REPORT OF THE 2022 ICCAT ATLANTIC SWORDFISH STOCK ASSESSMENT

(Online, 20-28 June 2022)

1. Opening, adoption of agenda and meeting arrangements

The meeting was held online, between 20-28 June 2022. The northern swordfish rapporteur Kyle Gillespie (Canada) opened the meeting and addressed the Swordfish Species Group, the "Group", with the southern rapporteur, Denham Parker (South Africa). The ICCAT Executive Secretary welcomed and thanked the participants. The SCRS Chair and the Assistance Executive Secretary highlighted the need to advance to the extent possible on all tasks of the Group, to avoid leaving substantial matter to be dealt with during the September meeting. The Chairman proceeded to review the Agenda, which was adopted without changes (**Appendix 1**).

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

Sections	*Rapporteur*
Items 1, 11, 12	N.G.Taylor
Item 2	D. Rosa, M. Ortiz
Item 3	A. Kimoto, M. Ortiz
Item 4, 8, 10	K. Gillespie
Item 5	N. Fisch, M. Ortiz, K. Gillespie
Item 6	R. Forselledo, D. Parker, B. Mourato
Item 7	C. Peterson
Item 9	K. Gillespie, G. Diaz

2. Updates on available data on catches, biology, size composition (limited to any updates since the data-preparatory meeting)

SCRS/2022/118 presented an update on the age and growth component of the swordfish research biology program, with a preliminary analysis of an age reading for the North Atlantic stock. Multiple readers read both spines and otoliths and biases were found between readers for both structures. The maximum modal age in spines was 7 years and in otoliths 5 years. The mean length at age from spines was similar to the mean lengths at age from the Arocha *et al.* (2003) study. Sampling, processing, and age readings will continue under the swordfish research biology program.

The Group was informed that a study of swordfish growth and reproduction has been conducted in the Gulf of Mexico noting that it could be interesting to include those samples in the current study, as it covers an area that is currently not sampled. USA scientists will try to contact this study's researchers.

The differences in maximum ages of spines readings in the current study and the study from Arocha *et al.* (2003) were noted. It was clarified that most likely this difference is due to the different length ranges of the two studies, as in the case of Arocha *et al.* (2003) there were samples of larger individuals than the ones included in the current reading for the North Atlantic. It was further noted that some fisheries are not fishing in areas where larger individuals were often caught, as is the case of the more offshore areas of the Grand Banks. This can hinder further sampling of these larger-size swordfish. Additional samples of large individuals may become available from the rod and reel fishery off Canada.

The Group expressed interest in proposing a continued program for biological sampling, undertaken by CPCs, that extends further than the current biology program, with specific sizes, and structures (hard parts) to be collected from different areas. It was noted that previous efforts have been taken to develop a research plan for swordfish, like the existing for other species groups (e.g., sharks; billfish), and these efforts could be renewed.

SCRS/2022/120 applied a method to derive steepness for the Beverton-Holt stock recruitment relationship from life-history parameters. The method used distributions of life history parameters to determine corresponding values of steepness for each combination. Similar to stocks such as the Atlantic bluefin tuna, Pacific bluefin tuna, and Pacific striped marlin, the resulting distribution of steepness was left-skewed. To refine the estimates, better estimates of the variance for the input parameters are needed as well as defining a correlation matrix for each. Once refined, the multivariate distribution could be used for priors on stock assessment models, input for the Operating Models in MSE, as well as a distribution that could be used to weight OM and stock assessment scenarios.

The Group discussed the presentation. They noted that this analysis was an important advancement of the method initially presented by Sharma and Arocha in 2017. In addition, they asked if the derived distribution had been compared for example to the RAM Legacy Stock Assessment Database. The authors responded that it has not but that too would be work for the future. It was noted that this method relies on the survival rates of larvae to juvenile stages, which is an area of limited research and large uncertainty.

3. Updates on fleet structure (limited to any updates since the data-preparatory meeting)

The Secretariat informed the Group that there were no updates to the Fleet structure for either the North or South Atlantic swordfish stocks since the data preparatory meeting. **Tables 1** and **2** show the fleet structure in detail used for the Stock Synthesis models during the assessment meeting. It was noted that compared to the 2017 Swordfish Stock Assessment (Anon., 2017), for the N-SWO synthesis model, a new fleet was introduced during the data preparatory meeting, the harpoon fleet operating primarily on large-size fish.

4. Summary of relative abundance indices to be used (limited to any updates since the data-preparatory meeting)

Indices of relative abundance submitted by CPC scientists remained largely unchanged from those accepted at the 2022 Swordfish Data Preparatory meeting (Anon., 2022a). The terminal data index value in the Japanese index of abundance was removed in all models for the North and South due to an analysis error. In some model scenarios, additional time blocks were applied to some indices, however these changes were not uniformly applied among the model runs. Specific changes to particular indices are noted in sections 5 and 6.

SCRS/2022/115 presented a combined index of abundance for the North Atlantic swordfish stock. This combined index has been used as a model input since the 1990s and is a collaborative effort between scientists from several CPCs. The 2022 version of the index includes catch and effort information from 7 ICCAT longline fleets: United States, Canada, EU-Spain, EU-Portugal, Japan, Morocco, and Chinese Taipei, which represent over 90% of annual swordfish catch. The index is used as an indicator in surplus production models and there is interest in its potential use as an indicator for a model-based MP in the N-SWO management strategy evaluation.

The version presented in this document differs from previous standardizations in that the finer resolution set-level data were not available for some fleets. ICCAT Task 2 Catch and Effort data were used and then supplemented with additional data submitted by CPC scientists. A delta-lognormal standardization model was applied, accounting for fleet, spatial zone, quarter and year (**Table 3; Figure 1**). The modeled biomass scale and trend were very similar to that calculated in the 2017 standardization (**Figure 2**).

The Group welcomed this index contribution, noting however, that that finer resolution set-level data were not available for some fleets. The Group discussed the advantages and disadvantages of developing and using a combined index versus using separate indices as input data in the models. A particular concern was the lower resolution of the 2022 combined index data. It was noted that it had been conflicts among the CPUEs that spurred initial development of the index in the 1990s. These have persisted and, in many cases, surplus production models have achieved better diagnostic results when using the combined index (e.g., 2017 BSP2), than using the full suite of CPC-provided indices.

The Group requested additional diagnostics which were prepared and presented during the meeting. These included residual plots, coefficients for the random effect residuals, and spatial-temporal distribution of zero catch records. The authors presented several descriptive plots showing the spatial and temporal distribution of catch and effort data (**Figure 3 & 4**). A bimodal distribution was noted in the log CPUEs from the late 1980s to present which characterizes the difference between swordfish targeting and non-target fleets (**Figure 5**). It was further noted that the model predicted large confidence bounds for the 1970s when data sources were sparse due to management regulations and resulting limitations on catch. The Group accepted the index for use in the North surplus production models while noting that the 2022 version of the combined index is likely not capturing important nuance related to gear changes due to the use of T2C&E data rather than use of finer scale data that has previously been submitted by CPCs.

5. North Atlantic Stock

5.1 Methods and Model Settings

To take stock dynamics uncertainty and the quality of data into account, the SCRS routinely considers a range of scenarios comprising alternative model structures and datasets (i.e., size composition) for a single stock assessment. In 2017, several modelling platforms were developed for the North Atlantic swordfish stock, with two being used for management advice: an age-structured integrated model using Stock Synthesis and a Bayesian biomass surplus production model created using BSP2. In 2022, four modelling platforms were presented for the North Atlantic stock: Stock Synthesis (SCRS/2022/124), JABBA (SCRS/2022/114), ASPIC and SPiCT (Lauretta *et al.,* 2020).

5.1.1 Initial Stock Synthesis Model

SCRS/2022/124 presented a preliminary age-structured assessment and model diagnostics for the North Atlantic Swordfish stock using Stock Synthesis. Many of the model settings were similar to the 2017 Stock Assessment (Anon., 2017). The model was an annual, sex-specific, age structured assessment. Natural mortality was fixed at 0.2 for both males and females across all ages. Sex-specific growth curves were fixed at the same values used in the 2017 stock assessment, with females reaching a larger asymptotic size (**Figure 6**). Female maturity was assumed to be 50% at age-5 and 100% for all older ages.

Recruitment was assumed to be dependent on female spawning stock biomass, where fecundity was made a function of body weight. The stock-recruitment function assumed a Beverton-Holt relationship, and initial attempts at estimating steepness failed thus it was fixed at 0.88 (the value estimated within the 2017 Stock Assessment (Anon., 2017)). Alternative model runs assuming steepness values of 0.7 and 0.8 were explored. Recruitment deviations were penalized in the likelihood assuming a lognormal distribution with the standard deviation of log recruitment fixed at 0.2 (the same value as the 2017 Stock Assessment (Anon., 2017)).

Selectivity was modeled as length based and separate selectivity block was added from 1993 onwards to reflect the regulatory change of adopting a minimum size (Rec. 90-02). This meant that two selectivity curves were estimated for each fleet which operated across the regulatory change, one prior to 1993 and another after. Discards were estimated within the model for each fleet using fleet specific retention functions, assumed to be knife edged at 119 cm. Dome shaped selectivity was assumed for EU-Spain, US, Japan, EU-Portugal, and Morocco longline fleets, and asymptotic selectivity was assumed for Canadian longline, Chinese Taipei longline, and “other” fleets (**Figure 7**). The effective sample sizes for the length compositions were calculated iteratively using Francis’ TA1.8 algorithm (Francis, 2011). Direct observations of the percent of sublegal fish dead at haulback were presented for US and CAN fleets from observer data, and for Chinese Taipei and EU-Portugal fleets from previous studies, suggesting an average of 78% of undersized swordfish are dead at-haulback (**Figure 8**). The fleet specific estimates that were available were used as discard mortality in the model while the overall average was used for the remaining fleets.

Several CPUE indices’ catchabilities were informed by the Atlantic Multidecadal Oscillation (AMO) environmental index, which led to better fits to the data and improved model diagnostics. The standard deviations (weighting) for each CPUE series were normalized using the estimated standard errors from the index standardization process such that the minimum standard deviation for each CPUE series (on the log scale) was set at 0.2 and the variability between years was maintained from the standardized estimates.

5.1.2 Additional runs

The Group decided to update the model using the overall average at-haulback mortality, as the estimates of discard mortality for the Chinese Taipei fleet were based on the study by Pan *et al.* (2022), which is the discard mortality reference for the Chinese LL fleet. However, the Chinese fleet has different fishing activities, and the Chinese and Chinese Taipei fleets also operate differently. The Group discussed the 2020 observation of the Japan longline CPUE in both Atlantic stock areas, and it was decided to drop this point from the model (see section 6.1). The Group requested additional runs with 2 different CPUEs. It was noted that the age-specific indices from the EU-Spain longline fleet (**Table 6**) did not appear to be correlated across ages with lags. That is to say, it would be expected in a year where the age-1 index was high that in the following year the age-2 index would increase. Largely, correlations such as these were not evident in the indices. The Group discussed whether the EU-Spain longline CPUE should remain split into age specific indices or rather as an aggregated-age EU-Spain longline index. A model fit to the combined EU-Spain longline index did not improve model diagnostics (**Figure 9**) thus it was decided to stick with the age specific indices for the EU-Spain longline fleet.

The Group also suggested an additional run, fitting to the combined longline index (SCRS/2022/115). The Group agreed not to use the combined index as there was no improvement in the model diagnostics (**Figure 10**). The Group further requested an additional three runs

- Update the maturity at age vector using the estimates from Sharma and Arocha (2017; **Figure 11**)
- The steepness for the base stock assessment model should be set to 0.75, for consistency with the MSE for Swordfish
- Fit to the observed discards and estimate the remaining discards for the fleets which did not report them, instead of allowing Stock Synthesis to freely estimate discards for each fleet.

The Group reviewed the effects of stepwise changes and accepted the update to the maturity vector as the model fit was not affected by the change (Maturity in **Table 4**). However, the Group decided to maintain the initial setting of steepness 0.88 as the model fit was not improved by setting steepness to 0.75 (Mat-h in **Table 4**).

The additional run which included a new maturity vector from Sharma and Arocha (2017), steepness fixed at 0.75, and discard data explicitly being fit within the objective function (for the fleets which reported discards) was not able to converge when fitting to Chinese Taipei and Japan longline discard data. Therefore, it was decided that an updated model run would be conducted with the Chinese Taipei and Japan longline total discards added to their respective landings, to be fit in the model. The Group noted that in some years (2000-2003) the Japan longline fleet discards were quite high and expressed interest in the model accounting for them (**Figure 12**).

The modified additional run that included only the US and Canada longline reported discard data in the objective function (Mat_h_dis in **Table 4**) deteriorated model diagnostic performance. The Group decided on a final base model for North Atlantic swordfish in Stock Synthesis using the new maturity vector, steepness fixed at 0.88, omitting the 2020 Japan longline CPUE data point, placing discards from Japan and Chinese Taipei longline fleets into their landings data, and freely estimating the discards from the remaining fleets.

The Group pointed out the importance of comparing dead discards estimated by Stock Synthesis with that derived from the available fisheries data, in order to more thoroughly ground-truth the Stock Synthesis-estimated dead discards. The Group agreed to continue exploring different model configurations to improve the estimation of dead discards to better match the observed discards. However, the Group stressed that model estimates should not be seen as replacement for actual reporting of dead discards.

The Group requested a comparison between estimated discards from the Stock Synthesis model and those reported by the fleets which reported discards. The Stock Synthesis model estimated that on average, 10.5% of the total removals were attributed to discards, where the reported discards equaled 2.5% of the total removals (**Figure 13**), and it was noted that only 4 fleets reported discards. The final base model for the age structured assessment freely estimated discards for each fleet.

5.1.3 JABBA Model Settings

The stock assessment software 'Just Another Bayesian Biomass Assessment', JABBA, was applied. This most updated version (v2.2.6) of JABBA was used and can be found online at: https://github.com/jabbamodel/JABBA and/ or https://www.iccat.int/en/AssessCatalog.html. The JABBA R package uses Bayesian state-space approaches for biomass dynamic stock assessment models (Winker *et al.*, 2018). The software runs quickly, generates reproducible stock status estimates and has in-built a suite of diagnostic tools. In 2017 a JABBA model was developed for the North Atlantic Stock but was not used for management advice. Methods and model settings are described in more detail in SCRS/2022/114.

Input data included the catch data provided by the Secretariat following the 2022 Swordfish Data Preparatory Meeting (Anon., 2022a). The CPUE indices followed those provided in the Data Preparatory Meeting with one change: the 2020 data point in the Japanese longline index was excluded (see section 6.1 for a detailed description of this change).

A total of 8 JABBA runs were completed for the North (**Table 5**). Two continuity runs were completed using the same model settings and assumptions used in 2017 but with updates to catch data and indices. In the first run, scenario 1 (S1), the nine CPUE indices developed by CPCs (**Table 6**) were used and in the second run, the combined index was used (S2). These continuity runs used a Schaefer production model with the initial model year set to 1950, initial depletion set to 0.85 (s.e. 0.1), r set to 0.424 (s.e. 0.4), and s.e. of 0.25 for all CPUEs, while K was freely estimated.

At the 2022 Swordfish Data Preparatory meeting, it was noted that input priors (r, B_{MSY}/K) related to the production function derived from simulations in an Age Structured Equilibrium Model (ASEM; Winker *et al.* 2020 and Winker *et al.*, 2018) should be tested among the model runs. North Atlantic swordfish life-history variables from Arocha and Lee (1996) and Arocha *et al.* (2003) and other sources and three assumptions on steepness (0.6, 0.75, 0.88) were used in the ASEM to estimate r and B_{MSY}/K (**Table 7**). The priors were used in JABBA models (S3 to S8), with all but S8 using the nine CPC CPUE indices. In all cases, K and initial depletion were freely estimated by the model.

During the meeting, it was noted that there appeared to be conflicts among the CPUEs. Additional runs were developed to test the influence of using differing index groupings. Index grouping 1, used in model S6, included the CPUE indices from Canada, the United States, EU-Spain, and EU-Portugal. Group 2, used in model S7, included indices from Japan, Chinese Taipei, and Morocco. These two index groupings are described in detail in section 5.2.3, below. S8 used the combined index.

The Group suggested that the scenarios include a K prior set to 200 kt with an initial depletion set to 0.85 with a c.v. of 0.4 and a beta distribution. This was done to allow the model to better capture declines in biomass in the early years of the fishery. Models S6, S7, S8 were subsequently run with these new model settings.

Finally, a model scenario with settings largely similar to the 2017 base case BSP2 model was developed, which became the 2022 JABBA reference case:

- Shaefer production model (i.e., B_{MSY}/K = 0.5)
- r-prior set to 0.42 (s.e. 0.4)
- initial depletion prior of 0.95 (s.e. 0.05) with a beta distribution, and
- s.e. for all CPUEs set to 0.23.

The differences between the 2022 JABBA and the 2017 BSP2 model included the updated combined index and catch data, and the use of a beta distribution (vs. lognormal distribution) for the initial depletion which limits the possible range of values to be <1.

5.1.4 ASPIC Model Settings

For the North SWO stock a continuity run was done with a surplus production model (SPM) using the same software (ASPIC-7) as in 2013/2017, with the catch series 1950–2020, and the combined biomass index of abundance (1963–2020). This continuity run used the same assumptions and settings as the 2017 base model: briefly, this involved assuming a logistic production model function, estimating MSY and F_{MSY}, and fixing the B1/K parameter at 0.85.

In addition to the continuity run, the ASPIC model was fitted using the series of indices of abundance reviewed and recommended during the 2022 Swordfish Data Preparatory meeting (Anon., 2022a). A total of 9 indices were available (**Figure 14, Table 6**) and initial runs included all indices assuming that they were proportional to biomass. Model fitting used the least squares (SSE) option in ASPIC, with a parameter B1/K fixed at 0.85, and a logistic (Shaefer) production model. However, due to conflicts in trends between several of the indices of abundance, the ASPIC run with all indices failed to converge to a reasonable solution. An index correlations analysis was performed on the 9 series to identify groups of indices with relatively lower negative correlation among them (**Figure 15**). This analysis suggested two groups of indices; Group 1 included the indices of Canada LL, USA LL, Spain LL, and Portugal LL, while Group 2 included the indices from Japan LL, Chinese Taipei LL, and Morocco LL. The ASPIC model was fitted to each of the group indices assuming that they represent an alternative state of nature of the N-SWO stock.

During the meeting, additional runs of the ASPIC model were explored in particular with the 2022 combined index. These runs included: i) estimating the initial parameter B1/K, and ii) using the maximum likelihood (MLE) estimation in ASPIC for considering the variance associated with each observation of the combined index in the fitting process.

5.1.5 SPiCT Model Settings

An alternative Stochastic Production model in Continuous Time (SPiCT) (Pedersen and Berg, 2017) was used to compare the results of the ASPIC model runs. This surplus production model enables state-space in the catch process with an explicit distinction of noise in-process error and observation error, a feature not available in the ASPIC model. SPiCT model structure is similar to JABBA, including Bayesian or frequentist approaches for fitting while including auxiliary information in the assessment evaluation in the form of priors. The SPiCT model has been routinely used in ICES assessments (ICES, 2019) and had been extensively tested and evaluated, although it is not currently part of the ICCAT software catalog.

SPiCT runs were done parallel to the ASPIC runs and were intended more for comparison and exploration of possible sources of variation, rather than for formulating management advice. These additional analyses presented were done with the SPiCT R package software version 1.3.5 available at https://github.com/DTUAqua/spict under the R-Studio 2022.02.0 version. Settings of the SPiCT models mirrored the setting of each ASPIC run as close as possible, for example, the surplus Logistic function shape was set with a prior on the SPiCT parameter n of 2 and s.e. 0.4, while ASPIC fixed parameter B1/K of 0.85 was implemented in SPiCT with an informative prior for the initial fraction of biomass (logbkfrac) of mean 0.85 with a standard deviation 0.2.

5.2 Model diagnostics

5.2.1 Stock Synthesis

For the preliminary Stock Synthesis model (SCRS/2022/124), fits to the CPUE indices and length compositions were acceptable. Many of the CPUE indices did not pass the runs test (8/13). The Group discussed that this is likely an artifact of the many CPUE indices included in the assessment and that conflict among them is causing the model to compromise and fit through their average, resulting in non-random patterns in residuals for many fits (and thus runs test failures). Hindcast cross-validation results also suggested many Mean Absolute Scaled Error (MASE) values did not predict the indices as well as a random walk. Retrospective patterns for the model were negligible. Likelihood profiles on the log of unfished recruitment suggested a minimum at the estimated value of 6.4 with a steep increase at values below this estimate however quite flat (less increase) above the minimum value, particularly for the index data. The jitter diagnostic showed that the model was largely stable to alternative initial parameter values. A jack-knife analysis also suggested the model was largely insensitive to removal of individual CPUE indices or length compositions. The age-structured production model diagnostic suggested similar stock trajectories of the base model compared to a model fit without recruitment deviations and fixed selectivities (and not fit to compositions).

The diagnostics were largely unchanged for the final Stock Synthesis Reference case, as fits to the CPUE indices were acceptable with a total root mean squared error (RMSE) across all fleets estimated at 25.9% (**Figure 16**). Five of the 13 CPUE indices passed the runs test (**Table 8, Figure17**). Hindcast cross-validation results also suggested many MASE values did not predict the indices as well as a random walk (**Table 8, Figure 18**). Fits to the length compositions were acceptable where total RMSE for observed and expected mean lengths equaled 5.4% (**Figure 16**). Retrospective patterns were negligible, with a Mohn's rho value of -0.02 for spawning biomass and 0.04 for F/F_{MSY} (**Figure 19**).

The Group discussed the merits of using the Stock Synthesis model to estimate dead discards for all fleets. It was agreed that it is important to capture the magnitude of total removals where possible, and thereby estimating dead discards for fleets for which these data are not available is an acceptable approach. However, the Group raised some concerns with replacing the reported dead discards with the dead discards estimated by the Stock Synthesis model, given that there are substantial differences between some of the reported and estimated discards. Approaches were outlined to potentially reduce such discrepancies. CPC scientists are strongly encouraged to compare dead discard estimated by Stock Synthesis to available data from the fisheries, to more thoroughly ground-truth the Stock Synthesis-estimated dead discards. The Group agreed to continue exploring different model configurations to improve the estimation of dead discards to better match the observed discards.

Based on the most important model diagnostics (described above), the Group agreed to the Stock Synthesis reference case for projections. An expanded set of diagnostics for the adopted reference case will be presented at the September 2022 Species Group meeting.

5.2.2 JABBA Model Diagnostics

All model runs were assessed with a common set of diagnostics and then evaluated for biological plausibility relative to previously accepted assessment models. Diagnostics followed Carvalho *et al.* (2021) and included examination of patterns within and among CPUE residuals via residuals plots and runs tests. Goodness-of-fit was estimated using root mean squared error (RMSE). Model convergence was evaluated with MCMC trace plots. In all scenarios described in section 5.1, MCMC traces indicated model convergence (**Figure 20**). Prior to posterior plots and median ratios were evaluated for all model scenarios. Due to the large number of scenarios, only a subset of models underwent further diagnostics tests with CPUE jackknife and hindcasting using MASE and retrospective analysis (model scenarios 3, 8, and the reference case).

The continuity run that used all the individual indices available in 2017 versus the same updated 2022 indices showed large discrepancies in terms of the state of the stock. This discrepancy appears to relate to a change that occurred in one or more of the indices rather than conflicts between indices that existed in the 2017 and the 2022 models. Continuity of models using the combined index with the 2017 assessment was stronger, exhibiting similar scale and trends in relative biomass and F. Further work is recommended to understand whether differences between the 2017 and 2022 versions of the indices are responsible for the stock status differences.

Models used one of four CPUE data inputs: all nine CPC data indices, group 1 or group 2 indices, or just the combined index. Models using all nine indices had similar fits to the data in all JABBA runs Overall root mean square error was ~28% in all cases, which is considered in the high range of a RMSE "pass" (30% being the RMSE "pass" cutoff). The index with the longest historical series is the Canadian longline index. Early in this CPUE time series there is a large positive residual associated with the Canadian index, followed by seven successive years of negative residuals, which indicates a possible poor fit to a biomass decline early in the history of the fishery. Additional residual patterns in the time series appeared to be associated with possible temporal autocorrelation patterns in the Spanish, US, and Chinese Taipei longline indices. These three indices, along with the Japanese late and Canadian longline indices often failed the runs tests. This suggests data-conflicts caused by opposing trends when compared to the other CPUE time series, as well as the presence of outliers. CPUE jackknife analysis showed a widespread in the scale of the B/B_{MSY} and F/F_{MSY} trends. The CPUE with the greatest impact when removed from the model was the Canadian longline index which resulted in a much lower biomass from 1985 and onward but the overall trend largely matched other jackknife runs. Similarly, removal of the Canadian index results in much higher fishing mortality from 1985 and onward. This is likely due to the Canadian longline index being the longest (1963-2020), and the model therefore relies heavily on this index to describe the initial decline due to fishing. The retrospective analysis indicated no obvious patterns and Mohn's rho values in all scenarios were very close to zero.

For model scenarios using steepness priors (S3-5), process error deviates were above zero in the last five years of the assessment time series (i.e., 2015 onwards). Combined index scenarios, on the other hand, showed processes error becoming negative around 2005 before increasing to zero in 2018. The process error deviates remain close to zero in the terminal assessment year. This pattern corresponded to a negative trend in the combined index from 2005 to 2015, followed by a steady increasing trend to the terminal assessment year.

To explore CPUEs conflicts further, two grouping of positively correlated indices were identified, described in section 5.1. The JABBA model was fitted to each group of indices assuming that they represented alternative states of nature of the N-SWO stock. Group 1 indices (Canada, Portugal, Spain, USA) resulted in implausibly high B/B_{MSY} ratios and implausibly low F/F_{MSY} ratios over the entire model time series (e.g., B/B_{MSY} never declined below 1.5). RMSE for this run was 21%, however, two of the four indices failed the runs test showing temporal autocorrelation patterns. Group 2 indices (Japan 1 & 2, Chinese Taipei 1 & 2, and Morocco) resulted in a higher RMSE (28%) but all indices passed the runs tests. F/F_{MSY} and B/B_{MSY} time series roughly matched the pattern and scale of the previous SWO assessments however the uncertainty bounds around the estimates were very large.

Model scenarios 2, 8, and the reference case used the combined index. In all cases, the index failed the runs test (**Figure 21**). However, RMSE was 18% or less (**Figure 22**). In cases where the combined CPUE was used, B/B_{MSY} and F/F_{MSY} scale and trend appeared more plausible given previous accepted model results and relative to indices using all nine CPC indices (which tended to show implausibly high levels of biomass throughout the time series).

The Group discussed differences in model outcomes among the CPUE data input groupings. Inclusion of all nine CPC CPUE indices or use of the Group 1 indices resulted in model estimates that the Group judged implausible. Use of the combined index or Group 2 indices resulted in biomass and fishing mortality estimates more consistent with previously accepted assessment models. The Group discussed the similarities and differences of the fleets included in CPUE groupings, for example, fishing location (inshore vs offshore) and targeting (target swordfish fishing vs bycatch) fishing. Despite identifying several similarities and differences, the Group was unable to attribute a common set of characteristics to each CPUE grouping. Additional analyses are required to understand why some CPUEs covaried while others did not. Based on the diagnostics and results, all the models using individual indices were considered inappropriate for management advice. Model scenario 2 was selected based on diagnostic tests (**Figures 23**, **24**, and **25**) and biological plausibility.

5.2.3 ASPIC Model Diagnostics

A presentation was provided on the preliminary results of the continuity case for the N-SWO fit with the ASPIC model (SCRS/2022/119). The continuity runs included two scenarios; a) continuity 1 (Cont1) where only the catch series was updated (1950 -2020) and used the 2017 Combined biomass index and b) continuity (Cont) case where the catch series was updated and included the 2022 Combined biomass index. These runs were evaluated because of the changes in the protocols for the data input in the 2022 Combined biomass index estimation, compared to the previous (2017, 2013, 2009) versions of this index.

Adding only the catch from 2016 to 2020 (and keeping the index used in 2017 unchanged) to the model produced very similar trends and benchmark estimates as in the 2017 run (**Table 9, Figure 26**). However, when replacing the Combined biomass index with the 2022 version, the trends of absolute biomass and fishing mortality varied, as also the benchmark estimates (**Table 9, Figure 27**). Both runs converged to a solution, and bootstrapped runs (1000) were completed with no indication of hitting boundaries. Other diagnostics indicated a good contrast (Ludwig and Hilborn 1985, Magnisson and Hilborn 2007) in the index information (0.49, Prager *et al.* 2016, **Figure 28**). The retrospective runs of removing up to 5 years of data (**Figure 29**) show some patterns with estimated Mohn's Rho values of 0.02 for F/F_{MSY} and -0.007 for B/B_{MSY}. The ASPIC run with all 9 indices of abundance indicated a negative correlation between several indices and although it converged to a solution, the diagnostic of the run (Prager 2016) indicated low contrast on predicted biomass and the indices (0.35, Prager 2016) as well as low estimated nearness index (0.15). The bootstrap runs for this model failed, having several of the runs hitting the boundary parameters repeatedly. Fitting the ASPIC model to each of the indices groups showed some improvement in the fits although they still reported a negative correlation among indices.

With the group 1 indices, the ASPIC fit run diagnostics indicate a low estimated contrast index (0.32) and low estimated nearness index (0.23), **Figure 30** shows the index fits and predicted biomass and fishing mortality trends. Bootstrap runs were completed with 5 out of 1000 hitting the F_{MSY} boundary. The retrospective runs indicated no particular pattern for the relative biomass or fishing mortality trends with estimated Mohn's Rho values of 0.001 and -0.004, respectively (**Figure 31**).

ASPIC fit to the group 2 indices show systematic problems in finding a stable solution. A further review of the indices, specifically a lag 1-year difference analysis (**Figure 32**) showed that the two initial observations of the Chinese Taipei LL index imply a large variation of about 3-fold of the relative stock biomass in a single year that the SPM can't fit with the rest of the input data. It was then decided to exclude these two observations (1977 and 1978) from the CTP LL index and rerun the ASPIC model (Group 2A run). This Grp2A model converged to a stable solution and diagnostics indicated a good contrast index (0.52), and high estimated nearness index (1.0, Prager *et al.* 2016), **Figure 33** shows the index fits and predicted biomass and fishing mortality trends. Bootstrap runs were completed with one run hitting the F_{MSY} boundary value. However, the retrospective runs indicated a strong pattern for the relative biomass or fishing mortality trends with estimated Mohn's Rho values of 0.64 and -0.391, respectively, in particular when removing the last 3 years of data (**Figure 34**).

For the ASPIC runs with individual indices of abundance a Jackknife diagnostic test was run by removing one index of abundance at the time and then re-fitting the model with the same specifications. Results of this test for the group 1 and group 2A indices are presented in **Table 10** and **Figure 35.**

Additional runs performed during the meeting with ASPIC included the estimation of the initial depletion biomass B1/K parameter with the 2022 combined index. This run results indicated a stable solution with an estimated contrast index of 0.58 and an estimated nearness index of 1.0, **Figure 36** shows the index fit and predicted biomass and fishing mortality trends. Bootstrap runs were completed but several (375 out of 1000) runs hit the bound for the B1/K parameter. The retrospective runs indicated a pattern for the relative fishing mortality trend in particular with estimated Mohn's Rho values of 0.028 and -0.004 for the relative biomass (**Figure 37**). Switching to the MLE estimation fitting method in ASPIC for the model with the 2022 biomass index and fixed B1/K at 0.85 converged to a stable solution and diagnostics indicated a good contrast index (0.50) and high estimated nearness index (1.0), **Figure 38** shows the index fits and predicted relative biomass and fishing mortality trends. Bootstrap runs were completed without any run hitting boundary parameters or not converging to a solution. The retrospective runs indicated a pattern, particularly for the relative fishing mortality (Mohn's Rho = -0.015) but less of a pattern for the relative biomass trends (0.014) (**Figure 39**).

5.2.4 SPiCT Model Diagnostics

One of the advantages of the SPiCT package is that within the software there is a complete series of model fit diagnostics for each run, facilitating the rapid evaluation of the model results. Model fit and results were evaluated following the guidelines of the SPiCT software developers (Pedersen *et al.*, 2021), and consistent with diagnostics recommended by the Group at the Data Preparatory meeting (Anon. 2022a). Briefly, a) model run convergence (e.g. fitoptconvergence equals 0), b) all variance parameters of the model are estimated and finite (all(is.finite(fit$sd)) = TRUE), c) no violation of model assumptions based on one-step-ahead residuals (bias, auto-correlation, normality) *p*-values not-significant (>0.05), d) consistent patterns in the retrospective analysis with calculation of the Mohn' rho estimator, e) realistic surplus production curve, with estimate value between 0.1 and 0.9 (calc.bmsyk(fit)), e) relative realistic variance parameters (logsdb, logsdc, logsdi, logsdf) with credible intervals for B/B_{MSY} and F/F_{MSY} that should not span more than 1 order of magnitude (calc.om(fit)), and f) check that initial values do not influence the parameter estimates (fit$check.ini$resmat) a "jitter test". Plots of residuals, one-step ahead (OSA) residual diagnostics, trends of biomass and fishing mortality, and production curves were produced for each case.

5.3 Stock status results

5.3.1 Stock Synthesis

Maximum likelihood estimates of SSB_{MSY} and F_{MSY} from the base SS3 model were 23,666 t and 0.16, respectively. Estimated total virgin biomass was 265,751 t and estimated virgin SSB was 120,466 t, resulting in a B_{MSY}/B_0 of ~ 0.20. MSY, including all removals (catch + discard) was estimated at 12,838 tons. Time series of maximum likelihood estimates of B/B_{MSY} indicate that at the start of the time series B/B_{MSY} = 5.01, decreased to a minimum of 0.76 in the year 2000, and subsequently increased to a terminal year estimate of 1.11 (**Figure 40**). Similarly, time series of maximum likelihood estimates of F/F_{MSY} indicate that it increased to a maximum value of 1.47 in 1995 and subsequently decreased to end the time series at 0.78 (**Figure 40**).

5.3.2 JABBA

Of the eight JABBA model scenarios prepared for the North, the Group selected the scenario 2 model (**Table 5**) with slight changes noted in section 5.1.3. The results suggest that the reference case model is stable and provides a reasonably robust fit to the data as judged by the presented model diagnostic results. Summaries of posterior quantiles for parameters and management quantities of interest are presented in **Table 11**. The MSY estimate is 12,799 t (10,864 – 15,289) and the median marginal posterior for B_{MSY} was 92,173 t (58,624 - 152,156 t). The F_{MSY} median estimate is 0.39 (0.08 - 0.227). There is a difference in estimated productivity between the 2017 BSP2 assessment (MSY = 14,400 t) and the current; the former estimated a slightly more productive stock. The Group noted that catch levels have been 4 – 5 thousand tonnes below MSY since the 2017 Stock Assessment (Anon., 2017). It was noted that the index input for this model, the combined index, in 2022 used a different level of resolution of the input data than the 2017 version which largely used set level catch and effort Data. It is unclear if the inclusion of this new index has resulted in a lower overall productivity estimate, however, the same pattern and scale in biomass, as well as productivity, was observed in the model scenario using Group 2 indices (12.8 kt vs 12.6 kt MSY, respectively).

The estimated B/B_{MSY} trajectory (**Figure 41**) gradually declines from the 1950s, dropping below B_{MSY} in 1994 before increasing back to B_{MSY} in 2004. Biomass then declines to approximately 0.8 B_{MSY} by 2014, increasing again from 2016 to the current estimated $B/B_{MSY}=0.91$. The F/F_{MSY} trajectory steadily increases to peaks in the late 1980s, and in the mid-1990s, and a more minor peak in 2012 - in each of these cases exceeding F_{MSY}. Since the F/F_{MSY} peak in the 2010s, F has declined and is now at approximately F/F_{MSY} 0.9 (0.6 – 1.31). The JABBA surplus production phase plot (**Figure 42**) showed a typical anti-clockwise pattern in the surplus production. Catches exceeded MSY for several years (mid-1980s to 2000 and again in the early 2010s) while biomass has stayed at or below B_{MSY} from 1994.

5.3.3 ASPIC

Results of the continuity runs indicated consistency with the 2017 Stock Assessment (Anon., 2017), showing similar trends in biomass and fishing mortality, however with the updated combined biomass index, the final status and estimates of benchmarks differ. The continuity run with the 2022 combined index resulted in a less productive stock, with a lower overall biomass trend (**Figure 27**). This is due to the index itself and not the updated catch series for the 2016-2020 period. It was noted that the combined index in 2022 used a different level of resolution of the input data, 2017 and previous versions of the combined index used the observation of catch and effort by fishing sets for most fleets, while in 2020 due to issues with confidentiality, data was gathered mostly from the Catch and Effort of Task2-CE ICCAT database, supplemented with some CPC national data provided. This level of data resolution prevented the inclusion of some information particularly on fishing gear type and their changes within fleets through the years. **Table 9** shows a comparison of the estimated parameters from the 2017 base case SA and the 2022 ASPIC continuity runs.

All ASPIC runs with the individual indices of biomass, either all together or the associated indices of groups 1 and 2, indicating a stock with much higher productivity (**Table 12**). In the case of the group 1 runs, the stock trend showed that it has never been exploited below the estimated B_{MSY}, or that fishing mortality has surpassed the estimated F_{MSY} (**Figure 30**). In the case of the group 2 runs, it was necessary to exclude some observations from the CTP LL index in 1977/78 to reach a stable solution, and in this case, the trends of fishing mortality and biomass were more comparable with the 2017 Stock Assessment (Anon., 2017), with the stock becoming overexploited after 1986, and the biomass being below B_{MSY} since then (**Figure 33**). This run, however, showed a strong retrospective pattern, and the relative trend changed drastically after eliminating the latest 3 years of data (**Figure 34**). These results in general were considered not consistent with previous stock assessments and the general perception of the N-SWO stock productivity.

The ASPIC runs with the estimation of the initial depletion biomass parameter B1/K and the 2022 combined index showed a more comparable trend of biomass and fishing mortality with the 2017 Stock Assessment (**Figure 36**). This run indicated that the stock experienced increasing exploitation (e.g., fishing mortality) from the 1960s to the early 1980s coinciding with increased catches in the 1960s, a relative slow down during the 1970s coinciding with the ban on some fisheries associated with the swordfish mercury bioaccumulation, followed by an increase in catches and mortality through the 1980s when the fishing mortality surpassed the estimated benchmark of F_{MSY} in 1986. As fishing rates continue to be above F_{MSY}, the stock biomass continued declining and by 1996 the biomass fell below B_{MSY}. Since the peak catches in

1986 were close to 20 thousand tones, catches decreased with some stabilization at around 15 thousand t in the 1991-96 period, but they were still above MSY, which continued to keep the stock in overfished status with fishing mortality also above the F_{MSY} benchmark. Only since 2014 when catches have dropped to around 10 thousand t, fishing mortality shows a decreasing trend although still above F_{MSY} and consequently, the biomass of the N-SWO stock remains still below B_{MSY}. By 2020, the terminal year of the current assessment, the stock was estimated at 0.86 B/B_{MSY} (0.75 – 1.01 80% CI) with relative fishing mortality of 1.11 F/F_{MSY} (0.91 – 1.34 80% CI) (**Table 13**).

Integrating into the ASPIC fit the variance associated with the 2022 combined index by using the MLE estimation (**Figure 38**) also show a comparable trend of biomass and fishing mortality with the 2017 Stock Assessment (Anon., 2017). In general, this run shows the decreasing trend of biomass since the 1960s, reaching overfishing status in 1986 and being overfished since 1994. The stock shows a decreasing trend of fishing mortality since 2014, with F/F_{MSY} just below 1 in 2018 when catches drop below 10 thousand t. By 2020, the stock status was 0.86 B/B_{MSY} (0.77 – 0.94 80% CI) and 1.05 F/F_{MSY} (0.93 – 1.20 80% CI) (**Table 13**). Compared to the run with that estimated B1/K, both models show a similar stock status and similar trajectories for the relative biomass and fishing mortality, however, the ASPIC MLE run indicates a more productive stock compared to the ASPIC Cont B1/K, with estimates of *r* of 0.140 and 0.187, respectively.

5.3.4 SPiCT

As the runs of SPiCT were not intended for management advice, but rather for comparison and diagnostics evaluations of the ASPIC runs, no results of the SPiCT are included in this report. Results of preliminary runs with SPiCT are provided in SCRS/2022/119.

5.4 Projections

5.4.1 JABBA

Stochastic projections were conducted for the JABBA base case model with 22 constant catch scenarios (0; 9,000 – 16,000 t) and the annual medians of B/B_{MSY} and F/F_{MSY} are provided in **Figures 43 and 44**. The initial catches for 2021-2022 were set to 10,476 t, which is the catch of the final year (2020) available in the catch data, and the projections were run until 2033. The projections sample the posteriors for all parameters including the leading parameters (r and K), the observation error parameters, and the process errors to propagate the uncertainty in these quantities to the future stock status. The Kobe 2 Strategic Matrices (**Table 14**) show the probability that overfishing is not occurring ($F<=F_{MSY}$), stock is not overfished ($B>=B_{MSY}$) and the joint probability of being in the green quadrant of the Kobe plot (i.e. $F<= F_{MSY}$ and $B>= B_{MSY}$). Equilibrium MSY is estimated to be 12,800 t however, considering process error, only catches up to 12,600 t are expected to allow the population to surpass and remain above the B_{MSY} throughout the projection time period with a greater than or equal to 50% probability. Future constant catches of 13,200 t (the current TAC) will result in a 46% chance that $B/B_{MSY} >1$ by 2033. If catches were to remain similar to the current catch (10,476 t), there is greater than or equal to 60% probability that the stock will be in the green quadrant by 2028.

5.4.2 Stock Synthesis

It was not possible to complete stock synthesis projections during the meeting. These will be completed and presented at the September 2022 Species Group meeting.

5.5 Synthesis of stock assessment results

The Group discussed the merits of the modeling platforms used to provide estimates of northern Swordfish stock status and considered both the number of models that would be used to provide advice as well their relative weighting in the projections used to generate the Kobe matrices.

The primary platforms considered were Stock Synthesis, ASPIC and JABBA. The principal difference in the parameterization and data used by these platforms is shown in **Table 15** and the resulting trends in F/F_{MSY} and B/B_{MSY} under a range of catch scenarios is depicted in **Figure 45.**

The B/B_{MSY} trajectories in SS3 and JABBA are highly divergent in scale for the first 40 years of the time series due to structural differences. From1995 and onwards, the scale and trend become very similar, with minor divergences from 2010 onward. In the terminal year, SS3 estimates that biomass slightly exceeds B_{MSY} while JABBA estimates the stock to be slightly below B_{MSY}. F/F_{MSY} trajectories between the modeling platforms are very similar in trend and scale with SS3 estimating a slightly lower F/F_{MSY} over the course of the time series. Both models estimate F to be below F_{MSY} in the terminal year.

It was noted that Stock Synthesis likely underestimates the overall stock status uncertainty, because it has a number of fixed parameter values that limit the posterior uncertainty intervals, and that at least one of the surplus production models could be used to characterize the additional uncertainty. Given that both ASPIC and JABBA would give more weight to surplus-production-model-based results if both were used in the integrated advice, it was initially suggested that SS and the surplus production model receive equal weights for the projections.

Noting that the 2017 Stock Assessment (Anon. 2017) advice for the northern swordfish stock was based on the integrated results from a single Bayesian surplus production model and a Stock Synthesis model, the Group decided that the 2022 advice would be based on the equally weighted and integrated outcomes from the base JABBA and Stock Synthesis models. Although ASPIC would not be used in projections, it would be used to describe stock status.

Because it was not possible to do the projections using Stock Synthesis at the meeting, it was not possible to generate a joint Kobe distribution for the projected status of the stock. This work will be completed intersessionally and will be provided at the 2022 Species Group meetings.

6. South Atlantic Stock

6.1 Methods and model settings

During the meeting, the Group examined two stock assessment methods, JABBA (SCRS/2022/117) and Stock Synthesis (SCRS/2022/116), for South Atlantic swordfish.

6.1.1 JABBA

The stock assessment software 'Just Another Bayesian Biomass Assessment', JABBA, was applied in the 2022 South Atlantic Swordfish Stock Assessment (Anon., 2022b). This most updated version (v2.2.6) of JABBA was used. JABBA is a fully documented, open-source R package (www.github.com/JABBAmodel) that has been formally included in the ICCAT stock catalogue (https://github.com/ICCAT/software/wiki/2.8-JABBA) and management advice for the 2017 Swordfish Assessment was derived from the JABBA model results (Anon., 2017).

Model settings

For the unfished equilibrium biomass *K,* we used default settings of the JABBA R package in the form of lognormal prior with a large CV of 100% and a central value that corresponds to eight times the maximum total catches and is consistent with other methods such as Catch-MSY (Martell and Froese, 2013) or SpiCt (Pederson and Berg 2017). Initial depletion was input as a "beta" prior ($\varphi = B_{1950}/K$) with mean = 0.95 and CV of 5% (**Table 16**). This distribution is considered more appropriate than a lognormal for initial depletion, given the understanding that there was very little fishing before the starting year of 1950. All catchability parameters were modelled with uniform priors, while additional observation variances were estimated for index by assuming inverse-gamma priors to enable model internal variance weighting. Instead, the process error of $\log(B_y)$ in year y was estimated "freely" by the model using an uninformative inverse-gamma distribution with both scaling parameters set at 0.001. Observation errors for CPUE estimates were fixed at 0.25 (**Table 16**).

Initial scenarios (SCRS/2022/117) considered three alternative specifications of the Pella-Tomlinson model type based on different sets of r priors and fixed input values of B_{MSY}/K. The input r priors for scenario (S1) are identical to those used in the previous two assessments (McAllister, 2014 and Winker *et al.*, 2017). The input r priors for scenarios S2 and S3 were objectively derived from age-structured model simulations (see details in Winker *et al.* 2019 and Winker *et al.*, 2018b), based on two different growth models for South Atlantic swordfish provided by Garcia *et al.* (2016) and Quelle *et al.* (2014), respectively, as well as other biological parameters (**Tables 17** and **18**).

