REPORT OF THE 2018 JOINT TUNA RFMO MANAGEMENT STRATEGY EVALUATION WORKING GROUP MEETING

(Seattle, USA – 13-15 June 2018)

1. Opening, adoption of Agenda and meeting arrangements

The meeting was held at the Fisheries Building, University of Washington (UW) in Seattle from June 13 to 15, 2018. Dr. David Die (USA), ICCAT Standing Committee on Research and Statistics (SCRS) Chairman and meeting Chairperson, opened the meeting and welcomed participants ("the Group"). The Chair also thanked the NOAA-NMFS for hosting the meeting and for providing all the logistical arrangements and the UW School of Fisheries for the use of facilities. The Chair proceeded to review the Agenda, which was adopted without changes (**Appendix 1**).

The List of Participants is included in **Appendix 2**. The following served as rapporteurs:

Sections	*Rapporteur*
Item 1	D. Die, J. Ianelli
Item 2	C. Davies
Item 3	R. Sharma, D. Butterworth
Item 4	L. Kell
Item 5	A. Preece
Item 6	J. Ianelli
Item 7	C. Minte-Vera
Item 8	P. de Bruyn
Item 9	D. Die

2. MSE process and stakeholder dialogue

2.1 Review of the approaches and processes used when developing MPs across tRFMOs

- Informal report on CCSBT (Dr. Campbell Davies)

A brief report on the history of the development, evaluation and implementation of management procedures (MPs) and the use of stock assessment in the CCSBT was provided. The CCSBT have developed a set of operating models (OMs) that describe the state and dynamics of the stock. These OMs are used for two purposes: i) Developing and testing fully specified management procedures (e.g., Kolody *et al*., 2008, Butterworth 2008, Hillary *et al*., 2016) and ii) periodic assessments of status of the stock. Since the adoption and implementation of the CCSBT MP, the process and schedule for stock assessment and setting of the Total Allowable Catch (TAC) has been implemented according to the Meta-rules, which were adopted along with the management procedure in 2011 (See Anon. 2013: Annex 10, Report of the 2013 meeting of the CCSBT Extended Scientific Committee for full specification). In this context stock assessment has two purposes: i) to estimate the stock status (relative depletion) to gauge if the objective of the Commission's rebuilding plan is met (i.e. $0.2SSB_0$ by 2035 with a probability of 70%) and ii) to see if the conditions for which the adopted management procedure was tested still apply or if there are exceptional circumstances that must be reviewed (see exceptional circumstances item 5 below). Stock assessment is a monitoring tool and is not used for advice to managers on the TAC. In the CCSBT case the stock assessment is off-set from the years when the MP is run to provide a 3-year block of TAC recommendations from the Extended Scientific Committee to the Commission.

The most recent stock assessment in 2017 (Anon. 2017, Hillary *et al*., 2017) showed that the Commission's interim rebuilding target is likely to be met substantially earlier than expected under the original management strategy evaluation (MSE) testing of the MP. Hence, exceptional circumstances applied; but the consequences were positive and the Extended Scientific Committee agreed that the current TAC should remain unchanged until the next scheduled TAC is calculated using the MP. Moreover, given that the Commission had decided to discontinue the scientific aerial survey used as input to the current MP, a new recruitment index was required. A large-scale pilot study using gene tagging to estimate abundance of 2-year-old juvenile southern bluefin tuna(SBT) was completed in 2018, and these data are planned to be used in a new MP. The context for the development of a new MP in CCSBT is quite different when compared to the previous occasions, where the focus was on reducing the risk of further declines and rebuilding the stock. The new MP will need to be able to achieve the current interim rebuilding target and, also, to provide for appropriate longer-term behaviour. Towards this end, the CCSBT initiated discussions on longer-term objectives for the stock and the fishery at a Strategy and Fisheries Management Working Group meeting in March 2018 (Anon. 2018, Davies *et al*., 2018). The Commissions current schedule aims to have a new MP tested, selected and adopted at the Commission meeting in 2019 (or 2020) and used to set the 3 year TAC blocks for 2021-23 and thereafter (Anon. 2017).

The Group noted that the the adoption and implementation of an MP does not preclude the need for periodic stock assessments. In the CCSBT case, stock assessment has an important role in assessing the performance of the MP and determining whether conditions have changed, relative to those for which the MP was tested; i.e. to determine whether exceptional circumstances exist. The Group noted further that the MSE process in the CCSBT had taken considerable time, particularly in the early stages. Most of the time was devoted to agreeing on the final set of operating models and associated uncertainties. Once the operating models were agreed, the technical process to test, select and adopt the MPs progressed much faster and the rate limiting step became the need for interative communication and feedback between the technical program, the Extended Scientific Committee and the Commission, which in an RFMO context usually takes place on an annual cycle.

• Informal report from IATTC (Drs. Carolina Minte-Vera and Juan L. Valero)
Preliminary MSE related work has been conducted for bluefin tuna, bigeye tuna, and dorado. Methods using assessment models based on the Stock Synthesis modelling platform for both operating and estimation models have been developed. The focus of ongoing comprehensive MSE work for the next 5 years is bigeye tuna, including spatial considerations. The dorado and bigeye tuna MSE related work has been performed by an external contractor in collaboration with IATTC Staff. In addition, IATTC staff participates in the Joint MSE Technical Working Group, and in Pacific-wide MSEs for albacore and Pacific bluefin tunas through the ISC (International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean) technical working groups.

Currently there are no dedicated channels of communication about MSE within the IATTC. However, there is an unfunded proposal for continuing development, communication and evaluation of management strategies (MSE) for tropical tuna fisheries in the EPO (Eastern Pacific Ocean) involving managers, scientists and other stakeholders. The aim is to provide training and enhance dialogue/communication among all participants in the MSE process for tropical tunas through the facilitation of a series of workshops during 2019-2020. There is a proposed CAPAM (Center for the Advancement of Population Assessment Methodology) workshop on operating models for 2019.

• Informal report from IOTC (Dr. Paul de Bruyn)
The IOTC recently made substantial progress with regards to MSE analyses. In 2015, Resolution 15/10 was adopted by the Commission specifying interim reference points for key stocks. These are key components for the development of harvest controle rules (HCRs) and evaluating MP performance. The following year, the Commission adopted Resolution 16/03 which established the Technical Committee on Management Procedures (TCMP). This Committee functions as an interface between the scientists and managers, proving a formal forum for dialogue between them and to enhance the decision making response of the Commission in relation to management procedures. A workplan has been developed for the TCMP to advance the MSE process, and the roles and responsibilities for the different groups have been agreed as well. Furthermore in 2016 a harvest control rule was adopted for skipjack tuna, as defined in Resolution 16/02. MSE is being conducted for other key IOTC species and appreciable progress has been made for bigeye and tropical tunas, while moderate progress has been made for albacore tuna. The process has also been initiated for swordfish but is in its infancy. IOTC has also developed standardized formats for the presentation of MSE results. These ensure consistency in the way in which information is presented for different species.

The Group noted the progress being made at IOTC, in particular the adoption of a HCR for skipjack tuna. It also noted, however, that ideally a range of different HCRs and the associated data inputs and assessment methods to be used in the implementation should be tested using MSE, and that the combination that best meets the objectives for the fishery should then be selected.

• Informal report from ISC – Pacific bluefin tuna (Dr. Shuya Nakatsuka)
Progress on MSE development in WCPFC/ISC was summarised briefly. WCPFC managers are refining operational management objectives, while the SPC is working on the scientific aspects. The Commission last year expressed a clear will to spend more time on MSE but how it will be achieved is unclear. The ISC recently held a workshop on Pacific bluefin tuna (PBF) MSE and started the initial discussion. This clarified the purpose of PBF MSE to be to evaluate both the rebuilding strategy and the long-term management strategy. Discussion on operational management objectives had also started. In addition to the standard aspects of evaluation, some additional management and social-related objectives were proposed, which will be discussed further and refined in future.

• Informal report from ICCAT (Dr. David Die)
The 2015 ICCAT Commission meeting adopted two recommendations that declared the intention of the Commission to use MSE as a process to support the development and adoption of harvest control rules. One recommendation called for the development of harvest control rule for northern albacore [Rec. 15-04]. The second recommendation [Rec. 15-07] identified the stocks of albacore north, bluefin tuna, swordfish north and tropical tunas as priority stocks for the MSE process, and established a preliminary calendar of work for the development of the MSE process for each. This calendar has been modified every year by the SCRS and the Commission. In 2017

the SCRS provided the Commission with the first full set of results testing management procedures for the northern albacore. These procedures all were based on "hockey stick" type harvest control rules with stock status being estimated using a production model. In 2017 the Commission adopted one such harvest control rule as an interim rule for the northern albacore stock [Rec. 17-04], and used that HCR to set the TAC for 2018-2020.

