REPORT OF THE 2022 ICCAT EASTERN ATLANTIC AND MEDITERRANEAN BLUEFIN TUNA STOCK ASSESSMENT MEETING

(Madrid, Spain, hybrid meeting, 4-9 July 2022)

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

The meeting was held at the ICCAT Secretariat in Madrid and online from 4 to 9 July 2022. Drs Enrique Rodríguez-Marín (EU-Spain) and John Walter (USA), the Rapporteurs for the eastern Atlantic and Mediterranean and western Atlantic bluefin tuna stocks (E-BFT and W-BFT), respectively, opened the meeting and served as Co-Chairs. The Executive Secretary and the SCRS Chair, Dr Gary Melvin (Canada), welcomed the participants. The Chairs proceeded to review the Agenda, which was adopted with some changes (**Appendix 1**).

The List of Participants is included in **Appendix 2**. The List of Documents and presentations presented at the meeting is attached as **Appendix 3**. The following served as rapporteurs:

Sections	*Rapporteur*
Items 1 and 11	A. Kimoto
Items 2.1 and 3.1	A. Gordoa, M. Ortiz, T. Rouyer
Items 2.2 and 3.2	M. Lauretta, P. Sampedro
Items 2.3 and 3.3	J.J. Maguire
Items 3.4 and 6	E. Rodriguez-Marin, J. Walter, A. Kimoto
Item 4	H. Arrizabalaga, E. Andonegi
Item 5	S. Miller, C. Peterson
Items 7 and 9	E. Rodriguez-Marin, J. Walter
Item 8	S. Tensek
Item 10	S. Deguara, M. Ortiz

2. Model diagnostics

2.1 VPA

SCRS/2022/101 presented the revised CAS of the inflated period (1998-2007) prepared by the small *ad-hoc* group following the recommendation of the Bluefin Tuna Species Group (BFTSG) at the BFT 2022 Data Preparatory meeting (Anon., 2022). Initially, in 2012 the NEI (not elsewhere included)-inflated catch was converted assuming the same size distribution as the purse seine fleet in the Mediterranean (PS-MED), but auxiliary information indicated that most of this unreported catch was preferentially medium and large size fish destined for international markets. Thus, the *ad-hoc* group recommended that the unreported catch NEI size distribution and their derivate estimates of catch-at-size (CAS) and catch-at-age (CAA) were estimated from all active fishing gears from 1998 - 2007, giving higher importance to gears with catches of medium and large fish. In the case of the purse seine fisheries, it was recommended to only use the size distribution of quarter 2. The revised CAS (ver2b) was considered a better estimate of the size distribution for the NEI-inflated catch (1998 – 2007) and adoption by the BFTSG was proposed.

In response to comments from the Group, it was clarified that the total catch in weight was not affected, but the catch in numbers was affected.

SCRS/2022/129 documented the 2022 assessment runs for East Atlantic bluefin tuna using virtual population analysis (VPA). The paper summarized the VPA data inputs, assumptions, provisional results, diagnostics and time series estimates of spawning stock biomass for the period 1968 to 2020, and recruitment for the period 1968 to 2019. The model incorporated revisions to key indices, particularly an index for small fish (western Mediterranean larval survey index: WMED_LARV). The author introduced a Shiny application that summarizes all VPA results in a graphical interface, which was made available to participants (https://bfttuna.shinyapps.io/shinyvpa/).

The Group welcomed this application and highlighted its utility for the meeting discussions. The list of VPA runs and model fitting statistics for each run are available in **Tables 1** and **2**, respectively.

The continuity run was based on the 2017 base case as this model could not be updated in 2020 and no other base case has been accepted since then. For the continuity run (Run 288), the F ratios (ratio of the fishing mortality rate on age 10+ to the fishing mortality rate on age 9) are estimated by 3 time blocks (1968-1980; 1981-1995; 1996-2007) and fixed to 1 for the last one (2008-2020). That run presented several issues, namely the strong retrospective patterns and instability of results, particularly in the estimates of absolute scale of biomass (**Figure 1**). The document presented several runs building on that run to explore different aspects, with the objective of improving the modelling that has been suggested during previous online meetings.

A first axis explored was the possibility of using 16+ as a plus group, which would make it possible to simplify the assumption made for the F-ratio as it could be easier to assume an F-ratio=1. The VPA is sensitive to that parameter with the age plus group 10+, so this was a primary source of potential improvement. The runs to explore using 16+ as a plus group (**Figure 2**, Runs 289 and 290) showed that assuming an F-ratio equal to one over the whole time period (1968-2020) was associated with a lack of fit to two key historical indices (Morocco_Spain Trap (MOR_SP_TP) and Japanese longline in the East Atlantic and Mediterranean (JPN_LL_EastAtl_MED) indices). The results from these runs showed several issues including very high estimated recruitment for recent years, continuous increase in spawning stock biomass (SSB) over the whole time period for runs assuming an F-ratio equal to one and a strong retrospective pattern. Using the Richards curve (**Table 2**, Runs 291 and 292) or additive variance for the indices (instead of multiplicative) (**Table 2**, Run 293), or fixing the selectivity for the WMED_LARV index (**Table 2**, Run 294) did not solve these problems. Runs using 16+ generally did not improve the diagnostics of the model.

The second axis focused on exploring the stability aspect of the continuity run (Run 288). A test on the effect of F-ratios to the overall scale of the VPA was requested by the Group during previous intersessional discussions. This test aimed to establish whether the scale of the VPA could be statistically resolved. This test consisted in fixing the F-ratio for the first year of the VPA at a given value and then estimating the different time blocks for the F-ratio. Results showed that a significant difference (i.e.,>2 units of objective function) could now be found across the tests (**Table 3**). This meant that F-ratios could not be estimated appropriately. Subsequent explorations therefore attempted to set the F-ratios to *a priori* values, looking at Mohn's rho statistics for retrospective bias to guide the exploration. Setting the F-ratio value to 1 for the F-ratio time blocks over 1968-1995 and slightly modifying the search settings (Run 295) improved the overall stability of the VPA (**Figure 3**). Then a change was made to the vulnerability constraint so that it would be applied to ages 5-9 instead of ages 1-9, the rationale being that ages 1-4 are not targeted by the biggest fleets (i.e., purse seiners, traps, longliners). This vulnerability constraint applied over 6 years plus a constraint on recruitment over 6 years produced a run with an improved retrospective pattern (Run 287, **Figure 3**).

Further runs to profile the F-ratio for both the 1968-1995 and the 2008-2020 time blocks showed that assuming an F-ratio of 0.75 for both was leading to the minimum objective function value (**Table 4**, Run 286: **Table 2** and **Figure 4**). Attempts at integrating the western Mediterranean GBYP aerial survey index (WMED_GBYP_AER) (Run 303) did not show a particularly good fit to this index (**Figure 5**) and no further test was carried out with this index. The Group then considered that the selectivity for the WMED_LARV index should be fixed and that the upper bound for terminal F estimates for ages 1-5 could be reduced to avoid solutions for which a terminal fishing mortality peaking at ages 4-6 was observed (Run 367). Further investigations showed that modifying the vulnerability and recruitment constraint strength back to the original values improved the objective function (Run 385, **Table 2**). Run 385 was found to converge correctly and did not display any problematic retrospective pattern.

Jittering the seed for the random number generator and the terminal F values showed consistent model fits, and bootstraps showed that the median of the bootstraps was close to the deterministic run (**Figure 6**). Removing one index at a time showed that the JPN_LL_NEAtlMed had an effect on the overall scale of the VPA, whereas removing other fleets had a reduced impact on the overall trend (**Figure 7**).
Several sensitivity runs were performed. Estimating the F-ratio for the time block 1996-2007 produced a solution with a slightly more negative objective function, but which showed a strong retrospective pattern (Run 386, **Figure 7**). A bidimensional profiling of the F-ratios for the first (1968-1995) and the second (2008-2020) time blocks for which the F-ratio is fixed showed that all but one of the runs had a difference in objective function that was larger than 2 (**Table 5**). That run (0 in the **Table 5**, Run 418) was very similar to Run 386 in terms of F-ratios and exhibited a strong retrospective pattern (**Figure 8**). Run 385 was therefore chosen as a base case for VPA by the Group.

Relative to the 2017 E-BFT VPA (Anon., 2017), model results were influenced by the addition and revision of input data, in particular the revision of the assumptions of the size distribution for the "Inflated Catch" of the 1998 – 2007 period (SCRS/2022/101) and other changes reported and discussed during the 2022 Data Preparatory meeting (Anon., 2022).

2.2 Stock Synthesis

The BFTSG tried to apply Stock Synthesis to the E-BFT stock in 2017 (Sharma *et al*., 2017), and the objective of this meeting is to update this 2017 model for the 2022 E-BFT stock assessment. There are two major changes from the 2017 stock assessment regarding fleet structure and selectivity assumptions. Sampedro *et al.* (2022) presented the input data and initial model configuration of a preliminary run for the 2022 stock assessment using Stock Synthesis at the BFT 2022 Data Preparatory meeting (Anon., 2022).

The preliminary Stock Synthesis runs presented at the BFT 2022 Data Preparatory Meeting (Anon., 2022) demonstrated the inability to estimate growth (L_{INF} in particular) within the model due to the lack of size-at-age information for older ages. SCRS/P/2022/046 presented Stock Synthesis growth estimates for the West Atlantic model, which includes large numbers of East Atlantic origin, otolith-aged fish, resulting in L_{inf} = 272 and 273 cm from the 2020 and 2021 assessments, respectively. The northern Canada handline and Norway purse seine (PS) fleets appear to catch the largest bluefin tuna observed, with upper modes near 270 cm and L_{MAX} near 340 cm. Distributions of size-at-age and estimates of mean size of older age classes in the mixed-stock West area fisheries support the Richards growth function. Following the recommendations from this study, the Group agreed to fix L_{INF} =271 cm, to assume a Richards growth model, and to assume asymptotic selectivity for the Norway PS fleet from 1970 to 1981 in the E-BFT Stock Synthesis model.

The Group reviewed the proposed base case for the assessment of E-BFT using Stock Synthesis (SCRS/2022/128). The model runs from 1950 to 2020 and was fitted to length composition data, conditional age-at-length (otolith and spines–length-age pairs), 16 fishing fleets and 11 indices of abundance (**Table 6**). Growth is modelled by a Richards function with L_{INF} fixed at 271 cm, and the Richards shape parameter is estimated by the model. A Beverton-Holt stock recruitment relationship was estimated in the model with the steepness and sigmaR fixed at 0.9 and 0.6, respectively. R0 is freely estimated.

The Group investigated several runs (**Table 7**) to improve the model diagnostics and the base case model, — run 16 reweight — was agreed by following changes in the proposed base case in SCRS/2022/128:

- Scale M internally using Lorenzen's method (age 20, reference M=0.1).
- Initial fishing mortality for Fleets 13 (Spain/Morocco/Portugal trap before 2011), 15 (Other trap) and 16 (Others) are estimated by the model.
- The growth parameter K is estimated by the model.
- Fleet selectivity is improved by improving the initial definition of parameters and including several priors when necessary.
- Balance the model by reweighting the length compositions using Francis's method (Francis, 2011).

The Stock Synthesis base model, run 16 reweight, showed relatively good convergence (final gradient = 5.84607e-05), with a positive definite Hessian matrix. Included in those estimates were four growth model parameters, three initial F parameters, and 75 recruitment deviations; the remaining parameters were fleet length-based selectivity parameters. Parameter estimates, asymptotic standard errors, and assigned priors are provided in **Table 8**. Priors were assigned only to selectivity parameters that showed very large standard deviations after initial model fitting to improve the overall stability of the model.

A jitter analysis was conducted to evaluate whether the model converged to a global solution by applying a random deviation to starting values of 10%. Some jitter runs indicated a lower negative log-likelihood than the base model (**Figure10**), associated with an improved fit to conditional age-at-length data, but demonstrated an associated shift in selectivity of the other longline fleet. The Group observed that scale and trend in stock biomass and recruitment in run 16 reweight were similar to the jitter runs with lower likelihood (**Figure 11**). Therefore, the Group agreed to use this model as the Stock Synthesis base case model (run 16 reweight).

Plots of the observed versus fit data and residual plots were examined to evaluate model fit to the indices (**Figures 12** and **13**) and length composition data (**Figure 14**). Overall, the model demonstrated a relatively good fit to the indices of abundance. Runs tests were applied to the residual series of each index and length composition in order to quantitatively evaluate the randomness of the overall fit to the different time-series. There was no evidence ($p \geq 0.05$) to reject the hypothesis of randomly distributed residuals for all indices except for Moroccan and Spanish traps (S1), early Spanish bait boats (S3) and the GBYP-western Mediterranean aerial survey (S11). Only one data point fell outside the three-sigma limits for the indices (**Figure 15**). In contrast, there was a systematic lack of fit to several fleet mean length (**Figure 16**), some of which demonstrated evidence of shifting selectivity over time that could not be effectively resolved in the allotted time while maintaining model stability.

A likelihood profile was created on the estimated mean unfished equilibrium recruitment (R0, log-scale) across a range of values from 7.5 to 8.5 (**Figure 17**). The profile of R0 by data component showed a consistent minimum for the equilibrium catch that informed the overall best estimate. There was a less defined profile for the other data source with no clear minimum.

The retrospective analysis (**Figure 18**) indicated that spawning stock biomass and fishing mortality were consistently estimated, with Mohn's rho estimates of -0.15 and 0.03, respectively. However, there was a clear retrospective bias in estimates of recent recruitment. Specifically, recruitment estimates since 2011 showed a high level of uncertainty around the estimated value and varied notably with each year of data removed. This retrospective bias led to the recommendation to patch the estimates of recent recruitment since 2011 at R0 for any model projections.

2.3 Other models

ASAP

The Age Structured Assessment Program (ASAP) was applied to eastern Atlantic and Mediterranean Atlantic bluefin tuna for the 2022 stock assessment (SCRS/2022/125). ASAP is a statistical catch-at-age model that is fitted to time series of observed catch, age composition, and indices of abundance. Previous single-fleet applications of ASAP for the 2017 and 2020 Atlantic Bluefin tuna assessments were updated and revised, and alternative models with multiple fleets were explored.

Multi-fleet ASAP models were developed to fit catch data and estimate selectivity for each index fleet as well as the Mediterranean purse seine fleet. Multi-fleet-based runs were retrospectively consistent and fit the available data well, with some residual patterns.

The Group realized that the CAA for the multi-fleet approach needed to be revised but there was insufficient time to complete this task during the meeting. The input data will be further verified and, if needed, corrected after the meeting. The discussion below is about the single fleet implementation.

ASAP is in an intermediate class of models between the complexity of Stock Synthesis and the relative simplicity of VPA. Previous implementations of ASAP for E-BFT have not suffered from scale issues, but since recent VPA assessments there have been problems estimating scale, the three class of models considered in 2022 were closely examined for their ability to determine scale. For VPA, this was done by profiling on the initial F ratio and estimating the F ratio in three different periods. For ASAP, this was done by profiling on mean recruitment (**Figure 19**) and initial F and by assuming no deviations in recruitment (**Figure 20**). For ASAP, the exercise showed that the estimate of mean recruitment and initial F had a low CV (10%).

3. Assessment results

3.1 VPA

3.1.1 Model fits

The results from Run 385 (**Table 1,** control file in **Appendix 5**) showed a decrease in spawning stock biomass from the 1970s to the 1990s, remaining at low levels before displaying an increase from 2010

(**Figure 21**). Recruitment followed the opposite trend until 2010, when it also started to increase. After remaining at a high level, fishing mortality for ages 2-5 showed a drop in 2007. The level has remained low since then. Fishing mortality for the plus group increased to a high level in the 1990s before decreasing in the late 2000s. It has been increasing since then. The fit to the indices was found to be acceptable for most of them, but the model did not fit the WMED_LARV, the SP_BB2 and the JPN_LL_NEA2 well (**Figure 22**).

The current assessment has yielded more stable performance than the 2017 assessment (**Figure 23**). The current assessment shows improvement in the SSB and R retrospective analysis (**Figure 24**).

3.1.2 Stock status

The same criteria used since 2017 for the determination of stock status have been used in the 2022 assessment for every model, including VPA. This has been achieved by comparing $F_{CURRENT}$ (geometric mean of apical F over years 2017-2019) with the estimated $F_{0.1}$. For VPA, the $F_{0.1}$ estimate is slightly affected by the recruitment assumed for recent years. The Group agreed to use two different scenarios. The first one was similar to 2017 to replace the four last years of recruitment (2017-2020) by the geometric average of recruitment over 2007-2016, and the second was to use the geometric mean over 1968-2016 (see section 6). For both these scenarios, $F_{CURRENT}$ was found to be above $F_{0.1}$, which indicated overfishing ($F_{CURRENT}/F_{0.1}$=1.16).

3.2 Stock synthesis

3.2.1 Model fits

The time series of spawning stock biomass (SSB), fishing mortality (biomass exploitation rate was used as a proxy), and recruitment (age 0) estimates for the base run (run 16 reweight, control file in **Appendix 6**) are plotted in **Figure 25.** SSB showed a sharp decline between 1950 and 1970 in response to an increase in harvest, and SSB remained at a lower and relatively stable level until 2010. The SSB showed a steady increase from 2010 to the end of the time series in 2020.

The model estimated distinct periods of low and high recruitments (**Figure 25**). Specifically, the period prior to 1989 showed lower estimates of recruitment compared to the period from 1989 to 2006. Similar levels of recruitment to the earlier period were estimated between 2007 and 2011 and, after that time, the estimates demonstrate high uncertainty, indicating that there is a lack of information in the model to inform of recent recruitment. Notably, strong recruitments were estimated for the years 1994 and 2003, consistent with prior model signals and research observations.

The exploitation rate in biomass was used as a proxy for fishing mortality as the ratio of catch over biomass. In general, exploitation rate estimates (**Figure 25**) were low at the beginning of the time series but increased sharply during the 1980s to reach peak fishing mortality in 1997 and remained high until 2007, when a significant decline in harvest occurred. The estimates of exploitation rates since 2010 have been consistently lower, with a terminal year harvest rate estimate in 2020 of approximately 7% of total biomass.

3.2.2 Stock Status

For Stock Synthesis, the $F_{0.1}$ estimate (exploitation rate) is 0.091, assuming the recent selectivity pattern (2018-2020). The current F (exploitation rate) calculated as the geometric mean of F for years 2018-2020, was 0.065, and $F_{CURRENT}$ relative to the $F_{0.1}$ reference point was 0.72, indicating that overfishing was not occurring in the stock.

3.3 Other models

3.3.1 Model fits

ASAP

In contrast to VPA, statistical age or length models, such as ASAP, do not assume that total catch or catch-at-age are known exactly. In the Data Preparatory meeting (Anon., 2022), discussions on uncertainties about the actual value of catches in the inflated period (1998-2007) were noted. The expectation was that actual catches may have been even higher than those estimated in the inflated series. To investigate this, the CV of total catches was increased from 0.1 to 0.20. However, increasing the CV of total catches during 1998-2007 resulted in predicted catches that were noticeably lower than the inflated catches for all years in that period, even less than the catches officially reported in some years. The Group noted that the inflated catches were based on information and were the best information available (Anon., 2017). The Group thought that the officially reported catches were an absolute minimum estimate. Assuming a CV=0.20 (base run 2, control file in **Appendix 7**) resulted in estimated total catches between the officially reported catch and the inflated catch (**Figure 26**). The Group noted that higher CVs for the inflated period and lower estimated catches result in estimated recruitment for the inflated period being lower.

The Group requested that CV = 0.10 and CV = 0.01 be applied for all years for comparison with the other modelling approaches. They were provided to the Group (**Figure 27**, only CV=0.01 was compared with the base run 2). The External Expert suggested trying to estimate catches in excess of the inflated catch in future assessments.

The single-fleet ASAP model generally fit the data well (**Figure 28**) and was retrospectively consistent for SSB and F but not for recruitment (**Figure 29**). However, there were residual patterns in age composition and uncertainty in selectivity parameters, particularly for the recent period (**Figure 30**). Model estimates suggest a substantial change in selectivity in the late 1990s, from full selection of young ages and partial selection of older ages before 1999, then partial selectivity of young ages and full selection of older ages since 1999. That is consistent with changes in regulation as well as increased monitoring, control and surveillance. Model results suggest that the stock decreased from the 1970s to the early 2000s then recovered over the last decade from recent strong recruitment and low fishing mortality (**Figure 31**).

Running ASAP without the western Mediterranean larval index and the French aerial surveys, the only two indices available for the Mediterranean Sea, suggests lower recruitment since the late 1990s (**Figure 32**). While higher than for 1968 to 1990, the average recruitment estimates for 2000 to 2020 are 1.45 times the average for 1968 to 1990 while, during the period of inflated catch, the average recruitment is 2.5 times higher than from 1968 to 1990.

3.3.2 Stock status

For ASAP, the Group agreed to use the ASAP run with 20% CV on the catch series and the $F_{0.1}$ estimate is 0.160, assuming the recent selectivity pattern (2015-2020). The current F (geometric mean of apical F over years 2018-2020) was 0.087, and $F_{CURRENT}$ relative to the $F_{0.1}$ reference point was 0.542, indicating that overfishing was not occurring in the stock.

3.4 Synthesis of assessment results

Three assessment model platforms were applied to perform the stock assessment of eastern Atlantic and Mediterranean bluefin tuna in 2022. As in previous assessments, a Virtual Population Analysis -2Box was used, and two alternative platforms, Stock Synthesis and the Age Structured Assessment Program (ASAP), were applied in the development of E-BFT stock assessment. This is the first time it has been possible to complete the assessment using three models for E-BFT. This allows us to compare results using platforms that use different approaches to assess the status of E-BFT.

For the stock status comparisons, the Group agreed to include the ASAP run with 20% CV (ASAP base run 2) on the catch series for the period from 1998 to 2007, which was considered the best model by the modelling team. This model estimated a lower catch series (i.e., total removals) for the "inflated period" (1998-2007): 5,649 – 17,304 t lower than the other assessment platforms VPA and Stock Synthesis that have a near-exact fit to the catch (**Figure 26**).

Several factors continue to influence the E-BFT stock assessment. The paucity of indices spanning the time period of fluctuations in catch in the Mediterranean; uncertainties about the true value of catches in the inflated period (1998-2007); the effect of management measures on obtaining juvenile abundance information and changes in fishing strategies and selectivity; and gaps in temporal and spatial coverage for detailed catch size and effort statistics for several fisheries, especially for purse seiners in the Mediterranean and prior to the implementation of stereo video cameras in 2014.

The three models show similar trends in SSB (**Figure 33, Table 9**), with a progressive decrease in SSB from the 1970s until the implementation of the Recovery Plan for this species established in 2007 (Rec. 07-04). Since the late 2000s, there has been a sharp increase in SSB though the magnitude and rate differ between the three models, with VPA indicating lower biomass and stock increase and the ASAP model indicating the greatest increase. Uncertainty in the rate and magnitude of increase in SSB can be seen across the three platforms and in sensitivity runs within each platform, especially in recent years (**Figure 33**).

The fishing mortality of the 2-5 age group and of fish older than 10 years (**Figure 33, Table 9**) showed an increasing trend since the 1970s, although the F 2-5 age group shows a marked decrease since the late 1990s, while the adult group (F age 10 plus) shows a drastic decrease in fishing mortality since the establishment of the 2007 Recovery Plan (Rec. 07-04). Recent increases in TAC up to the current levels also reflect increasing fishing mortality.

The recruitments estimated by the three assessment platforms (**Figure 33, Table 9**) show considerable variability, particularly in the recent period, but in general there are two periods, one with low recruitments before 1990 and one with higher recruitments thereafter. It is worth noting the identification by all three platforms of the strong 2003 year class. Estimates in the recent years indicate a clear increase in recruitment, although there is uncertainty as to the magnitude of this increase, reflected by the differences between the three models and the variability within each model. Estimates of total biomass (**Figure 34, Table 9**) indicate similarity between Stock Synthesis and VPA in recent years with ASAP indicating higher total biomass. Time series of exploitation rate also indicate broadly similar patterns (**Figure 34, Table 9**).

Stock status shown by the relationship between current fishing mortality and $F_{0.1}$, indicates a state of overfishing in the estimate obtained by the VPA ($F_{CURRENT(2017\text{-}2019)}/F_{0.1}$ with 95% confidence intervals= 1.16 (0.73 - 1.62)) across both recruitment scenarios while Stock Synthesis ($F_{CURRENT(2018\text{-}2020)}/F_{0.1}$ = 0.72 (0.62 - 0.80) using the exploitation rate proxy) and ASAP ($F_{CURRENT(2018\text{-}2020)}/F_{0.1}$=0.54 (0.48 - 0.60)) indicate that overfishing is not occurring. The different models showed a relatively broad range of stock status relative to the $F_{0.1}$ benchmark. The Group will take further consideration of strengths and weaknesses of each modelling platform for provision of stock status for the Executive summary.

4. Initial feedback from the independent review

The external reviewer Dr Ianelli presented his feedback on both the E-BFT stock assessment and the MSE process (SCRS/2022/132), mainly based on progress at the E-BFT Data Preparatory meeting (Anon., 2022), and highlighted issues related to catch data, indices, biological assumptions, and issues with different modelling platforms.

The Group thanked the reviewer for his participation in the process and insights so far, as they helped the Group to discuss the different issues and take decisions in a timely manner in order to improve the final assessment and associated management advice. Direct participation is also an opportunity for the reviewer to clarify any issues with the Group. Several topics were further discussed by the Group, as summarized below.

The Group discussed how best to specify time blocks on selectivity in Stock Synthesis, e.g., in the case of the baitboat fleet or when there is a cohort targeting effect. The reviewer recognized that this is a major topic; he suggested looking at the ASAP analyses and referred to a CAPAM (the Center for the Advancement of Population Assessment Methodology) workshop on this topic. The reviewer noted his preference for more statistical approaches but acknowledged that using different approaches made it possible to learn from their differences.

One of the fundamental problems with the data is related to the absolute scale of the removals during the “inflated catch” period. The Group noted that current ASAP estimates are lower than ICCAT’s best estimates that have been assumed for input to the VPA and Stock Synthesis platforms (these were based on historical capacity estimates) and suggested that the importance or otherwise of the uncertainty around total removals could be checked within the MSE.

In 2021, the West BFT (W-BFT) assessment was strongly criticized by the reviewer at that time because it did not account for mixing (Maunder, 2021). The Group clarified that mixing would also affect this assessment, but the problem was considered to be minor, as suggested by MSE efforts so far and historical VPA runs incorporating mixing. This is so because only a small fraction of the eastern stock is caught in the West area compared to the East area (thus not taken into account in this eastern assessment), and a small/negligible percentage of western-origin individuals are caught in East area (likely not affecting the eastern stock trends).

The Group was reminded that electronic tagging had not revealed substantial migration of western origin individuals into the East area. In addition, when analysing stock of origin in eastern stock samples, the low western stock proportions observed are typically within the assignment error rates for the different assignment methods (genetics and otolith chemistry).

The Group also questioned whether the supposedly negligible effects of mixing for the eastern stock assessment might become more relevant for earlier time periods when the ratio of the catch in the western area was larger compared to the catch in the Eastern area. That might have some influence on the trend in abundance for the eastern stock. However, the Group noted that it could not confidently allocate those catches to any of the stocks, and that the conclusion from the historical mixed-stock VPA was that mixing was not a source of bias in biomass estimates for the eastern stock.

Finally, according to the initial review, although there were different issues to look at and work on in the future, there was no hard impediment to continue with the assessment at this stage. It was noted that the reviewer will provide a final review of the whole process at the September Species Group meeting.

5. Topics related to the Management Strategy Evaluation

The Group received SCRS/2022/126 on updates to the BR Candidate Management Procedure (CMP). Slight modifications had been made to the weighting of indices and additional CMP variants had been developed in response to requests made at the Second Intersessional meeting of Panel 2 on BFT MSE (9-10 May 2022) (e.g., alternative tunings, percent TAC change restrictions, including a phase-in period, management cycle length). The Group noted that VarC (Variation in TAC (%)) needs to be recalculated for any variants with a 3-year management cycle since the current VarC values are based on TAC changes every 2 years.

As previously discussed with PA2, the SCRS plans to further tune the performance of each CMP to more directly target the thresholds that PA2 has identified for biomass performance (LD*: lowest depletion (i.e., SSB relative to dynamic SSB_{MSY}) over years 11-30 in the projection period; current threshold LD^*_{15}=0.40) and probability of being in the green quadrant of the Kobe plot (PGK; current threshold PGK=0.60). This performance tuning is conducted to achieve the thresholds that PA2 has established while improving yields. It is expected that CMPs with higher biomass performance (LD*) and higher green Kobe plot probabilities (PGK) during development tuning will be more able to increase their yield results when they are performance tuned.

One CMP developer presented results of BR CMPs tuned only to alternate levels of LD^* (LD^*_{15} = 0.4, LD^*_{12}=0.4, LD^*_{10}=0.4) as an initial example of the performance tuning process. LD^* was found to be useful for performance tuning and the target LD^*percentage would determine how aggressive the CMP would be. However, the analysis did not tune to PGK, another threshold criterion, so it may also be necessary to consider this status objective. Tuning solely to LD^*_{15}=0.4 may not meet PGK at 60% so this should be considered in further performance tuning. It found a relatively linear relationship between western and eastern median Br30 (Br (i.e., biomass ratio, or SSB relative to dynamic SSB_{MSY}) after 30 years) values for LD^* values between LD^*_{10} and LD^*_{15}, indicating that the results of tuning to different values of LD^* could be reasonably estimated through interpolation.

The CMP tuned more aggressively to LD^* experienced higher variability in catches and a wider range for predicted Br30 (i.e., reduced stability and larger risk). The analysis included worm plots for each CMP variant for individual OMs to show potential variability in catch and in biomass trajectories, and the Group agreed that worm plots are an effective way to illustrate why high variability may be undesirable. The Group also noted that the analysis reflected the trade-off between eastern stock safety and West area catch. During the development tuning process, where CMPs were tuned to median Br30 targets, performance was found to improve when the eastern stock Br30 median target was higher than the western stock Br30 median target (1.5, 1.25, respectively). However, in this initial performance tuning to LD*, median Br30 was higher for the western stock and lower for the eastern stock. This could be countered by using different LD* probabilities for the East and West areas if this is acceptable to Panel 2.

One of the Co-Chairs presented updated results compiled by the MSE Consultant (SCRS/P/2022/047), including an overview of the current Shiny App tools and new performance statistics. The Group discussed data requirements for finalizing performance statistic calculations, including C1. Catch data for 2021 are due to be submitted to the Secretariat by 31 July 2022, but indices are not usually updated until the Species Group meeting in late September. It was proposed that index developers make every effort to provide their updated indices by 15 August 2022, so they are available for developers sufficiently in advance of the Second Intersessional meeting of the BFT Technical Sub-Group on MSE (5-9 September 2022). If indices are not available in time, CMP developers could use expected index values (i.e., those predicted by the OMs) instead.

The Group noted that catch and biomass trajectory plots should also be presented separately for recruitment levels 1, 2 and 3, so as not to conflate CMP behaviour with recruitment scenario.

In discussing impacts of the +20%/-10% TAC change phase-in, the Group acknowledged that there was little effect on median status, but there was a slight reduction in Br30 tail distribution values as well as a slight penalty for longer-term yield. A participant cautioned that if the phase-in applies for the first 2 management cycles but the MSE is reconditioned in 5 or 6 years, the MP's regular stability provisions will not have been fully implemented before it is revisited and re-evaluated. The decision to adopt the phase-in provision as the default for CMPs should be made by Panel 2 in July to facilitate further CMP development.

