Collect. Vol. Sci. Pap. ICCAT, 81(3), SCRS/2024/076: 1-57 (2024)

PRELIMINARY 2024 STOCK ASSESSMENT OF MEDITERRANEAN ALBACORE (*THUNNUS ALALUNGA*) USING THE BAYESIAN STATE-SPACE SURPLUS PRODUCTION MODEL *JABBA*

C. Pinto[1], A. Kimoto[2] and H. Winker[3]

SUMMARY

*The 2023 SCRS planned to conduct a simple update of stock assessment of the Mediterranean albacore (*Thunnus alalunga*) stock in 2024. This document provides the updated model of the 2021 JABBA assessment with the 2024 Task 1 catch data in April and updated indices provided to the modeling group at least one week before the meeting. Among the indices used in the 2021 assessment, Spanish longline CPUE, and fisheries-independent Western Mediterranean larval density index were updated. We evaluated model plausibility using four objective model diagnostics: (1) model convergence, (2) fits to the data, (3) consistency (e.g. retrospective patterns) and (4) prediction skill. Results suggest that a simple update model (S1) improved diagnostics slightly from the 2021 model with the updated catch in 2024. This document also examined additional scenario that incorporated the updated Greek longline CPUE. Jackknife analyses revealed that removing W-Med larval index had strong effects on the stock status estimates. The additional model runs done during the meeting were attached in the Appendix.*

RÉSUMÉ

*En 2023, le SCRS avait prévu de réaliser une simple mise à jour de l'évaluation du stock de germon de la Méditerranée (*Thunnus alalunga*) en 2024. Ce document fournit le modèle actualisé de l'évaluation JABBA de 2021 avec les données de capture de la tâche 1 de 2024 du mois d'avril et les indices actualisés fournis au groupe de modélisation au moins une semaine avant la réunion. Parmi les indices utilisés dans l'évaluation de 2021, la CPUE de la palangre espagnole et l'indice de densité larvaire de la Méditerranée occidentale indépendant des pêcheries ont été mis à jour. Nous avons évalué la plausibilité des modèles en utilisant quatre diagnostics de modèle objectifs : (1) la convergence des modèles, (2) les ajustements aux données, (3) la cohérence (p.ex. les schémas rétrospectifs) et (4) la capacité de prédiction. Les résultats suggèrent qu'un modèle d'actualisation simple (S1) a légèrement amélioré les diagnostics par rapport au modèle de 2021 avec la prise actualisée en 2024. Ce document a également examiné un scénario supplémentaire qui incorporait la CPUE palangrière grecque actualisée. Les analyses de type* jacknife *ont fait apparaître que la suppression de l'indice larvaire de la Méditerranée occidentale avait des effets importants sur les estimations de l'état du stock. Les scénarios de modèles supplémentaires exécutés au cours de la réunion sont joints en appendice.*

RESUMEN

*En 2023 el SCRS programó una actualización simple de la evaluación del stock de atún blanco del Mediterráneo (*Thunnus alalunga*) en 2024. Este documento proporciona el modelo actualizado de la evaluación JABBA de 2021 con los datos de capturas de la Tarea 1 de 2024 en abril y los índices actualizados proporcionados al grupo de modelación al menos una semana antes de la reunión. Entre los índices utilizados en la evaluación de 2021, se actualizaron la CPUE del palangre español y el índice de densidad larvaria del Mediterráneo occidental independiente de la pesca. La plausibilidad de estos modelos se evaluó mediante cuatro diagnósticos objetivos del modelo: (1) la convergencia del modelo, (2) el ajuste a los datos, (3) la coherencia (por ejemplo patrones retrospectivos) y (4) la capacidad de predicción. Los resultados sugieren que un modelo de actualización simple (S1) mejoró ligeramente los diagnósticos del modelo de 2021 con la captura actualizada en 2024. Este documento también*

[1] DISTAV, University of Genova, Genova, Italy

[2] ICCAT Secretariat. Calle Corazón de Maria 8, Madrid, Spain 28002.

[3]The Secretariat of General Fisheries Commission of the Mediterranean Sea (GFCM-FAO), Italy. Email: hennning.winker@fao.org

examinó un escenario adicional que incorporaba la CPUE palangrera griega actualizada. Los análisis jackknife revelaron que la eliminación del índice larvario del Mediterráneo occidental tenía fuertes efectos sobre las estimaciones del estado del stock. Las ensyos adicionales del modelo realizadas durante la reunión se adjuntan en el Apéndice.

KEYWORDS

Mediterranean Albacore, JABBA, stock status,
biomass dynamic model, Model diagnostics, hindcasting

1. Introduction

The SCRS planned the Mediterranean albacore (ALB-Med) stock assessment 2024. Based on the workplan, the authors have updated the 2021 JABBA model with the available updated indices requested by the ALB-Med Group Chair.

The 2021 JABBA model was fitted to a relatively short CPUE index that started in 2001 and which was derived by applying a state-space approach (Winker et al. 2018) to obtain an average estimate of the four recent relative abundance indices and four historical abundance indices. A fixed observation error approach for the abundance indices was considered by assuming a standard error for log(CPUE) of 0.25 or 0.35. For the recent time series, (i) standardized Spanish longline CPUE (SPN LLALB), (ii) standardized Italian longline CPUE (ITA LL), and (iii) the fisheries-independent Western Mediterranean larval density index with a standard error (SD) for log(CPUE) of 0.25, and (iv) standardized Spanish tournament (SPN Tournament) with SD=0.35. The larval survey based on ichthyoplankton surveys around the Balearic Islands (W-Med Larval-Index) was considered as a proxy for spawning stock biomass. For the historical time series, (i) standardized Italian Ionian longline CPUE (ITA-Ionian LL), (ii) standardized Italian Ligurian longline CPUE (ITA-Ligurian LL bycatch), (iii) standardized Mediterranean South Italian longline CPUE (Med South ITALL), (iv) and nominal South Adriatic Italian longline CPUE with SD=0.35.

For the 2021 final JABBA model, following the 2017 final JABBA setting (Anon., 2017), a Fox production function ($B_{MSY}/K = 0.37$), a lognormal prior distribution for r with a mean of log(0.153), and a standard deviation for log(r) of 0.457, and a beta prior for the initial relative biomass ($\varphi = B_{1980}/K$) with a mean = 0.85 and a CV of 10% were assumed.

Before the ALB-Med Data Preparatory and Assessment meeting, the meeting Chair requested updates until 2022 on the standardized CPUEs used in the 2021 stock assessment. Spanish longline CPUE and the fisheries-independent Western Mediterranean larval density index have been provided at least one week before the meeting. The Spanish Tournament index and Italian longline CPUE were not updated because the data were not available. The updated Greek longline CPUE (GRC LLALB) was provided for the period between 2005 and 2022. This index was not used in the 2021 assessment because the index stopped in 2006 at that time.

In this paper, we present a simple update of the 2021 stock assessment for Mediterranean albacore stock based on the Bayesian State-Space Surplus Production Model software, JABBA (Winker 2018a). This document also explored an additional scenario introducing the updated Greek longline index.

2. Material and Methods

Materials

Task 1 Catch data for Mediterranean albacore were made available by ICCAT Secretariat for the period 1980-2022 (**Figure 1**) as of 22 April 2024. The available abundance indices were summarized in **Tables 1 - 2** and **Figures 2 - 3**. Several indices up to 2022 have been updated; Spanish longline CPUE, the fisheries-independent Western Mediterranean larval density index, and Greek longline CPUE.

Methods

This preliminary stock assessment is implemented using the Bayesian state-space surplus production model framework JABBA (Winker et al., 2018a). JABBA is implemented in R (R Development Core Team, https://www.r-project.org/) with JAGS interface (Plummer, 2003) to estimate the Bayesian posterior distributions of all quantities of interest by means of a Markov Chains Monte Carlo (MCMC) simulation. JABBA's inbuilt options include: automatic fitting of multiple CPUE time series and associated standard errors; estimating or fixing the process variance, optional estimation of additional observation variance for individual or grouped CPUE time series, and specifying a Fox, Schaefer or Pella-Tomlinson production function by setting the inflection point B_{MSY}/K and converting this ratio into the shape parameter m. JABBA also provides a comprehensive toolbox to conduct model diagnostics to objectively evaluate model results with plausible criteria recommended in Carvalho et al. 2021: (1) model convergence (2) fit to the data, (3) model consistency (retrospective pattern) and (4) prediction skill through hindcast cross-validation (Kell et al. 2017; 2021). A full JABBA model description, including formulation and state-space implementation, prior specification options and diagnostic tools is available in Winker et al (2018a). JABBA has evolved into a fully documented, open-source R package (https://github.com/JABBAmodel/JABBA), which has been included in the ICCAT stock catalogue (https://github.com/ICCAT/software/wiki/2.8-JABBA). JABBA has subsequently been applied in many recent ICCAT stock assessments.

Model Specifications

This document has worked on the following three scenarios.

Scenarios	*Descriptions for CPUE indices (with SD) in JABBA runs*
S4_2021	2021 final JABBA model CPUEs: SPN LLALB (SD=0.25), Larval W-Med (0.25), ITA LL (0.25), SPN Tournament (0.35), ITA-Ionian LL (0.35), ITA-Ligurian LL bycatch (0.35), Med South ITALL (0.35), South Adriatic ITALL (0.35)
S0	2011 final run (S4_2021) (i.e. maintain the 2021 CPUEs) + update 2024 catch data
S1	S0 + SPN LLALB (0.25) and Larval W-Med (0.25)
S3	S1 + GRC LLALB (0.25)

Before updating the available indices in 2024, Scenario 0 (S0) was considered by updating only catch information on the 2021 final model (S4_2021). After confirming that the model (S0) is consistent with the 2021 assessment, Scenario 1 (S1) was examined as a simple update of the 2021 assessment by incorporating the updated Spanish longline CPUE and the fisheries-independent Western Mediterranean larval density index, while all the other indices in the 2021 assessment were maintained. Finally, Scenario 3 (S3) was explored by adding the Greek longline index with the other updated indices. It should be noted that a set of indices for the assessment, especially the Greek longline index, needs to be discussed during the meeting.

For the unfished equilibrium biomass K, we used the default settings of the JABBA R package in the form of vaguely informative lognormal prior with a large CV of 100% and a central value that corresponds to eight times the maximum total catch and is consistent with other platforms, such as Catch-MSY (Martell and Froese, 2013) or the initial value for K in SpiCt (Pederson and Berg 2017). We assumed a Fox production function (B_{MSY}/K = 0.37), a lognormal prior distribution for r with mean of log(0.153) and a standard deviation for log(r) of 0.457 and initial beta prior for the relative biomass ($\varphi = B_{1980}/K$) with mean = 0.85 and CV of 10%, which is consistent with the 2021 and 2017 base-case models (Anon., 2021 and 2017). All catchability parameters were formulated as uninformative uniform priors, while 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. The models were run with three Monte-Carlo Markov Chains (MCMCs), each comprising 30,000 iterations sampled with a burn-in period of 5,000 for each chain and a thinning rate of five iterations. Accordingly, the marginal posteriors were represented by a total of 15,000 iterations for each model.

Model diagnostics

The evaluation model diagnostics follows the principles in Carvalho et al. (2021), who recommended to objectively evaluate the base-case candidate model based on the following four model plausible criteria: (1) model convergence (2) fit to the data, (3) model consistency (retrospective pattern) and (4) prediction skill through hindcast cross-validation (Kell et al. 2017; 2021).

Basic diagnostics of model convergence included visualization of the MCMC chains using MCMC trace-plots as well as Heidelberger and Welch (Heidelberger and Welch, 1992) and Geweke (1992) and Gelman and Rubin (1992) diagnostics as implemented in the coda package (Plummer et al., 2006).

To evaluate the JABBA fit to the abundance index data, the model predicted values were compared to the observed indices. JABBA-residual plots were used to examine (1) colour-coded lognormal residuals of observed versus predicted CPUE indices by fleet together with (2) boxplots indicating the median and quantiles of all residuals available for any given year; the area of each box indicates the strength of the discrepancy between CPUE series (larger box means higher degree of conflicting information) and (3) a loess smoother through all residuals which highlights systematically auto-correlated residual patterns to evaluate the randomness of model residuals. In addition, it depicts the root-mean-squared-error (RMSE) as a goodness-of-fit statistic. We conducted run tests to quantitatively evaluate the randomness of residuals (Carvalho et al., 2017). The runs test diagnostic was applied to residuals of the CPUE fit on log-scale using the function runs.test in the R package series, considering the 1-sided p-value of the Wald-Wolfowitz runs test (Carvalho et al. 2021). The runs test results can be visualized within JABBA using a specifically designed plot function that illustrates which time series passed or failed the runs test and highlights individual time-series data points that fall outside the three-sigma limits (e.g. Anhøj and Olesen, 2014).

To check for model consistency with respect to the stock status estimates, we also performed a retrospective analysis by removing one year of data at a time sequentially (n = 5), refitting the model and comparing quantities of interest (i.e. biomass (B), fishing mortality (F), B/B_{MSY}, F/F_{MSY}, B/B_0 and MSY) to the reference model that is fitted to full time series. To compare the bias between the models, we computed Mohn's (Mohn, 1999) rho (ρ) statistic and specifically the commonly used formulation Hurtado-Ferro et al. (2015).

Although the above model diagnostics are important to evaluate model convergence, the fit to the data and retrospective consistency, providing scientific advice should also involve checking that the model has prediction skill of future states under alternative management scenarios (Carvalho et al. 2021). To validate a model's prediction skill requires that the system be observable and measurable (Kell et al. 2021). Therefore, we applied a hindcasting cross-validation (HCXval) technique (Kell et al. 2016), where observations are compared to their predicted future values. HCxval is a form of cross-validation where, like retrospective analysis, recent data are removed, and the model refitted with the remaining data, but HCXval involves the additional steps of projecting ahead over the missing years and then cross-validating these forecasts against observations to assess the model's prediction skill. A robust statistic for evaluating prediction skill is the Mean Absolute Scaled Error (MASE), which scales the mean absolute error of prediction residuals to a naïve baseline prediction, where a 'prediction' is said to have 'skill' if it improves the model forecast when compared to the naïve baseline (Kell et al. 2021). A widely used baseline forecast for time series is the 'persistence algorithm' that takes the value at the previous time step to predict the expected outcome at the next time step as a naïve in-sample prediction, e.g., tomorrow's weather will be the same as today's. The MASE score scales the mean absolute error of the prediction residuals to the mean absolute error of a naïve in-sample prediction. A MASE score higher than one can then be interpreted such that the average model forecasts are no better than a random walk. Conversely, a MASE score of 0.5 indicates that the model forecasts twice as accurately as a naïve baseline prediction; thus, the model has prediction skill.

3. Results and Discussion

The revised Task 1 catch data in 2024 showed some updates since 2021 on the catch since 2015 with some (0-400 t) increase (**Figure 1**). The updated three indices have been provided to the modeling team at least one week before the meeting (**Figure 2**). The updated SPN LLALB CPUE and W-Med Larval-Index show some different values but generally similar trends from the ones in 2021. The GRC LLALB CPUE is now a longer time series between 2005 and 2022 with a gap between 2007 and 2011, and it shows a decreasing trend after 2014. Overall the available indices in **Figure 3** are many short historical indices and a few continuous indices. In the last 10 years, SPN LLALB CPUE, W-Med Larval-Index, and ITA LL CPUE show a general increasing trend while the other two indices show an opposite trend.

In the JABBA analysis, for all scenarios in this document (S0, S1, and S3) the MCMC convergence tests by Heidelberger and Welch (Heidelberger and Welch, 1992) and Geweke (1992) and Gelman and Rubin (1992) were passed by all estimable key parameters. Adequate convergence of the MCMC chains was also corroborated by visual inspection of trace plots (results available on request), which showed good mixing in general (i.e., moving around the parameter space).

As a start of our assessment exercises, we examined scenario S0 by incorporating the updated catch in 2024 into the 2021 assessment (**Figures 4 - 7**). We confirmed that Scenario S0 produced similar assessment results to the 2021 final model (Anon., 2021). The model fits to each relative abundance index and runstest results are shown in **Figures 4** and **5**, respectively. Both models appeared to fit the abundance trends reasonably well, and run tests conducted on the log-residuals provided no evidence to reject the hypothesis of randomly distributed residual patterns. However, the overall goodness-of-fit indicated a fairly low precision of the fits (RMSE = 50%) in **Figure 5**. The overall biomass and fishing mortality trends and surplus production curve are almost identical to the 2021 stock assessment (**Figure 7**).

Scenario S1 incorporated the updated indices in 2024 into S0 provided at least one week before the meeting, and this model is a simple update of the 2021 stock assessment as the SCRS planned. From S0, SPN LLALB CPUE and W-Med Larval-Index were updated up to 2022 in S1. All indices in S1 passed the runstest and their fits were similar to or slightly better than S0 (**Figure 8**). The estimated process error deviations had a similar trend for both S0 and S1, showing particularly strong variations in most recent years. The process deviations for the terminal year are close to zero and therefore to average expectation (**Figure 8**).

The overall goodness-of-fit (RMSE = 46.3%) has improved by the updated indices from S0 (**Figure 9**). The absolute biomass estimates for K and B_{MSY} were lower for S1 than for S0 (**Table 2**), which was also associated with an improved, smaller posterior to prior ratio of variance for K (PPRV = 0.074) for S1 compared to S0 (PPRV = 0.089) as shown in **Figures 6** and **10.** This indicates that the updated indices may hold information about the total biomass to effectively update the posterior of K given the relatively vague prior. The medians of marginal posteriors for r were estimated to be larger for S1 at 0.204 than for S0 at 0.188 (0.186 in the 2021 assessment) (**Table 2**). Estimates of the median MSY were very similar between both scenarios at around 3750 t (**Table 2**). **Figure 11** shows the ALB-Med assessment results for scenario S1; a simple update of the 2021 stock assessment. **Figure 12** shows the comparisons of the assessment results between S0 and S1.

The retrospective analysis applied over a horizon of five years to S1 (**Figure 13**) revealed consistent estimates without strong retrospective patterns and the Mohn's values (**Table 4**) for all evaluated quantities (B, F, B/B_{MSY}, B/K, and MSY) fell inside the acceptable thresholds of -0.15 and 0.2 for longer lived species (Huerto-Ferro et al., 2015).

The Jackknife index analysis, applied to S1 by removing one index at a time, showed that removing the W-Med Larval-Index had the most influential effect on the stock status trajectories and surplus production curve (**Figure 14**). The second most influential effect was the removal of the ITA-LL hist, resulting in an opposite trend between the mid-1980s and the late 1990s. Removing the rest of the time series did not affect the trajectories and the estimates for recent years (**Figure 14**).

The Greek longline CPUE (GRC LLALB) was provided to the modeling team well before the meeting. This index was not used in the 2021 stock assessment, because the index ended in 2006. For this meeting, GRC LLALB was recalculated for 2005 - 2022 with a gap between 2007 and 2011. This document provides an additional scenario (S3) by including this index in S1 with the other updated indices in 2024. Generally, the results of S3 were similar to S1 (**Figures 15-21**). However, including GRC LLALB did not let this index pass the runstest (**Figure 15**), due to their contrasting trends (**Figure 8**). The overall goodness-of-fit (RMSE = 47.6%) for S3 was not improved from S1 but PPRV for K (PPRV = 0.066) was improved (**Figures 16** and **17**).