The groups most engaged in the MSE process in ICCAT are: the SCRS, the Standing Working Group of Dialog between Scientists and Managers (SWGSM), and to a lesser extent the Commission panels.
During 2018 ICCAT has continued the process of MSE, by:

1) Conducting a series of capacity building workshops for technical specialists and managers.
2) Conducting a joint meeting of the Bluefin tuna and Swordfish working groups to advance the MSE development for these stocks.
3) Dedicating a large portion of the annual meeting of the SWGSM to issues related to MSE, most importantly to the calendar of MSE work, and the definition of exceptional circumstances.

The albacore MSE is focusing on evaluating additional variations of the MPs already tested, a review of the computer code and a review of the overall MSE process. The latter review is to include evaluation of the process used for consultation with stakeholders and the level of engagement of scientists in the technical MSE work. The MSE for bluefin has reached a point were candidate empirical management procedures are being tested within a framework of operating models that are spatially explicit, with two stocks and mixing between these stocks. The bluefin tuna MSE has, however, had to slow its progress to ensure buy-in of the MSE products from the Bluefin tuna working group. The swordfish and tropical tuna MSEs are only starting on the development of OMs and their conditioning during 2018.

Among the largest challenges faced by ICCAT regarding MSE are the number of concurrent MSE processes in which ICCAT is engaged, the complexity of the operating models being requested for tropical tunas and bluefin tuna, and the lack of dedicated funding from the Commission for these processes (with the exception of bluefin tuna, currently funded by the ICCAT Grande Bluefin Year Program(GBYP) project).

- Informal report from IPHC (Dr. Allan Hicks)

The International Pacific Halibut Commission (IPHC) has a long history of MSE-type analyses, starting with a simulation of management strategies conducted by Morris Southward in 1968. Recently, the IPHC has formed a Management Strategy Advisory Board (MSAB) consisting of stakeholders, agency representatives and science advisors that meets twice a year to guide the IPHC MSE process. Involving stakeholders has many benefits, but there has been some frustration that the process is moving too slowly. To alleviate this frustration, the MSE analysis is currently being carried out in two phases: first evaluating management procedures related to coastwide fishing intensity, and secondly evaluating procedures related to distributing the quota to IPHC Regulatory Areas along with the fishing intensity required to incorporate the entire harvest strategy. Completing the first phase, scheduled for January 2019, will be beneficial to show that progress is being made, provide experience to stakeholders when evaluating results, and determine an appropriate interim coastwide fishing intensity before evaluating the entire harest strategy. Recommendations on the entire harvest strategy, including distribution of the quotas to IPHC Regulatory Areas, is scheduled for January 2021.

One challenge that the IPHC MSE has encountered is how to report short-, medium-, and long-term results. The operating model is conditioned to reflect variability that is representative of long-term variability and is not a good predictor of short-term results. As an alternative approach, the IPHC ensemble of assessment models is purposefully designed to make short-term predictions. To summarize medium-term results, the IPHC will describe transitions from short-term to long-term time periods qualitatively, and run specific scenarios that may adequately describe the medium-term variability conditioned on that specific scenario.

- Informal report from IWC (Mr. Greg Donovan)

The long history (since the 1980s) of the use of MSE to test and select MPs in the International Whaling Commission (IWC) was summarised, with an emphasis on communication at the decision-making (Commission and stakeholders) and technical (Scientific Committee and Technical WG) levels. A primary role of decision makers is to provide the objectives that an MP is to meet and for which the SC and technical teams need to provide suitable performance measures. This is an iterative process between the decision-makers, the SC (as the technical review body) and the technical team developing the MSE. A second important step is agreeing on the "plausible" range of hypotheses for the stock(s) and the fishey. It is important to ensure that the range of uncertainty covered is sufficiently wide to avoid needing to recondition OMs every few years, as the objective of the MP approach is to have the selected management system in place for an extended period. Deciding on a "plausible range" of uncertainity is another important focus for communication to ensure, at least conceptually, that decision makers and the wider scientific group understand and agree with what the MP will be designed to achieve, what will be useful to measure performance in the MSE and the breadth of plausible hypotheses for the stock(s) (the OMs) against which the fishery performance will be tested. In this context, important considerations for the communication process include: i) do all scientist understand or, if not, at least trust those who do; ii) careful choice of performance statistics to reflect the objectives and be directly communicable to the appropriate audience; iii) careful handling and communication of uncertainty; iv) regular communication with stakeholders (using formal and informal meetings) which focusses on key messages and how objectives are met to obtain feedback and approval along the way; vi) knowing the audiences and their priorities; and vii) treating the audiences with respect. More general lessons from the IWC experience that may be useful in the deisgn and implementation of MSE processes in the tRFMOs include: i) the importance of consensus advice from the Scientific Committee to the Commission; ii) In general, Commissioners are not interested in the technical details, but rather are concerned with what the MP is likely to deliver and whether the objectives will be met, hence focus on the latter, but ensure the technical detail is available if requested; iii) identify key individuals and groups within the institution's structure to use as champions for progressing to MP adoption (given the size of the RFMOs and turn-over of personnel, it is not reasonable to expect all particpants to understand all aspects of the process); iv) ensure the SC Chair understands the process and assure continuity over the testing and adoption phase; and v) deliver clear messages focussed on the audiences' requirements (i.e. what is exciting and interesting for a technical developer is not necessarily exciting, or directly relevant, for a decision maker or stakeholder). Most of the debate about management procedure implementation in the Scientific Committee has centred around uncertainties in the number and distribution of different stocks of the same species in the region under consideration.

2.2 Stakeholder dialogue. Selling and communicating the process to managers. Discuss "intermediary group(s)" suggested to be established between the Commissions and their Scientific Committees.

- Update on approach being taken harvest strategy and MSE activities for tropical tuna in Indonesian archipelagic waters (Dr. Cambell Davies)

An overview of the consultative and technical process for the development of a harvest strategy framework for management of tropical tuna fisheries within the archipelagic waters of Indonesia was presented. In late 2014, the Indonesian Ministry for Marine Affairs and Fisheries, supported by a number of doners and stakeholders, including CSIRO, committed to the development of a harvest strategy for tropical tuna (skipjack and yellowfin, in the first instance) for the archipelagic waters of Indonesia as part of their commitment to implementing measures compatible with those of WCPFC. The process involved the constitution of a Steering Committee and Technical Working Group and convening of seven stakeholder workshops and five technical workshops over a period of two and a half years. The fishery monitoring series available have been collated, reviewed and analysed, and those considered suitable for longer-term development and implementation of potential harvest strategies identified and prioritised. Preliminary OMs for MSE, conditioned on the outputs of regional stock assessments conducted by SPC for skipjack and yellowfin, have been developed and versions of simple empricial CPUE and size-based harvest strategies developed for demonstration purposes. The stakeholder consultation process has: i) reviewed and refined objectives for the fishery and adopted limit reference points for both species within archipelagic waters that are consistent with those adopted by WCPFC; ii) reviewed manaagment measures currently available under domestic fisheries regulations; and iii) identified the regulatory, consultaltive and technical tasks required to complete the development of operational harvest strategices over the coming 3-5 years. The harvest strategy framework was officially launched by the Director of Capture Fisheries at the 3rd Bali Tuna Conference in Bali on the 31 of May 2018.

2.3 Feedback from other MSE meetings

Ms. Shana Miller presented a summary of the outcomes of an informal workshop convened in San Diego, California in January 2018 by The Pew Charitable Trusts, ABNJ, ISSF, The Ocean Foundation and CSIRO to consider approaches to communication of MSE concepts and processes in multi-lateral fora, such as the tRFMOs. The workshop considered that participation of - and thus communication among - managers, scientists and stakeholders is an integral component of the MSE process. The highly technical nature of MSE and newness of the approach to many audiences present considerable communication challenges and have, unfortunately, slowed progress in some cases. The presentation identified two areas in which the implementation of MSE in multilateral fora may be improved: i) the use of formally constituted "intermediary groups" as a forum for exchange at the management-science interface, and ii) the development of engaging, yet uncomplicated, visual communication tools for conveying key results to different audiences at each stage.

