REPORT OF THE 2018 ICCAT BLUEFIN TUNA SPECIES GROUP MSE INTERSESSIONAL MEETING

(Madrid, Spain 16-20 April 2018)

1. Opening, adoption of Agenda and meeting arrangements

The meeting was held at the ICCAT Secretariat in Madrid, 16-20 April 2018. Dr. Douglas Butterworth (Professor Emeritus, University of Cape Town) served as Chair for both the West and East-Mediterranean bluefin tuna, opened the meeting and welcomed participants. Dr. Miguel Neves dos Santos (ICCAT Assistant of the Executive Secretary) addressed the Group on behalf of the ICCAT Executive Secretary, welcomed the participants and highlighted the importance of the meeting for the ICCAT Management Strategy Evaluation (MSE) process regarding bluefin. The Chair proceeded to review the Agenda, which was adopted with changes (**Appendix 1**).

The List of Participants is included in **Appendix 2**. The List of Documents presented at the meeting is attached as **Appendix 3**. The abstracts of all the SCRS documents presented at the meeting are included in **Appendix 4**. The following served as Rapporteurs:

Sections	Rapporteur
Items 1 and 15	M. Neves dos Santos
Item 2	D. Die
Item 3	P. de Bruyn, C. Fernandez
Item 4	P. de Bruyn, C. Fernandez
Item 5	A. Gordoa, P. de Bruyn
Item 6	C. Fernandez, C. Brown
Item 7	N. Duprey, G. Diaz
Item 8	J. Walter, J.J. Maguiere
Item 9	A. Kimoto, S. Miller
Item 10	G. Merino
Item 11	G. Melvin, N. Abid
Item 12	S. Nakatsuka
Item 13	D. Butterworth, D. Die
Item 14	P. De Bruyn

2. Introduction to MSE/Management Procedures (MP) issues

The discussion concerning this agenda item was held together with the Swordfish Species Group.

2.1 Where is ICCAT with MSE?

The Chair of the SCRS summarized (SCRS/P/2018/019) the context around which the MSE work is being conducted by ICCAT. He noted that ICCAT recommendations (Rec. [15-04] and Rec. [15-07]) adopted in 2015 cemented the decision of the Commission regarding committing to an MSE process to support the development of harvest control rules. The Commission identified priority stocks, and Rec [15-04] tasked the SCRS with the development of a harvest control rule specifically for northern albacore. Rec [15-07] identified North albacore, bluefin tuna, North swordfish and tropical tunas stocks as priority and established a work plan and timetable that were subsequently modified every year since by the SCRS and the Commission. Changes to the timetable were again adopted in 2017 by the SCRS which also defined the major steps for the technical work to be completed as part of the MSE. These steps were detailed in a timetable chart in the 2017 SCRS report and reflected the earliest dates that the SCRS could provide enough information to the Commission to consider harvest control rule options for each stock: 2019 for Bluefin tuna, 2020 for northern swordfish and 2021 for tropical tunas. The SCRS provided advice on a variety of HCRs for northern albacore in 2017 and the Commission adopted an interim harvest control rule in 2017 [Rec. 17-04]. The SCRS Chair also pointed out that in May 2018 the Standing Working Group on Dialogue between Scientists and Managers (SWGSM) will focus on MSE and that a synthesis of the results of the current meeting would be provided to that meeting to facilitate discussions.

The Group thanked the Chair for this summary, and agreed that this information would be taken into account throughout the rest of the meeting.

2.2 What makes an MP an MP and an MSE an MSE

Presentation SCRS/P/2018/020 provided a summary of what the potential uses of MSE might be what types of Management Strategy are available as well as advice on MSE best practice.

The Group welcomed the presentation made on behalf of the author and acknowledged its relevance to the ICCAT MSE process. The Group stressed that the best practices and caveats regarding the MSE process and associated Management Procedures (MPs) highlighted in this presentation are important to take into account to move forward in this process. Of particular importance was the key observation that any MPs discussed and proposed should be clearly and fully specified so as to ensure complete reproducibility and reduce potential divergence in application.

2.3 Improving communication: the key requirement to improve the effectiveness of MSE processes

Presentation SCRS/P/2018/018 advised that the use of MSE to design and test candidate fisheries management approaches is expanding globally. Participation of managers, scientists and stakeholders should be an integral component of the MSE process. Open and effective communication among these groups is essential for the success of the MSE and the adoption of the management approach based on it. 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 drew on diverse experiences with MSE to identify two areas in which the implementation of MSE in multilateral fora may be improved: a) the use of formally constituted "dialogue groups" as a forum for exchange at the management-science interface, and b) the development of engaging, yet uncomplicated, visual communication tools for conveying key results to different audiences at each stage. While the presentation's focus was on the MSE processes underway in the Regional Fisheries Management Organizations (RFMOs) for tunas and tuna-like species, the advice provided is also pertinent for other fisheries pursuing MSE, international and domestic alike.

It was acknowledged that the need for a clear definition of MSE-related terms to be used by the Group is of fundamental importance, and as indeed these terms need to be standardized across RFMOs. There is great uncertainty in the use of certain terms, which in many cases mean different things to different people. It was noted that this presentation provided a draft glossary of terms targeted at managers and stakeholders. This glossary is not exhaustive, however, and advice was given that it is envisioned that at the Joint Tuna RFMO MSE Working Group meeting to be held in June, this glossary will be expanded and more technical definitions be added.

The structure and composition of the various groups that need to work to develop an MSE is also important and advice on this was provided. These groups occur at four levels: a) Sub groups conducting highly technical work providing summarized scientific information to b) a larger scientific body for review (like the SCRS) with discussion in c) both formal and informal dialogue-type intermediary group(s) (incorporating input from stakeholders) before very summarized recommendations are passed on to d) the Commission. The Commission's Secretariat has a role to play in this process as well as ensuring fluid communications between these groups and the dissemination of vital information. It was noted that the SWGSM and Panel meetings may not be adequate intermediary groups to allow true dialogue among scientists, managers and stakeholders, potentially necessitating the formation of additional informal groups, especially for more complicated MSE processes like that for Atlantic bluefin tuna.

To facilitate the ongoing MSE process, it was strongly suggested that there is a need to develop an MSE specific webpage for ICCAT, providing background information on the progress and developments, including information such as MSE-related management recommendations and timelines, as well as technical MSE development. A timeline for this will be discussed later.

The need to standardize the presentation of MSE outputs was also discussed.

The Group considered that the definition of management (including economic) objectives should be a primary step in the MSE process, although these objectives should start very broad and then be refined

iteratively as data and analyses become available and are integrated into the process. In other RFMOs it has been generally accepted that the performance of the MP or underlying HCR is more important to managers than the internal details of the MSE operating and MP models. The objectives and outputs may be defined at the decision-making level, but the technical aspects of the modelling should not be constrained from the outset.

2.4 The MSE/MP Trials Specification document

The ICCAT GBYP Core modelling Group external Contractor presented the Bluefin tuna Trials Specifications document, and elaborated thereon based on the work thus far of the Core modelling Group. It was stressed that the Trial Specifications document is a living document that will evolve over time and should be constantly updated. The Group agreed that in this case, the Bluefin tuna Trials Specification Document will be updated based on the recommendations arising from this meeting. This document as presented to the Group is included as **Appendix 7**. The Group stressed that trial specification documents should be developed for all species undergoing an MSE process (including one for the northern albacore MSE, which was used to provide advice to the Commission in 2017). In order to facilitate this, it was recommended that a template for a trial specification document be created, based on the current example, as this could be used for other species.

2.5 An example of initial CMP results and their graphical presentation

Document SCRS/2018/047 provided details on an initial exploratory exercise in which simple fixed proportion MP control rules are applied using composite abundance indices for the East and West areas, where these composites take weighted averages over standardized values of the agreed indices and are then averaged over the last three years for which they would be available.

The Group noted that the simplicity of presenting results is key. Too many outputs can be confusing and complicate the recommendations and outputs. Zeh plots, worm plots and basic projections are very useful to communicate information among scientists, but more simplified graphics showing the tradeoffs among key performance metrics (e.g., catch and stock status) are likely a sufficient level of detail for the Commission. Intermediate levels of detail are required for the intermediary bodies previously identified. The need to reduce the volume of model results was also discussed. Models that show very similar results should be removed as duplication is not beneficial. In addition, it may often be necessary to integrate results across models, although this should be done with caution so as not to hide or mask any uncertainties or key outcomes. In addition, the weighting of models is also important, based on relative plausibility. There are a number of ways of doing this with several examples available from other fora, and these should be discussed and defined. When presenting results, it was agreed that it is best not to disaggregate all the information but instead beneficial to cluster outputs to the extent possible (to make them simpler), but ensuring no important details are masked or omitted.

2.6 LRPs in assessments and in MSE/MPs (related to SWO agenda)

The Group was informed that the Swordfish Species Group were looking at methods to better define limit reference points or to verify that the currently adopted Limited Reference Points (LRP) for this species is suitable. The Group acknowledged that it is important to define exactly what is meant by an LRP as differences in definition in different fora can and has led to confusion. Furthermore it was agreed that an LRP is necessary at this stage, but how it can be estimated needs further discussion, possibly at the species-specific meetings.

2.7 Multi-year support for MSE

The Group strongly stressed that it is clear that MSE is a multi-year process (2-3 years minimum) that requires funding and technical support throughout its duration. The Commission needs to be made aware of this requirement and the necessary resources must be made available for the process to succeed.

2.8 Roadmap

The Group noted the SCRS MSE calendar was included as part of the MSE budget proposal (Appendix 13 2017 SCRS report). Although such calendar provides more details than the Commission MSE roadmap (ICCAT Report of Biennial Period 2016-2017, Part I, 2016 (Vol. 1), Annex 7.2) the Group agreed that more

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details are needed for each MSE process and also that the calendar has to be extended for a longer period. The final roadmap must include other stocks and realistic deadlines for each key milestone for advancing the MSE processes (including guillotines dates: dates by which final decisions must be made where revisiting these decisions will not be entertained). In addition, clear objectives/deliverables should be defined for the various groups and planned meetings well in advance to allow CPCs to plan their participation. It is important to understand that each group has different responsibilities and will provide decisions and recommendations of varying technical levels and complexities. The role of each Working Group needs to be clearly defined, and their decision-making responsibilities defined and agreed upon. The Group stressed that more time and dedicated meetings are required to advance the MSE process, and that this should not be conducted on the periphery of other meetings. A proposal is required to define the flow of the MSE process, which can be based on experiences in other RFMOs/organizations in which MSE has been successfully conducted.

Finally, the Group agreed that the roadmap contains two key schedules: a short-term schedule to complete the current implementation of MSEs, and a schedule of the frequency of the revisions of the MPs (i.e. reviews of the MSE). Review schedules may be agreed and finalized, but there should be a clearly defined process to allow earlier reviews/revisions of the MSE (i.e. "exceptional circumstances" provisions).

3. Review of available documents on Bluefin tuna MSE and MSE trials specifications document update

Several of these documents were presented during the meeting. The Summaries of these documents can be found in **Appendix 4**. The discussions surrounding these documents are included in the relevant sections that follow. Document SCRS/2018/041 was not fully discussed during the meeting, as a response document was submitted by some core modelling group members. The authors of SCRS/2018/041 who were present at the meeting provided a Working Paper summarizing some of their proposals for changes to the Trials Specification document. Discussions in the meeting were based on this Working Paper, though as it was not possible to consider all the proposals made, their further consideration was deferred to a following meeting (see also section 7 of this report for detailed discussions).

4. Specification (prioritized) of further OM conditioning and comparative presentations of initial Candidate Management Procedure (CMP) results to be attempted by ICCAT GBYP modelling expert during the meeting

The ICCAT GBYP modelling expert noted that he should be advised as soon as possible of any CMP that should be run during the meeting. Five CMPs were presented to the meeting. Each CMP developer gave the ICCAT GBYP modelling expert their "preferred" CMP attempt thus far, and it was agreed that the expert would run these during the meeting and prepare a comparative display of results. This was considered as priority 1.

The ICCAT GBYP modelling expert was requested to prepare a common format for plots, so as to facilitate comparison of results from different CMPs.

There was a request to try to implement an "F0.1 MP", in order to have a scenario representing "status quo" (i.e. current) management. Such an MP depends on the stock assessment model used to assess the stock. In the current MSE round it is not possible to implement MPs based on a VPA or other age-based assessment methodology, because simulating age-structured or length-structured catch data is a complex issue. Some approximation could be considered and a subgroup was requested to propose how to address this in the simulation. The subgroup suggested implementing two approaches, based on OM-independent and OM-dependent on interpretations of F0.1, respectively; details are provided in **Appendix 5**. In plenary discussions with the entire Group, there were a variety of views expressed as to whether or not the subgroup's suggestions were appropriate. The Group concluded that attempting an "F0.1 MP" mimicking the F0.1 strategy implemented in 2017 (based on VPA in the east and VPA/SS in the west) was not appropriate at this stage due to the lack of OM generated age-structured data needed to construct such models within the MP. Consideration of the generation of such data will not be part of the current MSE process.

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A concern was raised that, for the West area, the results of conditioning some OMs graphed in document Carruthers T., and Butterworth 2017 (obtained from fitting the M3 model, which includes stock mixing) looked quite different from the accepted stock assessment for the West, with non-matching SSB trends. For this reason, the ICCAT GBYP modelling expert was requested to prepare an OM that resulted in a closer match to the accepted stock assessment for the West. Before doing this work, in order to better understand the historic range of variability encompassed by all 12 OMs fitted in Carruthers T., and Butterworth 2017, a plot overlaying the time series of SSB estimates resulting from this set of OMs was prepared; separate plots were produced for the East and West areas, as well as for the East and West stocks. These plots showed that the 12 OMs result in a variety of trends in the historic time series of SSB estimates for the West, including some with recent increasing trends, and this reduced the concern initially raised about non-matching trends. It was agreed to include the accepted 2017 stock assessments biomass trends (VPA in the east and VPA and SS3 in the west) in the plots, and to start the plots at an earlier year than 1983. The final decision on an OM specification matching results from the agreed stock assessments was deferred to Agenda Item 8.

It was noted that all 12 OMs in document Carruthers T., and Butterworth 2017 estimated that the West stock has been above SSB_{MSY} in all years since 1983 (as indicated by Figure 4 of that document); this does not agree with the general perception scientists have of stock history. The Group was later informed that the SSB_{MSY} values calculated so far by the software package were not correct, so that any SSB_{MSY} calculations from OMs presented to date should be disregarded. The calculation of SSB_{MSY} will be corrected in a later version of the package. This is to be done after this meeting.

It was noted the residuals of the fit to the indices shown in Figure 3 of Carruthers T., and Butterworth 2017 appeared to be very similar across all 12 OMs fitted. Although the comment was made focusing on the CAN_CMB_RR index, it seemed to apply to all indices and was a feature already noted by the Core Modelling Group in their 2017 report. The ICCAT GBYP modelling expert noted that it should be kept in mind that in the OMs each of these indices is taken to represent bluefin biomass in a particular quarter of the year and spatial area, rather than bluefin biomass in the entire West or East areas; therefore the residuals of a given index also correspond to a particular quarter and spatial area. This, however, does not explain the similarity of residuals across OMs. The ICCAT GBYP modelling expert conducted some preliminary investigation of this issue during the meeting, but indicated that more time was needed to fully examine the issue. Providing the plots of actual fits to the data, and not only the residuals, might be informative.

Concerns were raised that some of the unexpected results from the fit of the 12 OMs to historic data (i.e. the results shown in Carruthers T., and Butterworth 2017) might be due to the fact that these stock assessments only start in 1983, so that information from earlier years was not taken into account (this could, e.g., affect estimates of stock productivity). The ICCAT GBYP modelling expert clarified that for the 12 OMs, calculations start from year 1864, with biomass and recruitment before 1983 being estimated using Stock Reduction Analysis due to the absence of sufficient age or length composition data to fit statistical catch-atage or catch-at-length models. The Group later decided to try to extend the age-structured assessment back to 1975 in order to make better use of available information. This is to be done after this meeting.

The Group discussed whether it is important that the OMs used in the MSE (obtained from fitting the M3 model, with stock mixing) should match the historic results from the agreed stock assessments. The conclusions from this discussion are reported under Agenda Item 7.

5. Initial review of experiences with and comments on the coding package

The participants to the meeting were requested to share their experiences from using the software package developed by the ICCAT GBYP modelling expert. The participants that had tried out the package before the meeting indicated that in general they found it very good and easy to use. General comments included:

- The package generates future values of indices for use in MPs. It is not clear how far back in time those indices go.
- A better introduction in the software manual on how to design an MP could be helpful; currently, this is somewhat buried in the manual (in Section 7 of the manual). This was considered advantageous, but of low priority.
- The model is extremely complex and therefore computationally intensive. Problems with computational memory requirements were experienced by some users. This is not surprising because

the M3 model contains 2 stocks, 14 fleets, 3 age groups, quarterly time step and 10 spatial areas. Routines and modifications are being developed to reduce the memory requirements, but the time taken to run the model is unavoidable.

- It is important to display performance across OMs in a way that is simple and facilitates understanding of results and comparisons between CMPs. A shiny application will be added to the software package. Appropriate ways of weighting across OMs should be considered and included in the package apart from the shiny app, to be able to add those results to the ones obtained from single OMs.
- Regarding the conditioning of OMs, more information is required to understand all the behaviour and properties of the M3 model. The ICCAT GBYP modelling expert noted that a report pdf file can already be generated with the software for each OM fitted to historical data. The file displays fit and diagnostic information for the OM fits to historic data. The ICCAT GBYP modelling expert requested that the Group indicate if additional elements, e.g. additional diagnostics, should be displayed in the file.
- Clarification was sought about how the data (indices) are used to condition OMs, as well as how the software generates them in the MSE when used in MPs. This is addressed in the discussion on abundance indices reported below.
- When a TAC is set for year *y*, the last year of finalised data at the time of setting the TAC is *y*-2 for surveys and CPUE indices and *y*-3 for catch data. For years *y*-2 and *y*-1 the catch can be assumed to be equal to the TAC. Therefore the software package should not allow the use of data for any year after *y*-2 in the TAC computations by CMPs, as in reality these data would not be available at the time TAC computations were conducted. Once a CMP is available, it is important to show the benefit of having more recent information. This can be done by showing how the catch changes for the same level of risk.
- The B_{MSY} calculation in the software package version available for the meeting was not correct. A corrected version will be produced as soon as possible.
- Options for reporting depletion statistics when the stock-recruitment regime changes through time need to be clarified. The discussion and conclusions are summarised below.

5.1 Abundance indices used to condition OMs and to specify MP

The Group requested clarification on the abundance indices used to condition the OMs. The key questions and discussions were as follows:

Which indices are used to condition (i.e. fit to historical data) OMs?

The indices included were those shown in Table 1 (commercial CPUE) and 2 (survey indices) of the Trial Specifications Document (**Annex 1 to Appendix 7**). It was stressed that each index was linked to the abundance of BFT in a particular quarter of the year and spatial area. The so-called "master index" in the Trial specifications document can be interpreted as a prior on the spatial distribution of bluefin, but the OMs are then fitted using the indices in Tables 1 and 2 of **Annex 1 to Appendix 7**. It was noted that CPUEs were fitted from 1983 onwards only. The Group stated that it may be worth adding the age groups to which each CPUE applies to the table for easy reference.

