# REPORT OF THE SECOND 2021 INTERSESSIONAL MEETING OF THE BLUEFIN TUNA SPECIES GROUP

*(Online, 2-9 September 2021)*

*The results, conclusions and recommendations contained in this Report only reflect the view of the Bluefin Tuna Species Group. Therefore, these should be considered preliminary until the SCRS adopts them at its annual Plenary meeting and the Commission revises them at its Annual meeting. Accordingly, ICCAT reserves the right to comment, object and endorse this Report, until it is finally adopted by the Commission.*

## 1. Opening, adoption of agenda and meeting arrangements and assignment of rapporteurs

The Second 2021 Intersessional Meeting of the Bluefin Tuna Species Group ("the Group") was held online from 2 to 9 September 2021. Drs John Walter (USA) and Enrique Rodríguez-Marín (EU-Spain), the Rapporteurs for the western Atlantic and eastern Atlantic and Mediterranean bluefin tuna stocks (BFT), respectively, opened the meeting and served as Co-Chairs.

On behalf of the Executive Secretary, Dr. Ai Kimoto, and the Vice SCRS Chair, Dr. Rui Coelho (EU-Portugal), welcomed the participants to the meeting. The Group Co-Chairs proceeded to review the Agenda which was adopted after some changes (**Appendix 1**).

The List of Participants is included in **Appendix 2**. The List of Documents and Presentations provided at the meeting is attached as **Appendix 3**. The abstracts of all SCRS documents and presentations provided are included in **Appendix 4**. The following served as rapporteurs:

| *Sections* | *Rapporteur* |
|---|---|
| Items 1, 10 | A. Kimoto |
| Items 2.1, 2.2 | N. Taylor |
| Item 2.3 | C. Peterson |
| Item 2.4 | N. Duprey |
| Item 2.5 | S. Miller |
| Item 2.6 | H. Arrizabalaga |
| Item 2.7 | T. Carruthers |
| Item 2.8 | A. Parma |
| Item 3.1 | T. Rouyer |
| Item 3.2 | S. Deguara |
| Item 3.3 | S. Tensek |
| Item 4 | J. Walter |
| Item 5 | A. Gordoa |
| Item 6 | G. Melvin |
| Items 7,9 | J. Walter, E. Rodriguez-Marin |
| Item 8 | A. Di-Natale, H. Peña |

## 2. MSE

### *2.1 BFT MSE Consultant's update on work since July BFT Technical Group meeting*

The MSE Consultant provided an update on work since the 2021 July BFT MSE Technical Group (BFT MSETG) meeting (SCRS/P/2021/050). The July BFT MSETG meeting report (Anon. 2021 in press) is now published on the ICCAT website. The list of tasks to complete following the July BFT MSETG meeting (Anon. 2021 in press), the actions taken to complete these tasks, and additional details of what was done are summarized in **Table 1**. The robustness test related to scale estimation within M3 was considered to be a secondary priority because the highest priority had been assigned to those tasks that were needed immediately for a direct presentation of the results to the Commission during the remainder of 2021.

With respect to the proposed "Pretty Good Trend" (PGT) metric (**Table 1**), the PGT metric was found to be non-informative and difficult to code, so it was modified to be the "Overfished Trend" (OFT), which is defined as:

$$OFT = \begin{matrix} \log(SSB) & \text{SSB} < \text{dynamic SSBMSY} \\ 0.1 & \text{SSB} > \text{dynamic SSBMSY} \end{matrix}$$

There were many important additions and improvements made to the Shiny app in order to address the issues identified (**Table 1**). Developers of Candidate Management Procedures (CMPs) were reminded that the most efficient way to use the Shiny app is to download the application and run it from a local machine. This will improve the speed of the application as many simultaneous requests to the Shiny Server can make it slow.

The following items remain outstanding:

1. Outstanding ROMs (robustness set of OMs)

- Hyperstability
- Brazilian catch (where the current implementation is partial only)
- Intermediate params
- US_RR_66_144 fit
- OM#35 fit to seasonal prior

2. Investigation of 'Brazilian catch' biomass histories

3. M3 scale estimation capability given data to 2019

### *2.2 Review of recommendations from the July BFT Technical Group*

The Group discussed how the recruitment scenarios had been addressed in the Operating Model (OM) development and the weighting of the levels corresponding to this axis of uncertainty (factor). The Group was reminded that the table of OM weights (**Table 2**) is provided in the section 9.2 in Trial Specification Document (TSD). The present weighting for the recruitment factor levels (R) were 0.4, 0.4 and 0.2, for R1, R2 and R3 respectively.

The Group discussed the Zeh plots. It was noted that Management Procedure (MP) performance can be compared using these plots, but that the difference in the medians between MPs need to be explained clearly. It was further noted that for some simulations, it is difficult to discriminate between CMPs with the Zeh plots. For each simulation, CMP performance can be normalized relative to the mean across all CMPs. This approach controls for simulated conditions, more clearly revealing the relative difference in performance among CMPs. This feature has now been added as an option in the Zeh plots of the Shiny app.

#### *2.2.1 Review of the acceptability of the reconditioned OMs*

The MSE Consultant provided a brief overview of the reconditioning results. Reconditioned OMs presented in June 2021 generally showed more consistency in fits to the indices relative to the original OM reference grid as described in SCRS/2021/124 and SCRS/2021/125. Many of the original OMs exhibited clear evidence of multiple conflicting fits or problematic 'one-way trip' behavior. With the refit OMs the greater consistency in the indices and clear contrast in the data meant that the models had fewer conflicts among indices and an improved ability to estimate key parameters.

Of the OMs that required refitting, the number was reduced from 64 to 32 (R3 is based on R1 fit). Broadly, statistics relating to fit are comparable (and where different showed improved fit). One exception is the western Mediterranean larval survey index (MED_LAR_SUV); but for projections this is due to updated data and in any case characterized by the fit from 2012 onwards. For the West area, a great deal of effort was made to refit the GLMs for the indices so that the biggest discrepancies in scale between previously 'flat' non-contrasting trajectories and new recent positive-slope trajectories allowed for contrast in the time series so that the statistical models could estimate scale. As a result of the updated West area data showing more contrast, the estimated $B_{MSY}$ for the western stock tended to be smaller for the new OM updates.

For length-composition data, the high weighting and low weighting factor levels show a tighter range of stock trajectories, and a tighter range of stock status. While stock status estimates were not always as high as previously estimated, the aforementioned contrast now estimated in stock size over time provides improved ability to estimate key parameters, and likely provides more plausible trajectories for stocks with long histories of exploitation.

When fits to other data types for the original and reconditioned OMs were compared, total catch fits, stock of origin (SOO) data, E-tag fits, and length composition fits were all very similar. In broad terms, the key conclusions of the reconditioning were that: there were no substantial changes, the eastern stock increase is now better determined (firmer); the western stock trend is now consistent among OMs; all OMs / stocks show recent increases (more optimistic); in general the conditioning of the OMs to the data is improved over the original models; and some of the large accumulations of bluefin in the plus group have been greatly reduced given the addition of senescence to the low M scenarios.

The Group also reviewed the MSETG's recommendations on which indices may be used in CMPs (Table 7.1 in TSD for list of recommended indices and rational for the recommendation). Further, the US Rod & Reel (RR) 66-114 and US RR 115-144 were combined into a single index. The GBYP aerial survey index has been reviewed and revised by an expert group and was re-evaluated for use in CMP development. The decision was taken to include the revised GBYP aerial survey index for the Balearic region among those which can be used in CMPs as this index was the one that was examined earlier as well as in the most-recent iterations of OM conditioning (see Section 3.3). Further evaluation of a combined index as well as model-based approaches are ongoing and may be considered for future use.

The Group also reviewed other indices that had been deemed suitable for CMP development and noted that these passed the diagnostic tests. The Group accepted the recommendations of the MSETG laid out in TSD-Table 7.1 (**Table 3**). No revisions to the OM reference grid were proposed and **the Group adopted the current reference grid** (**Table 4**).

*2.2.2 Review robustness tests*

With the exception of the Brazilian catches OM, non-linear indices, intermediate parameter levels for M and upweighting the US RR 66-144 index, all the priority robustness tests identified in the TSD document's Table 9.4 had been completed. The Brazilian catch OM needed only minor updates to complete conditioning. Because this meeting was focused on the reference grid, consideration of these four outstanding robustness tests was postponed until CMP performance against the reference grid was complete. While there may be a need for further robustness tests at a later date, **the Group had no proposals for additional robustness tests and the recommendations of the MSETG regarding robustness tests were adopted.**

*2.2.3 Consideration of any revisions to plausibility weighting of OMs*

The Group reviewed the reference grid noting that the MSETG had no proposed revisions to the plausibility weights for the reference grid shown in **Table 4**.

After some clarifications about the OM reference grid, the Group agreed to adopt the reference grid, noting that this was a major achievement that needs to be highlighted. Adopting the OM reference grid was an essential part of the process, making possible the progress to date in development tuning CMP procedures using that reference grid.

Participants were reminded that not all OMs in the reference grid were weighted equally. The Group reviewed the weight for each factor/level shown in the TSD's Section 9.2. It was noted that in addition to weighting specified in **Table 2,** the robustness tests will need to be accorded "weighting" in some sense so that these robustness tests are not accorded an importance disproportionate to their plausibility. The Group noted that the role of robustness tests in CMP selection will not be entirely clear until after the primary CMP selection against the reference grid has been completed, and consequently deferred discussions on this matter until later.

The Group discussed the OM uncertainty axes. It was noted that the West area assessment had been recently updated, and the question was posed of how the update of West area assessment might affect the reference grid. In response it was pointed out that with respect to the multi-year broader MSE process, there would always be new information provided in the process and that generally speaking, the guillotine rules (to no longer update OMs nor add new data) applied, so that OMs were not updated unless the new information indicated that the stock was outside the range of levels considered for the OM set (such updates take place on the next occasion the MP is reviewed, likely about five years after adoption). Given that the West area assessment update resulted in only an approximately 25% increase in equilibrium biomass scale, that the updated assessment falls within the existing range of OM scales that are covered in the OM reference grid. No changes were deemed necessary at this time. It was noted that the Group may wish to reevaluate their weighting of the OMs on the basis of this information later in the process.

Acknowledging that plausibility weights may change in the future, **the Group agreed on the Reference OM weights outlined in Table 2.**

*2.2.4 Short term development and communication timelines for MSE*

The Group reviewed the short-term timeline of the MSETG's detailed proposed workplan that included a detailed list of tasks to complete before the November 2021 ICCAT Commission meeting. The Group endorsed these proposals and incorporated them into an overall bluefin tuna workplan.

### *2.3 CMP Development and review*

*2.3.1 Round robin from CMP developers*

CMP developers each provided an update either through presentation of a paper (e.g., SCRS/2021/152; SCRS/2021/153; SCRS/2021/155; SCRS/2021/156) or orally, and mathematical descriptions are available in **Appendix 5**. Notably, several CMP developers reported that CMP performance as refined to maximize performance within the deterministic projection space did not always translate to acceptable performance when applied with stochasticity (e.g., the TC and AI auxiliary rule to actively respond to index trends did not work well with stochastic projections). Relatedly, CMP developers noted that tuning targets of selected CMPs developed under deterministic projections were not always replicated reasonably closely when CMPs were applied to stochastic projections (e.g., NC and AI). CMP developers also highlighted the value of parallel processing and increased computing power in the CMP development process.

*2.3.2 Review and comparison of CMP results*

The MSE Consultant presented a review and comparison of CMP results both formally (SCRS/P/2021/051) and informally (via the Shiny web application).

Notably, OM plausibility weights had a minimal impact on CMP performance for both the eastern and western stocks.

Differences in CMP performance when applied within a deterministic environment compared to a stochastic environment were highlighted. Primarily, the variability of resulting performance metrics was greater in the stochastic scenarios, and the lower probability percentiles for performance statistics were worse in stochastic scenarios compared to deterministic scenarios. These differences were found to be greater for the West area and western stock, where weighted median performance shifted between deterministic and stochastic projections especially for certain CMPs (as noted in Section 2.3.2; e.g., NC, AI), compared to the East area and eastern stock (**Figure 1**). The Group discussed the reasoning for these changes in performance, suggesting that it could be due to use of dynamic reference points. It was noted that **the magnitude of differences in deterministic versus stochastic CMP performance were CMP-specific and could likely be reduced with subsequent refinement**.

The Group questioned whether the current tuning protocol should be modified to account for differences in deterministic and stochastic CMP performance. Further investigation into the drivers of this differential performance (e.g., recruitment stochasticity or index variability) could help to answer this question, and the idea of having selected CMPs tuned to a specific tuning target under some set of stochastic projections was proposed. The Group supported tuning to stochastic results (if doing so was not computationally prohibitive) to ensure equitable comparison of the performance of each CMP. The MSE Consultant proposed the development of a dedicated tuning OM comprising a sample of stochastic OM replicates (SCRS/P/2021/054). The proposed tuning OM has the benefit that it is more representative of overall biomass performance for the complete stochastic grid and will also make CMP tuning more computationally efficient. The Group supported the interim proposal (**Appendix 6**); the dedicated tuning OM will be included in the next version of the MSE package and used by developers to tune their CMPs.

The Group noted that CMP performance reflects trade-offs between performance metrics, and it is unreasonable to expect a single CMP to outperform the others for every management objective. No single metric to describe the trade-offs in key performance metrics (e.g., Br30 (depletion after projection year 30) vs. C30 (mean catches over projected years 21-30)) was identified, leading the Group to conclude that human integration of the results will be crucial to comparing and selecting best CMPs. The Group discussed how tables, trade-off plots, and projection plots (catch and biomass 'worm') should be used for comparing and reducing the pool of CMPs (see Section 2.4). The Group agreed that preventing stock collapse is a prerequisite performance statistic for evaluating MP performance (e.g., focus on MPs for which lower percentiles of Br30>0) and that both short and long-term dynamics should be considered (see Section 2.4). The Group highlighted the need to consider and present comparison of CMP performance for each stock (eastern and western stocks). It was noted that there is an inherent trade-off in management performance of each area and that the Group would consider presentation of the trade-off between eastern stock and western stock performance closely moving forward.

The Group extracted the initial TACs in the first year (2023) of CMP implementation (C1) across all of the CMPs and found that there was relative consistency between the current management advice and the initial TACs. The Group remands it to the MSE Communications Team on how this might be used to inform further discussions. The Group noted strong sentiment that C1 carry low weight for choose CMPs as the focus should be on long-term performance.

The Group questioned whether performance metrics (e.g., Average Annual Variation in Catch: AAVC) should be presented separately for each recruitment scenario, reflecting the differential CMP performance required to achieve management objectives in each scenario. Relative CMP performance across recruitment scenarios was not found to appreciably change based on preliminary qualitative analyses.

*2.3.3 Condensing CMPs into 2-3 for further presentation at this stage*

Three Options for reducing the number of CMPs in contention for further consideration were proposed:

| Option | Proposal description |
|---|---|
| 1 | Satisficing |
| 2 | Ranking |
| 3 | Focus on Commission objectives |

**Option 1 Satisficing**: A proposal detailing a satisficing protocol was presented, wherein CMPs that fail to meet a minimum performance threshold would be eliminated from future consideration.

The MSE Consultant proposed six preliminary criteria for satisficing (**Appendix 7**):
(1) Maintenance of high biomass in East area (<25% of simulations drop below Br30=0.5)
(2) Maintenance of high biomass in West area (<25% simulations drop below Br30=0.5)
(3) Maintain high long-term catches in East area (<25% of simulations drop below C30=10kt across OMs)
(4) Maintain high long-term catches in West area (<25% of simulations drop below C30=1kt across OMs)
(5) Maintain low AAVC in East area (median AAVC < 25% across OMs)
(6) Maintain low AAVC in West area (median AAVC < 25% across OMs)

Based on the proposed 'strawman' satisficing criteria above, two CMPs passed all six of the satisficing criteria (revised AI4 and FZ4), and four CMPs passed five of six satisficing criteria (FZ1, revised AI2, FZ2, and BR4).

The Group discussed whether CMPs should be required to successfully pass each satisficing criteria and whether the strength of the satisficing criteria should be adjusted. Further CMP development should be conducted with these criteria in mind. It was agreed that input from the Commission is required before satisficing criteria could be further refined. **The Group was encouraged to scrutinize these proposed criteria and/or propose alternative or improved satisficing criteria and refer to direction provided from the July BFT MSETG meeting (Anon. 2021)**.

**Option 2 Ranking:** A proposal was presented to rank CMPs based on relative performance across highlighted performance statistics following discussion from the July BFT MSETG meeting (see Section 4.5 of that report).

These performance statistics include those highlighted in the July BFT MSETG meeting (Anon. 2021), where metrics include: AAVC, AvC10, Avc30, AvgBr30, Br30, LD, and OFT (see Section 2.4). CMPs would be ranked, by order or relative performance of each corresponding statistic, and the MPs that performed best across all performance statistics considered would continue onto further refinement. This Option2 reflects the requisite human dimension needed to compare and select CMPs for further presentation to the Commission.

The MSE Consultant presented tables of CMPs color coded and ranked for each performance statistic. The Group discussed the need to reduce the dimension of the tables (ideally to < 7 performance statistics), potential alternative performance statistics (e.g., incorporation of a combined east and west ranking criteria), and incorporation of satisficing criteria into these tables. **The Group proposed not to reduce the dimensionality of these tables at the current meeting until further CMP refinement and satisficing has been achieved**, and further emphasized the need to scrutinize plots of catch and biomass trajectories. It was agreed that this process should not be rushed and that all performance statistics should be retained at this time.

The Group questioned whether performance statistics would be weighted, because not all performance metrics included in the tables for CMP ranking are of equal importance. The Group noted that some metrics were crucial (e.g., LD and Br30 statistics), and that further ranking criteria should be informed by the Commission.

**Option 3 Focus on Commission objectives:** The third proposal was to specifically focus on the management objectives identified by the Commission (as presented in the preliminary results communication document in Section 2.5).

Four conceptual performance objectives were outlined by the Commission (e.g., where some relevant quantities and percentages were left blank or undefined). Where operational objectives were not fully defined, it was recommended that the associated trade-off space be fully explored and presented to the Commission. **The Group agreed that Option 3 could be readily folded into Options 1 and 2 and so was further excluded as a stand-alone recommendation.**

The Group proposed to combine Options 1-3 when condensing CMPs for further presentation. Notably, **the Group suggested that CMP condensing rely more heavily on satisficing (Option 1) by satisficing first before comparative ranking of CMPs (Option 2).** This was strongly supported because consideration of CMP performance must be measured in two stocks and areas (East and West), and because satisficing is easier to explain to stakeholders.

The Group further discussed utilization of the robustness set of OMs (ROMs) in the comparison and selection of CMPs for further presentation. It was noted that CMPs should minimally first pass the satisficing criteria, and performance across ROMs should also be considered in selecting an MP.

The Group prioritized the need to present stochastically tuned CMP results to the Commission to enable proper CMP comparisons. **CMP developers were tasked with re-tuning following the stochastic tuning method (Appendix 6) as soon as possible**. The Group further identified the key trade-offs inherent in BFT management on which the Commission's input was needed, including (1) catch versus recovery, (2) east-west catch trade-off, and (3) catch versus AAVC (see the following table and Section 2.5). For logistical purposes, trade-offs were prioritized as (1) > (3) > (2). The Group highlighted that at this stage CMP presentation should outline the management trade-off space and is not to select a best CMP, allowing time for further CMP refinement.

Overview of MSE workplan for 2021. A structured approach for conveying MSE outputs to the Commission and the Panel 2 later in 2021.

| ***Item*** | ***Action*** |
|---|---|
| 1 | Outputs should be those for stochastic (not deterministic) runs of CMPs against (primarily) the grid, as that better reflects reality. |
| 2 | Outputs should be development tuned to Br30 targets for ease of comparability. This tuning should ideally be for stochastic runs, rather than deterministic as at present. |
| 3 | The MSE Consultant's proposal to tune stochastic runs using, instead of a median across all the grid OMs, represents a computationally practical way forward; it will give results close to tuning stochastically across the whole grid. |
| 4 | All developers are to be requested to retune their CMPs to the existing set of tuning options (this should not be onerous), rerun their CMPs stochastically for the grid, and return the results to the MSE Consultant as soon as possible. |
| 5 | The **first objective** will be to use these results for the existing tuning options to illustrate the primary performance trade-off (catch vs recovery target in 30 years), to seek (in due course, not immediately) to obtain some indication from the Panel 2 and the Commission of some range in this trade-off space within which they might wish to see a final choice. |
| 6 | Only one of the CMPs need be used for this purpose. The best plots to use can be decided later (e.g., median AvC30 vs median Br30 or lower 5% Br30 for both East and West). |
| 7 | The **second objective** will be to show the east-west trade-off: i.e., for the same risk in Br30 terms, more catch in the East means less catch in the West area. This needs only one CMP for demonstration, but that will require the developer of that CMP to adjust control parameter values to maintain the East and West development tuning targets while, say, increasing East area but decreasing West area TACs. Ideally, but not necessarily, this CMP would be the same as the one used for (5). |
| 8 | The **third objective** is to demonstrate, for a single development tuning choice, the other trade-offs on which decision makers will ultimately need to advise, such as TAC variability vs average TAC over time for the same resource risk, and final catch at the end of the period compared to lowest depletion, etc. |
| 9 | Three CMPs should be selected for this last purpose. Their choice should NOT be with a view to their possibly being the current "best" three in some sense; rather that choice should be determined by having the three chosen span the widest range of performances on those further trade-off axes for a given development tuning, so as to best illustrate the range of options that might be achieved in practice. |
| 10 | Only these trade-off concepts, not any of the results suggested above, will be presented to the Panel 2 meeting commencing 15 September 2021 (there is not enough time allocated at that meeting for more, and also not enough time to obtain and prepare summaries of results from the above). |
| 11 | Results addressing all three objectives should be presented at the Panel 2 meeting associated with the Commission meeting later this year, bearing in mind that time constraints will preclude trying to achieve too much there:<br>a) Top priority is for results addressing the **first objective**<br>b) Next priority for results addressing the **third objective**<br>Results addressing the **second objective** could be elevated in this list; however, note that that will require some further and less straightforward work on the CMP selected for that process. |
| 12 | Initial results provided to the MSE Consultant as soon as possible should then be reported by the MSE Consultant to the BFT Species Group meeting on 21 September 2021, so as to allow a choice to be proposed and made for the CMPs to be used to address each of these three objectives. |

### *2.4 Performance measures and statistics for reporting*

*2.4.1 Review and trimming of existing measures*

*2.4.2 Statistics for reporting*

The MSE Consultant walked through the use of the Shiny app in displaying Performance Measures from various CMPs. The main focus was how the different Performance Measures can be displayed, how the different CMPs can be compared, and how Performance Measures for individual CMPs can be explored OM-by-OM. The Consultant also suggested that the Group be more strategic and begin looking beyond just the Br30 and AvC30 Performance Measures which have been the focus until now. Some of the highlights from the discussion were:

- AAVC (average annual variation in catch) is important for variability between management periods and links well to a specific objective of the MSE;

- C30 (median catch between years 21-30) is also important as it provides insight into what the TAC is most likely to be when it has settled, and it also provides a different perspective than C10 (median catch between years 1-10) or AvC30 (median catch between years 1-30) as these start at the same place (initial TAC);

- Comparing AvC30 and C30 allows for a CMP's long term catch to be explored as steep declines in long term catch can be masked by AvC30 values;

- For some performance measures, it is important to review not just the median but also the tails (lower and upper ends of the distribution);

- In the Shiny app the "P.Tab" can be used to adjust inter-quantile ranges; this can be useful to compare CMPs and remove those that are not achieving a required target;

- To compare a small number of CMPs (or a few different tuning targets for the same CMP) the Zeh multi plot is very useful. This function compares up to 3 CMPs across up to 3 performance measures at one time;

- For AAVC, care should be taken when reviewing this Performance Measures; a large value in a CMP may be what is letting the future TACs change rapidly enough to handle the radically different production-assumptions built into the different OMs, so that further exploration might be needed;

- The plots of trends tab (stochastic projections) allows users to explore the plots further to consider how the CMP is responding to the changing conditions.

Following this presentation and discussion, the Group reviewed the current list of Performance Measures in Table 10.1 in the TSD **(Table 5)** to confirm that the table included all the desired Performance Measures. The Group also reviewed the Performance Measures that the MSETG had highlighted as "key" Performance Measures needed for CMP evaluation. While reviewing the list of Performance Measures, the Group also reviewed what information had been provided so far on the MSE objectives in order to make sure there were Performance Measures linked to each objective to be evaluated (Res. 18-03 and 2020 Report of the Intersessional Meeting of Panel 2 and 2021 Report of the Intersessional Meeting of Panel 2). There were some concerns that the current list of Performance Measures did not capture a statistic measuring the status of the stocks relative to being in the green quadrant of the Kobe Plot ($B>B_{MSY}$ and $F<F_{MSY}$). A new measure to cover this objective was added to the list. The Group was generally satisfied with the list overall but did make some modifications as is laid out below.

The following Performance Measures were bolded to identify them as "key":

- LD (lowest depletion) added reporting the lower 5$^{th}$-percentile and lower 15$^{th}$-percentile in addition to the existing median statistic;

- OFT (overfished trend) and C30 were added to the list of key Performance Measures.

The Group also agreed that two statistics be added to the table but not as a "key" Performance Measure and one removed from TSD-Table 10.1:

- C1 (median catch in first management period). This would be useful to indicate variability in catches in the first iteration of the MP;

- F, overfishing related statistic. Details will be considered intersessionally by the Group.

- PGT (pretty good trend), deleted from the table.