Advice was provided on the structure, roles and communication needs of the four groups generally involved with MSE development: i) highly technical sub groups that develop the MSE, ii) a larger scientific body that reviews each stage of the technical development, iii) both formal and informal intermediary group(s) where the iterative dialogue occurs and recommendations are made, and iv) the Commission. It was noted that the tRFMOs' intermediary bodies, where they exist, may not be adequate as they are currently designed to allow more formal dialogue, potentially necessitating the formation of additional informal groups, especially for more complicated MSE processes. A paper summarising the views and recommendations from the workshop steering committee had been submitted for publication in a special issue of CJFAS on MSE (Miller *et al*., 2018).

2.4 Identification of additional key issues required to further facilitate adoption of Management Procedures in the tRFMOs

The issues discussed included:

- The increasing complexity of stock assessment models, concern that stock assessments are open to advocacy, and the need to clarify the role of stock assessment in tRFMOs when moving towards use of management procedures.
- The need to demonstrate clear demand amongst stakeholders for improvements to scientific advice and management.
- The need seen by some for more than one iteration of the MP development cycle so that the process from objectives to decisions, and implications and trade-offs, can involve review and refinement.
- International conventions articulate the responsibilities of Commissions and members in developing MPs.
- The difficulty to demonstrate whether management advice is precautionary, or robust to uncertainties, without MSE.

2.5 The Marine Stewardship Council (MSC) – harmonisation with MSE process

The recent re-certification of the Maldives pole and line skipjack fishery by the Marine Stewardship Council (MSC) was raised as an example where there was potential for misunderstanding of the technical process and implications for management due to a lack of consistency in terminology and technical process across the RFMOs. In this case the IOTC has formally adopted a harvest control rule (HCR) for the fishery which will be used to set the level of fishing based on the output from a stock assessment, but without specifying the full details of that assessment process. The potential for confusion arises because in their resolution to adopt the HCR, the IOTC acknowledges the need for implementing HCRs as components of "pre-agreed harvest strategies" frequently considered synonymous with management procedures, when by strict technical definition the adoption of a HCR alone does not constitute adoption of an MP. In addition to this definitional issue, in the absence of full MSE of the combination of the specific HCR, fully detailed stock assessment method and associated data inputs, it is not possible to asses the extent to which the adopted HCR is likely to meet its stated objectives.

The Group acknowledged that the adoption of a HCR for skipjack reflected incremental progress towards a fully tested MP, but there was concern that there was the potential for this to cause confusion among stakeholders and about the lack of consistency in application of terminology and technical process. It was also considered that this issue should be raised with MSC directly to explore the extent to which the terminology and technical processes in MSE could be harmonized with those used in the MSC, which is more closely aligned with the "best assessment plus HCR" paradigm and its associated reference points for the provision of management advice.

As an initial step towards mutual understanding, a presentation from the MSC on their use of HCR, harvest strategies, reference points and MSE as part of the certification process was provided by video link to the meeting. When a fishery enters MSC assessment, it is scored against three principles in the MSC requirements. These are Principle 1: the state of the stock, Principle 2: the ecosystem impact and Principle 3: the management system. Principle 1 is the area of the MSC requirements where MSE work is scored in relation to the target stock. The specific areas of Principle 1 where MSE outcomes are assessed are the Performance Indicator (PI) for Harvest Strategy (PI 1.2.1) and Harvest Control Rules (PI 1.2.2). In the context of the MSC requirements, fisheries that have developed and adopted a harvest strategy through MSE typically score at the 80 level (non-conditional pass) or above, and have used MSE outcomes to close conditions. An example of a tuna fishery that has closed a condition in this way is the Maldives Pole and Line skipjack fishery.

Discussion

The Group noted the progress that has been made with MSE processes, both consultative and technical, in each of the tRFMOs since the Group's first meeting, and recognized the benefit of sharing experience and recognizing both similarities and differences between the five tRFMOs which should inform the design and implementation of MSE processes for each RFMO. Furthermore, the Group noted the following points from the presentations and discussions, which could be used to guide processes across the tRFMOs:

- Roles and responsibilities for each body in the RFMO in the MSE process should be clearly articulated and agreeed by Commission as has been done in IOTC.
- Deciding on objectives is the role of the Commission. Generally, the associated Convention provides starting point, which can be refined for the particular fishery. The role of Scientific Committee and technical groups is to work with the Commission to translate the general objectives into a speficic quantitiative form and identify appropriate performance measures for the MSE testing.
- The communication strategy for the MSE technical process must ensure that the Scientific Committee and its appropriate working groups, the Commission and stakeholders have the opportunity for input and review of the MSE development. While it is not necessary for each group, or all particpants, to understand all the technical details, it is important that the MSE technical group draws on the breadth of knowledge and

expertise available to ensure that the OMs adequately reflect the plausible hypotheses for the stock(s) and the fishery, so that Commissioners, the Scientific Committee and stakeholders have confidence in the outcome of the process.

- Continuity of expertise and sufficient technical capacity is very important to a successful and timely process. If possible, avoiding running more than one or two MSE processes in parallel is desirable. It was suggested that multiple developers work on one species rather than doing one each.
- Substantive commitment of time and resources by the Commission is important to a successful technical process, as well as confidence and buy-in from the members and the Commission.

3. Conditioning operating models

3.1 Multispecies MSEs (such as for Tropical Tunas)

3.2 Spatial issues in OM and multi-stock/species structures

MSE should consider five key elements of uncertainty, i) estimation error, ii) implementation error, iii) observation error, iv) process error and v) model error. Currently, the tRFMOs are mainly focused on estimation, observation and process error. Implementation and model error consideration are lacking from most tRFMOs other than CCSBT. More could be learnt from the IWC process to improve the way MSE is conducted. Identifying key candidates OM's for the reference set and robustness test is important to decide from the onset using a guillotine approach (no back-tracking after decisions have been made as the MSE process continues further). In addition, assessing residual diagnostics using runs tests and prediction errors (i.e. using a leave one out (LOO) procedure) may provide guidance on model set up and predictive power in the short and long term, as discussed in the IPHC presentation.

Using a limited number of OMs may be preferable to complex grid design, e.g. with the main effects only providing enough contrast for testing a MP against an OM, capturing only the most important uncertainties which are also the most influential as regards impact on management recommendations. Criteria for assessing the smaller grid design could be determined from elasticity analysis or from the variance-covariance matrix using the base case or by running a larger grid, and determining the main axis of uncertainty to estimate a smaller grid design using multivariate techniques. Starting with a smaller grid design (for a Reference Set of OMs) makes more practical sense, as its difficult to check all diagnostics of all OMs run on a large grid. Less plausible or less influential uncertainties can be covered by robustness tests.

It is essential to "condition" OMs by fitting them to the available data to ensure that they are compatible with that information. That compatibility must be checked by examining standard model diagnostics. In particular if indications of model mis-specification are evident, that OM needs to be rejected, or at minimum its assumptions re-examined. Such checks can be difficult to conduct thoroughly when a large number of OMs are under consideration. When the design of the Reference Set involves crossing the factors for all the major uncertainties, such checking can be assisted by limiting to the "corner points" (e.g., crossing three factors each with three levels corresponds to a 3x3 cube, and one could restrict checks to the OMs corresponding to the 8 corner points rather than all 27 OMs). If results at these corners are satisfactory, it is not unreasonable to assume that the other OMs are satisfactory as well; however if they are not, the range covered by the level choices for certain factors may need to be reduced until such a criterion is satisfied.

In instances of very large sets of OMs (though these should be avoided if possible), for which analysts' checking all individual OMs is not practical, it should be possible to automate some simple tests, such as a runs test on time series of model fit residuals, to check for indications of mis-specification. Information external to that used in the OM fit itself may also be used in checking conditioning. For example environmental data might be able to place limits on plausible values for pristine resource abundance (K).

Spatial models with explicit movement are difficult to condition unless information from some tagging program with a balanced design is available. Nevertheless, care must be taken when fish movement is relatively limited over short periods of time; this can lead to localised depletion, and hence CPUE series trends that are not representative of the abundance trends for the stock as a whole. More attention needs to be given to uncertainties about stock structure for single species than has been the case in the past. Experience with developing MPs for whale stocks has shown this to be a major source of uncertainty which is not straightforward to address satisfactorily in the MP development process.

Taking account of multispecies interactions creates another layer of difficulty. It is best to start simple here, certainly ignoring biological (predator-prey) interactions initially, and focusing on operational interactions that arise from the fact that different fleets targeting different species will nevertheless take some mix of all species, so that the catch taken of one species will impact the catches taken of others. However, MPs should be robust to some of these uncertainties, and some sensitivities should be tested after the Reference Set is developed.