The Group noted that the indices in Tables 1 and 2 **Annex 1 to Appendix 7**. of the Trial Specifications document do not exactly coincide with those used in the agreed stock assessments, nor are they all being used in the same way (e.g. some indices time-series are split in the 2017 assessment but have not been split in the OM conditioning). This is partly due to the fact that the indices used for conditioning OMs were decided before the final stock assessment decisions were made in 2017.

A subgroup was tasked with reviewing the indices used in the final assessments and proposing which of those indices (series and time periods) should be used in conditioning OMs. It was noted that the OM is a spatial assessment and that the indices used in such an assessment are not necessarily the same ones that may be appropriate in spatially-aggregated assessments. It was also noted that the agreed stock assessments split some abundance index series in two periods, but that that splitting could sometimes be problematic in the MSE context because it could make some abundance indices look better than they actually are (which has implications for how the indices are then generated if used to provide inputs to MPs). The conclusions from the entire Group after reviewing the subgroup's proposal on indices are presented below, with the final series to be used included in **Annex 1 to Appendix 7**.

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- 1. If the index was used in any of the agreed 2017 stock assessments (West: SS or VPA; East: VPA) then use it in the OM conditioning (except where specifically stated otherwise), in the same manner that it was used in either SS or VPA. The sub-list below highlights specific indices that needs to be changed or added to the set of indices used in OM conditioning:
 - a) Split French Aerial survey index
 - b) Add US RR >177 index
 - c) Include the Japanese LL GOM 1974-1981 index
- 2. Changes relative to the indices used in the agreed stock assessments:
 - a) Remove the Canada Combined index, and replace it with two indices: SWNS (assign it to WATL) and Gulf of St Lawrence (assign it to GSL) as these separate indices contain spatially specific information.
 - b) Move the start date of all indices to 1975
 - c) In the development of CMPs developers are permitted to use data for all indices prior to 1975 in their management procedures; this maintains consistency with data provided to previous assessments.
- 3. Sensitivity/Robustness test OM
 - a) Alt. OM: split Med Larval index
- 4. At the 2018 September Species Group meeting consider recommending advancing the terminal year of indices datasets to 2016 or 2017 for MSE OM conditioning, provided first that these data updates are accepted by the bluefin session.

After this meeting, the OMs will be reconditioned using the indices agreed during this meeting. It was also agreed that the "master index" should be recalculated based on the new choices of indices.

How are the indices projected from the OMs?

A subset of the indices in Tables 1 and 2 of the Trial Specifications document **Annex 1 to Appendix 7** are projected into the future in each OM and can be used to develop CMPs. The statistical properties (variance and autocorrelation) of the residuals from the OM fits are used to generate data in the future years in the MSE assuming a log-normal distribution.

How are the indices selected that will be projected from the OMs (and therefore be available for CMP construction)?

Clarification was provided that the main criteria were:

- 1. Likely only 3-4 indices can be projected for each of the East and West as more become computationally burdensome.
- 2. They should each be a series that is very likely to continue in the future.
- 3. The statistical properties of the residuals from the OM fits should be understood, so that indices with realistic behaviour can be generated for the MSE. Indices showing time-trends in residuals should be avoided.
- 4. Longer time-series are preferable.

It was noted that in the East there are very few indices that meet all aspects of the selection criteria listed above for being included as projected indices by the OMs and being made available for use in CMPs. Should too strict a selection be placed on the eastern indices, it is likely none would remain available for being projected from OMs and therefore some flexibility must be used in the selection process.

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The Group considered the implications of survey indices being selected for use in a CMP if these are then discontinued in the future. If such a situation were to occur, the MP may need to be re-evaluated earlier than initially planned. A useful exercise, which should be conducted at a later stage, is to retune the CMP assuming none of the 3 surveys for the East are available (so that only 1 fishery dependant index remains); the CMP would then be re-evaluated so as to keep the same level of risk and the Group could then examine how much the catch would need to be reduced in the absence of these 3 surveys. This would better justify the necessity for supporting the continuation of these surveys to managers.

Further conclusions from the Group after reviewing the subgroup's proposal on indices is presented below,

- 1. Alternative projected indices from the OMs made available for CMPs input (beyond those listed in the Trials Specification document).
 - a) Include Canada Acoustic index as a western projected index from OMs available for CMP input.
 - b) Once the new, corrected, residual plots are available for eastern and western indices, re-evaluate the indices to be projected in the OMs and be available for CMP input.

5.2 Reporting depletion statistics when the stock-recruitment regime changes through time

The Chair of the meeting suggested that a dynamic B0 concept¹ could be used for reporting depletion. This dynamic B0 would be obtained by projecting BFT abundance from 1864 onwards assuming zero catch in all years. If the stock-recruitment relationship changes at a particular time, the dynamic B0 approach will change biomass values gradually over a period of several years, and depletion statistics (B/B0_dynamic) will not show (e.g. step function) behaviour which renders interpretation problematic. It was noted that a similar "dynamic B_{MSY} " concept could be used, with the dynamic B_{MSY} being a constant (i.e. time-invariant) fraction of the dynamic B0 (this holds for all the models being considered, as projections fix the selectivities at age at their current values). The ICCAT GBYP modelling expert was requested to prepare an illustrative plot for the next meeting to help understand the idea.

6. Presentation of initial CMPs and associated results by each developer/set of developers

IMPORTANT NOTE: all initial results of CMPs were explored only as early examples; this is especially important to appreciate as the OMs will be re-conditioned with different indices (see section 4) and the indices will extend back to 1975 (no longer 1983). Therefore any results were explored for discussion purposes only, and it is expected that any trends in the results could well change.

Brief presentations were provided by the 5 scientists that had prepared CMPs in advance of the meeting. The idea was to get an overview of the CMPs considered so far and to see the format of the comparative plots that the ICCAT GBYP modelling expert had been requested to prepare. Results from applications of CMPs will be different in September, after the planned OM-reconditioning and other expected developments. Therefore, results at this stage were considered for illustrative purposes only.

All of the CMPs presented are directly based on abundance indices used in the stock assessments, i.e. they are empirical rather than estimation/model-based. It was noted that developing some model-based MPs is possible with the existing structure of the OMs (e.g. MPs based on surplus production models, as was done for North albacore).

The technical details of some of the CMPs are provided in **Appendix 6** of this report and additional details can be found in the documents SCRS/2018/P_15; SCRS/2018/P_16; SCRS/2018/P_47; SCRS/2018/55; SCRS/2018/59.

Some lessons learnt from this work so far include the following.

The ICCAT GBYP modelling expert explained that models in the software package refer to precision and bias in catch data, but they do not refer to how the abundance indices used in MPs are generated; the generation of abundance indices is based on the statistical properties of the residuals from the OM fits. The "Perfect"

¹ Some CPCs used the term dynamic B0 differently from what is defined here.

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observation model is used for testing by developers and not really intended for their final presentation of results; if a CMP fails under the "Perfect" data, it should not be developed further. The "Good" model is the one to be used by default and the "Bad" model is mostly intended as a robustness test.

Discontinuities in HCRs (such as the existence of thresholds that have appreciable impacts on resulting TAC recommendations depending on which side of the threshold a certain variable falls) should be avoided. Such discontinuities are often problematic because noise in data or in results can end up strongly impacting on TAC recommendations. Instead, a linear relationship from slightly above to slightly below the intended threshold should be used.

Explanation was provided that certain parameters in HCRs (e.g. a target index value that may be used in the rule) often become tuning parameters in the MP and are chosen so as to achieve a particular performance. The number of years in a management period (the time period over which a TAC is set each time) could be of the order of 2 or 3 years, but this is to be discussed with the Commission.

For this initial development of the OMs, a 20% limit on interannual TAC changes was imposed when running all the CMPs, whether specified explicitly within the CMP or not. The Group agreed that imposing such a constraint by default in all CMPs was not appropriate at this stage, and should be removed from the running of CMPs. Managers should be asked to provide feedback on desired level of interannual TAC changes, although this feedback is likely better requested at a later date after initial results have been presented to the Commission.

Comments pertaining to the comparison plots presented by the ICCAT GBYP modelling expert were as follows.

The plots prepared by the ICCAT GBYP modelling expert to compare performance of different CMPs under different OMs were found to be very useful, although it was noted that it could be difficult to interpret the results across large numbers of OMs. A sub-group (N. Duprey, G. Merino, H. Arrizabalaga, S. Miller, J. Walter, S. Nakatsuka, A. Gordoa, D. Butterworth and A. Kimoto) was organized to work by correspondence on how best to present results in upcoming scientific meetings. The subgroup will be providing a report to the next meeting of this Bluefin MSE Group.

Some initial thoughts included the following:

- For the CMPs considered, the differences in performance across OMs were usually greater than the differences across CMPs. The Group reviewed plots on overall catch level, interannual catch variability and resulting stock depletion. Catch and variability of catch should be reported by area, whereas depletion statistics should be reported by stock. Reporting abundance of bluefin by area may also be of interest.
- Interannual catch variability should be considered when examining the results, as this may have important operational and management impacts; often the fishing industry is in favour of low interannual TAC changes, although this is not always the case. The information shown in the plots was based on averages over the modelled 30 year projection period. The Group considered it would be useful to include additional plots showing Annual Average Variation information separately for interannual increases and decreases in catch, i.e. taking into account the sign as well as the magnitude of the changes.
- Among the OMs for which results were displayed, the OM that incorporated a regime shift implied the highest risk for the East stock; this is why considering the regime shift scenario is crucial for identifying appropriate CMPs for bluefin tuna.
- The plots should be inspected for results that look suspect according to the experts' understanding of bluefin dynamics and productivity, e.g. MPs leading to high catches at a level that has been seen to be unsustainable in the past should lead to careful investigation of the associated OMs.
- There were some instances where probability intervals on the projected average catch were very small and developers should examine the MPs concerned carefully to try to understand what causes this. Conversely, CMPs with large probability intervals on the projected average catch, or which

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cover a large range of potential catches/depletion levels, might be problematic, and the CMP developer should explore further what attributes of their CMP might be causing this.

- Evaluation criteria for CMPs: A CMP that results in depleting the stock to very low levels is obviously a failure. However guidance on additional depletion level(s) of concern (e.g. limit reference points, thresholds) has not yet been developed, nor have other objective criteria to determine what constitutes a failure (or success). It was considered that it would be better to wait until the changes planned to OMs and CMPs are implemented (i.e. until September 2018, at least) so that the space of what is feasible is better understood before setting more specific guidelines.

7. Development of a standard format for ready comparison of key results across CMPs and across trials

Due to time restrictions, the Group agreed to postpone the discussion of this particular issue. To facilitate this future discussion, the Group requested that Dr. Carruthers and the following members of the Group: N. Duprey, G. Merino, H. Arrizabalaga, S. Miller, J. Walter, S. Nakatsuka, A. Gordoa, D. Butterworth and A. Kimoto work intersessionally to develop a proposal to be presented at the next meeting of the Group.

8. Possible amendments to the coding package and its associated trials (SCRS/2018/041) and response, and WP in preparation

As noted in Section 4, the set of OMs presented to the meeting in the Trial Specifications document and Carruthers T., and Butterworth 2017 will be reconditioned after this meeting using the abundance indices agreed during the meeting. There were concerns in the Group that the behaviour of OMs was not sufficiently understood and that the OMs could benefit from some changes to input specifications (SCRS-2018/041). After review of the existing OMs, the Group made several recommended modifications to better capture the nature of uncertainties (Table 7.1). The Group also discussed and agreed changes that would be implemented in the Reference set of OMs and in the Robustness trials (using the terminology of Section 9 of the Trials Specification Document).

These changes are provided in the following sections:

8.1 General OM conditioning

To be able to use the whole series of the GOM larval index (1977-present) and to better capture a longer time period of the stock dynamics, the Group agreed that OM conditioning should start in 1975.

8.2 Recruitment scenarios used in OMs

- For the West, the "high recruitment" scenario (level 2 of uncertainty axis 1 "future recruitment" in Reference set of OMs in the Trials Specification document) was not captured correctly in the OM and must be re-specified. Any results seen for that scenario should, therefore, be dismissed. The problem was that a very high value of steepness (*h*) was being estimated, leading to very little difference between the hockey-stick and the High stock-recruitment (SR) dynamics. The meeting agreed to use *h*=0.6 which was generally within the range of steepness estimated in previous stock assessments of Western Bluefin tuna. It was stressed that the recruitment scenarios considered in the Reference set of OMs are meant to capture a representative range of uncertainties, but do not imply any particular relative weighting between the different scenarios (this is a matter that would be discussed at a subsequent meeting). It is also essential to ensure that the stock recruitment relationship for the high recruitment scenario has a virgin recruitment (R0) that is substantially higher than that for the hockey-stick.
- It was also agreed to fix the hinge point of the hockey-stick SR used for the West according to specifications similar to those used in previous stock assessments, e.g. the SSB threshold (hinge) has been set to the average SSB during a time period (usually 1990-1995) with the lowest estimated SSB, and R0 was calculated as the geometric mean recruitment during the time period after 1976 (Anon. 2014).

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- It was also pointed out that level 3 of uncertainty axis 1 "future recruitment" in the Reference set of OMs is meant to capture a possible regime shift in recruitment. In the West, a regime shift could have occurred in 1975 and in East from 1987 to 1988. In the West, the hockey-stick (level 1) is a scenario meant to capture that a regime shift to a lower recruitment regime had occurred, whereas the Beverton-Holt form (level 2) assumes that recruitment can still become potentially very high. Explanation was provided that past experience indicated that the regime-shift scenario (level 3) is crucial to ensure MPs with good performance are identified. The methodological implications of regime shifts for performance evaluations of MPs were already discussed under the "dynamic B0" paragraph earlier in this report.
- The Group agreed that appropriate text is needed in the Trials Specification document, and plots of the stock-recruitment fits, as well as of the recruitment trends considered for each OM to explain the basis for the recruitment scenarios chosen for the Reference set of OMs.
- It was also noted that the SSB_{MSY} calculations needed to be redone as part of the OM reconditioning.

Abundance scenarios and extent to which results from conditioning OMs should match those from the agreed stock assessments:

Uncertainty axis 2 ("Abundance") in the Reference set of OMs presented by the ICCAT GBYP modelling expert, contains scenarios (levels B and C) in which the results from conditioning the OMs were "forced" to match certain features of the 2017 stock assessments. The Group discussed if such matching is appropriate, and additionally considered potential modifications to the scenarios examined under this factor. There was general agreement that differences between the OMs and the agreed stock assessments should be expected because the OMs contain many more features, such as spatial disaggregation and stock mixing, which are not included in the 2017 stock assessments. However, the results from conditioning OMs should be carefully inspected to check if there are substantial discrepancies with scientists' broad understanding of the overall stock dynamics of bluefin tuna. In particular, it is easier to obtain acceptance of the results if at least some of the OMs reflect the public perception of stock trends to some extent. For instance, some OMs for both stock areas should show that overfishing has occurred and that the stocks have been overfished during some periods. Another example would be in the eastern Atlantic, where OMs would not be expected to show increases in biomass at times when catches were in the order of 50,000 t per year.

Hence the Group recommends three proposals for abundance.

PROPOSALS: It was agreed that the Reference set of OMs should contain at least 3 scenarios for uncertainty axis 2 "abundance":

- A. Best estimate OM fit. If this implies large differences with the accepted assessments, the reason(s) for the differences should be identified.
- B. The trends and scales in SSB resulting from OM conditioning for both East and West are simultaneously forced to follow the results of the 2017 stock assessments closely in terms of both absolute magnitude and trend (the final assessments agreed by SCRS in 2017 should be used for this). This should help identify the reasons for any possible differences identified in A.
- C. This is similar to scenario A but including some broad constraints to prevent the results of the OM conditioning from diverging from the current general knowledge of past stocks dynamics. The Group considered that it would be appropriate to require that the results of the OM for both East and West BFT show that they were overfished at some point in the past. This means not just spawning stock biomass being lower than SSB_{MSY}, but also a low relative SSB level in certain time periods. Preventing SSB increases during past periods of high catches may also be considered and should be clearly explained if it is included in the scenario. These ideas are meant to reflect public perception of BFT being at low level (particularly in the east) around the turn of the century. The ICCAT GBYP modelling expert was given flexibility here, depending on outcomes found from various explorations.

The ICCAT GBYP modelling expert requested that the Group indicate the kinds of diagnostics that it would need to see and discuss to be comfortable with an OM. Many current diagnostics are available in operating-model specific reports that will be provided by the ICCAT GBYP modelling expert.

8.3 Movement and stock mixing

Substantial discussions were held to clarify how movement is modelled in the OMs (the OMs have an age and stock of origin-dependent movement probability between spatial areas that changes from quarter to quarter but is the same for all years). There was substantial discussion concerning the extent to which this assumption can be considered realistic, while understanding that the data available to estimate time-varying movement is limited. While movement rates for a given age, stock and quarter are assumed to be constant from year to year in the OMs, the stock composition in any particular region, quarter and year is variable. The OM uses the fits to the available electronic tag data as well as genetic and otolith micro-chemistry information to estimate movement rates; it should be noted that all data used to fit the OMs contribute to some extent to the estimation of movement rates. It is noteworthy that stock composition data obtained for the Canadian GSL region from genetics show increased representation of eastern stock bluefin tuna in recent years.

Other movement scenarios could be considered in the OMs such as increasing the weight of GSL in the gravity model, or allowing time-varying movement rates but, given time constraints and information content in the data, it was agreed to keep the baseline movement scenario used so far (e.g. same movement probabilities in all years). The increasing percentage of eastern origin fish in the GSL was noted, for which separating the GSL and SWNS indices in the OMs (see section 4) may address this issue.

There is a concern that movement rates may be overestimated by the fitting to the observed stock composition data, as the composition data always has some element of uncertainty and often has some non-negligible fraction of a much smaller stock, even in areas where it has previously been assumed that no mixing occurs. Hence movement rates may be overestimated and the spatial models, in order to improve fits, may put biomass in areas that are not currently fished, based on electronic tag information.

The Group had a strong preference that the Reference set of OMs encompass alternative mixing scenarios. Given the complexity of developing alternative scenarios, the Group outlined several proposals. Initially some were proposed to be included in the axis of uncertainty in developing the Reference set of OMs; however due to concerns around increasing the number of OMs (making the presentation of the results and running of the MSE difficult), the proposal was modified to include them as part of the robustness tests. There is, however an expectation that, provided the alternative mixing OMs meet performance criteria, they may be upgraded to the Reference set at a later meeting.

PROPOSALS: The Group agreed to two mixing scenarios (i and ii below) and one change to the treatment of tagging data (iii below):

- i) Halve the rates of mixing, e.g. if the observed fraction of Western fish in an assumed eastern year/area/quarter is 40%, this scenario will assume that it is only 20%. Such changes will reduce the estimated rates of movement between the East and West and may represent a plausible scenario. This set of OMs will be used for the robustness set, with high priority.
- ii) Condensing the 10-area model into a 7-area model, merging areas 6+7, 5+9 and 1+2. This is also recommended to be added as a robustness test; however noting this also corresponds to a structural change in the model which has major coding implications, it is therefore given a relatively low priority.
- iii) The Group also agreed that tagging of juveniles by AZTI in the Bay of Biscay will be used to estimate movement rates, assuming that those fish are of Eastern origin, based on previous otolith chemistry studies suggesting this is the case (Fraile *et al.* 2014). This change will be made across all OMs.