Figure 18 shows the ALB-Med assessment results for scenario S3, and **Figure 19** compares the assessment results between S1 and S3. The surplus production curve for S3 became thinner than S1 with a smaller *K* (**Figure 19**) and this estimate slightly affected the absolute values of historical biomass while the trends were similar between S1 and S3. Similar to the results for S1, no strong retrospective patterns were observed (**Figure 20**), and the Jackknife index analysis showed a stronger influence for S3 than S1 by removing W-Med Larval-Index (**Figure 21**).

Although some attempts were made to hindcasting cross-validation analysis, MASE scores were not estimable because most indices were not continuous for all scenarios considered in this document.

In this document, a simple update model (S1) showed slightly better model diagnostics compared to the model with the Greek longline index (S3). The evaluated quantities of biomass (*B*), fishing mortality (*F*), B/B_{MSY}, F/F_{MSY}, B/B_{0}, and MSY in S1 were close to the ones in the 2021 stock assessment (**Figure 22**) with slightly smaller *K* and *r* (**Table 3**). The estimated B/B_{MSY} showed a continuous decreasing trend over the assessment time period since 1980 with a large decrease from the early 2000s to the mid-2010s. The median of B/B_{MSY} was around 2.0 in the 1980s and 1990s, but it has been around 0.4-0.5 since 2013 after the decrease. Since the late 2010s, B/B_{MSY} showed a continuous increasing trend and the median of B/B_{MSY} in 2022 was 0.875 (95% credibility interval: 0.482-1.508). The estimated F/F_{MSY} showed a gradual increase since 1980, and the median of F/F_{MSY} has been over 1.0 after the early 2000s with some large peaks. Since the late 2010s, the estimated F/F_{MSY} has been decreased to 0.712 (95% credibility interval: 0.348-1.329) in 2022.

As highlighted by the jackknife analyses (**Figures 14** and **21**), excluding W-Med Larval-Index would change the perception of the stock to a more optimistic status; the stock has never experienced below B_{MSY}, nor over F_{MSY}. These results were already recognized in the 2021 stock assessment in the scenarios without the W-Med Larval Index. The large decrease in biomass from the early 2000s to the mid-2010s was mainly driven by this index (**Figure 8**). W-Med Larval index has a big gap in 2006 and 2011 but shows a steep decreasing trend between before and after this gap with about a 60% decrease. Although there are other indices in this period, they are relatively short and not continuous which did not contribute to defining the stock status. The authors have doubts about which indices truly reflect the stock status.

The surplus production curve became thinner with a smaller *K* (around 40 thousand) and a larger *r* (around 0.27).

These results might not match with our knowledge of the biology of albacore species when comparing to the North and South Atlantic albacore stocks (*r*=0.115, K=915 thousand by mpb for North Atlantic albacore in 2023, and *r*=0.222, K=336 thousand by JABBA for South Atlantic albacore in 2020).

This document provided a simple update (S1) of the 2021 ALB-Med stock assessment with the available information provided at least one week before the ALB-Med Data Preparatory and Assessment meeting. Additionally, the updated Greek longline index was considered although this index was not used in the 2021 stock assessment. It should be remembered that the Group needs to discuss the treatment of the Greek longline index because it was not used in the 2021 stock assessment. The Group might also need to revisit all indices because some indices used in the 2021 stock assessment were not updated.

Generally, any stock assessment needs good long-term continuous indices that represent the stock dynamics, especially in the surplus production models. For ALB-Med stock, there are many short historical indices and a few continuous indices, additionally available indices show conflicting trends in recent years. Since 2017 no continuous index covers the time series in **Table 2** (except the Greek longline index), making the assessment driven by the catch data. The collaborative joint index, e.g. Atlantic bigeye tuna (Kitakado et al., 2021) and yellowfin tuna (Matsumoto et al., 2024), could be a way to improve this stock assessment in the Mediterranean.

Finally, for the stock assessment work, the authors strongly request the SCRS to hold Data Preparatory and Stock Assessment meetings separately, to let the modeling team work smoothly with all the necessary input data agreed by the Group.

References

Anhøj, J., Olesen, A.V., 2014. Run charts revisited: A simulation study of run chart rules for detection of non-random variation in health care processes. PLoS One 9, 1–13. https://doi.org/10.1371/journal.pone.0113825

Anonymous, 2017. Report of the 2017 ICCAT albacore species group intersessional meeting (including assessment of Mediterranean albacore). Collect. Vol. Sci. Pap. ICCAT 74 (2) 331-378.

Anonymous, 2020. eport of the 2020 ICCAT Atlantic Albacore Stock Assessment Meeting (Online, 29 June - 8 July 2020). Collect. Vol. Sci. Pap. ICCAT 77 (7) 1-142.

Anonymous, 2021. Report of the intersessional meeting of the Albacore Species Group (including Med-ALB stock assessment) (Online, 21- 30 June 2021). Collect. Vol. Sci. Pap. ICCAT 78 (8) 1-101.

Anonymous, 2023. Report of the Atlantic Albacore Stock Assessment Meeting Hybrid/ Madrid (Spain), 26-29 June 2023). Collect. Vol. Sci. Pap. ICCAT 80 (3) 175-278.

Carvalho, F., Punt, A.E., Chang, Y.J., Maunder, M.N., Piner, K.R., 2017. Can diagnostic tests help identify model misspecification in integrated stock assessments? Fish. Res. 192, 28–40. https://doi.org/10.1016/j.fishres.2016.09.018

Carvalho, F., Winker H., Courtney D., Kapur M., Kell L., Cardinale M., Schirripa M., Kitakado T., Yemane D., Piner K. R., Maunder M. N., Taylor I. Wetzel C. R., Doering K., Johnson K. F., and Methot R. D.2021. A cookbook for using model diagnostics in integrated stock assessments. Fisheries Research Volume 204. https://doi.org/10.1016/j.fishres.2021.105959

Collette, B. B. and C. E. Nauen. 1983. FAO species catalogue, vol. 2, Scombrids of the world. FAO. Fisheries synopsis 125 (2): 137 p.

Gelman, A., Rubin, D.B., 1992. lnference from Iterative Simulation Using Multiple Sequences. Stat. Sci. 7, 457–472. https://doi.org/10.2307/2246093

Geweke, J., 1992. Evaluating the accuracy of sampling-based approaches to the calculation of posterior moments., in: Berger, J.O., Bernardo, J.M., Dawid, A.P., Smith, A.F.M. (Eds.), Bayesian Statistics 4: Proceedings of the Fourth Valencia International Meeting. Clarendon Press, Oxford, pp. 169–193.

Heidelberger, P., Welch, P.D., 1992. Simulation run length control in the presence of an initial transient. Oper. Res. 31, 1109–1144. https://doi.org/10.1287/opre.31.6.1109

Hurtado-Ferro, F., Szuwalski, C.S., Valero, J.L., Anderson, S.C., Cunningham, C.J., Johnson, K.F., Licandeo, R., McGilliard, C.R., Monnahan, C.C., Muradian, M.L., Ono, K., Vert-Pre, K.A., Whitten, A.R., Punt, A.E., 2015. Looking in the rear-view mirror: Bias and retrospective patterns in integrated, age-structured stock assessment models, in: ICES Journal of Marine Science. pp. 99–110. https://doi.org/10.1093/icesjms/fsu198

Kell, L. T., Kimoto, A., and Kitakado, T. 2016. Evaluation of the prediction skill of stock assessment using hindcasting. Fisheries Research, 183: 119–127. http://www.sciencedirect.com/science/article/pii/S0165783616301540.

Kell, L. T., Sharma, R., Kitakado, T., Mosqueira, I., Winker, H., Cardinale, M., and Fu, D. 2021. Validation of stock assessment models using prediction skill: Is it me or my model talking? ICES Journal of Marine Science: https://doi.org/10.1093/icesjms/fsab104.

Kitakado T., K. Satoh, Sl Lee, NJ Su, T Matsumoto, H Yokoi, K Okamoto, Kyung Lee M, Lim JH, Kwon Y, Wang SP, Tsai WP, Chang ST, and Chang FC. Update of trilateral collaborative study among Japan, Korea and Chinese Taipei for producing joint abundance indices for the Atlantic bigeye tunas using longline fisheries data up to 2019. Collect. Vol. Sci. Pap. ICCAT 78, 21, 169-196.

Martell, S., Froese, R., 2013. A simple method for estimating MSY from catch and resilience 504–514. https://doi.org/10.1111/j.1467-2979.2012.00485.x

Matsumoto T., Satoh K., Lauretta M., Park H., Sant'Ana R. Su NJ., Wang SP., Tsai WP., Lee SI., Lim JH., and Kitakado T. COLLABORATIVE STUDY OF YELLOWFIN TUNA CPUE FROM MULTIPLE ATLANTIC OCEAN LONGLINE FLEETS IN 2024. SCRS/2024/036.

Mohn, R., 1999. The retrospective problem in sequential population analysis: An investigation using cod fishery and simulated data. ICES J. Mar. Sci. 56, 473–488. https://doi.org/10.1006/jmsc.1999.0481

Plummer, M., 2003. JAGS: A Program for Analysis of Bayesian Graphical Models using Gibbs Sampling, 3rd International Workshop on Distributed Statistical Computing (DSC 2003); Vienna, Austria.

Plummer, M., Nicky Best, Cowles, K., Vines, K., 2006. CODA: Convergence Diagnosis and Output Analysis for MCMC. R News 6, 7–11.

Winker, H., Carvalho, F., Kapur, M., 2018. JABBA: Just Another Bayesian Biomass Assessment. Fish. Res. 204, 275–288. https://doi.org/http://doi.org/10.1016/j.fishres.2018.03.01

Table 1. Available abundance indices in 2024 prior to the ALB-Med Data Preparatory and Assessment Meeting.

Index	*Index name*	*unit*	*index period*	*index missing year(s)*
Spanish longline	SPN LLALB	number	2009-2022	2014, 2018, 2020
Western Med larval survey	Larval W-Med	number	2001-2022	2002-2003, 2006-2011, 2018, 2021
Italian longline	ITA LL	weight	2011-2019	
Spanish tournament	SPN Tournament	number	2005-2019	
Italian longline Ionian Sea	ITA-Ionian LL	weight	1995-2003	1996
Italian longline Ligurian Sea	ITA-Ligurian LL bycatch	weight	1994-1997	
Italian longline in South Med	Med South ITALL	weight	2004-2009	2007
Italian longline in South Adriatic	South Adriatic ITALL	weight	1984-2000	1988-1989, 1996-1997
Greek longline	GRC LLALB	weight	2005-2022	2007-2011

Table 2. Available Mediterranean albacore CPUE indices available to the 2024 stock assessment before the Albacore meeting in May 2024.

Name	SPN LLALB(n)		Larval W-Med		ITA LL(w)		SPN Tournament(n)		ITA-Ionian LL(w)		ITA-Ligurian LL bycatch(w)		Med South ITALL(w)		South Adriatic ITALL(w)	GRC LLALB(w)	
Fleet	EU-Spain		EU-Spain		EU-Italy		EU-Spain		EU-Italy		EU-Italy		EU-Italy		EU-Italy	EU-Greece	
Gear	LL		Larval Survey		LL		Recreational		LL		LL		LL		LL	LL	
Docs	SCRS/2024/031		SCRS/2024/069		SCRS/2021/115		SCRS/2021/103		SCRS/2021/115		SCRS/2021/115		SCRS/2021/115		Marano et al., 2005	SCRS/2024/XXX	
Use in 2024 assessment																	
Units	Num.	CV	Num.	CV	Wt.	SE	Num.	SE	Wt.	SE	Wt.	SE	Wt.	SE	Num. Nominal (Wt.)	Wt.	SD
1984															85.020		
1985															105.590		
1986															112.810		
1987															248.770		
1988																	
1989																	
1990															220.610		
1991															181.670		
1992															188.890		
1993															124.440		
1994											19.910	0.190			169.300		
1995									45.300	0.050	25.780	0.170			136.440		
1996											25.420	0.110					
1997									56.010	0.060	17.110	0.150					
1998									141.770	0.050					98.560		
1999									43.680	0.040					105.780		
2000									78.550	0.090					133.640		
2001			7.907	0.282					99.610	0.080							
2002									55.080	0.170							
2003									53.630	0.120							
2004			10.965	0.214									164.750	0.170			
2005			8.387	0.190			0.700	0.180					130.980	0.240		64.770	21.080
2006							0.940	0.240					273.550	0.230		79.640	10.590
2007							0.620	0.150									
2008							1.170	0.210					62.160	0.320			
2009	2.223	0.147					1.090	0.270					257.370	0.350			
2010	2.388	0.102					0.520	0.140									
2011	2.827	0.098			22.070	0.090	1.220	0.310									
2012	1.157	0.087	5.380	0.220	26.190	0.120	0.490	0.130								136.170	29.360
2013	1.128	0.132	3.361	0.344	26.510	0.200	2.280	0.560								243.830	33.980
2014			2.010	0.365	17.050	0.170	1.710	0.420								399.580	50.650
2015	1.135	0.093	0.651	0.342	26.710	0.190	0.650	0.120								152.000	40.470
2016	1.117	0.218	2.060	0.377	15.190	0.170	0.940	0.160								302.110	44.800
2017	2.336	0.194	2.606	0.259	13.910	0.190	1.090	0.190								132.670	16.850
2018					42.050	0.200	0.890	0.160								139.470	28.650
2019	1.405	0.166	1.954	0.346	55.970	0.310	0.720	0.130								109.990	22.330
2020			2.360	0.228												121.180	31.160
2021	2.507	0.146														177.050	49.350
2022	2.077	0.114	4.113	0.356												91.250	13.850
2023																	

Table 3. 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 Mediterranean albacore Scenarios 0, 1, and 3 model runs with the 2021 final model (S4_2021).

	2021_S4 (Anon. 2021)			S0		
Estimates	Median	2.50%	97.50%	Median	2.50%	97.50%
K	53241	31551	99528	53765	32233	97636
r	0.186	0.093	0.339	0.188	0.095	0.338
B_{MSY}/K	0.370	0.370	0.370	0.370	0.370	0.370
F_{MSY}	0.184	0.091	0.335	0.186	0.093	0.334
B_{MSY}	19703	11676	36833	19897	11928	36133
MSY	3654	2446	5090	3718	2478	5149
B_{1980}/K	0.805	0.527	1.153	0.799	0.514	1.154
B_{2022}/K				0.245	0.083	0.564
B_{2022}/B_{MSY}				0.662	0.225	1.525
F_{2022}/F_{MSY}				0.945	0.352	3.155

	S1			S3		
Estimates	Median	2.50%	97.50%	Median	2.50%	97.50%
K	50443	31046	87583	46641	28947	80541
r	0.204	0.107	0.350	0.222	0.115	0.386
B_{MSY}/K	0.370	0.370	0.370	0.370	0.370	0.370
F_{MSY}	0.202	0.106	0.346	0.219	0.114	0.382
B_{MSY}	18668	11489	32412	17261	10713	29806
MSY	3774	2637	5120	3793	2685	5136
B_{1980}/K	0.805	0.526	1.154	0.810	0.525	1.161
B_{2022}/K	0.324	0.178	0.558	0.298	0.168	0.541
B_{2022}/B_{MSY}	0.875	0.482	1.508	0.805	0.455	1.461
F_{2022}/F_{MSY}	0.712	0.348	1.329	0.768	0.346	1.445

Table 4. Summary Mohn's rho statistic for the Scenarios S0, S1, and S3 models, computed for a retrospective evaluation period of five years. The larger values show stronger retrospective bias.

	Stock Quantity					
Scenario	B	F	B/B_{MSY}	F/F_{MSY}	B/K	MSY
S0	-0.029	0.037	-0.001	0.011	-0.002	-0.003
S1	-0.011	0.020	-0.016	0.060	-0.013	-0.027
S3	-0.064	0.072	-0.014	-0.010	0.001	0.028

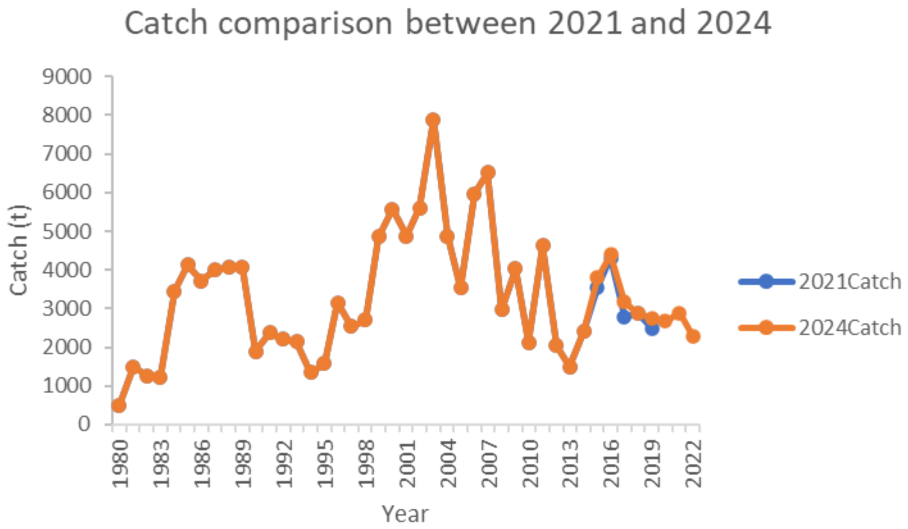


Figure 1. Task 1 Catch times series for the period 1980-2019 in metric tons (t) for Mediterranean albacore in 2024.