See **Table 5** for the newly updated version of the TSD's Table 10.1. The sentiment of the Group was not to reduce the list of Performance Measures now, but to wait until the CMPs are improved. Then the list could be reviewed to see if any are Performance Measures are correlated or redundant. It was recognized that the current list is too long to be fully digestible by the Commission, so that the MSE Communications Team will need to be provided with a subset for discussions with the Commission.

SCRS/2021/151 presented on the effects of phase-in periods on CMP conservation and yield performance. Overall, the Group found the document helpful and suggested it would beneficial if discussions with the Commission on a phase-in approach was needed. Some of the Group suggested that the document compare the historical "advice on TAC" opposed to the historical catches currently used in the document.

### *2.5 Messaging on MSE (material for SCRS and Commission, and other stakeholder groups)*

*2.5.1 Review of deliverables from MSE Communications Team: One page summary, Executive summary (4 pages), and Presentation and slides*

The July BFT MSETG meeting established an MSE Communications Team and tasked them with developing a series of materials for sharing with the Panel 2 and the Commission. These include a 4-page summary of the MSE structure and preliminary results, a 1-page summary and draft presentations for the September and November Panel 2 meetings in 2021. The materials will also be used by the MSE ambassadors during webinars in October 2021, pending approval of that program by Panel 2 during their meeting over 13-15 September 2021.

The Group agreed that the communications materials should focus on the scientific progress achieved over the past two years since the last substantive exchange between the SCRS and Panel 2 (i.e., the intersessional meeting in March 2019), rather than simply providing a general overview and rationale for MSE and the MP approach. The Commission has already committed to using MSE (Rec. 15-07), and there are general MSE communications materials available elsewhere (e.g., www.harveststrategies.org).

The draft 4-page MSE summary was presented to the Group, and comments were accepted throughout the meeting to improve the document. The Group agreed that the document should stress the input required from the Commission during the remainder of 2021, including guidance on acceptable level of risk in tradeoffs, operational management objectives, CMP structure (e.g., TAC setting interval, TAC caps, TAC variability) and reference points (e.g., $B_{lim}$). Preliminary results for anonymous, representative CMPs are also to be presented, primarily to illustrate tradeoffs.

There was some concern that the 4-page summary document included too much technical detail for the target audience of the Panel 2 and the ambassador sessions. As a result, some of the detail was moved to appendices.

An early draft of the slide presentation for the 12 November 2021, Panel 2 meeting was circulated to the Group but was not presented due to time constraints. Comments and suggestions will be accepted from the Group via email.

*2.5.2 Process for engagement to describe the BFT MSE process and to summarise results to date*

The MSE Communications Team will accept additional feedback from the Group on the 4-page summary and present a draft final version to the Bluefin Species Group on 21 September 2021. Upon approval, the 1-page summary will be developed, and the November 2021 slide presentation will be revised. The Co-Chairs will work with the SCRS Chair, in consultation with the MSE Communications Team, to develop a brief presentation for the 2021 September Panel 2 intersessional meeting.

Pending approval of the ambassador program by the Panel 2, a member of the MSE Communications Team will work with the Secretariat to schedule at least three webinars for October 2021 (one each in English, Spanish, and French). Ambassadors will use a modified version of the 2021 November Panel 2 presentation to ensure consistent content and messaging. The Secretariat and Group will explore the ability to record the webinars. All ambassador communications materials (i.e., 4-pager, 1-pager, presentation and other materials, including a to-be-developed glossary) will be posted on the ICCAT website.

### *2.6 General criteria for exceptional circumstances*

"Exceptional Circumstances" are situations (anticipated to occur infrequently) where compelling reasons arise for scientific recommendations for catch limits to eventually differ from those output by the MP adopted. Broad provisions are pre-specified, associated with an MP when adopted, under which Exceptional Circumstances might be declared. These provisions usually include data inputs moving outside the range (typically some specified probability interval) projected when the MP is adopted, lack of continued availability of some of those inputs, and catches appreciably exceeding TACs. The Panel 2 is currently developing an Exceptional Circumstances protocol for North Atlantic albacore tuna along these lines, which could help to inform a similar process for Atlantic bluefin tuna and swordfish.

Further provisions often need to be tailored to the MP adopted and are frequently finalised only in the year following such adoption to allow sufficient time for their careful specification. The Group considered that this would be an appropriate approach to follow in the case of the MP currently under development and decided not to discuss this Agenda item further at this time.

### *2.7 TSD*

The Trial Specification Document (TSD) is now relatively complete. The MSE Consultant agreed to update the TSD to reflect the comments of the code reviewer and more clearly describe the differing purpose and calculation of stochastic and deterministic simulations. The updated TSD was provided during the meeting, and the most recent version of the TSD that incorporated the changes in Section 2.4 is available in **Appendix 8**.

### *2.8 MSE Code review progress*

SCRS/P/2021/052 reported the progress of the MSE code review by the GBYP Contractor, which was initiated on 20 July 2021. The work completed to date includes a review of the TSD, the M3 ADMB operating model, and the majority of the R code for organizing data and inputs for model conditioning. The results of the review were all very positive, confirming that the mathematics of the OMs was correct, together with the computer code implementing this. Specific suggestions were made to improve completeness and clarity of the documentation, and to reduce the possibility of future coding errors, but all these suggestions were considered by the reviewer to be very minor.

The MSE Consultant acknowledged the detailed and useful suggestions received and considered that the MSE code reviewer had done a remarkable job, especially given the complexity of the model and code. The MSE code reviewer noted the highly competent work in producing the code and its documentation. Appreciation was also expressed for the thorough review of the code conducted previously by Dr. Carmen Fernández.

Although the review still needs to cover some components of the MSE package (projection code and outputs), as well as its computational efficiency, the results provided so far indicate that ICCAT can be confident about the validity of implementation of the main code components being used in the management strategy evaluation for Atlantic bluefin tuna.

## 3. Report out from BFT Technical Sub-groups and GBYP (Sub-group leads and GBYP Coordinator)

### *3.1 BFT Technical Sub-group on Assessment models (EBFT)*

The advances of the BFT Technical Sub-group on Assessment models for eastern bluefin tuna were presented (SCRS/P/2021/049). The Sub-group met in May 2021 to organize the work and define the teams that will operate on the different modeling platforms. Following that meeting, the teams developed work on their platform. The Virtual Population Analysis (VPA) and Stock Synthesis teams presented their ongoing exploratory work, which allowed them to identify problems and look for solutions. Particularly, Stock Synthesis modeling work showed promising progress in sight of the upcoming 2022 stock assessment. The Group noted the progress made by the Sub-group and it was indicated that work on other modeling platforms might start in 2022. It was noted that the Moroccan/EU-Portugal trap index included fish going into the Mediterranean but also outgoing from it, so that to better address this, it may be necessary to re-evaluate how to consider these data as either a single combined index or as separate information.

The Group also recommended that exploratory work on the VPA should keep in mind the effect of F-ratio that can introduce an effect comparable to doming selectivity when values below one are used. The Group also underlined that splitting indices for testing purposes was acceptable in exploratory work, but that this would need to be backed up by a strong a priori rationale for the other modeling stages as this discards a substantial amount of information. The Group then discussed the need for a workplan for this Sub-group to be prepared for the next steps leading to the 2022 assessment, which included potential index revision and inclusion of ageing data.

### *3.2 BFT Technical Sub-group on Growth in Farms*

SCRS/2021/144 presented growth and feeding data from a 30-month experiment carried out in Malta in which the increase in weight was presented along with the increase in length over the trial period which was found to be similar in scale to that seen in the GBYP Modal Progression Analysis (MPA) analysis presented in SCRS/2021/145. This document [SCRS/2021/145] summarised the analysis carried out on growth data coming from farm cage trials carried out in the Levantine Sea, western Mediterranean, eastern Mediterranean and the Adriatic Sea. The higher than wild size (length) increases determined in this analysis was used as the basis for the alternative model predicting weight increase described in SCRS/2021/147. During the MPA analysis of the GBYP farm growth data, it was observed that measured harvest lengths were typically slightly lower than the pre-harvest stereo video camera footage data; this anomaly needs to be analysed and considered when the final growth in farms tables are formulated. A summary of analysis of BFT growth in a cage which involved the use of an AI system analysing data coming from stereo video camera footage and acoustic measurements was presented in document SCRS/2021/157; the analysis followed the increase in length of the fish during the farming period and also presented measurements of other biometric data (width and height) with the objective of better estimating fish biomass. Issues such as distance to the camera, turbidity and depth of field of the stereo video camera were discussed, the consequence of which was that larger fish were less represented in the data set. It was agreed that the use of AI systems to measure biomass would greatly benefit compliance and control and such systems should continue to be developed.

Preliminary updated growth tables based on the analysis of stereo video camera footage and harvesting data from farms between 2015 and 2021 were presented in document SCRS/2021/147. In this document, two preliminary growth tables were presented, the first based on the assumption that BFT in cages grew in size (length) at the same rate as wild fish, the second table being based on growth in size data determined from the MPA analysis carried out with the GBYP farm trials data (SCRS/2021/145). It was asked whether the updated tables could be applied to a complete cage, but the models providing the growth percentages were determined using single fish so the use of the values for a whole cage depends on whether the distribution of the harvested fish is equally represented, what is certain is that it is very unlikely that the whole cage is at the upper limit of the confidence interval. It was also explained by the authors that the model better represents the growth around the 6 month and 12-month farming periods, being less accurate outside these points, and other approaches need to be explored going forward. From the analysis presented in this document, it is clear that there is a large variability associated with weight gain in farms.

A new length and weight (L-W) equation applicable to BFT caught in Portuguese traps, instead of the current equation, was presented in document SCRS/2021/146 using data collected over 15 years from the Portuguese traps; it was recommended to use the available data and use this new equation for tunas that have a low condition factor, because they are tunas that migrate out of the Mediterranean after spawning, and are those that are caught by Portuguese traps from the end of May onwards. During the general discussion, it was pointed out that the L-W equation applicable by Rodriguez-Marin et al (2015) best fitted the Moroccan catch transferred to cages. With the adoption of the new Portuguese L-W equation, there will be four separate equations applicable to the BFT catches transferred to cages: Moroccan traps (Rodriguez-Marin *et al*., 2015), Portuguese traps (SCRS/2021/146), purse seine (PS) catches in the Adriatic Sea (Katavic *et al*., 2017) and PS catches in the Mediterranean (Deguara *et al*., 2017). The dichotomy between the L-W equations used in stock assessment and those used for catches involving transfer to cages fish was mentioned as a subject that should be discussed by the SCRS.

SCRS/2021/150 summarised the situation with regards to the various study tasks being analysed by the BFT Technical Sub-group on Growth in Farms, some of which were described in detail in the documents presented to the SCRS, and the outcome of the analysis carried out so far. The document presented three tables, the two preliminary growth tables mentioned in SCRS/2021/147 and the third table which summarizes the increase in length data determined by the MPA analysis described in SCRS/2021/145 and was used as the basis for the model leading to the second preliminary growth table. The tables grouped the whole farm cage population and since some of the data used in the MPA analysis covered periods of only a few months, there is a risk that the analysis overestimates growth in farms if extrapolated over the whole year. At this stage there will be no separate tables for different geographical areas, but more analysis is required. This summary document indicated that more analysis is required before final tables can be formulated, the target being to present this by 2022.

Following the discussions and suggestions by the Group, the authors of SCRS/2021/147 revised the analyses and provided updated tables on expected weight at harvest and percent increase in weight of bluefin tuna as a function of time in farms and initial fork length at caging, but independent of assumptions on intrinsic (length) growth. New tables reflecting these changes are in Tables 1 and 2 of the Group's Responses to the Commission (see Section 6.2, item 21.26).

### *3.3 GBYP*

#### 3.3.1 GBYP matters

SCRS/2021/138 provided an overview and the final results of the activities carried out in GBYP Phase 10 and the beginning of Phase 11, which were presented to the Group by the GBYP Coordinator. The main activities/results, by line of activity, were the following:

- Data recovery and management – strategic shift from data recovery to data management through creation of databases.
- Tagging – new deployment methodology provided improvement in the collection of data since the retention period of the tags increased significantly as many tags popping up by the scheduled date; new approach for electronic tags deployment through close collaboration with CPC tagging programs provided numerous tag deployments with costs only associated to tag purchase; an electronic tagging workshop was carried out.
- Biological studies – sampling was carried out in mixing areas of the two stocks and Mediterranean farms; the analyses provided improved mixing rates between the two stocks; a second age reading calibration exercise was performed on 2000 otoliths previously analysed by an external service provider - Fish Ageing Services; growth in farms studies were completed; a close-kin workshop was carried out.
- Fisheries independent indices – reanalysis of the aerial survey series using design-based approach was carried out; feasibility study for the application of a model-based approach for aerial survey was developed; pilot aerial survey was carried out in 2021 in the Balearic Sea, combining digital and human observers-based system; a larval surveys coordination workshop was carried out.
- Modelling - the MSE development continued; the external revision of the MSE code was carried out.

The Coordinator also informed the Group on the need to get the official SCRS recommendation for the extension of GBYP program, since the previous recommendation from 2014 to extend it for 6 years is no longer valid. He also proposed a new strategic approach for future GBYP activities, in order to improve the programme efficiency and adapt it to a future scenario of decreasing funds.

The Group acknowledged the great work of the whole GBYP team, the numerous successful results provided by the Programme and its important contribution to the improvement of the scientific advice to the Commission. Nevertheless, it was stressed that communication with the managers should be improved, in order to inform them about the concrete outcomes of the Programme and on how these have directly contributed to the improvement of the stock assessment and MSE process. It was also recalled that the MSE process can be used to quantify the extent to which the collection of different types of additional data will help further improving management advice.

It was suggested that a list of GBYP activities for the future to be made and ranked by order of priority, to facilitate the decision-making process in a possible scenario of reduction of the available funds. Finally, time constraints prevented the Group from a more expansive discussion of future GBYP strategies and activities at this meeting. Ultimately, many such final decisions will need to be taken by the GBYP steering committee. To facilitate strategic planning and solicit input from many scientists and experts for a number of key activities, GBYP held two meetings in the past year, one devoted to electronic tagging and another to further consider the feasibility of close-kin mark recapture for eastern bluefin tuna.

SCRS/2021/137 presented the results of the calibration exercise which was carried out with the objective of ensuring that age readings provided by the Fish Ageing Services laboratory (FAS) followed the ICCAT reviewed reading protocol. Authors suggest applying a correction vector to otoliths read by FAS and with more than 10 annual bands, in order to incorporate the FAS readings into the GBYP age database.

3.3.2 GBYP aerial survey review and revised index

The GBYP Coordinator informed the Group about the results of the re-analysis of the whole aerial survey time series conducted by CREEM experts. The re-analyses using the design-based approach showed that the revised abundance estimates were mainly comparable to previous results for three areas, while these were different for one area although within confidence intervals. In terms of biomass, the two estimates were comparable for all regions, except for one area in one year, which may be due to different grouping of the data. The largest discrepancy between the previous and new results were those related to the expected mean fish weight. With respect to the model-based approach, the results showed that the number of groups and group sizes were slightly higher than for the design-based approach but were within the 95% confidence interval. Nevertheless, the selected model explained only small fractions of variation in density and there were large uncertainties around the estimated values and therefore further analyses, including more environmental covariates, are needed.

The Coordinator also informed the Group about the results of the pilot aerial survey carried out in the extended Balearic Sea area in 2021, which combined the usual methodology based on human observers, but also incorporated digital systems for continuous recording of images along the track. The human observers spotted 23 schools, mostly in the core area, while the digital system identified 15 schools, 5 of which were not recorded by the human observers. The results indicate that a combination of a digital and human observers-based system is the best option for BFT aerial surveys.

The Group reiterated the importance of GBYP aerial survey index for BFT assessment and the MSE process, as one of the few fishery independent indices that can potentially inform on BFT abundance trends. Some concerns were expressed about the reliability of the aerial survey results, since the proportion of missed sightings out of the core area could vary along the historical series of data, suggesting to carry out another pilot study next year to determine if a proportion of sightings out of the core area changes. The Coordinator explained that the schools spotted out of the core area were not that relevant, because they mostly referred to small schools and reminded the Group that the objective of the survey was to get a relative index of abundance and not estimates of absolute abundance.

The Group recommended to replace the previous aerial survey results with the revised survey results in the MSE.

## 4. Review of the Executive Summary for W-BFT

A draft of the Executive summary for W-BFT was provided by the Co-Chair, and most of the sections were adopted by the Group. This will be finalized at the Species Group meeting before the SCRS.

## 5. Review of Abundance indices and other fisheries indicators for E-BFT

The updated eastern abundance indicators were evaluated by the Group to evaluate whether they support the current TAC advice of 36,000 t recommended for 2022 (Rec. 20-07). To most effectively evaluate whether the indicators are in line with the assessment projections, and hence support the current TACs, the Committee compared updated indices with 80% prediction intervals from projection of the base VPA model from the 2017 assessment using observed catches in 2016-2020 (**Figure 2**). The projection interval comparison serves as a means to evaluate whether the updated indicators are within the range of expectation for the models. To interpret the implications of points outside of the 80% intervals, 20% of the observations might fall outside of the interval by random chance. Considering this, in general the indices fit reasonably well within the prediction intervals and do not suggest that the TACs advice needs to be revisited.

Spanish-Moroccan and Moroccan-Portuguese trap indices include both fish migrating inside and outside the Mediterranean and accounting for such dynamics require appropriate statistical treatments. The Group discussed the possibility to review the two trap indices through the indices Sub-group prior to the 2022 eastern bluefin stock assessment.

SCRS/2021/142 presented a fisheries dependent index based on purse seiners in the western Mediterranean, estimated with the catch rates of the Balfegó joint fishing PS fleet. The index fluctuates at high values since 2013, similar to Japanese longline index in the northeast Atlantic. Mean size of fish in the purse seine catch showed two different periods possibly not only due to population changes but also to changes in management regulations. The new protocol implemented by this fleet in 2021 includes among other measures a maximum size limit for the schools that can be caught. Consequently, the average haul size does not necessary reflect the average school size.

## 6. Responses to the Commission

### *6.1 Western Atlantic bluefin tuna*

***21.22 Provide advice to the Commission on the appropriate management measures, approaches, and strategies, including, inter alia, regarding TAC levels for the western Atlantic bluefin tuna stock for future years. Rec. 20-06, para 6 (17)***

**Background:** *17. In 2021, the SCRS will conduct a stock assessment for the western Atlantic bluefin tuna stock to incorporate the most recent available data, including any new abundance indices adopted by the Bluefin Tuna Species Group and provide advice to the Commission on the appropriate management measures, approaches, and strategies, including, inter alia, regarding TAC levels for that stock for future years. Such assessment shall be conducted in a way that does not negatively affect the other work of the SCRS, particularly the ongoing MSE process for bluefin tuna. In addition, an external expert will be contracted in accordance with the standard procedures of ICCAT. The expert will review the assessment in a manner consistent with established SCRS practices, prepare a report on their findings and present their findings/results to the Bluefin Tuna Species Group. No stock assessment will be required for the western Atlantic bluefin tuna stock in 2022 unless the SCRS is unable to perform an assessment in 2021.*

In 2021, the SCRS conducted a stock assessment for the western Atlantic bluefin tuna stock to incorporate the most recent available data up to 2020, including the revised abundance indices adopted by the Bluefin Tuna Species Group. The Committee provides advice to the Commission regarding TAC levels for the stock for 2022 and, in the absence of adoption of a Candidate Management Procedure, for years 2023 and 2024. Such assessment was conducted in a way that did not negatively affect the other work of the SCRS, particularly the ongoing MSE process for bluefin tuna. In addition, an external expert was contracted in accordance with the standard procedures of ICCAT. The expert reviewed the assessment in a manner consistent with established SCRS practices, and will provide a report on their findings to the Bluefin Tuna Species Group. No stock assessment will be required for the western Atlantic bluefin tuna stock in 2022.

***21.23 SCRS to report to the Commission in 2021 on CPCs efforts to enhance the collection and analysis of biological samples from Atlantic bluefin tuna fisheries, such as through sample contributions to the coordinated sampling plan recommended by the SCRS. Rec. 20-06, para 8 (20)***

**Background:** *20. CPCs that harvest Atlantic bluefin tuna should contribute to the research, including that being undertaken through ICCAT's GBYP. CPCs should make or continue special efforts to enhance the collection and analysis of biological samples from Atlantic bluefin tuna fisheries, such as through sample contributions to the coordinated sampling plan recommended by the SCRS. The SCRS will report to the Commission in 2021 on these efforts. In addition, it is important to continue to explore sampling and/or other approaches for enhancing, and where needed developing, accurate abundance indices for juvenile bluefin tuna. CPCs should also make special efforts to ensure complete and timely submission of any collected data to the SCRS.*

In recent years, many CPCs have substantially increased their collection of biological material for aging, genetics, growth and reproduction and stock of origin through systematic sampling of the fisheries. Sample coverage for the CPCs that capture Western Bluefin tuna averages 15% of the landed catch and provides essential data for genetic close-kin mark recapture (CKMR) and for monitoring stock composition, growth, and reproduction. Improvements in coverage could be obtained through increased sampling and dedicated national programs conducted in collaboration with GBYP. Initial calculations conducted as scoping for close-kin mark recapture studies for both Eastern and Western Bluefin tuna indicate that a minimum sample coverage should be equal or greater than 5% of each CPC's catch in number with larger samples sizes providing greater precision. Currently Mexico Golf of Mexico longline and Japan longline fisheries have relatively low sampling coverage. The Committee supports increasing biological sampling coverage in Mexican and Japanese longline fisheries for future possible CKMR studies. To get representative spatial coverage, the Group noted that this sampling should cover trips in all relevant BFT fisheries for a given CPC. In addition to getting samples from fishery sources, the Committee noted that increasing biological sampling from non-fisheries sources (e.g. larval survey and sampling at farms) would also help expand the sampling coverage and number samples for CKMR studies.

Table. Western-area-CPC-based biological sampling by for bluefin tuna over years 2016-2019, samples can include otoliths, gonads, genetic material, etc.

| *Year* | *Total No. of fish sampled** | *Total catch in number* | *Total sample coverage (%)* |
|---|---|---|---|
| 2016 | 1677 | 13218 | 13% |
| 2017 | 2374 | 13816 | 17% |
| 2018 | 2117 | 13923 | 15% |
| 2019 | 2617 | 17439 | 15% |

* Samples can include otoliths, gonads, genetic material, etc.

***21.24 The SCRS shall annually advise on the TAC. Rec. 20-07, paragraph 1 (Rec. 19-04, para. 5)***

**Background:** *5. The total allowable catches (TACs), inclusive of dead discards, for the years 2021 and 2022 shall be set at 36,000 t, respectively, in accordance with the SCRS advice. However, the 2022 TAC shall be reviewed and amended, as appropriate, at the 2021 Commission annual meeting based on new SCRS advice in 2021.*

The updated eastern abundance indicators were examined by the Group to evaluate whether or not it was necessary to change the current TAC advice of 36,000 t recommended for 2022 (Rec. 20-07). The inspection of the updated biomass indicators and the projections of 2017 assessment did not provide any evidence to alter the current management advice. No change in the current TAC advice of 36,000 t is recommended for 2022.

### *6.2 Eastern Atlantic and Mediterranean bluefin tuna*

***21.25 SCRS should review no later than 2021, and each time an eastern Atlantic and Mediterranean bluefin tuna stock assessment is performed, CPCs fishing capacity is commensurate with its allocated quota by using relevant yearly catch rates by fleet segment and gear proposed by the SCRS and adopted by the Commission in 2009. Rec. 20-07, para 4 (18)***

**Background:** *18. Each CPC shall adjust its fishing capacity to ensure that it is commensurate with its allocated quota by using relevant yearly catch rates by fleet segment and gear proposed by the SCRS and adopted by the Commission in 2009. Those parameters should be reviewed by the SCRS no later than 2021 and each time that a stock assessment for eastern Atlantic and Mediterranean bluefin tuna is performed, including specific rates for gear type and fishing area.*

The ICCAT Commission in 2019 requested to review and update the catch rates of fleets targeting E-BFT by main fishing gear and vessel size category to the SCRS. Since 2010 several changes and regulations have been implemented to the East bluefin tuna fisheries (Rec 10-04, Rec 12-03, Rec 14-05, Rec 18-02, Rec 19-04) that impacted the activity of the fleets targeting this resource both in the Mediterranean Sea as well in the East Atlantic. During this period also, Bluefin farming operations had become the main destination of the catches, particularly in the Mediterranean Sea, where the purse seine fleets are the main supplier of wild fish to the farms. And, the so-called "Joint-Fishing =Operations" (JFO), defined as 'any operation between two or more purse seine vessels where the catch of one purse seine is attributed to one or more other purse seine vessels in accordance with a previously agreed allocation key in Rec. 19-04 para 3 item g, have become the primary type of fishing operation for the East bluefin stock in terms of total catches (**Figure 21.25.1**).