This allowed for the parameterizations considered for the Stock Synthesis model to be based on range of stock recruitment steepness values for the stock-recruitment relationship (h = 0.6, h = 0.7 and h = 0.8), while admitting reasonable uncertainty about the natural mortality M (CV of 30% and the central value mean value of 0.2). Based on sensitivity analysis of the initial runs of S2 and S3, including the three 'steepness-specific' r input priors, a corresponding steepness of h = 0.7 was selected by the Group. This translates to an associated lognormal r prior of $\log(r) \sim N(\log(0.155),0.117)$ and a fixed input value of B_{MSY}/K = 0.38 for S2, and a lognormal r prior of $\log(r) \sim N(\log(0.138),0.1)$ and a fixed input value of B_{MSY}/K = 0.37 for S3 (**Table 19**).

Input data for the three initial scenarios (S1-S3) included the catch data (**Figure 46**) provided by the Secretariat following the 2022 Swordfish Data Preparatory Meeting (Anon., 2022a) with the agreed fleet structure (see Section 3), and the following indices of abundance (**Table 20** and **Figure 47**):

- Brazil longlines (1994-2020)
- EU-Spain longlines (1989-1999; 2000-2019)
- Japan longlines (1976-1993; 1994-2020)
- Uruguay longlines (2001-2012)
- Chinese Taipei longlines (1968-1990; 1998-2020)
- South Africa longlines (2004-2020)

With the exception of the EU-Spain longline index, the CPUE indices followed those provided in the 2022 Atlantic Swordfish Data Preparatory Meeting (Anon., 2022a). The authors reviewed the treatment of this index in the 2017 Stock Assessment (Anon., 2017) that indicated the implementation of a time-block for the EU-Spain longline index in 1999/2000 to account for the introduction of the "American-style" longline gear in the Spanish fleet had likely caused changes in swordfish catchability (García-Cortés *et al.*, 2010). The authors of the EU-Spain longline index noted that the CPUE standardization process included *gear* as a factor to account for this change. However, the Group was concerned that residual fits indicated that this change may not have been entirely captured in the CPUE standardization.

The results of an experimental study (Mejuto *et al.* 2011) on differences in catchability between American style longline and traditional gear were provide to the Group. The American-style gear was estimated to have 1.7 times the standardized catch rates. The Group compared the CPUE GLM model coefficients for the parameter *gear* to the estimated change in catchability between the two gear types to assess if the standardization process was fully effective. This comparison suggested that the inclusion of *gear* in the CPUE standardization did not fully account for the change in catchability as a result of changing gears. The catchability coefficient (q) estimated within JABBA for the "American-style" gear was approximately 1.5 times more than that of the "traditional" gear, indicating higher catch rates in the former despite the CPUE standardization process. The Group agreed to maintain the decision at the 2017 Stock Assessment (Anon., 2017) to split the EU-Spain longline index at 1999/2000.

The three initial model JABBA scenarios (S1-S3) were discussed as possible reference cases for the 2022 South Atlantic Swordfish Assessment (Anon., 2022b). Scenario one (S1) was a continuity run with the same r priors following expert knowledge used in the 2013 and 2017 Stock Assessments (Anon., 2014 and Anon., 2017). The Group suggested the priors for r be more objectively derived. Although Widely Applicable Information Criterion (WAIC) of the model fit approach was suggested for the model selection between S2 and S3, the Group considered that the scenario based on the sex-specific growth model (S2) by García *et al.* (2016) was more appropriate given the observed sexual dimorphism in swordfish growth. The Group agreed that the Reference case included a lognormal r prior of $\log(r) \sim N(\log(0.138),0.1)$ and a fixed input value of B_{MSY}/K = 0.37, with steepness h = 0.7.

The Group discussed the recent trends of the standardized CPUE series, and recognized conflicts among them and the increased uncertainties of the Japan longline index since 2012 (more than 0.3 of CV, **Table 20**). An additional run was suggested by weighting all of the indices with their coefficient variance to account for recent uncertainties. As CPUE indices are derived from various models, their CV's are generally not comparable. Therefore, weighting was done by normalizing all CPUE time series to an average of 0.25, thereby allowing the model to identify years with high variability while maintaining comparability between indices. However, there was little influence in the results (**Figure 48**); the Group agreed with the original assumption to use the fixed SD of 0.25.

The Group had a long discussion on the Japan longline index and requested that the authors of the index provide the nominal catch and effort series in the North and South Atlantic and review the treatment of the index in the 2017 Stock Assessment (Anon., 2017). The Group confirmed that both catch and effort have been steadily decreasing since the mid-2000's (**Figure 49**). The authors noted that the area of operation of the Japanese fleet in the South Atlantic has been shrinking since the early 2000s (it was also shrinking in the North Atlantic). There was debate as to whether a shrinking operational area would influence the CPUE standardization process for a bycatch species, where it was noted that standardization was run using a Geostatistical model, and therefore may have predictive implications given a shrinking area. While producing the graphs, errors in the catch and effort data for 2020 became apparent. The Group agreed, for both North and South stocks, to remove the 2020 annual CPUE estimate.

The Group was informed that the 2017 Stock Assessment (Anon., 2017) included a third time block split at 2005/2006 for the Japanese CPUE index to account for changes in fishing methods that might not be adequately captured in the standardization process, and this treatment improved the model fit. Kai and Yokawa (2014) noted that some changes in fishing operations might have occurred during the same period, such as the prohibition of retention that resulted in increased discards (2000-2005) and a shift toward shallower gear settings in the high latitude areas of the South Atlantic from the mid-2000's. The Group, therefore, decided to maintain consistency with the 2017 Stock Assessment and split the Japanese series in 2005/2006.

The final JABBA Reference case model settings are:

- the input r prior was objectively derived by García *et al.* (2016): a lognormal r prior of $\log(r) \sim N(\log(0.138),0.1)$
- a fixed input value of $B_{MSY}/K = 0.37$, with steepness $h = 0.7$.
- CPUEs
    - Brazil longlines (1994-2020)
    - EU-Spain longlines (1989-1999; 2000-2019)
    - Japan longlines (1976-1993; 1994-2005; 2006-2019)
    - Uruguay longlines (2001-2012)
    - Chinese Taipei longlines (1968-1990; 1998-2020)
    - South Africa longlines (2004-2020)

6.1.2 Stock Synthesis

The Stock Synthesis model (V3.30.18) was applied to South Atlantic swordfish as the first ever integrated age-structured model for this stock (SCRS/2022/116). The model was parametrized as a one-area, sex-specific stock with a temporal domain of 1950-2020. The annual catch, as according to the agreed fleet structure (**Table 20**), was provided by the Secretariat and the following standardized CPUE series from the 2022 Data Preparatory meeting (Anon. 2022a) were used in the model.

- Brazil longlines (1994-2020)
- EU-Spain longlines (1989-2019)
- Japan longlines (early 1976-1993; late 1994-2020)
- Historical Uruguay longlines (1982-2012)
- Chinese Taipei longlines (early 1968-1990; late 1998-2020)
- South Africa longlines (2004-2020)

Length-composition data were compiled by the Secretariat and covered most of the fleets operating in the South Atlantic (**Figure 50**). These data (lower jaw fork length, LJFL) were modeled assuming a multinomial distribution with 5 cm length bins (20 - 435 cm range). The effective sample sizes were equal to the natural logarithm of the number of observations, to reduce the effect of pseudo-replication in sampling and decrease the weight of length data in the overall model likelihood. The main life-history parameters used in the parametrization of the Stock synthesis model are provided in **Table 21**.

A standard Beverton-Holt stock recruit relationship was assumed with steepness and sigmaR being fixed at 0.7 and 0.4, respectively. The equilibrium recruitment (R0) was freely estimated without a prior. Deviations from the stock-recruitment ε were assumed to follow a lognormal distribution where recruitment deviations $\varepsilon_t \sim \mathrm{N}(0, \sigma_R^2)$. ε_t were constrained to be minima and maxima of -5 and 5, respectively. Recruitment deviations were assumed to be zero until the start of the informative data on size structure (i.e., continuous length composition series from the main fleets), and annual deviates were therefore only estimated from 1991 to 2017. Adjustment of bias correction on recruitment was set using the *r4ss* R package tuning suggestion. The Dirichlet-multinomial likelihood was applied for data-weighting for length composition data and an "additive variance" parameter was added to each CPUE.

The Group asked which Uruguayan longline index was included in the Stock Synthesis model. The authors noted that the initial model used the historical index in 1982-2012. The Group indicated that this was different to the discussions at the 2022 Atlantic Swordfish Data Preparatory meeting (Anon. 2022a), and subsequent to this discussion, the Uruguayan index derived from the observer program (2001-2012) was substituted and the model rerun. Following the discussions on the use of the EU-Spain longline index in JABBA, the same treatment to split the index at 1999/2000 was applied in the revised runs. The following indices were used in the final SS model runs:

- Brazil longlines (1994-2020)
- EU-Spain longlines (early 1989-1999; late 2000-2019)
- Japan longlines (early 1976-1993; late 1994-2020)
- Uruguay longlines (2001-2012)
- Chinese Taipei longlines (early 1968-1990; late 1998-2020)
- South Africa longlines (2004-2020)

Selectivity was parameterized as length-based for all fleets, with the model freely estimating the selectivity parameters. For the base case model, selectivity was assumed to be an asymptotic shape for all fleets ("Sel_Asym_model"). Examination of the fit indicated a poor length composition fit for some fleets, so the authors explored an alternative model ("Sel_DN model"), with the same parameters as the "Sel_Asym_model", except that the selectivity shapes of the fleets from Brazil, EU-Spain (first period), Japan (first period), and Chinese Taipei (both periods), which were set to be dome-shaped. Model diagnostics were assessed using the Carvalho *et al.* (2021) flow chart, using the R packages *ss3diags* and *r4ss* (Taylor *et al.*, 2021; Winker *et al.*, 2022).

Due to time constraints, including a scenario with the agreed treatment of the Japanese index, as presented in JABBA was not possible

6.2 Model Diagnostics

6.2.1 JABBA

At the 2022 Atlantic Swordfish Data Preparatory meeting (Anon. 2022a), the Group decided that the model evaluation diagnostics should follow the principles in Carvalho *et al.* (2021). The model trace plots indicated adequate convergence in all models, including the reference case. The reference case model appeared to fit CPUE data reasonably well, and the goodness-of-fit was estimated to be RMSE = 19.1% (**Figure 51**). The residual patterns in the beginning of the time series are driven by the CTP1 index, which is the main "historical" index. The initial conflict observed toward the end of the time series between the Japanese index and the other indices in S1-S3 was seemingly resolved through the use of the time-block. Run tests conducted on the log-residuals indicated that the CPUE residuals may not be randomly distributed for four of the ten indices: BRA, EU-SPN1, EU-SPN2 and CTP1 (**Figure 52**). This suggests data-conflicts caused by the opposite trends when compared to the other CPUE time series, as well as the presence of outliers. The Jackknife sensitivity analysis of CPUE indices showed that removing either of the Chinese Taipei indices resulted in the most optimistic stock status with *F/F_{MSY}* falling below one in both cases. This is likely due to the CTP1 index being the oldest (1968-1990), and the model therefore relies heavily on this index to describe the initial biomass decline due to fishing. In contrast, removing the Brazilian index resulted in the most negative status (**Figure 53**). However, B/B_{MSY} remained below one regardless of the removal of any of the indices.

The estimated process error deviations show a negative trend for the period 2015-2020 (**Figure 54**), which is likely the result of an overall decrease in landings since the mid 1990's as well as observed negative CPUE trends in recent years (BRA, CTP2 and ZAF). Thus, the model interprets the stock's productivity as having been below average in recent years. This is further exacerbated by the removal of the JPN3 annual estimate for the year 2020, as previously discussed, the effects of which can be seen in the retrospective analysis when comparing process error deviations between 2019 and 2020. A retrospective analysis for five years was run (**Figure 55**), which shows minimal retrospective deviations from the full model for B and B/B_{MSY} and the associated Mohn's rho fell within the acceptable range of -0.15 and 0.20 (Hurtado-Ferro *et al.* 2014; Carvalho *et al.* 2017). However, there is a notable difference in the process error deviations and fishing mortality between the full model and the model where 2020 is removed. This can be attributed to the removal of the 2020 annual estimate of the Japanese index. The removal drastically decreases the process error deviation estimate and increases fishing mortality. However, this is limited to 2020 and the remaining retrospective analysis has consistency.

The prior to posterior median ratio (PPMR) for r was close to 1, indicating that the posterior is heavily influenced by the prior (**Figure 56**). This was expected, given the low CV of 12% that was estimated in the development of the prior. In contrast, the resulting small prior to posterior variance ratio PPVRs observed for K indicate that the input data was more informative than the prior. The marginal posterior for initial depletion suggests that this parameter was also largely informed by the priors. Based on model diagnostics, the Group agreed that this scenario (S2 with the changes to the Japanese longline index) as the base case for the assessment.

6.2.2 Stock Synthesis

Overall, the model showed relatively good diagnostic performance, showing good convergence properties and run time of approximately 12 minutes. The final gradient of the model was 0.00021, and the Hessian matrix for the parameter estimates was positive definite. The total log-likelihood R0 profile showed that the length-composition gradient was more significant than other data sources but attaining a minimum at levels close to the minimum achieved in the log-likelihood profile for the CPUE indices (**Figure 57**). Changes in log-likelihood for the length composition by fleet showed consistency concerning the minimum value along the R0 profile among data sources. In contrast, the minimum log-likelihood for the indices by fleet indicated somewhat conflicting signals from multiple data sources (**Figure 57**).

The joint residual plots showed a random pattern for the residuals of the fits to the index for all fleets with a RMSE of 22.6% and 21.6%, for the "Sel_Asym_model", and "Sel_DN model", respectively (**Figure 57**). The longline fleets from Uruguay and Japan were the most influential and exhibited the highest discrepancies between CPUE series and model predictions (**Figure 58**). The results of the log-residuals runs test for each CPUE fit by year and model are provided in **Figure 59.** The CPUE time series from EU-Spain (early period), Japan (both periods) and Chinese Taipei (both periods) failed the runs test diagnostic procedure. The reason for failing the runs tests could be related to data-conflicts caused by the opposing in the other CPUE time series, and also by the presence of extreme values.

The results of an eight-year retrospective analysis applied to both models are depicted in **Figure 60** and show the absence of an undesirable retrospective pattern for both models. Hindcasting cross-validation results suggest that only late Chinese Taipei and South Africa longline indices have good prediction skills as judged by the Mean Absolute Scaled Error (MASE) scores of approximately lower than one (**Figure 61**), albeit the MASE score for the Brazil longline index was slightly higher than one. Overall, the MASE scores for the "Sel_DN_model'' presented a slight improvement in relation to the "Sel_Asym_model" (**Figure 61**).

Overall, the length composition data's fit was reasonable with few systematic departures for the "Sel_Asym_model" (**Figure 62**). However, the size composition of early EU-Spain longline, early Japan longline, Chinese Taipei longline and Brazil longline fleets presented some discrepancies across the bin sizes higher than 200 cm LJFL. Overall, the "Sel_DN model" provided a better fit to the observed length composition data (**Figure 63**). The joint residual plots and runs tests of the length composition fits also showed an improvement of model fits for the "Sel_DN model" (**Figures 62 and 63**). Estimated selectivities at length are depicted in **Figure 64.** The initial model had an asymptotic selectivity for all fleets and captured much larger fish, which help to explain the discrepancies across the bin sizes higher than 200 cm LJFL. On the other hand, the dome shape applied to the early EU-Spain longline, early Japan longline, Chinese Taipei longline, and Brazil longline fleets had a lower probability of capturing larger fish, which is more appropriate given their fleets' size composition (**Figure 64**). Given the diagnostic performance the Group agreed that the Sel_DN model could be used to determine the historical and current stock status.

6.3 Stock status results

6.3.1 JABBA

The Group requested comparison figures for B/B_{MSY} and F/F_{MSY} estimated in the 2013, 2017, and the initial 2022 Stock Assessment (Anon., 2022b) runs (S1-S3) (**Figure 65**) to check for a systematic trend in assessment results over time. The comparison confirmed that no systematic trend is apparent. The 2022 Stock Assessment provides similar trends to the previous assessments, and the annual estimates produced by the 2022 model generally fall between those from the 2013 and 2017 Assessments (Anon., 2014 and 2017). However, it is noted that the reference case is more pessimistic than runs S1-S3 after the treatment of the Japanese index.

The results suggest that the reference case model is stable and provides a reasonably robust fit to the data as judged by the presented model diagnostic results. Summaries of posterior quantiles for parameters and management quantities of interest are presented in **Table 22**. The MSY estimate is 11,480 t and the marginal posterior median for B_{MSY} was 74,641 t (60,179 - 92,946 t). The F_{MSY} median estimate is 0.154 (0.124 - 0.19). There is a notable difference in estimated productivity between the 2017 Stock Assessment (Anon., 2017) (*MSY* = 14,570 t) and the current, with the former assuming a more productive stock.

The trajectory of B/B_{MSY} showed an overall decreasing trend from 1970 to 2011, first going below B/B_{MSY} = 1 in 2001 (**Figure 66**). Thereafter, the decreasing trend stabilized somewhat but has remained at B/B_{MSY} < 1. The current median estimate is 0.77 (0.53 - 1.11). The F/F_{MSY} trajectory showed a gradual increasing trend between 1970 and the mid-1980s, and a sharp increase in the late-1980s to peak in 2007 (**Figure 66**). After 2007, F/F_{MSY} steadily decreased. The current median estimate of F/F_{MSY} is 1.03 (0.67 - 1.51). The resulting stock status for 2020 indicates that the stock is overfished ($B/B_{MSY}<1$) and overfishing is occurring ($F/F_{MSY}>1$).

JABBA surplus production phase plot (**Figure 67**) showed a typical anti-clockwise pattern. Catches largely exceeded MSY for several years while biomass remained above B_{MSY}. before 1999, and this continued for nearly 10 years more while biomass remained below B_{MSY}.

6.3.2 Stock Synthesis

For both Stock Synthesis models ("Sel_Asym_model" and "Sel_DN model"), the trajectory of SSB/SSB_{MSY} presented similar trends and showed a sharp decrease from the early 1980's to an overfished status up the 2000s, followed by a stable trend but remained at levels below SSB_{MSY} to the end of the time series (**Figure 68**). The F/F_{MSY} trajectory showed an overall increasing trend from the beginning of the time series to an overfishing status in the late 1990s, reaching its highest value in the mid-2000s. Thereafter, fishing mortality decreased, but still remained above F_{MSY}. Notably, there has been a slight increasing trend until the end of the time series (**Figure 68**). The recruitment deviations time series shows a highly variable pattern around zero, but with a negative trend in the 2014-2018 period (**Figure 68**).

Summaries of parameters and benchmarks are presented in **Table 23.** Yield curves presented similar shapes achieving its maximum level around 0.27 of SSB_0, with estimates of *MSY* of 9,560 t for the "Sel_Asym_model" and 10,442 t for the "Sel_DN_model" (**Table 23**, **Figure 69**). The resulting stock status for 2020 for both models are consistent and indicated that the stock is overfished ($B_{2020} < B_{MSY}$ **Table 23**) and overfishing is occurring ($F_{2020} > F_{MSY}$ **Table 23**) which precludes stock rebuilding because biomass remains below sustainable levels that can produce MSY. A comparison for SSB/SSB_{MSY} and F/F_{MSY} estimated in the 2013, 2017 and current SS3 models is presented in **Figures 70** and **71**, respectively.

6.4 Synthesis of assessment results

The Group compared the results for the two assessment models considered for South Atlantic swordfish (Stock Synthesis and JABBA). The annual trends in total biomass (JABBA) or total spawning stock biomass (Stock Synthesis), B/B_{MSY} and fishing mortality F/F_{MSY} produced by the models suggested similar population dynamics. However, the Stock Synthesis model assumes a much higher biomass at the start of the fishery (**Figure 72**). All models suggested a steep decline in stock biomass as the fishing mortality increased in the 1990s. The Group also noted that the fishing mortality remained above F_{MSY} after the steep increase. The Stock Synthesis results depict an increase in B/B_{MSY} from mid-2000's to late-2010's which is not observed in the JABBA results. This may be attributed to the different treatment of the Japan longline index between the models (split at 2005/2006 and omission of the 2020 annual estimate in JABBA). Despite this, the stock remained under the B_{MSY} for both models.

Given that the Stock Synthesis models for South Atlantic swordfish are still under development. This is the first time that an integrated model has been applied to the southern stock and that some of the size data used in it are under revision. The Stock Synthesis model showed reasonable robust fits to the data through the model diagnostic results (section 6.2) and the Group recommended that the development of the integrated age-structured models be continued for the following assessments of South Atlantic swordfish.

The Group agreed to use the JABBA Reference case for the management recommendations. The 2022 Stock Assessment (Anon., 2022b) final results (B/B_{MSY} and F/F_{MSY}) for South Atlantic swordfish by the production model JABBA Reference case showed an overall decreasing trend in B/B_{MSY} from 1970 to 2011 and relatively stable since then at around 0.8 (**Figure 73**). Fishing mortality showed a sharp increase in the late-1980s to peak in 2007 at 1.5 times F_{MSY} and dropped close to F_{MSY} (**Figure 73**).

The Kobe plot (**Figure 74**) by the production model (JABBA) Reference case indicates that the stock is overfished (B/B_{MSY} = 0.77, with 95% credibility confidence intervals: 0.53 - 1.13) and undergoing overfishing (F/F_{MSY} = 1.03, with 95% credibility confidence intervals: 0.67 - 1.51) (**Table 22**). There is a 56% probability that the stock currently falls within the red quadrant of the Kobe plot, a 36% probability that the stock falls within the yellow, and only a 9% chance that it is in the green.

6.5 Projections

The Group discussed whether to use the new internal setting in JABBA to apply an "AR1" autocorrelation coefficient to the projections. The biological aspect the AR1 attempts to describe is the lag in rebuilding biomass to translate into spawner biomass, in other words for cohorts to come through the population. But this is limited to a rebuilding phase. With default projection settings (i.e., no AR1), the process error deviation is fixed to zero in the first year of the projections. The modelers noted that this setting could result in optimistic projections when the stock is in a rebuilding phase and has negative process error deviations in the terminal year of the assessment. The alternative setting (AR1 applied) uses an estimated autocorrelation coefficient from the model process error to project process error deviations going forward, such that they tend toward zero over time (**Figure 75**). Both projection results were provided to the Group, which noted that the AR1 projections were substantially more pessimistic than the projections without AR1.

The Group noted that the use of an AR1 coefficient in SPM projections was a good idea in theory but its application in circumstances with large negative process error deviations in the terminal year (such as this assessment) required more review before being applied in practice. Specifically, the Group was concerned about the length of time the projected process error deviations remained negative when compared to the relatively rapid changes in process error deviations (from positive to negative, and vice-versa) within the model (**Figure 75**). The Group suggested combining the results from the default and the model using AR1 in order to bridge the divide between the more pessimistic AR1 model and more optimistic default. However, the Group decided that JABBA projections for the South Atlantic swordfish should not include the AR1 autocorrelation coefficient and should instead caution the Commission that the projections are likely to be optimistic. The Group recommended that further research into this projection setting, in the form of simulation testing and hindcast cross-validation, be prioritized.

Stochastic projections were conducted for the JABBA base case model with 21 constant catch scenarios (0; 6,000 -15,000 t). The annual medians of B/B_{MSY} and F/F_{MSY} are provided in **Figure 76**. For these projections, the initial catches for 2021-2022 were set to 9,826 t, which is the average of the previous three years (2018-

2020), and the projections were run until 2033. Projections of B/B_{MSY} increase and F/F_{MSY} decline in the period 2021-2022 because of the catch assumptions made for this period. Beginning in 2023, catches of 12,000 tons or more lead to a decline in the biomass, while catches over 11,000 t increase the fishing mortality (**Figure 76**). Projections for catches over 13,000 t resulted in values of $F/F_{MSY} > 2$ being reached by 2033. Although the median MSY value is 11,480 tons, for 2020 $B/B_{MSY} = 0.77$ so that catches at or below, 10,000 tons are required to rebuild the population to biomass levels that can produce MSY by 2033 (**Figure 76**).

The stochastic projection histograms of B/B_{MSY} and F/F_{MSY} illustrate the increased uncertainty when projecting over longer periods, particularly for F/F_{MSY} under high (13,000 t) constant catch scenarios (**Figure 77**). The rate of biomass increase is slow, even at low constant catches (8,000 t), as shown by the considerable overlap in B/B_{MSY} histogram distributions until the 2030's. The probabilities of stock depletion (i.e., $B < 10\%$ of B_{MSY}) are provided in **Table 24** and indicate that the stock could not sustain constant high TACs. There is a 49% probability of stock depletion by 2033 given constant catches of 15,000 t.

The Group reviewed the Kobe 2 Strategic Matrices (**Table 25**) for the probability that overfishing is not occurring ($F<=F_{MSY}$), stock is not overfished ($B>=B_{MSY}$) and the joint probability of being in the green quadrant of the Kobe plot (i.e., $F<= F_{MSY}$ and $B>= B_{MSY}$). Future constant catches of 14,000 t (the current TAC) will continue to decrease the stock biomass to an extent that there is only a 6% chance that $B/B_{MSY} >1$ by 2033. If catches were to remain similar to the current catch (9,826 t), there is a 55% chance that the stock will be in the green quadrant by 2033. Future constant catches of below 9,500 tons are expected to prevent overfishing ($F>F_{MSY}$) and an overfished status ($B<B_{MSY}$) with a greater than 60% probability by 2033.

The Group noted the recent decline in catches and that catches have been below the current MSY estimate since 2011, yet the biomass has not increased as expected from the 2017 Stock Assessment (Anon., 2017) projections. The new projections indicate that current catch levels may not decrease biomass but are equally unlikely to facilitate the required stock recovery. A decrease in catch is required to provide adequate opportunity for the stock to recover.

7. Implications of the assessment for northern swordfish MSE

The Group discussed the updated Stock Synthesis assessment model and the implications that this model update may have for the Operating Models (OMs) of the MSE. Notable changes from the previous 2017 Stock Synthesis assessment include updates to the catch and index data, the inclusion of the lengths of discarded fish, and an estimate of unreported dead discards based on these lengths. Reported dead discards are now fit as observational data and unreported discards estimated as 'regulatory discards' based on fishery length compositions. It was noted that because this structural change requires more data that is subject to possible conflict with other observational data, it may have implications on model stability.

The Group discussed the merits of estimating dead discards with the current Stock Synthesis approach. Additional details on these discussions are provided in Section 5 of this report.

The Group questioned whether the updated Stock Synthesis model should be used to as the new base OM model within the MSE. In consideration of the Group's concerns with estimating dead discards, the Group proposed adding the updated Stock Synthesis model to the MSE's OM uncertainty grid, which may also include various data-weighting configurations. The Group also noted that if the uncertainties surrounding discards were deemed appropriate for inclusion into the MSE uncertainty grid, that it might take the place of an existing component of the grid, such as the inclusion/exclusion of modelled environmental linkages. The Group also agreed to replace the base OM in the MSE with the updated Stock Synthesis model that includes using the data updated to 2020. The Group agreed to give the MSE technical team ample flexibility to explore alternative base OM configurations and provide appropriate guidance on the best way to move forward.

The Group also noted that a team should be put forth to explore and make recommendations on how indices are calculated for swordfish.

8. Recommendations

8.1 Research and Statistics

8.1.1 Recommendations with financial implication

To SCRS plenary on research funding

The Group recommends that a hand-held Argos electronic satellite tag receiver be purchased for use among ICCAT Species Groups. The receiver would help find the tag and thus scientists would be able to recover more detailed tagging data, retrieved directly from the tags.

To the SWO Species Group and the SCRS plenary on research funding

The Group recommends continued financial support of the ICCAT swordfish biology programme. The Group further recommends that a proposal be developed for formalization of a Research Programme similar to those in place for bluefin tuna, sharks, and billfish. The proposal should include the Atlantic and Mediterranean stocks and have descriptions of the various research activities that the Groups are proposing, and timeframes for such work to be carried out. Determining the final amount of this proposal will be addressed at subsequent Swordfish Species Group and Species Groups meetings.

The Group recommends that an expanded set of closed-loop simulations be conducted for the southern swordfish stock using Operating Models tailored to that stock. While the work will be predominantly done by CPC scientists and the Secretariat, a contractor will review the simulation setup and code €10,000.

8.1.2 Recommendations without financial implication

To the SCRS and ICCAT Secretariat

The Group recommends that the straight-curved lower jaw fork length relationships presented in SCRS/2022/061 be adopted for use for lengths conversions in the 2022 Stock Assessment (Anon., 2022). Pending further data collection and analysis the Group recommends that the conversion be considered for the ICCAT list of approved conversions.

Noting conflicting patterns in the CPUE indices developed by CPC scientists, the Group recommends that CPUE analysts form a Working Group that will work intersessionally to review the CPUE data inputs, treatments, and model assumptions and methods. The objective of this Group will be to diagnose conflicting trends in the CPUEs and improve the quality of indicators used in SWO assessment and N-SWO MSE.

To CPCs

The Group recommends that the submission of size samples to the ICCAT Secretariat, as part of the CPCs Task 1 and 2 data submission obligations, be completed using the ST04-T2SZ statistical form. Size samples reported with the ST04-T2SZ form shall include all samples collected by the CPC from all fisheries and size samples of dead and live discards (when applicable) collected by its National Observer Programme. This recommendation does not preclude CPCs from the optional reporting of size samples collected by their National Observer Programme using the ST09-DomObPrg form.

To WGSAM

Noting the spatial-temporal CPUE standardization approaches presented in this meeting (e.g., R-INLA), the Group recommends that the ICCAT Working Group on Stock Assessment Methods (WGSAM) evaluate these modeling approaches and provide recommendations on their use in index standardizations.

Review the inclusion of the SPICT model in the ICCAT software catalogue.

Review the "AR1" autocorrelation feature for projections within the JABBA model platform.

To National Scientists

The Group recommends that for future assessments, CPUE analysts form a small working group several months before the assessment data preparatory meeting. Noting the limited time within the data preparatory meeting for index review and short timelines for index revisions after the meeting, the small working group would allow for closer examination and detailed discussion on modeling approaches before formal submission of indices to the data preparatory meeting. The Group recommends that National Scientists document the history of their fleets participating in ICCAT fisheries. Reviews should document changes in gears, local and national fishing regulations, spatial patterns and other relevant factors that influence how ICCAT species are caught. These reviews are important for better accounting of fleet structure and dynamics in CPUE standardizations and assessments.

8.2 Management Recommendation

8.3 North

The management recommendation will be developed intersessionally and finally will be presented for adoption during the Species Group meeting in September 2022, after the joint projections by Stock Synthesis and JABBA are finalized and reviewed.

8.4 South

The Group discussed the management recommendation for South Atlantic swordfish, the following paragraph has been adopted by the Group.

South Atlantic swordfish is unlikely to achieve the Convention objectives by 2033 if catches increase above current levels (9,826 t). To rebuild the stock, catches of 9,500 t or less are required to reach the green quadrant of the Kobe plot by 2033, with at least 60% probability. Given the uncertainty of long-term projections, it is recommended the stock be closely monitored in the upcoming years to confirm rebuilding by reviewing available fishery indicators regularly.

9. Responses to the Commission

North Atlantic swordfish

SCRS shall review these data (catch, catch at size, location and month of capture) annually. Rec. 17-02, para 8

Background: *All CPCs catching swordfish in the North Atlantic shall endeavor to provide annually the best available data to the SCRS, including catch, catch at size, location and month of capture on the smallest scale possible, as determined by the SCRS. The data submitted shall be for broadest range of age classes possible, consistent with minimum size restrictions, and by sex when possible. The data shall also include discards (both dead and alive) and effort statistics, even when no analytical stock assessment is scheduled. The SCRS shall review these data annually.*

A detailed review of the available N-SWO data for inclusion in the 2022 Stock Assessment (Anon., 2022b) was conducted by the Group during the 2022 Swordfish Data Preparatory meeting (Anon., 2022a). The results of this review are summarized in the SCRS data catalogue (see Anon. 2022, Tables 1-5). Overall, the available catch, size, and effort data for the main fleets (the fleets that catch approximately 95% of the total catch) are quite complete, while the data for the minor fleets continue to be sparse. With respect to the reporting of dead and live discards, the Group observed that only a few CPCs have been providing these data (Anon. 2022, Tables 2-3).

SCRS should continue to monitor and analyze the effects of this measure (minimum size) on the mortality of immature swordfish. Rec. 17-02, para. 10

Background: *Notwithstanding the provisions of paragraph 9, any CPC may choose, as an alternative to the minimum size of 25 kg/ 125 cm LJFL, to take the necessary measures to prohibit the taking by its vessels in the Atlantic Ocean, as well as the landing and sale in its jurisdiction, of swordfish (and swordfish parts), less than*

119 cm LJFL, or in the alternative 15 kg, provided that, if this alternative is chosen, no tolerance of swordfish smaller than 119 LJFL, or in the alternative 15 kg, shall be allowed. For swordfish that have been dressed, a cleithrum to keel (CK) measurement of 63 cm can also be applied. A Party that chooses this alternative minimum size shall require appropriate record keeping of discards. The SCRS should continue to monitor and analyze the effects of this measure on the mortality of immature swordfish.

An answer to these requests was provided by the Committee in 2017, referring to Recommendations 16-03 paragraph 10, current 17-02 and 16-04, paragraph 7, current 21-03. To reiterate what was provided in 2017, the estimated hooking mortality for undersized swordfish is on average 78%. However, it is not clear how much the regulation may have reduced the encounter rate with small fish as a redistribution of fishing effort to avoid undersized swordfish could also have resulted in reduced total mortality. Currently, the Group is reviewing new studies and conducting further analysis to determine population level impacts of this at-haulback mortality and intends to provide advice to the Commission tentatively in 2023. In addition, the ongoing N-SWO MSE work might provide further insight on this issue. The Committee reiterates that reporting of dead discards and the corresponding lengths of the discarded fish are essential to address the efficacy of this recommendation.

SCRS to provide advice on conservation and management measures for North Atlantic swordfish, Rec. 21-02, para 5

Background: *The Commission shall establish at its 2022 meeting conservation and management measures for North Atlantic swordfish on the basis of the SCRS advice resulting from a stock assessment that will be carried out by the SCRS in 2022 as well as the Resolution by ICCAT on Criteria for the Allocation of Fishing Possibilities (Res. 15-13).*

In 2022, SCRS conducted a Data Preparatory meeting (Anon. 2022a) and a Stock Assessment meeting (Anon. 2022b) for both the northern and southern swordfish stocks. Both meetings were held online. Details of the stock assessment methods, results, and management advice are provided in the 2022 Swordfish Stock Assessment Report (Anon., 2022b).

South Atlantic Swordfish

*Interim limit reference (LRP) of 0.4*B_{MSY} or any more robust LRP established through further analysis, Rec. 17-03, para 12 (Rec. 21-03)*

Background: *When assessing stock status and providing management recommendations to the Commission in 2021, the SCRS shall consider the interim limit reference (LRP) of 0.4*B_{MSY} or any more robust LRP established through further analysis.*

There was no analysis conducted for southern swordfish on this issue in 2022. The SCRS through the WGSAM has proposed the formulation of a study group to broadly address Limit Reference Points in the coming years.

SCRS shall report to the Commission the results of the 2022 South Atlantic Swordfish Stock Assessment, Rec. 21-03, para 2

Background: *The SCRS will carry out a stock assessment of South Atlantic swordfish in 2022 and report the results to the Commission.*

In 2022, SCRS conducted a Data Preparatory meeting (Anon. 2022a) and a Stock Assessment meeting (Anon., 2022b) for both the northern and southern swordfish stocks. Both meetings were held online. Details of the stock assessment methods, results, and management advice are provided the 2022 Swordfish Stock Assessment Report (Anon., 2022b).

10. Review of the workplan

The workplan below is specific to items emerging from this meeting and is in addition to the N-SWO MSE workplan in Table 14 of the 2022 Atlantic Swordfish Data Preparatory Meeting report (Anon. 2022a).

The North Atlantic swordfish stock assessment analysts and the Secretariat will finish the runs required to develop projections for SS3 and then combine projection results from these runs with JABBA projections to develop joint Kobe plots and tables for generating the management advice.

The N-SWO MSE technical team will work to recondition the operating model grid using the updated indices, catch data, and the 2022 SS3 base case. The MSE technical team will explore alternative base OM configurations, particularly with regard to discarding and mortality and provide appropriate guidance on the best way forward. These results will be reviewed at the Species Group meeting in September 2022.

The North and South Atlantic swordfish rapporteurs will draft the Executive Summary considering analysis and advice in this assessment report (S-SWO) and the subsequent and relevant analysis to be completed (N-SWO) before the swordfish Species Group meeting in September 2022.

Beginning intersessionally in 2022, a subgroup of the Working Group will engage in more detailed analysis of the CPUE data to address concerns about conflicting indices.

The South Atlantic assessment analysts will continue to develop the South Atlantic swordfish Stock Synthesis model, with the aim of producing projections using this model in the future stock assessments. In addition, the Group will expand on the closed-loop simulations for MP performance.

11. Other matters

SCRS/2022/121 did preliminary closed-loop simulations for the southern swordfish stock. The analysis used the prior on steepness from SCRS/2022/120 as custom parameters for steepness, natural mortality, and the von Bertalanffy growth parameters. It then used openMSE's Rapid Conditioning Model to fit a single fleet model to catch and CPUE data from the Southern stock to generate an OM for the Southern swordfish stock. The analysis showed that there was a range of Candidate Management Procedures that could be considered acceptable for use but that these would strongly depend on management objectives.

The Group discussed the presentation. They debated the best way to capture the distribution of steepness in OMs since a left-skewed distribution of steepness could make some combinations of steepness unlikely. While a parsimonious way of capturing steepness in OMs would be to use a prior such as SCRS/2022/120, doing so requires that there be a reliable estimate of larval survival which is often difficult to obtain.

12. Adoption of the report and closure

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

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Table 1. Fleet structure for the N-SWO stock synthesis model.

North Atlantic swordfish

FL	Fishery ID	Description	Time	Catch/Size (FlagName*)	Catch/Size (GearGrpCode*)	CPUE	CPUE: Retained/ Discards	Size: Retained/Discards
1	SPNLL	EU-Spain LL (longline)	1950-2020	EU-España	LL	1982-2019 by age	Retained	Retained
2	USALL	USA LL	1950-2020	USA	LL	1993-2020	Both	Both
3	CANLL	Canada LL	1950-2020	Canada	LL	1962-2020	Retained	Both
4	JPNLL1	Japan LL early	1950-1993	Japan	LL	1976-1993	Retained	Both
5	JPNLL2**	Japan LL late	1994-2020	Japan	LL	1994-2020 (no 2000-2005)	Retained	Both
6	PORLL	EU-Portugal LL	1950-2020	EU-Portugal	LL	1999-2020	Both	Both
7	CTPLL1	Chinese Taipei LL early	1950-1989	Chinese Taipei	LL	1968-1989	Retained	Both
8	CTPLL2	Chinese Taipei LL late	1990-2020	Chinese Taipei	LL	1997-2020	Retained	Both
9	MORLL	Morocco LL	1950-2020	Maroc	LL	2005-2020	Retained	Retained
10	Harpoon	Canada/USA Harpoon	1950-2020	Canada, USA	HP	-		
11	Others	LL by the other CPCs, and all other gears except HP	1950-2020	LL (except the flags listed above), and all other gears except HP	borrow USALL FL2	-		

*FlagName and GearGrpCode are in ICCAT database

**Time block is defined: 1994-2009, 2010-2020

Table 2. Fleet structure for the S-SWO stock synthesis model.

South Atlantic swordfish

FL	Fishery ID	Description	Time	Catch/Size (FlagName*)	Catch/Size (GearGrpCode*)	CPUE
1	SPNLL	EU-Spain LL	1950-2020	EU-Espana	LL	1989-2019
2	BRALL	Brazil LL	1950-2020	Brazil	LL	1994-2020
3	JPNLL1	Japan LL early	1950-1993	Japan	LL	1976-1993
4	JPNLL2	Japan LL late	1994-2020	Japan	LL	1994-2020
5	CTPLL1	Chinese Taipei LL early	1950-1990	Chinese Taipei	LL	1968-1990
6	CTPLL2	Chinese Taipei LL late	1991-2020	Chinese Taipei	LL	1997-2020
7	ZAFLL	South Africa LL	1950-2020	South Africa	LL	2004-2020
8	URYLL	Uruguay LL	1950-2013	Uruguay	LL	2001-2012
9	PORLL	Portugal LL	1950-2020	Portugal	LL	-
10	OthLL	LL by the other CPCs	1950-2020	all others	LL	-
11	Others	All others	1950-2020	all others	all	-

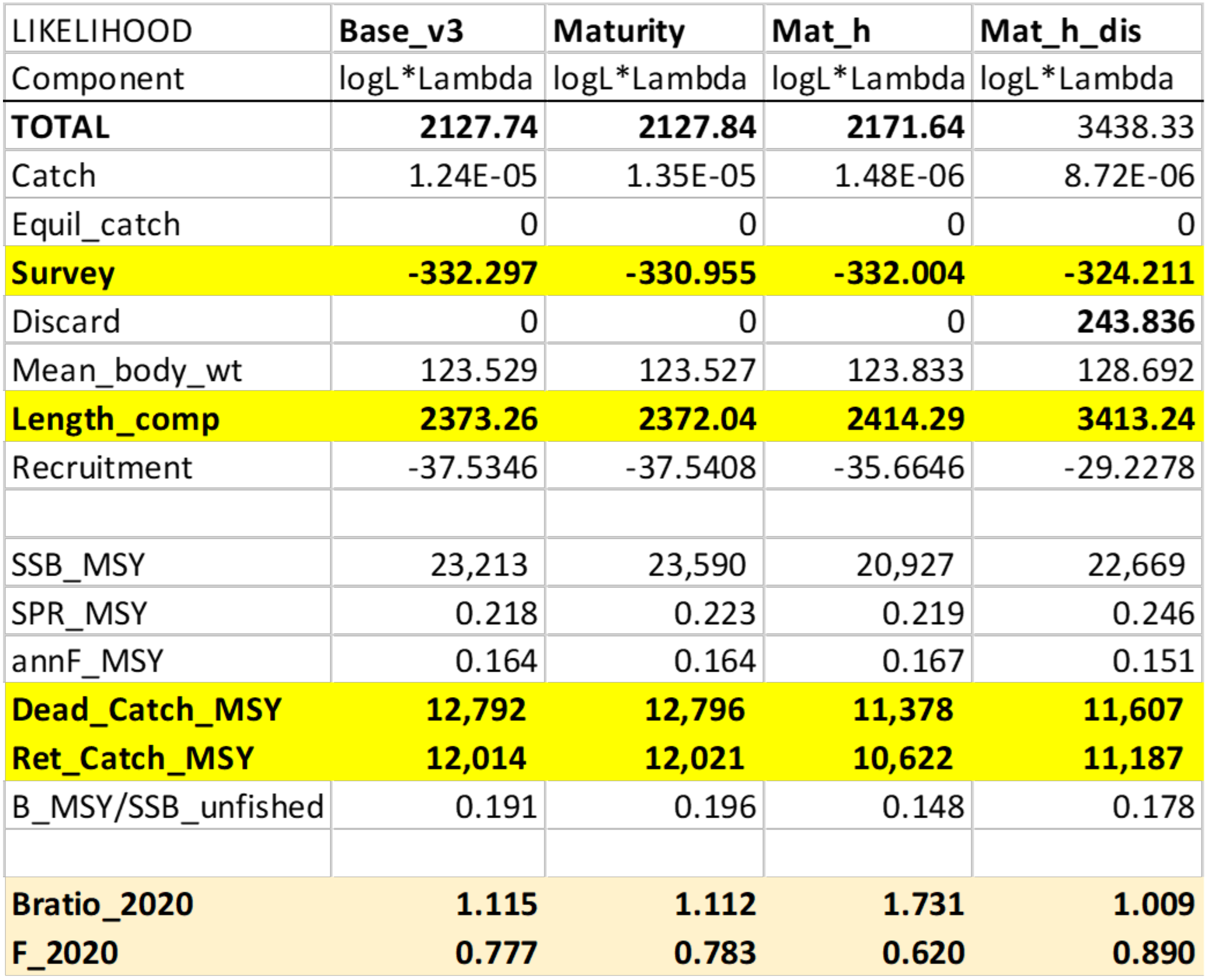
*FlagName and GearGrpCode in ICCAT database

Table 3. Model factors and their deviance profiles for the positive catch rate value component and the proportion positive component of the delta-lognormal model. Highlighted rows are for factors that explain a relatively high proportion of the total deviance i.e., approximately 5%.

Model factors positive catch rates values	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	67875.3			
Year	57	59072.9	8802.4	17.2%	< 0.001
Year Zone	13	52831.6	6241.3	12.2%	< 0.001
Year Zone Qtr	3	52456.8	374.7	0.7%	< 0.001
Year Zone Qtr FlagName	6	19399.0	33057.9	64.6%	< 0.001
Year Zone Qtr FlagName Year*Qtr	171	19111.4	287.5	0.6%	< 0.001
Year Zone Qtr FlagName Year*Qtr Zone*Qtr	39	19005.4	106.0	0.2%	< 0.001
Year Zone Qtr FlagName Year*Qtr Zone*Flagname	42	18019.7	1091.7	2.1%	< 0.001
Year Zone Qtr FlagName Year*Qtr Year*Zone	710	16729.0	2382.4	4.7%	< 0.001
Year Zone Qtr FlagName Year*Qtr Year*Flagname	205	16721.1	2390.3	4.7%	< 0.001

Model factors proportion positives	d.f.	Residual deviance	Change in deviance	% of total deviance	*p*
1	0	14245.7			
Year	57	12529.3	1716.4	20.8%	< 0.001
Year Qtr	3	12482.1	47.2	0.6%	< 0.001
Year Qtr Zone	13	11662.4	819.7	9.9%	< 0.001
Year Qtr Zone Flagname	6	7756.5	3905.8	47.4%	< 0.001
Year Qtr Zone Qtr*Zone	39	7645.2	111.4	1.4%	< 0.001
Year Qtr Zone Zone*Flagname	44	7213.4	543.1	6.6%	< 0.001
Year Qtr Zone Year*Zone	717	6196.6	1560.0	18.9%	< 0.001
Year Qtr Zone Year*Flagname	209	6006.0	1750.5	21.2%	< 0.001

Table 4. Summary statistics of fit regarding stepwise changes to the assessment of North Atlantic Swordfish in Stock Synthesis including an update of the maturity vector from initial model to Sharma and Arocha, (2017; Maturity), steepness fixed at 0.75 (Mat_h), and discard data being explicitly fit within the objective function (Mat_h_dis).