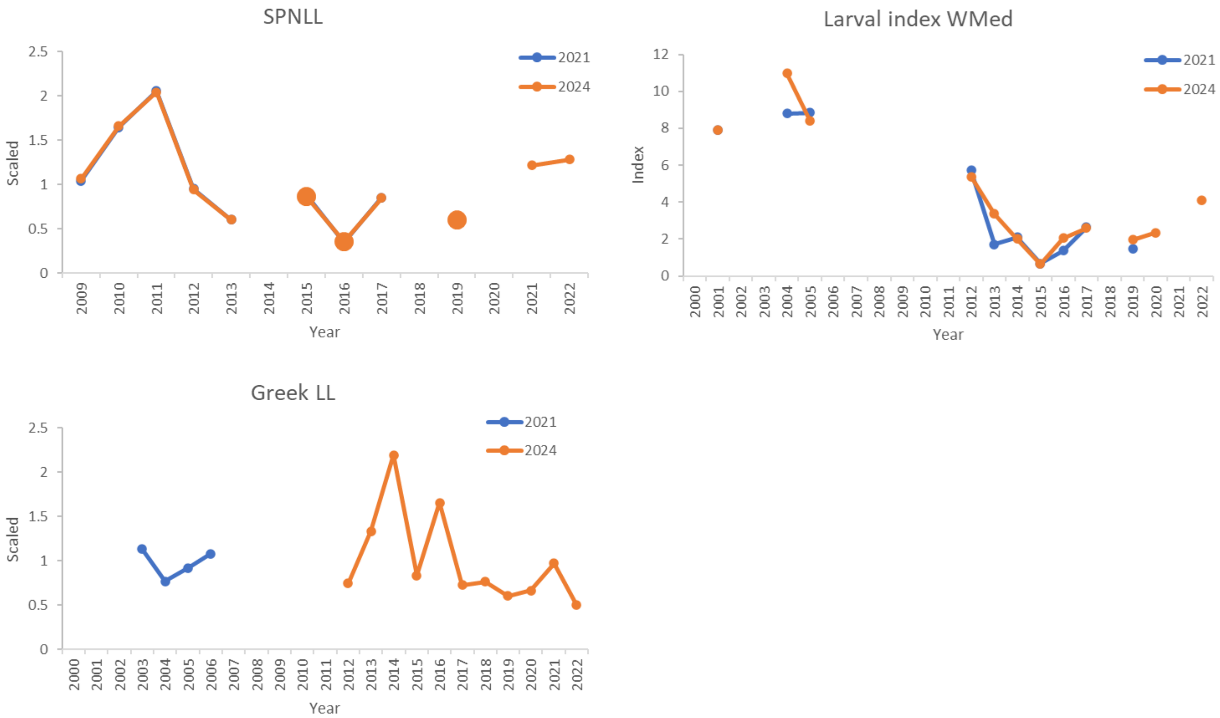
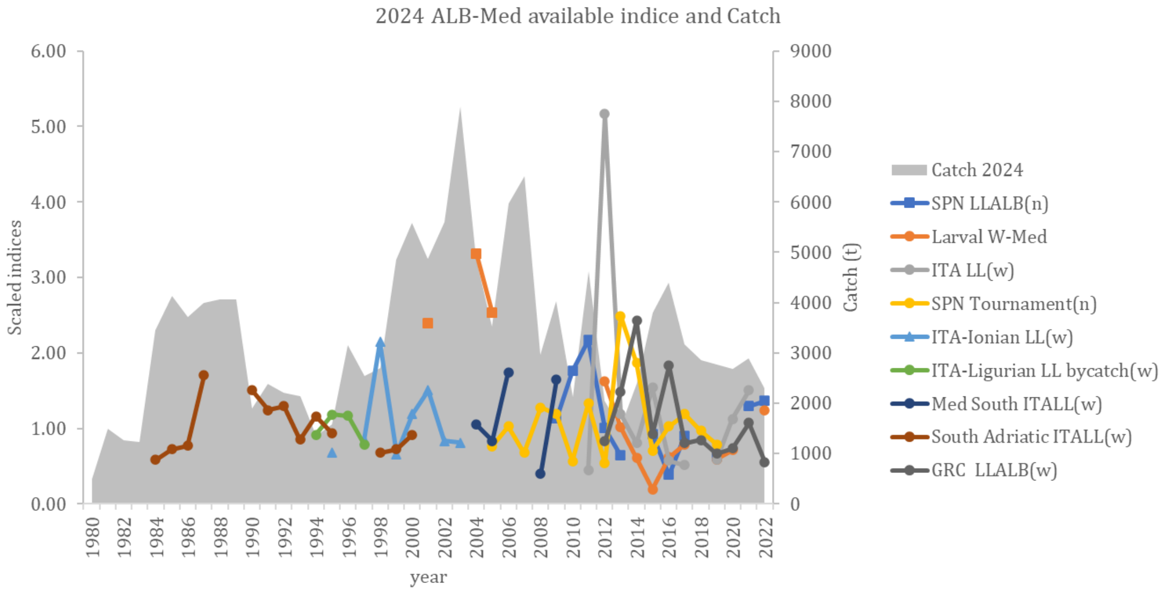


Figure 2. The updated standardized abundance indices in 2024 compared to its value in 2021.

a) 1980-2022



b) Zoom: 2013-2022 (the recent 10 years)

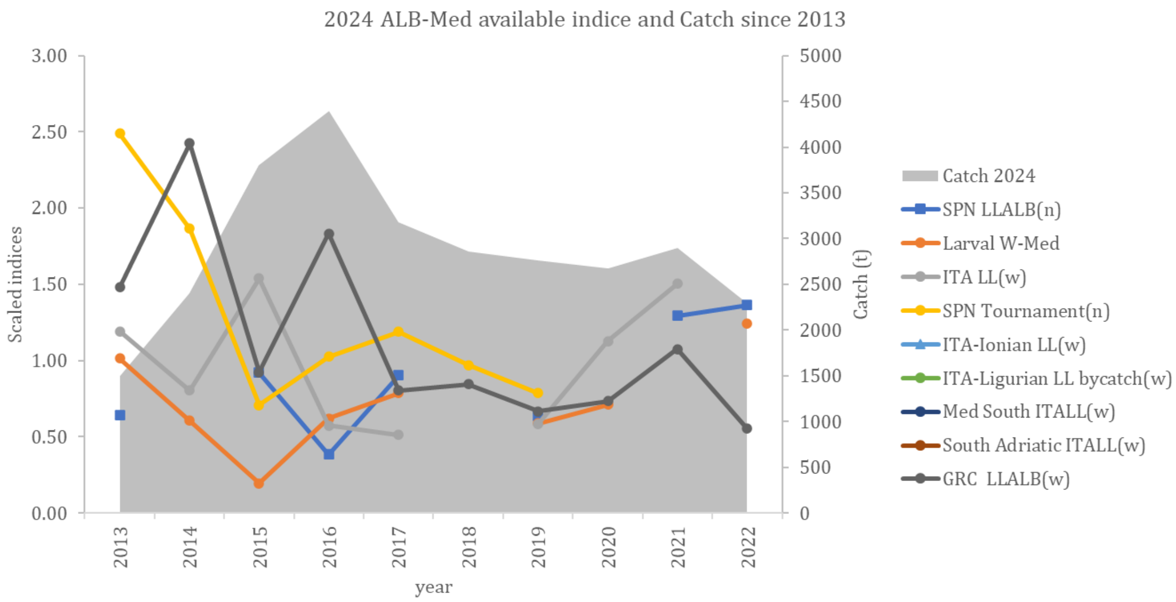


Figure 3. Available abundance indices with total catch for the 2024 ALB-Med stock assessment for the period a) 1980-2022, and b) 2013-2022.

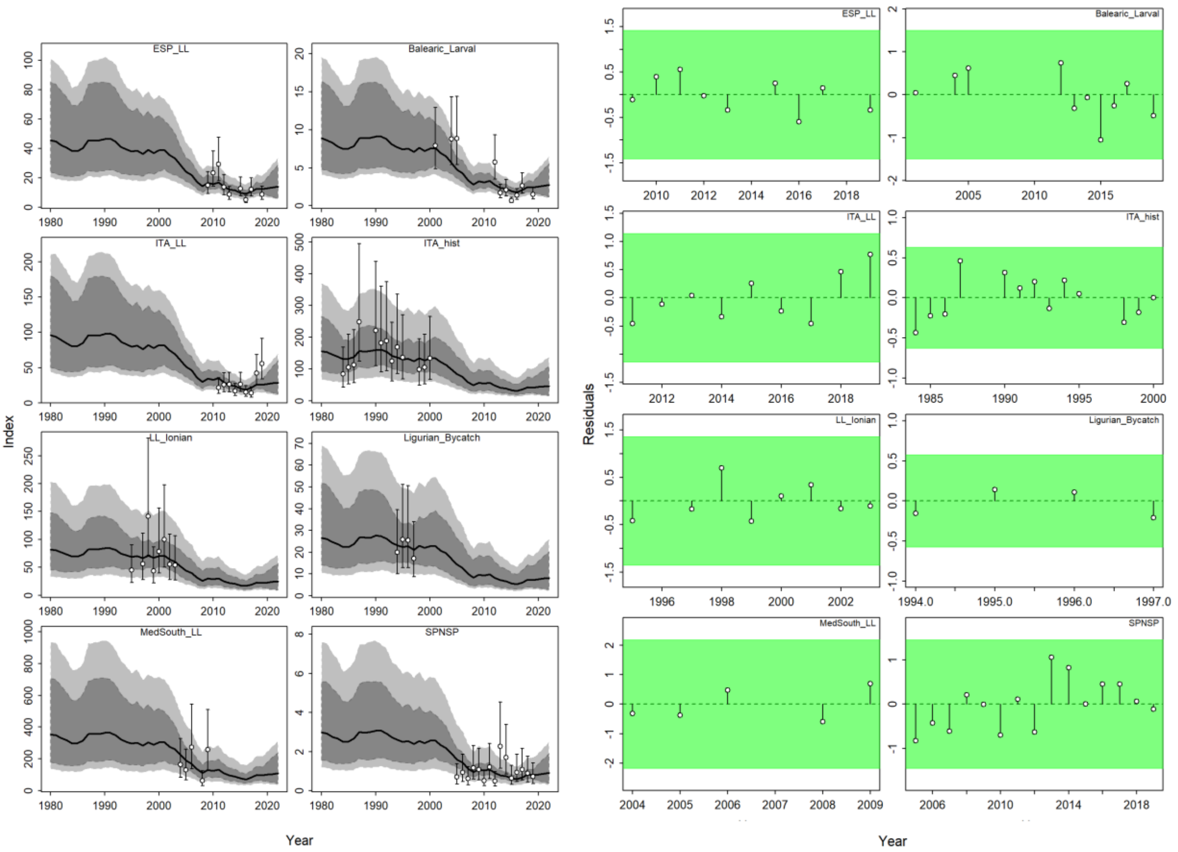


Figure 4. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line) CPUE (left) and Runs tests to quantitatively evaluate the randomness of the time series of index residuals (right) for the ALB-Med scenario S0 with 2024 catch and 2021 indices. On the left panel, the dark-shaded grey areas show 95% credibility intervals of the expected mean CPUE and light-shaded grey areas denote the 95% posterior predictive distribution intervals. On the right panel, green areas indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels (not shown here) 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 (3- sigma rule).

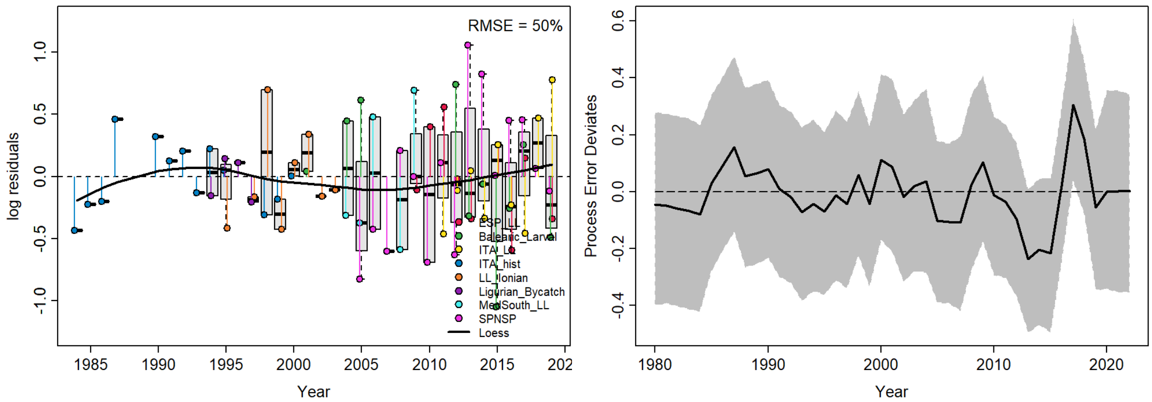


Figure 5. JABBA residual diagnostic plots of relative abundance indices (left panel) and process error deviation (right panel) for the ALB-Med scenario S0. Left panel: Boxplots indicating the median and quantiles of all residuals available for any given year, and solid black lines indicate loess smoother through all residuals. Right panel: Process error deviation (median: solid line) with a shaded grey area indicating 95% credibility intervals.

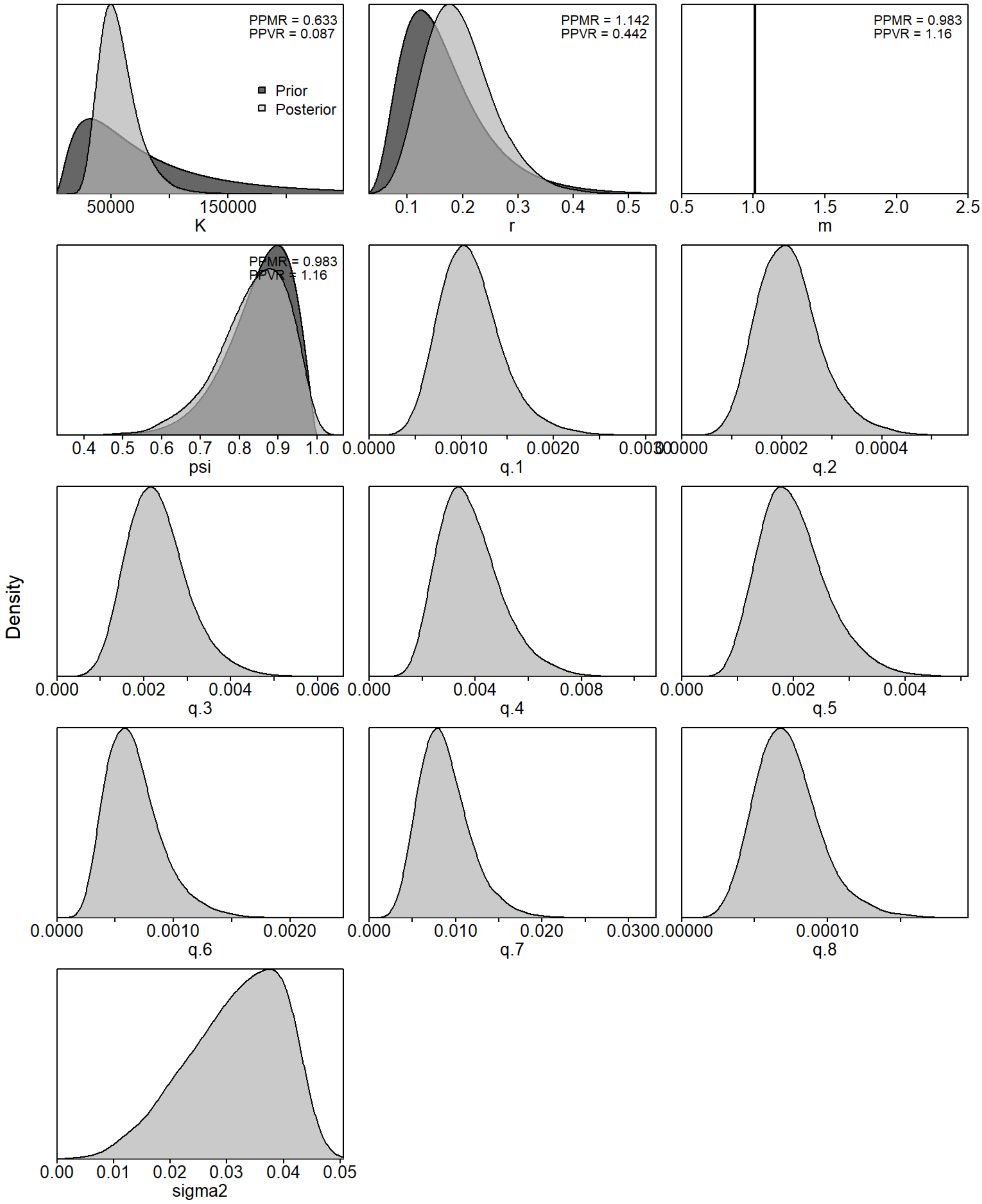


Figure 6. Prior and posterior distributions of various model and management parameters for the scenario S0 model for Mediterranean albacore. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.

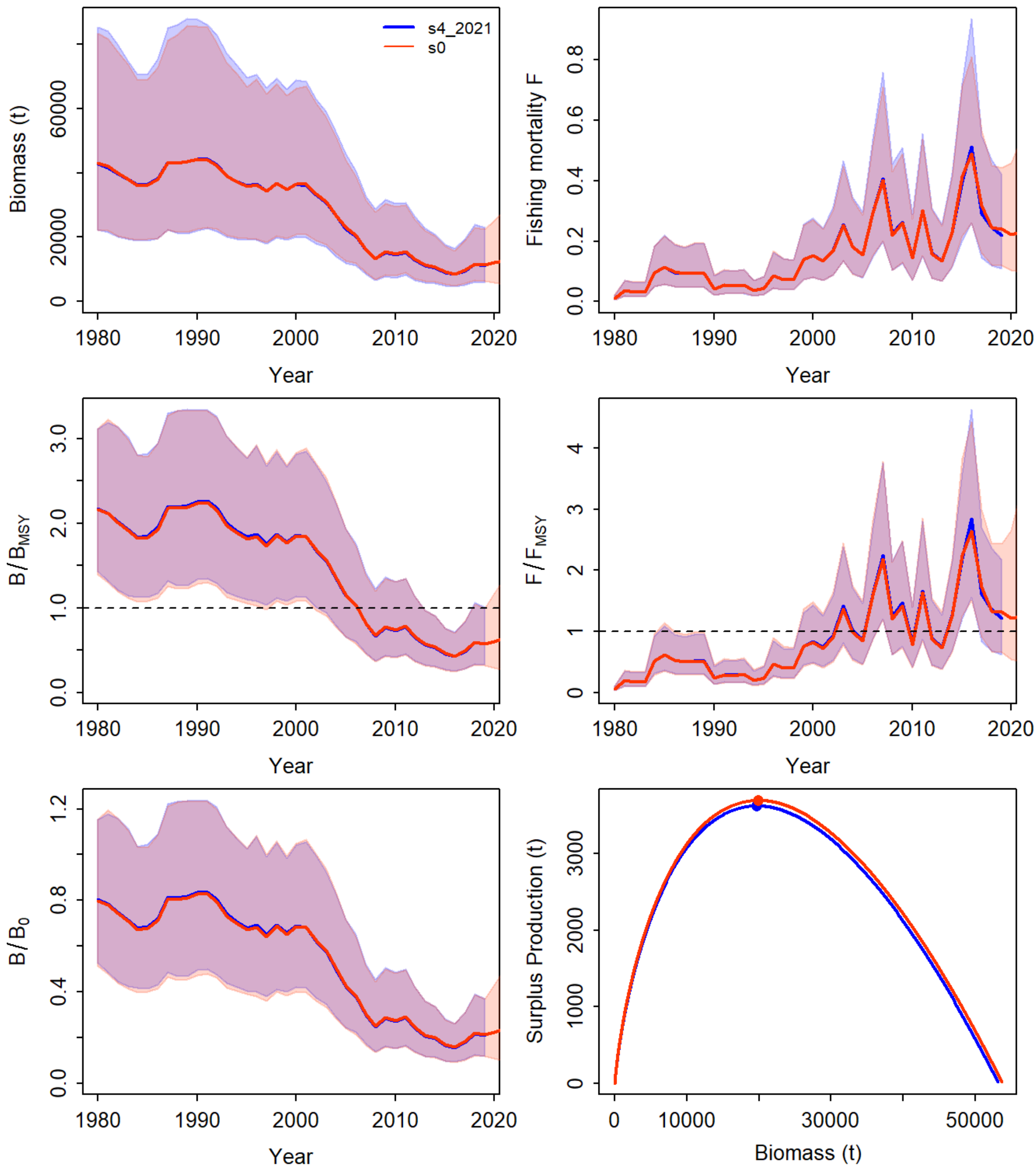


Figure 7. Comparison stock trajectory estimates for the Mediterranean albacore S4_2021 (the 2021 final stock assessment model) and S0 scenarios, showing trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).

