REPORT OF THE 2021 BIGEYE STOCK ASSESSMENT MEETING

(Online, 19- 29 July 2021)

1. Opening, adoption of agenda, and meeting arrangements

The meeting was held online due to the current COVID-19 pandemic situation. Dr David J. Die (USA), the Tropical Tunas Species Group ("the Group") coordinator and Bigeye tuna rapporteur, opened the meeting and welcomed participants. Dr Miguel Neves dos Santos (ICCAT Assistant Executive Secretary) also welcomed the participants and thanked the efforts made by all participants to attend the meeting remotely.

The Secretariat provided information on how to use the online platform for the meeting (Zoom application). The Chair reviewed the Agenda, which was adopted (**Appendix 1**).

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

Sections	*Rapporteur*
Items 1, 8	M. Ortiz, D. Die
Item 2	A. Kimoto, M. Ortiz
Item 3	M. Schirripa, B. Mourato, G. Merino
Item 4	A. Norelli, S. Cass-Calay, B. Mourato, G. Merino, D. Gaertner, N. Taylor, D. Die
Item 5	H. Murua, K. Kitakado
Item 6	G. Diaz, A. Maufroy
Item 7	J. Santiago, F. Sow

2. Summary of available data for assessment and updates since the data preparatory meeting

The Secretariat provided an overview of the fisheries data available for the assessment meeting including updates compiled since the data preparatory meeting.

2.1 Fisheries Statistics, size, and CAS estimates

Following the recommendations and the intersessional work plan agreed by the Group during the data preparatory meeting, the following fisheries statistics were provided by the Secretariat:

a) Updated Task 1 nominal catches (NC) for bigeye tuna including data provided by April 30, 2021;
b) Updated Task 2 catch and effort (CE) for tropical tunas including catch and effort of the ETRO_PS1991-2020 separating catches by fishing mode (PS sets on free schools and FAD/FOBs). This update included a full revision (1991-2019) provided by the EU-France national scientists;
c) Updates of the Ghana fisheries statistics for tropical tunas (SKJ, BET, YFT) 2018-2020 (SCRS/2021/133);
d) Update Task 2 size data including information from Ghana PS and BB fisheries, revisions of the EU-France, and revisions of the Chinese Taipei longline size data (SCRS/2021/113);
e) Estimates of Task 2 catch-at-size (CAS) based on the update Task 2 SZ and provided CAS information by CPCs;
f) Estimates of Catch Distribution (CatDis) of bigeye 1950-2019 by quarter and 5x5 lat-lon grids;
g) Updated conventional tagging information for bigeye up to July 16, 2021.

The Secretariat in collaboration with the modelling teams also provided the basic data inputs for the preliminary assessment models including the following data:

a) Estimates of size-frequency distributions for bigeye tuna according to the fleet structure agreed during the data preparatory meeting (2019 Yellowfin Stock Assessment, SCRS/2021/113) for input to the Stock Synthesis models. The size-frequency data were further reviewed and adjusted during the intersessional work by the modelling teams after careful evaluation of the size trends, selectivity changes and preliminary assessment model runs;
b) Estimates of catch by each fleet component in the Stock Synthesis model, including seasonal distribution for some of the fleets;

c) Estimates of total removals for the surplus production models;
d) Estimates of catch removals for 2020, following the Group recommendations from the data preparatory meeting.

Task 1 Nominal catches of Bigeye tuna

Since the data preparatory meeting, and prior to the start of this assessment meeting, two CPCs provided Task 1 nominal catches of bigeye tuna EU-Spain and Ghana. **Table 1** shows the catch removals for BET for the period 1950-2019 used as input for the assessment models. At the data preparatory meeting, it was agreed that 2019 would be the terminal year for the assessment, as data for 2020 were incomplete and preliminary. During the data preparatory meeting, the Group recommended a protocol for estimating catches for years 2020 and 2021 to be used for projection purposes (see the Report of the Bigeye Tuna Data Preparatory Meeting, Anon. 2021). The Group reviewed these estimates for 2020 and noted the following:

- The data submitted by EU-Spain for 2020 after the data preparatory meeting represented only the catches from the Canary Islands fisheries fleets. EU scientists provided during the current meeting the estimates of bigeye tuna catches for all fleets in the amount of 6,050 t for 2020.
- Curaçao provided during the current meeting the estimates of BET catches for all fleets in the amount of 1,519 t for 2020.
- Guatemala provided during the current meeting the estimates of BET catches for all fleets in the amount of 906 t for 2020.
- The US provided during the current meeting the estimates of BET catches for all fleets in the amount of 816 t for 2020.
- Some of the catches reflected in the bigeye tuna catch limits adopted by the Comission in 2020 (including suggested limits) (Rec. 19-02) represent allocations, but not realized catches. That is the case of Nicaragua, the Russia Federation, and the Philippines. The Secretariat confirmed that these CPCs have not reported catches of tropical tunas in recent years. Therefore, the Group agreed not to use their catch limit values for the estimation of 2020 and its catches were set to 0 for 2020.
- Furthermore, for other CPCs with bigeye tuna catch limits (Rec. 19-02), the Group agreed to use the reported catches of 2020 (Brazil, Canada, Curaçao, Chinese Taipei, El Salvador, EU, Ghana, Guinea Equatorial, Guatemala, Japan, Korea Rep., Maroc, Mexico, Senegal, Trinidad and Tobago, and USA).
- For CPCs that have bigeye tuna catch limits and that had not reported catch for 2020, it was agreed to use the lowest of the values between the catch average of 2017-2019 and bigeye tuna catch limit adopted by the Commission.
- Finally, for those CPCs with no catch limits, it was agreed to use the carryover estimated as the average from 2017-2019 catches.

The Secretariat expressed the difficulties associated with process catches that were reported during the meeting, especially so close to the regular deadline for the data submission of 31 July. The importance of adhering to the data submission deadlines agreed upon by the Group in the workplan was stressed.

The Group estimated catches of bigeye tuna for 2020 (**Table 2**). The estimates of BET catch 2020 included the *faux-poissons* estimates (1,030 t) (Mixed flags EU Tropical) based on the average 2017-2019, as no other information was provided. The estimated total bigeye tuna catch for 2020 was 59,919 t. This value was based on the following: first, the 2020 reported catch represented 80% of the 2020 catch estimated by the Group and second, catches of CPCs that reported catches for 2020 were below previous years. Therefore, it is expected that the remaining 20% of estimated catches would also follow the trend of the reported catch. It was noted that the 2020 catch estimated during the current meeting (59,919 t) is lower than the initial estimate provided at the beginning of the meeting from the protocol approved during the data preparatory meeting (68,825 t), in part due to the updated reported catch values from some CPCs, and recommendations on unreported catches made by the Group during the current meeting. It was further noted that the bigeye tuna fishery in 2020 was particularly different from prior years, possibly due in part to the effects of the COVID-19 pandemic and the changes in the tropical tunas closure regime between 2019 and 2020 (although final catches by month were not reviewed). The Group decided to use 61,500 t, the TAC allocated by the Commission for 2021, as the best estimate available of the bigeye tuna catch for 2021.

Task 2 Size samples of bigeye tuna

SCRS/2021/113 presented a review and preliminary analysis of the size samples of Atlantic bigeye tuna available for the stock assessment models. Size samples were reviewed and standardized to straight fork length units, and aggregated to size-frequency samples by main fleet/gear, year, and quarter. A minimum of 50 measurements were adopted for a size sample, while skewness, kurtosis, and coefficient of variance indicators were used to assess outliers. Overall size sampling is sufficient since 1970s. Among the major fleets, as defined according to their relative contribution to the total catch, size sampling is sufficient only for longlines.

The Group inquired as to the relative proportion of samples for the purse seine fleets. It was noted that the ratio estimator should use the same units for comparison, i.e., weight or numbers of fish for both catch and size samples. After revising the information presented, the Secretariat provided an updated table with the relative proportion of size samples using the weight of the measured fish. The results also indicated that compared to the total catch of PS, the size sampling in these fisheries is still relatively low compared to other fisheries. It was noted that the stock synthesis modelling team made some decisions on the use of the size-frequency samples provided, based on a detailed review of the size trends, and potential shifts in selectivity (SCRS/P/2021/047). Briefly, the size selectivity of Ghana baitboat and purse seine fleets showed similar size distribution and no apparent changes in selectivity over time, thus it was maintained as a single fleet as in prior assessment. As recommended by the Group at the data preparatory meeting, Ghana size data from 1996 to 2008 were excluded. Review of seasonal size data for the late PS free school shows no evidence that supports separating the selectivity of this fleet in quarterly periods. During the data preparatory meeting it was indicated that in the previous bigeye assessment and the last yellowfin assessment some of the size data for Chinese Taipei were excluded, as size sampling provided then did not include size samples from scientific observers. Chinese Taipei scientists recently provided updated size data including the observer information, that were thoroughly reviewed by the modelling Group. The stock synthesis modelling team concluded that the data were consistent and sufficient, and decided not to exclude any size data from Chinese Taipei. Data from South Africa BB size composition were excluded by the stock synthesis modelling team from the fleet BB Dakar South. For the fleet USA rod and reel, the stock synthesis modelling team decided to use only USA RR size data, excluding other gears such as GN/TW or CAN HL size samples as differences in mean size were observed for these fisheries and catches were smaller than those from the USA RR. Finally, the stock synthesis modelling team noted that for some fleets, BB Dakar 1962-1980 and Brazil HL, there were very few size sample observations and these were not used.

Document SCRS/2021/133 presented the estimates of fisheries statistics for the baitboat and purse seine fisheries of Ghana 2012-2020. Catch and landing data collected and managed by the Fisheries Scientific Survey Division (FSSD) of Ghana included both landings and logbook information from 2005 up to 2020. The estimation of the total catches, catch composition, fishing effort, catch at size, and size sampling for YFT, BET, SKJ and other by-catch spp were estimated following the Tropical Tunas Species Group recommendations. Estimates were provided for the 2012-2020 period where sufficient sampling and coverage by Ghana observers was available.

The Group noted that since 2015 the catches of bigeye have decreased in both PS and BB gears, while the catches of yellowfin and skipjack have increased during the same period. It was inquired if there have been any changes in Ghana fishing operations that could account for this decrease in BET catches. The Group requested that the Secretariat prepare some maps of fishing effort distribution by 5x5 and quarter-year to evaluate if there have been shifts in the spatio-temporal distribution of fishing effort, as well in the proportion of bigeye catch compared to the total catch of tropical tunas (SKJ, YFT, BET). Authors of SCRS/2021/113 indicated that prior analyses have suggested that higher proportions of bigeye catches are found in offshore areas, while closer to coastal areas the proportion of yellowfin increases, and the proportion of bigeye decreases (**Figure 1**). The requested maps showed some changes in the distribution of fishing effort with higher values in the central Gulf of Guinea and coastal areas in recent years (**Figure 2**), where lower proportions of bigeye are normally found.

The Group noted that the spatial distribution of BB catches and effort from Ghana fisheries showed fishing activities being conducted in high seas, something not commonly observed in other BB fleets. Ghanaian scientists confirmed the accuracy of the information on the spatial distributions of the BB catches contained in the ICCAT database.

Conventional tagging

The Secretariat provided a summary of conventional tagging information for bigeye tuna (**Table 3**). Since the data preparatory meeting a total of 34 new BET tag recoveries have been reported, including a fish recaptured after four years at large after release by the AOTTP programme. The Group inquired as to the tag seeding data and requested a summary of this information. The Secretariat provided an updated summary of the tag seeding experiments (**Table 4**).

2.2 Relative indices of abundance

No new indices or updates of indices of abundance were presented at the meeting. The stock synthesis modelling team indicated that the spatial distribution used for the catch by fleet and size-frequency data by fleet inputs of stock synthesis were the same as those used in the 2019 yellowfin tuna stock assessment. This decision was made to harmonize the bigeye and yellowfin stock assessments for future MSE work and to follow the decision made at the Bigeye Tuna Data Preparatory Meeting (Anon., 2021). This spatial fleet structure is different from the spatial stucture used in the estimation of the joint longline index adopted during the data preparatory meeting. **Figure 3** shows the comparison of the geographical areas used in each case. However, it was noted that the catches and the number of CPUE observations used in the joint longline index corresponding to non-matching areas (i.e. areas previously included in the index coverage, but not included in the current coverage, southern part of the Gulf of Mexico, Caribbean Sea, or east of 5° East towards the African coast) are very low. Thus, the stock synthesis modeling team concluded that differences in the geographical areas would have limited impact on the models. The Group recommended that consistent spatial-temporal structure be used for future combined relative abundance indices from longline for bigeye and yellowfin stocks.

The Group was informed that due to time constraints the EU purse seine free school and purse seine dFAD indices could not be presented at this meeting. However, as the same standardization approaches are currently being used to develop the yellowfin EU purse seine index in the Indian Ocean, the same type of models will be applied in the future to tropical tuna species in the Atlantic Ocean.

3. Stock Assessment Models and other data relevant to the assessment

The following process was used to run assessment models. An uncertainty grid encompassing the major axes of uncertainty (natural mortality, steepness and recruitment variation) was agreed during the data preparatory meeting for Stock Synthesis. Production models were expected to develop their own grid encompassing the equivalent range of uncertainty for the two axes of uncertainty that such models can explicitly consider (natural mortality and steepness). Uncertainty in recruitment variation, represented by sigma R in the Stock Synthesis model, cannot be easily implemented in production models.

The Group noted that the data preparatory meeting report states: "The Group felt that using 17 as the maximum age should be the reference case in the 2021 assessment model…". This recommendation came during the discussions on estimates of maximum age, prior to the development of the uncertainty grid that was agreed at the data preparatory meeting. The agreement about the uncertainty grid included support for continuing with the method used in the last assessment to consider all parameter combinations of the grid to be equally valid unless a combination should be rejected on the basis of unsatisfactory diagnostics: "The Group decided to continue with the use of the uncertainty grid approach to quantifying model uncertainty...The modeling team has the discretion to make necessary changes to the model configuration based on identified issues or diagnostic performance." Given such agreements reached at the data preparatory meeting, the modelling teams decided to use the combination of maximum age = 20, steepness =0.8 and sigma R =0.4 as reference case. This reference case model was defined solely for the purpose of constructing the initial runs of the assessment and for comparison with sensitivity runs. The reference case model was given the same weight than any of the other models of the uncertainty grid in the estimation of stock status and development of forecasts. A full set of diagnostics was run for all models in the uncertainty grid and for selected sensitivity runs.

During the meeting, additional sensitivity runs were run upon examination of the results of the initial runs prepared prior to the meeting. Description of such runs are included in section 4 of this report.

3.1 Statistically integrated model, Stock Synthesis

Stock Synthesis (Methot and Wetzel, 2013) is an integrated statistical catch-at-age model that incorporates many of the important processes (mortality, fishery selectivity, growth, reproduction, etc.) that operate in conjunction to predict annual size-at-age, total removals (landed as well as discarded), fleet length compositions, age compositions, and fleet catches-per-unit-effort. Many of these processes are interrelated, and therefore the associated model parameters are correlated. Stock Synthesis provides a statistical platform to integrate these different metrics into an overall objective function, and in turn, account for the joint uncertainty of biological processes and fishery dynamics. Stock Synthesis is comprised of three subcomponents: 1) a population subcomponent that recreates an estimate of the numbers/biomass at age using estimates of natural mortality, growth, fecundity, etc.; 2) an observational sub-component that consists of observed (measured) quantities such as CPUE or proportion at length/age; and 3) a statistical sub-component that uses likelihoods to quantify the fit of the observations to the recreated population.

A seasonal model was constructed for Atlantic BET covering a timeframe from 1950-2019 (**Figure 4**). Initial stock biomass in 1950 was assumed to be in an unfished, virgin stock condition. Fleet structure comprised 22 fleets, including five purse seine fleets, a Ghana baitboat and purse seine combined fleet, four baitboat fleets, nine longline fleets, two handline fleets, and other combined gears (**Table 5**). The fleet structure definitions represented a significant modification from the 2018 BET assessment.

Two abundance indices were modeled, the joint longline index broken into two periods 1959-1978 and 1979-2019, and the quarterly acoustic echosounder buoy index associated with FADs covering the period 2010-2019 (**Figure 5**). The joint longline index was assumed to have a selectivity of older fish, equivalent to the Japan longline fleet in the tropical Atlantic (fleet 11). The acoustic buoy index was assumed to have the same selectivity as the purse seine fleet operating on FADs. Index CVs were scaled to an average CV = 0.2, while retaining the interannual variability estimated by the standardization models.

Length data for each fleet, year, and season were provided by the Secretariat after all CPC data updates were completed following the data preparatory meeting (**Figure 6**). Length compositions were input as number of fish observed per 4cm size bin. The effective sample sizes were equal to the log10 (# of observations), to reduce the effect of pseudo-replication in sampling and decrease the weight of length data in the overall model likelihood.

The assumption of growth remain unchanged from the previous assessment modeled as a Richards curve published by Hallier *et al.*, 2005 (**Table 6**). Weight in kilograms was estimated from straigth fork length (SFL) in centimeters assuming the relationship: Wt = (2.396E-05)*SFL^2.9774 (Parks *et al.*, 1982).

Maturity and fecundity assumptions remain unchanged from the previous assessment. Fecundity was modeled as a direct function of female body weight. Maturity assumptions were as follows: 0% mature individuals at ages 0-2, 50% mature individuals at age 3, and 100% mature individuals at ages 4 and older. As detailed in the 2021 BET data preparatory report, age-specific M assumptions were modifed significantly from the previous assessment, based on new information on maximum observed age and the regression (Then *et al.*, 2015) used to estimate the scale of M at older ages. The Group noted how such new information compares with estimates used by other tuna RFMOs for stocks of BET and yellowfin tuna (**Figure 7**). Similar to previous assessments, M-at-age was modeled as a Lorenzen function of weight-at-age (Lorenzen, 1996) assuming three alternative maximum ages of i) 17, ii) 20, and iii) 25. The resulting alternative natural mortality vectors encompass a wider range of values compared to those used in the prior assessment (**Figure 8, Table 7**).

Selectivity was estimated directly for each of the 21 fleets (fleet 20 was mirrored to fleet 8), assuming a cubic spline function for fleets 1- 5, 21, and 22 to model bimodality of length composition observations. Fleets 7-16 and 19 were modeled as double normal functions, and fleets 17 and 18 were assumed to have asymptotic logistic selectivity (**Table 5**). Age 0 fish were allowed to be potentially included in the selectivity calculations of all fleets. Selectivity at age was derived by stock synthesis, based on the model estimated fleet selectivity-at-length.

The stock-recruitment relationship followed a Beverton-Holt function with virgin recruitment (R0) freely estimated across a range of fixed steepness (h=0.7, 0.8, and 0.9) and annual recruitment deviation (sigma-r=0.2, 0.4, and 0.6) values defined by the uncertainty grid. Annual recruitment deviations were estimated only for the period 1974 to 2019. Prior to 1974 recruitment was derived from the stock-recruitment relationship. The lognormal bias correction ($-0.5\sigma^2$) for the mean of the stock-recruit relationship was applied with a bias correction ramp applied as recommended by Methot and Taylor, 2011.

The length data component variance adjustments followed the methods of Francis, 2011.

For each of the model runs, the estimated parameters included 89 selectivity parameters, R0, catchability parameters for each abundance index, three seasonal recruitment allocations, and annual recruitment deviations. Model parameter standard deviations were derived from the variance-covariance matrix. It was noted that estimates of spawning stock biomass (SSB) refer to the end of the year SSB, and the fishing mortality refers to mortality rates over the entire year.

A continuity model run (SSM Continuity) was constructed for comparison with the 2018 assessment based on the same biological assumptions, including M-at-age and one index of abundance, the joint longline index. However, the 2021 fleet structure was used for the continuity run. Additional sensitivity analyses included runs with each abundance index removed, and a run with lower CV weighting on the indices of abundance. Three sensitivity analyses were conducted based on initial guidance from the data preparatory workshop (**Table 8**):

- *SSM Sensitivity* 1: The Joint LL Early Series was removed from the model.
- *SSM Sensitivity 2:* The Buoy Index was removed from the model.
- *SSM Sensitivity 3:* A lower index CV was used.

The uncertainty grid comprised 27 models with all combinations of fixed alternative assumptions of natural mortality (maximum age = 17, 20 and 25), steepness (h = 0.7, 0.8 and 0.9) and standard deviation in recruitment (sigma_r) (0.2, 0.4, 0.6). This alternative runs of the uncertainty grid are listed in **Table 9**. Examination of model diagnostics was done by following the recommendations of Carvalho *et al*., 2021.

3.2 Surplus Production models, JABBA and MPB

Surplus Production model MPB

A preliminary assessment of Atlantic BET using the biomass dynamic model mpb was conducted (SCRS/2021/120). This model used total catch from 1950 to 2019 and, the joint longline index for two periods (early 1959-1978 and late 1979-2019) and introduced these as two separate indices with independent catchability. The first version of the model is configured as a Fox's model starting in 1950. The Group agreed to develop production model scenarios to be as much as possible equivalent to those included in the uncertainty grid of stock synthesis. This was achieved by selecting shape parameters that would mimic the SSB_{MSY}/SSB_0 ratios estimated in the reference uncertainty grid adopted for the Synthesis model runs (B_{MSY}/K in the biomass production models). These shape parameters and their associated B_{MSY}/K ratios are shown in **Table 10.**

In addition to the models of the uncertainty grid, the Group proposed a series of sensitivity runs:

- *MPB Sensitivity 1 :* Use the recent CPUE only starting in 1985.
- *MPB Sensitivity 2 :* Use the logistic (Schaefer) model.
- *MPB Sensitivity 3 :* Add the Brazilian longline CPUE.
- *MPB Sensitivity 4 :* Add the Buoy Abundance Index (Buoy Abundance Index).
- *MPB Sensitivities 5 :* Add both the Brazilian longline CPUE and the BAI.
- *MPB Sensitivity 6-8:* Modify the shape parameter so that the $B_{MSY}\sim K$ ratio was more skewed to more productive levels (0.33, 0.31 and 0.27).

The following diagnostics were used to examine the reliability and quality of model fits: residual examination, likelihood profiles for r and K, retrospective analysis, and Mohn's rho.

Just Another Bayesian Biomass Assessment (JABBA)

The Group reviewed the preliminary stock assessment results from the Bayesian state-space production model JABBA (SCRS/2021/132; Winker *et al*., 2018a), of the Atlantic BET stock updated with data up to 2019. This model used total catch from 1950 to 2019 and the Joint longline index for two periods (early 1959-1978) and late (1979-2019). These indices were introduced as two separate indices with independent catchability (CVs were scaled to 0.2 average). For the unfished equilibrium biomass *K,* the default settings of the JABBA R package in the form of vaguely informative lognormal prior with a large CV of 100% was used. The initial depletion prior ($\varphi = B_{1950}/K$) to all scenarios was defined by a beta distribution with mean = 0.93 and CV of 5%. All catchability parameters were formulated as uninformative uniform priors. The process error of log(B_y) in year y for all scenarios were defined by an inverse-gamma distribution with shape parameter equal to 9.606 and rate parameter equal to 0.03 as used by Winker *et al.*, 2018b in the 2018 Atlantic BET stock assessment.

To provide continuity, initial JABBA run was parametrized with the same priors and model structure used in the 2018 Atlantic bigeye tuna stock assessment (ICCAT, 2019). In addition, JABBA runs were designed to represent the uncertainty grid agreed during the 2021 BET data preparatory meeting. Only combinations of maximum age, and steepness were considered for JABBA resulting in nine distinct models (**Table 11**) in addition to the continuity run. For each of these runs, alternative r prior distributions were developed. Priors were associated with a specific shape parameter of a Pella-Tomlinson production function and obtained from an Age-Structured Equilibrium Model (ASEM) approach with Monte-Carlo simulations (Winker *et al.*, 2019). This approach resulted in more informative priors to r, which followed a lognormal distribution and the shape parameter m (B_{MSY}/K) directly derived from the ASEM output of EB_{MSY}/EB_0 (EB-Exploitable biomass; see details in Winker *et al.*, 2019) being fixed. Additional model runs were also provided by allowing the parameter m to be freely estimated internally by the Pella-Tomlinson model. **Table 11** provides a summary of the parametrization of JABBA model scenarios.

JABBA is implemented in R (R Development Core Team, https://www.r-project.org/) with JAGS interface (Plummer, 2003) to estimate the Bayesian posterior distributions of all quantities of interest by means of a Markov Chains Monte Carlo (MCMC) simulation. The JAGS model is executed from R using the wrapper function *jags()* from the library r2jags (Su and Yajima, 2012), which depends on rjags. In this study, three MCMC chains were used. Each model was run for 30,000 iterations, sampled with a burn-in period of 5,000 for each chain and thinning rate of five iterations. Basic diagnostics of model convergence included visualization of the MCMC chains using MCMC trace-plots as well as Heidelberger and Welch (Heidelberger and Welch, 1992) and Geweke (1992) and Gelman and Rubin (1992) diagnostics as implemented in the coda package (Plummer *et al.*, 2006).

Extensive model diagnostics were provided to evaluate the model fits, residual runs tests, retrospective patterns and hindcast prediction skill. To check for systematic bias in the stock status estimates, a retrospective analysis was also performed, by systematically removing one year of data at a time sequentially over a period of eight years (n = 9), followed by refitting the model after each data removal and comparing quantities of interest (i.e. biomass, fishing mortality, B/B_{MSY}, F/F_{MSY}, B/B_0 and MSY) to the reference model that is fitted to full data time series. To compare retrospective bias among models, Mohn's rho (ρ) statistic was computed, by using the formulation defined by Hurtado-Ferro *et al.*, 2014. A model-free hindcasting cross-validation (HCXval) technique by Kell *et al.*, 2016 was applied, where observations are compared to their predicted future values of CPUE by calculating the Mean Absolute Scaled Error (MASE) proposed by Hyndman and Koehler, 2006, which scales the mean absolute error of prediction residuals to a naïve baseline prediction, where a 'prediction' is said to have 'skill' if it improves the model forecast when compared to the naïve baseline.

4. Stock Status results

4.1 Catch integrated models, Stock Synthesis

Stock Synthesis model convergence and fit diagnostics of the reference case

Stock Synthesis converged to a stable solution, with a negative log-likelihood consistent across the jittered parameter starting values (**Figure 9**). The final model gradient was 0.000067, lower than a target of 0.0001, and was considered acceptable for model convergence, particularly since the solution was stable across different starting parameter values.

The model showed a general lack-of-fit to the acoustic buoy index, but considerably better fit to the joint longline index (**Figure 10**). In general, the residual errors in both indices showed non-random patterns, evidenced by failure to pass the diagnostic runs test (**Figure 11**). In particular, a lack-of-fit to the declining trend in the acoustic buoy index in the early 2010s as well as the increasing trend in the terminal years was apparent. The fit to the long-term trend in the joint longline index was considerably better, but inter-annual changes in the index were not well captured by the model. The residual pattern in the recent period of the joint longline index was notably better than the residual patterns of the acoustic buoy index and early period joint longline index.

Fits to the overall length composition (**Figure 12**) and associated annual model residuals (**Figure 13**) provided a primary diagnostic of model performance. Overall, the reference case demonstrated acceptable fit to the aggregated length composition data of all fleets. The annual residual patterns appeared mostly randomly distributed and deemed adequate for the major harvesting fleets, while the fleets with relatively smaller removals showed some non-random patterns in residuals. This was likely a result of variance reweighting, which resulted in better model fits to fleets with large amounts of length composition data. In general, the residual patterns of length composition showed improvement compared to the 2018 assessment, likely due to the redefining of fleets to create compositions that are more consistent across the time series.

Deviations from the stock-recruitment curve estimated as recruitment deviates indicated high variability in year-to-year recruitment deviations but strong time correlations, with periods where recruitment deviations increased followed by periods where recruitment deviations decreased. Recruitment deviations increased from 1974-1983, 1987-1998 and 2006-2018 and decreased in the intervening years (**Figure 14**). Overall the recruitment deviation was unbiased (**Figure 15**). A list of model parameters is presented in **Table 12**, including estimated values and their associated asymptotic standard errors, initial parameter values, minimum and maximum values, priors if used, and whether the parameter was fixed or estimated.

Since steepness (h) and the sigmaR of the Beverton-Holt curve were fixed, the main productivity parameter estimated in Stock Synthesis was the average level of age-0 recruitment at unfished equilibrium spawning biomass (R0). Like in the 2018 assessment, the likelihood profile from the reference case indicated a maximum likelihood estimate of steepness near 10 (natural log scale), equivalent to approximately 27 million age 0 recruits: with relatively good agreement between data sources on the best estimate (**Figure 16**).

In the reference case for the current assessment, the spawning stock biomass was estimated to be relatively constant in recent decades (**Figure 17**). Similar to the 2018 assessment results, estimates of SSB were well determined as evidenced by the 95% confidence intervals (**Figure 17**). Spawning biomass was assumed to be near unfished level in the model start year (1950), after which there was a period of decline between 1960 and 2000, followed by steady biomass levels since then (**Figure 17**).

The SSB trend estimated by the 2021 Stock Synthesis continuity run shows a similar trend to that of the 2021 reference case but differs from the SSB trend estimated by Stock Synthesis in 2018 (**Figure 18**). Estimates of SSB obtained in 2018 suggested continuous decline of SSB in the 2000s.

Removing the early period of the joint longline index from the 2021 reference case did not visibly change the results. Removing the acoustic buoy index decreased the SSB slightly. Using a lower CV increased the SSB slightly. Overall, the reference case was not overly sensitive to any of these changes (**Figure 19**).

Changes from the 2018 stock assessment

The Group noted that the reference case[1] from the 2018 assessment that was used to build the uncertainty grid estimated the stock was overfished ($SSB_{2017}/SSB_{MSY} = 0.51$) and undergoing overfishing ($F/F_{MSY} = 1.89$). The 2021 reference case estimate for the relative biomass in 2017 ($SSB_{2017}/SSB_{MSY} = 0.79$) was 54% higher than was estimated for that same year in the 2018 reference case and the estimate for relative fishing mortality ($F_{2017}/F_{MSY} = 1.15$) was 39% lower.

To investigate this discrepancy, a second set of stepwise sensitivity analyses were conducted by the Group to describe the effect of key changes in the Stock Synthesis model configuration between the 2018 assessment and the 2021 reference cases. The stepwise comparisons were built using the 2018 reference model as a starting model.

1. 2018 Reference case

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[1] M at age from 2018 for maxage=15, steepness 0.8, SigmaR 0.4, 2018 joint longline index, 2018 fleet structure, 2018 catch and size data.

2. 2018 Reference case replacing the 2018 joint longline index with the 2021 joint longline index
3. Previous model but replacing the 2018 mortality at age with the 2021 mortality at age for maxage=20.

The results of the stepwise comparison of these three models with the 2021 reference case (**Figure 20**) suggests that the new Joint longline index, the new 2021 mortality at age vector and the inclusion of the new buoy index all had significant influence on the perception of stock status, all resulting in a more optimistic stock status than the 2018 reference case. The use of the 2021 Joint LL CPUE in place of the 2018 Joint longline index accounts for a 26% increase in the perception of relative biomass in 2017 over estimates from the previous assessment, and a 17% reduction in the estimate of relative fishing mortality. The use of the new M at age vector accounts for a 28% increase in the perception of relative biomass in 2017 over estimates from the previous assessment, and a 21% reduction in the estimate of relative fishing mortality. The inclusion of the buoy acoustic index, which references juvenile bigeye tuna, also resulted in a more optimistic recent stock status had, likely due to the effect of that index on recent estimates of recruitment. Diagnostics for these different sensitivity runs were not substantially different (**Figure 21, Table 14**).

The new 2021 M at age vector and the buoy index represent improvements in the information used in the assessment. The method and data used to develop the 2021 joint longline index were influenced by the challenges of the COVID-19 pandemic and were not determined to be an improvement over the approach used to develop the 2018 joint longline index, however, the 2021 joint index has the benefit of extenting the time series up until 2019 . The Group considered including models in the uncertainty grid that replaced the 2021 joint longline index with the 2018 jointline index or to include both indices but the Group could not achieve consensus that this was a better option than retaining the previously agreed uncertainty grid with the 2021 joint lonline index.

Uncertainty grid evaluation

The uncertainty grid included three natural mortality vectors derived from three different assumptions of maximum age, three values of steepness and three values of sigmaR (**Table 9**) resulted in 27 model runs for the uncertainty grid.

Estimates of unfished recruitment ranged from 18 million to 56 million age-0 recruits across the 27 model uncertainty grid (**Table 13, Figure 22**). Differences in natural mortality assumptions contributed the most to this broad range of estimates. Differences in steepness values contributed less to the estimates of unfished recruitment. Sigma R assumptions had the least influence in the estimates of R0.

Estimates of F_{MSY} ranged from 0.09 to 0.22 (exploitation in biomass), with the highest F_{MSY} estimated under the assumption of high natural mortality (max age =17) and high steepness assumptions h=0.9. The overall estimates of stock status spanned the range of overfished and overfishing to not-overfished and not undergoing overfishing (**Figure 23**), depending on the assumptions of natural mortality, steepness, and sigma R. In general, higher natural mortality (lower maximum age) and higher steepness assumptions led to a more optimistic perceptions of stock status.
Diagnostic analyses of the 27 runs in the uncertainty grid did not reveal large differences in performance, and thus no case was eliminated from the uncertainty grid (**Table 15**).

Historical Trend in Management References

Management benchmarks (i.e. MSY, SSB_{MSY} and F_{MSY}) are dependent on the overall selectivity of the fisheries. The historical trend in MSY, SSB_{MSY} and F_{MSY} (**Figure 24**) was computed, and evaluated by the Group. The Group noted that the catch at MSY has declined over time while the spawning stock biomass needed to support MSY has increased (**Figure 24**, left panel). Furthermore, the fishing mortality that produces MSY has also declined over time (**Figure 24**, right panel). Similar historical trends have been reported in previous assessments of bigeye and yellowfin tuna. The Group discussed that these changes are due to the increased catches from surface fleets (including those that use FADs), which exploit younger fish than the longline fleet. As surface (FAD and baitboat) associated catches of bigeye tuna increase, and selectivity shifts toward smaller, younger fish, the MSY is reduced and the stock size needed to produce MSY increases. These trends are not unexpected, and should be carefully considered by managers when making decisions about allocations of TAC between various fleet components (e.g. longline, purse seine, baitboat).

4.2 Surplus Production models, JABBA and MPB

Surplus Production model MPB

The model had difficulties to converge but the diagnostics of fit were relatively good except for the likelihood profile (SCRS/2021/120 Figure 4). It was also noted that the model had difficulties finding global minima for the two biological parameters of the model [intrinsic growh rate (r) and carrying capacity (K)].

The model presented as a reference case (Fox's model) of the biomass dynamic model mpb estimated that the stock is overfished and subject to overfishing (**Figures 25** and **26**). The residuals of fit, retrospective analysis and hindcast indicate that the model fitted the catch and joint longline index well. However, the likelihood profile suggested that the model has difficulties in finding global minima for the estimated parameters (SCRS/2021/120). The medians and associated intervals (95% CI) of the posterior distribution of biological parameters and reference points obtained from the bootstrapped fit (500 iterations) of the MPB reference case are shown in **Table 16**.

Most of the sensitivity runs initially requested (removing the early joint longline index, adding the buoy index or the Brazilian longline index) did not produce major changes in the outcome of the assessment or the estimated parameters and Reference Points, except the sensitivity runs where changes were made to the stock's productivity (**Figure 27 and Table 17**).

During the current meeting additional sensitivity scenarios were developed, to analyze the potential impact of the omission/inclusion of certain relative abundance indices and alternative assumptions about the productivity of the stock (see section 3.2). The Group agreed to produce model runs with the B_{MSY}/K ratio as representative of the parameters used in the uncertainty grid developed for Stock Synthesis 3 (**Table 10**).

All deterministic models in the uncertainty grid showed similar trends of relative biomass (**Figure 25**) and relative fishing mortality (**Figure 26**), and all were more optimistic than the initial reference case (Fox). All models show that biomass moderately declined in the early years of the fishery (1960-1985) and more sharply between 1990 and 2005. However, only the models with steepness set at 0.7 (3 from a total of 9) estimated that the stock was overfished in the middle of the 2000s decade after a period when fishing mortality levels exceeded F_{MSY} (1994-2004 with differences between models). All models show a recovery trend since then and all estimate that the current stock level is on average above B_{MSY}. These scenarios indicated that the stock is not overfished and is not subject to overfishing.

Changes from the 2018 stock assessment

The Group also requested additional sensitivity model runs fitting the most recent catch estimates and the joint longline index (1950-2017) used in the 2018 stock assessment. The estimated trends and reference points of the models using the 2018 joint longline index suggested a different stock status and historical trends compared to the status and trends estimated with the 2021 uncertainty grid parameter combinations used in the 2021 stock assessment. Sensivity runs that used the 2018 joint lonline index suggest a different stock status, i.e. the stock would be estimated to be overfished and subject to overfishing in 2017.

Just Another Bayesian Biomass Assessment (JABBA)

The Group discussed the uncertainty grid developed in the data preparatory meeting and agreed that it covers much of the uncertainty of the population dynamics of bigeye tuna and that scenario S06 (ASEM M = 20 | h = 0.8) (**Table 11**) can be considered as the reference case of the JABBA uncertainty grid. All scenarios appeared to fit reasonably well to both joint longline indices (i.e. early and late), with few large deviations for some particular years (SCRS/2021/132). The goodness-of-fit for all scenarios was satisfactory with RMSE statistics around 12%. For some JABBA runs (S01, S02, S04, S07 and S09) the early joint longline index failed in the runs test diagnostic procedure, while only four runs (S03, S06, S08 and S10) provided no evidence to reject the hypothesis of randomly distributed residual patterns for both joint CPUEs (SCRS/2021/132).

The medians and associated credibility intervals (95% CIs) of the marginal posteriors for the main parameters and reference points for all JABBA scenarios are shown in **Table 18**. For comparison with the 2018 assessment, plots of the posterior distributions and process error deviates were only presented for scenarios S01 and S06 (**Figure 28**). The annual process error deviates for all scenarios showed a similar stochastic pattern with a constant average around zero (**Figure 29**), which suggest no evidence of model misspecifications and data conflicting. The medians of the marginal posteriors of K ranged from 1,259,079 t (S04) to 1,510,055 t (S01). The median of the marginal posteriors for r were very similar between the different scenarios, ranging from 0.129 to 0.166 (**Table 18**), while the range of MSY median estimates was narrow among all ten scenarios (S01: 79,351 t; S06: 83,946 t). The low values of the posterior to prior median (PPMR) ratio and the posterior to prior variance (PPVR) ratios observed for the K parameter and the similarity of the marginal posteriors for r between the distinct scenarios (**Table 18**) can indicate that the median estimates for these parameters were largely informed by the data (**Figure 28**).