LIKELIHOOD	**Base_v3**	**Maturity**	**Mat_h**	**Mat_h_dis**
Component	logL*Lambda	logL*Lambda	logL*Lambda	logL*Lambda
TOTAL	**2127.74**	**2127.84**	**2171.64**	3438.33
Catch	1.24E-05	1.35E-05	1.48E-06	8.72E-06
Equil_catch	0	0	0	0
Survey	**-332.297**	**-330.955**	**-332.004**	**-324.211**
Discard	0	0	0	**243.836**
Mean_body_wt	123.529	123.527	123.833	128.692
Length_comp	**2373.26**	**2372.04**	**2414.29**	**3413.24**
Recruitment	-37.5346	-37.5408	-35.6646	-29.2278
SSB_MSY	23,213	23,590	20,927	22,669
SPR_MSY	0.218	0.223	0.219	0.246
annF_MSY	0.164	0.164	0.167	0.151
Dead_Catch_MSY	**12,792**	**12,796**	**11,378**	**11,607**
Ret_Catch_MSY	**12,014**	**12,021**	**10,622**	**11,187**
B_MSY/SSB_unfished	0.191	0.196	0.148	0.178
Bratio_2020	**1.115**	**1.112**	**1.731**	**1.009**
F_2020	**0.777**	**0.783**	**0.620**	**0.890**

Table 5. JABBA model setting scenarios evaluated for the North Atlantic stock.

Scenario	Steepness	CPUE indices used	Production curve	Notes
S1	**r = 0.424; s.e. 0.4**	**All except combined**	**Schaefer**	**JABBA 2017 assumptions but with CPC-provided indices**
S2	**r = 0.424; s.e. 0.4**	**Only combined**	**Schaefer**	**2017 continuity with updated data (BSP2/JABBA)**
S3	**h = 0.75**	**All except combined**	**Pella-Tomlinson**	**Steepness sensitivity**
S4	**h = 0.88**	**All except combined**	**Pella-Tomlinson**	**Steepness sensitivity; continuity with a SS3 run**
S5	**h = 0.60**	**All except combined**	**Pella-Tomlinson**	**Steepness sensitivity**
S6	**h = 0.75**	**Grp 1 indices: US, Canada, EU_Portugal, EU_Spain**	**Pella-Tomlinson**	**Grp 1 correlated indices, median steepness**
S7	**h = 0.75**	**Grp 2 indices: Japan (1&2), Chinese Taipei (1&2), Morocco**	**Pella-Tomlinson**	**Grp 2 correlated indices, median steepness**
S8	**h = 0.75**	**Only combined**	**Pella-Tomlinson**	**Only combined, median steepness**

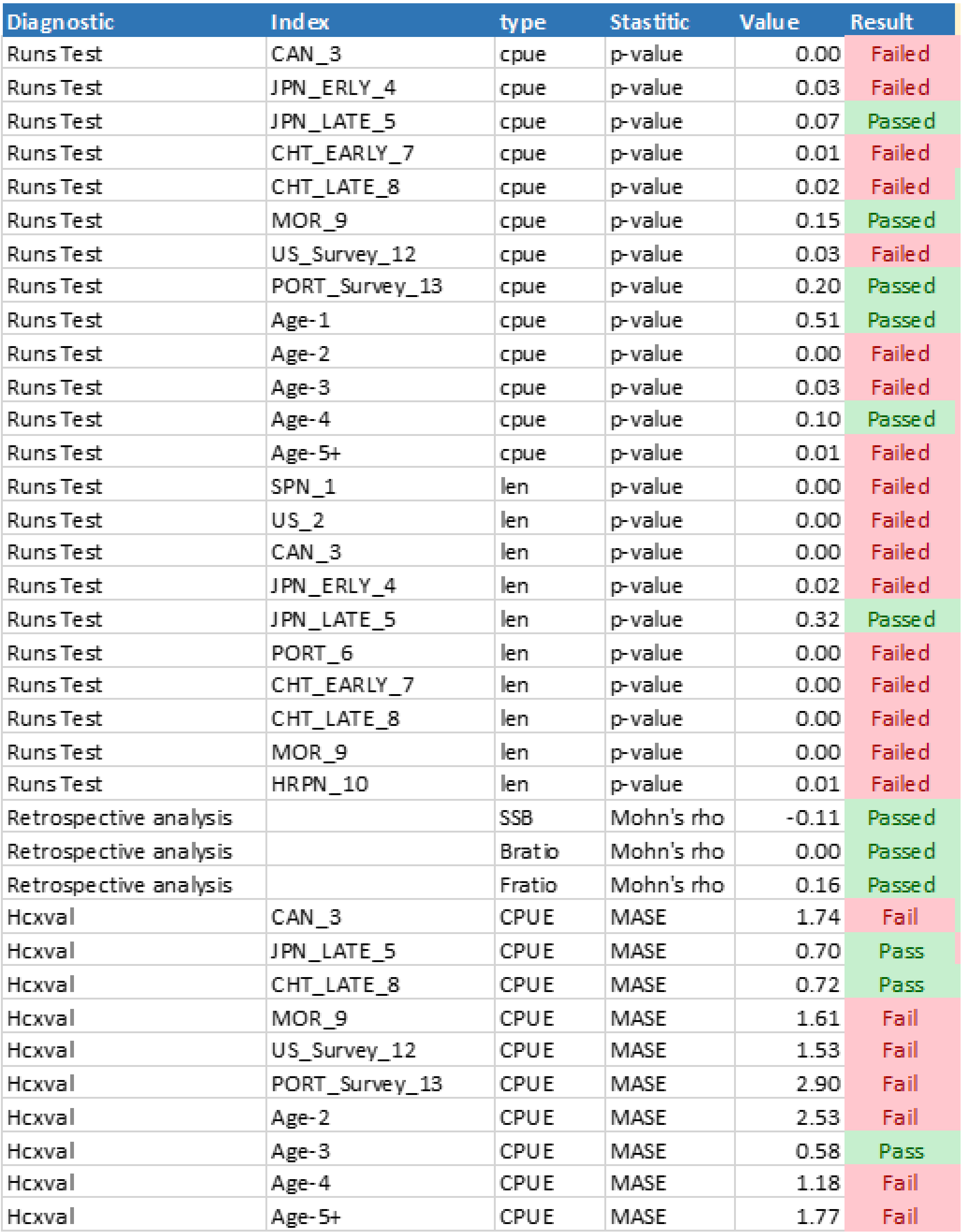
Table 6. Abundance indices used in the stock assessment for the North Atlantic in 2022.

series	CAN LL		PRT LL		w_SPN LL		SPN LL Age1		SPN LL Age2		SPN LL Age3		SPN LL Age4		SPN LL Age5+		JPN LL1		JPN LL2		USA LL		CTP LL1		CTP LL2		MOR LL		Combined LL (T2CE)	
Use in 2022 stock assessment	Yes		Yes		Only for production models		Only for Stock Synthesis		Only for Stock Synthesis		Only for Stock Synthesis		Only for Stock Synthesis		Only for Stock Synthesis		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
units of index	number		weight		weight		number		number		number		number		number		number		number		number		number		number		weight		weight	
source	SCRS/2022/048		SCRS/2022/054		SCRS/2021/087		SCRS/2021/089		SCRS/2021/089		SCRS/2021/089		SCRS/2021/089		SCRS/2021/089		SCRS/2022/046		SCRS/2022/046		SCRS/2022/055		SCRS/2022/050		SCRS/2022/050		SCRS/2022/056		SCRS/2022/115	
Year	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV
1959																														
1960																														
1961																														
1962	116.907	0.192																												
1963	215.329	0.074																											1.353	0.182
1964	83.145	0.060																											1.122	0.163
1965	57.614	0.060																											1.417	0.152
1966	60.041	0.056																											1.459	0.161
1967	80.199	0.054																											1.491	0.160
1968	53.968	0.050																							0.176	0.118					1.370	0.164
1969	52.049	0.052																							0.222	0.098					1.433	0.162
1970	66.685	0.057																							0.168	0.084					1.609	0.152
1971																									0.226	0.091					1.881	0.149
1972																									0.212	0.120					2.081	0.157
1973																									0.231	0.122					2.447	0.159
1974																									0.214	0.096					2.447	0.150
1975																									0.116	0.102					1.407	0.157
1976																	0.520	0.115					0.055	0.098					0.981	0.163
1977																	0.660	0.152					0.056	0.093					1.023	0.168
1978																	0.800	0.175					0.063	0.112					1.321	0.169
1979	95.109	0.099															0.640	0.156					0.072	0.146					1.409	0.182
1980	81.564	0.076															0.490	0.143					0.150	0.130					1.102	0.172
1981	86.259	0.102															0.650	0.154					0.147	0.107					1.198	0.158
1982	67.354	0.109					0.201	0.323	0.851	0.233	0.784	0.211	1.251	0.218	1.354	0.207	0.580	0.121					0.140	0.105					1.246	0.159
1983	57.796	0.113					0.312	0.254	0.728	0.185	0.828	0.170	0.993	0.176	1.042	0.156	0.560	0.179					0.132	0.098					0.935	0.160
1984	58.151	0.110					0.306	0.254	0.595	0.183	0.822	0.168	1.024	0.174	1.099	0.154	0.610	0.148					0.100	0.091					0.948	0.156
1985	67.649	0.107					0.302	0.247	0.848	0.181	0.898	0.166	1.047	0.172	1.010	0.152	0.560	0.161					0.085	0.088					1.074	0.156
1986	113.244	0.110			253.193	0.025	0.439	0.240	1.075	0.177	0.993	0.163	0.986	0.169	0.914	0.148	0.390	0.154					0.097	0.087					0.729	0.158
1987	81.966	0.105			273.806	0.030	0.677	0.246	1.591	0.181	1.248	0.167	1.097	0.173	0.926	0.153	0.380	0.132					0.082	0.113					1.090	0.148
1988	78.358	0.105			240.088	0.030	0.834	0.238	1.339	0.176	1.071	0.162	0.930	0.168	0.799	0.147	0.370	0.162					0.060	0.219					1.214	0.140
1989	73.796	0.098			245.296	0.028	0.693	0.238	1.550	0.176	0.957	0.162	0.847	0.168	0.724	0.147	0.420	0.167					0.058	0.252					1.149	0.139
1990	106.685	0.092			240.257	0.026	0.391	0.239	1.726	0.176	1.272	0.162	0.869	0.168	0.688	0.147	0.480	0.229											1.102	0.140
1991	71.231	0.067			245.875	0.026	0.350	0.238	1.270	0.176	1.330	0.162	1.025	0.168	0.782	0.146	0.490	0.265											0.912	0.140
1992	83.744	0.066			243.178	0.026	0.381	0.237	1.238	0.175	1.215	0.162	1.063	0.167	0.887	0.146	0.430	0.326											0.802	0.140
1993	72.766	0.052			213.719	0.027	0.467	0.237	1.244	0.175	1.053	0.162	0.861	0.167	0.757	0.146	0.570	0.351			0.890	0.090							0.757	0.141
1994	52.189	0.044			208.285	0.025	0.469	0.237	1.350	0.175	0.906	0.161	0.740	0.167	0.641	0.145			0.640	0.469	0.930	0.090							0.666	0.140
1995	64.597	0.045			232.781	0.023	0.490	0.235	1.727	0.174	1.246	0.160	0.852	0.166	0.677	0.145			0.480	0.333	0.940	0.090							0.640	0.140
1996	39.607	0.050			198.582	0.023	0.492	0.235	1.108	0.174	0.917	0.161	0.678	0.166	0.537	0.145			0.500	0.400	0.740	0.100							0.514	0.142
1997	56.902	0.051			201.665	0.022	1.023	0.236	1.302	0.175	0.747	0.161	0.576	0.167	0.440	0.146			0.530	0.377	0.940	0.090			0.227	0.128			0.549	0.138
1998	78.927	0.054			209.816	0.021	0.900	0.236	1.823	0.175	0.781	0.161	0.523	0.167	0.447	0.146			0.590	0.661	1.330	0.100			0.246	0.151			0.646	0.138
1999	105.153	0.053	174.444	0.164	227.905	0.022	1.067	0.239	2.132	0.177	1.130	0.163	0.603	0.169	0.374	0.148			0.570	0.246	1.310	0.100			0.085	0.102			0.621	0.140
2000	77.968	0.056	255.882	0.202	313.035	0.020	1.074	0.240	2.537	0.177	1.435	0.163	0.847	0.169	0.641	0.148					1.010	0.090			0.108	0.128			0.571	0.149
2001	89.886	0.052	200.413	0.212	290.929	0.021	1.156	0.239	2.431	0.177	1.332	0.163	0.686	0.169	0.501	0.147					1.010	0.090			0.109	0.109			0.587	0.154
2002	142.518	0.058	179.819	0.188	274.227	0.023	0.838	0.239	1.881	0.176	1.192	0.163	0.700	0.168	0.539	0.147					0.890	0.090			0.128	0.098			0.608	0.152
2003	99.170	0.055	243.856	0.203	282.560	0.025	0.833	0.240	2.042	0.178	1.340	0.164	0.842	0.170	0.622	0.149					0.790	0.090			0.108	0.107			0.642	0.153
2004	91.752	0.053	368.221	0.204	287.224	0.025	0.812	0.243	1.451	0.179	0.867	0.165	0.657	0.171	0.517	0.149					0.810	0.090			0.066	0.087			0.722	0.142
2005	108.850	0.052	324.088	0.217	286.596	0.026	0.808	0.244	1.518	0.180	0.856	0.166	0.519	0.172	0.497	0.151					1.340	0.090			0.095	0.088	460.410	0.120	0.730	0.140
2006	94.680	0.052	282.679	0.176	261.191	0.030	1.222	0.246	1.593	0.182	0.768	0.168	0.503	0.174	0.510	0.153			0.320	0.344	1.070	0.090			0.154	0.090	260.970	0.107	0.764	0.139
2007	88.354	0.057	324.212	0.170	303.696	0.030	1.499	0.252	2.152	0.186	0.846	0.172	0.407	0.178	0.534	0.158			0.520	0.327	1.340	0.090			0.090	0.110	220.150	0.114	0.835	0.139
2008	111.881	0.059	312.692	0.180	347.409	0.029	1.350	0.253	3.113	0.187	1.177	0.172	0.560	0.179	0.586	0.159			0.570	0.316	1.210	0.090			0.060	0.114	344.510	0.116	0.889	0.141
2009	96.165	0.061	350.800	0.187	313.178	0.028	0.609	0.256	2.360	0.188	1.282	0.173	0.643	0.180	0.595	0.161			0.580	0.293	1.040	0.090			0.075	0.116	310.440	0.117	0.596	0.141
2010	143.174	0.059	306.155	0.200	312.269	0.028	0.738	0.249	2.365	0.183	1.124	0.169	0.529	0.175	0.490	0.156			0.580	0.328	0.750	0.090			0.055	0.105	479.560	0.108	0.558	0.146
2011	107.587	0.057	310.568	0.179	332.831	0.028	1.198	0.250	1.643	0.183	0.977	0.169	0.654	0.175	0.651	0.156			0.490	0.327	1.040	0.090			0.119	0.106	323.900	0.112	0.723	0.143
2012	112.765	0.057	336.720	0.174	338.169	0.028	0.850	0.254	2.416	0.186	1.050	0.172	0.654	0.178	0.920	0.156			0.640	0.406	1.050	0.090			0.158	0.118	351.750	0.111	0.773	0.142
2013	110.571	0.058	355.741	0.158	336.536	0.029	0.668	0.259	1.744	0.190	0.927	0.175	0.597	0.182	0.675	0.163			0.360	0.417	0.920	0.090			0.087	0.121	319.070	0.106	0.638	0.144
2014	89.168	0.055	310.863	0.155	325.510	0.030	0.630	0.260	1.930	0.188	1.162	0.173	0.838	0.180	0.972	0.161			0.480	0.542	0.730	0.090			0.103	0.150	231.600	0.111	0.659	0.146
2015	92.028	0.055	309.594	0.150	323.177	0.030	0.870	0.256	2.620	0.187	1.453	0.172	1.033	0.178	1.138	0.159			0.530	0.434	0.750	0.090			0.099	0.113	237.660	0.109	0.566	0.145
2016	69.059	0.055	344.115	0.150	357.174	0.035			1.304	0.188	0.923	0.173	0.720	0.180	1.003	0.160			0.460	0.435	0.760	0.090			0.080	0.105	384.180	0.128	0.489	0.145
2017	64.408	0.054	319.880	0.163	325.279	0.037			1.350	0.191	0.769	0.176	0.652	0.183	1.004	0.166			0.560	0.429	0.790	0.090			0.079	0.103	596.270	0.115	0.502	0.146
2018	56.807	0.060	344.478	0.145	317.192	0.038			1.785	0.197	0.872	0.182	0.609	0.189	0.745	0.171			0.510	0.451	0.960	0.090			0.095	0.106	437.930	0.111	0.635	0.149
2019	84.936	0.059	462.670	0.141	318.244	0.037			2.881	0.199	1.316	0.185	0.811	0.192	1.092	0.177			0.500	0.560	1.130	0.090			0.090	0.103	486.000	0.128	0.592	0.148
2020	80.734	0.058	449.623	0.116															0.550		1.110	0.100			0.110	0.099	543.340	0.121	0.778	0.144

Table 7. Life history parameters used to estimate r prior distributions and median shape parameter with corresponding B_{MSY}/K values for the North Atlantic swordfish JABBA assessment. The priors are generated using an Age-Structured Equilibrium Model (ASEM).

Parameter	Mean	CV	Distribution	Description	Source
M	0.2	0.35	Lognormal	Natural Mortality (1/year)	-
L_{inf} (cm) female	312.27	0.1	Lognormal	Von Bertalanffy asymptotic length	Arocha et al. (2003)
L_{inf} (cm) male	223.12				
K female	0.0926	0.1	Normal	Von Bertalanffy growth parameter	Arocha et al. (2003)
K male	0.1522				
t_0 female	-3.762	0.2	Normal	Von Bertalanffy age at zero length	Arocha et al. (2003)
t_0 male	-3.4875				
A female	3.4E-06	-	Exponential	Weight at length parameter (GG-LJFL)	Arocha et al. (2003)
A male	3.4E-6				
B female	3.2623	-	Exponential	Weight at length parameter (GG-LJFL)	Arocha et al. (2003)
B male	3.2623				
L_{50} (cm) female	179	0.2	Lognormal	Length at 50% maturity	Arocha et al. (1996)
L_{50} (cm) male	135				
t_{max} (y)	15	0.2	Lognormal	Longevity	FishLife
L_c (cm)	119	Fixed	Lognormal	Length at 50% selectivity	25th percentile LF
h	0.6, 0.75, 0.88	Range	Fixed	Steepness	-

Table 8. Summary of model diagnostics for the base Stock synthesis model for North Atlantic Swordfish.



Diagnostic	Index	type	Stastitic	Value	Result
Runs Test	CAN_3	cpue	p-value	0.00	Failed
Runs Test	JPN_ERLY_4	cpue	p-value	0.03	Failed
Runs Test	JPN_LATE_5	cpue	p-value	0.07	Passed
Runs Test	CHT_EARLY_7	cpue	p-value	0.01	Failed
Runs Test	CHT_LATE_8	cpue	p-value	0.02	Failed
Runs Test	MOR_9	cpue	p-value	0.15	Passed
Runs Test	US_Survey_12	cpue	p-value	0.03	Failed
Runs Test	PORT_Survey_13	cpue	p-value	0.20	Passed
Runs Test	Age-1	cpue	p-value	0.51	Passed
Runs Test	Age-2	cpue	p-value	0.00	Failed
Runs Test	Age-3	cpue	p-value	0.03	Failed
Runs Test	Age-4	cpue	p-value	0.10	Passed
Runs Test	Age-5+	cpue	p-value	0.01	Failed
Runs Test	SPN_1	len	p-value	0.00	Failed
Runs Test	US_2	len	p-value	0.00	Failed
Runs Test	CAN_3	len	p-value	0.00	Failed
Runs Test	JPN_ERLY_4	len	p-value	0.02	Failed
Runs Test	JPN_LATE_5	len	p-value	0.32	Passed
Runs Test	PORT_6	len	p-value	0.00	Failed
Runs Test	CHT_EARLY_7	len	p-value	0.00	Failed
Runs Test	CHT_LATE_8	len	p-value	0.00	Failed
Runs Test	MOR_9	len	p-value	0.00	Failed
Runs Test	HRPN_10	len	p-value	0.01	Failed
Retrospective analysis		SSB	Mohn's rho	-0.11	Passed
Retrospective analysis		Bratio	Mohn's rho	0.00	Passed
Retrospective analysis		Fratio	Mohn's rho	0.16	Passed
Hcxval	CAN_3	CPUE	MASE	1.74	Fail
Hcxval	JPN_LATE_5	CPUE	MASE	0.70	Pass
Hcxval	CHT_LATE_8	CPUE	MASE	0.72	Pass
Hcxval	MOR_9	CPUE	MASE	1.61	Fail
Hcxval	US_Survey_12	CPUE	MASE	1.53	Fail
Hcxval	PORT_Survey_13	CPUE	MASE	2.90	Fail
Hcxval	Age-2	CPUE	MASE	2.53	Fail
Hcxval	Age-3	CPUE	MASE	0.58	Pass
Hcxval	Age-4	CPUE	MASE	1.18	Fail
Hcxval	Age-5+	CPUE	MASE	1.77	Fail

Table 9. Comparison of the ASPIC estimates and benchmarks from the continuity runs for the N-SWO stock updating the catch series (1950 – 2020) and using the 2017 Combined biomass index (Cont1), or updating the catch series and using the 2022 Combined biomass index (SCRS/2022/119) (Continuity). These runs assumed a logistic surplus production function and fixed the B1/K at 0.85, the same settings as the ASPIC base case for the 2017 assessment.

	Base 2017	**Continuity**	**Cont 1**
power	2	2	2
B1.K	0.85	0.85	0.85
MSY	13.358	11.223	13.387
Fmsy	0.1956	0.0786	0.1965
Bmsy	68.281	142.742	68.118
K	136.563	285.484	136.236
r	0.391	0.157	0.393
phi	0.5	0.5	0.5
q.01	0.01192523	0.005745929	0.011947
B.Bmsy	1.050	0.835	1.259
F.Fmsy	0.775	1.120	0.629
Y.eq	13.324557	10.91717	12.48666
Y.Fmsy	13.959813	9.429214	16.46778

Table 10. N-SWO ASPIC diagnostic Jackknife test on indices of abundance for Group 1 and 2A. Estimated parameter and derived benchmarks. Yellow highlighted cells indicated runs with solutions that hit boundary conditions and should be considered with caution.

Group 1 index

	RM_CanLL	**RM_PORLL**	**RM_SPNLL**	**RM_USALL**
power	2	2	2	2
B1.K	0.85	0.85	0.85	0.85
MSY	15.875	19.017	20.235	16.552
Fmsy	0.2125	0.3586	0.2875	0.3145
Bmsy	74.716	53.034	70.394	52.628
K	149.432	106.069	140.788	105.257
r	0.4249	0.7172	0.5749	0.6290
phi	0.5	0.5	0.5	0.5
q.01	0.00929	0.01160	0.00850	0.01270
q.02	0.01010	0.01245	0.00853	0.01256
q.03	0.00985	0.01204	0.00885	0.01396
q.04				
B.Bmsy	1.534	1.653	1.677	1.579
F.Fmsy	0.455	0.352	0.326	0.424
Y.eq	11.343	10.900	10.963	11.009
Y.Fmsy	23.150	28.548	31.235	24.189

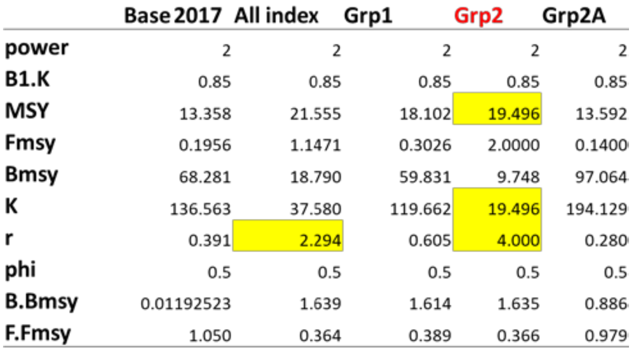
Group 2A index

	RM_JPN1LL	**RM_JPN2LL**	**RM_CTP1LL**	**RM_CTP2LL**	**RM_MARLL**
power	2	2	2	2	2
B1.K	0.85	0.85	0.85	0.85	0.85
MSY	18.965	13.517	19.947	15.208	12.517
Fmsy	2.0000	0.1524	2.0000	0.3107	0.0964
Bmsy	9.483	88.710	9.974	48.950	129.873
K	18.965	177.420	19.947	97.899	259.747
r	4.0000	0.3047	4.0000	0.6214	0.1928
phi	0.5	0.5	0.5	0.5	0.5
q.01	0.06772	0.00859	0.06765	0.01604	0.00571
q.02	0.06252	0.00683	0.06295	0.03202	0.00891
q.03	0.05722	0.01227	0.05351	0.01232	0.00464
q.04	0.06339	0.01333	0.05927	0.03100	0.00786
B.Bmsy	1.634	0.922	1.657	0.877	0.863
F.Fmsy	0.366	0.924	0.344	0.887	1.058
Y.eq	11.337	13.434	11.341	14.979	12.281
Y.Fmsy	23.111	12.534	24.433	13.576	10.870

Table 11. Summary of posterior quantiles presented in the form of marginal posterior medians and associated the 95% credibility intervals (5% LCI and 95% UCI) of parameters for the reference case JABBA model for North Atlantic swordfish.

	Median	**LCI**	**UCI**
K	184345.6	117248	306311.6
r	0.277828	0.160736	0.454829
Initial depletion	0.963947	0.815413	0.998656
σ_{proc}	0.057	0.036	0.1
m	2	2	2
F_{MSY}	0.139	0.08	0.227
B_{MSY}	92172.8	58623.99	153155.8
MSY	12799.37	10863.85	15289.38
B_{MSY}/K	0.5	0.5	0.5
B_{1950}/K	0.963	0.814	1.007
B_{2020}/K	0.456	0.336	0.615
B_{2020}/B_{MSY}	0.912	0.672	1.229
F_{2020}/F_{MSY}	0.899	0.599	1.313

Table 12. N-SWO ASPIC estimated parameters and derived benchmarks from the runs to All nine indices, group 1, 2, and 2A of individual indices of abundance compared to the 2017 SA base case.



	Base 2017	All index	Grp1	Grp2	Grp2A
power	2	2	2	2	2
B1.K	0.85	0.85	0.85	0.85	0.85
MSY	13.358	21.555	18.102	19.496	13.592
Fmsy	0.1956	1.1471	0.3026	2.0000	0.1400
Bmsy	68.281	18.790	59.831	9.748	97.064
K	136.563	37.580	119.662	19.496	194.129
r	0.391	2.294	0.605	4.000	0.280
phi	0.5	0.5	0.5	0.5	0.5
B.Bmsy	0.01192523	1.639	1.614	1.635	0.886
F.Fmsy	1.050	0.364	0.389	0.366	0.979

Table13. N-SWO ASPIC estimated parameters and derived benchmarks from the 2017 base case stock assessment and the 2022 runs of models with the estimated B1/K parameter and combined index (Cont B1/K) and the MLE estimation and fixed B1/K (Cont MLE) parameter at 0.85.

	Base 2017 SA	**Cont B1/K**	**Cont MLE**
power	2	2	2
B1.K	0.85	1.327136	0.85
MSY	13.358	10.959	11.633
Fmsy	0.1956	0.0700	0.0935
Bmsy	68.281	156.486	124.466
K	136.563	312.973	248.931
r	0.391	0.140	0.187
phi	0.5	0.5	0.5
q.01	0.01192523	0.0050419	0.006717919
B.Bmsy	1.050	0.861	0.859
F.Fmsy	0.775	1.112	1.053
Y.eq	13.324557	10.74594	11.39983
Y.Fmsy	13.959813	9.47655	10.05161

Table. 14. Kobe 2 Strategic Matrices for the JABBA reference case. Top: probability that overfishing is not occurring (F<=FMSY); middle: probability that the stock is not overfished (B>=BMSY); and bottom: the joint probability of being in the green quadrant of the Kobe plot (i.e. F<= FMSY and B>= BMSY)

Probability F<=F_{MSY}

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
9000	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%	88%
10000	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
11000	69%	69%	70%	70%	70%	70%	70%	70%	70%	70%	70%
12000	58%	58%	58%	59%	59%	59%	59%	59%	59%	59%	58%
12500	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%	53%
12600	52%	52%	52%	52%	52%	52%	52%	52%	52%	52%	51%
12700	50%	51%	51%	51%	51%	51%	51%	51%	51%	50%	50%
12800	49%	50%	50%	50%	50%	50%	50%	50%	49%	49%	49%
12900	48%	48%	49%	49%	49%	49%	49%	48%	48%	48%	48%
13000	47%	47%	47%	47%	47%	47%	47%	47%	47%	47%	46%
13100	46%	46%	46%	46%	46%	46%	46%	46%	46%	45%	45%
13200	45%	45%	45%	45%	45%	45%	45%	45%	45%	44%	44%
13300	44%	44%	44%	44%	44%	44%	44%	44%	43%	43%	43%
13400	43%	43%	43%	43%	43%	43%	43%	43%	42%	42%	42%
13500	42%	42%	42%	42%	42%	42%	42%	42%	41%	41%	41%
13600	41%	41%	41%	41%	41%	41%	41%	40%	40%	40%	39%
13700	40%	40%	40%	40%	40%	40%	40%	39%	39%	38%	38%
13800	39%	39%	39%	39%	39%	39%	39%	38%	38%	38%	37%
14000	37%	37%	37%	37%	37%	37%	37%	36%	36%	35%	35%
15000	29%	28%	28%	28%	28%	27%	27%	27%	26%	26%	25%
16000	21%	21%	21%	21%	20%	20%	19%	19%	18%	18%	17%

Probability B>=B_{MSY}

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0	49%	69%	81%	88%	92%	94%	96%	97%	97%	98%	98%
9000	49%	55%	60%	63%	66%	68%	70%	71%	73%	74%	75%
10000	49%	54%	57%	60%	62%	64%	65%	66%	67%	68%	68%
11000	49%	52%	54%	56%	58%	59%	60%	61%	61%	61%	61%
12000	49%	51%	52%	53%	53%	54%	54%	55%	55%	55%	55%
12500	49%	50%	51%	51%	51%	51%	51%	51%	51%	51%	51%
12600	49%	50%	50%	51%	51%	51%	51%	51%	51%	50%	50%
12700	49%	50%	50%	50%	50%	50%	50%	50%	50%	50%	49%
12800	49%	50%	50%	50%	50%	50%	50%	49%	49%	49%	49%
12900	49%	50%	49%	49%	49%	49%	49%	49%	49%	48%	48%
13000	49%	49%	49%	49%	49%	49%	48%	48%	48%	47%	47%
13100	49%	49%	49%	49%	48%	48%	48%	48%	47%	47%	46%
13200	49%	49%	49%	48%	48%	48%	48%	47%	47%	46%	46%
13300	49%	49%	49%	48%	47%	47%	47%	47%	46%	46%	45%
13400	49%	49%	48%	48%	47%	47%	46%	46%	45%	45%	44%
13500	49%	49%	48%	47%	47%	46%	46%	45%	45%	44%	44%
13600	49%	49%	48%	47%	46%	46%	45%	45%	44%	44%	43%
13700	49%	48%	48%	47%	46%	45%	45%	44%	43%	43%	42%
13800	49%	48%	47%	46%	45%	45%	44%	43%	43%	42%	42%
14000	49%	48%	47%	46%	45%	44%	43%	42%	42%	41%	40%
15000	49%	46%	44%	42%	40%	39%	38%	37%	36%	35%	34%
16000	49%	45%	42%	39%	37%	34%	33%	31%	30%	29%	27%

Probability F<=F_{MSY} and B>=B_{MSY}

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0	49%	69%	81%	88%	92%	94%	96%	97%	97%	98%	98%
9000	49%	55%	60%	63%	66%	68%	70%	71%	73%	74%	75%
10000	49%	54%	57%	60%	62%	64%	65%	66%	67%	68%	68%
11000	49%	52%	54%	56%	58%	59%	60%	60%	61%	61%	61%
12000	48%	50%	51%	52%	53%	53%	53%	54%	54%	54%	54%
12500	47%	48%	49%	49%	49%	50%	50%	50%	50%	50%	50%
12600	46%	47%	48%	48%	49%	49%	49%	49%	49%	49%	49%
12700	46%	47%	47%	48%	48%	48%	48%	48%	48%	48%	48%
12800	45%	46%	47%	47%	47%	47%	47%	47%	47%	47%	47%
12900	45%	45%	46%	46%	46%	46%	46%	46%	46%	46%	46%
13000	44%	45%	45%	45%	45%	45%	46%	46%	45%	45%	45%
13100	44%	44%	44%	45%	44%	45%	45%	45%	44%	44%	44%
13200	43%	43%	44%	44%	44%	44%	44%	44%	43%	43%	43%
13300	42%	43%	43%	43%	43%	43%	43%	43%	42%	42%	42%
13400	41%	42%	42%	42%	42%	42%	42%	42%	41%	41%	41%
13500	41%	41%	41%	41%	41%	41%	41%	41%	40%	40%	40%
13600	40%	40%	40%	40%	40%	40%	40%	40%	39%	39%	39%
13700	39%	39%	39%	39%	39%	39%	39%	39%	38%	38%	38%
13800	38%	38%	38%	38%	38%	38%	38%	38%	37%	37%	37%
14000	36%	37%	37%	37%	36%	36%	36%	36%	35%	35%	35%
15000	28%	28%	28%	28%	28%	27%	27%	26%	26%	26%	25%
16000	21%	21%	21%	21%	20%	20%	19%	19%	18%	18%	17%

Table. 15. Estimates of benchmark by Stock Synthesis, ASPIC and JABBA.

Assessment model	JABBA	ASPIC	Stock Synthesis
unit	Biomass	Biomass	SSB
discards	Reported	Reported	reported plus estimated
K or B0	184,346	248,900	265,751
r or steepness	0.278	0.187	0.884
MSY	12,799	11,630	12,838
B_{MSY} or SSB_{MSY}	92,173	124,500	23,666
B_{2020}/B_{MSY} or SSB_{2020}/SSB_{MSY}	0.91	0.86	1.17
F_{2020}/F_{MSY}	0.90	1.05	0.78

Table 16. Summary of prior values, and associated distributions, used in the JABBA reference case model for the South Atlantic swordfish.

Parameter	Description	Prior	*m*	CV
K	Unfished biomass	lognormal	175,000	100%
ψ (*psi*)	Initial depletion	beta	0.95	5%
s^2 *(proc)**	Process error variance	inverse-gamma	0.001	0.001
r	Population growth rate	lognormal	0.155	12%
h	steepness	fixed	0.7	-
B_{MSY}/K	Ratio of BMSY to K	fixed	0.38	-
q	CPUE catchability coefficient	uniform	-	-
Observation error	Std. Dev for CPUE	fixed	0.25	-

* both scaling parameters set at 0.001 as Obs. Error is fixed at 0.25.

Table 17. Life history parameters used to estimate *r* prior distributions and median shape parameter with corresponding B_{MSY}/K values for S2 (Garcia *et al.* growth model) of the for South Atlantic swordfish assessment. The priors are generated using an Age-Structured Equilibrium Model (ASEM).

Parameter	**Mean**	**CV**	**Distribution**	**Description**	**Source**
M	0.2	0.35	Lognormal	Natural Mortality (1/year)	-
L_{inf} (cm) female	307.86	0.1	Lognormal	Von Bertalanffy asymptotic length	Garcia et al. (2016)
L_{inf} (cm) male	238.91				
K female	0.093	0.1	Normal	Von Bertalanffy growth parameter	Garcia et al. (2016)
K male	0.145				
t_0 female	-2.246	0.2	Normal	Von Bertalanffy age at zero length	Garcia et al. (2016)
t_0 male	-1.736				
A female	1.69E-06	-	Exponential	Weight at length parameter (GG-LJFL)	SCRS/2017/079 Forselledo et al.(2017)
A male	4.61E-06				
B female	3.32	-	Exponential	Weight at length parameter (GG-LJFL)	SCRS/2017/079 Forselledo et al.(2017)
B male	3.12				
L_{50} (cm) female	156	0.2	Lognormal	Length at 50% maturity	Hazin et al. (2002)
L_{50} (cm) male	125				
D	L_{50} x0.05	0.2	Lognormal	Logistic maturity ogive	Knife-edge
t_{max} (y)	15	0.2	Lognormal	Longevity	FishLife
L_c (cm)	119	fixed	Fixed	Length at 50% selectivity	25th percentile LF
H	0.6-0.8	fixed	Range	Steepness	-

Table 18. Life history parameters used to estimate *r* prior distributions and median shape parameter with corresponding B_{MSY}/K values for S3 (Quelle *et al.* growth model) of the for South Atlantic swordfish assessment. The priors are generated using an Age-Structured Equilibrium Model (ASEM).

Parameter	Mean	CV	Distribution	Description	Source
M	0.2	0.35	Lognormal	Natural Mortality (1/year)	-
L_{inf} (cm)	358.7	0.1	Lognormal	Von Bertalanffy asymptotic length	Quelle et al. (2014)
K	0.092	0.1	Normal	Von Bertalanffy growth parameter	Quelle et al. (2014)
t_o	-1.929	0.2	Normal	Von Bertalanffy age at zero length	Quelle et al. (2014)
A female	1.69E-06	-	Exponential	Weight at length parameter (GG-LJFL)	SCRS/2017/079 Forselledo et al.(2017)
A male	4.61E-06				
B female	3.32	-	Exponential	Weight at length parameter (GG-LJFL)	SCRS/2017/079 Forselledo et al.(2017)
B male	3.12				
L_{50} (cm) female	156	0.2	Lognormal	Length at 50% maturity	Hazin et al. (2002)
L_{50} (cm) male	125				
D	L_{50}x0.05	0.2	Lognormal	Logistic maturity ogive	Knife-edge
t_{max} (y)	15	0.2	Lognormal	Longevity	FishLife
L_c (cm)	119	fixed	Fixed	Length at 50% selectivity	25th percentile LF
H	0.6-0.8	fixed	Range	Steepness	-

Table 19. Results for *r* prior distributions and median shape parameter with corresponding B_{MSY}/K values generated an Age-Structured Equilibrium Model (ASEM).

Parameter	Scenario		
	S1 (Continuity)	**S2 (Garcia)**	**S3 (Quelle)**
r	0.42	0.155	0.138
sd of log(*r*)	0.37	0.117	0.1
B_{MSY}/K	0.4	0..38	0.37
shape *m*	2	1.05	1.03

Table 20. Abundance indices used in the stock assessment for the South Atlantic in 2022.

series	BRA LL		w_SPN LL1		w_SPN LL2		JPN LL1		JPN LL2		JPN LL3*		URU LL**		ZAF LL		CTP LL1		CTP LL2	
Use in 2022stock assessment	Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes		Yes	
units of index	count		weight		weight		count		count		count		count							
source	SCRS/2022/057		SCRS/2021/088		SA meeting		SCRS/2022/046		SCRS/2022/046		SA meeting		SCRS/2017/078		SCRS/2022/049		SCRS/2022/051		SCRS/2022/051	
Year	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV	Std.	CV
1968																	0.329	0.091		
1969																	0.264	0.067		
1970																	0.275	0.064		
1971																	0.324	0.069		
1972																	0.249	0.068		
1973																	0.270	0.091		
1974																	0.250	0.075		
1975																	0.212	0.079		
1976							1.110	1.045									0.117	0.076		
1977							1.260	1.151									0.127	0.068		
1978							1.090	1.229									0.145	0.068		
1979							1.210	0.686									0.191	0.079		
1980							1.430	0.531									0.190	0.070		
1981							1.020	0.343									0.204	0.067		
1982							0.910	0.253									0.180	0.067		
1983							0.890	0.247									0.176	0.080		
1984							1.210	0.207									0.207	0.088		
1985							1.610	0.224									0.155	0.077		
1986							1.210	0.364									0.142	0.070		
1987							2.010	0.219									0.161	0.074		
1988							1.600	0.144									0.188	0.092		
1989			522.857	0.053			1.190	0.143									0.213	0.093		
1990			396.324	0.037			1.750	0.143									0.181	0.077		
1991			384.849	0.034			0.810	0.136												
1992			349.279	0.031			0.740	0.176												
1993			302.030	0.026			0.800	0.250												
1994	1.052	0.106	345.977	0.027					0.680	0.353										
1995	1.436	0.078	395.588	0.026					0.580	0.310										
1996	1.581	0.071	355.344	0.025					0.560	0.196										
1997	1.492	0.075	337.808	0.022					0.470	0.170										
1998	1.261	0.089	328.532	0.024					0.460	0.174									0.149	0.076
1999	1.056	0.106	355.546	0.025					0.470	0.170									0.103	0.061
2000	0.948	0.118			429.918	0.027			0.450	0.156									0.126	0.056
2001	0.884	0.127			380.510	0.024			0.460	0.174			6.47						0.101	0.051
2002	0.901	0.124			364.596	0.024			0.480	0.167			4.13	0.76					0.101	0.048
2003	1.042	0.107			320.908	0.026			0.390	0.205			6.17	0.43					0.099	0.054
2004	0.842	0.133			312.412	0.034			0.370	0.270			5.22	0.42	541.840	0.094			0.075	0.045
2005	0.858	0.130			379.162	0.033			0.480	0.250			5.21	0.43	465.709	0.093			0.071	0.046
2006	0.980	0.114			382.244	0.032					0.720	0.208	5.50	0.34	396.897	0.090			0.101	0.052
2007	1.205	0.093			371.557	0.033					0.650	0.262	4.96	0.39	387.234	0.088			0.079	0.050
2008	1.097	0.102			359.345	0.029					0.590	0.237	3.23	0.44	324.829	0.092			0.093	0.052
2009	1.080	0.104			393.047	0.028					0.490	0.265	3.51	0.41	314.951	0.087			0.076	0.051
2010	1.060	0.120			381.832	0.029					0.550	0.255	3.29	0.45	355.085	0.091			0.063	0.053
2011	1.038	0.122			369.940	0.028					0.340	0.265	2.00	0.43	239.930	0.095			0.067	0.049
2012	0.991	0.113			394.411	0.031					0.450	0.356	5.08	0.47	250.163	0.104			0.065	0.053
2013	0.871	0.128			397.743	0.032					0.480	0.292			379.342	0.090			0.089	0.055
2014	0.953	0.117			416.847	0.033					0.600	0.317			319.594	0.091			0.072	0.054
2015	1.120	0.100			450.238	0.034					0.580	0.362			406.649	0.090			0.075	0.058
2016	0.993	0.113			491.217	0.037					0.630	0.381			436.313	0.091			0.078	0.057
2017	0.793	0.141			479.270	0.036					0.720	0.375			323.263	0.089			0.072	0.056
2018	0.877	0.127			421.234	0.033					0.670	0.522			263.436	0.089			0.063	0.055
2019	0.684	0.164			419.139	0.028					0.710	0.648			376.817	0.087			0.060	0.057
2020	0.628	0.178									0.780	0.731			240.583	0.091			0.070	0.058

* the 2020 year value was not used in the final stock assessment

** this index was not updated because the fishery has ceased.

Table 21. Life-history parameters for the South Atlantic swordfish SS3 models.

	Females	Males	Reference
Linf	308	239	Garcia et al. (2016)
K	0.093	0.145	Garcia et al. (2016)
t0	-2.246	-1.736	Garcia et al. (2016)
a	1.69e-06	4.61e-06	Forselledo et al. (2017)
b	3.32	3.12	Forselledo et al. (2017)
L50	156	-	Hazin et al. (2002)
L100	180	-	Hazin et al. (2002)
A50	5	-	ICCAT (2017, 2022)
A100	6	-	ICCAT (2017, 2022)
M	0.2	0.2	ICCAT (2017, 2022)
MaxAge	25	25	ICCAT (2017, 2022)

Table 22. Summary of posterior quantiles presented in the form of marginal posterior medians and associated 95% credibility intervals (5% LCI and 95% UCI) of the parameters for the reference case JABBA model for South Atlantic swordfish, σproc is the process error, m is the Pella-Tomlinson shape parameter, FMSY is the fishing mortality rate that produces Maximum Sustainable Yield (MSY), BMSY is the biomass at MSY, and K is the unfished biomass.

	Median	LCI	UCI
K	196401.3	158348.5	244567.7
r	0.163942	0.132067	0.202944
Initial depletion	0.96357	0.825653	0.998642
σ_{proc}	0.066	0.027	0.116
m	1.068	1.068	1.068
F_{MSY}	0.154	0.124	0.19
B_{MSY}	74641.26	60179.47	92946.64
MSY	11480.9	9793.981	13265.93
B_{MSY}/K	0.38	0.38	0.38
B_{1950}/K	0.954	0.782	1.11
B_{2020}/K	0.293	0.203	0.423
B_{2020}/B_{MSY}	0.772	0.534	1.113
F_{2020}/F_{MSY}	1.027	0.666	1.51

Table 23. Summaries of parameters and benchmarks with the standard deviations for the South Atlantic swordfish SS3 models.