4. Albacore Case Study

4.1 Progress at the Various RFMOs

4.1.1 ICCAT

1) The North Atlantic albacore MSE process took place in parallel to other MSEs: see SCRS papers since 2009 (e.g., Kell *et al*. 2010a, Kell *et al*. 2010b, Kell *et al*., 2014), dialogue meetings (and Panels) and Commission Recommendations (adoption of LRPs, requests to evaluate linear, model based HCRs, performance statistics).
2) The HCRs were tested using an MP that simulates the data and methods used in the latest stock assessment input to HCRs with options for F_{target} and $B_{threshold}$ (F_{lim} was fixed).
3) The latest assessment was within the range of the OM and MP estimates.
4) In 2018 ICCAT adopted a model-based linear harvest control rule (F_{target}=0.8 and $B_{threshold}$=1). If $B>B_{MSY}$, the TAC will not change more than 20%.
5) This is an interim HCR: the SCRS has been asked to consider/investigate:
   a. Peer review
   b. Exceptional circumstances
   c. Carry over effect
   d. Identify OMs not consistent with the data
   e. Alternative MPs, including constraints such as:
      i. Min TAC
      ii. 20% max TAC change when $B<B_{threshold}$
      iii. 20% down – 25% up max TAC change when $B<B_{threshold}$

The main process, as discussed with the Group, was that ICCAT aims at a two-phase review of the North Atlantic albacore: coding and process. The question was raised of whether the joint tRFMO MSE Group could play a reviewer role.

4.1.2 IOTC

The IOTC Scientific Committee chair provided a brief overview of the MSE for Albacore (ALB) at the IOTC. The process to conduct MSE for IOTC ALB was first outlined in 2012, whereby the IOTC Working Party on Methods (WPM) recommended the construction of an OM using the estimated population variables from the stock assessment of the IOTC Working Party on Temperate Tunas (WPTmT). The majority of work on the OM has commenced under and been reported to the IOTC WPM where a modelling expert has taken responsibility for developing the OM and leading the MSE process for this species. For the last two years, the progress made on the ALB MSE has also been reported to the newly formed Technical Committee on Management Procedures (TCMP), which is a forum that provides an interface between scientists and managers and facilitates dialogue between the various stakeholders on matters related to MSE. The TCMP has provided feedback on technical matters and objectives which have been used to progress the ALB MSE work.

The IOTC ALB OM has been constructed using as base case the last stock assessment exercise, carried out in 2016 using the Stock Synthesis 3 modelling platform. Structural uncertainty in this model has been incorporated into the OM conditioning by means of a grid of alternative formulations for various model parameters that were not being estimated from data. An initial set of simulation runs for two possible management procedures have been conducted: exploration runs, tentative evaluation runs (for two MPs) and some robustness tests. The 2 MPs mainly differ in the method used to assess stock status: trends in the main CPUE series, or a surplus production stock assessment. Both depend on the availability of an index of abundance generated in a similar manner to what is currently being used by WPTmT for the albacore stock assessment. One of them also requires good estimates of total catches from all fleets.

The TCMP in 2017 defined 4 interim tuning objectives for exploration. Ideally the Commission will have narrowed down the tuning objectives to 1 or 2 before selection. The TCMP 2017 identified 4 interim tuning objectives for exploration:

• TB1: Pr(mean(SB(2019:2038)>=SB(MSY)) = 0.5. Average SB over the period 2019-2038 exceeds SB MSY in exactly 50% of the simulations).
• TB2: Pr(Kobe green zone 2019:2038) = 0.5. The stock status is in the Kobe green quadrant over the period 2019-2038 exactly 50% of the time (averaged over all simulations).
• TB3: Pr(Kobe green zone 2019:2038) = 0.6. The stock status is in the Kobe green quadrant over the period 2019-2038 exactly 60% of the time (averaged over all simulations).
• TB4: Pr(Kobe green zone 2019:2038) = 0.7. The stock status is in the Kobe green quadrant over the period 2019-2038 exactly 70% of the time (averaged over all simulations).

TCMP01 further recognized the desirability of other MP constraints:
• Total Allowable Catch (TAC) to be set every 3 years (and held constant between settings)
• A maximum of 15% change to the TAC (increase or decrease) relative to the previous TAC

In 2018, the TCMP noted that the ALB MSE has examined CPUE-based and model-based MPs, with additional assumptions, including 3 year TAC setting, 15% TAC change constraint and a 2 year implementation lag, and tuning objectives following those agreed in TCMP01. The TCMP requested that future analyses assume the current 3 year implementation lag.

4.1.3 IATTC/ISC/WCPFC

Overview of the North Pacific Albacore Management Strategy Evaluation (ISC)

The presentation provided an overview of the MSE being developed for North Pacific albacore tuna (NPALB) by the ISC Albacore Working Group (ALBWG). WCPFC and IATTC have agreed to start developing an MSE framework for NPALB to examine the performance of candidate alternative management strategies for NPALB given uncertainty. The uncertainties to be considered in this first round of NPALB MSE were agreed upon and prioritized at the 3rd ISC MSE WS in October 2017 in Vancouver, Canada. This first set of operating models were developed to consider uncertainties in the factors agreed to be highest priority by the ISC ALBWG: 1) Recruitment – autocorrelation and various values of steepness parameter, 2) Natural mortality – various values of natural mortality parameters, 3) Growth – various values of growth parameters, and 4) Juvenile movement (via time varying age selectivity). Three values each of steepness, growth and mortality were considered, and 27 different OMs were constructed. All the OMs consist of a population dynamics model of NPALB with a fishery model component relating the modeled dynamics to catch, CPUE and size composition data. Like the stock assessment used in the management procedure for NPALB, the OMs were developed using the Stock Synthesis modelling platform. Unlike the assessment model, the OMs had time varying age selectivity for the Eastern Pacific surface fleet and autocorrelated recruitment deviations. Those OMs that failed to converge and those that produced unrealistic spawning biomass (SSB) estimates were not included in a preliminary run of the full MSE feedback simulation. In these simulations, data with error was generated from the OMs and fed into the assessment model currently used for NPALB. Different harvest control rules were then used to generate a TAC from the estimates of stock status generated by the assessment and specified control points for the control rules. A TAC, with adjustment for an implementation error was then fed back as catch into the OM. The simulation loop was run for 30 years.

4.2 Progress On Key Research Areas

The intention of the albacore case study was to take advantage of the work being conducted across the tRFMOs and to provide an opportunity for collaborate. A number of collaborative scientific papers have been proposed for peer review journals; work is ongoing, and is being conducted on github https://github.com/laurieKell/xval/wiki to ensure openness, transparency and opportunity for collaboration. Many of the issues discussed by the Group, however, are of general interest, so that work has been extended to cover a greater range of case studies.

A multi-authored paper on the current status of Operating Model Design in tRFMOs: Issues and lessons learnt has been submitted and is in review. This reviews the range of operating models developed by the tRFMOs. Most of the OMs were primarily based on a stock assessment paradigm using fisheries dependent data. In some cases, they were developed for peculiarities of the species (e.g., Indian Ocean skipjack/Atlantic bluefin tuna), and may incorporate explicit spatial structure. Several common challenges are identified, which should be clearly documented so that tRFMOs can learn from each other and standardised approaches developed. For example, getting agreement on the scenarios to consider, and how to weight or reject them should be agreed from the onset. In most cases a grid-based deign that deals with structural uncertainty has been used; however, processes related to sampling and non-stationarity of ecological processes important should also be examined. Methods for data-weighting and determining which models are more plausible require further work. The tRFMOs may also be able to learn from other fisheries management organisations (e.g. the IWC) that have considereable experience in the application of MSE. Future work should also explore spatial issues in OMs, including situations with multi-stock fisheries (e.g. tropical tunas). The current approach using assessment models as the basis for OM design is a good starting point, though additional processes (e.g., observation error and time series processes) should be taken into account in OM designs.

After the meeting work continued on the issues identified by a small technical group. Papers include the use of validation of scenarios, based on Atlantic bluefin, identification of key scenarios to include in OM designs, and conditioning of Observation Error Models on data.

