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STOCK STATUS OF ATLANTIC WHITE MARLIN IN 2025: INITIAL JABBA MODEL RUNS

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SUMMARY

*The 2025 stock assessment of Atlantic white marlin (*Kajikia albida*) applied a Bayesian state-space surplus production model (JABBA) using updated catch and CPUE data from 1956 to 2023. Four model configurations explored alternative hypotheses, grouped broadly into two patterns: Group 1-type scenarios, which suggested the stock is recovering but not fully rebuilt, and Group 2 scenario, which indicated a more optimistic stock status with rebuilding largely achieved. All models showed consistent overall trends in biomass and fishing mortality, although the magnitude of estimates varied among scenarios. Kobe plots and jackknife analyses revealed that, despite differences in scale, the general trajectory of stock recovery was similar across configurations. Given the uncertainties associated with life history parameters, stock structure, catch data, and CPUE trends, combining information from both Group 1- and Group 2-type models could represent a viable and precautionary approach for management advice, providing a balanced view of potential stock conditions.*

RÉSUMÉ

*L'évaluation du stock de makaire blanc de l'Atlantique (*Kajikia albida*) de 2025 a appliqué un modèle de production excédentaire état-espace de type bayésien (JABBA) en utilisant des données actualisées de capture et de CPUE de 1956 à 2023. Quatre configurations de modèles ont permis d'explorer d'autres hypothèses, regroupées en deux grandes catégories : les scénarios de type groupe 1, qui suggèrent que le stock se rétablit mais n'est pas totalement rétabli, et les scénarios de type groupe 2, qui indiquent un état du stock plus optimiste avec un rétablissement largement atteint. Tous les modèles ont montré des tendances générales cohérentes en ce qui concerne la biomasse et la mortalité par pêche, bien que l'ampleur des estimations varie d'un scénario à l'autre. Les diagrammes de Kobe et les analyses par eustachage (« jack-knife ») ont fait apparaître que, malgré les différences d'échelle, la trajectoire générale du rétablissement des stocks était similaire d'une configuration à l'autre. Compte tenu des incertitudes associées aux paramètres du cycle vital, à la structure du stock, aux données de capture et aux tendances des CPUE, la combinaison des informations provenant des modèles des groupes 1 et 2 pourrait constituer une approche viable et prudente pour les avis de gestion, en fournissant une vision équilibrée de l'état potentiel du stock.*

RESUMEN

*En la evaluación de 2025 del stock de aguja blanca del Atlántico (*Kajikia albida*) se aplicó un modelo bayesiano de producción excedentes estado-espacio (JABBA) utilizando datos actualizados de capturas y CPUE desde 1956 hasta 2023. Cuatro configuraciones de modelos exploraron hipótesis alternativas, agrupadas a grandes rasgos en dos patrones: Escenarios de tipo Grupo 1, que sugerían que el stock se está recuperando pero no está totalmente recuperado, y escenarios de tipo Grupo 2, que indicaban un estado más optimista del stock con una recuperación ampliamente alcanzada. Todos los modelos mostraron tendencias generales coherentes en la biomasa y la mortalidad por pesca, aunque la magnitud de las estimaciones varió entre los distintos escenarios. Los gráficos de Kobe y los análisis jackknife revelaron que, a pesar de las diferencias de escala, la trayectoria general de recuperación del stock era similar en todas las configuraciones. Dadas las incertidumbres asociadas a los parámetros del ciclo biológico, la estructura del stock, los datos de capturas y las tendencias de la CPUE, la combinación de información procedente de modelos de tipo Grupo 1 y Grupo 2 podría representar un enfoque viable y precautorio para el asesoramiento en materia de ordenación, proporcionando una visión equilibrada de las condiciones potenciales del stock.*

KEYWORDS

Abundance, stock assessment, marlins, Atlantic, stock status, CPUE fits, biomass model

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1. Introduction

The most recent stock assessment for Atlantic white marlin (*Kajikia albida*) was conducted by the International Commission for the Conservation of Atlantic Tunas (ICCAT) in 2019 (ICCAT, 2019). Two modelling approaches were applied to estimate stock status: (i) a Bayesian state-space surplus production model (JABBA), and (ii) an integrated age-structured model (Stock Synthesis). Both models indicated that the stock was overfished, but that overfishing was not occurring at that time. This assessment was further detailed by Mourato *et al*. (2020), who described the development and application of JABBA model specifically for assessing Atlantic white marlin stock.

In support of the 2025 Atlantic white marlin stock assessment, a JABBA model was developed using updated catch and standardized CPUE time series through 2025. JABBA is a Bayesian state-space surplus production model formally included in the ICCAT stock assessment toolbox (https://github.com/ICCAT/software/wiki/2.8-JABBA). Between the 2025 ICCAT White Marlin Data Preparatory Meeting and the Stock Assessment Meeting, several informal technical discussions were held among modelers to review model assumptions, configurations, and preliminary outputs. The present document incorporates recommendations arising from those discussions.

This document presents preliminary results from the updated JABBA model, including estimates of key population parameters, trends in biomass and fishing mortality, stock status relative to reference points, and model diagnostics.

2. Material and methods

2.1 Fishery data

Total catch data for Atlantic white marlin (Kajikia albida) covering the period 1956–2023 were obtained from the ICCAT Secretariat. These data represent reported landings as provided by CPCs (**Figure 1**).

Indices of relative abundance were made available as standardized catch-per-unit-of-effort (CPUE) time series, which were assumed to be proportional to stock biomass for the purpose of the assessment. After discussions during the 2025 ICCAT White Marlin Data Preparatory Meeting, the Group agreed to use the following seven CPUE indices in the stock assessment (**Figure 2**):

- Brazil, longline: 1978–2010
- Chinese Taipei, longline: 1968–1997, 1998–2023
- Japan, longline: 1959–1977, 1978–1992, 1993–2013, 2014–2023
- USA, longline: 1993–2023
- Venezuela, gillnet: 1991–2023
- Venezuela, longline: 1991–2017
- Mexico, longline: 1993–2023

These CPUE indices were selected based on consistency in standardization methods, temporal coverage, and representativeness across the major components of the fishery. The model incorporates these series as relative abundance indicators assumed to be proportional to biomass, with appropriate weightings as determined during the assessment (see model configuration section). The model base period spans from 1956 to 2023 to cover the full extent of available catch and effort data, with CPUE series incorporated according to the years specified above.

2.2 JABBA stock assessment model fitting procedures

This stock assessment was conducted using the most recent version of JABBA (v2.2.9), available at: https://github.com/jabbamodel/JABBA. JABBA provides several inbuilt functionalities, including the automatic fitting of multiple CPUE time series with associated standard errors, the option to estimate or fix the process variance, the optional estimation of additional observation variance for individual or grouped CPUE series, and the specification of alternative production functions (Fox, Schaefer, or Pella-Tomlinson) by setting the BMSY/K inflection point, which is internally converted into the corresponding shape parameter *m*.

For the unfished equilibrium biomass (*K*), the model applied the default prior used in JABBA, a vaguely informative lognormal distribution with a coefficient of variation of 100% and a central value set at eight times the maximum total catch. The initial depletion prior ($\varphi = B_{1956}/K$) was specified as a beta distribution with a mean of 0.99 and a coefficient of variation of 1%, reflecting the assumption of minimal fishing impact prior to the starting year of 1956. The beta distribution was preferred over a lognormal distribution as it better represents the low uncertainty associated with the initial depletion.

Catchability parameters for all CPUE indices were assigned uninformative uniform priors. Additional observation variances for CPUE series were estimated assuming inverse-gamma priors to allow internal variance weighting by the model. The process error for log-transformed biomass was freely estimated using an uninformative inverse-gamma prior, with both shape parameters set at 0.001. The observation error for CPUE inputs was fixed at 0.05.

For the 2025 stock assessment, the Group agreed to continue using the approach developed in Winker *et al*. (2020) to estimate the r prior. This method is based on different assumptions about Atlantic white marlin life history parameters, including maximum age, growth parameters, and other updated biological inputs. It allows for the initial parameterization of the age-structured model across a range of stock-recruitment steepness values (h), while also accounting for reasonable uncertainty in natural mortality (M).

The initial JABBA model trials will use the following biological inputs and assumptions: natural mortality (M) was set at 0.2 with a coefficient of variation of 30%; length at 50% maturity was specified as 145.04 cm LJFL for females and 140.03 cm LJFL for males (Pinheiro *et al*., 2021); growth parameters included L_∞ of 172.0 cm LJFL and 160.6 cm LJFL, with k values of 0.32 and 0.54 for females and males respectively, and t_0 set at –1 (Drew *et al*., 2010); maximum age was assumed to be 20 years (Winker *et al*., 2020); size-at-age parameters were adapted from Winker *et al*. (2020) to inform prior estimation for JABBA; and the stock-recruitment steepness (h) was assumed to be 0.6, consistent with the 2019 stock assessment. Removals incorporated into the model include reported landings, dead discards, and the dead fraction of live discards, as estimated by the Group (see Section 3).