	Sel_Asym_Model		Sel_DN_Model	
	estimate	*std dev*	*estimate*	*std dev*
SSB_0	9.03E+04	4.10E+03	1.04E+05	3.74E+03
Total biomass at virgin conditions	2.05E+05	9.34E+03	2.38E+05	8.52E+03
SSB_{MSY}	2.47E+04	1.14E+03	2.82E+04	1.02E+03
F_{MSY}	1.28E-01	1.47E-03	1.24E-01	1.47E-03
MSY	9.56E+03	4.16E+02	1.04E+04	3.51E+02
SSB_{MSY}/SSB_0	2.74E-01	7.07E-04	2.70E-01	9.35E-04
SSB_{2020}/SSB_{MSY}	7.93E-01	8.74E-02	8.35E-01	1.15E-01
F_{2020}/F_{MSY}	1.31E+00	1.41E-01	1.14E+00	0.153227

Table 24. Estimated projection probabilities (%) of stock depletion (B < 10% of B_{MSY}) for the reference case model for South Atlantic swordfish. Stochastic projections were conducted over the period 2023-2033 with a range of fixed TACs (6,000 – 15,000 t), including a zero catch-scenario.

Probability of Stock Depletion (B < 10% of B_{MSY})

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
6000	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
6500	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7000	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7500	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8000	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8500	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9000	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%
9500	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%
9826	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	2%
10000	0%	0%	0%	0%	0%	0%	1%	1%	1%	2%	2%
10500	0%	0%	0%	0%	0%	0%	1%	1%	2%	3%	3%
11000	0%	0%	0%	0%	0%	1%	1%	2%	3%	4%	5%
11500	0%	0%	0%	0%	0%	1%	2%	3%	4%	6%	8%
12000	0%	0%	0%	0%	1%	1%	2%	4%	6%	8%	11%
12500	0%	0%	0%	0%	1%	2%	4%	6%	8%	12%	15%
13000	0%	0%	0%	0%	1%	2%	5%	8%	12%	16%	21%
13500	0%	0%	0%	0%	1%	4%	7%	10%	15%	21%	27%
14000	0%	0%	0%	1%	2%	5%	8%	14%	20%	27%	33%
14500	0%	0%	0%	1%	2%	6%	11%	18%	25%	33%	41%
15000	0%	0%	0%	1%	3%	8%	14%	22%	31%	40%	49%

Table 25. Estimated projection probabilities (%) for the reference case model for South Atlantic swordfish. Projection probabilities are provided for F<=F_{MSY} (top); B>=B_{MSY} (middle); F<=F_{MSY} and B>=B_{MSY} (bottom). Stochastic projections were conducted over the period 2023-2033 with a range of fixed TACs (6,000 – 15,000 t), including a zero catch-scenario. 9826 tonnes is the mean of the last 3 years, taken as the current catch.

Probability F<=F_{MSY}

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
6000	95%	97%	98%	98%	99%	99%	99%	99%	100%	100%	100%
6500	92%	94%	96%	97%	98%	98%	99%	99%	99%	99%	99%
7000	88%	91%	93%	95%	96%	97%	97%	98%	98%	98%	98%
7500	82%	86%	89%	91%	93%	94%	95%	96%	96%	97%	97%
8000	75%	80%	83%	86%	88%	90%	91%	92%	93%	94%	95%
8500	68%	72%	76%	79%	82%	84%	85%	87%	88%	89%	90%
9000	59%	64%	68%	71%	74%	76%	78%	80%	81%	83%	84%
9500	51%	55%	59%	62%	65%	67%	69%	71%	72%	74%	75%
9826	46%	50%	53%	56%	58%	60%	62%	64%	65%	67%	68%
10000	43%	47%	49%	52%	54%	57%	59%	60%	62%	64%	65%
10500	35%	38%	40%	42%	44%	46%	48%	49%	50%	52%	53%
11000	29%	31%	32%	33%	35%	36%	37%	38%	39%	40%	40%
11500	23%	24%	25%	25%	26%	27%	27%	28%	28%	29%	29%
12000	18%	18%	19%	19%	19%	19%	19%	20%	20%	20%	20%
12500	13%	14%	14%	14%	14%	14%	14%	13%	13%	13%	13%
13000	11%	10%	10%	10%	10%	10%	9%	9%	9%	9%	9%
13500	8%	8%	7%	7%	7%	6%	6%	6%	6%	6%	5%
14000	6%	6%	5%	5%	5%	4%	4%	4%	4%	3%	3%
14500	5%	4%	4%	3%	3%	3%	3%	2%	2%	2%	2%
15000	4%	3%	3%	2%	2%	2%	2%	2%	1%	1%	1%

Probability B>=B_{MSY}

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0	21%	48%	74%	90%	96%	99%	99%	100%	100%	100%	100%
6000	21%	33%	46%	59%	70%	77%	83%	88%	92%	94%	95%
6500	21%	32%	44%	56%	66%	74%	80%	85%	88%	91%	93%
7000	21%	31%	41%	52%	62%	70%	75%	80%	85%	88%	90%
7500	21%	30%	39%	48%	57%	65%	70%	76%	80%	83%	86%
8000	21%	29%	37%	45%	53%	60%	65%	70%	74%	78%	81%
8500	21%	28%	34%	41%	48%	54%	59%	64%	68%	72%	75%
9000	21%	27%	32%	38%	44%	49%	53%	58%	61%	65%	68%
9500	21%	26%	31%	35%	39%	44%	48%	51%	55%	58%	60%
9826	21%	25%	29%	33%	36%	40%	43%	47%	50%	52%	55%
10000	21%	25%	29%	32%	35%	39%	41%	45%	47%	49%	52%
10500	21%	24%	27%	29%	31%	34%	36%	38%	40%	41%	43%
11000	21%	23%	25%	26%	28%	29%	30%	32%	33%	34%	35%
11500	21%	22%	23%	24%	24%	25%	25%	26%	26%	27%	27%
12000	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%
12500	21%	20%	19%	19%	18%	18%	17%	17%	16%	16%	16%
13000	21%	19%	18%	17%	16%	15%	14%	13%	13%	12%	12%
13500	21%	18%	17%	15%	14%	12%	11%	10%	10%	9%	9%
14000	21%	18%	15%	13%	12%	10%	9%	8%	7%	7%	6%
14500	21%	17%	14%	12%	10%	8%	7%	6%	6%	5%	4%
15000	21%	16%	13%	10%	8%	7%	6%	5%	4%	3%	3%

Probability F<=F_{MSY} and B>=B_{MSY}

TAC (t)	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
0	21%	48%	74%	90%	96%	99%	99%	100%	100%	100%	100%
6000	21%	33%	46%	59%	70%	77%	83%	88%	92%	94%	95%
6500	21%	32%	44%	56%	66%	74%	80%	85%	88%	91%	93%
7000	21%	31%	41%	52%	62%	70%	75%	80%	85%	88%	90%
7500	21%	30%	39%	48%	57%	65%	70%	76%	80%	83%	86%
8000	21%	29%	37%	45%	53%	60%	65%	70%	74%	78%	81%
8500	21%	28%	34%	41%	48%	54%	59%	64%	68%	72%	75%
9000	21%	27%	32%	38%	44%	49%	53%	58%	61%	65%	68%
9500	21%	26%	31%	35%	39%	44%	48%	51%	55%	58%	60%
9826	21%	25%	29%	33%	36%	40%	43%	47%	50%	52%	55%
10000	20%	25%	28%	32%	35%	39%	41%	45%	47%	49%	52%
10500	20%	23%	26%	29%	31%	33%	35%	38%	40%	41%	43%
11000	20%	22%	24%	25%	27%	28%	30%	31%	32%	33%	35%
11500	18%	19%	21%	22%	23%	23%	24%	24%	25%	26%	26%
12000	16%	16%	17%	18%	18%	18%	18%	18%	19%	19%	19%
12500	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%	13%
13000	10%	10%	10%	10%	9%	9%	9%	9%	9%	9%	8%
13500	8%	8%	7%	7%	7%	6%	6%	6%	6%	5%	5%
14000	6%	6%	5%	5%	5%	4%	4%	4%	4%	3%	3%
14500	5%	4%	4%	3%	3%	3%	3%	2%	2%	2%	2%
15000	4%	3%	3%	2%	2%	2%	2%	2%	1%	1%	1%

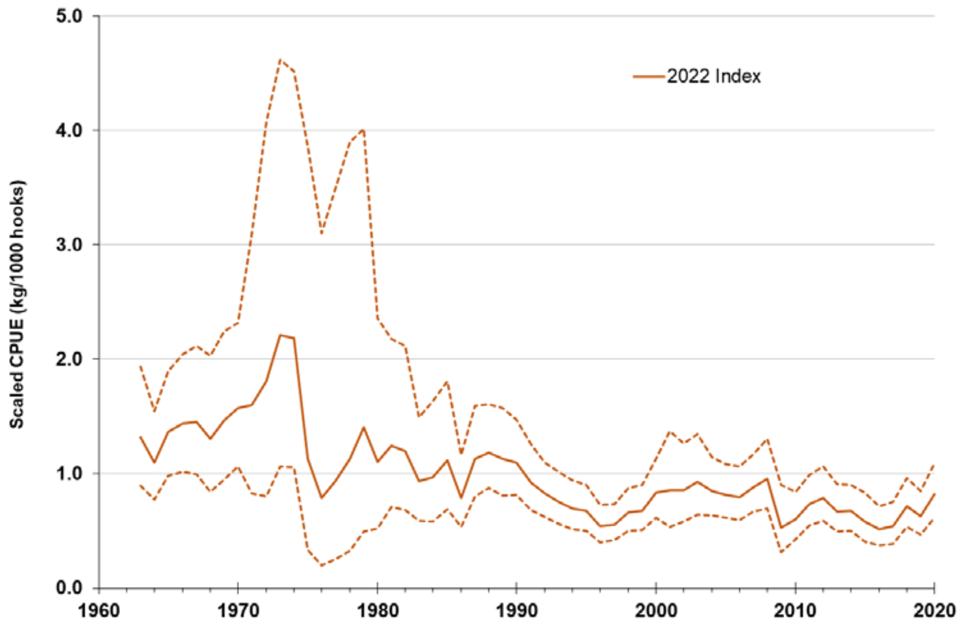


Figure 1. Standardized model trend for the 2022 combined index. The dashed line is the 95% confidence bounds of the model estimates.

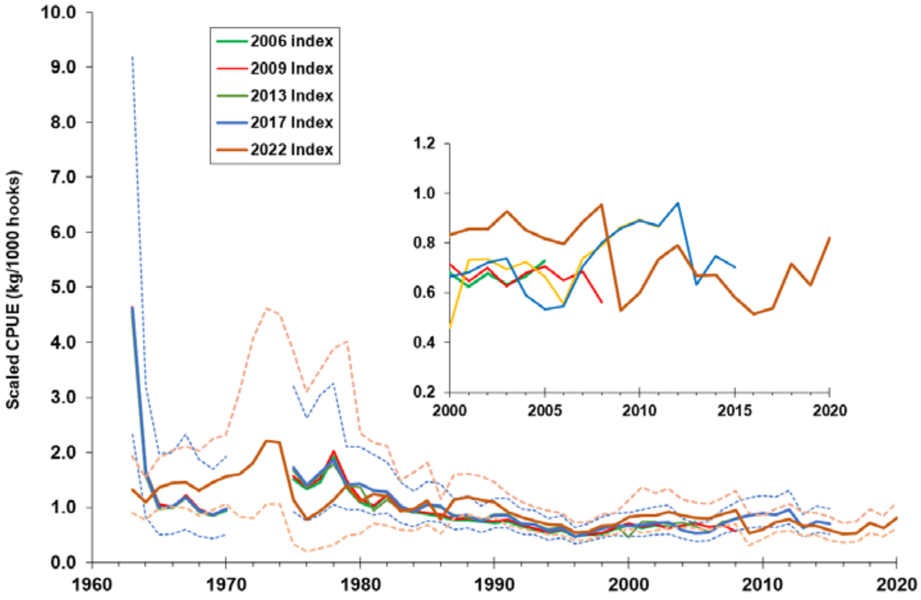
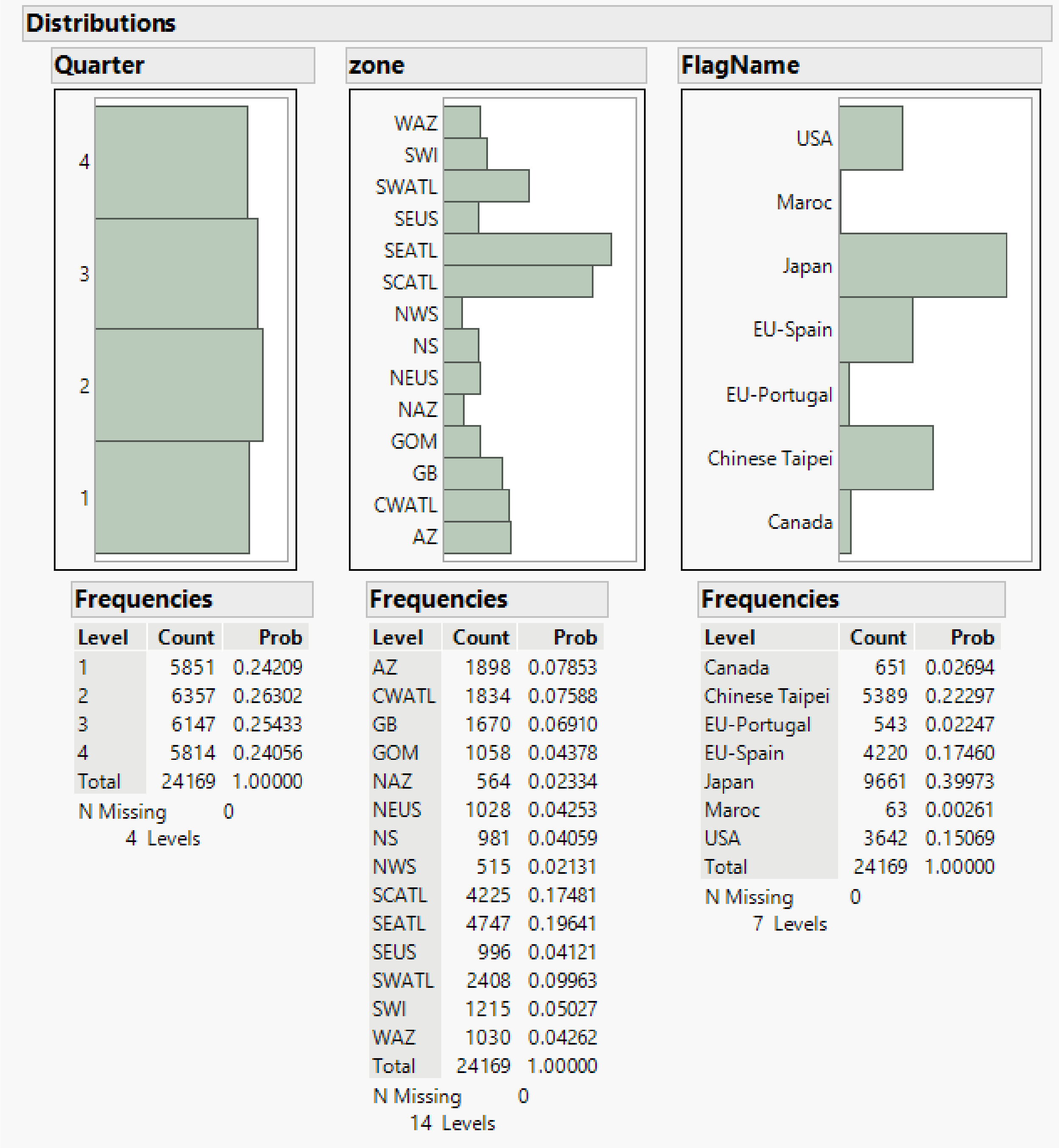


Figure 2. The 2022 standardized model plotted with previous standardization exercises. The 2017 and 2022 model confidence bounds are plotted as dashed lines.



Distributions

Quarter

Frequencies

Level	Count	Prob
1	5851	0.24209
2	6357	0.26302
3	6147	0.25433
4	5814	0.24056
Total	24169	1.00000

N Missing 0

4 Levels

zone

Frequencies

Level	Count	Prob
AZ	1898	0.07853
CWATL	1834	0.07588
GB	1670	0.06910
GOM	1058	0.04378
NAZ	564	0.02334
NEUS	1028	0.04253
NS	981	0.04059
NWS	515	0.02131
SCATL	4225	0.17481
SEATL	4747	0.19641
SEUS	996	0.04121
SWATL	2408	0.09963
SWI	1215	0.05027
WAZ	1030	0.04262
Total	24169	1.00000

N Missing 0

14 Levels

FlagName

Frequencies

Level	Count	Prob
Canada	651	0.02694
Chinese Taipei	5389	0.22297
EU-Portugal	543	0.02247
EU-Spain	4220	0.17460
Japan	9661	0.39973
Maroc	63	0.00261
USA	3642	0.15069
Total	24169	1.00000

N Missing 0

7 Levels

Figure 3. Data frequency input observations for the 2022 standardized index by factor used in the model: quarter, zone, and flag name.

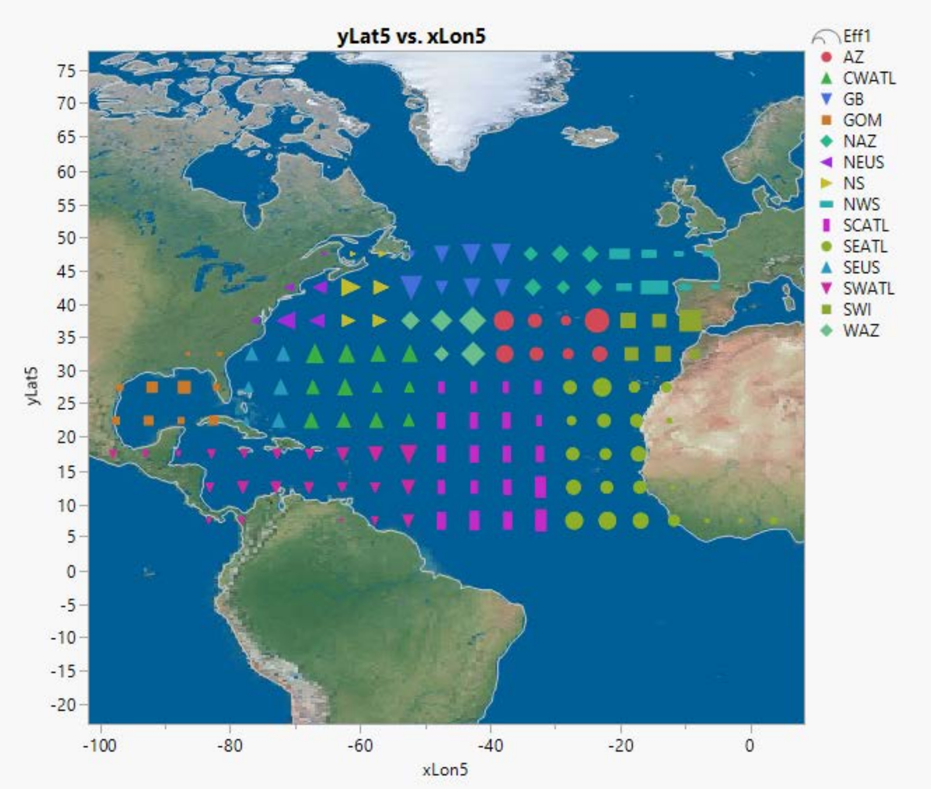


Figure 4. Spatial distribution of the fishing effort (task 2 CE) of the input CPUE for the N-SWO combined index. Size of marker is proportional to the sum of fishing effort (number of hooks) in each 5x5 cell. Color-shape of marker corresponds to the geographical areas considered in the standardization model (see SCRS/2022/115 for details).

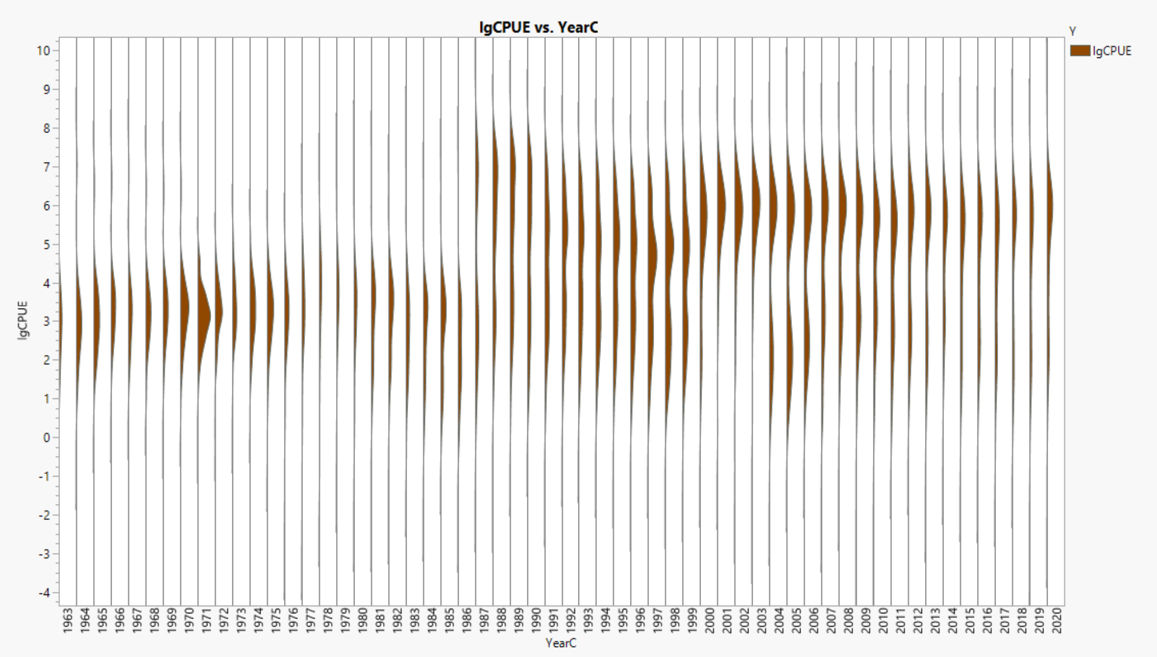


Figure 5. Nominal log(CPUE) distribution by year. N-SWO input Combined biomass index 2022.

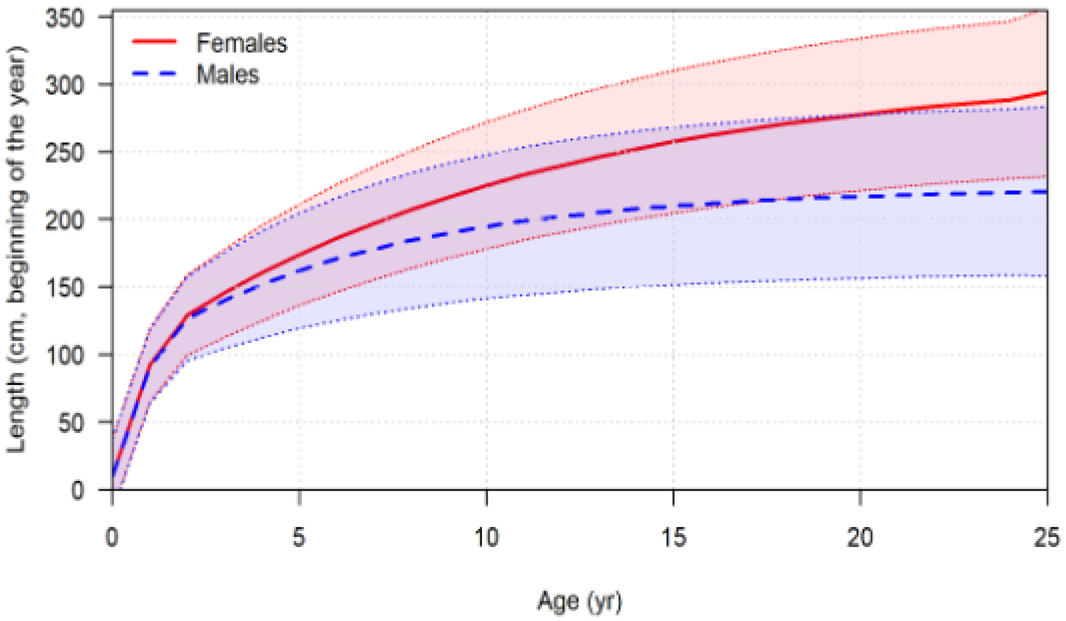


Figure 6. Sex specific growth assumed for the stock assessment of North Atlantic Swordfish conducted using stock synthesis.

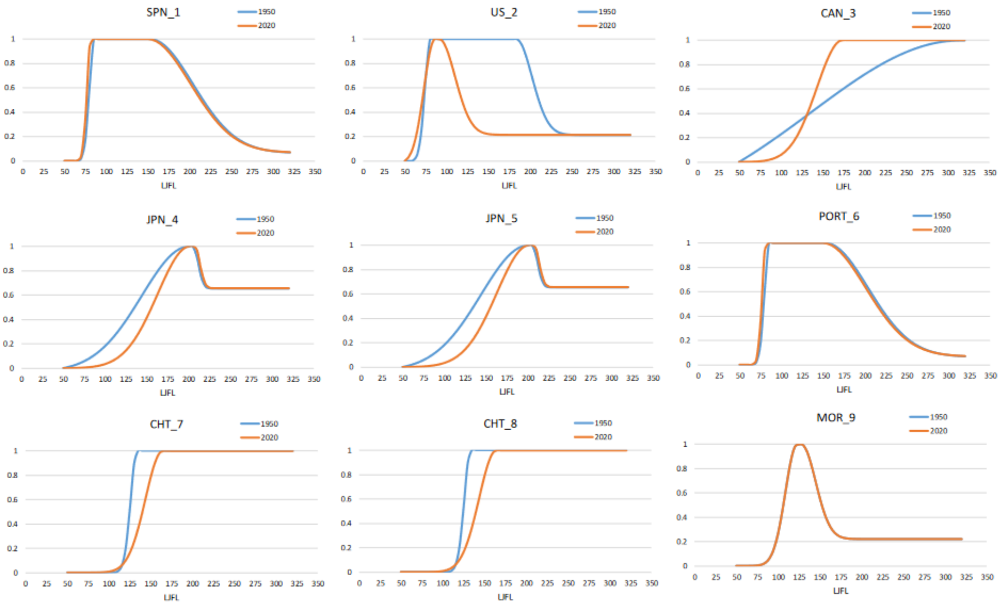


Figure 7. Model estimates of selectivity for each fleet in the NA-SWO stock assessment using stock synthesis. The blue lines depict selectivity prior to the minimum size regulation implemented in 1992 and the orange lines depicts electivity after this period.

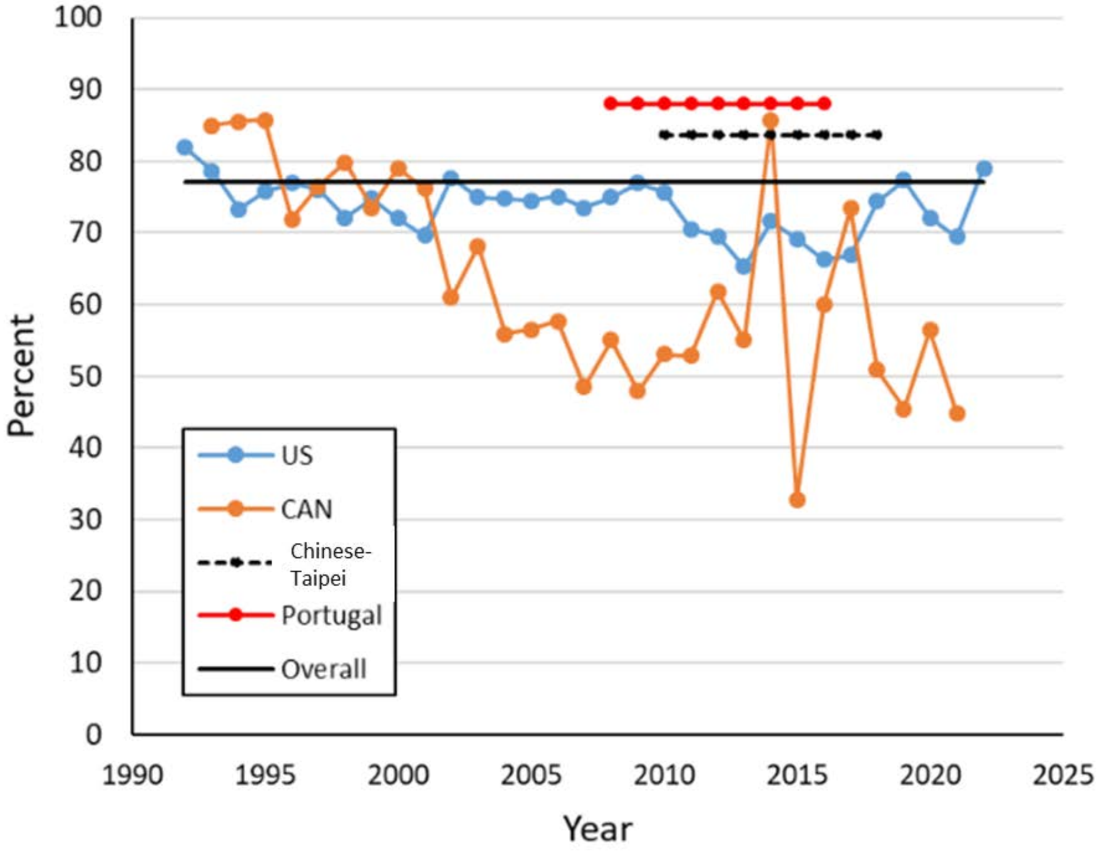


Figure 8. Direct observations of at-haulback mortality for swordfish from the US and CAN LL fleets, which estimated it from observer data, and from Chinese Taipei longline and EU-Portugal longline fleets taken from previous studies (Coelho and Muñoz-Lechuga, 2019; Pan *et al*., 2022) for the initial Stock Synthesis model for the North Atlantic swordfish stock. The black line depicts the overall mean across all values.

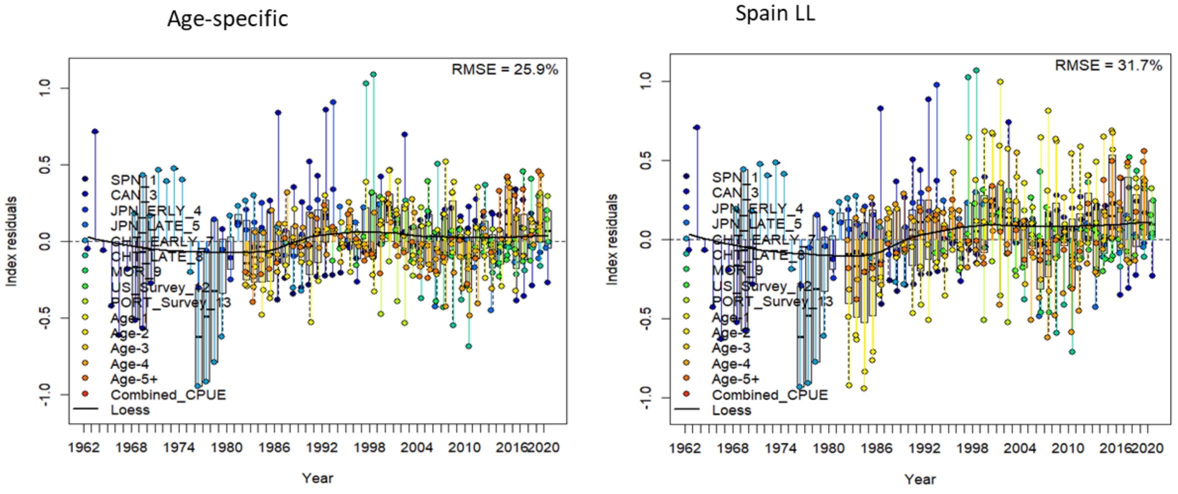


Figure 9. Comparison of RMSE for the models with age-specific (left) and age-aggregated (right) EU-Spain longline index.

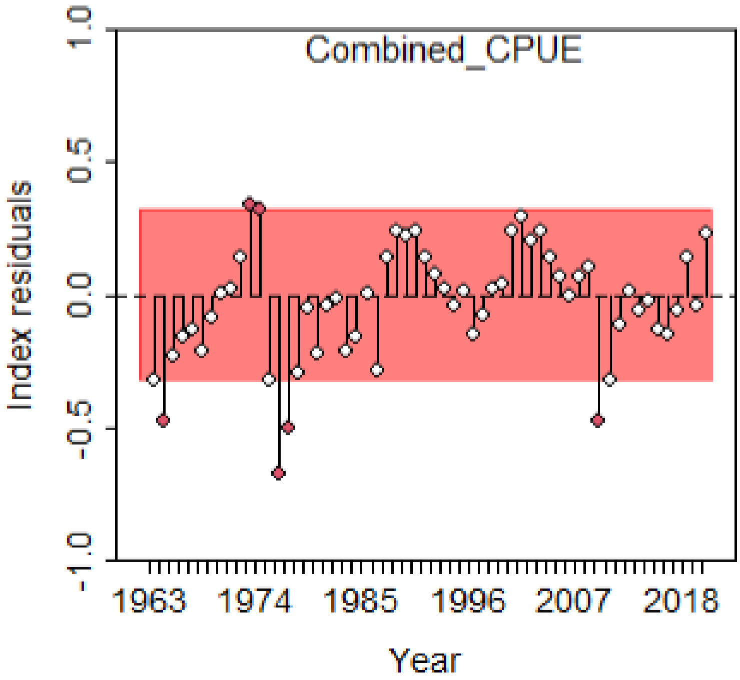


Figure 10. The result of the runs test for the model with fit with a combined index in the SS3 model (SCRS/2022/124).

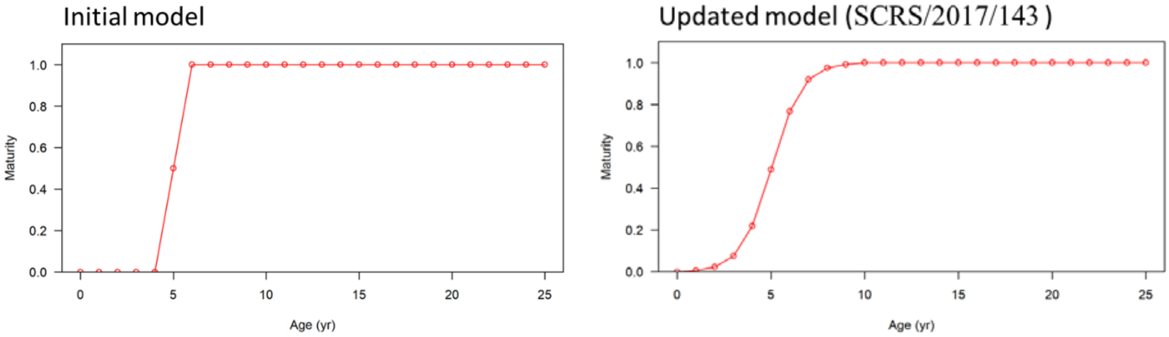


Figure 11. Two different maturity vectors used in the Stock Synthesis model: initial setting (left) and the vector from Sharma and Arocha, (2017).

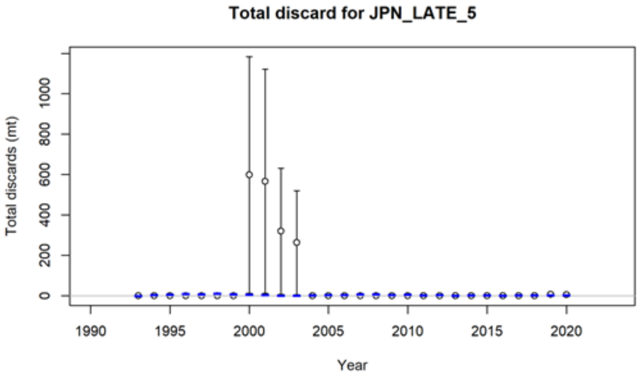


Figure 12. Japan longline fleet reported discards (black circles) and associated uncertainty (error bars of CVs) assigned in the Stock Synthesis model of swordfish in the North Atlantic. Blue dashes are estimated discards.

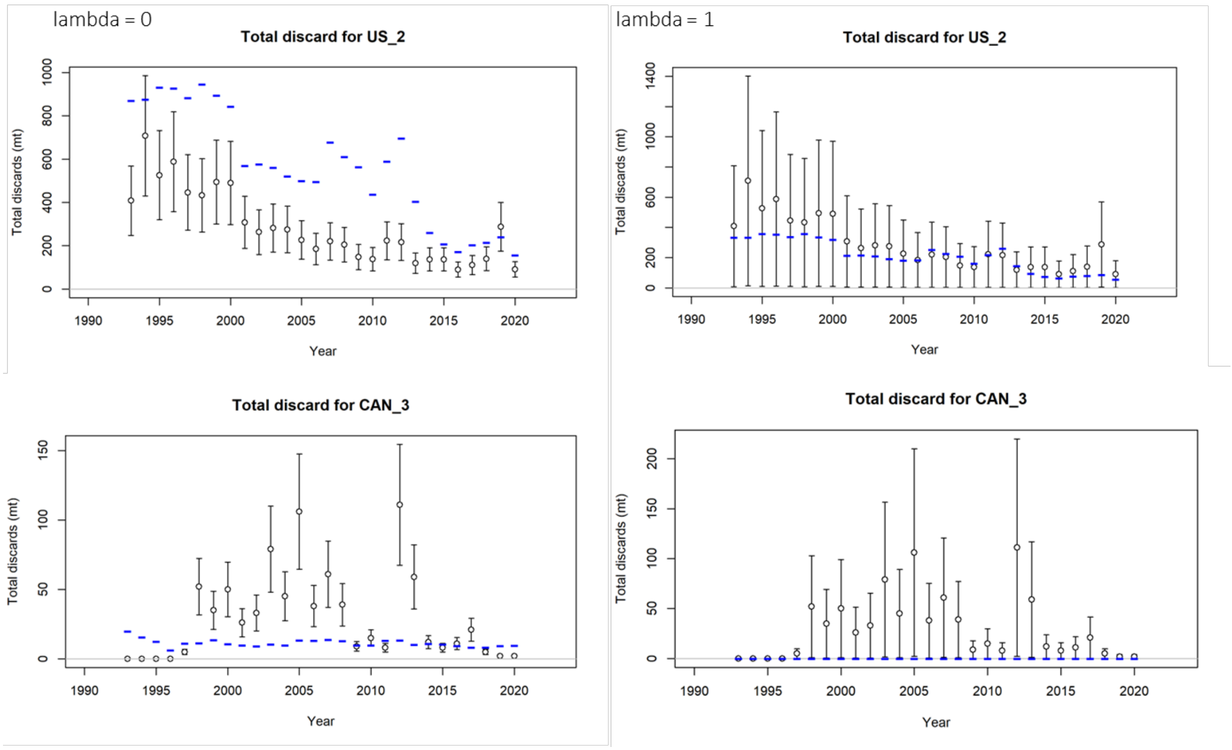


Figure 13. US and CAN reported discard data (black circles) with error bars (CVs) and estimated discards (blue dashes). The left panel represents a model where the discards were freely estimated for all fleets in the SS3 model (not fit in objective function) and the right panel represents a model where the reported discard data for only the US (top row) and CAN (bottom row) longline fleets were fit in the objective function but freely estimated in the other fleets.

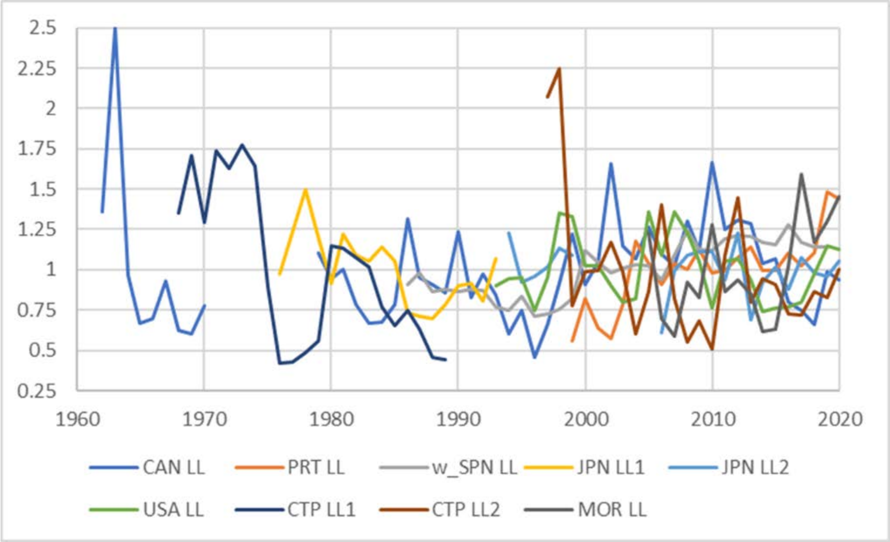
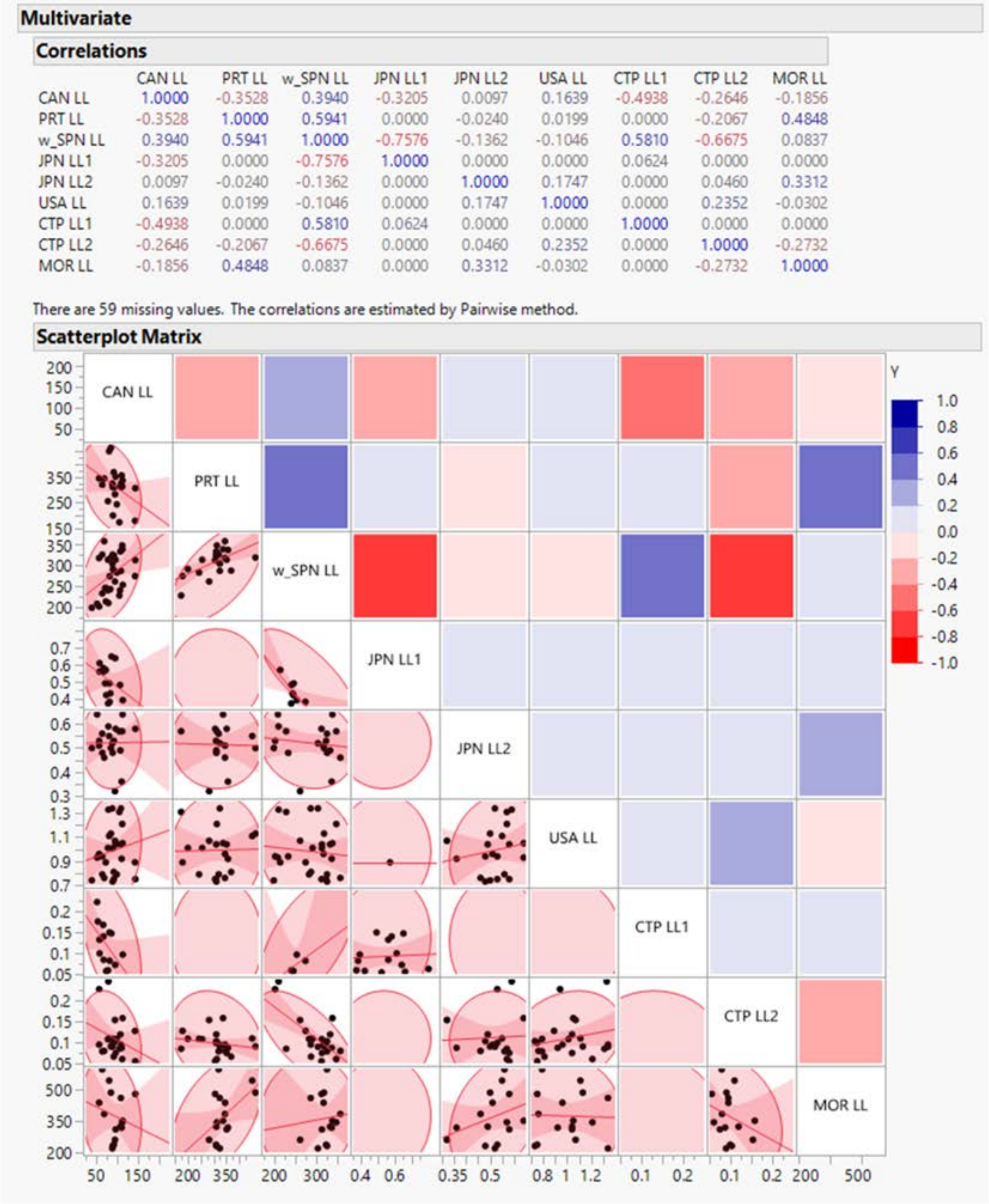


Figure 14. N-SWO indices of abundance available for the surplus production models. Plotted indices are scaled to each index's mean for comparison purposes.



Multivariate

Correlations

	CAN LL	PRT LL	w_SPN LL	JPN LL1	JPN LL2	USA LL	CTP LL1	CTP LL2	MOR LL
CAN LL	1.0000	-0.3528	0.3940	-0.3205	0.0097	0.1639	-0.4938	-0.2646	-0.1856
PRT LL	-0.3528	1.0000	0.5941	0.0000	-0.0240	0.0199	0.0000	-0.2067	0.4848
w_SPN LL	0.3940	0.5941	1.0000	-0.7576	-0.1362	-0.1046	0.5810	-0.6675	0.0837
JPN LL1	-0.3205	0.0000	-0.7576	1.0000	0.0000	0.0000	0.0624	0.0000	0.0000
JPN LL2	0.0097	-0.0240	-0.1362	0.0000	1.0000	0.1747	0.0000	0.0460	0.3312
USA LL	0.1639	0.0199	-0.1046	0.0000	0.1747	1.0000	0.0000	0.2352	-0.0302
CTP LL1	-0.4938	0.0000	0.5810	0.0624	0.0000	0.0000	1.0000	0.0000	0.0000
CTP LL2	-0.2646	-0.2067	-0.6675	0.0000	0.0460	0.2352	0.0000	1.0000	-0.2732
MOR LL	-0.1856	0.4848	0.0837	0.0000	0.3312	-0.0302	0.0000	-0.2732	1.0000

There are 59 missing values. The correlations are estimated by Pairwise method.

Scatterplot Matrix

Figure 15. Correlation analysis performed on the nine indices of abundance available for the N-SWO stock. The top table shows the pair-wise correlation values. The lower diagonal matrix shows the actual correlation points and the predicted linear relationship, while the shade colors of the upper diagonal matrix show the correlation value with negative values in red and positive values in blue.