In general, all models showed similar trends for the medians of B/B_{MSY} and F/F_{MSY} over time, with scenarios with maximum age at 17 producing slightly more pessimistic stock status estimates (**Figure 30**). The trajectory of B/B_{MSY} decreased from the mid-1960s to around 2000, followed by a stable trend until 2019. The F/F_{MSY} trajectory gradually increased from the beginning of time series until late 1990s, followed by a decreasing trend up to the middle of 2000s. Afterward, the relative fishing mortality remained with a relatively stable trend slightly below the F_{MSY} level (**Figure 30**). Despite some slight differences, all JABBA scenarios were consistent in terms of stock status (F/F_{MSY}; B/B_{MSY}) indicating that the Atlantic bigeye tuna stock is not overfished neither experiencing overfishing, with B_{2019} above B_{MSY} and F_{2019} below F_{MSY} (**Table 18**). The Group agreed that these JABBA assessment model runs showed reasonable fits to the data, no evidence of an undesirable retrospective pattern and a satisfying prediction skill to forecast into the future (**Figures 31 and 32**).

The Group noted that trends in relative biomass and fishing mortality estimated by JABBA for the 2021 reference case were more optimistic than equivalent trends estimated in the 2018 assessment. Hence, the Group requested additional sensitivity model runs to evaluate these discrepancies:

- Model 2018 with 2018 joint longline index and current catch estimates for 1950- 2017
- Model 2018 | with 2021 joint longline index and current catch estimates for 1950- 2017

These two sensitivity runs showed similar trends for the medians of B/B_{MSY} and F/F_{MSY} until middle-1990s. After 2000, the relative biomass for the model with the 2018 joint longline index showed that bigeye stock remained overfished and experiencing overfishing until 2017. The model with the 2021 joint longline index resulted in a stock that has not experienced overfishing and has not being overfished in recent times (**Figure 33**).

4.3 Synthesis of Assessment Results

The Group reviewed the stock assessment results for each of the alternative stock assessment models considered (Stock Synthesis, JABBA, and MPB), and the different assumptions about population dynamics included in the uncertainty grid. The uncertainty grid for the Stock Synthesis included 27 models, whereas the grid for each production model only included nine as it was decided it was not appropriate to include an axis of uncertainty related to SigmaR in the production models. For many uncertainty grid scenarios, the results from the two production models were generally similar. The median B/B_{MSY} and F/F_{MSY} trajectories between the production models (JABBA and MPB) and the Stock Synthesis models depicted similar patterns but the scale of biomass and fishing mortality ratios in the production models and the Stock Synthesis differed depending on the scenario considered (**Figures 34** and **35**). The 27 Stock Synthesis models created wide uncertainty bounds for these trajectories, and the biomass trajectories from all the production models fell within these bounds. The time series of B/B_{MSY} and F/F_{MSY} from the different production models in the uncertainty grid were similar for the last two decades but differed in the earlier period. These trajectories differed in the early part of the time series for Stock Synthesis depending on the assumed value of steepness (**Figures 36** and **37**). Biomass and fishing mortality trajectories estimated by Stock Synthesis model and the production models were different when both types of models used the same assumption about maximum age. Stock Synthesis F/F_{MSY} estimates for the last decade were lower than the production model estimates when the maximum age was assumed to be 17 (corresponding to higher natural mortality) and were higher when maximum age was assumed to be 25 (**Figures 36** and **37**). Accordingly, the key conclusion was that although each of the axis uncertainty somewhat contributes to the overall uncertainty in the estimates of stock status, the maximum age assumption, and its associated estimates of natural mortality, have the greatest influence on the estimated stock status.

The Group discussed possible reasons for the observed differences among the median trajectories between model types. Possible reasons for the divergences included effects of mortality at age, changing cohort effects, and changes in selectivity. Many of such changes cannot be explained by production models as these models do not capture selectivity changes or the passage of strong cohorts affecting the vulnerable biomass and the fishing mortality estimates. Among the possible historical changes in selectivity discussed by the Group were changes in fleet structure, including the increased use of FADs that began in the 1990s, and deep longlines in the mid-80s. It was noted that fishery impact plots are a possible way to identify any fleet-specific effects on the stock synthesis model results, but this analysis was not available at this meeting. The Group recommended that the fishing impact plots be prepared for the September 2021 Species Group meeting. The Group further discussed the assumption about selectivity used in the JABBA models for deriving the prior of *r*. The Group noted that, as per the 2018 assessment, the point estimate for longline selectivity at age 1 was used for deriving the priors.

The Group discussed which of the options for calculating the fishing mortality was being used in this year's Stock Synthesis grid. In the 2018 BET assessment the fishing mortality reported was the average of ages 1-7. It was noted that the Stock Synthesis option used to calculate fishing mortality in this year's assessment was the same as the one used in the 2019 yellowfin tuna assessment, where fishing mortality is reported as an annual exploitation rate in biomass (obtained by weighting the fishing mortality of each age group by the biomass of that age group). This produces a fishing mortality estimate more comparable to the one provided by production models and is a more appropriate indicator of fishing pressure for stocks that have suffered changes in overall selectivity. It also means that the values of fishing mortality reported in the 2018 assessment are not strictly comparable to the values reported in the current assessment.

In addition, the Group discussed how comparable production model runs were to the grid of Stock Synthesis models that used different maximum age (and the correspondant natural mortality) and steepness assumptions. The Group noted that for each such scenario, the production model priors on the intrinsic rate of growth had been re-calculated for each combination of maximum age and steepness. These recalculated priors, however, were not that much different between scenarios. The assumption about maximum age had the greatest influence in the production model results because this value determined the shape of the production function in the Pella-Tomlinson model.

The differences among surplus production models (JABBA and MPB) and the Stock Synthesis results were not unexpected. The Stock Synthesis models are more complex representations of the fishery because they account for changes in size and age structure and overall fleet selectivity. Age-structured models explicitly account for fleet specific changes in the contribution of fleets of different selectivity to the overall harvest. Given the much greater number of parameters estimated by Stock Synthesis models in comparison to production models, it is expected that that Stock Synthesis estimates would have broader uncertainty intervals. Hence, the Group agreed to follow the same approach that was used in the 2018 stock assessment i.e., to provide estimates of stock status and to develop management recommendations based on the results of the Stock Synthesis uncertainty grid (27 models). It was also agreed, like in 2018, to give each model in the uncertainty grid equal weight.

Concerns were raised regarding the decisions of the data used in the assessment and the appropriateness of the choices made to build the uncertainty grid. Among these concerns were the change in methodology used to develop the joint longline index for this assessment (a consequence of the COVID-19 pandemic, which precluded in-person meetings and thereby prevented analyses of set-by-set data and the inclusion of a significant factor in the standardization). Another concern was the appropriateness of the choices in maximum age included in the uncertainty grid which increased the range of natural mortality values that were considered to a greater extend than what was considered in the 2018 assessment. Sensitivity analyses demonstrated that part of the changes in stock status revealed in the current assessment are partially influenced by the adoption of the 2021 joint longline index and the new choices of natural mortality. As the Group was unable to agree on a better way to include such additional sources of uncertainty in the assessment, the Group agreed that the current stock status is more uncertain than what the Group has been able to quantify.

The Group produced a Kobe plot for the 27 Stock Synthesis deterministic runs (**Figure 38**) to represent the uncertainty across the different Stock Synthesis models in the uncertainty grid. To also incorporate the within model uncertainty in stock status, a Kobe plot based on multivariate log normal (MVLN) approximation of the posterior density across the 27 Stock Synthesis model uncertainty grid was also provided representing the 2019 values of relative fishing mortality and relative biomass (**Figure 39**). For each Stock Synthesis model in the grid, the MVLN was sampled 10,000 times. In addition, Kobe plots for three factors in the uncertainty grid were produced: maximum age (**Figure 40**), steepness (**Figure 41**), and sigma R (**Figure 42**). From these figures, it can be observed, that the maximum age assumption has greater influence on the stock status than steepness or SigmaR. **Table 19** shows the median and 95% credibility intervals of the Stock Synthesis-uncertainty grid estimates (across all 27 runs and the 10,000 samples for each run) of spawning stock biomass relative to SSB_{MSY}(SSB/SSB_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) for all years from1952 to 2019. For the year 2019 it is estimated that the probability of being overfished and being subject to overfishing is 48.9% and the probability of being in the green zone of the Kobe plot is 41.1%.

As it was reported in 2018, changes in the historical proportion of catch harvested by the major gears have led to historical changes in the overall Atlantic fleet selectivity for bigeye tuna. Such changes in overall selectivity were particularly strong in the period when the purse seine fleets increased their harvest and started using FADs. The increase of selectivity on younger fish has reduced MSY and increased the biomass of the spawning stock required to produce it. The average MSY in the last decade is about 20% lower than the average MSY in the 1980s and the average SSB required to support such MSY is about 10% greater than the average SSB required to support MSY in the 1980s (**Figure 24 left panel**). For the same reasons Fmsy has been decreasing as well and in the last decade Fmsy is about 20% lower than Fmsy was in the 1980s (**Figure 24 right panel**). Changes in MSY corresponding to increased selectivity of small fish in the fishery have important consequences to future MSE and stock assessment scenarios in that Management Procedures that can achieve one objective of the stock being in the green quadrant of the Kobe matrix, may not necessarily achieve another objective - to maximize catches.

5. Projections

The Group recommended that final management advice be developed from the distribution of the projections for the 27 Stock Synthesis runs of the uncertainty grid. The Group agreed to conduct these projections using the following specifications.

- Projection interval: the Group agreed to make projections over a 15 year interval, 2020-2034 as this is the final year of the recovery plan stated in Rec. 19-02.
- 2020 fixed at 59,919 t as estimated by the Group (see section 2.1) and 2021 catch fixed at the 2021 TAC of 61,500 t.
- Catch scenarios: constant catch projections including 0 t, and from 35,000 – 90,000 t, in 2,500 t intervals.
- Recruitment: based on the estimated stock recruitment relationship with no recruitment deviations.
- Selectivity and relative contribution of fleets to catches: The average of the selectivity from last three years of the model (2017-2019) was used for projections. The quarterly catch by Stock Synthesis fleet (**Table 20**) was calculated using average of the last three years (2017-2019) from the CATDIS (section 2.1) and used for the projections.
- Projections were conducted using the Monte-Carlo multivariate lognormal (MVLN) described in Walter *et al*. 2019 with 10000 iterations.

For consistency with the 2018 executive summary and K2SM, projections of spawning stock biomass and fishing mortality relative to SSB_{MSY} and F_{MSY} benchmarks were calculated for each of the 27 Stock Synthesis uncertainty grid runs. The mean of the 27 runs was then calculated for each projection year (**Figures 43** and **44**). As a result of the assumptions made of the catches in 2020 and 2021 and positive recruitment deviations estimated for the period 2015-2019, these deterministic projections show that regardless of the catch projected, the SSB/SSB_{MSY} increases and F/F_{MSY} declines in the period 2020-2022. Beginning in 2023 catches of 70,000 or more lead spawning stock declines and catches lower than 70,000 lead to stock increases. The current TAC of 61,500 t leads to a slow but continuous increase in spawning stock.

During the meeting only preliminary Monte-Carlo projections were examined by the Group. Time constraints did not allow for their thorough evaluation, and inconsistencies on the behaviour of preliminary estimates of the Kobe 2 Strategy Matrix (K2SM) resulted in the Group agreeing that the preliminary results obtained during the meeting needed to be reviewed intersessionally by the modelling group and by the Group before being considered final. Once finalized, the K2SM will be presented to the Group for consideration at the September Tropical Tunas Species Group meeting. The Tropical Tuna Species Group will be notified by the Chair when the analytical team has completed the intersessional work.

As was the case of the 2018 projections, for some runs, the modelled stock could not sustain a certain level of constant catch for the entire projection period. In this case, Stock Synthesis returned implausible values for F/F_{MSY} or SSB/SSB_{MSY} that were in some instances extremely large fishing mortality rates, associated with very small levels of biomass. To prevent this undesirable projection behavior, a ceiling of 9 on F/ F_{MSY} and a floor of 0.1 or 0.2 on SSB/SSB_{MSY} were used to effectively prevent the stock from complete collapse during projections runs, as it was done during the 2018 assessment. The percentage of model projections that reach these bounds at 0.1 or 0.2 for SSB/SSB_{MSY} or 9 for F/F_{MSY} were presented in the 2018 assessment and will be presented by the modelling group at the September Tropical Tunas Species Group meeting.

The Group noted that, considering that catch limits adopted in Rec. 19-02 entered into force in 2020, the catch allocation between fleets may have changed and, hence, the assumption used in the projections to calculate fleet proportions from the catches of 2017-2019 might not be the best choice for projections. Nevertheless, the detailed 2020 catch information to produce alternative catch proportions by fleet was not available at this meeting and, thus, the Group agreed to further review this issue at the Tropical Tunas Species Group meeting, when more accurate 2020 catches by fleet will be available.

6. Recommendations

6.1 Management

The results of the assessment, based on the median of the entire uncertainty grid shows that in 2019 the Atlantic bigeye tuna stock was overfished (median SSB_{2019}/SSB_{MSY} = 0.94 and 80% CI of 0.71 and 1.37) and was not undergoing overfishing (median F_{2019}/F_{MSY}=1.00 and 80% CI of 0.63 and 1.35). The average of MSY was estimated as 86,833 t with (80% CI of 72,210 and 106,440) from the uncertainty grid deterministic runs.

Although the projections reviewed by the Group were considered preliminary, these results indicated that a future constant catch of 61,500 t, which is the TAC established in Rec. 19-02, will have a high probability of maintaining the stock in the green quadrant of the Kobe plot by 2034. This would leave the stock in a state consistent with the Convention and objectives the recovery plan in Rec. 19-02.
The Commission should be aware that increased harvests of small fishes have had negative consequences for the productivity of bigeye tuna fisheries (e.g. reduced yield at MSY and increased SSB required to produce MSY) (**Figure 24**). Therefore, should the Commission wish to increase longterm sustainable yield, the Committee continues to recommend that effective measures be found to reduce fishing mortality of small bigeye tunas.

The preliminary Kobe 2 Strategy Matrix incorporates certain quantifiable sources of uncertainty through the use of an uncertainty grid. The main sources of uncertainty included in the K2SM were three values of natural mortality (as calculated using alternative estimates of maximum age), three values of steepness, and three values of SigmaR, and an approximation of within model uncertainty. However, through sensitivity runs the Group identified other sources of relevant uncertainties that were not included in the development of the K2SM, (including the appropriateness of the range of natural mortalities used in the uncertainty grid and the change in methodology used to develop the joint longline index - see section 4.3).

Given the inability of the Group to agree on the appropriate way to incorporate these additional uncertainties into the assessment, the Group agreed that the current stock status is more uncertain than what the Group has been able to quantify and recommends that the K2SM be interpreted with caution. Until the SCRS can properly address such unquantified sources of uncertainty, the Commission should consider adopting a precautionary TAC, one that would shift the stock status of BET towards the green zone of the Kobe plot with a high probability.

6.2 Research and Statistics

The Group had an extensive discussion on all research needs in relation to supporting stock assessments, preparing for the SKJ stock assessment of 2022, progressing the MSE tropical tuna initiatives and responding to Commission requests. Each of these are treated in individual sub-sections below.

Stock assessments

Considering the sensitivity of the BET and YFT stock assessment results to the natural mortality assumptions, the Group recommended that for all tropical tunas:

- Additional work be conducted with AOTTP tagging data to reduce the uncertainty of survival/natural mortality estimates;
- Explore the use of electronic tagging data from past or future tag deployments for the estimation of natural mortality;
- Further work be conducted on ageing to improve the precision of maximum age estimates;
- The Working Group on Stock Assessment Methods (WGSAM) examine the regression methodology used to estimate the scale of M at older ages (Then *et al*. 2015);
- Review the guidelines soon to be provided following the CAPAM mortality workshop (https://capamresearch.org/Natural-Mortality-Workshop) to be considered for future stock assessments of tropical tunas.

The Group also noted the need for further improvement of relative abundance indices, and recommended, in particular, further improvements of the joint LL CPUE index, PS CPUE index and PS acoustic buoy index. In the case of the LL CPUE index, the Group recommended that the index be developed using set by set data, include more fleets, and avoid aggregating the information as much as possible. The Group also recommended that the WGSAM use the LL simulator (LLSIM) to analyze the effects of the methodology used when standardizing the LL joint CPUE index.

Noting that the COVID-19 pandemic or other situations may prevent national scientists to physically meet in workshops, and acknowledging the issues related with remotely sharing high level resolution data, the Group recommended that the Commission propose an improved framework to ensure that future joint CPUE indices are built with the most detailed data possible, even in the case of remote collaboration.

Noting that the CPUE indices have a strong influence on the assessment results, the Group recommended that the methodology to estimate the indices be harmonized between stock assessments and tropical tuna species.

The Group recommended increasing the range of size and number of hard samples for ageing of YFT to improve growth estimates of this species.

Finally, the Group suggested that a small group led by the Tropical Tunas Coordinator work with the Secretariat to estimate potential costs for AOTTP tagging recoveries for the upcoming years 2022 and 2023 to be included in next year's research funding request.

Noting that experts had not been nominated prior to the start of the 2021 BET stock assessment meeting, the Group recommended that the external review initially recommended for the 2021 BET stock assessment be withdrawn.

Preparation of the 2022 SKJ assessment

The Group noted that an assessment of the western and eastern stocks of Atlantic skipjack tuna is planned for 2022 and that the Group intends to attempt to use stock synthesis models for the first time for both of these stocks. Changing assessment platforms from production models to stock synthesis requires additional work and, hence the Group recommended that the stock assessment process include both a data preparatory and a stock assessment meeting. The Group also recommended that these meetings be conducted earlier than usual in the year and that 2020 be used as the terminal year.

The Group recommended that an external expert be contracted to review the 2022 SKJ stock assessment process and that this expert participates in both the the data preparatory and stock assessment meetings.

Noting the importance of relative abundance indices in stock assessment, the Group recommended that various relative abundance indices be prepared for the 2022 SKJ data preparatory meeting:

- A PS CPUE index, that should provide additional information on the components of FOB fishing effort (including number of FAD deployments, operational FOB buoys, FOB fishing sets) and the relationship between these components;
- A PS acoustic buoy index;
- BB CPUE indices for western and eastern BB fisheries. The Group noted that some of BB CPUE indices have been prepared in the past by the Secretariat and encouraged national scientists to provide BB CPUE indices for the 2022 SKJ stock assessment;
- A larval index for the Gulf of Mexico.

In spite of noting that the relative contribution of LL fisheries to SKJ catches is generally low, the Group encourages national scientists from CPCs with significant SKJ catches, to estimate relative abundance indices from CPUE data.

The Group also recommended that alternative CPUE standardization methods are explored, in particular for PS and BB CPUE indices.

Length-weight conversion factors are an important component of the development of basic stock assessment catch inputs. The Group therefore recommended that length-weight conversion factors be reviewed and updated by national scientists in collaboration with the Secretariat prior to the SKJ data preparatory meeting.

The Group noted the importance of having guidance on fleet structure and recommended that a table of landings of skipjack per fleet be prepared by the Secretariat. The Group also recommended that decisions on fleet structure for the Stock Synthesis model to be used in the stock assessment be consistent with the fleet structure previously used for YFT and BET.

The Group noted that various tasks should be conducted with data from the AOTTP tagging program, including:

- Investigating differences in growth rates among skipjack stocks and areas and updates of any other growth estimation conducted with AOTTP tag recovery data;
- Evaluating movement rates between regions using AOTTP tag recovery data;
- Updating the tag capture/recapture matrix;
- Evaluating the usefulness of analyzing SKJ spines collected in the frame of the AOTTP program to provide additional information on SKJ ageing. The Group recommended that this last task be conducted before the end of 2021 so that the data can be ready before the 2022 SKJ data preparatory meeting.

MSE of tropical tunas

The Group noted that a list of tasks for mixed species and western SKJ tuna MSEs had been proposed in March 2021 at the Tropical Tunas MSE Technical Group meeting. The Group was informed by the Rapporteur of the western skipjack tuna that the team will not be able to meet the objective of reconditioning the Operating Model for the Western SKJ MSE by the end of the 2021. The Group therefore recommended that such task, originally planned for 2021, be postponed to 2022. **Table 22** provides updated details of the tasks planned for the tuna MSEs in 2021 and 2022 and the overall plan of activities for this program until 2025. This list of tasks was used to develop the updated roadmap to be provided to the Commision for approval that appears in section 7.1.8 of this report.

Floating Object (FOB) management and fishing closures

The Group noted ongoing discussions at the level of the Commission and Panel 1 on the management of FOB fisheries. The Group recommended to:

(i) Explore the relationship between FOB management measures, including limitations of FOB fishing sets, number of FOB operational buoys, and number of FOB buoy / FAD deployments;
(ii) Assess the efficiency (e.g. reduction of BET and YFT juveniles catches) and the appropriateness of the current 3-month FOB closure (i.e. duration of the closure, choice of the closure period, etc.).

Noting that that the Group had experienced issues when attempting to address requests for the Commission, often due to imprecise terminology regarding FOB fisheries, and noting such the FAD Working Group last met in 2017, the Group recommended that the FAD Working Group be revitalized in 2022.

The Group recommended that the relationship between catch limits and full fisheries closures be further explored.

Finally, the Group noted that some of the submitted ST-07 forms (Task 3 – Activity of Trop support vessels authorized to operate in the ICCAT Convention area) are incomplete. More specifically, information on the 'Fishing Vessel Association' is not being include (Columns H, I, J in form ST-07). The Group recommends that CPCs fully complete all required fields in form ST-07 . Failing to do so greatly decreases the SCRS ability to complete analyses requested by the Commission.

6.2.1 With financial implications

Table 21 summarizes the Group recommendations on research and statistics and highlights recommendations that are considered as high priority and/or have financial implications.

7. Other matters

7.1 Responses to the Commission

The Group noted that many responses to Commission requests were not provided last year because of the challenges of COVID-19. In order to update the responses, it was agreed to follow a three-step process: 1) evaluate if sufficient information had been provided last year; 2) analyse any new information provided to the SCRS on the different items and c) identify tasks to be conducted from now to the SCRS meeting in September.

7.1.1 Discards in purse seine fisheries, Rec. 17-01, para 4

The Group was unable to provide a detailed response this year. It must be stressed that a previous study (Sarralde *et al.*, 2007) conducted with observers on board Spanish purse seiners in the mid 2000s estimated these discards were small, (0.2 t per free school set and 1.1 t per FOB set. New guidelines and best practices adopted by fleets and the discard prohibition (Rec. 17-01) that entered into force in 2018 suggest that current discards are probably fewer than the levels indicated in the study by Sarralde *et al.*, 2007.

7.1.2 Discards in purse seine fisheries, Rec. 17-01, para 5

The Group was reminded that it is an ICCAT obligation that CPCs provide information on discards for all fleets and species. Task 1 table shows that the earliest reports of bigeye discards come from 2011 but sporadic submissions of bigeye discards start in 2015 and are just limited to very few CPCs. The Group needs reliable data to provide a response to this request but discard reports are too inconsistent to be currently of use to develop a response. Discards of the purse seine fleet are probably small because 1) most of the bycatch (particularly small tunas species and other bony fish) form part of the so called *faux poisson*, and 2) of the discard prohibitions in Rec. 17-01.

The Secretariat clarified that the information on discarded fish should be provided as part of the Task 1 Nominal catch estimation (ST02) and that the observers form (ST09) is to submit bycatch information. The ST02 form currently allows the reporting of landings, discards and discards alive, but this is not the case for ST09. Moreover, the information on the ST09 is provided in numbers and represents just a fraction of the total, giving an incomplete picture of discards.

It was indicated that it would be useful for the SCRS and the Commission to review reports of discards from the purse seine fleets that have been reported in ST02 and since 2019 in ST09. Information for 2020 will only be available after the 31st July deadline. The Secretariat informed that document SCI-08 regularly provides this type of information for both the SCRS and the Commission.

It was noted that Rec. 17-01 is not exclusively directed to purse seine fleets (para 5) but also to the other major gears targeting tropical tunas. **Table 23** shows the most important CPCs and gears contributing to the bigeye tuna catch and reporting discards in ST02 or ST09.

7.1.3 The TAC for 2022 and future years, Rec. 19-02, para 3

Projections used to produce the K2SM will be provided in September. Refer to the Executive Summary outlook section for this response.

7.1.4 Fishing prohibited with FADs, Rec. 19-02, para 28

The Group discussed the information available to evaluate the current temporal closure to FAD fisheries. The Group noted that an analysis of historical monthly catches will be of limited use because it would not reflect the behaviour of fleets under the current FAD closure. Furthermore, it was also noted that the Commission request refers to catch in 2020 and 2021 but such catch data are not available yet.

The Group recalled a study presented to the AOTTP symposium (Perez *et al*., Past and current dFADs fishing moratoria in Eastern Atlantic ocean: what can AOTTP data tell about the current dFAD moratorium efficiency for the conservation of juvenile tunas and about alternate protected time-areas). This study evaluated the efficiency of two moratoria (Rec. 15-01 and Rec. 98-01) using AOTTP tagging data. While the study concluded that both moratoria were efficient for limiting recaptures on juvenile skipjack and yellowfin during the November-February period, no conclusion could be drawn for bigeye due to the lack of limitations on the number of bigeye tuna released inside and outside the FAD time area closure.

The Group agreed to prepare a table with the recent evolution of monthly PS tropical tuna catches by fishing mode and species, using Task 2 information from 2010 to 2019, indicating the different time area FAD closures that have been in place. Tables will include percentages across months by species and across species by month. This task will be completed by the time of the species group meeting in September 2021.

There was a discussion on the impact of the moratoria on the efficiency and operation of the purse seine fleet, particularly on the meaning of efficiency in this context. It was suggested to draft a research recommendation on this issue due to the fact that there was not a clear request from the Commission on this. It was suggested to conduct an analysis in terms of yield per recruit; and also, to analyse the information in terms of identifying months that minimize yellowfin and bigeye juveniles while maintaining skipjack catches. And all this in the context of the changes of B_{MSY} and MSY due to changes in selectivity. In addition to the table, the Group agreed to obtain, from the most recent Stock Synthesis results the evolution of one-year old fishing mortality of bigeye and yellowfin for surface fleets using FADs (purse seine and baitboat). This will be prepared by the September meeting and could be used to help with this response.

7.1.5 Maximum number of FAD sets which should be established per vessel or per CPC, Rec. 19-02, para 31

A recent SCRS paper prepared for Panel 1 (SCRS/2021/135) included tables that could be useful to respond to this request. The document contains information on the catch, effort in fishing time, number of FAD deployments, FAD loss, types of FADs and other variables for the purse seine fleets. Upon review by the Group some of the figures in the paper were updated to correct some errors in location information. The figures from the document that indicate locations of lost FADs denote the last position that a given FAD transmitted. Such positions can represent FADs that are too far to be retrieved and therefore lost to the fleet when the beacon ceases to transmit. They can also represent positions where another vessel retrieves the FAD and resuses the FAD, and in the process the beacon is disconnected.

The Group noted that the data requested from fleets deploying FADs in Rec. 19-02 may not necessarily include the compulsory submission of the precise data that would be necessary to evaluate recommendations about an appropriate number of FAD sets. For example, although the number of FAD sets is one of multiple effort metrics that CPCs have the option to chose among when reporting catch and effort, most CPCs chose other effort metrics in their reports.

For the SCRS to provide guidance on the number of FADs per fleet it would be necessary to have the information on the past and current number of FAD sets. Moreover, fishing effort on FADs is a complex interaction of factors such as number of FADs deployed, FADs monitored by vessel, technology of the buoy, use of supply vessels, among others.

There was agreement that there is not enough information to provide advice on the number of FAD sets per vessel as requested by the Commission. Furthermore it was clarified that any potential evaluation the SCRS could do would be on the number of FADs per fleet and not on the number of FADs per CPC or vessel. The Group concluded that more guidance from the Commission was needed to provide a more precise response.

7.1.6 Impact of support vessels on the catches of juvenile yellowfin and bigeye tuna, Rec. 19-02, para 33

Very few submissions of information and often inconsistent have been received in the Secretariat to help responding to this request. **Table 24** shows the number of CPC/Flags that have provided ST07 Supply Vessel form by year and **Table 25** the CPC/Flags that have indicated in ST07 whether or not they had activity of supply vessels for tropical tuna fisheries. As seen in these tables, availability of data is limited. For most of the ST07 forms submitted there is no information available to make the linkage between catches of the PS vessels and the supporting supply vessel(s). The Group was informed about analyses that are currently being conducted by EU scientists in the context of the standardization of the PS FAD CPUE and that incorporate a supply vessel effect in the standardization process. It is expected that this work will be finished by the time of the skipjack assessment in 2022 and will provide additional information to this request by the Commission. The Group is unable to provide a final response to this request from the Commission.

7.1.7 SCRS recommendation on presence of a human observer on board in accordance with Annex 7 and/or an Electronic Monitoring system, Rec. 19-02, para 55

In the last billfishes intersessional meeting (March 2021), a sub-group was created to start addressing this request for longline or other fisheries. Several tasks were defined such as: 1) the collection and analysis from literature review (e.g., reports and documents) regarding results from comparison between human observers and EMS, 2) the description of current knowledge and data items that can be collected by EMS 3) the possible knowledge gaps and needs for additional experimental trials, 4) the review of the draft related to EM guidelines produced by the IMM.

This billfish sub-group is preparing a draft and will report back to the Billfishes Species Group during the meeting in September. The Group proposed to incorporate this issue in the discussions of the SC-STAT in September within the "other matters" section with the aim of widening the scope of the EMS Sub-Group to other species groups (e.g., tropicals, swordfish, sharks). This work will continue after the 2021 SCRS plenary and during 2022 and the SCRS will provide a response to this request to the Commission in 2022.

7.1.8 Refine the MSE process in line with the SCRS roadmap and continue testing the candidate management procedures, Rec. 19-02, para 62

An updated roadmap in the same format to that produced by the Commission will be prepared for the upcoming species group meeting in September by the Chair of the Group using the information contained in **Table 22**.

7.1.9 Efficacy that full fishery closures along the lines of those proposed in PA1_505A/2019, Rec.19-02, para 66a

The Group expected an update of Herrera *et al.*, 2020 by the scientists that presented the document to the SCRS but the update was not received, thus the Chair of the Group will contact the authors to see if they will provide an update by the September species group meeting.

7.1.10 Estimate of capacity in the Convention area, to include at least all the fishing units that are large-scale or operate outside the EEZ of the CPC they are registered in, Rec. 19-02, para 66b

The Group agreed to prepare tables of the evolution of number of large purse seine and longline vessels from the information provided in the ST01 forms. It was not clear whether some CPCs provide this information in terms of registered/authorized or active vessels. Therefore, at least for the purse seine component, the Group agreed to update the table with the recent evolution number of large-scale purse seiners by CPC operating in the Atlantic Ocean estimated as it was done in Restrepo *et al*., 2020.

7.1.11 Develop TORs for an evaluation and monitoring control and surveillance mechanisms in place in ICCAT CPCs Rec 19-02, para 66c

The Secretariat will prepare the TORs by September in collaboration with SCRS scientists.

8. Adoption of the report and closure

Although parts of the report were adopted during the meeting most sections could not be adopted. The participants were asked to provide suggestions of changes to the report to the Chair by close of business 31 July 2021. The first full draft of the report was made available to participants on 2 August 2021 and was adopted by correspondence on 27 August 2021

The Chair explained the proposed plan of work in preparation for the one day meeting of the Group during the species group meeting of late September 2021. The Chair and Tropical Tunas Rapporteurs will prepare drafts of the bigeye Executive Summary, the responses to the Commission, the 2021 workplan and research recommendations. These drafts will be made available to participants of the current meeting in the Owncloud and circulated to Head Scientists of each CPC for review and comments by 31 August 2021. Comments should be provided to the Chair by 10 September 2021 so that the Chair can update the documents and make them available to the SCRS in the Owncloud of the species group meeting as second drafts by 15 September 2021.

The Chairs and the Secretariat thanked all the participants for their efforts to work effectively and efficiently throughout the meeting. The meeting was adjourned.

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Table 1. Task 1 reported catches (t) of bigeye tuna (*Thunnus obesus*) by area, gear, and flag. (vr 2021-07-22).

			1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
TOTAL	A+M		**808**	**1,651**	**2,018**	**2,951**	**2,932**	**4,808**	**2,779**	**8,720**	**4,290**	**7,732**	**9,113**	**17,060**	**23,132**	**26,039**	**23,631**	**39,394**	**25,386**	**25,252**	**23,911**	**41,880**	**55,029**	**46,972**	**56,662**	**63,703**	**60,627**	**44,668**	**54,735**	**52,431**	**45,830**	**63,597**	**67,773**	**73,557**	**59,435**	**70,978**
1-Landings		Bait boat	808	1,651	2,018	2,951	2,932	4,808	2,769	8,266	3,837	6,254	6,127	5,805	7,112	10,927	5,698	9,822	5,320	11,434	3,792	10,296	11,617	9,296	13,620	17,922	14,632	10,380	13,469	14,708	9,725	12,350	10,124	6,950	9,853	11,480
		Longline	-	-	-	-	-	-	10	454	453	1,478	2,986	11,255	16,020	15,112	17,928	29,572	20,046	13,726	19,683	28,526	39,904	33,293	38,453	39,535	41,347	27,847	29,531	28,796	27,560	41,787	41,658	51,851	33,757	43,303
		Other surf.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	90	346	256	315	244	163	247
		Purse seine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	20	92	436	3,058	3,508	4,383	4,589	6,246	4,648	6,441	11,730	8,837	8,199	9,204	15,560	14,351	15,503	15,870
2-Landings(FP)		Purse seine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	116	161	158	77
3-Discards		Longline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Purse seine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1-Landings	CP	Angola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Barbados	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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		Brazil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37	28	70	197	181	678	1,183	812	782	698	505	776	521	698
		Canada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23	-	-	-	-	-	-	-	-
		Cape Verde	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	111	95	146	142	131	115	50	47	464	45	27	72	200	293	167
		China PR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Curaçao	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Côte d'Ivoire	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	130	-	339	721	-	6	1,640	1,129	1,295	628	1,425	1,308	1,041	450
		EU-España	-	-	-	-	-	-	-	-	-	-	-	-	98	491	144	1,017	1,145	1,272	1,399	4,072	7,418	4,015	5,681	4,515	8,882	7,436	9,736	6,849	5,419	8,430	10,010	9,332	8,794	13,617
		EU-France	-	-	-	-	-	-	-	-	-	-	-	-	400	2,400	840	10	60	1,740	155	3,088	2,828	3,624	3,224	4,007	4,079	5,821	7,076	7,407	5,775	5,612	6,456	5,601	6,923	3,585
		EU-Ireland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EU-Italy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EU-Poland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-
		EU-Portugal	808	1,651	2,018	2,951	2,932	4,808	2,769	8,266	3,837	6,254	6,127	5,805	6,588	8,021	4,684	8,670	4,133	8,051	1,597	5,133	2,892	3,962	5,855	10,945	6,813	2,929	4,522	5,350	3,483	3,706	3,086	1,861	4,075	4,354
		El Salvador	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		FR-St Pierre et Miquelon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Gabon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
		Ghana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	73	84	170	237	124	238	332	780	791	491	2,162
		Great Britain	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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		Japan	-	-	-	-	-	-	10	454	453	1,478	2,904	11,044	15,746	14,505	17,366	28,663	17,578	9,012	11,345	9,504	21,299	19,665	22,014	22,946	17,548	8,170	10,144	9,863	12,150	20,922	22,091	33,513	15,212	24,870
		Korea Rep	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	289	320	263	4,079	7,353	5,730	6,018	7,831	10,493	6,923	8,090	9,716	8,022	10,235	12,274	10,809	9,383	8,989
		Liberia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Libya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Maroc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	170	324	394	414	387	622	625	552	120
		Mauritania	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Mexico	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Namibia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Nigeria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Norway	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Panama	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	182	2,710	2,081	2,091	2,135	1,493	2,127	513	4,518	2,500	3,182	3,930	3,322
		Philippines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Russian Federation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		S Tomé e Príncipe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Senegal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	241	177	15	550	83	148	24	109	187	93	43	43	40	9	26
		Sierra Leone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		South Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	286	214	-	-	-	-	-	-	-	1	-	-	-	-	-	19	422	381	137	187	60
		St Vincent and Grenadines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Trinidad and Tobago	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	191	41
		UK-Bermuda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		UK-Sta Helena	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	22	8	9	14	23	14	19
		UK-Turks and Caicos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		USA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	18	195	544	212	113	865	67	28	331	248	212	202	158	422	315	539
		USSR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	385	680	1,820	1,677	2,580	2,729	1,637	2,961	3,367	3,652	4,907	4,086	2,202	2,229	2,813	2,832	635	352	1,233
		Uruguay	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	86	397	605	714
		Venezuela	-	-	-	-	-	-	-	-	-	-	26	48	67	54	137	160	329	224	185	136	92	117	15	24	-	21	464	244	347	661	1,684	1,027	4,284	4,142
	NCC	Chinese Taipei	-	-	-	-	-	-	-	-	-	-	-	-	20	47	54	-	672	2,521	6,039	8,538	6,191	5,639	4,314	3,499	4,464	3,701	3,364	2,970	2,486	2,561	1,887	2,147	1,623	925
		Guyana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	NCO	Argentina	-	-	-	-	-	-	-	-	-	-	56	163	213	235	187	400	200	75	347	100	44	-	25	18	95	176	84	23	-	-	-	-	-	-
		Benin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40	45	-	-
		Cambodia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Congo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-
		Cuba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	89	300	217	886	4,100	3,200	2,000	2,600	2,400	1,900	1,300	1,800	2,300	2,300	1,385	711	521	421	447
		Dominica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Faroe Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		NEI (ETRO)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		NEI (Flag related)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	46	369
		Saint Kitts and Nevis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Seychelles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sta Lucia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Togo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	52
		Vanuatu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2-Landings(FP)	CP	Belize	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Cape Verde	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Curaçao	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Côte d'Ivoire	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EU-España	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	41
		EU-France	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	96	93	14
		Guatemala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Guinée Rep	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Panama	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	NCO	Mixed flags (EU tropical)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	116	65	58	23
3-Discards	CP	Canada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EU-France	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Japan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Korea Rep	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		South Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		UK-Bermuda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	NCC	Chinese Taipei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