The Group considered several other options for different mixing scenarios such as use of only one source of mixing information at a time (e.g. only microchemistry or only DNA) or to allow time-varying movement or average mixing rates (Hazin *et al.* 2018), but these were not considered for alternative OMs at this point in time.

The Group also discussed the fact that the agreed VPA stock assessments are known to be sensitive to the assumed Fratio, which points to an unknown level of cryptic biomass. Concern was expressed that large amounts of cryptic biomass could impact the OMs, by moving large quantities of fish outside the range of the fishery. To address this, the Group agreed that the spatial distribution of the vulnerable and non-vulnerable (cryptic) biomass by stock in each area should be plotted over time.

8.4 Catchability and indices

Noting that recommendations for indices used in the historical OM conditioning are captured in section 4, only aspects of future index specifications are discussed in this section of the report.

PROPOSAL:

A. Apply a 2% increase in catchability for projected fishery-dependent CPUE indices in a robustness test.

This proposal is to apply a 2% increase in catchability for the forecast components of OMs to protect against undetected depletion. This is to be applied as a robustness test. This would apply only to fishery-dependent indices of stock sizes. It is assumed that fishery-independent indices of stock size will have constant catchability. If the methods to collect the fishery independent indices of stock size are changed in future, it is assumed that a calibration coefficient will be derived at the time that occurs. The two percent value is based on estimated change in catchability for one of the stock size indices over a 45-year period.

The Group noted that catchability will not necessarily always increase. For some indices, environmental factors may decrease catchability and changes in catchability are not necessarily expected to be monotonic. The Group suggested that these changes, including step changes in catchability, be included in robustness tests as a second priority.

A proposal was considered for including index-specific variance, autocorrelation and non-linearity in the projected indices. There were concerns that the method of estimation of the autocorrelation and non-linearity may have been inappropriate and that these estimates should be re-examined for a revised Trials specification document. Once the estimation procedure has been finalised and reconditioning completed according to decisions made at this meeting, the Group agreed to re-run the estimation of autocorrelation and non-linearity and, if statistically justified, use those in a robustness test.

8.5 Summary of recommended OM changes

Overall, the following changes are recommended by the Group to the OMs (**Table 1** below); they are denoted according to whether they apply to all OMs, the Reference set OMs only or the robustness set OMs only.

Reference set

Three major uncertainty axes: future recruitment, abundance and natural mortality/maturity (in combination) for conditioning and projections. These axes assume that the options of East and West are linked across the rows of the table below. This is done with the intention of capturing extremes.

Table 1. Recommended changes to Reference set OMs.

	West	East
<u>Futur</u>	<u>e recruitment</u>	
1	Hockey-stick with fixed hinge point starting from 1975	88+ B-H with <i>h</i> =0.98
2	B-H with h= 0.6 fixed, high R0 *	88+ B-H with <i>h</i> =0.70
3	Hockey-stick changes to B-H after 10 years	88+ B-H with <i>h</i> =0.98 changes to 50-87 B-H with <i>h</i> =0.98 after 10 years

<u>Abundance</u>

A Best estimate

B East-West area spawning biomasses match 2017 VPA assessment

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<u>Spaw</u>	ning fraction both stocks	Natural Mortality rate both stocks
Ι	Younger	High
II	Younger	Low
III	Older	High
IV	Older	Low

C Prior on trend and/or depletion to match perception of heavy exploitation

*High recruitment should reflect higher R0 than for hockey-stick.

Combinations for Reference Set

A full cross of (1, 2, 3) x (A, B, C) x (I, II, III, IV), i.e. 36 scenarios in total.

Recommended changes to robustness set OMs (Appendix 7 section 9b)

High priority

- 1. Robustness to less mixing (50%): crossed design with 4 tests, corresponding to 1A, 2A, 1B, 2B in **Table 1** above.
- 2. Future catches in both the West and the East + Med are each year 20% bigger than the TAC as a result of IUU fishing (of which the MP is not aware)
- 3. An undetected increase in future catchability for CPUE-based abundance indices of 2% per annum
- 4. Non-linear index-abundance relationships: revise estimates based on more appropriate statistical estimation and revise projection components of OMs
- 5. Robustness to more mixing crossed design with 4 tests, corresponding 1A, 2A, 1B, 2B in **Table 1** above).

Low priority

- 1. Future recruitment change as in 3), but with probability of 0.05 for each of the first 20 years of projection.
- 2. Alternative assignments to stock of origin of historical catches from the South Atlantic (off Brazil).
- 3. Seven area model. Condensing the 10-area model into a 7-area model, merging areas 6+7, 5+9 and 1+2.

"Second round" issues (not in this current MSE process)

The following aspects of uncertainty are recommended to be postponed at this time for consideration rather in a "second round":

- 1. More than two stocks
- 2. Use of CAL (CAS in ICCAT) data in an MP
- 3. TACs allocated on a spatially more complex basis than the traditional West and East + Med
- 4. Changes in technical measures affecting selectivity
- 5. Changes in stock distributions in the future
- 6. Future changes in proportional allocation of TACs amongst fleets

9. Presentation of results of possible refinements of CMPs developed during the meeting

Due to meeting time constraints and the need to first make amendments to the OMs in the coding package, there were no further refinements to the CMPs presented made during the meeting.

10. Agreement of a tuning specification (possibly more than one) to facilitate comparison of future results presented (e.g. median target level of biomass at the end of the projection period for each of the West and the East populations for a single specified trial)

A fuller explanation of tuning is provided in **Appendix 8**.

The Group noted that the development tuning control parameter value will be specific for each of the two stocks.

Every developer will be able to decide their own preferred tuning. The separate development tuning is to help differentiate the performance of two CMPs in conditions where their median depletion after 30 years is the same.

For the development tuning, in one particular trial every developer will tune to get median $SSB/SSB_{MSY}=1$ in projection year 30 for a central OM in addition to their own preferred tuning. This exercise will be for internal use between the developers and the MSE Group.

When presenting results to decision makers, performance metrics will be averaged across OMs.

11. Initial discussion and specification of aspects where input from Commission/stakeholders will likely assist future refinement of CMPs (this will relate, in part, to increased detail regarding objectives and trade-offs)

The Standing Working Group on Dialogue between Scientists and Managers (SWGSM) meeting (21-23 May 2018) will have an agenda item specific to bluefin tuna MSE (item 6.2). The objective is to initiate input from stakeholders to assist in future refinement of CMPs. Furthermore, there is a need for guidance on the general ICCAT MSE roadmap and the recommendations on MSE to be provided to the Commission.

Input to be provided to the SWGSM will be in the form of a synthesis of the report of this meeting. The SCRS Chair will prepare this synthesis and circulate it to all participants of this meeting by 28 April. Feedback on this synthesis will be required by 5 May. After that the SCRS Chair will modify the report and make it available to all (including SWGSM participants) by 9 May².

The Synthesis will have the following goals:

- Status update on MSE-related work by the SCRS
 - Summarize work progress to date, and demonstrate the importance of continued resourcing of the GBYP MSE work
 - Provide sufficient and understandable information to ensure useful feedback from the SWGSM participants and increase SWGSM participants' engagement in the MSE work conducted by the SCRS
 - To convey to Commission a realistic schedule for completing the MSE. Based on experiences elsewhere, even in a very optimistic situation the Bluefin tuna Species Group will likely need at least four more one-week meetings dedicated to this MSE. The current schedule which suggests completing MSE by 2019 needs to be revised accordingly.

- Consideration of candidate management procedures (CMPs)

- Describe the general types of characteristics of the MPs being proposed so that SWGSM participants can provide feedback on:

² This report was finalized on 9/5/2018, by which time these deadlines had not been met and the draft synthesis document was yet to be produced by the Chair of the SCRS.

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- The acceptability of such types of MPs
- Possible TAC constraints
- General objectives for MPs in broad terms (e.g. priorities amongst resource conservation, maximizing catches and minimizing the extent of TAC changes made, with advice on the intervals between TAC changes which are preferred)
- Understand when further input on more detailed MP objectives will be required and useful.

- Transparency and communication of MSE results

- Obtain guidance on possible modifications to the current MSE process to improve the communication of MSE results and the engagement of SWGSM participants in the MSE development.

12. Work programme for further CMP refinement, with deadlines, leading to results sought for presentation at the September 2018 Bluefin Species Group meeting

Tentatively the following near-term work schedule was suggested by the Group. The Group discussed intensively the feasibility of the September meeting of the Group (item 5) and many concerns were expressed about the heavy meeting schedule. It was explained by the Secretariat that moving the date of the meeting would require re-writing of the contract for GBYP modelling. The general purpose of the meeting was understood to be for further discussion of re-conditioning of OMs and review of results of revised CMPs, continuing building upon the discussions of the current meeting.

- 1. End of May Completion of updates to the OM based on this meeting (the ICCAT GBYP modelling expert)
- 2. Mid-June Comments on updated OMs
- 3. Early July ICCAT GBYP modelling expert circulates updated package on the basis of finalised revisions
- 4. Mid July to early September:
 - a) Developers rerun adjusted CMPs on updated package;
 - b) documents prepared on further conditioning issues requiring attention
- 5. Activities occurring after early September are driven by the recommendations in section 13. Decisions in this regard will be made by the SCRS Chair, BFT Rapporteurs and the Secretariat.

13. Recommendations

The Group identified a number of challenges faced by the Bluefin tuna Species Group in effectively participating and engaging in the Bluefin tuna MSE process:

- The need for mechanisms, including well planned meetings, which facilitate the engagement of the Bluefin Species Group at different levels and which ensure maintaining the momentum of the MSE process.
- The difficulties encountered by Bluefin Species Group members to engage effectively in the process earlier because of the demands put by the 2017 Bluefin Stock Assessment.
- The fact that further engagement of the Bluefin tuna Species Group in the MSE process is best achieved by meetings of the Species Group that are substantial in length (3+ days) and focused on the single topic of MSE.
- The difficulties faced by many CPCs to effectively engage in the multiple concurrent sessions occurring during the species Group week in September because of the limited number of scientists in the respective CPC delegations.
- The additional length of periods away from home generated by adding meeting days prior to the species Group week.

Given these challenges the Group recommends that:

- The decision of the number of days allocated to the Bluefin Species Group meeting of September, the agenda of such meeting, and the timing of the next core modelling Group meeting should consider the challenges above.
- Future core modelling Group meetings should encourage participation of anybody interested in providing input into the MSE process.
- The objectives and agenda of any core modelling Group meeting be widely circulated to all of the SCRS well in advance to help participation of all interested scientists in such a meeting.
- In early 2019 the SCRS conducts a one week intersessional meeting of the Bluefin tuna Species Group focusing on MSE.

Specific recommendations to the developer of the BFT MSE framework and the core modelling Group are included elsewhere in this report. There are a few general recommendations to the SCRS relevant to experiences from the Bluefin MSE:

- Other MSE processes in the SCRS should consider the advantages that the MSE framework developed by the ICCAT GBYP project may have for their own MSE processes. Such advantages include the current application of this framework to an ICCAT stock, the power and flexibility of the different modules of the framework and the experience acquired by several SCRS scientists in the use of this framework.
- The input from the Bluefin tuna Species Group to the SWGSM meeting (21-23 May 2018) should be in the form specified and following the process described in section 12 of this report.
- The establishment of a section solely dedicated to MSE in the ICCAT webpage. This section should contain descriptions of all MSE processes and the most important scientific outputs from such processes.
- Rapporteurs or designated representatives from Species Groups engaged in MSE processes should do everything possible to attend SCRS meetings that focus on MSE, even if the meeting is not a meeting of their respective Species Group.
- The SCRS should ask the Commission to identify a dedicated source of funding for the MSE processes, because all require a longer commitment than the typical 2-year funding cycle used by the Commission.
- A trial specification document should be developed and maintained for any MSE process initiated within the Commission. A template for such document should be developed.

14. Other matters

No other matters were discussed.

15. Adoption of the report and closure

The report was adopted by the Group and the meeting was adjourned.

References

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Adopted Agenda MSE Bluefin Tuna

- 1. Opening, adoption of Agenda and meeting arrangements
- 2. Introduction to Management Strategy Evaluation (MSE)/ Management Procedures (MP) issues
- 3. Review of available documents on Bluefin tuna MSE and MSE trials specifications document update
- 4. Specification (prioritized) of further OM conditioning and comparative presentations of initial Candidate Management Procedure (CMP) results to be attempted by GBYP modelling expert during the meeting
- 5. Initial review of experiences with and comments on the coding package
 - 5.1. Abundance indices used to condition OMs and to specify MPs
 - 5.2. Reporting depletion statistics when the stock-recruitment regime changes through time
- 6. Presentation of initial CMPs and associated results by each developer/set of developers
- 7. Development of a standard format for ready comparison of key results across CMPs and across trials
- 8. Possible amendments to the coding package and its associated trials (SCRS/2018/041) and response, and WP in preparation.
 - 8.1. General OM conditioning
 - 8.2. Recruitment scenarios used in Oms
 - 8.3. Movement and stock mixing
 - 8.4. Catchability and indices
 - 8.5. Summary of proposed OM changes
- 9. Presentation of results of possible refinements of CMPs developed during the meeting
- 10. Agreement of a tuning specification (possibly more than one) to facilitate comparison of future results presented (e.g. median target level of biomass at the end of the projection period for each of the west and the east populations for a single specified trial)
- 11. Initial discussion and specification of aspects where input from stakeholders will likely assist future refinement of CMPs (this will relate, in part, to increased detail regarding objectives and trade-offs)
- 12. Work programme for further CMP refinement, with deadlines, leading to results sought for presentation at the September Bluefin Species Group meeting.
- 13. Recommendations
- 14. Other matters
- 15. Adoption of the report and closure

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ICCAT GBYP PROGRAMME

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Reference	Title	Authors
SCRS/2018/041	Potential further considerations on the conditioning of Operating Models of Atlantic bluefin tuna	Kimoto A., Walter J., Lauretta M., Sharma R., and Rouyer T.
SCRS/2018/047	Results for initial explorations of simple candidate "fixed proportion" MPs for Atlantic Bluefin tuna based on the operating models package circulated	Butterworth D.S., Miyagawa M., and Jacobs M.R.A.
SCRS/2018/055	Designing and testing a multi-stock spatial management procedure for Atlantic bluefin tuna	Carruthers T.
SCRS/2018/059	A candidate Management Procedure for bluefin tuna	Hanke A.
SCRS/P/2018/015	Preliminary evaluation of MPs for Atlantic bluefin using MSE	Merino G., Arrizabalaga H., Rouyer T., and Gordoa A.
SCRS/P/2018/016	An extremely preliminary evaluation of some empirical management procedures	Walter J.
SCRS/P/2018/017	Overview of a MSE reference document: 'Specifications for MSE Trials'	Carruthers T., and Butterworth D.
SCRS/P/2018/018	Improving communication: the key requirement to improve the effectiveness of MSE processes	Miller S., Anganuzzi A., Butterworth D., Davies C., Donovan G., Nickson A., Rademeyer R., and Restrepo V.
SCRS/P/2018/019	Current state of MSE/HCR Process in ICCAT	Die D.
SCRS/P/2018/020	What makes an MP an MP and an MSE an MSE?	Punt A.E.

List of Papers and Presentations

SCRS Documents and Presentations Abstracts as Provided by the Authors

SCRS/2018/041 - ICCAT BFTWG completed the stock assessment using multiple stock assessment methods in 2017, and they are going to proceed the MSE process: development of MP in 2018. It is well recognized that the performance results of MPs often depend on the design of the OM and its conditioning that capture the range of potential population dynamics. It is therefore critical to consider them carefully before moving to the development of MP, but this has been monumental task given the complexity of ABFT. ICCAT GBYP core modelling group has developed the OM by incorporating the mixing between two stocks, and the trial specifications. However, the 2017 stock assessment raised a number of issues that may require further consideration for the OMs, particularly related to time varying catchability and selectivity, effective sample sizes for composition data and stock mixing dynamics that are limited information. Overall, we commend the work of the ICCAT GBYP Core modelling group for producing the current OM and framework for evaluating MPs. Our purpose in this document is not to criticize this work but to foster clarification and further discussion about key uncertainties that have emerged during the 2017 assessment.

SCRS/2018/047 - In an initial exploratory exercise, simple fixed proportion MP control rules are applied using composite abundance indices for the East and West areas, where these composites take weighted averages over standardised values of the agreed indices and are then averaged over the last three years for which they would be available. These candidate MPs (CMPs), which also impose a 20% cap on biennial TAC changes, show ready ability to achieve median depletion close to the MSY spawning biomass for each stock within a 30-year projection period for a number of members of the Reference Set of Operating Models (OMs). Two insights from the analyses are first that discussion is needed regarding the most appropriate statistic to use to measure resource depletion in circumstances where some OMs allow for changes in stock recruitment relationships at some time during the projection period considered. The second is that resource depletion can at times be too great for the OM for which the historical abundance of the East stock shows a large increase over recent years. Typical TAC changes are also greater than desirable for adequate stability from an industrial viewpoint. Suggestions are made for further work towards improving MP performances in these respects.

SCRS/2018/055 - A candidate management procedure to set total allowable catch advice from indices of abundance was designed that has two novel aspects. Firstly, it combines catch rate indices by area and spawning biomass indices by stock to infer regional abundance. This configuration has the advantage that TACs are set according to multiple sources of information and mixing is accounted for, for example allowing TACs in the western area to respond to fluctuations in productivity in the Eastern stock. Secondly, the MP implements a harvest control rule that accounts for both stock status (B/B_{MSY}) and exploitation rate (F/F_{MSY}). The advantage of this approach is that for example, a stock that is overfished and recovering (underfishing) does not necessarily incur a TAC reduction. These two features are intended to maintain a 'steady hand' in the face of potentially large fluctuations in the productivity of both East and West stocks. A preliminary test of the MP was carried out for 8 reference operating models.

SCRS/2018/059 - A management strategy evaluation framework developed for Bluefin tuna (ABTMSE version 2.7.0) was used to test the performance of a management procedure (MP) developed following consultation with stakeholders in the Canadian Bluefin tuna fishery. The single DFO MP and several constant catch MPs applied in the western stock management area were evaluated against a single constant catch scenario for the east.

SCRS/P/2018/015 - Not provided by the author. *SCRS/P/2018/016* - Not provided by the author. *SCRS/P/2018/017* - Not provided by the author. *SCRS/P/2018/018* - Not provided by the author. *SCRS/P/2018/019* - Not provided by the author. *SCRS/P/2018/020* - Not provided by the author.

Approximate F0.1 CMP Proposal from the Subgroup

Two approaches were put forward by the subgroup. These are options 1 and 2 below.

OPTION 1. This uses an F0.1 interpretation which is OM-independent. From the agreed VPA assessments, we have F0.1-based TACs for 2018 and a few additional future years. The idea is to take these projections at F=F0.1 forward for 30 years from these agreed VPAs. Then use those 30-year future catches as fixed catch values to input to all different OMs.