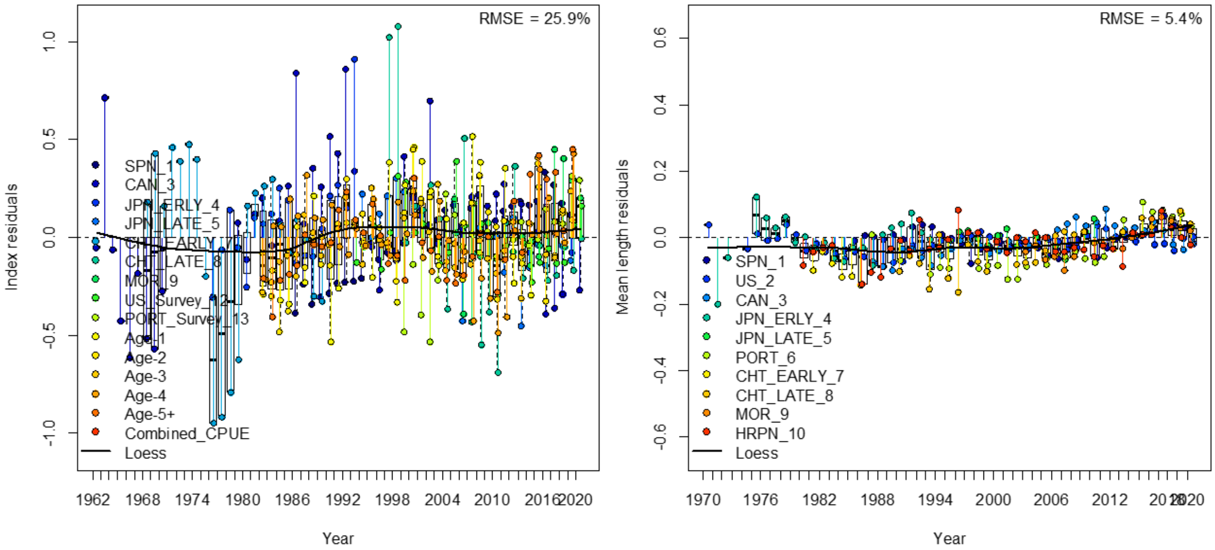


Figure 16. Root mean squared error for fits to the indices (left) and length compositions (right) for the North Atlantic swordfish reference stock assessment using stock synthesis.

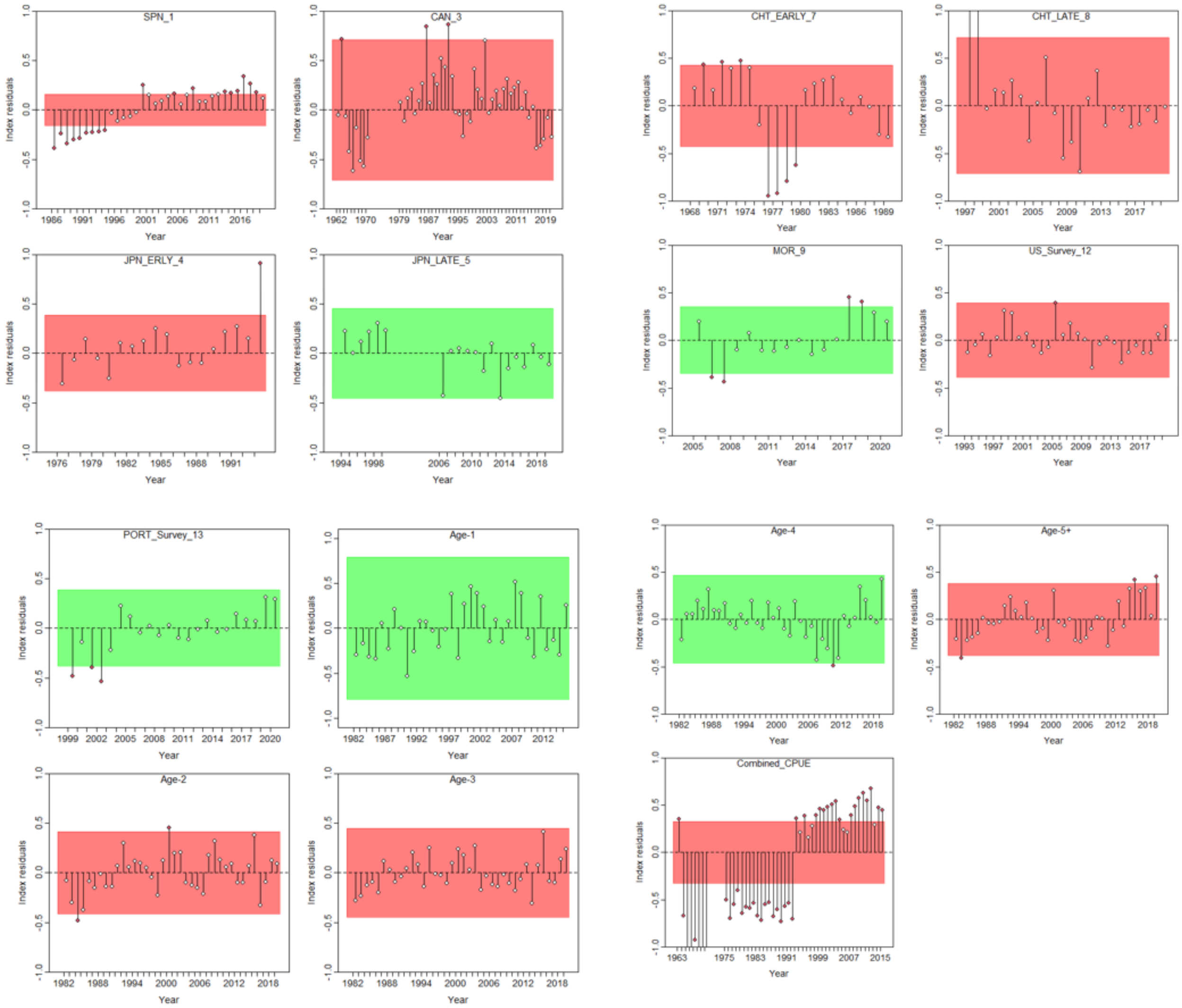


Figure 17. Runs tests for fits to the indices for the North Atlantic swordfish reference stock assessment using stock synthesis. SPN_1 and Combined_CPUE were not used in the SS3 model.

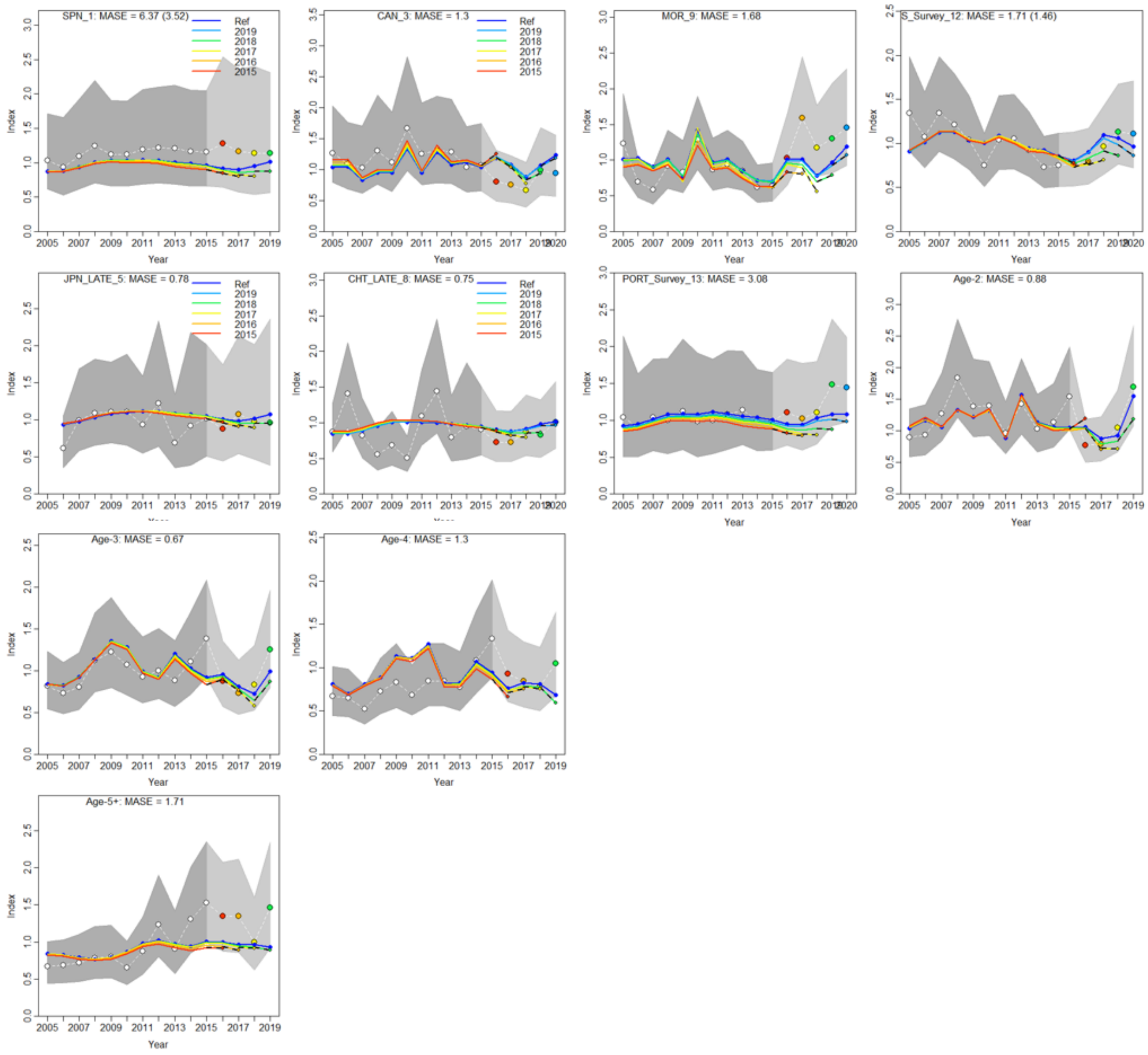


Figure 18. Hindcasting cross-validation (HCxval) results for three catch-per-unit-effort (CPUE) fits from the North Atlantic swordfish SS3 model, showing observed (large points connected with dashed line), fitted (solid lines) and one-year ahead forecast values (small terminal points). HCxval was performed using one reference model (Ref) and five hindcast model runs (solid lines) relative to the expected catch-per-unit effort (CPUE). The observations used for cross validation are highlighted as color-coded solid circles with associated 95% confidence intervals (light-gray shading). The model reference year refers to the endpoints of each one-year-ahead forecast and the corresponding observation (i.e., year of peel + 1). The mean absolute scaled error (MASE) score associated with each CPUE time series is denoted in each panel. The SPN_1 CPUE was not used in the final model.

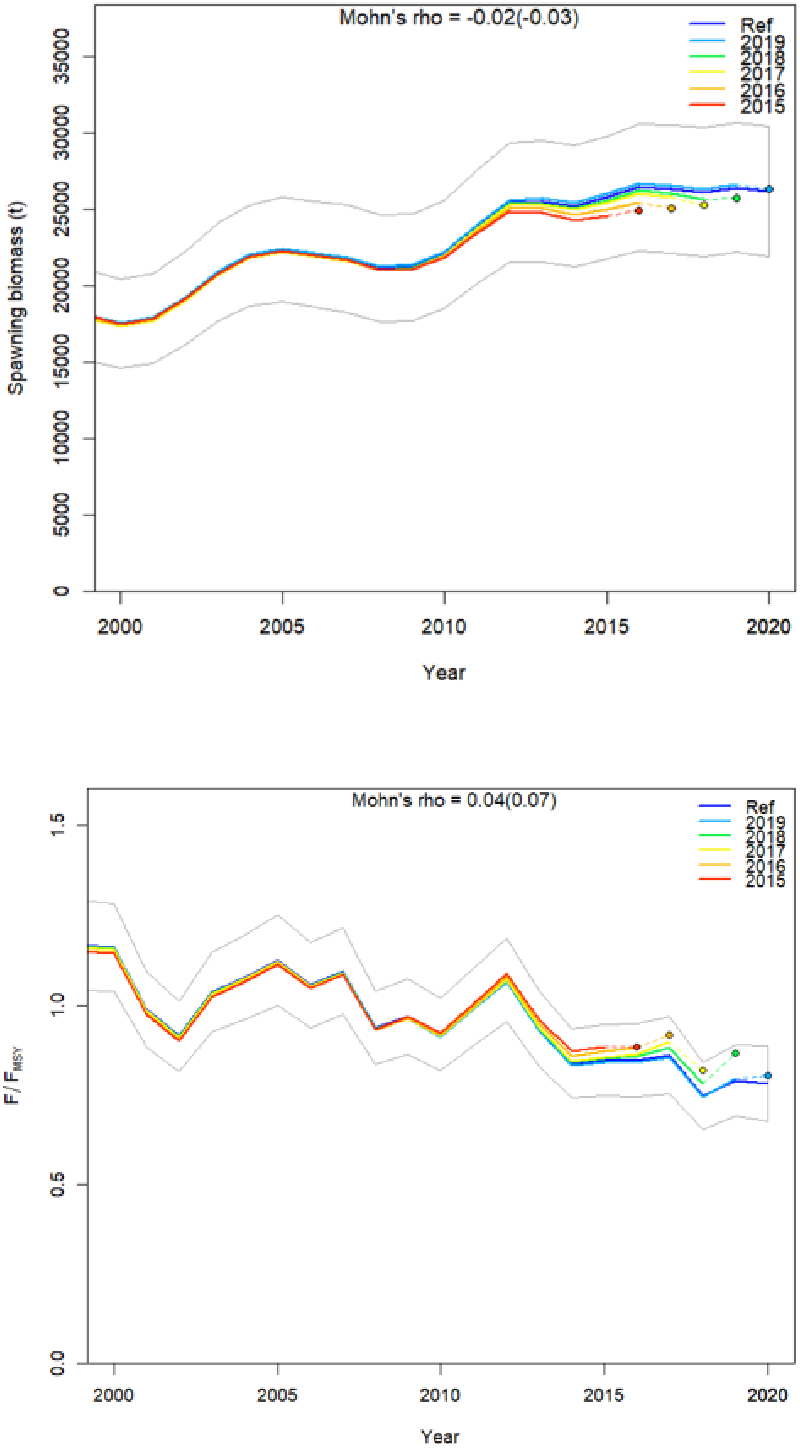


Figure 19. Retrospective analysis of spawning stock biomass (SSB) estimates for North Atlantic swordfish SS3 models conducted by re-fitting the reference model (Ref) after removing five years of observations, one year at a time sequentially. Mohn's rho statistic and the corresponding 'hindcast rho' values (in brackets) are printed at the top of the panels. One-year-ahead projections denoted by color-coded dashed lines with terminal points are shown for each model. Grey shaded areas are the 95 % confidence intervals from the reference model.

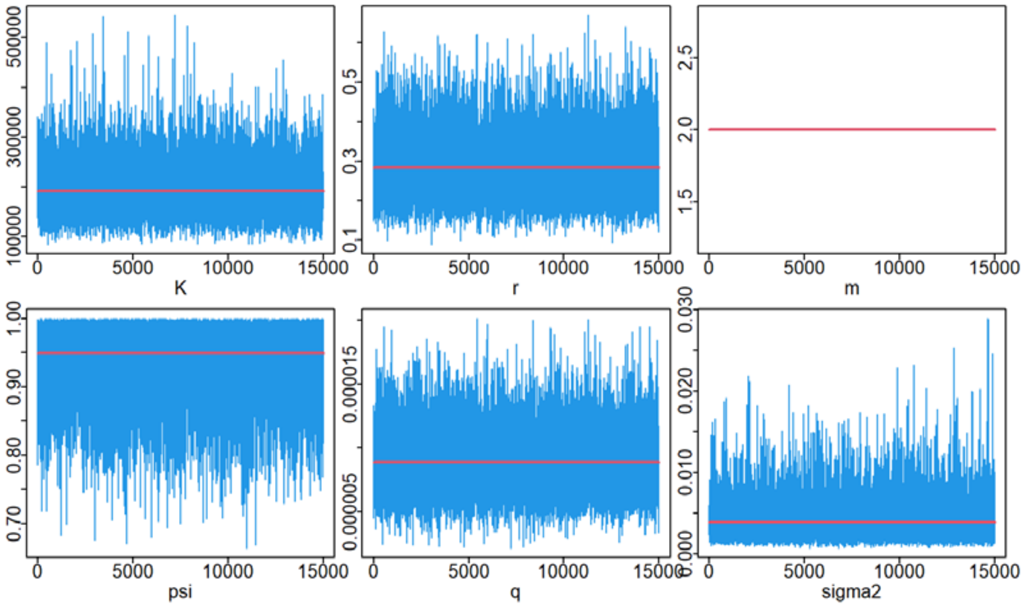


Figure 20. MCMC trace plots for the North Atlantic swordfish JABBA reference case model.

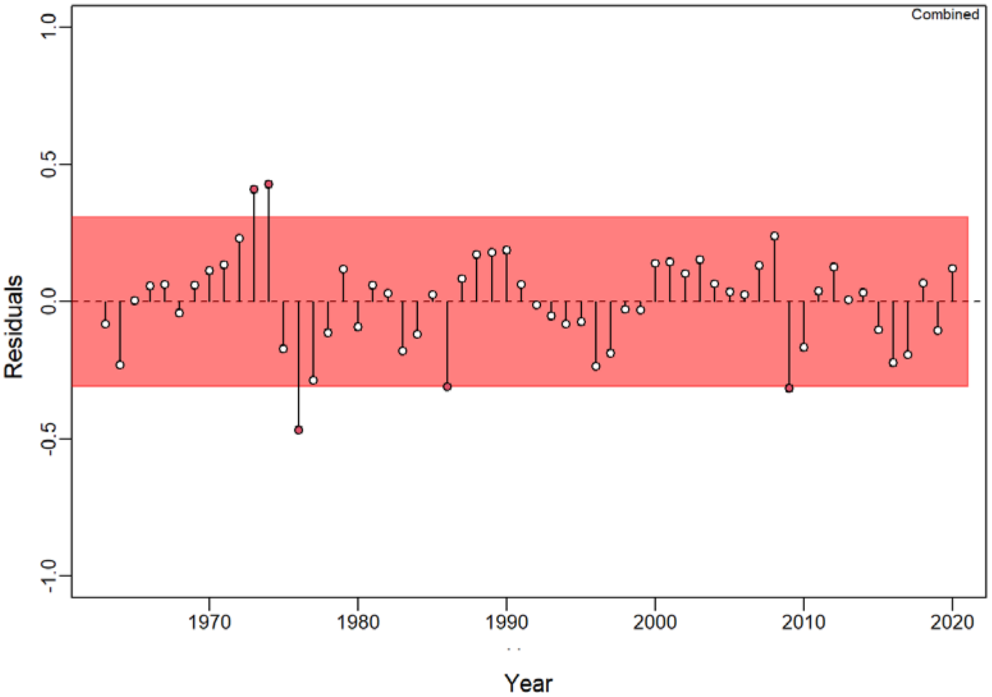


Figure 21. Runs test to evaluate the randomness of the time series of CPUE residuals for the reference case model for the North Atlantic swordfish JABBA assessment. A green panel would indicate no evidence of lack of randomness of time-series residuals (p>0.05) while a red panel, as shown here, indicates possible autocorrelation. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

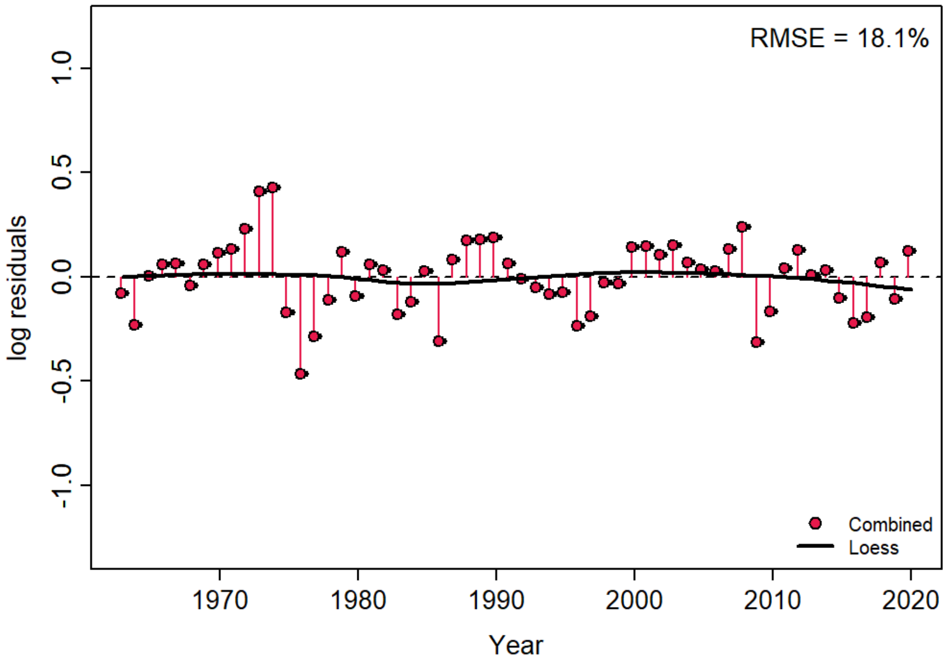


Figure 22. Residual diagnostic plots of CPUE indices for the North Atlantic swordfish JABBA reference case model. Lines indicate the residuals for the combined index for any given year, and solid black lines indicate a Loess smoother.

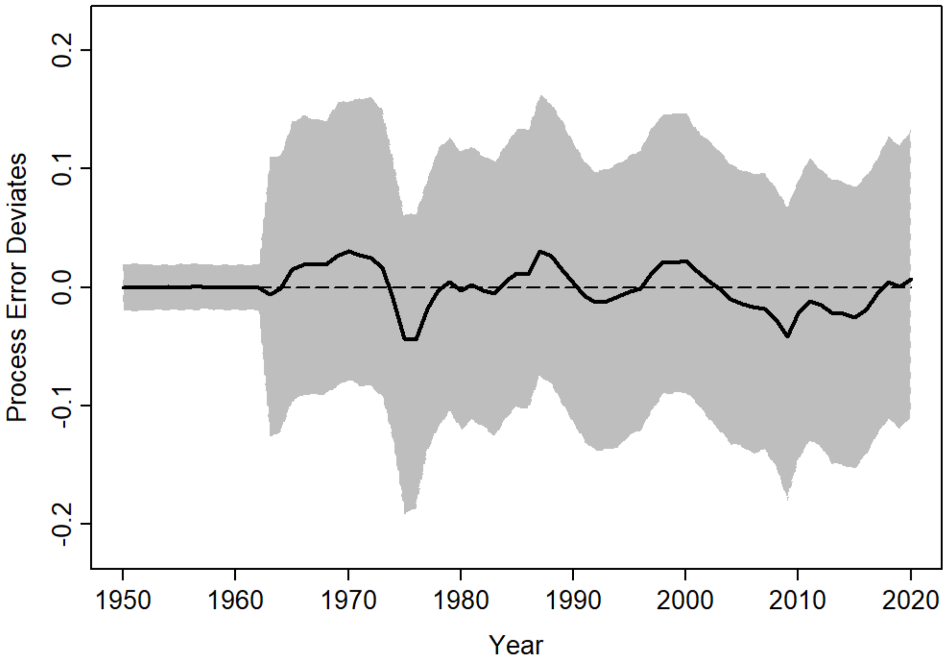


Figure 23. Process error deviations (median: solid line) from the reference case model for the North Atlantic swordfish JABBA assessment. Shaded grey area indicates 95% credibility intervals.

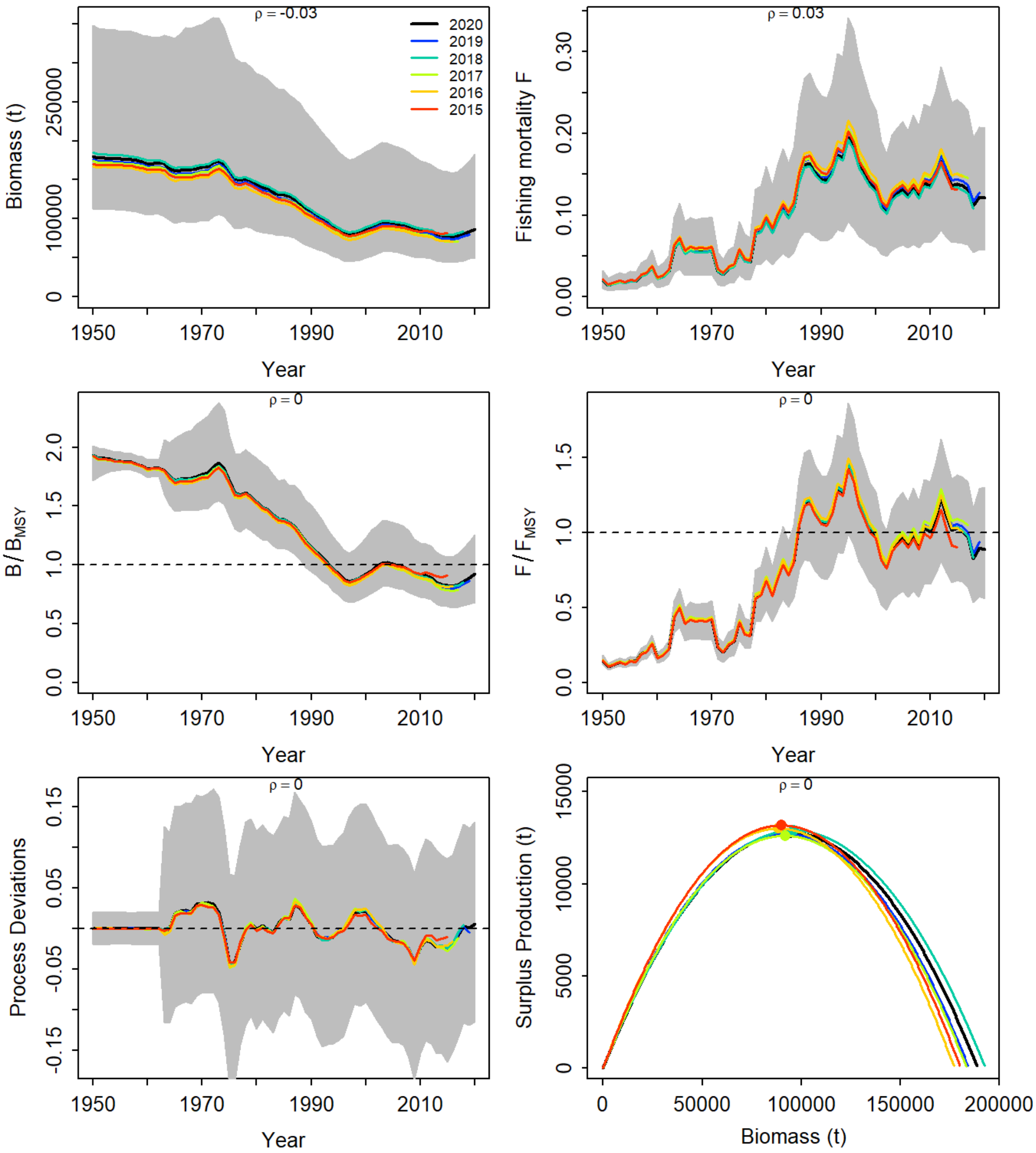


Figure24. Retrospective analysis performed to the reference case model of the North Atlantic swordfish assessment, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).

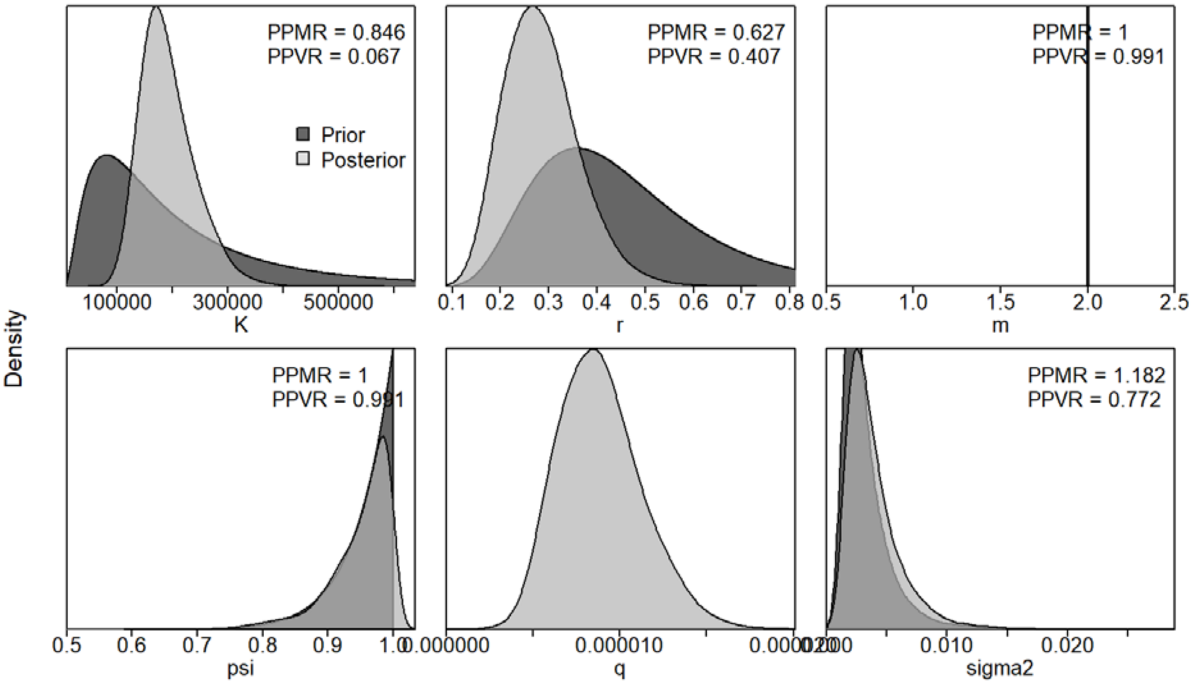


Figure 25. Prior and posterior distributions of various model and management parameters for the reference case model for the North Atlantic swordfish JABBA assessment. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.

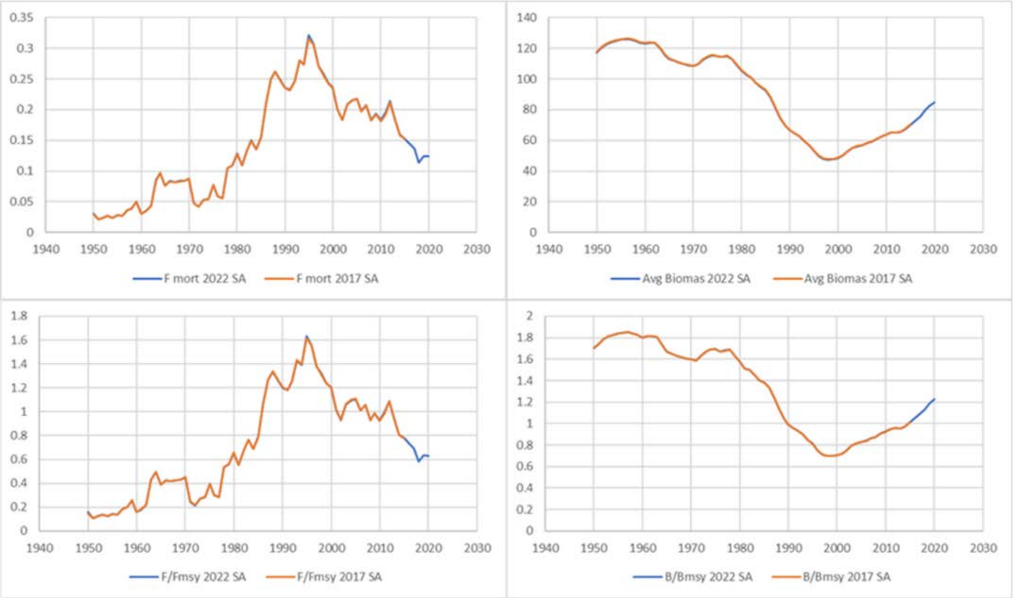


Figure 26. Comparison of the biomass and fishing mortality trends trajectories of the 2017 ASPIC base case (2017 SA) and the continuity case (2022 SA) when updating only the catch series (2016-2020) and using the 2017 Combined biomass index.

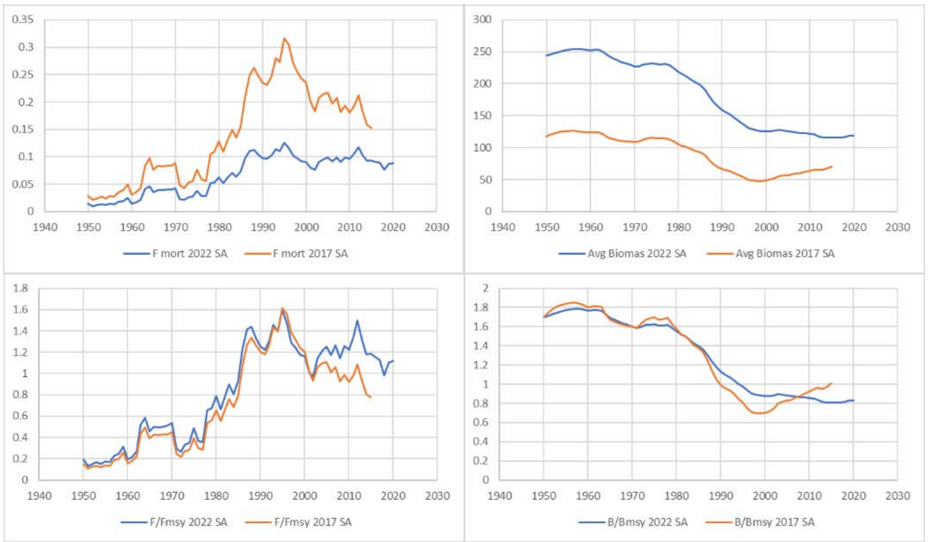


Figure 27. Comparison of the biomass and fishing mortality trends trajectories of the 2017 ASPIC base case (2017 SA) and the continuity case (2022 SA) when updating both the catch series (2016 – 2020) and using the 2022 Combined biomass index.

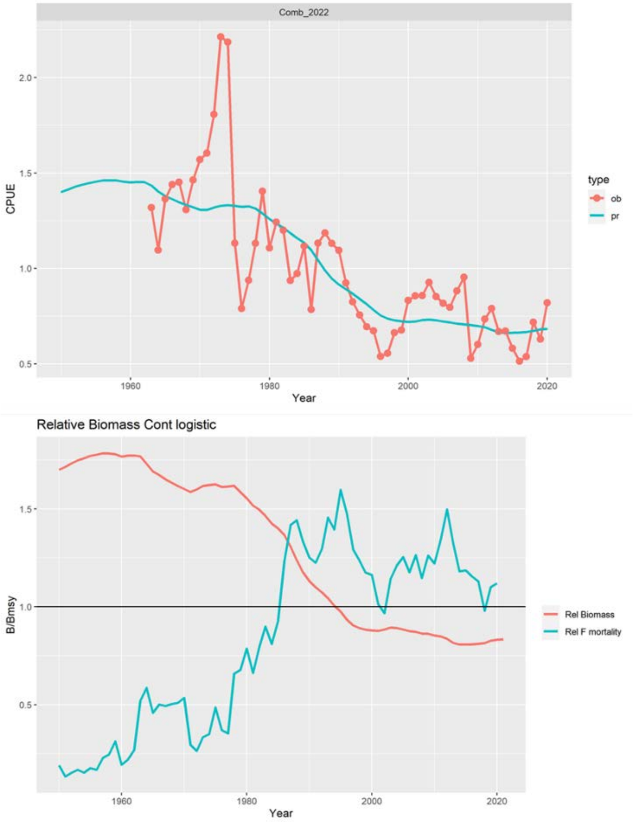


Figure 28. ASPIC continuity run with the 2022 combined index and catch series 1950 -2020. The top plot shows the fit to the index series (pr) and the index observed values (ob), and the bottom plot shows the relative biomass and fishing mortality trends estimated by the model.

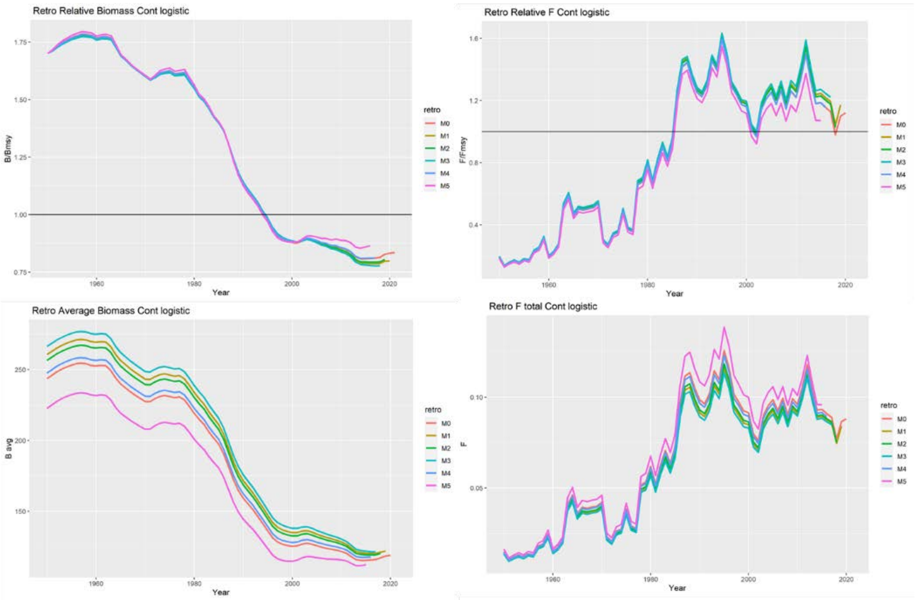


Figure 29. ASPIC continuity run: diagnostic plot. Five-year retrospective runs of the relative biomass and fishing mortality (top row) and absolute values (bottom row).

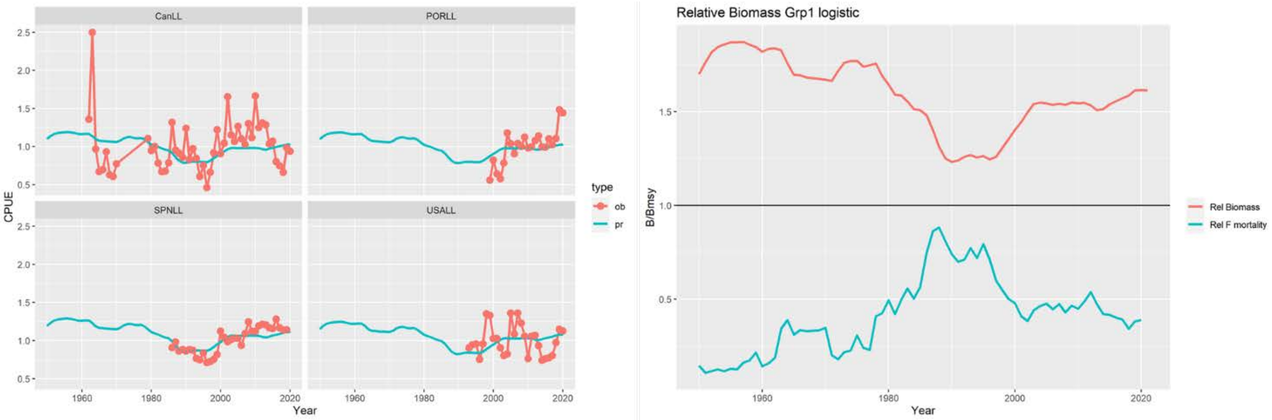


Figure 30. ASPIC group 1 indices run: left plot shows the fit to the indices of abundance and the right plot the relative biomass and fishing mortality trends.

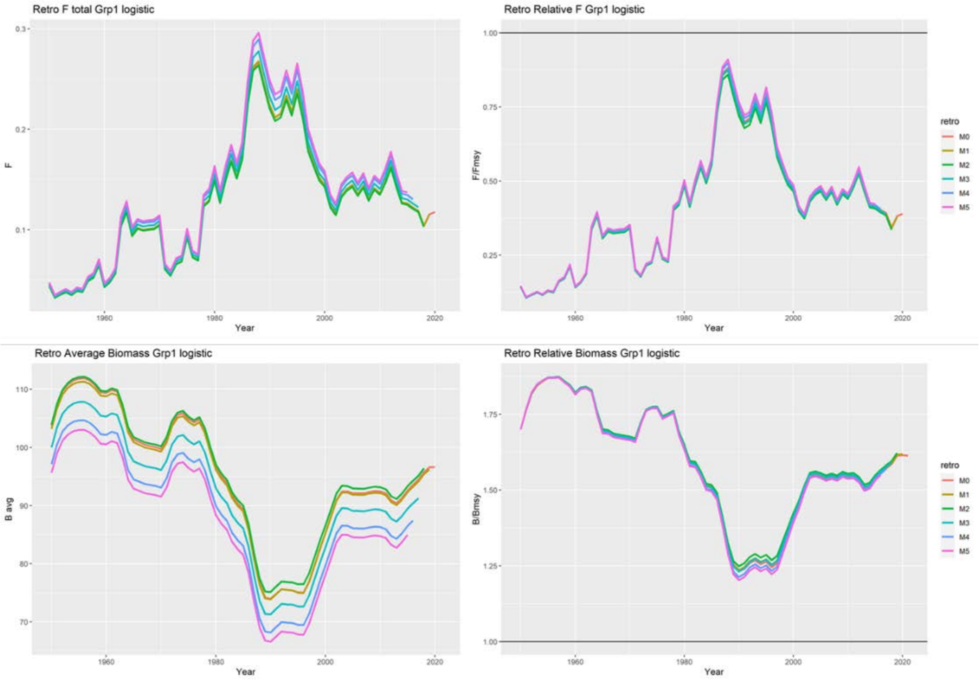


Figure 31. ASPIC group 1 indices run: diagnostic five-year retrospective run for the absolut (left column) and relative (right column) fishing mortality and biomass trends.

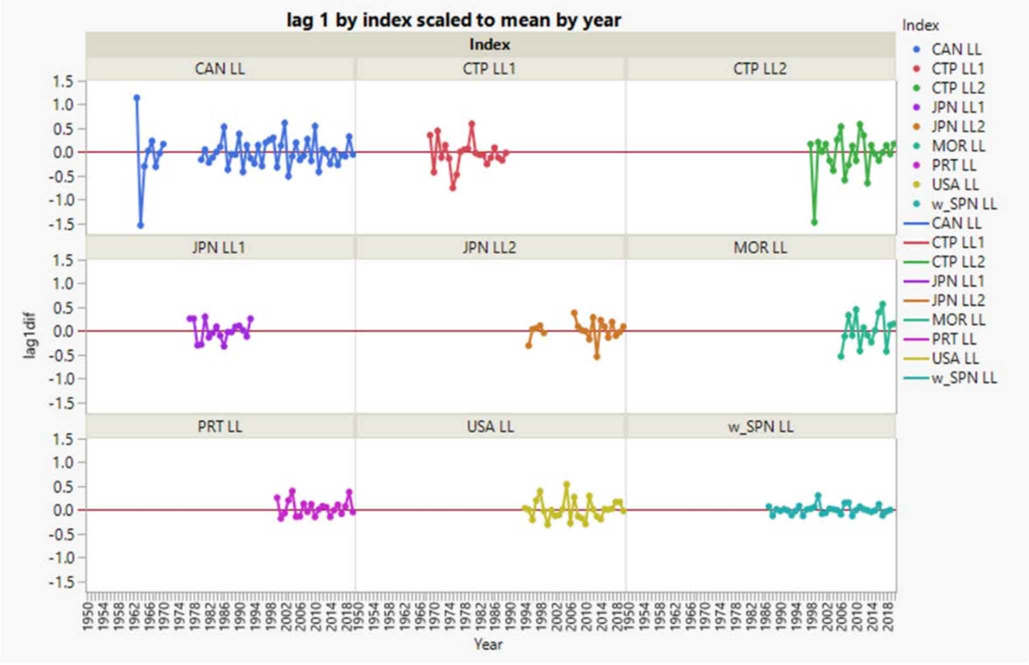


Figure 32. N-SWO indices of abundance lag 1-year analysis. Indices were scaled to their mean, large values (+, -) indicate a large variation of the relative stock biomass in one year.

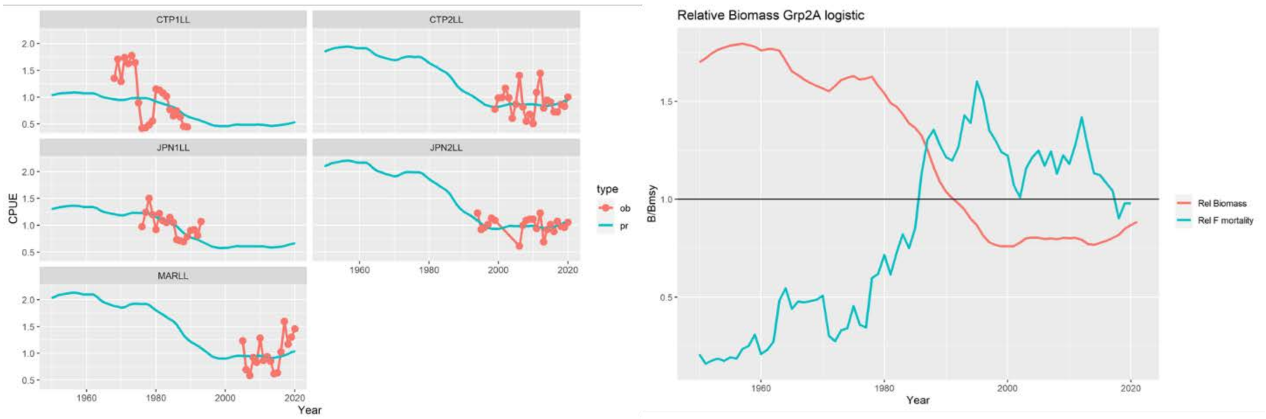


Figure 33. ASPIC group 2A indices run: left plot shows the fit to the indices of abundance and the right plot the relative biomass and fishing mortality trends.