There was considerable discussion about whether to use a 2- or 3-year management cycle. A 3-year management cycle was tested for 2 CMPs: BR and TC. The results for the BR CMP variants tuned to a common LD^*_{15} are shown in Table 3 of **Appendix 8**. The 3-year cycle was slower to react to signals to decrease TAC and thus had a lower 50%ile biomass status (Br30) and slightly reduced AvC30 (median TAC (t) over years 1-30) coupled with slightly higher variability in TAC changes. To compensate, the SCRS explored greater allowable TAC reductions (+20%/-35% stability) that improved Br30 status slightly for both eastern and western stocks. Performance was only slightly inferior and practical considerations (stability, reduction in administrative burden) may support a 3-year management cycle. This decision should be made by Panel 2 in July to facilitate further CMP development and the SCRS noted that this will be time-consuming for all developers to implement.

A further consideration was raised that the 3-year management cycle may be more robust to missing index data. It was pointed out that missing index data is not necessarily a reason to use a longer management cycle since CMPs have been designed with moving averages to readily handle missing data (e.g., by replacing them with a null value or the prior value) regardless of the management cycle.

The May 2022 PA2 meeting also requested that the SCRS evaluate a symmetrical stability provision of +20%/-20% compared to the default +20%/-30%. The +20%/-20% option was slower to implement necessary TAC decreases and thus had lower yield and biomass performance (i.e., greater risk) (Table 4 of **Appendix 8**). The SCRS has not yet evaluated +20%/-20% with a 3-year cycle but expects performance to be worse, since not even +20%/-30% had satisfactory performance in terms of the agreed B_{LIM} (a biomass Limit Reference Point; 40% of dynamic SSB_{MSY} for the purposes of the MSE) requirements. Nonetheless, if Panel 2 requires symmetrical stability provisions for practical considerations, the SCRS recommends that this decision be made at the July meeting to facilitate further CMP development.

A CMP developer presented the four FZ-type CMPs, and the Group decided to proceed with FO CMP for the present, based on better performance according to the quilt plots and this CMP's more straightforward structure without a smoother.

The Co-Chair presented the updated 4-page MSE results summary that will be submitted to Panel 2 in the July meeting (**Appendix 8**). It includes background information for each of the PA2 agenda's decision points. It will be critical to get input on these from PA2 at the meeting, anticipating that this Group will need to recommend a manageable number of CMPs with multiple tuning levels in September for presentation to PA2 in October.

The Group received a presentation on a new tool that automatically calculates each CMP's TACs for the first three 2-year management cycles based on user-input index values. The Group agreed that the tool could help CPCs and stakeholders to understand how CMPs work and how the values of indices influence the TAC. If possible, the tool developer will circulate a refined version later in the week so that it can be shared with Panel 2.

The Group discussed potential avenues for receiving additional CPC and stakeholder feedback between the Panel 2 meetings in July and September. A survey was considered but deemed too problematic in various respects. The SCRS Chair agreed that the ambassador meetings have proven to be an effective venue for an exchange of information. Everyone can speak and ask any questions they want, and the dialogue goes both ways – from stakeholder/CPC to SCRS and vice versa. However, ambassador meetings are not an official means of obtaining stakeholder feedback and that remains the purview of each CPC. The Group will aim to convene additional ambassador meetings, in late July and also in early October if possible. Naturally, CPC scientists can engage with their stakeholders at any time.

The Group noted that TAC advice for 2023 will be provided based on the MSE, yet scientific advice will be produced based on the current eastern assessment. Language will be included in the chapeau of the SCRS executive summary, stating that MP adoption is the priority and that the management advice is provided in case an MP is not adopted by the Commission at its meeting later this year. Similarly, backup advice should be provided for W-BFT.

6. Projections and management advice

The Group decided to review the preliminary short-term projections by each stock assessment model. The Group recommended that projection settings among models need to be comparable insofar as possible. The projections were conducted for the period between 2021 and 2024 at $F_{0.1}$ and 36,000 t, by assuming the current TAC 36,000 t for both catches in 2021 and 2022. All projections assumed the same natural mortality, maturity-at-age, and weight-at-age/length as values used in the stock assessments (**Table 10** for VPA, **Table 11** for Stock Synthesis, and **Table 12** for ASAP). To provide the uncertainty of each estimate, VPA used 500 bootstrap iterations, Stock Synthesis used 500 iterations of MVLN (multivariate log normal approach, Walter and Winker, 2019), and ASAP used 500 MCMC iterations.

Key requirements for projections are to address the major sources of uncertainty in each model relative to recent recruitment estimates. This involves two decisions, the first being what recruitment to project forward in time and the second whether model estimated recruitments are reliable or should be replaced or 'patched' back in time with assumed values. The Group reviewed model diagnostics, notably retrospective patterns and confidence intervals on recruitment deviations to determine time periods (noted below for each model) where recruitment appeared reliably estimated to inform the patch time periods.

Time periods for the patch applied for VPA for the years 2017-2020, a similar 4-year patch as in the 2017 stock assessment. The average years for recruitment were a long-term average (1968-2016) and a short-term average (2007-2016) (**Figure 35**, SCRS/P/2022/043). The rationale for the short-term average is an assumption that future recruitment is likely to be similar to 10 recent years, which is estimated to be relatively high, and the current assessment improves results in R retrospective analysis compared to the 2017 stock assessment (Anon., 2017) (**Figure 23**). Nonetheless, recruitment for these years is highly uncertain and the Group considered that an equally plausible hypothesis could be that recruitment would revert to the long-term average (1968-2016), an assumption akin to the 'medium' recruitment scenario often entertained for E-BFT (Anon., 2013 and Anon., 2015). A number of other recruitment scenarios were considered but not chosen by the Group. The Group recommended equally weighting the short- and longer-term recruitments for projections, stock status and management advice.
For Stock Synthesis, the recruitments were replaced for years 2012 to 2020 as the recruitment deviations overlapped zero for nearly the entire time period, indicating that there was substantial uncertainty in estimated recruitment (**Figure 18**). This was achieved by not estimating recruitment deviations for these years and was a rather large intervention in the model. Model runs with and without this recruitment deviation were run and indicate that the model converged on a very similar solution. For projected recruitment, Stock Synthesis used the long-term mean (R0) under the assumption that future recruitment is likely to be similar to the long-term average.

For ASAP, 2 recruitment options were recommended. The first was to use the entire time series (1968-2020) and the second was a truncated time series (1968-2012) for future recruitment. For the truncated series, the average of 1968-2012 was used for years 2006-2020. The rationale for the entire time series was similar to that for the VPA and Stock Synthesis under the assumption that short-term recruitment would be similar to the long-term average. The second was to use the truncated series to avoid using recruitment estimates over the years where the retrospective pattern in recruitment appeared substantial (**Figure 29**). To be comparable with the other two stock assessment models, the ASAP model with catch CV 1% was used for the projection exercises. The Group also reviewed the ASAP projection with CV 20%.

The summary of main projection settings for each model follows below:

Model (number)	Catch (tonnes) for 2021 and 2022	Patch (years)	Selectivity (years)	Recruitment (years)
VPA run 385	36,000 and 36,000	2017-2020	2017-2019	2007-2016
VPA run 385	36,000 and 36,000	2017-2020	2017-2019	1968-2016
SS3 Run 16 reweight	36,000 and 36,000 catch by fleet was obtained by the average catch rate (2018-2020) by fleet	2012-2020	2017-2020	The long-term mean (R0)
ASAP catch CV 1% and 20%	36,000 and 36,000	2017-2020	2015-2020	1968-2020
ASAP catch CV 1% and 20%	36,000 and 36,000	2006-2020	2015-2020	1968-2012

Projection results, stock status and management recommendations

The Group reviewed short-term projection results for each model (**Figures 36-38**) at $F_{0.1}$ and 36,000 t. Stock status determinations relative to fishing mortality and management recommendations will be finalized at the September Species Group meeting. For informing stock status, the Group recommends considering the results of all three models with the final determination to be conducted in September. For the purposes of continuity, the Group recommends only projecting the VPA for consideration of quantitative TAC advice for the Kobe 2 Strategy Matrix (K2SM).

Any TAC advice that the SCRS may eventually provide on the basis of this assessment will be highly dependent upon the absolute biomass scale estimated by the models. A primary impediment to estimating the absolute scale of the population is illegal, unreported and unregulated catch which, if it cannot be quantified and considered in the scientific assessment, results in underestimates of the total yield and an inability to estimate reliable MSY-related benchmarks. For example, the scale of the population estimated by the models is highly dependent on the assumed magnitude of the 'inflated catch' during the late 1990s and early 2000s. The Group is aware of ongoing, unquantified IUU that represents a serious impediment to being able to determine the productivity of the stock and provide reliable TAC advice. In response, we encourage the identification and quantification of IUU so that the SCRS can provide more accurate biomass-based catch advice and obtain a more accurate scientific understanding of stock productivity.

7. Draft Executive Summary sections

Due to time constraints, the Group did not revise the Executive Summary. The Co-Chairs will work on the draft intersessionally and it will be discussed during the next Bluefin Tuna Species Group meeting (20-21 September 2022).

8. Update on GBYP activities

The GBYP Coordinator gave presentation SCRS/P/2022/049 to inform the Group about the recent GBYP activities, as well as the future plans. Currently, GBYP is running Phase 11 and Phase 12 in parallel (partially). Phase 11 will end on 31 August 2022 and Phase 12 will end in in March 2023. The Coordinator also informed the Group that the EU funding system has changed and further modifications are expected, which will affect not only GBYP but also other ICCAT scientific programs.

With respect to data management, joint efforts are ongoing at the Secretariat to develop both an electronic tagging database (ETAGS) and a biological database. The external expert who will provide advice on ETAGS has already been contracted by GBYP and a progress report will be presented in September 2022. In addition, the first steps towards the design of the biological database have been taken.

Electronic tagging deployments have ultimately been achieved through formal collaboration with national teams both in the Atlantic and in the Mediterranean, and this has significantly lowered operational costs. In June a tagging campaign was carried out in Levantine Sea and 13 tags were released. During 2022 the deployment of a further 51 tags is planned, in close collaboration with 11 institutions. It was noted that important improvements have been observed in tag retention times and tag recovery rates, which will allow for improvements in movement matrices used in MSE. The Group was asked again to provide inputs for defining tagging priorities. It was acknowledged that some feedback on electronic tagging issues has already been provided through paper by Aarestrup *et al*. (2022), but further inputs from the BFTSG were required. The Group was also informed that the global workshop on electronic tagging methodologies will be organized soon.

Regarding biological studies, the Phase 11 biological sampling and analyses were completed, and the final report will shortly be available on the GBYP webpage. A new Call for Tenders will be launched soon, and it will be focused on providing sound conclusions on stock structure and mixing, based on all the information gathered during the last decade. The Group was asked for its advice in defining the research priorities for future studies. It was also informed about the workshop for coordination of biological sampling efforts, which will be organized in 2022 or 2023. As for the close-kin related studies, the Coordinator informed the Group about its progress and reminded it about a series of agreed steps and the associated time frame. It was recalled that the immediate goal is to elaborate a concrete and realistic work-plan, including cost analysis, to be presented to the SCRS Plenary and Commission for approval in 2023.

With respect to the fishery independent indices, a larval survey workshop is planned in the second part of the year. Advice has recently been provided to Turkish scientists on BFT larvae identification and once data from the 2018 and 2019 larval survey are available, further advice will be provided so that the national team can generate preliminary larval indices for the eastern Mediterranean. Regarding aerial surveys, the results of the analyses of 2021 survey in the Balearic Sea are available and the value of the 2021 index has been provided to the Group. The campaigns in 2022 have been successfully carried out in the western and central Mediterranean and the analysis will be finished by next year. Work will also continue this year on habitat modelling to allow for a reliable model-based analysis of overall aerial survey results.

Regarding modelling approaches, GBYP has continued to provide considerable support to the MSE process. It has integrated the different survey and research results into a mixed-stock modelling framework that formally addresses the major sources of uncertainty identified by the assessments. In addition, it has funded the external review of the E-BFT stock assessment. Future plans also include support to the development of alternative/improved stock assessment models.

Finally, the Coordinator provided an outline of Phase 12 activities. He also presented possible mid-term activities in order to improve GBYP efficiency and adapt it to a probable future scenario of decreasing funds. They include a progressive shift from basic data provision to data management/analysis and coordination of the activities, in close cooperation with CPCs as the main data providers.

The Group was interested in the new results from the aerial survey in 2021 and the Coordinator explained that they are already available, but should be taken with caution due to some changes in relation to previous surveys, such as the change in professional and scientific observers and the fact that, following recommendations from the external experts that reviewed GBYP aerial surveys, an extended sampling area was also surveyed and an automated system for continuously taking images along the transects was tested, which changed the timing of the survey slightly. Thus, he recommended continuing to pursue habitat modelling efforts, which would take account of environmental effects. By default, scientific data points are retained for use unless it can be empirically determined that something exceptional happened that would justify removing such a data point. While the Group expressed concern about the changes that may have occurred in overlap of the survey with the distribution of fish in 2021, the decision on how to treat the index will be made at the September Species Group meeting based on a review of empirical information that must be brought to the BFT MSE Technical Sub-group meeting in September for initial consideration.

The Group acknowledged that great progress has been made lately in GBYP, namely in terms of changing priorities from data collection towards consolidating results. The discussion also highlighted that, after 11 years of a dedicated programme, absorbing substantial amounts of financial resources, alternative ways to move forward must be explored to support the truly necessary basic activities, since a budget reduction in future phases has been announced on several occasions by the major sponsor. The Group reiterated the need to ensure funding continuity. It was recognized that support for the GBYP through voluntary contributions is not sustainable due to decreasing overall funds and the disproportionate amount of funding dedicated to bluefin tuna research compared to other SCRS Groups.

It was therefore recommended to pursue other sources of funding, in addition to voluntary contributions, preferably through the regular budget of the Commission. Although the science budget has increased substantially over recent years as a part of the Commission's regular budget, it was suggested that a clear statement should be sent through the SCRS to the Commission to increase it further, to a level closer to the SCRS request. Securing a stable budget over time would allow for better planning of mid- and long-term activities. The need to better define research priorities at the SCRS level was also highlighted, as well as the importance of including it within the new SCRS strategic plan. In addition, funding priorities should be improved, with clearly defined priorities and outcomes. The Group also identified the need to find ways to better communicate with managers in order to show how the funds have been spent, but particularly how they contribute to improving data collection (otherwise not available) and filling knowledge gaps with the aim of providing more reliable/robust scientific management advice.

It was also recognized that CPCs should assume a part of the activities currently carried out through GBYP funding, by incorporating them into their national programs. However, it was stressed that GBYP could have a major role in ensuring that these are well coordinated and follow the same line of priorities previously defined by the SCRS. The possible role of GBYP in coordination was clearly acknowledged, especially with regards to biological sampling.

It was announced that the GBYP workshop on sampling and research planning has already been scheduled for late 2022/early 2023 in order to improve the coordination of sampling activities. In this regard, a special reference was made to the Secretariat engagement with the EU Regional Coordination Group on Large Pelagics (RCGLP), which is the body responsible for coordinating regional/thematic data collection amongst EU Member States, as well as with end-users (i.e., ICCAT and other RFMOs) under the EU data collection framework.

9. Recommendations

The Group raised several recommendations:

- The Group recommends continuing the development of fishery-independent indices of abundance based on acoustic methods taking into consideration the representativeness of the surveys. There are currently several research groups working on the acoustic assessment of Atlantic bluefin tuna. Cooperation between the different initiatives should be developed.
- The Group recommends developing new abundance indices in the Mediterranean Sea (e.g., the Levantine Sea larval index and the Sardinian trap index), as this is where most of bluefin tuna catches are harvested yet there are very few abundance indicators.
- The Group reiterated the need to revise historical size distribution from other purse seine fleets and other areas i.e., southern Mediterranean and Levantine Sea.
- Noting that the collection, processing and ageing of samples could reduce uncertainty in the advice provided to managers, the Group recommends increasing coordination among the different CPC teams working on these issues and GBYP, in order to provide length-at-age data from hard part readings or report on samples in their possession.
- The Group recommends the continuation of pilot studies, including feasibility analysis and planning for close-kin mark recapture for eastern Atlantic and Mediterranean bluefin tuna, and

the prioritization of a review for operational implementation of close-kin mark recapture as soon as it becomes technically and logistically feasible.

- The Group recommends that unreported historical catch series be re-examined and, more broadly, the uncertainty in these series be determined in order to develop a set of potential catch series that could be used in future assessments.

10. Other matters

SCRS/2022/127 presented natural mortality (M) for E-BFT and two similar tuna species, Pacific bluefin tuna and southern bluefin tuna. Three types of natural mortality assumptions were used in the E-BFT stock assessment and/or MSE: the fixed values at all ages, an age-specific vector, and a smooth decreasing curve rescaled with the Lorenzen mortality function. The current natural mortality assumption is more logical compared to the previous assumptions. However, both the parameter M used in Atlantic bluefin tuna and Pacific bluefin tuna was partially based on the M assumptions of southern bluefin tuna (SBT). It is suggested that the recent M assumption be improved through experiments instead of taking the assumptions made for SBT as a reference. Continued biological investigation to estimate natural mortality of the Atlantic bluefin tuna is needed.

The Group acknowledged the comprehensive summary information on M for Atlantic BFT and encourage authors to participate in current research programs on this topic. It was noted that some of the parameters of M included in the summary table of the document, in particular for the early stages of Atlantic BFT MSE (2015/2017) should be removed as they were only preliminary developments of the MSE process, not used for advice or assessment, and may misinform readers. It was further clarified that for SBT and Atlantic BFT MSE, estimates of M included parameter(s) for senescence of older ages to avoid unrealistic estimates of plus group accumulated biomass in population models. The Group notes that the combination of acoustic tags coupled with an array of receivers is exceptionally powerful for obtaining estimates of natural mortality. The current estimates of Atlantic BFT M for older ages come from estimates obtained via acoustic tags (Block *et al.,* 2019).

The Group noted that, for Atlantic BFT, there are relatively very good estimates of M for older ages from current research programs regarding acoustic telemetry from Canada and Stanford University (USA) studies (Block *et al*., 2019). There is still a need to validate M for younger ages in particular, and genetic tag studies or close kin genetic estimates, together with the acoustic tagging of juveniles, are likely the best research areas to achieve these objectives. It was further noted that estimates of M based on bio-energetic consumption rates and ecological interactions for bluefin tuna would be difficult to achieve due to the limited data available. Finally, the Group also noted the need for scientists to continue research on estimates of M for tuna and other ICCAT species and welcomed the interest of the authors to collaborate on these research projects within the SCRS.

The objective of the work presented in SCRS/2022/103 was to apply marginal increment analysis (MIA) and marginal edge analysis (EA) to determine the timing of band deposition. MIA was also analysed using General Additive Models. The results indicated that the opaque band starts to form in July and finishes forming in November. There is minimal marginal edge growth from the end of the year to the beginning of the following year, and this is when the translucent band begins to form, before reaching its maximum development in June. MIA and EA have shown that the annulus has been formed in November in the Atlantic bluefin tuna otolith.

Considering the conclusions of the work, whereby the current 1 July adjustment criterion would be adjusted to 30 November, the Group discussed how much this could affect the age allocation of BFT in current catch datasets. There was insufficient information to determine if there were any differences between bands formed in fish caught in the Mediterranean and the Atlantic, although the author suggests that differences are not to be expected, but small differences between juveniles and adults are more likely. Whilst the implications of this new analysis must still be understood, it was explained that the marginal edge type related to the catch date and the birth date must be considered to transform the band count into ages.

SCRS/2022/131 described the characteristics of the Balfegó purse seine (PS) fleet from an operational point of view, with the objective to be able to determine alternative ways of understanding how to improve the standardization of the Balfegó PS fleet CPUE. The paper highlighted the factors associated with fishing activity, such as annual variability in size of the fishing fleet, the narrow spatial and temporal window in which the fleet was operational, and the daily catch limitations due to the number of possible daily transfers. Nominal and standardized catch rates were presented along with the rest of the E-BFT indices.

The Group appreciated the operational details provided in this paper. Various factors which might have influenced or influence the capability of the fleet to catch fish were discussed, including past/current regulations, technological changes (e.g., aerial spotting prior to prohibition of use; horizontal sonars). It was pointed out that since approximately 2009, the fleet has been using technological external support based on oceanographic conditions to forecast tuna location on a daily basis. Operationally, there are practical limitations to actual catch rates because there is a maximum size for schools when being surrounded during a set, with big schools often being split to enable net setting on smaller schools. It was clarified that this practice affects the determination of catch rates based on sets but not determination of the daily catch rates where effort is taken into account. Although the size of BFT in the fishing area covered in the paper typically consists of large fish, in 2022 an increase in the incidence of schools of smaller fish (80-90 kg) was observed; the fleet does not set nets around these schools of smaller fish.

The paper showed that the nominal Balfegó CPUE indices are in line with the dynamics of the Japanese longline index in the northeast Atlantic, but not with the Moroccan and Portuguese trap index (the paper did not explore why this occurred). The Group agreed that having a data matrix with all the operational and environmental information greatly assists modelers in understanding how to move forward for alternative CPUE standardization methods.

SCRS/P/2022/048 on the update on the growth of farmed E-BFT was made available to the Group and presented for discussion. Briefly, the results of the individual fish tagging experiment from 3 experiments in Croatia and Portugal indicated an increase of growth in size compared to wild fish growth models. These results are in agreement with the results presented last year from the Mode progression analysis (MPA) for small (< 100 cm SFL) and medium (100 – 180 cm SFL) fish. These results were incorporated into the modelling of growth in farms using the Regional Observer Program (ROP) harvest database. The ROP harvest database was updated and includes data from 2015-2021 with over 250 thousand samples covering all active bluefin tuna farms.

The Group made specific recommendations on the preliminary analysis related to the tagging input data that will be included in the analysis of growth in farms to be presented prior to the next meeting. It was agreed the BFT Technical Sub-group on farm growth will meet intersessionally to update the work to be provided at the September 2022 Species Group meeting, together with a draft of the response to the Commission.

11. Adoption of the report and closure

The Report of the 2022 Eastern Atlantic and Mediterranean Bluefin Tuna Stock Assessment Meeting was adopted. Drs Rodríguez-Marín and Walter and the SCRS Chair thanked participants and the Secretariat for their hard work and collaboration to finalize the report on time. The meeting was adjourned.

References

Aarestrup K., Alemany F., Arregui I., Arrizabalaga H., Cabanellas-Reboredo M., Carruthers T., Hanke A., Lauretta M., Pagá A., Rouyer T., Tensek S., Walter J., Rodriguez-Marin E. 2022. Update of electronic tagging data and methodologies for Atlantic bluefin tuna in order to plan future tagging activities. Collect. Vol. Sci. Pap. ICCAT, 79 (3): 196-210.

Anonymous. 2013. Report of the 2012 Atlantic bluefin tuna stock assessment session (Madrid, Spain – 4-11 September 2012). Collect. Vol. Sci. Pap. ICCAT, 69 (1): 1-198.

Anonymous. 2015. Report of the 2014 Atlantic bluefin tuna stock assessment session (Madrid, Spain – 22-27 September 2014). Collect. Vol. Sci. Pap. ICCAT, 71 (2): 692-945.

Anonymous. 2017. Report of the 2017 ICCAT bluefin stock assessment meeting (Madrid, 20-28 July 2017). Collect. Vol. Sci. Pap. ICCAT, 74 (6): 2372-2535

Anonymous. 2022. Report of the 2022 eastern Atlantic and Mediterranean bluefin tuna data preparatory meeting (including BFT MSE) (online, 18-26 April 2022). Collect. Vol. Sci. Pap. ICCAT, 79 (3): 1-140

Block B.A., Whitlock R., Schallert R.J., Wilson S., Stokesbury M.J., Castleton M., Boustany A. 2019. Estimating natural mortality of Atlantic bluefin tuna using acoustic telemetry. *Scientific reports*, *9*(1): 1-14.

Francis R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68: 1124-1138.

Maunder M. 2021. Review of the 2021 West Atlantic bluefin tuna assessment. Collect. Vol. Sci. Pap. ICCAT, 78 (3): 1114-1124.

Sampedro P., Kimoto A., Ortiz M., Sharma R., Fukuda H., Gordoa A., Lauretta M., Rouyer T., Sunderlöf A., Tsukahara Y., Walter J., Rodríguez-Marín E. 2022. Data and initial model set-up for the 2022 stock synthesis stock assessment of the eastern Atlantic and Mediterranean bluefin tuna. Collect. Vol. Sci. Pap. ICCAT, 79 (3): 304-326.

Sharma R., Walter J., Kimoto A., Rouyer T., Lauretta M., Kell L.T., Porch C. 2017. Eastern Atlantic Ocean bluefin tuna stock assessment 1950-2015 using Stock Synthesis. SCRS/2017/175 (withdrawn).

Walter J., Winker H. 2019. Projections to create Kobe 2 strategy matrix using the multivariate log-normal approximation for Atlantic yellowfin tuna. Collect. Vol. Sci. Pap. ICCAT, 76 (6): 725-739.

Table 1. List of VPA run descriptions conducted during the meeting.

Run	Modifications
288	Continuity run, updated CAA (V2b), updated WMED_LARV
289	Run 288, plus group = 16+
290	Run 289, set F-ratio=1 for all years
291	Run 289, use Richards curve
292	Run 289, F-ratio=1 and use Richards curve
293	Run 289, Try additive variance for indices
294	Run 289, Selectivity is estimated for WMED_LARV
295	Run 288, change F-term priors and change search settings, F-ratio for 1968-1980 and 1981-1995 = 1
287	Run 295, Constraint of 0.5 on vulnerability on ages 5-9 over 6 years (before was ages 1-9 and 3 years) and Constraint of 0.5 on recruitment over 6 years (before was no constraint)
286	Run 287, change F-term priors and change search settings, F-ratio for 1968-1980 and 1981-1995 = 0.75
303	Run 286, add WMED_GBYP_AER survey
304	Run 303, remove WMED_LARVsurvey
367	Run 286 fix selectivity for WMED_LARV, and constrain bounds for terminal F
385	Run 288(Continuity run) + constraint on fixed selectivity for WMED_LARV + terminal F bound constraints + vulnerability strength = 0.3
386	Run 385 Estimate the F-ratio

Table 2. List of model fitting statistics for the VPA runs conducted during the meeting.

																			Index						
Run	obj_func	obj_func_ with_cte	nb_param	nb_data	AIC	AICc	BIC	chi_square	mohnSSB	mohnRec	mohnF25	mohnFplus	FR_AER1	FR_AER2	JPN_LL_ EastAtlMed	JPN_LL1_ NEA	JPN_LL2_ NEA	MOR_POR _TP	MOR_SP_ TP	SP_BB1	SP_BB2	WMED_ GBYP_AER	WMED_ LARV
286	-68.97	99.19	26	183	250.38	259.38	333.83	147.78	0.04	0	0.07	-0.09	4.11	2.93	17.66	10.75	6.09	7.06	10.15	4.58	0.07	NA	-9
287	-67.28	100.88	26	183	253.77	262.77	337.22	153.3	0.14	-0.1	0.47	-0.29	4.2	3.13	20.27	10.05	5.93	5.84	6.71	5.13	-0.68	NA	-7.58
288	-56.57	111.59	28	183	279.18	289.73	369.05	160.65	0.51	-0.25	0.69	-0.52	4	-3.15	20.34	11.1	5.37	5.3	8.11	5.53	-1.5	NA	-6.74
289	-41.9	126.27	34	183	320.53	336.61	429.66	174.9	5.08	1.43	-0.47	-0.98	4.3	1.23	7.64	5.54	6.87	3.02	-5.71	9.24	1.17	NA	-14.31
290	-33.84	134.33	31	183	330.65	343.79	430.15	161.79	-0.14	-0.36	1.5	-0.48	3.92	0.34	-6.7	9.11	5.31	-4.56	0.55	8.07	1.68	NA	-1.49
291	-75.32	92.85	34	183	253.7	269.78	362.82	177.78	-0.06	0.17	0.19	-0.19	3.66	1.49	21	12.15	10.62	-0.33	3.91	11.34	0.79	NA	0.5
292	-37.36	130.81	31	183	323.61	336.75	423.11	162.84	0.07	0.51	0.87	-0.2	3.81	1.36	-6.16	9.13	6.22	0.03	3.43	9.87	1.08	NA	-1.22
293	-34.78	133.38	31	183	328.76	341.9	428.26	162.12	-0.54	0.3	1.38	22.78	3.2	0.56	-6.68	9.61	5.24	-4.74	0.88	8.39	1.53	NA	-0.94
294	-34.75	133.41	31	183	328.82	341.96	428.32	158.81	-0.09	0.62	-0.02	3.45	3.94	0.99	-6.63	9.02	5.03	-5.06	0.4	8.12	1.26	NA	-0.75
295	-60.54	107.63	26	183	267.26	276.26	350.7	155.19	0.16	0.31	0.5	-0.25	4.18	1.31	20.23	10.11	6.45	5.72	6.94	5.08	-0.85	NA	-7.66
297	-69.53	98.63	26	183	249.27	258.27	332.71	148.1	-0.03	-0.17	0.63	-0.11	4.11	2.93	17.75	10.72	6.09	7.04	10.13	4.57	0.09	NA	-8.45
303	-68.85	105.75	28	190	267.49	277.58	358.41	150.89	-0.08	-0.27	0.92	-0.03	4.06	3.01	16.74	10.95	5.91	7.08	10.61	4.64	-0.1	0.07	-8.49
304	-72.67	88.14	26	175	228.29	237.77	310.57	147.35	0.13	1.37	-0.4	-0.08	4.11	-0.55	17.68	10.79	6.4	7.06	10.06	4.65	0.12	-1.23	NA
367	-69.54	98.63	26	183	249.26	258.26	332.7	148.25	0.01	-0.02	0.11	-0.08	4.11	2.93	17.64	10.74	6.07	7.07	10.17	4.56	0.06	NA	-8.36
377	-56.15	112.02	26	183	276.03	285.03	359.48	143.22	0.11	0.05	0.2	-0.13	3.94	0.94	15.12	11.26	5.68	7.03	11.17	4.82	-0.38	NA	-7.82
378	-63.09	105.08	26	183	262.16	271.16	345.6	148.03	-0.05	0.47	0.16	-0.06	4.09	4.83	17.29	10.83	5.84	7.07	10.35	4.61	0	NA	-8.7
379	-73.68	94.48	26	183	240.97	249.97	324.41	147.63	-0.01	-0.31	1.15	-0.15	4.13	2.33	18.01	10.68	6.16	7.05	9.92	4.57	0.17	NA	-9.25
380	-73.69	94.47	26	183	240.95	249.95	324.39	147.58	0.02	-0.12	0.29	-0.11	4.11	2.37	17.71	10.74	6.14	7.07	10.1	4.59	0.09	NA	-9.07
381	-64.94	103.23	26	183	258.45	267.45	341.9	146.54	0.07	-0.19	0.49	-0.16	4.14	2.53	18.32	10.59	5.9	7	9.76	4.54	0.22	NA	-9.09
382	-72.71	95.45	26	183	242.91	251.91	326.35	148.42	-0.09	1.23	1.14	-0.04	4.11	2.71	17.71	10.74	6.2	7.07	10.1	4.59	0.09	NA	-9.2
383	-63.21	104.95	26	183	261.91	270.91	345.35	147.37	0.01	0.71	0.42	-0.05	4.11	3.23	17.66	10.77	5.98	7.07	10.12	4.61	0.09	NA	-8.97
384	-66.91	101.25	26	183	254.5	263.5	337.95	147.57	-0.11	0.11	0.31	-0.01	4.07	4.53	16.91	10.91	5.89	7.09	10.53	4.63	-0.07	NA	-8.61
385	-74.26	93.91	26	183	239.81	248.81	323.26	147.94	0.07	-0.07	0.23	-0.14	4.12	2.38	17.82	10.71	6.14	7.05	10.07	4.56	0.1	NA	-8.5
386	-75.13	93.04	28	183	242.08	252.62	331.94	143.21	0.31	-0.15	0.36	-0.34	3.68	2.49	16.63	12.39	5.77	6.95	11.06	4.7	-0.49	NA	-7.41
392	-75.11	93.06	26	183	238.11	247.11	321.56	143.81	0.22	-0.03	0.1	-0.25	3.76	2.5	16.94	12.24	5.87	6.97	10.87	4.6	-0.38	NA	-7.69
418	-75.1	93.07	26	183	238.14	247.14	321.59	143.66	0.1	-0.13	0.32	-0.18	3.69	2.5	16.9	12.35	5.74	6.82	10.93	4.68	-0.58	NA	-7.22

Table 3. A test on the effect of F-ratios on the overall scale of the VPA based on the Continuity run (Run 288).