Given the update to length-at-50% maturity (L50), and to enable continuity with previous assessments, the Group also requested a run using the r prior from the 2019 stock assessment, specified as $\log(r) \sim N(\log(0.181), 0.180)$ and a fixed input value of $B_{MSY}/K = 0.39$. This prior was based on an L50 of 160.4 cm LJFL as reported by Arocha and Barrios (2009).

For the 2025 stock assessment of Atlantic white marlin (*Kajikia albida*), four alternative model configurations were tested to explore the influence of different CPUE index groupings on model outputs and to represent plausible alternative states of nature:

- **Group_0**: All available standardized CPUE indices, representing the full dataset without exclusions.
- **Group_1**: A subset of indices with correlated trends, selected to represent one plausible state of nature. This group included BRA-LL, CTP-LL1, JPN-LL1, JPN-LL2, JPN-LL3, JPN-LL prior, USA-LL, and MEX-LL.
- **Group_2**: An alternative subset of indices reflecting a different correlated trend structure, consisting of BRA-LL, CTP-LL1, JPN-LL1, JPN-LL prior, VEN-LL, and VEN-GN.
- **Group_1 + CTP-LL2**: This configuration was based on Group_1 with the addition of CTP-LL2 to evaluate the impact of including this index on model performance and diagnostics.

The models applied a minimum CV of 0.3 for CPUE indices where the reported CV was ≤ 0.3, and used the reported CV where it exceeded 0.3, consistent with the approach adopted in the 2019 stock assessment.

2.3 Model diagnostics

JABBA was implemented in R (R Development Core Team, https://www.r-project.org/) with a JAGS interface (Plummer, 2003) to estimate posterior distributions through Markov Chain Monte Carlo (MCMC) simulation. In this assessment, three chains were run for 30,000 iterations each, with a burn-in of 5,000 iterations and a thinning rate of five. Convergence diagnostics included visual inspection of trace plots and formal tests such as Heidelberger and Welch (1992), Geweke (1992), and Gelman and Rubin (1992), as implemented in the *coda* package (Plummer *et al*., 2006). Model fit to abundance indices was evaluated by comparing predicted versus observed CPUE, using residual plots with color-coded lognormal residuals by fleet, boxplots summarizing annual residual distributions (where larger boxes indicate greater discrepancies among indices), and loess smoothers to detect patterns of autocorrelation. Root-mean-squared error (RMSE) was calculated as a goodness-of-fit measure. The randomness of residuals was assessed using runs tests (Carvalho *et al*., 2017; 2021), applied on the log-scale residuals of CPUE fits using the *tseries* package's runs.test function and the one-sided p-value of the Wald-Wolfowitz runs test. Model consistency was examined through retrospective analysis by sequentially removing one year of data over five peels, refitting the model, and comparing outputs (biomass, fishing mortality, B/BMSY, F/FMSY, B/B0, MSY) to the full model. Bias in estimates was quantified using Mohn's rho (Mohn, 1999) following the formulation of Hurtado-Ferro *et al.* (2015). Prediction skill was assessed through hindcast cross-validation (HCXval; Kell *et al.*, 2016), where recent data points were removed, the model refitted, and forecasts projected forward over the omitted years for validation. Prediction skill was quantified using the Mean Absolute Scaled Error (MASE), which compares model forecast accuracy against a naïve baseline. A MASE score below one indicates predictive skill (e.g., a MASE of 0.5 means forecasts are twice as accurate as the baseline), whereas a score above one suggests forecasts are no better than a random walk (Kell *et al.*, 2021).

3. Results and discussion

The results of the MCMC convergence diagnostics (Heidelberger and Welch, 1992; Geweke, 1992; Gelman and Rubin, 1992), along with visual inspection of the trace plots, indicated that all models achieved satisfactory convergence and exhibited a high degree of stability throughout the simulations.

The four model scenarios (Group_0, Group_1, Group_1 + CTP-LL2, Group_2) displayed clear differences in fit quality, residual patterns, RMSE, and process error deviates (**Figures 3 - 7**). Group_0, which included all indices, showed the highest level of data conflict. Several indices failed the runs tests (e.g., BRA-LL, CTP-LL1, CTP-LL2, VEN-LL), and residuals revealed systematic deviations (**Figure 5**). The RMSE was the highest (62.3%; **Figure 6**). The process error deviates exhibited a clear negative trend from around 1985 to 2020 (**Figure 7**), suggesting the model compensated for declining CPUE trends with progressively lower productivity signals. Group_1 showed the most consistent performance, with most indices passing the runs tests and residuals distributed more randomly (**Figure 4**). The RMSE was the lowest across scenarios at 49.2% (**Figure 6**). The process error deviates also showed a negative trend over the same period (**Figure 7**), though less pronounced than in Group_0, indicating reduced but still present data tensions. Group_1 + CTP-LL2 reintroduced much of the conflict seen in Group_0. The inclusion of CTP-LL2 led to systematic residual patterns and an RMSE of 61.5% (**Figure 6**). The process error deviates again showed a negative trend from the mid-1980s to 2020 (**Figure 7**), reflecting conflicting CPUE signals and greater compensatory adjustments by the model. Group_2 presented intermediate results, with an RMSE of 58% (**Figure 6**). While some indices (e.g., BRA-LL, JPN-LL1) contributed well, CTP-LL1 and Venezuelan indices showed clear residual patterns (**Figure 4**). The process error deviates also exhibited a long-term negative trend from 1985 to 2020, although this trend appeared slightly attenuated compared to other scenarios, suggesting a modest improvement in balancing data conflicts (**Figure 7**). Overall, Group_1 provided the residual behavior, the lowest RMSE, while Group_2 presented the less pronounced compensatory trends in the process error deviates. The other scenarios highlighted the challenges of reconciling conflicting CPUE indices, particularly with the inclusion of CTP-LL2 and Venezuelan series.

The marginal posterior distributions and prior densities for all four scenarios are shown in **Figure 8**. Across scenarios, the prior to posterior median ratios (PPMR) for r were consistently below 1 but close, confirming that the posteriors were strongly influenced by the priors, as expected given the low CVs applied in prior development. Conversely, the small PPVR values for K indicated that data were informative for this parameter, consistent with the use of wide priors for K. Initial depletion (φ) posteriors remained largely determined by the priors, as shown by PPMR and PPVR values near 1 across all models. Results were broadly consistent among scenarios, with minor differences in the degree of posterior updating for r and K. Summaries of posterior quantiles for key management parameters are presented in **Table 1**. Across the four scenarios (Group_0, Group_1, Group_1_CTP_LL2, Group_2), estimates of MSY were similar, ranging from approximately 1,450 t to 1,650 t. BMSY median estimates were also consistent, varying between ~9,100 and ~9,500 t, while FMSY was stable across models, around 0.16. The surplus production curves (**Figure 9**) showed overlapping trajectories, with Group_2 suggesting slightly higher MSY values.

Biomass trajectories **(Figure 9**) indicated a general decline from the 1960s to 1980 across all scenarios. From the 1980s onwards, biomass stabilized and showed modest increases in Group_2, which yielded higher recent biomass estimates compared to the other models. Similarly, B/B_{MSY} trajectories displayed a decline until around 1980, followed by relative stability and a slight increase in recent years, particularly in Group_2. Current B/B_{MSY} estimates range from ~0.5 (Group_1_CTP_LL2) to above 1.5 (Group_2). Fishing mortality (F) and F/F_{MSY} trajectories (**Figure 9**) showed peaks during the 1970s and 2000s, with a marked decline since the late 2000s. Current F/F_{MSY} estimates for all models are below 1, indicating that fishing pressure is within sustainable levels. Group_2 estimates the lowest recent F/F_{MSY} values, reinforcing the perception of reduced fishing pressure. Overall, stock status appears to have improved since the 2000s, with all scenarios indicating current fishing mortality below FMSY, but the biomass bellow or above B_{MSY} in some cases. Group_2 stands out by suggesting a more optimistic stock condition, with higher biomass and lower fishing mortality levels.

A five-year retrospective analysis was conducted for all four scenarios (Groups 0, 1, 1_CTP_LL2, and 2), with the results shown in **Figure 10**. The retrospective patterns were minimal across scenarios, as illustrated by the biomass, fishing mortality, and B/B_{MSY} trajectories, with Mohn's rho estimates for B and B/BMSY generally falling within the acceptable range of -0.15 to 0.20 (Hurtado-Ferro *et al.*, 2014; Carvalho *et al.*, 2017). Hindcasting cross-validation (**Figure 11**) revealed that certain indices exhibited poor predictive performance across scenarios. For example, the CTP-LL2 index consistently showed high MASE values near 3, suggesting weak predictive skill. The USA-LL index also produced MASE scores above 1.3 in all models, indicating moderate predictive capacity. In contrast, indices like JPN-LL3 and MEX-LL achieved MASE scores close to or slightly above 1, reflecting better alignment between predictions and observations. The VEN-GN index showed acceptable predictive skill, with MASE values near 1 in the scenarios where it was included. Overall, the Group 2 scenario and Group 1 models tended to perform slightly better in terms of predictive skill, with marginally lower MASE values for most indices compared to Group 0. This suggests that the model fit and predictive performance were more robust when these configurations were applied.