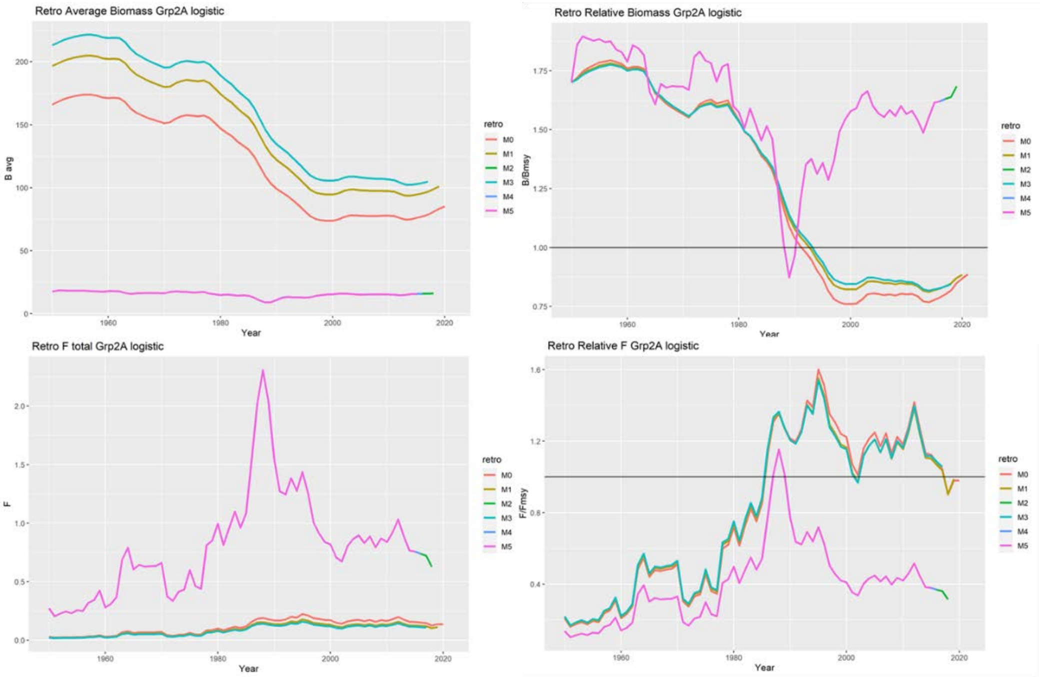


Figure 34. ASPIC group 2A indices run: diagnostic five-year retrospective run for the absolut (left column) and relative (right column) fishing mortality and biomass trends.

Figure 35. ASPIC diagnostic Jackknife test was performed on the Group 1 (Grp1, left column) and Group 2A (Grp2A, right column) indices of abundance. Plotted are the relative fishing (top row) and biomass (bottom row) trends, each line represents the run results when excluded the index indicated in the legend.

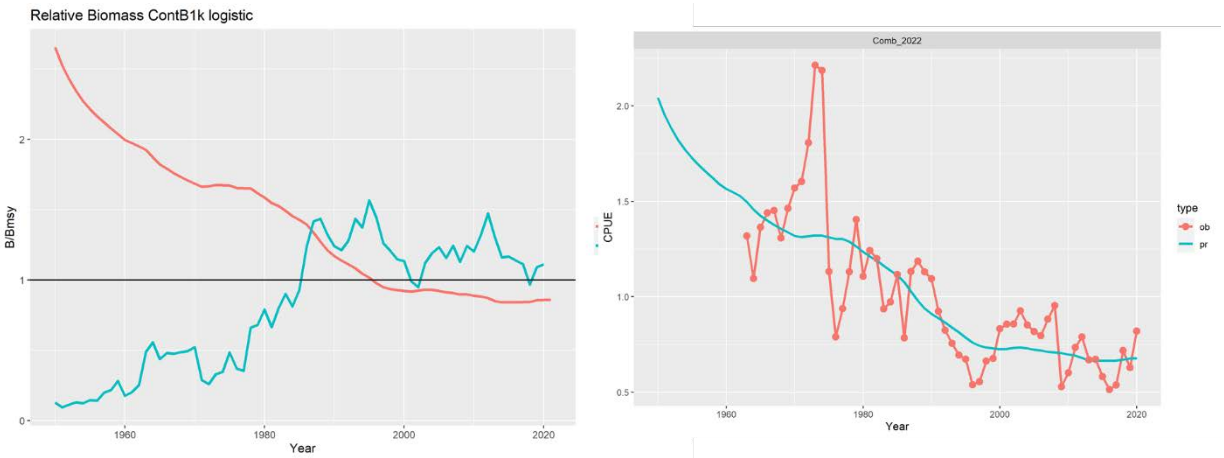


Figure 36. ASPIC fit 2022 combined biomass index and estimating B1/K parameter run: left plot shows the fit to the combined index of abundance and the right plot the relative biomass and fishing mortality trends.

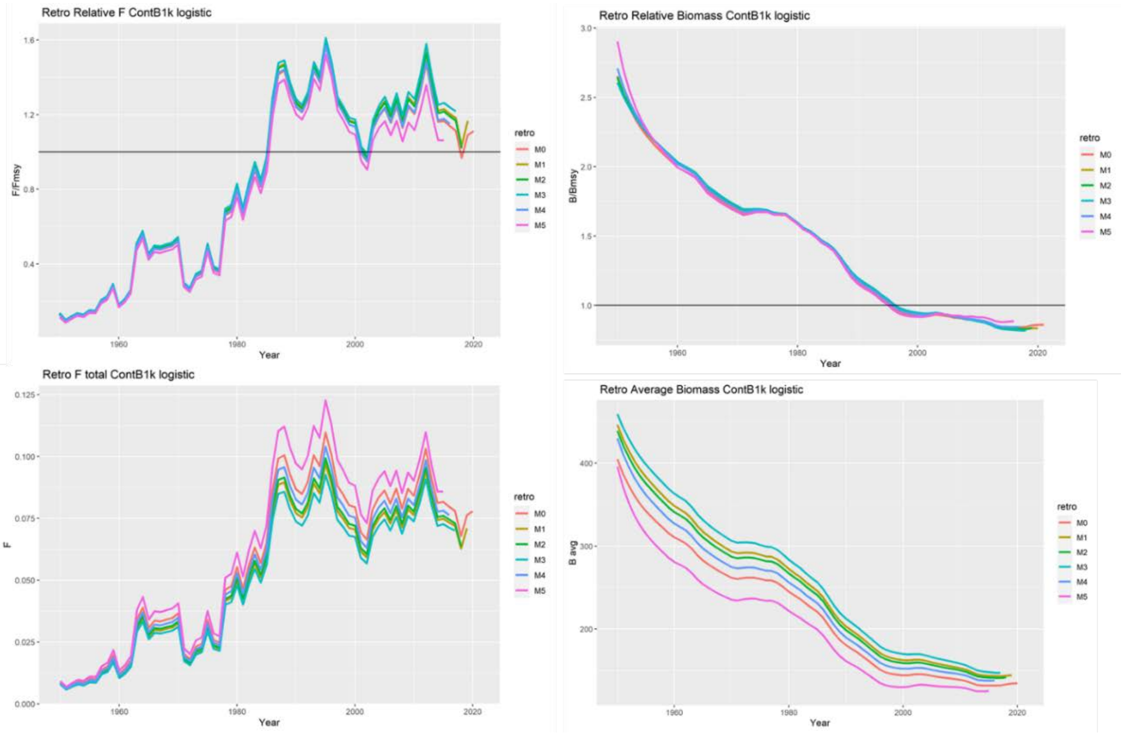


Figure 37. ASPIC fit 2022 combined biomass index and estimating B1/K parameter run: diagnostic five-year retrospective run for the relative (top row) and absolute (bottom row) fishing mortality and biomass trends.

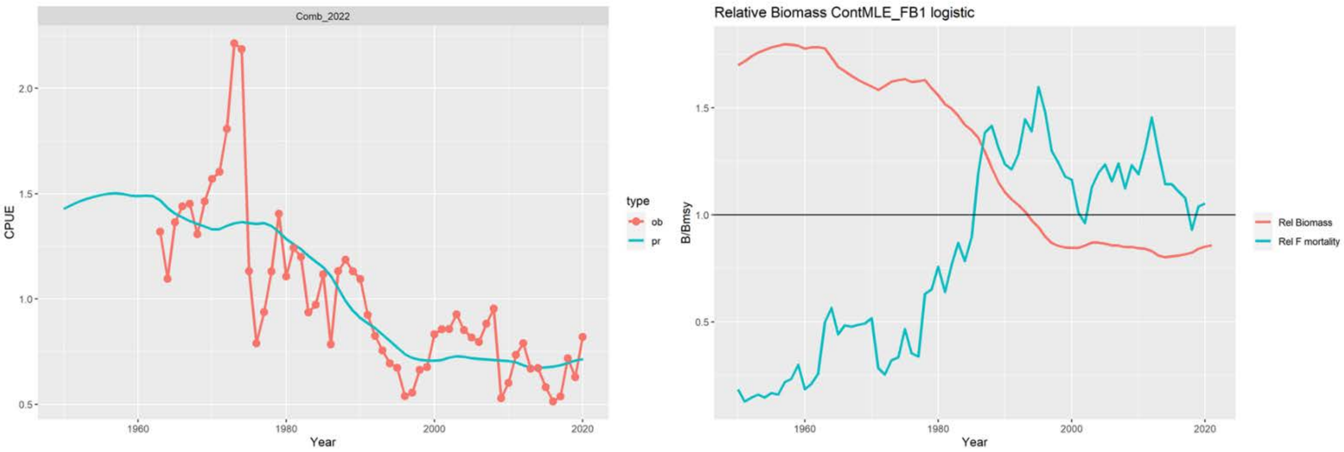


Figure 38. ASPIC fit 2022 combined biomass index with MLE estimation run: left plot shows the fit to the combined index of abundance and the right plot the relative biomass and fishing mortality trends.

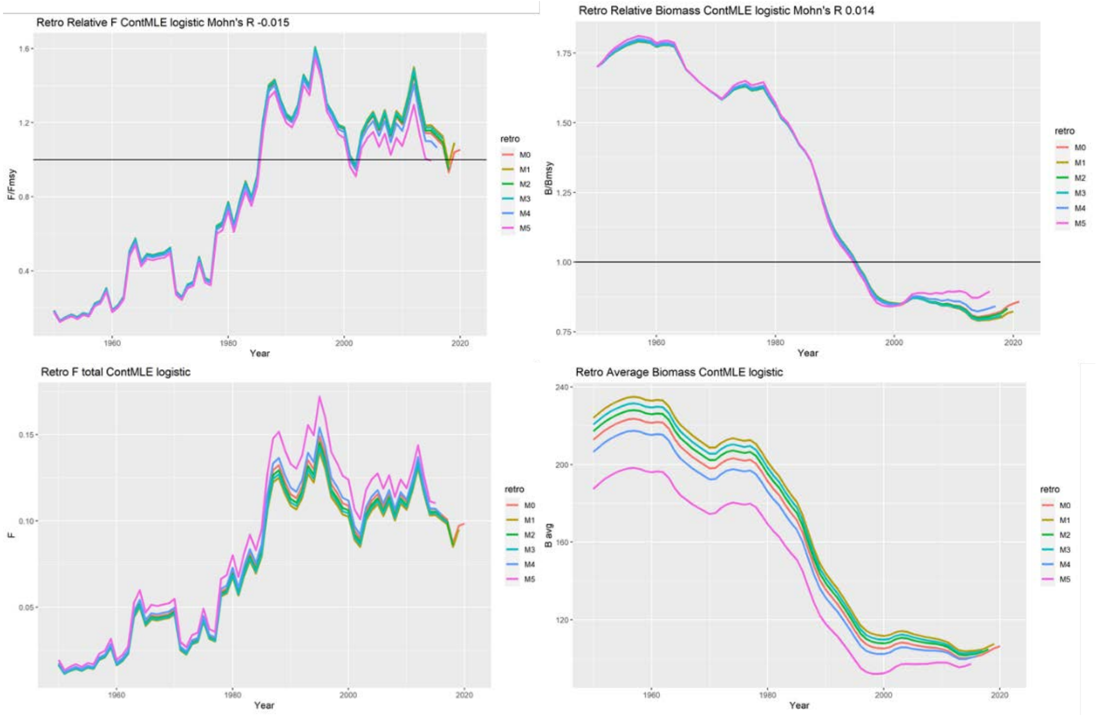


Figure 39. ASPIC fit 2022 combined biomass index with MLE estimation run: diagnostic five-year retrospective run for the relative (top row) and absolute (bottom row) fishing mortality and biomass trends

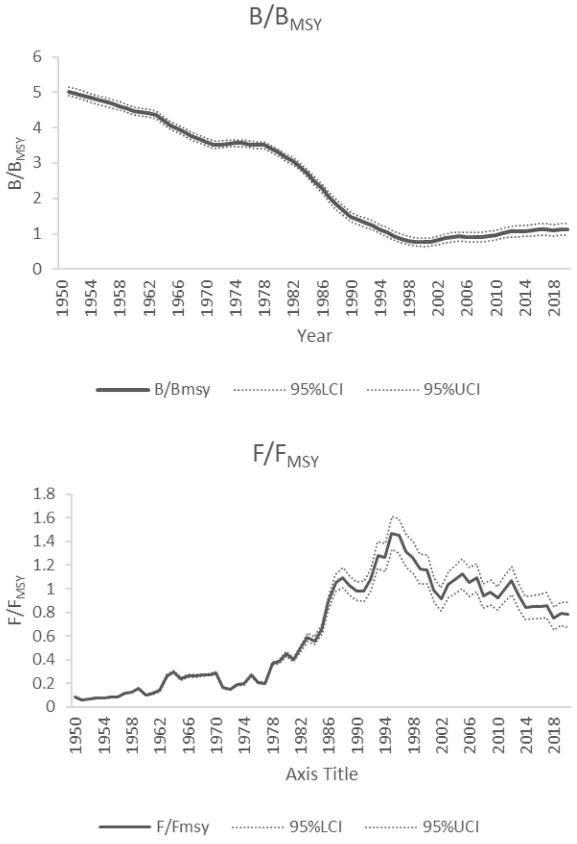


Figure 40. Stock Status (B/B$_{MSY}$ and F/F$_{MSY}$) trajectories for the updated SS3 stock assessment for the North Atlantic Swordfish.

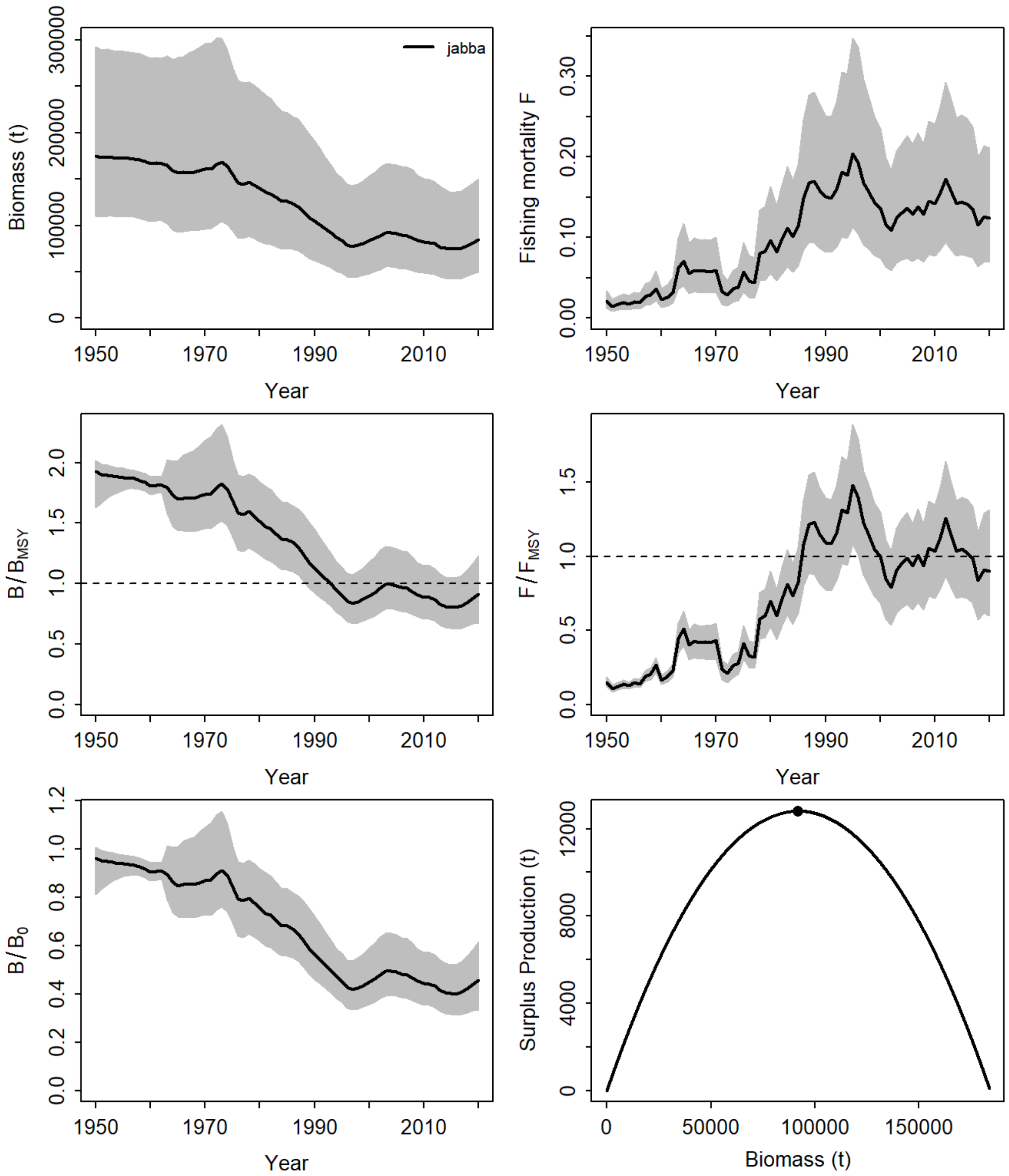


Figure 41. Biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels), and biomass relative to K (B/K) and surplus production curve (bottom panels) for the JABBA reference case model for North Atlantic swordfish.

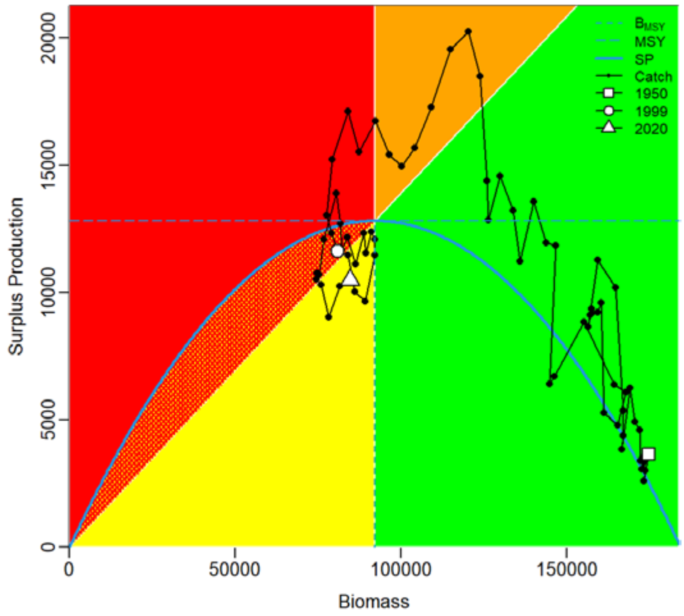


Figure 42. JABBA Kobe phase plot for the reference case showing trajectories of the catches in relation to *B_{MSY}* and *MSY* for the North Atlantic swordfish.

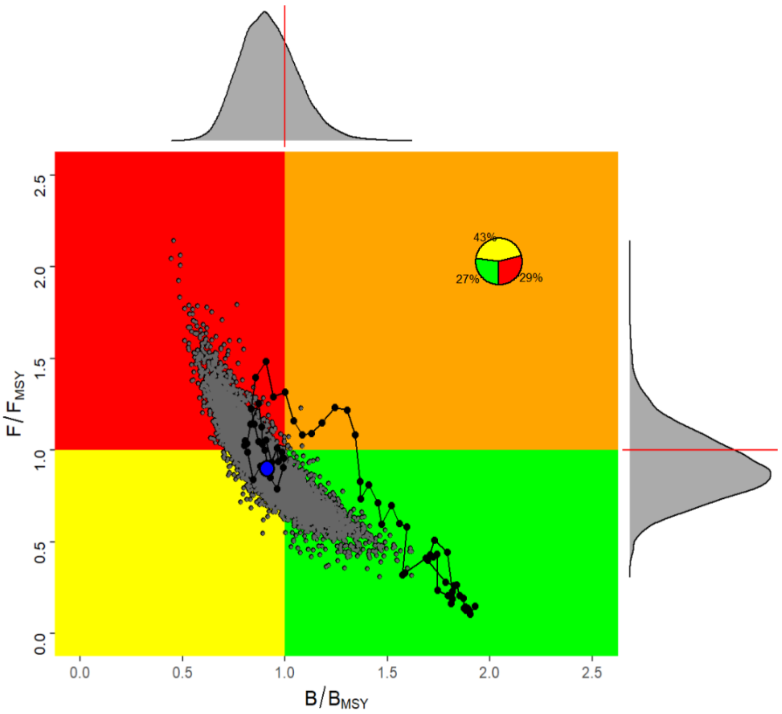


Figure 43. Kobe plot showing estimated trajectories (1950-2020) of B/B_{MSY} and F/F_{MSY} for the JABBA reference case model for the North Atlantic swordfish assessment. The probability of terminal year points falling within each quadrant is indicated in the pie chart.

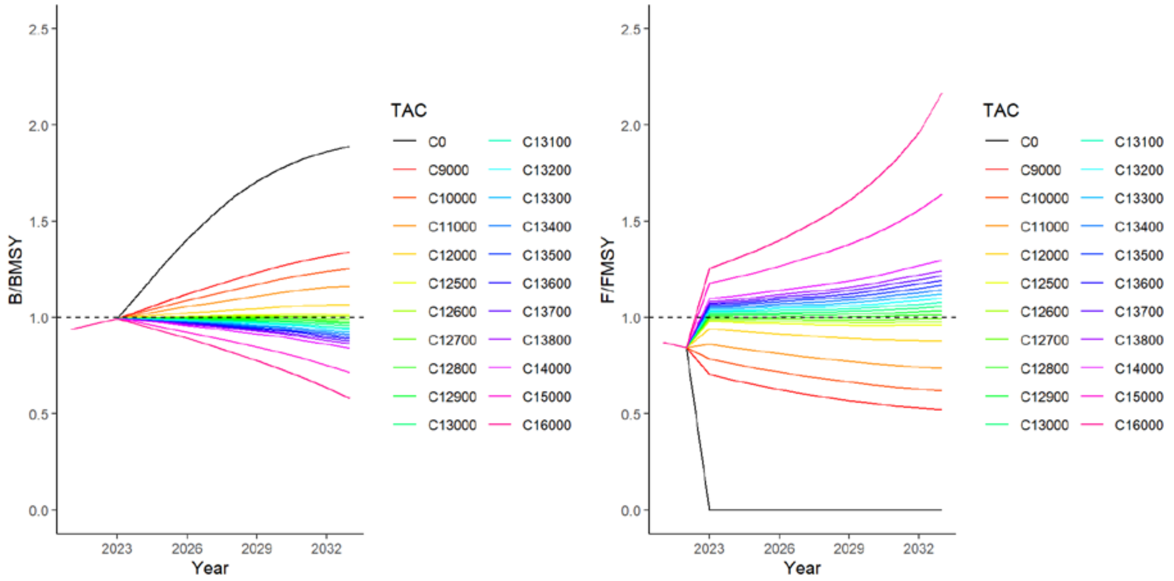


Figure 44. Projections for *B/B*$_{MSY}$ and *F/F*$_{MSY}$ based on the JABBA reference case model for North Atlantic swordfish for various levels of future catch ranging from 9,000 – 16,000 tons, including a zero-catch scenario. The initial catch for the years 2021-2022 were set to 10,476 t, which is the catch of the final year (2020) available in the catch data. The projections are run until 2033. The dashed lines denotes *B*$_{MSY}$ and *F*$_{MSY}$.

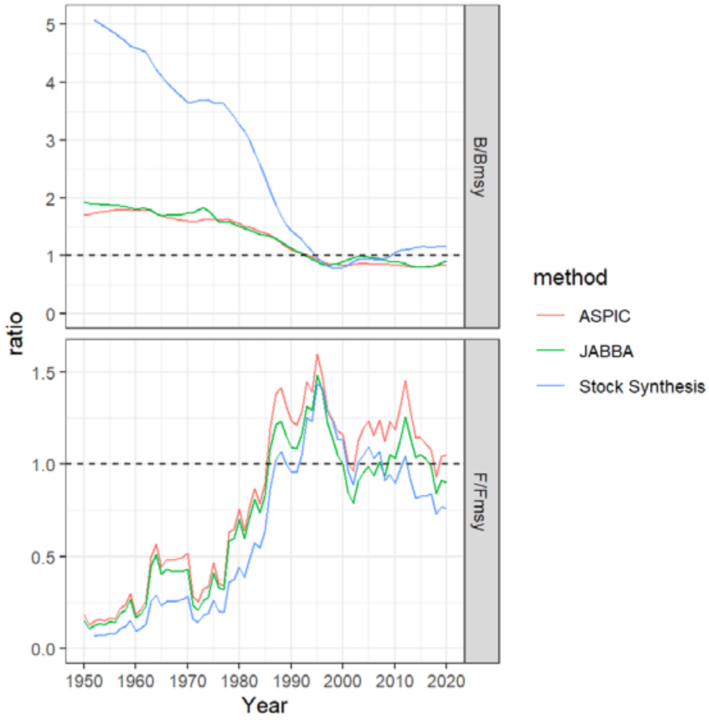


Figure 45. Trajectories of B/B$_{MSY}$ (top panel) and F/F$_{MSY}$ (bottom panel) using Stock Synthesis (blue), ASPIC (red) and JABBA (green).

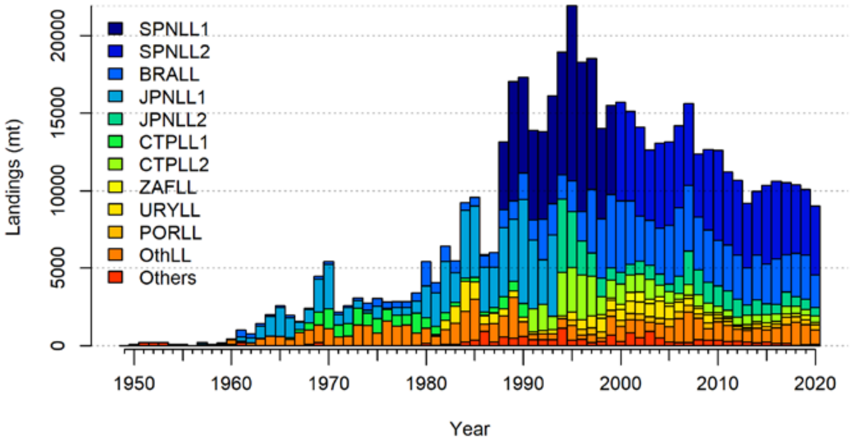


Figure 46. Catch (t) by fleet for South Atlantic swordfish.

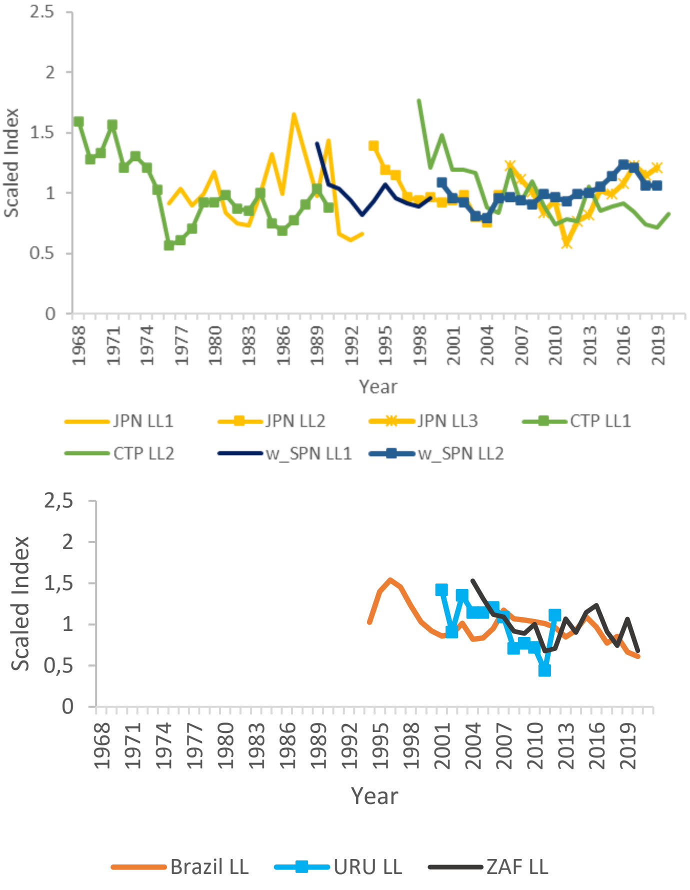


Figure 47. Normalized CPUE indices used in the reference case model for South Atlantic swordfish. Indices that were split (JPN, EU-SPN and CTP) are shown on the top, and the rest (BRA, URU and ZAF) are shown at the bottom.

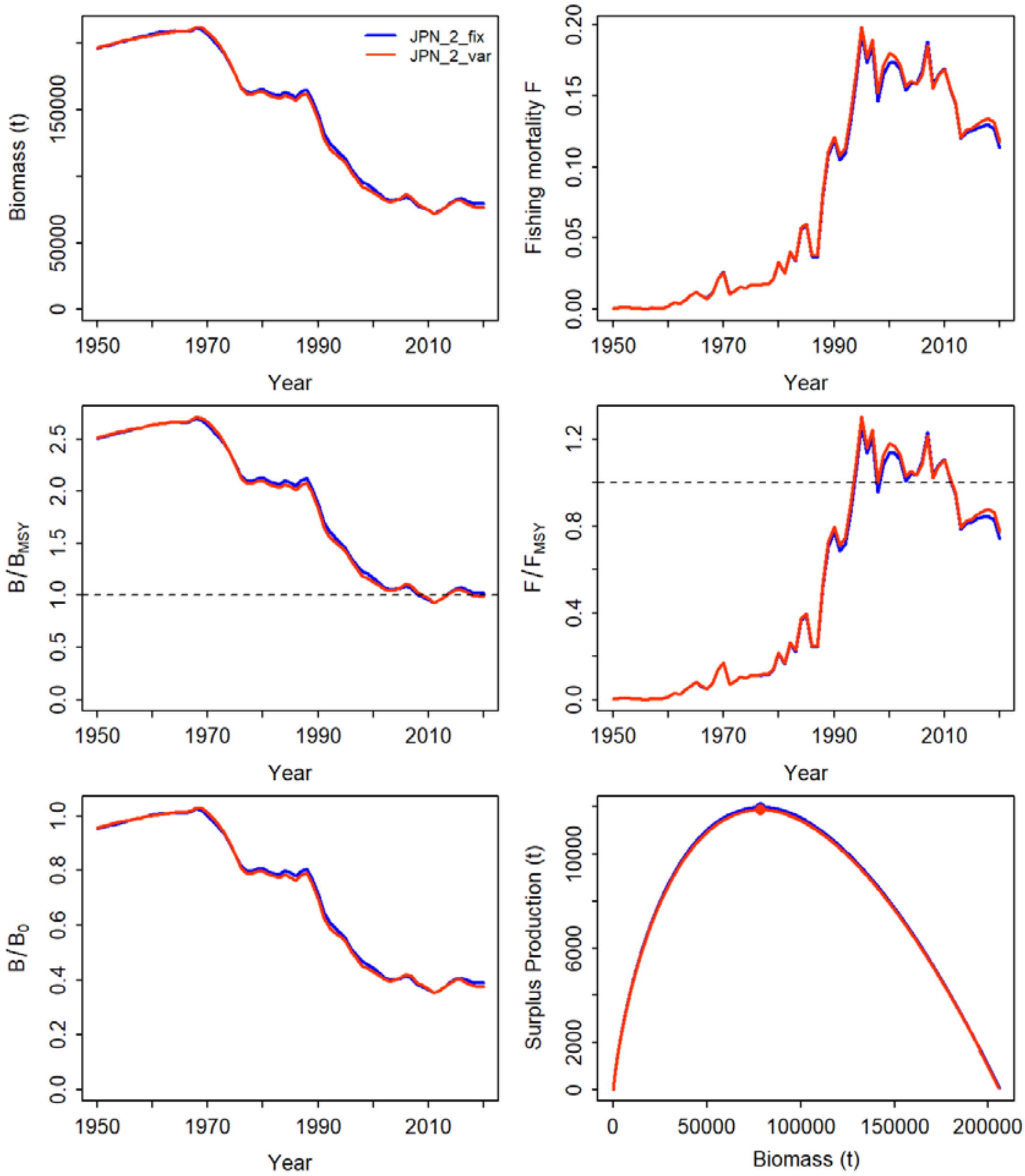
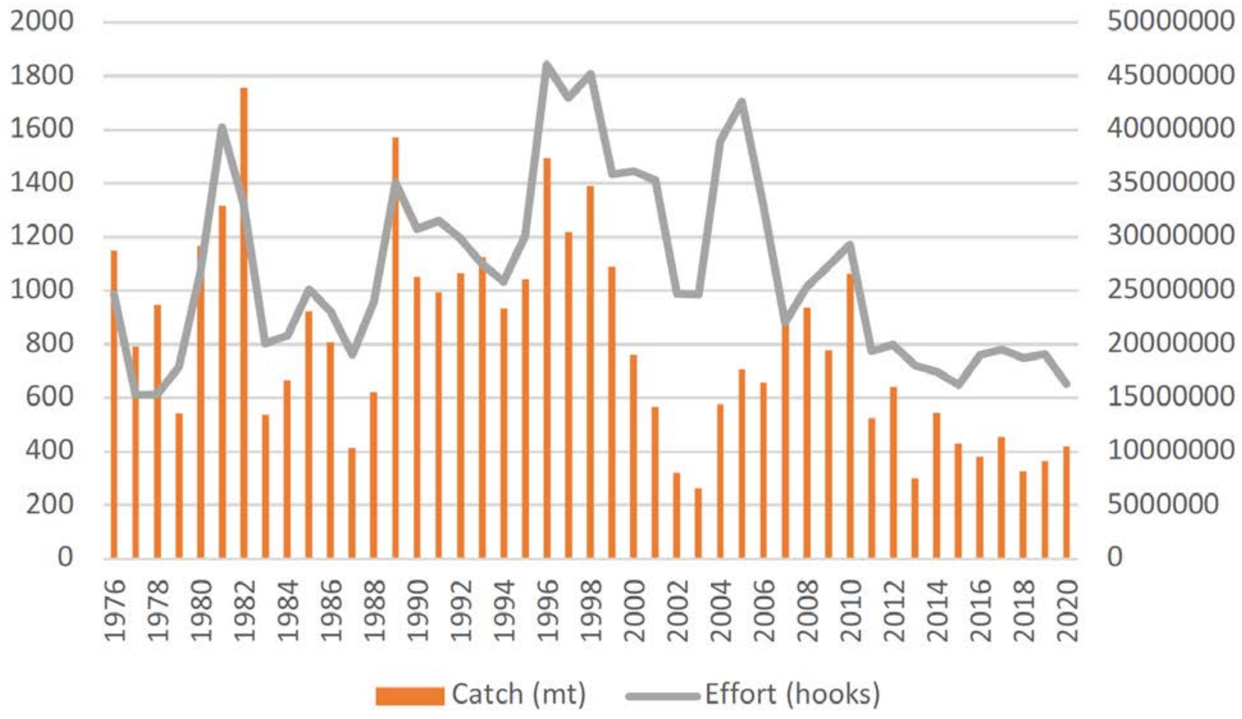


Figure 48. An additional run was suggested by weighting all indices with their coefficient variance to account for recent uncertainties.

North Atlantic



South Atlantic

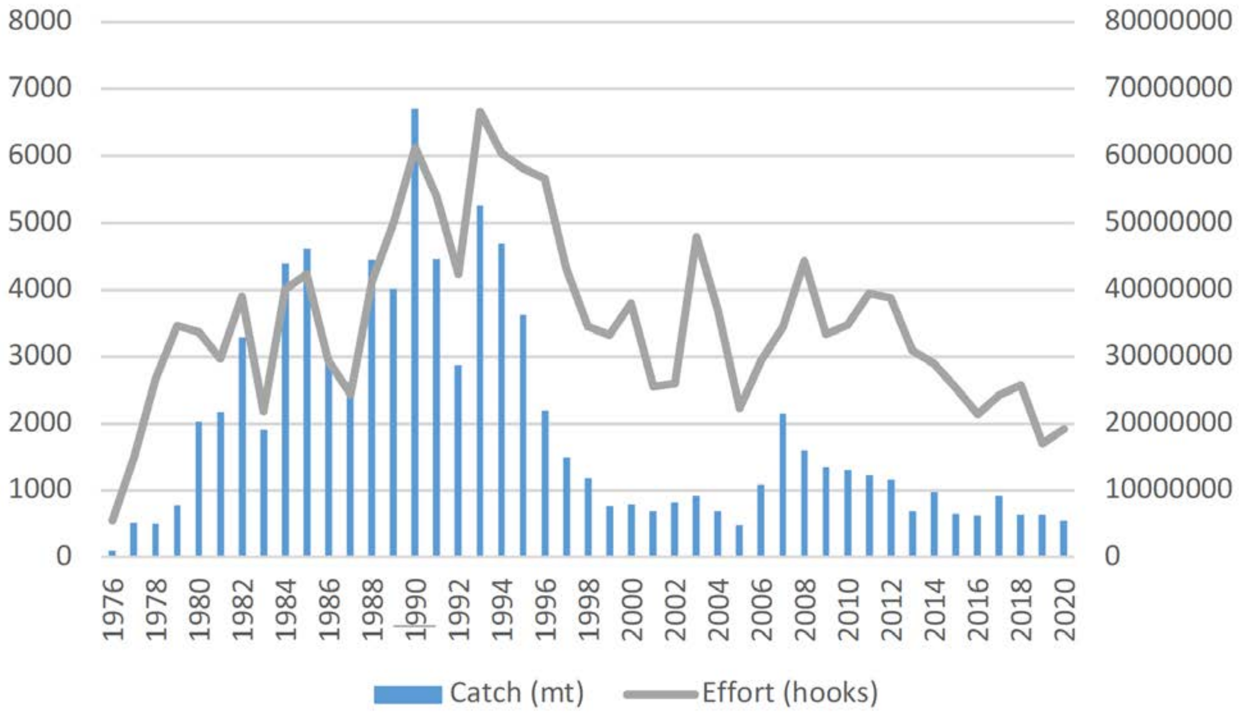


Figure 49. Nominal catch and effort by the Japan longline fleets in the North (top) and South (bottom) Atlantic.

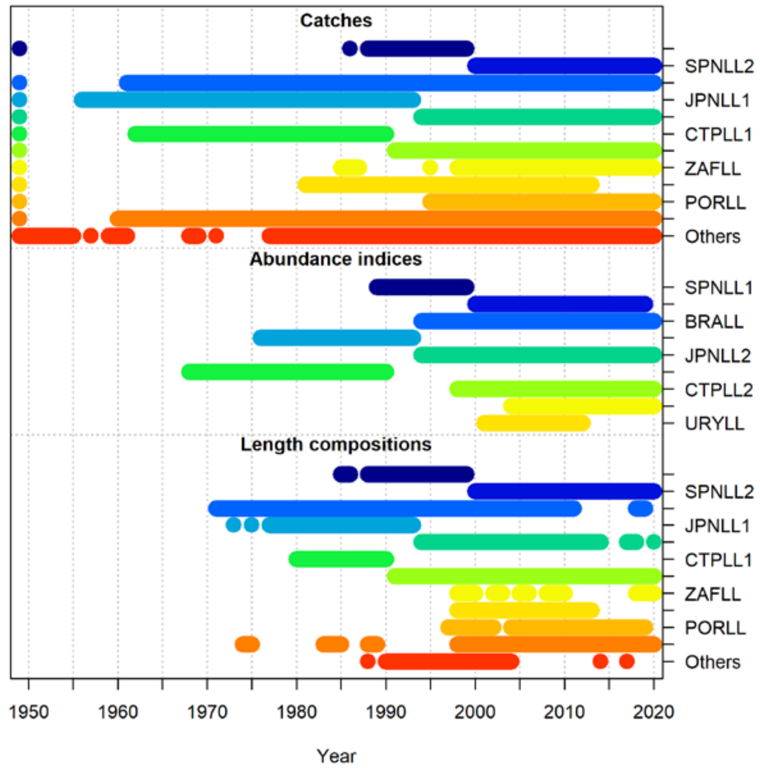


Figure 50. Summary of data available by year for southern swordfish for the SS model.

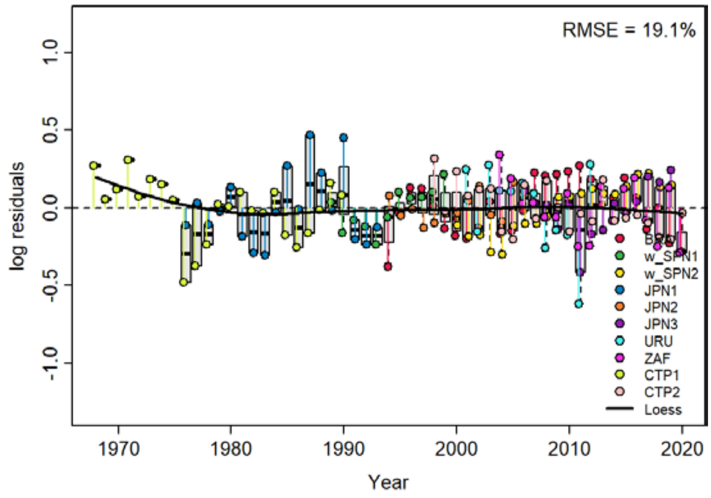


Figure 51. Residual diagnostic plots of CPUE indices for the South Atlantic swordfish JABBA reference case model. Boxplots indicate the median and quantiles of all residuals available for any given year, and solid black lines indicate a Loess smoother through all residuals.