OPTION 2: This uses an F0.1 interpretation which is OM-specific. Option 2A is preferred to 2B but may not be doable, particularly because the stock mixing may complicate the calculation. If 2A is not doable, then 2B will be used.

- A) Calculate the true F0.1 (by age) for 2018 for each OM (OM-dependent). Characterize uncertainty in biomass estimates in stock assessments by using a fixed CV (to be determined) and apply F0.1 (30 years into the future) to these noisy estimates of stock biomass.
- B) Calculate the F-at-age in each OM that corresponds to the 2018 TAC and interpret that as F0.1 (OM-dependent). Project 30 years into the future using the F-at-age identified in this way to compute anual catches to which error is added as for A) above.

Note: As regards the CV mentioned in Option 2 as to be determined, one suggestion made was to use the estimate from Ralston et al. (2011) "A meta-analytic approach to quantifying scientific uncertainty in stock assessments", Fish. Bull. 109:217–231). This suggests a lower bound of 37%.



EBFT bootstrap median yield at F0.1

Figure 1. Catch series for Option 1 for EBFT. This comes from projecting the EBFT VPA forward at constant F=F0.1, using the 6-year average recruitment (constant mean, but with some variability) into the future.

Technical details of some of the CMPs

A. The DMM (Doug, Mitsuyo and Melissa) initial Candidate Management Procedure

The DMM initial CMP is in essence a constant fishing mortality approach. It is applied separately to composite indices aggregated over those abundance indices available for each of the East and the West areas respectively. The control parameters setting this mortality may differ for the two areas, and each aggregate abundance index is averaged over the last three years for which data would be available so as to reduce variability in the index and consequently in TACs. TACs for each area are restricted not to change by more than 20% when the TAC is revised every second year. Details are provided below.

Aggregate abundance indices

An aggregate abundance index is developed for each of the East and the West areas by first standardising each index available for that area to an average value of 1 over the past years for which the index appeared reasonably stable¹, and then taking a weighted average of the results for each index, where the weight is inversely proportional to the variance (σ^2) shown by that standardised index over the chosen years. The mathematical details are as follows.

 J_y is an average index over *n* series (*n*=4 for the East area and *n*=3 for the West area)

$$J_{y} = \frac{\sum_{i}^{n} w_{i} \times I_{y}^{i*}}{\sum_{i}^{n} w_{i}}$$
(1)

where

and where the standardised index for each index series (i) is:

 $w_i = \frac{1}{\left(\sigma^i\right)^2}$

$$I_{y}^{i*} = \frac{I_{y}^{i}}{Average of historical I_{y}^{i}}$$

The actual index used in the CMPs, J_{av} , is the average over the last three years for which data would be available at the time the MP would be applied, hence²:

$$J_{av,y} = \frac{1}{3} \left(J_{y-2} + J_{y-3} + J_{y-4} \right)$$
(2)

where the J applies to either to the East or to the West area³.

CMP specifications

The CMP sets the TAC every second year simply as a multiple of the J_{av} value for the area at the time, but subject to the change in the TAC for each area being restricted to a maximum of 20% (up or down). The formulae are given below.

For the East area:

$$TAC_{E,y} = \left(\frac{TAC_{E,2018}}{J_{E,2016}}\right) \cdot \alpha \cdot J_{av,y-2}^{E} \qquad (3a)$$

If $TAC_{E,y} \ge 1.2 * TAC_{E,y-1}$ then $TAC_{E,y} = 1.2 * TAC_{E,y-1}$

¹ These years commence from 2012 (JPN_LL_NEAtl2), 2010 for FR_AER_SUV, 2013 for MED_LAR_SUV, 2011 for MED_AER_SUV and JPN_LL2, 1994 for US_RR_115_144, and 1984 for GOM_LAR_SUV.

² For the French and Mediterranean aerial survey, there is no value for 2014 and 2015 respectively. These years are omitted from this averaging where relevant.

³ The reason that the subscript on J_{av} is y-2 here is that one would set a TAC for year y during year y-1, at which time the most recent abundance indices available would be for year y-2.

If
$$TAC_{E,y} \le 0.8 * TAC_{E,y-1}$$
 then $TAC_{E,y} = 0.8 * TAC_{E,y-1}$

For the West area:

$$TAC_{W,y} = \left(\frac{TAC_{W,2018}}{J_{W,2016}}\right) \cdot \beta \cdot J_{av,y-2}^{W}$$
(3b)
If $TAC_{W,y} \ge 1.2 * TAC_{W,y-1}$ then $TAC_{W,y} = 1.2 * TAC_{W,y-1}$
If $TAC_{W,y} \le 0.8 * TAC_{W,y-1}$ then $TAC_{W,y} = 0.8 * TAC_{W,y-1}$

B. The DFO Candidate Management Procedure

A.R. Hanke

The DFO western MP (DFO7_40_10) uses index 7 (GOM_LAR_SUV) to predict stock status and derive a TAC recommendation. Healthy, cautious, critical and super critical zones are defined by the reference values 1.0, 0.4 and 0.1. The stock status at the conclusion of a management cycle is determined by comparing the ratio of the index value at the end of a cycle to a base value of the index. The base value is the mean of the index values in the last 3 years of the historical period.

In addition to an evaluation of status based on the index, the MP also determines the trend in the index over the most recent 4 years in order. The magnitude and direction of the trend affects the TAC recommendation conditional on stock status and comprise the control rules.

These control rules are as follows:

- 1. When the stock is in the healthy zone and the trend is positive, the TAC is increased by a scalar of 0.3 applied to the magnitude of the trend. Thus a slope of 1.0 increases the TAC by 30%. Otherwise, if the trend is negative there is no adjustment in the TAC.
- 2. When the stock is in the cautious zone and the trend is negative, the TAC is decreased by a scalar of 0.1 applied to the magnitude of the trend. Thus a slope of -1.0 decreases the TAC by 10%. Otherwise, if the trend is positive there is no adjustment in the TAC.
- 3. When the stock is in the critical zone, the TAC is decreased by a scalar of 0.1 applied to the magnitude of the trend 50%. In the event that the status falls below the critical zone, the TAC is set to 0.

In mathematical terms the MP works as follows:

$$I_{base} = \sum_{y=2012}^{2015} I_y / 4$$

$$I_{ratio} = I_n / I_{base}$$

$$\beta = I_j - \alpha/Y_j, \qquad j = y_{n-3}, \dots, y_n$$

Healthy Zone

$$I_{ratio} \ge 1 \land \beta \ge 0, \qquad TAC_{y_{n+1}} = (1 + \beta \times 0.3) \times TAC_{y_n}$$

$$I_{ratio} \geq 1 \ \land \ \beta < 0, \qquad TAC_{y_{n+1}} = \ TAC_{y_n}$$

Cautious Zone

 $I_{ratio} < 1 \land I_{ratio} \ge 0.4 \land \beta < 0, \qquad TAC_{y_{n+1}} = (1 + \beta \times 0.1) \times TAC_{y_n}$

 $I_{ratio} < 1 \land I_{ratio} \ge 0.4 \land \beta \ge 0, \qquad TAC_{y_{n+1}} = TAC_{y_n}$

Critical Zone A

 $I_{ratio} < 0.4 ~ \wedge ~ I_{ratio} \ge 0.1$, $TAC_{y_{n+1}} = ~ 0.5 \times TAC_{y_n}$

Critical Zone B

 $I_{ratio} < 0.1$, $TAC_{y_{n+1}} = 0$

If $TAC_{W,y} \le 0.8 * TAC_{W,y-1}$ then $TAC_{W,y} = 0.8 * TAC_{W,y-1}$

A constant catch MP (CurEC100) was developed for the eastern stock that set the TAC according to the management recommendations for 2016 through 2020 (Rec [14-04]; Rec [17-07]). The resulting schedule of removals for the eastern stock was 19,296 MT, 23,155 MT, 28,200 MT, 32,240 MT and 36,000 MT in years 2016 to 2020. Following 2020 the TAC was fixed at 36,000 MT. However, when a greater than 1 year management cycle is invoked, ABT-MSE will adjust this schedule by omitting TAC recommendations that do not fall on the terminal year of the cycle and repeat those that do.

C. EU Candidate Management Procedure (CMP)

Gorka Merino, Haritz Arrizabalaga, Tristan Rouyer, Ana Gordoa

The CMPs first attempted for the East and Western areas are empirical and are only different on the indices used and the targets. In particular, for the Eastern stock three indices were tested: JPN-LL-NEAtl12, FRE-AER-SUV, MED-AER-SUV and an average of the three. For the West we tried the GOM-LAR-SUV index. For both areas we tried two targets (100% and 75% of current values).

At a later stage, the average indices for the East and the target of 100% for both areas were selected for further testing.

Thus, the CMP consists on TAC adaptations as a response to the following indices' dynamics:

- East: Average of the JPN-LL-NEAtl12, FRE-AER-SUV and MED-AER-SUV.
- West: GOM_LAR_SUV

The CMP calculates the relation of the average value of the index in each management period of the simulation (curl) with a target (Targ), which is set relative to its value at the beginning of the simulation (I0). In this case the target is set at the value at the beginning of the simulation, Targ=1.

Targ= x * I0 Irat= curI/Targ

The new TAC is set proportionally to the relation between the current value and the target: newTAC=oldTAC * Irat

In addition, this CMP includes a stability constraint that allows only for small increases of TAC in each management period (Irat < +5%) and moderate reductions (Irat> -20%).

D. The MPx (MP with optional mixing, Tom Carruthers) initial Candidate Management Procedure

The MPx CMP aims to maintain a constant fishing mortality rate at biomass approximately at B_{MSY} levels. To achieve this the MP uses calibrated regional indices to infer regional biomass from which TACs are adjusted depending on both stock status (regional biomass levels relative to a target level) and the implied fishing rate (current catch levels divided by the estimated regional biomass relative to a target fishing rate). The MPx CMP has a highly flexible harvest control rule that allows for either no adjustment relative to target fishing rate or no adjustment relative to target biomass (or varying levels of sensitivity to these). Optionally, the MPx CMP can also use Atlantic-wide indices to infer regional mixing by including mixing parameters in the set of control parameters.

Vulnerable biomass and fishing rate estimation

MPx provides TAC advice in a given time period *t* using Spawning Stock Biomass indices (*I*^{SSB}) averaged over two calendar years (indices are available up to the year before current, e.g. 2016), by stock *s* and Catch Rate Indices (*I*^{CR}) by area *a*, calibrated to current stock assessments of vulnerable biomass *B* (estimates of catchability *q* for SSB and CR indices). In order to, for example, interpret Eastern area SSB in terms of Western area biomass, an estimate of stock mixing is required $\theta_{s=East_stock,a=West}^{mix}$ that is the fraction of East stock spawning biomass that can be expected to be vulnerable to fishing in the West.

(1)
$$B_{a,t}^{SSB} = \frac{1}{2} \sum_{t=y-2}^{y-1} \sum_{s} I_{s,t}^{SSB} q_s^{SSB} \theta_{s,a}^{mix}$$

(2)
$$B_{a,t}^{CR} = \frac{1}{2} \sum_{t=y-2}^{y-1} I_{a,t}^{CR} q_a^{CR}$$

The *q* parameters are calibrated to 2016 estimates spawning biomass (by stock) θ_s^{SSB} , and vulnerable biomass (by area) θ_a^B :

(3)
$$q_s^{SSB} = \frac{\theta_{s,2016}^{SSB}}{I_{s,2016}^{SSB}}$$

(4)
$$q_a^{CR} = \frac{\theta_{a,2016}^B}{I_{a,2016}^{CR}}$$

The estimates of vulnerable biomass *B* arising from the calibrated indices can be used to estimate the fishing mortality rate using observations of catches *C*

(5)
$$F_{a,t}^{CR} = -\ln\left(1 - \frac{C_{a,t}}{B_{a,t}^{CR}}\right)$$

(6)
$$F_{a,t}^{SSB} = -\ln\left(1 - \frac{C_{a,t}}{B_{a,t}^{SSB}}\right)$$

Combining inference from SSB and CPUE indices

Assessment estimates of vulnerable biomass at MSY (θ^{BMSY}) can be used to calculate current vulnerable biomass relative to B_{MSY} , here inference from catch rate and spawning indices is equally weighted as the geometric mean:

(7)
$$\Delta_{a,t}^{B} = exp\left(\frac{1}{2}\left[ln\left(\frac{B_{a,t}^{SSB}}{\theta_{a}^{BMSY}}\right) + ln\left(\frac{B_{a,t}^{CR}}{\theta_{a}^{BMSY}}\right)\right]\right)$$

The same approach was used to combined estimates of *F* relative to *F*_{MSY}:

(8)
$$\Delta_{a,t}^{F} = \exp\left(\frac{1}{2}\left[ln\left(\frac{F_{a,t}^{SSB}}{\theta_{a}^{FMSY}}\right) + ln\left(\frac{F_{a,t}^{CR}}{\theta_{a}^{FMSY}}\right)\right]\right)$$

CMP specifications

TACs in the following year are based on TAC in the previous time step multiplied by a factor $\varphi_{a,t}$:

(9)
$$TAC_{a,t+1} = TAC_{a,t} \varphi_{a,t}$$

where the factor $\varphi_{a,t}$ is determined by adjustments for fishing rate $\delta_{a,t}^F$ and stock status $\delta_{a,t}^B$:

(10)
$$\tilde{\varphi}_{a,t} = \delta^F_{a,t} \, \delta^B_{a,t}$$

The adjustment to *F* is the inverse of F/F_{MSY} ($\Delta_{a,t}^F$) where the magnitude of the adjustment is determined by β^F . The parameter α^F controls the target *F* level where $F/F_{MSY} = 1$ and $B/B_{MSY} = 1$. For example, at a value of 0.8, the MP deliberately aims to underfish at 80% of F_{MSY} when the stock is at *BMSY* and current *F* is F_{MSY} . Note that when $\alpha^F = 1$ and $\beta^F = 1$ the *F* adjustment $\delta_{a,t}^F$ is the inverse of $\Delta_{a,t}^F$ and hence recommends F_{MSY} fishing rate (and depends on the assumption that biomass will be comparable at t+1).

(11)
$$\delta_{a,t}^{F} = \alpha^{F} \exp\left(\beta^{F} \ln(1/\Delta_{a,t}^{F})\right)$$

The adjustment to biomass is exponentially related to the disparity between current biomass and B_{MSY} . The term $|\Delta_{\alpha,t}^B - 1|$ is the positive absolute difference (modulus). The magnitude of the adjustment for biomass is controlled by the parameter α^B while the (extent of the TAC change for biomass levels far from BMSY) is controlled by the exponent β^B . This is analogous to a traditional harvest control rule (e.g. '40-10') and throttles fishing rates at low stock sizes to speed recovery while also increasing fishing rates at high stock sizes to exploit additional biomass. When $\alpha^B = 0$ there is no biomass adjustment and $\delta_{a,t}^B$ is invariant to β^B .

(12)
$$\delta_{a,t}^{B} = \begin{cases} exp\left[\left(\alpha^{B}|\Delta_{a,t}^{B}-1|\right)^{\beta^{B}}\right] & 1 < \Delta_{a,t}^{B} \\ exp\left[-\left(\alpha^{B}|\Delta_{a,t}^{B}-1|\right)^{\beta^{B}}\right] & \Delta_{a,t}^{B} \le 1 \end{cases}$$

This generalized TAC harvest control rule can accommodate a wide range of control schemes of varying sensitivity to estimates of current exploitation rate and stock status. The default values of the control parameters for the biomass and fishing rate estimation and the harvest control rule are included in **Table Appendix 6** D.1.

TAC adjustment limits

The maximum rate of TAC adjustment is determined by θ^{down} and θ^{up} that control the maximum extent of downward and upward adjustment respectively:

(13)
$$\varphi_{a,t} = \begin{cases} \theta^{down} & \tilde{\varphi}_{a,t} < \theta^{down} \\ \tilde{\varphi}_{a,t} & \theta^{down} < \tilde{\varphi}_{a,t} < \theta^{up} \\ \theta^{up} & \theta^{up} < \tilde{\varphi}_{a,t} \end{cases}$$

 θ^{down} and θ^{up} are fixed at 20% and the MP updates the TAC every two years.

Description	Value	
Biomass calculation		
$I_{East_stock}^{SSB}$	Spawning stock biomass index for eastern stock	MED_LAR_SUV
$I_{West_stock}^{SSB}$	Spawning stock biomass index for western stock	GOM_LAR_SUV
I_{East}^{CR}	Vulnerable biomass catch rate index for eastern area	JPN_LL_NEATL2
I ^{CR} West	Vulnerable biomass catch rate index for western area	US_RR_115_144
$ heta^{BMSY}_{East}$	Eastern area biomass at maximum sustainable yield	220 kt
$ heta_{West}^{BMSY}$	Western area biomass at maximum sustainable yield	37 kt
$ heta_{East}^{FMSY}$	Eastern area fishing mortality rate at MSY	0.1
$ heta_{West}^{FMSY}$	Western area fishing mortality rate at MSY	0.1
$ heta^{SSB}_{East_stock,2017}$	Spawning stock biomass of the eastern Stock in 2017	320 kt
$ heta^{SSB}_{West_stock,2017}$	Spawning stock biomass of the western Stock in 2017	27 kt
$ heta^B_{East,2017}$	Vulnerable biomass in the eastern area in 2017	200 kt
$ heta^B_{West,2017}$	Vulnerable biomass in the western area in 2017	50 kt
$ heta_{West,East}^{mix}$	Fraction of western stock in eastern area	0.3
$ heta_{East,West}^{mix}$	Fraction of eastern stock in western area	0.2
Harvest control rule		
$lpha^B$	The magnitude of the adjustment for biomass relative to	1
β^B	Exponent parameter controlling extent of the	2
$lpha^F$	adjustment for biomass relative to BMSY Target fishing mortality rate (fraction of FMSY) at F/FMSY	0.8
eta^F	= 1 and B/B_{MSY} = 1 The magnitude of the adjustment for fishing rate relative to F_{MSY}	0.5

Table Appendix 6 D.1. Round 1 control parmeter values for biomass estimation, fishing rate estimation and the specification of the harvest control rule.

E. A simple index-based CMP (J. Walter)

The MP is exactly the generic index-based MP outlined in the Trial Specifications document. The mathematical details are as follows:

 $I_{curr} = \frac{\sum_{i=k}^{y} I_{y}}{k}$ If $I_{curr} > t^{*}(1+\Delta)$ then TAC_y=TAC_{y-1} * (1+ Δ) If $I_{curr} < t^{*}(1-\nabla)$ then TAC_y=TAC_{y-1} * (1- ∇) else TAC_y=TAC_{y-1}

where I_{curr} is the average of the index over the previous k years, t is the target value for the index which if the index is higher than $t^*(1+\Delta)$, then the TAC increases by a factor of $1+\Delta$; if I_{curr} is less $t^*(1-\nabla)$ then the TAC in year y decreases by a factor of $1-\nabla$.

To apply this to an index it is necessary to define the index and the control parameters of the target value, the percentage increase and the percentage decrease and the number of years over which to average the index.