Fratio	obj_func	obj_func_with_cte	nb_param	nb_data	AIC	AICc	BIC	chi_square	mohnSSB	mohnRec	mohnF25	mohnFplus
0.25	-54.33	113.83	28	183	283.67	294.21	373.53	143.56	-0.07	55.34	0.46	-0.18
0.5	-56.71	111.46	28	183	278.91	289.46	368.78	139.62	0.17	43.26	1.03	-0.37
0.75	-57.03	111.13	28	183	278.27	288.81	368.13	141.62	0.18	0.25	0.53	-0.33
1	-58.22	109.95	28	183	275.9	286.44	365.76	142.54	0.23	-0.13	0.45	-0.37
1.25	-57.71	110.46	28	183	276.92	287.47	366.79	142.92	0.22	-0.27	0.48	-0.39
1.5	-56.47	111.69	28	183	279.39	289.93	369.25	139.82	0.81	0.24	-0.14	-0.58

Table 4. Profile of the F-ratio for the 1968-1995 (top panel) and the 2008-2020 (middle panel) time blocks, and both (bottom panel) time blocks based on the Continuity run (Run 288).

1968-1995 time block

Fratio	obj_func	obj_func_with_cte	nb_param	nb_data	AIC	AICc	BIC	chi_square	mohnSSB	mohnRec	mohnF25	mohnFplus
0.5	-66.46	101.71	26	183	255.42	264.42	338.86	146.65	-0.06	-0.42	1.47	-0.25
0.75	-67.67	100.49	26	183	252.98	261.98	336.43	150.23	0.05	-0.28	0.72	-0.31
1	-67.28	100.88	26	183	253.77	262.77	337.22	153.3	0.14	-0.10	0.47	-0.29
1.25	-65.89	102.28	26	183	256.56	265.56	340.01	155.46	0.14	-0.08	0.48	-0.27

2008-2020 time block

Fratio	obj_func	obj_func_with_cte	nb_param	nb_data	AIC	AICc	BIC	chi_square	mohnSSB	mohnRec	mohnF25	mohnFplus
0.5	-53.92	114.24	26	183	280.48	289.48	363.93	141.14	-0.26	-0.12	0.28	0.40
0.75	-66.13	102.04	26	183	256.08	265.08	339.52	151.95	-0.07	-0.15	0.35	-0.03
1	-67.28	100.88	26	183	253.77	262.77	337.22	153.3	0.14	-0.10	0.47	-0.29
1.25	-60.68	107.49	26	183	266.98	275.98	350.43	151.06	0.82	0.08	0.30	-0.63

1968-1995 and 2008-2020 time blocks

Fratio	obj_func	obj_func_with_cte	nb_param	nb_data	AIC	AICc	BIC	chi_square	mohnSSB	mohnRec	mohnF25	mohnFplus
0.5	-66.91	101.26	26	183	254.51	263.51	337.96	137.03	-0.07	-0.33	0.91	-0.08
0.625	-67.84	100.33	26	183	252.66	261.66	336.1	141.05	0.02	-0.14	0.42	-0.11
0.75	-68.97	99.19	26	183	250.38	259.38	333.83	147.78	0.04	-0.00	0.07	-0.09
0.875	-68.87	99.3	26	183	250.59	259.59	334.04	152.05	0.05	-0.10	0.30	-0.20
1	-67.28	100.88	26	183	253.77	262.77	337.22	153.3	0.14	-0.10	0.47	-0.29
1.125	-64.54	103.62	26	183	259.25	268.25	342.7	153.01	0.39	0.04	0.35	-0.44
1.25	-57.37	110.79	26	183	273.59	282.59	357.04	151.83	0.30	1.08	-0.17	-0.41

Table 5. A bidimensional profiling of the F-ratios for the first (1968-1995) and the second (2008-2020) time blocks for which the F-ratio is fixed. Values in green and blue show Runs 385 and 418, respectively.

FratioBlock1 \ FratioBlock2	0.25	0.50	0.75	1.00	1.25	1.50
1.50	61.1	28.5	10.9	6	8.9	13.9
1.25	52.8	22.8	7	4.2	8.8	14.7
1.00	40.3	16.3	3.5	3	9.7	16.5
0.75	26.9	9.5	0.8	3	12.4	20.1
0.50	16	3.4	0	4.8	14.2	25.8
0.25	12.3	3.3	3.6	10.1	21.4	32.6

Table 6. Names and fishery definitions of the fleets used for the Stock Synthesis proposed base case (Run 8, SCRS/2022/128). Selectivity: CS: cubic spline; DN: double normal: LG: logistic.* Indices not included in the fit of Run 8.

Fleet Number	Fleet Acronym	Description	Gear	start	end	Selectivity
1	F01_BB_BB_pre2006	BaitBoat (SP, FR) for 1950 to 2006	BaitBoat	1950	2006	CS
2	F02_BB_BB_post2007	BaitBoat (SP, FR) for 2007 to 2020	BaitBoat	2007	2020	CS
3	F03_LL_JPN_EATL_MED	Japanese longline in the East and Mediterranean for 1957 to 2(	Longline	1957	2009	DN
4	F04_LL_JPN_NEATL_pre2009	Japanese longline in the Northeast Atlantic for 1971 to 2009	Longline	1971	2009	DN
5	F05_LL_JPN_NEATL_post2010	Japanese longline in the Northeast Atlantic for 2010 to 2020	Longline	2010	2020	DN
6	F06_LL_OTH	Other countries longliners for 1961 to 2020	Longline	1961	2020	CS
7	F07_PS_NOR	Norwegian purseiners for 1950 to 1986 (/2016-20)	Purseine	1950	2020	LG
8	F08_PS_HRV	Croatian purseiners for 1991 to 2020	Purseine	1991	2020	CS
9	F09_PS_MED_pre2008	Purseiners (SP, FR) for 1966 to 2008 1,3,4Q	Purseine	1966	2007	CS
10	F10_PS_MED_pre2008Q2	Purseiners (SP, FR) for 1966 to 2008 2Q	Purseine	1966	2008	CS
11	F11_PS_MED_post2009	Purseiners (SP, FR) for 2009 to 2020	Purseine	2009	2020	CS
12	F12_PS_OTH	Purseiners other countries	Purseine	1950	2020	CS
13	F13_TP_pre2011	Traps (SP, PT, MA) for 1950 to 2011	Traps	1950	2011	DN
14	F14_TP_post2012	Traps (SP, PT, MA) for 2012 to 2020	Traps	2012	2020	DN
15	F15_TP_OTH	Traps from other countries (DZ, LY, TN, TR, IT)	Traps	1950	2020	DN
16	F16_OTH	Other gears	Other	1950	2020	Mirror F06

Fleet Number	Survey	Area - Type (Units) - Age	start	end	Selectivity
17	S1_MOR_SPN_TP	East Atlantic & Med - CPUE (numbers) - Age 6+	1981	2011	Mirror - F13_TP_pre2011
18	S2_MOR_POR_TP	East Atlantic & Med - CPUE (numbers) - Age 10+	2012	2020	Mirror - F14_TP_post2012
19	S3_SPN_BB1	East Atlantic - CPUE (biomass) - Age 2-3	1952	2006	Mirror - F01_BB_BB_pre2006
20	S4_SPN_FR_BB2	East Atlantic - CPUE (biomass) - Age 3-6	2007	2014	Mirror - F02_BB_BB_post2007
21	S5_JPN_LL_EAtlMed	East Atlantic & Med - CPUE (numbers) - Age 6-10	1975	2009	Mirror - F03_LL_JPN_EATL_MED
22	S6_JPN_LL1_NEA	NEast Atlantic - CPUE (numbers) - Age 4-10	1990	2009	Mirror - F04_LL_JPN_NEATL_pre2009
23	S7_JPN_LL2_NEA	NEast Atlantic - CPUE (numbers) - Age 4-10	2010	2020	Mirror - F05_LL_JPN_NEATL_post2010
24	S8_WMED_LARV	West Med - Survey (numbers) - SSB	2001	2020	SSB
25	S9_FRA_AER1	West Med - Survey (numbers) - Age 2-4	2000	2003	Ages 2-4
26	S10_FRA_AER2	West Med - Survey (numbers) - Age 2-4	2009	2020	Ages 2-4
27	S11_WMED_GBYP_AER	Balearic Sea - Survey (biomass) - SSB	2010	2019	SSB
28*	S12_WCMED_GBYP_AER	WCMed - Survey (biomass) - SSB	2010	2019	SSB
29*	S13_JPN_LL_VAST1	NEast Atlantic - CPUE (numbers) - Age 4-10	1995	2009	Mirror - F04_LL_JPN_NEATL_pre2009
30*	S14_JPN_LL_VAST2	NEast Atlantic - CPUE (numbers) - Age 4-10	2010	2020	Mirror - F05_LL_JPN_NEATL_post2010

Table 7. The list of runs explored for the Stock Synthesis model based on the proposed base case (Run 8, SCRS/2022/128).

Run	Definition	Description of changes
Run 8	Proposed Base Model	Based on Run 82 of EBFT assessment meeting in 2017: 1) Model runs from 1950-2020; 2) Updating information 2016-2020; 3) 16 fishing fleets 4) 11 abundance indices, including the new index GBYP - WMED; 4) All fleet selectivity models were redefined and assumption of logistic selectivity for Norwegian Purseines; 5) Linf fixed at 271 cm; K fixed at 0.233871; 6) M from age0 : 0.82, 0.41. 0.32, 0.26, 0.22, 0.19, 0.17, 0.15, 0.14, 0.13, 0.12, 0.12; age12-20: 0.11; age21-30: 0.1
Run 16	Natural mortality internally estimated	Based on Run 8: 1) Natural mortality is estimated by the model by Lorenzen's method and using Mage20=0.1 as reference age.
Run 16noCAAL	Impact of removing age information	Based on Run 16: 1) Conditional-at-length information excluded.
Run 17	Growth fixed using Ailloud et al. (2017) and no age information included	Based on Run 16: 1) Growth parameters fixed (Ailloud et al., 2017): Linf=271; K=0.22; Richards shape parameter=-0.11; 2) Conditional age-at-length (CAAL) excluded.
Run 18	Growth fixed using WBFT assessment 2021 and no age information included	Based on Run 16: 1) Growth parameters fixed using WBFT assessment 2021 parameters: Linf=284 cm; K=0.295175; Richards parameter=-0.993398; 2) CAAL excluded; 3) Improve selectivity parameters definition.
Run 18CAAL	Impact of including age information	Based on Run 18: 1) Including information of conditional age-at-length.
Run 19	Considering an offset for R0	Based on Run 18: 1) Include an offset for R0 with two periods : 1950-1985 / 1986-2020.
Run 20	Initial Fs estimated by the model	Based on Run 18: 1) initial Fs for fleets 13, 15 and 16 are estimated by the model.
Run 21	Recruitment deviations start in 1988	Based on Run 18: 1) Recruitment deviations estimates start in 1988.
Run 16 reweight	Base model	Based on Run 16: 1) Initial Fs are estimated by the model; 2) K is estimated by the model; 3) Selectivity parameters for some fleets were re-defined and priors included ; 4) Model was balanced (length composition reweighting) using Francis' method

Table 8. Parameter estimates, asymptotic standard errors, and assigned priors for the Stock Synthesis base model (run 16 reweight).

Parameter	Value	Phase	Min	Max	Init	Status	Parm_StDev	Gradient	Pr_type	Prior	Pr_SD
L_at_Amin_Fem_GP_1	54.448	2	40	60	54.5407	OK	0.269	3.81E-06	No_prior	NA	NA
VonBert_K_Fem_GP_1	0.213	2	0.15	0.3	0.215202	OK	0.004	7.47E-06	No_prior	NA	NA
Richards_Fem_GP_1	-0.144	3	-1	0.5	-0.167415	OK	0.045	6.94E-06	No_prior	NA	NA
CV_young_Fem_GP_1	0.075	3	0.05	0.15	0.0743705	OK	0.001	1.57E-07	No_prior	NA	NA
CV_old_Fem_GP_1	0.056	3	0.05	0.15	0.0560185	OK	0.002	2.29E-08	No_prior	NA	NA
SR_LN(R0)	8.062	1	6	15	8.06135	OK	0.029	5.85E-05	No_prior	NA	NA
InitF_seas_1_flt_13F13_TP_pre2011	0.024	1	0	0.2	0.0233254	OK	0.007	-4.61E-07	No_prior	NA	NA
InitF_seas_1_flt_15F15_TP_OTH	0.004	1	0	0.2	0.0043933	OK	0.001	-4.08E-07	No_prior	NA	NA
InitF_seas_1_flt_16F16_OTH	0.004	1	0	0.2	0.0035386	OK	0.001	-1.91E-07	No_prior	NA	NA
SizeSpline_GradHi_F01_BB_BB_pre2006(1)	-0.250	2	-1	0.5	-0.251612	OK	0.059	-5.46E-06	No_prior	NA	NA
SizeSpline_Val_1_F01_BB_BB_pre2006(1)	-6.343	3	-10	0	-6.34335	OK	0.630	-6.47E-07	Normal	-6.3434	0.63
SizeSpline_Val_2_F01_BB_BB_pre2006(1)	-3.755	3	-8	1	-3.77889	OK	0.707	5.42E-07	No_prior	NA	NA
SizeSpline_Val_3_F01_BB_BB_pre2006(1)	-3.110	3	-8	1	-3.12907	OK	0.682	-4.93E-06	No_prior	NA	NA
SizeSpline_Val_4_F01_BB_BB_pre2006(1)	-3.454	3	-8	1	-3.46757	OK	0.677	3.68E-06	No_prior	NA	NA
SizeSpline_Val_5_F01_BB_BB_pre2006(1)	-10.674	3	-25	1	-10.7573	OK	1.531	4.15E-06	No_prior	NA	NA
SizeSpline_GradHi_F02_BB_BB_post2007(2)	-0.200	3	-1	1	-0.198329	OK	0.146	1.26E-09	No_prior	NA	NA
SizeSpline_Val_1_F02_BB_BB_post2007(2)	-6.781	3	-10	-2	-6.7809	OK	0.680	-4.58E-09	Normal	-6.781	0.68
SizeSpline_Val_2_F02_BB_BB_post2007(2)	-4.352	3	-9	0	-4.34227	OK	0.791	-9.45E-09	No_prior	NA	NA
SizeSpline_Val_3_F02_BB_BB_post2007(2)	-3.620	3	-8	1	-3.61553	OK	0.829	-3.58E-09	No_prior	NA	NA
SizeSpline_Val_4_F02_BB_BB_post2007(2)	-3.783	3	-8	1	-3.77471	OK	0.834	-8.65E-09	No_prior	NA	NA
SizeSpline_Val_5_F02_BB_BB_post2007(2)	-7.122	3	-15	1	-7.06553	OK	2.115	-8.37E-09	No_prior	NA	NA
Size_DblN_peak_F03_LL_JPN_EATL_MED(3)	244.332	3	180	270	242.404	OK	7.908	5.52E-08	No_prior	NA	NA
Size_DblN_top_logit_F03_LL_JPN_EATL_MED(3)	-9.108	3	-20	-5	-9.10815	OK	0.910	-4.74E-09	Normal	-9.1074	0.91
Size_DblN_ascend_se_F03_LL_JPN_EATL_MED(3)	7.805	2	5	10	7.78574	OK	0.201	-1.88E-08	No_prior	NA	NA
Size_DblN_descend_se_F03_LL_JPN_EATL_MED(3)	5.986	2	4	10	6.12706	OK	0.973	4.94E-08	No_prior	NA	NA
Size_DblN_peak_F04_LL_JPN_NEATL_pre2009(4)	202.787	3	150	220	201.866	OK	7.522	2.63E-08	No_prior	NA	NA
Size_DblN_top_logit_F04_LL_JPN_NEATL_pre2009(4	-9.219	3	-20	-5	-9.21939	OK	0.920	-1.45E-10	Normal	-9.219	0.92
Size_DblN_ascend_se_F04_LL_JPN_NEATL_pre2009(	7.559	2	5	10	7.54912	OK	0.229	-3.57E-08	No_prior	NA	NA
Size_DblN_descend_se_F04_LL_JPN_NEATL_pre2009	7.053	2	5	10	7.07304	OK	0.665	1.20E-08	No_prior	NA	NA
Size_DblN_peak_F05_LL_JPN_NEATL_post2010(5)	200.402	3	150	220	200.506	OK	2.801	2.83E-08	No_prior	NA	NA
Size_DblN_top_logit_F05_LL_JPN_NEATL_post2010(	-8.387	3	-15	-5	-8.38697	OK	0.840	-3.75E-08	Normal	-8.386	0.84
Size_DblN_ascend_se_F05_LL_JPN_NEATL_post2010	5.922	2	3	9	5.92393	OK	0.232	-8.02E-09	No_prior	NA	NA
Size_DblN_descend_se_F05_LL_JPN_NEATL_post201	6.470	2	4	9	6.46892	OK	0.275	2.81E-09	No_prior	NA	NA
SizeSpline_GradHi_F06_LL_OTH(6)	-0.153	4	-0.4	0.01	-0.141672	OK	0.087	-5.20E-08	No_prior	NA	NA
SizeSpline_Val_1_F06_LL_OTH(6)	4.032	3	0	8	4.03158	OK	0.400	-3.50E-08	Normal	4.03158	0.4
SizeSpline_Val_2_F06_LL_OTH(6)	8.817	3	0	20	8.68987	OK	1.033	-4.99E-07	No_prior	NA	NA
SizeSpline_Val_3_F06_LL_OTH(6)	9.190	3	0	20	9.03224	OK	0.878	-3.28E-07	No_prior	NA	NA
SizeSpline_Val_4_F06_LL_OTH(6)	10.729	2	0	20	10.5746	OK	0.976	7.19E-08	No_prior	NA	NA
SizeSpline_Val_5_F06_LL_OTH(6)	10.718	2	0	20	10.406	OK	1.313	8.40E-07	No_prior	NA	NA
SizeSpline_GradHi_F08_PS_HRV(8)	-0.779	4	-1.5	0	-0.776449	OK	0.145	-5.82E-08	No_prior	NA	NA
SizeSpline_Val_1_F08_PS_HRV(8)	-36.985	3	-60	-10	-37.0304	OK	3.729	-1.83E-07	Normal	-37.478	3.8
SizeSpline_Val_2_F08_PS_HRV(8)	-7.406	2	-25	7	-7.44049	OK	3.675	7.98E-08	No_prior	NA	NA
SizeSpline_Val_3_F08_PS_HRV(8)	-38.306	2	-80	-10	-38.2607	OK	3.729	7.35E-08	Normal	-37.813	3.8
SizeSpline_GradHi_F09_PS_MED_pre2008(9)	-0.049	4	-0.5	0.1	-0.04791	OK	0.055	-1.01E-06	No_prior	NA	NA
SizeSpline_Val_1_F09_PS_MED_pre2008(9)	-1.410	3	-8	1	-1.42879	OK	1.394	-2.83E-07	No_prior	NA	NA
SizeSpline_Val_2_F09_PS_MED_pre2008(9)	-0.376	3	-4	4	-0.406692	OK	1.348	-8.53E-08	No_prior	NA	NA
SizeSpline_Val_3_F09_PS_MED_pre2008(9)	0.799	2	-3	4	0.772305	OK	1.358	-1.90E-06	No_prior	NA	NA
SizeSpline_Val_4_F09_PS_MED_pre2008(9)	0.665	2	-2	4	0.630642	OK	1.345	1.11E-06	No_prior	NA	NA
SizeSpline_Val_5_F09_PS_MED_pre2008(9)	-3.045	2	-5	-1	-3.04521	OK	0.300	5.26E-07	Normal	-3.0452	0.3
SizeSpline_GradHi_F10_PS_MED_pre2008Q2(10)	-0.163	4	-0.5	0	-0.157989	OK	0.063	-6.90E-08	No_prior	NA	NA
SizeSpline_Val_1_F10_PS_MED_pre2008Q2(10)	-77.869	2	-100	-10	-77.8917	OK	1.935	-1.69E-07	Normal	-77.997	7.8
SizeSpline_Val_2_F10_PS_MED_pre2008Q2(10)	-4.796	2	-25	20	-4.79567	OK	0.479	-5.24E-07	Normal	-4.7953	0.48
SizeSpline_Val_3_F10_PS_MED_pre2008Q2(10)	-3.168	2	-25	20	-3.16805	OK	0.601	-4.32E-07	No_prior	NA	NA
SizeSpline_Val_4_F10_PS_MED_pre2008Q2(10)	-2.723	2	-25	20	-2.71833	OK	0.622	-6.92E-07	No_prior	NA	NA
SizeSpline_Val_5_F10_PS_MED_pre2008Q2(10)	-3.168	2	-25	20	-3.18056	OK	0.633	-5.59E-07	No_prior	NA	NA
SizeSpline_Val_6_F10_PS_MED_pre2008Q2(10)	-3.125	2	-25	20	-3.17715	OK	0.661	5.69E-07	No_prior	NA	NA
SizeSpline_Val_7_F10_PS_MED_pre2008Q2(10)	-3.214	2	-25	20	-3.21264	OK	0.797	1.72E-06	No_prior	NA	NA
SizeSpline_GradHi_F11_PS_MED_post2009(11)	-0.045	4	-0.4	0.1	-0.045029	OK	0.044	-2.80E-09	No_prior	NA	NA
SizeSpline_Val_1_F11_PS_MED_post2009(11)	-3.991	4	-6	2	-4.01985	OK	0.513	1.39E-09	No_prior	NA	NA
SizeSpline_Val_2_F11_PS_MED_post2009(11)	-1.102	4	-3	2	-1.12285	OK	0.454	-6.59E-09	No_prior	NA	NA
SizeSpline_Val_3_F11_PS_MED_post2009(11)	0.150	4	-1	3	0.127214	OK	0.438	7.17E-09	No_prior	NA	NA
SizeSpline_Val_4_F11_PS_MED_post2009(11)	-1.306	4	-3	0	-1.30644	OK	0.130	2.84E-09	Normal	-1.3065	0.13
SizeSpline_GradHi_F12_PS_OTH(12)	-0.128	4	-0.3	0.1	-0.121342	OK	0.051	-2.79E-07	No_prior	NA	NA
SizeSpline_Val_1_F12_PS_OTH(12)	-3.600	2	-8	0	-3.59953	OK	0.360	-1.30E-07	Normal	-3.5994	0.36
SizeSpline_Val_2_F12_PS_OTH(12)	0.135	2	-4	4	0.111955	OK	0.538	-7.37E-07	No_prior	NA	NA
SizeSpline_Val_3_F12_PS_OTH(12)	-0.391	2	-4	4	-0.409651	OK	0.512	-3.88E-07	No_prior	NA	NA
SizeSpline_Val_4_F12_PS_OTH(12)	0.894	2	-2	3	0.868864	OK	0.544	1.88E-07	No_prior	NA	NA
SizeSpline_Val_5_F12_PS_OTH(12)	0.154	2	-5	1	0.0669469	OK	0.773	4.58E-07	No_prior	NA	NA
Size_DblN_peak_F13_TP_pre2011(13)	230.277	3	180	250	229.733	OK	7.970	3.24E-07	No_prior	NA	NA
Size_DblN_top_logit_F13_TP_pre2011(13)	-9.425	3	-15	-5	-9.42526	OK	0.940	1.28E-08	Normal	-9.425	0.94
Size_DblN_ascend_se_F13_TP_pre2011(13)	7.422	2	5	10	7.42766	OK	0.296	-3.55E-07	No_prior	NA	NA
Size_DblN_descend_se_F13_TP_pre2011(13)	5.573	2	4	9	5.72499	OK	0.979	8.73E-08	No_prior	NA	NA
Size_DblN_peak_F14_TP_post2012(14)	226.793	3	180	260	226.896	OK	12.292	1.43E-09	No_prior	NA	NA
Size_DblN_top_logit_F14_TP_post2012(14)	-8.931	3	-15	-5	-8.93106	OK	0.890	-5.52E-08	Normal	-8.9308	0.89
Size_DblN_ascend_se_F14_TP_post2012(14)	7.429	2	5	10	7.4075	OK	0.486	-5.18E-08	No_prior	NA	NA
Size_DblN_descend_se_F14_TP_post2012(14)	7.436	2	3	10	7.42223	OK	1.801	-5.50E-09	No_prior	NA	NA
Size_DblN_peak_F15_TP_OTH(15)	143.586	3	110	180	143.136	OK	6.622	2.56E-07	No_prior	NA	NA
Size_DblN_top_logit_F15_TP_OTH(15)	-7.625	3	-12	-4	-7.6247	OK	0.761	-4.47E-10	Normal	-7.627	0.76
Size_DblN_ascend_se_F15_TP_OTH(15)	6.196	2	4	8	6.17412	OK	0.437	-9.70E-08	No_prior	NA	NA
Size_DblN_descend_se_F15_TP_OTH(15)	9.413	2	7	10	9.42498	OK	0.360	1.51E-07	No_prior	NA	NA

Table 9. Estimates of spawning stock biomass (SSB), biomass, recruitments (age 1), exploitation rate, fishing mortalities for ages 2 to 5 and ages older than 10 of VPA (run 385), Stock Synthesis (run 16 reweight), and ASAP (base run 2) for East Atlantic and Mediterranean bluefin tuna with 95% confidence intervals.

				SSB (t)					
Year	VPA_Run385	VPA_LCI	VPA_UCI	SS3 Run16 reweight	SS3_LCI	SS3_UCI	ASAP24_CV20%	ASAP_LCI	ASAP_UCI
1950				948312	867727	1028897			
1951				906005	828706	983304			
1952				850853	776821	924885			
1953				791021	720192	861850			
1954				731864	664198	799530			
1955				665532	600969	730095			
1956				611613	550024	673202			
1957				554599	495826	613372			
1958				503476	447331	559621			
1959				462140	408336	515944			
1960				422455	370587	474323			
1961				385462	335255	435669			
1962				348694	299940	397448			
1963				325627	278144	373110			
1964				303115	256728	349502			
1965				283127	237557	328697			
1966				269193	224367	314019			
1967				251332	207169	295495			
1968	239886	225595	254177	241577	198041	285113	298517	167814	429220
1969	268535	251363	285707	227349	184715	269983	302262	181636	422888
1970	289262	269871	308653	217305	175684	258926	312785	193123	432447
1971	312317	290725	333909	209343	168730	249956	320678	203842	437514
1972	338769	314753	362785	201616	162110	241122	323296	215647	430945
1973	357986	332087	383885	196387	157949	234825	337840	230996	444684
1974	361138	334205	388071	183091	145780	220402	348278	246199	450357
1975	390251	359828	420674	171307	135172	207442	333246	244870	421622
1976	341777	313755	369799	160201	125261	195141	331347	246561	416133
1977	348119	318087	378151	156965	123170	190760	328222	246333	410111
1978	324933	295734	354132	154088	121462	186714	330418	252571	408265
1979	306248	277742	334754	152885	121440	184330	339616	261598	417634
1980	285850	258232	313468	149085	118911	179259	329467	258836	400098
1981	262676	236270	289082	146804	118012	175596	325726	258523	392929
1982	259767	232305	287229	137017	109793	164241	312538	249287	375789
1983	238255	211413	265097	128455	102903	154007	298936	239223	358649
1984	225662	198370	252954	117831	94055	141607	284182	227324	341040
1985	221093	192433	249753	109679	87692	131666	269586	215923	323249
1986	218158	187975	248341	105891	85688	126094	256107	204673	307541
1987	198189	169056	227322	103146	84604	121688	258815	206710	310920
1988	193336	162974	223698	96442	79603	113280	247444	197315	297573
1989	190146	158177	222115	95675	80539	110811	235190	186894	283486
1990	179195	147217	211173	94336	80723	107950	225334	178841	271827
1991	169154	137258	201050	97337	85067	109608	218791	173580	264002
1992	179847	145221	214473	103931	92927	114935	210975	167226	254724
1993	184727	148707	220747	118599	108317	128881	205841	163280	248402
1994	176157	140348	211966	122636	112698	132574	197922	158506	237338
1995	177291	138244	216338	119190	109280	129100	195195	156901	233489
1996	180321	139522	221120	119528	109445	129611	203174	163998	242350
1997	187843	148655	227031	124364	113815	134913	205358	165639	245077
1998	204471	162519	246423	133042	122166	143918	230288	182170	278406
1999	212993	173578	252408	132804	121870	143738	202259	163055	241463
2000	212344	176190	248498	130192	118938	141446	204723	165307	244139
2001	215239	180808	249670	125693	114371	137015	189040	153088	224992
2002	230005	196468	263542	120564	109734	131394	183762	148574	218950
2003	232150	202096	262204	118414	108011	128817	174179	141061	207297
2004	225485	195874	255096	114524	104529	124519	165248	133808	196688
2005	217045	186252	247838	114978	105440	124516	156222	126836	185608
2006	208083	174617	241549	117273	107296	127250	154393	125397	183389
2007	196382	159317	233447	114069	101055	127083	152852	123076	182628
2008	197695	156547	238843	132993	114961	151025	163178	130593	195763
2009	198233	152836	243630	160552	135876	185228	184320	147560	221080
2010	205366	155021	255711	196484	164627	228341	215737	173309	258165
2011	225260	167243	283277	228182	189928	266436	250257	201341	299173
2012	233559	170022	297096	256261	212004	300518	285616	230667	340565
2013	240117	170593	309641	282773	232465	333081	326757	263065	390449
2014	249978	172102	327854	310567	254521	366613	362876	291232	434520
2015	269948	179081	360815	334093	272908	395278	400688	319724	481652
2016	294593	186219	402967	365250	297344	433156	447932	355971	539893
2017	320202	191591	448813	396367	320774	471960	502611	396985	608237
2018	354918	198455	511381	425000	340473	509527	545825	427915	663735
2019	396904	209603	584205	453514	357174	549854	579404	449930	708878
2020	444216	227399	661033	484878	371370	598386	626966	481863	772069

Table 9. Continued.