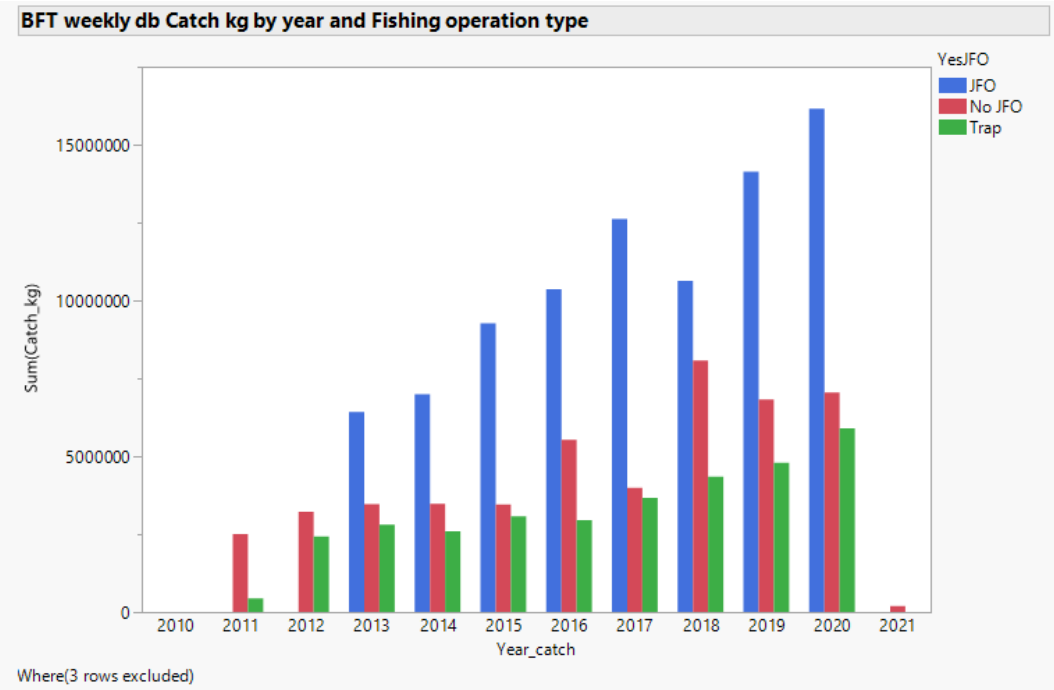


**Figure 21.25.1.** Annual trend of the E-BFT catch (kg) by the main type of fishing operations based on the information provided by the weekly/monthly reports 2011-2021. JFO refers to Joint-Fishing operations between two or more purse-seines (PS). No JFO refers to standard catch by a single PS, 2021 represents partial data submitted until Feb-2021.

Given these changes in the fisheries and the stricter management regulations in place on the east bluefin tuna stock, the SCRS outlined as the main objective to estimate catch rates, that we define as nominal CPUE (CPUE) per vessel (i.e., catch and effort, measured as fishing days from the VMS data that is associated with each vessel) rather than aggregated catches over a large group of vessels and time as was done in SCRS 2020. Document SCRS/2021/037 presented preliminary results of the analyses carried out by the Secretariat.

At the Secretariat, there are several sources of information on the catch and potential fishing effort for East bluefin tuna in addition to the regular fisheries statistics of Task 1NC and Task2 CE, that include data with information of catch and effort by vessel and/or fishing activity. These databases include:

a) The weekly/monthly reports of catches of bluefin tuna database, that extend from 2008 to present. In this data, JFO records included the 'actual vessels" that performed the catch in addition to the "allocation catch" that represents only a catch value for TAC monitoring purposes.
b) The Bluefin Catch Documentation [BCD (2010-2016) and eBCD (2016-present)] databases, that record the catch by a vessel of bluefin tuna.
c) The Regional Observer Program (ROP), this data is provided by the consortium to the Secretariat and includes information on the catch and vessel(s) for those fishing operations on the East bluefin stock that are required to be monitored by current management regulations, and
d) The east bluefin VMS database (2008-present), that keeps records of vessel signals transmitted for authorized bluefin vessels.

The initial task has been to review and quality control of the available data and summarize the information by the source evaluating what is the coverage of each source compared to the total catch, and what features for catch and effort units are useful to provide estimates of nominal CPUEs. One of the main issues with nominal CPUEs has to deal with the "JFOs", where due to management from ICCAT or national regulations, authorized vessels can share/redistribute catch allocations for monitoring purposes although they may not participate in the actual fishing operation. Indeed, JFOs are becoming the main option for CPCs, being reflected in the increased catch by JFO per year, but also the number of vessels registered under a given JFO (**Figure 21.25.2**). These allocations of catch within a JFO clearly do not represent actual or true nominal catch for individual vessels.

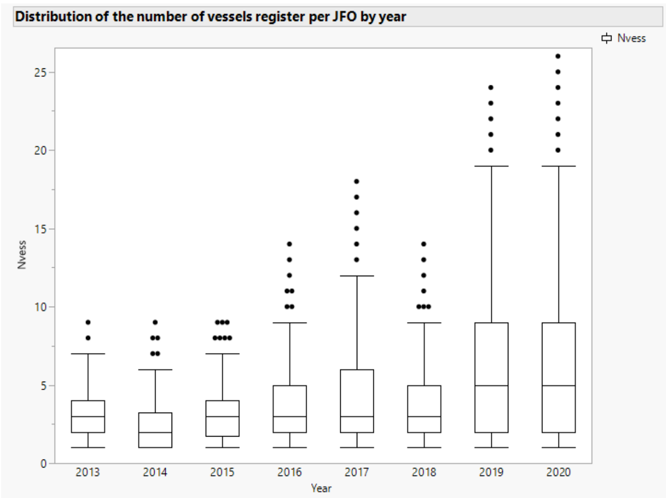


**Figure 21.25.2.** Box-plot distribution of the number of vessels registered per JFO 2013 - 2020.

Prior to 2010 the Commission required the registration of all vessels (> 20 m LOA) that participate in bluefin tuna fisheries, which is annually updated by CPCs. There are over 3000 vessels registered for E-BFT fisheries, however in reality a smaller proportion of these vessels (~12%) account for about 86% of the catch as reported in the weekly database (2013 – 2020). This "core" fleet is composed of vessels with a minimum annual catch of 5 t and at least 4 years of BFT reported catch, they represent a consistent and active fleet catching bluefin that can provide reliable estimates of catch rates per vessel category and gear. By linking the weekly database with the VMS and the eBCD data, has been possible to estimate fishing effort (fishing days at sea), and catch/trip activity per vessel.

Preliminary results of c CPUE by single vessel activity (i.e. fishing trip) are presented for the main fishing gear and by vessel size category. They show that purse seiners (PS) have overall higher CPUE compared to longliners (LL) or baitboats (BB) operations, and also higher for JFOs compared to single PS standard vessel operations (**Figure 21.25.3**). Analyses also have shown that from registered vessels, the "core" fleet that has operated more consistently in the fishery, do have high CPUE compared to those vessels that are more sporadic in catch and fishing activity (**Table 1**, **Figure 21.25.4**). Similar results were obtained for the LL fleet (**Figure 21.25.5**).

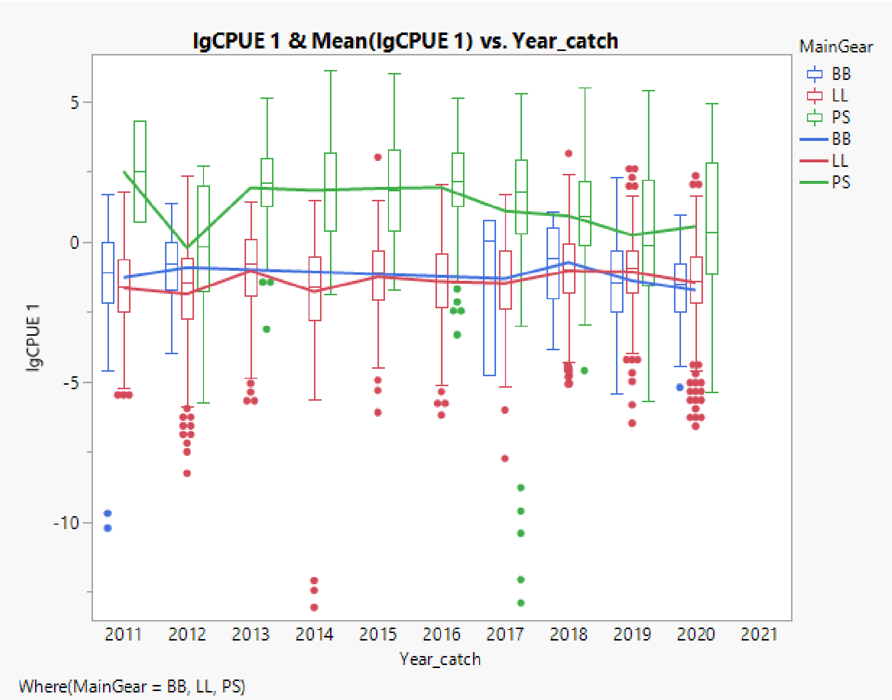


**Figure 21.25.1**. Distribution of the log-nominal E-BFT CPUEs (tones per day fishing) for the main fishing gears by year from the weekly dBase 2011 – 2020. Note that these CPUEs do not necessarily reflect the same treatment of the data as used to develop indices to monitor stock relative abundance.

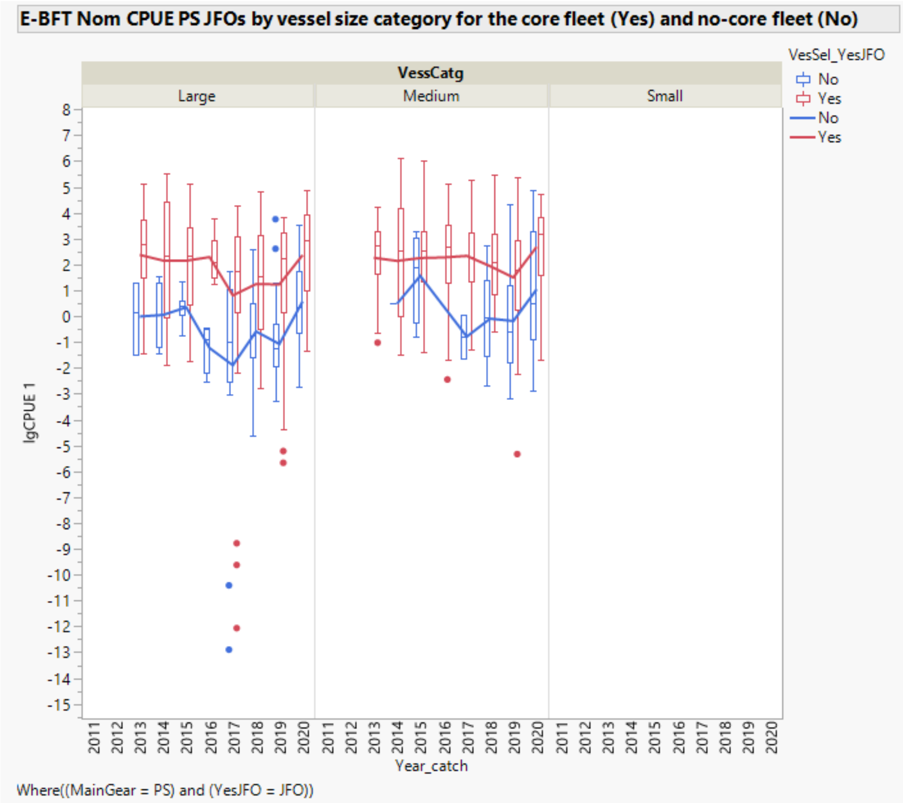


**Figure 21.25.4.** Distribution of E-BFT nominal log-CPUE (tonnes per day fishing) for the PS fleet registered as JFOs by vessel size category and "core" (Yes) vs rest of PS fleet (No) fleet 2013-2020.


**Figure 21.25.5.** Distribution of E-BFT nominal log-CPUE for the LL fleets standard fishing operations by vessel size category (Large, Medium, Small) and "core" (Red lines) *vs.* rest of LL fleet (Blue lines) fleet for the period 2013-2020.

**Table 1.** Preliminary estimates of nominal catch rates (CPUE, tones per day fishing) by vessel gear type, size category, and whether in JFO fishing operation (shaded rows) or not. "Core Fleet" is composed of vessels with a minimum annual catch of 5 t and at least 4 years of BFT reported catch Values provided are the mean and upper 90% confidence bounds (5% low, 95% upper) of by vessel observed catch rates from the BFT weekly report dbase 2013-2020.

| Vessel category | Core Fleet | JFO fishing | Nominal CPUE mean t/day fishing | low 95% CPUE | upp 95% CPUE |
|---|---|---|---|---|---|
| PS Large LOA >= 40 m | Yes | Yes | 13.14 | 0.38 | 147.92 |
| PS Large LOA >= 40 m | No | No | 0.46 | 0.05 | 9.53 |
| PS Large LOA >= 40 m | No | Yes | 4.57 | 0.09 | 74.23 |
| PS Medium 24 <= LOA < 40 m | Yes | No | 15.37 | 1.82 | 90.76 |
| PS Medium 24 <= LOA < 40 m | Yes | Yes | 3.93 | 0.16 | 74.68 |
| PS Medium 24 <= LOA < 40 m | No | No | 1.06 | 0.03 | 25.87 |
| PS Medium 24 <= LOA < 40 m | No | Yes | 8.68 | 0.55 | 93.60 |
| PS Small LOA < 24 m | Yes | No | 1.61 | 1.18 | 2.21 |
| PS Small LOA < 24 m | No | No | 3.35 | 0.79 | 12.25 |
| LL Large LOA >= 40 m | Yes | No | 0.35 | 0.05 | 1.48 |
| LL Large LOA >= 40 m | No | No | 0.27 | 0.03 | 1.21 |
| LL Medium 24 <= LOA < 40 m | No | No | 0.03 | 0.00 | 0.16 |
| LL Small LOA < 24 m | Yes | No | 0.23 | 0.01 | 2.54 |
| LL Small LOA < 24 m | No | No | 0.10 | 0.01 | 2.26 |
| BB Medium 24 <= LOA < 40 m | Yes | No | 0.26 | 0.02 | 2.70 |
| BB Medium 24 <= LOA < 40 m | No | No | 0.25 | 0.01 | 3.92 |
| BB Small LOA < 24 m | Yes | No | 0.34 | 0.04 | 2.72 |
| BB Small LOA < 24 m | No | No | 1.00 | 1.00 | 1.00 |

The analysis will continue in 2021, with a focus on the estimation of average fishing activity by fleet components and estimation of fishing effort units for other gears such as the bluefin tuna traps. It is important to indicate, that the 2008 catch rates tables also provided an estimate of "Probable yields" by simply multiplying the catch rates times the number of register active vessels, and the Commission estimated fishing capacity by dividing the allocation by the catch rates If the Commission intends to use newly provide CPUE to calculate fishing capacity, it will be required to also have estimates of "potential fishing activity" in addition to the number of registered vessels, as the CPUE rates represent average catch (t) of bluefin per fishing activity (hours, days fishing, trip, etc.) and are NOT by year. Thus, simply multiplying these nominal CPUEs times the number of vessels will be inappropriate. Similarly, the catch rates from 2008 currently used by the Commission are not appropriate for fishing capacity calculations as noted in the 2019 SCRS report (Anon. 2020).

Given the current management regulations including seasonal closure/opening, quota allocation by CPC/vessel, and the type of fishing operation (JFO) that catch most of the bluefin tuna each year, an analysis of fishing effort needs to be done to estimate some equivalent unit of "potential number of days (trips)" per main gear and vessel category that can operate during a calendar year. Hence, when this potential number of days* average CPUE per day would provide a more robust and consistent "annual probable yield" estimate.

Finally, it is noted that in 2020, Norway provided an SCRS document (Nøttestad *et al.,* 2020) with an analysis of their purse seine fleet catch rates in the northeast Atlantic. The SCRS encourages CPCs to carry out their fleet catch rate analyses to contrast the results of the ongoing research study.

## 7 Recommendations on management, research and statistics

### *7.1 General recommendations to the Commission that have financial implications*

The following recommendations were putted forward by the Group for 2022:

- Continued funding to support the essential work of GBYP including funding of Tagging and reward (€280,000), biological studies (€160,000), sample collection and shipping (€100,000), other fisheries related studies (e.g. fisheries independent indices; €400,000), Workshops (€80,000), MSE development process (€160,000), and the coordination (€320,000).
- Three meetings devoted to MSE refinement and dialogue with Panel 2 (coordinated by GBYP, costs included above).
- Two meetings of the Bluefin Tuna Working Group (MSE and EBFT Data Preparatory) and an MSE/EBFT Stock Assessment (costs included above).
- Support for the specified sub-group (SG) on EBFT modelling (the request would be for travel for the modelling sub-group to an in-person meeting [nine modelers to be decided at September Species Group meeting, costs included above]).
- External expert to review EBFT assessment to attend both DP and SA meetings (€10,000).
- Support the Ambassador meetings (to be held in 2021) and potential continuation into 2022 (costs included above).
- The Group supports a review of the overall MSE process (all species) at ICCAT in the near future.

The Table below contains the overall funding requests for bluefin tuna (including GBYP) for 2022:

| **Bluefin tuna** | 2022 (€) |
|---|---|
| **Tagging, rewards and awareness** | |
| Electronic and conventional tagging, rewarding and awareness | 280,000.00 |
| **Fishery Independent Indices** | |
| **Biological studies:** | |
| Microchemistry | 40,000.00 |
| Age and growth | 40,000.00 |
| Genetic | 80,000.00 |
| **Other** (if any, ie. fisheries independent indices**)** | |
| Aerial surveys | 350,000.00 |
| Development of Model-based approaches | 50,000.00 |
| **Sample collection and shipping** | 100,000.00 |
| **Workshops/meetings** | |
| GBYP workshops (TBD, probably further WS for BFT sampling coordination and Close Kin) | 80,000.00 |
| **MSE** | |
| Progress of the BFT MSE + process review | 160,000.00 |
| **Sub-TOTAL** | **1,180,000.00** |
| **Programme coordination** (include staff salaries, SC external member contract, SC members travel and ICCAT staff participation) | 320,000.00 |
| **TOTAL** | **1,500,000.00** |

### *7.2 Other general recommendations*

Other recommendations include:

- Habitat and environmental variables represent an important source of variability in existing indices of BFT relative abundance, the Committee recommends continued explorations of factors that may account for differential availability or catchability.

- The Committee reiterates the importance to continue the work in developing and implementing alternative assessment models for E-BFT and to consider revisions to trap indices and possible inclusion of other indices.

## 8. Presentation of other scientific papers

SCRS/2021/136 reported some continuous daily spawning activities of bluefin tuna in the traditional traps in Sardinia (EU-Italy), between 25 May and 20 June 2020. These direct observations are important for better describing the spawning behavior of the species, which is capable to spawn at any time of the complete day under the suitable conditions. Furthermore, it was noticed the unusual presence of many medium-large tunas, all with clear skin damages. Possibly some of those escaped after a storm from a farm in Spain in January 2020. Tunas with natural marks produced by shark bites were 5% of the harvested ones, possibly showing long-distance migrations.

SCRS/2021/158 described the use of omnidirectional fisheries sonar to estimate tuna biomass. Moreover, a first calibration of a Furuno FSV-25 sonar using net-CDF files was presented. In general, good calibration results were obtained. Calibration results agreed with previous works using different sonars and data formats. A positive relationship between the sonar estimates and the catch was found. This fact implies that the proposed methodology for single school abundance estimation could help the skipper to reduce uncertainty when estimating the size of the targeted school and open new chances for the development of abundance indicators.

The possible influence of the use of sonar on marine mammals was discussed, and it was pointed out that in most of the European countries its use is not forbidden. It was also discussed about other sonar systems that can provide with individual fish size estimates but was mentioned the lack of scientific evidence of the accuracy of this estimates. Trade-offs between spatial resolution and range from different acoustic systems; higher frequencies systems can provide higher resolution of targets but with a limited range. The use of these new sonars as a promising biomass estimation tool was also welcomed with interest.

## 9. Other matters

The Group considered the request (SCRS/2021/154) to develop a biomass limit reference point ($B_{lim}$). The Group agreed that, for practical purposes and consistency with existing metrics in the MSE, the limit reference point should be in terms of SSB, that it should be dynamic as reference points are dynamic in the OMs. But given the complexity of the issue, and the fact that the value for $B_{lim}$ is intimately linked to the probability of broaching e.g. lower $B_{lim}$ values should be associated with lower probabilities of breaching, the Group recommended further consideration be taken. The Group noted that, additionally, it would be useful for the Developer to amend the package to calculate $SSB_{lim}$ at 10 and 15% of $SSB_0$ and to output probabilities for these two values.

The Group reviewed a draft of detailed workplan for 2022 (**Appendix 9**). This will be finalized at the Species Group meeting before the SCRS.

## 10. Adoption of the report and closure

The Report of the Second 2021 ICCAT Intersessional Meeting of the Bluefin Tuna Species Group was adopted. Drs Rodríguez-Marín and Walter, and the SCRS Chair thanked the participants and the Secretariat for their hard work and collaboration to finalize the report on time. The meeting was adjourned.

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Katavic I., Grubisic L., Mihanovic M., Petrina Abreu I., Talijancic I., Bubic T.S., and Zuzul I. 2017. Length-weight relationships applicable to bluefin tuna juveniles (*Thunnus thynnus*) caught for farming purposes during the purse seine fishing season in the Adriatic. ICCAT Collect. Vol. Sci. Pap.74(6): 3515-3522.

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Ortiz M., Gallego JL., Mayor C., A. Parrilla, and Samedy V. 2021.Preliminary analyses of the ICCAT VMS data 2010-2011 to identify fishing trip behaviour and estimate fishing effort. SCRS/2021/037.

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**Table 1.** Recommendation and task list (Recommendation/Task) identified at the July 2021 BFT MSE Technical Group meeting, the status of the tasks (status) and the details about what actions were taken to complete the tasks.

| Class | Recommendation/task | Actions taken | Details |
|---|---|---|---|
| 1 | Catch-at-length graphing glitch resolved | Resolved at July 2021 meeting | |
| 2 | Robustness test: Intermediate Parameter ROMs | Postponed due to tight time constraints | |
| 2 | Robustness test: Hyperstability ROMs | Postponed due to tight time constraints | |
| 2 | Robustness test: Brazilian catch (post 1965 correction included) | Postponed due to tight time constraints | |
| 2 | Robustness test: US_RR_66_144 fit | Postponed due to tight time constraints | |
| 2 | Robustness test: OM#35 fit to seasonal prior | Postponed due to tight time constraints | |
| 3 | AAVC metric needs coding as a mean by simulation. | Package development | AAVC metric fixed (now mean % absolute difference across projected years per sim) |
| 3 | PGT metric revised to quantitative (now overfished, OFT) | Package development | PGT is now 'overfished trend' |
| 3 | OM weighting in tuning | Package development | Added OM_wt vector to package:<br>Added new function to return weighted Br30: |
| 4 | Shiny app updates (e.g. OM weighting) | Many updates to Shiny apps were made | a. OM weighting<br>b. Deselect / Select all in CMP<br>c. Select by CMP type and tuning<br>d. Download MSE results data<br>e. East – west trade-off plot<br>f. By-simulation normalization option for Zeh plot (to reveal relative performance differences controlling for simulated dynamics) |
| 5 | Investigation of M3 scale estimation | Postponed due to tight time constraints | |

**Table 2.** Plausibility weights for OMs by factors (rows) and levels (columns). (TSD- Table 9.3)

| Factor/Level | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Recruitment** | 0.40 | 0.40 | 0.20 | |
| **Spawn/M** | 0.50 | 0.50 | | |
| **Scale** | 0.30 | 0.30 | 0.15 | 0.25 |
| **Length comp** | 0.50 | 0.50 | | |

**Table 3.** Index selection and simulation for potential inclusion in CMPs (TSD- Table 7.1.)

| Index | Details | Selectivity | Recommended for CMPs | STD value* | AC* |
|---|---|---|---|---|---|
| CAN GSL RR | 1988-2020, Q3, GSL | 14: RRCAN | No | - | - |
| CAN SWNS RR | 1996-2020, Q3, W Atl | 14: RRCAN | Yes | OM-estim | OM-estim |
| US RR 66-144 | 1995-2020, Q3, W Atl | 15: RRUSAFS (50 –150cm) | Yes | OM-estim | OM-estim |
| US RR 66-114 | 1995-2020, Q3, W Atl | 15: RRUSAFS (50 –125cm) | No*** | OM-estim | OM-estim |
| US RR 115-144 | 1995-2020, Q3, W Atl | 15: RRUSAFS (100 – 150cm) | No*** | OM-estim | OM-estim |
| US RR 177+ | 1993-2020, Q3, W Atl | 16: RRUSAFB (175cm+) | No | - | - |
| JPN LL West2 | 2010-2020, Q4, W Atl | 18: LLJPNnew | Yes | OM-estim | OM-estim |
| US-MEX GOM PLL | 1994-2019, Q2, GOM | 1: LLOTH | Yes | OM-estim | OM-estim |
| GOM LAR SUV | 1977-2019 (gaps 1979-1980, 1985), Q2, GOM | SSB | Yes | OM-estim | OM-estim |
| CAN ACO SUV2 | 2017-2018, Q3, GSL | 14: RRCAN (150cm+) | No** | - | - |
| MOR POR TRAP | 2012-2020, Q2, S Atl | 13: TPnew | Yes | OM-estim | OM-estim |
| JPN LL NEAtl2 | 2010-2019, Q4, N Atl | 18: LLJPNnew | Yes | OM-estim | OM-estim |
| FR AER SUV2 | 2009-2019 (gap 2013), Q3, Med | 15: RRUSAFS | Yes | OM-estim | OM-estim |
| GBYP AER SUV BAR | 2010-2018 (gaps 2012, 2014, 2016), Q2, Med | SSB | Yes | 0.45# | 0.2# |
| W-MED LAR SUV | 2001-2019 (gaps 2006, 2007, 2009, 2011), Q2, Med | SSB | Yes | OM-estim (years 2012-2019) | OM-estim (years 2012-2019) |

* OM-estim means OM-specific estimates from the index residuals of the corresponding OM fit (Section 7.5). When the estimated AC is < 0, it is fixed at AC=0 for the projections with that OM.
** The Canadian acoustic survey index is simulated in the BFT MSE package, but should not be used in CMPs at this time because of uncertainty about calibration in the change to a different vessel.
*** Not recommended for CMPs but still projected for sensitivity runs.
# GBYP AER SUV BAR index will be refit by the MSE Contractor and SE and AC re-evaluated with a preference given to using estimated SE and AC values

**Table 4.** Factors and levels of key uncertainty factors the Reference Grid operating models (TSD- Table 9.1)

| Factor: **Recruitment*** | | |
|---|---|---|
| | Western stock | Eastern stock |
| level **1** | B-H with h=0.6 ("high R0") switches to h = 0.9 ("low R0") starting from 1975 | 50-87 B-H h=0.98 ("low R0") switches to 88+ B-H *h*=0.98 ("high R0") |
| level **2** | B-H with h=0.6 fixed, high R0 | B-H with h=0.7 fixed, high R0 |
| level **3** | Historically as in level 1. In projections, "low R0" switches back to "high R0" after 10 years | Historically as in level 1. In projections, 88+ B-H with *h*=0.98 ("high R0") switches back to 50-87 B-H with *h*=0.98 ("low R0") after 10 years |

| Factor: **Spawning fraction/Natural mortality rate for both stocks** | |
|---|---|
| level **A** | Younger spawning (E+W same)/High natural mortality |
| level **B** | Older spawning (different for the 2 stocks)/Low natural mortality (with senescence) |

| Factor: **Scale**** | | |
|---|---|---|
| | West area | East area |
| level **--** | 15kt | 200kt |
| level **-+** | 15kt | 400kt |
| level **+-** | 50kt | 200kt |
| level **++** | 50kt | 400kt |

| Factor: **Length composition weighting in likelihood** | |
|---|---|
| level **L** | 0.05 |
| level **H** | 1 |

* For recruitment factor level 1 two stock-recruitment relationships are estimated each corresponding to an historical time period. In both the western stock and the eastern stock the steepness of the stock-recruitment curves are specified for these two time periods but unfished recruitment (R0) is re-estimated to capture a regime shift in stock productivity. Recruitment factor level 3 only differs from level 1 in projections, where the estimated regime shift switches back to earlier productivity. Hence, recruitment factor level 3 does not require fitting, historical fit is the same as factor level 1.