A USRR 115_144 index CMP for East and West areas

A candidate management procedure (CMP) based on the USRR 115_144 index for both East and West areas. It alters the current TAC according to the ratio of the index averaged over *k* years relative to the chosen target value of the index. The concept of using this index for both East and West areas comes from the observation that this index is for ages 4 and 5 year old fish, which are of mixed Eastern and Western origin in the fishery that this index comes from. Hence this index is the first index to see recruits from both stocks and may be useful for tracking recruitment. The CMP exactly follows the example MP in the trial specification document. As such it is it not expressly particularly designed for good performance and further MP development may change control parameter settings or the actual design of any CMP that uses the **USRR 115_144** index.

To create an MP based on the USRR 115_144 index (index 6) as <u>the</u> single index for both East and Western areas we specified the Δ as 0.05 and ∇ as 0.2. Two years were chosen to average the index (*k*=2) and several different values for the target were explored from 0.25-0.8.

SPECIFICATIONS FOR MSE TRIALS FOR BLUEFIN TUNA IN THE NORTH ATLANTIC

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1. BASIC CONCEPTS AND STOCK STRUCTURE

This first item intends to cover only the broadest overview issues. More detailed technical specifications are included under subsequent items.



Figure 1.1. Spatial definitions tabled by the 2015 ICCAT data preparatory meeting (Anon. 2015) with simplification to a single Mediterranean area.

Baseline

Spatial areas at the resolution of the reported PSAT tagging data and the stock of origin data (which do not have sufficient resolution to divide the Mediterranean area into Eastern and Western sub areas)(Figure 1.1)

Alternative low priority future options

The MAST model (Taylor et al. 2011) areas which are the same Figure 1.1 but simplified such that the Central Atlantic is merged with the Western Atlantic.



II) Stock mixing

Baseline

A two-stock model similar to Figure 1.2A but adhering to the spatial structure of Figure 1.1A and including the mixing for West Africa which was discovered after the Tenerife meeting.

Possible alternative options

A two-stock model with no mixing

2. PAST DATA AVAILABLE

Table 2.1 provides an overview of the data that may be used to condition operating models for Atlantic bluefin tuna. The Table indicates those data that have been gathered, those that are currently available and those that have already been used in conditioning operating models.
I) Raw data

A preliminary demonstration operating model has been fitted to the fishery, tagging and survey data that are currently available (Table 2.1, field 'Used in OM'). Currently the operating model is fitted to ICCAT Task II landings data scaled upwards to annual Task I landings.

The ICCAT catch at size data set was used to estimate gear selectivity for each of the baseline fleet types.

The pop-off satellite archival tag data from several sources (NOAA, DFO, WWF, AZTI, UNIMAR, IEO, UCA, FEDERCOOPESCA, COMBIOMA, GBYP, Stanford University) have been compiled by NOAA (M. Lauretta) and used in the preliminary model to estimate movements among areas. In total 319 tags provided information on 929 quarterly transitions (Table 2.2).

Catch data provide scale to stock assessments. In a similar way, spatial stock of origin data are necessary to estimate the relative magnitude of the various stocks in a multi-stock model (to correctly assign catches to stock). Currently the model uses stock of origin data derived from the otolith microchemistry research of AZTI, UMCES and DFO (Table 2.3).

There is uncertainty in regard to the stock of origin of bluefin catches in the South Atlantic which reported prior to 1970. Currently these are dealt with in the same way as all other catches: they are assigned to the areas of Figure 1.1A by uprating Task II catches (that are reported spatially) to the annual Task I catch data. It follows that these South Atlantic catches are combined with north Atlantic catches in the areas W.Atl and E.Atl (Figure 1.1A) and assumed to have the same stock of origin. Currently all the stock of origin data come from analyses undertaken in the north Atlantic only (e.g. otolith microchemistry).

II) Analysed data

In the absence of a trip-level and fleet-specific regional abundance indices, a master index was calculated from Task II CPUE data and standardized assessment indices. The motivation for this was to produce indices of standardized effort by year, subyear and area (fleet specific catch divided by the master index) for operating model conditioning. The index was calculated using the following linear model (for more detail on this approach see Carruthers 2017, SCRS/2017/019):

$$\log(CPUE_{y,r,m,f}) = \alpha_{y,r} + \beta_{m,r} + \delta_{f,r} + \varepsilon$$
(2.1)

where *y*, *r*, *m* and *f* refer to years, areas, subyears and fleets, respectively.

The Task II CPUE data provide information about the approximate spatial / season distribution of the stock within years (Table 2.2). The standardized assessment indices provide the primary information about trend within area over years (Table 2.3).

Flag	Gear	Details
Japan	Longline	1.38m fish
USA	Longline	13,156 fish
Canada	Rod and reel	9,131 tonnes
Morocco	Trap	15,996 tonnes
Spain	Baitboat	35,625 tonnes

Table 2.2. The Task II CPUE data used to derive the master index.

Table 2.3. The standardized CPUE indices of the assessments that are used to derive trend information for the master index and also fit the operating models.

Flag	Gear	Details
Spain	Baitboat	1952-2006, Q3, E Atl
Spain / France	Baitboat	2007-2014, Q3, E Atl
Morocco / Spain	Trap	1981-2011, Q2, SE Atl
Morocco / Portugal	Trap	2012-2016, Q2, SE Atl
Japan	Longline	1975-2009, Q2, SE Atl
Japan	Longline	1990-2009, Q4, NE Atl
Japan	Longline	2010-2017, Q4, NE Atl
US (66cm - 114cm)	Rod and reel	1993-2015, Q3, W Atl
US (115cm - 144cm)	Rod and reel	1993-2015, Q3, W Atl
US (145cm +)	Rod and reel	1980-1992, Q3, W Atl
US (195cm +)	Rod and reel	1984-1992, Q3, W Atl
US	Longline	1987-1991, Q2, GOM
US	Longline	1992-2016, Q2, GOM
Japan	Longline	1976-2009, Q4, W Atl
Japan	Longline	2010-2017, Q4, W Atl
Canada	Rod and reel	1984-2016, Q3, W Atl
Italy	Trap	1993-2010, Q2, Med

Туре	Details
French aerial survey	2000-2016, Q2, Med
Larval survey	2001-2015, Q2, Med
Canadian acoustic survey	1994-2015, Q3, GSL
Larval survey	1977-2016, Q2, GOM
Aerial survey	1975-2009, Q2, Med

Table 2.4. Fishery-independent indices used in the fitting of operating models.

The master index can be used to predict relative abundance (and hence standardized effort) for any fleet with catches over the full range of years, subyears and areas (Figure 2.1).

The operating models are also fitted to the standardized indices used in the VPA stock assessments (Table 2.3) and range of fishery-independent indices (Table 2.4). These fishery independent indices include a western larval index in the Gulf of Mexico (Lamkin et al., 2014and an Eastern larval index in the Western Mediterranean (Ingram et al., SCRS/2015/035).

In order to predict observed catch at size from model predicted catch at age, operating models made use of an inverse age-at-length key (probability of length strata given age). These keys are developed from the base-case stock assessment growth curves for Eastern and Western stocks and an assumed coefficient of variation of 10% (variability in length at age).

There are four sources of derived data that are priorities moving forward:

- a defensible inverse age-length key for each stock preferably disaggregated by time,
- finalized fishery-independent larval surveys for both the Western and Eastern stocks,
- standardized abundance indices based on trip-level catch rate data and
- electronic tag data by age class
- (most importantly) a greater quantity of stock of origin data by age class spanning a greater range of subyear and area combinations.

Note that the preliminary operating model has been fitted to a relative abundance index derived from ICCAT task II catch and effort data, primarily those from the Japanese longline fleet. Set specific data are not available at this level, such as hooks per basket (depth), bait type and soak time that often substantially affect the derived index of abundance. It is important to produce a trip-level index that is standardized for these covariates if possible.

Further, currently the stock of origin data are relatively numerous but very sparse and only available for about 20% of subyear-area combinations (Table 2.3) (currently the operating model does not have stock of origin data for the Western Mediterranean and the Gulf of St Laurence). Coupled with sparse PSAT tagging data at this resolution

(Table 2.2), there is limited information to estimate age-specific movement and allow the model to apportion catches to stock in these time-area strata correctly. There are however a large number of studies that may provide estimates of the stock of origin the data of which are not currently used to condition the operating model (e.g. otolith microchemistry, SNP, otolith shape and mitochondrial DNA analyses). Along with additional electronic tagging data by age class, provision of these stock of origin data by age class is arguably the highest priority for successfully conditioning future operating models.

III) Assumptions

The following are the default assumptions made in the model. Some of them may be relaxed in the robustness trials.

The age-length key is static and not adjusted according to fishing mortality rate and length selectivity of fishing.

CPUE indices are considered to be proportional to exploitable biomass (weighted by the selectivity indices).

Larval indices are assumed to be proportional to spawning stock biomass in the area in which they were collected in contrast to stock-wide spawning stock biomass (for scenarios where the two are not proportional).

Table 2.1. Overview of data that may be used to inform operating models for Atlantic bluefin tuna (available online <u>here</u>). Cells shaded green reflect sources for which data are available ('Collab',the Core modelling group CMG, or the ICCAT secretariat) and whether data that are available have also been used in conditioning preliminary operating models ('used in OM?')

Type of data (Informs)	Year range	Til	Spatial	Can be by	Ву	Contact	Collab		Avail	able to:		Used in
.,,,			range	quarter?	age-class?			тс	CMG	ICCAT	ALL	OM?
1. CPUE indices (relative abundance, m	ovement, perfo	rmance	at stakehold	er level)								
1.1. ICCAT task II CPUE	1950-2015		All	Y	N	Carlos Palma (ICCAT)	Y	Y	Y	Y	Y	Y
	1976-2013			Y	N		Y	Y	N	N	N	Y
1.2. Japanese LL standardized spatial	1990-2013	00	E, NE, W, C	Y	N	Ai Kimoto	Y	Y	Ν	N	Ν	Y
	1992-2015		w	Y	N		Y	Y	N	N	Ν	Y
1.3. USA LL standardized spatial	1992-2004		GOM	Y	N		Y	Y	Ν	N	Ν	Y
	2005-2015	00	GOM	Y	N	Matt Lauretta (NOAA)	Y	Υ	Ν	Ν	Ν	Y
1.4. USA HL standardized spatial	1980-2015		W	Y	N		Y	Ν	N	Ν	Ν	Ν
1.5. USA RR standardized spatial	1992-2015	00	W	Y	N		Y	Υ	Y	Y	Y	Y
1.6. USA-CAN LL standardized spatial	1992-2014	00	W, C	Y	N	M. Lauretta (NOAA) /	Y	Ν	Ν	N	Ν	N
1.7. USA-CAN HL standardized spatial	1993-2014	~~	W, C	Y	N	A. Hanke (DFO)	Y	Ν	N	N	Ν	N
1.8. CAN LL standardized		60	W, GSL	Y	N		Y	Ν	Ν	N	Ν	N
1.9. CAN HL standardized	1981-2014	00	GSL	Y	N	Alex Hanke (DFO)	Y	Ν	N	N	Ν	N
	1988-2014		W	Y	N		Y	Ν	N	N	Ν	N
1.10. CAN CMB RR	1984-2015	00	W	Y	N	Alex Hanke (DFO)	Y	Y	Y	Y	Y	Y
1.11 TWN LL standardized	1960-2004	2004	W, NE, E	Y	N	Julia Huang (NTOU)	N	Ν	N	N	Ν	N
1.12. MOR-SPN TRAP standardized	1982-2011	2011	WM	Y	N	N. Abid	Y	Y	Y	Y	Y	Y
1.13. MOR-POR TRAP standardized	2012-2015	00	W, WM	Y	N	N. Abid	Y	Y	Y	Y	Y	Y
1.14. ESP TRAP standardized			W, WM	Y	N	Jose Miguel de la Serna	N	Ν	Ν	Ν	Ν	Ν
1.15. ITA (SAR) TRAP standardised	1993-2010	2010	CM	Y	N	Pierantonio Addis	Y	Y	Y	Y	Y	Y
1.16 ESP BB	1981 - 2006	2006	EATL	Y	N	Haritz Arrizabalaga	Y	Y	Y	Y	Y	Y
1.17 SP-FR BB	2007-2014	2014	EATL	Y	N	Haritz Arrizabalaga	Y	Y	Y	Y	Y	Y
2. Larval indices (SSB, movement)												
2.1. USA	1977-2015		GOM	Y	N	Walter Ingram (NOAA)	Y	Y	Y	Y	Y	Y
2.2 ESP	01-'05 '12-'15	2018	W Med	Y	Ν	Franciso Alemany (IEO)	Y	Y	Y	Y	Y	Y
3. Catches (stock size, harvest rate)												
3.1. ICCAT task I	4050 2045		non-spatial	N	N	Coulos Poless (ICCAT)	Y	Y	Y	Y	Y	N
3.2. ICCAT task II	1950-2015	60	All	Y	N	Carlos Palma (ICCAI)	Y	Y	Υ	Y	Y	Ν
3.3. ICCAT CATDIS					N		Y	Y	Y	Y	Y	Y
3.4 GBYP	1512-1950		E, M	Y	N	Carlos Palma (ICCAT)	Y	Y	Y	Y	Y	Y
4. Catch composition (selectivity, deple	tion)											
4.1. ICCAT catch-at-size	1950-2015	00	All	Y	N	Carlos Palma (ICCAT)	Y	Y	Y	Y	Y	Y
4.2. Stereo video caging	2014	ended	WM, EM	Y	N	Mauricio Ortiz (ICCAT)	N	Ν	Ν	N	Ν	Ν
4.3. Canadian fisheries						Alex Hanke (DFO)	N	Ν	Ν	N	Ν	N
4.4 GBYP Historical catches	1910-1950	=	E, M	Y	N	Carlos Palma (ICCAT)	Y	Y	Y	Y	Y	Y
5. Conventional tags (feasible moveme	nt, growth, GTG	i hetero	ogeneity)									
5.1. ICCAT	1954-2014	2015	All	Y	Y	Carlos Palma (ICCAT)	Y	Y	Y	Y	Y	Stock defs
6. SI archival tags (feasible movement)												
6.1. LPRC (n=4000)	2011-2015		W	Y	Y	Molly Lutcavage	Y	Y	N	N	N	Y
6.2. AZTI (n=20)	2007-2011		NE	Y	Y	Igor Arregui	Y	Y	N	N	N	Y
7 PSAT tags (movement)												
7.1. LPRC (n=423)	2005-2009	ended	w	Y	Y	Molly Lutcavage	Y	Y	N	N	N	Y
7.2. DFO (n=135)	2013-2015	00	GSL,W,GOM	Ŷ	Ŷ	Alex Hanke (DFO)	Y	Y	N	N	N	Y
7.3. Stanford (n=1783)	1996-2010		W	Ŷ	Y	Barbara Block	Y	Y	N	N	N	Y
7.4. GBYP (n = 103)	2012-2014	2015	E, M	Y	Y	Antonio Di Natale	Y	Y	N	N	N	Y
7.5. WWF (n = 100)	2008-2015	2015	All	Y	Y	Pablo Cermeno	Y	Y	N	N	N	Y
7.6. SEFSC (NOAA)	2010-2013	2013	GOM,W,GSL	Y	Y	Craig Brown	Y	Y	N	N	N	Y
7.7. Acadia (NS)	2010-2011	2011	GSL	Y	Y	Mike Stokesbury	Y	Y	N	N	Ν	Y
7.8. UCA	2011	ended	W, C, WM	Y	Y	Antonio Medina	Y	Y	Ν	Ν	Ν	Y

Table 2.1 continued.