				Biomass (t)					
Year	VPA_Run385	VPA_LCI	VPA_UCI	SS3 Run16 reweight	SS3_LCI	SS3_UCI	ASAP24_CV20%	ASAP_LCI	ASAP_UCI
1950				961594	881009	1042179			
1951				918292	840992	995591			
1952				862914	788882	936947			
1953				804225	733396	875055			
1954				746866	679199	814532			
1955				681302	616740	745865			
1956				628965	567376	690555			
1957				572696	513923	631468			
1958				520233	464087	576378			
1959				477031	423227	530834			
1960				436108	384241	487976			
1961				396765	346557	446972			
1962				358879	310125	407633			
1963				336702	289218	384185			
1964				317686	271300	364073			
1965				299251	253681	344820			
1966				283249	238423	328075			
1967				263853	219690	308015			
1968	285600	268262	302938	251123	207587	294659	362371	223417	501325
1969	297400	278321	316479	238294	195660	280927	357764	229245	486283
1970	304400	284085	324715	230291	188670	271912	365750	238773	492727
1971	331600	308854	354346	223244	182631	263858	384540	260766	508314
1972	356000	330943	381057	216633	177127	256140	386733	272855	500611
1973	377400	350178	404622	213581	175143	252018	402431	289382	515480
1974	381800	353357	410243	202378	165067	239689	417673	309495	525851
1975	412300	380094	444506	190396	154261	226531	397801	303833	491769
1976	366600	336478	396722	177859	142919	212798	393769	303531	484007
1977	371400	339330	403470	169919	136124	203713	389094	301939	476249
1978	344200	313269	375131	166049	133422	198675	386478	303635	469321
1979	325900	295598	356202	165475	134030	196919	393436	310467	476405
1980	301700	272692	330708	163590	133416	193764	380987	305819	456155
1981	281300	253316	309284	161668	132876	190460	374961	303411	446511
1982	283200	253651	312749	153533	126309	180756	368732	301277	436187
1983	264300	235149	293451	145627	120075	171179	362486	298369	426603
1984	254100	224118	284082	134629	110852	158405	349283	287960	410606
1985	245700	214354	277046	127890	105903	149877	328230	270239	386221
1986	244300	211429	277171	125332	105130	145535	316944	261015	372873
1987	223300	191761	254839	125803	107261	144345	315631	259267	371995
1988	223300	190457	256143	121229	104390	138067	310991	256501	365481
1989	226400	191841	260959	127452	112316	142588	301592	248748	354436
1990	218900	184538	253262	138832	125219	152446	297807	246747	348867
1991	219400	185016	253784	147408	135138	159679	299976	249900	350052
1992	234100	196712	271488	155340	144336	166344	301427	252658	350196
1993	239400	200550	278250	167310	157028	177592	310540	262951	358129
1994	242100	203356	280844	174028	164090	183966	330543	285126	375960
1995	251700	210229	293171	177324	167415	187234	320379	275979	364779
1996	250100	208229	291971	178964	168881	189046	323726	278278	369174
1997	255500	216216	294784	179717	169168	190266	320596	273848	367344
1998	267600	226160	309040	177127	166251	188002	327305	271425	383185
1999	277300	239591	315009	178472	167538	189407	292167	245639	338695
2000	277800	242935	312665	176184	164930	187439	293800	247011	340589
2001	275700	241285	310115	173606	162284	184928	272660	229536	315784
2002	281400	246067	316733	170753	159923	181583	269205	226591	311819
2003	277600	243534	311666	172098	161694	182501	261214	220438	301990
2004	272300	237811	306789	172040	162045	182035	255890	216243	295537
2005	263000	226597	299403	172787	163249	182324	243436	205708	281164
2006	249500	210372	288628	172988	163011	182965	246140	207991	284289
2007	233000	189982	276018	156379	143365	169393	248928	209118	288738
2008	225000	177905	272095	171490	153459	189522	256617	213619	299615
2009	226500	173826	279174	192604	167928	217280	275425	227225	323625
2010	234900	175896	293904	223477	191620	255335	306192	250904	361480
2011	258200	189380	327020	254248	215994	292502	341184	278676	403692
2012	273800	195637	351963	287370	243113	331626	386313	315784	456842
2013	280100	194852	365348	320402	270094	370710	435445	354477	516413
2014	301100	201934	400266	353639	297593	409685	504589	409809	599369
2015	328100	211875	444325	386199	325015	447384	530234	428594	631874
2016	381200	232644	529756	421685	353780	489591	577169	464257	690081
2017	400400	232222	568578	451101	375508	526694	650694	520309	781079
2018	430700	234818	626582	480323	395796	564850	705032	559965	850099
2019	460200	235078	685322	505672	409331	602012	743004	585008	901000
2020	472600	225317	719883	527340	413832	640847	800251	624002	976500

Table 9. Continued.

				R(age1)					
Year	VPA_Run385	VPA_LCI	VPA_UCI	SS3 Run16 reweight	SS3_LCI	SS3_UCI	ASAP24_CV20%	ASAP_LCI	ASAP_UCI
1950				619340					
1951				595190					
1952				683551					
1953				809974					
1954				969926					
1955				1210680					
1956				1021330					
1957				897374					
1958				1036640					
1959				767721					
1960				524917					
1961				464818					
1962				499026					
1963				579710					
1964				724594					
1965				1306730					
1966				527076					
1967				307412					
1968	952569	915938	1016073	663237			1114800	773682	1455918
1969	761415	737704	802568	545538			1185090	820020	1550160
1970	959166	931464	1007098	860638			1775830	1299726	2251934
1971	1347759	1303575	1424151	762649			1879110	1383269	2374951
1972	945180	917505	993069	954843			1482460	1062079	1902841
1973	1263823	1203595	1368030	649778			1060880	728229	1393531
1974	1436519	1383612	1528002	1550120			1796200	1328936	2263464
1975	1162414	1105603	1260690	885876			1137200	788888	1485512
1976	1366369	1298247	1484223	747970			1396070	1008578	1783562
1977	900868	863508	965432	457504			1253460	891389	1615531
1978	769933	738386	824437	709932			1185260	856019	1514501
1979	811534	764631	892604	691637			643851	416334	871368
1980	1225461	1174429	1313715	825704			1259560	920519	1598601
1981	1171809	1119077	1263061	804001			1053460	736606	1370314
1982	1481732	1406279	1612379	679473			1363100	982546	1743654
1983	2267481	2175796	2426260	1338200			2188650	1695044	2682256
1984	1250277	1185178	1363027	937058			1231250	873021	1589479
1985	1207180	1133834	1334320	738827			1035500	711845	1359155
1986	2007394	1933999	2134806	1346330			2031710	1554666	2508754
1987	1539480	1464895	1669235	1422790			1295980	915583	1676377
1988	2616677	2551657	2723191	1573080			2203320	1670455	2736185
1989	2649847	2543468	2799286	1297950			2072780	1532584	2612976
1990	2923355	2847272	3035257	3232230			2576500	1932189	3220811
1991	3292533	3204159	3412402	3913320			3042080	2268252	3815908
1992	3850347	3677997	4041774	1642510			3949560	2962680	4936440
1993	4135862	3994585	4283253	2112840			4779210	3619498	5938922
1994	4069719	3989614	4150731	3386090			4396610	3331703	5461517
1995	4631145	4571214	4711224	4623240			4445930	3379533	5512327
1996	4244162	4180298	4299238	2381140			4767840	3650111	5885569
1997	3210173	3145074	3275715	3050570			3327840	2468576	4187104
1998	3826774	3662573	4022859	2547790			2463860	1815786	3111934
1999	3448325	3181903	3767176	1503280			2148140	1595302	2700978
2000	2449526	2344684	2648618	3811770			2195220	1619529	2770911
2001	2195305	2084629	2405450	2594570			2120560	1553924	2687196
2002	2562746	2372160	2924570	2679550			2125990	1574642	2677338
2003	2118730	1978749	2384160	2864030			2490870	1874489	3107251
2004	2672458	2485444	3026745	4119080			3233760	2529356	3938164
2005	1823561	1647212	2157664	2863690			2472170	1859278	3085062
2006	1466805	1310683	1762769	2863870			2445930	1805108	3086752
2007	1364880	1193036	1690647	2514990			2349040	1692009	3006071
2008	1347949	1094584	1828608	1382370			2328480	1618921	3038039
2009	1342315	1067024	1864691	902934			2319600	1595400	3043800
2010	1408294	1090797	2011138	1314750			2123250	1404342	2842158
2011	1722277	1286748	2549582	1604990			2477390	1610952	3343828
2012	2218714	1573658	3444400	874240			2749590	1826332	3672848
2013	2706381	1848570	4099031	2264720			3303090	2156372	4449808
2014	3315854	2207793	5019920	2702610			4612340	3110647	6114033
2015	3421524	2175235	5518785	2223710			2572110	1576920	3567300
2016	4475371	3022224	7682137	2404670			2306140	1390820	3221460
2017	4552691	3516704	8283249	3519150			5187660	3376346	6998974
2018				1712790			5339560	2863492	7815628
2019				2505140			2592230	835639	4348821
2020				1742250			1902160	148195	3656125

Table 9. Continued.

	Exploitation rate								
Year	VPA_Run385	VPA_LCI	VPA_UCI	SS3 Run16 reweight	SS3_LCI	SS3_UCI	ASAP24_C\	ASAP_LCI	ASAP_UCI
1950				0.03	0.02	0.03			
1951				0.03	0.03	0.03			
1952				0.04	0.04	0.05			
1953				0.05	0.04	0.05			
1954				0.05	0.04	0.05			
1955				0.06	0.05	0.06			
1956				0.04	0.04	0.05			
1957				0.06	0.05	0.06			
1958				0.06	0.05	0.06			
1959				0.05	0.05	0.06			
1960				0.05	0.05	0.06			
1961				0.06	0.06	0.07			
1962				0.07	0.06	0.08			
1963				0.05	0.04	0.05			
1964				0.05	0.04	0.06			
1965				0.05	0.05	0.06			
1966				0.05	0.04	0.06			
1967				0.07	0.06	0.08			
1968	0.05	0.05	0.04	0.05	0.04	0.06	0.04	0.03	0.07
1969	0.05	0.05	0.05	0.06	0.05	0.07	0.04	0.03	0.07
1970	0.04	0.04	0.03	0.05	0.04	0.05	0.03	0.02	0.05
1971	0.03	0.04	0.03	0.05	0.04	0.06	0.03	0.02	0.04
1972	0.03	0.03	0.03	0.05	0.04	0.06	0.03	0.02	0.04
1973	0.03	0.03	0.03	0.05	0.04	0.06	0.03	0.02	0.04
1974	0.05	0.05	0.05	0.09	0.07	0.11	0.05	0.04	0.06
1975	0.05	0.05	0.05	0.11	0.09	0.13	0.05	0.04	0.07
1976	0.06	0.06	0.05	0.12	0.09	0.14	0.06	0.05	0.07
1977	0.05	0.05	0.04	0.11	0.09	0.13	0.05	0.04	0.06
1978	0.04	0.05	0.04	0.09	0.07	0.11	0.04	0.03	0.05
1979	0.04	0.04	0.03	0.07	0.06	0.09	0.03	0.03	0.04
1980	0.05	0.05	0.04	0.08	0.07	0.10	0.04	0.03	0.05
1981	0.05	0.05	0.04	0.09	0.07	0.10	0.04	0.03	0.05
1982	0.08	0.08	0.07	0.14	0.11	0.16	0.06	0.05	0.08
1983	0.08	0.09	0.07	0.14	0.12	0.17	0.06	0.05	0.08
1984	0.10	0.10	0.08	0.17	0.14	0.20	0.08	0.06	0.09
1985	0.09	0.10	0.08	0.16	0.14	0.19	0.07	0.06	0.09
1986	0.08	0.09	0.07	0.15	0.13	0.18	0.06	0.05	0.08
1987	0.08	0.09	0.07	0.15	0.12	0.17	0.06	0.05	0.08
1988	0.11	0.12	0.09	0.19	0.16	0.22	0.08	0.07	0.10
1989	0.09	0.10	0.08	0.17	0.15	0.20	0.08	0.06	0.09
1990	0.11	0.12	0.09	0.19	0.16	0.21	0.08	0.07	0.10
1991	0.12	0.13	0.10	0.19	0.17	0.21	0.09	0.08	0.11
1992	0.13	0.15	0.11	0.22	0.20	0.23	0.11	0.09	0.13
1993	0.14	0.16	0.12	0.22	0.21	0.23	0.11	0.09	0.13
1994	0.19	0.21	0.16	0.28	0.27	0.29	0.13	0.12	0.15
1995	0.19	0.21	0.15	0.27	0.26	0.29	0.14	0.12	0.16
1996	0.20	0.23	0.17	0.29	0.28	0.31	0.16	0.14	0.18
1997	0.20	0.23	0.17	0.29	0.27	0.30	0.16	0.14	0.19
1998	0.18	0.21	0.15	0.28	0.26	0.29	0.13	0.11	0.16
1999	0.17	0.20	0.15	0.28	0.27	0.30	0.14	0.12	0.17
2000	0.18	0.20	0.15	0.28	0.27	0.29	0.14	0.12	0.17
2001	0.18	0.20	0.15	0.28	0.27	0.30	0.15	0.13	0.18
2002	0.17	0.19	0.15	0.29	0.27	0.30	0.16	0.14	0.19
2003	0.18	0.20	0.15	0.29	0.28	0.31	0.17	0.15	0.20
2004	0.18	0.20	0.15	0.29	0.28	0.30	0.16	0.14	0.19
2005	0.19	0.21	0.16	0.29	0.28	0.31	0.15	0.13	0.17
2006	0.20	0.22	0.16	0.29	0.27	0.31	0.15	0.13	0.18
2007	0.26	0.30	0.21	0.35	0.32	0.38	0.18	0.15	0.21
2008	0.11	0.13	0.08	0.16	0.14	0.17	0.09	0.08	0.11
2009	0.09	0.10	0.07	0.12	0.10	0.13	0.07	0.06	0.08
2010	0.05	0.06	0.04	0.06	0.05	0.07	0.04	0.03	0.04
2011	0.04	0.05	0.03	0.04	0.04	0.05	0.03	0.02	0.03
2012	0.04	0.05	0.03	0.04	0.04	0.05	0.03	0.02	0.03
2013	0.05	0.06	0.03	0.05	0.04	0.05	0.03	0.03	0.04
2014	0.04	0.06	0.03	0.04	0.03	0.05	0.03	0.02	0.03
2015	0.05	0.06	0.03	0.05	0.04	0.05	0.03	0.03	0.04
2016	0.05	0.07	0.03	0.05	0.04	0.06	0.03	0.03	0.04
2017	0.06	0.08	0.04	0.06	0.05	0.07	0.04	0.03	0.05
2018	0.06	0.09	0.04	0.06	0.05	0.07	0.04	0.03	0.05
2019	0.07	0.10	0.04	0.06	0.05	0.08	0.04	0.03	0.05
2020	0.07	0.11	0.04	0.07	0.05	0.08	0.04	0.04	0.06

Table 9. Continued.

	F ages 2-5								
Year	VPA_Run3!	VPA_LCI	VPA_UCI	SS3 Run16	SS3_LCI	SS3_UCI	ASAP24_CV20%	ASAP_LCI	ASAP_UCI
1950				0.05	0.04	0.06			
1951				0.10	0.07	0.13			
1952				0.16	0.10	0.22			
1953				0.18	0.11	0.24			
1954				0.26	0.16	0.35			
1955				0.31	0.20	0.42			
1956				0.15	0.10	0.20			
1957				0.16	0.11	0.20			
1958				0.15	0.11	0.19			
1959				0.13	0.09	0.16			
1960				0.05	0.04	0.06			
1961				0.06	0.05	0.07			
1962				0.07	0.05	0.08			
1963				0.06	0.05	0.08			
1964				0.06	0.05	0.08			
1965				0.08	0.06	0.10			
1966				0.15	0.13	0.18			
1967				0.11	0.09	0.13			
1968	0.05	0.04	0.05	0.11	0.08	0.15	0.07		
1969	0.04	0.04	0.05	0.12	0.10	0.15	0.08		
1970	0.04	0.04	0.04	0.15	0.12	0.18	0.05		
1971	0.05	0.05	0.05	0.18	0.13	0.22	0.05		
1972	0.08	0.08	0.09	0.13	0.10	0.15	0.05		
1973	0.06	0.06	0.07	0.14	0.11	0.16	0.05		
1974	0.13	0.12	0.14	0.11	0.09	0.13	0.08		
1975	0.07	0.07	0.08	0.11	0.09	0.12	0.09		
1976	0.12	0.11	0.13	0.13	0.10	0.15	0.10		
1977	0.08	0.07	0.09	0.14	0.12	0.16	0.09		
1978	0.08	0.07	0.08	0.13	0.11	0.15	0.07		
1979	0.07	0.06	0.07	0.11	0.09	0.12	0.06		
1980	0.08	0.07	0.08	0.10	0.09	0.12	0.07		
1981	0.08	0.07	0.09	0.10	0.08	0.11	0.07		
1982	0.14	0.13	0.15	0.15	0.12	0.18	0.11		
1983	0.12	0.11	0.13	0.19	0.16	0.22	0.14		
1984	0.16	0.14	0.17	0.19	0.17	0.22	0.16		
1985	0.21	0.19	0.23	0.21	0.17	0.24	0.16		
1986	0.12	0.10	0.13	0.19	0.16	0.22	0.14		
1987	0.16	0.14	0.17	0.19	0.16	0.22	0.14		
1988	0.17	0.15	0.18	0.23	0.20	0.27	0.19		
1989	0.17	0.15	0.19	0.18	0.16	0.21	0.17		
1990	0.20	0.18	0.21	0.16	0.14	0.18	0.19		
1991	0.19	0.17	0.20	0.15	0.13	0.17	0.20		
1992	0.18	0.16	0.18	0.15	0.14	0.17	0.22		
1993	0.22	0.21	0.23	0.19	0.17	0.20	0.22		
1994	0.15	0.14	0.15	0.24	0.22	0.27	0.25		
1995	0.13	0.12	0.14	0.23	0.20	0.25	0.25		
1996	0.20	0.19	0.21	0.22	0.20	0.24	0.30		
1997	0.18	0.17	0.19	0.21	0.20	0.23	0.30		
1998	0.22	0.21	0.22	0.22	0.20	0.24	0.26		
1999	0.15	0.15	0.16	0.24	0.21	0.27	0.14		
2000	0.14	0.13	0.14	0.28	0.24	0.31	0.14		
2001	0.16	0.15	0.17	0.23	0.20	0.26	0.16		
2002	0.14	0.13	0.15	0.28	0.24	0.31	0.16		
2003	0.14	0.13	0.15	0.21	0.18	0.24	0.18		
2004	0.14	0.12	0.15	0.24	0.21	0.26	0.17		
2005	0.11	0.09	0.12	0.22	0.20	0.25	0.15		
2006	0.12	0.10	0.13	0.21	0.18	0.24	0.09		
2007	0.18	0.14	0.20	0.32	0.28	0.37	0.11		
2008	0.15	0.12	0.17	0.08	0.06	0.09	0.06		
2009	0.05	0.04	0.06	0.04	0.03	0.05	0.04		
2010	0.05	0.04	0.06	0.02	0.02	0.03	0.02		
2011	0.02	0.02	0.03	0.02	0.01	0.02	0.02		
2012	0.01	0.01	0.01	0.02	0.01	0.02	0.02		
2013	0.02	0.01	0.03	0.02	0.01	0.02	0.02		
2014	0.02	0.01	0.02	0.01	0.01	0.02	0.01		
2015	0.02	0.02	0.03	0.01	0.01	0.01	0.02		
2016	0.02	0.01	0.03	0.01	0.01	0.02	0.02		
2017	0.02	0.02	0.04	0.02	0.01	0.02	0.02		
2018	0.02	0.01	0.03	0.02	0.01	0.02	0.03		
2019	0.02	0.01	0.03	0.02	0.01	0.03	0.03		
2020	0.02	0.01	0.03	0.02	0.01	0.03	0.03		

Table 9. Continued.

	F ages 10+								
Year	VPA_Run385	VPA_LCI	VPA_UCI	SS3 Run16 reweight	SS3_LCI	SS3_UCI	ASAP24_CV20%	ASAP_LCI	ASAP_UCI
1950				0.03	0.03	0.04			
1951				0.03	0.03	0.04			
1952				0.04	0.04	0.05			
1953				0.05	0.04	0.05			
1954				0.04	0.04	0.05			
1955				0.06	0.05	0.06			
1956				0.05	0.05	0.06			
1957				0.07	0.06	0.07			
1958				0.07	0.06	0.08			
1959				0.06	0.05	0.07			
1960				0.07	0.06	0.08			
1961				0.08	0.07	0.09			
1962				0.09	0.08	0.11			
1963				0.06	0.05	0.07			
1964				0.07	0.06	0.08			
1965				0.07	0.06	0.08			
1966				0.05	0.04	0.06			
1967				0.08	0.07	0.10			
1968	0.06	0.05	0.06	0.06	0.04	0.07	0.05	0.03	0.07
1969	0.07	0.07	0.08	0.07	0.05	0.08	0.05	0.03	0.07
1970	0.05	0.04	0.05	0.05	0.04	0.06	0.04	0.02	0.05
1971	0.04	0.04	0.04	0.05	0.03	0.06	0.04	0.02	0.05
1972	0.03	0.03	0.03	0.05	0.04	0.06	0.03	0.02	0.05
1973	0.02	0.02	0.02	0.05	0.04	0.06	0.03	0.02	0.04
1974	0.04	0.03	0.04	0.12	0.09	0.14	0.06	0.04	0.08
1975	0.05	0.04	0.05	0.15	0.11	0.18	0.07	0.04	0.09
1976	0.05	0.05	0.06	0.16	0.12	0.21	0.07	0.05	0.09
1977	0.04	0.04	0.05	0.14	0.10	0.18	0.06	0.04	0.08
1978	0.04	0.03	0.04	0.11	0.08	0.15	0.05	0.03	0.07
1979	0.03	0.03	0.03	0.10	0.07	0.13	0.04	0.03	0.05
1980	0.04	0.04	0.05	0.12	0.08	0.15	0.05	0.03	0.07
1981	0.04	0.04	0.04	0.12	0.09	0.15	0.05	0.03	0.07
1982	0.06	0.06	0.07	0.19	0.14	0.24	0.08	0.05	0.11
1983	0.07	0.06	0.07	0.18	0.14	0.22	0.09	0.05	0.12
1984	0.07	0.06	0.08	0.23	0.17	0.29	0.10	0.06	0.14
1985	0.06	0.05	0.07	0.22	0.16	0.28	0.10	0.06	0.14
1986	0.06	0.05	0.07	0.21	0.15	0.27	0.09	0.05	0.13
1987	0.06	0.05	0.07	0.19	0.14	0.24	0.09	0.05	0.13
1988	0.08	0.07	0.09	0.27	0.20	0.35	0.12	0.07	0.17
1989	0.07	0.05	0.08	0.26	0.19	0.33	0.11	0.06	0.15
1990	0.08	0.06	0.09	0.33	0.24	0.42	0.12	0.07	0.17
1991	0.10	0.08	0.11	0.39	0.28	0.50	0.13	0.08	0.18
1992	0.10	0.08	0.12	0.47	0.35	0.59	0.14	0.09	0.20
1993	0.09	0.07	0.11	0.51	0.38	0.64	0.14	0.08	0.19
1994	0.24	0.18	0.30	0.82	0.60	1.03	0.16	0.09	0.22
1995	0.30	0.20	0.41	0.89	0.68	1.10	0.16	0.10	0.22
1996	0.38	0.22	0.62	1.00	0.77	1.23	0.19	0.11	0.26
1997	0.42	0.24	0.70	1.01	0.80	1.21	0.19	0.11	0.26
1998	0.33	0.20	0.54	0.77	0.64	0.90	0.17	0.09	0.24
1999	0.41	0.25	0.68	0.67	0.56	0.77	0.26	0.17	0.36
2000	0.46	0.27	0.79	0.70	0.58	0.82	0.26	0.17	0.36
2001	0.37	0.23	0.62	0.77	0.63	0.91	0.29	0.19	0.39
2002	0.35	0.23	0.57	0.67	0.56	0.78	0.29	0.19	0.40
2003	0.34	0.23	0.53	0.69	0.58	0.79	0.32	0.21	0.44
2004	0.35	0.24	0.50	0.65	0.55	0.76	0.31	0.20	0.41
2005	0.41	0.29	0.60	0.71	0.59	0.83	0.28	0.18	0.37
2006	0.43	0.29	0.62	0.80	0.65	0.95	0.32	0.22	0.42
2007	0.45	0.33	0.58	0.83	0.65	1.01	0.39	0.26	0.52
2008	0.09	0.07	0.11	0.48	0.38	0.58	0.21	0.14	0.27
2009	0.08	0.06	0.10	0.32	0.25	0.38	0.15	0.11	0.20
2010	0.03	0.02	0.04	0.15	0.12	0.18	0.08	0.05	0.10
2011	0.04	0.03	0.05	0.10	0.08	0.12	0.06	0.04	0.07
2012	0.05	0.03	0.06	0.08	0.06	0.10	0.05	0.04	0.07
2013	0.05	0.04	0.07	0.08	0.06	0.09	0.06	0.04	0.07
2014	0.07	0.05	0.08	0.06	0.05	0.08	0.05	0.04	0.06
2015	0.07	0.05	0.09	0.07	0.05	0.08	0.04	0.02	0.06
2016	0.08	0.05	0.10	0.07	0.06	0.09	0.05	0.03	0.07
2017	0.09	0.06	0.13	0.08	0.06	0.10	0.05	0.03	0.07
2018	0.12	0.07	0.17	0.09	0.07	0.12	0.06	0.03	0.08
2019	0.13	0.08	0.19	0.10	0.08	0.13	0.06	0.03	0.09
2020	0.11	0.06	0.18	0.11	0.08	0.14	0.06	0.03	0.10

Table 10. Projection settings for selectivity, weight-at-age and natural mortality-at-age (M) for VPA.

Age	Maturity	Selectivity (recent 2007-2016)	Selectivity (recent 1968-2016)	Weight	M
1	0	0.0031	0.0033	4.116	0.38
2	0	0.1830	0.1905	10.004	0.3
3	0.25	0.0900	0.0919	21.465	0.24
4	0.5	0.1785	0.1785	35.707	0.2
5	1	0.2165	0.2165	49.844	0.18
6	1	0.1554	0.1554	68.257	0.16
7	1	0.1972	0.1972	93.386	0.14
8	1	0.3746	0.3746	113.555	0.13
9	1	1.0000	1.0000	136.736	0.12
10+	1	0.7500	0.7500	Growth curve	0.10

Table 11. Projection settings for selectivity, weight-at-age and natural mortality-at-age (M) for Stock Synthesis.

Age	M	Weight	Selectivity
0	0.502	0.045	0.000
1	0.322	3.532	0.013
2	0.266	7.903	0.156
3	0.226	15.533	0.121
4	0.195	27.285	0.206
5	0.173	43.536	0.251
6	0.156	64.033	0.244
7	0.143	87.95	0.369
8	0.134	114.095	0.623
9	0.126	141.162	0.830
10	0.120	167.948	0.944
11	0.116	193.487	0.998
12	0.112	217.103	1.000
13	0.109	238.401	0.957
14	0.107	257.217	0.887
15	0.105	273.566	0.810
16	0.103	287.579	0.738
17	0.102	299.457	0.677
18	0.101	309.435	0.627
19	0.101	317.756	0.588
20	0.100	324.654	0.558
21	0.100	330.346	0.534
22	0.099	335.023	0.516
23	0.099	338.855	0.501
24	0.099	341.987	0.490
25	0.098	344.54	0.481
26	0.098	346.619	0.474
27	0.098	348.309	0.468
28	0.098	349.682	0.463
29	0.098	350.796	0.457
30	0.098	352.259	0.455

Table 12. Projection settings for selectivity, weight-at-age and natural mortality-at-age (M) for ASAP.

Age	base2-Selectivity	weight	M
1	0.008	5	0.38
2	0.284	12	0.30
3	0.205	24	0.24
4	0.421	34	0.20
5	0.451	50	0.18
6	0.309	67	0.16
7	0.337	91	0.14
8	0.534	114	0.13
9	0.931	137	0.12
10	1.000	163	0.12
11	0.941	186	0.11
12	0.860	209	0.11
13	0.700	234	0.11
14	0.573	257	0.10
15	0.476	279	0.10
16	0.341	328	0.10

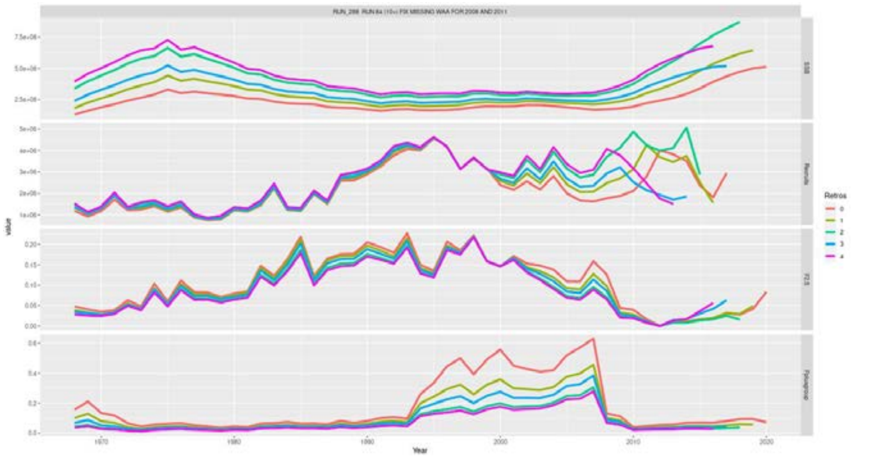

Figure 1. VPA Continuity run in 2022 (Run 288). Trends for SSB, recruitment, fishing mortality at ages 2-5 and fishing mortality for the plus group (age 10 plus) are shown. The different colours represent the different peels of removing one year of data as part of a retrospective analysis.

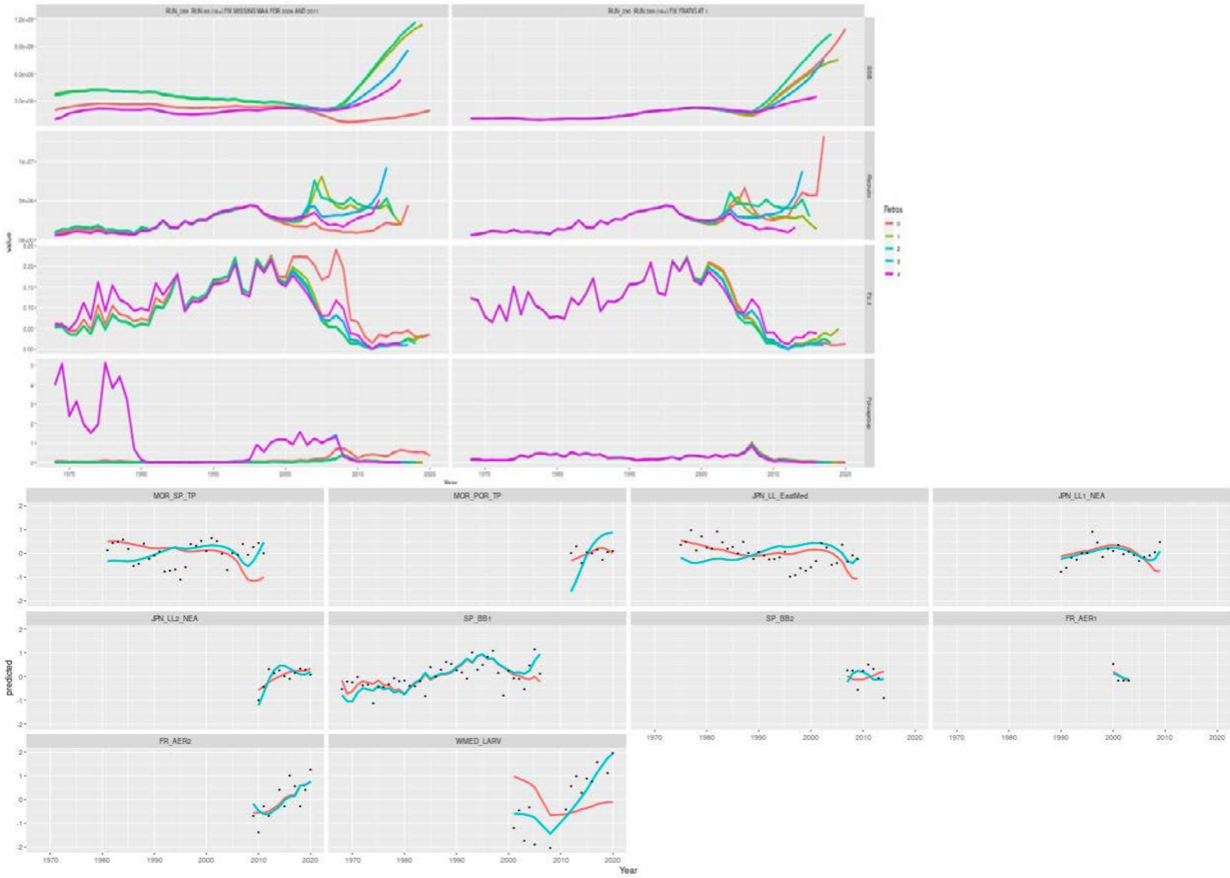

Figure 2. VPA exploratory runs for the possibility of using 16+ as a plus group. Top panels show trends for SSB, recruitment, fishing mortality at ages 2-5 and fishing mortality for the plus group (age 10 plus) for Runs 289 (left) and 290 (right). The different colours represent the different peels of removing one year of data as part of a retrospective analysis. Bottom panels show the fit to indices for Run 289 (green lines) and Run 290 (red lines).