			1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
TOTAL	A+M		**78,010**	**65,433**	**57,323**	**66,375**	**78,722**	**85,264**	**97,211**	**100,106**	**113,790**	**134,932**	**128,047**	**120,767**	**110,255**	**107,954**	**121,425**	**103,434**	**91,636**	**75,802**	**87,596**	**90,043**	**67,954**	**59,192**	**69,895**	**63,172**	**76,427**	**76,074**	**76,749**	**71,317**	**66,976**	**75,307**	**79,795**	**79,338**	**78,617**	**72,971**	**75,646**
1-Landings		Bait boat	17,518	15,661	13,444	9,747	12,673	18,283	17,748	16,258	16,472	20,358	25,697	18,352	21,289	19,190	22,203	12,150	14,388	8,465	11,237	20,244	13,122	10,631	10,579	6,335	11,565	7,853	12,849	10,510	9,214	8,726	8,014	6,787	8,436	7,977	7,344
		Longline	52,595	39,942	35,570	47,766	58,420	56,537	61,655	62,484	62,891	78,908	74,872	74,930	68,312	71,857	77,227	72,011	56,123	47,351	55,356	49,400	37,961	34,182	46,231	41,063	43,533	42,516	37,899	34,930	32,245	36,769	40,378	36,344	35,186	32,062	34,226
		Other surf.	415	550	626	469	605	284	332	513	622	967	551	353	534	428	672	451	766	221	447	286	716	527	431	192	241	476	957	961	2,764	4,950	5,958	6,395	7,146	4,571	5,873
		Purse seine	7,435	9,231	7,069	7,792	6,380	9,413	15,535	19,216	31,515	32,667	25,260	26,592	19,127	15,490	20,139	17,460	20,103	19,552	19,689	19,094	15,129	13,310	11,962	14,810	20,007	24,235	23,767	24,080	22,122	24,253	24,418	28,624	26,838	27,284	27,108
2-Landings(FP)		Purse seine	46	48	613	600	644	747	1,941	1,636	2,290	2,032	1,667	540	993	989	1,184	1,363	257	214	867	1,019	1,026	542	692	772	1,081	994	1,277	823	632	609	989	1,187	972	1,049	1,069
3-Discards		Longline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	14	0	0	2	0	0	26	15
		Purse seine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	-	38	2	10
1-Landings	CP	Angola	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	253
		Barbados	-	-	-	-	-	-	-	-	-	-	-	-	24	17	18	18	6	11	16	19	27	18	14	14	7	12	7	15	11	26	30	19	16	29	14
		Belize	-	-	-	-	-	-	-	-	-	-	10	-	5	195	-	134	96	-	-	-	-	4	60	70	234	249	1,218	1,242	1,336	1,502	1,877	1,764	1,961	2,135	2,307
		Brazil	419	873	756	946	512	591	350	790	1,256	601	1,935	1,707	1,237	776	2,024	2,768	2,659	2,582	2,455	1,496	1,081	1,479	1,593	958	1,189	1,173	1,841	2,120	3,623	6,456	7,750	7,660	7,258	5,096	6,249
		Canada	-	11	144	95	31	10	26	67	124	111	148	144	166	120	263	327	241	279	182	143	187	196	144	130	111	103	137	166	197	218	257	171	214	237	193
		Cape Verde	112	86	60	117	100	52	151	305	319	385	271	299	228	140	9	2	-	1	1	1	1,077	1,406	1,247	444	545	554	1,037	713	1,333	2,271	2,764	1,680	1,107	1,418	880
		China PR	-	-	-	-	-	-	-	-	70	428	476	520	427	1,503	7,347	6,564	7,210	5,840	7,890	6,555	6,200	7,200	7,399	5,686	4,973	5,489	3,720	3,231	2,371	2,232	4,942	5,852	5,514	4,823	5,718
		Curaçao	-	-	-	-	-	-	-	-	-	-	-	1,893	2,890	2,919	4,016	3,098	3,757	2,221	3,203	3,526	27	416	252	1,721	2,348	2,688	3,441	2,890	1,964	2,315	2,573	3,598	2,844	3,530	2,787
		Côte d'Ivoire	76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	790	576	47	507	635	441	12	544	1,239	384	2,334
		EU-España	10,340	10,884	9,702	8,475	8,263	10,355	14,705	14,656	16,782	22,096	17,849	15,393	12,513	7,110	13,739	11,250	10,133	10,572	11,120	8,365	7,618	7,454	6,675	7,494	11,966	11,272	13,100	10,914	10,082	10,736	10,058	11,469	11,544	8,400	9,117
		EU-France	4,226	4,122	3,435	4,024	3,261	5,023	5,590	6,877	12,648	12,262	8,262	9,135	5,955	5,583	5,413	5,873	5,533	4,437	4,048	2,989	2,814	2,984	1,525	1,130	2,313	3,355	3,507	3,756	3,222	3,837	2,801	4,772	4,039	4,055	5,118
		EU-Ireland	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	10	-	-	0	33	-	-	-	-	-	-	-	-	-	-	0	0	-	-
		EU-Italy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-
		EU-Poland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EU-Portugal	6,457	7,428	5,036	2,818	5,295	6,233	5,718	5,796	5,616	3,099	9,662	5,810	5,437	6,334	3,314	1,498	1,605	2,590	1,655	3,204	4,146	5,071	5,505	3,422	5,605	3,682	6,920	6,128	5,345	3,869	3,135	2,187	3,146	4,405	3,146
		El Salvador	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	992	1,450	1,826	2,634	2,464
		FR-St Pierre et Miquelon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	21	0	28	6	-	2	3	-	2	-	-	0	0	-	-	-	-	-
		Gabon	-	-	-	-	-	-	-	-	1	87	10	-	-	-	184	150	121	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Ghana	1,887	1,720	1,178	1,214	2,158	5,031	4,090	2,866	3,577	4,738	5,517	4,751	10,174	10,647	11,704	5,632	9,864	6,480	9,061	17,888	8,860	2,307	2,559	3,372	4,515	6,253	3,541	4,468	2,963	4,175	5,918	5,194	3,838	3,636	2,917
		Great Britain	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	32	0	-	-	-	-	-	-	0	-	-
		Grenada	-	-	-	-	-	-	65	25	20	10	10	-	1	0	0	0	0	0	-	-	-	-	10	31	-	-	-	-	-	-	18	23	33	27	26
		Guatemala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	736	831	998	949	836	998	913	1,011	282	262	163	993	340	1,103	1,602	1,488	1,623
		Guinea Ecuatorial	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	50	-	58	-	3	10	17	4	11	7	8
		Guinée Rep	-	-	-	-	-	-	-	-	-	-	334	2,394	885	-	-	-	-	-	-	-	-	-	-	-	-	328	322	1,516	1,429	902	-	-	-	-	-
		Honduras	-	-	-	-	-	-	-	44	-	-	61	28	59	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Iceland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Japan	32,103	23,081	18,961	32,064	39,540	35,231	30,356	34,722	35,053	38,503	35,477	33,171	26,490	24,330	21,833	24,605	18,087	15,306	19,572	18,509	14,026	15,735	17,993	16,684	16,395	15,205	12,306	15,390	13,397	13,603	12,390	10,365	10,994	9,854	9,477
		Korea Rep	10,704	6,084	4,438	4,919	7,896	2,690	802	866	377	386	423	1,250	796	163	124	43	1	87	143	629	770	2,067	2,136	2,599	2,134	2,646	2,762	1,908	1,151	1,039	675	562	432	623	540
		Liberia	-	-	-	-	206	16	13	42	65	53	57	57	57	57	57	57	57	57	57	-	-	-	-	-	-	-	-	-	-	-	-	27	98	1	3
		Libya	-	-	-	-	-	-	-	508	1,085	500	400	400	400	400	400	400	31	593	593	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-
		Maroc	30	-	8	2	8	68	206	81	774	977	553	654	255	336	1,444	1,160	1,181	1,154	1,399	1,145	786	929	700	802	795	276	300	300	308	300	309	350	410	500	850
		Mauritania	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
		Mexico	-	-	-	-	-	-	-	-	1	4	-	2	6	8	6	2	2	7	4	5	4	3	3	1	1	3	1	1	2	1	2	2	3	3	3
		Namibia	-	-	-	-	-	-	-	-	-	715	29	7	46	16	423	589	640	274	215	177	307	283	41	146	108	181	289	376	135	240	465	359	141	109	79
		Nigeria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	0	-	-	-	-	-	-	-
		Norway	-	-	-	60	-	-	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Panama	4,461	5,173	5,701	3,865	3,242	6,150	7,446	9,991	10,138	13,234	9,927	4,777	2,098	1,252	580	952	562	211	-	1,521	2,310	2,415	2,922	2,263	2,405	3,047	3,462	1,694	2,774	2,315	1,289	2,337	1,664	2,067	3,052
		Philippines	-	-	-	-	-	-	-	-	-	-	-	-	-	1,154	2,113	975	377	837	855	1,854	1,743	1,816	2,368	1,874	1,880	1,399	1,267	532	1,323	1,964	-	-	-	-	-
		Russian Federation	-	-	-	-	-	-	-	5	-	-	-	13	38	4	8	91	-	-	-	-	1	1	26	73	43	-	-	-	-	-	-	-	-	-	-
		S Tomé e Príncipe	-	-	-	5	8	6	3	4	4	3	6	4	5	6	5	4	4	4	4	11	6	4	-	92	94	97	100	103	107	110	633	421	393	2	6
		Senegal	61	132	377	102	2	-	10	5	8	123	357	190	272	789	1,372	915	1,159	497	322	490	770	1,318	1,293	734	1,144	969	479	436	606	369	1,031	1,500	2,978	2,870	2,272
		Sierra Leone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		South Africa	102	168	200	561	367	296	72	43	88	79	27	7	10	53	55	249	239	341	113	270	221	84	171	226	159	145	153	47	435	332	193	121	257	282	432
		St Vincent and Grenadines	-	-	-	-	-	0	154	818	1,740	812	519	596	545	1,937	2,940	1,921	1,143	130	103	18	-	114	567	171	293	396	38	25	16	30	496	622	889	428	504
		Trinidad and Tobago	22	-	-	1	19	57	263	-	3	29	27	37	36	24	19	5	11	30	6	5	9	12	27	69	56	40	33	33	37	59	77	37	25	17	13
		UK-Bermuda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	1	1	-	0	0	0	0	0	0	0	0	0	-	-	-	0
		UK-Sta Helena	-	-	5	1	1	3	3	10	6	6	10	10	12	17	6	8	5	5	4	6	18	25	18	28	17	11	190	51	19	17	44	77	70	45	4
		UK-Turks and Caicos	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2	-	-	-	-	-
		USA	639	1,085	1,074	1,127	847	623	975	813	1,090	1,402	1,209	882	1,138	929	1,263	574	1,085	601	482	416	484	991	527	508	515	578	866	727	903	892	1,082	568	836	921	832
		USSR	870	1,071	1,887	1,077	424	95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Uruguay	597	177	204	120	55	38	20	56	48	37	80	124	69	59	28	25	51	67	59	40	62	83	22	27	201	23	15	2	30	-	-	-	-	-	-
		Venezuela	2,918	1,136	349	332	115	161	476	270	809	457	457	189	274	222	140	221	708	1,241	847	1,060	243	261	318	122	229	85	264	98	94	169	132	156	318	165	28
	NCC	Chinese Taipei	1,220	1,125	1,488	1,469	940	5,755	13,850	11,546	13,426	19,680	18,023	21,850	19,242	16,314	16,837	16,795	16,429	18,483	21,563	17,717	11,984	2,965	12,116	10,418	13,252	13,189	13,732	10,805	10,316	13,272	16,453	13,115	11,845	11,630	11,288
		Guyana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	25	34	53	2
	NCO	Argentina	100	41	72	50	17	78	22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Benin	-	15	6	7	8	10	10	7	8	9	9	9	30	13	11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Cambodia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Congo	8	19	10	10	14	15	12	12	14	9	9	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Cuba	239	171	190	151	87	62	34	56	36	7	7	5	-	-	-	-	-	16	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Dominica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	0	-	-	-	-	-	-	-	-	-	0	0	0	0	-	-
		Faroe Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		NEI (ETRO)	-	-	-	-	-	-	357	364	42	356	915	-	7	-	-	-	362	68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		NEI (Flag related)	354	758	1,406	2,155	4,650	5,856	8,982	6,146	4,378	8,964	10,697	11,862	16,565	23,484	22,190	15,092	7,907	383	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Saint Kitts and Nevis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	4	1	-	-
		Seychelles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	58	-	162	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Sta Lucia	-	-	-	-	0	-	-	1	-	0	0	-	0	-	0	-	1	2	2	0	2	-	-	0	-	0	0	0	-	-	6	10	24	13	13
		Togo	18	24	22	7	12	12	6	2	86	23	6	33	33	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Vanuatu	-	-	-	-	-	-	470	676	1,807	2,713	2,610	2,016	828	-	314	-	-	-	-	104	109	52	132	91	34	42	39	23	9	4	-	-	-	-	-
2-Landings(FP)	CP	Belize	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	46	42	16	41	23	-	-	-	-	-
		Cape Verde	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75	28	37	38	61	102	40	22	45	97	-	-	-	-	-
		Curaçao	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	25	20	13	117	59	46	60	34	42	-	-	-	-	-
		Côte d'Ivoire	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	95	45	-	-	-	-	-	-
		EU-España	24	34	355	204	192	242	625	571	764	605	371	58	255	328	487	474	-	-	223	244	143	88	49	190	250	211	216	98	80	143	-	-	-	-	-
		EU-France	3	8	154	233	281	352	653	686	1,032	970	713	314	437	467	553	607	229	205	446	397	222	79	26	51	150	122	394	192	56	54	-	-	-	-	-
		Guatemala	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	56	28	15	26	9	18	6	11	5	15	-	-	-	-	-
		Guinée Rep	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	72	-	60	20	22	74	203	288	245	209	-	-	-	-	-
		Panama	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	151	106	135	97	85	38	70	41	80	27	-	-	-	-	-
	NCO	Mixed flags (EU tropical)	20	7	103	164	172	153	663	379	494	457	582	169	301	193	143	281	28	8	198	378	294	189	348	337	375	324	257	-	-	-	989	1,187	972	1,049	1,069
3-Discards	CP	Canada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
		EU-France	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	-	38	2	10
		Japan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26	15
		Korea Rep	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
		South Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-
		UK-Bermuda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	NCC	Chinese Taipei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	14	-	-	-	-	-	-	-

Table 2. Estimates of BET 2020 catches by CPC. Columns 2017-2020 show the Task 1 catch reported by CPCs. Avg Catch 2017/2019 represents the average of reported catches for the 2017-2019 period. Commission BET Catch shows the Catch limits suggested in Rec. 19-02. Estimate 2020 Catch provides the estimated catch derived from reported catches and estimates of unreported catches made by the Group (see section 2.1 text for further details).

Catch t **CPC flag**	**2017**	**2018**	**2019**	**2020**	**Avg catch 2017/19**	**Commission BET Catch**	**Estimate 2020 Catch**
Angola	3		253		128	3	3
Barbados	16	29	14		20	23	20
Belize	1,961	2,135	2,307		2,134	1,603	1,603
Brazil	7,258	5,096	6,249	6,284		6,043	6,284
Canada	214	237	193	102		1,575	102
Cape Verde	1,107	1,418	880		1,135	1,782	1,135
China PR	5,514	4,823	5,718		5,352	4,462	4,462
Chinese Taipei	11,845	11,630	11,288	9,226		11,201	9,226
Côte d'Ivoire	1,239	384	2,334		1,319	559	559
Curaçao	2,844	3,530	2,787	1,519		1,519	1,519
Dominica	0				0		0
El Salvador	1,826	2,634	2,464	1,518		1,553	1,518
EU-España	11,544	8,400	9,117	6,050		8,056	6,050
EU-France	4,077	4,057	5,128	2,036		4,429	2,036
EU-Ireland	0				0		0
EU-Italy		7			7		7
EU-Portugal	3,146	4,405	3,146	3,055		3,058	3,055
FR-St Pierre et Miquelon							
Ghana	3,838	3,636	2,917	2,933		3,716	2,933
Great Britain	0				0		0
Grenada	33	27	26		29		29
Guatemala	1,602	1,488	1,623	906		1,827	906
Guinea Ecuatorial	11	7	8	6			6
Guinée Rep						11	11
Guyana	34	53	2		29	29	29
Japan	10,994	9,881	9,492	9,302		13,080	9,302
Korea Rep	432	623	540	587		1,000	587
Liberia	98	1	3		34	32	32
Maroc	410	500	850	1,033		5,150	1,033
Mauritania							
Mexico	3	3	3	3		2	3
Mixed flags (EU tropical)	972	1,049	1,069		1,030		1,030
Namibia	141	109	79		110	301	110
Nigeria							
Panama	1,664	2,067	3,052		2,261	1,707	1,707
Philippines							
S Tomé e Príncipe	393	2	6		134	389	134
Saint Kitts and Nevis	1				1		1
Senegal	2,978	2,870	2,272	2,700		1,323	2,700
South Africa	257	282	432		324	226	226
St Vincent and Grenadines	889	428	504		607	509	509
Sta Lucia	24	13	13		17		17
Trinidad and Tobago	25	17	13	10		49	10
UK-Bermuda			0		0		0
UK-Sta Helena	70	45	4		40		40
UK-Turks and Caicos							
Uruguay							
USA	836	921	832	816		1,575	816
Vanuatu							
Venezuela	318	165	28		170	194	170
Totals	**78,617**	**72,971**	**75,646**	**48,086**			**59,919**

Table 3. Summary of the bigeye tuna conventional tag information by year of release as of 16 July 2021. Releases represent the number of tagged fish released and Recaptures, the corresponding number of tagged fish recovered and reported after given years at liberty. Bars in the releases and recaptures columns represent histogram of numbers. Unk represents number of recaptured fish for which the year of recapture is unknown. % recapture represents the percent of fish released in any given year that were recaptured. Colors in the year columns represent the relative number of recaptured fish, dark green representing fewer recaptures and dark red greater recaptures.

Number of tag Bigeye tuna (*Thunnus obesus*)

Year	Releases	Recaptures	Years at liberty < 1	1 - 2	2 - 3	3 - 4	4 - 5	5-6	Unk	% recapt*
1960	2	0								
1962	9	0								
1963	45	0								
1964	34	0								
1965	4	0								
1966	21	0								
1967	3	0								
1969	2	0								
1971	4	4	2	2						100.0%
1972	17	17	14						3	100.0%
1973	126	125	124	1						99.2%
1974	17	16	11	1					4	94.1%
1975	16	16	14	1					1	100.0%
1977	9	9	9							100.0%
1978	108	107	101	5		1				99.1%
1979	11	0								
1980	939	92	72	10					10	9.8%
1981	690	208	189	8	1				10	30.1%
1982	7	0								
1983	5	3	3							60.0%
1984	23	5	3	1					1	21.7%
1985	5	0								
1986	96	90	87						3	93.8%
1987	23	0								
1988	10	0								
1989	28	2	1	1						7.1%
1990	69	0								
1991	215	1		1						0.5%
1992	255	1	1							0.4%
1993	220	3		2	1					1.4%
1994	257	32	27	4					1	12.5%
1995	157	12	10	1				1		7.6%
1996	119	21	18	3						17.6%
1997	609	243	233	8	2					39.9%
1998	45	7	6	1						15.6%
1999	3659	1464	1381	58	9	1			15	40.0%
2000	1414	192	174	14	2	1			1	13.6%
2001	356	14	9	4					1	3.9%
2002	1212	138	129	6	1				2	11.4%
2003	272	46	43	3						16.9%
2004	4	0								
2005	24	1							1	4.2%
2006	11	0								
2007	3	0								
2008	1	1				1				100.0%
2009	8	0								
2011	8	2	1				1			25.0%
2013	18	0								
2014	1	1	1							100.0%
2016	9146	2558	2350	129	26	8	1		44	28.0%
2017	6403	1683	1557	74	9	1			42	26.3%
2018	5642	527	417	84	3				23	9.3%
2019	2004	304	286	8					10	15.2%
2019	1047	73	63	10						7.0%
Grand Total	35433	8018	7336	440	54	13	2	1	172	22.6%

Table 4. Summary of the AOTTP tag seeding experiments database as of July 14, 2021. First table has details on the country and institution conducting the experiment and the number of seeded fish (fish with a tag introduced in the catch without the knowledge of the crew) per year and team. Second table represents the number of seeded fish per species and fleet type. Third table contains the number of seeded fish reported.

Seeding releases			**Year**							
country	**Institution**	**Team**	**unk**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**
Senegal (SEN)	ISRA (Dakar)	T02	11	4	96	30	75	35	10	261
Côte D'Ivoire (CIV)	CRO (Abidjan)	T03			76	158	38	45	3	320
España (EU.ESP)	IEO (Canarias)	T04					8	15		23
Cape Verde (CPV)	INDP (S.Vicente)	T05				5				5
South Africa (ZAF)	CapMarine (Cape	T06			5	14				19
Ghana (GHA)	MFRD (Tema)	T07			146	28	157	50		381
Brasil (BRA)	FADURPE (Recife)	T09				68				68
Total			**11**	**4**	**323**	**303**	**278**	**145**	**13**	**1077**

Seeding releases

Gear	BET	LTA	SKJ	UNK	YFT	Total
BB	44	7	178	40	179	448
PS	106	1	280	2	226	615
UNCL	3		6		5	14
Grand Total	153	8	464	42	410	1077

Reported tags from seeding releases

Gear	BET	LTA	SKJ	UNK	YFT	Total
BB	41	5	146	35	116	343
PS	79	1	227	2	157	466
UNCL	3		6		5	14
Grand Total	123	6	379	37	278	823

Table 5. Definition of fleet structure for Stock synthesis. PS = Purse seines, BB: Baitboat, LL: longline, RR: Rod and Reel, HL: Handline; 5KCS: 5-Knot Cubic Spline, DN: Double Normal; ASY: Asymptotic logistic.

N	*Name*	*Area*	*Year*	*Selectivity*	*Flags*	Remarks
1	PS early	2, 1	Before 1985	5KCS	*All except Ghana/USA/Venezuela*	
2	PS transition	2, 1	1986-1990	5KCS	*All except Ghana/USA/Venezuela*	
3	PS Free School	2, 1	After 1991	5KCS	*All except Ghana/USA/Venezuela*	
4	PS FAD	2, 3	All	5KCS	*All except Ghana/USA/Venezuela*	
5	BB+PS Ghana	2	All	5KCS	*Ghana*	
6	BB-South Dakar	2(S10N)	All	5KCS	*All except Ghana*	Size by South Africa is removed
7	BB-North Dakar early	2(N10N)	Before 1980	DN	*All except Ghana*	
8	BB-North Dakar late	2(N10N)	After 1981	DN	*All except Ghana*	
9	BB_North_Azores	1,3	All	DN	*All except Ghana*	
10	LL North Japan	1	All	DN	*Japan*	
11	LL Tropical Japan	2	All	DN	*Japan*	
12	LL South Japan	3	All	DN	*Japan*	
13	LL North Other	1	All	DN	*All except Japan and Chinese Taipei*	Now excluding Chinese Taipei LL (#16-18), and the catches from other gears have also been separated to a new fleet (#22) and two new fleets (#19 and 20).
14	LL Tropical Other	2	All	DN	*All except Japan and Chinese Taipei*	See note for #13
15	LL South other	3	All	DN	*All except Japan and Chinese Taipei*	See note for #13
16	LL North China Taipei	1	All	DN	*China Taipei*	New fleet prior was part of #13
17	LL Tropical China Taipei	2	All	ASY	*China Taipei*	New fleet prior was part of #14
18	LL South China Taipei	3	All	ASY	*China Taipei*	New fleet prior was part of #15
19	RR West Atlantic	1	All	DN	*USA/Canada/UK-Sta Helena*	New fleet prior was part of #13, use only size by USA RR, catch is “oth” in CATDIS
20	HL Brazil	2	All	Mirrored to fleet 8	*Brazil*	New fleet prior was part of #14. catch is “oth” in CATDIS
21	PS West Atlantic	1	All	5KCS	*USA/Venezuela*	New fleet prior was part of #13
22	Other	1,2,3	All	5KCS	*All others*	New fleet prior was part of #13-15

Table 6. Parameters of the bigeye tuna Richards growth model.

Parameter	*Value*	*Parameter*	*Value*
L_at_Age min	*57.6*	*Richards*	*0.00034*
L_at_Age max	*178.6*	*CV_young fish*	*0.1*
K	*0.42*	*CV_old fish*	*0.067*

Table 7. Natural mortality at age assumptions used in the Stock Synthesis uncertainty grid.

	Natural Mortality-at-Age		
Age	Max_Age = 17	Max_Age = 20	Max_Age = 25
0	0.978	0.820	0.668
1	0.613	0.514	0.419
2	0.481	0.403	0.329
3	0.414	0.347	0.283
4	0.375	0.314	0.256
5	0.350	0.293	0.239
6	0.333	0.279	0.228
7	0.322	0.270	0.220
8	0.313	0.263	0.214
9	0.307	0.258	0.210
10	0.303	0.254	0.207

Table 8. Table of reference and sensitivity run specifications.

Model	**Name**	**Description**
14	Reference	Max_age =20, Steepness 0.8, SigmaR=0.4
S1	sensitivity 1	Continuity run (no buoy index, M vector from 2018)
S2	sensitivity 2	Reference without early Combined LL index
S3	sensitivity 3	Reference without buoy index

Table 9. Uncertainty grid alternative assumptions. Max_age represent vectors of natural mortality obtained under different assumptions of maximum age (See **Table 7**). Bolded values correspond to the reference case.

Parameter	**Value1**	**Value2**	**Value3**
Max_Age	17	**20**	25
steepness	0.7	**0.8**	0.9
sigma R	0.2	**0.4**	0.6

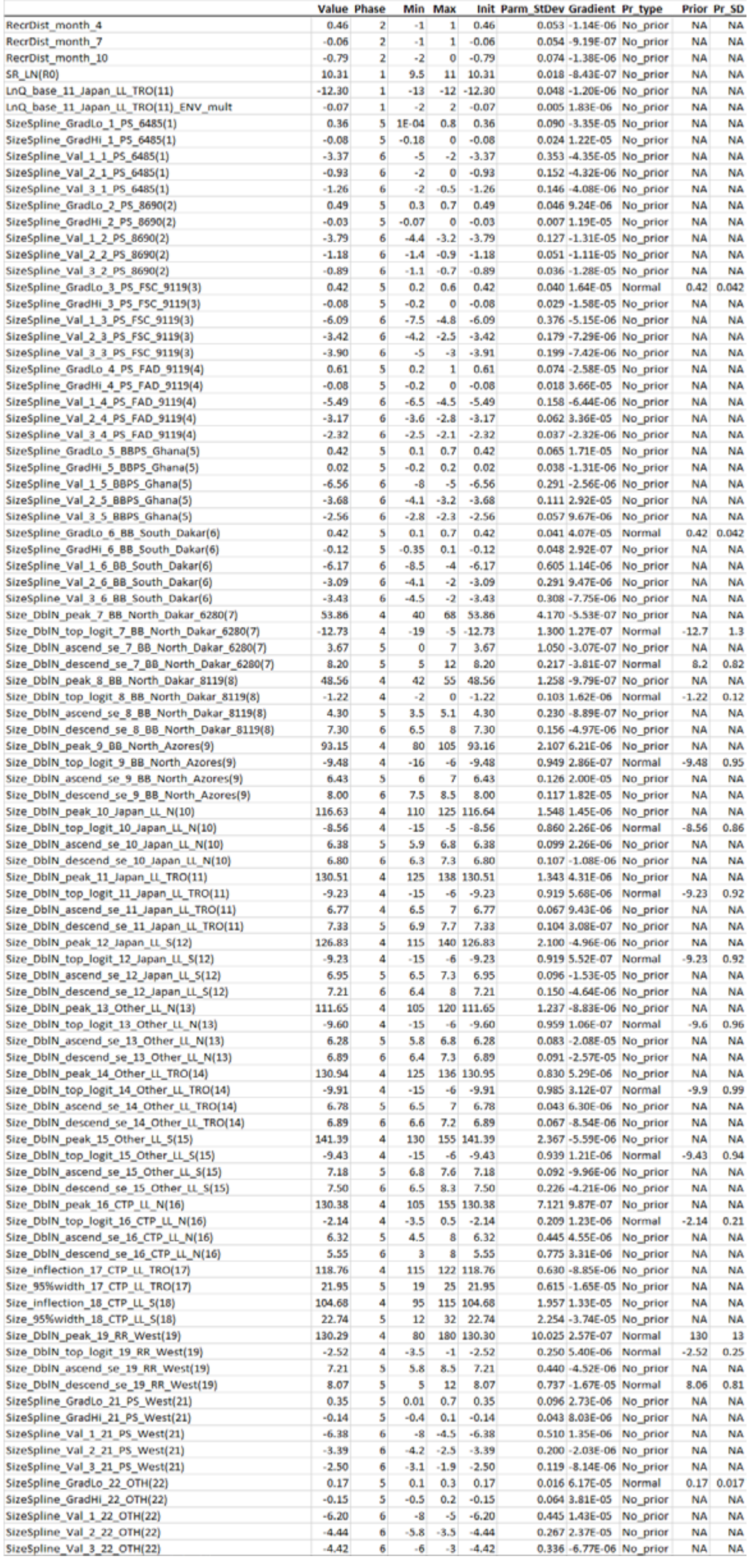
Table 10. Shape parameters and their associated B_{MSY}/K ratios for the uncertainty grid considered for mpb models.

Scenario	shape (p)	B_{MSY}/K
M17_h7	-0.2560	0.315
M17_h8	-0.3806	0.284
M17_h9	-0.4960	0.251
M20_h7	-0.2150	0.324
M20_h8	-0.3350	0.296
M20_h9	-0.4450	0.266
M25_h7	-0.1879	0.33
M25_h8	-0.3081	0.303
M25_h9	-0.4180	0.274

Table 11. Summary of the uncertainty grid scenarios for JABBA runs for the Atlantic bigeye tuna.

Scenario	**Parametrization**	**Model**	**r**	**B_{MSY}/K**
S01	Continuity Model 2021	Fox	Range - c(0.05, 0.5)	0.37
S02	Maximum Age 17 | h = 0.7	Pella-Tomlinson	lnorm - c(0.230, 0.349)	0.33
S03	Maximum Age 17 | h = 0.8	Pella-Tomlinson	lnorm - c(0.251, 0.389)	0.33
S04	Maximum Age 17 | h = 0.9	Pella-Tomlinson	lnorm - c(0.272, 0.413)	0.34
S05	Maximum Age 20 | h = 0.7	Pella-Tomlinson	lnorm - c(0.186, 0.288)	0.32
S06	Maximum Age 20 | h = 0.8	Pella-Tomlinson	lnorm - c(0.198, 0.331)	0.31
S07	Maximum Age 20 | h = 0.9	Pella-Tomlinson	lnorm - c(0.211, 0.369)	0.30
S08	Maximum Age 25 | h = 0.7	Pella-Tomlinson	lnorm - c(0.149, 0.239)	0.31
S09	Maximum Age 25 | h = 0.8	Pella-Tomlinson	lnorm - c(0.155, 0.260)	0.29
S10	Maximum Age 25 | h = 0.9	Pella-Tomlinson	lnorm - c(0.161, 0.293)	0.27

Table 12. Parameter estimates for selectivity, recruitment, and catchability, starting values, and priors for Stock Synthesis reference case (Max_age =20, Steepness 0.8, SigmaR=0.4).



	Value	Phase	Min	Max	Init	Parm_StDev	Gradient	Pr_type	Prior	Pr_SD
RecrDist_month_4	0.46	2	-1	1	0.46	0.053	-1.14E-06	No_prior	NA	NA
RecrDist_month_7	-0.06	2	-1	1	-0.06	0.054	-9.19E-07	No_prior	NA	NA
RecrDist_month_10	-0.79	2	-2	0	-0.79	0.074	-1.38E-06	No_prior	NA	NA
SR_LN(R0)	10.31	1	9.5	11	10.31	0.018	-8.43E-07	No_prior	NA	NA
LnQ_base_11_Japan_LL_TRO(11)	-12.30	1	-13	-12	-12.30	0.048	-1.20E-06	No_prior	NA	NA
LnQ_base_11_Japan_LL_TRO(11)_ENV_mult	-0.07	1	-2	2	-0.07	0.005	1.83E-06	No_prior	NA	NA
SizeSpline_GradLo_1_PS_6485(1)	0.36	5	1E-04	0.8	0.36	0.090	-3.35E-05	No_prior	NA	NA
SizeSpline_GradHi_1_PS_6485(1)	-0.08	5	-0.18	0	-0.08	0.024	1.22E-05	No_prior	NA	NA
SizeSpline_Val_1_1_PS_6485(1)	-3.37	6	-5	-2	-3.37	0.353	-4.35E-05	No_prior	NA	NA
SizeSpline_Val_2_1_PS_6485(1)	-0.93	6	-2	0	-0.93	0.152	-4.32E-06	No_prior	NA	NA
SizeSpline_Val_3_1_PS_6485(1)	-1.26	6	-2	-0.5	-1.26	0.146	-4.08E-06	No_prior	NA	NA
SizeSpline_GradLo_2_PS_8690(2)	0.49	5	0.3	0.7	0.49	0.046	9.24E-06	No_prior	NA	NA
SizeSpline_GradHi_2_PS_8690(2)	-0.03	5	-0.07	0	-0.03	0.007	1.19E-05	No_prior	NA	NA
SizeSpline_Val_1_2_PS_8690(2)	-3.79	6	-4.4	-3.2	-3.79	0.127	-1.31E-05	No_prior	NA	NA
SizeSpline_Val_2_2_PS_8690(2)	-1.18	6	-1.4	-0.9	-1.18	0.051	-1.11E-05	No_prior	NA	NA
SizeSpline_Val_3_2_PS_8690(2)	-0.89	6	-1.1	-0.7	-0.89	0.036	-1.28E-05	No_prior	NA	NA
SizeSpline_GradLo_3_PS_FSC_9119(3)	0.42	5	0.2	0.6	0.42	0.040	1.64E-05	Normal	0.42	0.042
SizeSpline_GradHi_3_PS_FSC_9119(3)	-0.08	5	-0.2	0	-0.08	0.029	-1.58E-05	No_prior	NA	NA
SizeSpline_Val_1_3_PS_FSC_9119(3)	-6.09	6	-7.5	-4.8	-6.09	0.376	-5.15E-06	No_prior	NA	NA
SizeSpline_Val_2_3_PS_FSC_9119(3)	-3.42	6	-4.2	-2.5	-3.42	0.179	-7.29E-06	No_prior	NA	NA
SizeSpline_Val_3_3_PS_FSC_9119(3)	-3.90	6	-5	-3	-3.91	0.199	-7.42E-06	No_prior	NA	NA
SizeSpline_GradLo_4_PS_FAD_9119(4)	0.61	5	0.2	1	0.61	0.074	-2.58E-05	No_prior	NA	NA
SizeSpline_GradHi_4_PS_FAD_9119(4)	-0.08	5	-0.2	0	-0.08	0.018	3.66E-05	No_prior	NA	NA
SizeSpline_Val_1_4_PS_FAD_9119(4)	-5.49	6	-6.5	-4.5	-5.49	0.158	-6.44E-06	No_prior	NA	NA
SizeSpline_Val_2_4_PS_FAD_9119(4)	-3.17	6	-3.6	-2.8	-3.17	0.062	3.36E-05	No_prior	NA	NA
SizeSpline_Val_3_4_PS_FAD_9119(4)	-2.32	6	-2.5	-2.1	-2.32	0.037	-2.32E-06	No_prior	NA	NA
SizeSpline_GradLo_5_BBPS_Ghana(5)	0.42	5	0.1	0.7	0.42	0.065	1.71E-05	No_prior	NA	NA
SizeSpline_GradHi_5_BBPS_Ghana(5)	0.02	5	-0.2	0.2	0.02	0.038	-1.31E-06	No_prior	NA	NA
SizeSpline_Val_1_5_BBPS_Ghana(5)	-6.56	6	-8	-5	-6.56	0.291	-2.56E-06	No_prior	NA	NA
SizeSpline_Val_2_5_BBPS_Ghana(5)	-3.68	6	-4.1	-3.2	-3.68	0.111	2.92E-05	No_prior	NA	NA
SizeSpline_Val_3_5_BBPS_Ghana(5)	-2.56	6	-2.8	-2.3	-2.56	0.057	9.67E-06	No_prior	NA	NA
SizeSpline_GradLo_6_BB_South_Dakar(6)	0.42	5	0.1	0.7	0.42	0.041	4.07E-05	Normal	0.42	0.042
SizeSpline_GradHi_6_BB_South_Dakar(6)	-0.12	5	-0.35	0.1	-0.12	0.048	2.92E-07	No_prior	NA	NA
SizeSpline_Val_1_6_BB_South_Dakar(6)	-6.17	6	-8.5	-4	-6.17	0.605	1.14E-06	No_prior	NA	NA
SizeSpline_Val_2_6_BB_South_Dakar(6)	-3.09	6	-4.1	-2	-3.09	0.291	9.47E-06	No_prior	NA	NA
SizeSpline_Val_3_6_BB_South_Dakar(6)	-3.43	6	-4.5	-2	-3.43	0.308	-7.75E-06	No_prior	NA	NA
Size_DblN_peak_7_BB_North_Dakar_6280(7)	53.86	4	40	68	53.86	4.170	-5.53E-07	No_prior	NA	NA
Size_DblN_top_logit_7_BB_North_Dakar_6280(7)	-12.73	4	-19	-5	-12.73	1.300	1.27E-07	Normal	-12.7	1.3
Size_DblN_ascend_se_7_BB_North_Dakar_6280(7)	3.67	5	0	7	3.67	1.050	-3.07E-07	No_prior	NA	NA
Size_DblN_descend_se_7_BB_North_Dakar_6280(7)	8.20	5	5	12	8.20	0.217	-3.81E-07	Normal	8.2	0.82
Size_DblN_peak_8_BB_North_Dakar_8119(8)	48.56	4	42	55	48.56	1.258	-9.79E-07	No_prior	NA	NA
Size_DblN_top_logit_8_BB_North_Dakar_8119(8)	-1.22	4	-2	0	-1.22	0.103	1.62E-06	Normal	-1.22	0.12
Size_DblN_ascend_se_8_BB_North_Dakar_8119(8)	4.30	5	3.5	5.1	4.30	0.230	-8.89E-07	No_prior	NA	NA
Size_DblN_descend_se_8_BB_North_Dakar_8119(8)	7.30	6	6.5	8	7.30	0.156	-4.97E-06	No_prior	NA	NA
Size_DblN_peak_9_BB_North_Azores(9)	93.15	4	80	105	93.16	2.107	6.21E-06	No_prior	NA	NA
Size_DblN_top_logit_9_BB_North_Azores(9)	-9.48	4	-16	-6	-9.48	0.949	2.86E-07	Normal	-9.48	0.95
Size_DblN_ascend_se_9_BB_North_Azores(9)	6.43	5	6	7	6.43	0.126	2.00E-05	No_prior	NA	NA
Size_DblN_descend_se_9_BB_North_Azores(9)	8.00	6	7.5	8.5	8.00	0.117	1.82E-05	No_prior	NA	NA
Size_DblN_peak_10_Japan_LL_N(10)	116.63	4	110	125	116.64	1.548	1.45E-06	No_prior	NA	NA
Size_DblN_top_logit_10_Japan_LL_N(10)	-8.56	4	-15	-5	-8.56	0.860	2.26E-06	Normal	-8.56	0.86
Size_DblN_ascend_se_10_Japan_LL_N(10)	6.38	5	5.9	6.8	6.38	0.099	2.26E-06	No_prior	NA	NA
Size_DblN_descend_se_10_Japan_LL_N(10)	6.80	6	6.3	7.3	6.80	0.107	-1.08E-06	No_prior	NA	NA
Size_DblN_peak_11_Japan_LL_TRO(11)	130.51	4	125	138	130.51	1.343	4.31E-06	No_prior	NA	NA
Size_DblN_top_logit_11_Japan_LL_TRO(11)	-9.23	4	-15	-6	-9.23	0.919	5.68E-06	Normal	-9.23	0.92
Size_DblN_ascend_se_11_Japan_LL_TRO(11)	6.77	4	6.5	7	6.77	0.067	9.43E-06	No_prior	NA	NA
Size_DblN_descend_se_11_Japan_LL_TRO(11)	7.33	5	6.9	7.7	7.33	0.104	3.08E-07	No_prior	NA	NA
Size_DblN_peak_12_Japan_LL_S(12)	126.83	4	115	140	126.83	2.100	-4.96E-06	No_prior	NA	NA
Size_DblN_top_logit_12_Japan_LL_S(12)	-9.23	4	-15	-6	-9.23	0.919	5.52E-07	Normal	-9.23	0.92
Size_DblN_ascend_se_12_Japan_LL_S(12)	6.95	5	6.5	7.3	6.95	0.096	-1.53E-05	No_prior	NA	NA
Size_DblN_descend_se_12_Japan_LL_S(12)	7.21	6	6.4	8	7.21	0.150	-4.64E-06	No_prior	NA	NA
Size_DblN_peak_13_Other_LL_N(13)	111.65	4	105	120	111.65	1.237	-8.83E-06	No_prior	NA	NA
Size_DblN_top_logit_13_Other_LL_N(13)	-9.60	4	-15	-6	-9.60	0.959	1.06E-07	Normal	-9.6	0.96
Size_DblN_ascend_se_13_Other_LL_N(13)	6.28	5	5.8	6.8	6.28	0.083	-2.08E-05	No_prior	NA	NA
Size_DblN_descend_se_13_Other_LL_N(13)	6.89	6	6.4	7.3	6.89	0.091	-2.57E-05	No_prior	NA	NA
Size_DblN_peak_14_Other_LL_TRO(14)	130.94	4	125	136	130.95	0.830	5.29E-06	No_prior	NA	NA
Size_DblN_top_logit_14_Other_LL_TRO(14)	-9.91	4	-15	-6	-9.91	0.985	3.12E-07	Normal	-9.9	0.99
Size_DblN_ascend_se_14_Other_LL_TRO(14)	6.78	5	6.5	7	6.78	0.043	6.30E-06	No_prior	NA	NA
Size_DblN_descend_se_14_Other_LL_TRO(14)	6.89	6	6.6	7.2	6.89	0.067	-8.54E-06	No_prior	NA	NA
Size_DblN_peak_15_Other_LL_S(15)	141.39	4	130	155	141.39	2.367	-5.59E-06	No_prior	NA	NA
Size_DblN_top_logit_15_Other_LL_S(15)	-9.43	4	-15	-6	-9.43	0.939	1.21E-06	Normal	-9.43	0.94
Size_DblN_ascend_se_15_Other_LL_S(15)	7.18	5	6.8	7.6	7.18	0.092	-9.96E-06	No_prior	NA	NA
Size_DblN_descend_se_15_Other_LL_S(15)	7.50	6	6.5	8.3	7.50	0.226	-4.21E-06	No_prior	NA	NA
Size_DblN_peak_16_CTP_LL_N(16)	130.38	4	105	155	130.38	7.121	9.87E-07	No_prior	NA	NA
Size_DblN_top_logit_16_CTP_LL_N(16)	-2.14	4	-3.5	0.5	-2.14	0.209	1.23E-06	Normal	-2.14	0.21
Size_DblN_ascend_se_16_CTP_LL_N(16)	6.32	5	4.5	8	6.32	0.445	4.55E-06	No_prior	NA	NA
Size_DblN_descend_se_16_CTP_LL_N(16)	5.55	6	3	8	5.55	0.775	3.31E-06	No_prior	NA	NA
Size_inflection_17_CTP_LL_TRO(17)	118.76	4	115	122	118.76	0.630	-8.85E-06	No_prior	NA	NA
Size_95%width_17_CTP_LL_TRO(17)	21.95	5	19	25	21.95	0.615	-1.65E-05	No_prior	NA	NA
Size_inflection_18_CTP_LL_S(18)	104.68	4	95	115	104.68	1.957	1.33E-05	No_prior	NA	NA
Size_95%width_18_CTP_LL_S(18)	22.74	5	12	32	22.74	2.254	-3.74E-05	No_prior	NA	NA
Size_DblN_peak_19_RR_West(19)	130.29	4	80	180	130.30	10.025	2.57E-07	Normal	130	13
Size_DblN_top_logit_19_RR_West(19)	-2.52	4	-3.5	-1	-2.52	0.250	5.40E-06	Normal	-2.52	0.25
Size_DblN_ascend_se_19_RR_West(19)	7.21	5	5.8	8.5	7.21	0.440	-4.52E-06	No_prior	NA	NA
Size_DblN_descend_se_19_RR_West(19)	8.07	5	5	12	8.07	0.737	-1.67E-05	Normal	8.06	0.81
SizeSpline_GradLo_21_PS_West(21)	0.35	5	0.01	0.7	0.35	0.096	2.73E-06	No_prior	NA	NA
SizeSpline_GradHi_21_PS_West(21)	-0.14	5	-0.4	0.1	-0.14	0.043	8.03E-06	No_prior	NA	NA
SizeSpline_Val_1_21_PS_West(21)	-6.38	6	-8	-4.5	-6.38	0.510	1.35E-06	No_prior	NA	NA
SizeSpline_Val_2_21_PS_West(21)	-3.39	6	-4.2	-2.5	-3.39	0.200	-2.03E-06	No_prior	NA	NA
SizeSpline_Val_3_21_PS_West(21)	-2.50	6	-3.1	-1.9	-2.50	0.119	-8.14E-06	No_prior	NA	NA
SizeSpline_GradLo_22_OTH(22)	0.17	5	0.1	0.3	0.17	0.016	6.17E-05	Normal	0.17	0.017
SizeSpline_GradHi_22_OTH(22)	-0.15	5	-0.5	0.2	-0.15	0.064	3.81E-05	No_prior	NA	NA
SizeSpline_Val_1_22_OTH(22)	-6.20	6	-8	-5	-6.20	0.445	1.43E-05	No_prior	NA	NA
SizeSpline_Val_2_22_OTH(22)	-4.44	6	-5.8	-3.5	-4.44	0.267	2.37E-05	No_prior	NA	NA
SizeSpline_Val_3_22_OTH(22)	-4.42	6	-6	-3	-4.42	0.336	-6.77E-06	No_prior	NA	NA