The first of these is a cross validation case study and the aim of the paper is use prediction residuals to evaluate model misspecification, over-parameterisation and prediction skill. Two procedures are used: i) leave-one-out to calculate the prediction residuals and then compare these to the model residuals; if the prediction residuals are much greater than the model residuals then the model is overfitted; and ii) hindcast, or step 1,2,3 ahead predictions to compare prediction skill using the Mean Absolute Scaled Error. Three stock assessment models with different treatments of process and measurement error are considered, namely Stock Synthesis, SAM and VPA. The Stock Synthesis analysis is based on two runs with a different number of estimated parameters. The two

Stock Synthesis runs are then reconfigured as an Age Structured Production Model by fixing the selection pattern parameter in order to evaluate whether dynamics are driven primarily by a production function or recruitments

When conducting Management Strategy Evaluation using an operating model conditioned on a stock assessment, often a full factorial design is used based on scenarios reflecting uncertainty in difficult-to-estimate parameters, data weights and model specifications situations. The aim of this paper is to evaluate the use of more parsimonious designs using the OM grids developed for Atlantic bluefin tuna, North Atlantic and Indian Oceans albacore and swordfish. The operating models are grouped into clusters based on their i) production functions and ii) time series. If the performance of a MP depends on i) production functions or ii) time series, then it is neccessary to run only a limited number of OM from each cluster. This hypothesis is tested by performing a cross validation where an OM is selected from each cluster and an MSE conducted. This is then repeated for another set of OMs by cluster and the performances of the MPs compared.

4.3 Future cross RFMO collaboration on ALB MSE

The areas addressed by this theme, both technical issues and those related to communication, are of general interest to the Group, and require collaboration across the tRFMOs but also with other organisations such as the IWC, IPHC, ICES and MSC.

The work done under this theme has required several small technical working groups, with all work being available via a github site and wiki. These types of activities need to be supported in the future if progress is to be made.

5 Provisions for Exceptional Circumstances

Dr. Ann Preece (CSIRO) provided a description of the meta-rules/exceptional circumstances provision for the SBT MP. Each year the CCSBT Extended Scientific Committee (ESC) formally evaluates evidence for exceptional circumstances using the agreed process specified in the management procedure (MP) Meta-Rules. Exceptional circumstances are events, or observations, that are outside the range for which the CCSBT MP was tested during the MSE development phase and, therefore, indicate that application of the Total Allowable Catch (TAC) generated by the MP may be highly risky, or highly inappropriate. The SBT meta-rules include: a review of the input monitoring series for the MP, and fishery and stock indicators (annual); periodic assessments of the status of the stock via reconditioned operating models (3 year intervals, off-set from the MP TAC setting years); and in depth review of the MP performance (6 year intervals). The aim of the meta-rules process is to determine whether there is evidence for exceptional circumstances and decide what, if any, action should be taken to deviate from the TAC recommended by the MP (see Attachment 10 of the 2013 ESC report : Anon. 2013). The exceptional circumstances process under the SBT meta-rules involves the following three steps: 1) determining whether exceptional circumstances exist; 2) a "process for action" that examines the severity (and implications) of the exceptional circumstances for the operation of the MP, and the types of actions that may be considered; and 3) "Principles for action" that determine how recommendations from the management procedure might be altered, if at all, based on the most recent reconditioning of the OM. The meta-rules and their provision for exceptional circumstances have been invoked on a few occasions since the implementation of the MP in 2011. They have had considerable value in providing a structured process for the ESC to identify and consider unexpected events/circumstances, and to provide recommendations to the Commission on appropriate action.

Dr. David Die described the discussions on exceptional circumstances at ICCAT. In 2017 ICCAT requested its scientific committee to develop criteria for the identification of exceptional circumstances. Following the experience of other tRFMOs the scientific committee of ICCAT is proposing that in general these exceptional circumstances represent cases when new observations or new knowledge suggest that reality was not properly represented by the operating model used to evaluate the management procedures through the MSE. Invoking exceptional circumstances can then trigger a management action that is different to the one evaluated by the MSE, including the temporary abandoning of the management procedure. The ICCAT scientific committee, through its methods working group and the standing working group to enhance dialogue between fisheries scientists and managers, agreed to propose two criteria that would help define exceptional circumstances:

1. When there is evidence that the stock is in a state not previously considered to be plausible in the context of the MSE and/or
2. When there is evidence that the data required to apply the HCR are not available or are no longer appropriate.

Furthermore, the standing group also agreed that the regular process of review of MSE and management procedures should include a review of the existing criteria, definitions of exceptional circumstances and of the actions triggered when these circumstances are invoked. The current definitions and criteria for exceptional circumstances will be presented to the ICCAT Commission in November 2018 for their consideration.

Dr. Doug Butterworth summarised recent discussions in the NAFO Scientific Council about developing Exceptional Circumstances (EC) provisions associate with the revised MP recently adopted for Greenland halibut. This is an empirical MP based on an aggregate abundance index which takes a weighted average over the results from five different surveys. The EC provisions include rules which specify how many failed surveys are admissible before EC would be declared. There were two key areas where differences of views needed to be balanced in the NAFO SC discussions. The first concerned declaring EC more frequently but being unlikely to modify advice from the MP, compared to declaring these less frequency but then being near certain to recommend modifying MP-generated advice. The second was between specifying specific probabilities for well-defined rules as to what constituted EC occurrence (in this case such were agreed for the range anticipated for future values of the aggregate abundance index), compared to allowing scope for expert judgement particularly in instances where it was not feasible to develop specific rules for the very large number of "exceptional" eventualities that could be envisaged. Care needs to be taken when computing probability envelopes for future "observations". This is straightforward for a future survey index because that observation is independent of the operating model prediction; however such calculations become much more difficult when comparing assessment model quantities such as recent recruitments because of the non-independence arising, inter alia, from the use of partially common data.

Mr. Greg Donovan described aspects of IWC processes. An implementation review process for every agreed implementation of a management procedure (for commercial whaling, where the procedure is generic, the implementation involves specification of a particular case-specific variant of the generic procedure involving in particular the basis for specifying the spatial distribution of the overall catch limit output) is formally conducted every 5-6 years. This is believed to be sufficient to detect any changes needed to the implementation as a result of ongoing monitoring and new analyses. However, if a major discrepancy with the assumptions underlying the previous review is detected through consideration of these data or analyses before this 5-6 year period has elapsed, what is known as a 'special' early implementation review may be called for by the IWC's Scientific Committee. Calling such a Review does not necessarily (although it may) mean revising the Committee's advice to the Commission. The Committee has not tried to compile a formal comprehensive list of what factors might trigger' such an early review, which implies unexpected/unpredictable factors "exceptional circumstances" but has compiled a list of the types of factors that may vary from major mortality events to very low abundance estimates or environmental catastrophes.

Dr. Allan Hicks commented on progress at the IPHC on meta-rules. The quota setting process at IPHC consists of an annual assessment that provides short-term advice to Commissioners. This decision-making step is at the end of the process and switching to a paradigm that eliminates quota negotiations and a management procedure that defines the TAC may be challenging. The IPHC MSE is currently focused on developing and evaluating management procedures, and IPHC will have to consider defining exceptional circumstances and "meta-rules" before a new management framework is implemented.

The Group discussion clarified the role of the meta-rules as a safety-net around implementation of the MP, and that adjustments to recommend management advice are considered only if exceptional circumstances indicate that the management procedure is not working and there is additional risk to the stock (or sometimes fishery). The meta-rules do not involve operational constraints that are part of the MP, and therefore are not tested in MSE of the MP.

The MP meta-rules can (as they do for SBT) specify the role of the stock assessment in providing updated information on the population dynamics and productivity of the stock and whether or not management action is working as intended. The stock assessment does not necessarily need to match the MP or MSE operating models, and the depth (thoroughness and complexity) of the stock assessment could potentially vary, with very comprehensive assessments occurring less frequently. The cost-reduction benefit of adopting a fully specified management procedure is in the cessation of debate over the specification of the models that provide management advice; in contrast to fully specified MPs, stock assessments can incorporate a wide range of uncertainties and alternative model specifications, and are still required for stock status advice. The tuna RFMOs (tRFMOs), when developing fully specified MPs, may wish to consider separation of providing MP advice from years in which stock assessments are updated. This helps reinforce the separate roles of: operating models for MSE testing of MPs; MPs for management advice (e.g., TAC, TAE); and stock assessments for updated stock status advice.

Hard bounds for the determination of exceptional circumstances are specified in some meta-rules. For example, in some meta-rules, the indices used in MPs must be within the 95% probability interval of operating model projection trajectories of those indices. As discussed in the NAFO example, estimates such as recruitment cannot have similar hard bounds (for technical statistical reasons) but can still be reviewed to determine a relative degree of difference from the expected trajectories. It is important that the indices, and standardisation of those indices, are fully specified in the MP, so that the indices themselves are implemented in the same manner as they were tested, and cannot be contested or modified during implementation to achieve a certain outcome.