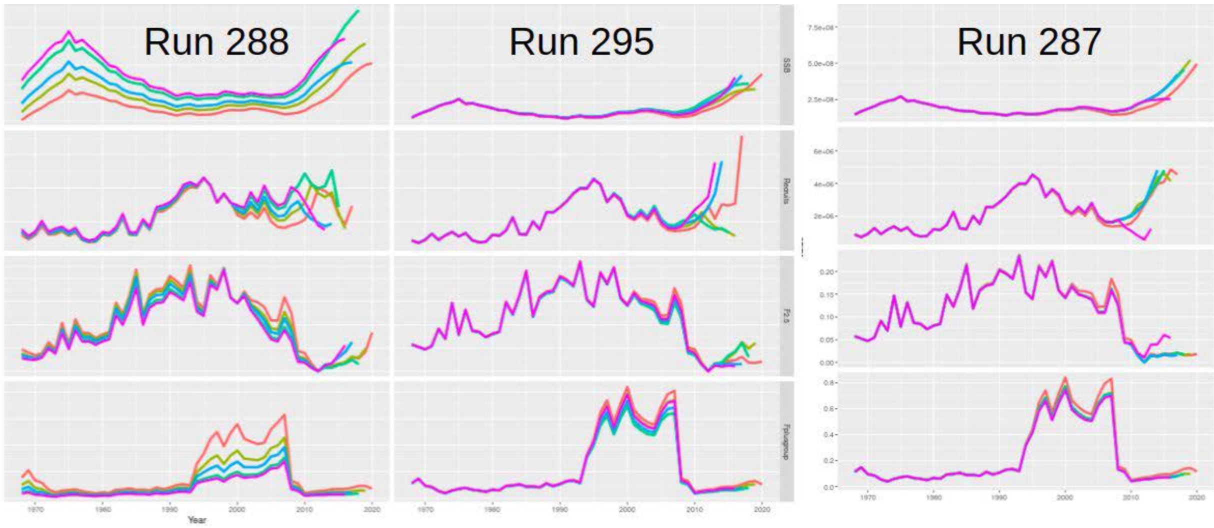

Figure 3. VPA exploratory runs for exploring the stability aspect of the continuity run (Run 288). Trends for SSB, recruitment, fishing mortality at ages 2-5 and fishing mortality for the plus group (age 10 plus) for Runs 288 (left), 295 (middle) and 287 (right). The different colours represent the different peels of removing one year of data as part of a retrospective analysis.

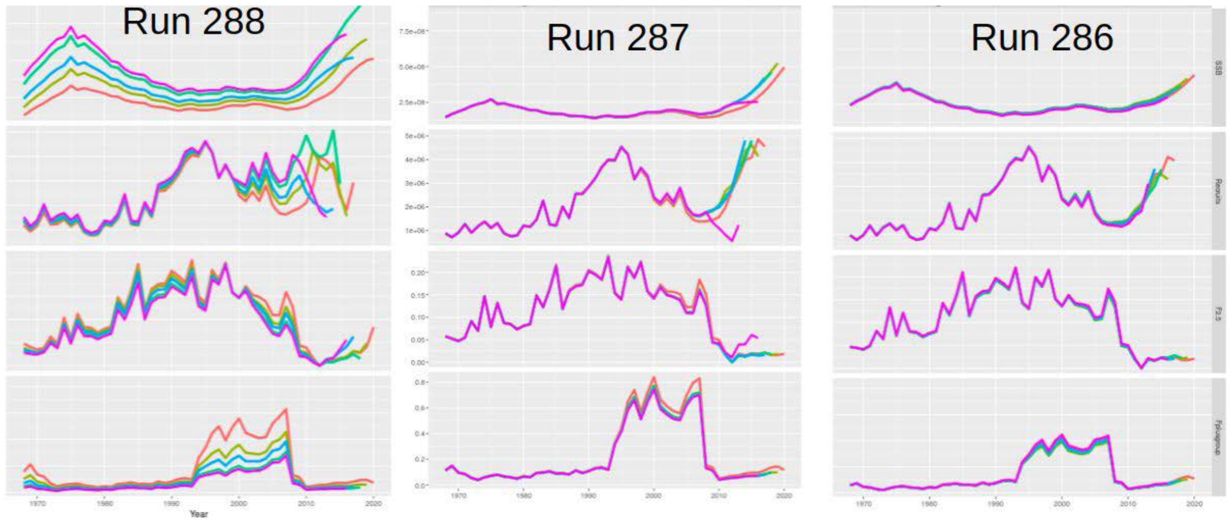

Figure 4. VPA exploratory runs for exploring the stability aspect of the continuity run (Run 288). Trends for SSB, recruitment, fishing mortality at ages 2-5 and fishing mortality for the plus group (age 10 plus) for Runs 288 (left), 287 (middle) and 286 (right). The different colours represent the different peels of removing one year of data as part of a retrospective analysis.

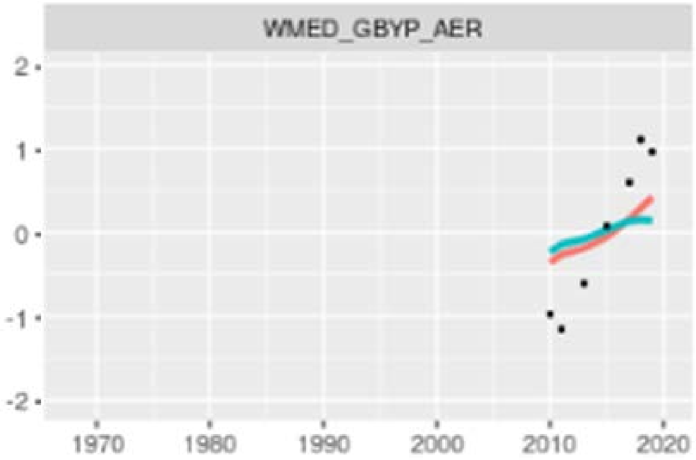

Figure 5. Fit to the western Mediterranean GBYP aerial survey index in VPA Runs 303 (red) and 304 (green).

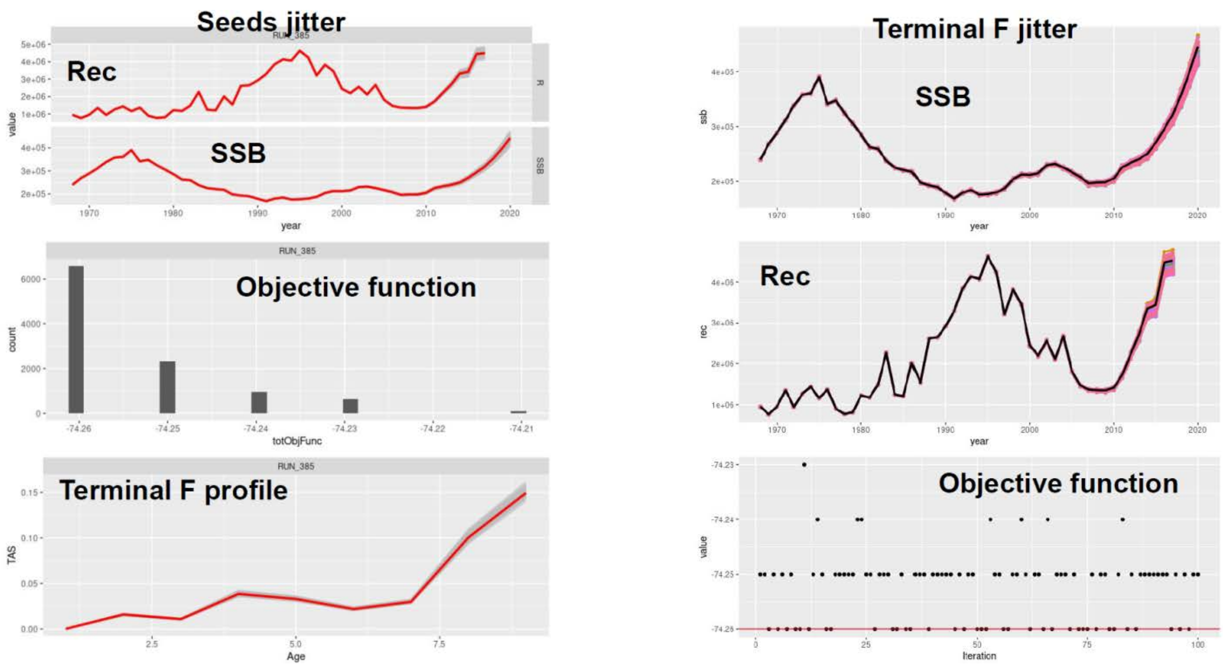

Figure 6. Jittering the seed for the random number generator and the terminal F based on VPA Run 385.

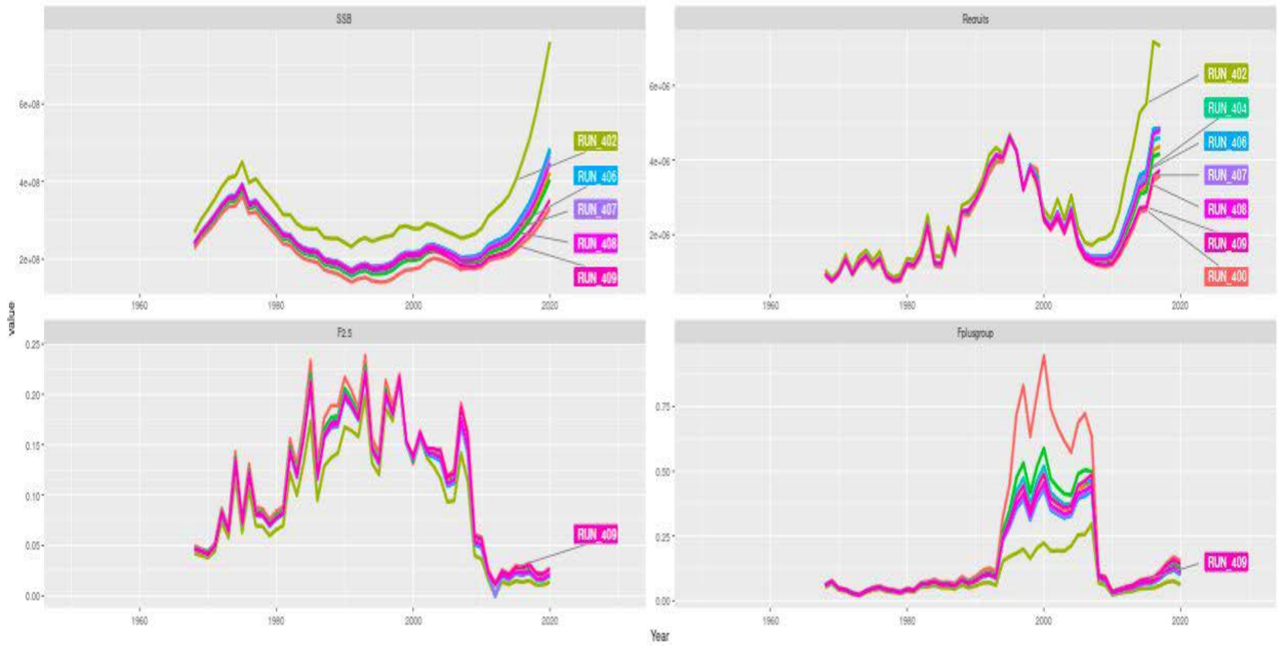

Figure 7. Jackknife analysis based on VPA Run 385 (red line). The most influential index was JPN_LL_NEAtlMed in green.

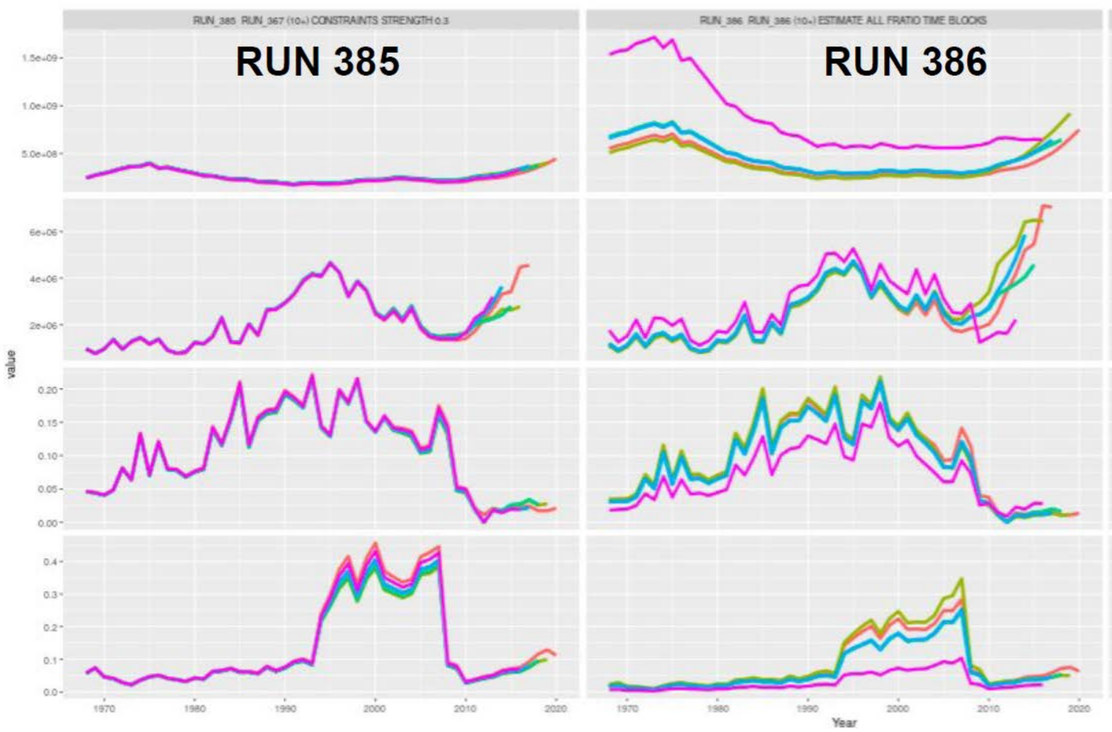

Figure 8. VPA exploratory runs for estimating the F-ratio for the time block 1996-2007 (Run 386). Trends for SSB, recruitment, fishing mortality at ages 2-5 and fishing mortality for the plus group (age 10 plus) for Runs 288 (left), 287 (middle) and 286 (right). The different colours represent the different peels of removing one year of data as part of a retrospective analysis.

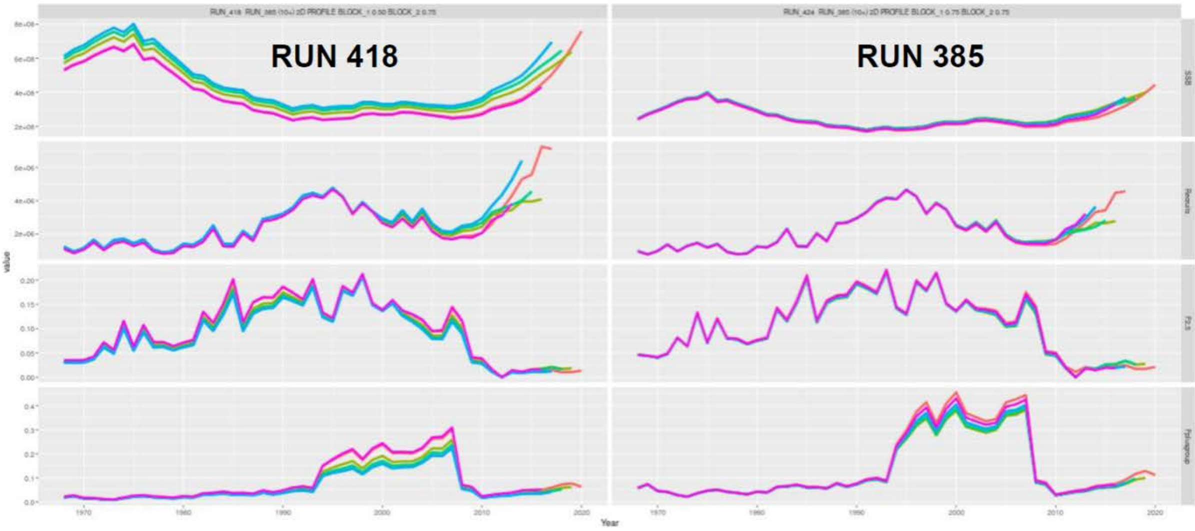

Figure 9. VPA exploratory runs for exploring the run had a difference in objective function that was larger than 2 (**Table 5**). Trends for SSB, recruitment, fishing mortality at ages 2-5 and fishing mortality for the plus group (age 10 plus) for Runs 418 (left), and 385 (right). The different colours represent the different peels of removing one year of data as part of a retrospective analysis.

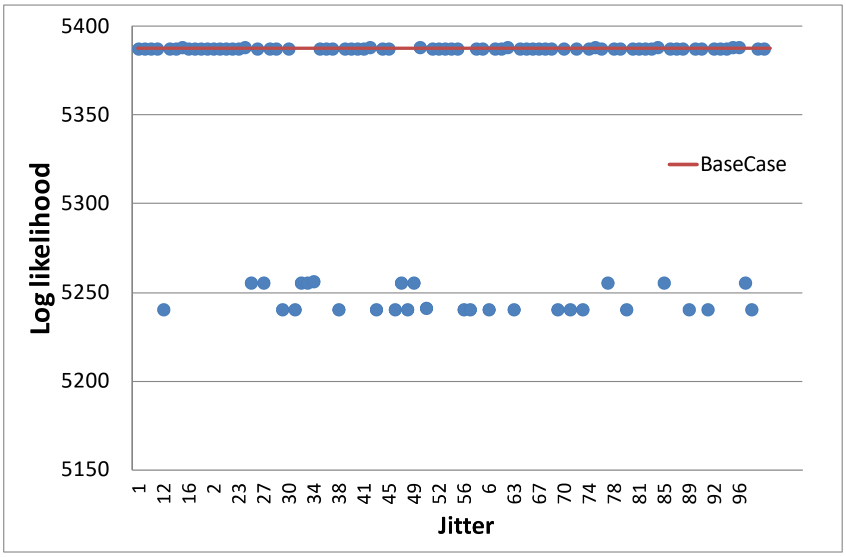

Figure 10. Negative log-likelihood values produced from the 100 jitter trials in which initial parameter values were jittered by 10% for the Stock Synthesis base case run (run 16 reweight).

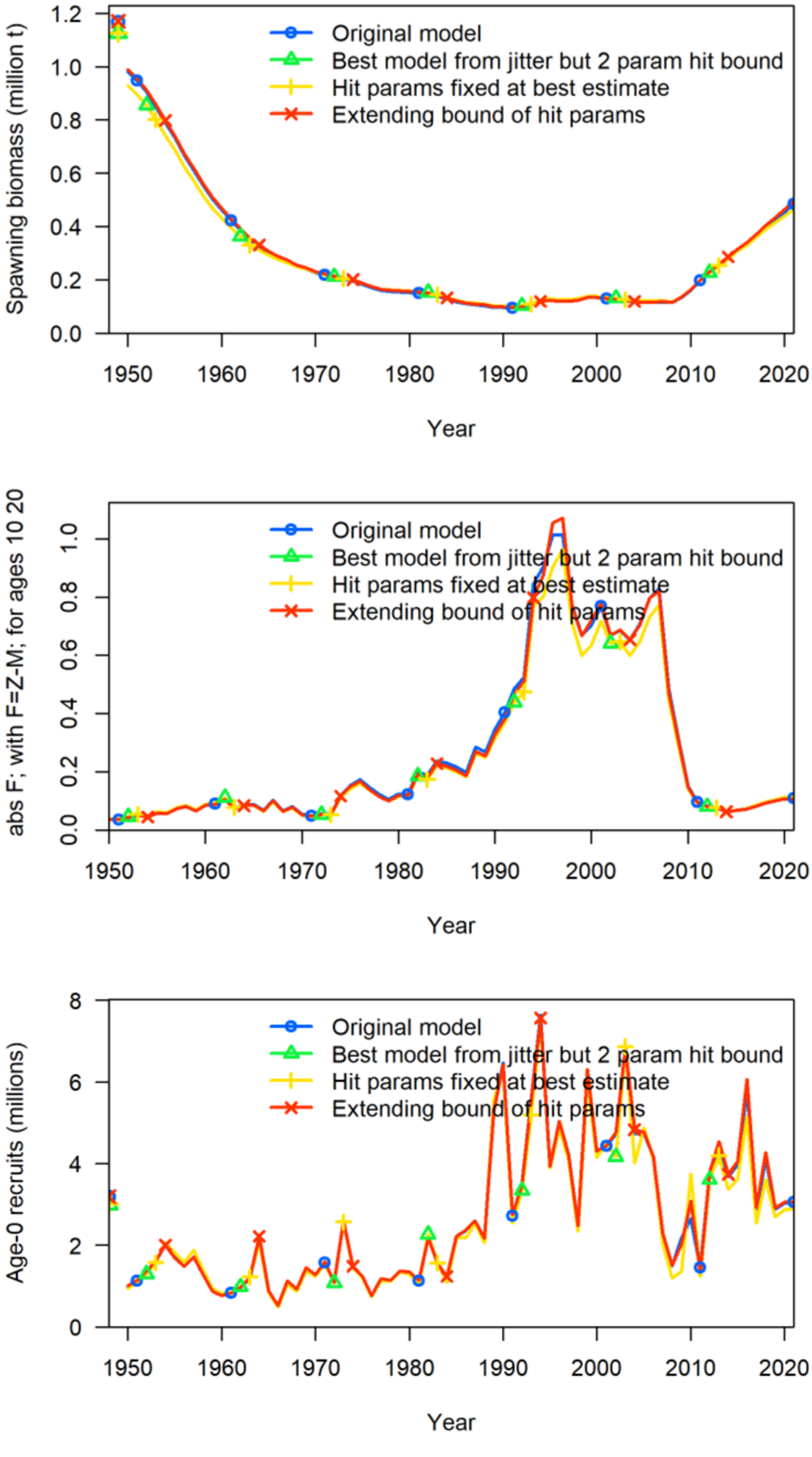

Figure 11. Comparison of stock trends between the base case (run 16 reweigh in blue line) and other runs with lowest negative log-likelihood.

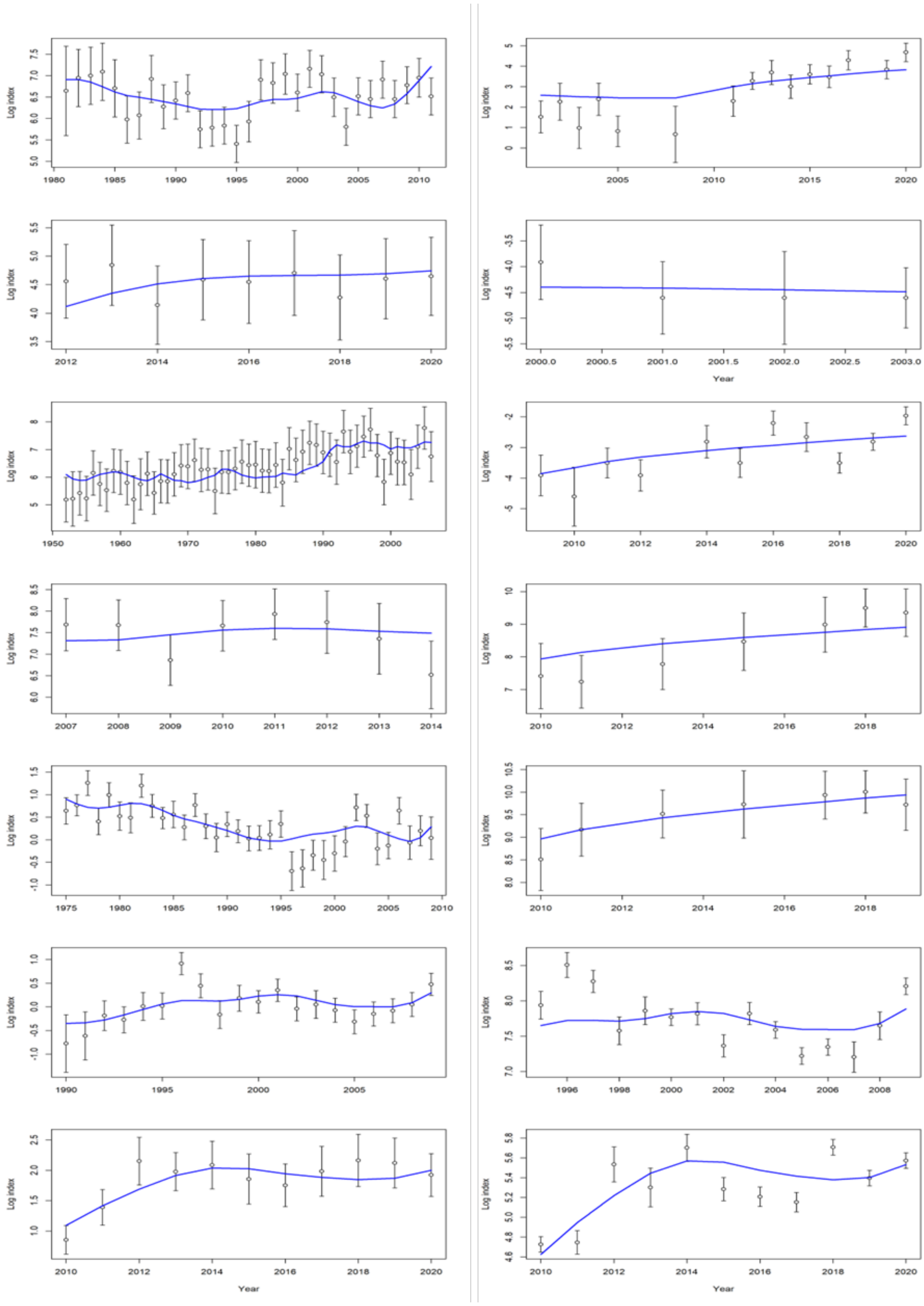

Figure 12. Stock Synthesis model fits to East Atlantic bluefin tuna indices of relative abundance for the base run (run 16 reweight).

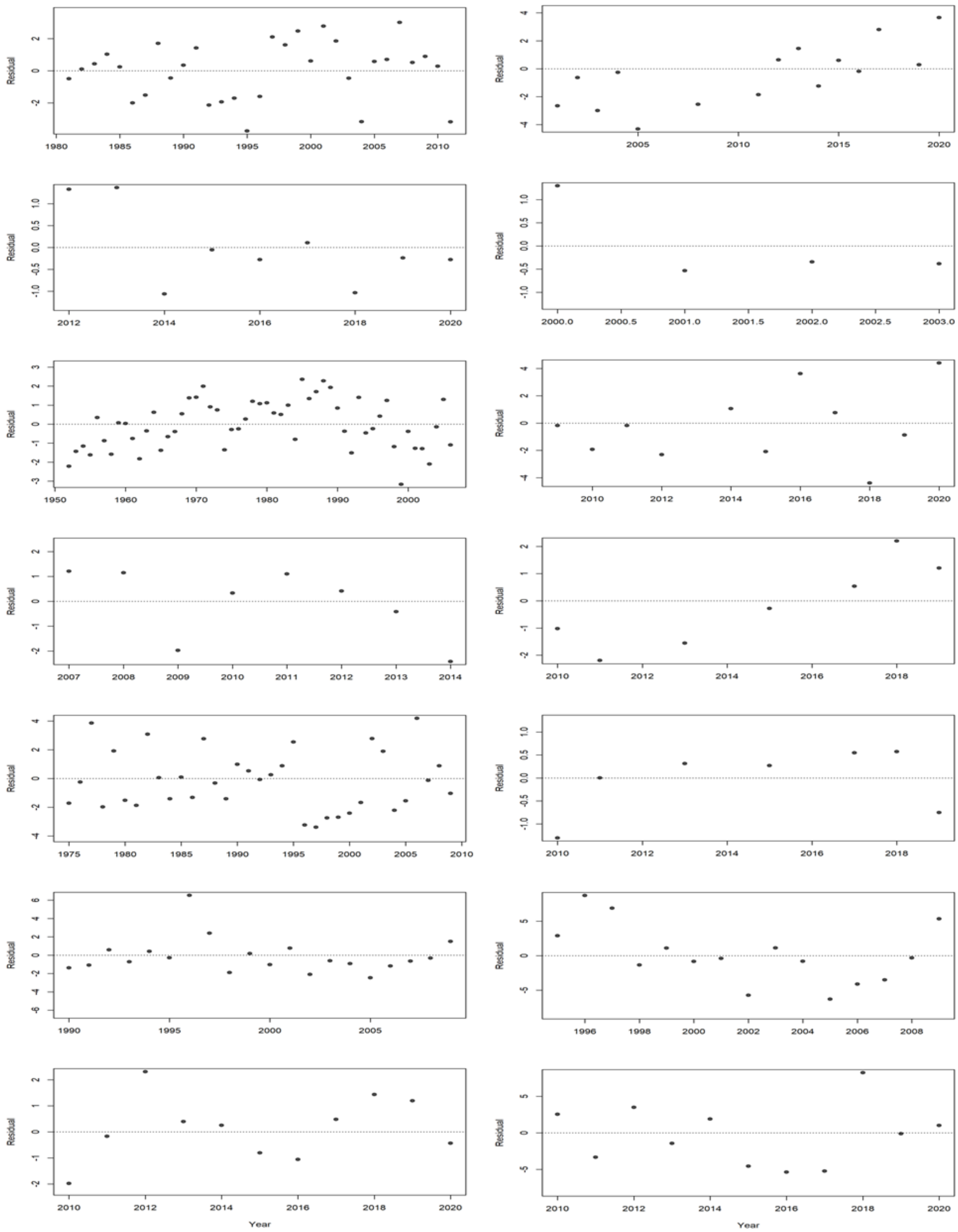

Figure 13. Stock Synthesis model fit residual errors around East Atlantic bluefin tuna indices of relative abundance for the base run (run 16 reweight).

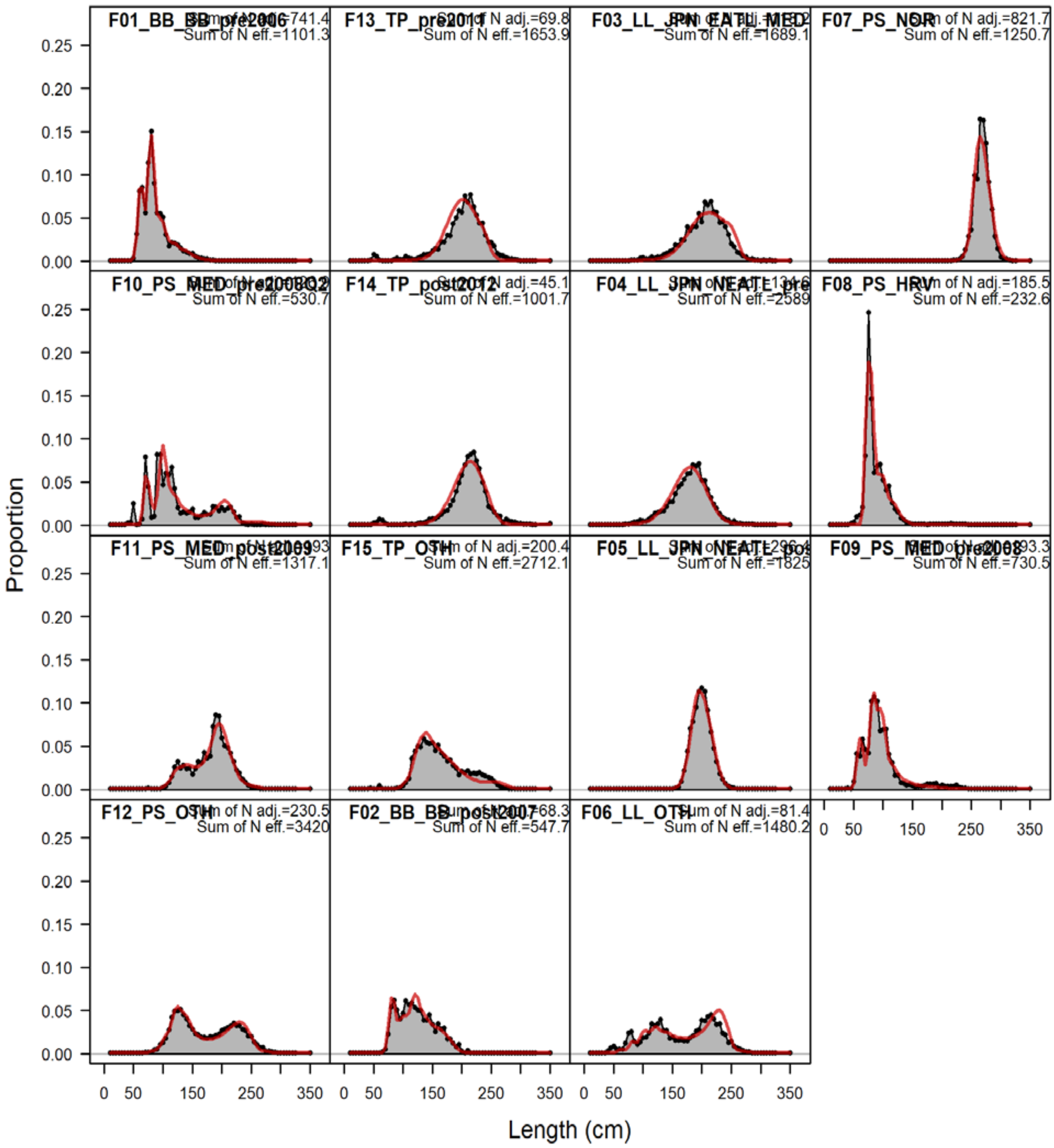

Figure 14. Stock Synthesis fits to East Atlantic bluefin tuna length compositions by fleet for the base run (run 16 reweight). The grey distributions show the observed aggregated length composition by fleet and the red line shows the model predicted length composition.