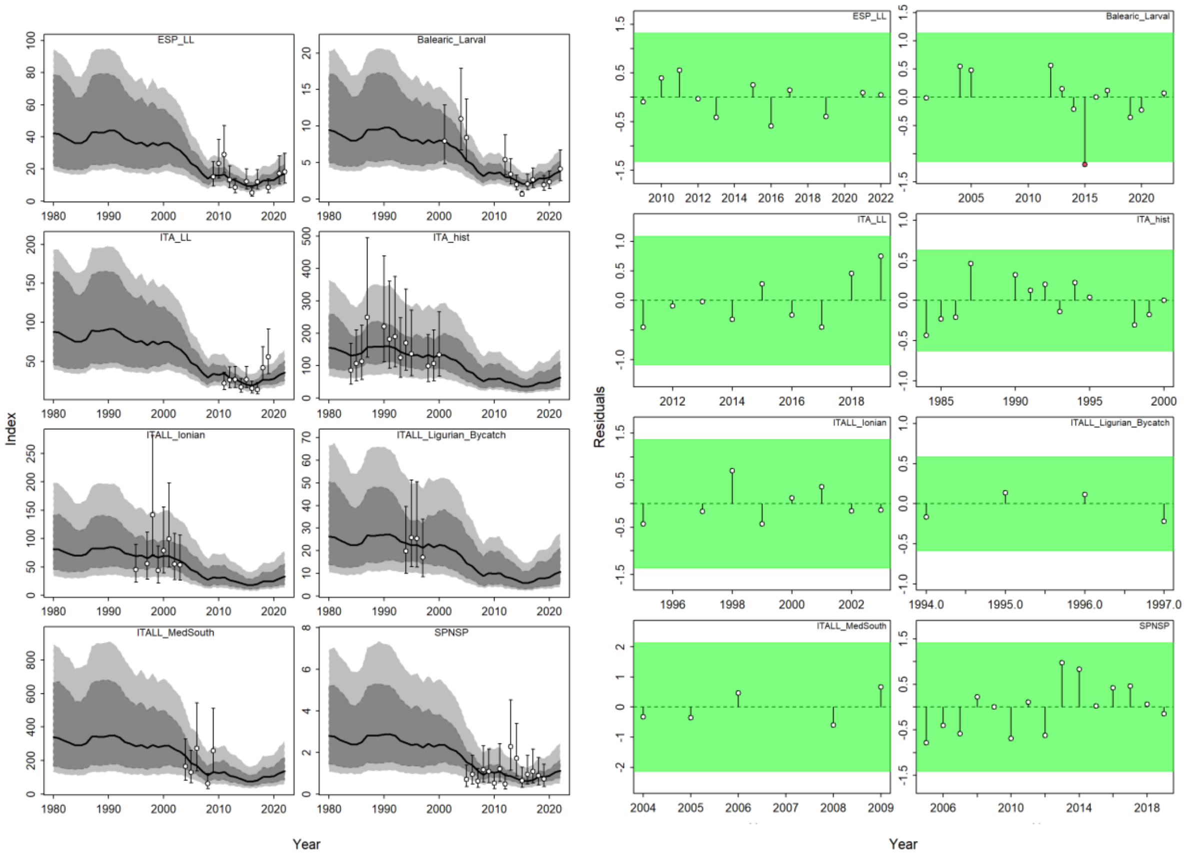


Figure 8. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line) CPUE (left) and Runs tests to quantitatively evaluate the randomness of the time series of index residuals (right) for the ALB-Med scenario S1 with 2024 catch and indices (Greek longline was not included). On the left panel, the dark shaded grey areas show 95% credibility intervals of the expected mean CPUE and light shaded grey areas denote the 95% posterior predictive distribution intervals. On the right panel, green areas indicate no evidence of lack of randomness of time-series residuals (p>0.05) while red panels (not shown here) 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 (3- sigma rule).

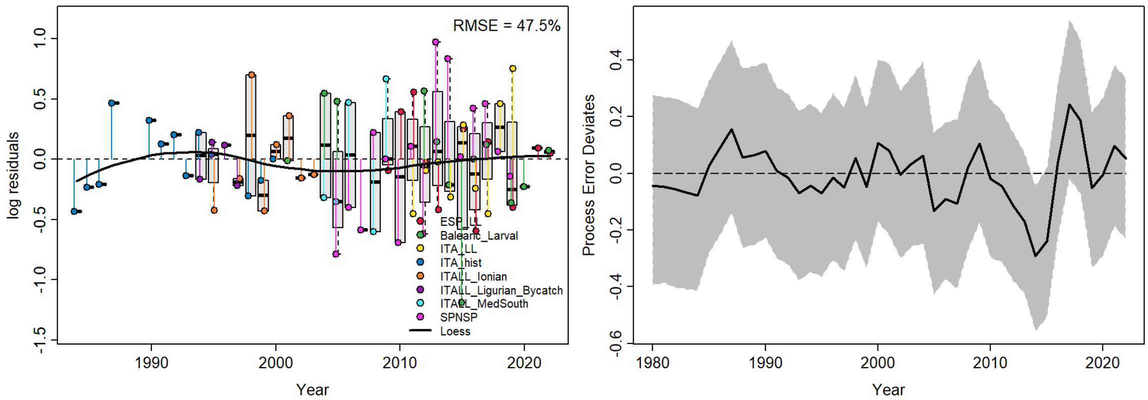


Figure 9. JABBA residual diagnostic plots of relative abundance indices (left panel) and process error deviation (right panel) for the ALB-Med scenario S1. Left panel: Boxplots indicating the median and quantiles of all residuals available for any given year, and solid black lines indicate loess smoother through all residuals. Right panel: Process error deviation (median: solid line) with a shaded grey area indicating 95% credibility intervals.

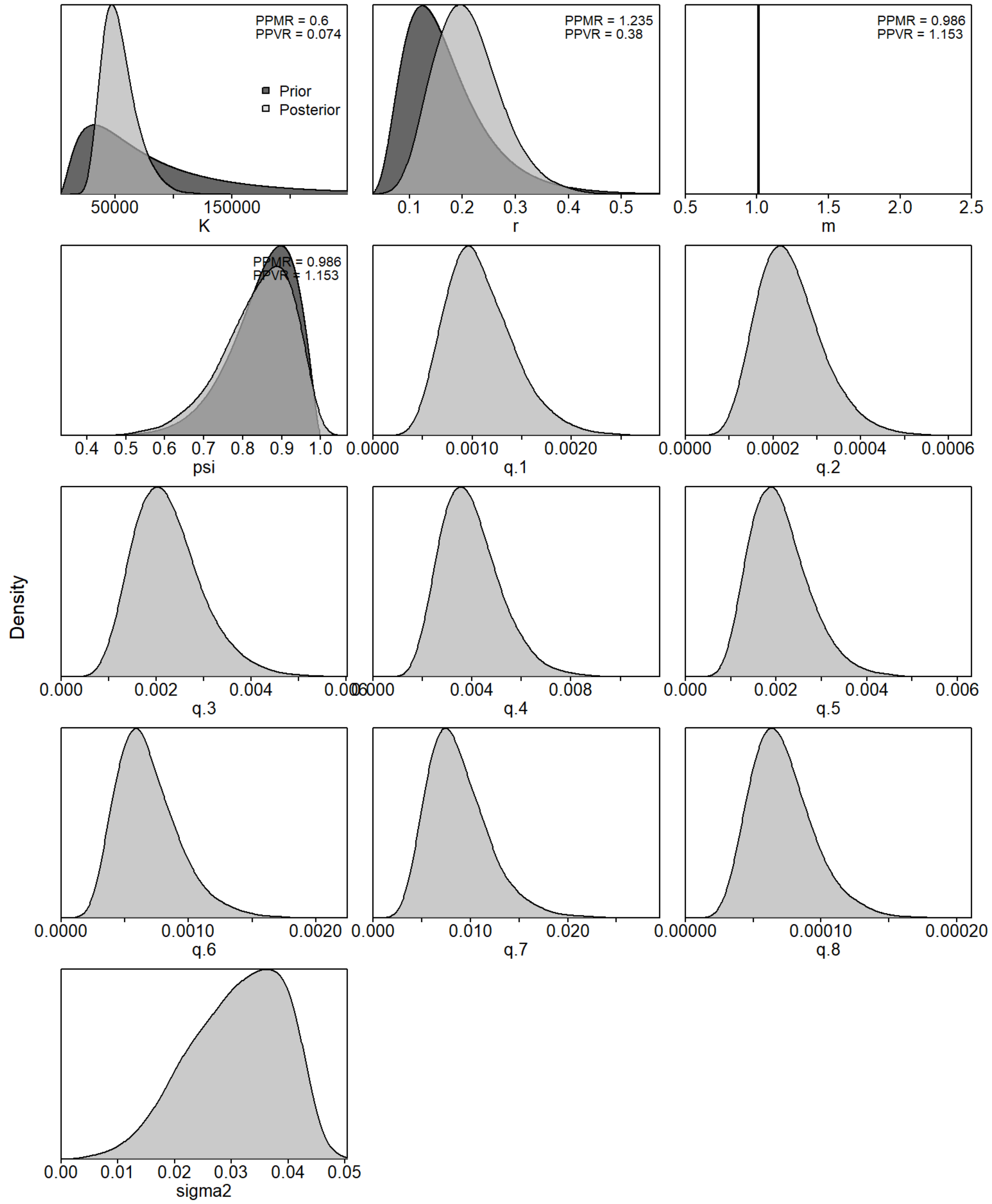


Figure 10. Prior and posterior distributions of various model and management parameters for the scenario S1 model for Mediterranean albacore. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.

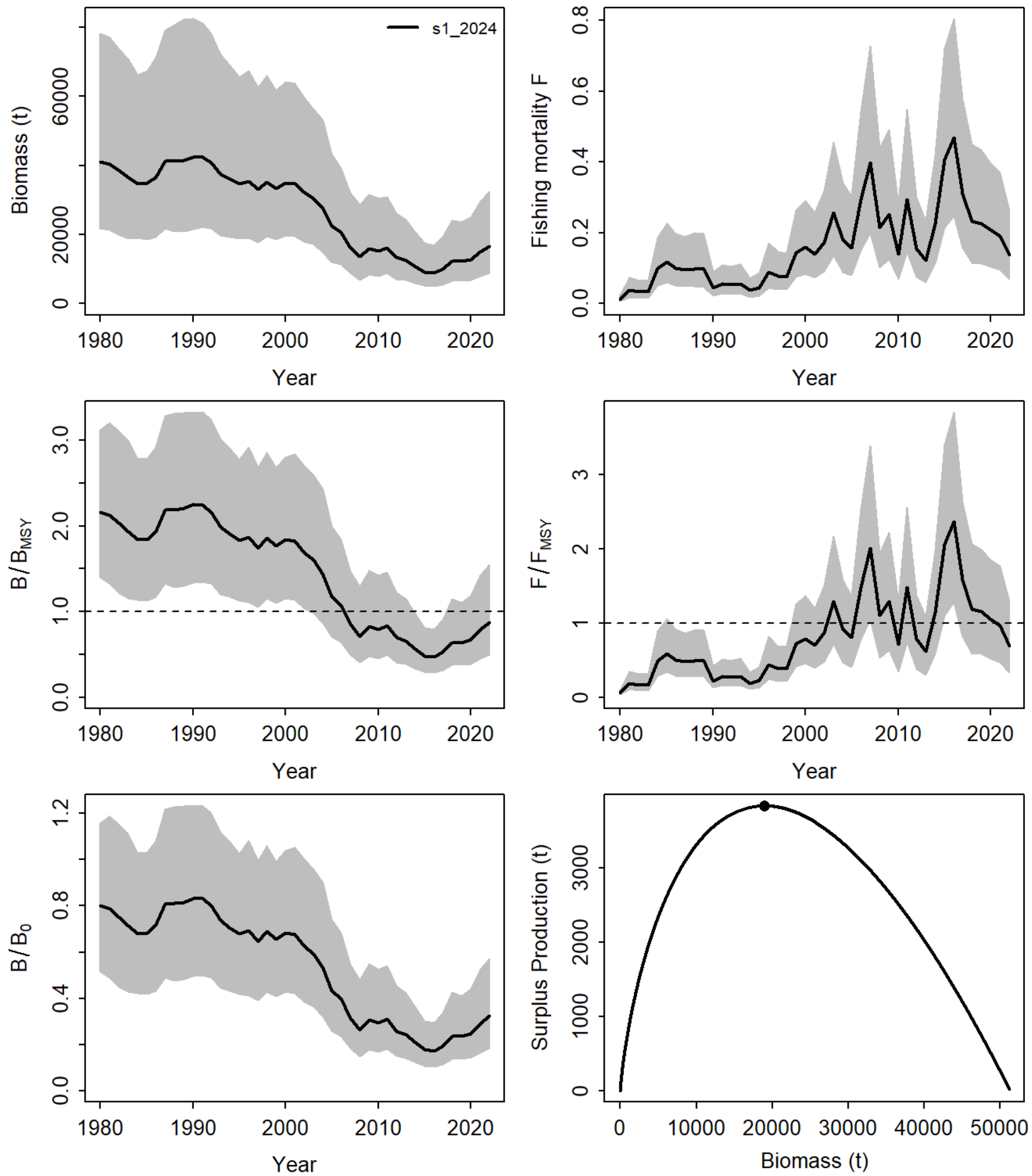


Figure 11. JABBA ALB-Med stock assessment scenario S1 results. Upper panels: estimated biomass and fishing mortality with associated 95% credibility interval; middle panels: biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}); bottom panels: biomass relative to B_0 (B/B_0) and surplus production curve.

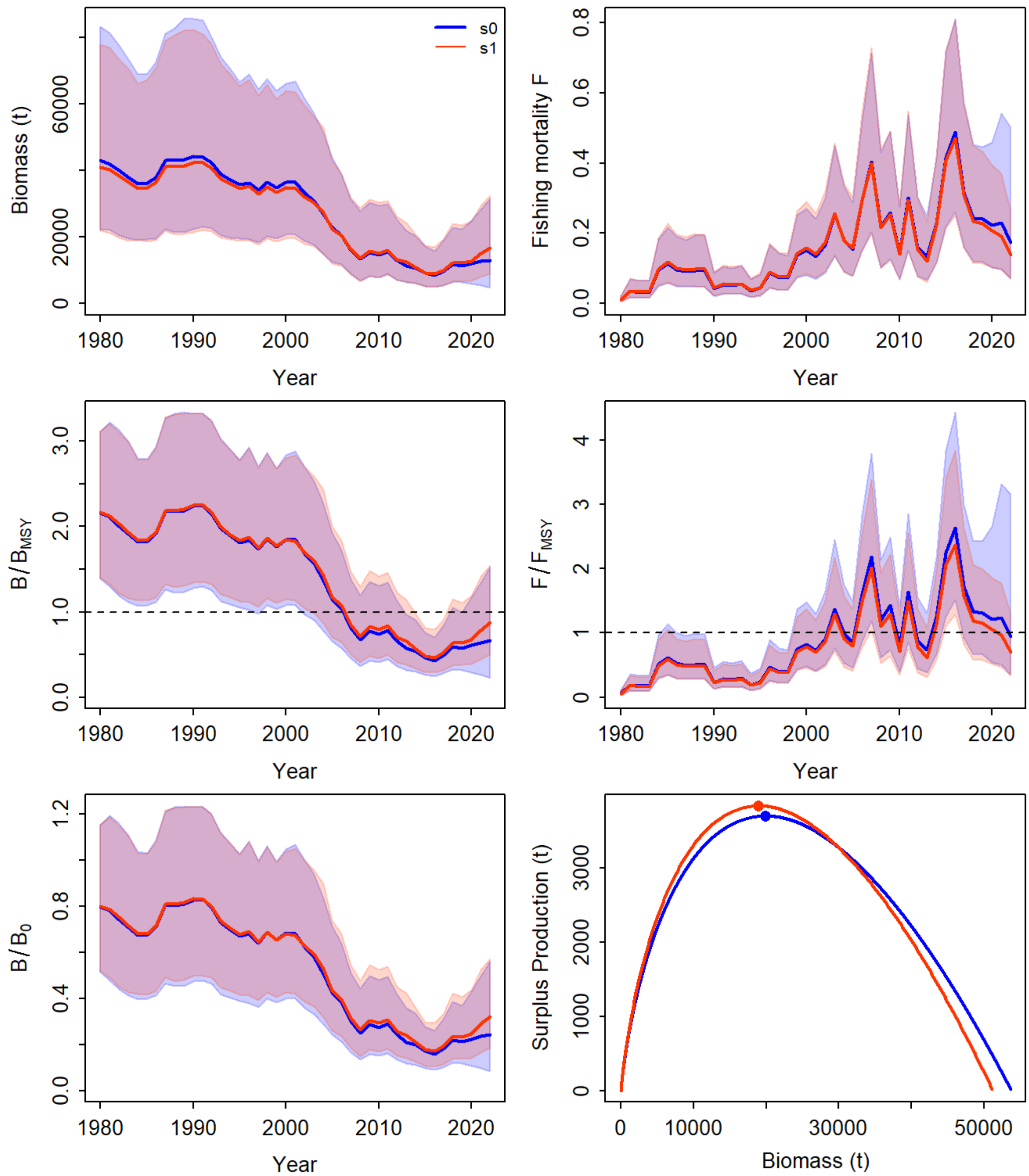


Figure 12. Comparison stock trajectory estimates for the Mediterranean albacore scenarios S0 and S1, showing trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).