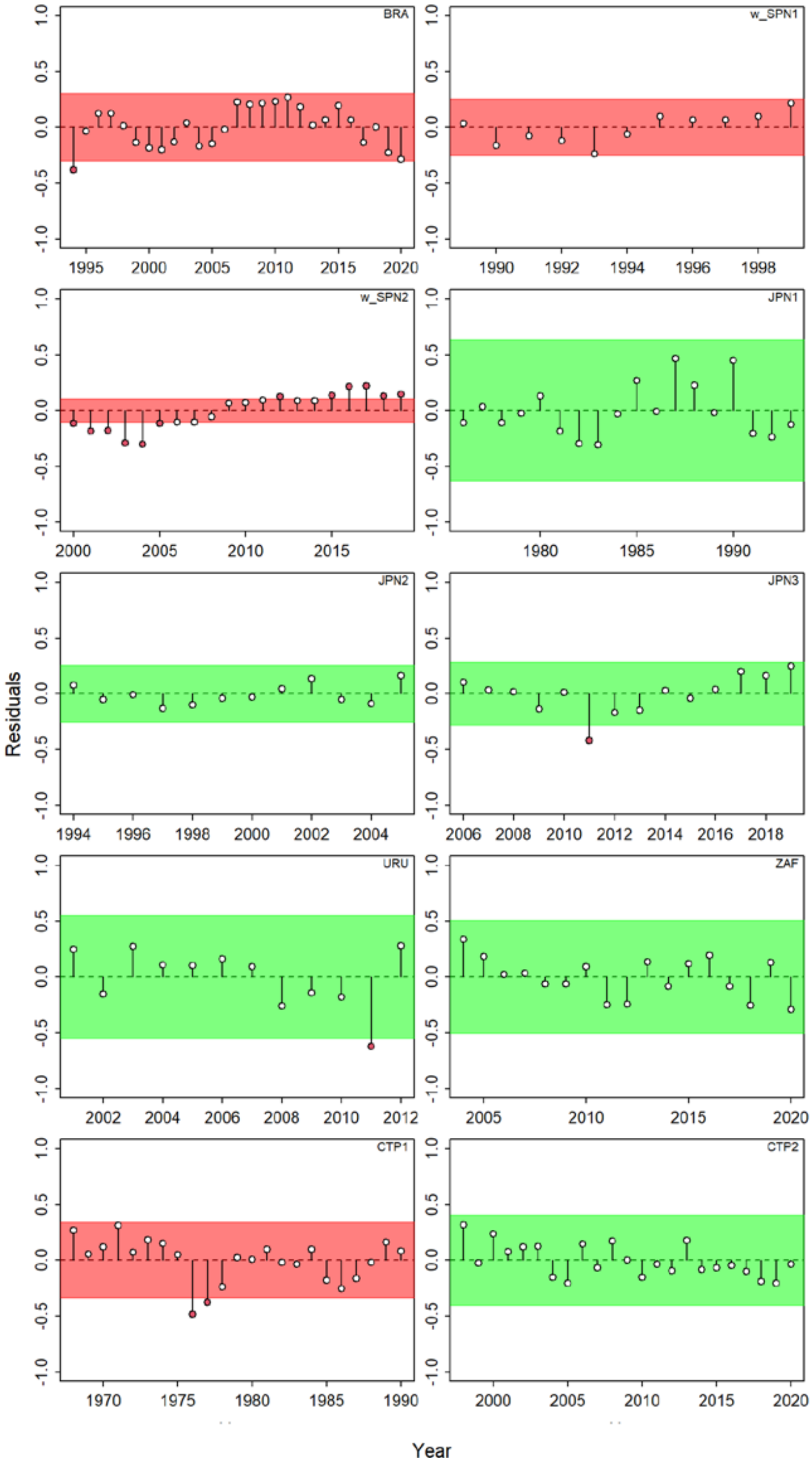


Figure 52. Runs tests to evaluate the randomness of the time series of CPUE residuals by fleet for the reference case model for the South Atlantic swordfish JABBA assessment. Green panels indicate no evidence of lack of randomness of time-series residuals (*p*>0.05) while red panels indicate possible autocorrelation. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

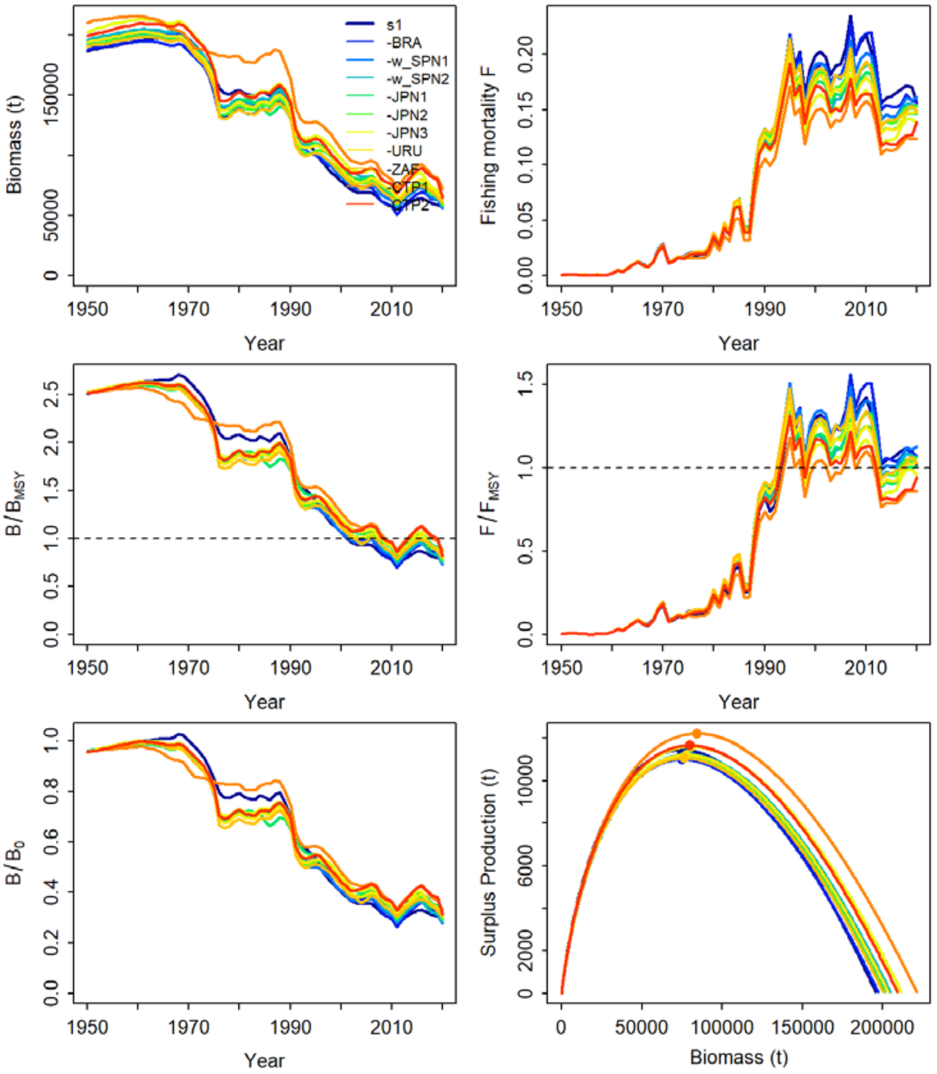


Figure 53. Jackknife index analysis performed to the reference case JABBA model of the South Atlantic swordfish assessment, by removing one CPUE fleet at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).

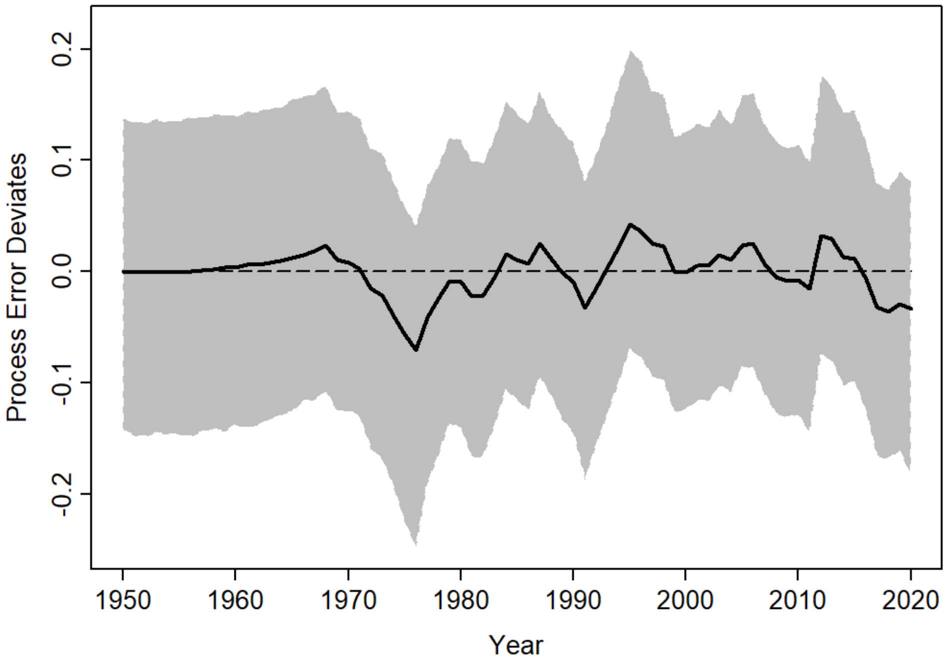


Figure 54. Process error deviations (median: solid line) from the reference case model for the South Atlantic swordfish JABBA assessment. Shaded grey area indicates 95% credibility intervals.

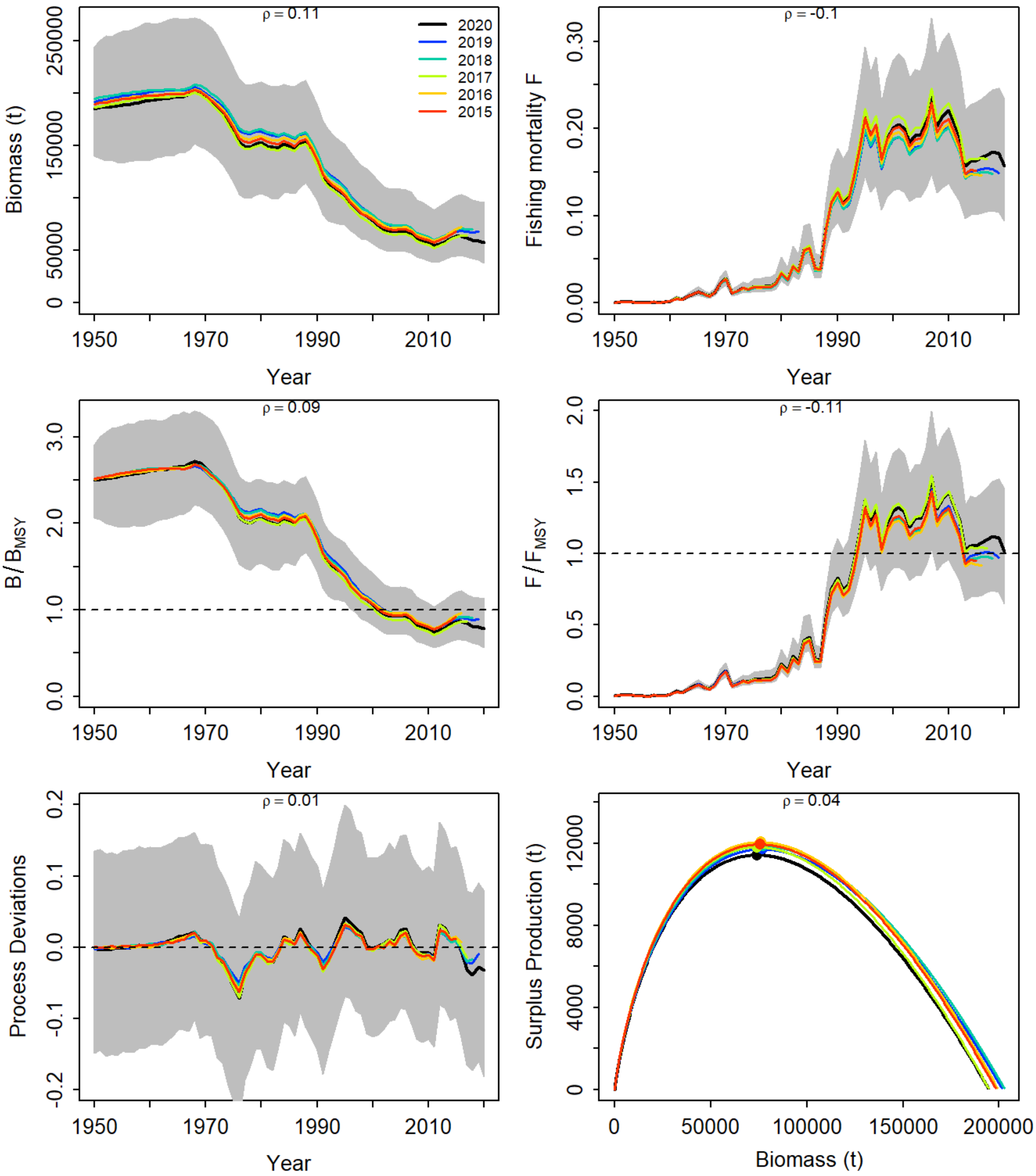


Figure 55. Retrospective analysis performed to the reference case model of the South Atlantic swordfish assessment, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).

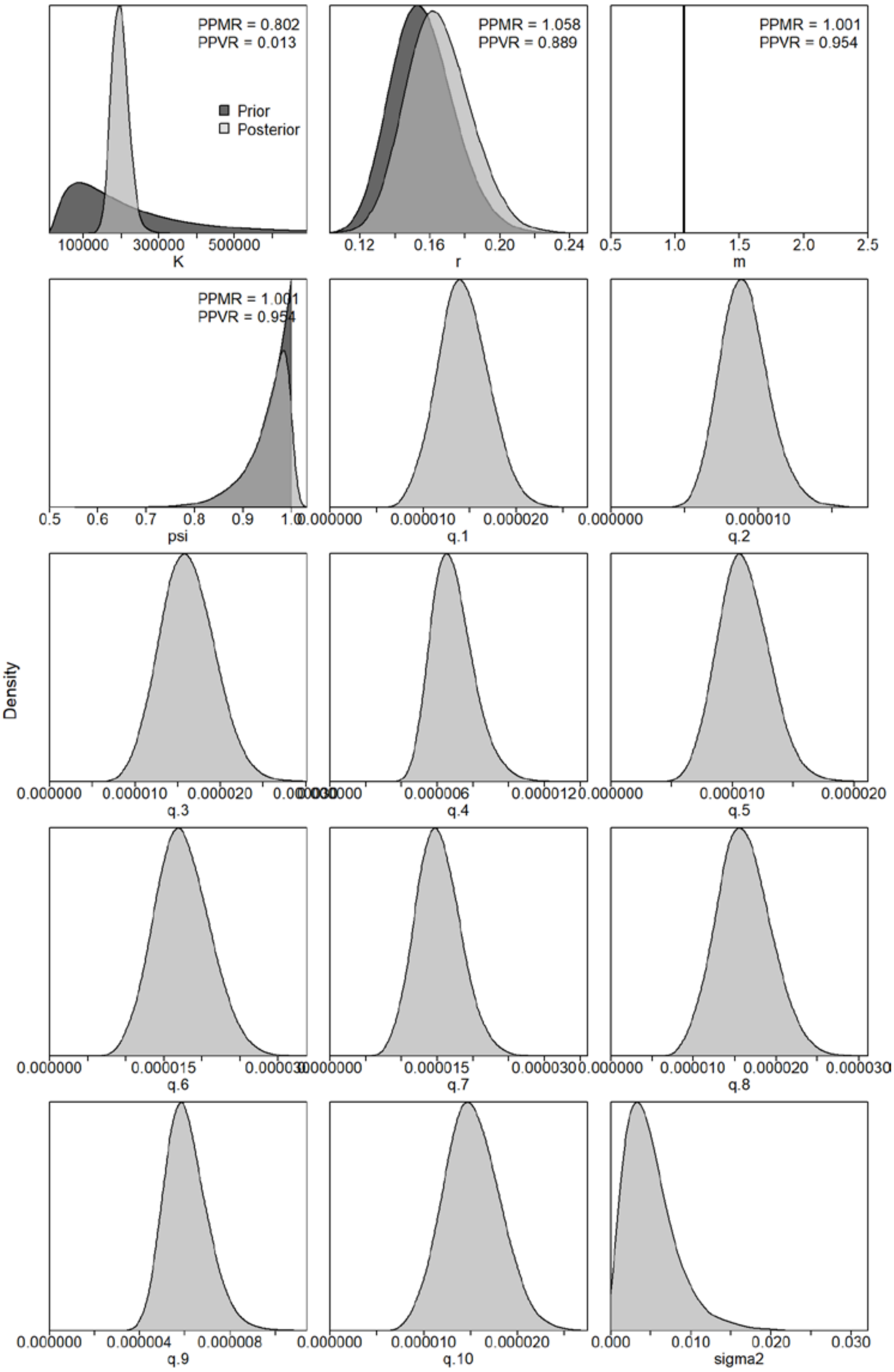


Figure 56. Prior and posterior distributions of various model and management parameters for the reference case model for the South Atlantic swordfish JABBA assessment. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.

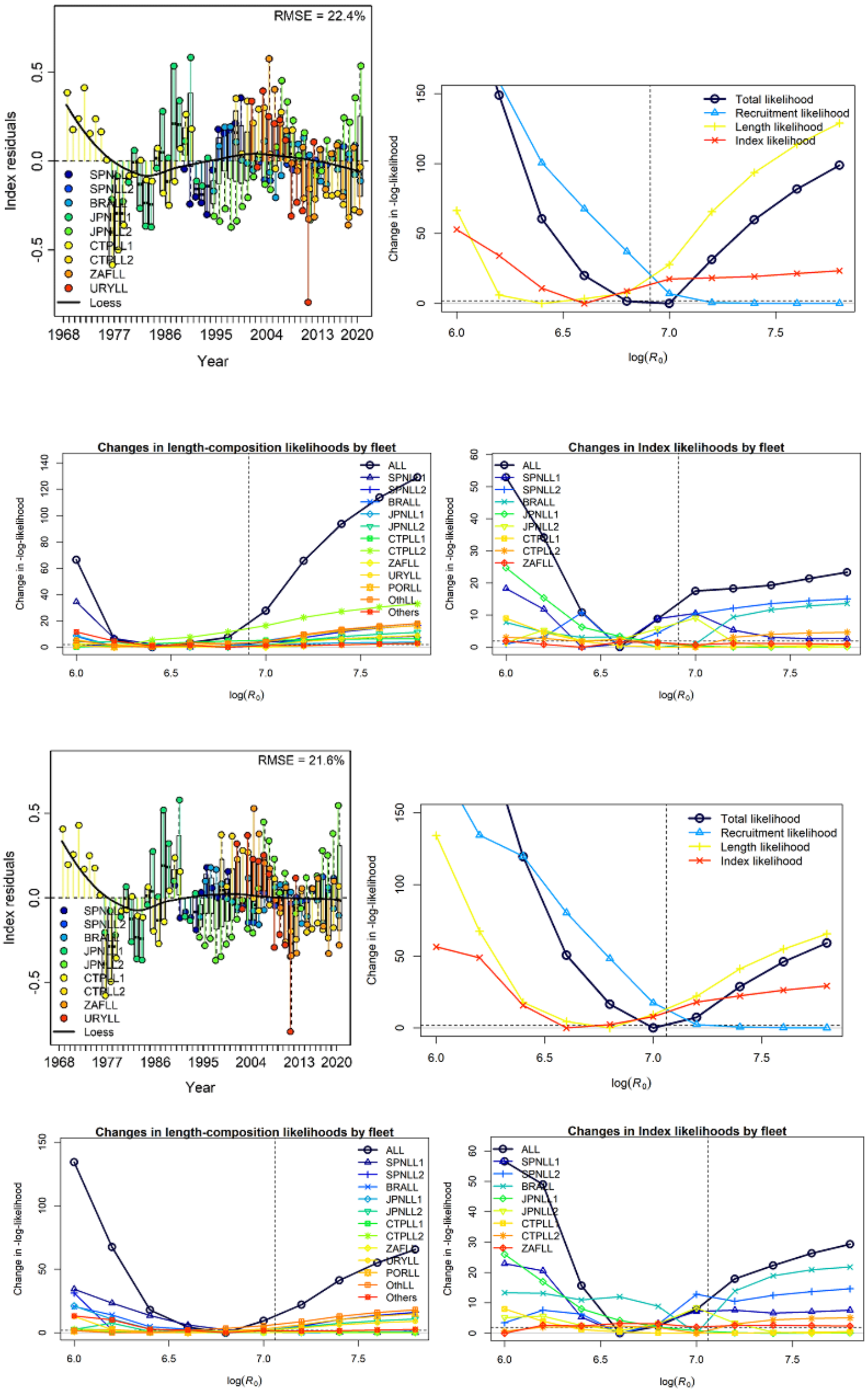


Figure 57. Joint residuals plot for the index fits and likelihood profiles for R0 for the South Atlantic swordfish SS3 models. Upper panels ("Sel_Asym_model"): Lower panels ("Sel_DN model").

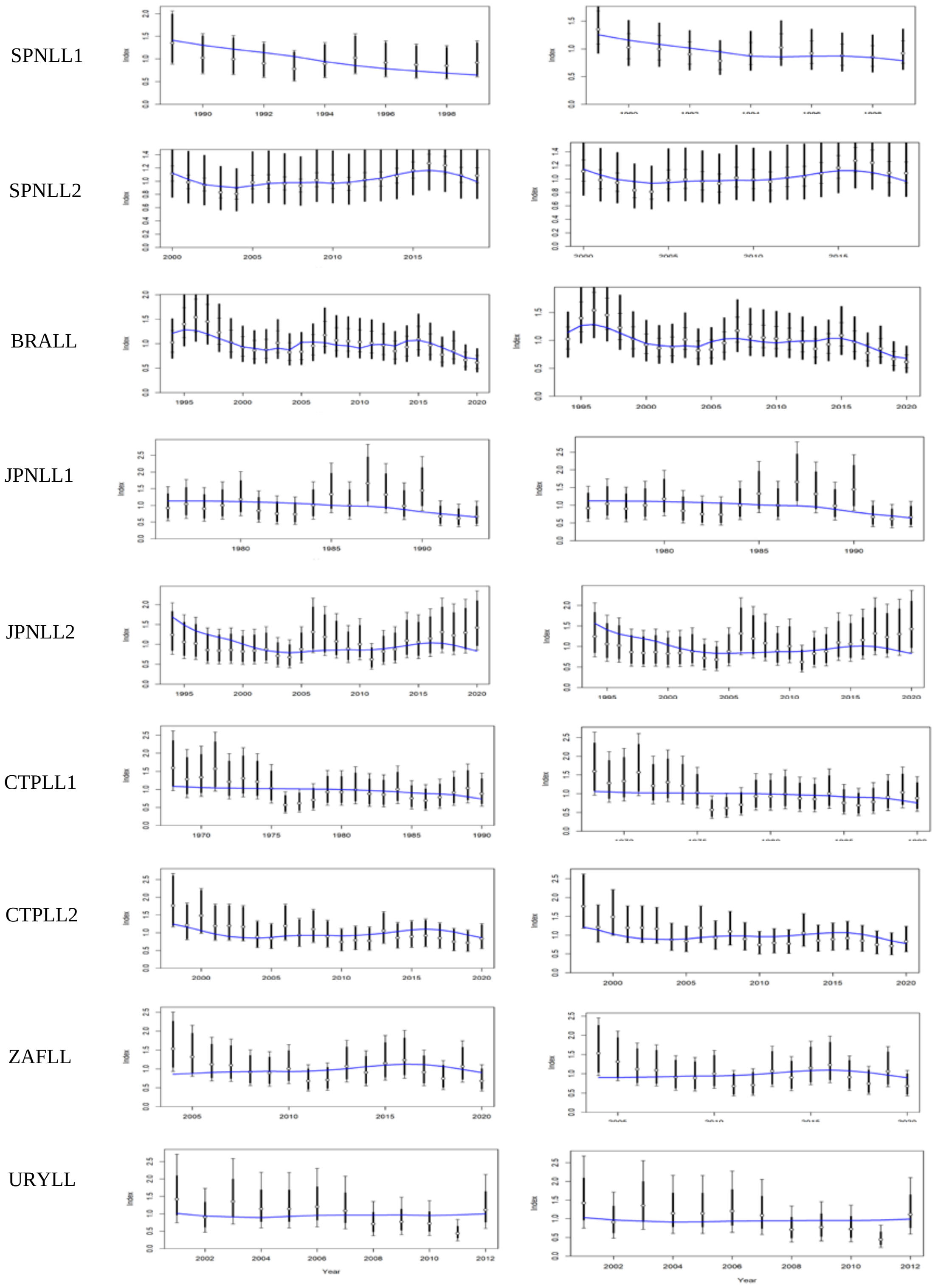


Figure 58. CPUE fits for each fleet for the South Atlantic swordfish SS3 models. Left panels ("Sel_Asym_model"); Right panels ("Sel_DN model").

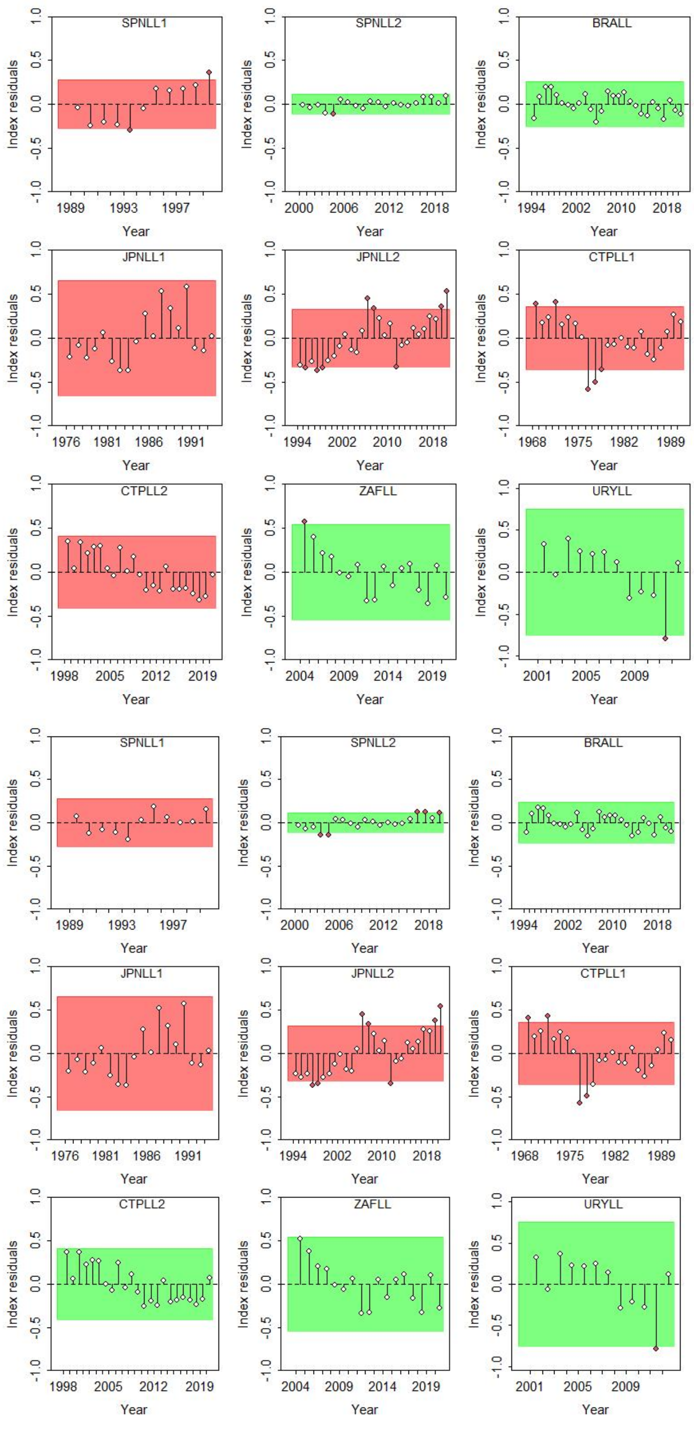


Figure 59. Runs tests to quantitatively evaluate the randomness of the time series of CPUE residuals by fleet for the SS3 models. Green panels indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule). Upper panels (“Sel_Asym_model”): Lower panels (“Sel_DN model”).

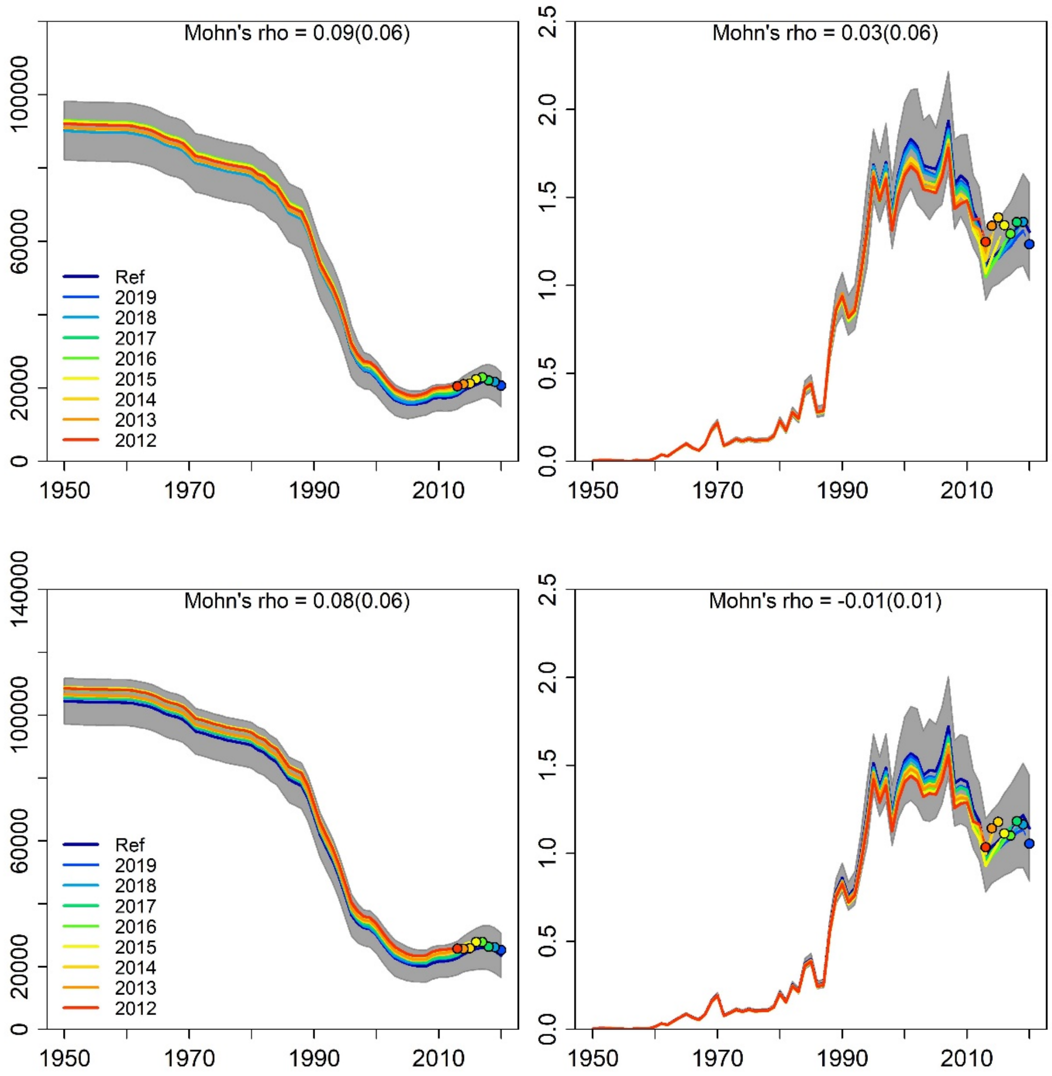


Figure 60. Retrospective analysis for the South Atlantic swordfish SS3 model (Sel_Asym_model – upper panels and Sel_DN model – lower panels), by removing one year at a time sequentially (n=8) and predicting the trends in biomass and relative fishing mortality.

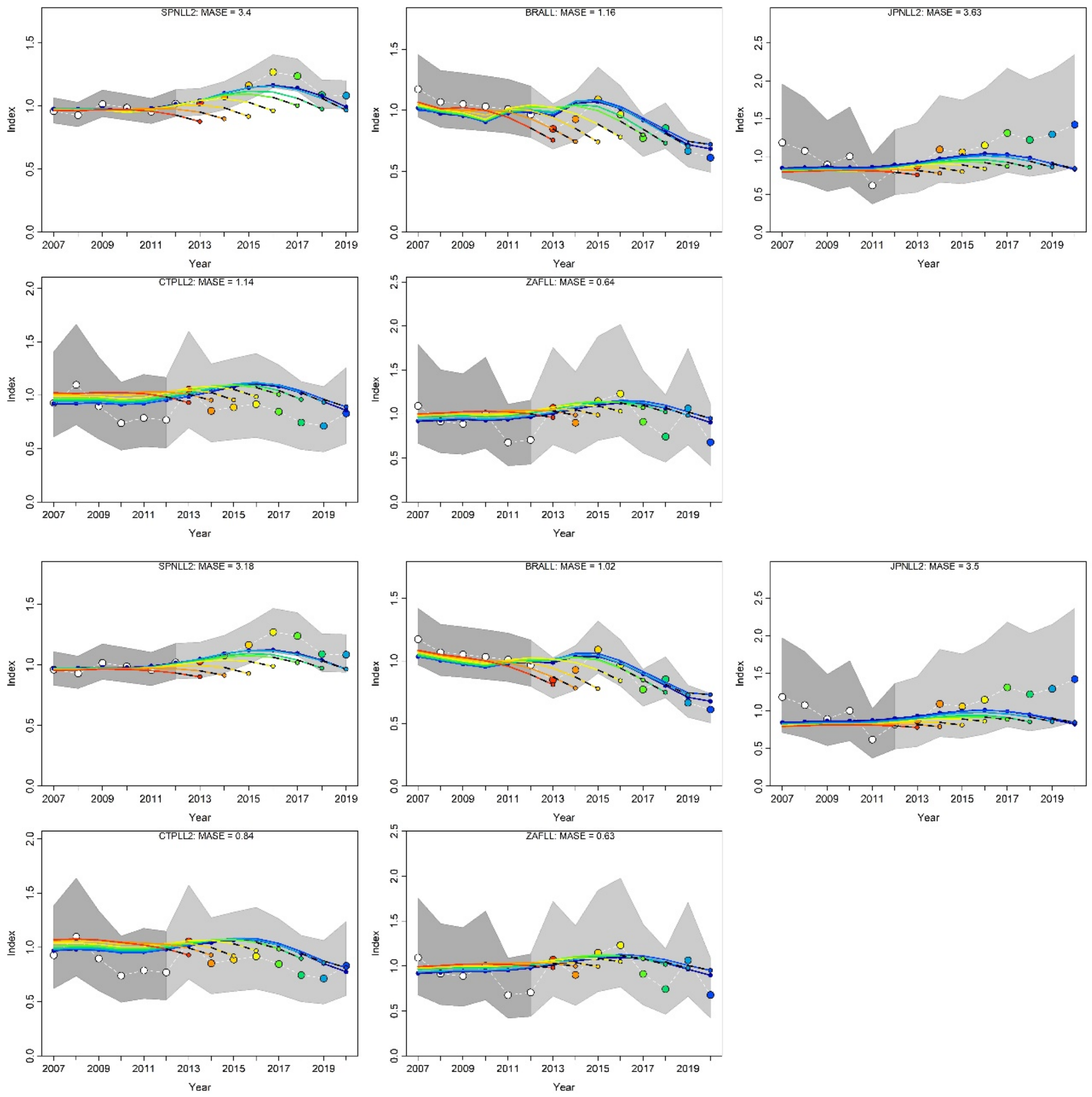


Figure 61. Hindcasting cross-validation results for the two SS3 models for the South Atlantic swordfish (Sel_Asym_model: – upper panels and Sel_DN model – lower panels), showing one-year-ahead forecasts of CPUE values (2013-2020), performed with eight hindcast model runs relative to the expected CPUE. 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).

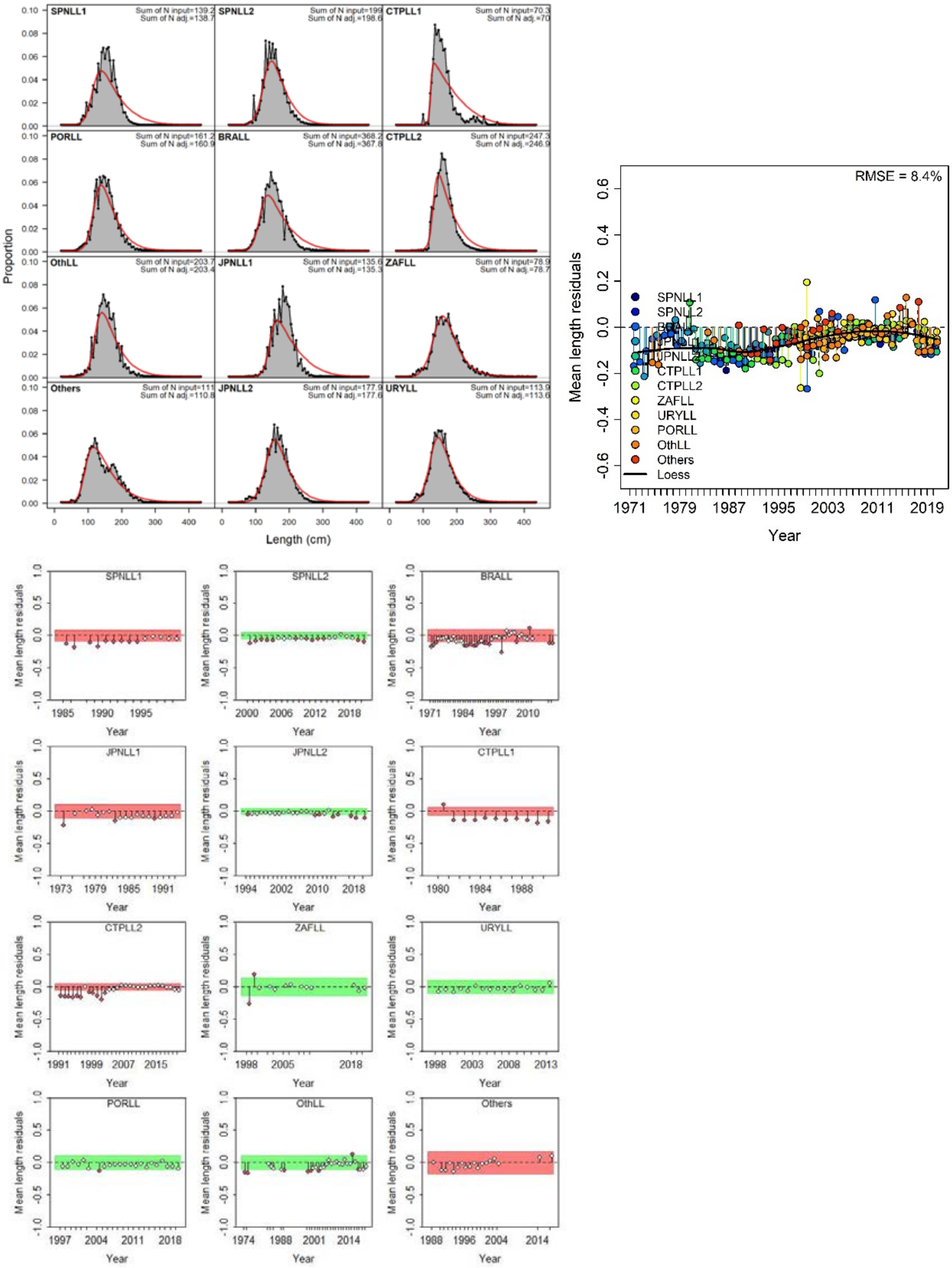


Figure 62. Model fits to the aggregated length compositions for each fleet (upper left panels), joint residuals plot for the length composition fits (upper right panel) and runs tests to length composition fits (lower panels) for the South Atlantic swordfish SS3 (“Sel_Asym_model”). Green panels indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

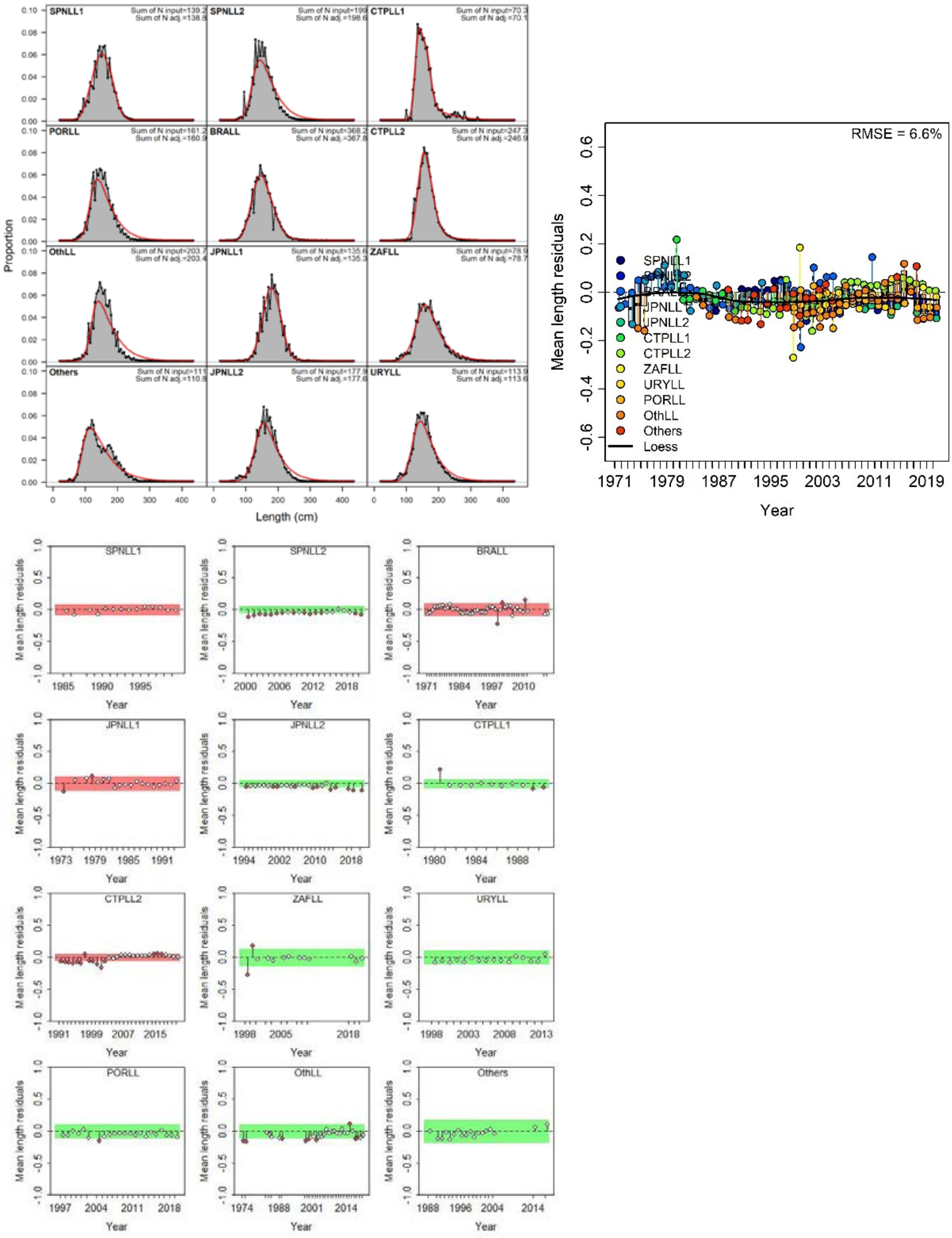
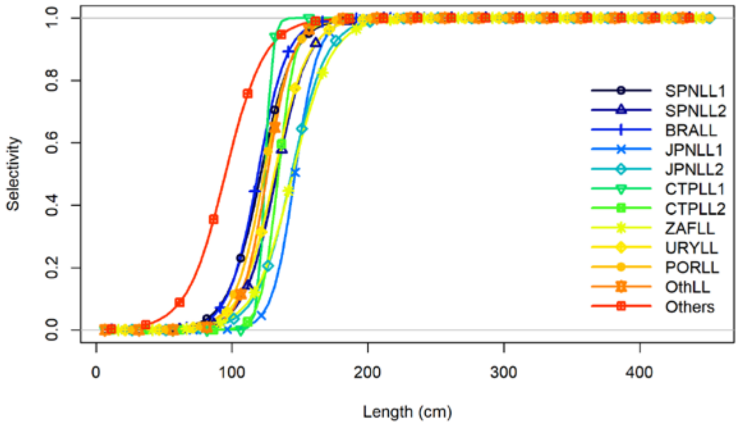


Figure 63. Model fits to the aggregated length compositions for each fleet (upper left panels), joint residuals plot for the length composition fits (upper right panel) and runs tests to length composition fits (lower panels) for the South Atlantic swordfish SS3 ("Sel_DN model"). Green panels indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).



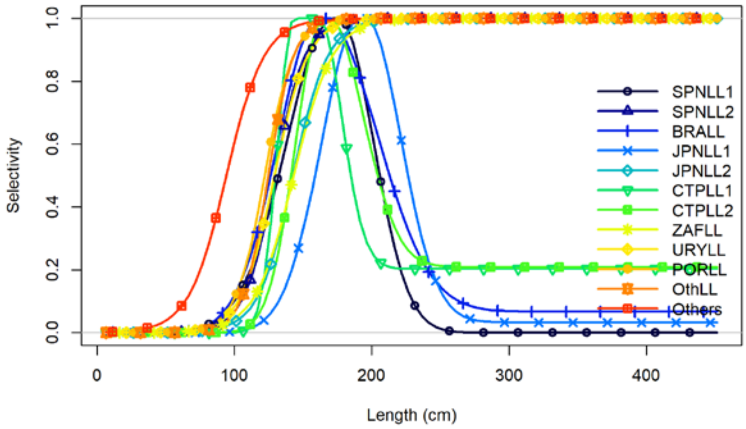


Figure 64. Selectivities at length shapes for the "Sel_Asym_model" (upper panel) and alternative model (Sel_DN model; lower panel).

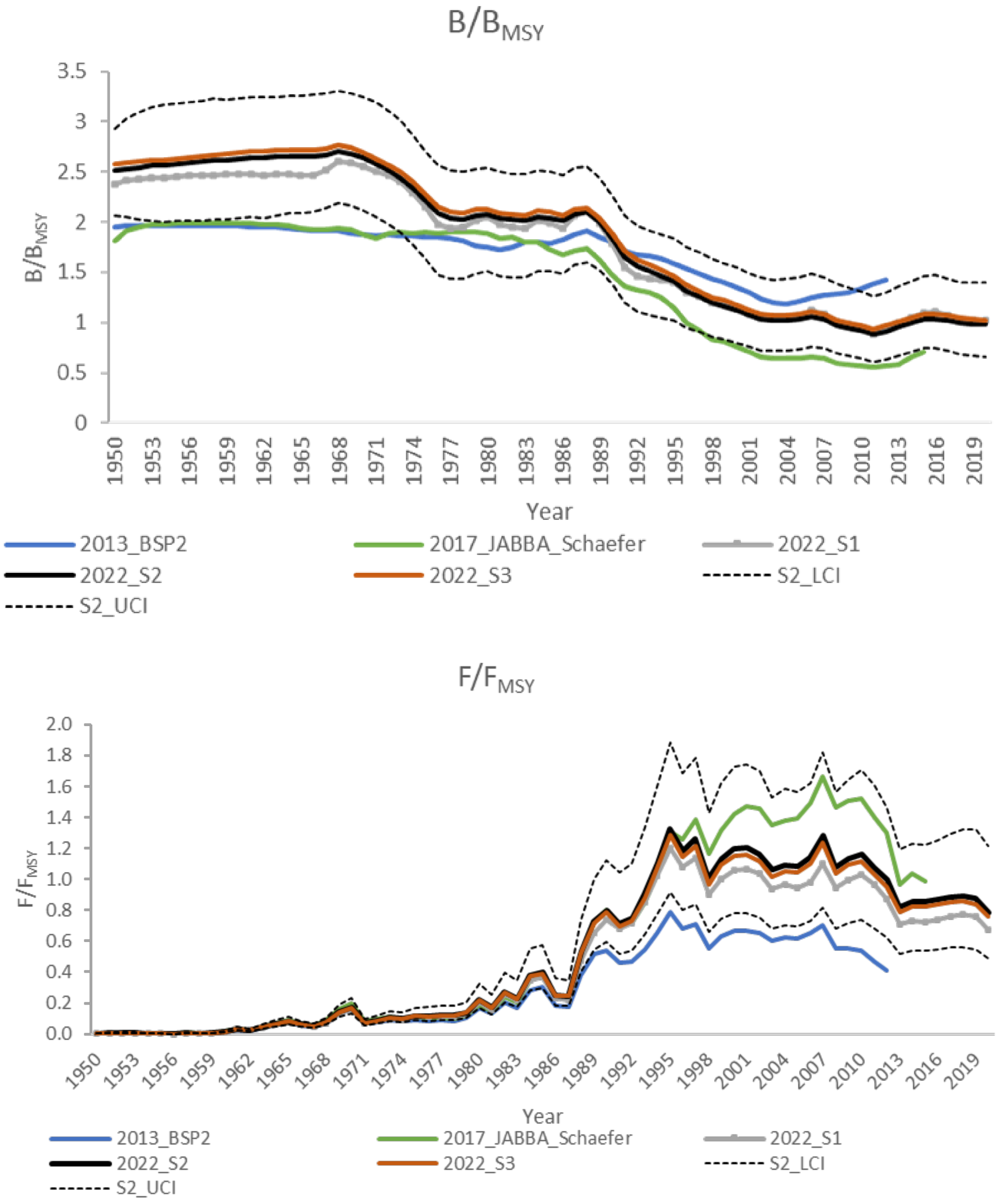


Figure 65. Comparisons of B/B_{MSY} and F/F_{MSY} estimated in the 2013, 2017, and 2022 stock assessments models (S1 – S3, not including SS models) for the South Atlantic swordfish stock.