Table 13. Model objective function, estimates of R0 and F_{MSY} across the Stock Synthesis uncertainty grid. In bold is the reference case.

Model	Run name	MaxAge	Steepness	SigmaR	Obj_Function	R0_estimate	F_{MSY}
1	M17_h0.7_sig-	17	0.7	0.2	5837.3	4.56E+07	0.13
2	M17_h0.7_sig-	17	0.7	0.4	5848.0	4.88E+07	0.13
3	M17_h0.7_sig-	17	0.7	0.6	5862.5	5.60E+07	0.13
4	M17_h0.8_sig-	17	0.8	0.2	5836.8	4.26E+07	0.16
5	M17_h0.8_sig-	17	0.8	0.4	5848.6	4.53E+07	0.16
6	M17_h0.8_sig-	17	0.8	0.6	5861.4	5.15E+07	0.16
7	M17_h0.9_sig-	17	0.9	0.2	5836.9	4.05E+07	0.19
8	M17_h0.9_sig-	17	0.9	0.4	5848.7	4.30E+07	0.19
9	M17_h0.9_sig-	17	0.9	0.6	5861.0	4.84E+07	0.199
10	M20_h0.7_sig-	20	0.7	0.2	5868.3	3.13E+07	0.11
11	M20_h0.7_sig-	20	0.7	0.4	5881.1	3.34E+07	0.11
12	M20_h0.7_sig-	20	0.7	0.6	5904.4	3.82E+07	0.11
13	M20_h0.8_sig-	20	0.8	0.2	5859.3	2.83E+07	0.14
14	M20_h0.8_sig-	**20**	**0.8**	**0.4**	**5872.7**	**3.00E+07**	**0.14**
15	M20_h0.8_sig-	20	0.8	0.6	5894.3	3.39E+07	0.14
16	M20_h0.9_sig-	20	0.9	0.2	5853.6	2.62E+07	0.16
17	M20_h0.9_sig-	20	0.9	0.4	5867.2	2.77E+07	0.17
18	M20_h0.9_sig-	20	0.9	0.6	5887.5	3.10E+07	0.17
19	M25_h0.7_sig-	25	0.7	0.2	5996.6	2.27E+07	0.09
20	M25_h0.7_sig-	25	0.7	0.4	6005.0	2.43E+07	0.09
21	M25_h0.7_sig-	25	0.7	0.6	6040.5	2.77E+07	0.09
22	M25_h0.8_sig-	25	0.8	0.2	5968.6	2.02E+07	0.11
23	M25_h0.8_sig-	25	0.8	0.4	5978.9	2.14E+07	0.11
24	M25_h0.8_sig-	25	0.8	0.6	6011.8	2.41E+07	0.11
25	M25_h0.9_sig-	25	0.9	0.2	5948.1	1.82E+07	0.13
26	M25_h0.9_sig-	25	0.9	0.4	5959.4	1.92E+07	0.13
27	M25_h0.9_sig-	25	0.9	0.6	5990.1	2.15E+07	0.13

Table 14. Summary of the retrospective analysis, hindcasting analysis, final gradient and RMSEs (root mean square error) of index and size composition for the sensitivity runs exploring the effects of changes between the 2018 and 2021 assessment. The retrospective and hindcast period (2018—2014) is same for the uncertainty grid except for the longline index. The longline index is available before 2017 in the bigeye tuna stock assessment in 2018. When the hindcast analysis is applied to the index for the same period (2018—2014), only three years results (2014—2016) will be obtained. Therefore 7 years (2018—2012) hindcast analysis for the LL index is applied to get 5 years results (2016—2012). For your reference, the results (MASE) of the longline for the three years period (2014—2016) is also presented.

run	Mohn's rho (hindcast)	MASE (index 11_LL) for 5 years (2016-2012)	MASE (4_PS_FAD _S1)	MASE (4_PS_FAD _S2)	MASE (4_PS_FAD _S3)	MASE (4_PS_FAD _S4)	MASE (index 11_LL) for 3 years (2016-2014)	Final gradient	RMSE Index (%)	RMSE size composition (%)
M17_h0.8_sigmaR0.4_LL2018	-0.2 (-0.24)	3.44	1.29	1.09	1.63	2.02	4.21	5.93E-06	25.0	15.5
M20_h0.8_sigmaR0.4_LL2018	-0.16 (-0.22)	3.04	1.21	1.11	2.41	2.94	4.24	6.30E-05	24.6	15.8
M25_h0.8_sigmaR0.4_LL2018	-0.1 (-0.16)	1.88	1.27	1.17	3.09	3.86	3.06	9.12E-05	25.0	16.1

Table 15. Summary of the retrospective analysis and hindcasting analysis and the final gradient and RMSEs (root mean square error) of index and size composition for the 27 runs of the uncertainty grid.

Model	Mohn's rho (hindcast)	MASE (index 11_LL)	MASE (4_PS_FAD_ S1)	MASE (4_PS_FAD_ S2)	MASE (4_PS_FAD_ S3)	MASE (4_PS_FAD_ S4)	final gradient	RMSE Index (%)	RMSE size composition (%)
1	-0.06 (-0.08)	2.68	1.42	1.28	2.77	3.10	6.09E-05	23.8	15.5
2	-0.11 (-0.15)	3.47	1.22	1.12	2.00	2.47	9.17E-05	23.2	15.6
3	-0.12 (-0.16)	3.70	1.23	1.04	1.74	2.15	6.96E-05	23.0	15.6
4	-0.03 (-0.05)	2.45	1.41	1.28	2.64	2.89	8.79E-05	23.8	15.5
5	-0.10 (-0.13)	3.35	1.22	1.11	1.87	2.34	9.66E-05	23.1	15.6
6	-0.11 (-0.15)	3.62	1.24	1.03	1.63	2.01	6.88E-05	22.9	15.6
7	-0.00 (-0.03)	2.27	1.40	1.27	2.54	2.76	8.56E-05	23.8	15.5
8	-0.09 (-0.12)	3.25	1.23	1.10	1.78	2.23	9.05E-05	23.1	15.6
9	-0.10 (-0.14)	3.53	1.26	1.03	1.58	1.93	8.64E-05	22.9	15.6
10	-0.04 (-0.08)	3.01	1.38	1.33	3.33	3.86	9.07E-05	24.4	15.7
11	-0.07 (-0.11)	3.46	1.24	1.14	2.55	3.14	6.42E-05	23.6	15.8
12	-0.07 (-0.11)	3.53	1.17	1.08	2.29	2.64	9.46E-05	23.5	15.8
13	-0.03 (-0.06)	2.88	1.38	1.30	3.14	3.58	9.42E-05	24.1	15.7
14	-0.07 (-0.11)	3.46	1.22	1.13	2.38	2.85	8.20E-05	23.5	15.8
15	-0.07 (-0.11)	3.57	1.15	1.07	2.13	2.45	8.78E-05	23.3	15.8
16	-0.01 (-0.05)	2.72	1.37	1.26	2.99	3.34	6.36E-05	24.0	15.7
17	-0.06 (-0.10)	3.43	1.21	1.12	2.24	2.63	8.37E-05	23.4	15.7
18	-0.06 (-0.11)	3.59	1.14	1.05	1.98	2.30	9.20E-05	23.2	15.8
19	0.01 (-0.04)	2.87	1.33	1.43	3.90	4.54	9.22E-05	25.7	16.0
20	0.00 (-0.04)	3.09	1.26	1.19	3.23	3.91	8.63E-05	24.8	16.1
21	0.01 (-0.04)	3.07	1.22	1.13	3.00	3.46	6.65E-05	24.9	16.2
22	0.02 (-0.03)	2.92	1.34	1.41	3.75	4.34	7.88E-05	25.3	16.0
23	0 (-0.05)	3.23	1.25	1.15	3.05	3.68	9.10E-05	24.5	16.1
24	0.01 (-0.04)	3.25	1.20	1.12	2.82	3.21	7.53E-05	24.5	16.1
25	0.03 (-0.02)	2.88	1.34	1.37	3.58	4.11	9.73E-05	25.0	16.0
26	0 (-0.05)	3.31	1.24	1.14	2.87	3.43	9.92E-05	24.2	16.0
27	0 (0.04)	3.38	1.19	1.10	2.64	2.93	7.64E-05	24.1	16.1

Table 16. Biological parameters and MSY based benchmarks, stock status and estimated model parameters for the surplus production MPB-Reference Case (Fox), and the uncertainty grid calculated with bootstraps.

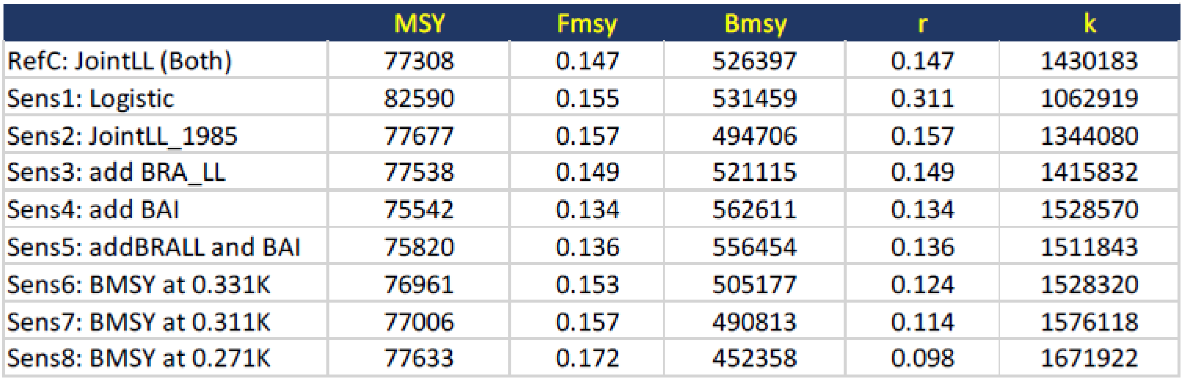
Model		**FOX**	
Variable	**Median**	**95%LCI**	**95%UCI**
MSY	66973	76490	80070
B_{MSY}	451080	545184	843543
F_{MSY}	0.084	0.140	0.176
r (yr-1)	0.084	0.140	0.176
K	1225550	1481222	2291842

Model		**M17_h0.7**			**M17_h0.8**			**M17_h0.9**	
Variable	**Median**	**95%LCI**	**95%UCI**	**Median**	**95%LCI**	**95%UCI**	**Median**	**95%LCI**	**95%UCI**
MSY	69924	76106	83952	64167	73280	86971	68719	76570	93670
B_{MSY}	426346	522954	721218	486373	598384	771948	433788	525243	661721
F_{MSY}	0.106	0.144	0.185	0.084	0.125	0.158	0.105	0.150	0.182
r (yr-1)	0.079	0.107	0.138	0.052	0.077	0.098	0.053	0.075	0.092
K	1353412	1660090	2289468	1712185	2106498	2717497	1726698	2090733	2633984

Model	**M20_h0.7**			**M20_h0.8**			**M20_h0.9**		
Variable	**Median**	**95%LCI**	**95%UCI**	**Median**	**95%LCI**	**95%UCI**	**Median**	**95%LCI**	**95%UCI**
MSY	69301	75996	81954	70590	76412	85067	71555	77135	90279
B_{MSY}	436187	528520	745153	420641	505168	668792	402143	478536	596512
F_{MSY}	0.102	0.143	0.181	0.116	0.149	0.189	0.132	0.159	0.198
r (yr-1)	0.080	0.112	0.142	0.077	0.099	0.126	0.073	0.088	0.110
K	1344779	1629446	2297333	1421682	1707366	2260382	1510090	1796956	2239967

Model	**M25_h0.7**			**M25_h0.8**			**M25_h0.9**		
Variable	**Median**	**95%LCI**	**95%UCI**	**Median**	**95%LCI**	**95%UCI**	**Median**	**95%LCI**	**95%UCI**
MSY	68893	76031	80398	70105	76254	83561	71922	76881	89962
B_{MSY}	434908	526921	752828	428500	506686	685448	398307	482229	619207
F_{MSY}	0.099	0.144	0.182	0.112	0.151	0.186	0.129	0.158	0.200
r (yr-1)	0.080	0.117	0.148	0.078	0.104	0.129	0.075	0.092	0.117
K	1316599	1595150	2279040	1416191	1674597	2265405	1454131	1760510	2260585

Table 17. Estimated model parameters and benchmarks for selected deterministic sensitivity runs of MPB.



	MSY	Fmsy	Bmsy	r	k
RefC: JointLL (Both)	77308	0.147	526397	0.147	1430183
Sens1: Logistic	82590	0.155	531459	0.311	1062919
Sens2: JointLL_1985	77677	0.157	494706	0.157	1344080
Sens3: add BRA_LL	77538	0.149	521115	0.149	1415832
Sens4: add BAI	75542	0.134	562611	0.134	1528570
Sens5: addBRALL and BAI	75820	0.136	556454	0.136	1511843
Sens6: BMSY at 0.331K	76961	0.153	505177	0.124	1528320
Sens7: BMSY at 0.311K	77006	0.157	490813	0.114	1576118
Sens8: BMSY at 0.271K	77633	0.172	452358	0.098	1671922

Table 18. Summary, including MSY based benchmarks, of posterior quantiles denoting the median and the 95% confidence intervals of parameter estimates for the JABBA scenarios (S01-S10).

	S01			**S02**			**S03**			**S04**			**S05**		
	mu	lci	uci	mu	lci	uci	mu	lci	uci	mu	lci	uci	mu	lci	uci
K	1510055	963714	2602941	1299586	914940	1967797	1295431	915770	1976656	1259079	880690	1931649	1284136	939889	1874208
r	0.143	0.076	0.238	0.157	0.100	0.232	0.157	0.100	0.230	0.166	0.105	0.246	0.153	0.101	0.216
ψ**(psi)**	0.964	0.825	0.999	0.963	0.821	0.999	0.963	0.825	0.999	0.963	0.821	0.999	0.964	0.822	0.999
σ_{proc}	0.053	0.041	0.072	0.054	0.041	0.073	0.054	0.041	0.074	0.054	0.042	0.073	0.054	0.041	0.073
F_{MSY}	0.143	0.076	0.237	0.193	0.123	0.286	0.194	0.124	0.283	0.194	0.123	0.287	0.200	0.132	0.282
B_{MSY}	555796	354708	958047	428977	302010	649545	427605	302284	652469	428207	299519	656945	411019	300835	599886
MSY	79351	64369	94062	82688	71483	97663	82652	71518	99916	82828	71417	98781	82104	71621	96483
B_{1950}/K	0.954	0.798	1.081	0.953	0.796	1.081	0.953	0.802	1.082	0.952	0.793	1.082	0.952	0.799	1.080
B_{2019}/K	0.384	0.283	0.513	0.386	0.286	0.518	0.385	0.291	0.538	0.391	0.286	0.537	0.370	0.273	0.502
B_{2019}/B_{MSY}	1.042	0.770	1.394	1.168	0.866	1.570	1.166	0.881	1.629	1.150	0.842	1.580	1.155	0.853	1.568
F_{2019}/F_{MSY}	0.922	0.609	1.372	0.786	0.515	1.134	0.789	0.481	1.122	0.800	0.505	1.168	0.801	0.520	1.157

	S06			**S07**			**S08**			**S09**			**S10**		
	mu	lci	uci	mu	lci	uci	mu	lci	uci	mu	lci	uci	mu	lci	uci
K	1313070	940614	1999410	1313276	929370	2010445	1420759	1027115	2033436	1353754	1002481	1982140	1375997	989492	2046832
r	0.148	0.095	0.214	0.144	0.090	0.211	0.135	0.093	0.190	0.135	0.090	0.191	0.129	0.084	0.185
ψ**(psi)**	0.963	0.824	0.999	0.962	0.823	0.999	0.963	0.820	0.999	0.962	0.816	0.999	0.964	0.820	0.999
σ_{proc}	0.054	0.042	0.073	0.054	0.042	0.073	0.053	0.041	0.072	0.054	0.041	0.072	0.054	0.041	0.072
F_{MSY}	0.204	0.131	0.296	0.211	0.132	0.310	0.187	0.129	0.263	0.211	0.141	0.297	0.227	0.148	0.326
B_{MSY}	407157	291666	619977	393828	278701	602896	440549	318488	630528	392580	290713	574808	371518	267162	552642
MSY	82852	71853	100966	83096	71644	98521	82056	71204	99655	82761	71837	98111	83946	72435	101152
B_{1950}/K	0.953	0.796	1.080	0.951	0.797	1.079	0.953	0.795	1.081	0.951	0.793	1.079	0.954	0.798	1.080
B_{2019}/K	0.378	0.279	0.523	0.376	0.279	0.506	0.378	0.285	0.520	0.370	0.278	0.496	0.373	0.275	0.508
B_{2019}/B_{MSY}	1.220	0.898	1.687	1.254	0.929	1.687	1.220	0.919	1.675	1.275	0.957	1.712	1.381	1.020	1.882
F_{2019}/F_{MSY}	0.752	0.463	1.097	0.732	0.474	1.065	0.759	0.474	1.079	0.720	0.471	1.028	0.653	0.412	0.962

Table 19. Stock Synthesis uncertainty grid estimates (across all 27 runs) of spawning stock biomass relative to SSB$_{MSY}$ and fishing mortality relative to F$_{MSY}$ between 1952 and 2019 for Atlantic bigeye tuna. The median and 80% confidence intervals provided are based on 10000 iterations of the MVNL approximation.

	SSB/SSB$_{MSY}$			F/F$_{MSY}$		
	Median	80% LCI	80% UCI	Median	80% LCI	80% UCI
1952	3.370	3.050	3.870	0.010	0.010	0.010
1953	3.360	3.050	3.860	0.010	0.010	0.010
1954	3.360	3.040	3.860	0.010	0.010	0.010
1955	3.350	3.030	3.840	0.020	0.020	0.020
1956	3.340	3.030	3.840	0.010	0.010	0.010
1957	3.330	3.020	3.820	0.030	0.030	0.040
1958	3.320	3.010	3.810	0.020	0.010	0.020
1959	3.310	3.010	3.800	0.030	0.030	0.040
1960	3.300	2.990	3.780	0.040	0.030	0.040
1961	3.270	2.970	3.750	0.070	0.060	0.080
1962	3.240	2.950	3.700	0.090	0.080	0.110
1963	3.200	2.920	3.650	0.110	0.090	0.120
1964	3.170	2.890	3.610	0.100	0.080	0.110
1965	3.110	2.840	3.540	0.170	0.140	0.190
1966	3.090	2.820	3.520	0.110	0.090	0.130
1967	3.080	2.810	3.500	0.110	0.090	0.130
1968	3.070	2.800	3.500	0.100	0.090	0.120
1969	3.040	2.770	3.460	0.160	0.130	0.190
1970	3.000	2.740	3.410	0.180	0.150	0.210
1971	2.940	2.690	3.320	0.240	0.200	0.280
1972	2.890	2.650	3.270	0.210	0.180	0.250
1973	2.840	2.600	3.200	0.260	0.210	0.300
1974	2.770	2.540	3.120	0.300	0.250	0.350
1975	2.710	2.490	3.050	0.290	0.240	0.340
1976	2.620	2.410	2.960	0.220	0.190	0.260
1977	2.440	2.250	2.770	0.290	0.240	0.330
1978	2.270	2.080	2.590	0.290	0.240	0.340
1979	2.170	1.960	2.530	0.270	0.220	0.310
1980	2.070	1.830	2.480	0.390	0.310	0.460
1981	1.940	1.690	2.380	0.440	0.340	0.520
1982	1.840	1.570	2.330	0.500	0.370	0.600
1983	1.810	1.500	2.370	0.420	0.300	0.510
1984	1.790	1.440	2.410	0.510	0.350	0.630
1985	1.780	1.400	2.470	0.570	0.380	0.710
1986	1.800	1.380	2.550	0.480	0.310	0.620
1987	1.800	1.360	2.570	0.420	0.270	0.550
1988	1.780	1.340	2.510	0.490	0.320	0.640
1989	1.690	1.280	2.360	0.600	0.400	0.780
1990	1.570	1.200	2.150	0.680	0.460	0.880
1991	1.480	1.140	2.010	0.820	0.550	1.050
1992	1.400	1.080	1.900	0.880	0.600	1.130
1993	1.320	1.010	1.790	1.050	0.710	1.350
1994	1.210	0.920	1.660	1.320	0.880	1.690
1995	1.100	0.840	1.530	1.370	0.910	1.760
1996	0.990	0.760	1.390	1.420	0.940	1.840
1997	0.900	0.680	1.280	1.400	0.920	1.840
1998	0.850	0.630	1.240	1.450	0.930	1.940
1999	0.810	0.590	1.220	1.670	1.040	2.290
2000	0.820	0.570	1.280	1.470	0.880	2.080
2001	0.870	0.580	1.390	1.310	0.770	1.920
2002	0.890	0.580	1.430	1.090	0.630	1.640
2003	0.850	0.550	1.390	1.250	0.720	1.910
2004	0.830	0.530	1.350	1.310	0.740	2.020
2005	0.850	0.540	1.380	1.010	0.570	1.570
2006	0.860	0.550	1.390	0.880	0.500	1.360
2007	0.840	0.540	1.340	1.040	0.600	1.590
2008	0.820	0.540	1.310	0.960	0.560	1.460
2009	0.790	0.520	1.240	1.170	0.690	1.760
2010	0.780	0.520	1.220	1.190	0.700	1.760
2011	0.780	0.530	1.210	1.200	0.710	1.760
2012	0.810	0.550	1.250	1.100	0.650	1.600
2013	0.840	0.590	1.280	1.020	0.610	1.460
2014	0.830	0.590	1.250	1.140	0.700	1.600
2015	0.790	0.580	1.180	1.210	0.750	1.670
2016	0.790	0.590	1.170	1.210	0.760	1.650
2017	0.810	0.610	1.190	1.180	0.750	1.590
2018	0.850	0.650	1.240	1.050	0.660	1.400
2019	0.940	0.710	1.370	1.000	0.630	1.350

Table 20. Assumed catch in 2020 and 2021 by quarter by fleet.

By Fleet YrQTr		**Avg% 2017/19**				**Catch_est 2020**				**Catch_est 2021**			
Fleet ID	Fleet Name	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**	**Qtr 1**	**Qtr 2**	**Qtr 3**	**Qtr 4**
1	PS_6485					-	-	-	-	-	-	-	-
2	PS_8690					-	-	-	-	-	-	-	-
3	PS_FSC_9119	0.32	0.17	0.36	0.15	1,638.75	876.65	1,836.78	753.17	1,681.99	899.79	1,885.24	773.04
4	PS_FAD_9119	0.26	0.24	0.20	0.30	3,808.37	3,499.42	2,892.64	4,357.88	3,908.85	3,591.75	2,968.96	4,472.86
5	BBPS_Ghana	0.19	0.26	0.31	0.24	515.14	720.52	845.21	658.77	528.74	739.53	867.51	676.15
6	BB_South_Dakar	0.36	0.19	0.19	0.26	94.85	49.74	49.60	69.05	97.35	51.05	50.91	70.87
7	BB_North_Dakar_6280					-	-	-	-	-	-	-	-
8	BB_North_Dakar_811	0.20	0.31	0.32	0.17	155.63	246.95	250.69	136.85	159.74	253.47	257.31	140.46
9	BB_North25N_Azores	0.03	0.45	0.42	0.10	158.52	2,213.29	2,073.25	495.66	162.71	2,271.69	2,127.95	508.73
10	Japan_LL_N	0.07	0.16	0.17	0.61	5.33	12.88	13.84	49.43	5.47	13.22	14.21	50.74
11	Japan_LL_TRO	0.51	0.08	0.14	0.27	3,109.43	487.53	849.09	1,674.66	3,191.47	500.40	871.50	1,718.85
12	Japan_LL_S	0.07	0.24	0.40	0.28	134.53	430.76	727.66	512.04	138.08	442.12	746.86	525.55
13	Other_LL_N	0.16	0.23	0.33	0.28	208.21	290.25	420.71	351.10	213.70	297.91	431.81	360.37
14	Other_LL_TRO	0.42	0.20	0.14	0.23	3,245.78	1,545.26	1,104.89	1,807.06	3,331.42	1,586.03	1,134.04	1,854.74
15	Other_LL_S	0.10	0.19	0.33	0.38	64.97	116.99	202.97	236.76	66.68	120.08	208.33	243.01
16	CTP_LL_N	0.37	0.28	0.30	0.05	9.61	7.49	8.00	1.19	9.87	7.69	8.21	1.22
17	CTP_LL_TRO	0.27	0.19	0.17	0.37	2,415.91	1,658.08	1,486.30	3,287.80	2,479.65	1,701.82	1,525.52	3,374.55
18	CTP_LL_S	0.08	0.44	0.32	0.16	22.08	129.66	93.34	47.16	22.66	133.08	95.80	48.40
19	RR_West	0.01	0.30	0.60	0.09	1.97	85.37	168.24	24.67	2.02	87.62	172.68	25.32
20	HL_BRA	0.18	0.19	0.18	0.45	620.42	644.47	635.05	1,540.99	636.79	661.48	651.80	1,581.65
21	PS_West	0.18	0.48	0.07	0.27	20.21	55.66	8.22	30.67	20.75	57.12	8.44	31.48
22	OTH	0.22	0.28	0.29	0.21	205.49	252.38	265.85	193.21	210.91	259.04	272.87	198.31

Table 21. Summary of recommendations on research and statistics. Recommendations that are considered as high priority / have financial implications are highlighted in grey and bold characters.

Category	Topic	Task	High priority	Financial implication
2021 BET and other TRO assessments	Natural mortality assumptions	Use of AOTTP and electronic data to reduce uncertainty in survival/natural mortality estimates	No	No
		Further work on ageing to improve the precision of maximum age estimates	No	?
		Examination of Then et al. methodology by WGSAM	No	No
		Adapt CAPAM guidelines	No	No
	Abundance indices	Improve all CPUE indices. Use of the LLSIM by the WGSAM to analyze the effects of the methodology used to standardize the joint LL CPUE index.	No	No
		Harmonize CPUE standardization methodology between stock assessments and TRO species	Yes	No
	AOTTP	Estimate potential cost of AOTTP tag recoveries in 2022 and 2023	Yes	No
2022 SKJ assessment	Logistics	Organize both a Data Preparatory and a Stock Assessment meeting. These meetings should be organized earlier than usual in the year. 2020 data should be ready for the Data Preparatory meeting.	Yes	No
	External review	**Contract an external expert to review the full stock assessment process, prior to the start of 2022 SKJ Data Preparatory meeting.**	**Yes**	**Yes**
	Abundance indices	National scientists - Prepare PS CPUE, PS acoustic buoy, BB CPUE and Gulf of Mexico larval indices. Explore alternative standardization methods.	Yes	No
		National scientists - If relevant, prepare LL CPUE indices	Yes	No
	Other data preparation and treatment	Secretariat – Update length-weight conversion factors	Yes	No
		Secretariat – Prepare a table of landings per fleet. This will be used to define fleet structure in stock assessment models and harmonized with other TRO stock assessments.	Yes	No
	AOTTP	Investigate differences in growth using AOTTP tag recovery data	Yes	No
		Evaluation exchange rates between regions using AOTTP tag recovery data	Yes	No
		Update of the tag capture/recapture matrix	Yes	No
		Improve SKJ ageing using spines collected in the frame of AOTTP	**Yes**	**Yes**

Table 21. Continued.

Category	**Topic**	**Task**	**High priority**	**Financial implication**
YFT data	Growth and natural mortality estimates	Increase sample size for YFT to improve growth estimates of this species, as well as estimates of natural mortality.	No	No
Tropical Tuna MSEs	**WSKJ MSE** **Multispecies MSE**	See Table 6.2.2 for details	**Yes**	**Yes**
FOB management and fishing closures		Explore the relationship between FOB management measures, including limitations of FOB fishing sets, number of FOB operational buoys, and number of FOB buoy / FAD deployments	Yes	No
		Assess the efficiency (e.g. reduction of BET and YFT juveniles catches) and the appropriateness of the current 3-month FOB closure (i.e. duration of the closure, choice of the closure period, etc)	Yes	No
		Revitalize the FAD WG	Yes	No

Table 22. Detail of development and proposed activities for the MSE initiatives for tropical tunas. The updated MSE Roadmap for the Commission is presented in section 7.1.8 of this report.

	SCRS	**Commission**[2]
2015		Commission provides initial guidance for the development of harvest strategies for priority stocks, including tropical tunas [Rec. 15-07]
2016		Commission identifies performance indicators for the MSE for tropical tunas (Annex 9 [Rec. 16-01]). Commission adopts MSE roadmap, including plan for activities for tropical tunas for 2016-2021
2017	SCRS reviews performance indicators for YFT, SKJ, and BET	SWGSM recommends a multispecies approach for development of MSE framework for tropical tunas
2018	SCRS develops MSE implementation plan for 2018-2021	
	SCRS conducts bigeye tuna stock assessment	
2019	SCRS conducts yellowfin tuna stock assessment SCRS agrees on developing a Western Skipjack (WSKJ) MSE and a Multispecies MSE (Eastern Skipjack, Bigeye and Yellowfin tuna)	Commission updates MSE roadmap for the period 2019-2024[3] and requests that the SCRS *"refines the MSE process in line with the SCRS roadmap and continue testing the candidate management procedures. On this basis, the Commission shall review the candidate management procedures, including pre-agreed management actions to be taken under various stock conditions. These shall take into account the differential impacts of fishing operations (e.g. purse seine, longline and baitboat) on juvenile mortality and the yield at MSY."* [Rec 2019-02].