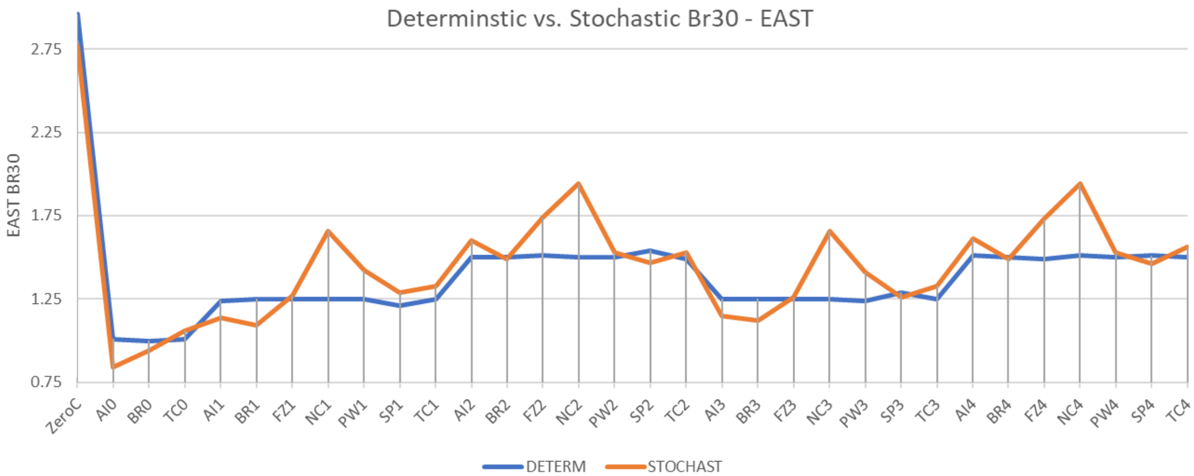
**The scale factor is intended to reflect extremes of area-specific spawning stock biomass based very approximately on the 2017 stock assessment values. The numbers correspond with mean SSB values over the years 1968-2015 in the West area and 1974-2015 in the East areas. The fitting criterion in the conditioning of any OM includes penalty terms to ensure that the output SSB trajectories for the East and West areas for that OM have means over the periods indicated that match the two values applying to that OM as given in the table.

**Table 5.** Performance Measures calculated as part of the MSE outputs for each OM and CMP. Performance Measures in bold text indicate the key 7 ones (TSD-Table 10.1).

| *Measure* | *Measure Description* | *Statistic(s)** |
|---|---|---|
| **AAVC** | **Average annual variation in catches (AAV)** among CMP update times $t$ (note that except where the resource is heavily depleted so that catches become limited by maximum allowed fishing mortalities, catches will be identical to TACs) defined by: $AAVC = \frac{1}{nt}\sum_{t=1}^{nt} \lvert C_t - C_{t-1} \rvert / C_{t-1}$ (13.1) | Median |
| **AvC10** | **Mean catches over first 10 projected years**. Required to provide short-term vs long-term (AvC30) yield trade-offs. | Median |
| **AvC30** | **Mean catches over first 30 projected years** | Median |
| **AvgBr** | **Average Br** (spawning biomass relative to dynamic $SSB_{MSY}$) over projection years 11-30 | Median and 5th percentile |
| **Br30** | **Depletion** (spawning biomass relative to dynamic $SSB_{MSY}$) **after projection year 30** | Median and 5th percentile |
| **OFT** | '**Overfished Trend**': Average trend (in log space) of SSB over projection years 31 - 35 when Br30 < 1. $OFT = \begin{cases} 0.1 & SSB_{30} \geq dynSSB_{MSY} \\ m(\log SSB_{31:35}) & SSB_{30} < dynSSB_{MSY} \end{cases}$ Where $m(\vec{x})$ is the gradient of a line of best fit through the vector $\vec{x}$, found via least squares | Median |
| **LD** | **Lowest depletion** (spawning biomass relative to dynamic $SSB_0$) over the 30 years for which the CMP is applied. | Median, 5th, and 15th percentile of LD to map to the Panel 2 recommendation |
| C1 | Catch in first year of CMP implementation | Median |
| C20 | Mean catches over projected years 11-20 | Median |
| **C30** | **Mean catches over projected years 21-30** | Median |
| D10 | Depletion (spawning biomass relative to dynamic $SSB_0$) after the first 10 projected years | Median |
| D20 | Depletion (spawning biomass relative to dynamic $SSB_0$) after projection year 20 | Median |
| D30 | Depletion (spawning biomass relative to dynamic $SSB_0$) after projection year 30 | Median |
| DNC | D30 using the MP relative to D30 had no catches been taken over the 30 projected years | Median |
| LDNC | LD using the MP relative to LD had no catches been taken over the 30 projected years. | Median |
| POS | Probability of Over-Fished status (spawning biomass < $SSB_{MSY}$) after 30 projected years. | Median |
| F** | Overfishing related statistic. | |

* For each of these distributions, 5%-, 50%- and 95%iles are to be reported from 200 replicates. The choice of these percentiles may need further exploration with stakeholders.

** This performance statistic will be considered intersessionally by the Group.



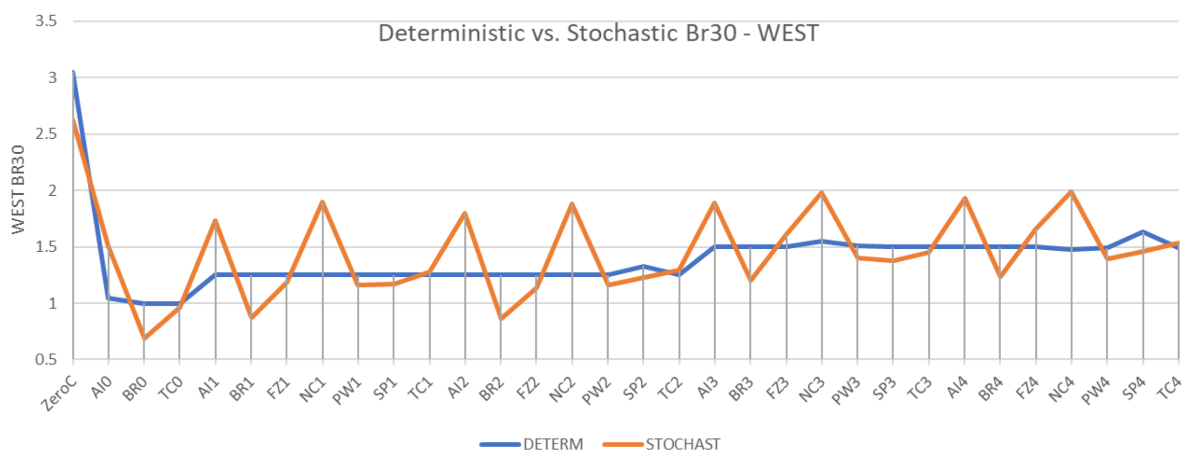




**Figure 1.** Weighted Br30 calculated under deterministic (blue line) versus stochastic (orange line) projections across CMPs for the eastern (top) and western (bottom) stocks.

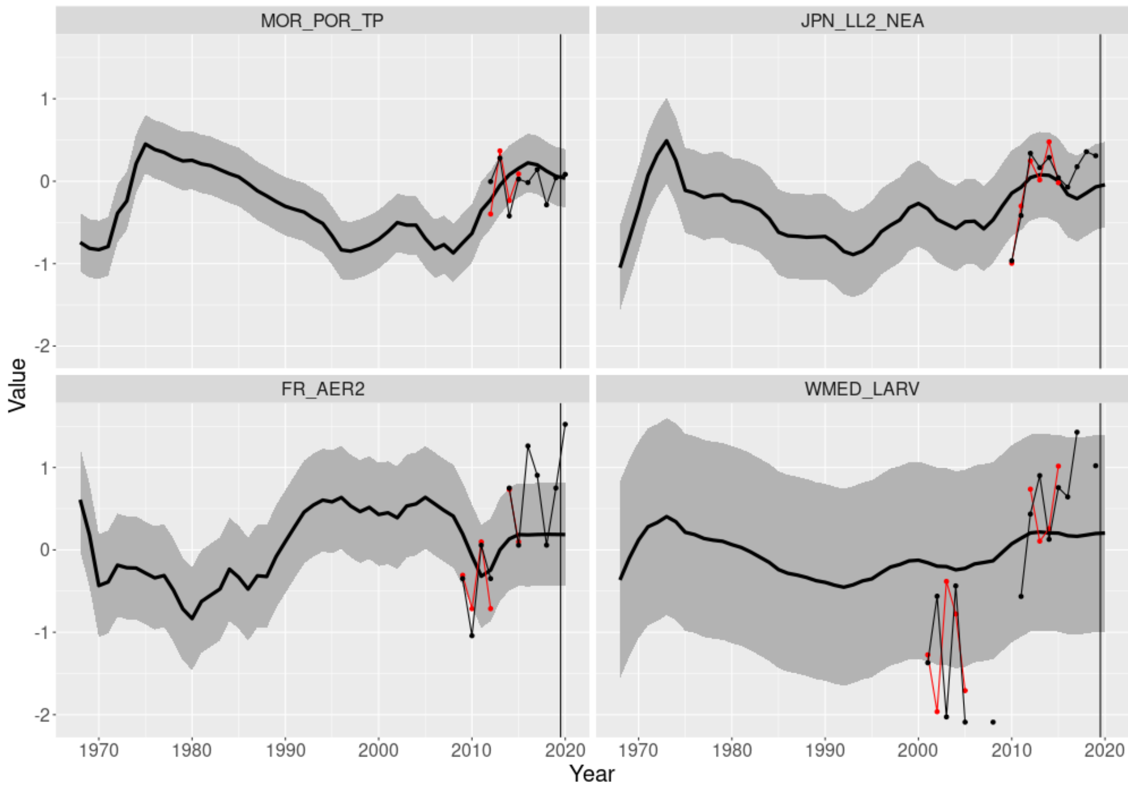



**Figure 2.** Updated indices (values post 2019, vertical black line) compared with 80% prediction intervals from the 2017 VPA projected forward with observed catches and 6-year average recruitment. Red points are the indices used in the assessment and black points are the updated or revised index values. Thick black lines are the central tendency of the population component corresponding to the index. To interpret the implications of points outside of the 80% intervals, 20% of the observations might fall outside of the interval by random chance. Note that the methodology used to produce the Western Mediterranean Larval Index has been substantially revised since the 2017 Stock Assessment, which produced notably different fluctuations between the original and updated indices.

**Appendix 1**

## Agenda

1 Opening, adoption of agenda and meeting arrangements
2. MSE
  2.1 BFT MSE Consultant's update on work since July BFT Technical Group meeting
  2.2 Review of recommendations from the July BFT Technical Group
    2.2.1 Review of the acceptability of the reconditioned OMs
    2.2.2 Review robustness tests
    2.2.3 Consideration of any revisions to plausibility weighting of OMs
    2.2.4 Short term development and communication timelines for MSE
  2.3 CMP Development and review
    2.3.1 Round robin from CMP developers
    2.3.2 Review and comparison of CMP results
    2.3.3 Condensing CMPs into 2-3 for further presentation at this stage
  2.4 Performance measures and statistics for reporting
    2.4.1 Review and trimming of existing measures
    2.4.2 Statistics for reporting
  2.5 Messaging on MSE (material for SCRS and Commission, and other stakeholder groups)
    2.5.1 Review of deliverables from MSE Communications Team: One page summary, Executive summary (4 pages), and Presentation and slides
    2.5.2 Process for engagement to describe the BFT MSE process and to summarise results to date
  2.6 General criteria for exceptional circumstances
  2.7 TSD
  2.8 MSE Code review progress
3 Report out from BFT Technical Sub-groups and GBYP (subgroup leads and GBYP coordinator)
  3.1 BFT Technical Sub-group on Assessment models (EBFT)
  3.2 BFT Technical Sub-group on Growth in Farms
  3.3 GBYP
    3.3.1 GBYP matters
    3.3.2 GBYP aerial survey review and revised index
4 Review of the Executive summary for W-BFT
5. Review of Abundance indices and other fisheries indicators for E-BFT
6. Responses to the Commission
  6.1 Western Atlantic bluefin tuna
  6.2 Eastern Atlantic and Mediterranean bluefin tuna
7 Recommendations on management, research and statistics
8. Presentation of other scientific papers
9. Other matters
10. Adoption of the report and closure

**Appendix 2**

## List of Participants

### *CONTRACTING PARTIES*

**ALGERIA**
**Ferhani**, Khadra
Centre National de Recherche et de Développement de la Pêche et de l'Aquaculture (CNRDPA), 11 Boulevard Colonel Amirouche, BP 67, 42415 Tipaza Bou Ismail
Tel: +213 550 735 537, Fax: +213 24 32 64 10, E-Mail: ferhani_khadra@yahoo.fr; ferhanikhadra@gmail.com

**Kouadri-Krim**, Assia
Sous-Directrice infrastructures, industries et services liés à la pêche, Ministère de la Pêche et des Productions Halieutiques, Direction du développement de la pêche, Route des Quatre Canons, 1600
Tel: +213 558 642 692, Fax: +213 214 33197, E-Mail: assiakrim63@gmail.com

**CANADA**
**Busawon**, Dheeraj
Fisheries & Oceans Canada, St. Andrews Biological Station, 125 Marine Science Drive, St. Andrews, NB E5B 0E4
Tel: +1 506 529 5889; +1 506 467 5651, Fax: +1 506 529 5862, E-Mail: Dheeraj.Busawon@dfo-mpo.gc.ca

**Carruthers**, Thomas
2150 Bridgman Ave, Vancouver Columbia V7P 2T9
Tel: +1 604 805 6627, E-Mail: tom@bluematterscience.com

**Duprey**, Nicholas
Senior Science Advisor, Fisheries and Oceans Canada - Fish Population Science, Government of Canada, 200-401 Burrard Street, Vancouver, BC V6C 3R2
Tel: +1 604 499 0469; +1 250 816 9709, E-Mail: nicholas.duprey@dfo-mpo.gc.ca

**Gillespie**, Kyle
Fisheries and Oceans Canada, St. Andrews Biological Station, Population Ecology Division, 125 Marine Science Drive, St. Andrews, New Brunswick, E5B 0E4
Tel: +1 506 529 5725, Fax: +1 506 529 5862, E-Mail: kyle.gillespie@dfo-mpo.gc.ca

**Hanke**, Alexander
Scientist, St. Andrews Biological Station, Fisheries and Oceans Canada, 531 Brandy Cove Road, St. Andrews, New Brunswick E5B 2L9
Tel: +1 506 529 5912, Fax: +1 506 529 5862, E-Mail: alex.hanke@dfo-mpo.gc.ca

**EGYPT**
**Abdelnabi Fetouh**, Mohamed
Researcher, National Institute of Oceanography and Fisheries (NIOF), 14 Aly Abn Aby Taalep, Abo Qir, 11694 Alexandria, Cairo
Tel: +202 279 21341, Fax: +202 792 1339, E-Mail: ma_fotouh@outlook.com

**Badr**, Fatma Elzahraa
Agreements Administration (GAFRD), New Cairo
Tel: +202 281 17010, Fax: +202 281 117 007, E-Mail: fatima.elzahraa.medo@gmail.com

**Badr**, Abdelrazek Mohamed
Fisheries Specialist, New Cairo
Tel: +201 228 708 220, Fax: +202 281 117 007, E-Mail: abdelrazek.mohamed004@gmail.com

**Hussain**, Shimaa
Fisheries Specialist, New Cairo
Tel: +201 011 487 000, Fax: +202 281 117 007, E-Mail: shimaa_hussin8@yahoo.com

**Wahba**, Rana Adel
International Cooperation Representative, New Cairo
Tel: +201 206 692 278, Fax: +202 281 117 007, E-Mail: rana.adel.wahba@gmail.com; cindrella_ranosh@hotmail.com

**EUROPEAN UNION**
**Álvarez Berastegui**, Diego
Instituto Español de Oceanografía, Centro Oceanográfico de Baleares, Muelle de Poniente s/n, 07010 Palma de Mallorca, España
Tel: +34 971 133 720; +34 626 752 436, E-Mail: diego.alvarez@ieo.es

**Andonegi Odriozola**, Eider
AZTI, Txatxarramendi ugartea z/g, 48395 Sukarrieta, Bizkaia, España
Tel: +34 661 630 221, E-Mail: eandonegi@azti.es

**Arrizabalaga**, Haritz
Principal Investigator, AZTI Marine Research Basque Research and Technology Alliance (BRTA), Herrera Kaia Portualde z/g, 20110 Pasaia, Gipuzkoa, España
Tel: +34 94 657 40 00; +34 667 174 477, Fax: +34 94 300 48 01, E-Mail: harri@azti.es

**Biagi**, Franco
Senior Expert Marine & Fishery Sciences, Directorate General for Maritime Affairs and Fisheries (DG-Mare) - European Commission, Unit C3: Scientific Advice and data collection, Rue Joseph II, 99, 1049 Brussels, Belgium
Tel: +322 299 4104, E-Mail: franco.biagi@ec.europa.eu

**Bridges**, Christopher Robert
Heinrich Heine University, Düsseldorf AG Ecophysiology, Institute for Metabolic Physiology: Ecophysiology / TUNATECH GmbH Merowinger, Platz 1, 40225 Duesseldorf Nrw, Germany
Tel: +4901739531905, E-Mail: bridges@hhu.de; christopher.bridges@uni-duesseldorf.de

**Castillo Gutiérrez**, Isabel
Instituto Español de Oceanografía, Promontorio San Martin s/n, 39004 Santander, España
Tel: +34 942 291 716, E-Mail: isabel.castillo@ieo.es

**Coco**, Ornella
Scientific Consultant and Lecturer in training and dissemination activities on Fisheries and Marine Biology, Oceanis Srl, 89043 Salerno, Italy
Tel: +39 342 582 8477, E-Mail: ornellacoco.biomol@gmail.com

**Di Natale**, Antonio
Director, Aquastudio Research Institute, Via Trapani 6, 98121 Messina, Italy
Tel: +39 336 333 366, E-Mail: adinatale@costaedutainment.it; adinatale@acquariodigenova.it

**Espinosa Rosello**, Victor
Universidad Politécnica de Valencia, c/Paranimf, 1, 46730 Grao de Gandia, Valencia, España
Tel: +34 637 851769, Fax: +34 962 849327, E-Mail: vespinos@fis.upv.es

**Garibaldi**, Fulvio
University of Genoa - Dept. of Earth, Environmente and Life Sciences, Dipartimento si Scienze della Terra, dell'Ambiente e della Vita (DISTAV), Corso Europa, 26, 16132 Genova, Italy
Tel: +39 335 666 0784; +39 010 353 8576, Fax: +39 010 357 888, E-Mail: largepel@unige.it; garibaldi.f@libero.it

**Gordoa**, Ana
Senior scientist, Centro de Estudios Avanzados de Blanes (CEAB - CSIC), Acc. Cala St. Francesc, 14, 17300 Blanes, Girona, España
Tel: +34 972 336101; +34 666 094 459, E-Mail: gordoa@ceab.csic.es

**Grubisic**, Leon
Institute of Oceanography and Fisheries in Split, Setaliste Ivana Mestrovica 63 - P.O. Box 500, 21000 Split, Croatia
Tel: +385 914 070 955, Fax: +385 21 358 650, E-Mail: leon@izor.hr

**Lino**, Pedro Gil
Research Assistant, Instituto Português do Mar e da Atmosfera - I.P./IPMA, Avenida 5 Outubro s/n, 8700-305 Olhão, Faro, Portugal
Tel: +351 289 700504, E-Mail: plino@ipma.pt

**Males**, Josip
Institute of Oceanography and Fisheries, Šetalište I. Meštrovića 63, 21000 Split, Croatia
Tel: +385 214 08000, Fax: +385 213 58650, E-Mail: josip-males@hotmail.com; males@izor.hr

**Pappalardo**, Luigi
Scientific Coordinator, OCEANIS SRL, Vie Maritime 59, 84043 Salerno Agropoli, Italy
Tel: +39 081 777 5116; +39 345 689 2473, E-Mail: gistec86@hotmail.com; oceanissrl@gmail.com

**Parejo Lázaro-Carrasco**, Aída
Instituto Español de Oceanografía - IEO, Promontorio San Martín s/n, Av. de Severiano Ballesteros, s/n, 39004 Cantabria, Santander, España
Tel: +34 942 29 17 16, E-Mail: aida.parejo@ieo.es

**Pinto**, Cecilia
Università di Genova DISTAV, Dipartimento di Scienze della Terra, dell'Ambiente e della Vita Corso Europa 26, 16132 Genova Liguria, Italy
Tel: +39 340 496 6905, E-Mail: cecilia.pinto@edu.unige.it

**Rodríguez-Marín**, Enrique
Ministerio de Ciencia, Innovación y Universidades, Instituto Español de Oceanografía, C.O. de Santander, Promontorio de San Martín s/n, 39004 Santander, Cantabria, España
Tel: +34 942 291 716, Fax: +34 942 27 50 72, E-Mail: enrique.rmarin@ieo.es

**Rouyer**, Tristan
Ifremer - Dept Recherche Halieutique, B.P. 171 - Bd. Jean Monnet, 34200 Sète, Languedoc Rousillon, France
Tel: +33 782 995 237, E-Mail: tristan.rouyer@ifremer.fr

**Saber Rodríguez**, Sámar
Ministerio de Ciencia, Innovación y Universidades, Instituto Español de Oceanografía. Centro Oceanográfico de Murcia, 30740 San Pedro del Pinatar, Murcia, España
Tel: +34 968 180 500, E-Mail: samar.saber@ieo.es

**JAPAN**
**Butterworth**, Douglas S.
Emeritus Professor, Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701 Cape Town, South Africa
Tel: +27 21 650 2343, E-Mail: doug.butterworth@uct.ac.za

**Daito**, Jun
Chief, Japan Tuna Fisheries Co-operative Association, 31-1, Eitai 2-Chome, Koto-ku, Tokyo 135-0034
Tel: +81 356 462 382, Fax: +81 356 462 652, E-Mail: daito@japantuna.or.jp

**Fukuda**, Hiromu
Head of Group, Highly Migratory Resources Division, Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, 234-8648
Tel: +81 45 788 7936, E-Mail: fukudahiromu@affrc.go.jp

**Miura**, Nozomu
Assistant Director, International Division, Japan Tuna Fisheries Co-operative Association, 2-31-1 Eitai Koto-ku, Tokyo 135-0034
Tel: +81 3 5646 2382, Fax: +81 3 5646 2652, E-Mail: miura@japantuna.or.jp; gyojyo@japantuna.or.jp

**Nagai**, Daisaku
Manager, Japan Tuna Fisheries Co-Operative Association, 31-1, EITAI 2-CHOME, Koto-ku, Tokyo 135-0034
Tel: +81 356 462 382, Fax: +81 356 462 652, E-Mail: nagai@japantuna.or.jp

**Nakatsuka**, Shuya
Deputy Director, Highly Migratory Resources Division, Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 2-12-4, Fukuura, Kanazawa Kanagawa, 236-8648
Tel: +81 45 788 7950, E-Mail: snakatsuka@affrc.go.jp

**Rademeyer**, Rebecca
Marine Resource Assessment and Management Group, Department of Mathematics and Applied Mathematic - University of Cape Town, Private Bag, 7700 Rondebosch, South Africa
Tel: +651 300 442, E-Mail: rebecca.rademeyer@gmail.com

**Tsukahara**, Yohei
ScientistHighly Migratory Resources Division, Fisheries Stock Assessment Center, Fisheries Resources Institute, Highly Migratory Resources Division, Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 2-12-4, Fukuura, Kanagawa, Yokohama, Shizuoka Shimizu-ku 236-8648
Tel: +81 45 788 7937, Fax: +81 54 335 9642, E-Mail: tsukahara_y@affrc.go.jp