For cases where there is evidence for exceptional circumstances and potentially substantial impact from implementing the MP management recommendation, the meta-rules can include specification to guide how to determine the percentage change to a management recommendation, i.e. from results from reconditioned operating models. For an example, see Attachment 10 of the CCSBT Report of the Scientific Committee, 2013 (Anon. 2013).

6. Computational aspects

Throughout the meeting computational aspects were raised by the Group. Specifically, these dealt with managing the structural uncertainty and conditioning of operating models. Presentations on the added computational demands for estimating objective weights among alternative models and parameter values used for an OM highlighted the need for efficient computational methods. Tradeoffs between model complexity (and perhaps reduced transparency) and computational efficiency continue to be a challenge.

7. Dissemination of results

7.1 Tools to facilitate dissemination (wiki, websites, github, email lists, templates etc)

• How to present and communicate results to stakeholders to get buy-in (presentation Dr. Laurie Kell)
The presentation covered a collaborative work in progress entitled: "On the role of visualization in the management of fisheries" (by Levontin, Kell, Leach and Mumford) which addresses the use of graphic design and data visualization tools that can be used to convey the complexity of the operating models used in MSE as well as the MSE results.

As the governance in fisheries has become more open to stakeholder participation, the demand for scientific information has also grown in complexity: the assessment task is no longer limited to ensuring a maximum sustainable yield from a single stock, but considers species and habitat interactions, as well as social and economic aspects. Modelling has emerged as the backbone of the decision making and it risks disempowering non-experts, subverting the intent towards more inclusive governance. One counterbalance is more effective communication methods, in particular taking advantage of visualization and web interactive design. Four key themes should be a priority for new generic visualization tools:

•Uncertainties as perceived by stakeholders (preferably, alongside a standardized elicitation approach);
•Assumptions made in models;
•Results of modelling (in space and time, trade-offs, as well as portrayals of disagreement among models); and
•Reliability of modelling and how the models are validated (there is a need to develop and apply best practice for model validation).

The presentation stressed that it is essential to work with designers and to seek feedback from stakeholders, as well as from bodies such as MSC, in the process. Several teams are currently working independently on improving visualizations and creating open source tools. While it is good to have many initial options, there is a need for a consistent approach to design in order to facilitate graphicacy – visual literacy or skills to interpret graphics – both in the stakeholder and the scientific community. Graphic designers, and other experts in visual communication, should be recruited to help with this task and the efforts of different designer groups should be coordinated."

7.2 MSE glossary

Communication between scientists, policy makers, and stakeholders is vitally important. In order to facilitate dialogue various bodies have developed glossaries that attempts to define and explain the terminology used.
Two of those glossaries were presented.

• Draft Glossary from San Diego workshop paper (Ms. Shana Miller)
A brief glossary of key MSE-related terms targeted at fishery managers and stakeholders was presented. The glossary will be published as an appendix in a scientific journal later this year (Miller *et al.*, 2018) and could be a useful resource when the Group starts working on developing a nontechnical [laypersons'] MSE glossary. The participants were invited to comment on the draft glossary.

• Draft Technical concepts and glossary for harvest strategies, management procedures and MSE (Dr. Campbell Davies)
The presentor noted that a draft document describing the key technical concepts and technical gloassary, specifically focused on terms associated with harvest strategies, management procedures and management strategy evaluation had been developed, based on available glossaries (e.g., ISSF, Pew Charitable Trusts, Rademeyer *et al.*, 2007, IOTC) by a number of individuals with experiences across multiple RFMOs and national processes. The purpose of the draft was provide a basis: i) to clarify key technical definitions amongst scientists

involved in MSE processes across tRFMOs (and more broadly), and ii) using the outcome of i) develop a consistent non-technical glossary and descriptions of key concepts and processes for communication with Scientific Committees, Commissions, Dialogue Groups and stakeholders.

A discussion followed the two presentations of glossaries and the Group decided that the technical glossary only with definitions will be circulated and commented upon by the Group to make it a Group product. This glossary would be finalized in three months (deadline for 15 September 2018, the final product is reproduced as **Appendix 3**). From this technical glossary, two other documents will be derived, one that will have a more elaborated text with explanations, and a laypersons' glossary.

7.3 Available visualisation tools (shiny apps and others)

• Use of Punt's shinny app in ABNJ workshops (verbal report Dr. David Die)

The Global Environment Facility's (GEF) Areas Beyond National Jurisdiction (ABNJ) project "Sustainable Management of Tuna Fisheries and Biodiversity Conservation in the ABNJ" has been sponsoring a series of workshops for managers and stakeholders in all tRFMO. The workshops had used demonstration tools such as "shiny apps", in particular a shiny app develped by Dr. Andre Punt on a simple MSE for tunas available at https://puntapps.shinyapps.io/tunamse/

Other shiny apps have been developed in ICCAT for for Atlantic bluefin tuna MSE by Dr. Tom Carruthers and for North Atnaltic swordfish MSE by Sea plus plus. The codes are available: https://github.com/ICCAT/abft-mse/, https://pl202.shinyapps.io/Swordfish_MSE_Vis/.

The work of Mr. Nokome Bentley was also mentioned: https://github.com/iotcwpm/SKJ

There was general agreement that these "toys" are useful tools to help learn the concepts. However, caution should be exercised so as not to give an oversimplified idea of the MSE process by using simple tool. Ideally stakeholders/managers should get access to those kinds of tools or "toys" only after some preliminary results that make sense in the context of a fishery become available.

7.4 Future avenues of development

Storing the MSE results in a database and building visualization tools that can facilitate the access to the results by the stakeholders/managers could be a way to proceed. Also, it was suggested that it would be proposed to Dr. Andre Punt that he include some standardized graphs that the Group agree upon on his shinny app so it can be used as a teaching tool among tRFMOs.

8. Conclusions and Recommendations

MSE process and stakeholder dialogue

1) The Group **stresses** that a successful and efficient MSE technical process should not be assigned to a single individual – it is an iterative process that should involve a consistent, core group of experts that regularly reports on progress to other scientists, managers and other stakeholders and implements their feedback. In addition, experience with previous MSE initiatives has highlighted the value of a 'guillotine' mechanism if the whole process is to avoid back-tracking and to meet deadlines for completion within a reasonable period of 2-3 years:
    a) the first guillotine should apply to data selection, after which no new data may be taken into account in the process;
    b) the second guillotine applies to agreement on a set of satisfactorily conditioned operating models, after which MPs testing is based on those accepted models alone.

   Further data or scenarios with their associated OMs that are forthcoming after these guillotine dates can be taken into account when the accepted MP enters a subsequent review and revision process (under an agreed schedule).
2) The Group **recommends** that each RFMO identifies all stakeholders, ideally at the outset, and clarifies their role and input within their MSE process. Not all stakeholders need to be involved in all aspects of the process; however, transparency and trust is critical and must be established. Mechanisms to achieve this, such as the use of "intermediary groups" (e.g. Miller *et al*., 2018) should be established.
3) In addition to scientists, the Group **advises** that consideration should be given to the use of other experts (e.g., managers, industry and/or conservation representatives) with experience of the MSE implementation process, to provide capacity building workshops for managers. This may facilitate better targeted information sharing as scientists may have a tendency to concentrate more on technical issues. In addition to the present capacity building efforts, consideration should also be given to more targeted

approaches to individuals closer to decision process; this could include one-on-one meetings (with either a single individual or a group from a single country).

4) Small technical task groups to discuss and advance key aspects of the MSE process that are of common interest to the Tuna RFMOs are beneficial (and see 5 below). Care should be taken to ensure communication is maintained and that the work of these task groups is presented back to the larger tRFMO MSE WG and appropriate RFMO working groups.
5) Reviews of an MSE can be considered at 3 levels:
   i. *Broad:* the overall MSE process (i.e. the rationale, framework and workplan);
   ii. *More detailed:* specific MSE components e.g. review of operating models (OMs) and their conditioning (see 7 below); and
   iii. *Specific:* validation of the technical code developed for MSEs at the various RFMOs, i.e. confirm that the code is correct and consistent with the equations documented in the full 'trial specifications document' (see 12 below).