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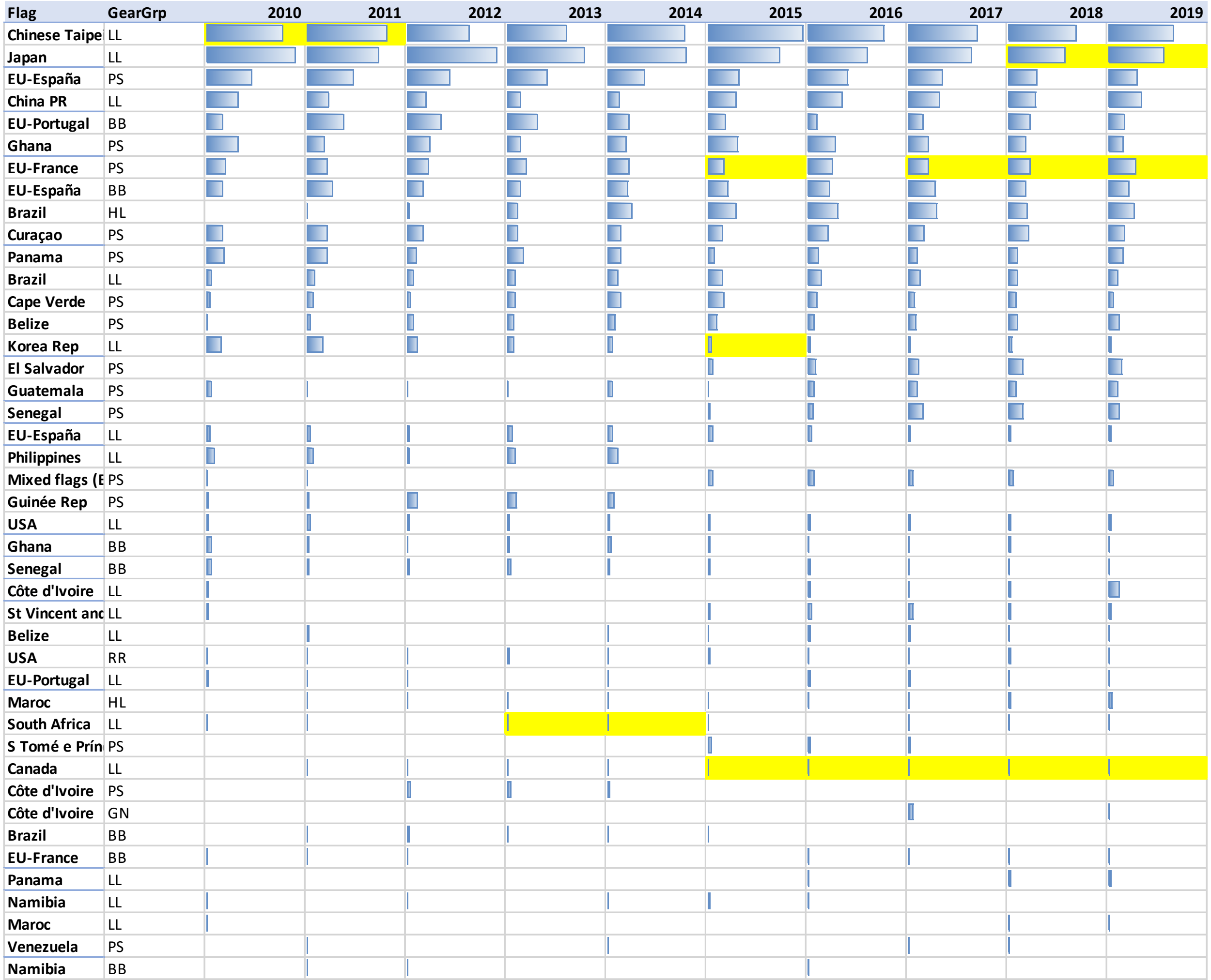
[2] Commission to decide if activities are best conducted in Panel 1 or in plenary

[3] https://iccat.int/mse/en/COM_ROADMAP_ICCAT_MSE_PROCESS_ENG.pdf

2020	COVID slows progress on Multispecies MSE but SCRS develops a preliminary OM for WSKJ MSE.	
2021	SCRS agrees on major sources of uncertainty to be considered in the MSE and candidate performance indicators for Tropical tuna MSEs	Commission to review and provide feedback on: - management objectives and performance indicators to be used for tropical tunas MSE - proposed update if tropical tuna MSE roadmap
	SCRS conducts bigeye tuna stock assessment	
	SCRS modifies OM for WKSJ to include the whole of the western Atlantic.	
	JCAP/ICCAT Training workshops on MSE and HCR for Portuguese and Spanish speaking scientists and managers	
2022	SCRS conducts skipjack stockassessment	
	SCRS reconditions OMs for SKJ in WSKJ MSE model and ESKJ in mixed species MSE model in light of new SKJ assessments	
	SCRS initiates developmentand testing of candidate Management procedures (MP) for western SKJ	Commission considers WSKJ MSE simulations and initial candidate MPs developed by SCRS. Commission agrees on final set of MPs to be evaluated in the WSKJ MSE
	Independent review of tropical tuna MSE process and technical review of Western SKJ MSE	

2023	SCRS conduct Yellowfin assessment	
	SCRS reconditions yellowfin OM in light of assessment results	
	SCRS initiates developmentand testing of initial candidate MPs for multispecies MSE and final set of MPs for WSKJ	Commission considers multispecies MSE simulations and initial candidate MPs developed by SCRS. Commission agrees on final set of MPs to be evaluated in the multispecies MSE
	Independent technical review of Western Multispecies MSE	Commission considers final evaluation of WSKJ MPs
2024	SCRS tests final set of MP candidates for Multispecies MSE	Commission considers final evaluation of MPs for multispecies MSE.
	SCRS provides advice on exceptional circumstances for the implementation of the MP	Oct -Dec Final delivery of multi - stock MSE, including fully conditioned operating models and candidate management procedures to Commission
		Commission to: a) reviews and endorse guidance on management responses in the case of exceptional circumstances, and b) considers adopting interim MP(s) for BET, YFT and Eastern SKJ
2025 and beyond	Once an MP is adopted, SCRS to conduct periodic assessments to ensure that the conditions considered in MP testing are still applicable to the stock	Commission to continue use of the MP to set management measures on the predetermined timescale defined in the MP setting
	On the predetermined timescale for MP setting, SCRS to evaluate existence of exceptional circumstances	

Table 23. Combinations of CPCs and gears reporting bigeye tuna catches in the ICCAT Convention area. Only those that are responsible of more than 1000 tons in the decade are shown. They are ordered from high to low according to total catch in the 2010s. Blue bars indicate BET catch levels. In yellow are highlighted those combinations of CPC-gear-year that have provided discard reports.



Flag	GearGrp	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Chinese Taipe	LL	🟨	🟨								
Japan	LL									🟨	🟨
EU-España	PS										
China PR	LL										
EU-Portugal	BB										
Ghana	PS										
EU-France	PS						🟨		🟨	🟨	🟨
EU-España	BB										
Brazil	HL										
Curaçao	PS										
Panama	PS										
Brazil	LL										
Cape Verde	PS										
Belize	PS										
Korea Rep	LL						🟨				
El Salvador	PS										
Guatemala	PS										
Senegal	PS										
EU-España	LL										
Philippines	LL										
Mixed flags (E	PS										
Guinée Rep	PS										
USA	LL										
Ghana	BB										
Senegal	BB										
Côte d'Ivoire	LL										
St Vincent anc	LL										
Belize	LL										
USA	RR										
EU-Portugal	LL										
Maroc	HL										
South Africa	LL				🟨	🟨					
S Tomé e Prín	PS										
Canada	LL						🟨	🟨	🟨	🟨	🟨
Côte d'Ivoire	PS										
Côte d'Ivoire	GN										
Brazil	BB										
EU-France	BB										
Panama	LL										
Namibia	LL										
Maroc	LL										
Venezuela	PS										
Namibia	BB										

Table 24. Number of CPC/Flags that have provided ST07 Supply vessel forms by year to the ICCAT Secretariat.

Num registers	**Year**						
Flag	**2013**	**2014**	**2016**	**2018**	**2019**	**2020**	**Yrs report**
BLZ			1		6		2
BOL				1	1		2
CUW	1	1			1		3
EU_FRA					1	1	2
EU-ESP					1		1
FR_SPM					1		1
LBY				1			1
LCA					1		1
MEX					1	1	2
PAN					2		1
SEN					1		1
SLV						1	1
UK_BMU					1		1
UK_SHN					1		1
UK_TCA					1		1
UK_VGB					1		1
Grand Total	**1**	**1**	**1**	**2**	**20**	**3**	

Table 25. Number of CPC/Flags that have reported ST07 and indicated whether they had (YES) or did not have (NO) activity of support vessels for Tropical Tuna fisheries (red zero values).

N reports		**Year**					
Trop Tun	**Flag**	**2013**	**2014**	**2016**	**2018**	**2019**	**2020**
Supply Vess	LBY				1		
NO	**BOL**				**0**	**0**	
	EU_FRA					**0**	**0**
	FR_SPM					**0**	
	LCA					**0**	
	MEX					**0**	**0**
	UK_BMU					**0**	
	UK_SHN					**0**	
	UK_TCA					**0**	
	UK_VGB					**0**	
Yes	BLZ			1		6	
	CUW	1	1			1	
	EU-ESP					1	
	PAN					2	
	SEN					1	
	SLV						1

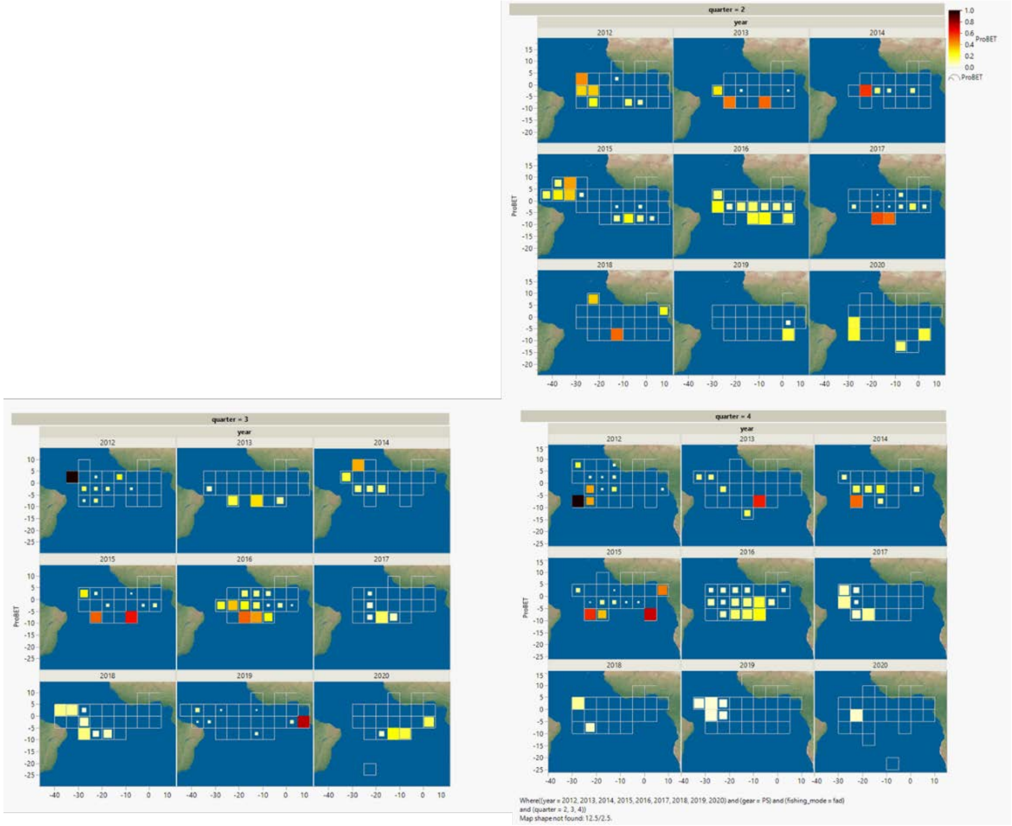


Figure 1. BET proportion in the total catch of tropical species (YFT, SKJ, BET) by 5x5 year and quarter. Quarter 1 Jan-Mar was excluded due to the time area closures effects.

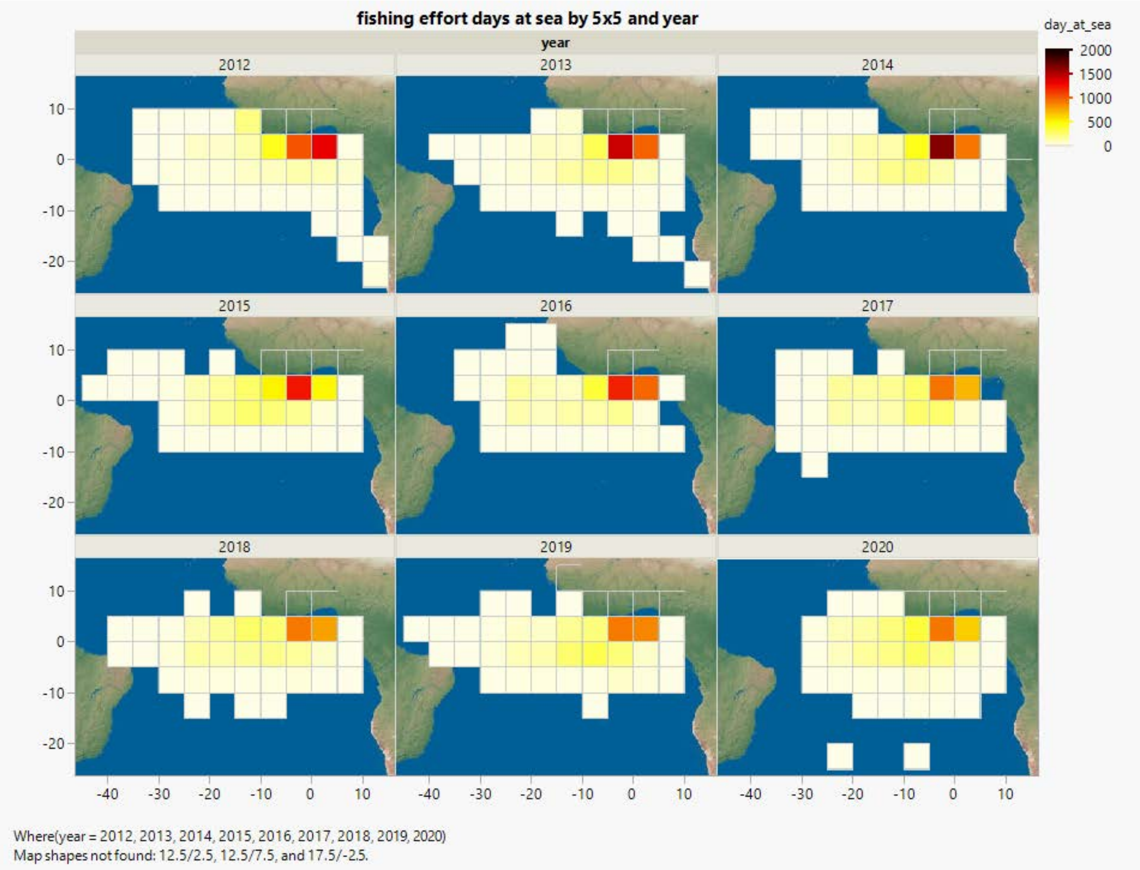


Figure 2. Total fishing effort, days-at-sea 5x5 and year from the Ghana tropical fisheries fleets. Grids shown represent a non-zero fishing effort estimate.

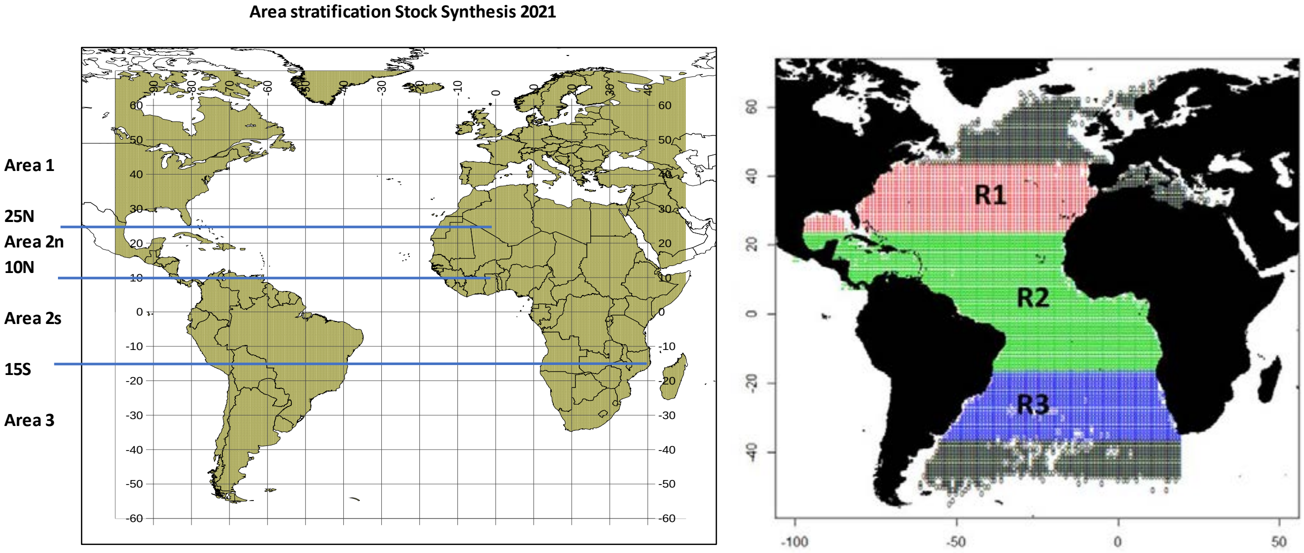


Figure 3. Comparison of the geographical area stratification used for the Stock Synthesis fleet structure (left) and for the combined longline index estimation for the 2021 BET stock assessment (right) (Kitakado *et al*., 2021).

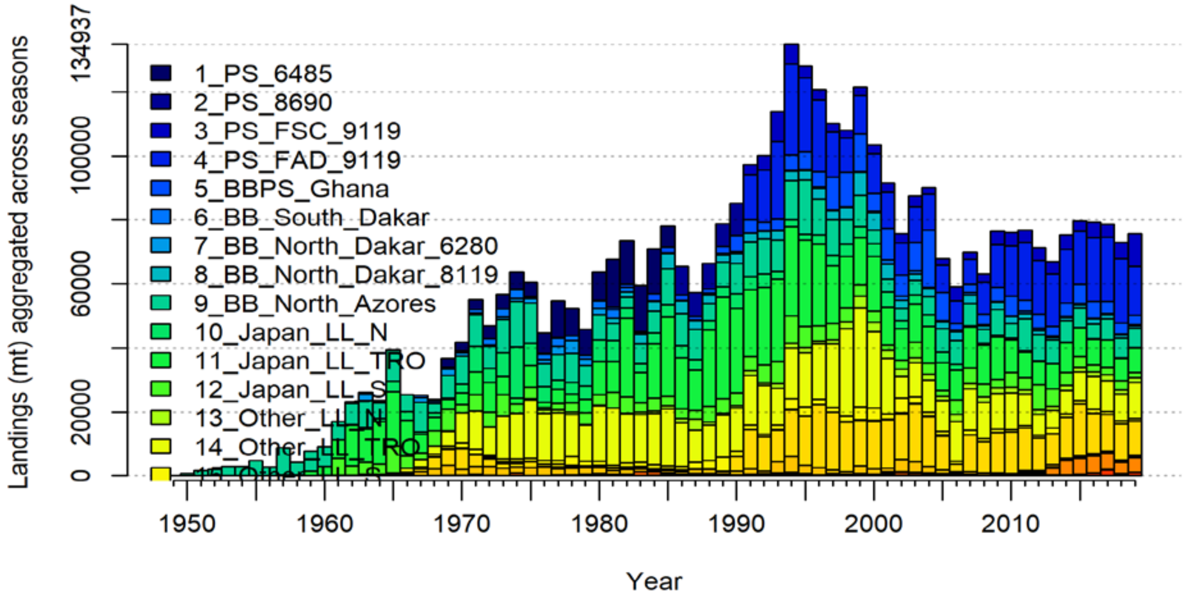


Figure 4. Landings (mt) for each of the fleets defined in the stock synthesis models. (**Table 5** contains details of fleet definitions).

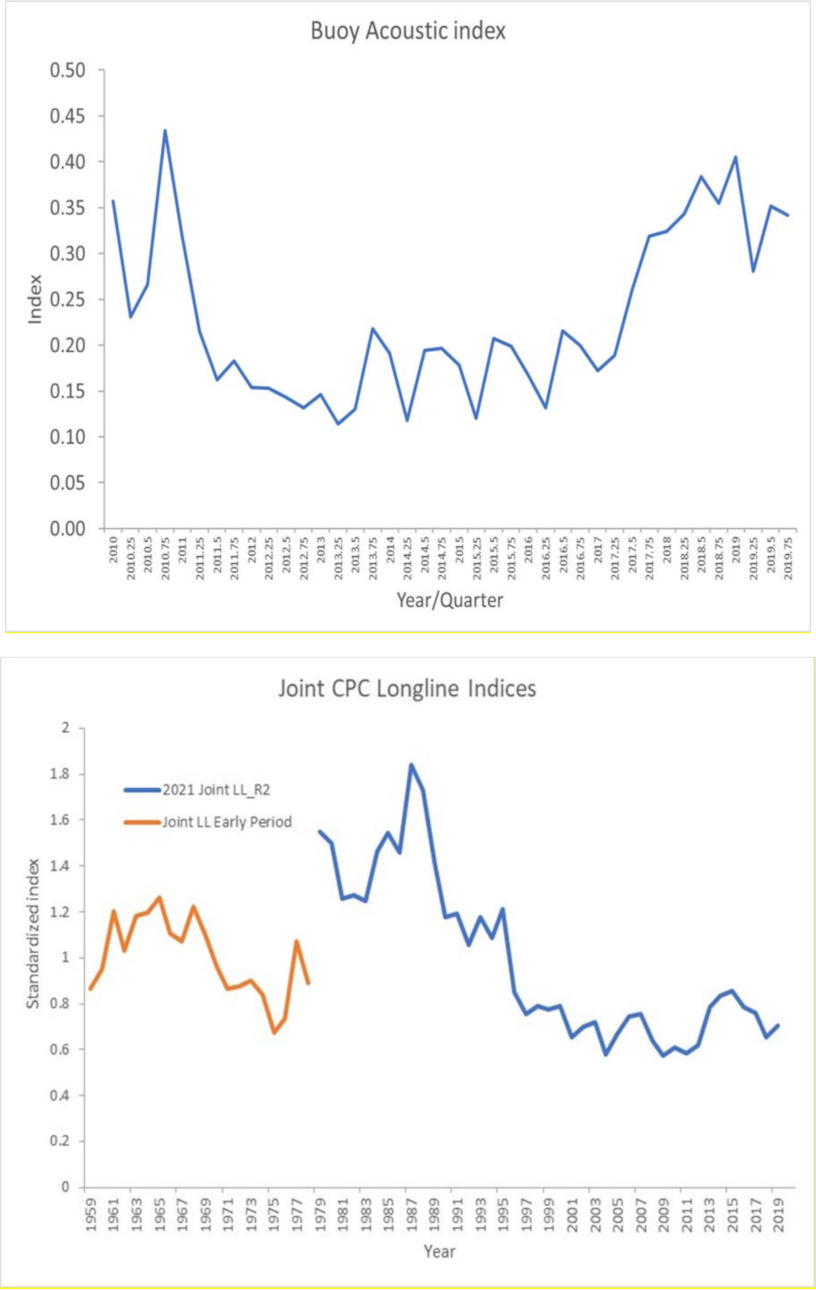


Figure 5. Abundance indices used for in stock synthesis models. Quarterly acoustic buoy index (top panel) for 2010 to 2019 and annual joint longline index for 1959 to 2019 (bottom panel).

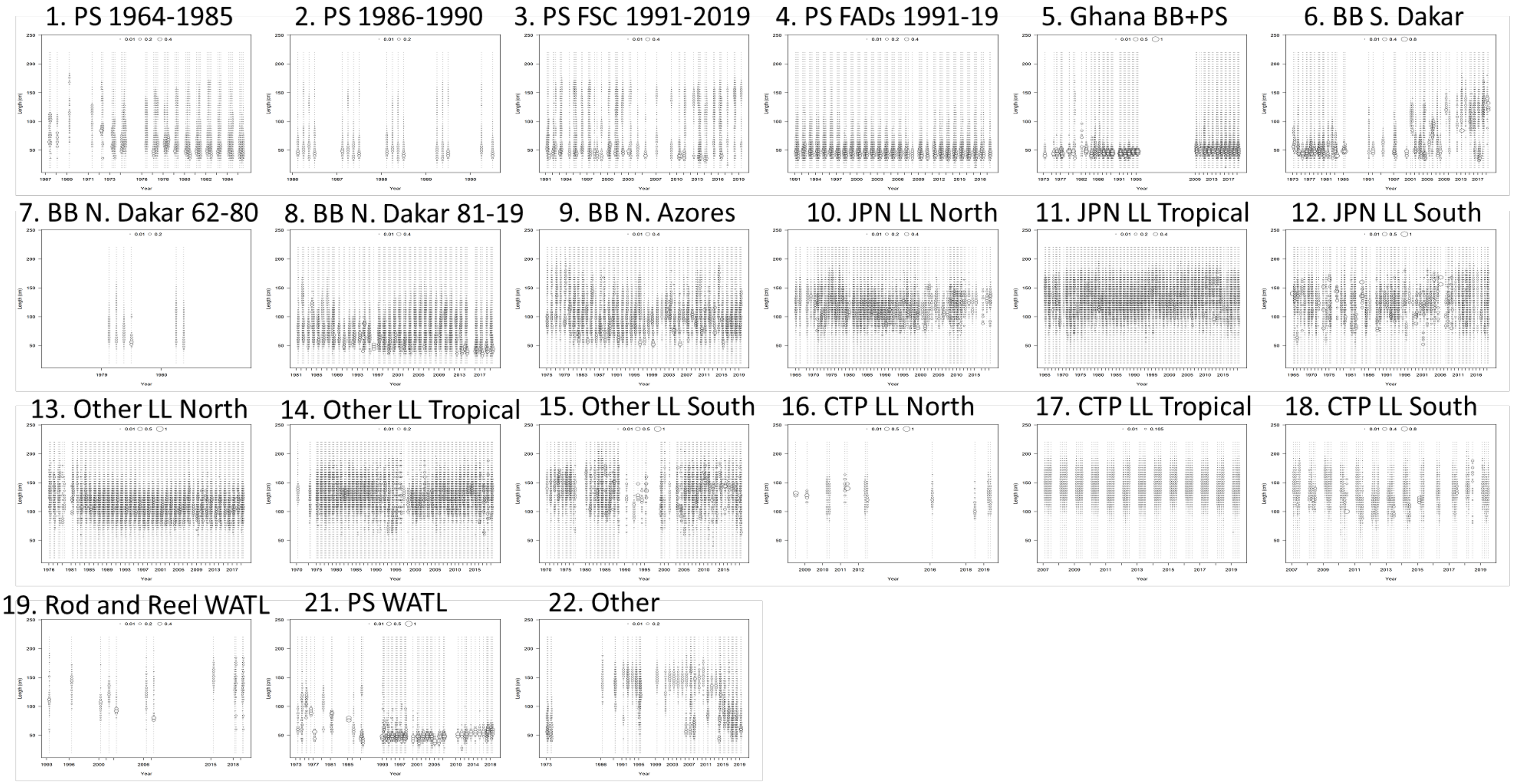
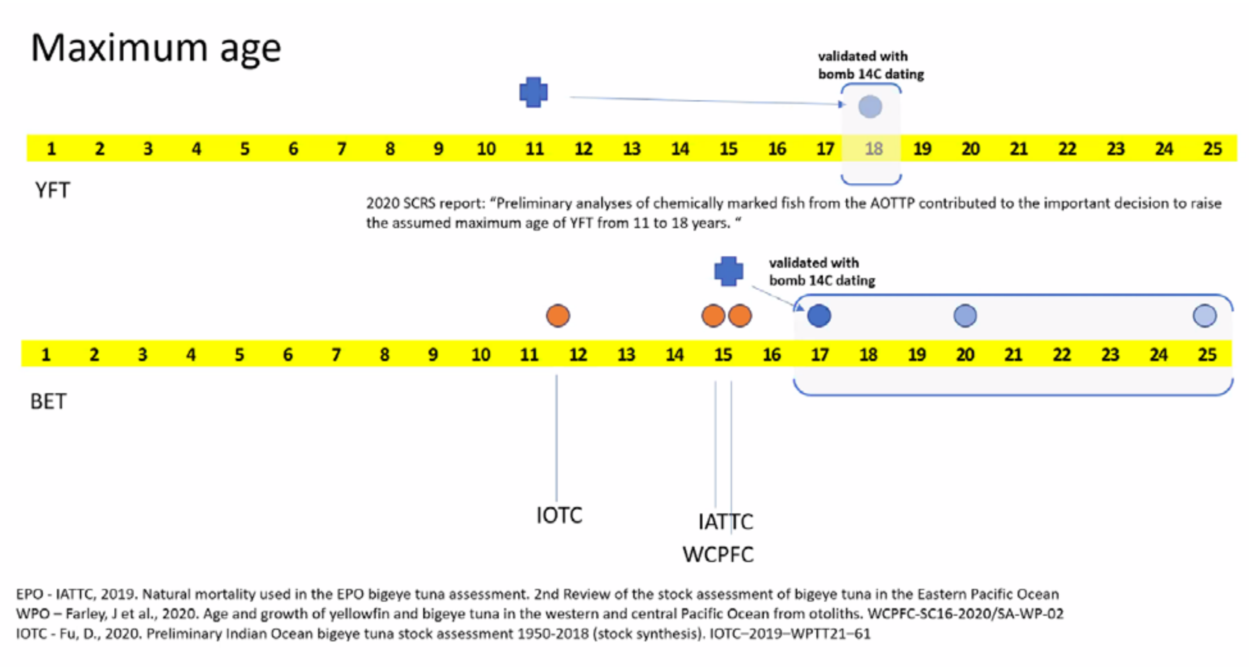


Figure 6. Annual length frequency bubble plots for fleets considered in stock synthesis models. (**Table 5** contains details of fleet definitions).



2020 SCRS report: "Preliminary analyses of chemically marked fish from the AOTTP contributed to the important decision to raise the assumed maximum age of YFT from 11 to 18 years. "

EPO - IATTC, 2019. Natural mortality used in the EPO bigeye tuna assessment. 2nd Review of the stock assessment of bigeye tuna in the Eastern Pacific Ocean
WPO – Farley, J et al., 2020. Age and growth of yellowfin and bigeye tuna in the western and central Pacific Ocean from otoliths. WCPFC-SC16-2020/SA-WP-02
IOTC - Fu, D., 2020. Preliminary Indian Ocean bigeye tuna stock assessment 1950-2018 (stock synthesis). IOTC–2019–WPTT21–61

Figure 7. Estimates of maximum age used in the assessment of stocks of bigeye tuna and yellowfin tuna by various RFMOs. Red circles represent estimates for BET used in IOTC, IATTC and WCPFC. Blue symbols correspond to estimates used in ICCAT stock assessments. Blue crosses represent estimates used by ICCAT in the assessment prior to the most recent assessment of each stock. Circles represent estimates of maximum age used in the ICCAT assessments of yellowfin (2019) and bigeye tuna (2021). The 2021 ICCAT assessment of bigeye used three values of maximum age in the uncertainty grid.

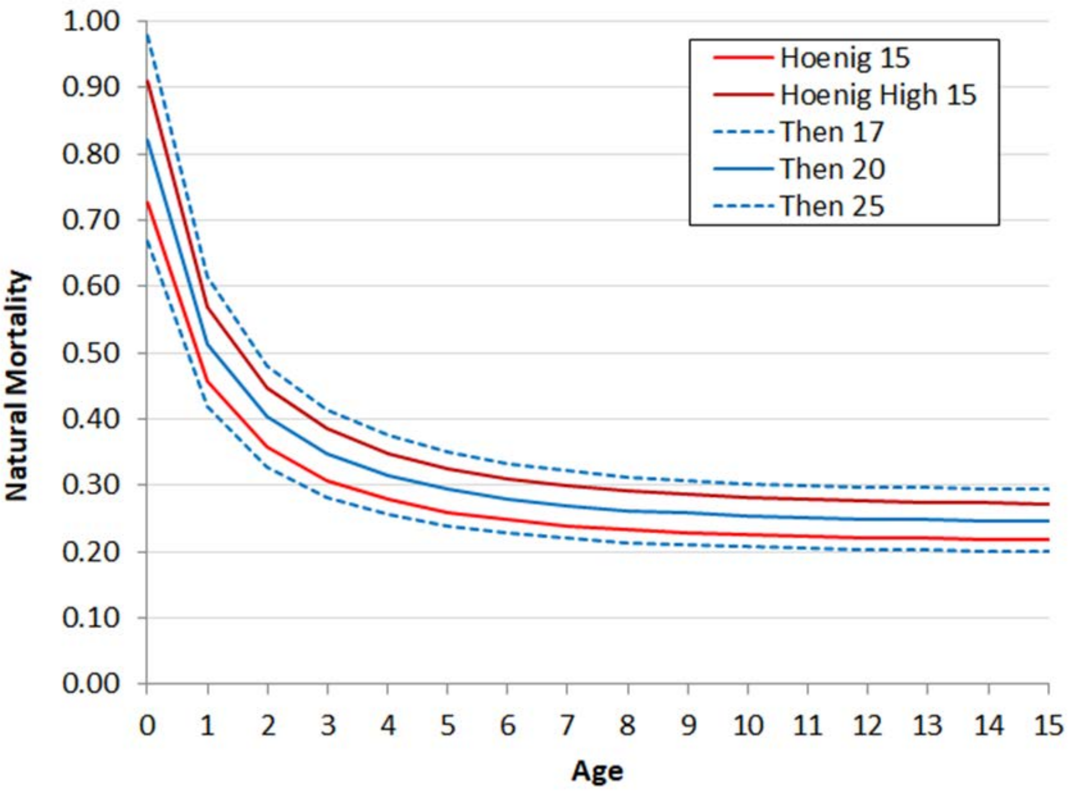


Figure 8. Natural mortality at age assumptions used for the Stock Synthesis model runs. Red lines represent assumptions used in the 2018 BET assessment. Blue lines represent the assumptions made in the current assessment.

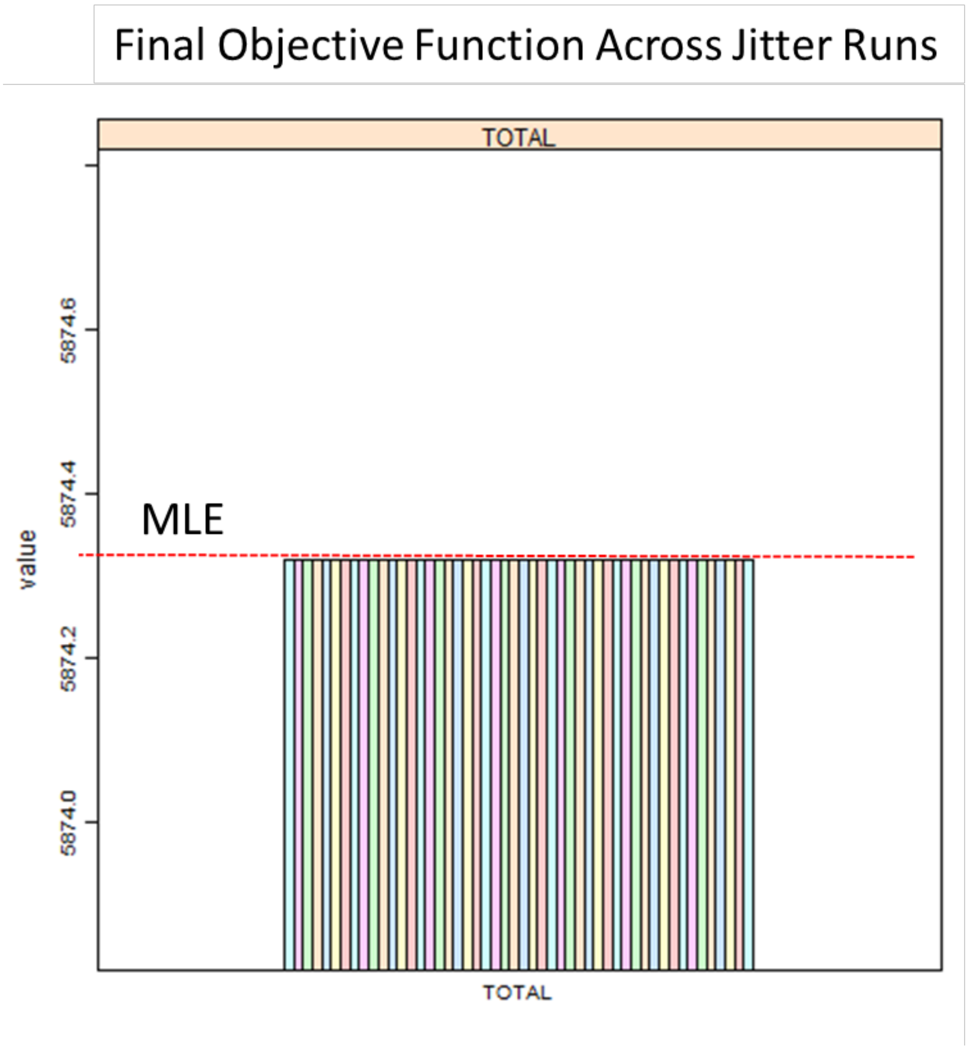


Figure 9. Final objective function for the stock synthesis reference case across jittered starting parameter values.

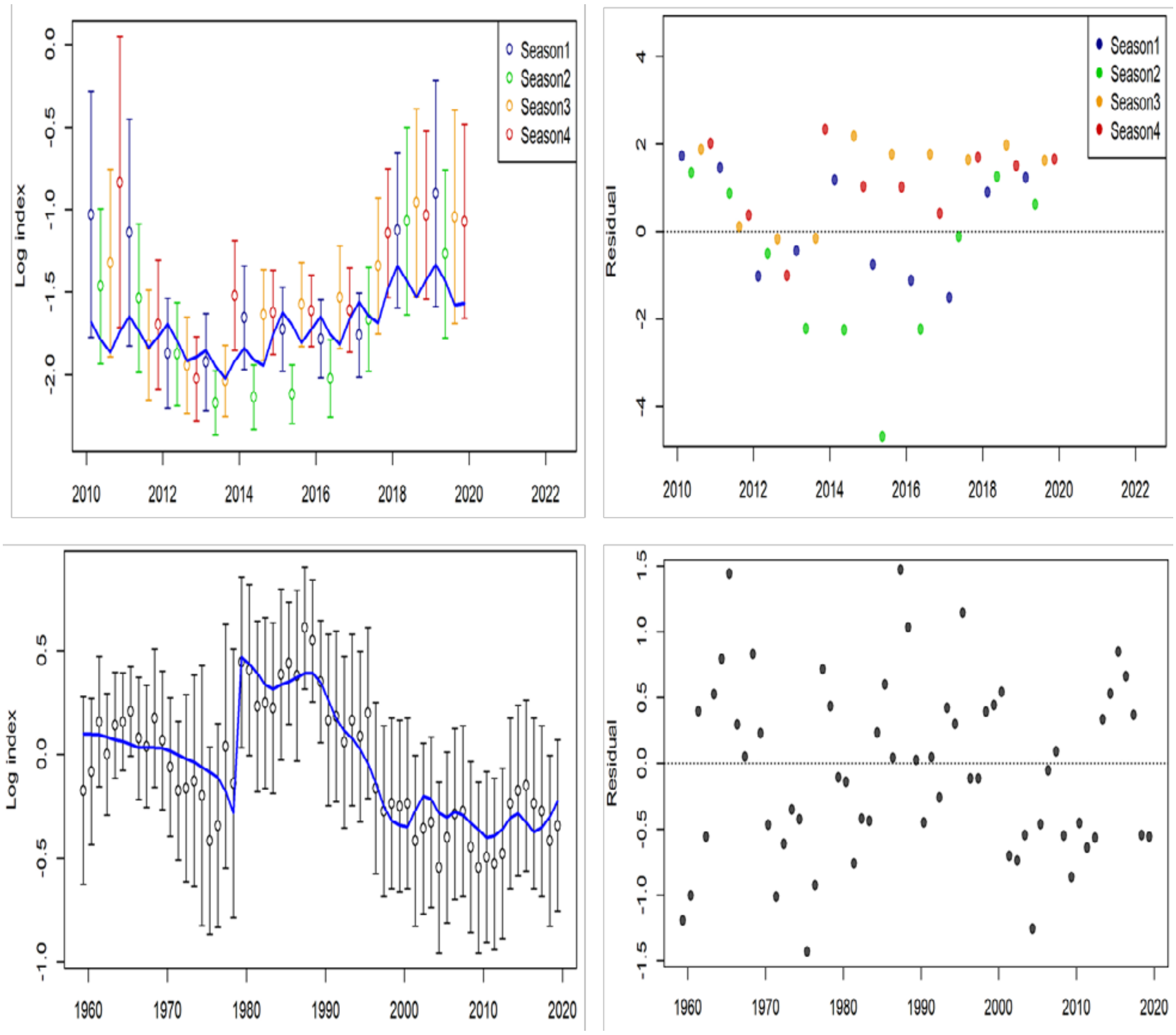


Figure 10. Stock Synthesis reference case fits (left panels) and residuals (right panels) to the acoustic buoy index (top panels) and joint longline index (lower panels). Solid blue lines represent predictions and bars represent observations with their CVs.