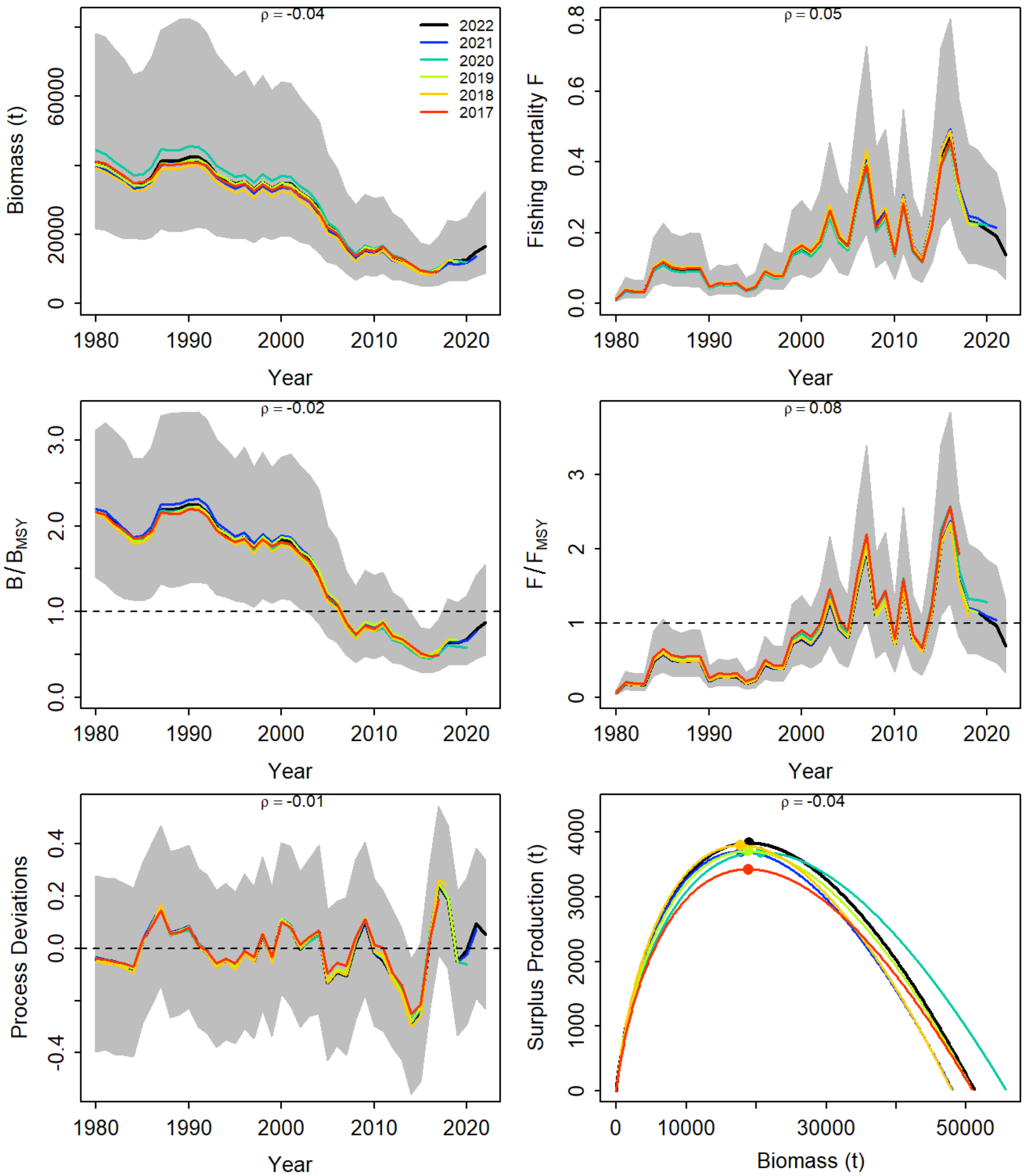


Figure 13. Retrospective analysis performed for the ALB-Med scenario S1, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.

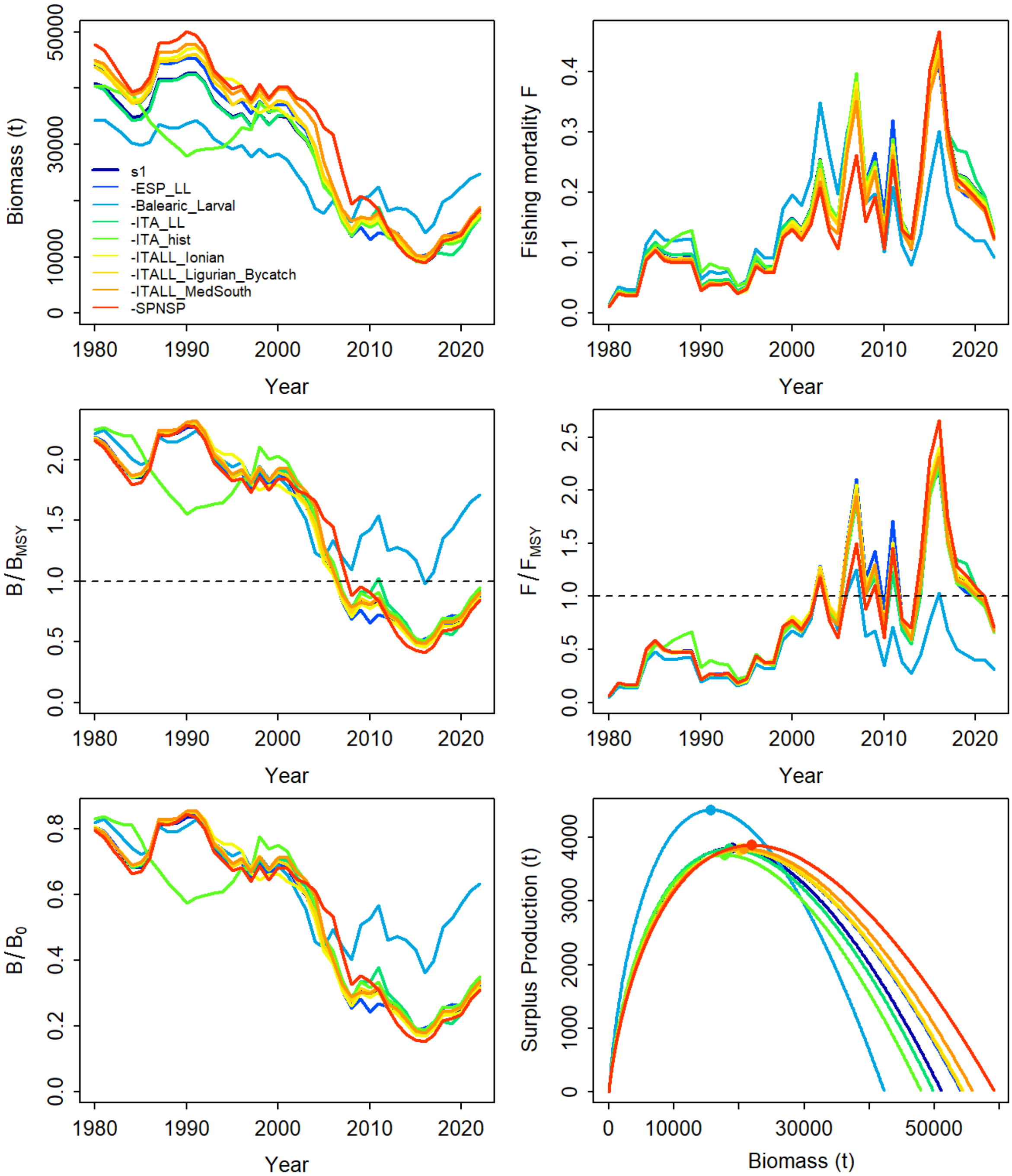


Figure 14. Jackknife index analysis performed on the ALB-Med scenario S1, by removing one index at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.

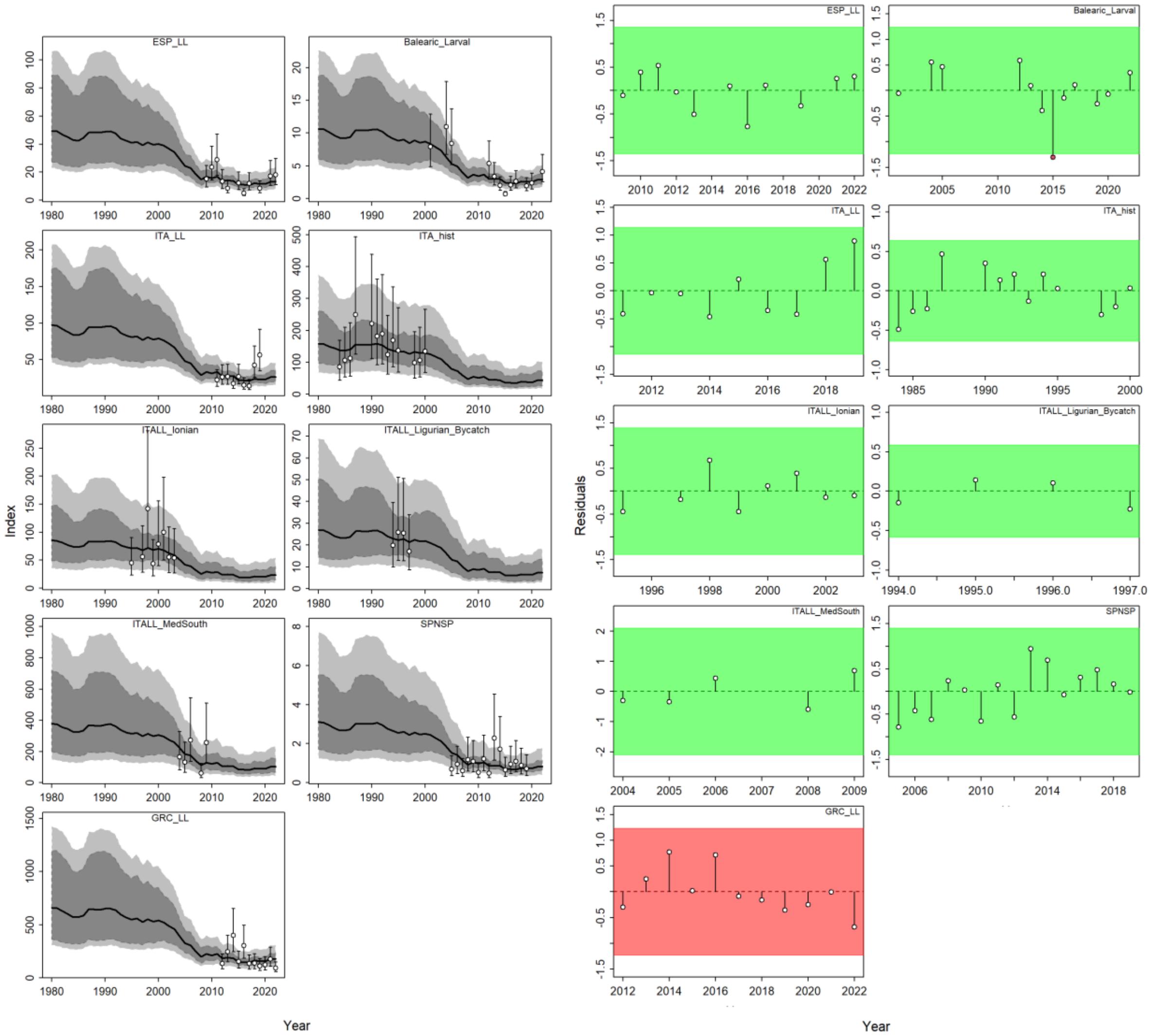


Figure 15. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line) CPUE (left) and Runs tests to quantitatively evaluate the randomness of the time series of index residuals (right) for the ALB-Med scenario S3 with 2024 catch and indices including Greek longline CPUE. On the left panel, the dark-shaded grey areas show 95% credibility intervals of the expected mean CPUE and light-shaded grey areas denote the 95% posterior predictive distribution intervals. On the right panel, green areas 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 (3- sigma rule).

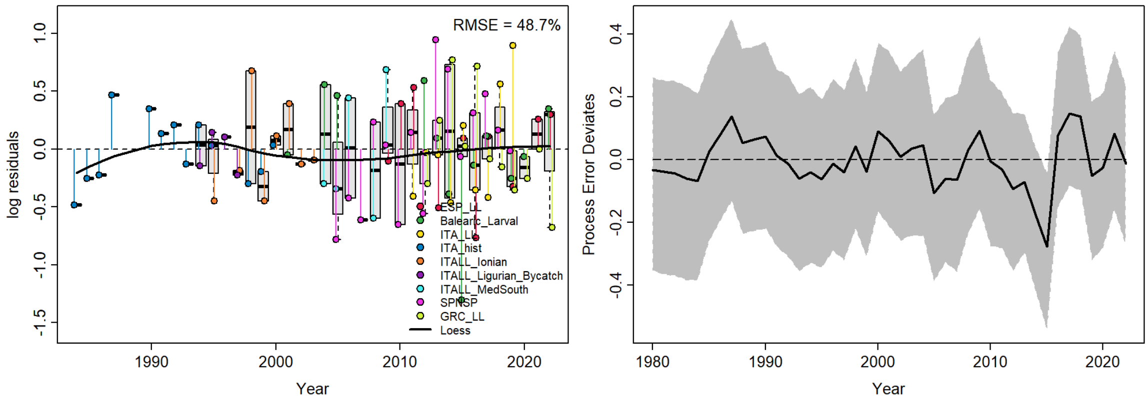


Figure 16. JABBA residual diagnostic plots of relative abundance indices (left panel) and process error deviation (right panel) for the ALB-Med scenario S3. Left panel: Boxplots indicating the median and quantiles of all residuals available for any given year, and solid black lines indicate loess smoother through all residuals. Right panel: Process error deviation (median: solid line) with a shaded grey area indicating 95% credibility intervals.

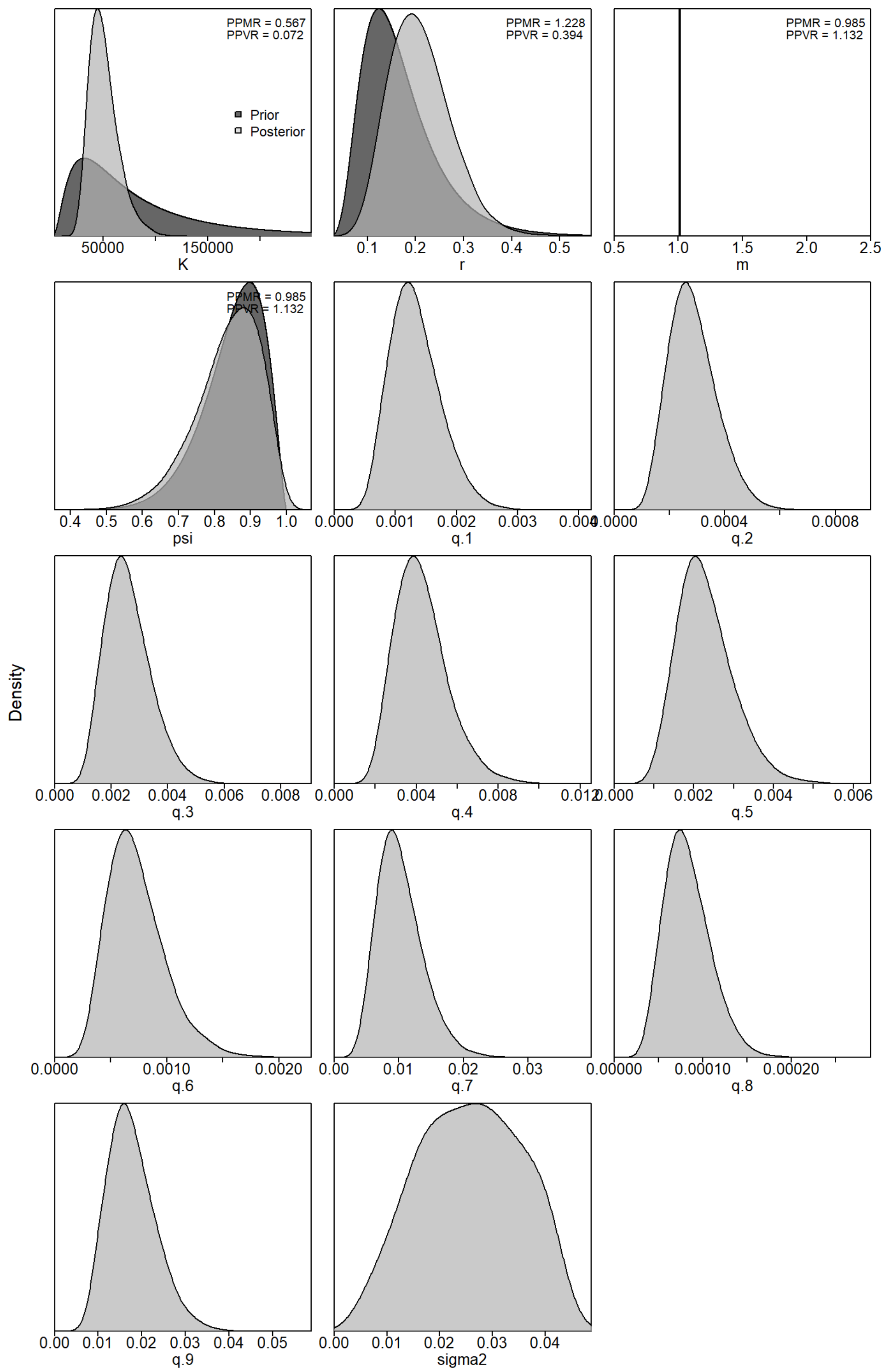


Figure 17. Prior and posterior distributions of various model and management parameters for the scenario S3 model for Mediterranean albacore. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.

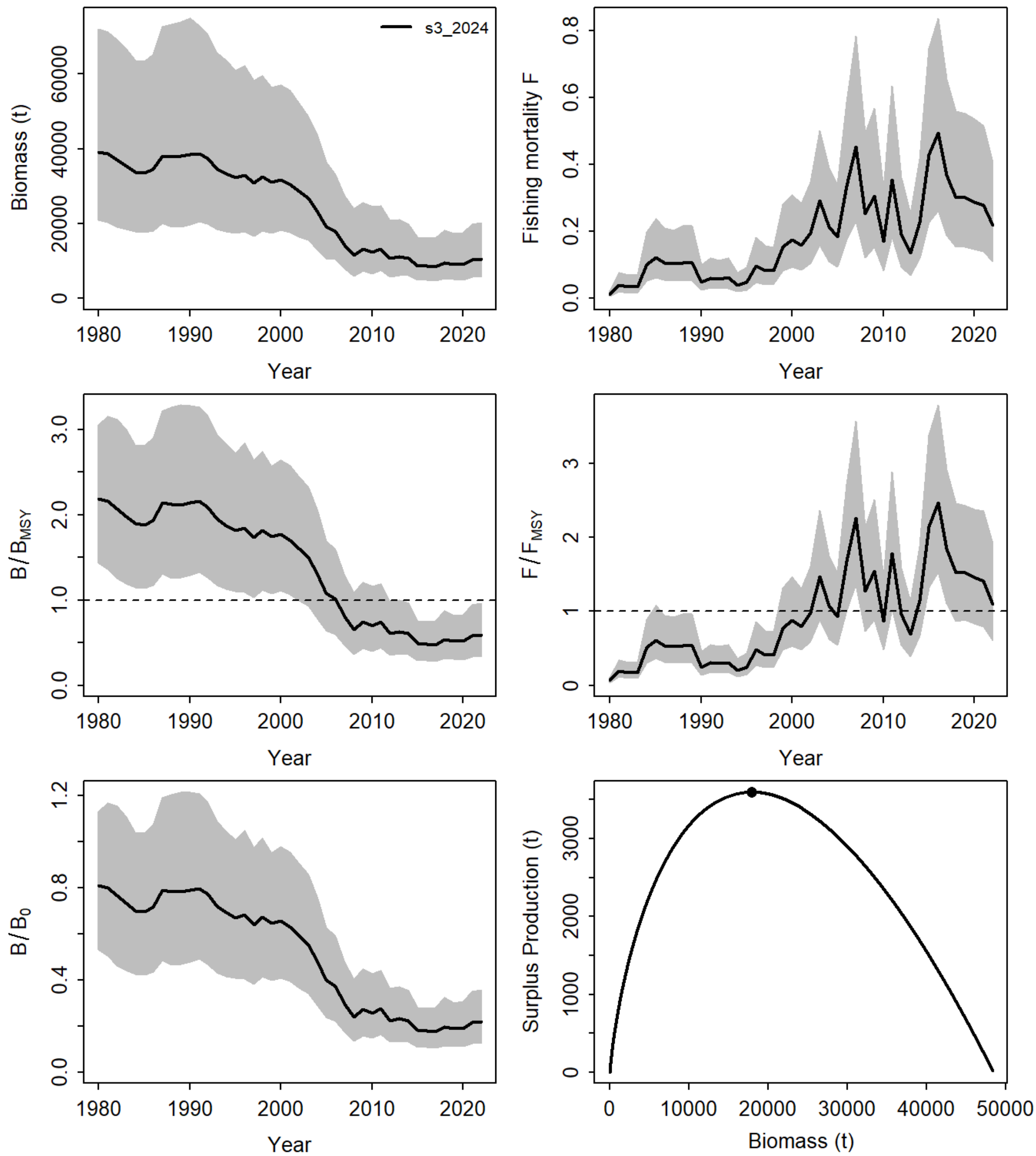


Figure 18. JABBA ALB-Med stock assessment scenario S3 results. Upper panels: estimated biomass and fishing mortality with associated 95% credibility interval; middle panels: biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}); bottom panels: biomass relative to B_0 (B/B_0) and surplus production curve.