   The Group **recommends** that RFMOs should decide at an early stage how this review process will occur (including internal review through Scientific and other RFMO Committees and groups and/or the appointment of independent external experts on technical and process aspects of MSE), noting that review must be iterative, not occur only at the end of the process. Should one or more RFMOs request that this Group is involved in the review process (this would provide a level of consistency amongst RFMOs), then long-term funding, support and expertise will be required. One option is that this Group could be directly involved in the first two levels as an advisory body, providing advice and facilitating contact with key experts to conduct one, or more, stages of the review and recommend appropriate sources of expertise for the validation exercise. The Group **noted**, that transparency for the wider community was an important aspect of the review process and that the use of experts independent of the RFMO has been valuable in a number of case studies.
6) The Group recognizes that obtaining MSC (or similar) certification is a key motivator for fishing industries. However, concern has arisen about the applicability of the current MSC guidelines/criteria to fisheries managed under approaches developed using MSE. This is because the MSC's approach seems to be based on the "best assessment plus HCR" paradigm with its associated reference points, and these concepts often do not translate readily to the rather different management framework based on the precautionary MSE process. The Group therefore **recommends** that dialogue takes place with the MSC (perhaps leading to a joint workshop) to discuss their criteria for certification in an MSE context.

Conditioning operating models

7) With respect to OMs, the Group **advises** that it is valuable to limit their number to that needed to adequately address the key uncertainties, with a focus on those that may have management implications in the future (see 9 below). However, it **stresses** that this limitation should not be taken too far – the OMs should consider a range of plausible scenarios which is sufficiently broad that tested MPs or HCRs[1] do not require amendment or retesting too often.
8) The Group also **stresses** that it **essential** that all OMs are adequately conditioned i.e. ensure that they are sufficiently consistent with the historical data to be considered plausible. Whilst conditioning is a case-specific process, there are some general guidelines that should be followed including: the use of standard model fit diagnostics for indications of model mis-specification (automated where possible); focusing on the conditioning of 'limit' cases, which may be sufficient to justify the assumption that conditioning in between these is adequate.
9) Stock structure has been found elsewhere (e.g. with whales) to be a major source of uncertainty with strong conservation and management implications. It is also difficult to model. Thus far, this issue has not been given much emphasis in fishery MSE development. The Group **recommends** that much more attention is dedicated to this issue, including a focus on the research needed to provide the necessary data to develop and parametrize the OMs needed.
10) Shortage of time precluded discussion of the topic of how to weight the scenarios for which OMs are developed in relation to their relatively plausibility. The Group **agrees** that this is an important and difficult issue that should be taken up with high priority in future meetings.
11) With respect to multispecies MSE, the Group **recommends** that initial OM developments focus on technical interactions (i.e., fleet and fishing operation levels with fleets focusing primarily on one species being unable to avoid catching others).

[1] Harvest control rules with discontinuities (leading to potentially large changes in recommended catches) should generally be avoided.

Computational aspects

12) The Group **stresses** that it is **essential** that the mathematical specifications for all code developed for MSE purposes is fully documented as part of a trials specification document; and that the code is validated and made publicly available, since it will ultimately be used to provide management recommendations.

Dissemination of results

13) The Group **recommends** that visualization approaches for presenting MSE results (e.g. for case study stocks) should be tested with various focus groups to check their suitability for each forum/stakeholder group. Feedback will help to develop more effective and targeted formats.
14) The Group **recommends** the creation of a common 'GitHub' or similar site to submit code for individual components of the various sets of MSE initiatives, including graphical presentations of results. This will also facilitate sharing of code on a modular basis that could be helpful to MSEs across RFMOs.

Further Work

15) In terms of its further work, the Group **recommends** that**:**
    i. refinements to the draft glossary be made such that it can be finalized in three months' time (this should eventually include a lay glossary as well as a technical glossary);
    ii. it continues to discuss the topic of 'Exceptional Circumstances'; this will be coordinated by Ann Preece and David Die;
    iii. further consideration is given to the relative merits of model-based vs empirical MPs as it has been suggested (e.g. see Punt 2018) that there is little difference between model-based and empirical MPs in terms of performance, but that the latter have advantages in terms of easier understanding by stakeholders and simpler testing;
    iv. a comprehensive joint tRFMO MSE WG website is developed that provides information and updates regarding the activities of the Group in a clear manner, as well as links to each RFMO's MSE webpages (a website manager should be identified and supported); and
    v. the Chair develops a workplan, possibly in conjunction with a steering committee, to develop an agenda for the next meeting as well as a workplan and priorities for further activities.

9. Adoption of the report and closure

Due to the limited time, only the agenda item 8 regarding conclusions and recommendations was fully reviewed and adopted in the meeting. The Group adopted the whole report with all detailed sections later by correspondence. The meeting was adjourned.

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Appendix 1

Agenda

1. Opening, adoption of Agenda and meeting arrangements
2. MSE process and stakeholder dialogue
2.1. Review of the approaches and processes used when developing MPs across tRFMOs
2.2. Stakeholder dialogue. Selling and communicating the process to managers. Discuss "intermediary group(s)" suggested to be established between the Commissions and their Scientific Committees.
2.3. Feedback from other MSE meetings (e.g. San Diego, January 2018)
2.4. Identification of additional key issues required to further facilitate adoption of Management Procedures in the tRFMOs
2.5. The Marine Stewardship Council (MSC) – harmonisation with MSE process
3. Conditioning operating models
3.1. Multispecies MSEs (such as for Tropical Tunas)
3.2. Spatial issues in OM and multi-stock/species structures
4. Albacore Case Study
4.1. Progress at the various RFMOs
4.1.1.ICCAT
4.1.2.IOTC
4.1.3.IATTC/ISC/WCPFC
4.2. Progress on key research areas (if any)
4.3. Future cross RFMO collaboration on ALB MSE.
5. Provisions for Exceptional Circumstances
6. Computational aspects
6.1. Software and Code validation
6.2. Available tools to facilitate MSE
6.3. Organisation of the MSE exercise (consultants, centralised, individuals)
7. Dissemination of results
7.1. Tools to facilitate dissemination (wiki, websites, github, email lists, templates etc)
7.2. MSE glossary
7.3. Available visualisation tools (shiny apps and others)
7.4. Future avenues of development
8. Group recommendations
9. Closure and adoption of report

Appendix 2

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Appendix 3

Glossary of terms for harvest strategies, management procedures and management strategy evaluation

- This glossary was developed to encourage a consistent use of terms associated with harvest strategies, management procedures and management strategy evaluation processes underway across the five tuna RFMOs.
- It was developed from a range of sources, including ISSF, Rademeyer *et al*. 2007, IOTC, PEW Charitable Trust and a range of MSE practitioners with broad experience across tuna and other fisheries.
- A draft of the glossary was reviewed by participants in the 2018 Joint tuna RFMO Management Strategy Evaluation Working Group Meeting in Seattle and adopted for the purposes of improving consistency and clarity of communication in tRFMO MSE processes.
- The glossary is available for use by others with appropriate acknowledgement. (Anon. 2018. Glossary of terms for harvest strategies, management procedures and management strategy evaluation, http://www.tuna-org.org/Documents/MSEGlossary_tRFMO_MSEWG2018.pdf.)

Terms commonly used in Management Strategy Evaluation or Management Procedure literature

Term	Definition	Abbreviation/Symbol
Average Annual Variation (in catch/TAC)	The absolute value of the proportional TAC change each year, averaged over the projection period.	**AAV**
Biomass	Stock biomass, which may refer to various components of the stock. Often spawning stock biomass (SSB) of females is used, as the greatest conservation concern is to maintain the reproductive component of the resource.	**B**
Candidate Management Procedure	An MP (defined below) that has been proposed, but not yet adopted.	**CMP**
Conditioning	The process of fitting an Operating Model (OM) of the resource dynamics to the available data on the basis of some statistical criterion, such as a Maximum Likelihood. The aim of conditioning is to select those OMs consistent with the data and reject OMs that do not fit these data satisfactorily and, as such, are considered implausible.	
Error	Differences, primarily reflecting uncertainties in the relationship between the actual dynamics of the resource (described by the OMs) and observations. Four types of error may be distinguished, and simulation trials may take account of one or more of these: • Estimation error: differences between the actual values of the parameters of the OM and those provided by the estimator when fitting a model to the available data; • Implementation error: differences between intended management actions (as output by an MP) and those actually achieved (e.g. reflecting over-catch); • Observation error (or measurement error): differences between the measured value of some resource index and the corresponding value calculated by the OM; • Process error: natural variations in resource dynamics (e.g., fluctuations about a stock-recruitment curve or variation in fishery or survey selectivity /catchability).	