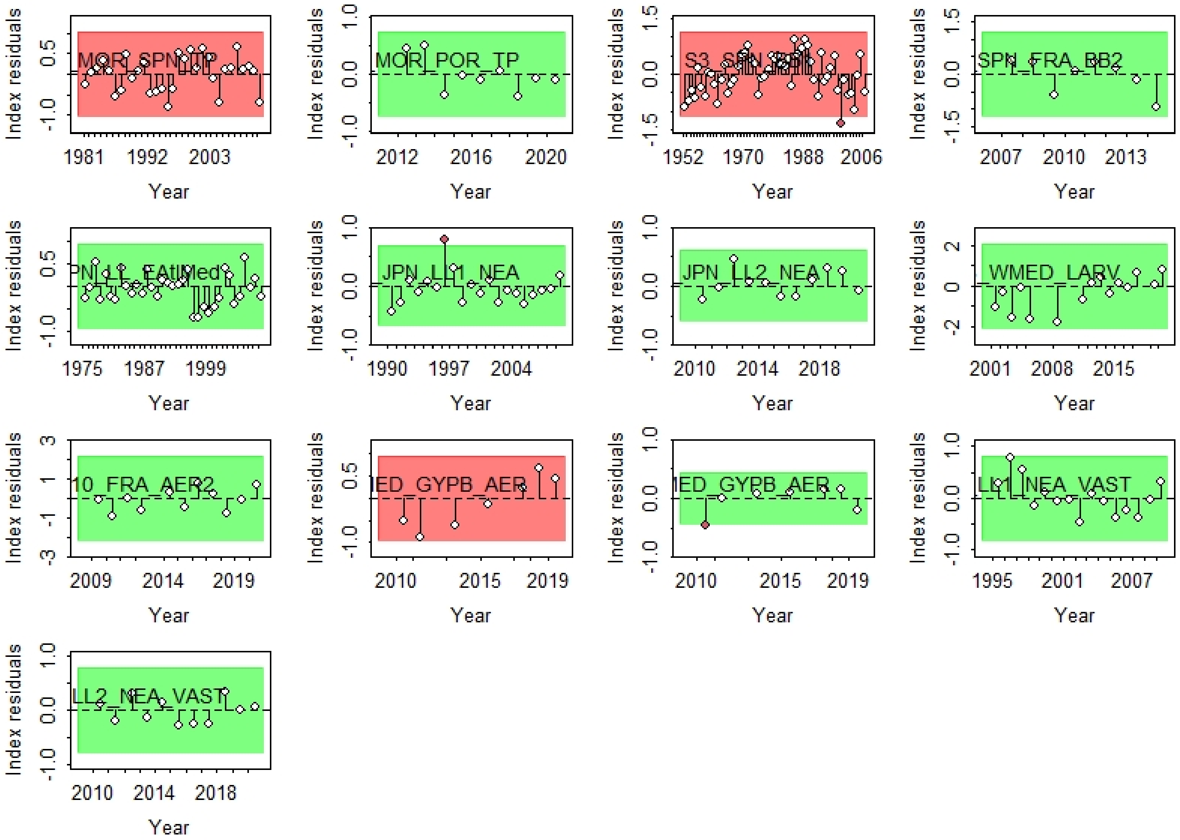

Figure15. Diagnostic residual runs test on model fits to the indices of abundance for the base run (run 16 reweight).

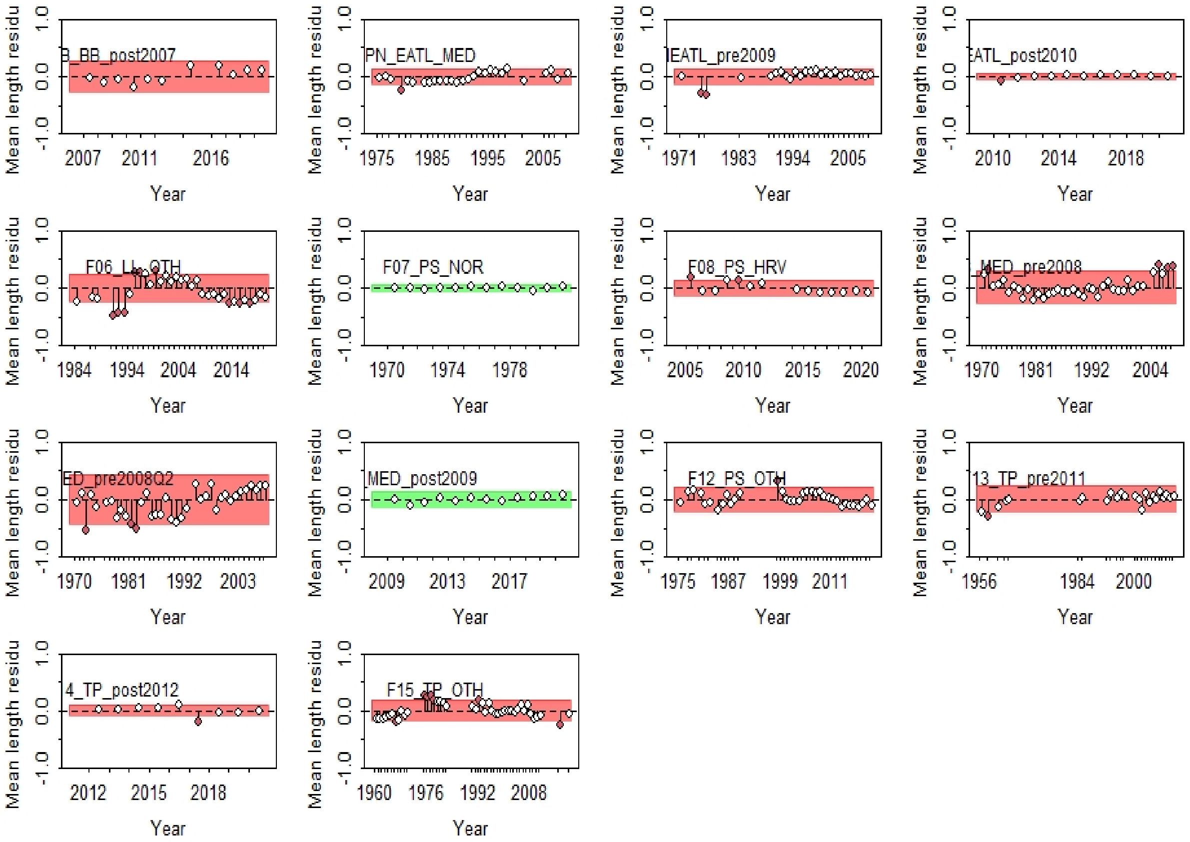

Figure 16. Diagnostic residual runs test on model fits to the fleet length compositions for the base run (run 16 reweight).

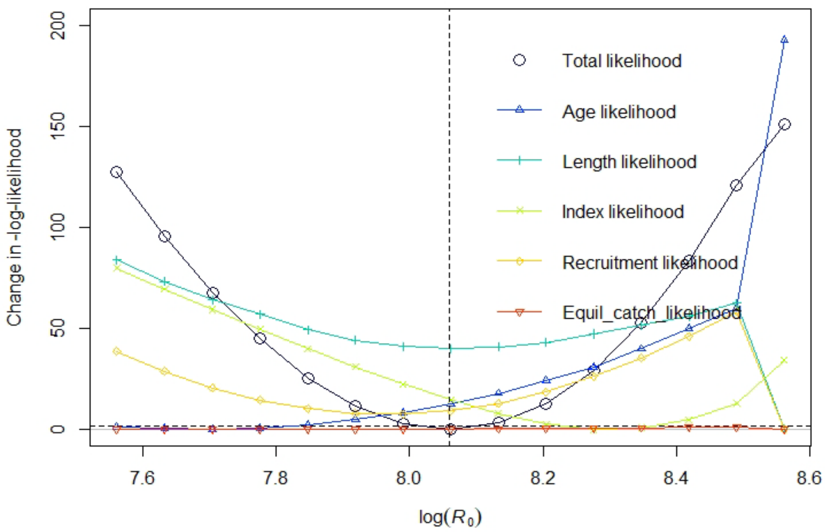

Figure 17. Stock Synthesis likelihood profile on unfished mean equilibrium recruitment for the base run (run 16 reweight).

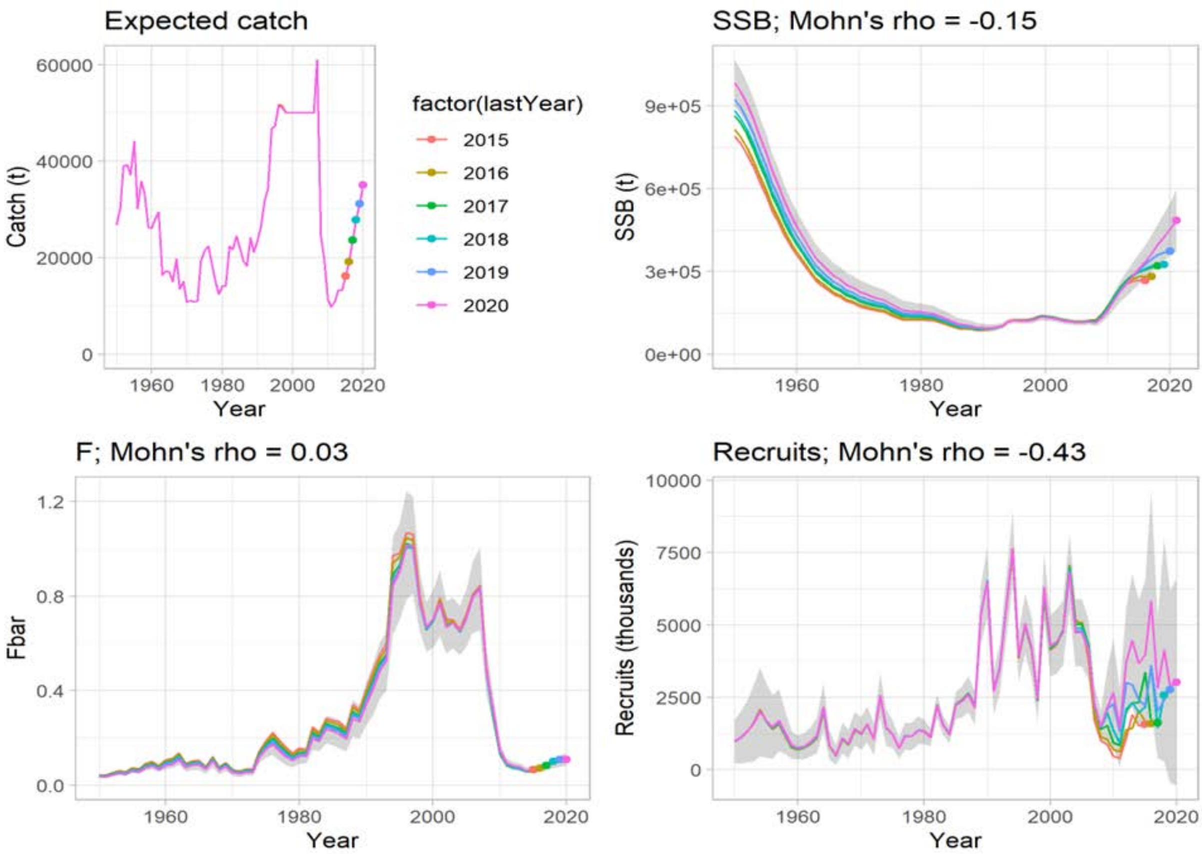

Figure 18. Stock Synthesis retrospective analysis with Mohn's rho values indicated on the top of the plots for the base run (run 16 reweight).

Figure 19. Likelihood profiles for the estimate of mean recruitment for the data components of the single-fleet ASAP application to eastern Atlantic and Mediterranean Atlantic bluefin tuna (base run 2).

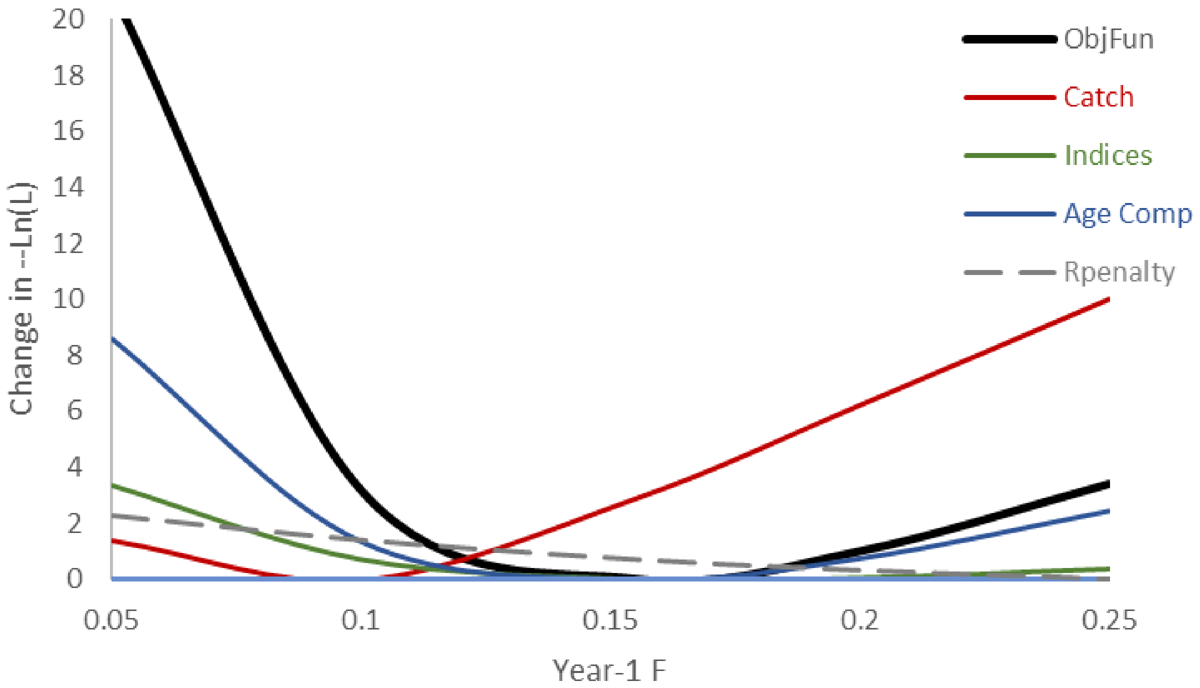

Figure 20. Likelihood profiles for the estimate of initial F and by assuming no deviations of the single-fleet ASAP application to eastern Atlantic and Mediterranean Atlantic bluefin tuna (base run 2).

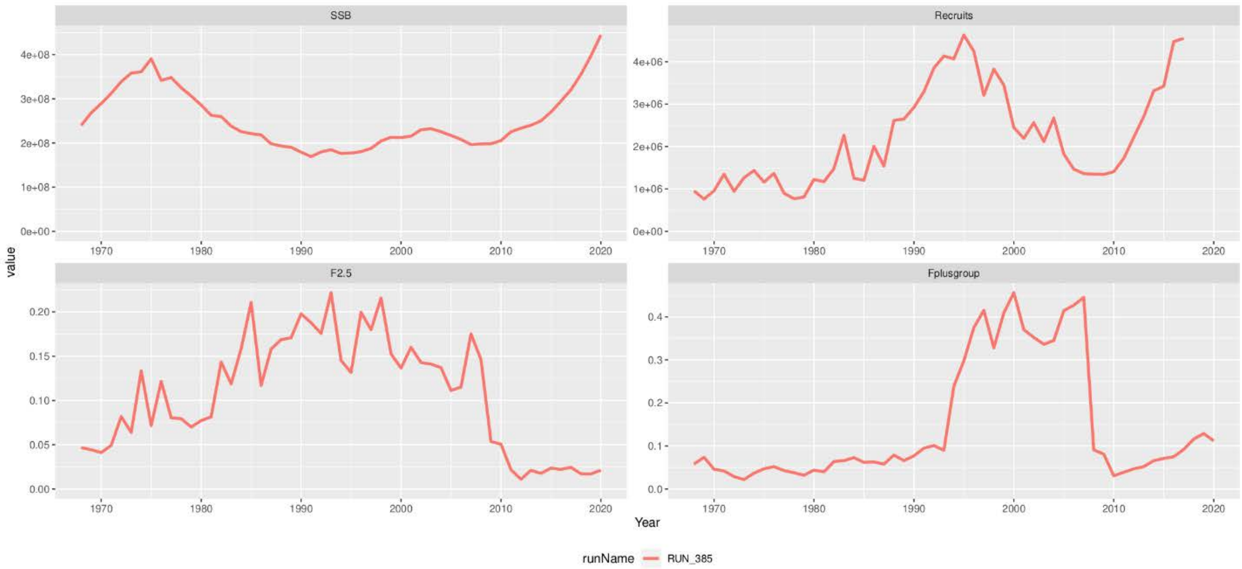

Figure 21. Spawning stock biomass (in thousand metric ton), recruitment (in million), and fishing mortality (average over ages 2 to 5, and 10+) estimates from VPA Run 385 (base case) for the period between 1968 and 2020. Recruitments from the last four years (2017-2020) are not shown because they are poorly estimated.

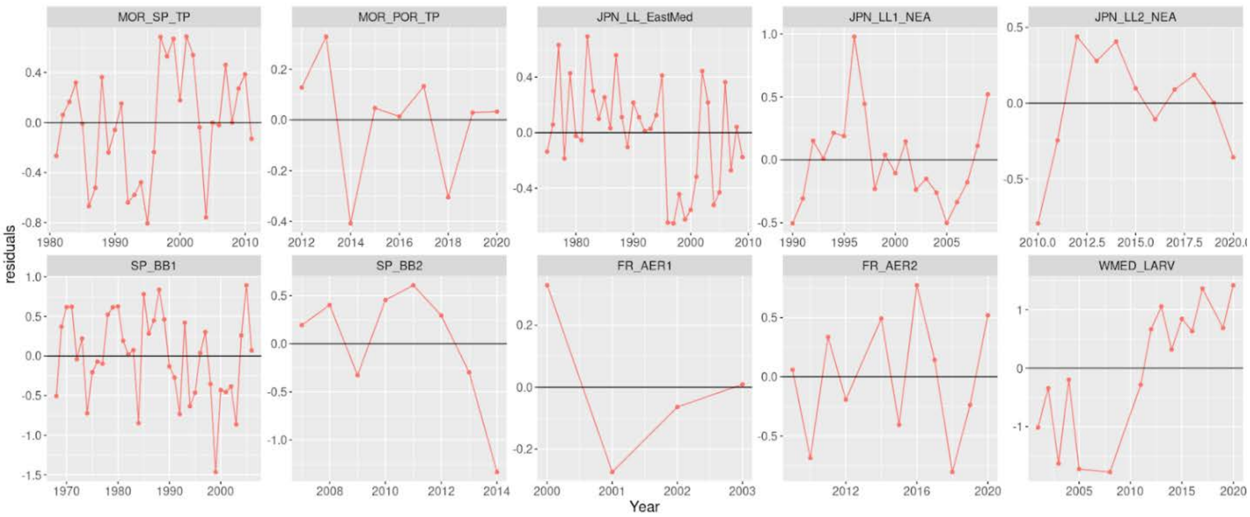

Figure 22. Residuals from the fits to the indices for VPA Run 385.

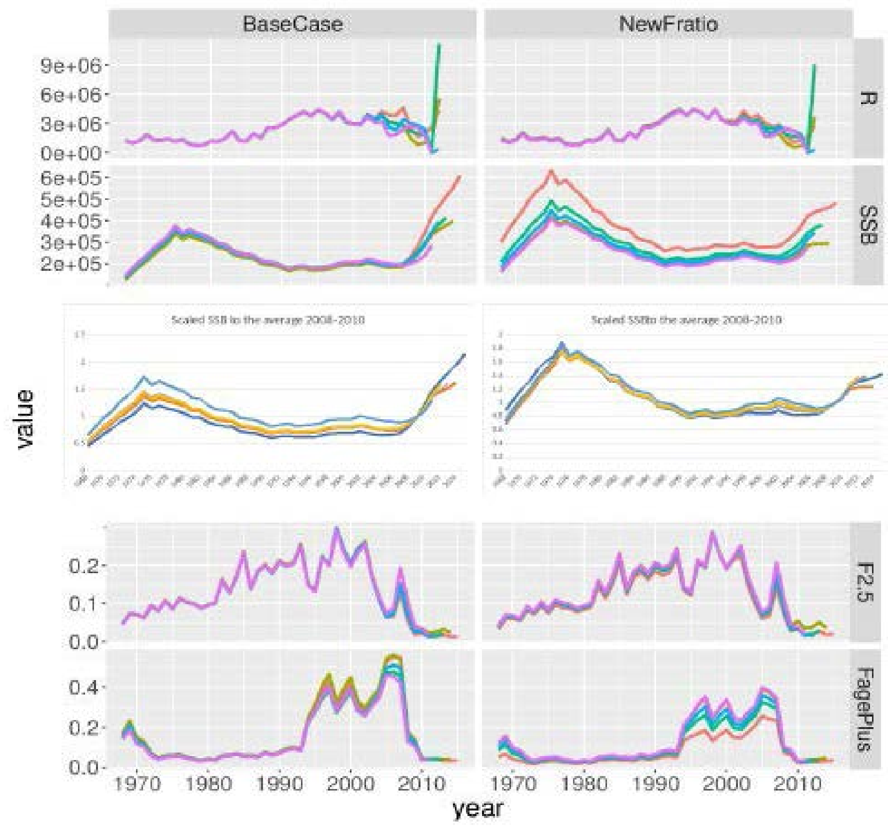

Figure 23. 2017 E-BFT VPA stock assessment: Retrospective estimates of recruitment (in millions), SSB, relative SSB and fishing mortality (average over ages 2 to 5, and 10+) from the revised VPA base run adopted during the Species Group meeting. Recruitments from the last four years (2012-2015) are not shown because they are poorly estimated.

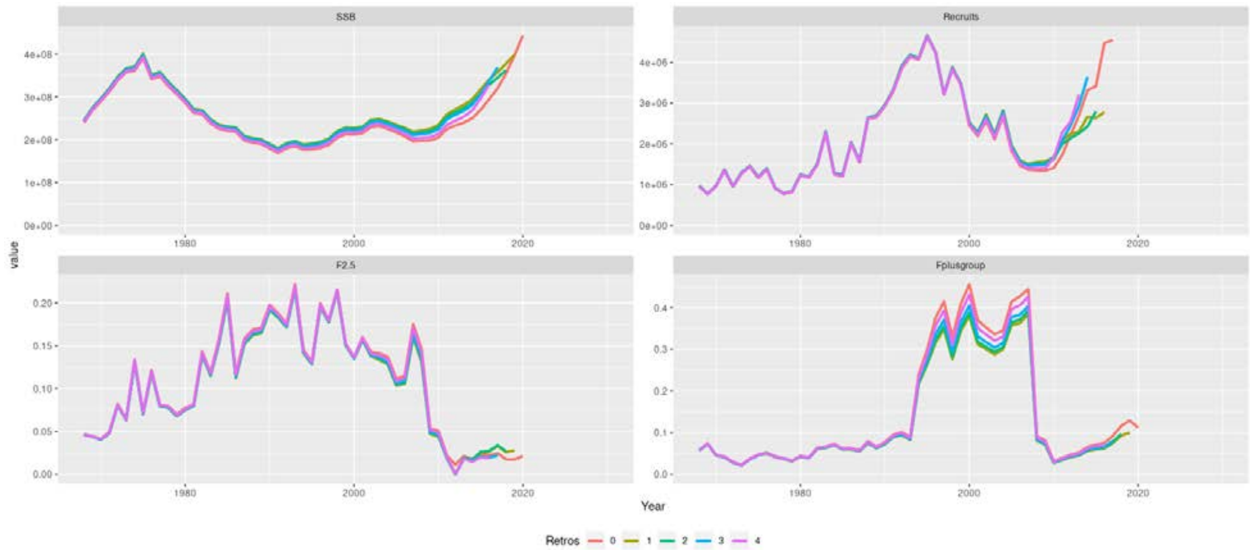

Figure 24. VPA Retrospective analysis: Trends for SSB, recruitment, fishing mortality at ages 2-5 and fishing mortality for the plus group (age 10 plus) for Run 385. The different colours represent the different peels of removing one year of data as part of a retrospective analysis.

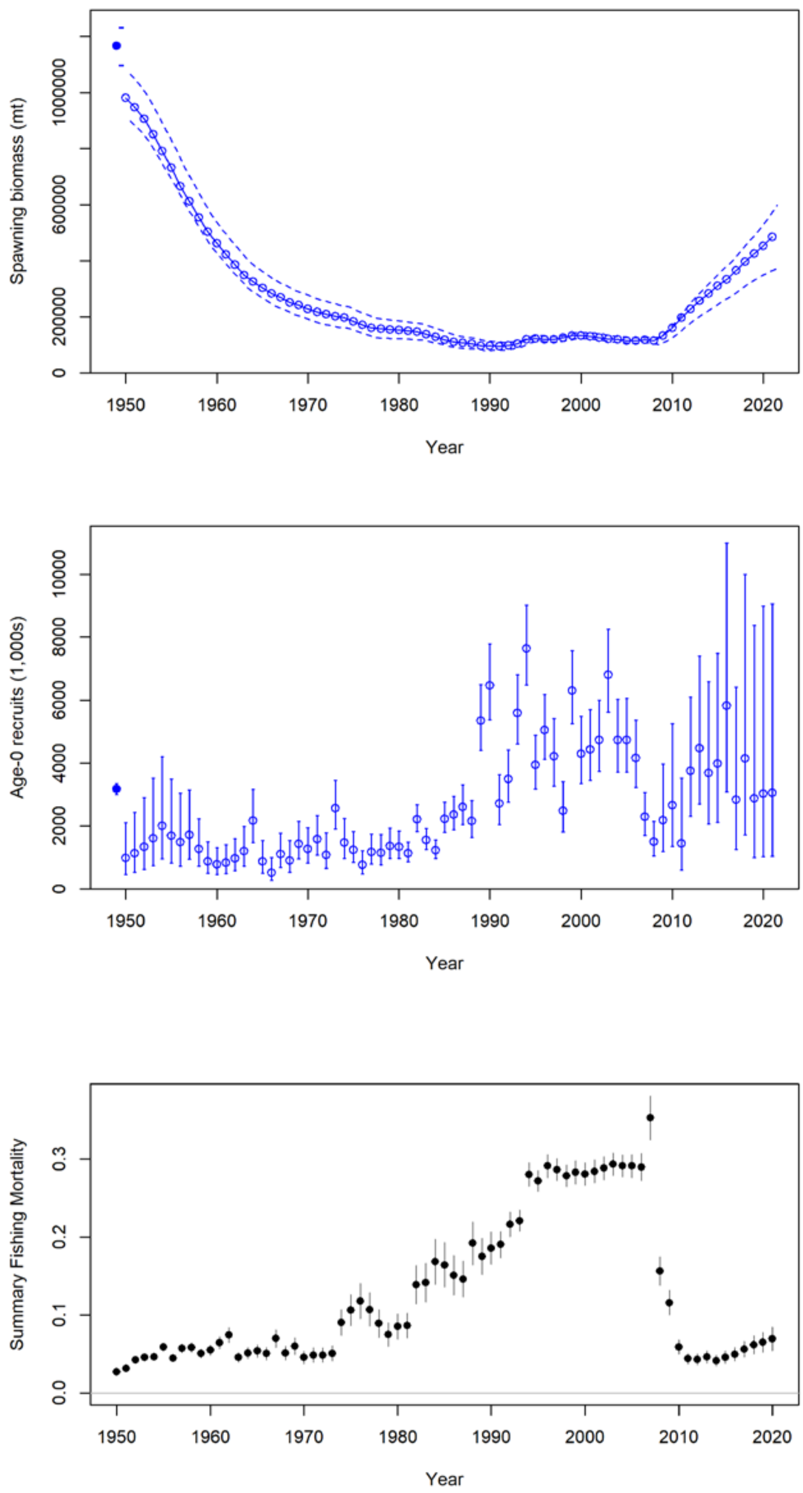

Figure 25. The time series of spawning stock biomass (SSB), fishing mortality (biomass exploitation rate was used as a proxy), and recruitment (age 0) for the Stock Synthesis Run 16 reweight.

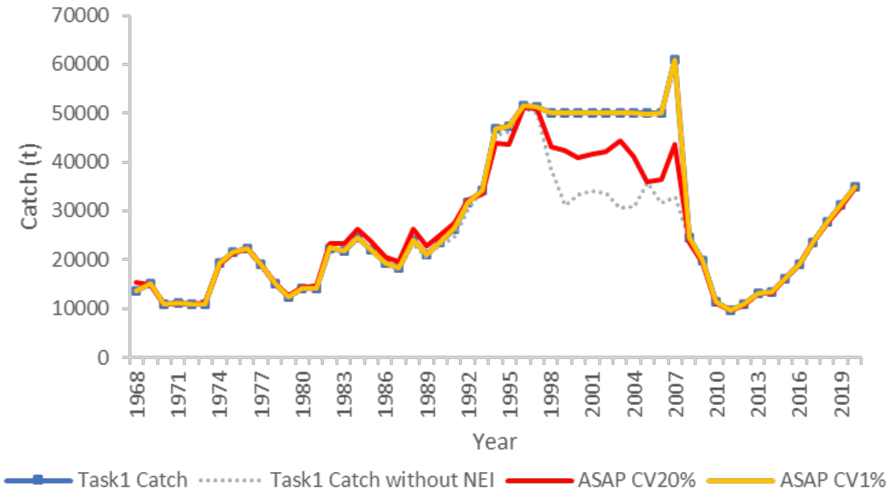

Figure 26. Predictions of catch with ASAP CV 20% (red line) and CV 1% assumptions (yellow line), and Task 1 catch with (blue line with squares)/without NEI flags (dotted line).