The jackknife sensitivity analysis (**Figure 12**) illustrates how the removal of individual CPUE indices affects the stock assessment results. Although the figure presents multiple overlapping trajectories that make it challenging to distinguish each individual scenario, the overall patterns remain consistent. In general, all trajectories follow similar temporal trends, with comparable shapes and directions over time. The main effect of excluding specific indices appears to be a change in the magnitude or scale of the estimates rather than in the overall trends themselves. Biomass, B/B_{MSY}, B/B_0, fishing mortality, and F/F_{MSY} all show consistent dynamics across the different jackknife scenarios, with only moderate variation in absolute levels. The surplus production curves also retain a broadly similar shape, with minor shifts in MSY and B_{MSY} estimates depending on the index removed. Nonetheless, there are some exceptions where the exclusion of certain indices produced more pronounced changes in the magnitude of the trajectories, particularly in biomass or productivity estimates, suggesting that some indices contribute disproportionately to shaping model outcomes. This analysis suggests that while individual indices can affect the scale of stock status indicators, the overall trends and conclusions about stock productivity remain robust.

The Kobe plots (**Figure 13**) generated for the different model scenarios (Group_0, Group_1, Group_1_CTP_LL2, and Group_2) reveal notable differences in the interpretation of current stock status for the Atlantic white marlin. Group_0 suggests that approximately 95% of the posterior distribution for 2023 falls within the yellow quadrant, indicating that while the stock is not overfished, fishing mortality may still exceed sustainable levels, with only 5% in the green quadrant where both biomass and fishing mortality would be considered at safe levels. Group_1 shows a similar pattern, with around 90.5% in the yellow quadrant and 9.5% in the green. The Group_1_CTP_LL2 scenario provides an almost identical picture, with 95.4% of the posterior in the yellow quadrant and 4.6% in the green. In contrast, Group_2 points to a considerably more optimistic status, with about 84.2% of the posterior falling in the green quadrant and 15.8% in the yellow, suggesting that under this scenario the stock is very likely not overfished and is experiencing sustainable fishing pressure. These contrasting results between Group_1-type scenarios and Group_2 reflect two competing hypotheses about the stock: one where the stock is recovering but not yet rebuilt, and another where rebuilding has largely occurred. Given these uncertainties driven by potential inconsistencies between catch data, CPUE trends, and low fishing mortality estimates, as well as the possibility of reduced recruitment in recent decades, or even unreported catches, a combined or integrated approach that accounts for both hypotheses may provide a more balanced and precautionary basis for management advice.

4. References

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Table 1. Summary of posterior quantiles presented in the form of marginal posterior medians and associated the 95% credibility intervals of parameters for the Bayesian state-space surplus production models for Atlantic white marlin.

	Group 0			Group 1		
Estimates	***Median***	***2.5%***	***97.5%***	***Median***	***2.5%***	***97.5%***
K	22809.350	15783.486	35200.942	23067.698	16171.383	33595.413
r	0.193	0.144	0.261	0.194	0.148	0.257
σ_{proc}	0.197	0.158	0.213	0.195	0.152	0.213
F_{MSY}	0.163	0.121	0.220	0.163	0.124	0.217
B_{MSY}	9123.324	6313.107	14079.736	9226.659	6468.258	13437.553
MSY	1507.761	1145.503	2032.750	1487.641	1127.267	2033.508
B_{1956}/K	0.899	0.613	1.248	0.908	0.620	1.253
B_{2023}/K	0.213	0.102	0.449	0.252	0.111	0.493
B_{2023}/B_{MSY}	0.532	0.256	1.122	0.631	0.277	1.233
F_{2023}/F_{MSY}	0.235	0.106	0.453	0.205	0.087	0.442
	Group 1 + CTP LL2			**Group 2**		
Estimates	***Median***	***2.5%***	***97.5%***	***Median***	***2.5%***	***97.5%***
K	22606.233	16878.707	35750.809	23673.559	16648.930	35236.364
r	0.187	0.140	0.253	0.207	0.156	0.282
σ_{proc}	0.197	0.158	0.213	0.188	0.123	0.211
F_{MSY}	0.158	0.118	0.213	0.174	0.131	0.237
B_{MSY}	9042.081	6751.175	14299.672	9468.992	6659.268	14093.904
MSY	1464.167	1110.398	1986.605	1654.081	1250.367	2389.028
B_{1956}/K	0.901	0.618	1.257	0.920	0.644	1.249
B_{2023}/K	0.189	0.083	0.447	0.582	0.269	1.049
B_{2023}/B_{MSY}	0.473	0.207	1.119	1.456	0.673	2.623
F_{2023}/F_{MSY}	0.275	0.108	0.579	0.078	0.036	0.176

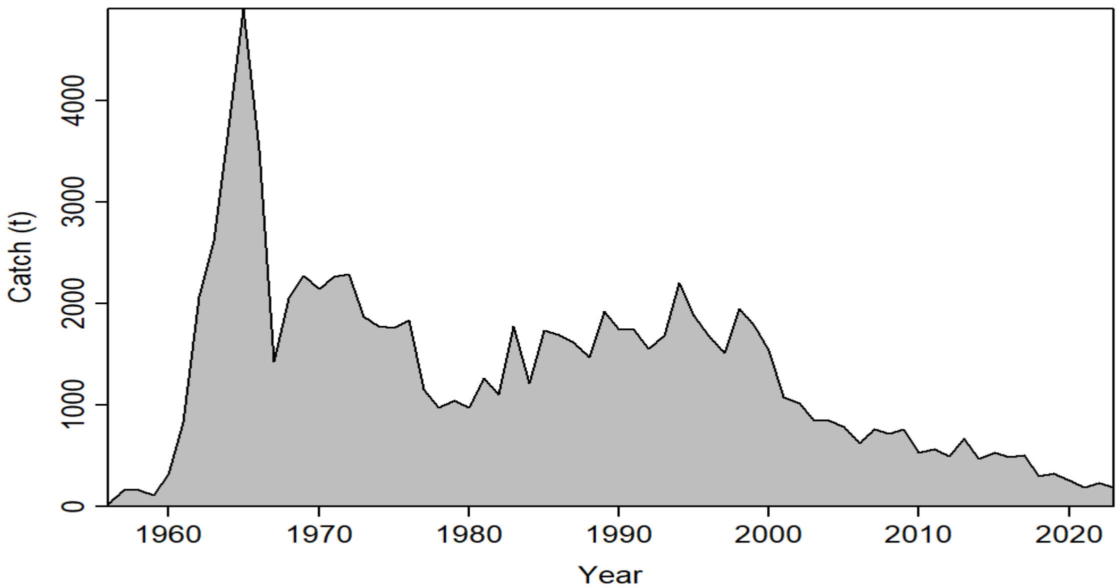

Figure 1. Available catch times series in metric tons (t) for Atlantic white marlin for the period 1956 - 2023.