**Uozumi**, Yuji
Adviser, Japan Tuna Fisheries Co-operation Association, Japan Fisheries Research and Education Agency, 31-1 Eitai Chiyodaku, Tokyo Koutou ku Eitai 135-0034
Tel: +81 3 5646 2380, Fax: +81 3 5646 2652, E-Mail: uozumi@japantuna.or.jp

**KOREA REP.**
**Lee**, Mi Kyung
Scientist, National Institute of Fisheries Science, 216 Gijanghaean-ro, Gijang-eup, Gijang-gun, 46083 Busan
Tel: +82 51 720 2332, Fax: +82 51 720 2337, E-Mail: ccmklee@korea.kr; cc.mklee@gmail.com

**MOROCCO**
**Abid**, Noureddine
Chercheur et ingénieur halieute au Centre Régional de recherche Halieutique de Tanger, Responsable du programme de suivi et d'étude des ressources des grands pélagiques, Centre régional de l'INRH à Tanger/M'dig, B.P. 5268, 90000 Drabed, Tanger
Tel: +212 53932 5134; +212 663 708 819, Fax: +212 53932 5139, E-Mail: noureddine.abid65@gmail.com

**Bensbai**, Jilali
Chercheur, Institut National de Recherche Halieutique à Casablanca - INRH/Laboratoires Centraux, AIN DIAB PRES DU CLUB EQUESTRE OULAD JMEL, Rue Sidi Abderrhman / Ain Diab, 20100 Casablanca
Tel: +212 661 59 8386, Fax: +212 522 397 388, E-Mail: bensbaijilali@gmail.com

**NORWAY**
**Mjorlund**, Rune
Directorate of Fisheries, Strandgaten 229, 5004 Bergen
Tel: +47 952 59 448, E-Mail: rune.mjorlund@fiskeridir.no

**Nottestad**, Leif
Principal Scientist, Institute of Marine Research Research Group on Pelagic Fish, P.O. Box 1870 Nordnesgaten, 33, 5817 Bergen, Hordaland county
Tel: +47 5 99 22 70 25, Fax: +47 55 23 86 87, E-Mail: leif.nottestad@hi.no

**Pena**, Hector
Postboks 1870 Nordnes, 5817 Bergen Hordaland
Tel: +47 974 30436, E-Mail: hector.pena@hi.no

**TUNISIA**
**Zarrad**, Rafik
Chercheur, Institut National des Sciences et Technologies de la Mer (INSTM), BP 138 Ezzahra, Mahdia 5199
Tel: +216 73 688 604; +216 972 92111, Fax: +216 73 688 602, E-Mail: rafik.zarrad@gmail.com

**UNITED STATES**
**Brown**, Craig A.
Chief, Highly Migratory Species Branch, Sustainable Fisheries Division, NOAA Fisheries Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, Florida 33149
Tel: +1 305 586 6589, Fax: +1 305 361 4562, E-Mail: craig.brown@noaa.gov

**Cadrin**, Steven Xavier
Associate Professor, SMAST - University of Massachusetts, School for Marine Science & Technology, Department of Fisheries Oceanography, 836 South Rodney French Blvd, Fairhaven, MA 02744
Tel: +1 508 910 6358, Fax: +1 508 910 6374, E-Mail: scadrin@umassd.edu

**Golet**, Walter
School of Marine Sciences, The University of Maine/Gulf of Maine Research Institute, 350 Commercial Street, Portland, Maine 04101-4618
Tel: +1 207 228 1671, E-Mail: walter.golet@maine.edu

**Kerr**, Lisa
Gulf of Maine Research Institute, 350 Commercial Street, Portland ME 04101
Tel: +1 301 204 3385; +1 207 228 1639, E-Mail: lkerr@gmri.org

**Lauretta**, Matthew
Fisheries Biologist, NOAA Fisheries Southeast Fisheries Center, 75 Virginia Beach Drive, Miami, Florida 33149
Tel: +1 305 361 4481, E-Mail: matthew.lauretta@noaa.gov

**Peterson**, Cassidy
NOAA Fisheries, 101 Pivers Island Rd, Miami, FL 28516
Tel: +1 252 838 0885, E-Mail: cassidy.peterson@noaa.gov

**Schalit**, David
President, American Bluefin Tuna Association, 176 Mulberry Street - 4th floor, New York 10013
Tel: +1 917 573 7922, E-Mail: dschalit@gmail.com

**Walter**, John
Research Fishery Biologist, NOAA Fisheries, Southeast Fisheries Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, Florida 33149
Tel: +305 365 4114; +1 804 815 0881, Fax: +1 305 361 4562, E-Mail: john.f.walter@noaa.gov

**Weiner**, Chris
33 Park Street, #4, Portland, Maine 04101
Tel: +1 978 886 0204, E-Mail: chrisweiner14@gmail.com

**Weiner**, Stephen
PO Box 465, Maine Ogunquit 03907
Tel: +1 978 764 3637, E-Mail: weinersb@gmail.com

***OBSERVERS FROM NON-GOVERNMENTAL ORGANIZATIONS***

**FEDERATION OF MALTESE AQUACULTURE PRODUCERS – FMAP**

**Deguara**, Simeon
Research and Development Coordinator, FEDERATION OF MALTESE AQUACULTURE PRODUCERS – FMAP, Central Complex, Naggar Ste., Mosta, MST 1761, Malta
Tel: +356 994 23123, E-Mail: dsd@aquabt.com

**PEW CHARITABLE TRUSTS - PEW**

**Cox**, Sean
School of Resource and Environmental Management, Simon Fraser University, 8888 University Drive, British Columbia Burnaby V5A1S6, Canada
Tel: +1 78 782 5778; +1 604 763 1414, Fax: +1 778 782 4968, E-Mail: spcox@sfu.ca

**Galland**, Grantly
Officer, Pew Charitable Trusts, 901 E Street, NW, Washington, DC 20004, United States
Tel: +1 202 540 6953; +1 202 494 7741, Fax: +1 202 552 2299, E-Mail: ggalland@pewtrusts.org

**Johnson**, Samuel D.N.
Landmark Fisheries Research, 213-2414 Saint Johns Street, Port Moody, BC V3H2B1, Canada
Tel: +1 604 365 7133, E-Mail: sdnjohnson@landmarkfisheries.com; samuelj@sfu.ca

**Wilson**, Ashley
Pew Charitable Trusts, The Grove, 248A Marylebone Road, London NW1 6JZ, United Kingdom
Tel: +44 794 016 1154, E-Mail: awilson@pewtrusts.org

**THE OCEAN FOUNDATION**

**Aalto**, Emilius
120 Ocean View Blvd, CA Pacific Grove 93950, United States
Tel: +1 203 809 6376, E-Mail: aalto@cs.stanford.edu

**Miller**, Shana
The Ocean Foundation, 1320 19th St., NW, 5th Floor, Washington, DC 20036, United States
Tel: +1 631 671 1530, E-Mail: smiller@oceanfdn.org

**SCRS CHAIRMAN**

**Melvin**, Gary
SCRS Chairman, St. Andrews Biological Station - Fisheries and Oceans Canada, Department of Fisheries and Oceans, 285 Water Street, St. Andrews, New Brunswick E5B 1B8, Canada
Tel: +1 506 652 95783, E-Mail: gary.d.melvin@gmail.com; gary.melvin@dfo-mpo.gc.ca

**SCRS VICE-CHAIRMAN**
**Coelho**, Rui
Researcher, SCRS Vice-Chairman, Portuguese Institute for the Ocean and Atmosphere, I.P. (IPMA), Avenida 5 de Outubro, s/n, 8700-305 Olhão, Portugal
Tel: +351 289 700 504, E-Mail: rpcoelho@ipma.pt

**INVITED EXPERT**
**Parma**, Ana
Principal Researcher, Centro para el Estudio de Sistemas Marinos, CONICET (National Scientific and Technical Research Council), Blvd. Brown 2915, U 9120 ACF Puerto Madryn, Chubut, Argentina
Tel: +54 (280) 488 3184 (int. 1229), Fax: +54 (280) 488 3543, E-Mail: anaparma@gmail.com; parma@cenpat-conicet.gob.ar

*****

**ICCAT Secretariat**
C/ Corazón de María 8 – 6th floor, 28002 Madrid – Spain
Tel: +34 91 416 56 00; Fax: +34 91 415 26 12; E-mail: info@iccat.int

**Manel**, Camille Jean Pierre
**Neves dos Santos**, Miguel
**Ortiz**, Mauricio
**Palma**, Carlos
**Kimoto**, Ai
**Taylor**, Nathan
**Alemany**, Francisco
**Pagá**, Alfonso
**Tensek**, Stasa

**Appendix 3**

## List of Papers and Presentations

| Number | Title | Authors |
|---|---|---|
| SCRS/2021/136 | Bluefin tuna (*Thunnus Thynnus*, linnaeus 1758) spawning in sunny days, some long-distance migrants and several tuna evaders in Sardinian traps | Di Natale A., and Greco G. |
| SCRS/2021/137 | Calibration of Atlantic bluefin tuna otolith reading conducted by an independent fish ageing laboratory contracted by the ICCAT research programme GBYP | Rodriguez-Marin E., Busawon D., Addis P., Allman R., Bellodi A., Castillo I., Garibaldi F., Karakulak S., Luque P.L., Parejo A., and Quelle P. |
| SCRS/2021/138 | ICCAT Atlantic-Wide Research Programme for Bluefin tuna (GBYP) Activity report for Phase 10 and the first part of Phase 11 (2020-2021) | Alemany F., Tensek S., and Pagá García A. |
| SCRS/2021/142 | Bluefin CPUE time series of the Balfegó purse seine joint fishing fleet from 2003 to 2021 and the new operational protocol implemented in 2021 | Gordoa, A., and Navarro, J. |
| SCRS/2021/144 | Tuna Ocean Restocking (TOR) pilot study – long-term growth rates and food conversion ratios in Atlantic bluefin tuna broodstock in captivity | Bridges C.R., Borutta F, Schulz S., Na'amnieh S., Vassallo-Agius R., Psaila M., and Ellul S. |
| SCRS/2021/145 | Modal Progression Analyses to determine BFT seasonal growth rates in farms | Alemany F., Pagá A., Deguara S., and Tensek S. |
| SCRS/2021/146 | Review of the size and weight data of Eastern bluefin tuna (*Thunnus Thynnus*) from Portugal trap/farm | Lino P.G., Ortiz M., Morikawa H., and Santos M. |
| SCRS/2021/147 | Preliminary results analyses of weight gain of bluefin tuna (*Thunnus Thynnus*) in farms from the farm harvest database 2015 -2020. | Ortiz M., Mayor C., and Paga A. |
| SCRS/2021/150 | The BFT farm growth sub-group status of analysis | Anonymous |
| SCRS/2021/151 | The effects of phase-in periods on Atlantic bluefin tuna Candidate Management Procedure performance | Johnson S.D.N., and Cox S.P. |
| SCRS/2021/152 | Refinements of the BR CMP as at August 2021 | Butterworth D.S., and Rademeyer R.A. |
| SCRS/2021/154 | A proposal for a $B_{lim}$ for Atlantic bluefin tuna | Andonegi E., and Walter J. |
| SCRS/2021/155 | Atlantic bluefin tuna constant harvest rate and index-based Candidate Management Procedures; tuning to ABT_MSE package 7.3.1 | Peterson C., Lauretta M., and Walter J. |
| SCRS/2021/156 | Comparing deterministic and stochastic results of two Candidate Management Procedures developed for the bluefin tuna Management Strategy Evaluation | Duprey N., and Hanke A. |
| SCRS/2021/157 | Automated BFT growth monitoring in cages from a ventral perspective | Muñoz-Benavent P., Puig-Pons V., Morillo-Faro A., Andreu-García G., Espinosa V., and Pérez-Arjona I. |
| SCRS/2021/158 | Biomass estimation of spawing Atlantic bluefin tuna (*Thunnus thynnus*) schools using omnidirectional fisheries sonars | Smith J.D., Peña H., Puig-Pons V., Espinosa V., Macaulay G.J., and Pérez-Arjona I. |

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| SCRS/P/2021/049 | Advances of the Modeling Sub-group | Anon. |
| SCRS/P/2021/050 | BFT MSE Consultant's update on work since July meeting | Carruthers T. R. |
| SCRS/P/2021/051 | Updated CMP results | Carruthers T. R. |
| SCRS/P/2021/052 | Status update for the M3 & ABTMSE R Package code review | Aalto E. |
| SCRS/P/2021/054 | Proposal to develop a dedicated stochastic OM for use in CMP development tuning | Carruthers T. R. |

**Appendix 4**

**SCRS Document and Presentations Abstracts as provided by the authors**

*SCRS/2021/136* Atlantic bluefin tuna spawning behaviour has been studied extensively in the wild for many years in the daytime, but more recent studies supposed that the bluefin tuna spawning happens only in night times, but in cages. Spawning in daytime was again noticed in 2020 in two tuna traps in Sardinia, with direct observations and this additional information further improves those on biology and behaviour. Furthermore, in 2020 there was the evidence that several tunas going to the Sardinian traps were possibly some of those escaped from a farm in Spain, between 20th and 21st January 2020. This fact further confirms the course of bluefin tunas before the spawning period in this part of the western Mediterranean Sea. Several tunas showed also natural marks possibly due to the cookie-cutter shark, a species of shark which is not present in the Mediterranean Sea, but has a southern and central Atlantic distribution, a sign of long-distance migration. The 2021 harvested production of the traditional tuna trap in Isola Piana (Carloforte) was again certificated by Ecocrest

*SCRS/2021/137* A calibration exercise was carried out with the objective of ensuring that age readings provided by the Fish Ageing Services laboratory (FAS) follow the ICCAT reviewed reading protocol. There were found differences in band counts between ICCAT expert readers and FAS readings. These differences start from specimens with more than 10 bands and are more pronounced for older specimens. The results of the present calibration are very similar to those of the previous one. These differences in readings appear to be due to the fact that FAS uses the entire section of the otolith to count annual bands, whereas ICCAT readers focus on the inner part of the ventral arm. Analyses conducted to establish which reading is more appropriate, growth function estimation and cohort follow-up analysis, seem to indicate that ICCAT readers are more accurate than FAS readers. We suggest applying a correction vector to otoliths read by FAS and with more than 10 annual bands, in order to incorporate the FAS readings into the GBYP age database. This ageing bias vector has been obtained from the current and previous calibrations.

*SCRS/2021/138* The ICCAT GBYP Phase 10 has been implemented between 1 January 2020 and 31 July 2021. Phase 11 was initiated on 1 January 2021, with planned duration of one year, therefore temporarily overlapping with Phase 10. As in previous years, GBYP program has promoted and funded several activities in the following lines: (a) data mining, recovery and management, (b) biological studies, (c) stock indices: aerial survey on spawning aggregations, (d) tagging, including awareness and rewarding campaign and (e) further steps of the modelling approaches. The present report summarizes the final results of the activities carried out in Phase 10 and describes the activities initiated in Phase 11, and their preliminary results, if available.

*SCRS/2021/142* This study updated the CPUE series of the Balfegó joint fishing fleet (CPUE) and catch structure. The trend of CPUE experimented important increases from 2011 that peaked in 2014 and relaxed in 2015; since then, it has remained at high values. The CPUE is contrasted with the Japanese longline indices and both showing a similar time pattern. These results are indicative that the catch rates of Purse seiners in Balearic waters are consistent with JP LL trends in the NE Atlantic and reliable as an abundance index of the eastern population and should be used to overcome the lack of fisheries indices in the Mediterranean. This document also includes a description of the operational protocol implemented by this fleet in 2021 to minimise technical, labour and biological risks.

*SCRS/2021/144* In April 2018 a pilot broodstock cage (30 m in diameter and 20 m deep) containing 48 adult Atlantic bluefin tuna (ABFT) was established 6 km off the coast of Malta from fish caught under ICCAT licence in Tunisian waters in July 2017. At transfer from towing cage to grow out cage stereo camera determinations of length were made and biomass calculated. These data were later used during transfer from the growout cage to the broodstock cage to determine initial biomass. Feeding was carried out three times a week with mainly MSC certified baitfish and during the spawning season supplemented with squid for three months. Divers monitored water temperature at feeding and cage temperature at top and bottom were automatically monitored throughout the whole of the feeding period which lasted from April 1st, 2018 until 4th October 2020 (30 months). At the end of the experimental period all the remaining fish (43) were harvested and Standard Fork Length (SFL), Round Weight (RWT) and biological samples were taken from each fish. It is evident that on comparison of length weight relationships for transferred wild fish and the broodstock held in a cage facility, that a much greater increase in weight for a given length in captive fish is shown. Calculations of the growth rates in the facility over a 30 months period averaged 7.1% of the RWT per month. This led to an average increase in weight per fish of 213% over 30 months. From the known amount of feed and the end biomass of the fish on harvesting, a food conversion ratio (FCR) of 13,4 could be calculated.

*SCRS/2021/145* As part of the studies carried out by GBYP in response to the Commission's Recommendation 18-02, paragraph 28, concerning BFT growth in farms, Modal Progression Analyses (MPA) were carried out on the length distributions of farmed BFT obtained from bi-tri monthly stereo-camera footages and direct measures taken at harvesting. This has been carried out using data from growth trials performed in most of the areas where tuna farming takes place (Western Med, Adriatic Sea, Central Med and Levantine Sea). The objective was to determine the seasonal growth rates by modal groups. Results have shown that growth rates of farmed fish, not only in weight but also in length, are higher than in wild fish, both in juveniles and adult fish, and that most of growth occurs during the warm season, from early Summer to mid-Autumn.

*SCRS/2021/146* A review of the size-weigh data of eastern bluefin tuna caught by Portuguese trap/farm and comparison with current length weight relationships is presented. The data analysis shows that the use of the Deguara et al. (2017) equation used in the stereoscopical-camera system and the adopted SCRS equation (Rodrigues-Marin, 2016) to significantly overestimates the weight of the caged tuna, which present a low condition factor during the most important tuna trap fishing season (June to August) off the Algarve (southern Portugal). Therefore, this study suggests that for this location the use of a new regional equation is more appropriate, as the current equation used for the estimation of the weight of fish at caging significantly overestimate the real weight of the fish.

*SCRS/2021/147* Fattening of bluefin has become one of the main operations and destination of the catches of eastern bluefin in the Mediterranean Sea. Since 2008 a regional observer program (ROP-BFT) collects size and weight measures of harvested bluefin. Data from 2015-2020 harvest operations were reviewed to estimate the weight gain of eastern bluefin in farming operations. It was also estimated the potential growth associated with farming as function of days-at-farm, size at catch, and farm. Preliminary results from in situ tagging experiments and from size-mode progression analysis data from stereoscopic camera experiments indicated an increase in length growth of the farmed with respect to the wild ones for medium and large E-BFT fish. A preliminary analysis and results estimating a farm-growth model equation are presented. This study addressed part of the 2018 ICCAT Commission request on the maximum expected growth of farmed E-BFT.

*SCRS/2021/150* The Commission has requested the SCRS to update the farmed Atlantic bluefin tuna growth table published in 2009. In this request, the use of individual fish to determine growth was emphasized as well as the consideration of differences between geographical areas. The GBYP launched a series of studies in 2019, which continued during 2020 and 2021, and a sub-group on growth of BFT in farms was established in 2020 within the BFT Species Group to ensure the best scientific data would be provided to the Commission. The sub-group discussed how to carry out this request using different approaches and assessing their limitations. To facilitate this process, the analyses required were split into a number of study tasks. This document summarises the outcome of the analysis carried out so far and presents two preliminary Tables with updated % growth in cages as a function of starting size and duration between caging. These two Tables differ in the assumption of growth in size during the farming period relative to wild fish.

*SCRS/2021/151* resented their paper on the effects of phase-in periods on CMP conservation and yield performance. Phase-in periods for management procedure adoption may be politically more favourable, as they avoid sudden changes in catch limits that are often unacceptable to fishery stakeholders. Phase-in periods used a weighted average to smooth the transition from status-quo management over K = 1, 5,or 10 years, with weights linearly interpolated between 100% status quo in 2020 and 100% adopted CMP in year 2020 + K. Results show that slowly phasing in CMPs does not pose a large conservation or yield risk, in both deterministic and stochastic simulations.

*SCRS/2021/152* The BR CMP is refined slightly, with the principal change being the removal of caps on the TACs in the East and West areas for the first 10 years of operation. These restrictions are replaced by limitations on the extent of TAC increase allowed that depends on the recent trend in the composite abundance index for the area in question. Deterministic and stochastic results are provided for the most recent set of tunings specified by the Bluefin Tuna MSE Technical Group.

*SCRS/2021/154* Limit reference points are intended to mark the limit below which the stock biomass should not fall, and to avoid high fishing mortality that represents overfishing. Fishery management strategies should then ensure that the risk of exceeding limit reference points is very low. After having explored the different options existing in the literature and given the characteristics of the Atlantic Bluefin tuna population, a proposal of using 10% of the B0 as a proxy of $B_{lim}$ was made.

*SCRS/2021/155* We evaluated two candidate management procedures for Atlantic bluefin tuna using the ABT_MSE package in R. The first procedure applied a constant harvest rate strategy for both the east and west stocks. The second procedure evaluated the ability to achieve SSB of the West stock at or above current estimates (measured by stock-of-origin indices). Observations from indices of abundance were assumed proportional to spawning biomass and juvenile abundance for each stock and area, respectively, with no observation error (observation model = Perfect_Obs). Each procedure was compared against zero-catch scenarios for comparison of trade-offs among strategies. The constant procedures were tuned to the median Br30=1 across five selected OMs that characterized the general clusters in the larger OM grid.

*SCRS/2021/156* Two candidate management procedures were tuned to median Br30 targets and then run stochastically. The OMs were explored for how the stochastic results differed compared to the deterministic results.

*SCRS/2021/157* The present work describes the results obtained with an autonomous monitoring system installed from 28th July 2020 to 23rd May 2021 in a fattening cage in Balfegó (West Mediterranean) containing 724 BFT. The system is able to provide thousands of accurate automatic measurements per day, so the evolution of tuna sizes can be studied in detail thanks to such a great amount of information. Regarding the tuna length and width, the results suggest that from July 2020 to May 2021 the growth in length is approximately between 6 and 26 cm (between 2% and 21%) and the growth in maximum width between 3.0 and 8.0 centimeters (between 9% and 17%), depending on the fish length. The acoustic system is also used to estimate the height of the fish to provide a more accurate biomass estimation. Different expressions deduced from slaughtered fish are proposed based on formulae relating weight and dimensions (length, width and height) of Bluefin tuna fattened in captivity. The results confirm that the availability of more than one dimension reduces error in the estimate.

*SCRS/2021/158* In this work omnidirectional fisheries sonar was used to estimate tuna biomass. Moreover, the first calibration of a Furuno FSV-25 sonar using net CDF files is presented. In general, good calibration results were obtained. Calibration results agreed with previous works using different sonars and data formats. A positive relationship between the sonar estimates and the catch was found. This fact implies that the proposed methodology for single school abundance estimation could help the skipper to reduce uncertainty when estimating the size of the targeted school and open new chances for the development of abundance indicators.

*SCRS/P/2021/049* The presentation provides a summary of the work undertaken by the modeling subgroup since its creation. After meeting in May 2021, teams were formed around specific platforms. Since then the VPA and SS3 teams made some substantial advances, with promising fits for SS3. Several aspects of the work are still ongoing for these platforms and other platforms will move on in 2022. A preliminary workplan in sight of the 2022 stock assessment was briefly discussed.

*SCRS/P/2021/050* This presentation provides the summary of the MSE Consultant's work since BFT MSE Technical meeting in 2021 July. MSE packages and Shiny app have been updated following the instructions by the Group.

*SCRS/P/2021/051* This presentation provides the updated CMP comparisons by the MSE Consultant. The current list of CMPs includes 8 types and 5 tunings (in total 32 CMPs). Impact of OM weighting, comparisons between deterministic and stochastic results, and some performance metrics were provided.

*SCRS/P/2021/052* Objectives 1 & 2 of the Atlantic bluefin MSE code review were completed, with initial line-by-line analysis finding no major implementation errors in the M3 code and the R support code. The Technical Specifications Document is mostly complete, with a few areas identified for further clarification. Objective 3, the review of the ABTMSE package, is ongoing, as is analysis of computational efficiency, and will be completed in time for the final report.

*SCRS/P/2021/054* Development tuning is required to allow CMPs to be compared while controlling for projected biomass which is a fundamental performance consideration and shares a prevailing trade-off with yields. However deterministic and stochastic results did not always correspond tightly with the tuning targets. The BFT MSE Consultant provides alternative method to solve this problem, because it is not feasible to tune CMPs to Br30 across all stochastic reference grid OMs due to computationally intensive.

**Appendix 5**

## Mathematical descriptions for CMPs

### Mathematical description for the BR CMPs (Butterworth and Rademeyer, SCRS/2021/152)

The CMP is empirical, based on inputs related to abundance indices which are first standardised for magnitude, then aggregated by way of a weighted average of all indices available for the East and the West areas, and finally smoothed over years to reduce observation error variability effects. TACs are then set based on the concept of taking a fixed proportion of the abundance present, as indicated by these aggregated and smoothed abundance indices. The details are set out 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 stable[1], and then taking a weighted average of the results for each index, where the weight is inversely proportional to the variance of the residuals used to generate future values of that index in the future modified to take into account the loss of information content as a result of autocorrelation. The mathematical details are as follows.