Type on tark (minoms) Team (minoms) Team (minoms) Team (minoms) Construction (minoms) 3. Ordelith microchemistry (stock of origin)	Turno of data (Informs)	Voor rongo	та	_{та} Spatial	Can be by	Ву	Contact	Collab	Available to:			Used in	
B. Otolith microchemistry (stock of origin) Y Y Y David Secor Y Y N N N Y S.J. MOAG Y Y N N N Y Y N N N Y S.J. AZTI (n=183) 2009-2011 ended E Y Y Alex Hanke (DFO) Y Y N N N Y S.G. GBV2 (n=1371) 2009-2011 Alex Hanke (DFO) Y Y N N N Y Y Alex Hanke (DFO) Y Y N N N N Y Y Y N	Type of data (morms)	feat fallge		range	quarter?	age-class?	contact	Collab	тс	CMG	ICCAT	ALL	OM?
B. Otelih microchemistry (stock of origin) Y Y Y David Secor Y Y N N N N Y Y N N N Y Y N N N N Y Y N N N Y Y N N N Y Y N N N Y Y N N N Y Y N N N Y Y N N N Y Y N N N Y Y N N N Y Y Y N N N Y Y N N Y													
B.1_LMCES_TANU 2012-2013 V Y V David Second Y Y N N N Y B.3_ACTL(nct182) 2009-2011 ended E Y Y Y N N N Y B.3_GDYL(nct182) 2009-2014 All Y Y N N N Y B.5_GBYP(n=13271) 2009-2014 All Y Y N N N N Y Y N N N Y	8. Otolith microchemistry (stock of orig	;in)											
B.2. MOAA Y V V V V V V N N N V B.3. ACTL (not SB) 2009-2011 ended E Y Y N Y Y N N N N Y<	8.1. UMCES, TAMU	2012-2013			Y	Y	David Secor	Y	Y	N	N	N	Y
33. AZT (h=182) 2009-2011 ended E Y Y N N N Y 34. DEC/UMCES 2011-2013 - W, GSL Y Y Alex Hanke (DFO) Y Y N N N 9. Oblith shape analysis (stock of origin) - - - N GBYP (n=122) 2013-E, W, C, WM Y N GBYP Y N N N N 10. SMP (population structure, genetic structure) - All N GBYP (n=123) N	<u>8.2. NOAA</u>					Y		Y	Y	N	N	N	Y
34_0_EOC_UMCES 2011-2013 W, GSL Y Y Alex Hanke (DFC) Y Y Y N N N Y <t< td=""><td>8.3. AZTI (n=189)</td><td>2009-2011</td><td>ended</td><td>E</td><td>Y</td><td>Y</td><td>Igaratza Fraile</td><td>Y</td><td>Y</td><td>N</td><td>N</td><td>Ν</td><td>Y</td></t<>	8.3. AZTI (n=189)	2009-2011	ended	E	Y	Y	Igaratza Fraile	Y	Y	N	N	Ν	Y
B.S. GRYP. In=1321) 2009-2014 All Y Y GBYP Y	8.4. DFO / UMCES	2011-2013		W, GSL	Y	Y	Alex Hanke (DFO)	Y	Y	N	N	Ν	Y
9.0.tolith shape analysis (stock of origin) 9.1. GRYP (n=172) 2011-2013 2015 E, W, C, WM Y N GBVP Y N	8.5 GBYP (n=1371)	2009-2014		All	Y	Y	GBYP	Y	Y	Y	Y		Y
9.1. GBYP (n=172) 2011-2013 2015 F, W, C, WM Y N GBYP Y N	9. Otolith shape analysis (stock of origi	n)											
10.5.NP (population structure, genetic structure) N Gianpaolo Zmpicinini N	9.1. GBYP (n=172)	2011-2013	2015	E, W, C, WM	Y	Ν	GBYP	Y	Ν	N	Ν	Ν	N
10.1. Med HCMR N Gianpaolo Zmpicinini N	10. SNP (population structure, genetic	structure)											
10.2. GBYP (n=789) 2011-2015 All N GBYP Y Y N	10.1. Med HCMR	(N	Gianpaolo Zmpicinini	N	Ν	N	N	N	N
10.3 NOAA/VIMS/CSIRO 2015	10.2. GBYP (n=789)	2011-2015		All		N	GBYP	Y	Y	N	N	N	Y
Lock GMD Lock GMD <thlock gmd<="" th=""> <thlock gmd<="" th=""> L</thlock></thlock>		2015		GOM/M	N	N	John Walter	N	N	N	N	N	N
11. Other genetics on population structure, genetic structure, 11.1. mtDNA N Barbara Block N <td>10.4 GBYP Historical UB</td> <td>200 BC - 1927</td> <td>1927</td> <td>E, M</td> <td>Y</td> <td>N</td> <td>Alessia Cariani</td> <td>Y</td> <td>N</td> <td>N</td> <td>N</td> <td>N</td> <td>N</td>	10.4 GBYP Historical UB	200 BC - 1927	1927	E, M	Y	N	Alessia Cariani	Y	N	N	N	N	N
11. Other genetics on population structure (population structure, genetic structure) 11.1. mtDNA N Barbara Block N													
11.1. mtDNA N <th< td=""><td>11. Other genetics on population struct</td><td>ture (population</td><td>n struct</td><td>ure, genetic s</td><td>tructure)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th<>	11. Other genetics on population struct	ture (population	n struct	ure, genetic s	tructure)								
11.2. Micro Sat/ mtDNA (n=320 / 147) 2003 ended GOM, WM Y N Carlsson N </td <td>11.1. mtDNA</td> <td></td> <td></td> <td></td> <td></td> <td>N</td> <td>Barbara Block</td> <td>N</td> <td>Ν</td> <td>N</td> <td>Ν</td> <td>Ν</td> <td>N</td>	11.1. mtDNA					N	Barbara Block	N	Ν	N	Ν	Ν	N
12. Fish. Ind. surveys (relative abundance, movement) 12.1. ICCAT Aerial 2010-2015 M Y N Antonio Di Natale Y <t< td=""><td>11.2. Micro Sat/ mtDNA (n=320 / 147)</td><td>2003</td><td>ended</td><td>GOM, WM</td><td>Y</td><td>Ν</td><td>Carlsson</td><td>N</td><td>Ν</td><td>N</td><td>N</td><td>N</td><td>N</td></t<>	11.2. Micro Sat/ mtDNA (n=320 / 147)	2003	ended	GOM, WM	Y	Ν	Carlsson	N	Ν	N	N	N	N
12.1. ICCAT Aerial 2010-2015 M Y N Antonio Di Natale Y	12. Fish. Ind. surveys (relative abundan	ice, movement)											
12.2 French Aerial 2000-2015 M Y N Tristan Rouyer Y </td <td>12.1. ICCAT Aerial</td> <td>2010-2015</td> <td></td> <td>Μ</td> <td>Y</td> <td>N</td> <td>Antonio Di Natale</td> <td>Y</td> <td>Y</td> <td>Y</td> <td>Y</td> <td>Υ</td> <td>Y</td>	12.1. ICCAT Aerial	2010-2015		Μ	Y	N	Antonio Di Natale	Y	Y	Y	Y	Υ	Y
12.3. USA Aerial2015WYNMolly LutcavageYYY	12.2 French Aerial	2000-2015		Μ	Y	Ν	Tristan Rouyer	Y	Υ	Y	Y	Υ	Y
12.4. USA Acoustic2015WWYNMolly LutcavageYYYNNN	12.3. USA Aerial	2015-		W	Y	Ν	Molly Lutcavage	Y	Y	Y	Y	Υ	Y
12.5. SOG Hydro acoustic curtain (OTN) proposed W, WM Y N Mike Stokesbury N <t< td=""><td>12.4. USA Acoustic</td><td>2015-</td><td></td><td>W</td><td>Y</td><td>N</td><td>Molly Lutcavage</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td><td>Y</td></t<>	12.4. USA Acoustic	2015-		W	Y	N	Molly Lutcavage	Y	Y	Y	Y	Y	Y
13. Growth, aging (age-length keys, length-age keys) 13.1. Age-length keys (NOAA) Y N John Walter Y N N N N N N N 13.2. Age-length keys (IEO) 2010-2012 ended E, WM Y N Rodriguez-Marin Y N <t< td=""><td>12.5. SOG Hydro acoustic curtain (OTN)</td><td>proposed</td><td>ł</td><td>W, WM</td><td>Υ</td><td>Ν</td><td>Mike Stokesbury</td><td>N</td><td>Ν</td><td>Ν</td><td>Ν</td><td>Ν</td><td>N</td></t<>	12.5. SOG Hydro acoustic curtain (OTN)	proposed	ł	W, WM	Υ	Ν	Mike Stokesbury	N	Ν	Ν	Ν	Ν	N
13.1. Age-length keys (NOAA) Y N John Walter Y N	13 Growth aging (age-length keys len	eth-age keys)											
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13.2. Age-length keys (IEO) 2010-2012 ended E, WM Y N Rodriguez-Marin Y N<	10111186 1018111019 (110101)						Enrique	1					
13.3. Age-length keys (DFO) 2010-2013 ended GSL, W Y N Alex Hanke (DFO) Y N	13.2. Age-length keys (IEO)	2010-2012	ended	E, WM	Y	N	Rodriguez-Marin	Y	Ν	Ν	N	N	N
13.4. Derived from tagging 1963-2012 ended Es, W s Y N Lisa Allioud Y Y N N Y 13.5. Age-length keys (GBYP) 2011-2015 E, M Y N Antonio Di Natale Y N Y N N Y N 13.6 Ageing calibration (GBYP) 2014 E, M Y N Antonio Di Natale Y N Y N N Y N 14. Maturity (Spawning biomass) 1975-1981 ended GOM Y N Guillermo Diaz (NOAA) Y N N N N 14.2 Mediterranean M Y N GBYP Y N	13.3. Age-length keys (DFO)	2010-2013	ended	GSL, W	Y	N	Alex Hanke (DFO)	Y	Ν	N	N	N	N
13.5 Age-length keys (GBYP) 2011-2015 E, M Y N Antonio Di Natale Y N Y N 13.6 Ageing calibration (GBYP) 2014 E, M Y N Antonio Di Natale Y N Y Y N 14. Maturity (Spawning biomass) 14.1. Western (NOAA) 1975-1981 ended GOM Y N Guillermo Diaz (NOAA) Y N N N N 14.2 Mediterranean M Y N GBYP Y N N N N N 15. Other ecological data (spatial distribution, covariates for CPUE standardization, steepness, natural mortality rate, spawning locations etc.) 15.1. Larval ecology (IEO) ended WM Y N Diego Alvarez Berastegui N N N N N	13.4. Derived from tagging	1963-2012	ended	Es, W s	Y	N	Lisa Allioud	Y	Y	Ν	N	Ν	Y
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	15.2. Habitat model				Y	N	Jean-Noel Druon		N	N	N	N	N

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Figure 2.1. The master index. Areas correspond to those of Figure 1.1.

Table 2.2. The recorded quarterly transitions for electronic tags of NOAA, DFO, WWF, AZTI, UNIMAR, IEO, UCA, FEDERCOOPESCA, COMBIOMA, GBYP of known stock of origin (i.e. those tags entering either the Gulf of Mexico or the Mediterranean). For example, there are 20 tags that at some point entered the Gulf of Mexico (Western fish) that exhibited a movement from the Gulf of St Laurence to the Western Atlantic.



Voor	N	Area	N	Quarter	N
rear	N	Area	IN	Quarter	IN
1974	2	GOM	304	1	413
1975	152	WATL	1992	2	876
1976	67	GSL	621	3	1679
1977	26	NCATL	1	4	497
1978	98	NEATL	4		
1996	75	EATL	48		
1997	34	SEATL	239		
1998	43	MED	256		
1999	21				
2000	6				
2002	55				
2009	81				
2010	145				
2011	1064				
2012	705				
2013	497				
2014	394				

Table 2.3. Distribution of fish that were sampled and assigned stock of origin across years, areas and quarters (N=3465).

3. BASIC DYNAMICS

I) Overview

The current operating model ('M3') is based on conventional age-structured accounting (e.g. Quinn and Deriso 1999, Chapter 8) which is common to stock assessment models such as Stock Synthesis 3 (Methot and Wetzel 2013), CASAL (Bull et al. 2012), Multifan-CL (Fournier et al. 1998) and iSCAM (Martell 2015).

The standard age-structured equations are complicated somewhat by the subyear temporal structure in which ageing and recruitment occur in a particular subyear. In this version of the model, spawning occurs for all stocks in a subyear *ms*, after subyear 1 (spawning in the Mediterranean and Gulf of Mexico is thought to occur after a period of movement early in the year).

II) Equations

Numbers of individuals N, for stock s, in a model year y, in the first subyear m=1, age class a, and area r are calculated from individuals that have moved \vec{N} , in the previous year, final subyear n_m , of the same age class subject to combined natural and fishing mortality rate Z:

$$N_{s,y,m=1,a,r} = \vec{N}_{s,y-1,n_m,a,r} \cdot e^{-Z_{s,y-1,n_m,a,r}}$$
(3.1)

where total mortality rate is calculated from annual natural mortality rate M, divided by the fraction of the year represented by the subyear t_m , and fishing mortality rate F, summed over all fleets f:

$$Z_{s,y,m,a,r} = t_m M_{s,a} \sum_f F_{y,m,a,r,f}$$
(3.2)

Fishing mortality rate at age is derived from fishing mortality rate by length class FL and the conditional probability of fish being in length class l, given age a (an inverse agelength key, LAK).:

$$F_{y,m,a,r,f} = \sum_{l} FL_{y,m,l,r,f} \cdot LAK_{s,a,l}$$
(3.3)

The fishing mortality rate at length is calculated from an index of fishing mortality rate I, an estimated catchability coefficient q, a season and area specific deviation FD, and a length selectivity ogive s, by fleet:

$$FL_{y,m,l,r,f} = q_f \cdot I_{y,f} \cdot FD_{m,r} \cdot s_{f,l}$$
(3.4)

Selectivity is calculated by a double normal ogive and an estimate of mean length *L* for a length class *l*:

$$s_{f,l} = \begin{cases} \left(-\frac{L_l - smax_f}{\sigma_{f,A}^2}\right)^2 & L_l \le smax_f \\ \left(-\frac{L_l - smax_f}{\sigma_{f,D}^2}\right)^2 & L_l > smax_f \end{cases}$$
(3.5)

where *smax* is the fleet-specific length at maximum vulnerability, and σ_A and σ_D are parameters controlling the width of the ascending and descending limbs of the selectivity respectively. Large values of σ_D approximate a 'flat topped' logistic selectivity.

In the spawning subyear ms, ages advance by one and recruitment occurs. The model includes a plus group which is the final age class n_a :

$$N_{s,y,ms,a,r} = \begin{cases} \vec{N}_{s,y,ms-1,a-1,r} \cdot e^{-Z_{s,y,ms-1,a-1,r}} & a < n_a \\ \vec{N}_{s,y,ms-1,a-1,r} \cdot e^{-Z_{s,y,ms-1,a-1,r}} + \vec{N}_{s,y,ms,a,r} \cdot e^{-Z_{s,y,ms,a,r}} & a = n_a \end{cases} (3.6)$$

Recruitment is derived from a mean recruitment estimate for each stock over the whole time period \overline{R} which is assumed to occur in user-specified spawning areas *rs*.

$$N_{s,y,ms,1,rs} = \bar{R}_s \exp\left(\varepsilon_{R,y} - \sigma_R^2/2\right)$$
(3.7)

where ε_R is a random normal deviate with variance σ_R^2 and $\sigma_R^2/2$ is the bias correction to ensure that on average, recruitment deviations have a mean of 1.

Under projections the operating models use various approaches for modelling recruitment including Beverton-Holt and 'hockey stick' forms that predict recruitment from stock-wide spawning biomass. Spawning stock biomass is calculated from moved stock numbers in the previous year, and subyear prior to spawning subyear *ms*, weight of individuals at age *w*, and the fraction of individuals mature at age *mat*:

$$SSB_{s,y} = \sum_{a} \sum_{rs} \vec{N}_{s,y-1,ms-1,a,r} \cdot e^{-Z_{s,y,ms-1,a,r}} \cdot w_{s,a} \cdot mat_{s,a}$$
(3.8)

where weight is calculated from length at age *l*:

$$w_{s,a} = \alpha_s \cdot l_{s,a}^{\beta_s} \tag{3.9}$$

and the fraction mature at age is assumed to be a logistic function of age with parameters for the age at 50% maturity γ , and slope ϑ :

$$mat_{s,a} = 1/(1 + e^{(\gamma_s - a)/\vartheta_s})$$
(3.10)

Stock numbers for subyears that are not the first subyear of the year and are not the spawning subyear are calculated:

$$N_{s,y,m,a,r} = \vec{N}_{s,y,m-1,a,r} \cdot e^{-Z_{s,y,m-1,a,r}}$$
(3.11)

In each subyear, after mortality and recruitment, fish are moved according to an agespecific Markov transition matrix mov that represents the probability of a fish moving from area k to area r at the end of the subyear m:

$$\vec{N}_{s,y,m,a,r} = \sum_{k} N_{s,y,m,a,k} \cdot mov_{s,m,a,k,r}$$
(3.12)

The movement matrix is calculated from a log-space matrix lnmov and a logit model to ensure each row (k) sums to 1:

$$mov_{s,m,a,k,r} = e^{lnmov_{s,m,a,k,r}} / \sum_{r} e^{lnmov_{s,m,a,k,r}}$$
(3.13)

Size/age stratification for movement models will initially be attempted for three age groups: 0-2, 3-8 and 9+ years (this will be kept the same for the Western Atlantic and the Eastern Atlantic/Mediterranean, but should be re-evaluated for the East as future data become available).

Movements from an area k to an area r that are considered to be implausible (e.g. from the Eastern Mediterranean to the Gulf of Mexico) are assigned a large negative number (essentially zero movement) in corresponding cells in these movement matrices. For each area k, from which individuals can move, one value is assigned zero and all other possible movements are assigned an estimated parameter ψ (since rows must sum to 1, there is one less degree of freedom):

$$lnmov_{s,m,a,k,r} = \begin{cases} -1E10 & no movement from k to r \\ 0 & first assigned possible movement from k to r \\ \Psi_{s,m,k,r} & other possible movements from k to r \end{cases}$$
(3.14)

This movement model can be simplified to estimate only those movements for which data have been observed (e.g.at least one tag track or conventional tagging observation).

Compared with spatially aggregated models, initialization is more complex for spatial models, particularly those that need to accommodate seasonal movement by age and may include regional spawning and recruitment. The equilibrium unfished age structure / spatial distribution cannot be calculated analytically. For any set of model parameters it is necessary to determine these numerically by iteratively multiplying an initial guess of age structure and spatial distribution by the movement matrix. The solution used here is to iterate the transition equations above (Equations 3.1, 3.6, 3.7, 3.11, 3.12) given a fishing mortality rate averaged over the first five years of model predictions until the spatial distribution of stock numbers converges for each of the subyears.

Prior to this iterative process an initial guess at the spatial and age structure of stock numbers \hat{N} is made based on the movement matrix and natural mortality rate at age *M*:

$$\widehat{N}_{s,m,a,r} = \overline{R}_s \cdot e^{-\sum_1^a M_{s,a}} \cdot \sum_k \frac{1}{n_r} \cdot mov_{s,m,a,k,r}$$
(3.15)

In years prior to the initial model year (e.g. before 1983), historical catches \overline{C} for eastern and western areas (east/west of 45 degrees longitude) are used to initialize the model using stock reduction analysis (i.e. catches are removed without error from the asymptotic estimates of unfished numbers \widehat{N}). Mean historical annual catches were divided up among areas and seasons assuming the same seasonal and spatial pattern of catches as the initial years of the modelled time series (e.g. 1961-1965).

Stock numbers for initialization years (e.g. 1864-1982) are calculated using the same equations (i.e. Eqn 3.11 and 3.12) as model years (e.g. 1983 – 2016). The exception is that rather than using effort data, selectivities and an inverse age-length key (Eqns 3.3 and 3.4), fishing mortality rate at age is derived from mean historical catches and the assumption is made that these are taken without error in the middle of the time step with natural mortality rate occurring both before and after fishing:

$$F_{i=1,m,a,r,f} = \begin{cases} -\log\left(1 - \frac{\bar{c}_{m,a,r}}{\bar{N}_{s,m,a,r}e^{-(t_m M_{s,a})/2}}\right) & i = 1\\ -\log\left(1 - \frac{\bar{c}_{m,a,r}}{\bar{N}_{s,y-1,n_m,a,r}e^{-(t_m M_{s,a})/2}}\right) & i > 1, m = 1\\ -\log\left(1 - \frac{\bar{c}_{m,a,r}}{\bar{N}_{s,y,m-1,a,r}e^{-(t_m M_{s,a})/2}}\right) & i > 1, m > 1 \end{cases}$$
(3.16)

where *i*=1 is the first year and calculates fishing mortality rates from asymptotic numbers \hat{N} (Eqn. 3.15).

Baseline

Recruitment freely estimated (no stock-recruitment model assumed when fitting operating model to data)

Recruitment calculated from stock-wide SSB for projections only

Gravity movement model used to calculate Markov movement matrix by subyear and stock

Movement calculated only for those transitions recorded by tagging

Alternative options

Hockey stick SR relationship (West) Recruitment calculated from spawning area SSB

Markov movement matrix by subyear and stock (following model updates the gravity model – a specific case of the more general Markov model – seemed an appropriate choice for the Baseline).

Movement calculated for all transitions except stock exclusive spawning areas.

III) Fleet structure and exploitation history

No.	Fleet code	Gear code	Flag	Start	End	Areas	Quarters
1	LLOTH	LL	Not JPN	1960	2015	Any	Any
2	LLJPN	LL	JPN	1960	2015	Any	Any
3	BBold	BB	ALL	1960	2008	Any	Any
4	BBnew	BB	ALL	2009	2015	Any	Any
5	PSMedRec	PS	ALL	2009	2015	Med	Any
6	PSMedLOId	PS	ALL	1960	2008	Med	2
7	PSMedSOld	PS	ALL	1960	2008	Med	Not 2
8	PSWestOld	PS	ALL	1960	1986	Not Med	Any
9	PSWestnew	PS	ALL	1987	2015	Not Med	Any
10	TPOId	ТР	ALL	1960	2008	Any	Any
11	TPnew	ТР	ALL	2009	2015	Any	Any
12	RRCan	RR	CAN	1988	2015	Any	Any
13	RRUSA	RR	USA	1988	2015	Any	Any
14	All other fleets	s -	-	1960	2015	Any	Any

Table 3.1. Fleet definitions. Note that some fleets may be partitioned.