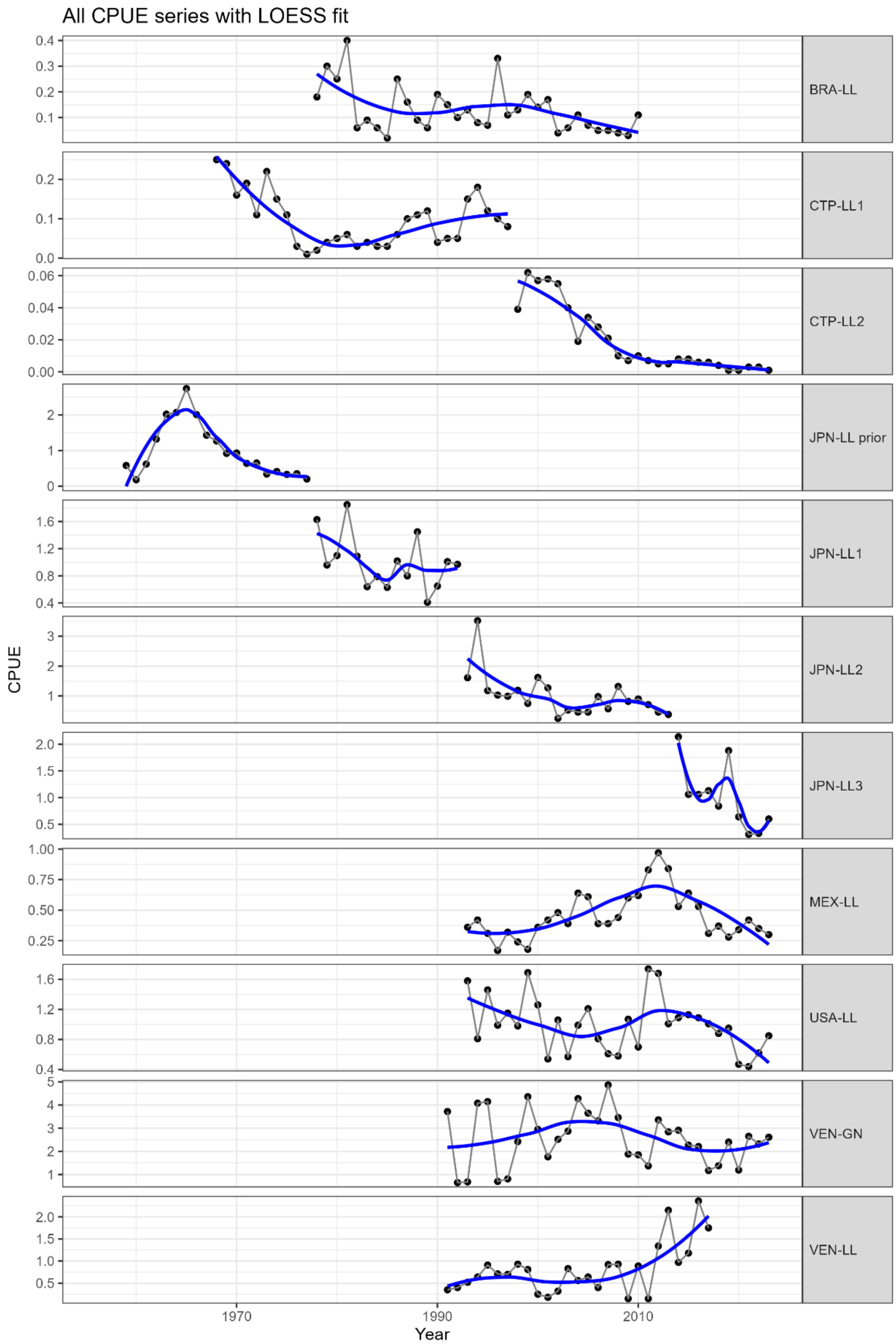

Figure 2. Available standardized CPUE series for Atlantic white marlin assessment. Points are the observed value; Blue lines represents the results of smoothing regression analysis.

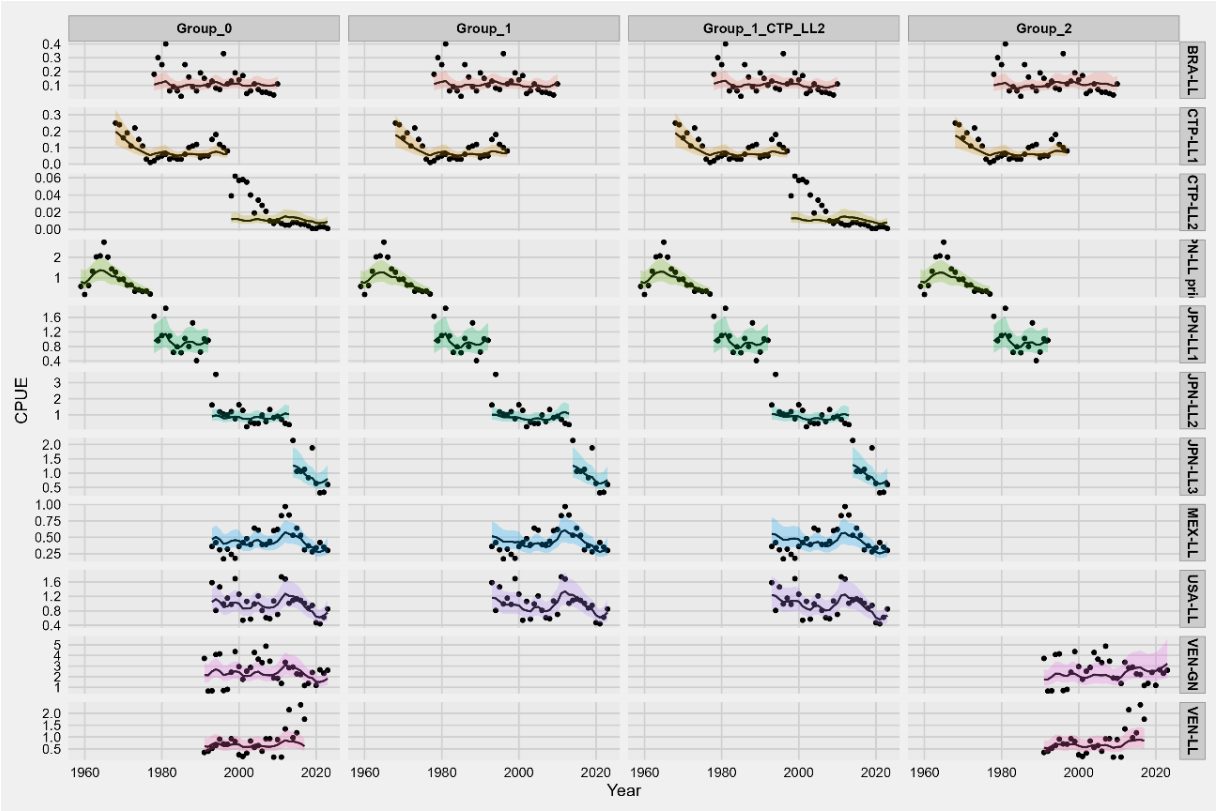

Figure 3. Time-series of observed (circle) and predicted (solid line) CPUE of Atlantic white marlin for all JABBA model scenarios. The shaded areas show 95% credibility intervals of the expected mean CPUE.

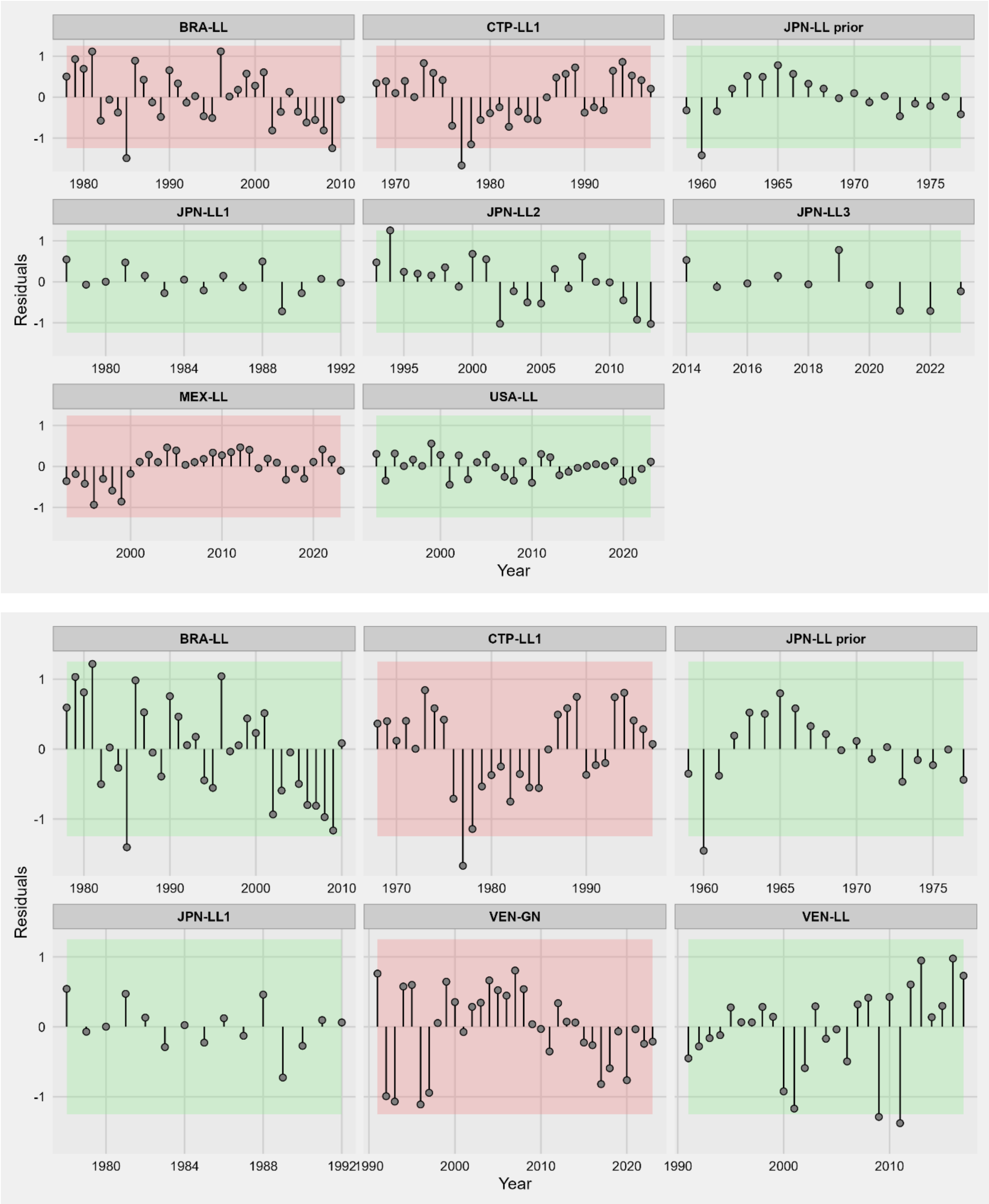

Figure 4. Runs tests to evaluate the randomness of the time series of CPUE residuals for JABBA model scenarios Group 1 (upper panel) and Group 2 (bottom panel). Green panels indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels indicate possible autocorrelation. The inner shaded area shows three standard errors from the overall mean.