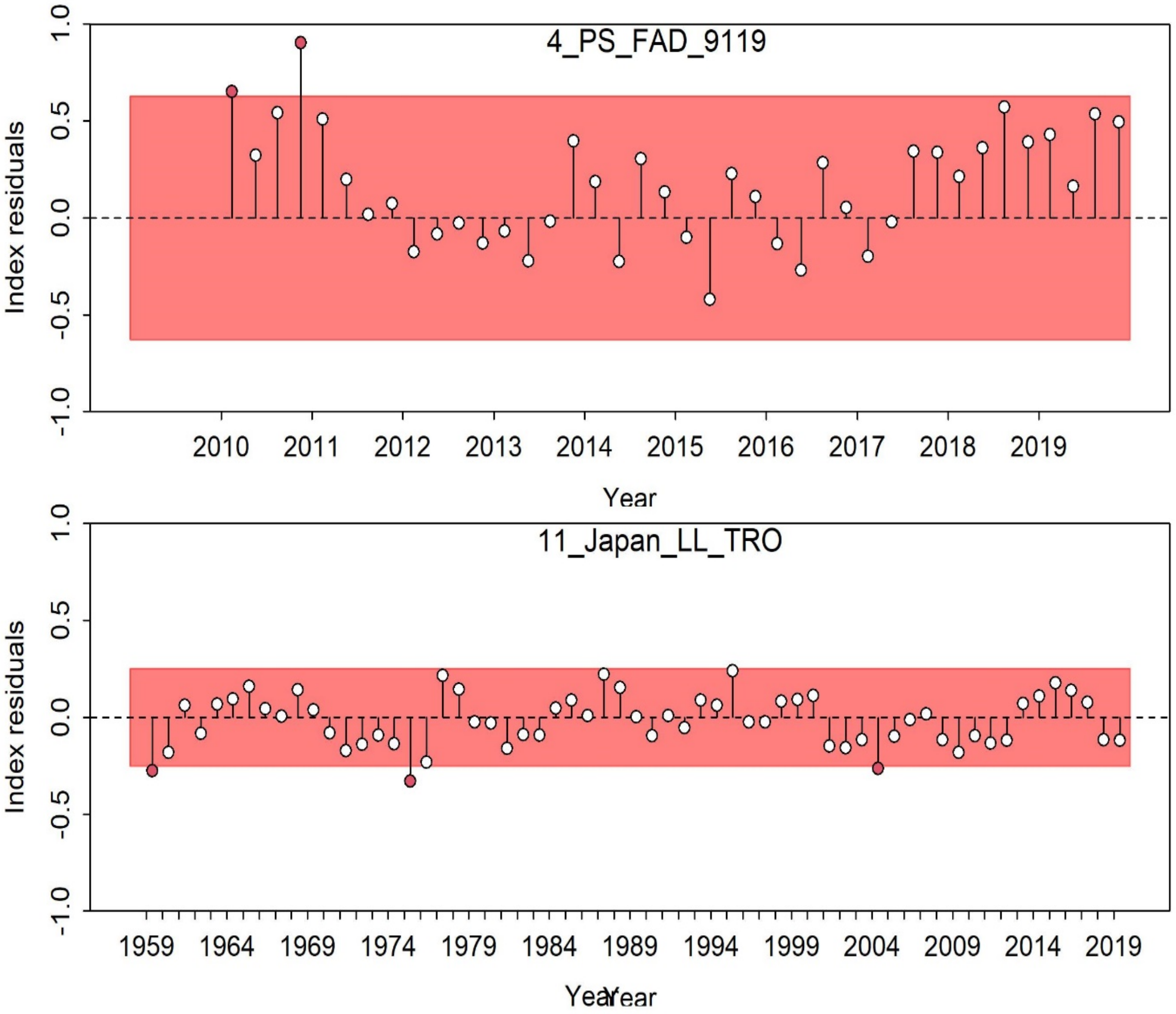


Figure 11. Diagnostic runs test on residual fits to indices of abundance (acoustic buoy upper panel, joint longline index lower panel) for Stock Synthesis reference case. Red circles represent outliers and the red box represents overall failure of the runs test.

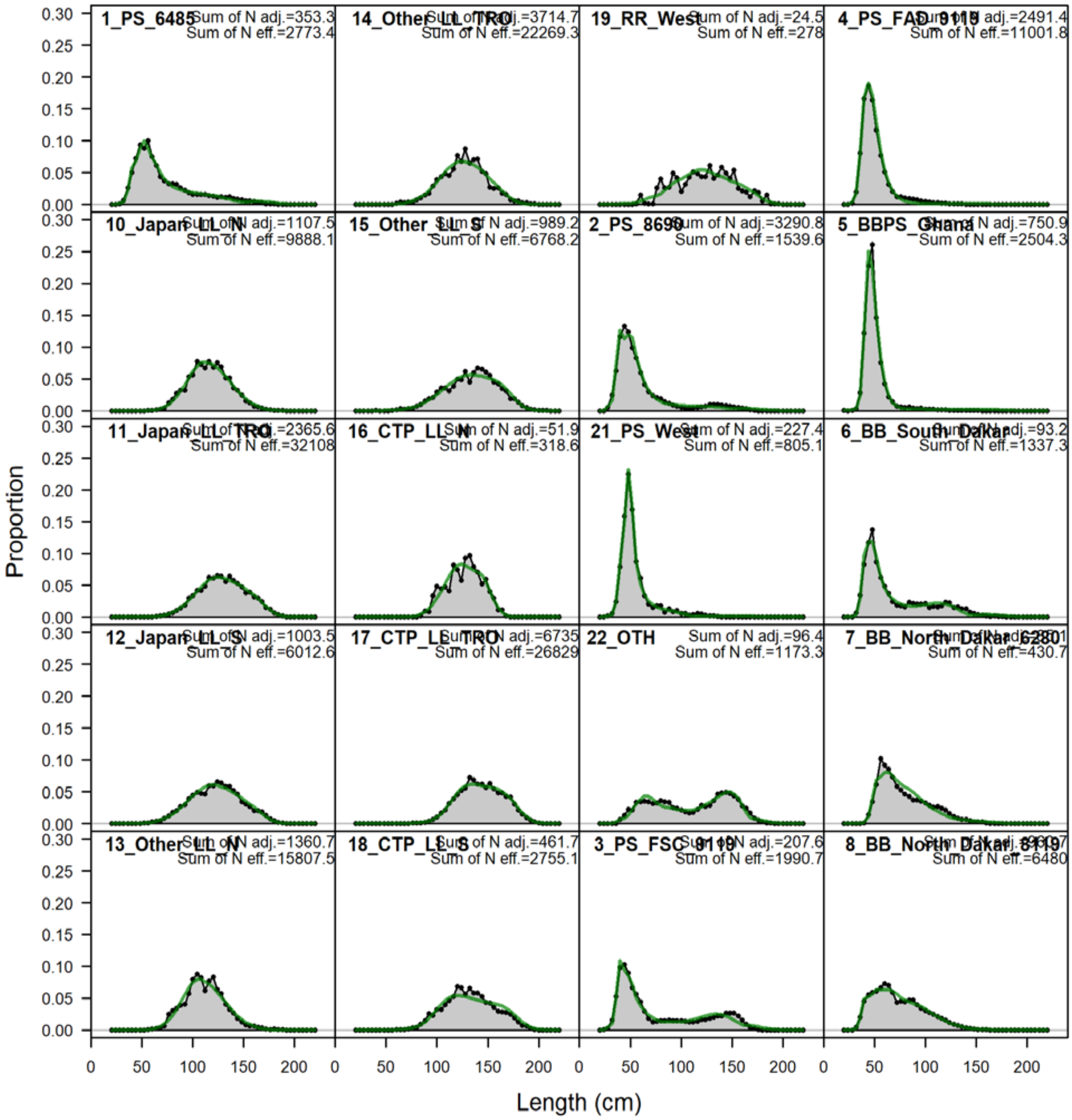


Figure 12. Fits to fleet aggregated length compositions for the Stock Synthesis reference case. Black dots represent the observed length data aggregated for all years. Green lines represent model predictions.

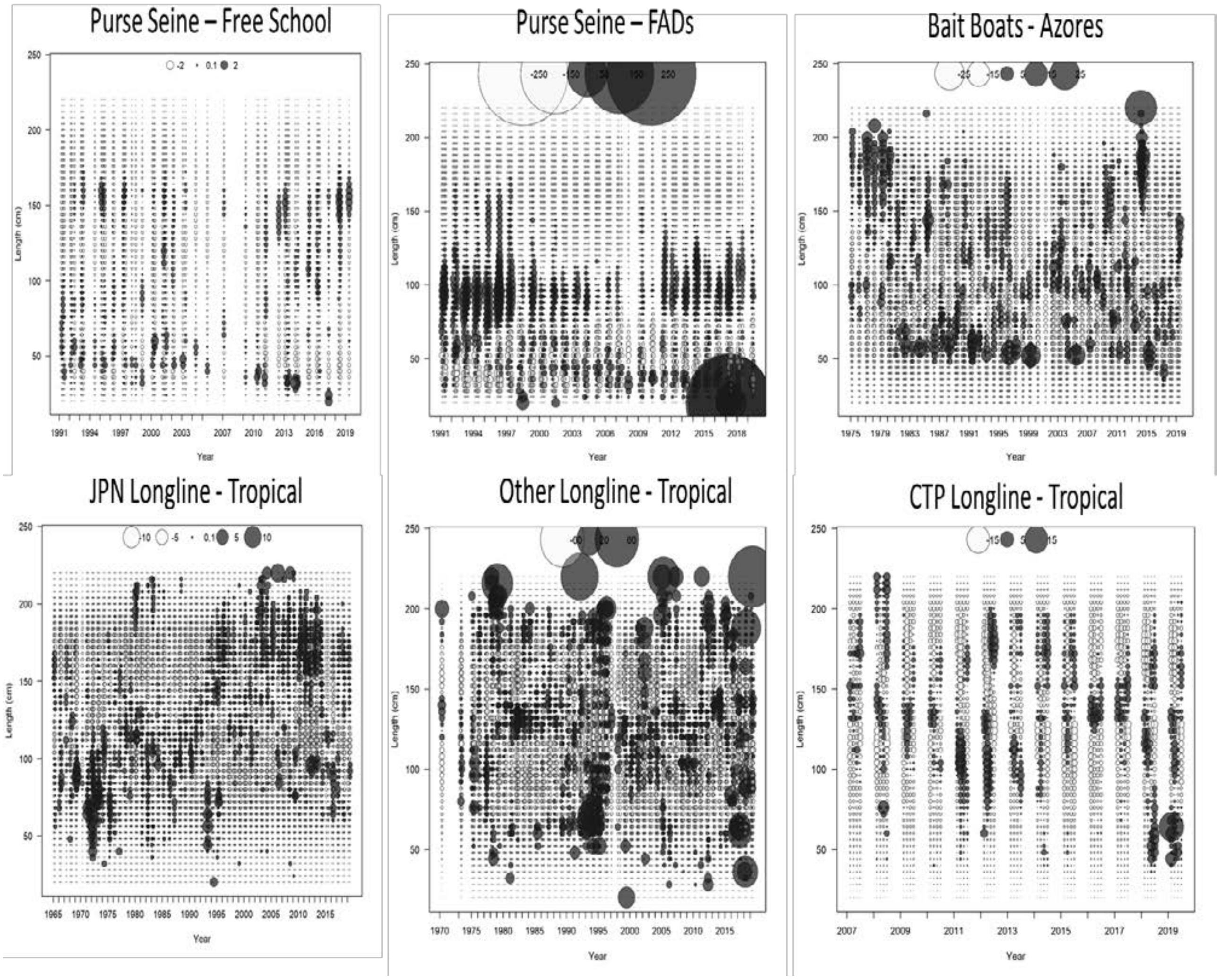


Figure 13. Residuals to bigeye tuna length composition data of the major harvesting fleets for Stock Synthesis reference case. Diameter of the circle represents the value of residual; white circles represent negative. residuals and dark circles positive residuals.

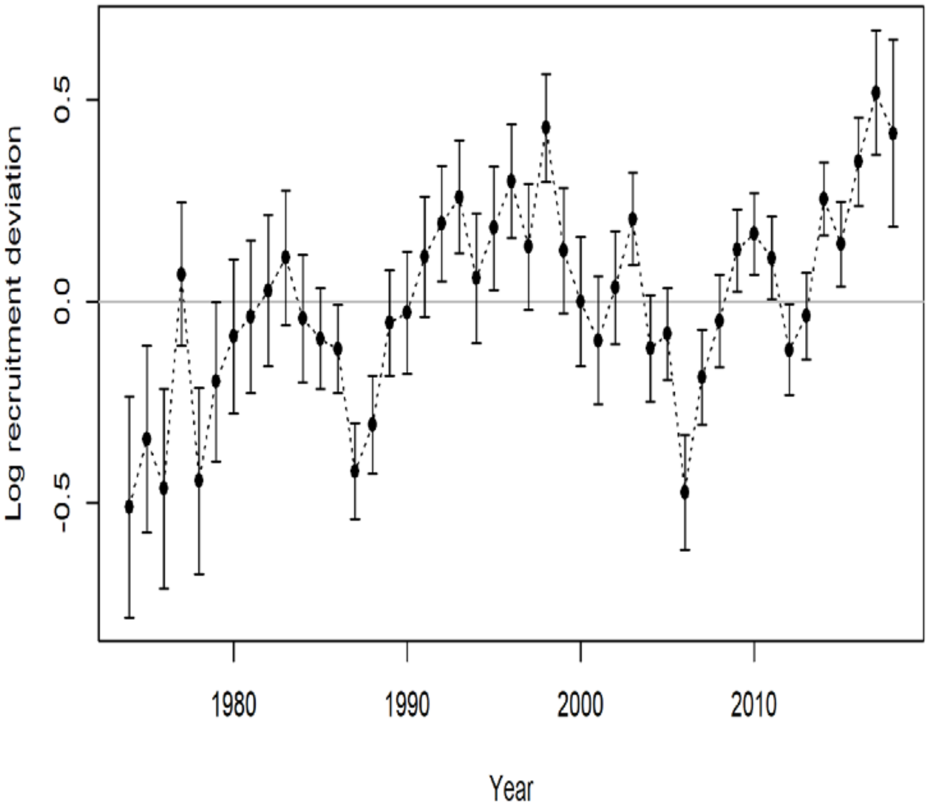


Figure 14. Estimated recruitment deviations for the period 1974-2018 for Stock Synthesis reference case.

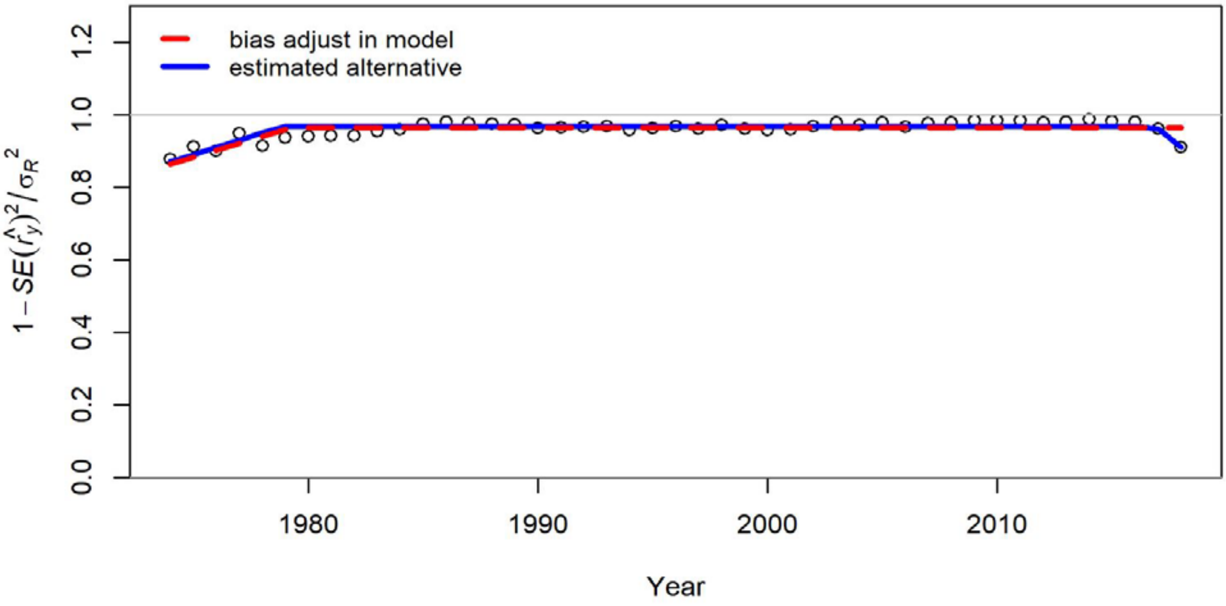


Figure 15. The bias corrections for recruitment deviates in the Stock Synthesis reference case.

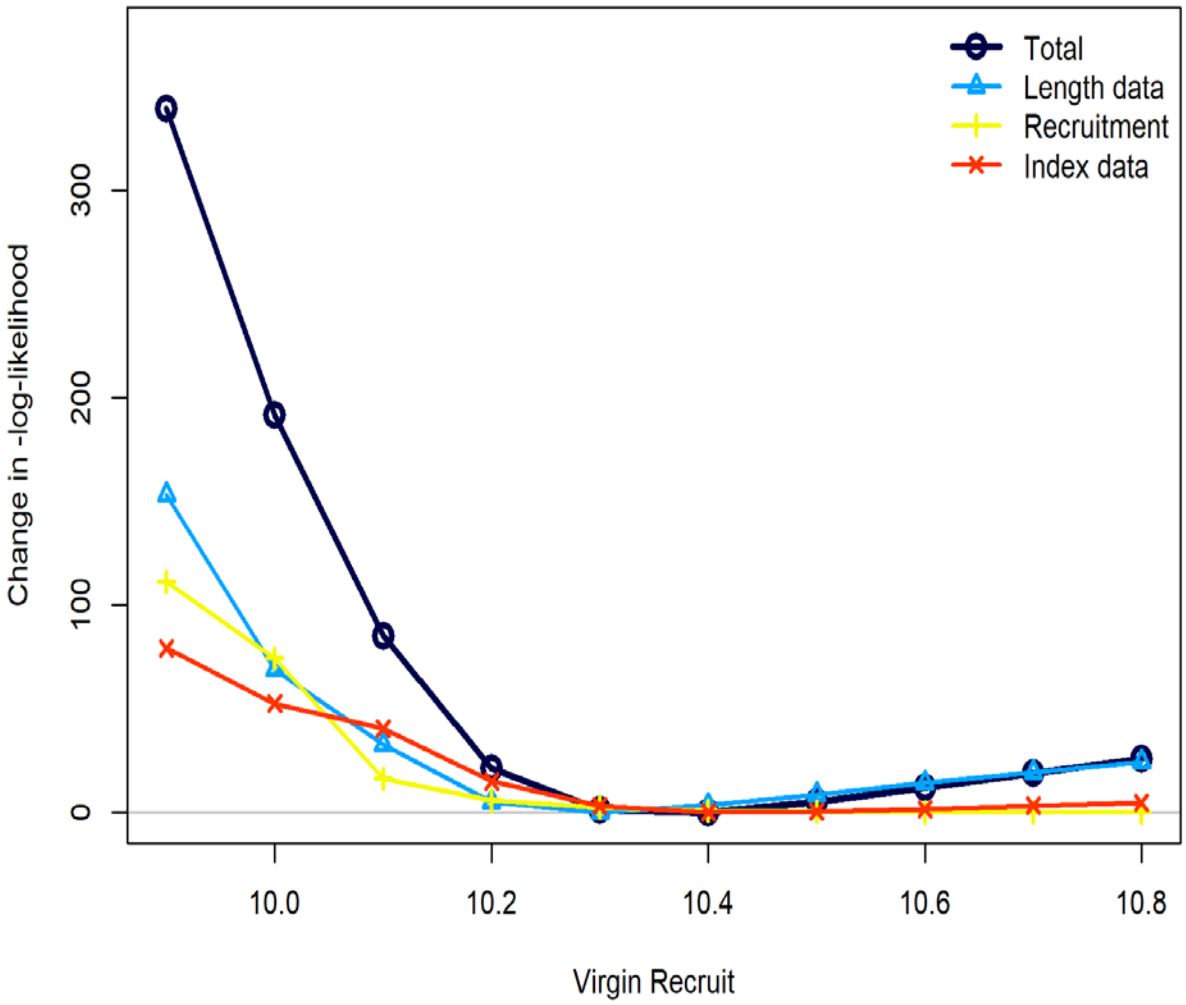


Figure 16. Likelihood profile of virgin recruitment (log scale) from Stock Synthesis reference case.

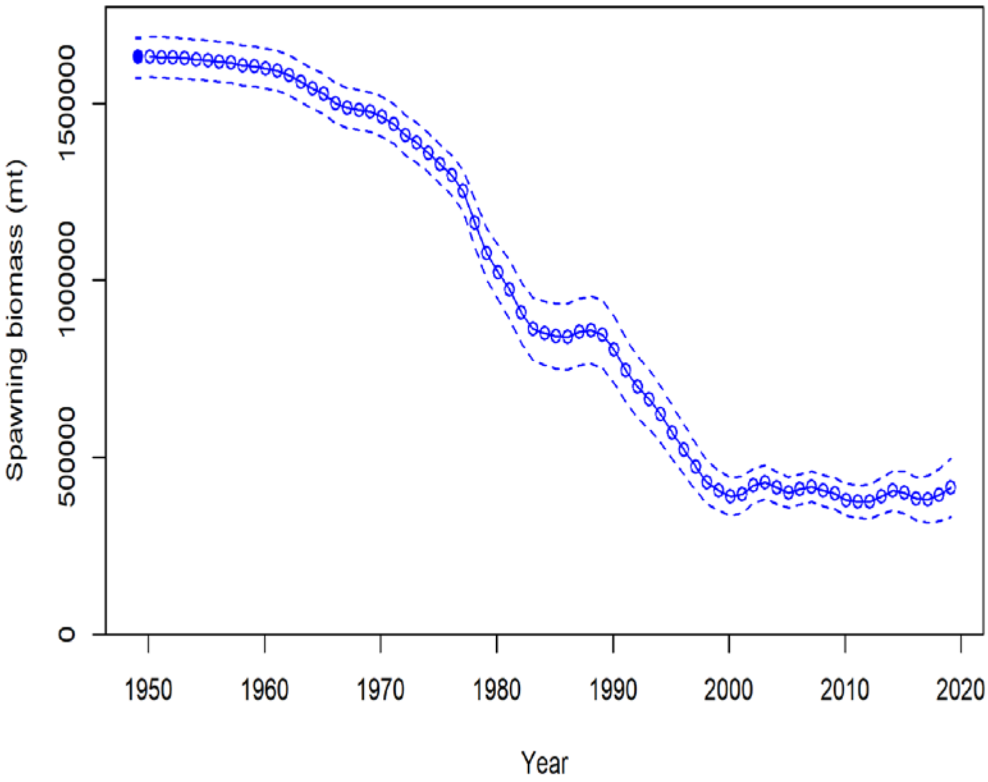


Figure 17. Spawning stock biomass estimates from the Stock Synthesis reference case.

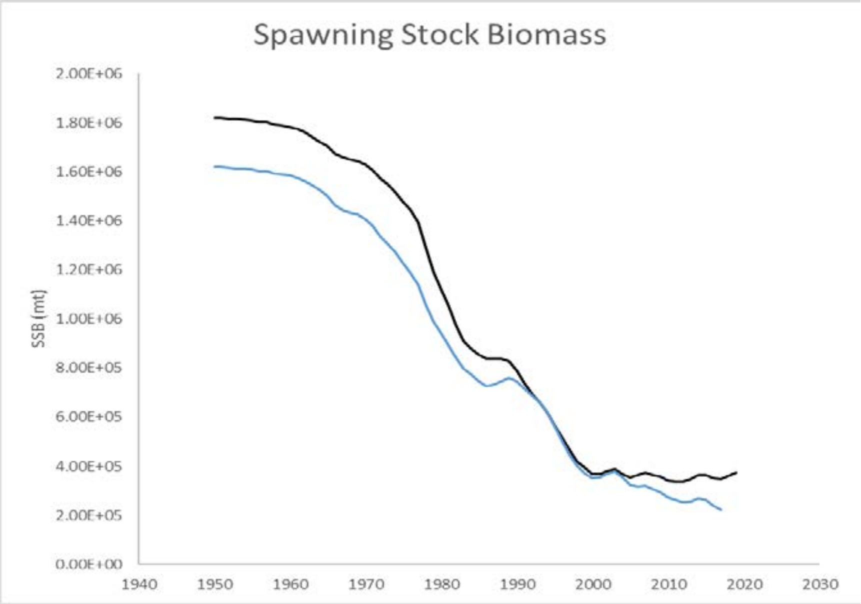


Figure 18. Comparison of spawning stock biomass estimates between the 2021 continuity model run (black) and 2018 assessment reference case run (blue).

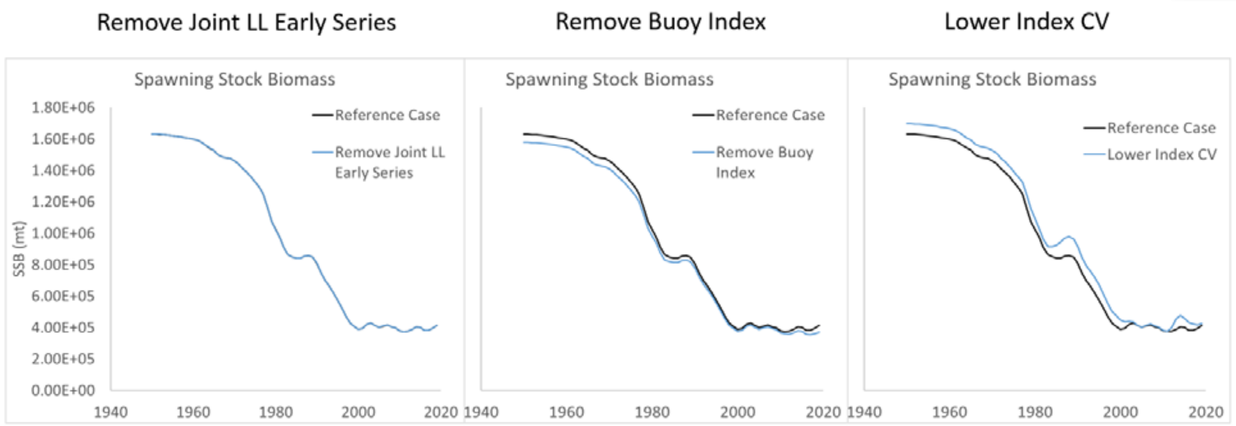


Figure 19. Sensitivity of SSB (mt) trends from the Stock Synthesis reference case to the removal of certain relative index of abundance or to lowering the CV for relative abundance indices.

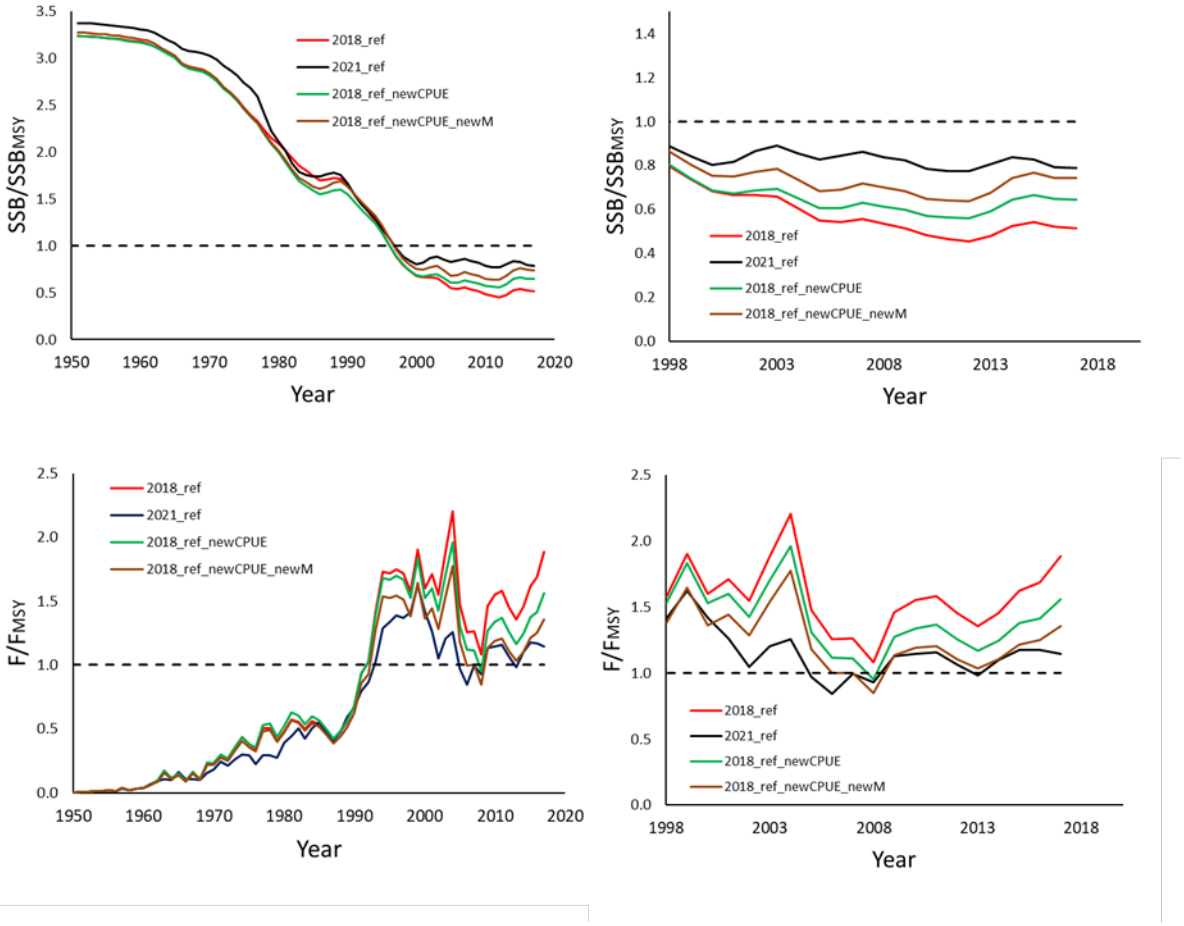


Figure 20. SSB/SSB$_{MSY}$ and F/F$_{MSY}$ trends from stepwise sensitivity runs of Stock Synthesis built to assess the influence of changes made since the 2018 stock assessment. Lines represent the 2018 (2018_ref) and 2021 (2021_ref) reference cases, the 2018 reference case replacing the 2018 joint longline index with the 2021 joint longline index (2018_ref_new_CPUE) and this last case with the replacement of the 2018 natural mortality with the 2021 natural mortality (2018_ref_new_CPUE_new_M).

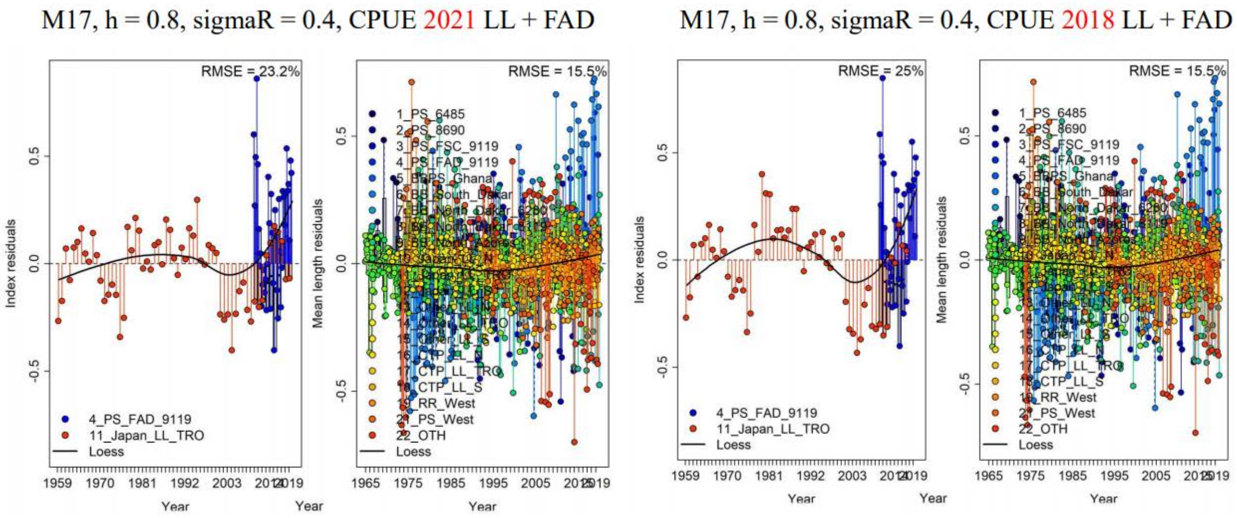


Figure 21. Comparison of residuals of the 2021 Stock Synthesis reference case (left panels) and the residuals of the sensitivity run where the 2021 joint longline index has been replaced with the 2018 joint longline index (right panels).

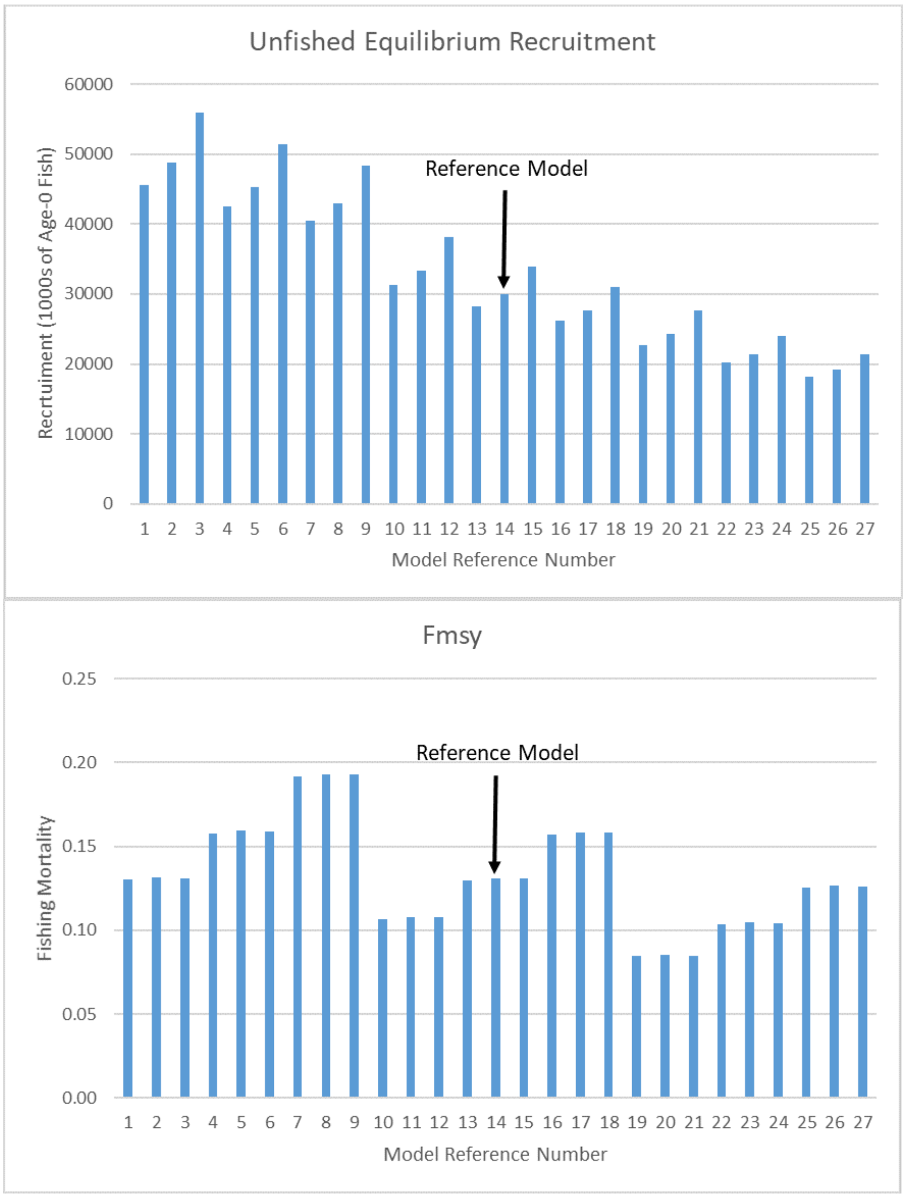


Figure 22. Estimates of recruitment at unfished spawning stock biomass and Fmsy for the 27 model Stock Synthesis models of the uncertainty grid. The model reference number on the x-axis corresponds to the model configuration listed in **Table 13.**

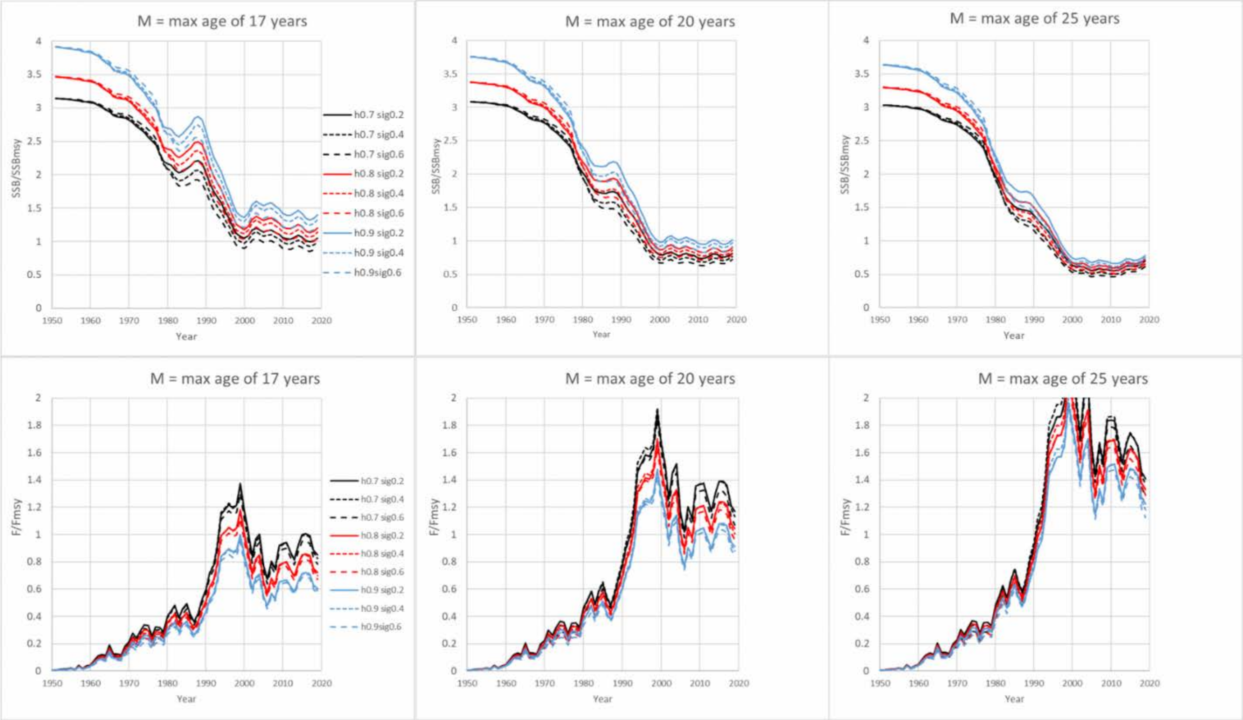


Figure 23. Time series of stock status trends across the 27 Stock Synthesis models of the uncertainty grid. Panels in each column represent the different assumptions of maximum age and thus natural mortality. Upper panels represent SSB/SSB$_{MSY}$ trends and lower panels F/F$_{MSY}$ trends. Individual lines represent different combinations of steepness and sigmaR.

