The isopleths show the probability the stock will be in the green zone for a given year and TAC. For example, all values above the 0.6 isopleth will have a less than 60% chance of being in the "green" zone for a given year and projected TAC.

of different management action on future stock status. The presentation of this information allows fisheries managers to understand and visually assess the consequences, with probabilities, of management actions, thus ensuring that the PA can be incorporated in the decision making process.

Although from the examples provided above it is clear most tuna-RFMOs have adopted procedures that can be considered precautionary in nature, there is still much to be done to ensure that they fully embrace the approach. Also, the precautionary measures adopted by these RFMOs are not consistent across all oceans. Through the Kobe process the tuna-RFMOs have improved their collaboration and co-operation in order to deal with issues of shared interest. This forum provides an excellent opportunity for tuna-RFMOs to harmonise their efforts and provide leadership amongst international RFMOs in terms of applying modern fisheries management should they be able to translate these Kobe discussions into tangible and operational management actions.

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