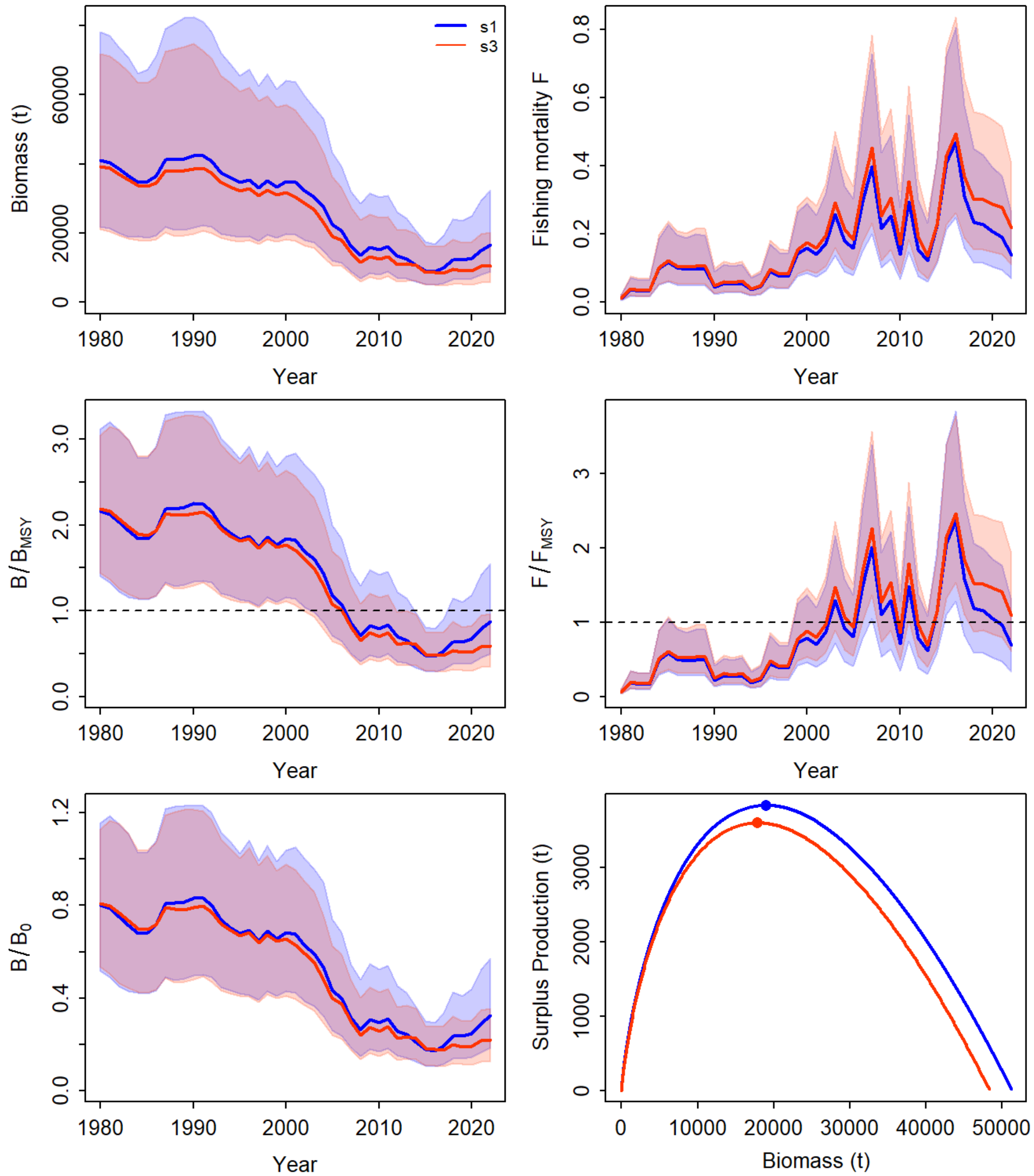


Figure 19. Comparison stock trajectory estimates for the Mediterranean albacore scenarios S1 and S3, showing trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).

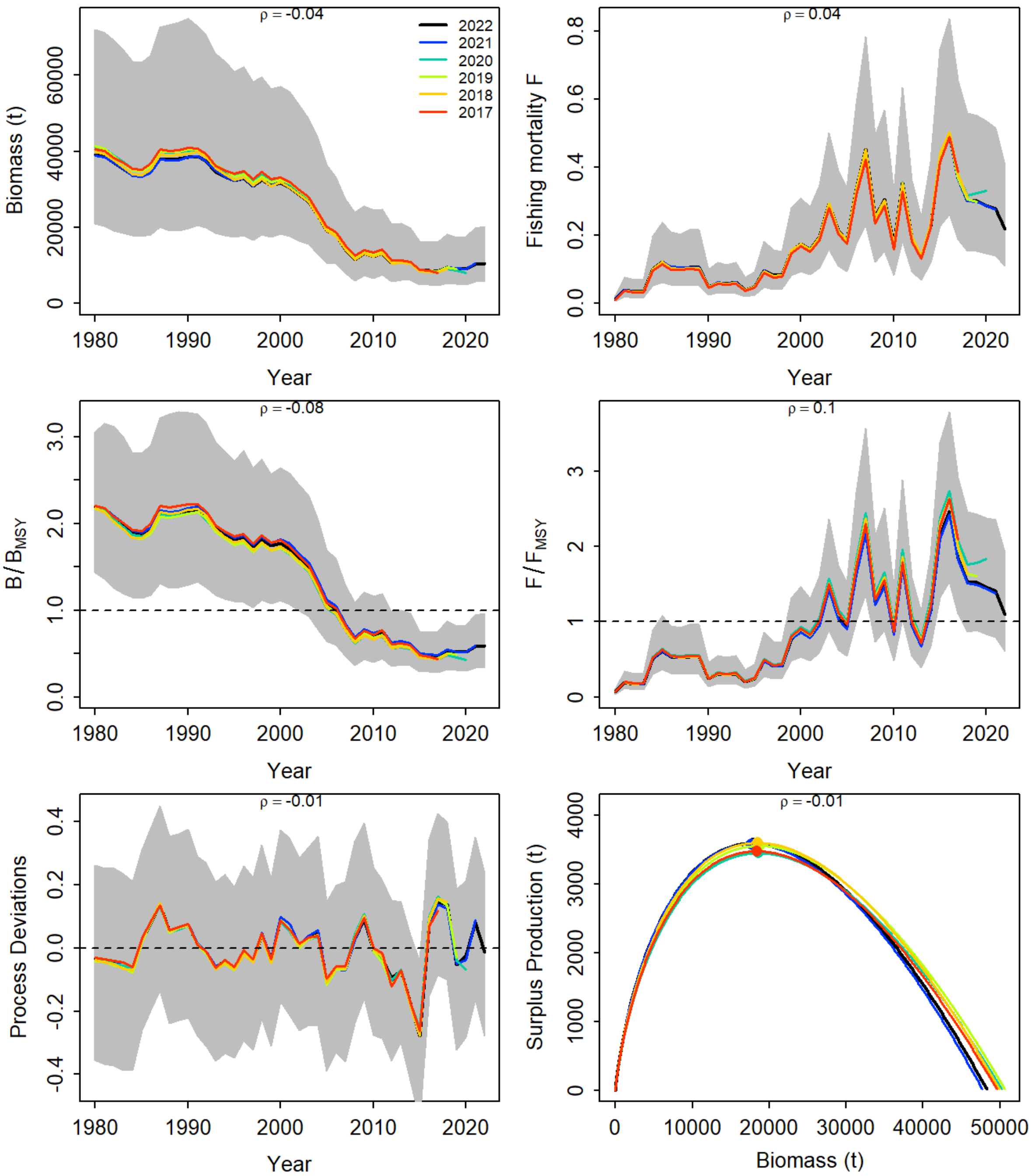


Figure 20. Retrospective analysis performed for the ALB-Med scenario S3, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.

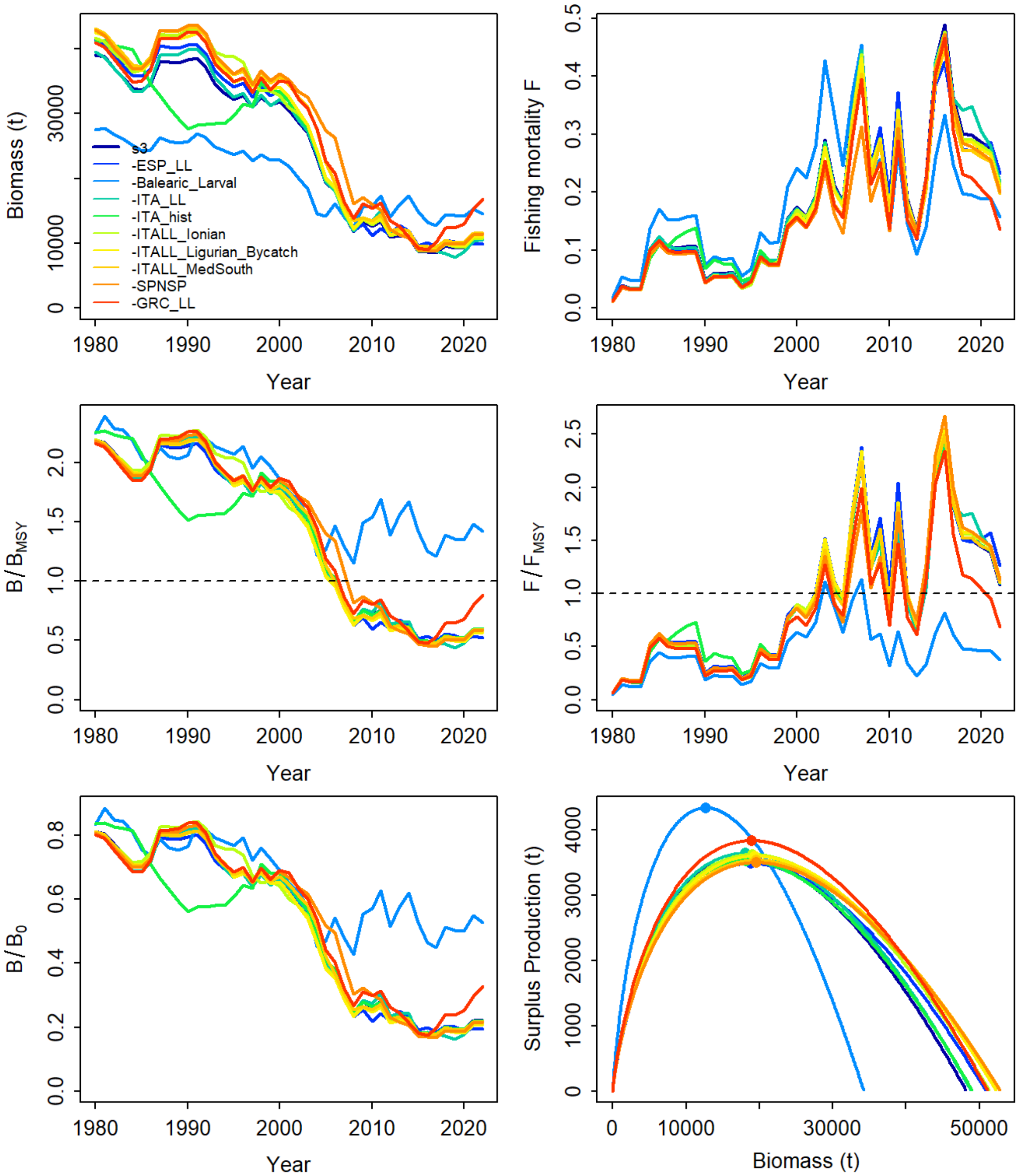


Figure 21. Jackknife index analysis performed on the ALB-Med scenario S3, by removing one index at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.

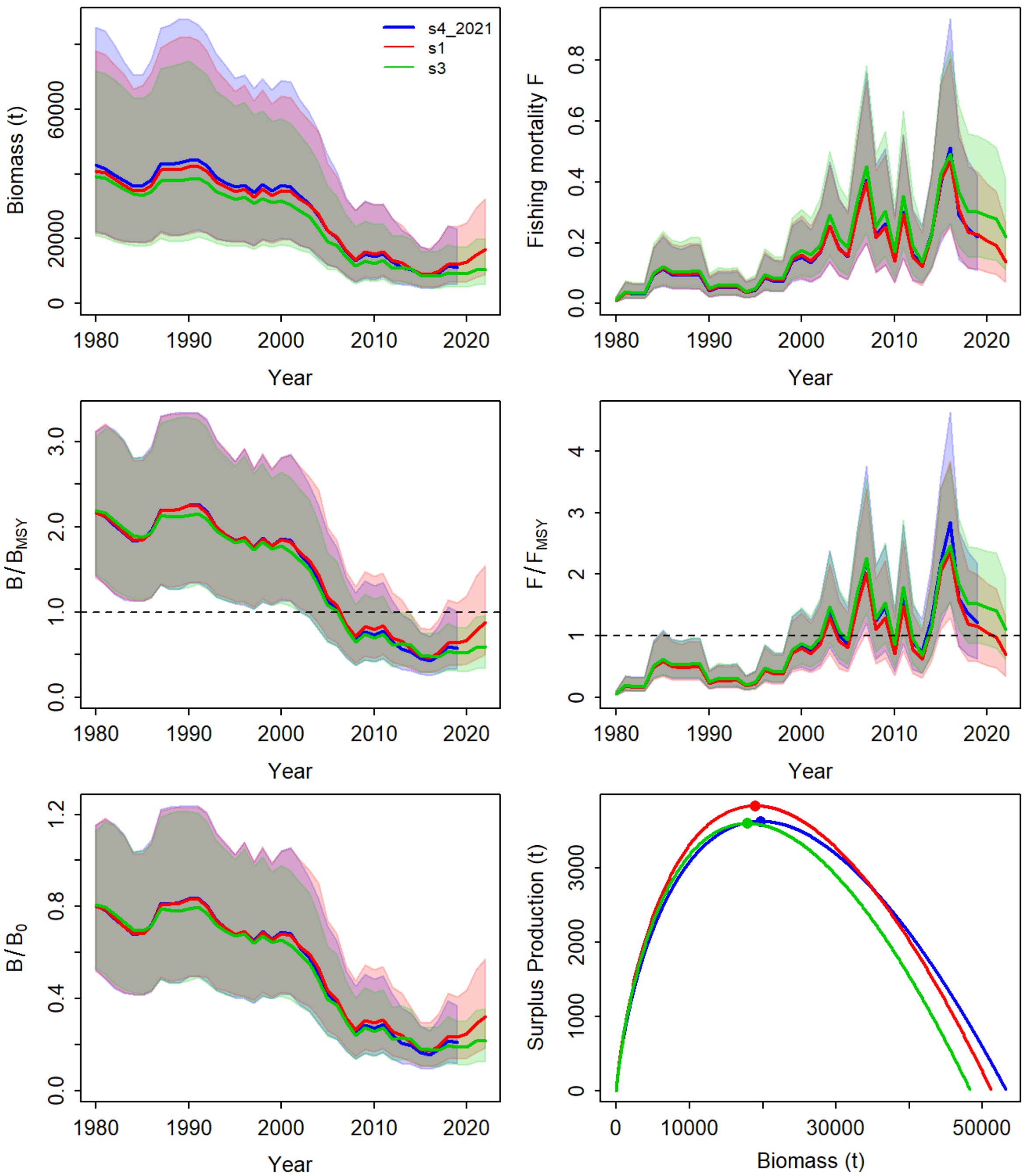


Figure 22. Comparison stock trajectory estimates for the Mediterranean albacore scenarios S1 (red line) and S3 (green line) with the 2021 stock assessment result (blue line), showing trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).

Appendix

Additional scenarios requested by the Group during the Albacore Mediterranean Data Preparatory and Stock Assessment Meeting

During the meeting held on 13-18 May 2024, 6 additional scenarios were considered by the Group. The Group considered S12 and S19 as final results during the meeting. The results of additional scenarios except S12 and S19 that can be found in the report were provided in this Appendix.

The list of additional JABBA scenarios requested by the Group. Mohn's rho values are in **Appendix Table 1** for all scenarios.

S12: Based on S3, drop 3 years from the Spanish longline index and remove the Italian longline index. Results are shown in the meeting report.

S14: Based on S12, down weight (SE=0.35) the initial 3 years from the W-Med Larval Index. Results are shown in **Appendix Figures 1-6**.

S15: Based on S12, remove the initial 3 years from the W-Med Larval Index. Results are shown in **Appendix Figures 7-12**.

S16: Based on S12, split the W-Med Larval Index into two time series. Results are shown in **Appendix Figures 13-18**.

S17: Based on S16, add the Cyprus longline index. Results are shown in **Appendix Figures 19-24**.

S18: Based on S16, changing the lower bound of the K prior parameter to 25,000 t. Results are shown in **Appendix Figures 25-30**.

S19: Based on S16, changing the lower bound of the K prior parameter to 30,000 t. Results are shown in the meeting report.

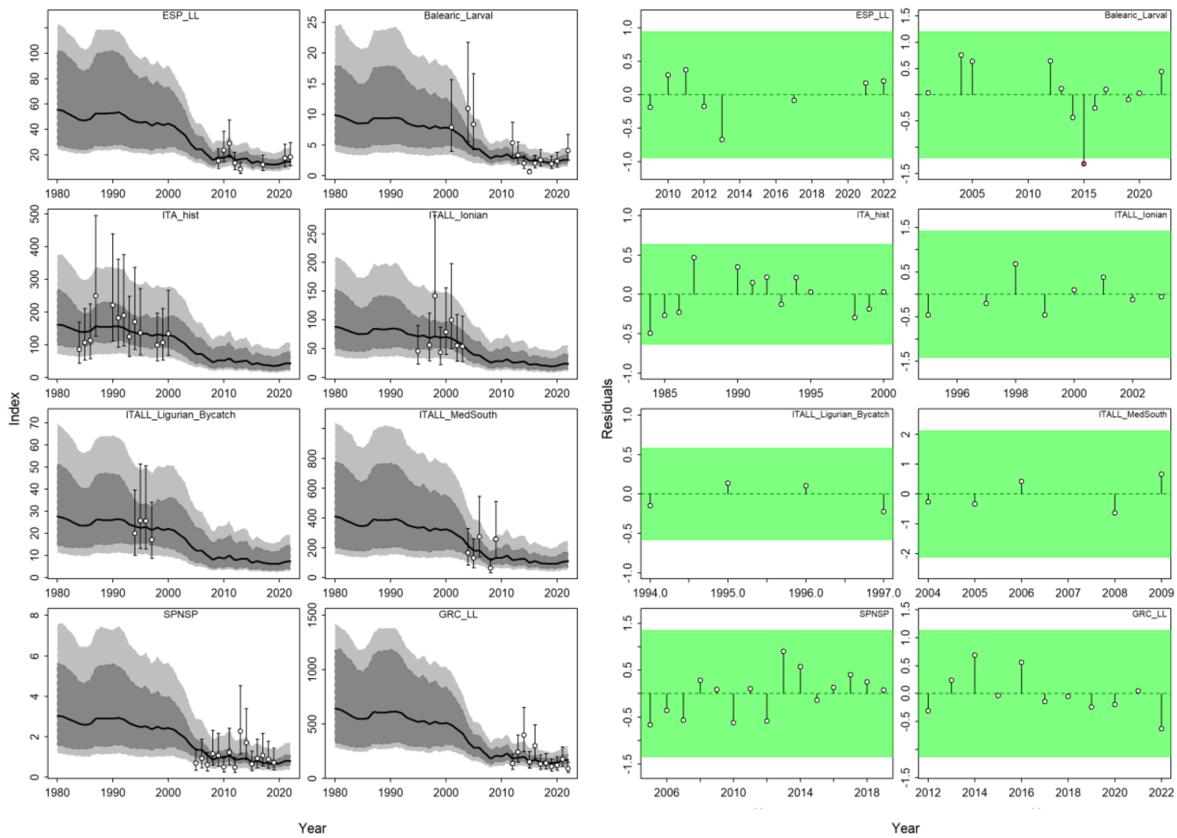
All JABBA scenarios considered in the meeting.