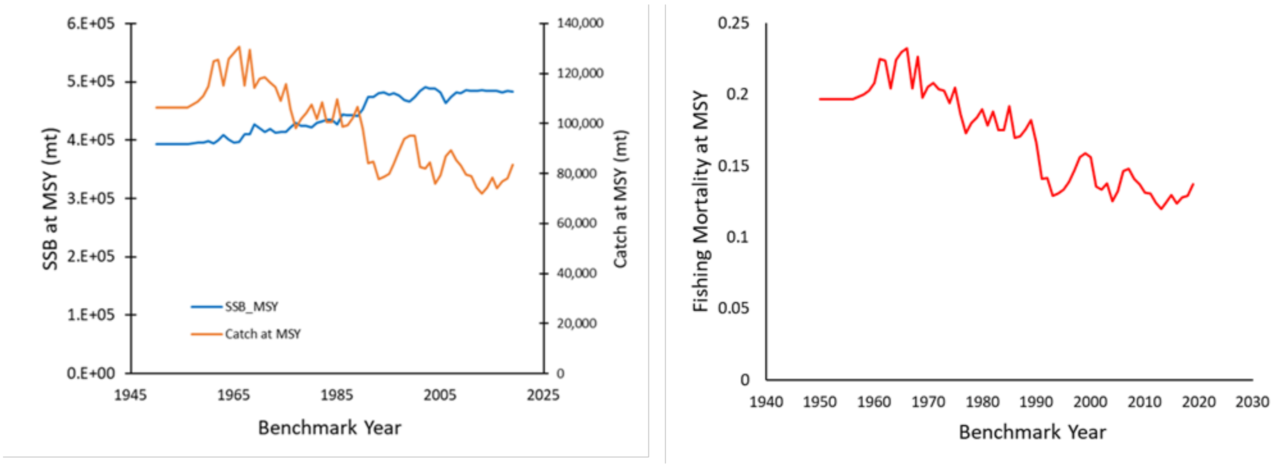


Figure 24. Dynamic SSB/SSB_{MSY} and catch at MSY (left panel) and F/F_{MSY} (right panel) by benchmark year, demonstrating the effects of changes in selectivity for bigeye tuna using the SS 2021 reference case.

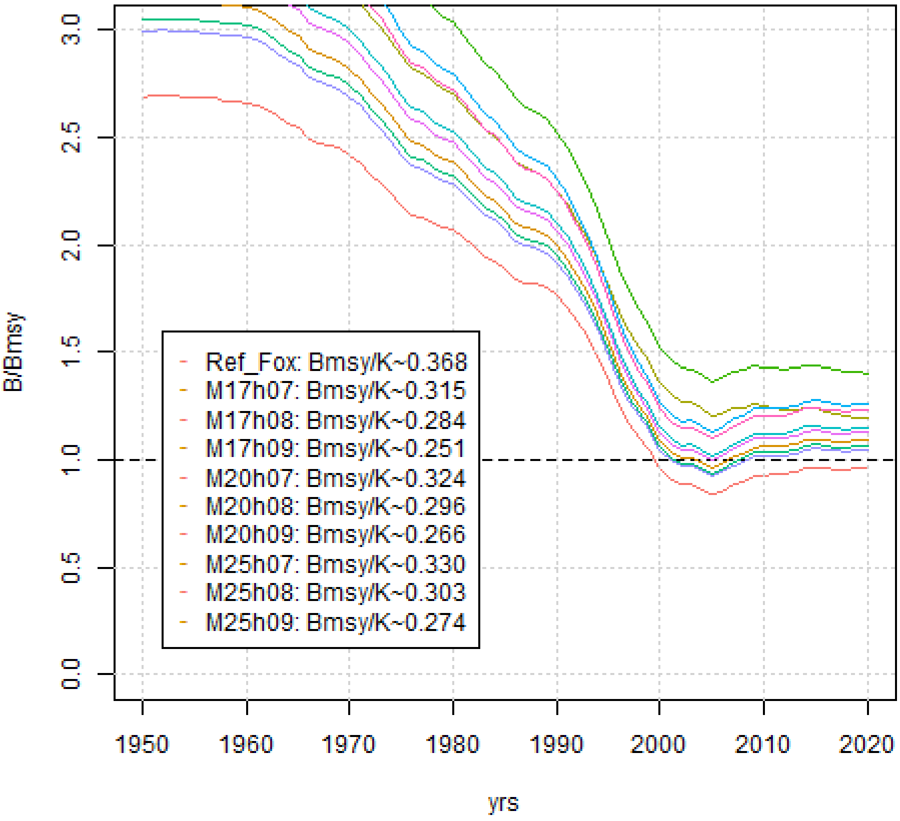


Figure 25. B/B_{MSY} trajectories from the deterministic MPB runs for the Reference Case and 9 uncertainty grid runs.

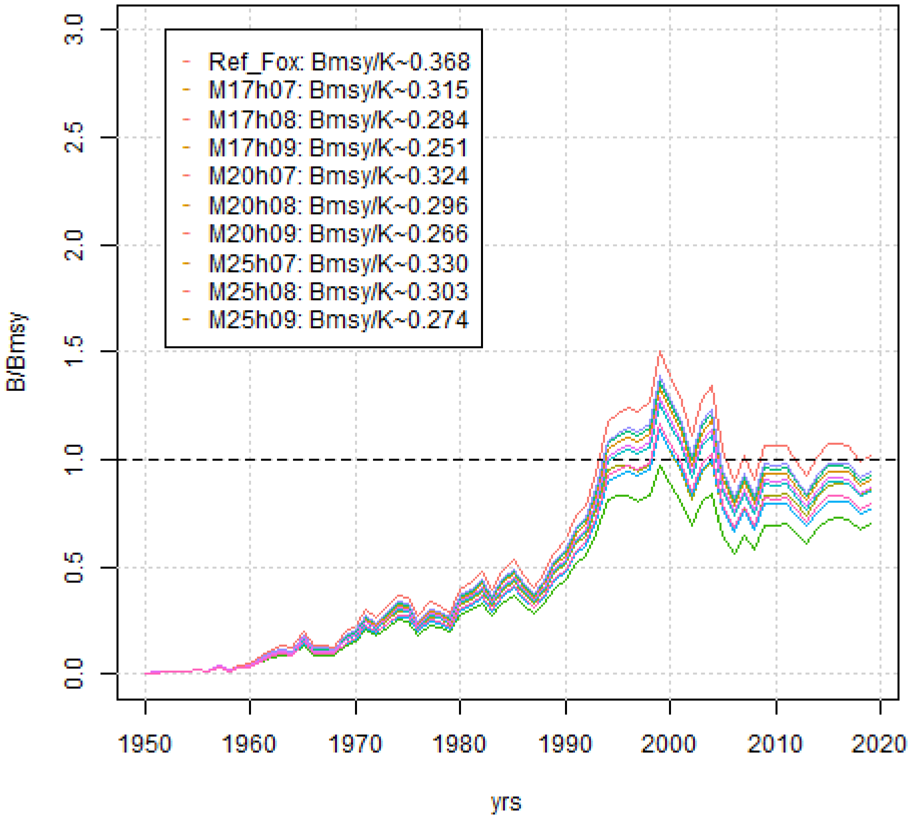


Figure 26. F/F_{MSY} trajectories from the deterministic MPB runs for the Reference Case and 9 uncertainty grid runs.

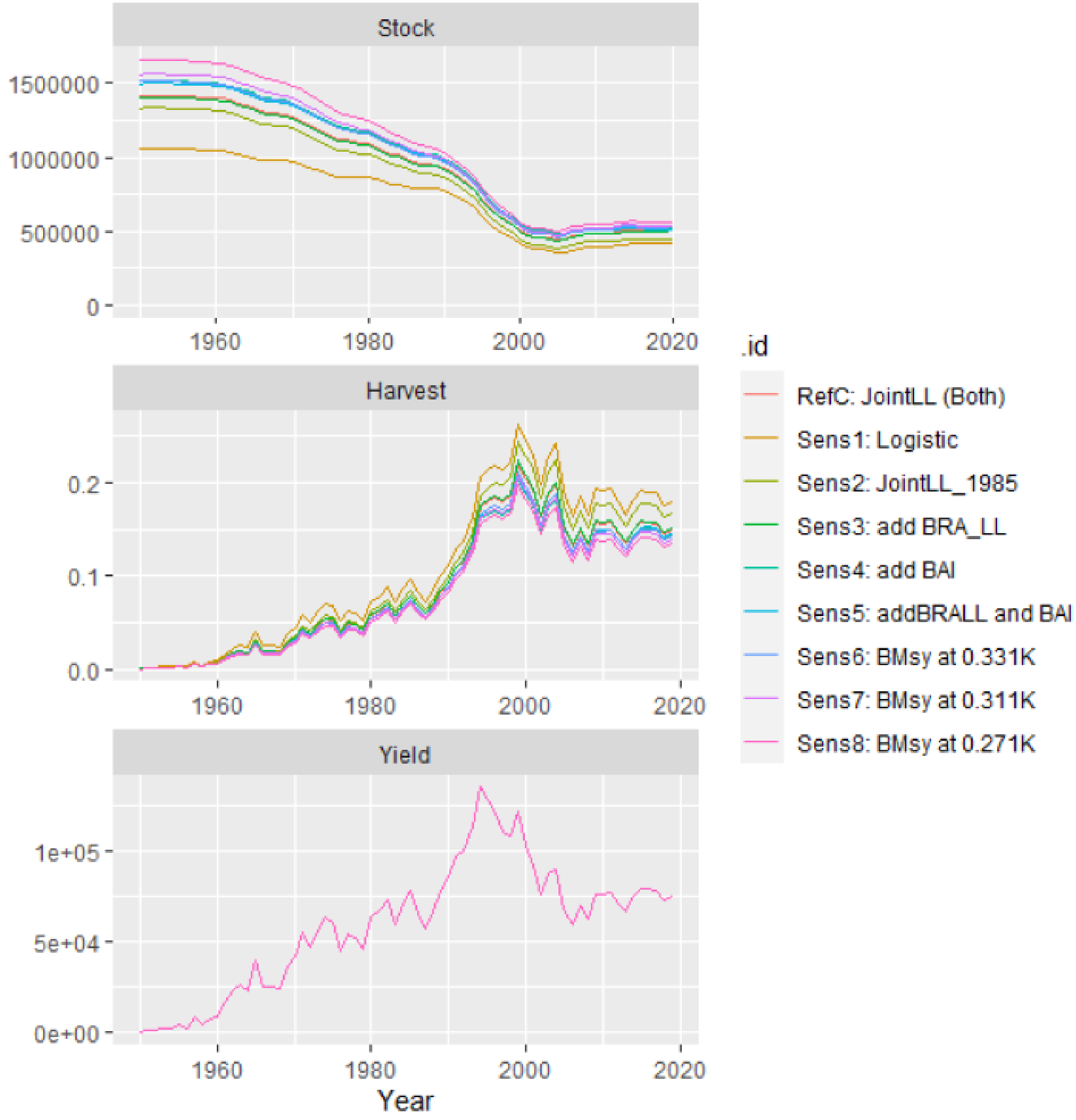


Figure 27. Biomass and Fishing mortality estimates from selected deterministic sensitivity MPB runs.

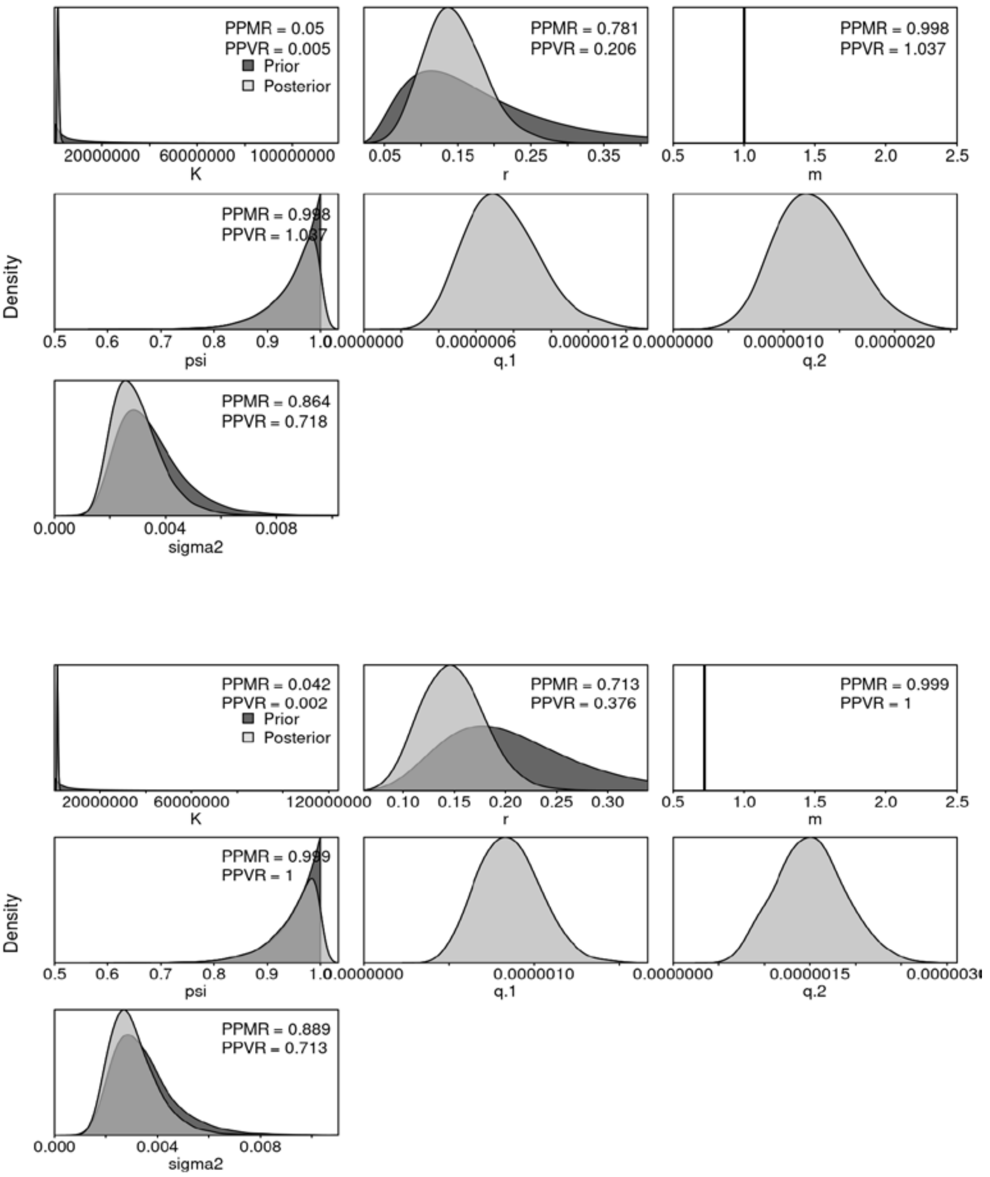


Figure 28. JABBA prior and posterior distributions of various parameters for the JABBA scenarios S01(upper panels) and S06 (bottom panels) fitted for the Atlantic bigeye tuna. PPRM: Posterior to Prior Ratio of Medians; PPRV: Posterior to Prior Ratio of Variances.

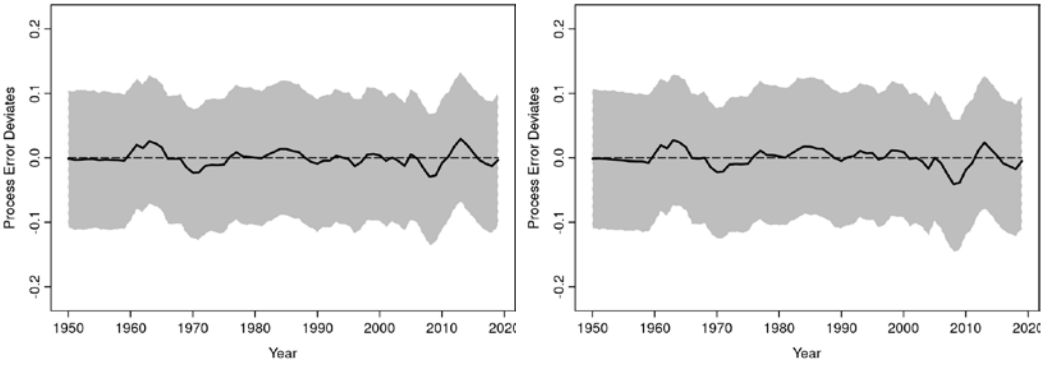


Figure 29. JABBA process error deviates (median: solid line) with shaded grey area indicating 95% credibility intervals for the JABBA scenarios S01(left panel) and S06 (right panel).

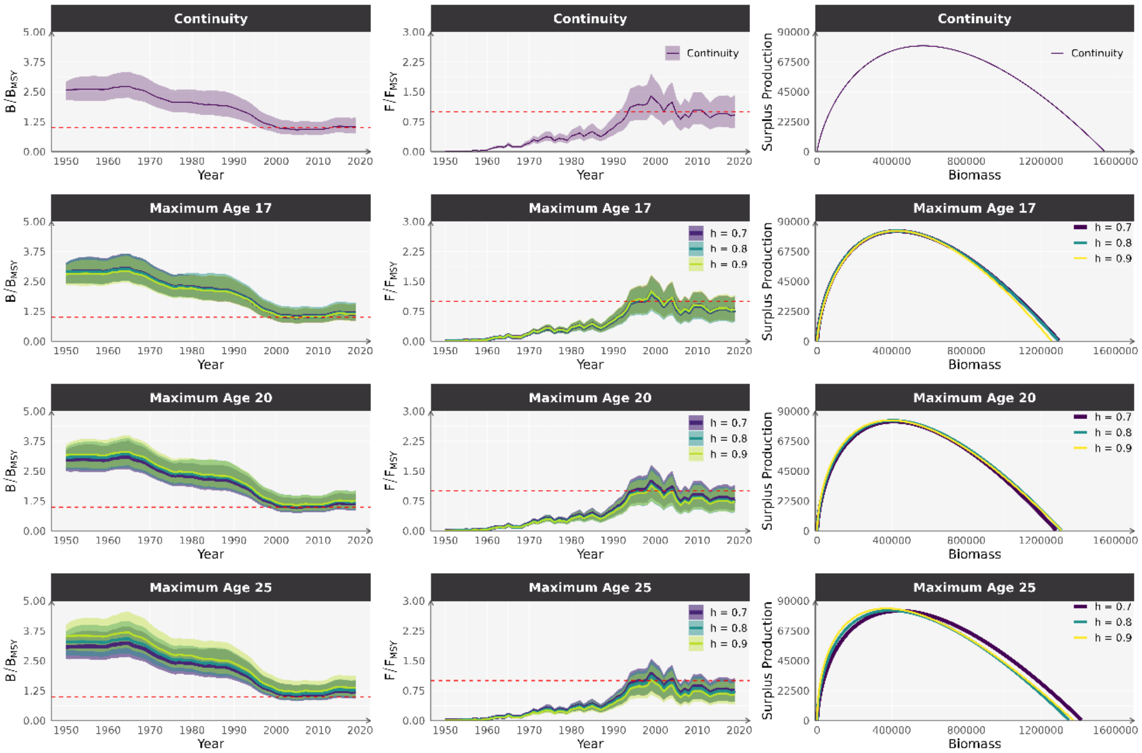


Figure 30. Trends in biomass and fishing mortality (left panels), biomass relative to B$_{MSY}$ (B/B$_{MSY}$) and fishing mortality relative to F$_{MSY}$ (F/F$_{MSY}$) (middle panels) and surplus production curve (right panels) for uncertainty grid scenarios of the Bayesian state-space surplus production JABBA model.

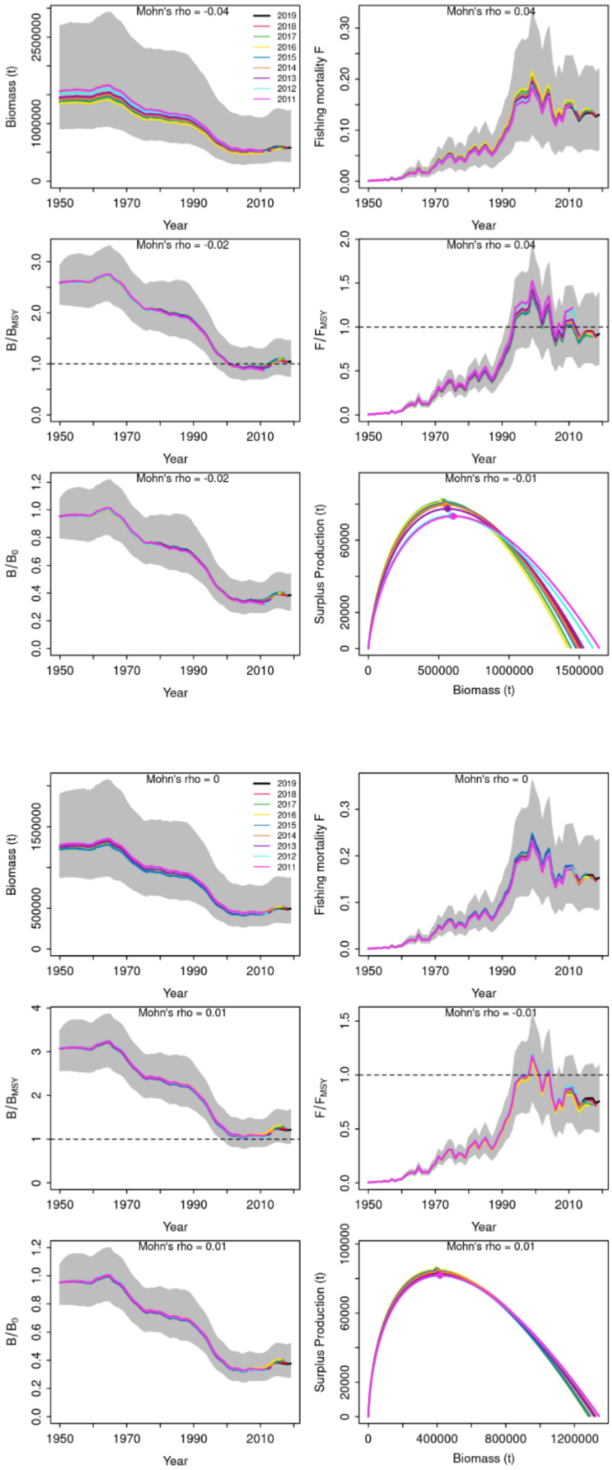
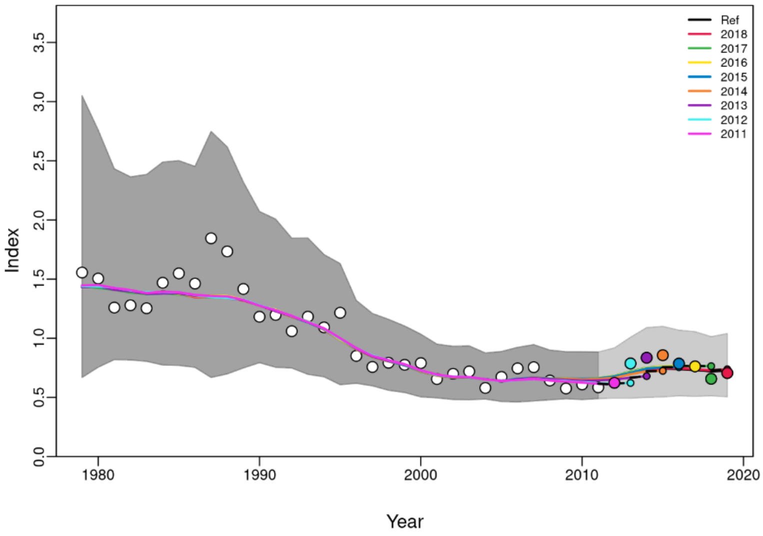


Figure 31. JABBA retrospective analysis conducted for the scenarios S01 (upper panels) and S06 (bottom panels) for Atlantic bigeye tuna, by removing one year at a time sequentially (n=8) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).



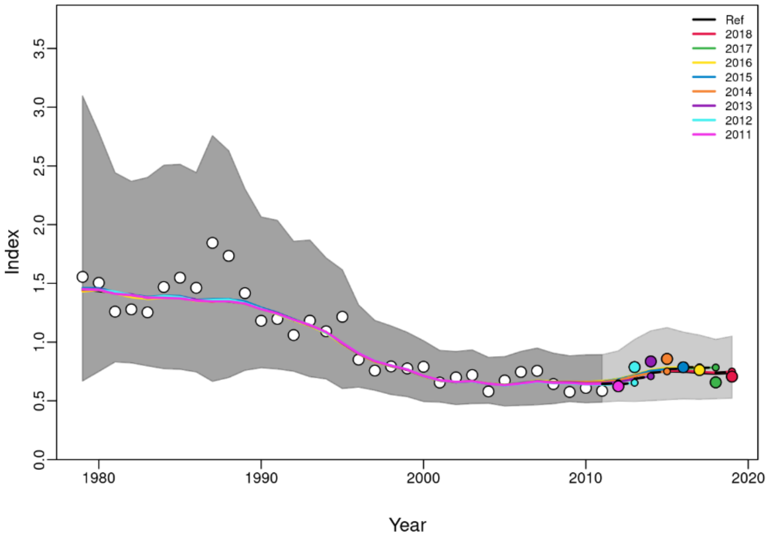


Figure 32. JABBA Hindcasting cross-validation results (HCxval) for the scenarios S01 (upper panel) and S06 (bottom panel) for Atlantic bigeye tuna, showing one-year-ahead forecasts of CPUE values (2011-2019), performed with eight hindcast model runs relative to the expected CPUE. The CPUE observations, used for cross-validation, are highlighted as color-coded solid circles with associated light-grey shaded 95% confidence interval. The model reference year refers to the end points of each one-year-ahead forecast and the corresponding observation (i.e. year of peel + 1).

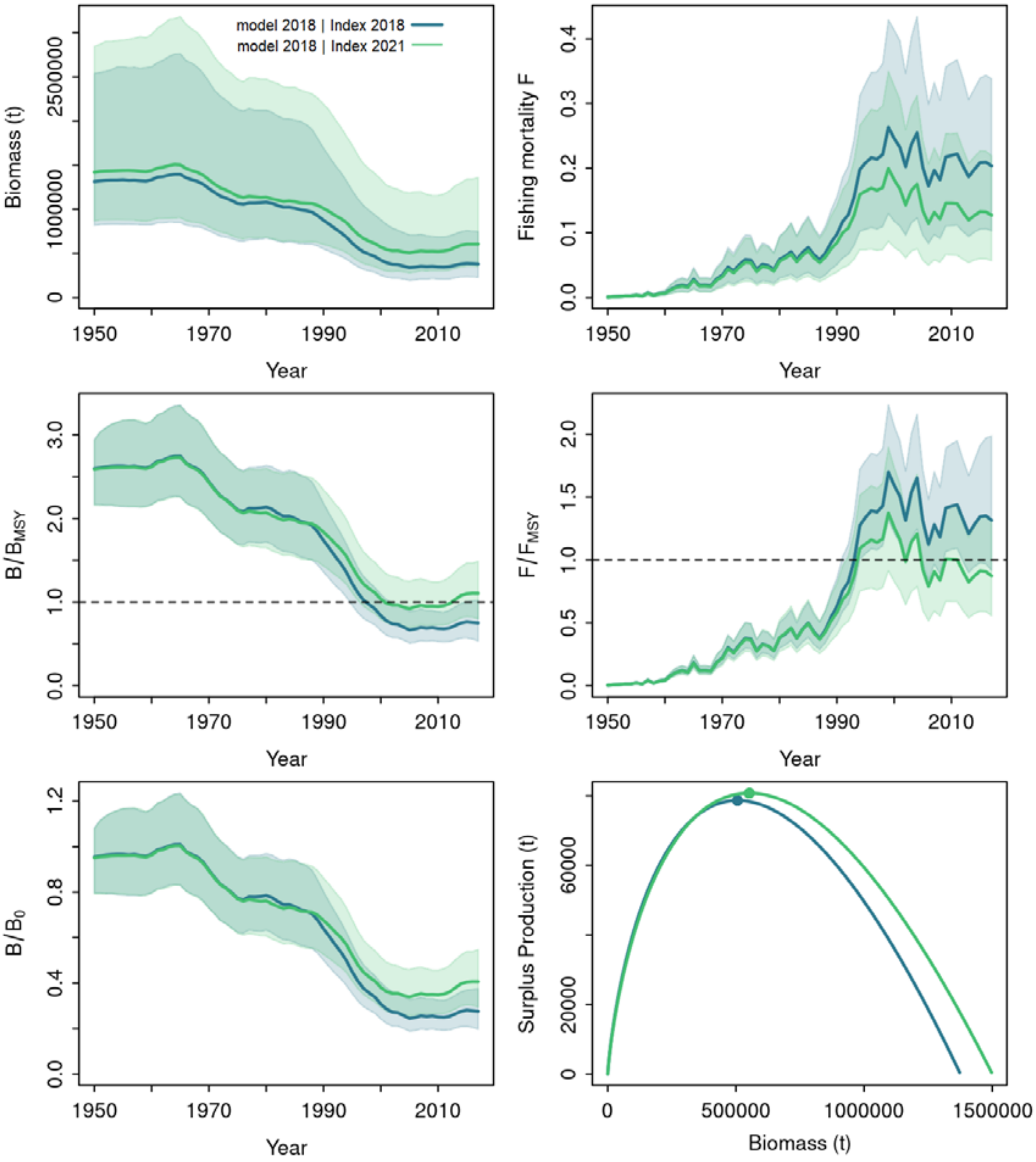


Figure 33. Comparisons of JABBA sensitivity scenarios using the 2021 joint index or the 2018 joint index. Trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).

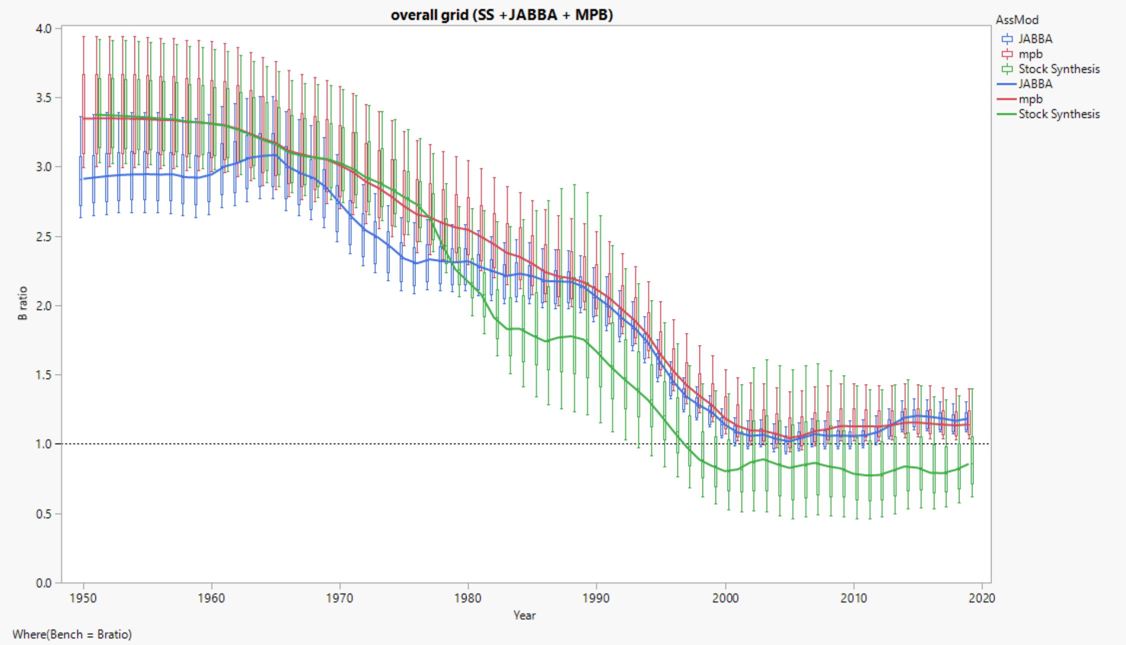


Figure 34 Comparison of estimates of SSB/SSB$_{MSY}$ (Stock Synthesis) or B/B$_{MSY}$ (production models – MPB and JABBA) between 1950 and 2019 by all runs for Atlantic bigeye tuna. The box plots represent the annual distribution of relative biomass estimates from deterministic models in the uncertainty grid, the lines represent the median of the distribution for each model type (Stock Synthesis, MPB, JABBA).

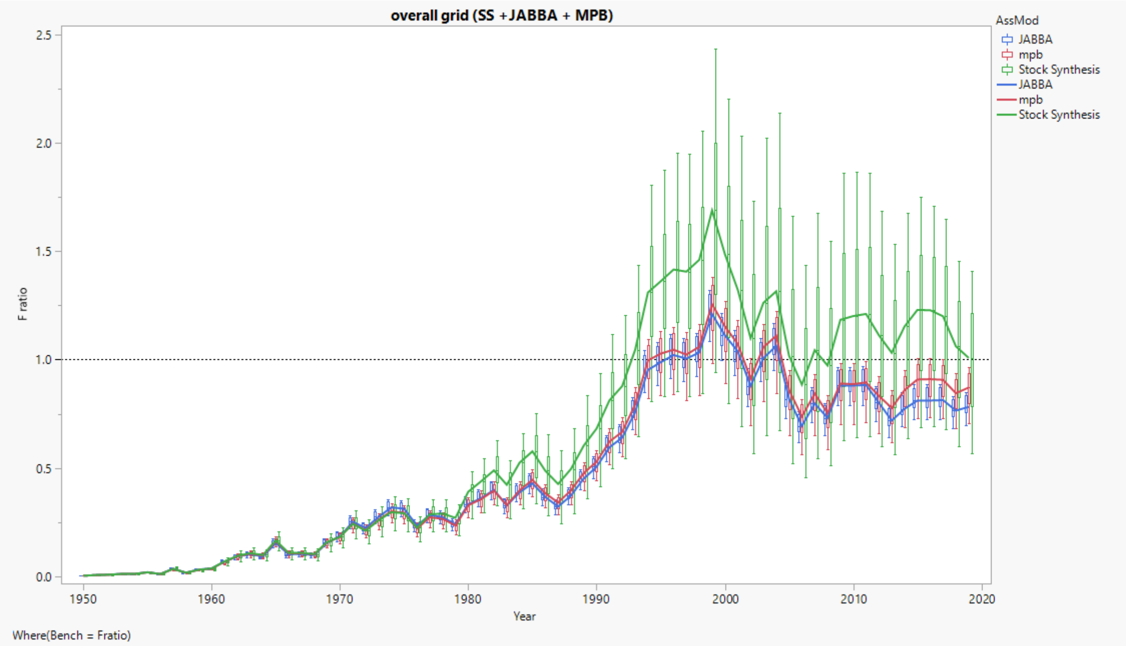


Figure 35. Comparison of estimates of F/F$_{MSY}$ between 1950 and 2019 by all runs for Atlantic bigeye tuna. The box plots represent the annual distribution of relative fishing mortality estimates from deterministic models in the uncertainty grid, the lines represent the median of the distribution for each model type (Stock Synthesis, MPB, JABBA).

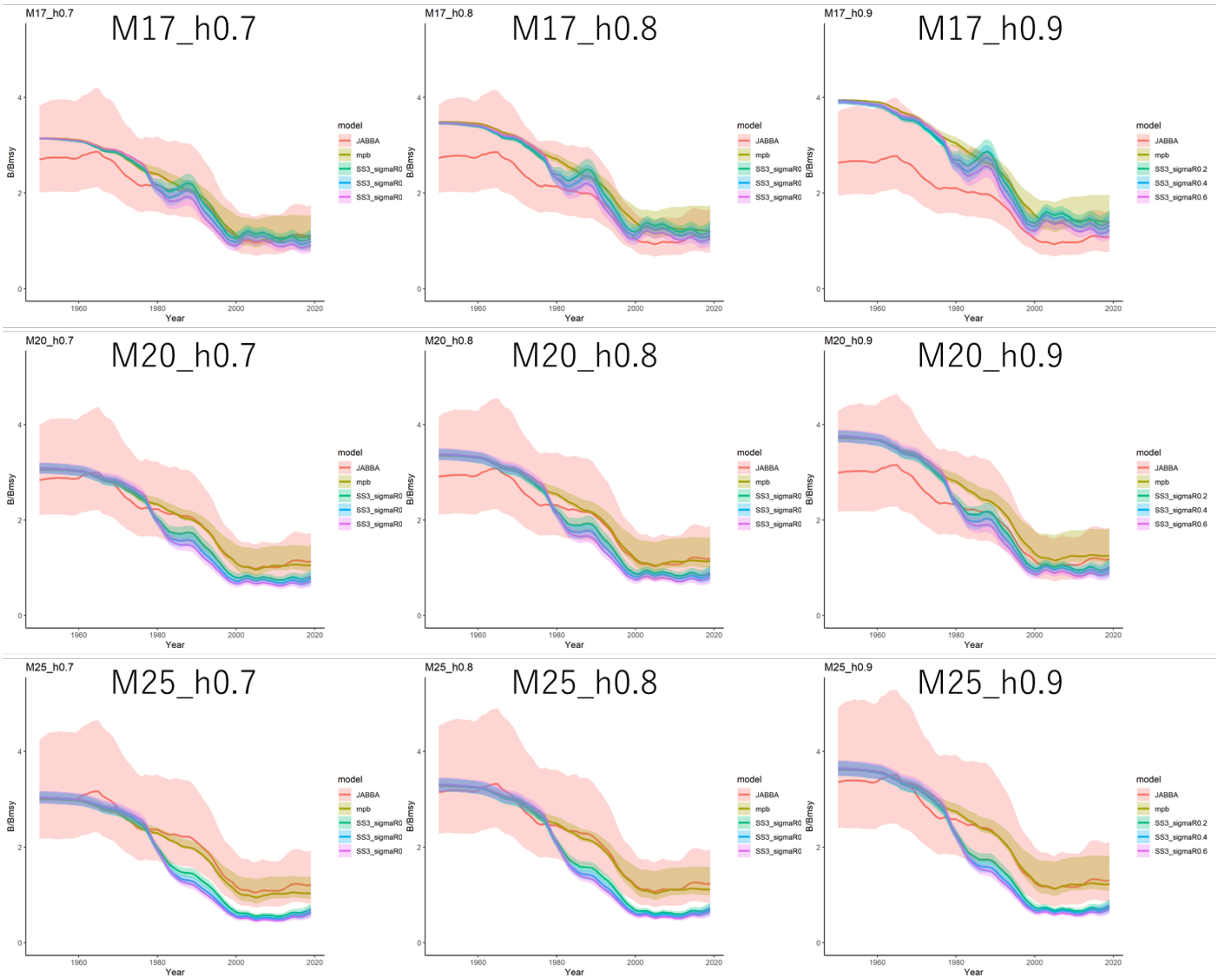


Figure 36. Comparisons of the median and 95 confidence or credibility intervals of B/B$_{MSY}$ (production models) or SSB/SSB$_{MSY}$ (Stock Synthesis) trajectories between the production models (JABBA and MPB) and the Stock Synthesis models by the scenarios of maximum age (M=17, 20, and 25) and steepness (h=0.7, 0.8, and 0.9). For the Stock Synthesis models, each panel includes three different assumptions of sigma R (sigmaR=0.2, 0.4, and 0.6). The confidence intervals were calculated based on 5000 MVNL iterations for Stock Synthesis and 500 bootstrap iterations for MPB, and the credibility intervals for JABBA were based on 30000 MCMC iterations.