$J_y^{E/W}$ is an average index over *n* series (*n*=4 for the East area and *n*=6 for the West area)[2]:

$$J_y^{E/W} = \frac{\sum_i^n w_i \times I_y^{i*}}{\sum_i^n w_i} \qquad \text{(A1)}$$

where

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

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

$$I_y^{i*} = I_y^i \Big/ Average\ of\ historical\ I_y^i \qquad \text{(A2)}$$

$\sigma^i$ is computed as

$$\sigma^i = \frac{SD^i}{1-AC^i}$$

where $SD^i$ is the standard deviation of the residuals in log space and $AC^i$ is their autocorrelation, averaged over the OMs, as used for generating future pseudo-data. Table 1 lists these values for $\sigma^i$.

2017 is used for the "average of historical $I_y^i$".

The actual index used in the CMPs, $J_{av,y}^{E/W}$, is the average over the last three years for which data would be available at the time the MP would be applied, hence:

$$J_{av,y}^{E/W} = \frac{1}{3}\left(J_y^{E/W} + J_{y-1}^{E/W} + J_{y-2}^{E/W}\right) \qquad \text{(A3)}$$

where the $J_{av,y}^{E/W}$ applies either to the East or to the West area.

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[1] These years are for the Eastern indices: 2014-2017 for FR_AER_SUV2, 2012-2016 for MED_LAR_SUV, 2015-2018 for GBYP_AER_SUV_BAR, 2012-2018 for MOR_POR_TRAP and 2012-2019 for JPN_LL_NEAtl2; and for the Western indices: 2006-2017 for GOM_LAR_SURV, 2006-2018 for all US_RR and MEXUS_GOM_PLL indices, 2010-2019 for JPN_LL_West2 and 2006-2017 for CAN_SWNS.

[2] For the aerial surveys, there is no value for 2013, (French) and 2018 (Mediterranean). These years were omitted from this averaging where relevant. Note also that the GBYP aerial survey has not been included at this stage.

*CMP specifications*

The BR Fixed Proportion CMPs tested set the TAC every second year simply as a multiple of the $J_{av}$ value for the area at the time (see Figure 1), 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:

$$TAC_{E,y} = \begin{cases} \left(\frac{TAC_{E,2020}}{J_{E,2017}}\right) \cdot \alpha \cdot J^E_{av,y-2} & \text{for } J^E_{av,y} \geq T^E \\ \left(\frac{TAC_{E,2020}}{J_{E,2017}}\right) \cdot \alpha \cdot \frac{\left(J^E_{av,y-2}\right)^2}{T^E} & \text{for } J^E_{av,y} < T^E \end{cases}$$

(A4a)

For the West area:

$$TAC_{W,y} = \begin{cases} \left(\frac{TAC_{W,2020}}{J_{W,2017}}\right) \cdot \beta \cdot J^W_{av,y-2} & \text{for } J^W_{av,y} \geq T^W \\ \left(\frac{TAC_{W,2020}}{J_{W,2017}}\right) \cdot \beta \cdot \frac{\left(J^W_{av,y-2}\right)^2}{T^W} & \text{for } J^W_{av,y} < T^W \end{cases}$$

(A4b)

Note that in equation (A4a), setting $\alpha = 1$ will amount to keeping the TAC the same as for 2020 until the abundance indices change. If $\alpha$ or $\beta > 1$ harvesting will be more intensive than at present, and for $\alpha$ or $\beta < 1$ it will be less intensive.

Below $T$, the law is parabolic rather than linear at low abundance (i.e. below some threshold, so as to reduce the proportion taken by the fishery as abundance drops); this is to better enable resource recovery in the event of unintended depletion of the stock. For the results presented here, the choices $T^E = 1$ and $T^W = 1$ have been made.

<u>Constraints on the extent of TAC increase and decrease</u>

Maximum increase (note that this section has been changed from earlier versions):

For the West area, the maximum increase is fixed at 20%:
If $TAC_{i,y} \geq 1.2 * TAC_{i,y-1}$ then

$$TAC_{W,y} = 1.2 * TAC_{W,y-1} \qquad \text{(A5a)}$$

For the East area, unless otherwise specified, the maximum increase allowed from one TAC to the next is a function of the immediate past trend in the indices, $s^E_y$:

$$maxincr = \begin{cases} 0 & s^E_y \leq 0 \\ \text{linear btw 0 and 0.2} & 0 < s^E_y < 0.1 \\ 0.2 & 0.1 \leq s^E_y \end{cases} \qquad \text{(A5b)}$$

where
$s^E_y$ is a measure of the immediate past trend in the average index $J^E_y$ (equation A1), computed by linearly regressing $lnJ^E_y$ *vs* year *y'* for y'=y-6 to y'=y-2 to yield the regression slope $s^E_y$.

If $TAC_{E,y} \geq (1 + maxincr) * TAC_{i,y-1}$

then $TAC_{i,y} = (1 + maxincr) * TAC_{i,y-1}$ (A5c)

Maximum decrease:

If $TAC_{i,y} \leq 0.8 * TAC_{i,y-1}$

then $TAC_{i,y} = (1 - maxdecr) * TAC_{i,y-1}$ (A6)

where

$$maxdecr = \begin{cases} 0.2 & J^{i}_{av,y-2} \geq J_{i,2017} \\ \text{linear btw 0.2 and } D & 0.5J_{i,2017} < J^{i}_{av,y-2} < J_{i,2017} \\ D & J^{i}_{av,y-2} \leq 0.5J_{i,2017} \end{cases} \quad \text{(A7)}$$

where $D$= 0.3 in implementations.

Maximum TAC

A cap on the maximum allowable TAC is set. This can potentially improve performance, particularly in the event of a shift to a lower productivity regime. By ensuring that TACs have not risen so high that they cannot be reduced sufficiently rapidly following such an event to adjust for the lower resource productivity. In investigations to date, this has been found to be useful to implement for the East area, where TACs can otherwise rise to in excess of 70 kt.

Trend-based term in the West

The TAC in the West is further adjusted if a measure of immediate past trend in the indices is below a threshold value:

If $s^W_y \leq s^{threshold}$

$$TAC_{W,y} \rightarrow \left[1 + \gamma\left(s^W_y - s^{threshold}\right)\right]TAC_{W,y} \quad \text{(A8)}$$

where

$s^W_y$ is a measure of the immediate past trend in the average index $J_y$ (equation 1), and

$\gamma$ and $s^{threshold}$ are control parameter values.

This trend measure is computed by linearly regressing $lnJ_y$ *vs* year *y'* for y'=y-6 to y'=y-2 to yield the regression slope $s^W_y$.

**Mathematical description for the base case generic EA_x CMPs (Andonegi et al., SCRS/2021/032)**

## 1. Mathematical description of the base case generic EA_x CMPs

Both CMPs, $EA_{2n+1}$ and $EA_{2n}$ are empirical, based on inputs related to abundance indices which are first standardised for magnitude, then aggregated by way of a weighted average of all indices available for the East and the West areas. TACs are then set based on the concept of taking a fixed proportion of the abundance present, as indicated by these aggregated abundance indices. The details are set out below.

### *1.1. Data sets*

Same four indices have been selected for each stock in each of the two CMPs, aiming at best reflecting the dynamics of each of the stocks. For the East, the French Aerial Survey (FR_AER_SUV2), the Mediterranean Larval (MED_LAR_SUV), the Moroccan-Portuguese Trap (MOR_POR_TRAP) and the Japanese Longline (North East Atlantic - JPN_LL_NEAtl2) indices are used. For the West, the Gulf of Mexico Larval (GOM_LAR_SUV), the US Rod & Reel 66-114 (US_RR_66_114), the US Gulf of Mexico Pelagic Long Line (US_GOM_PLL2) and the Japanese Longline (West - JPN_LL_West2) indices are selected. The standard deviation and the autocorrelation values estimated for each of these indices have been published in the report of the MSE Technical Group meeting hold in February 2020 (ICCAT, 2020) and can be found in Table 1.

### *1.2. Status Estimator: the aggregated abundance index*

*1.2.1. The $EA_{2n+1}$ CMP*

An aggregate abundance index is developed for each of the East and the West areas by first standardising each index available for that area by the average value of the last 4 years of historical observations and then taking a weighted mean of the results for each index (see Equation 2). Then the weighted mean of all indices was used to calculate the status estimator *Irat*. The weight of each of the indices is inversely proportional to the variance of the residuals. Future values of the indices are generated considering both the variance and autocorrelation (see Equations 3 & 4).

In the *$EA_{2n+1}$ CMP, the aggregated abundance index is then calculated as follows:*

$$Irat_y = \frac{\sum_i^n w_i * I_{i,y}^*}{\sum_i^n w} \quad (1)$$

where

$$I_{i,y}^* = \frac{I_{i,y}}{\sum_{y=1}^{i} I_{i,y}} \quad (2)$$

and

$$w = \frac{1}{\sigma_i^2} \quad (3)$$

being

$$\sigma_i = \frac{SD_i}{(1 - AC_i)} \quad (4)$$

The actual index used in the *$EA_{2n+1}$ CMP*, $Irat_{av,y}$, for both the East and the West area, is the average over the last three years for which data would be available at the time the MP would be applied:

$$Irat_{av,y} = \frac{1}{3}(Irat_y + Irat_{y-1} + Irat_{y-2}) \quad (5)$$

*1.2.2. The $EA_{2n}$ CMP*

The difference with the previous CMP is that the status estimator is now calculated as the weighted median of the aggregated index, which is previously standardized in the same way that the $EA_{2n+1}$ one. SO, the mathematical description of this CMP is similar to the previous one, but replacing the weighted mean (Equation 1) by a weighted median.

### *1.3. The Harvest Control Rule (HRC)*

The EAx CMPs tested set the TAC every second year simply as a multiple of the *Iratav* value for the area at the time, but subject to a maximum TAC change of 20% (up or down) for each area. The TAC is then defined as follows:

$$TAC_{y+1} = \begin{cases} TAC_y * \propto Irat_n & if \;\; 0.8 < Irat_n < 1.2 \\ 0.8 * TAC_y & if \;\; Irat_n \leq 0.8 \\ 1.2 * TAC_y & if \;\; Irat_n \geq 1.2 \end{cases} \tag{6}$$

where

$$Irat_n = \gamma * Irat + (1-\gamma) \tag{7}$$

and

$$\propto = 1/Itar \tag{8}$$

**Table 1.** Indices used to estimate the aggregated index for each ABF area, together with the σ and w values obtained from equations 3 and 4, using the information published in the ICCAT BFT MSE Technical Group meeting report (ICCAT, 2020).

| | Sigma (σ) | Weight (w) |
|---|---|---|
| EAST | | |
| FR_AER_SUV2 | 1.00 | 1.00 |
| MED_LAR_SUR | 0.56 | 3.189 |
| MOR_POR_TRAP | 0.56 | 3.189 |
| JPN_LL_NEAtl2 | 0.45 | 4.939 |
| WEST | | |
| GOM_LAR_SUR | 0.58 | 2.977 |
| US_RR_66-114 | 1.47 | 0.463 |
| US_GOM_PLL2 | 0.98 | 1.041 |
| JPN_LL_West2 | 0.62 | 2.601 |

**Mathematical description for TN_x (Tsukahara and Nakatsuka, SCRS/2021/041)**

**Used index:**
(West TAC) GOM_LAV, US_RR_66_114 and JPN_LL_West2
(East TAC) GOM_LAV and JPN_LL_NEAtl2

Index ratio for GOM_LAV, JPN_LL_West2 and JPN_LL_NEAtl2 are calculated by bellow:

$$Index\ ratio = \frac{mean(Index[y-2:y-6])}{mean(Index[y-5:y-9])} \tag{1}$$

**<u>West TAC</u>**

If index ratio of GOM_LAV is less than 0.8, then

$$new\ TAC = current\ TAC * \min(0.8, Ratio\ of\ JPN\_LL\_West2)$$

Else if any USRR_66_114 values in recent 5 years are less than historical third values, then

$$new\ TAC = current\ TAC * \min(0.9, Ratio\ of\ JPN\_LL\_West2)$$

Else new ratio of TAC is calculated with tuning parameter, k_west, as bellow

$$(Ratio\ of\ TAC\ change) = \begin{cases} \max(0.5, Ratio\ of\ JPN\_LL\_West2\ * k_{west}^{-1} - (0.95 * k_{west}^{-1} - 0.95)) & if\ Ratio\ of\ JPN\_LL\_West2 \leq 0.95 \\ \min(1.5, Ratio\ of\ JPN\_LL\_West2\ * k_{west} - (1.05 * k_{west} - 1.05)) & if\ Ratio\ of\ JPN\_LL\_West2 \geq 1.05 \end{cases}$$

$$new\ TAC = current\ TAC * Ratio\ of\ TAC\ change$$

Finally, the minimum TAC from this CMP is 1kt for west area, then

$$new\ TAC = \max(new\ TAC, 1kt)$$

**<u>East TAC</u>**

If index ratio of GOM_LAV is less than 0.6, then

$$new\ TAC = current\ TAC * \min(0.8, Ratio\ of\ JPN\_LL\_West2)$$

Else new ratio of TAC is calculated with tuning parameter, k_east, to be within 50% changes, as bellow

$$(Ratio\ of\ TAC\ change) = \begin{cases} \max(0.5, Ratio\ of\ JPN\_LL\_NEAtl2\ * k_{east}^{-1} - (0.95 * k_{east}^{-1} - 0.95)) & if\ Ratio\ of\ JPN\_LL\_NEAtl2 \leq 0.95 \\ \min(1.5, Ratio\ of\ JPN\_LL\_NEAtl2\ * k_{east} - (1.05 * k_{east} - 1.05)) & if\ Ratio\ of\ JPN\_LL\_NEAtl2 \geq 1.05 \end{cases}$$

$$new\ TAC = current\ TAC * Ratio\ of\ TAC\ change$$

Finally, the minimum TAC from this CMP is 10kt for east area, then

$$new\ TAC = \max(new\ TAC, 10kt)$$

**Mathematical description for Lauretta-Peterson- Walter CMPs (SCRS/2020/155)**

PW is an update of the original LW CMP (renamed to distinguish between subsequent versions of LW CMP).

Our procedure is based on constant harvest rate (ConstU) strategies for both the east and west stocks. In the MSE, the indices of abundance are assumed to be proportional to vulnerable biomass, i.e. the base parameterization assumes time-invariant catchability. Therefore, a relative harvest rate for each stock can be calculated as follows:

$$harvest\ rate = catch/abundance$$

$$relative\ abundance = catchability * abundance$$

$$relative\ harvest\ rate = \frac{catch}{relative\ abundance}$$

Under this approach, management procedures for east and west stocks were designed to apply a constant harvest rate strategy tracking catches and comparing to stock-of-origin indices of spawning biomass. For the West stock, the MexUS_GOM_PLL index is used, and for the East stock, the JPN_LL_NEAtl2 index is used.

$$U_{target} = \frac{\overline{C_{t52:t50}}}{\overline{I_{t52:t50}}} \cdot x$$

*where*
*U=relative harvest rate*
*C=catch in mt*
*I=relative abundance index*
*t=model year, and*
*x=constant multiplier*

$$U_{current} = \frac{\overline{C_{t-2:t-0}}}{\overline{I_{t-2:t-0}}}$$

$$TAC_{t+1:t+3} = \frac{U_{current}}{U_{target}} \cdot TAC_{t-2:t-0}$$

*where*
*TAC=total allowable catch limit*

**Mathematical description for Hanke and Duprey CMPs (SCRS/2021/156)**

***An $F_{0.1}$ based cMP***

This cMP sets the TAC using an estimate of $F_{0.1}$ and the current abundance of the stock. The $F_{0.1}$ calculation depends on choosing 3 indicators from each management area that index the relative abundance of young, middle aged and older stock components. Prior to use, these indicators are subjected to a range normalization and the average value for the most recent 3 years is determined:

$$I'_{sm} = (I_{sm} - \min(I_{sm}))/(\max(I_{sm}) - \min(I_{sm}))$$

$$I'_{md} = (I_{md} - \min(I_{md}))/(\max(I_{md}) - \min(I_{md}))$$

$$I'_{lg} = \left(I_{lg} - \min\left(I_{lg}\right)\right)/(\max\left(I_{lg}\right) - \min\left(I_{lg}\right))$$

$$\overline{I'_{sm}} = \frac{1}{3}\sum\nolimits_{N-2}^{N} I'_{sm}$$

$$\overline{I'_{md}} = \frac{1}{3}\sum\nolimits_{N-2}^{N} I'_{md}$$

$$\overline{I'_{lg}} = \frac{1}{3}\sum\nolimits_{N-2}^{N} I'_{lg}$$

$$I_{tot} = \overline{I'_{sm}} + \overline{I'_{md}} + \overline{I'_{lg}}$$

$F_{0.1}$ is a calculation based on a yield-per-recruit analysis from *fishmethods* (Nelson, 2019) that follows the modified Thompson-Bell algorithm :

$$Z_a = M_i + PR_a * F_a$$

$$N_{a+1} = N_a * e^{-Z_a}$$

$$\overline{N}_a = (1 - e^{-Z_a}) * \frac{N_a}{Z_a}$$

$$\overline{N}_{a+} = \frac{N_{a+}}{Z_{a+}}$$

$$C_a = (N_a - N_{a+1}) * \frac{PR_a * F_a}{Z_a}$$

$$Y_a = \overline{W}_a C_a = PR_a * \overline{F}_a B_a$$

where the ages *a* for each management area are as defined in the 2015 VPA,

$Y_a$, $C_a$, $N_a$, $B_a$ = Yield, Catch, Numbers and Biomass at age respectively,

$W_a$ = Weight at age is from the 2015 VPA for the west and 2017 VPA for the east,

$F_a$ = Fishing mortality at age,

$M_a$ = Natural mortality at age scaled to the Lorenzen function (Walter et. al. 2018),

$Z_a$= Total mortality at age ($F_a$+$M_a$),

$PRe_{1:10}$ = the partial recruitment vector applied to fishing mortality (F) to obtain partial F-at-age is calculated from the east MP indicators,

$PRw_{1:16}$ = the partial recruitment vector applied to fishing mortality (F) to obtain partial F-at-age is calculated from the east MP indicators,

$q$ = an index and stock specific tuning parameter.

East values

$$a = \{1,2,3,4,5,6,7,8,9,10)\}$$

$$W_{1:10} = \{3.0, 10.0, 19.0, 35.0, 50.0, 69.0, 90.0, 113.0, 138.0, 205.0)\}$$

$$M_{1:10} = \{0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12\}$$

$$PRe_{1:10} = \left\{ \frac{\overline{I'_{sm}}}{I_{tot}}_{1:4} \; \frac{\overline{I'_{md}}}{I_{tot}}_{5:6} \; \frac{\overline{I'_{lg}}}{I_{tot}}_{7:10} \right\}$$

$$I_{sm,md,lg} = \{ FR\_AER\_SUV2, JPN\_LL\_NEAtl2, MED\_LAR\_SUV \}$$

$$I_{bm} = \{ MED\_LAR\_SUV \}$$

$$q = 1.875\text{E} - 7$$

West values

$$a = \{1,2,3,4,5,6,7,8,9,1011,12,13,14,15,16)\}$$

$$W_{1:16} = \{3.1,9.8,15.1,19.9,43.3,60.5,89.9,111.6,144.8,174,201.1,225.5,247.7,264,283.5,340\}$$

$$M_{1:16} = \{0.40, 0.33, 0.27, 0.23, 0.20, 0.18, 0.16, 0.14, 0.13, 0.12, 0.12, 0.11, 0.11, 0.11, 0.11, 0.11\}$$

$$PRw_{1:16} = \left\{ \frac{\overline{I'_{sm}}}{I_{tot}}_{1:4} \; \frac{\overline{I'_{md}}}{I_{tot}}_{5:6} \; \frac{\overline{I'_{lg}}}{I_{tot}}_{7:16} \right\}$$

$$I_{sm,md,lg} = \{ US\_RR\_66\_144, CAN\ SWNS, MEXUS\_GOM\_PLL \}$$

$$I_{bm} = \{ MEXUS\_GOM\_PLL \}$$

$$q = 2.136444\text{e} - 07$$

The $F_{0.1}$ estimate is based on yield-per-recruit calculation for F ranging from 0 to 10 in increments of 0.01. The last age in the $a$ vector is a plus group and the oldest age in the plus group is 35.

Eastern and Western area TAC

$$TAC_{N+1} = \begin{cases} F_{0.1} * \dfrac{I_{bm,N}}{q}, \; I_{tot} > 0 \\ 0.2 * \dfrac{I_{bm,N}}{q}, I_{tot} = 0 \end{cases}$$

Constraint on TAC increase (upper=1.26, lower=0.6)

$$TAC_{N+1} = TAC_N * \left( 0.6 + \frac{1}{1.5 + e^{-8*\left(\frac{TAC_{N+1} - TAC_N}{TAC_N}\right)}} \right)$$

## ***A simple indicator based cMP***

This cMP tracks the relative abundance of an indicator and sets a TAC based on the ratio of the most recent 3 years of index values relative to the 3 years prior to that.

Eastern management procedure index

$$I_{bm} = \{ MOR\_POR\_TRAP \}$$

Western management procedure index

$$I_{bm} = \{\, MEXUS\_GOM\_PLL \,\}$$

The basis for the TAC calculation is the $I_{ratio}$ estimate and depends on the most recent 6 years of index values:

$$I_{ratio} = \left(\frac{1}{3}\sum\nolimits_{N-2}^{N} I_{bm}\right) \Big/ \left(\frac{1}{3}\sum\nolimits_{N-5}^{N-3} I_{bm}\right)$$

Index-Catch difference

In order to avoid situations where the population is changing faster than the trend in catch, the difference between the scaled index and catch is used to make an adjustment that attempts to make the two more similar. See figure 1 for example.

$$Scale(x) = \frac{(x - \overline{x})}{sd(x)}$$

$$Diff = abs(Scale(I_{bm}) - Scale(C_{obs})\,)$$

where $C_{obs}$ is a vector of observed catches.

$$\Delta Diff = \frac{Diff_N}{Diff_{N-1}}$$

Western area TAC

$$TAC_{N+1} = \begin{cases} TAC_N, & I_{ratio} \geq 1 \ \wedge \ (\Delta Diff \leq 1 \ \vee \ \Delta Diff \geq 2) \\ 1.05 * TAC_N, & I_{ratio} \geq 1 \ \wedge \ (1 < \Delta Diff < 2) \\ I_{ratio} * 1.05 * TAC_N, & I_{ratio} < 1 \ \wedge \ (\Delta Diff \leq 1 \ \vee \ \Delta Diff \geq 2) \\ I_{ratio} * 0.9648 * TAC_N, & I_{ratio} < 1 \ \wedge \ (1 < \Delta Diff < 2) \end{cases}$$

Eastern area TAC

$$TAC_{N+1} = \begin{cases} TAC_N, & I_{ratio} \geq 1 \ \wedge \ (\Delta Diff \leq 1 \ \vee \ \Delta Diff \geq 2) \\ 1.05 * TAC_N, & I_{ratio} \geq 1 \ \wedge \ (1 < \Delta Diff < 2) \\ I_{ratio} * 1.072 * TAC_N, & I_{ratio} < 1 \ \wedge \ (\Delta Diff \leq 1 \ \vee \ \Delta Diff \geq 2) \\ I_{ratio} * 0.9648 * TAC_N, & I_{ratio} < 1 \ \wedge \ (1 < \Delta Diff < 2) \end{cases}$$

**Mathematical descriptions for TC: fixed harvest rate, index-based CMP accounting for stock mixing (SCRS/2021/165)**

*Data smoothing*

In order to reduce noise in both indices and catches, the MP uses a polynomial ('loess') smoothing function *S()*. Smoothed catches $\tilde{C}$ and smoothed are (A) and stock (S) indices $\tilde{I}$ are calculated from the raw observed catches C and indices I by area $a$ and index type $i$, using the same smoothing parameter ω:

$$\tilde{I}^A_{a,i} = S(I^A_{a,i}, \omega) \quad (1)$$
$$\tilde{I}^S_{a,i} = S\left(I^S_{a,i}, \omega\right) \quad (2)$$
$$\tilde{C}_a = S(C_a, \omega) \quad (3)$$

The function is parameterized such that the approximate number of smoothing parameters is a linear function of the length of the time series. The effect of the ratio of smoothing parameters to length of the time series $\omega$, is illustrated in Figure 1.