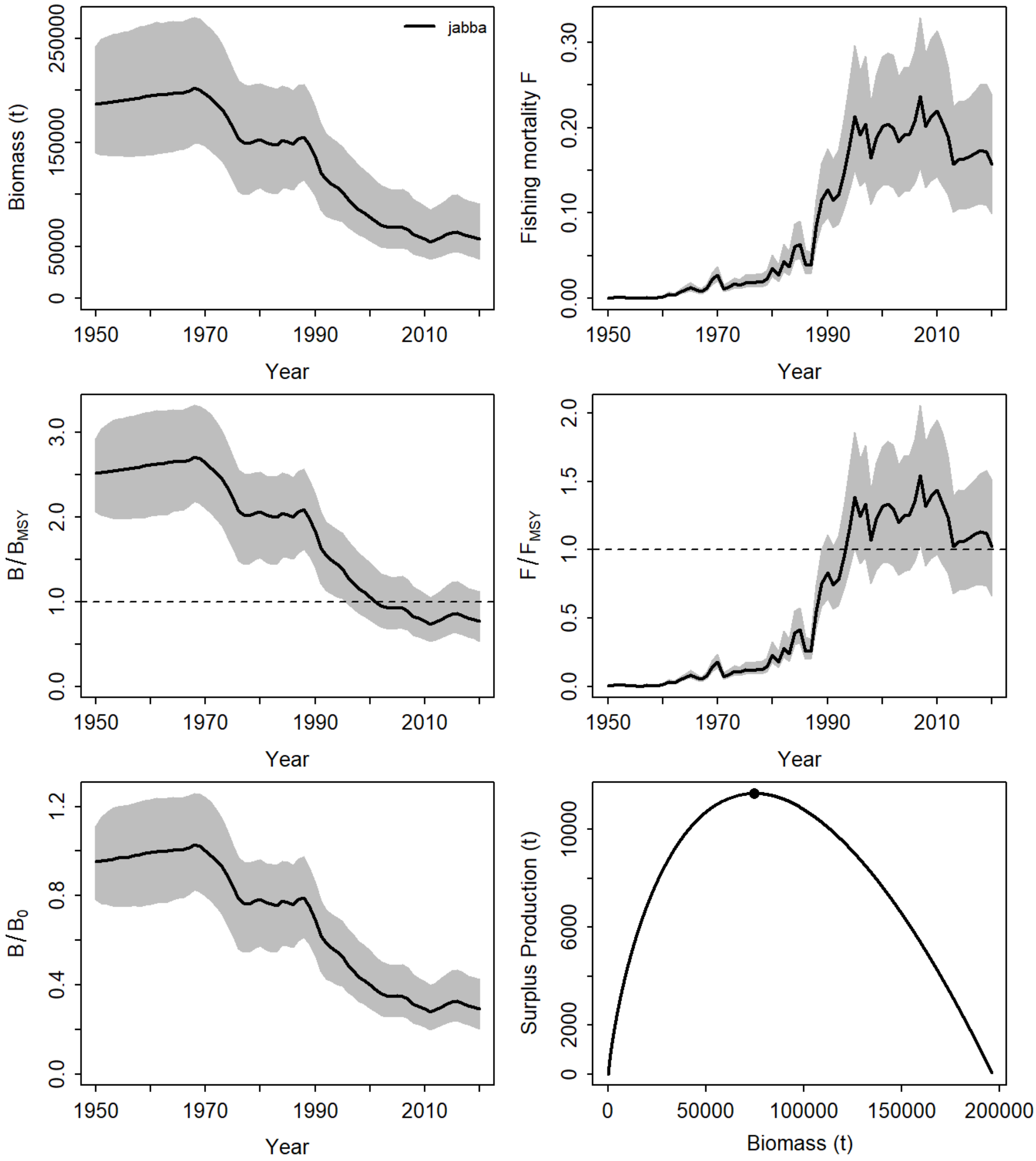


Figure 66. Biomass and fishing mortality (upper panels), biomass relative to *B_{MSY}* (*B/B_{MSY}*) and fishing mortality relative to *F_{MSY}* (*F/F_{MSY}*) (middle panels), and biomass relative to *K* (*B/K*) and surplus production curve (bottom panels) for the JABBA reference case model for South Atlantic swordfish.

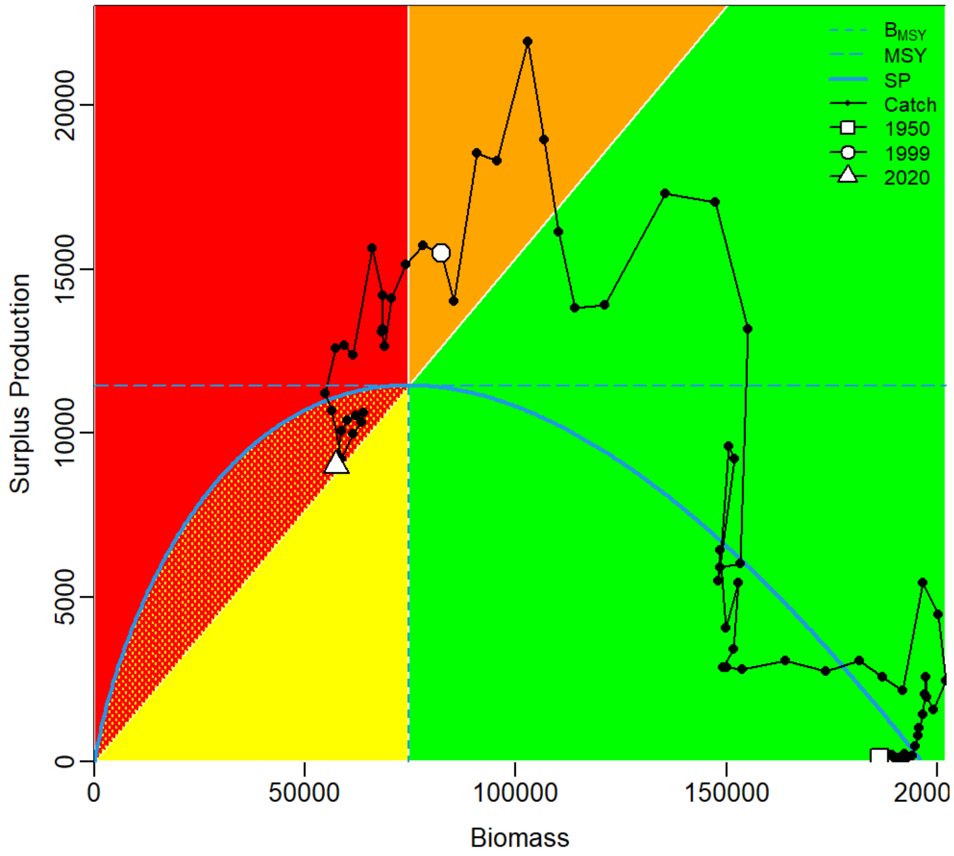


Figure 67. JABBA Kobe phase plot for the reference case showing trajectories of the catches in relation to *B_{MSY}* and *MSY* for the South Atlantic swordfish.

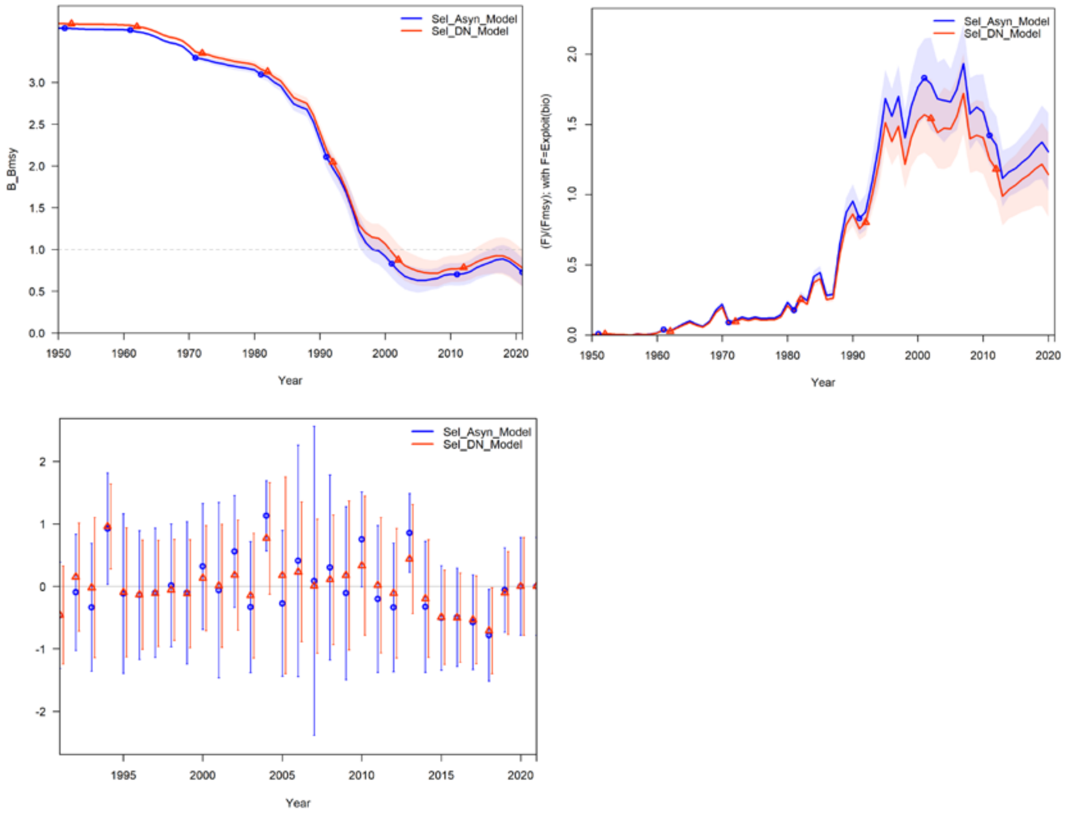


Figure 68. Trends in spawning biomass relative to SSB_{MSY} (SSB/SSB_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}), and annually estimated recruitment deviations from the for the South Atlantic swordfish SS3 models.

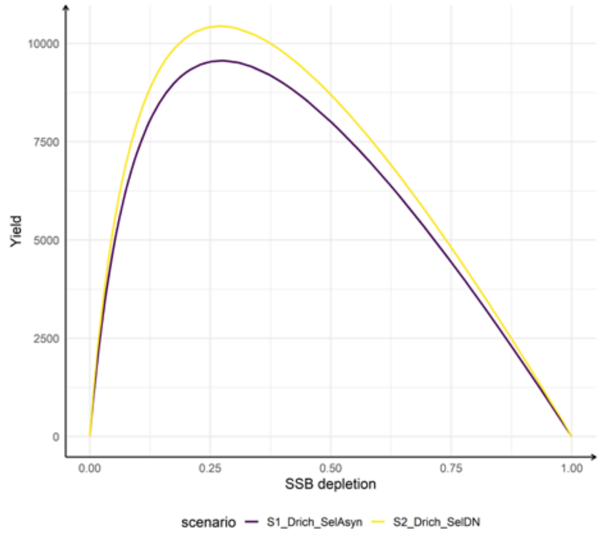


Figure 69. Yield curve by depletion levels of spawning biomass for the two SS3 models for the South Atlantic swordfish.

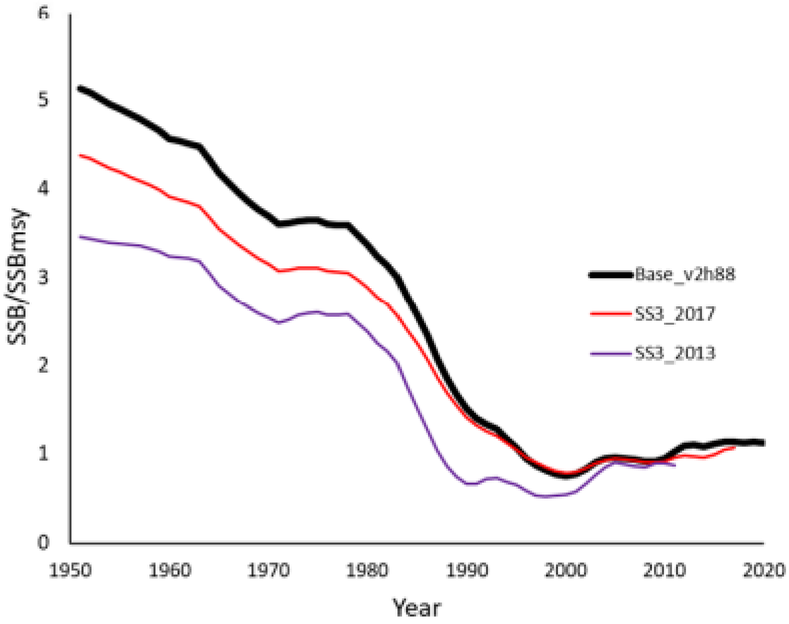


Figure 70. Comparison of the Biomass relative to B_{MSY} (B/B_{MSY}) for the SS3 reference case model for North Atlantic swordfish 2022 (base v2h88), and the 2013 and 2017 reference cases.

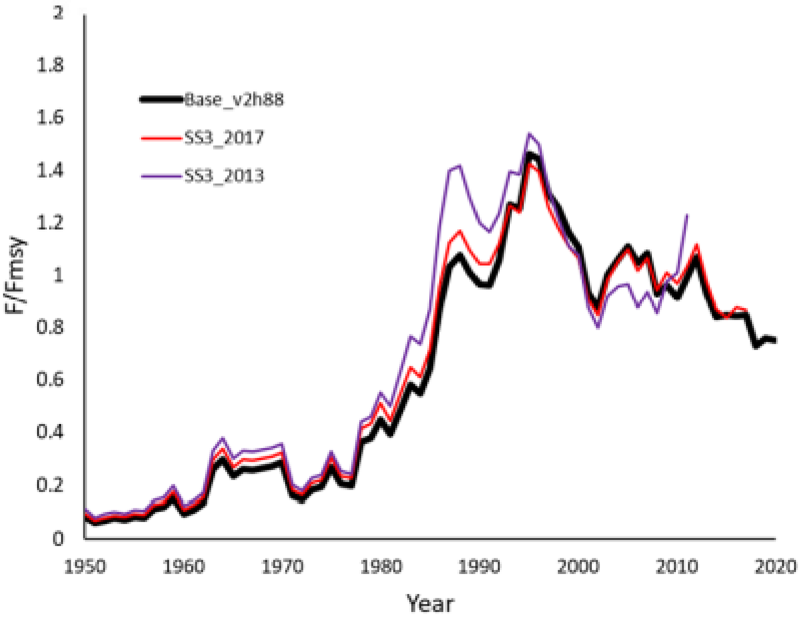


Figure 71. Comparison of the Fishing mortality relative to F_{MSY} (F/F_{MSY}) for the SS3 reference case model for North Atlantic swordfish 2022 (Base v2h88) and the 2013 and 2017 reference cases.

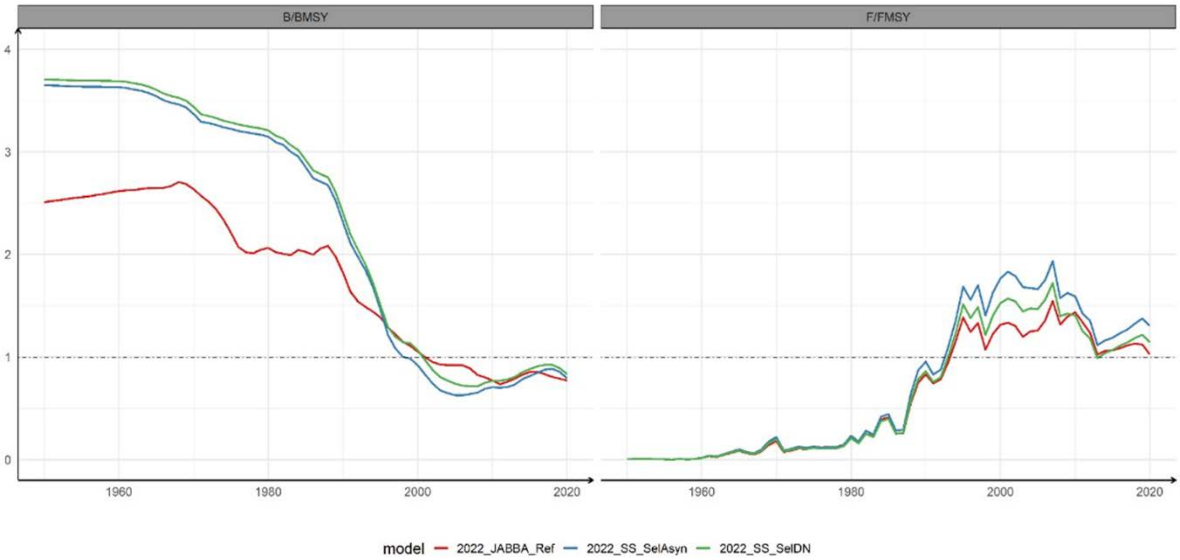


Figure 72. Comparisons of B/B_{MSY} and F/F_{MSY} between JABBA Reference case and two Stock Synthesis runs for the South Atlantic swordfish stock.

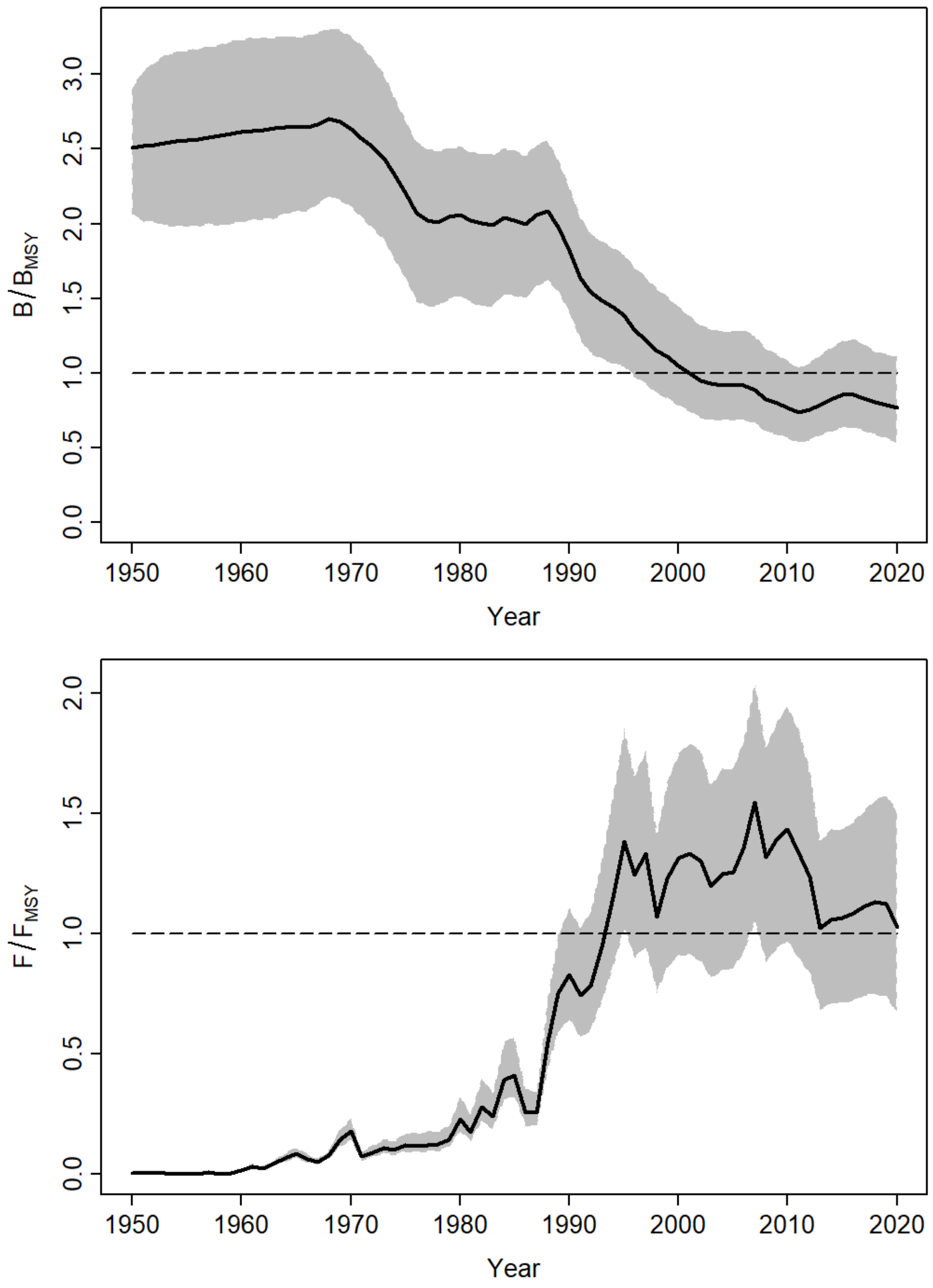


Figure 73. The 2022 stock assessment trends (*B/B$_{MSY}$* and *F/F$_{MSY}$*) for the JABBA reference case model for South Atlantic swordfish.

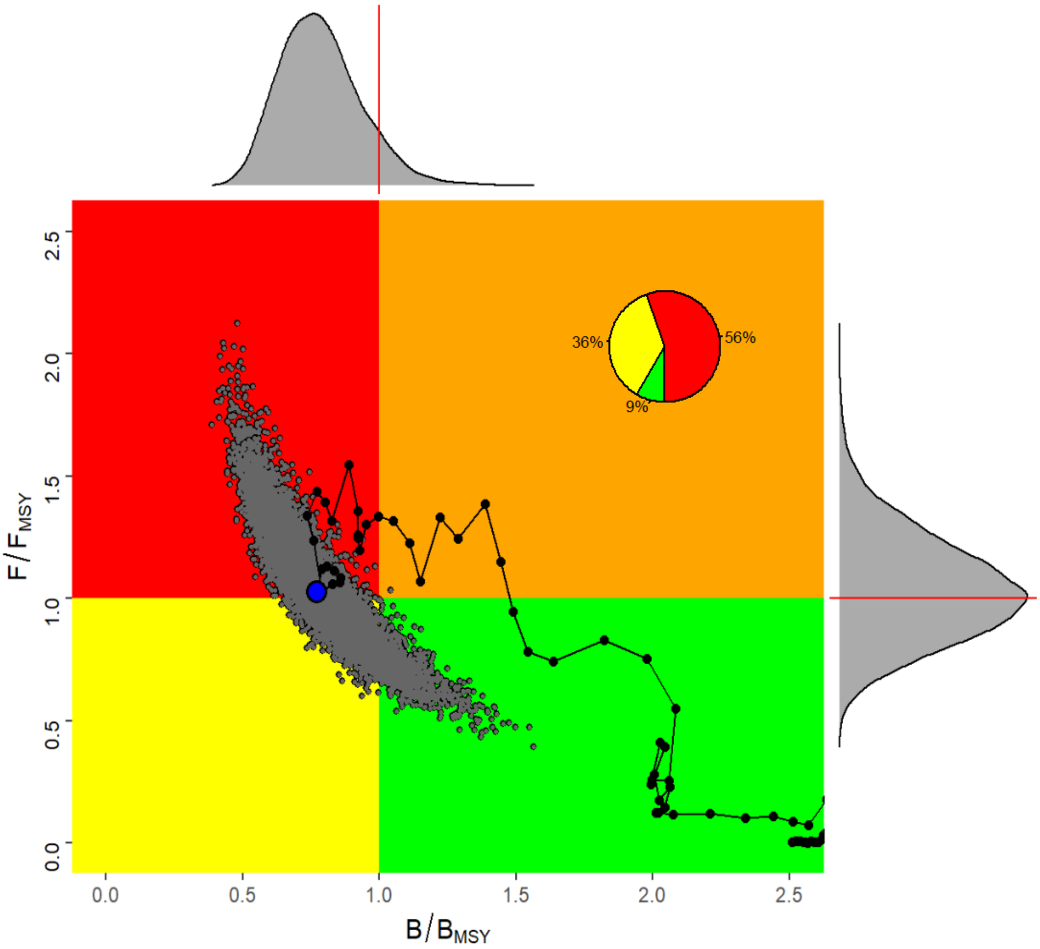
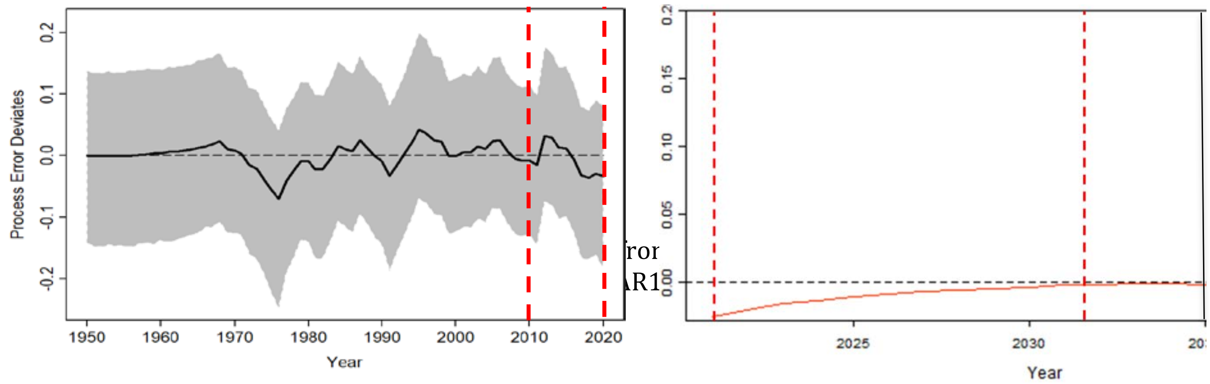


Figure 74. Kobe plot showing estimated trajectories (1950-2020) of B/B_{MSY} and F/F_{MSY} for the JABBA reference case model for the South Atlantic swordfish assessment. The probability of terminal year points falling within each quadrant is indicated in the pie chart.



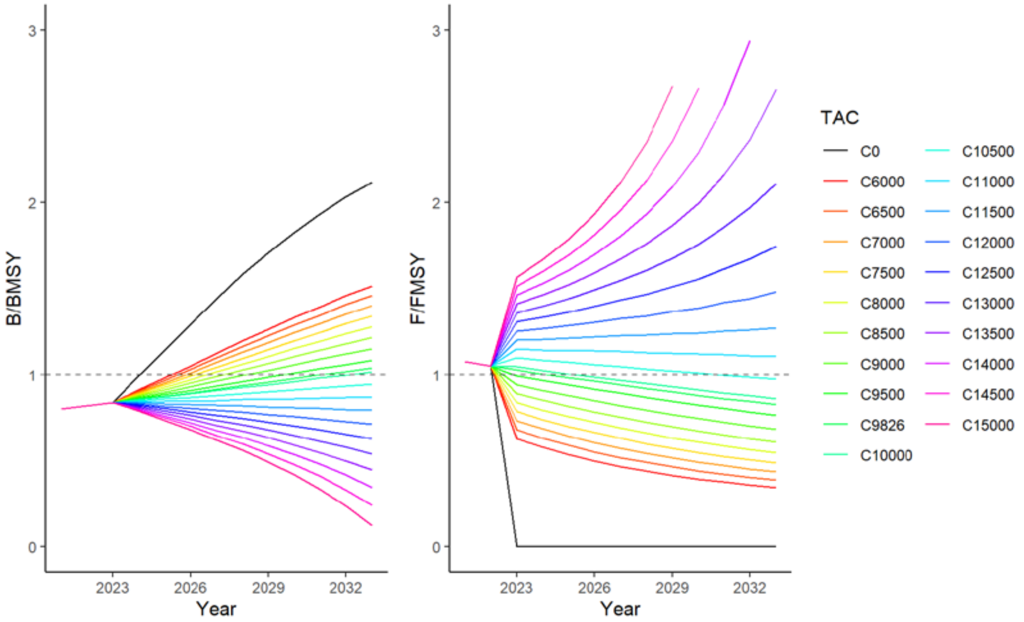


Figure 76. Projections for B/B_{MSY} and F/F_{MSY} based on the JABBA reference case model for South Atlantic swordfish for various levels of future catch ranging from 6,000 – 15,000 tons, including a zero-catch scenario. The initial catch for the years 2021-2022 was set to the average of the last three years (2018-2020) reported catch – 9,826 tons. The projections are run until 2033. The dashed line denotes B_{MSY}.

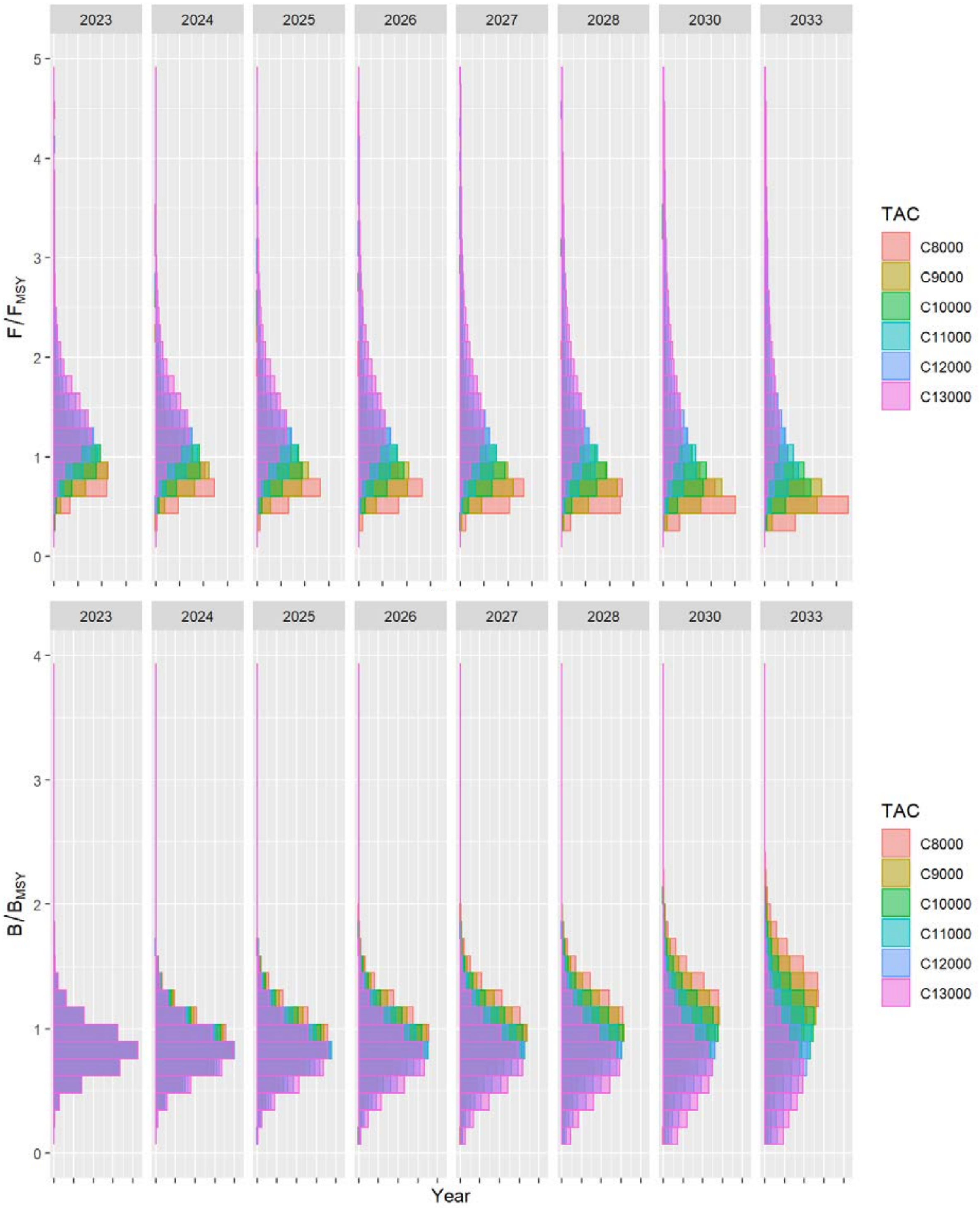


Figure 77. Histogram distributions of stochastic projections for F/F_{MSY} (top) and B/B_{MSY} (bottom) based on the JABBA reference case model for South Atlantic swordfish for various levels of future catch ranging from 8,000 – 13,000 tons. The projections are run until 2033 in varying timeframes (2023-2028;2030;2033).

Appendix 1

Agenda

1. Opening, adoption of agenda and meeting arrangements

2. Updates on available data on catches, biology, size composition (limited to any updates since the data preparatory meeting)

3. Updates on fleet structure (limited to any updates since the data-preparatory meeting)

4. Summary of relative abundance indices to be used (limited to any updates since the data-preparatory meeting)

5. North Atlantic stock

   5.1 Methods and model settings
   5.2 Model Diagnostics

      5.2.1 Stock Synthesis
      5.2.2 JABBA
      5.2.3 Other models

   5.3 Stock status results
   5.4 Projections
   5.5 Synthesis of stock assessment results

6. South Atlantic Stock

   6.1 Methods and model settings
   6.2 Model Diagnostics

      6.2.1 JABBA
      6.2.2 Stock Synthesis
      6.2.3 Other models

   6.3 Stock status results
   6.4 Projections

7. Implications of the assessment for N-SWO MSE

8. Recommendations

   8.1 Research and Statistics
   8.2 Management

9. Responses to the Commission

10. Review of the workplan

11. Other matters

12. Adoption of the report and closure

Appendix 2

List of participants *

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Appendix 3

List of Papers and presentations

DocRef	Title	Authors
SCRS/2022/114	North Atlantic swordfish stock assessment 1950-2020 using Just Another Bayesian Biomass Assessment (JABBA)	Gillespie K. and Parker D.
SCRS/2022/115	Updated combined biomass index of abundance of the North Atlantic swordfish stock 1963-2020	Gillespie K. and Ortiz M.
SCRS/2022/116	Preliminary Stock Assessment of South Atlantic Swordfish (*Xiphias gladius*) Using Stock Synthesis Model	Mourato B., Kikuchi E., Gustavo Cardoso L., Sant'Ana R., and Parker D.
SCRS/2022/117	Assessment of the South Atlantic Swordfish (*Xiphias gladius*) Stock Using JABBA	Parker D, Kikuchi E., and Mourato B.
SCRS/2022/118	Update of the Age and Growth Component of the Swordfish Biology Project with Preliminary Age Reading Results	Rosa D., Rosa D., Busawon D., Quelle P., Krusic-Golub K., Garibaldi F., Mariani A., Di Natale A., Schirripa M., Alves Bezerra N., Su Gustavo Cardoso L., Arocha F., Lombardo S., Campello T., Travassos P., Brown C., Hanke A., Gillespie K., and Coelho R.
SCRS/2022/119	Preliminary Evaluation of the North Atlantic Swordfish (*Xiphias gladius*) Stock Using the Surplus Production Model ASPIC	Ortiz M., Kimoto A.
SCRS/2022/120	A prior distribution on steepness for northern swordfish derived from life-history information	Taylor N.G., Sharma R.
SCRS/2022/121	Preliminary closed-loop simulation of Management Procedure Performance for Southern Swordfish	Taylor N.G., Murato B., and Parker D.
SCRS/2022/124	Model Configuration and Diagnostics for SS3 North Atlantic Swordfish Assessment	Schirripa M. J.
SCRS/P/2022/042	Stock Status and Projections from the Reference Case Model for South Atlantic Swordfish (*Xiphias gladius*) Stock Using JABBA	Parker D, Kikuchi E., Mourato B.L., and Kimoto A.
SCRS/P/2022/044	The use of AR1 in Projecting with JABBA	Parker D, Winker H.
SCRS/P/2022/045	North Atlantic Swordfish Projection	Kimoto A., Winker H., Shirripa M., Parker D., Gillespie K., and Ortiz M.

Appendix 4

SCRS Documents and Presentation Abstracts as provided by the authors

SCRS/2022/114 - JABBA was used to fit a Bayesian State-Space Surplus Production Model for the North Atlantic swordfish stock for years 1950 to 2020. ICCAT Task I data, CPUEs from nine CPCs, and a combined index were used in model development. Eight assessment scenarios were developed: two continuity runs (S1 and S2), three runs with varying steepness assumptions (S3 – S5), and three runs that used different sets of CPUE indicators (S6 – S8). S1 and S2 used the same model assumptions as those used in the 2017 BSP2 assessment model but with updates to data and indices. The r-priors for S3 – S5 that were used to approximate a range of steepness values were objectively derived from an Age-structured Equilibrium Model with Monte-Carlo simulations. Correlated indices were grouped together for S6 and S7, while S8 used the combined index. Models using CPUEs provided from CPCs (particularly S6 group CPUEs) often indicated implausibly high biomass scale across the timeseries. A variation on S2 (using the combined index) was selected as a reference case model. The reference case estimated MSY at 12,799 t, indicating a slightly less productive stock than was assumed in 2017. The model indicates that the stock in the yellow quadrant of the Kobe biplot with B2020/BMSY at 0.912 (0.672 – 1.229) and F2020/FMSY at 0.899 (0.599 – 1.313). Preliminary projections were completed and will be combined with SS3 projections and presented to the SCRS in September 2022.

SCRS/2022/115 - A combined index of abundance was completed for the North Atlantic swordfish stock for years 1962 – 2020. Some form of combined index has been used as a model input for North Atlantic swordfish assessments since the 1990s and is a collaborative effort between scientists from several CPCs. The 2022 version of the index includes catch and effort information from 7 ICCAT longline fleets: United States, Canada, Japan, Morocco, Chinese Taipei, EU-Spain, and EU-Portugal, which represent over 90% of annual swordfish catch. The index is used as an indicator in surplus production models and there is interest in its potential use as an indicator for a model-based MP in the N-SWO management strategy evaluation. The version presented in 2022 from previous standardizations in that the finer resolution set-level data were not available for some fleets. ICCAT Task II Catch and Effort data were extracted and then supplemented with additional data submitted by CPC scientists. A delta-lognormal standardization model was applied, accounting for fleet, spatial zone, quarter and year. The modeled biomass scale and trend were very similar to that calculated in the 2017 standardization.

SCRS/2022/116 - We first attempted to apply the Stock Synthesis model for the South Atlantic swordfish with the best available data through 2020. Our results suggest reasonably robust fits to the data as judged by the presented model diagnostic results. The resulting stock status for 2020 was generally consistent and predicted with high probabilities that current fishing levels are sufficiently high to preclude rebuilding (F > FMSY), whereas biomass remains below sustainable levels that can produce MSY (SSB < SSBMSY). As such, our models conclusively estimate that stock is overfished and subject to overfishing, with more than 90% probability for the red quadrant of Kobe biplot. Sensitivities analysis for important life-history parameters (such as, natural mortality and steepness) showed a high uncertainty about the stock's productivity. Research should be prioritized on estimating these important biological parameters to improve the parametrization of integrated age-structured models for the following assessments of South Atlantic swordfish

SCRS/2022/117 - Bayesian State-Space Surplus Production Models were fitted to South Atlantic swordfish (*Xiphias gladius*) catch and CPUE data using the 'JABBA' R package. This document presents details on the model diagnostics and stock status estimates for three preliminary models (S1-S3). The input r prior for S1 are identical to those used in the previous two assessments, while r priors for S2 and S3 were objectively derived from an Age-structured Equilibrium Model with Monte-Carlo simulations. In general, our results suggest that all candidate models are stable and provide robust fits to the data as judged by the presented model diagnostic results. Differences were observed in MSY with the S1 estimate being larger (13,224 t) than S2 and S3, which themselves were alike (11,849 and 11,723 t, respectively). Similarly, differences in biomass trends and fishing mortality between model S1 and models S2, S3 were obvious, with the S1 model indicating a more productive stock. However, when observed relative to MSY (i.e., B/BMSY and F/FMSY over time) all three models have remarkably similar trends that depict a recovering stock. Estimates of 2020 values from the three models indicate that the stock is moving from the "recovery" yellow quadrant into the green quadrant of the Kobe biplot (B2020/BMSY: 0.98 – 1.03; F2020/FMSY:0.68- 0.79). Furthermore, the probability that current fishing mortality is sufficiently low enough to facilitate stock rebuilding (yellow + green) is cumulatively above 85% in each model.

SCRS/2022/118 - Swordfish (*Xiphias gladius*) is a billfish species which occurs in tropical and temperate waters worldwide and is of the main targets of surface pelagic longlines. Since 2018, ICCAT has been developing a biology program for swordfish with a specific component on the age and growth of the species in the Atlantic (including the Mediterranean Sea). For this component, both spines and otoliths are being collected and sectioned. Sampling and processing is being conducted for both Atlantic stocks and the Mediterranean stock. A preliminary age reading was conducted for spines and otoliths by multiple readers for the North Atlantic stock. Spines and otoliths were from samples ranging between 90 to 218 cm LJFL for spines and 93 to 213 cm LJFL for otoliths. Bias was found between readers for both spines and otoliths. Maximum modal ages in spines was 7 years and in otoliths 5 years. Mean length at age from spines for individuals that had a modal age was similar to mean lengths at age from Arocha et al. (2003). Work on this component will continue on sampling to fill sampling gaps, processing of collected samples, age readings and growth modelling.

SCRS/2022/119 - A continuity run of the North Atlantic swordfish stock was done with the surplus production model ASPIC vr 7 using the catch and CPUE series from 1950 to 2020. Additional runs were explored with ASPIC using the 9 series of indices of abundance revised during the data preparatory meeting. However, due to conflicting trends between indices, it was necessary to split the indices into two groups that minimized the negative correlations. Even with the split of indices, none of the runs with individual indices provided results that were considered consistent with prior assessments and the general knowledge of the stock. Using the MLE estimation of ASPIC with the continuity run and the 2022 Combined biomass index provided reliable and consistent results, that passed all the diagnostic tests. This run was then proposed forward to be considered for the management advice of the N-SWO stock.

SCRS/2022/120 - We expand the derivation of the Beverton and Holt steepness parameter h by Sharma and Arocha 2017 by simulating steepness values for a range of input parameters including, natural mortality, the von Bertalanffy growth, maturity, as well as early life history information. We derived or assume standard deviations for all 15 quantities used for this derivation to simulate the resultant distribution of steepness. We present it with the corresponding distributions life-history parameter distributions used to derive the distribution of steepness. The prior could be improved by developing a correlation matrix for the parameters so that a multivariate distribution. This could be used to draw parameter combinations would be expected to correlate in practice for deriving the distribution of steepness. Having a distribution for steepness, and associated life-history parameters used to derive it means that it is possible to input distributions of steepness, growth, and mortality parameters as custom parameters in Operating Models for swordfish and others MSE so that these parameters can be appropriately weighted in Operating Models and so that values of steepness are coherent with the other life history parameters.

SCRS/2022/121 - I present some preliminary closed-loop simulations for southern Atlantic swordfish. I condition an Operating Model using OpenMSE's Rapid Conditioning Model and using a joint multivariate prior for steepness derived from maturity, growth, and natural mortality information from northern swordfish to integrate across the uncertainty in these quantities in a single operating model. Then I test data-moderate MPs similar to those used for southern Swordfish stock assessment including delay difference and surplus production models to illustrate their performance. The preliminary results show that there most of these Candidate Management Procedure meet minimal satisficing criteria. If the tolerance for being below the limit reference is very small, then it this criterion has strong discriminatory power. To be informative for management, this preliminary exercise would have to be expanded to include stock specific priors, a broader set of operating models, and finalized quantitative objectives.

SCRS/2022/124 - This paper describes stock assessment model configuration, diagnostics and results for the 2022 fully integrated assessment model for North Atlantic swordfish (*Xiphias gladius*). The CPUE indices used exhibited conflicts between themselves. Likewise, there was conflict between the trends suggested by the CPUE indices in general and those of the length compositions. These conflicts contributed to the overall uncertainty in the assessment results. An attempt was made to estimate the total discards of the fishery based on all observation adata available. A suite of diagnostics were performed on the assessment model that further highlighted the conflicting data trends and the need for fixing, or providing informative priors, on several parameters. The stock was found not to be overfished and overfishing not to be occurring. Evaluation of the effectiveness of the current minimum size regulation was difficult to ascertain due to the period of time that has passed since the inception as well as the lack of observations of the amount and characteristics of discards.

SCRS/P/2022/042 - Stock status and projection results for the South Atlantic swordfish were provided using the JABBA reference case model were provided during the meeting. The presentation contains Kobe plot, projections with constant catch scenarios from 6,000 to 15,000, and Kobe 2 matrix.

SCRS/P/2022/044 - During the meeting, a potential technical issue regarding the assumption of process errors in JABBA projection with a new AR1 autocorrelation method was found. The authors explored the appropriateness of the use of the new AR1 method and compared the projections with/without AR1 options. The projections that included the AR1 function were more pessimistic.

SCRS/P/2022/045 - This presentation provided preliminary projections for North and South Atlantic swordfish stocks for the 2022 stock assessments. Projections were prepared for Stock Synthesis and JABBA in the North and JABBA in the South. A range of potential catch values were used to generate chicken feet plots and Kobe 2 Strategy Matrices for B/B_{MSY}, F/F_{MSY}, and joint B/B_{MSY}-F/F_{MSY} probabilities. Projections will be be further refined for the September 2022 SCRS meetings.