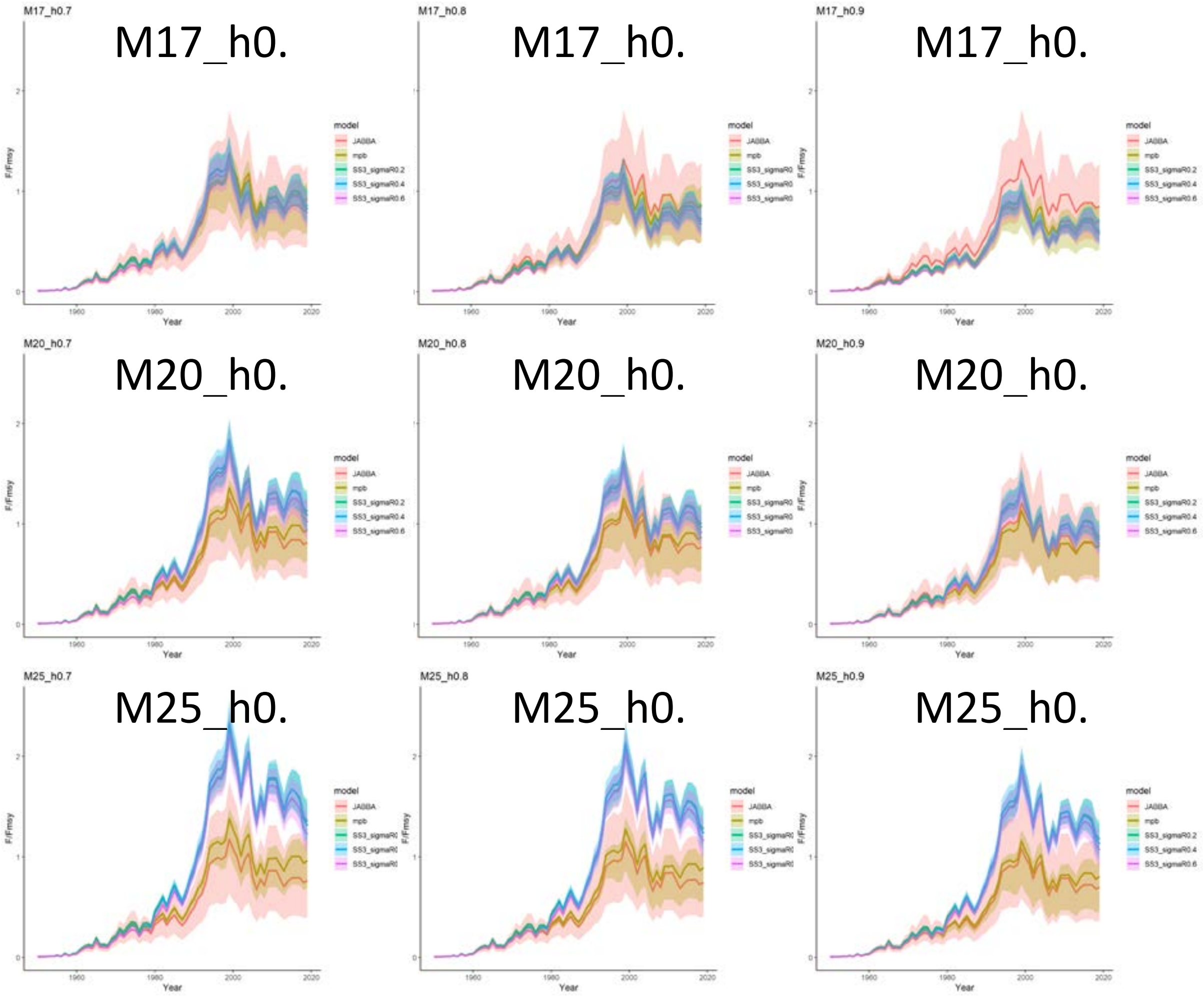


Figure 37. Comparisons of the median and 95 confidence or credibility intervals of F/F$_{MSY}$ trajectories between the production models (JABBA and MPB) and the Stock Synthesis models by the scenarios of maximum age (M=17, 20, and 25) and steepness (h=0.7, 0.8, and 0.9). For the Stock Synthesis models, each panel includes three different assumptions of sigma R (sigmaR=0.2, 0.4, and 0.6). The confidence intervals were calculated based on 5000 MVNL iterations for Stock Synthesis and 500 bootstrap iterations for MPB, and the credibility intervals for JABBA were based on 30000 MCMC iterations.

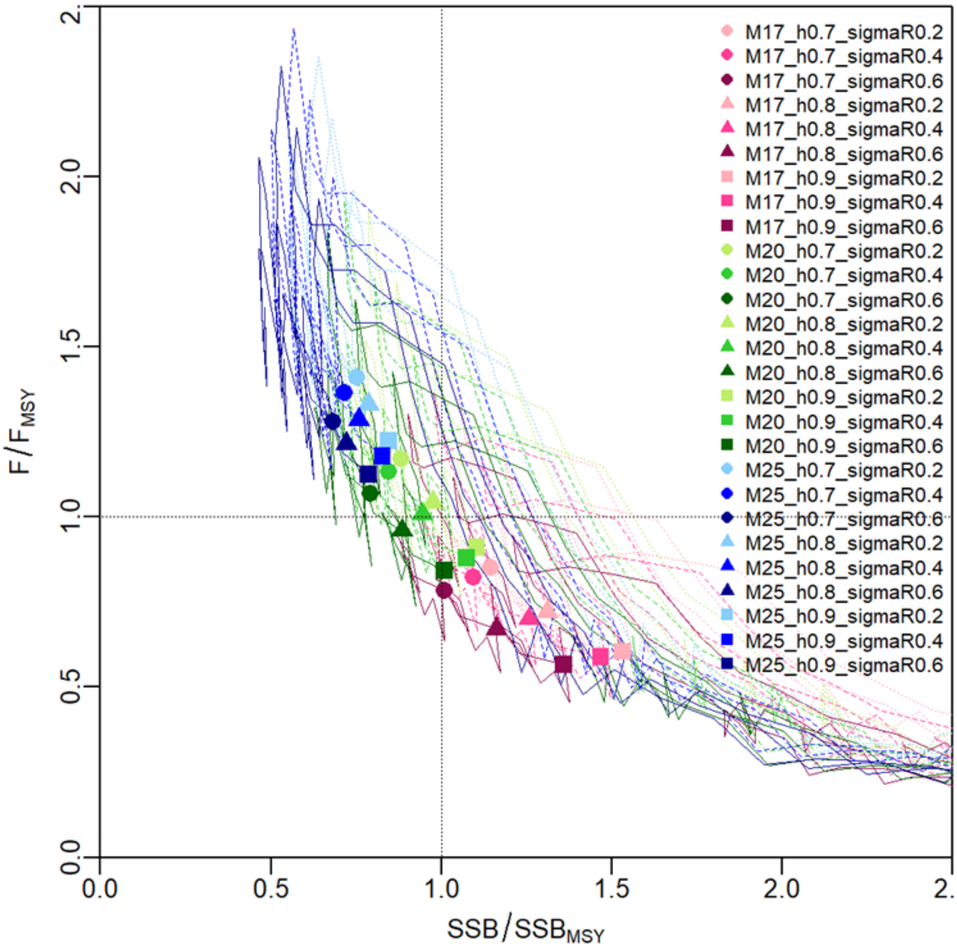


Figure 38. Kobe phase plot for the deterministic runs of the 27 Stock Synthesis uncertainty grid runs for Atlantic bigeye tuna. For each run the benchmarks are calculated from the year-specific selectivity and fleet allocations. Symbols represent the estimates of relative fishing mortality and relative spawning stock biomass for 2019. Lines represent the historical evolution of the deterministic estimates.

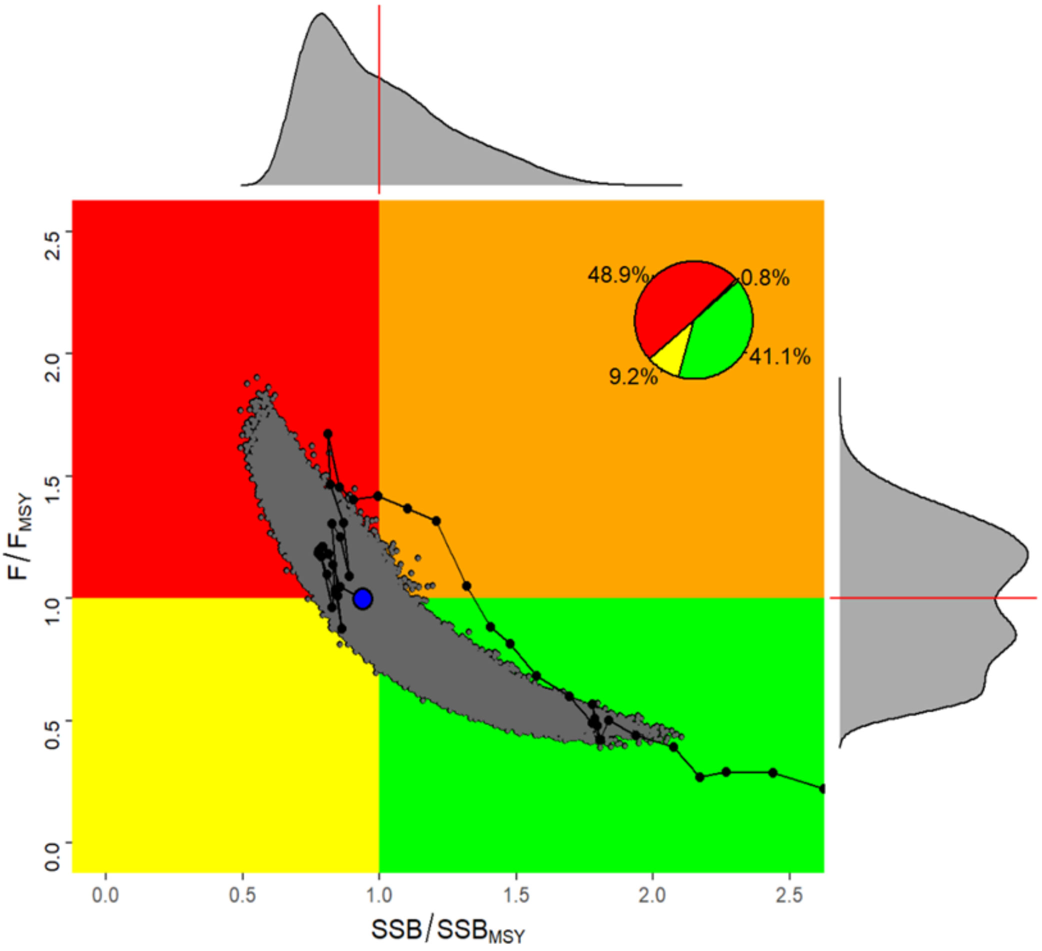


Figure 39. Kobe phase plot for the 27 Stock Synthesis uncertainty grid runs for Atlantic bigeye tuna. For each run the benchmarks are calculated from the year-specific selectivity and fleet allocations, and based on 10000 MVNL iterations. The blue point shows the median of 270,000 iterations for SSB_{2019}/SSB_{MSY} and F_{2019}/F_{MSY} for the entire set of runs in the grid. Black line with black symbols represents the historical evolution of the median of all runs. Grey points represent the 2019 estimates of relative fishing mortality and relative spawning stock biomass for 2019 for each of the 270,000 iterations. The upper graph represents the smoothed frequency distribution of SSB/SSB_{MSY} estimates for 2019. The right graph represents the smoothed frequency distribution of F/F_{MSY} estimates for 2019. The inserted pie graph represents the percentage of each 2019 estimate that fall in each quadrant of the Kobe plot.

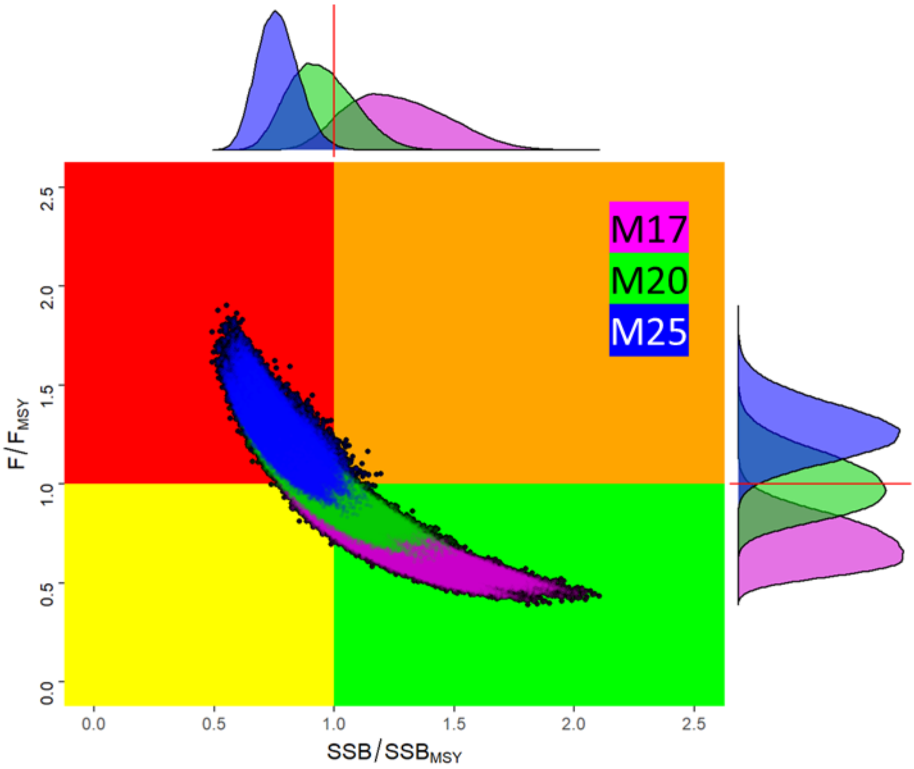


Figure 40. Kobe phase plot for the 27 Stock Synthesis uncertainty grid runs by three different maximum age (M) assumptions for Atlantic bigeye tuna (M: pink=17; green=20, blue=25). For each run the benchmarks are calculated from the year-specific selectivity and fleet allocations, and based on 10000 MVNL iterations. The smoothed frequency distributions represent the 2019 estimates of SSB/SSB$_{MSY}$ (top) and F/F$_{MSY}$ (right).

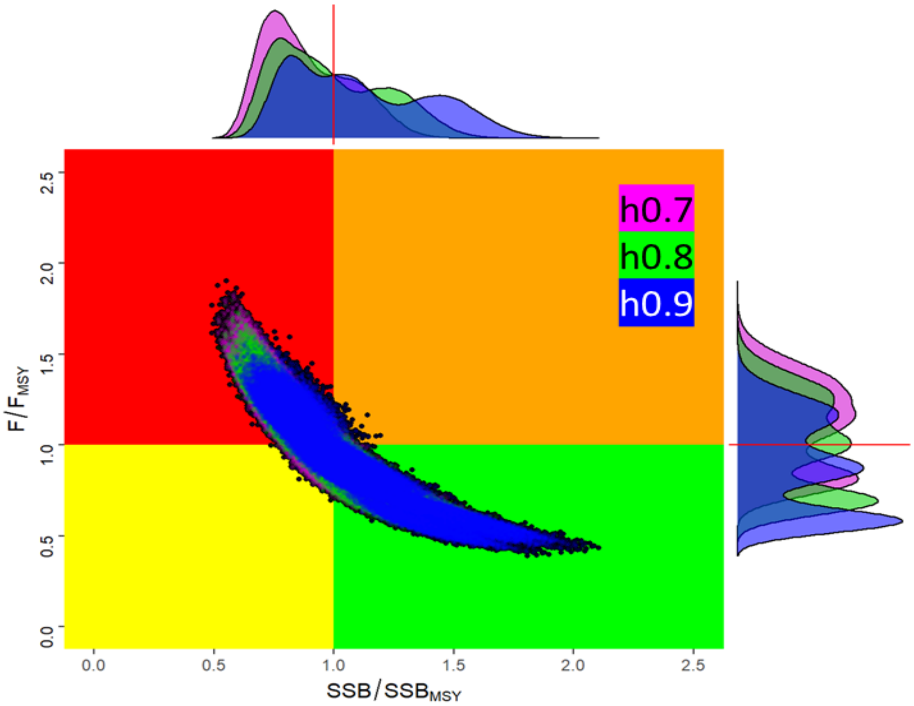


Figure 41. Kobe phase plot for the 27 Stock Synthesis uncertainty grid runs by three different steepness (h) assumptions for Atlantic bigeye tuna (h: pink=0.7; green=0.8, blue=0.9). For each run the benchmarks are calculated from the year-specific selectivity and fleet allocations, and based on 10000 MVNL iterations. The smoothed frequency distributions represent the 2019 estimates of SSB/SSB$_{MSY}$ (top) and F/F$_{MSY}$ (right).

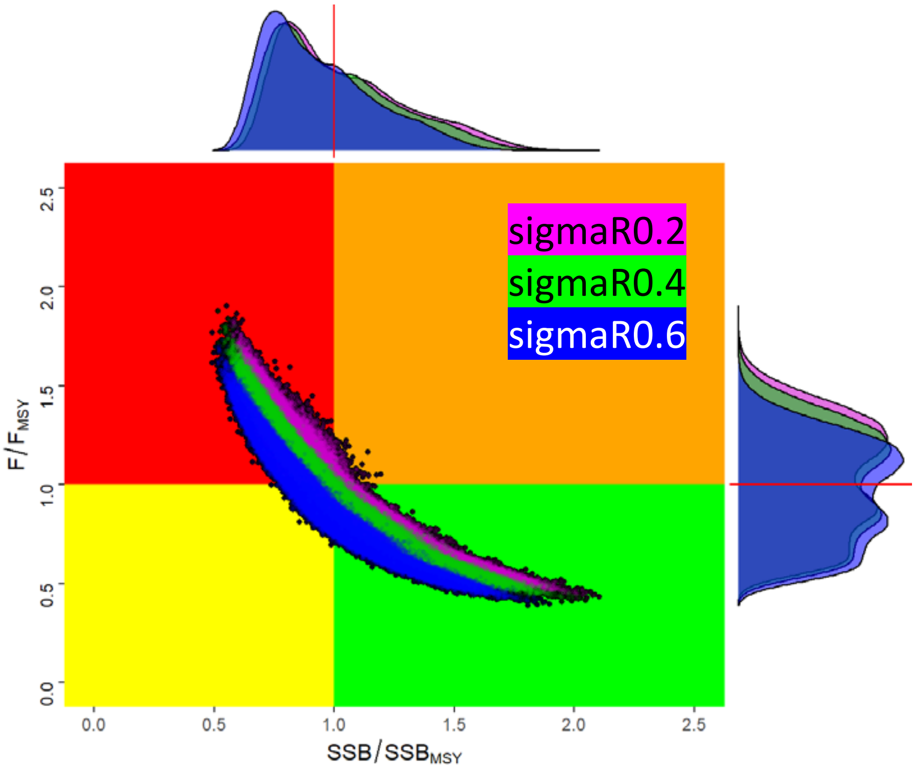


Figure 42. Kobe phase plot for the 27 Stock Synthesis uncertainty grid runs by three different sigma R assumptions for Atlantic bigeye tuna (sigma R: pink=0.2; green=0.4, blue=0.6). For each run the benchmarks are calculated from the year-specific selectivity and fleet allocations, and based on 10000 MVNL iterations. The smoothed frequency distributions represent the 2019 estimates of SSB/SSB$_{MSY}$ (top) and F/F$_{MSY}$ (right).

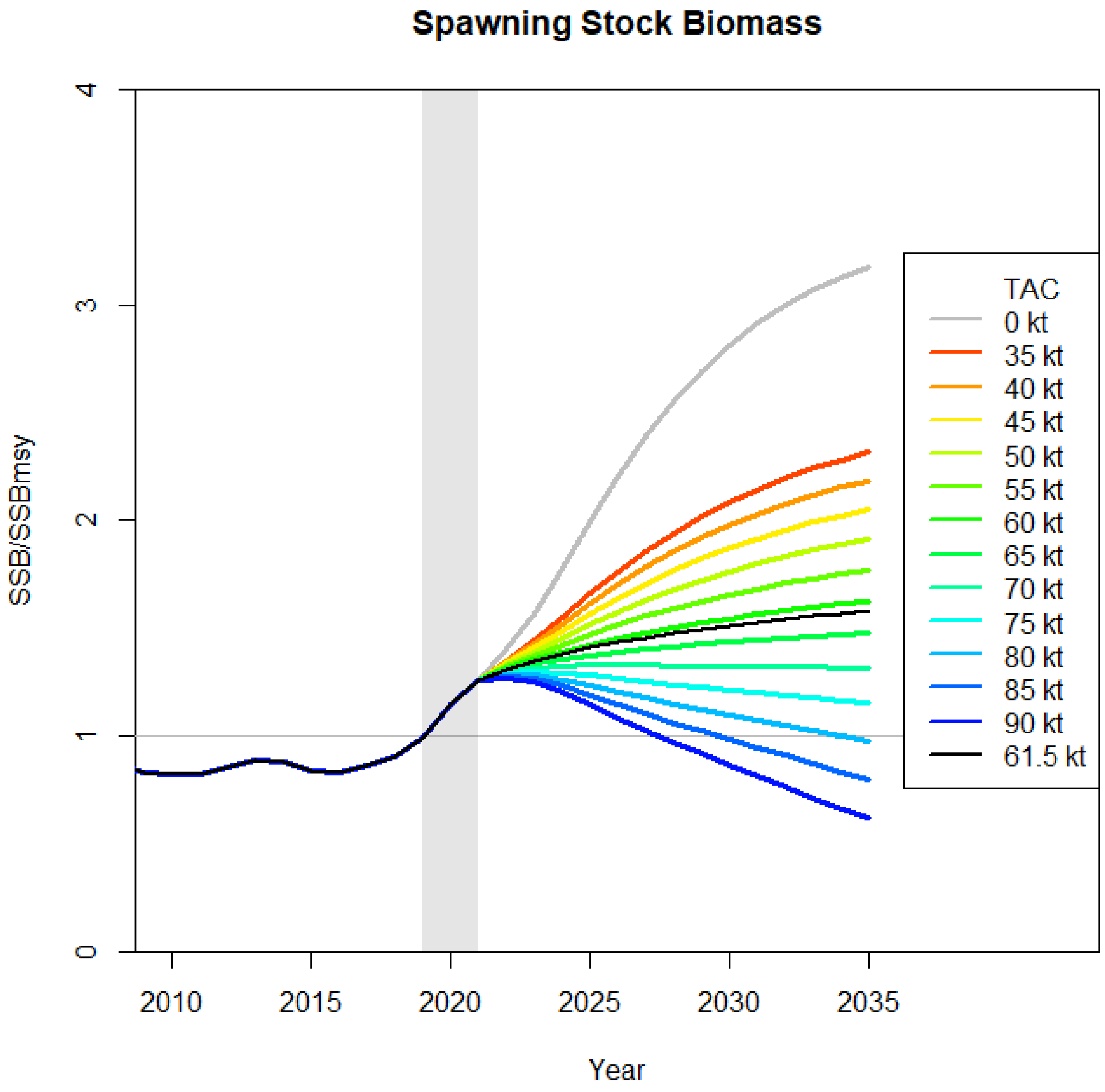


Figure 43. Deterministic projections of SSB/SSB$_{MSY}$ for the 27 Stock Synthesis uncertainty grid runs at 35-90 thousand mt constant TACs for Atlantic bigeye tuna. The lines are the mean of 27 runs and the black line is for the current TAC (61,500 t). The grey bar represents the period when catches for 2020 and 2021 are fixed to 59,919 mt and 61,500 t respectively.

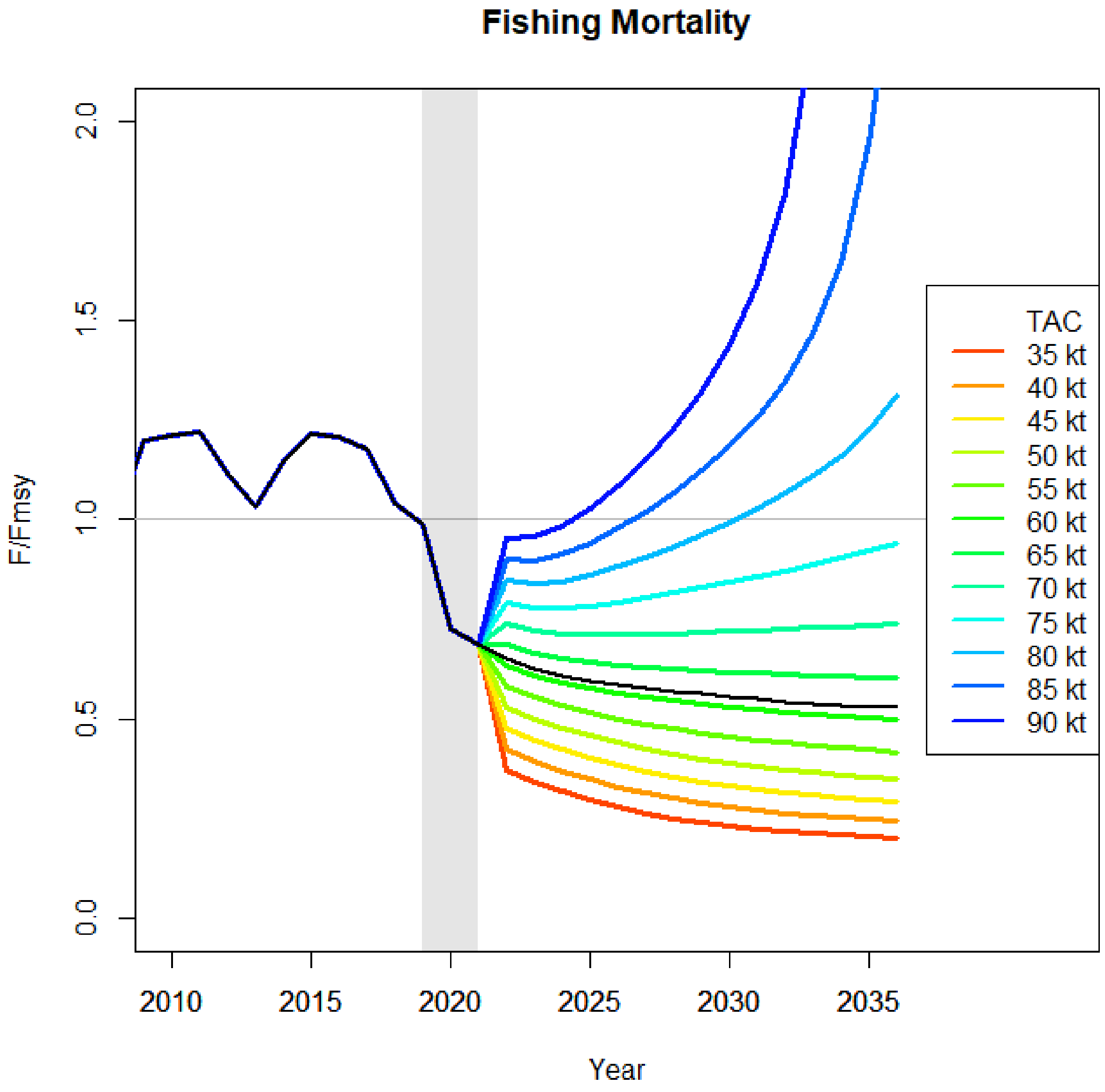


Figure 44. Deterministic projections of F/F$_{MSY}$ for the 27 Stock Synthesis uncertainty grid runs at 35-90 thousand mt constant TACs for Atlantic bigeye tuna. The lines are the mean of 27 runs and the black line is for the current TAC (61, 500t). The grey bar represents the period when catches for 2020 and 2021 are fixed to 59,919 mt and 61,500 mt respectively.

Appendix 1

Annontated Agenda

1. Opening, adoption of Agenda and meeting arrangements
2. Summary of available data for assessment and updates since Data Preparatory meeting
    - 2.1 Fisheries statistics, size, and CAS estimates
    - 2.2 Relative indices of abundance
3. Stock Assessment Models and other data relevant to the assessment
    - 3.1 Statistically integrated model, Stocks Synthesis
    - 3.2 Surplus Production models, JABBA and MPB
4. Stock status results
    - 4.1 Catch integrate model, Stocks Synthesis
    - 4.2 Surplus Production models, JABBA and MPB
    - 4.3 Synthesis of assessment results
5. Projections
6. Recommendations
    - 6.1 Management
    - 6.2 Research and statistics
        - 6.2.1 With financial implications
7. Other matters
    - 7.1 Responses to the Commission
8. Adoption of the report and closure

Appendix 2

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Appendix 3

List of SCRS Papers and Presentations

Reference	Title	Authors
SCRS/2021/113	Review and Preliminary Analyses of size samples of Atlantic bigeye tuna (*Thunnus obesus*)	Ortiz M., and Kimoto A.
SCRS/2021/120	Stock Assessment For Atlantic Bigeye Using A Biomass Production Model	Merino G., Urtizberea A., Santiago J., and Laborda A.
SCRS/2021/131	Datos estadísticos de la pesquería de túnidos de las Islas Canarias durante el periodo 2000 a 2020	Delgado R.
SCRS/2021/132	Just another Atlantic Bigeye Tuna Stock Assessment: Preliminary Results Using A Bayesian State-Space Surplus Production Model (JABBA)	Sant'Ana, R., Mourato B., Kimoto A., Ortiz M. and Winker H.
SCRS/2021/133	Estimation Of Ghana Tasks 1 and 2 Purse Seine And Baitboat Catch 2012 – 2020: Data Input 2021 Bigeye Tuna Stock Assessment	Ortiz M., Carlos P., Aviyi S., and Bannerman P.
SCRS/2021/134	Atlantic Bigeye Tuna Stock Synthesis Analyses	Lauretta M., Schirripa M., Die D., Hiroki Y., Kimoto A., Norelli A., Okamoto K., Ortiz M., Satoh K., Takayuki M., and Urtizberea A.
SCRS/2021/135	Summary and review of the FOB/FADs deployed ST08-FADsDEP ICCAT database 2011-2019.	Ortiz M., and Mayor C.

Number	Title	Authors
SCRS/P/2021/047	Summary of some data treatment for BET 2021 SS3 input files	Kimoto A., Ortiz M., Lauretta M., and Urtizberea A.
SCRS/P/2021/048	Why is the estimate of stock status so different this time?	Schirripa M.

Appendix 4

SCRS Documents and Presentation Abstracts as provided by the authors

SCRS/2021/113 - Size sampling data of Atlantic bigeye tuna was reviewed, and preliminary analyses were performed for its use within the stock evaluation models. Size data is normally submitted to the Secretariat by CPCs under the Task 2 requirements; for the major fisheries, CPCs have also to submit Catch at Size. The size samples data was revised, standardized, and aggregated to size frequencies samples by main fishery/gear type, year, and quarter. Preliminary analyses indicated a minimum number of 50 fish measured per size-frequency sample, with size information since 1965 for the purse seine, baitboat, and longline fishing gears. For Atlantic bigeye tuna, the size sampling proportion among the major fishing gears is consistent with the proportion of the catch.

SCRS/2021/120 - In this paper we present a stock assessment for Atlantic Ocean bigeye using a biomass dynamic model. Overall, using the Joint Longline CPUE index presented to the data preparatory meeting and the catch series made available by ICCAT Secretariat, we estimate that the stock is overfished and undergoing overexploitation with a 62% of probability. In this document we show the estimated trends, reference points and a set of diagnostics of fit for further discussion and possible refinement to be explored during the stock assessment session in July 2021.

SCRS/2021/131 - This document presents a summary of the development and current composition of the Canary Islands baitboat fleet and the catches made between 2000 and 2020. This paper also presents size histograms of the different species caught in 2019 and the average between 2014 and 2018. Until 2019, an estimate of the nominal fishing effort was made, distinguishing between vessels smaller and larger than 50 GRT, considering the former (vessels less than 50 GRT) carry out daily trips, whereas the latter carry out trips lasting more than a day, with an average of 9 days at sea. In 2020, the effort of part of the fleet has been obtained directly from the logbooks, while the unloadings without logbook have continued to be calculated as before, that is, vessels less than 50 tons with 1-day at sea and larger with 9-days at sea.

SCRS/2021/132 - Bayesian State-Space Surplus Production Models were fitted to Atlantic bigeye tuna (*Thunnus obesus*) catch and CPUE data using the 'JABBA' R package. This update in the bigeye stock status is in accordance with the 2020 SCRS work plan. The five scenarios were based on the previous assessment and on uncertainty grid proposed during the 2021 BET Data Preparatory Meeting, which in summary corresponded to a continuity run based on a Fox production function and an uninformative lognormal r prior and to a 'maximum-age' and 'steepness-specific' alternatives for r prior lognormal distribution with an associated shape parameter of a Pella-Tomlinson production function from an Age-Structured Equilibrium Model (ASEM). In general, all scenarios showed similar trend for the trajectories of B/B_{MSY} and F/F_{MSY} over time, with a stepwise decreasing trend marked by a soft decrease among two sharply decrease patterns The first sharply decrease moment can be observed between the years 1965 and 1975, the second one between the years 1990 and 2000, and the soft decrease among both (1975 – 1990). In general, kobe biplots shown a typical anti-clockwise pattern with the median quantity estimated for the last year observed in a green area. However, based on the continuity run scenario, when compared the cumulative probabilities of the green and orange regions (58.2%) against the cumulative probabilities of the red and yellow regions (41.8%) it suggests a quite similar chances of the current biomass levels are above or below the limit of the B_{MSY} or even close to the limit of the B_{MSY}.

SCRS/2021/133 - Information from the AVDTH Ghana fisheries and other sources was used to estimate the task I and II for the Ghanaian tuna baitboat and purse seine fisheries during 2012 – 2020. Catch and landing data collected and managed by the Marine Fisheries Research Division (MRFD) of Ghana included both landings and logbook information from 2005 up to 2020. The estimation of total Ghana catches catch composition and quarterly spatial (1°x1°) distribution followed the recommendations from the SCRS Tropicals working group agreed during the bigeye data preparatory meeting. Sampling for species composition and size distribution were reviewed to determine appropriate sampling for the different components of the Ghana fleets by major gear type. In summary, estimates of total yellowfin catch from the AVDTH database were lower compared to prior reports.

SCRS/2021/134 - This paper presents the preliminary results of the Stock Synthesis analysis for bigeye tuna. Modifications from the last assessment included changes in fleet structure, different natural mortality assumptions, and addition of a relative abundance index based on acoustic biomass observations from FAD buoys. Growth, maturity, steepness and recruitment variation assumptions remained the same as prior analyses. Model structural uncertainty comprised a grid of 27 alternative parameterizations of steepness, annual recruitment deviation and natural mortality. Sensitivity analyses demonstrated the effects of recent data additions/treatments and the exclusion of different indices of abundance. Standard model diagnostics were conducted using SS and the SSdiags R package, and included fits to index and length compositions, jitter of starting parameters, randomness tests of model residuals, retrospective analyses, profiles of key estimated parameters, and hindcasting.

SCRS/2021/135 - A summary and preliminary review of the data submitted for the FOB/FADs deployment by CPCs to the ICCAT Secretariat is presented for the 2011-2019 period.

SCRS/P/2021/048 - To understand how the individual changes in observational data and parameter assumptions resulted in the overall change in the estimation of stock status, some changes were made stepwise to examine the effects of individual changes in isolation of the others. The first attempt to examine changes was made by starting with the 2021 reference model and working backwards, changing the model back to the 2018 configuration. Four changes were examined: model_1, replace the 2021 with the 2018 LL CPUE index and remove the acoustic CPUE; model_2, start with model_1 and add the acoustic CPUE; model_3, start with model_2 and change back to the maximum age; and model_4, start with model_3 and change the lambda on the length data from 1.0 to 0.1. The effects of the changes were examined by comparing the estimates of SSB, SSB/SSB_{MSY} and F/F_{MSY}. Changing back to the 2018 CPUE and adding the acoustic CPUE accounted for a great deal of the change in the estimates of SSB. Changing back to the old maximum age and reducing the lambda on the length data accounted for more change, but not as much. Changing back to the 2018 CPUE while keeping the acoustic CPUE in accounted for the largest change in the SSB/SSB_{MSY}. Changing back to the 2018 CPUE and back to the old previous maximum age accounted for the largest difference in the F/F_{MSY}.

The second attempt (Part 2 of the presentation) worked forward by starting with the 2018 model configuration and working forward, changing the model to the 2021 configuration. Updating the 2018 model with the 2021 LL CPUE and using the new maximum ages accounted for approximately 50% of the difference in estimates of SSB. Regarding estimates of SSB/SSB_{MSY}, Updating the 2018 model only with the 2021 LL CPUE accounted for roughly 50% of the difference while also changing to the new maximum age accounted for roughly 75% of the total change. Similar trends were found for estimates of F/F_{MSY}. This work concludes that the difference between the 2018 and 2021 estimate of stock status can largely be accounted for by the use of the new treatment of the LL CPUE index and the change in the assumed maximum age of the fish.

SCRS/P/2021/047 - The BET SS3 modelling team has reviewed the data provided by the Secretariat, and some important decisions on the data treatment for the SS3 input file were summarized in this presentation. For example, it was recommended to use the YFT 2019 area stratification to harmonize the MSE work among species, and to use all size data by Chinese-Taipei because they are officially revised. Based on these data treatment, the SS3 runs were set up for BET.