Base	Scenarios	Descriptions for CPUE indices (with SD) in JABBA runs
	S4_2021	2021 final JABBA model CPUEs: SPN LLALB (SD=0.25), Larval W-Med (0.25), ITA LL (0.25), SPN Tournament (0.35), ITA-Ionian LL (0.35), ITA-Ligurian LL bycatch (0.35), Med South ITALL (0.35), South Adriatic ITALL (0.35)
S4_2021	S0	2011 final run (S4_2021) (i.e. maintain the 2021 CPUEs) + update 2024 catch data
S0	S1	S0 + rev SPN LLALB (0.25) + Larval W-Med (0.25)
S1	S3	S0 + rev SPN LLALB (0.25) + Larval W-Med (0.25) + GRC LLALB (0.25)
S3	S12	S0 + rev SPN LLALB (0.25) + Larval W-Med (0.25) - ITA LL (2021) + GRC LLALB (0.25)
S12	S14	S0 + rev SPN LLALB (0.25) + Larval W-Med (0.25)(early 3 points, SE0.35) - ITA LL (2021) + GRC LLALB (0.25)
S4	S15	S0 + rev SPN LLALB (0.25) + Larval W-Med (0.25)(no early 3 points) - ITA LL (2021) + GRC LLALB (0.25)
S4	S16	S0 + rev SPN LLALB (0.25) + Split Larval W-Med (0.25) - ITA LL (2021) + GRC LLALB (0.25)
S11	S17	S0 + rev SPN LLALB (0.25) + Split Larval W-Med (0.25) - ITA LL (2021) + GRC LLALB (0.25) +CYPLL (0.25)
S16	S18	S16 + lower limit 25000 in K bounds
S16	S19	S16 + lower limit 30000 in K bounds

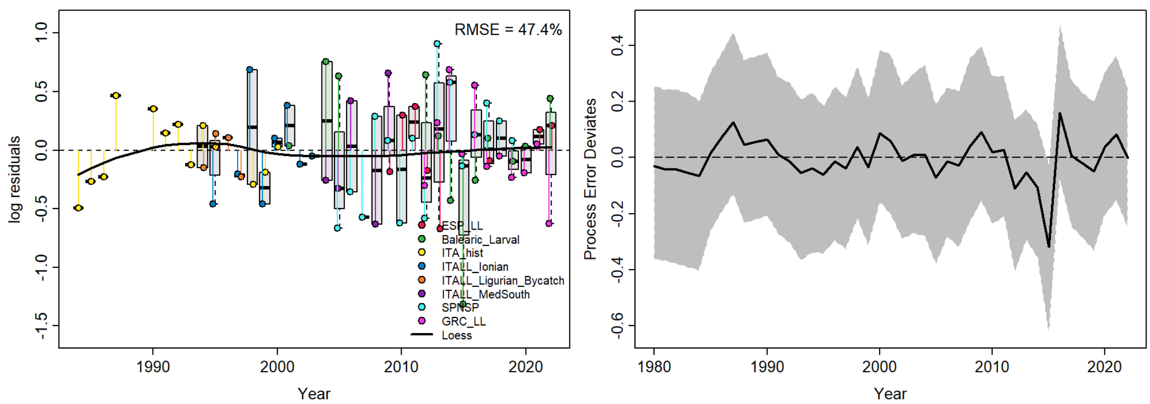
Appendix Table 1.

Mohn's rho for the JABBA scenarios considered by the Group

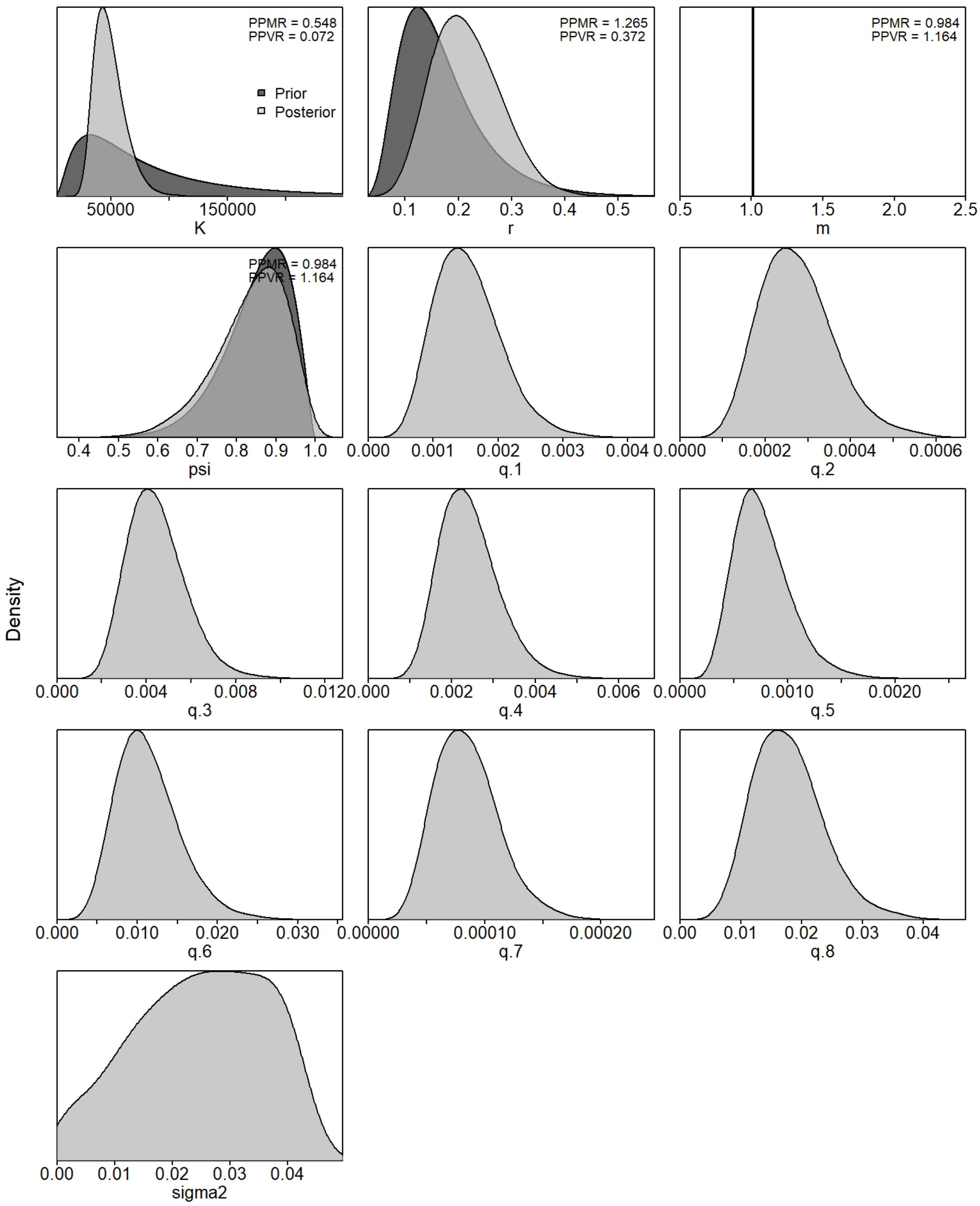
	Stock Quantity					
Scenario	*B*	*F*	B/B_{MSY}	F/F_{MSY}	*B*/*K*	MSY
S1	-0.037	0.045	-0.015	0.083	-0.015	-0.038
S3	-0.039	0.042	-0.076	0.100	-0.007	-0.014
S12	-0.079	0.097	-0.107	0.154	0.007	-0.017
S14	-0.057	0.067	-0.087	0.117	0.005	-0.020
S15	-0.104	0.111	-0.211	0.397	0.005	-0.065
S16	-0.095	0.103	0.138	-0.175	-0.006	0.104
S17	-0.097	0.103	-0.136	0.298	0.003	0.009
S18	-0.096	0.101	-0.134	0.214	0.005	-0.050
S19	-0.098	0.108	-0.087	0.130	0.006	-0.021



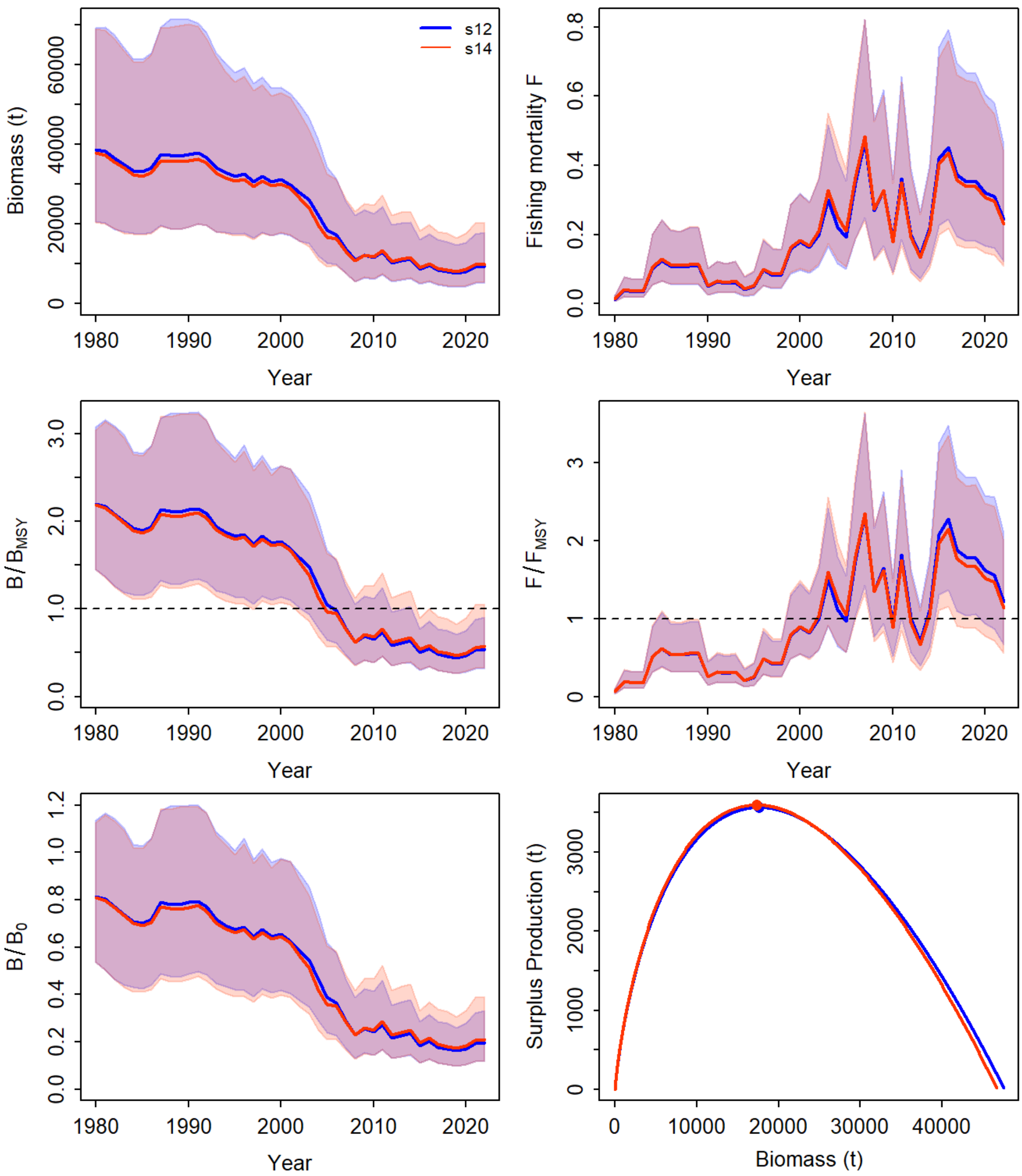
Appendix Figure 1. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line) CPUE (left) and Runs tests to quantitatively evaluate the randomness of the time series of index residuals (right) for the ALB-Med scenario S14 with 2024 catch and indices including Greek longline CPUE. On the left panel, the dark-shaded grey areas show 95% credibility intervals of the expected mean CPUE and light-shaded grey areas denote the 95% posterior predictive distribution intervals. On the right panel, green areas 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 (3- sigma rule).



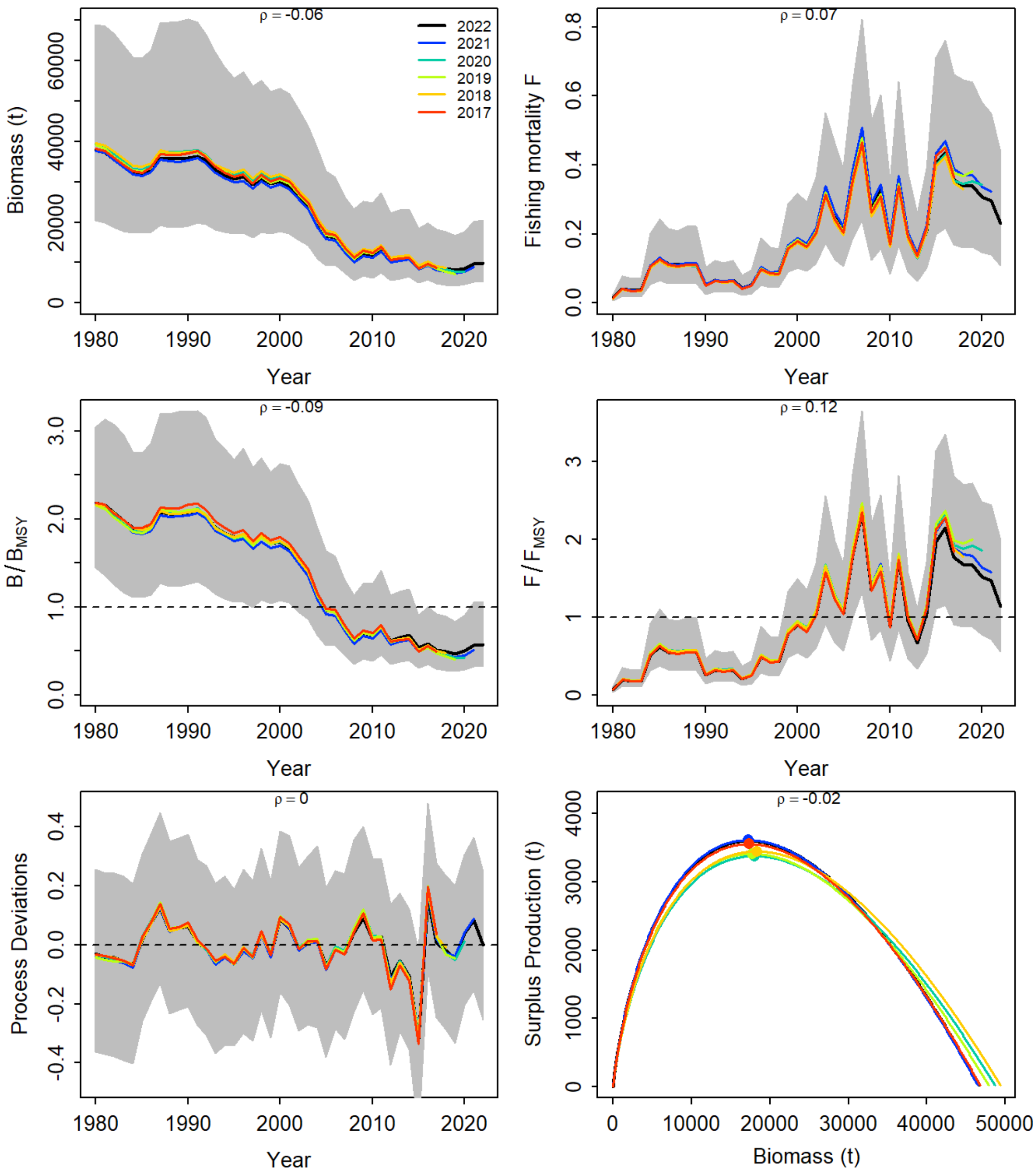
Appendix Figure 2. JABBA residual diagnostic plots of relative abundance indices (left panel) and process error deviation (right panel) for the ALB-Med scenario S14. Left panel: Boxplots indicating the median and quantiles of all residuals available for any given year, and solid black lines indicate loess smoother through all residuals. Right panel: Process error deviation (median: solid line) with a shaded grey area indicating 95% credibility intervals.