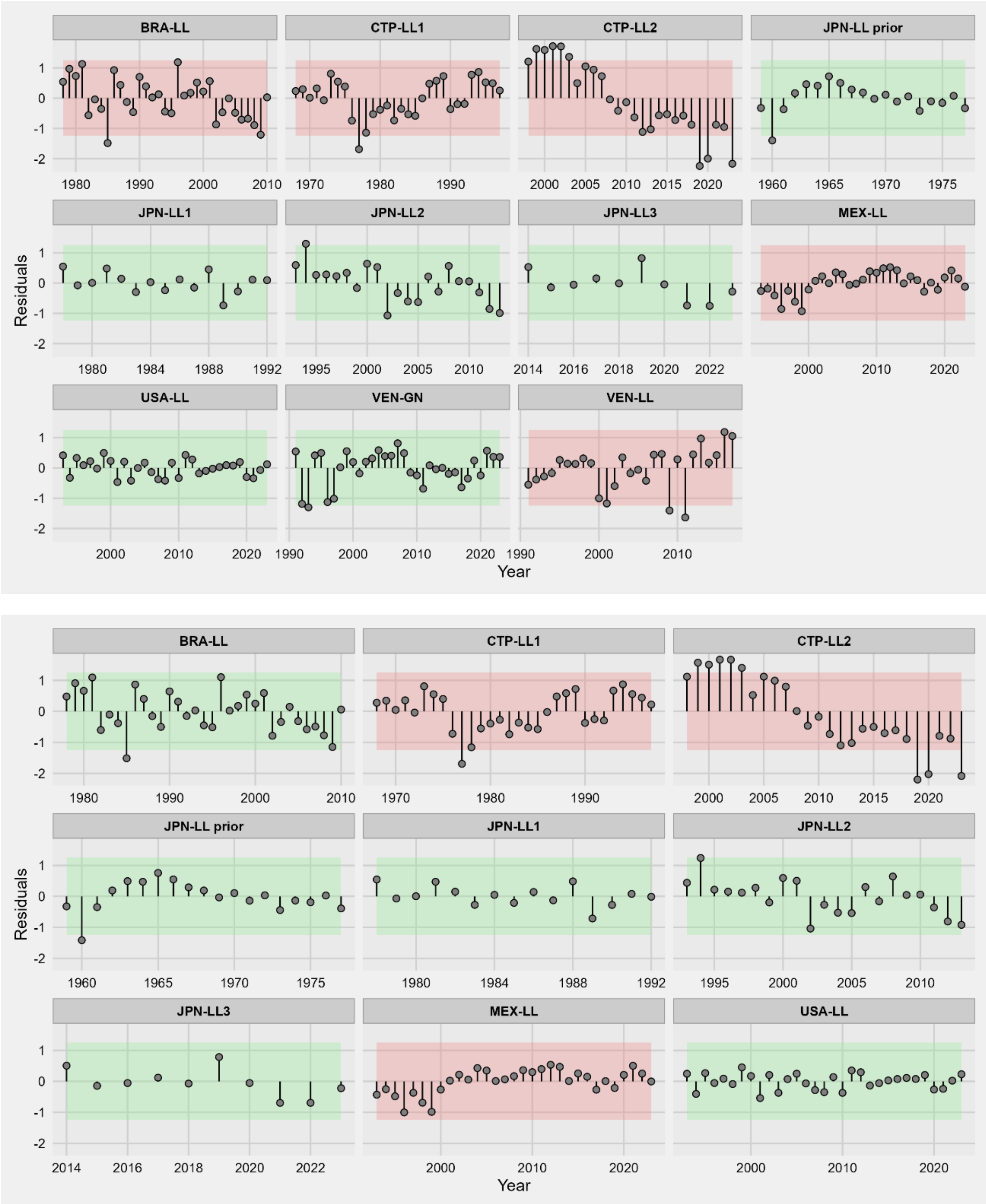

Figure 5. Runs tests to evaluate the randomness of the time series of CPUE residuals for JABBA model scenarios Group 0 (upper panel) and Group 1 + CTP LL2 (bottom panel). Green panels indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels indicate possible autocorrelation. The inner shaded area shows three standard errors from the overall mean.

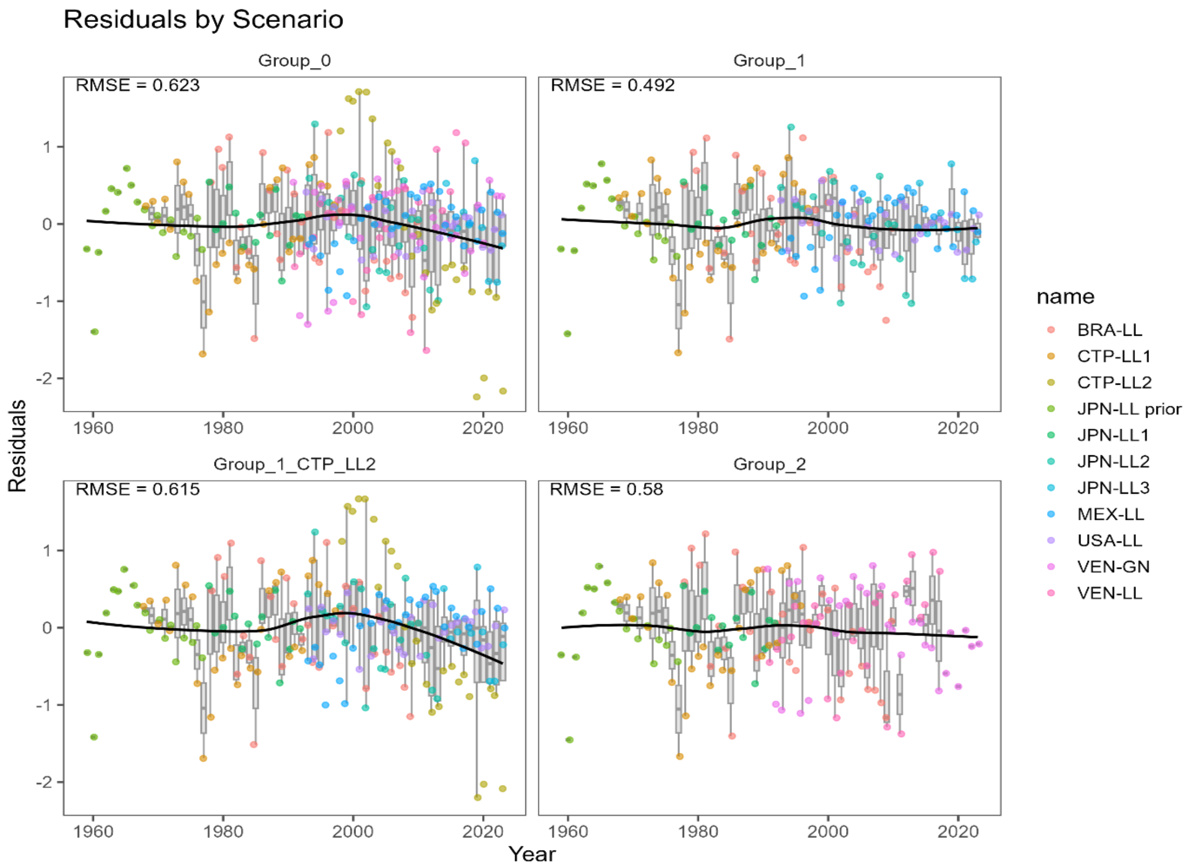

Figure 6. Residual diagnostic plots of CPUE indices for the Atlantic white marlin JABBA model scenarios. Boxplots indicate the median and quantiles of all residuals available for any given year, and solid black lines indicate a loess smoother through all residuals.