Baseline

A 14-fleet model based on the definitions of Table 3.1.

Alternative options

A proposal for alternatives may need to be developed and reviewed in the future.

4. MANAGEMENT OPTIONS

Notes:

- a) The following section is included to provide some suggestions on possible structures to MP developers of management options to be included in the MPs. The suggestions offered are illustrative clearly they will need to be discussed with stakeholders as the process develops.
- b) As above, for convenience they have been set out in baseline and alternative option form. It is recommended that many of the choices for the final MP options be made later in the process, so that they can be informed by results from trials which show the pro/con trade-offs amongst such options.
- c) The specifics of future candidate MPs will be left to their developers to determine based on the results of their application to the finalised trials. However those candidates need to take account of the broad desired characteristics/limitations set out below.
- d) HCRs need not to explicitly include reference points

I) Spatial strata for which TACs are set

Baseline

Conventional West and East/Mediterranean regions (Figure 1.1):

West: areas 1-4 (GOM, CAR, WATL, GSL).

East+Med: areas 5-10 (SCATL, NCATL, NEATL, EATL, SEATL, MED).

Alternative options

Various possibilities exist, based on alternative combinations of the spatial strata defined in Item 1. For example, separating out the central Atlantic (Figure 1.1A).

West: areas 1-4 (GOM, CAR, WATL, GSL).

Central: areas 5-6 (SCATL, NCATL).

East+Med: areas 7-10 (NEATL, EATL, SEATL, MED).

However it is suggested that consideration of such more complex options be postponed to a "second round".

II) Options for the frequency of setting TACs

Baseline

Every two years, for both West and East+Med (or alternative spatial strata) together

Alternative options

- i) Every three years
- ii) Every four years

III) Upper limits on TACs

[Note that this option has potential advantages for reducing risk and avoiding overcapitalisation.]

Baseline

No upper limit

Alternative options

West	e.g.	5 000,	6 000 mt
East +Med	e.g.	30 000,	40 000 mt

IV) Minimum extent of TAC change

<u>Baseline</u>

No minimum.

Alternative options

West	e.g.	200,	300 mt
East +Med	e.g.	1 000,	2 000 mt

V) Maximum extent of TAC change

[Note the underlying rationale is to promote industrial stability.]

Baseline

West	20%
East +Med	20%

Alternative options

West	15%
East +Med	15%

Note that developers of candidate MPs should consider including options which:

- a) Override such restrictions on the maximum extent of reduction if abundance indices drop below specified thresholds.
- b) Allow for greater increases (in terms of tonnage) if a TAC has had to be reduced to a low level and indices confirm subsequent recovery.

VI) Technical measures

Size restrictions might be considered on a fleet and/or spatial stratum basis. However, for a "first round" it is suggested that these not be included explicitly, but instead be considered to be effected implicitly through the selectivity prescriptions for future catches by the various fleets which are set out under item 6 below.

5. FUTURE RECRUITMENT AND DISTRIBUTION SCENARIOS

See also section 9 of this document.

I) West

Functional forms fitted to assessment outputs for the years 1970+

- a) Hockey stick
- b) Beverton Holt with steepness *h* estimated

II) East + Mediterranean

Functional forms fitted to years 1950+

- a) Beverton Holt with h = 0.98 for 1950-1982, 1983+ and 1950+
- b) Beverton Holt with h = 0.70 for 1950-1982, 1983+ and 1950+

Note that 1950-1982 is "low" recruitment, and 1983+ is "high" recruitment.

III) Future regime shifts

West

- a) None
- b) After 10 years of projection, switch to other regime
- c) Probability of 0.05 every projection year of switch to other regime

East+Med

- a) 1983+ relationship continues unchanged
- b) 1983+ relationship changes to 1950-1982 relationship after 10 years
- c) Probability of 0.05 every projection year of a swop between 1983+ and 1950-1982 relationships

Note that for option c), it might be better to preclude changes over, say, the last 10 years of a 30-year projection period to ease interpretation of results through the reduction of transient effects.

IV) Statistical properties

Residuals are taken to be lognormally distributed about the relationship assumed with the standard deviation of the log recruitments (σ_R) invariant over time.

Baseline

Uncorrelated residuals with $\sigma_R = 0.5$. (a common value obtained from the RAM legacy database).

Alternative options

 σ_R and autocorrelation as estimated from the residuals for the conditioning concerned (post model fit, not within model fit, for greater statistical stability). For East+Med this will refer to the 1950+ fits.

V) Possible future distributional changes

Plausible options for future distributional changes (in relative terms) in response to changes in abundance and to possible environmental changes will be considered in a "second round".

6. FUTURE CATCHES

Baseline

- a) Future catches will be taken to equal future TACs (up to a maximum harvest rate of 95%).
- b) The allocation of these future catches amongst fleets will be set equal to the average over 2012-2014
- c) The spatial distribution per stratum (see item 1 above) of these future catches will be set equal to the average over 2012-2014
- d) The selectivity function for each fleet for the most recent period for which this is estimated in the conditioning of the trial concerned will be taken to apply for all future years
- e) If the TAC is changed, the proportional allocation by fleet will remain unchanged, as will the proportional distribution by spatial stratum.

Alternative options

Clearly many are possible, but are probably best delayed until a "second round". Were substantial changes to eventuate during a period when an MP was in operation, this would in any case likely necessitate re-tuning and re-testing or a modified MP.

The impacts of possible IUU catches should perhaps be considered under robustness trials (see item 9 below).

7. GENERATION OF FUTURE DATA

Note that these are for use as input to MPs, so need to be chosen carefully from a set of those highly likely to be regularly (i.e. annually) available. This is because application of the MP relies on these data being available in this way, so difficulties can (and have in other cases) obviously arise should they fail to do so. Though any candidate MP proposed

should include a rule to deal with the absence of just one future value from an input series, any more than that would require re-tuning and re-testing of a modified MP, which is preferably planned to be avoided given the associated extra costs.

Consideration is also needed of the "delays" associated in such data becoming available for input to an MP. The customary default is that for computation of the TAC for year *y*, the most recent data finalised and available will be for year *y*-2. Any changes to that will require motivation and specification.

I) Baseline suggestions

West

- a) Gulf of Mexico larval index of spawning stock abundance
- b) US RR 115-144cm index of exploitable abundance
- c) JLL_W CPUE index of exploitable abundance

East+Med

- a) JLL_NEA CPUE index of exploitable abundance
- b) Western Mediterranean larval index of spawning stock abundance
- c) GBYP aerial survey of adults
- d) Juvenile aerial survey Gulf of Lyon

II) Alternative options

Obviously many additions or alternatives to the suggestions made are possible. The reasons behind the initial suggestions above are respectively lengthy continuity (though admitting a concern about the decrease in spatial coverage of the JLL_NEA index over time) and fishery-independence. Accordingly the East + Med might be extended to include trap or baitboat indices.

Including additional indices of abundance will increase the workload (see below), so might be better postponed to a "second round".

Catch-at-length series could also be considered for inclusion, but raise further technical complications regarding the specification of how they are generated, so are likely best deferred from consideration until a "second round".

III) Relationships with abundance

For baseline trials, abundance indices will be taken to be linearly proportional to the appropriate component of the underlying model biomass in the stratum/strata concerned.

Possible alternatives to this are considered under Robustness trials (see item 9 below).

IV) Statistical properties

Baseline

- a) Residuals are taken to be lognormally distributed; standard deviation of the log recruitments (σ) invariant over time.
- b) The values of σ will be estimated
- c) No Autocorrelation of residuals
- d) The conditioning results will be inspected for model mis-specification regarding the fit to the series concerned; if so the bias identified will be modelled to continue into the future in a "plausible" way.

Alternative options

- a) Fix σ values for all trials based on a central trial from the Reference set (see item 9 below).
- b) If additional CPUE indices to the single one initially suggested are included, residuals need to be examined for correlation, with this being taken into account in generating future values.

Other aspects

Currently a 'master' relative abundance index is used for the Mixed stock model which provides an estimate of relative abundance across all time-area strata (e.g. by year, quarter and area). The approach taken here is to include multiple fleets by dividing their catches by this 'master' index to provide an index of fishing mortality rate (a partial F) leaving only catchability by fleet to be estimated rather than several thousands of individual F parameters (by fleet, year, quarter and area). Simulation testing reveals that this approach provides unbiased estimates of central quantities such as abundance, stock depletion, mixing rate and selectivity. However the construction of the 'master' index is critical and this is an important axis of uncertainty for operating models.

MP input series (e.g. as suggested in section I, above) may however be specific fleet indices, rather than this master relative abundance index, and hence require generation into the future. This will be effected by including these series in the conditioning with comparisons to the resource components which they are assumed to reflect, but with a very low weight in the log-likelihood so as not to impact estimates of other parameters in the model fit. The estimates of the catchability coefficients, and statistical properties of the residuals of this fit will be used in generating values for this series forward in time.

Note that consideration should at some stage also be given to new data types that are only now becoming available (e.g. aerial surveys, genetic tagging). These will not at this stage have been collected over a sufficient length of time to be able to serve as MP inputs, but the overall testing process can be used to provide insight into their potential future utility.

8. PARAMETERS AND CONDITIONING

For the Baseline model, spawning is assumed to occur in areas 'GOM' for the West stock and 'W.Med' + 'E.Med' for the East + Mediterranean stock (Figure 1.1A).

I) *Fixed parameters*

Number of parameters	Symbol
n_s	Н
n_s	Linf
n_s	Κ
n_s	t_0
$n_a \cdot n_s$	М
2-3	Θ
$n_a \cdot n_s$	mat
	Number of parameters n_s n_s n_s n_s $n_a \cdot n_s$ $2-3$ $n_a \cdot n_s$

Table 8.1. The parameters that are fixed (user specified	d)
--	----

Parai	neter		West								East						
Steep	ness		N/A (hockey-stick)							0.98							
(Bev.	-Holt))	Estimated 0.7														
Туре			Richards growth von Bert. grow									growth	ı				
A2		34															
<i>L1</i> (c)	m)					33.0											
<i>L2</i> (cr	m)					270.6				Lir	nf (cm)	318.	8			
K						0.22				K 0.093							
p 0						-0.12				<i>t0</i> -0.97							
Natu	ral mo	ortality	y rate	at age	(East	and V	Vest)										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+		
High	0.38	0.30	0.24	0.20	0.18	0.16	0.14	0.13	0.12	0.12	0.11	0.11	0.11	0.10	0.10		
Low	0.36	0.27	0.21	0.17	0.14	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.07		
Select least	tivity o one fle	of at eet				-	Japa	inese I	ongli	ne flee	t is asy	mptot	ic	-			
Spaw fracti	ning on																
Age		0	12	3	4 5	6	7	8	9	10	11	12	13+				

Table 8.2. Parameter values of baseline and alternative options

Younger	0	0	0	0.25	0.5	1	1	1	1	1	1	1	1	1
Older (East)	0	0	0	0.15	0.3	0.45	0.6	0.75	0.9	1	1	1	1	1
Older (West)	0	0	0	0	0	0	0	0.01	0.04	0.19	0.56	0.88	0.98	1

II) Estimated parameters

The majority of parameters estimated by the model relate to movement probabilities and annual recruitment deviations (Table 8.3).

Table 8.3. The parameters estimated by the model. The example is for a possible bluefin tuna operating model of 8 areas (Figure 1), 4 subyears, 14 fleets, 32 years and 18 ages and 3 movement age classes.

Parameter	Number of parameters	
Mean total recruitment	1	1
Fraction of total rec. that is Eastern	1	1
Fraction of stock recruitment in SRA phase	<i>n_{stocks}</i>	2
Length a modal selectivity	<i>n</i> _{fleets}	14
Ascending precision of selectivity	<i>N</i> fleets	14
Descending precision of selectivity	Nfleets-1	13
Recruitment deviations	$(n_{years + n_{ages} + 1}) \cdot n_{stocks} \cdot n_{ageclass}$	262
Fleet catchability (q)	N fleets	5
F deviation (FD)	nseasons · nareas	40
Movement	$n_{areas} \cdot n_{seasons} \cdot n_{stocks}$	80
	Total	432

Parameter	Prior	Likelihood component			
All operating models					
Total recruitment	log-uniform(<i>LB</i> = 11.5, <i>UB</i> = 16.5)	-lnL _{rec}			
Fraction of recruitment that is eastern	logit-uniform($LB = -\infty$, $UB = \infty$)	-lnL _{fracrec}			
Fraction of stock recruitment in SRA phase	logit-uniform($LB = -2.0$, $UB = 2.0$)	-lnL _{histrec}			
Selectivity	lognormal($\mu = 0, \sigma = 0.9$) (<i>LB</i> = -3.0, <i>UB</i> = 3.0)	-lnL _{sel}			
Fleet catchability (q) (mean F)	log-uniform($LB = -10.0, UB = 1.0$)	$-lnL_q$			
Fishery independent index catchability	log-uniform($LB = -2.3, UB = 2.3$)	-lnL _{qI}			
Fishery dependent index catchability	log-uniform($LB = -6.0, UB = 4.0$)	-lnL _{qD}			
F deviation (FD, Eqn 3.4)	$lognormal(\mu = 0, \sigma = 0.2)$	-lnL _{FD}			
Movement deviations (from fully mixed)	lognormal($\mu = 0, \sigma = 1.0$) (<i>LB</i> = -6.0, <i>UB</i> = 6.0)	-lnL _{mov}			
Recruitment deviations	$lognormal(\mu = 0, \sigma = 0.5)$	-lnL _{recdev}			
Some operating models					
Mean SSB by area (reference set, 2B)	lognormal($\mu_{Eastern} = ln(3E+5), \ \mu_{Western} = ln(2.7E+4), \ \sigma = 0.01$)	-lnL _{muSSB}			
Eastern area SSB change (reference set, 2C)	lognormal($\mu = ln(3), \sigma = 0.01$)	-InL _{SSBinc}			

Table 8.4. Prior probability distributions for model parameters with mean μ and standard deviation σ , and lower and upper bounds *LB* and *UB*, respectively.

A summary of likelihood functions can be found in Table 8.4.

For each fleet f, total predicted catches in weight \hat{C} , are calculated from the Baranov equation:

$$\hat{C}_{y,m,r,f} = \sum_{s} \sum_{a} w_{s,a} \cdot N_{s,y,m,a,r} \cdot (1 - e^{-Z_{s,y,m,a,r}}) \cdot \left(\frac{F_{y,m,a,r,f}}{Z_{s,y,m,a,r}}\right)$$
(8.1)

Similarly predicted catches in numbers at age (CAA) are given by:

$$\widehat{CAA}_{s,y,m,a,r,f} = N_{s,y,m,a,r} \cdot (1 - e^{-Z_{s,y,m,a,r}}) \cdot \left(\frac{F_{y,m,a,r,f}}{Z_{s,y,m,a,r}}\right)$$
(8.2)

This can be converted to a prediction of total catches in numbers by length class *CAL* using a stock specific inverse age-length key, *LAK*:

$$\widehat{CAL}_{y,m,l,r,f} = \sum_{s} \sum_{a} \widehat{CAA}_{s,y,m,a,r,f} \cdot LAK_{s,a,l}$$
(8.3)

The model predicts spawning stock biomass indices \widehat{Issb} , that are standardized to have a mean of 1 for each stock over the total number of years n_y :

$$\widehat{Issb}_{s,y} = n_y \cdot SSB_{s,y} / \sum_y SSB_{s,y}$$
(8.4)

The model predicts exploitable biomass indices \hat{I} , by fleet that are standardized to have a mean of 1 for each fleet:

$$\hat{I}_{y,m,r,f} = n_y \cdot n_m \cdot n_r \cdot V_{y,m,r,f} / \sum_y \sum_m \sum_r V_{y,m,r,f}$$
(8.5)

where exploitable biomass V is calculated as:

$$V_{y,m,r,f} = \sum_{l} \left(s_{f,l} \cdot \sum_{s} \sum_{a} \left(N_{s,y,m,a,r,f} \cdot LAK_{s,a,l} \cdot w_{s,a} \right) \right)$$
(8.6)

The model predicts stock of origin composition of catches \overline{SOO} , from predicted catch numbers at age:

$$\overline{SOO}_{s,y,m,r,f} = \sum_{a} \widehat{CAA}_{s,y,m,a,r,f} / \sum_{s} \sum_{a} \widehat{CAA}_{s,y,m,a,r,f}$$
(8.7)

A log-normal likelihood function is assumed for total catches by fleet. The negative loglikelihood is calculated as:

$$-lnL_{c} = \sum_{y} \sum_{m} \sum_{r} \sum_{f} ln(\sigma_{catch}) + \frac{\left(\ln(\hat{c}_{y,m,r,f}) - \ln(c_{y,m,r,f})\right)^{2}}{2 \cdot \sigma_{catch}^{2}}$$
(8.8)

Similarly the negative log-likelihood components for indices of exploitable biomass and spawning stock biomass are calculated as:

$$-lnL_{i} = \sum_{y} \sum_{m} \sum_{r} \sum_{f} ln(\sigma_{index}) + \frac{\left(ln(l_{y,m,r,f}) - ln(l_{y,m,r,f})\right)^{2}}{2 \cdot \sigma_{index}^{2}}$$
(8.9)

$$-lnL_{SSB} = \sum_{s} \sum_{y} ln(\sigma_{SSB}) + \frac{\left(ln(\overline{lssb}_{s,y}) - ln(lssb_{s,y})\right)^2}{2 \cdot \sigma_{SSB}^2}$$
(8.10)

The length composition data are assumed to be distributed multinomially. In traditional stock assessment settings catch composition data may often dominate the likelihood function due to the large number of observations. This is exacerbated by a failure to account for non-independence in size composition samples. There are two possible solutions: (1) manually specify the effective sample size (ESS) of length-composition samples or (2) use a multinomial likelihood function that includes the conditional maximum likelihood estimate of the ESS (perhaps even a freely estimated ESS, S. Martell personal communication). In this version of the code, ESS is user-specified.