Term	Definition	Abbreviation/Symbol
Estimator	The statistical estimation process within a population model (assessment or OM); in a Management Strategy Evaluation (MSE) context, the component that provides information on resource status and productivity from past and generated future resource-monitoring data for input to the Harvest Control Rule (HCR) component of an MP in projections.	
Exceptional circumstances	Specifications of circumstances (primarily related to future monitoring data falling outside the range covered by simulation testing) where overriding of the output from a Management Procedure should be considered, together with broad principles to govern the action to take in such an event.	
Feedback Control	Rules or algorithms based, directly or indirectly, on trends in observations of resource indices, which adjust the management actions (such as a TAC change) in directions that will change resource abundance towards a level consistent with decision makers' objectives.	
Harvest Control Rule (also Decision Rule)	A pre-agreed and well-defined rule or action(s) that describes how management should adjust management measures in response to the state of specified indicator(s) of stock status. This is described by a mathematical formula.	**HCR**
Harvest Strategy	Some combination of monitoring, assessment, harvest control rule and management action designed to meet the stated objectives of a fishery. Sometimes referred to as a Management Strategy (see below). A fully specified harvest strategy that has been simulation tested for performance and adequate robustness to uncertainties is often referred to as a Management Procedure.	**HS**
Implementation	The practical application of a Harvest Strategy to provide a resource management recommendation.	
Kobe Plot	A plot that shows the current stock status, or a trajectory over time for a fished population, with abundance on the horizontal axis and fishing mortality on the vertical axis. These are often shown relative to B_{MSY} and to F_{MSY}, respectively. A Kobe plot is often divided into four quadrants by a vertical line at $B=B_{MSY}$ and a horizontal line at $F=F_{MSY}$.	
Limit Reference Point	A level of biomass below, or fishing mortality above, which an actual value would be considered undesirable, and which management action should seek to avoid.	**LRP**
Management Objectives	The social, economic, biological, ecosystem, and political (or other) goals for a given management unit (i.e. stock). These typically conflict, and include concepts such as maximising catches over time, minimising the chance of unintended stock depletion, and enhancing industry stability through low inter-annual variability in catches. For the purposes of Management Strategy Evaluation (MSE) these objective need to be quantified in the form of Performance statistics (see below).	**Objectives, MOs**

Term	Definition	Abbreviation/Symbol
Management Plan	In a broad fisheries governance context, a Management Plan is the combination of policies, regulations and management approaches adopted by the management authority to reach established societal objectives. The management plan generally includes the combination of policy principles and forms of management measures, monitoring and compliance that will be used to regulate the fishery, such as the nature of access rights, allocation of resources to stakeholders, controls on inputs (e.g. fishing capacity, gear regulations), outputs (e.g. quotas, minimum size at landing), and fishing operations restrictions (e.g. closed areas and seasons). Ideally, the Management Plan will also include the Harvest Strategy for the fishery or a set of principles and guidelines for the specification, implementation and review of a formal Management Procedure for target and non-target species.	
Management Procedure	A management procedure has the same components as a harvest strategy. The distinction is that each component of a Management Procedure is *formally specified, and the combination* of monitoring data, analysis method, harvest control rule and management measure has been simulation tested to demonstrate adequately robust performance in the face of plausible uncertainties about stock and fishery dynamics.	**MP**
Management Strategy	Synonymous with harvest strategy. (But note that this is also used with a broader meaning in a range of other contexts.)	
Management Strategy Evaluation	A process whereby the performances of alternative harvest strategies are tested and compared using stochastic simulations of stock and fishery dynamics against a set of performance statistics developed to quantify the attainment of management objectives.	**MSE**
Maximum Economic Yield	The (typically annual) yield that can be taken continuously from a stock sustainably (i.e. without reducing its size) that maximizes the economic yield of a fishery in equilibrium. This yield occurs at the effort level that creates the largest positive difference between total revenues and total costs of fishing (including the cost of labor, capital, management and research etc.), thus maximizing profits.	**MEY**
Maximum Sustainable Yield	The largest (typically annual) yield that can be taken continuously from a stock sustainably (i.e. without reducing its size). In real, and consequently stochastic situations, this is usually estimated as the largest average long-term yield that can be obtained by applying a constant fishing mortality F, where that F is denoted as F_{MSY}.	**MSY**
Observation Model	The component of the OM that generates fishery-dependent and/or fishery-independent resource monitoring data from the underling true status of the resource provided by the OM, for input to an MP.	

Term	Definition	Abbreviation/Symbol
Operating Model(s)	A mathematical–statistical model (usually models) used to describe the fishery dynamics in simulation trials, including the specifications for generating simulated resource monitoring data when projecting forward in time. Multiple models will usually be considered to reflect the uncertainties about the dynamics of the resource and fishery.	**OM(s)**
Performance statistics/measures	A set of statistics used to evaluate the performance of Candidate MPs (CMPs) against specified management objectives, and the robustness of these MPs to important uncertainties in resource and fishery dynamics.	
Plausibility (weights)	The likelihood of a scenario considered in simulation trials representing reality, relative to other scenarios also under consideration. Plausibility may be estimated formally based on some statistical approach, or specified based on expert judgement, and can be used to weight performance statistics when integrating over results for different scenarios (OMs).	
Precautionary Approach	An approach to resource management in which, where there are threats of serious irreversible environmental damage, lack of full scientific certainty is not used as a reason for postponing cost-effective measures to prevent environmental degradation.	**PA**
Reference case (also termed reference scenario or base case)	A single, typically central, conditioned OM for evaluating Candidate MPs (CMPs) that provides a pragmatic basis for comparison of performance statistics of the CMPs.	**RC (or BC)**
Reference set (also termed base-case or evaluation scenarios)	A limited set of scenarios, with their associated conditioned OMs, which include the most important uncertainties in the model structure, parameters, and data (i.e. alternative scenarios which have both high plausibility and major impacts on performance statistics of Candidate MPs).	**RS**
Research-conditional option	Temporary application of an MP that does not satisfy conservation performance criteria, accompanied by both a research programme to check the plausibility of the scenarios that gave rise to this poor performance and an agreed subsequent reduction in catches should the research prove unable to demonstrate implausibility.	
Robustness tests	Tests to examine the performance of an MP across a full range (i.e. beyond the range of the Reference Set of models alone) of plausible scenarios. While plausible, robustness test OMs are typically considered to be less likely than the reference set OMs, and often focus on particularly challenging circumstances with potentially negative consequences to be avoided.	
Scenario	A hypothesis concerning resource status and dynamics or fishery operations, represented mathematically as an OM.	

Term	Definition	Abbreviation/Symbol
Simulation trial/test	A computer simulation to project stock and fishery dynamics for a particular scenario forward for a specified period, under controls specified by a HS or MP, to ascertain the performance of that HS or MP. Such projections will typically be repeated a large number of times to capture stochasticity.	
Spawning Biomass, initial	Initial spawning biomass prior to fishing as estimated from a stock assessment.	**SSB_0**
Spawning Biomass, current	Spawning biomass (SSB) in the last year(s) of the stock assessment.	**$SSB_{current}$**
Spawning Biomass at MSY	The equilibrium spawning biomass that results from fishing at F_{MSY}. In the presence of recruitment variability, fishing a stock at F_{MSY} will result in a biomass that fluctuates above and below SSB_{MSY}.	**SSB_{MSY}**
Stationarity	The assumption that population parameter values are fixed (at least in expectation), and not varying systematically, over time. This is a standard assumption for many aspects of stock assessments, OMs and management plans.	
Stock assessment	The process of **estimating** stock abundance and the impact of fishing on the stock, similar in many respects to the process of conditioning OMs.	
Target Reference Point	The point which corresponds to a state of a fishery and/or resource which is considered desirable and which management aims to achieve.	**TRP**
Trade-offs	A balance, or compromise, achieved between desirable but conflicting objectives when evaluating alternative MPs. Trade-offs arise because of the multiple objectives in fisheries management and the fact that some objectives conflict (e.g. maximizing catch vs minimizing risk of unintended depletion).	
Tuning	The process of adjusting values of control parameters of the Harvest Control Rule in a Management Procedure to achieve a single, precisely-defined performance statistic in a specified simulation test. This reduces confounding effects to allow the performance of different candidate MPs to be compared more readily with respect to other management objectives. For example, in the case of evaluating rebuilding plans, all candidate MPs might be tuned to meet the rebuilding objective for a specified simulation trial; then the focus of comparisons among MPs is performance and behaviour with respect to catch and CPUE dimensions.	
Weight(s)	Either qualitative (e.g. high, medium, low) or quantitative measures of relative plausibility accorded across a set of scenarios.	
Worm plot	Time series plots showing a number of possible realizations of simulated projections of, for example, catch or spawning biomass under the application of an MP for a specific OM or weighted set of OMs.	