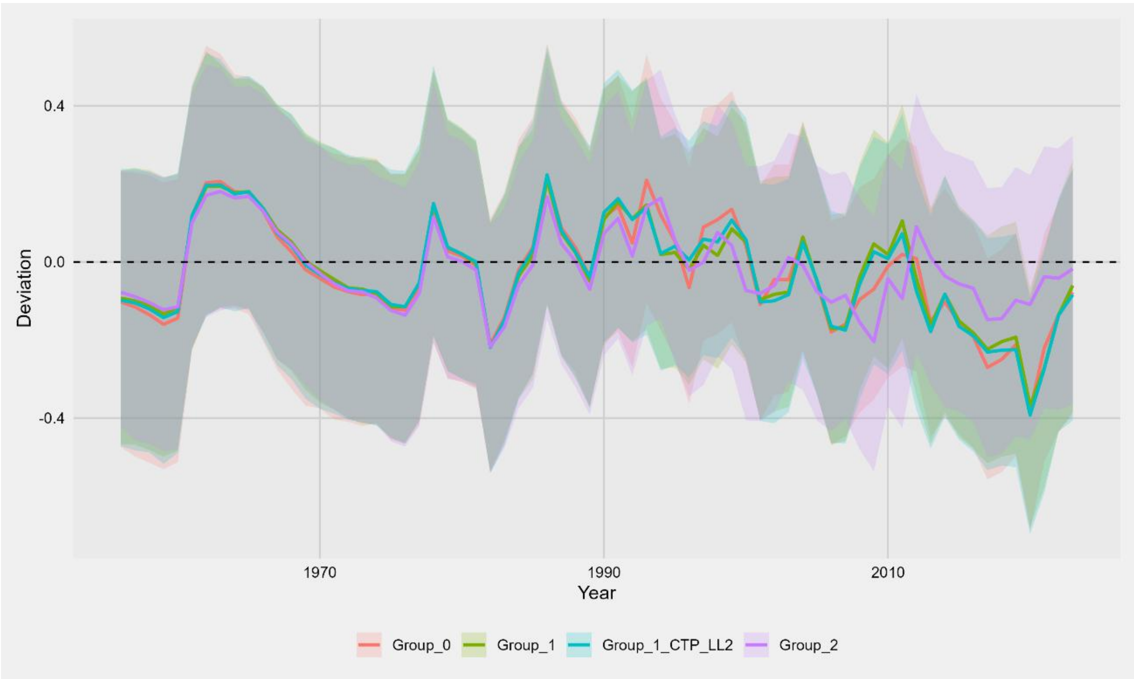

Figure 7. Process error deviates (median: solid line) for the Atlantic white marlin JABBA model scenarios. Shaded grey area indicates 95% credibility intervals.

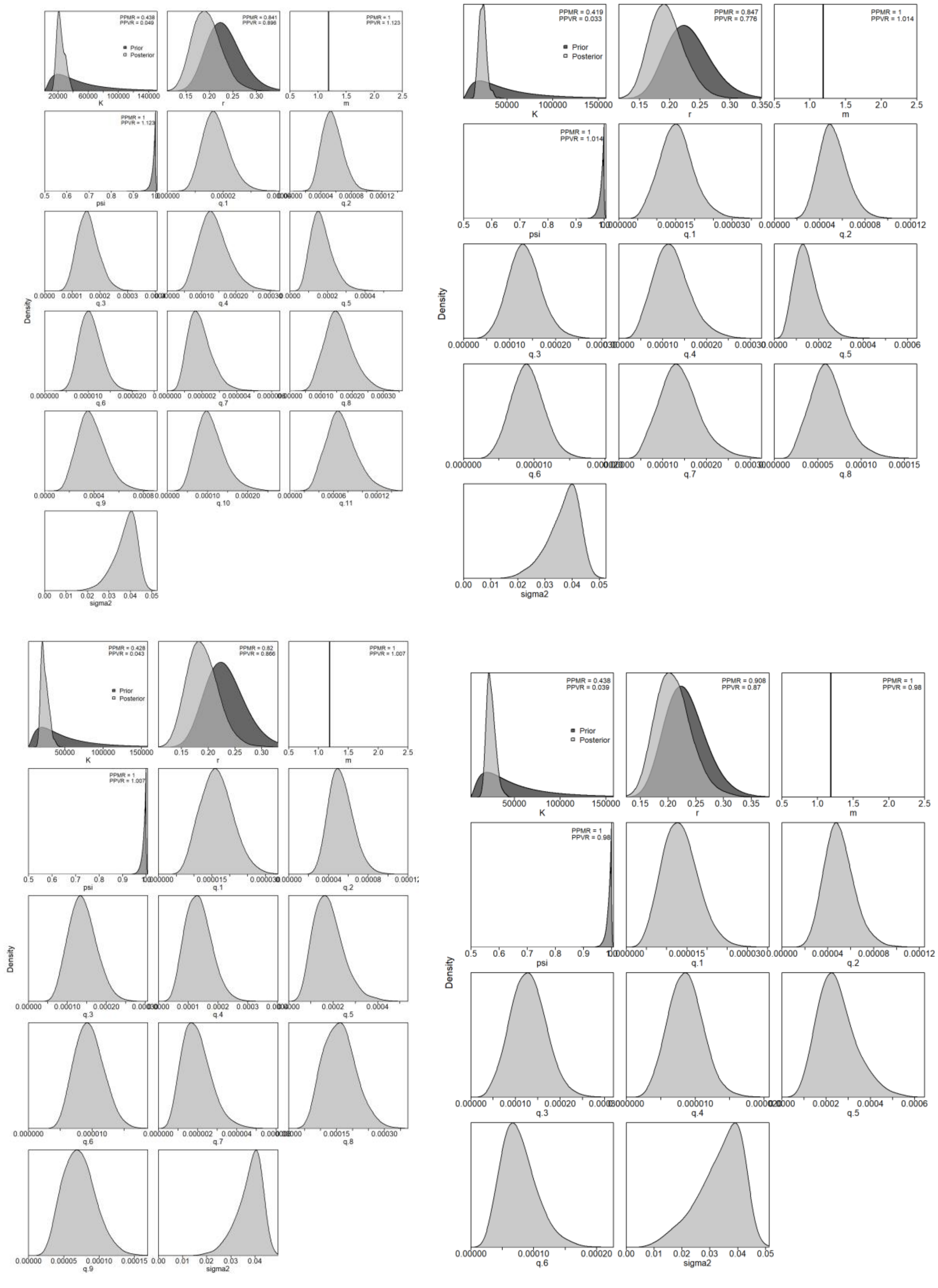

Figure 8. Prior and posterior distributions of various model and management parameters for the JABBA model scenarios for Atlantic white marlin models; Group 0 (upper left panel); Group 1 (upper right panel); Group 1 + CTP LL2 (bottom left panel) and Group 2 (bottom right panels). PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variance.