*Vulnerable biomass and fishing rate estimation*

A multi-stock, multi-area management procedure 'MPx', was designed to provide TAC advice in a given time period $t$ using Stock biomass indices ($I^S$) by stock $s$ and Catch Rate Indices ($I^A$) by area $a$, calibrated to current stock assessments of vulnerable biomass $B$ (estimates of catchability $q$ for stock and area indices) (Figure 2). In order to, for example, interpret West area biomass in terms of Eastern stock biomass, an estimate of stock mixing is required $\theta^{mix}_{s=East\_stock,a=West}$ that is the fraction of Eastern stock biomass that can be expected to be vulnerable to fishing in the West area. Where there are more than one spawning stock index ($n_{s,i} > 1$) or more than one area index ($n_{a,i} > 1$) overall biomass estimates were the mean of those from the multiple indices:

$$B^S_{a,t} = \frac{\sum_s \sum_i \tilde{I}^S_{s,i,t} q^S_{s,i} \theta^{mix}_{s,a}}{n_{s,i}} \quad (4)$$

$$B^A_{a,t} = \frac{\sum_s \sum_i \tilde{I}^A_{a,i,t} q^A_{a,i}}{\mathrm{n}_{a,\mathrm{i}}} \quad (5)$$

The $q$ parameters are calibrated to 2016 estimates spawning biomass (by stock) $\theta^S_s$, and vulnerable biomass (by area) $\theta^A_a$:

$$q^S_s = \frac{\theta^S_{s,2016}}{\tilde{I}^S_{s,2016}} \quad (6)$$

$$q^A_a = \frac{\theta^A_{a,2016}}{\tilde{I}^A_{a,2016}} \quad (7)$$

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

$$F^A_{a,t} = -\ln\left(1 - \frac{C_{a,t}}{B^A_{a,t}}\right) \quad (8)$$

$$F^S_{a,t} = -\ln\left(1 - \frac{C_{a,t}}{B^S_{a,t}}\right) \quad (9)$$

*Combining inference from SSB and CPUE indices*

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

$$\Delta_{a,t}^{B} = exp\left(\frac{1}{2}\left[ln\left(\frac{B_{a,t}^{S}}{\theta_{a}^{BMSY}}\right) + ln\left(\frac{B_{a,t}^{A}}{\theta_{a}^{BMSY}}\right)\right]\right) \tag{10}$$

The same approach was used to combined estimates of *F* relative to *FMSY*:

$$\Delta_{a,t}^{F} = \exp\left(\frac{1}{2}\left[ln\left(\frac{F_{a,t}^{S}}{\bar{\theta}_{a}^{FMSY}}\right) + ln\left(\frac{F_{a,t}^{A}}{\bar{\theta}_{a}^{FMSY}}\right)\right]\right) \tag{11}$$

*A harvest control rule for TAC adjustment based on estimates of B/BMSY and F/FMSY*

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

$$TAC_{a,t+1} = TAC_{a,t}\ \varphi_{a,t} \tag{12}$$

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

$$\tilde{\varphi}_{a,t} = \delta_{a,t}^{F}\ \delta_{a,t}^{B} \tag{13}$$

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

$$\delta_{a,t}^{F} = \alpha^{F}\ exp\left(\beta^{F}\ ln\left(1/\Delta_{a,t}^{F}\right)\right) \tag{14}$$

The adjustment according to biomass is exponentially related to the disparity between current biomass and BMSY. The term $|\Delta_{a,t}^{B} - 1|$ is the positive absolute difference (modulus). The magnitude of the adjustment for biomass is controlled by the parameter $\alpha^{B}$ while the (extent of the TAC change for biomass levels far from BMSY) is controlled by the exponent $\beta^{B}$. 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 (Figure 3). When $\alpha^{B}$ = 0 there is no biomass adjustment and $\delta_{a,t}^{B}$ is invariant to $\beta^{B}$.

$$\delta_{a,t}^{B} = \begin{cases} exp\left[\left(\alpha^{B}|\Delta_{a,t}^{B} - 1|\right)^{\beta^{B}}\right] & 1 < \Delta_{a,t}^{B} \\ exp\left[-\left(\alpha^{B}|\Delta_{a,t}^{B} - 1|\right)^{\beta^{B}}\right] & \Delta_{a,t}^{B} \leq 1 \end{cases} \tag{15}$$

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.

*TAC adjustment limits*

The maximum rate of TAC adjustment is determined by $\theta^{down}$ and $\theta^{up}$ and the minimum amount is controlled by $\theta^{min}$:

$$\hat{\varphi}_{a,t} = \begin{cases} \theta^{down} & \tilde{\varphi}_{a,t} < \theta^{down} \\ \tilde{\varphi}_{a,t} & \theta^{down} < \tilde{\varphi}_{a,t} < (1-\theta^{min}) \\ 1 & (1-\theta^{min}) < \tilde{\varphi}_{a,t} < (1+\theta^{min}) \\ \tilde{\varphi}_{a,t} & (1+\theta^{min}) < \tilde{\varphi}_{a,t} < \theta^{up} \\ \theta^{up} & \theta^{up} < \tilde{\varphi}_{a,t} \end{cases} \quad (16)$$

**Table 1**. The input data, parameters of the current default MPx managment procedure.

| Description | | Value |
|---|---|---|
| *Biomass calculation* | | |
| $\mathrm{I}^{S}_{East\_stock}$ | Spawning stock biomass index for eastern stock | MED_LAR_SUV (#2), GBYP_AER_SUV_BAR (#5) |
| $\mathrm{I}^{S}_{West\_stock}$ | Spawning stock biomass index for western stock | GOM_LAR_SUV (#4) |
| $\mathrm{I}^{A}_{East}$ | Vulnerable biomass catch rate index for eastern area | MOR_POR_TRAP (#6), JPN_LL_NEATL2 (#7) |
| $\mathrm{I}^{A}_{West}$ | Vulnerable biomass catch rate index for western area | US_RR_177 (#10), JPN_LL_West2 (#12) |
| $\theta^{BMSY}_{East}$ | Eastern area biomass at maximum sustainable yiel d | 800 kt |
| $\theta^{BMSY}_{West}$ | Western area biomass at maximum sustainable yield | 20 kt |
| $\theta^{FMSY}_{East}$ | Eastern area harvest rate at MSY | 0.06 |
| $\theta^{FMSY}_{West}$ | Western area fishing mortality rate at MSY | *tuned* (0.004 – 0.04) |
| $\theta^{S}_{East\_stock,recent}$ | Mean Vuln. biomass of eastern stock in 2013-2017 | 800 kt |
| $\theta^{S}_{West\_stock,recent}$ | Mean Vuln. biomass of western stock in 2013-2017 | 20 kt |
| $\theta^{A}_{East,recent}$ | Mean Vuln. biomass in eastern area in 2013-2017 | 730 kt |
| $\theta^{A}_{West,recent}$ | Mean Vuln. biomass in western area in 2013-2017 | 120 kt |
| $\theta^{mix}_{West,East}$ | Fraction of western stock in eastern area | 0.1 |
| $\theta^{mix}_{East,West}$ | Fraction of eastern stock in western area | 0.05 |
| *Harvest control rule* | | |
| $\alpha^{B}$ | The magnitude of the adjustment for biomass relative to BMSY | 0 (no biomass adjustment) |
| $\beta^{B}$ | Exponent parameter controlling extent of the adjustment for biomass relative to BMSY | NA (given $\alpha^{B}$ = 0) |
| $\alpha^{F}$ | Target fishing mortality rate (fraction of FMSY) at F/FMSY = 1 and B/BMSY =1 | 1 |
| $\beta^{F}$ | The magnitude of the adjustment for fishing rate relative to FMSY | 0.33 |
| *Data smoothers* | | |
| $\omega$ | The ratio of the No. polynomial smoothing parameters to the number of years of time series data. I.e. loess(dat, enp.target = $\omega \cdot n_t$) | 0.15 |

**Table 1. Continued.**

| Description | | Value |
|---|---|---|
| *TAC adjustment limits* | | |
| $\theta^{up}$ | The maximum fraction that TAC can increase | 0.25 |
| $\theta^{down}$ | The maximum fraction that TAC can decrease | 0.25 |
| $\theta^{min}$ | The minimum fractional change in TAC | 0.025 |
| $\theta_{East}^{TACmin}$ | Minimum TAC for the East area | 10 kt |
| $\theta_{West}^{TACmin}$ | Minimum TAC for the West area | 0.5 kt |
| $\theta_{East}^{TACmax}$ | Maximum TAC for the East area | 80 kt |
| $\theta_{West}^{TACmax}$ | Maximum TAC for the West area | 4.5 kt |
| $\theta_{West}^{TACmax\_near}$ | Near-term maximum TAC for the West area | 2 kt |
| $\theta_{West}^{n\_near}$ | Western near-term period | 25 years |
| *Index recalibration rule* | | |
| $\gamma^{n}$ | The length of the time series for detecting slope of indices | 6 |
| $\gamma^{East}$ | The magnitude of F reduction in the East area in relation to the slope in Eastern stock biomass index | 1 |
| $\gamma^{West}$ | The magnitude of F reduction in the West area in relation to the slope in Western stock biomass index | 2 |

**Mathematical descriptions for SP: fixed harvest rate Schaefer surplus production model accounting for stock mixing**

*Modelling approach*

CMPs were tested using the computationally efficient state-space surplus production (SP_SS) and delay-difference (DD_SS) TMB assessments included in the R package SAMtool (Huynh et al. 2021). Data simulated from the ABTMSE package were converted inside the CMP code, to the data format for the R package MSEtool (Hordyk et al. 2021). The SAMtool assessments were then used to provide TAC advice according to estimated biomass and a constant UMSY harvest control rule. The delay-difference model was not sufficiently numerically stable to converge in greater than 95% of simulations and was not considered further given time constraints.

The state-space surplus production assessment was configured as the standard Schaefer model (where the production function is symmetric and BMSY is half of carrying capacity *K*) and the model freely estimates intrinsic rate of increase *r*, and *K*. Process error was included as a log-normal error on annual biomass[3]. The surplus production model was generally numerically stable when specified with a process error CV of 10% and an index observation error CV of 30% (approximately 99% convergence rate in the projection years of all 48 deterministic reference grid OMs). In situations where the SP model did not converge, TAC advice remained unchanged.

*Stock-specific catch reconstruction and post-assessment upscaling.*

Historical catches by stock were reconstructed assuming that no western fish mix eastwards and that the fraction of catches in the West area that should be assigned to the western stock is in proportion to the fraction of western spawning stock biomass in the West area ($\Delta_y$).

In historical years (2019 and earlier) this fraction of SSB was calculated as the 25th percentile of the result across all reference grid OMs (Figure 1). In years after 2019, $\Delta_y$ was calculated from the stock-specific SSB indices in the Gulf of Mexico (GOM_LAR_SUV) and Mediterranean (MED_LAR_SUV). To estimate the fraction of western SSB in the west area, calibration factors δ were calculated from mean $\Delta$ and index values *I*, over the most recent *n* historical years:

$$\delta_{western\ stock} = \sum_{y=2019-n+1}^{2019} \Delta_y \Big/ \sum_{y=2019-n+1}^{2019} I_{GOM\_LAR\_SUV,y} \tag{1}$$

$$\delta_{eastern\ stock} = \sum_{y=2019-n+1}^{2019} (1-\Delta_y) \Big/ \sum_{y=2019-n+1}^{2019} I_{MED\_LAR\_SUV,y} \tag{2}$$

Then for any future year $\Delta_y$ was calculated by:

$$\Delta_y = \frac{\delta_{western\ stock} I_{GOM\_LAR\_SUV,y}}{\delta_{western\ stock} I_{GOM\_LAR\_SUV,y} + \delta_{eastern\ stock} I_{MED\_LAR\_SUV,y}} \tag{3}$$

This vector of $\Delta_y$ can be reasonably noisy in future years due to observation error in the indices. To counter this, a less temporally variable loess smoothed vector $\hat{\Delta}$ was calculated:

$$\hat{\Delta} = LOESS(\Delta) \tag{4}$$

Given a complete vector of $\hat{\Delta}_y$ values, the area-based catches can be divided into stock catches for assessment purposes:

$$C_{western\ stock,y} = \hat{\Delta}_y\, C_{West\ area,y} \tag{5}$$

$$C_{eastern\ stock,y} = C_{East\ area,y} + (1-\hat{\Delta}_y)\, C_{West\ area,y} \tag{6}$$

The stock-specific TAC is calculated as a constant harvest rate control rule:

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[3] For further details on the implementation of these data-rich CMPs go to www.openMSE.com

$$TAC_{stock,y+1} = r_{stock} B_{stock,y} / 2 \tag{7}$$

Where $r$ is the intrinsic rate of increase and $B$ is the biomass estimated by the state-space surplus production model.

After assessment, area-based TAC advice is reconstructed by:

$$TAC_{west\ area,y} = \theta_{West}\, TAC_{western\ stock,y} / \hat{\Delta}_y \tag{8}$$

$$TAC_{east\ area,y} = \theta_{East} \left( TAC_{eastern\ stock,y} - TAC_{west\ area,y} + TAC_{western\ stock,y} \right) \tag{9}$$

Where $\theta$ are area – specific tuning parameters that control the level of exploitation rate (hence the SP CMPs assume constant harvest rates). Tuning to 1.00 – 1.00 could not be achieved possibly due to TAC caps for both areas. For a list of CMP control parameters see Table 1.

**Table 1**. The input data, parameters of the current SP managment procedure. CMP parameters highlighted in yellow have been revised for the reconditioned operating models.

| **Description** | | **Value** |
|---|---|---|
| *TAC adjustment limits* | | |
| $\theta^{up}$ | The maximum fraction that TAC can increase | 0.25 |
| $\theta^{down}$ | The maximum fraction that TAC can decrease | 0.35 |
| $\theta^{min}$ | The minimum fractional change in TAC | 0.05 |
| $\theta_{East}^{TACmin}$ | Minimum TAC for the East area | 10 kt |
| $\theta_{West}^{TACmin}$ | Minimum TAC for the West area | 0.5 kt |
| $\theta_{East}^{TACmax}$ | Maximum TAC for the East area | 45 kt |
| $\theta_{West}^{TACmax}$ | Maximum TAC for the West area | 5 kt |
| $\theta_{West}^{TACmax\_near}$ | Near-term maximum TAC for the West area | 3 kt |
| $\theta_{West}^{n\_near}$ | Western near-term period | 4 years |
| $n$ | Number of years used in calculation of δ calibration factors | 5 years |
| *Data smoothers* | | |
| $\omega$ | The ratio of the No. polynomial smoothing parameters to the number of years of time series data. I.e.<br>loess(Δ, enp.target = $\omega \cdot n_y$) | 0.15 |
| *Assessment parameters* | | |
| $\gamma$ | *CV of lognormal process error (estimated annual biomass)* | 0.1 |
| $\sigma$ | *CV of lognormal observation error (indices)* | 0.3 |
| *Tuning parameters* | | |
| $\theta_{West}$ | Multiplier on West area TAC | 0.691 – 1.08 |
| $\theta_{East}$ | Multiplier on East area TAC | 0.358 – 0.838 |

**Mathematical descriptions for AI: fixed harvest rate CMP using estimates of area-based vulnerable biomass from an artificial neural network.**

Details of the neural network configuration are available in Table 1.

Simulated datasets were generated by projecting nine constant fishing mortality rate CMPs for all 96 stochastic reference set operating models. These nine CMPs comprised high, medium and low harvest rates in the West area crossed with high, medium and low harvest rates in the East area. These simulations created a range of simulated outcomes for both stocks. The stochastic operating models include 48 simulations each. Over 9 CMPs this leads to 41,472 simulated projections (96 x 48 x 9). In each of these projections a single projection year was sampled, and for this year eight types of data were recorded:

(1) current index level of all 13 indices subject after Loess smoothing (13 data points);
(2) the mean level of the index in the projection to date (13 data points);
(3) the slope in the index in the first 4 projection years (13 data points);
(4) the slope in the index in the first 6 projection years (13 data points);
(5) mean catches over the last three years in both ocean areas (2 data points);
(6) mean catches in both ocean areas to date (2 data points);
(7) the projection year;
(8) the total simulated biomass in each ocean area of fish age 3 or older (2 data points).

This results in 57 independent variables (input layer features) and 1 dependent variable (the output layer - area biomass of fish age 3+) for training two neural networks, one for predicting total biomass of 3+ fish in the East area and another for predicting total biomass of age 3+ fish in the West area. Only one projection year was sampled per simulation to ensure all data points originate from independent time series. Random seeds were generated to ensure that the projected simulated data and dynamics were not the same as those used in MSE testing.

The wider dataset of 41,472 'observations' was split into three component datasets, a training set, a validation set and a testing set. The training set was used to fit the neural network using the backpropagation algorithm. The validation set was used to monitor training and where possible adjust meta parameters of the fitting and network design to improve accuracy. The testing set remained completely independent of the process of fitting or the selection of training hyperparameters that controlled the network fitting process. The split of these data was approximately 75% training, 20% validation, 5% testing.

Prior to fitting, data were all normalized to have mean 0 and standard deviation 1. The parameters of this data normalization was saved in the neural network design to ensure it was preserved when predictions are made from the new datasets provided to a CMP. To focus estimation on smaller stock sizes where CMP performance is most critical, the highest 10% of simulated biomasses were removed from the fitting (include many optimistically high outliers) and fit was conducted by minimizing mean squared error on log area biomass.

It has been shown that two hidden layers are sufficient to characterize the structure of any non-linear problem, and that at least two are required to capture complex hierarchical interactions. It follows that a three-layer (two hidden layers) neural network was investigated allowing for deep learning. As is typically the case in the design of neural networks, the width (number of nodes) and depth (number of hidden layers) was decided by ad-hoc experimentation as it is specific to each problem. In both East and West neural networks, relatively high accuracy was achieved with two hidden layers comprising 24 in the first layer and 24 in the second (Figures 1 and 2). This leads to 2,017 parameters per neural network which are the weights among the layers (the coloured lines of Figure 1), in addition to the biases in the hidden and output layers (one for each of the nodes in the lower three layers of nodes in Figure 1) (2,017 = 57 x 24 + 24 x 24 + 24 x 1 + 24 + 24 + 1). In general, the validation loss rate (the mean squared error in log total biomass of age 3+ fish) stopped improving after 350 epochs (iterations of fitting) (see Figure 2 for mean absolute error plots).

The neural networks were used in fixed harvest rate CMPs. The TACs in each area were set by the 3+ biomass estimate from the corresponding neural network multiplied by a tuning parameter that is the fixed harvest rate in each area. CMPs AI1, AI2 and AI3 were tuned to an eastern stock Br30 (spawning stock biomass, SSB relative to dynamic SSB MSY after 30 projected years) of approximately 1.55 and western stock Br30 of 1.00, 1.25 and 1.50, respectively. Similarly to other CMPs, the TAC advice arising from the A.I.

CMPs were constrained by minimum (10kt East, 0.5kt West) and maximum (50kt East, 4kt West) levels in addition to maximum percentage increases (25%) and decreases (35%). If the new TAC is less than a 5% different from the previous TAC no change is implemented.

**Table 1. Neural network configuration**

| **Configuration** | **Used in this analysis** | **Alternatives** |
|---|---|---|
| **1. Software** | KERAS R package (Falbel et al. 2021) + Tensorflow (2021) + NVIDIA CUDA (NVIDIA 2021) | neuralnet R package (Fritsch *et al.* 2016)<br>nnet R package (Ripley 2016) (and many others) |
| **2. Network type** | Simple recurrent | Fully recurrent, Recursive, Multilayer perceptron, Convoluted, Bi-directional, Hierarchical, Stochastic, Long short-term memory, Sequence to sequence, Shallow, Echo state |
| **3. Training algorithm (optimizer)** | 'rmsprop' | 'adam', 'sgd', 'adamax', 'adadelta', 'adagrad' |
| **4. Cost function** | Mean squared error | Mean absolute error, mean squared, logarithmic error, mean absolute percentage error |
| **5. Intensiveness of training** | 500 epochs (sufficient for stabilization of cost function, Figure 2) | - |
| **6. Input data types** | • Current index level (13 indices, each loess smoothed)<br>• Index slope: first 4 yr. of projection<br>• Index slope first 6 yrs of projection<br>• Index<br>• Mean index level in projection<br>• Projection year number<br>• Mean catch levels in projection (both East and West area) | |
| **7. Output data** | East / West Area specific biomass (age 3+) | Stock biomass, stock biomass x exploitation rate |
| **8. Size of training / validation / testing data sets** | 31,519 / 7,880 / 2,074<br>(approx. 75% / 20% / 5%) | - |
| **9. Network design (number of neurons in consecutive layers demarked by ':') and Activation functions** | **Input layer**: 57 (data types)<br>**Hidden layers**: 24:24 (2,401 parameters)<br>**Output layer**: 1<br>**Activation functions:** rectified linear unit | Linear, sigmoid, hyperbolic, tangent |
| **10. Neural net performance evaluation** | **Validation**: cross-validation<br>**Estimation performance**: mean squared error / mean absolute error<br>**Management performance**: MSE testing with ABT-MSE package | |
| | | |

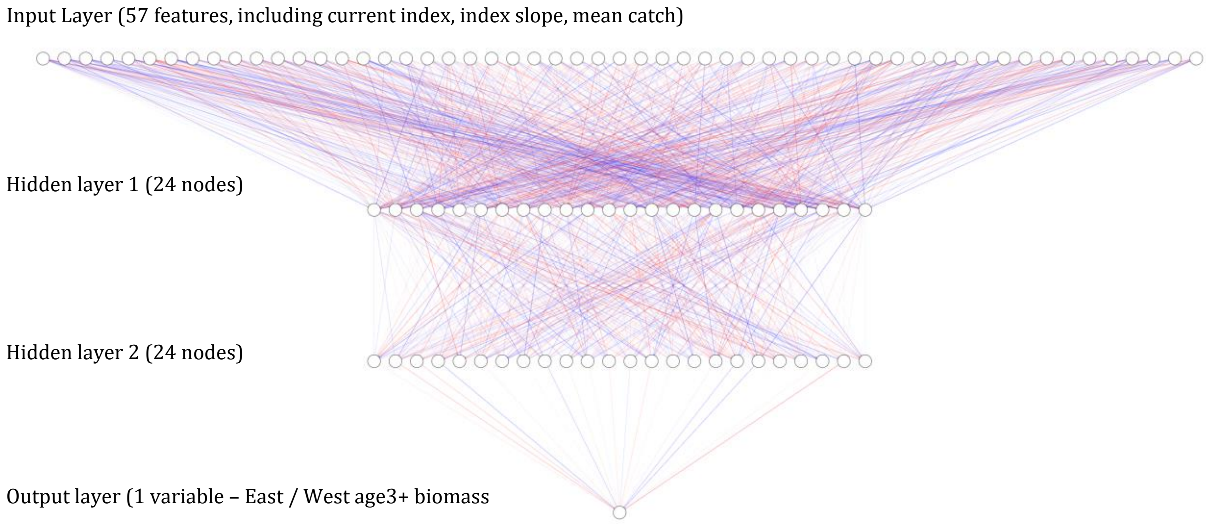


**Figure 1.** Neural network design. Lines represent estimated weights, circles represent nodes for which a bias is estimated per node for each hidden layer and the output layer.

**Appendix 6**

## Proposal to develop a dedicated stochastic OM for use in CMP development tuning

### Methods

Each stochastic OM of the reference set has multiple replicates. It is possible to sample one of these replicates for each OM. For example, replicate 4 for OM #1, replicate 1 for OM #2, replicate 7 for OM #3, and so on, creating a sample of replicate numbers: [4, 1, 7, …]. A total of 1000 of these samples was drawn (1000 ways in which the full grid stochastic OMs could be sampled).

For each of the samples, a weighted median Br30 was calculated for each CMP. These sample-derived Br30 values were then then compared with the overall stochastic Br30 to evaluate whether a given sample was indicative of Br30 overall and could therefore be used in CMP development tuning (Figure 1).

### Results

Of the 1000 sets of samples, just 7 provided an R-squared value greater than 0.95 for both stocks and achieved an estimated slope between 0.925 and 1.075 (Figure 2). Of these, sample 72 achieved slope values close to 1 and R-squared values greater than 0.975 for both stocks.

The correlation (or lack thereof) among Br30 calculated from individual stochastic OMs and the Br30 calculated from the entire reference grid of stochastic OMs are available in Figure 3 and 4. OM 7 appeared to work well for the western stock (linear relationship and approximately 1:1 through the tuning range of 1.00 to 1.50) (Figure 4). However, this was not the case for the eastern stock, and tuning to OM 7 Br30 would not translate to a Br30 tuning across the whole grid (Figure 3).

### Proposal

**Sample 72 should be used to develop a new, dedicated tuning OM that is included in the ABTMSE R package for the purpose of CMP development tuning.**

Consistent with the current approach, CMP developers calculate MSE results using the dedicated tuning OM, and then obtain weighted Br30 estimates using the Br30_Wt() function. CMP developers then adjust tuning parameters to obtain the desired eastern and western Br30 tuning targets. As before, for each of the tuned CMPs, developers then calculate MSE results for the full set of stochastic operating models, including the robustness set.

### Advantages of the approach

Tuning is undertaken using stochastic simulations that are representative of the full reference grid of OMs. Computation is approximately halved (just 48 simulations – one per reference grid OM) from the previous deterministic tuning procedure (48 operating models with two identical deterministic simulations per OM – 96 simulations total).

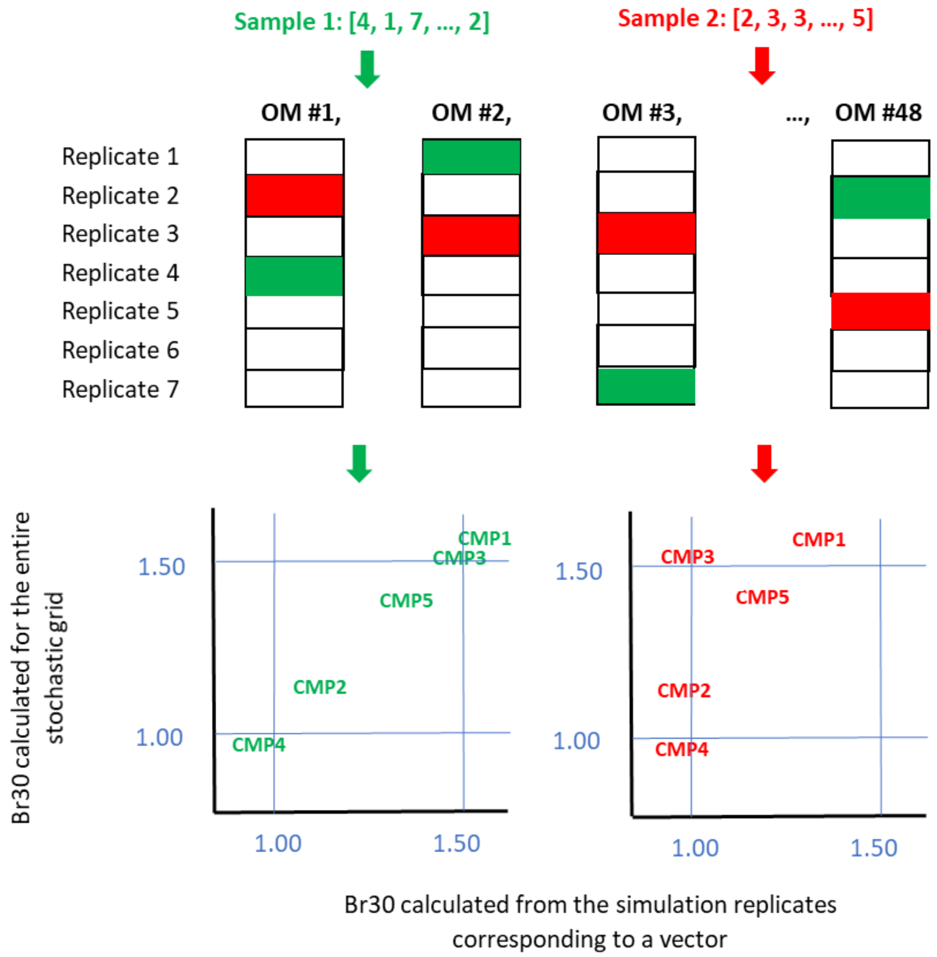


**Figure 1.** Illustration of the method used to find a sample of stochastic OM simulation replicates for use in CMP development tuning. For two samples of simulations (each sample comprising one replicate per stochastic grid OM), are used to calculate Br30 for all CMPs. These are then compared with the Br30 calculated from all reference set OMs. The simulations of Sample 1 produce Br30 scores that exhibit a close 1:1 relationship with overall Br30 for all stochastic OMs, suggesting that Sample 1 could be used as a computationally efficient way of tuning CMPs. In the case of Sample 2, CMPs could be tuned to 1.00 and still provide a wide range of outcomes in terms of overall Br30 for the entire stochastic reference set, making this sample unsuitable for CMP development tuning.