The negative log-likelihood component for length composition data is calculated as:

$$-lnL_{CAL} = -\sum_{y} \sum_{m} \sum_{l} \sum_{r} \sum_{f} CAL_{y,m,l,r,f} \cdot ln(\hat{p}_{y,m,l,r,f}) / ESS_{f}$$

$$(8.11)$$

where the model predicted fraction of catch numbers in each length class p, is calculated as:

$$\hat{p}_{y,m,l,r,f} = \widehat{CAL}_{y,m,l,r,f} / \sum_{l} \widehat{CAL}_{y,m,l,r,f}$$
(8.12)

Similarly the negative log-likelihood component for PSAT tagging data of known stock of origin (SOO), released in year y, subyear m, area r and recaptured in year y, subyear m, and area k is calculated as:

$$-lnL_{PSAT} = -\sum_{s}\sum_{y}\sum_{m}\sum_{y2}\sum_{m2}\sum_{r}\sum_{k}PSAT_{s,y,m,y2,m2,k} \cdot ln(\hat{\theta}_{s,y,m,y2,m2,r,k})$$
(8.13)

where recapture probabilities θ , are calculated by repeatedly multiplying a distribution vector *d*, by the movement probability matrix *mov*. For example for a tag released on a fish of stock 1 in year 2, subyear 3, and area 4, the probability of detecting the tag in year 3, subyear 2 for the various areas is calculated as:

$$\hat{\theta}_{s=1,y=2,m=3,y=3,m=2,r=4,1:n_r} = \left(\left(d \cdot mov_{s,m=3} \right) \cdot mov_{s,m=4} \right) mov_{s,m=1}$$
(8.14)

where

$$d_k = \begin{cases} 0 & k \neq r \\ 1 & k = r \end{cases}$$
(8.15)

The negative log-likelihood component for PSAT tagging data of unknown stock of origin PSATu, is currently weighted according to the compound probability that a fish is of a particular stock given the track history for that tag. For example for a tag t, tracked in series of years y_i , subyears m_i , and regions r_i , the weight w, of that tag for a specific stock is calculated as:

$$w_{t,s} = \frac{\prod_{i} [(\sum_{a} N_{si,yi,mi,ai,ri})/(\sum_{s} \sum_{a} N_{si,yi,mi,ai,ri})]}{\prod_{i} [1 - (\sum_{a} N_{si,yi,mi,ai,ri})/(\sum_{s} \sum_{a} N_{si,yi,mi,ai,ri})]}$$
(8.16)

This is simply the product of fractions of that stock in those time-area strata divided by the product of the fractions of other stocks in those time-area strata. An alternative approach would be to compare the relative probabilities of the observed movements among the stocks although it is unclear whether this circularity (PSAT data are a primary source of information regarding movement) could lead to estimation problems.

The weighted negative log-likelihood function is similar to that of the stocks of known origin but includes the appropriate weighting term for each tag:

$$-lnL_{PSAT} = -\sum_{t}\sum_{s}\sum_{y}\sum_{m}\sum_{y2}\sum_{m2}\sum_{r}\sum_{k}PSATu_{t,s,y,m,y2,m2,k} \cdot ln(\hat{\theta}_{s,y,m,y2,m2,r,k}) \cdot w_{t,s}$$

$$(8.17)$$

The negative log-likelihood component for stock of origin data *SOO* is also calculated assuming a multinomial distribution:

$$-lnL_{SOO} = -\sum_{s}\sum_{y}\sum_{m}\sum_{r}\sum_{f}SOO_{s,y,m,r,f} \cdot ln(\widehat{SOO}_{s,y,m,r,f})$$
(8.18)

In order to fit the operating models to assessment model predictions (Factor 2 level B) a likelihood function is included for mean spawning \overline{SSB} by Eastern/Western area k,

$$-lnL_{muSSB} = \sum_{k} ln(\sigma_{muSSB}) + \frac{\left(\ln(\overline{SSB}_{k}) - \ln(\overline{\overline{SSB}}_{k})\right)^{2}}{2 \cdot \sigma_{muSSB}^{2}}$$
(8.19)

where \overline{SSB} is the mean annual SSB estimated from the VPA stock assessments (around 300 000 tonnes in the East, 27 000 tonnes in the West) and operating model predicted spawning biomass \overline{SSB} is calculated:

$$\overline{SSB}_{k} = \frac{1}{n_{y}n_{m}} \sum_{y} \sum_{s} \sum_{m} \sum_{a} \sum_{r} (\vec{N}_{s,y-1,ms-1,a,r} \cdot e^{-Z_{s,y,ms-1,a,r}} \cdot w_{s,a} \cdot mat_{s,a})^{area_{k,r}}$$
(8.20)

and *area* is a switch that is either 1 or zero depending on whether the area r is in the Eastern or Western assessment areas.

In order to fit the operating models to assessment model spawning biomass increases (Factor 2 level C) a likelihood function is included for spawning biomass increases by area:

$$-lnL_{SSBinc} = \sum_{k} ln(\sigma_{SSBinc}) + \frac{\left(\ln\left(\frac{SSB_{k,y2}}{SSB_{k,y1}}\right) - \ln(SSBinc)\right)^2}{2 \cdot \sigma_{SSBinc}^2}$$
(8.21)

where *SSB* is the spawning biomass in eastern/western area k and *SSBinc* is the fractional increase in VPA assessment spawning biomass in area k from year y1 to year y2 (this is 3 between years 2006 and 2015).

The global penalised negative log-likelihood $-lnL_T$, to be minimized is the summation of the weighted negative log-likelihood components for the data and priors (Table 8.4):

$$-lnL_{T} = -[\omega_{c} \cdot lnL_{c} + \omega_{i} \cdot lnL_{i} + \omega_{SSB} \cdot lnL_{SSB} + \omega_{CAL} \cdot lnL_{CAL} + \omega_{PSAT} \cdot lnL_{PSAT} + \omega_{SOO} \cdot lnL_{SOO} + \omega_{muSSB} \cdot lnL_{muSSB} + \omega_{SSBinc} \cdot lnL_{SSBinc} + \omega_{rec} \cdot lnL_{rec} + \omega_{fracrec} \cdot lnL_{fracrec} + \omega_{histrec} \cdot lnL_{histrec} + \omega_{sel} \cdot lnL_{sel} + \omega_{q} \cdot lnL_{q} + \omega_{qI} \cdot lnL_{qI} + \omega_{qD} \cdot lnL_{qD} + \omega_{FD} \cdot lnL_{FD} + \omega_{mov} \cdot lnL_{mov} + \omega_{recdev} \cdot lnL_{recdev}]$$

$$(8.22)$$

Type of data	Disaggregation	Function	Likelihood component
Total catches (weight)	year, subyear, area, fleet	Log-normal	lnL_c
Index of exploitable biomass (assessment CPUE index)	year, subyear, area, fleet	Log-normal	lnLi
Index of spawning stock biomass (e.g. a larval survey)	year, stock	Log-normal	lnL _{SSB}
Length composition	year, subyear, area	Multinomial	lnLcal
PSAT tag (known stock of origin)	stock, year, subyear, area, age class	Multinomial	lnL _{PSAT}
Stock of origin	year, subyear, area, age class	Multinomial	lnLsoo

Table 8.5. Summary of the negative log-likelihood function contributions from various data

III) Characterising uncertainty

Baseline

Include within-model uncertainty via MCMC sampling of posteriors for model parameters.

Alternative options

Include within-model uncertainty (parameter uncertainty) via Monte Carlo sampling from the inverse Hessian matrix of model parameters.

Concentrate on among-model uncertainty using the maximum posterior density estimates of model parameters and a prior model weight based on expert judgement. Uniform weights will be used to start, possibly updated later using a Delphi-type approach.

9. TRIAL SPECIFICATIONS

A. Reference set

Three major uncertainty axes: future recruitment; current abundance; and natural mortality/maturity (in combination) for conditioning and projections. These axes assume that the options of East and West are linked across rows of the table below. This is done with the intention of capturing extremes.

	West	East							
Futu	re recruitment								
1	Hockey-stick	83+ B-H with <i>h</i> =0.98							
2	B-H with <i>h</i> estimated	83+ B-H with <i>h</i> =0.70							
2	Hockey-stick changes to	83+ B-H with <i>h</i> =0.98 changes to 50-							
3	B-H after 10 years	82 B-H with $h=0.98$ after 10 years							
Abundance									
А	Best estimate								
В	East-West area spawning	biomass matches VPA assessment							
С	Recent eastern area SSB inc	creases 3x to match VPA assessment							
Spav	vning fraction both stocks	Natural Mortality rate both stocks							
Ι	Younger	High							
II	Younger	Low							
III	Older	High							
IV	Older	Low							

Note: when modifying current abundance a highly informative prior will be placed on either the spawning biomass by Eastern-Western area (B) or the trend (fractional increase) in the eastern area (C).

Combinations for Reference Set

A full cross of (1, 2, 3) x (A, B, C) x (I, II, III, IV), i.e. 36 scenarios in total.

Discussion will be required regarding whether, in addition to considering results for each of these scenarios individually, they should also be considered for all scenarios in combination, and if so how the scenarios should be weighted (if at all) in such a combination.

B. Robustness trials

High priority

- 1) Future catches in both the West and the East+Med are each year 20% bigger than the TAC as a result of IUU fishing (of which the MP is not aware)
- An undetected increase in catchability for CPUE-based abundance indices of 1% per annum
- 3) Non-linear index-abundance relationships
- 4) Alternative mixing scenario
- 5) Reference OM #1 assumptions but forcing SSB fit to that of the Western VPA assessment

Low priority

- 1) Future recruitment change as in 3), but with prob of 0.05 for each of the first 20 years of projection
- 2) Alternative assignments to stock of origin of historical catches from the South Atlantic (off Brazil)

"Second round" issues

The following aspects of uncertainty are suggested to be postponed at this time for consideration rather in a "second round":

- 1) More than two stocks
- 2) More than two indices of abundance used as input to a MP
- 3) Use of CAL data in an MP
- 4) TACs allocated on a spatially more complex basis than the traditional west and East+Med
- 5) Changes in technical measures affecting selectivity
- 6) Changes in stock distributions in the future
- 7) Future changes in proportional allocation of TACs amongst fleets

10. PERFORMANCE MEASURES/STATISTICS

Projections under candidate MPs will be for 100 years (unless this leads to computational difficulties) commencing in 2017. Prior to that, for projecting for years between the last year of the condition and 2017, the catches will be set equal to the TACs already set, with abundance index data (and any further monitoring data such as catch-at-length) not yet available for those years being generated as specified under item 7. Note that considering a period as lengthy as 100 years is not to imply high reliability for projections for such a long time, but to be able take account of transient effects that persist for some time for a long-lived species.

I) Summary measures/statistics

- a) Annual average catch for the first, second and third 10-year period of MP application (C10, C20 and C30, respectively).
- b) Spawning biomass depletion calculated relative to the deterministic equilibrium in the absence of catches for the recruitment function that applies after 10, 20 and 30 years of MP application (D10, D20 and D30, respectively)
- c) The lowest spawning biomass depletion over the 30 years for which the MP is applied (LD).
- d) Spawning biomass depletion after 30 years, but calculated relative to the trajectory that would have occurred had no catches been taken over the full period for which MP application is being considered (DNC)
- e) The lowest spawning biomass depletion over the 30 years for which the MP is applied, but calculated relative to the zero catch trajectory specified in d (LDNC).
- f) Kobe or alternative Kobe indicators: catch/biomass instead of Fmsy (POF); and biomass/biomass at a theoretical maximum MSY (POS); and the probability of both underfishing and underfished status (probability green kobe zone: PGK).
- g) Average annual variation in catches (AAVC) defined by:

$$AAV = \frac{1}{30} \sum_{y=2017}^{2046} \left| C_y - C_{y-1} \right| / C_{y-1}$$
(13.1)

For each of these distributions, 5%-, 50%- and 95% iles are to be reported from 200 replicates. Note the reason for measures/statistics c) and e) is to compensate for regime changes. The choice of these percentiles may need further exploration with stakeholders.

Further stakeholder orientated measures may need to be included. These must be scientifically based, easily understood by stakeholders and such that managers may readily request the evaluation of any changes in options.

II) Summary plots

Catch and spawning biomass trajectories plotted as:

- a) Annual medians with 5% and 95% ile envelopes
- b) 10 worm plots of individual realisations

Note that repetitions for different options for selectivity may be needed.

III) Level of reporting

Baseline

- a) Catch-related measures/statistics by traditional West and East+Med regions.
- b) Spawning biomass depletions measures/statistics by separate stocks

Alternative options

Many can be conceived, likely related primarily to catch and depletion by some combination of stock and/or spatial stratum. However these might be left for a "second round", as they would become more pertinent in the face of greater model complexities possibly introduced at that time, such as changing spatial distributions of stocks and/or catches (resulting from changed proportional allocations to different fleets).

Annex 1 to Appendix 7

Flag	Gear	Years	Season	Area	age	Reference	On going	VPA in 2017	SS in 2017	ОМ	CI	Comment
Spain	Baitboat	1952-2006	Q3	E Atl	2-3	SCRS/2014/54	Ν	Y	Y	Y		2017 VPA did not use 1952-1968
Spain / France	Baitboat	2007-2014	Q3	E Atl	3-6	SCRS/2015/169	Ν	Y	Y	Y		
Morocco / Spain	Trap	1981-2011	Q2	SE Atl	6+	SCRS/2014/060	Ν	Y	Y	Y		
Morocco / Portugal	Trap	2012-2015	Q2	SE Atl	10+	SCRS/2017/082	Y	Y	Y	Y		
Japan in East and Med	Longline	1975-2009	Q2	SE Atl+Med	6-10+	SCRS/2012/131	Ν	Y	Y	Y		
Japan in Northeast	Longline	1990-2009	Q4	NE Atl	4-10+	SCRS/2017/025	Ν	Y	Y	Y		
Japan in Northeast	Longline	2010-2015	Q4	NE Atl	4-10+	SCRS/2017/025	Y	Y	Y	Y	Y	
Norway	Purse seine	1955-1980	Q3	NE Atl	10+	Nominal Task2	Ν	Ν	Ν	Ν		Used in 2014 VPA
US (66cm - 114cm)	Rod and reel	1993-2015	Q3	W Atl	2-4	SCRS/2016/198	Y	Y	Y	Y		
US (115cm - 144cm)	Rod and reel	1993-2015	Q3	W Atl	4-6	SCRS/2016/198	Y	Y	Y	Y	Y	
US (<145cm)	Rod and reel	1980-1992 (gap in 1984)	Q3	W Atl	1-5	SCRS/1993/067	Ν	Y	Y	Y		
US (195cm +)	Rod and reel	1983-1992	Q3	W Atl	9-16	SCRS/1993/067	Ν	Y	Y	Y		
US (177cm +)	Rod and reel	1993-2015	Q3	W Atl	8-16	SCRS/2016/198	Y	Ν	Y	Y		use for OM
US in GOM	Longline	1987-1991	Q2	GOM	8-16	SCRS/2015/199	Ν	N	Y	Y		Not used in 2017 VPA due to no PCAA
US in GOM	Longline	1992-2015	Q2	GOM	8-16	SCRS/2015/199	Y	Y	Y	Y		
Japan in GOM	Longline	1974-1981	Q2	GOM	8-16	SCRS/1991/071	Ν	Y	Y	Y		
Japan in West	Longline	1976-2009	Q4	W Atl	2-16	SCRS/2017/025	Ν	Y	Y	Y		
Japan in West	Longline	2010-2015	Q4	W Atl	5-16	SCRS/2017/025	Y	Y	Y	Y	Y	
Canada combined	Rod and reel	1984-2015	Q3	W Atl	7-16	SCRS/2017/020	Y	Ν	Y	Ν		Remove from OM
Canada GSL	Rod and reel	1984-2015	Q3	GSL	8-16	SCRS/2017/020	Y	Ν	Ν	Y		use for OM
Canada SWNS	Rod and reel	1988-2015	Q3	WAtl	5-16	SCRS/2017/020	Y	Ν	Ν	Y		use for OM

Table 1. The standardized CPUE indices of the assessments that are used to derive trend information for the master index and also fit the operating models. Candidate indices (CI) initially chosen to project from the OMs for candidate management procedures (CMP).

Туре	Year	Season	Area	Age	Reference	On	VPA	SS	ОМ	CI	Comment
						going					
French aerial survey	2000-2003	Q3	Med	2-4	SCRS/2016/153	N	Y	Y	Y		Note split time series
French aerial survey	2009-2015 (gap in 2013)	Q3	Med	2-4	SCRS/2016/153	Y	Y	Y	Y	Y	Note split time series, June-Oct
Larval survey in Med	2001-2015 (gap in 2006- 2011)	Q2	Med	3- 10+	SCRS/P/2017/033	Y	Y	Y	Y	Y	Concern about gear change
Canadian acoustic survey	1994-2015	Q3	GSL	8-16	SCRS/2017/016	Y	Y	Y	Y	Y	This should be elevated to cand. MP. 2016 value will be available by the end of this April
Larval survey in GOM	1977-2015 (gaps in 1979- 1980, 1985)	Q2	GOM	8-16	SCRS/2014/057	Y	Y	Y	Y	Y	Use full time series starting in 1977
GPYP Aerial survey	2010-2015 (gaps in 2012, 2014)	Q2	Med	3+	SCRS/2015/144	Y	Ν	N	Y	Y	

Table 2. Fishery-independent indices used in the fitting of operating models.

Appendix 8

TUNING OF CMPs

(D. Butterworth)

Tuning (adjustment on CMP control parameter values) of CMPs conventionally takes place at two stages of the MSE process, and for two quite different reasons and audiences.

CMP development

At this stage there will be a number of CMP developers. Each will have their preferred CMP(s) (with their associated control parameter values/tunings) which have been adjusted for results somewhere on the axis from very conservative to highly aggressive as regards the catch *vs* resource depletion trade-off.

This then causes a problem in comparing results from the preferred MPs provided by different developers who will have made different selections along this axis, because comparisons are confounded by these differences. The purpose of "development tuning" is to remove this confounding so as to compare on a level playing field. It is achieved by each developer, in addition to their own preferred tuning, providing results for a common alternative tuning which meets some specified performance criterion. This is typically expressed in terms of resource depletion for a particular OM. For example, this might be that median spawning biomass should equal SSB(MSY) after 30 years of projection for OM1.

The reasons this is done is that such comparisons provide important insight into the properties of a CMP through such fair comparison with similar results for another. For example, performance across the other OMs might show that procedure to be less robust to uncertainty in its performance compared to another CMP. Further, in seeing where his/her CMP performs worse than another CMP, a developer learns where to concentrate in improving their CMP (for their preferred tuning).

This development tuning and its results are considered only within the technical scientific sub-group involved in the MSE process.

MP finalisation

"Finalisation tuning" takes place only during the last stages of the MSE process, when one or a few CMPs are being selected for recommendation to the Commission. At that stage of the process:

- Only one or two CMPs will have survived.
- The Commission will have provided feedback as to the range of catch vs depletion options it wishes to consider.
- The overview scientific committee (e.g. the bluefin session) will have agreed how results are to be weighted over a Reference Set of OMs to provide aggregate performance statistics.

Thus for example, this feedback might have indicated an objective to be securing spawning biomass after 30 years to be close to SSB(MSY). The finalisation tuning would then adjust CMP control parameters to provide a median SSB after those 30 years for this statistic weighted over the Reference Set OMs as agreed. If options are requested by the Commission, then three finalisation tunings of each surviving CMP to be reported might correspond to:

Median (SSB(30)/SSB(MSY)) = 0.9; 1.0; and 1.1

Current proposal

The current proposal concerns ONLY "development tuning" (decisions regarding finalisation tuning become both possible and relevant only much later in the process).

The proposal is to tune to Median (SSB(30)/SSB(MSY)) = 1.0 for a specified OM (median is selected rather than a lower percentile, which might better reflect risk, because with a limited number of simulations for reasons of computation time, the median will be more robustly estimated.

The tuning must be achieved for both west and east stocks. This is possible as any CMP will have separate control parameters for the west and east areas, so that there is sufficient flexibility in the choices of values for those parameters to meet the tuning criterion for both stocks.

It remains to specify the OM for which this tuning is to be conducted. It is proposed that this be an OM for which the historical SSB trajectory in the middle of the range for the reconditioned Reference Set of OMs, and that this selection be made by Tom Carruthers on consideration of the results for these reconditioned OMs.