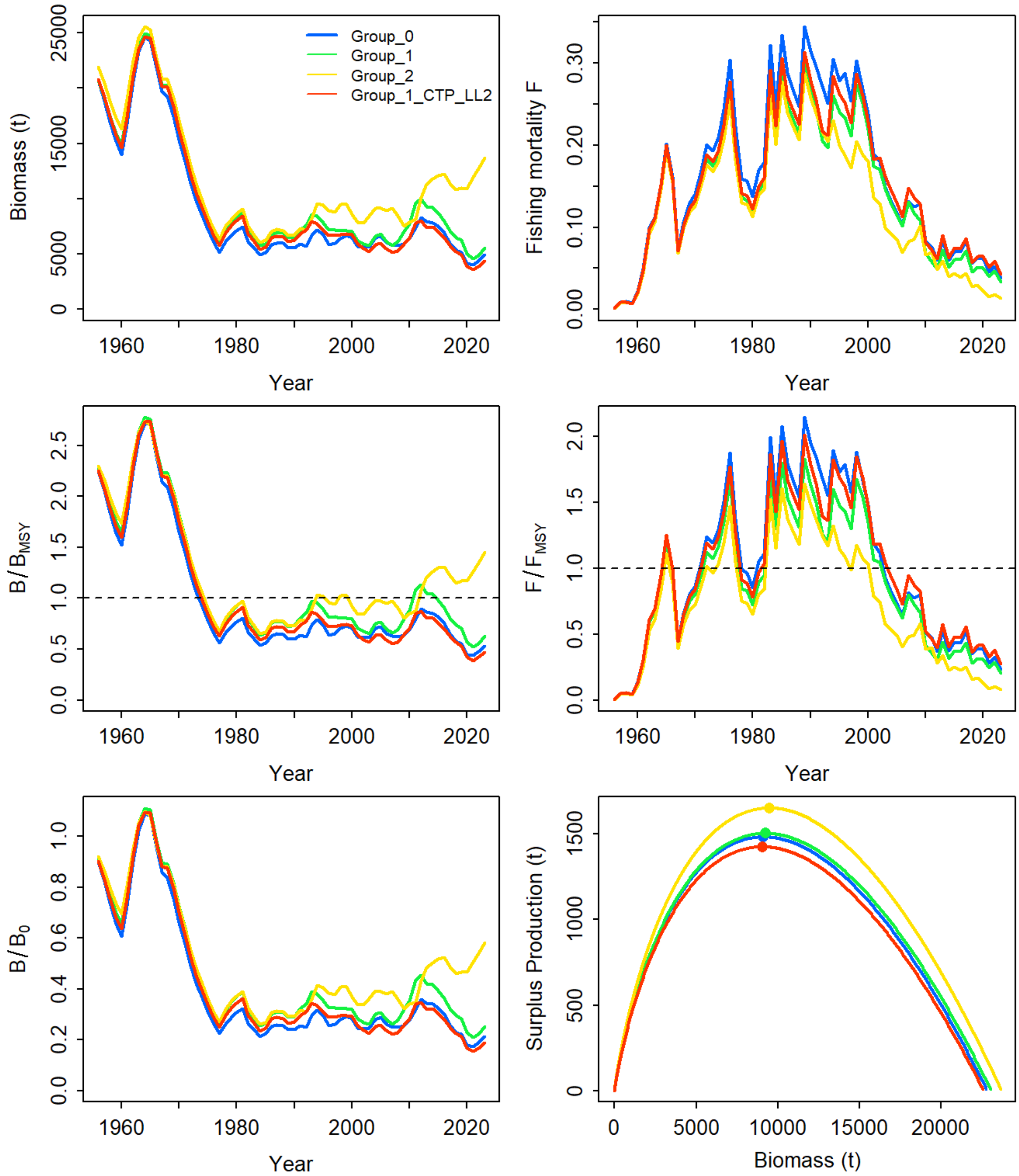

Figure 9. Comparison of biomass, fishing mortality (upper panels), biomass relative to *K* (*B/K*) and surplus production curve (middle panels), and biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (bottom panels) among JABBA scenarios for Atlantic white marlin.

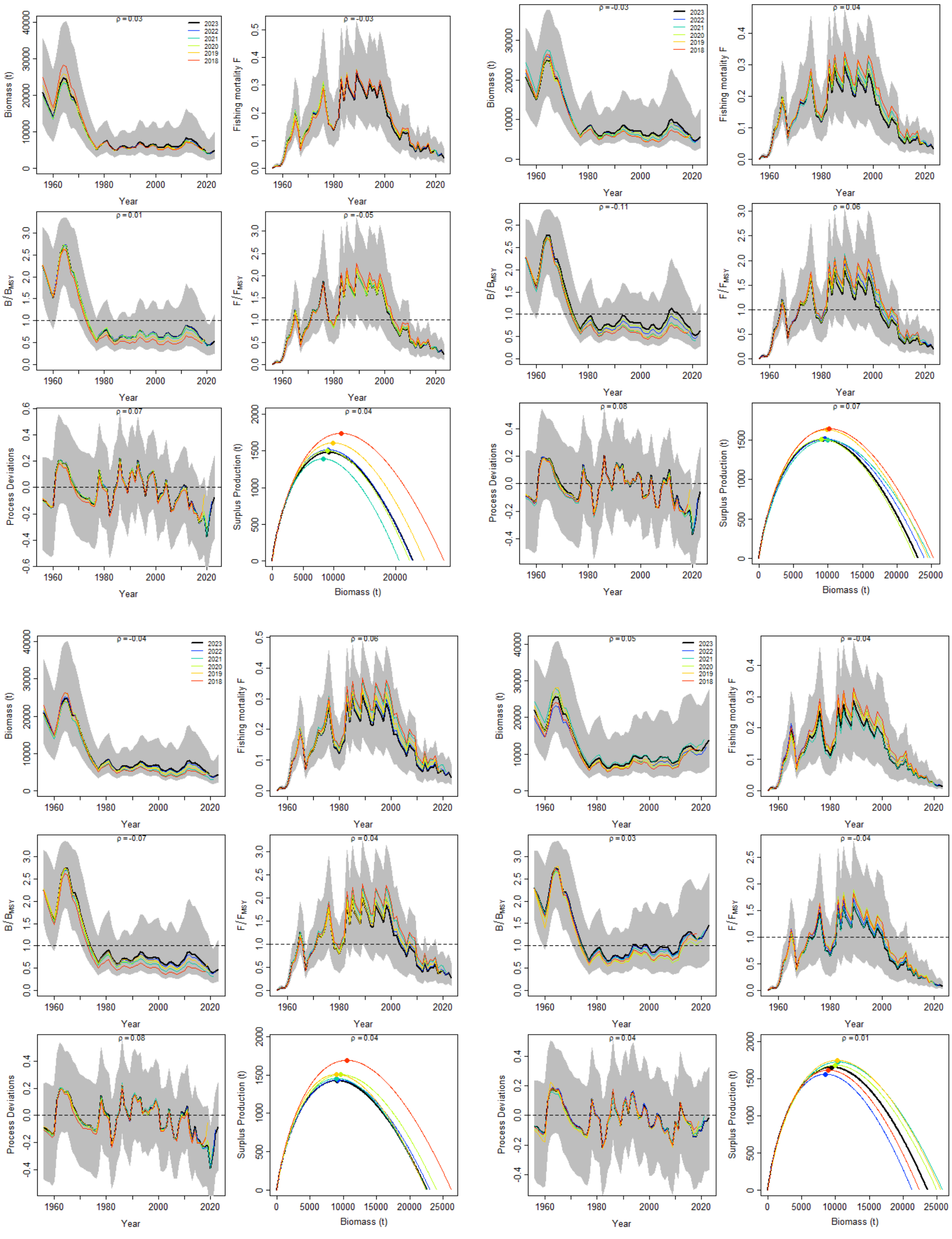

Figure 10. Retrospective analysis performed to the JABBA models: Group 0 (upper left panel); Group 1 (upper right panel); Group 1 + CTP LL2 (bottom left panel) and Group 2 (bottom right panels), for the Atlantic white marlin assessment, by removing one year at a time sequentially (n=5) and predicting 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).

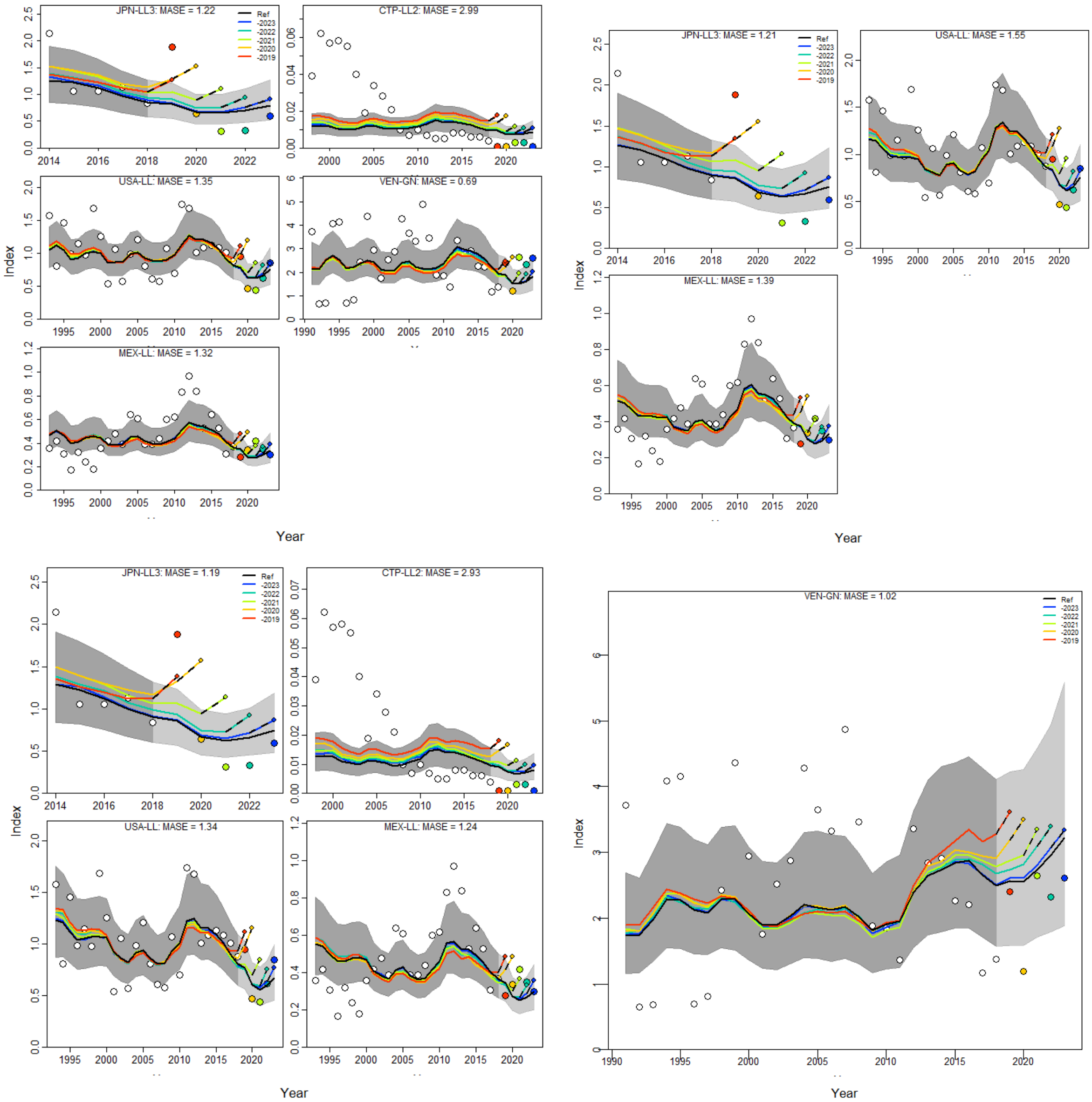

Figure 11. Hindcasting cross-validation results for the JABBA models for the Atlantic white, showing one-year-ahead forecasts of CPUE values (2019-2023), performed with five hindcast model runs relative to the expected CPUE. The CPUE observations, used for cross-validation, are highlighted as color-coded 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). Panels: Group 0 (upper left panel); Group 1 (upper right panel); Group 1 + CTP LL2 (bottom left panel) and Group 2 (bottom right panels).