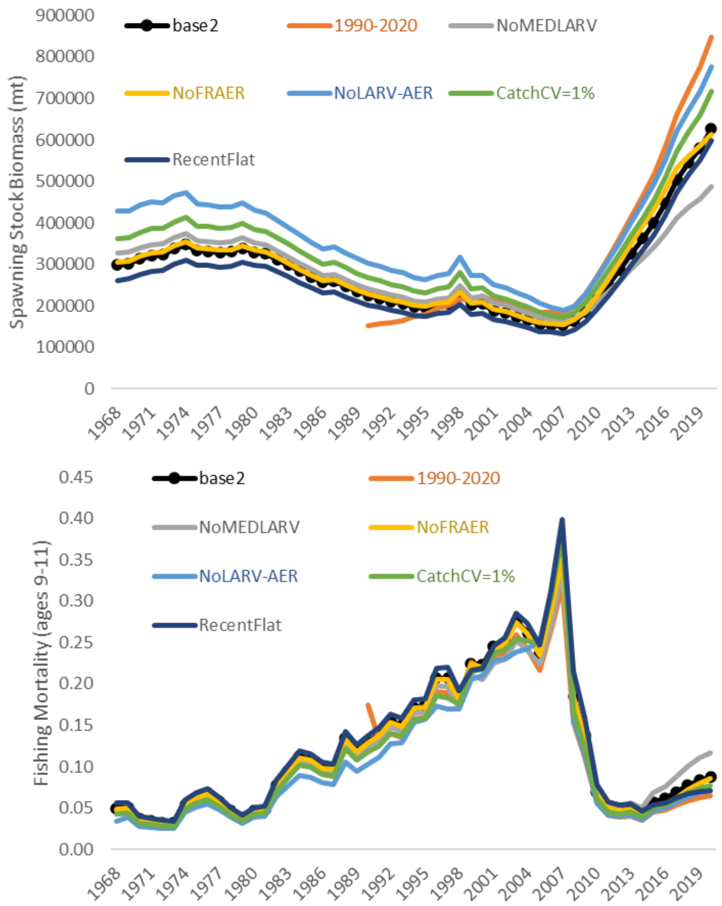

Figure 27. CV = 0.20 (base 2) and CV = 0.01 for all years for comparison with the other modelling approaches.

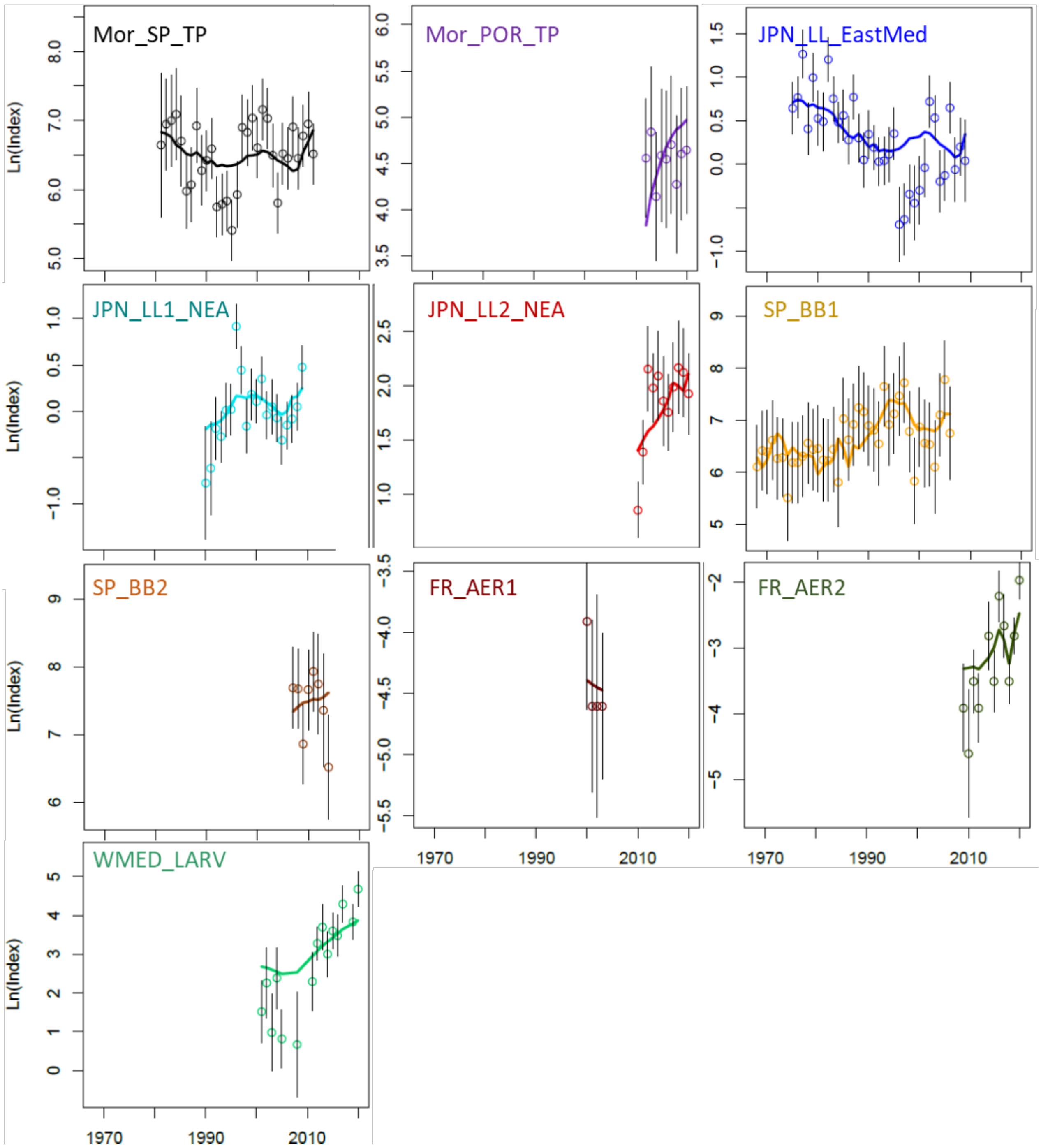

Figure 28. Stock index predictions (lines) and observed values (circles with confidence limits) from the single-fleet ASAP application to eastern Atlantic and Mediterranean Atlantic bluefin tuna (base run 2).

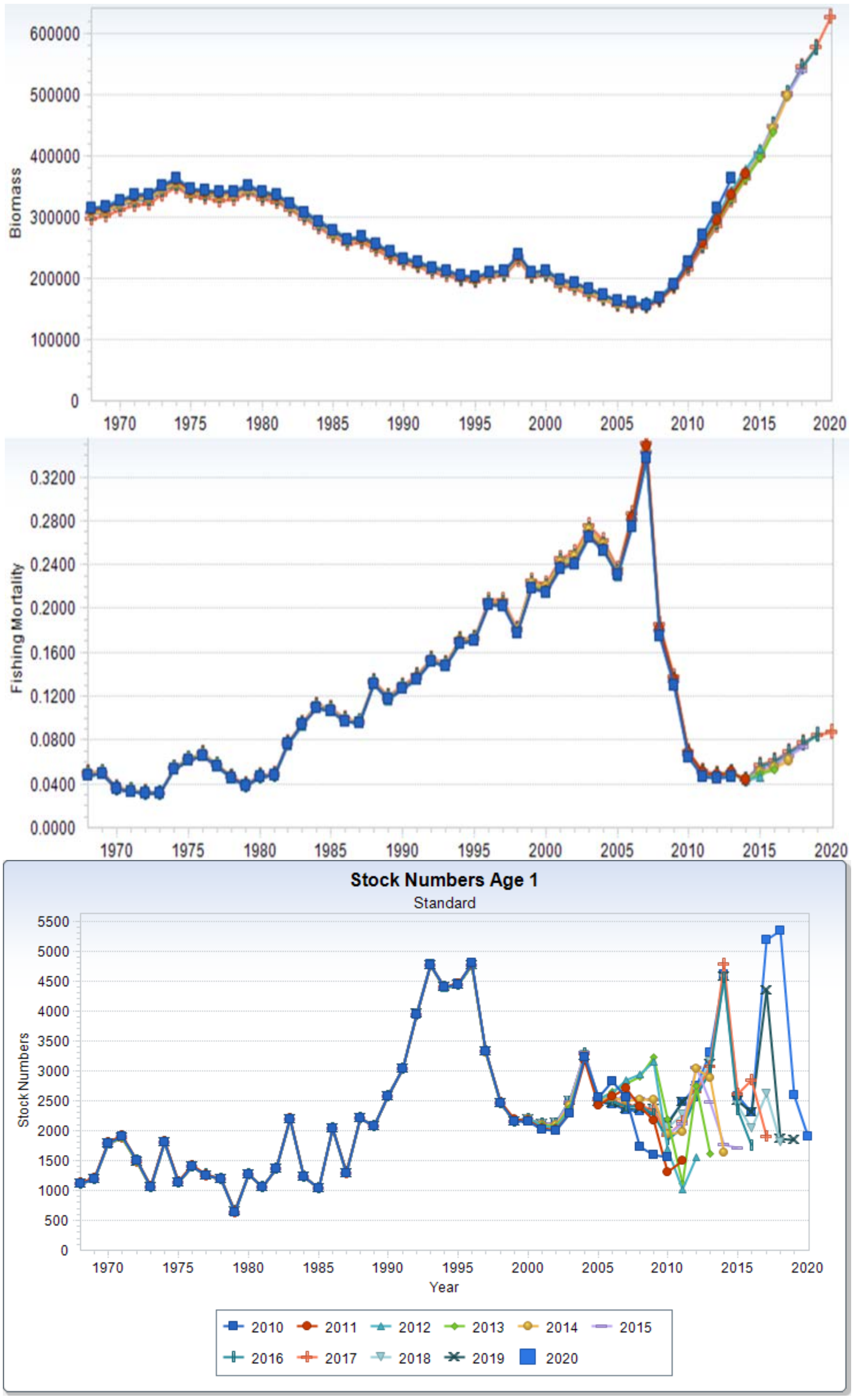

Figure 29. Retrospective estimates of SSB and age 9-11 fishing mortality from single-fleet ASAP application to eastern Atlantic and Mediterranean Atlantic bluefin tuna (base run 2).

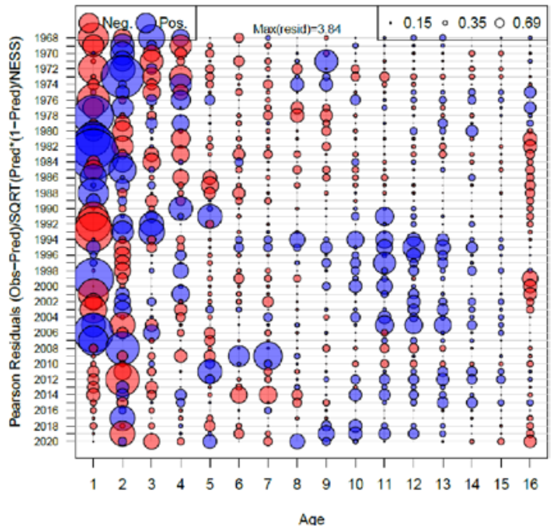

Figure 30. Pearson residuals of fishery age composition from single-fleet ASAP application to eastern Atlantic and Mediterranean Atlantic bluefin tuna (base run 2).

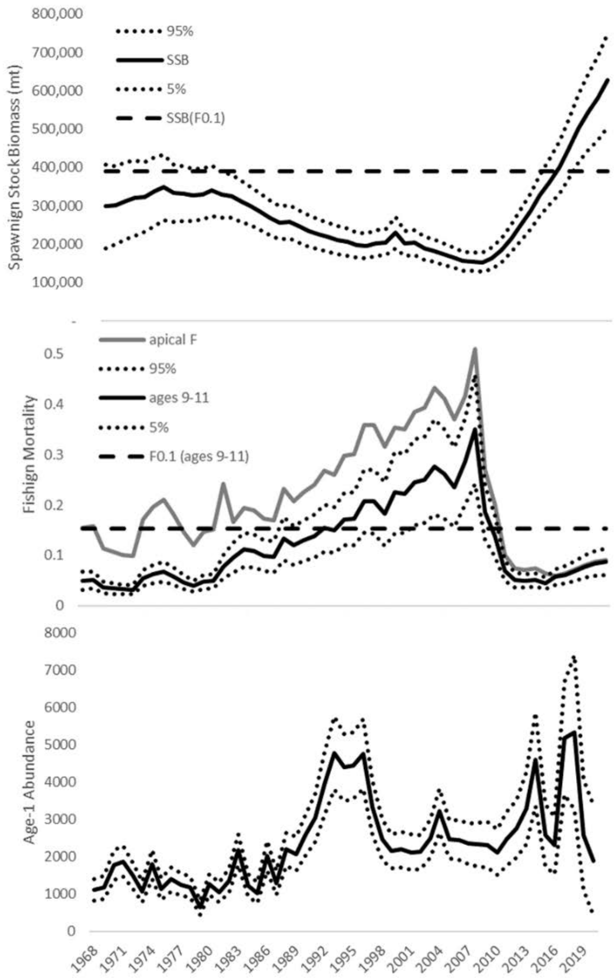

Figure 31. Estimates of SSB (top), fishing mortality (middle) and recruitment (bottom) with 90% confidence intervals and candidate reference points from the single-fleet ASAP application to eastern Atlantic and Mediterranean Atlantic bluefin tuna (base 2 run).

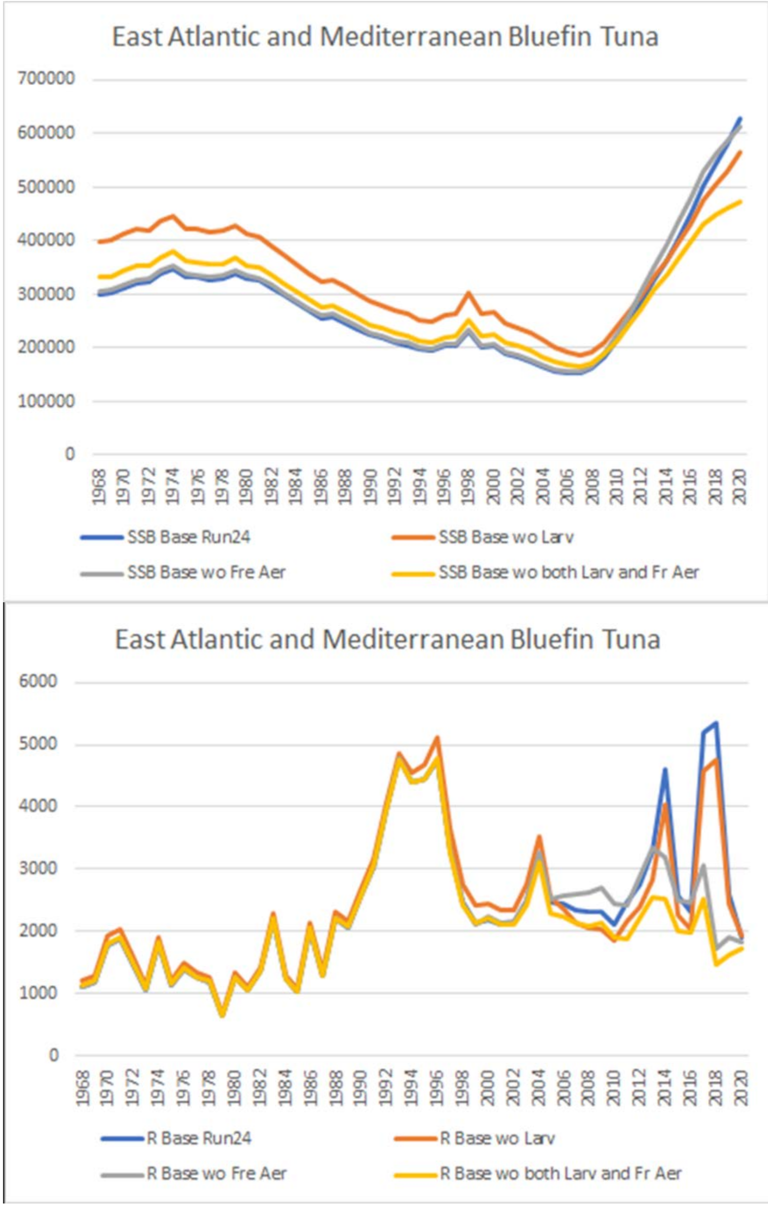

Figure 32. The single-fleet ASAP sensitivity analyses in SSB and recruitment based on base run 2 without excluding W-Med Larval and French aerial surveys.

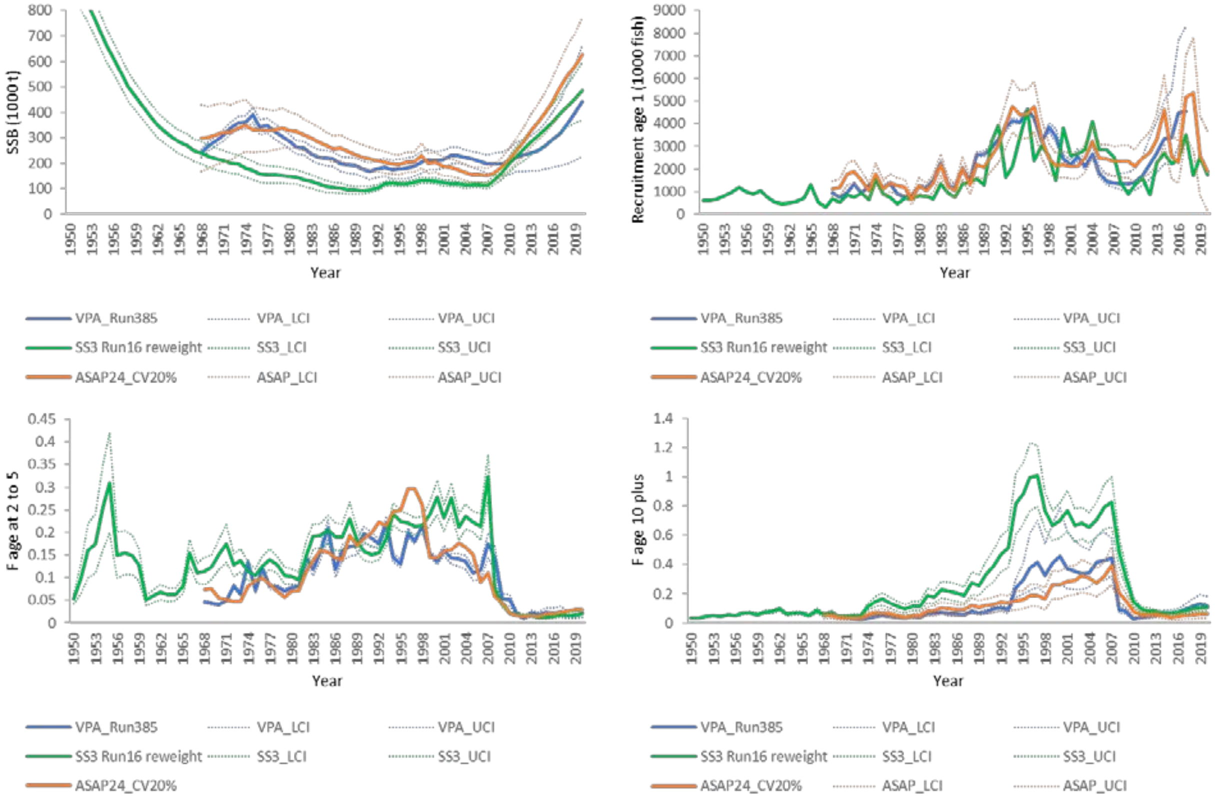

Figure 33. Comparisons of the trends in estimated spawning stock biomass (SSB), recruitment (age 1), F at age 2 to 5, and F at age 10 plus group between base cases by model platforms: VPA run 385 (blue lines), Stock Synthesis run 16 reweight (green lines), and ASAP run 24 with 20% CV (orange lines).

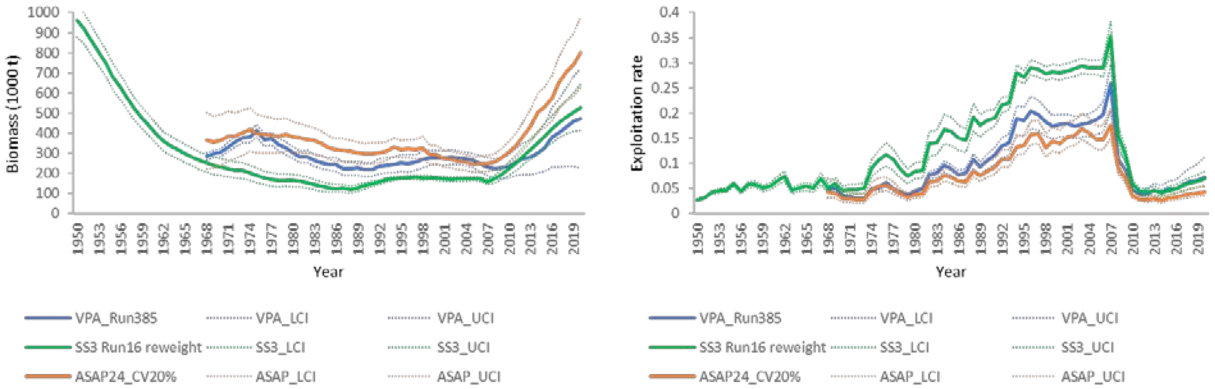

Figure 34. Comparisons of the trends in estimated total biomass and exploitation rate between base cases by model platforms: VPA run 385 (blue lines), Stock Synthesis run 16 reweight (green lines), and ASAP run 24 with 20% CV (orange lines)

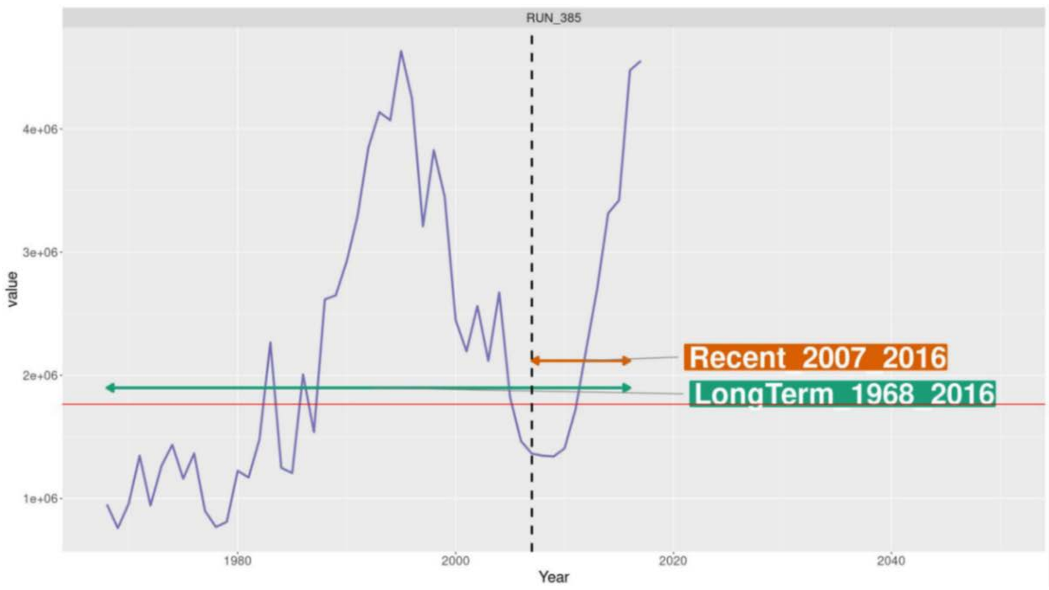

Figure 35. The assumptions of future recruitment: a long-term average (1968-2016) and a short-term average (2007-2016) for VPA projection based on Run 385.

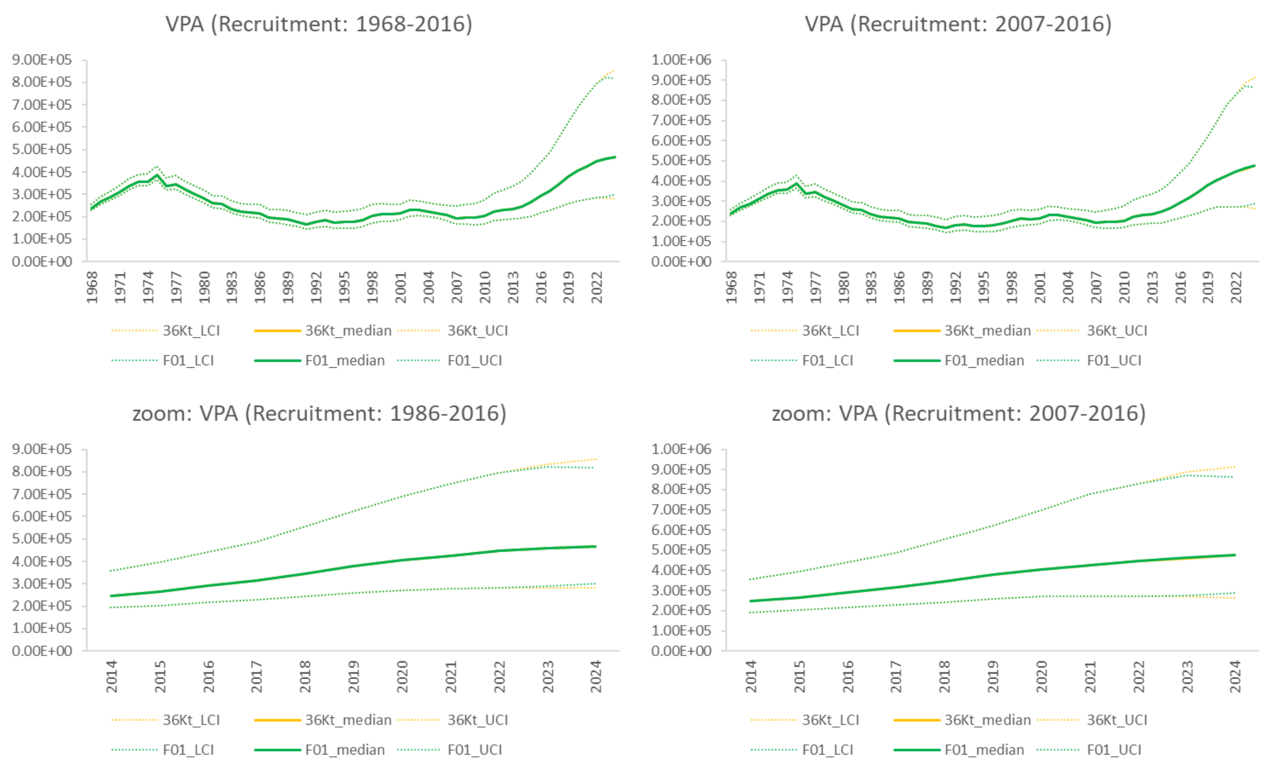

Figure 36. Projected spawning stock biomass (SSB) with 95% confidence intervals in VPA Run 385 projection with 2 recruitment scenarios (left: the average between 1986 and 2016 and right: the average between 2007 and 2016). The top panels show the entire assessment period and the projection until 2024, and the bottom panels only show since 2014.

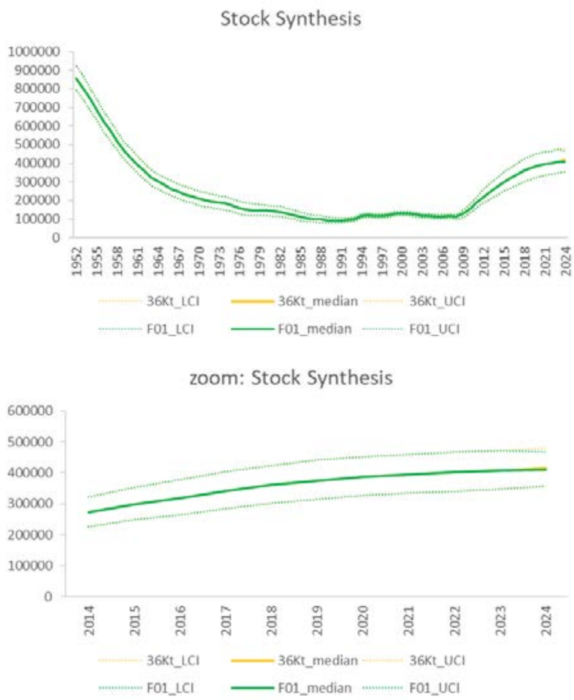

Figure 37. Projected spawning stock biomass (SSB) with 95% confidence intervals in Stock Synthesis Run 16 reweight projection. The top panel shows the entire assessment period and the projection until 2024, and the bottom panel shows since 2014.

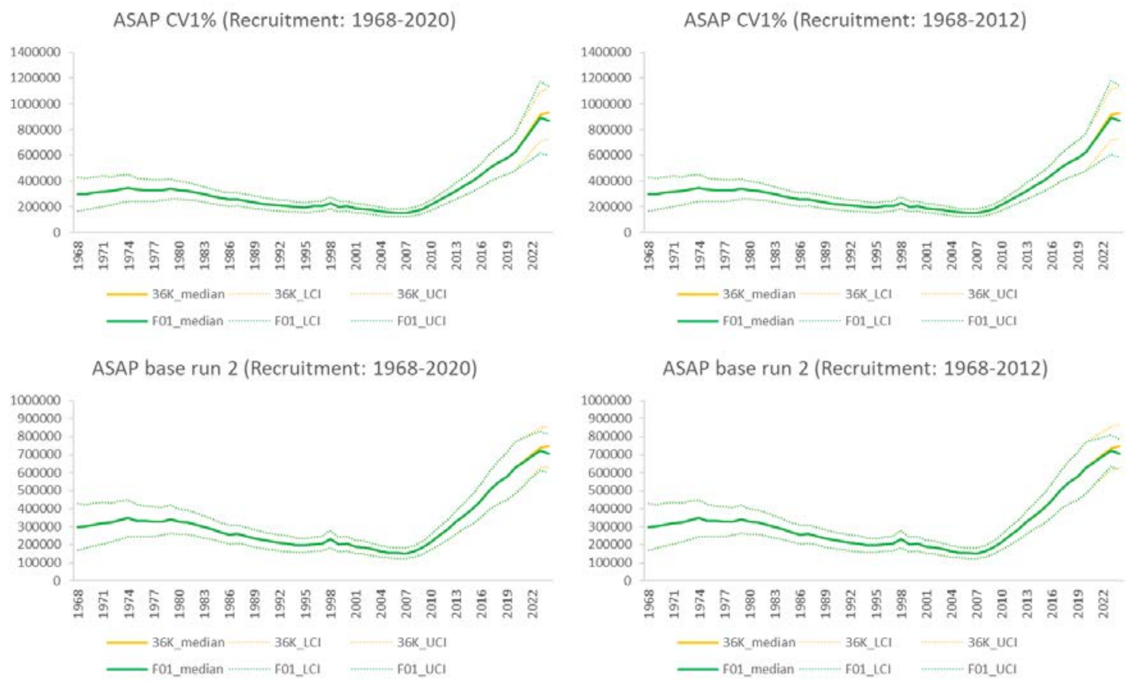

Figure 38. Projected spawning stock biomass (SSB) with 95% confidence intervals in ASAP CV1% on the inflated catch projection (upper panels) and in ASAP CV20% (base run 2) on the inflated catch projection (lower panels) with 2 recruitment scenarios (left: the average between 1986 and 2020 and right: the average between 1968 and 2012.