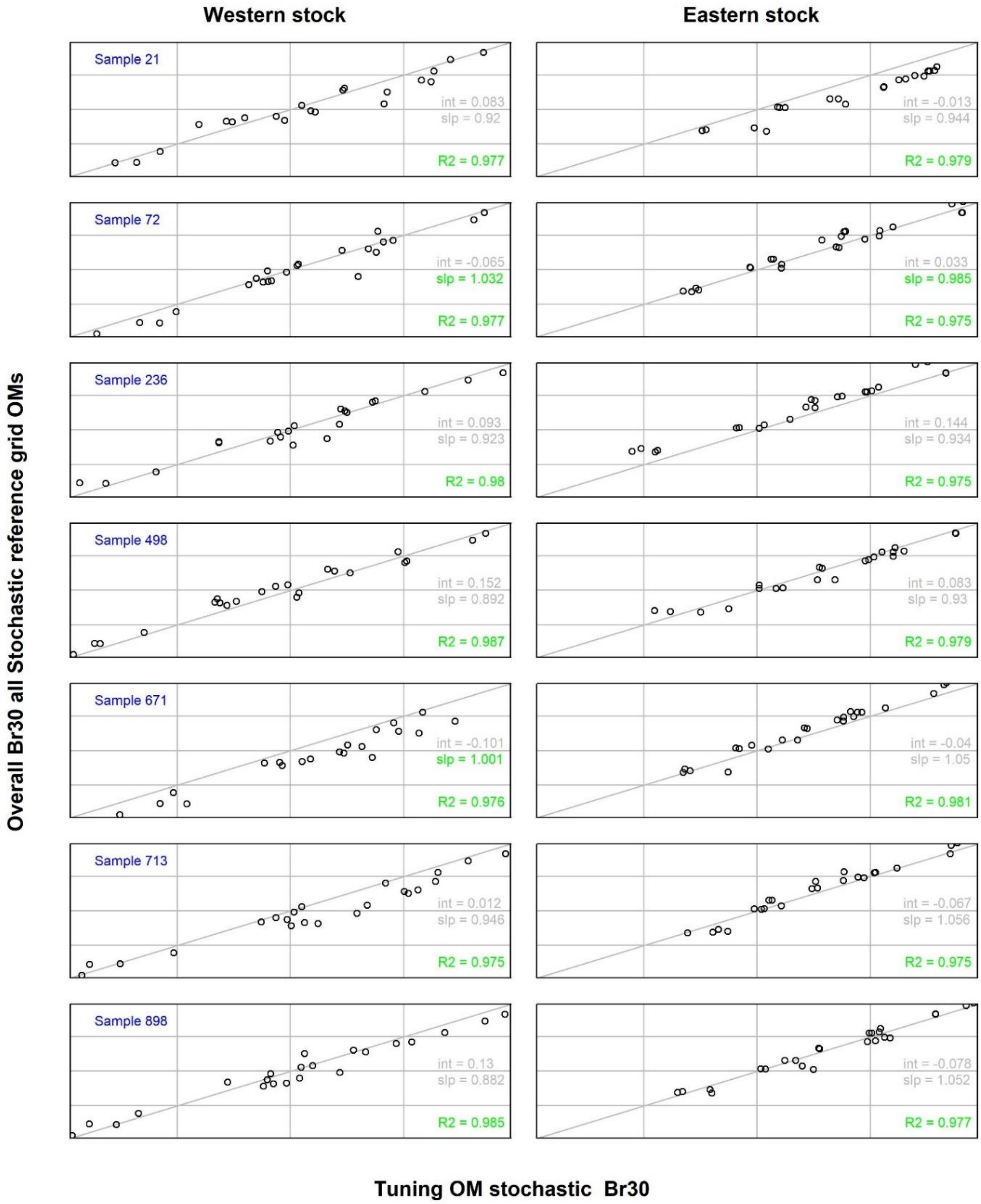


**Figure 2.** Correlation of Br30 derived from the simulation replicates corresponding to various vectors (horizontal-axis) and Br30 calculated across all stochastic grid OMs (vertical-axis, the same on all panels). Each row of panels corresponds to vector stochastic parameters (one per reference set OM). The plotted points correspond to the 32 tuned CMPs submitted to the September Intersessional meeting. R-squared statistics (R2) are shown in each panel and values above 0.95 are coloured green. Estimated linear intercept (int) and slope (slp) are also shown in each panel. Slope estimates which are between 0.95 and 1.05 are colored green. Vertical and horizontal grey lines are the 1.00, 1.25 and 1.50 development tunings. The results in this plot are for the 7 of the 1000 sampled vectors that could achieve an R-squared higher than 0.95 for both stocks, and a slope value between 0.925 and 1.075 for the eastern stock.

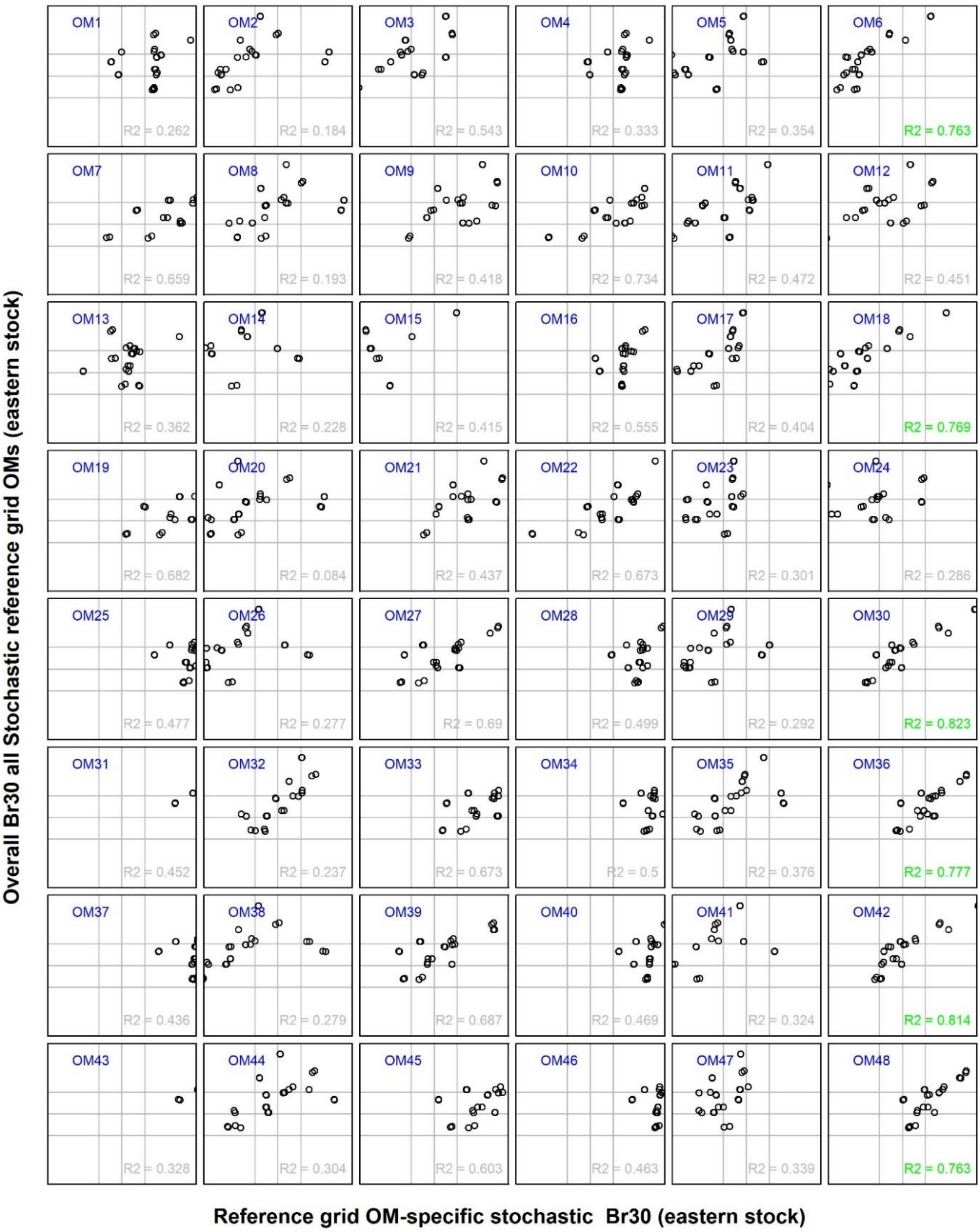


**Figure 3.** Correlation of **eastern** Br30 for each stochastic reference grid OM (horizontal-axis) and Br30 calculated across all stochastic reference grid OMs (vertical-axis, the same on all panels). The plotted points correspond to the 32 tuned CMPs submitted to the September Intersessional meeting. R-squared statistics are plotted in each panel and higher values are colored green. Vertical and horizontal grey lines are the 1.00, 1.25 and 1.50 development tunings.

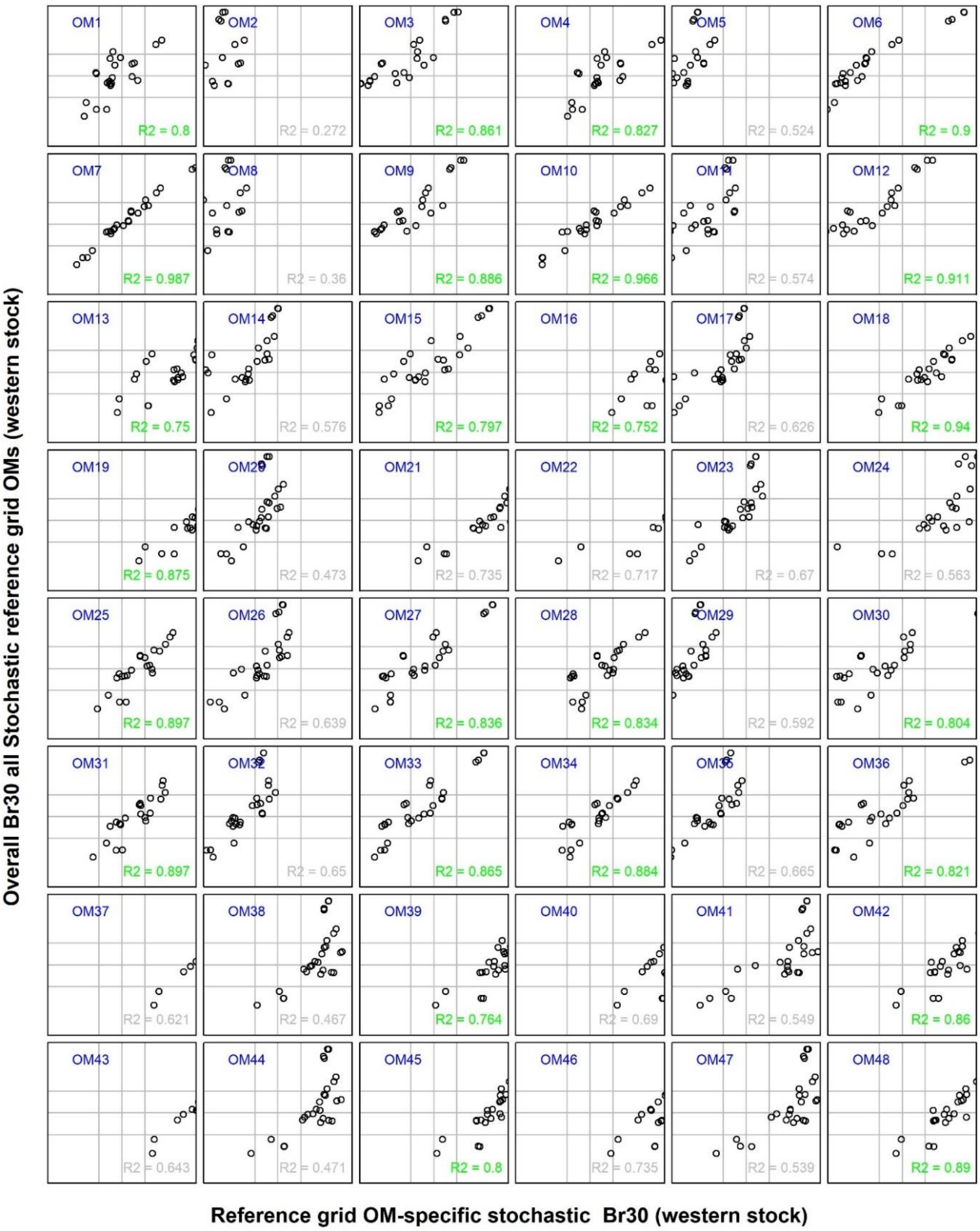


**Figure 4.** Correlation of **western** Br30 for each stochastic reference grid OM (horizontal-axis) and Br30 calculated across all stochastic reference grid OMs (vertical-axis, the same on all panels). The plotted points correspond to the 32 tuned CMPs submitted to the September Intersessional meeting. R-squared statistics are plotted in each panel and higher values are colored green. Vertical and horizontal grey lines are the 1.00, 1.25 and 1.50 development tunings.

**Appendix 7**

## An illustrative example of satisficing

### Introduction

At this preliminary stage, a relatively large number of performance metrics have been identified for comparing CMPs. Visualising performance is challenging for Atlantic bluefin tuna because these metrics are duplicated across stocks/areas.

Satisficing is an approach to CMP selection that simplifies performance evaluation by removing CMPs from consideration that do not meet particular performance requirements. This can be used to ensure that minimum performance standards are met for critical performance axes, and can simplify comparisons among a smaller set of remaining metrics for a reduced set of CMPs.

In this working paper a very simple satisficing procedure is described for **illustrative** purposes. The performance metrics, levels and probabilities are **demonstrative only**.

### Method

Six satisficing steps were developed that combine

- a metric (e.g. SSB relative to dynamic $SSB_{MSY}$ in projection year 30: Br30),
- a level of that metric (e.g. Br30 = 0.5) and
- an acceptable probability of exceeding that level (e.g. greater than 75%)

in the formulation of criteria for narrowing the list of CMPs for further consideration (Table 1).
The ABT MSE Shiny app was used (https://apps.bluematterscience.com/ABTMSE/) to conduct the satisficing.

**NOTE**: this illustrative example uses result for the AI CMPs that were updated during the meeting.

**Table 1**. An example of CMP satisficing using the ABT MSE Shiny app (https://apps.bluematterscience.com/ABTMSE/).

| | | |
|---|---|---|
| Base settings: | OM SET 1 > Select all reference OMs<br>Options > Select all<br>Options > Stochastic | |
| **Settings** | **Criteria** | **CMPs removed** |
| **Satisficing 1. Long-term biomass eastern stock** | | |
| P.Tab.2<br>Inter-quartile range = 50<br>Performance metric = Br30 eastern | Remove CMPs for which more than 25% of simulations drop below Br30 = 0.5 in the eastern stock | AI0, AI1, AI3, BR0, BR1, BR3, TC0 |
| **Satisficing 2. Long-term biomass western stock** | | |
| P.Tab.2<br>Inter-quartile range = 50<br>Performance metric = Br30 eastern | Remove CMPs for which more than 25% of simulations drop below Br30 = 0.5 in the wastern stock | AI0, AI1, AI2, AI3, BR0, BR1, BR2 |
| **Satisficing 3. Long-term catch East area** | | |
| P. Tab. 2.<br>Inter-quartile range = 50<br>Performance metric = C30 eastern | Remove CMPs for which more than 25% of simulations drop below C30 = 10kt in the East | AI0, AI1, AI3, BR0, BR1, BR2, BR3, BR4, TC0, TC1, TC2, TC3, TC4, NC1, NC2, NC3, NC4, PW1, PW2, PW3, PW4 |
| **Satisficing 4. Long-term catch West area** | | |
| P. Tab. 2<br>Inter-quartile range = 50<br>Performance metric = C30 eastern | Remove CMPs for which more than 25% of simulations drop below C30 = 1kt in the West | AI0, AI3, BR0, TC0, TC1, TC2, TC3, TC4, NC1, NC2, NC3, NC4, |
| **Satisficing 5. Average annual variability in yield East area** | | |
| P. Tab. 2<br>Performance metric = AAVC eastern | Remove CMPs for which median AAVC is greater than 25% for East | FZ1, FZ3, PW1, PW2, PW3, PW4, SP1, SP2, SP3, SP4 |
| **Satisficing 6. Average annual variability in yield West area** | | |
| P. Tab. 2<br>Performance metric = AAVC western | Remove CMPs for which median AAVC is greater than 25% for West | FZ2, SP1, SP2, SP3, SP4 |

**Table 2.** Satisficing criteria applied to the 32 CMPs submitted to the September Intersessional meeting. A CMP that passes a satisficing criterion is assigned a of value 1 (green) and a value of zero (red) if it does not pass. The Total column sums CMP pass/fail values across each row and is colored coded based on the value with green values indicating CMPs that passed a greater number of satisficing criteria. These results are for illustrative purposes only. Note that the AI results were updated during the meeting.

| | 1 | 2 | 3 | 4 | 5 | 6 | | |
|---|---|---|---|---|---|---|---|---|
| **CMP** | **Br30 E** | **Br30 W** | **C30 E** | **C30 W** | **AAVC E** | **AAVC W** | **Total** | **CMP** |
| **AI0** | 0 | 0 | 0 | 0 | 1 | 1 | 2 | **AI0** |
| **BR0** | 0 | 0 | 0 | 0 | 1 | 1 | 2 | **BR0** |
| **TC0** | 0 | 1 | 0 | 0 | 1 | 1 | 3 | **TC0** |
| **AI1** | 0 | 0 | 0 | 1 | 1 | 1 | 3 | **AI1** |
| **BR1** | 0 | 0 | 0 | 1 | 1 | 1 | 3 | **BR1** |
| **FZ1** | 1 | 1 | 1 | 1 | 0 | 1 | 5 | **FZ1** |
| **NC1** | 1 | 1 | 0 | 0 | 1 | 1 | 4 | **NC1** |
| **PW1** | 1 | 1 | 0 | 1 | 0 | 1 | 4 | **PW1** |
| **SP1** | 1 | 1 | 1 | 1 | 0 | 0 | 4 | **SP1** |
| **TC1** | 1 | 1 | 0 | 0 | 1 | 1 | 4 | **TC1** |
| **AI2** | 1 | 0 | 1 | 1 | 1 | 1 | 5 | **AI2** |
| **BR2** | 1 | 0 | 0 | 1 | 1 | 1 | 4 | **BR2** |
| **FZ2** | 1 | 1 | 1 | 1 | 1 | 0 | 5 | **FZ2** |
| **NC2** | 1 | 1 | 0 | 0 | 1 | 1 | 4 | **NC2** |
| **PW2** | 1 | 1 | 0 | 1 | 0 | 1 | 4 | **PW2** |
| **SP2** | 1 | 1 | 1 | 1 | 0 | 0 | 4 | **SP2** |
| **TC2** | 1 | 1 | 0 | 0 | 1 | 1 | 4 | **TC2** |
| **AI3** | 0 | 0 | 0 | 0 | 1 | 1 | 2 | **AI3** |
| **BR3** | 0 | 1 | 0 | 1 | 1 | 1 | 4 | **BR3** |
| **FZ3** | 1 | 1 | 1 | 0 | 0 | 1 | 4 | **FZ3** |
| **NC3** | 1 | 1 | 0 | 0 | 1 | 1 | 4 | **NC3** |
| **PW3** | 1 | 1 | 0 | 1 | 0 | 1 | 4 | **PW3** |
| **SP3** | 1 | 1 | 1 | 1 | 0 | 0 | 4 | **SP3** |
| **TC3** | 1 | 1 | 0 | 0 | 1 | 1 | 4 | **TC3** |
| **AI4** | 1 | 1 | 1 | 1 | 1 | 1 | 6 | **AI4** |
| **BR4** | 1 | 1 | 0 | 1 | 1 | 1 | 5 | **BR4** |
| **FZ4** | 1 | 1 | 1 | 1 | 1 | 1 | 6 | **FZ4** |
| **NC4** | 1 | 1 | 0 | 0 | 1 | 1 | 4 | **NC4** |
| **PW4** | 1 | 1 | 0 | 1 | 0 | 1 | 4 | **PW4** |
| **SP4** | 1 | 1 | 1 | 1 | 0 | 0 | 4 | **SP4** |
| **TC4** | 1 | 1 | 0 | 0 | 1 | 1 | 4 | **TC4** |

**Appendix 8**

**SPECIFICATIONS FOR MSE TRIALS FOR BLUEFIN TUNA IN THE NORTH ATLANTIC**
**Version 21-3: 9 September 2021**

Specifications for the MSE trials are contained in a living document that is under constant modification. The most recent version of the document (Version 21-3: September 9, 2021) can be found here.

**Appendix 9**

## Draft of Detailed proposed workplan for remainder of 2021 and 2022

Note that this is a proposal from the BFT Group and represents their view of the necessary meetings and tasks for 2021 and 2022.

| ***Date*** | ***Milestone/meeting*** | ***Participants / Meeting type*** |
|---|---|---|
| 13-15 September 2021 | Panel 2 meeting (short presentation on MSE progress (SCRS Chair/West BFT Chair)) | Panel 2 |
| 20-25 September 2021 | Species Group meeting (1 day for BFT), focus solely on Executive Summary and responses to the Commission | SCRS/Secretariat |
| 27 September – 2 October 2021 | SCRS | SCRS/ Secretariat |
| October 2021 | Offer Informal "Ambassador" webinars | SCRS/Panel 2/Commission/others/ Secretariat |
| 12 November 2021 | Panel 2 MSE meeting. Dialogue with the Panel 2 on CMPs, operational management objectives and performance indicators. At this point the SCRS should have 2-3 CMPs and tangible performance statistics values to show tradeoffs. | Panel 2/Secretariat |
| Late 2021/ early 2022 | Different teams (VPA and SS) of the Technical Sub-group on Assessment models to meet; Sub-group on growth in farms | BFT Technical Sub-group on Assessment models (EBFT) |
| December 2021 | Webinar to integrate Panel 2 advice | BFT MSETG/ Secretariat |
| 1 Dec 2021- 1 Feb 2022 | CMP Developers incorporate Panel 2 advice | BFT MSETG/ Secretariat |
| February | Meeting to present advances on different platforms and take directions | BFT Technical Sub-group on Assessment models (EBFT) |
| February | Technical Sub-group on Abundance indices for helping reviewing the Moroccan and Spanish as well as the Moroccan and Portuguese trap indices, or other potential indices | BFT Technical Sub-group on Assessment models (EBFT) and Sub-group on Abundance indices. |
| March 2022 | Panel 2 meeting (second iteration of CMP refinement)<br>- recommend final operational management objectives and identify performance indicators<br>- develop guidance on range of appropriate management responses should exceptional circumstances be found to occur<br>- to further incorporate recommendations and further refine CMPs to meet operational management objectives<br>- begin guidance on a range of appropriate management responses should exceptional circumstances be found to occur. 1-day on MSE. | Panel 2/ Secretariat |
| April 2022 | BFTSG intersessional meeting (EBFT Data prep + MSE, possibly separate meetings). This meeting would incorporate an essential milestone to agree upon the top 2-3 CMPs for consideration. (__ days) | BFTSG/ Secretariat |
| May/June 2022 | Panel 2 meeting (third iteration of CMP refinement to incorporate further recommendations). This meeting could likely be remote and 1-day. | Panel 2/ Secretariat |
| July 2022 | Sub-group on growth in farms | BFTSG/ Secretariat |
| July/ September 2022 | BFTSG intersessional meeting (EBFT Assessment + MSE, possibly separate meetings) BFTSG completes MSE, incorporating feedback from Commission through Panel 2/ SWGSM ( __days) | BFTSG/ Secretariat |

| | | |
|---|---|---|
| September 2022 | Species Group meeting/SCRS (finalize CMPs) | SCRS/ Secretariat |
| October/ November 2022 | Panel 2 meeting, SCRS presents completed MSE to Panel 2, Panel 2 selects CMPs to present to the Commission. | Panel 2/ Secretariat |
| November 2022 | SCRS presents to the Commission CMPs, the Commission adopts an interim MP at the Annual Meeting, including a 2-year TAC | Commission |