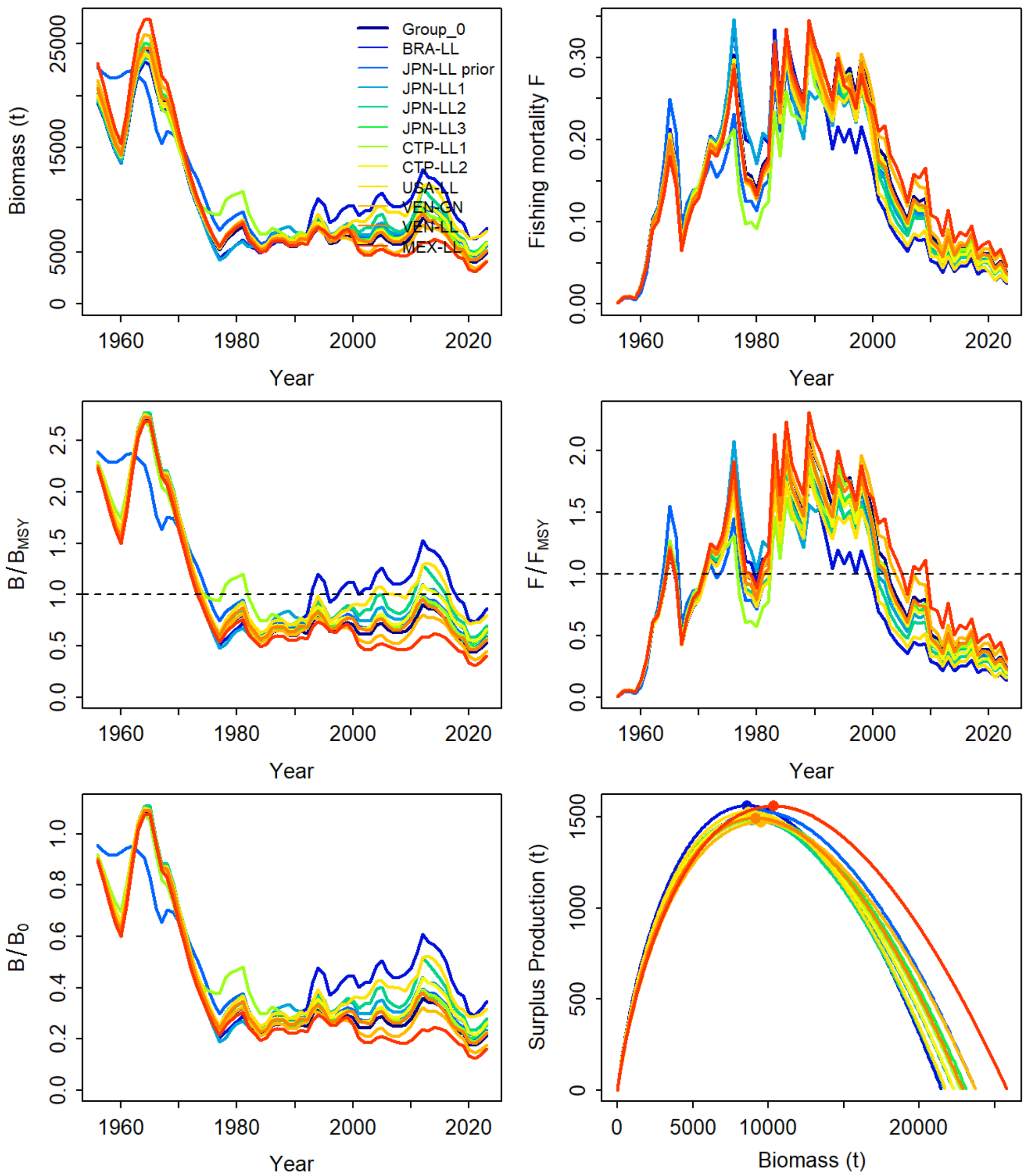

Figure 12. Jackknife index analysis performed to the S1 JABBA model of the Atlantic white marlin assessment, by removing one CPUE fleet at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels)

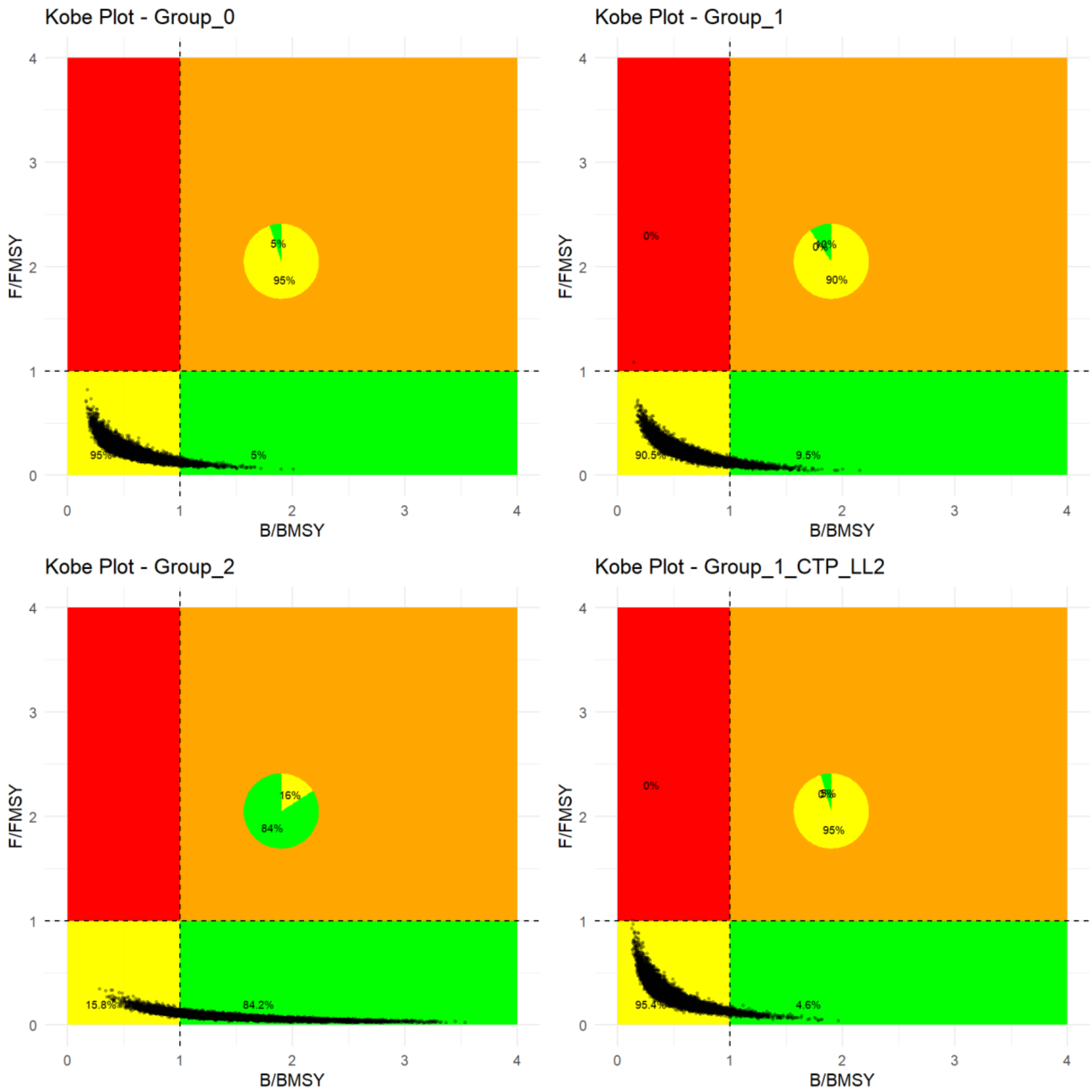

Figure 13. Kobe phase plot showing of B/B_{MSY} and F/F_{MSY} for the Atlantic white marlin assessment. Black points represents the joint posteriors of the terminal assessment year. The probability of terminal year points falling within each quadrant is indicated in the figure legend.