Appendix 1

Agenda

1. Opening, adoption of agenda, meeting arrangements and assignment of rapporteurs
2. Model diagnostics
   - 2.1 VPA
   - 2.2 Stock synthesis
   - 2.3 Other models
3. Assessment results
   - 3.1 VPA
     - 3.1.1 Model fits
     - 3.1.2 Stock status
   - 3.2 Stock synthesis
     - 3.2.1 Model fits
     - 3.2.2 Stock status
   - 3.3 Other models
     - 3.3.1 Model fits
     - 3.3.2 Stock status
   - 3.4 Synthesis of assessment results
4. Initial feedback from the independent review
5. Topics related to the Management Strategy Evaluation (Wednesday, 12-18:00 CEST)
6. Projections and management advice
7. Draft Executive Summary sections
8. Update on GBYP activities
9. Recommendations
10. Other matters
11. Adoption of the report and closure

Appendix 2

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Appendix 3

List of documents and presentations

Reference	*Title*	*Authors*
SCRS/2022/101	Review of the catch and catch-at-age estimation for the E-BFT catch inflated estimates 1998 - 2007	Ortiz M., Kimoto A., Lauretta M., Palma C., Rouyer T., Gordoa A., Di Natale A., Rodriguez-Marin E., and Walter J.
SCRS/2022/103	Determination of annual periodicity in annuli formation in Atlantic bluefin tuna otoliths	Rodriguez-Marin E., Busawon D., Luque PL., Castillo I., Stewart N., Krusic-Golub K., Parejo A. and Hanke A.
SCRS/2022/125	2022 ASAP stock assessment of the eastern Atlantic and Mediterranean bluefin tuna	Carrano C., Maguire J-J., Kerr L., Walter J., Lauretta M., Rouyer T., and Cadrin S.X.
SCRS/2022/126	BR CMP as at June 2022	Butterworth D., Rademeyer R.A.
SCRS/2022/127	A brief review of natural mortality for the eastern Atlantic and Mediterranean bluefin tuna, pacific bluefin tuna and southern bluefin tuna	Feng J., Zhang F., and Zhu J.
SCRS/2022/128	2022 proposed base case model for eastern Atlantic and Mediterranean bluefin tuna assessment using stock synthesis	Sampedro P., Tsukahara Y., Lauretta M., Fukuda H., Sharma R., Gordoa A., Rouyer T., Kimoto A., Walter J.and Rodríguez-Marín E.
SCRS/2022/129	Final data, explorations, model set-up and diagnostics for the 2022 VPA stock assessment of the eastern Atlantic and Mediterranean bluefin tuna stock	Rouyer T., A. Kimoto, R. Zarrad, M. Ortiz, C. Palma, C. Mayor, M. Lauretta, Gordoa A., Rodriguez Marin E. and Walter J.
SCRS/2022/131	Characteristics of the Balfegó purse seine fleet, CPUE approaches contextualize with the eastern stock indicators	Gordoa A., Bahamón N., Ortiz M., and Santiago J.
SCRS/2022/132	Eastern Atlantic bluefin tuna assessment review Report from the data preparation meeting held in April	Ianelli J.
SCRS/P/2022/043	Model results and initial projections for the 2022 VPA stock assessment of the eastern and Atlantic Mediterranean bluefin tuna stock	Rouyer T., Kimoto A., Zarrad R., Ortiz M., Palma C., Mayor C., Lauretta M., Gordoa A., Rodriguez-Marin E. and Walter J.
SCRS/P/2022/046	Some considerations for modeling growth of east Atlantic bluefin tuna in stock synthesis	Lauretta M., Sampedro P.
SCRS/P/2022/047	Updated CMP results	Carruthers T.
SCRS/P/2022/048	An update on the analysis of weight gain of farm E-BFT	Ortiz M., Mayor C., Paga A., and Alemany F.
SCRS/P/2022/049	Updating on GBYP matters	Alemany F., Tensek S., and Paga A.

Appendix 4

SCRS document abstracts as provided by the authors

SCRS/2022/101 – During the 2022 Eastern Atlantic and Mediterranean Bluefin Tuna Data Preparatory Meeting, the Bluefin Species Group (BFTSG) agreed to revise the assumptions and update the catch-at-size/ catch-at-age (CAS/CAA) intersessionally by replacing the "NEI (inflated)" partial catches component (1998-2007) with a new set of combined Mediterranean size samples. A small ad-hoc group was formed to carry out this task and proposed an alternative CAS/CAA for the 2022 E-BFT stock assessment, this document summarizes these analyses. This document provides the revised CAS (version 2b) and two CAA based on the von Bertalanffy and the Richards growth curves. The small group agreed that this revised CAS is a better estimate of the size distribution for the NEI-inflated catch and proposed adoption by the BFTSG, and also recommended that this revision would be applied only to VPA (Virtual Population Analysis) and possibly ASAP (Age Structured Assessment Program).

SCRS/2022/103 – Controversies remain regarding the periodicity, or seasonality, of otolith growth band formation which directly influences the correct age determination of Atlantic bluefin tuna using otoliths. Thereby, the aim of this work was to apply marginal increment analysis (MIA) and marginal edge analysis (EA) to determine the timing of band deposition. The index of completion (MIA) was also analyzed using General Additive Models. The results indicated that the opaque band starts to form in July and finishes forming in November. From the end of the year and the beginning of the following year there is minimal marginal edge growth, and this is when the translucent band begins to form and reaches its maximum development in June. MIA and EA have evidenced that the annulus has been formed in November in the Atlantic Bluefin tuna otolith. This would mean delaying the date of the current 1 July adjustment criterion to November 30.

SCRS/2022/125 – The Age Structured Assessment Program (ASAP) was applied to eastern Atlantic and Mediterranean Atlantic bluefin tuna for the 2022 stock assessment. ASAP is a statistical catch-at-age model that requires a time series of observed catch, age composition, and indices of abundance. Previous single-fleet applications of ASAP for the 2017 and 2020 Atlantic Bluefin tuna assessments were updated and revised, and alternative models with fleet structure were explored. The single-fleet ASAP model generally fit the data well, and were retrospectively consistent, but residual patterns in age composition and uncertainty in selectivity parameters could not be resolved. Model estimates suggest a substantial change in selectivity in the late 1990s, from full selection of young ages and partial selection of older ages before 1999, then partial selectivity of young ages and full selection of older ages since 1999. Model results suggest that the stock decreased from the 1970s to the early 2000s then recovered over the last decade from recent strong recruitment and low fishing mortality. Multi-fleet ASAP models were developed to fit catch data and estimate selectivity for each index fleet as well as the Mediterranean purse seine fleet. Multi-fleet-based runs were retrospectively consistent and fit the available data well, with some residual patterns. Results suggest stock recovery in the last decade from relatively low fishing mortality and strong recruitment. However, in contrast to the historical stock trajectory indicated by single-fleet runs, estimates of stock size from multi-fleet runs were low for the 1960s to the early 2000s. Status determination from single-fleet and multi-fleet runs was similar: the estimate of 2020 fishing mortality was much less than F0.1, and the estimate of 2020 spawning biomass was much greater than SSBF0.1.

SCRS/2022/126 – The BR CMP is further adjusted in a few respects, especially as regards the relative weights given to the different indices of abundance to secure improved median TAC trajectories. Results are provided for the four basic development tunings, plus variants for one of those tunings in relation to TAC change constraints and the period between TAC changes. Furthermore, the CMP is tuned to the most aggressive option possible under the Blim constraint at 15% and at 10% conservation performance for the eastern population seems too poor for the former, as is catch performance for the West area for the latter.

SCRS/2022/127 – A brief review is presented regarding the natural mortality used in the stock assessment for eastern Atlantic and Mediterranean bluefin tuna over the past decades and in management strategy evaluation in recent years. Furthermore, the variation of natural mortality assumptions of Pacific bluefin tuna and Southern bluefin tuna is also reviewed. There were three types of natural mortality assumptions used in the stock assessment and/or management strategy evaluation as follows: the fixed values at all ages, an age-specific vector, and a smooth decreasing curve rescaled with the Lorenzen mortality function. The current natural mortality assumption is more logical compared to those previous assumptions. A long-term biological investigation of Atlantic bluefin tuna is needed to provide more available information about natural mortality.

SCRS/2022/128 – This document presents the proposed base case for the assessment of the eastern Atlantic and Mediterranean population of bluefin tuna using Stock Synthesis in 2022. The model runs from 1950 to 2020 and was fitted to length composition data, conditional age-at-length (otolith and spines–length-age pairs), 16 fishing fleets and 11 indices of abundance. Growth is modelled by a Richards function with L_{INF} fixed at 271 cm, K fixed at 0.23387, and the shape parameter is estimated by the model. A Beverton-Holt stock recruitment relationship was estimated in the model with the steepness and sigmaR fixed at 0.9 and 0.6, respectively. R0 is freely estimated. Although the diagnostics indicate an acceptable stability of the model, there are important conflicts between the catch information, length composition and index data. The model fits to length compositions were not good, but the model followed most of the indices fairly well. The model results showed that the SSB decreased from 1950 until the 1970s, remaining relatively stable at low values during the 1980-2009 period, and showing a sharp and steady increased since 2010. Model diagnostics indicated that the different source of data provides contradicting information about the stock, resulting in biases in the results.

SCRS/2022/129 – This document presents the modelling work done for the 2022 stock assessment for the eastern and Mediterranean Bluefin tuna stock during informal modelling subgroup meetings in June 2022. This document presents various runs built upon the base case for the 2017 stock assessment. These runs aim to address issues identified in the 2020 update assessment and aspects discussed during the informal meetings held in June 2022, regarding the inclusion of updated catch-at-age data, improvement of model stability in relation to F_{RATIO} estimates, the selection of the age for the plus group and inclusion of the WMED_GBYP_AER index. Following several explorations, the present work contains two runs that displayed improved diagnostics compared to previous runs. These models have improved retrospective patterns and no problematic issue was found through jittering the random number generator, jittering the starting values for the terminal F estimate, bootstrapping or through jackknife analysis.

SCRS/2022/131 – This study describes the characteristics of the fleet including its operational particularities in order to comprehend the fishing effort of this fleet and the possible factors of standardisation of its CPUEs. In order to estimate the CPUEs with different approaches and discuss the information provided by each of them. Finally, the different estimates are contextualised with all the indicators of the eastern stock.

SCRS/2022/132 – The reviewer for the East Atlantic and Mediterranean Bluefin Tuna stock assessment provided a review report from the data preparation meeting held in April.

SCRS/P/2022/043 – During the meeting, the Group requested future projections using VPA for the E-BFT stock assessment, this presentation provided the stock status and short-term projection applying F0.1 or 36000 t.

SCRS/P/2022/046 – The preliminary Stock Synthesis runs demonstrated an inability to estimate growth (L_{INF} in particular) within the model, due to lack of size-at-age information of older ages. SS estimates of growth for the West Atlantic model, which includes large numbers of East Atlantic origin, otolith-aged fish, resulted in L_{INF} = 272 and 273 cm from the 2020 and 2021 assessments, respectively. The northern fleets of Canada HL and Norway PS appear to catch the largest bluefin tuna observed with upper modes near 270 cm and L_{MAX} near 340 cm. Distributions of size-at-age and estimates of mean size of older age classes in the mixed-stock West area fisheries support the Richards growth function. It was recommended to fix L_{INF} =271 and assume a Richards growth model in the East Atlantic Stock Synthesis model, and to assume asymptotic selectivity for the Norway PS during the period 1970 to 1981.

SCRS/P/2022/047 – The MSE Expert presented the tasks completed since last meeting in New Metrics (v7.6.6): PrpOF: Proportion U > UMSY (i.e., probability of overfishing, projection years 1-30), AvUrel: mean U / UMSY (projection years 1-30), new tab in shiny app: 'Proj F' which shows U/MSY quantiles, projections only go out to 40 years and 2059. 40 projection years were necessary because the first three years (i.e., 2020-2022) are before the CMP is applied, the next 35 are needed to show the overfished trend metric (OFT, calculated from CMP years 31- 35). Results compiled for 6 CMPs: TC, BR, AI, PW, LW, FZ in the new version (v7.6.6).

SCRS/P/2022/048 – No text was provided by the author(s).

SCRS/P/2022/049 – No text was provided by the author(s).

Appendix 5

Control, parameter and data files for eastern bluefin tuna VPA run 385

This Appendix is available as an electronic document.

Appendix 6

Control, parameter and data files for eastern bluefin tuna Stock Synthesis run 16 reweight

This Appendix is available as an electronic document.

Appendix 7

Control and data file for eastern bluefin tuna ASAP base run 2

This Appendix is available as an electronic document.

Appendix 8

Atlantic Bluefin Tuna MSE – Results, Decisions, & Next Steps

Executive Summary

This document presents updated results from the Atlantic bluefin tuna management strategy evaluation (MSE) process from new analyses conducted to address feedback received at the 9-10 May 2022 Panel 2 meeting. The intention is to provide sufficient information to facilitate discussion among scientists, fishery managers and stakeholders, as well as decision-makers, at the 14 July 2022 meeting of Panel 2.

Candidate Management Procedures

There are currently 6 candidate management procedures (CMPs) under development by the SCRS (**Table 1**). All calculate separate total allowable catches (TACs) for the West and East management areas. The SCRS rigorously reviewed all available western and eastern indices, resulting in two indices being deemed unsuitable in their present condition to be used for CMP inputs. After this, the choice of indices used in each CMP has been at the discretion of developers with emphasis placed on whether the CMPs perform well when using these indices. We present recent results from 6 CMPs to show key performance trade-offs for management objectives in a 'quilt plot' (**Figure 1**) that ranks the most recent results of these CMPs on 5 key performance statistics for both East and West. A second plot (**Figure 2**) includes 10 additional statistics for background. The performance statistics are described in **Table 2**.

The July Panel 2 agenda specifies four main decision points:

- Decision point 1 (PA2 Agenda Item 6.a): 2-year vs. 3-year management cycle and symmetric stability
  - 3-year management cycles were tested for 2 CMPs: BR and TC. The results for the BR CMP variants tuned to a common LD*15 value are shown in **Table 3** and summarized below.
  - The 3-year cycle was slower to react to signals to decrease TAC and thus had lower 50%ile biomass status (Br30) and slightly reduced AvC30 coupled with slightly higher variability in TAC changes.
  - To compensate, SCRS explored greater allowable TAC reductions (+20%/-35% stability) that improved Br30 status slightly for both eastern and western stocks.
  - Performance was only slightly inferior and practical considerations (stability, reduced administrative burden) may support a 3-year management cycle; this decision should be made at this meeting to facilitate further CMP development and the SCRS notes that this will be time-consuming for all developers to implement.
  - The May PA2 meeting requested that the SCRS evaluate a symmetrical stability provision of +/-20% compared to the default +20%/-30%. The +20/-20 option was slower to implement necessary TAC decreases and thus had lower yield and biomass performance (i.e., greater risk) (**Table 4**). The SCRS has not yet evaluated +20/-20 with a 3-year cycle but expects performance to be worse, since not even +20/-30 had satisfactory performance in terms of the agreed B_{LIM} requirements. Nonetheless, to facilitate further CMP development, Panel 2 should decide at this meeting whether symmetrical stability provisions are required.

- Decision point 2 (PA2 Agenda Item 6.b*)*: Incorporation of 'phase-in' as default
  - As per PA2 guidance in May, all CMPs were tested with a phase-in (i.e., limiting any downward TAC change to 10% for the first two 2-year management cycles). The phase-in made little difference to long-term biomass (risk) or yield outcomes, and thus is confirmed as a viable approach; this decision should be made at this meeting to facilitate further CMP development.

- Decision point 3 (PA2 Agenda Item 6.c): Culling of CMPs that fail the thresholds defined at the May PA2 meeting
  - Lowest depletion, LD* (>15% probability of falling below B_{LIM}, i.e., 40% of dynamic SSBMSY).

  - o Two CMPs (i.e., EA and TN) were withdrawn by their developers due to difficulties in meeting this LD* 15% threshold; this decision to remove these CMPs has been made by their individual developers so no decision is necessary by Panel 2.
- 60% PGK (i.e., probability of being in the green quadrant of the Kobe matrix in year 30).
  - o All 6 CMPs meet or nearly meet this (**Figure 1**) for the default tuning level (median Br30 of 1.25 for the western stock and 1.50 for the eastern).

– Decision point 4: Culling of lowest performing CMPs
  - Of the 6 presented CMPs, does Panel 2 want to cull any now? The SCRS does not expect any culling to occur now.
  - Examining the quilt plots in **Figures 1** and **2**, are there certain performance statistics or trends that are considered undesirable, concerning or unacceptable by PA2?

Feedback is also sought on the following points related to CMP structure and behaviour and the path forward:

– Preferences on yield path
  - Recent high abundance is expected to result in increased catches (both in the East and the West) in the short term, followed by a decline. Should the possibility of reducing the size of the peak of this pulse in TACs to spread it over a longer period be investigated?

– Index selection for CMPs
  - Number of indices: Some CMPs use all 10 of the approved indices to set TACs, while others use as few as 2 per management area (**Figure 1**).

– Performance tuning
  - The SCRS will discuss the process of performance tuning to achieve higher yield performance while meeting minimum safety and status objectives.

– Process for obtaining feedback from CPCs of their stakeholder preferences relative to CMP decisions (see also Next steps below)
  - How may the SCRS assist in CPC-planned stakeholder outreach?

Next steps

After the Panel 2 meeting on 14 July, one remaining Panel 2 meeting will take place before the Commission Plenary, scheduled for 14 October 2022. This will follow the September meetings of the SCRS Bluefin MSE Technical Subgroup, Bluefin Species Group, and SCRS Plenary meeting. The Bluefin Species Group also hopes to convene additional Ambassador meetings (tentatively, in late July and early October) in English, French and Spanish, and some summary materials are available in Arabic.

Other resources

Atlantic Bluefin Tuna MSE splash page, including the interactive Shiny App (ENG only)

– CMP Results and Plotting
– CMP Performance Overview with Quilt Plots
– CMP Performance with Spider Plot

Harveststrategies.org MSE outreach materials (multiple languages, including Arabic)

Table 1. Table of Candidate Management Procedures (CMPs). All indices are referenced at the end of the table.

CMP	Indices used		Detailed description	Strengths/Weaknesses	References
	EAST	WEST			
FO	FR AER SUV2 JPN LL NEAtl2 W-MED LAR SUV	US RR 66-144, CAN SWNS RR US-MEX GOM PLL	Uses an estimated F0.1 applied to an estimate of biomass to provide TAC advice. The F0.1 estimate is based on the relative abundance of young, medium and old fish for each area (which is informed from the areas indices noted on the left). Estimated biomass for each area is derived from an index from that area and a period of reference years.	Strengths: - performs well across several indicators. - uses indices that represent various age class to calculate TAC	SCRS/2020/144 SCRS/2021/122
AI	All	All	An artificial neural network is trained on simulated projected data for all indices (from both sides of the ocean) and a management value V, that is the true simulated vulnerable biomass in each area multiplied by a harvest control rule. Once trained, the neural network can predict V using new index data (simulated or real). Area-specific TAC is then calculated as a constant fraction of V.	Strengths: - performs well across several indicators. - Uses all indices Weaknesses: - lacks a clear relationship between index values and TAC, due to machine learning component. - struggles to achieve LD and PGK	SCRS/2021/028
BR	All	All	TACs are set based on relative harvest rates (with some slight initial time dependence) for a reference year (2018) applied to the 2-year moving average of a combined master abundance index for each of the West and East areas. These master indices are weighted averages across the indices available for the area based on their variances and to achieve smoother TAC trends over time.	Strengths: - strong performance, across most indicators. - Uses all indices	SCRS/2021/121 SCRS/2021/152 SCRS/2022/082 SCRS/2022/126
LW	W-MED LAR SUV JPN LL NEAtl2	GOM LAR SUV MEXUS_LL	LW uses a 3-yr average of catch divided by relative SSB to estimate a constant harvest rate metric. All 4 indices on the left are used for the West area to account for stock mixing; Med larval and JPN East LL are used for the East area.	Strengths: - performs well across several indicators. Weaknesses: - has struggled to achieve some of PA2 identified thresholds for PGK.	SCRS/2021/127

PW	W-MED LAR SUV JPN LL NEAtl2	GOM LAR SUV MEXUS_LL	Similar to LW, PW uses indices in the East and the West (as specified on the left) to achieve a constant exploitation rate. It adjusts Western TAC according to Eastern indices under the assumption that Western TACs are supported by Eastern mixing.	Strengths: - performs well across several indicators. Weaknesses: - poor stability and yield.	SCRS/2021/155 SCRS/2022/078
TC	MOR POR TRAP JPN LL NEAtl2 W-MED LAR SUV GBYP AER SUV BAR	US RR 66-144 JPN_LL_West 2 GOM_LAR_SUV	Two fishery indices for each area (West: JPN_LL_West2, US_RR_66_144. East: JPN_LL_NEAtl2, MOR_POR_TRAP) and three stock-specific fishery independent indices (West: GOM_LAR_SUV. East: MED_LAR_SUV, GBYP_AER_SUV_BAR) are used to predict area biomass assuming a fixed rate of stock mixing (e.g., a fixed fraction of the Eastern stock enters the West area). The TAC is calculated for each area by multiplying the predicted area biomass by a constant harvest rate.	Strengths: - highest stability Weaknesses: - increased stability causes somewhat lower biomass and yield performance.	SCRS/2020/150 SCRS/2020/165

East indices: FR AER SUV2 – French aerial survey in the Mediterranean; JPN LL NEAtl2 – Japanese longline index in the Northeast Atlantic; W-MED LAR SUV – Larval survey in the western Mediterranean; MOR POR Trap – Moroccan-Portuguese trap index; GBYP AER SUV BAR – GBYP aerial survey in the Balearics.

West indices: US RR 66-144 – U.S. recreational rod & reel index for fish 66-144 cm; CAN SWNS RR – Canadian Southwest Nova Scotia handline index; US-MEX GOM PLL – U.S. & Mexico combined longline index for the Gulf of Mexico; GOM LAR SUV – U.S. larval survey in the Gulf of Mexico; JPN LL West2 - Japanese longline index for the West Atlantic.

Table 2. Table of Operational Management Objectives and Performance Statistics.

Management Objectives (Res. 18-03) + May 2022 PA2 guidance	**Primary Performance Statistics (Tuning Objective & Quilt 1)**	**Secondary Performance Statistics (Quilt 2)**
Status The stock should have a greater than [60]% probability of occurring in the green quadrant of the Kobe matrix. (To be evaluated at intermediate points between zero and 30 years, and at the end of the 30-year period.)	**Br30** – Br [i.e., biomass ratio, or spawning stock biomass (SSB) relative to dynamic SSBMSY[1]] after 30 years. **PGK**: probability of being in the Kobe green quadrant (i.e., SSB>dSSBMSY and U<UMSY2[2]) in year 30.	**AvgBr** – Average Br over projection years 11-30. **Br20** – Br after 20 years. **POF** – Probability of overfishing (U>UMSY) after 30 projected years. **PNRK -** Probability of not being in the red Kobe quadrant (SSB > SSBMSY or U < UMSY) after 30 projected years. **OFT** – Overfished Trend, SSB trend if Br30<1. **PrpOF** – Proportion U > U_{MSY} (i.e., probability of overfishing in projection years 1-30). (*See presentation. Not currently in quilt plot.*) **AvUrel** – mean U/U_{MSY} in projection years 1-30. (*See presentation. Not currently in quilt plot.*) **U/U_{MSY}** – exploitation rate (U) in biomass divided by exploitation rate at MSY. (*Shown as a trajectory in the presentation rather than in a quilt plot*).
Safety There should be no more than a [15]% probability of the stock falling below BLIM at any point during the years 11-30 of the projection period.	**LD*** – Lowest depletion (i.e., SSB relative to dynamic SSB_{MSY}) over years 11-30 in the projection period. LD* value is evaluated relative to SCRS-proposed B_{LIM} (40% of dynamic SSB_{MSY}).[3] LD5%, LD10% and LD15% will all be evaluated, with the latter in Quilt 1 and the former 2 in Quilt 2.	
Yield Maximize overall catch levels.	**AvC10** – Median TAC (t) over years 1-10. **AvC30** – Median TAC (t) over years 1-30.	**C1** – TAC in first 2 years of MP (i.e., 2023-24). **AvC20** – Median TAC (t) over years 1-20.
Stability Any change in TAC between management periods should be no more than a 20% increase or a [20][30]% decrease, except during the application of the MP in the first two management periods, where any TAC change shall not exceed a 20% increase or a 10% decrease.	**VarC** – Variation in TAC (%) between 2-year management cycles.	

[1]Dynamic SSB_{MSY} is a set fraction of dynamic SSB_0, which is the spawning stock biomass that would occur in the absence of fishing, historically and in the future. Dynamic SSB_{MSY} can change over time since it is based on current recruitment levels, which fluctuate due to time-varying dynamics in the models.
[2]The exploitation rate (U) is annual catch (in tonnes) divided by the total annual biomass in tonnes. U_{MSY} is the fixed harvest rate (U) corresponding with SSB/SSB_{MSY}=1 at year 50.
[3]SCRS proposed a B_{LIM} of 40% of dynamic SSBMSY for the purposes of the MSE for CMP testing and performance tuning. Status relative to B_{LIM} is calculated as the lowest depletion (spawning biomass relative to dynamic SSB_{MSY}) over projection years 11-30 for which the CMP is applied across the plausibility weighted operating models. B_{LIM} is proposed as a performance statistic, not as an 'active' or functional trigger for determining a management action.

Table 3. Performance for management cycle variations of the BR CMP tuned to a common LD*15 (0.4 of dynamic SSB_{MSY}) for comparative purposes. Performance statistics are described in **Table 2.** The 3-year cycle (BR5c) was slower to react to signals to decrease TAC and thus had slightly worse performance for status, yield and stability when compared to the 2-year cycle (BR5a). Improved status (Br30 5th and 50th percentiles) can be achieved with a 3-year management cycle by allowing for greater reductions in TAC as shown by BR5d.

			East						**West**					
Variant	**Mgmt Cycle**	**Stability**	**Br30 50% tile**	**Br30 5% tile**	**LD*15**	**LD*10**	**Difference in AvC30 (kt)**	**VarC**	**Br30 50% tile**	**Br30 5% tile**	**LD*15**	**LD*10**	**Difference in AvC30 (kt)**	**VarC**
BR5a	2-year	+20/-30	1.03	0.24	0.4	0.31	-	19.7	1.07	0.41	0.4	0.32	-	13.56
BR5c	3-year	+20/-30	1.1	0.20	0.4	0.28	-1.81	20.1	1.15	0.37	0.4	0.29	-0.11	15.12
BR5d	3-year	+20/-35	1.13	0.31	0.4	0.34	-2.37	20.9	1.17	0.42	0.4	0.31	-0.08	15.33

Table 4. Comparative performance for variations of the BR CMP with symmetric TAC change restrictions. Performance statistics are described in **Table 2**. Performance of BR2g (+20/-20 stability) has slightly lower yields (AvC30) compared to BR2a (+20/-30 stability), as well as poorer conservation (LD*) performance.

			East					**West**				
Variant	**Mgmt Cycle**	**Stability**	**Br30 50% tile**	**LD*15**	**LD*10**	**Difference in AvC30 (kt)**	**VarC**	**Br30 50% tile**	**LD*15**	**LD*10**	**Difference in AvC30 (kt)**	**VarC**
BR2a	2-year	+20/-30	1.5	0.66	0.58	-	16.56	1.25	0.49	0.38	-	12.61
BR2g	2-year	+20/-20	1.49	0.55	0.46	-0.27	14.53	1.24	0.46	0.32	-0.01	12.15

Figure 1. Primary 'Quilt' plot for the West and East for tuning level 2 (i.e., Br30=1.25 for West and Br30=1.5 for East) using the default weighting scheme (i.e., 0 for PGK; 0.5 for AvC10 and AvC30; 1.0 for VarC and LD15) and ordered relative to the total column. Colour scale represents relative performance from dark (best) to light (worst) within a column. This plot shows the top 5 performance statistics chosen on the basis of removing duplicative statistics and focusing on the four operational performance statistics of safety, status, stability and yield. The five statistics and associated percentiles are PGK: probability of being in the Kobe green quadrant (i.e., $SSB>SSB_{MSY}$ and $U<U_{MSY}$) in year 30; AvC10: average catch (kilotons, kt) over years 1-10 (50%tile); AvC30: average catch (kt) over years 1-30 (50%tile); VarC: Variation in catch (kt) between 2-year management cycles (50%tile); LD*(15%): 15%tile of lowest depletion over years 11-30. PGK is not weighted in the scoring as all CMPs are tuned to achieve similar biomass status. Ordering is achieved by scaling each column according to its minimum and maximum, within a column, giving a rank order from 0 (best) to 1 (worst), weighting columns according to the default weighting, obtaining an average for West and East and then taking the average across East and West (Tot). See **Table 2** for more detailed descriptions of performance statistics. The 'a' for each CMP refers to the +20/-30 stability tuning without phase-in.

CMP	West					East					Tot	# indices
	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)	PGK (Mean)	AvC10 (50%)	AvC30 (50%)	VarC (50%)	LD (15%)		
BR2a	0.63	3.02	2.72	12.61	0.49	0.78	40.9	32.65	16.56	0.66	0.26	10
AI2a	0.58	3.03	2.77	16.43	0.53	0.71	41.16	37.62	16.17	0.65	0.27	10
TC2a	0.61	2.83	2.64	6.71	0.4	0.73	33.43	29.21	8.18	0.54	0.48	7
FO2a	0.62	2.84	2.77	14.29	0.48	0.64	37.37	30.46	13.93	0.47	0.53	6
LW2a	0.59	2.68	2.56	15.63	0.5	0.72	34.63	30.27	17.21	0.6	0.58	4
PW2a	0.67	2.37	2.29	17.11	0.45	0.74	35.36	29.93	13.27	0.6	0.71	4

Figure 2. Secondary quilt plots, shown separately for East and West, which depict the following 10 performance statistics - C1: catch in the first year of CMP application (50%); AvC20: average catch (kilotons, kt) over years 11-20 (50%tile); AvgBr: spawning biomass relative to dynamic SSB_{MSY} over projection years 11-30 (50%), Br20: Depletion (spawning biomass relative to dynamic SSB_{MSY}) in projection year 20 (50%); Br30: Depletion (spawning biomass relative to dynamic SSB_{MSY}) in projection year 30 (5%); LD* (5%): 5%tile of lowest depletion over years 11-30; LD* (10%) 10%tile of lowest depletion over years 11-30; POF: Probability of Overfishing ($U > U_{MSY}$) after 30 projected years (mean); PNRK: Probability of not Red Kobe ($SSB > SSB_{MSY}$ or $U < U_{MSY}$) after 30 projected years (mean), OFT: Overfished trend, SSB trend over projection years 31 - 35 when Br30 < 1. See **Table 2** for more detailed descriptions of performance statistics. The 'a' for each CMP refers to the +20/- 30 stability tuning without phase-in. Order of the CMPs is the same as in quilt plot 1.

East

CMP	C1 (50%)	AvC20 (50%)	AvgBr (50%)	Br20 (50%)	Br30 (5%)	LD (5%)	LD (10%)	POF (Mean)	PNRK (Mean)	OFT (P>0)
BR2a	43.2	34.05	1.49	1.45	0.73	0.49	0.58	0.03	0.99	0.96
AI2a	32.27	40.51	1.53	1.51	0.47	0.42	0.55	0.11	0.9	0.86
TC2a	37.26	28.84	1.59	1.58	0.52	0.37	0.47	0.07	0.94	0.9
FO2a	43.2	29.83	1.52	1.5	0.3	0.25	0.37	0.21	0.81	0.84
LW2a	43.2	30.14	1.52	1.5	0.55	0.44	0.53	0.08	0.95	0.92
PW2a	41.14	30.2	1.53	1.5	0.57	0.43	0.52	0.06	0.97	0.93

West

CMP	C1 (50%)	AvC20 (50%)	AvgBr (50%)	Br20 (50%)	Br30 (5%)	LD (5%)	LD (10%)	POF (Mean)	PNRK (Mean)	OFT (P>0)
BR2a	2.71	2.73	1.34	1.31	0.54	0.28	0.38	0.22	0.83	0.86
AI2a	2.82	2.83	1.35	1.31	0.63	0.32	0.42	0.26	0.87	0.87
TC2a	2.68	2.59	1.42	1.41	0.35	0.18	0.27	0.28	0.78	0.86
FO2a	2.41	2.78	1.38	1.35	0.48	0.3	0.38	0.26	0.81	0.85
LW2a	2.53	2.56	1.34	1.3	0.49	0.28	0.38	0.26	0.81	0.84
PW2a	2.42	2.27	1.23	1.18	0.49	0.28	0.38	0.09	0.95	0.94