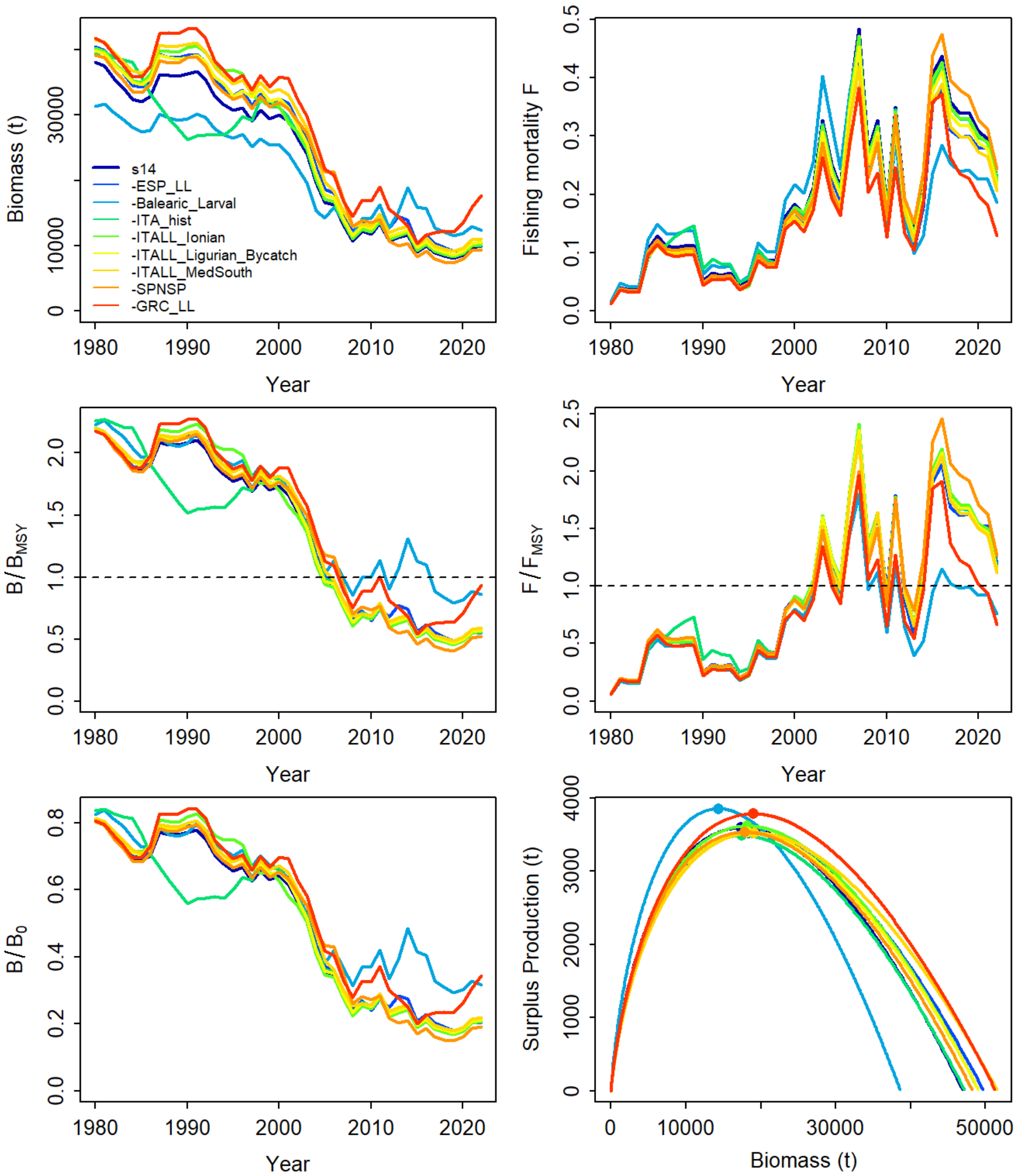
Appendix Figure 3. Prior and posterior distributions of various model and management parameters for the scenario S14 model for Mediterranean albacore. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.



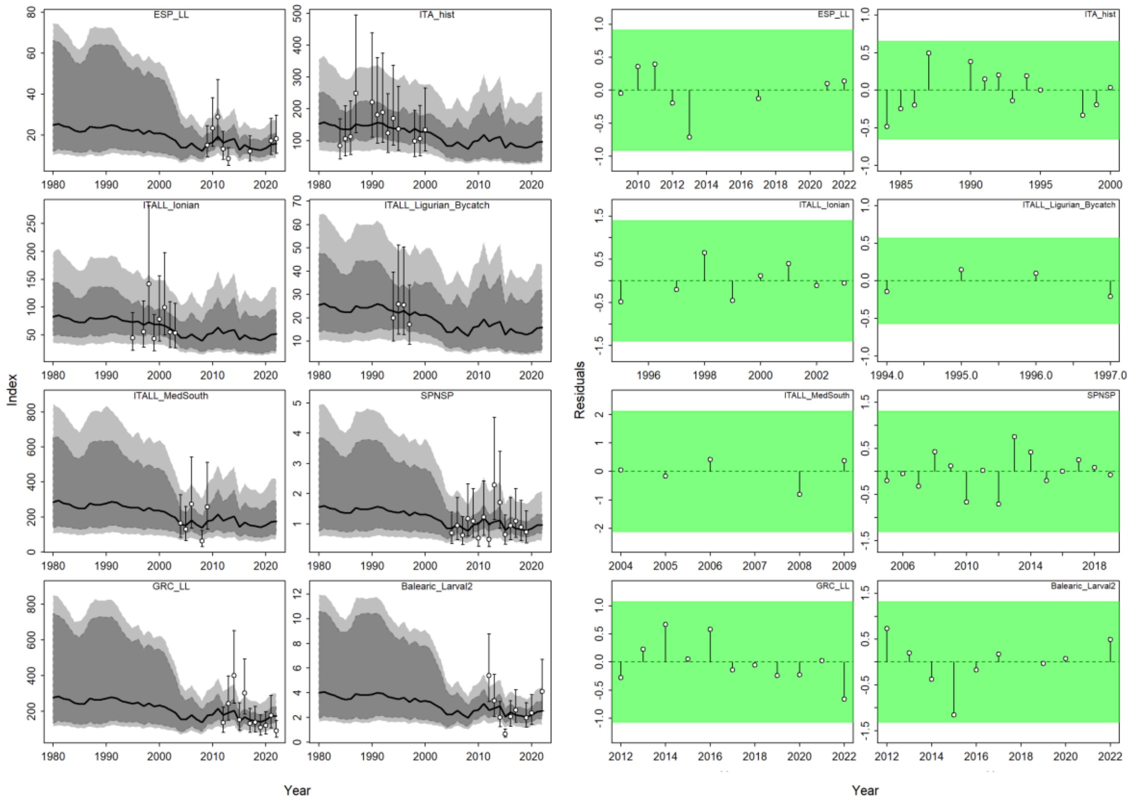
Appendix Figure 4. Comparison stock trajectory estimates for the Mediterranean albacore scenarios S12 and S14, showing trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).



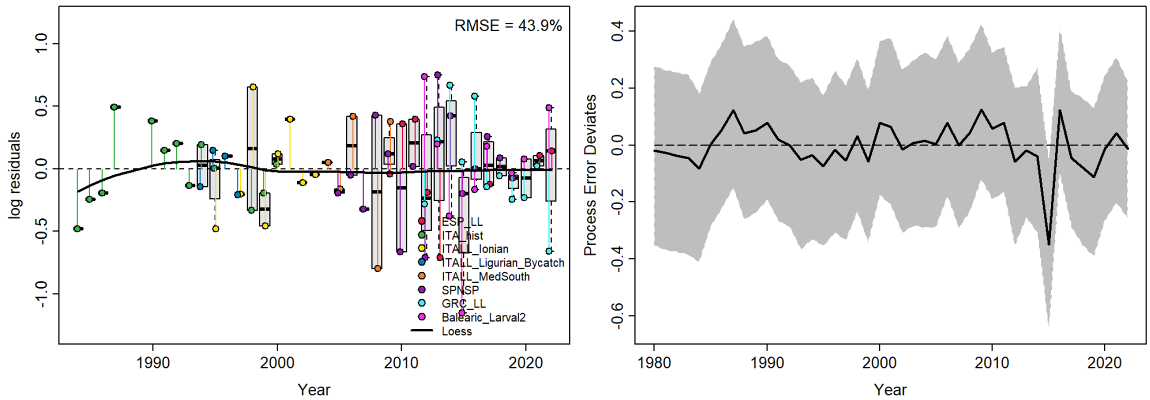
Appendix Figure 5. Retrospective analysis performed for the ALB-Med scenario S14, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.



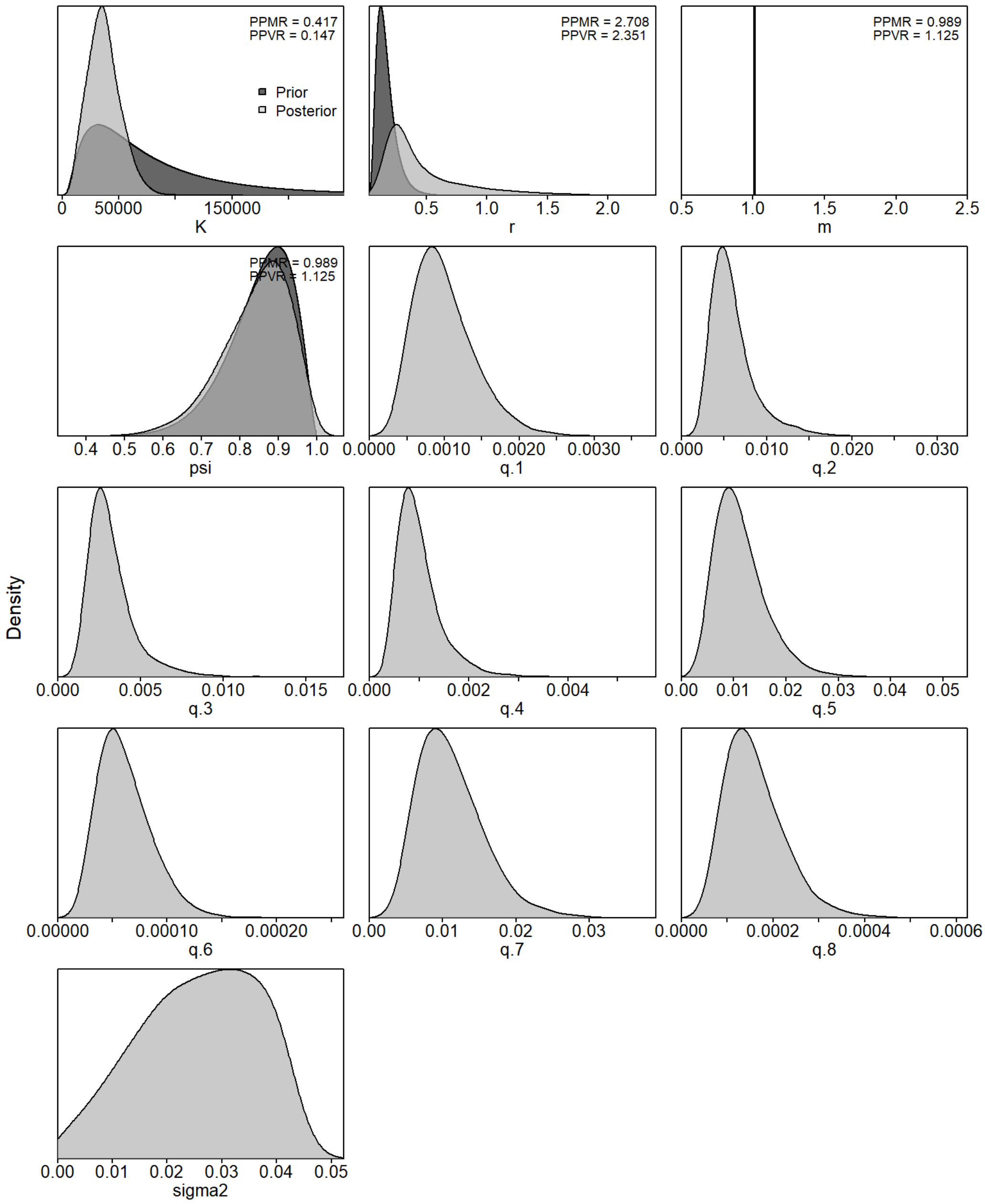
Appendix Figure 6. Jackknife index analysis performed on the ALB-Med scenario S14, by removing one index at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.



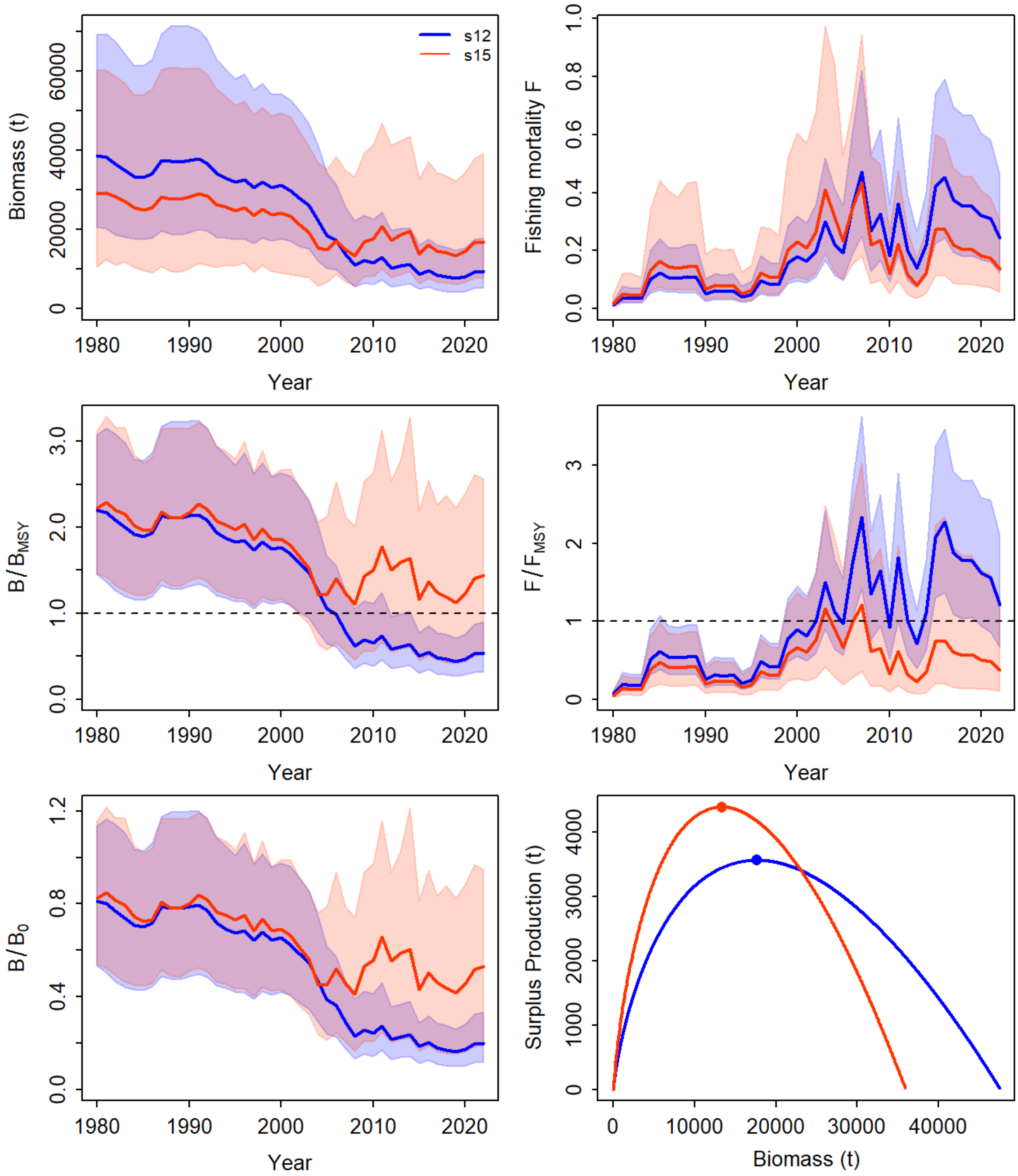
Appendix Figure 7. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line) CPUE (left) and Runs tests to quantitatively evaluate the randomness of the time series of index residuals (right) for the ALB-Med scenario S15 with 2024 catch and indices including Greek longline CPUE. On the left panel, the dark-shaded grey areas show 95% credibility intervals of the expected mean CPUE and light-shaded grey areas denote the 95% posterior predictive distribution intervals. On the right panel, green areas 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 (3- sigma rule).



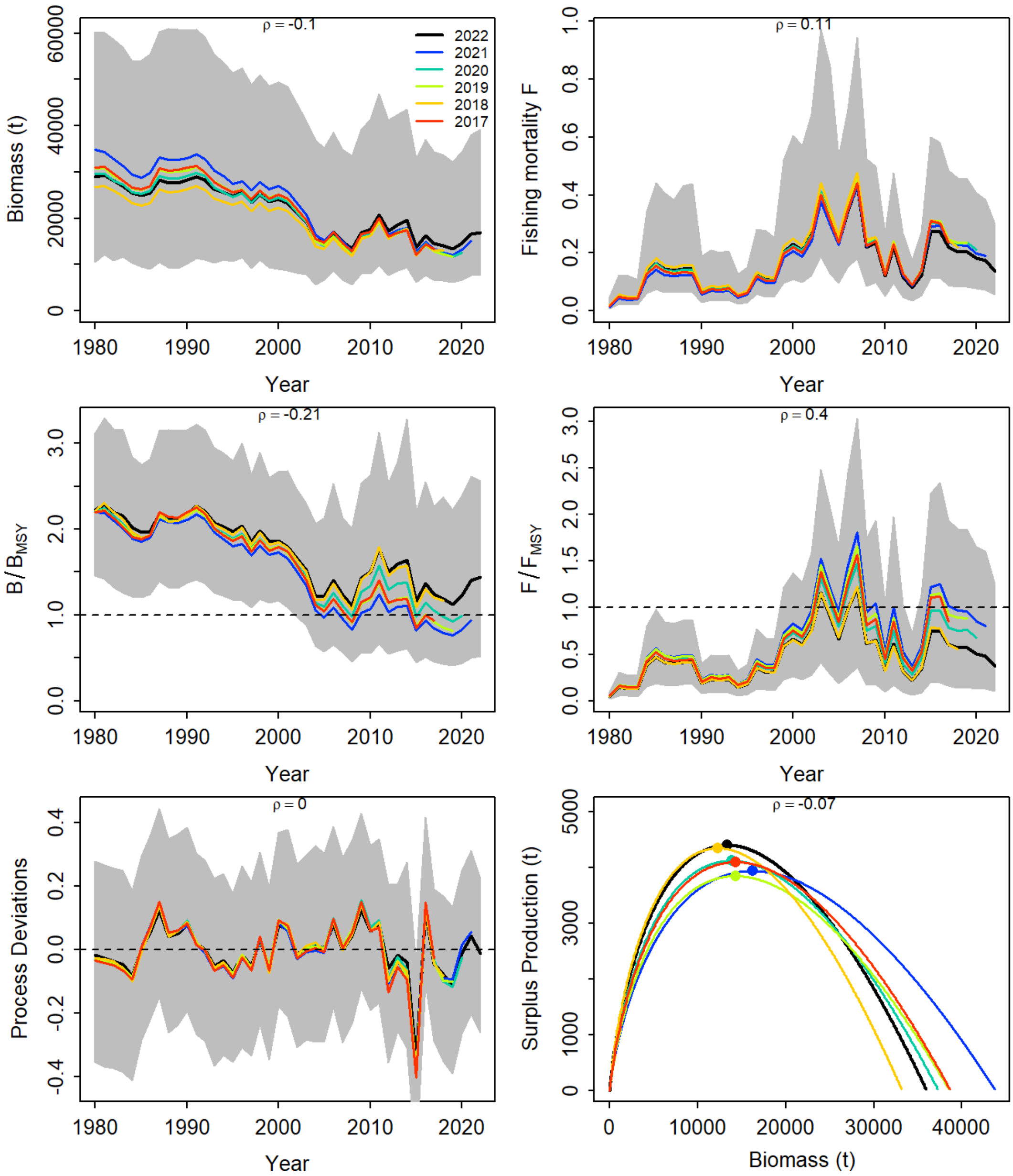
Appendix Figure 8. JABBA residual diagnostic plots of relative abundance indices (left panel) and process error deviation (right panel) for the ALB-Med scenario S15. Left panel: Boxplots indicating the median and quantiles of all residuals available for any given year, and solid black lines indicate loess smoother through all residuals. Right panel: Process error deviation (median: solid line) with a shaded grey area indicating 95% credibility intervals.



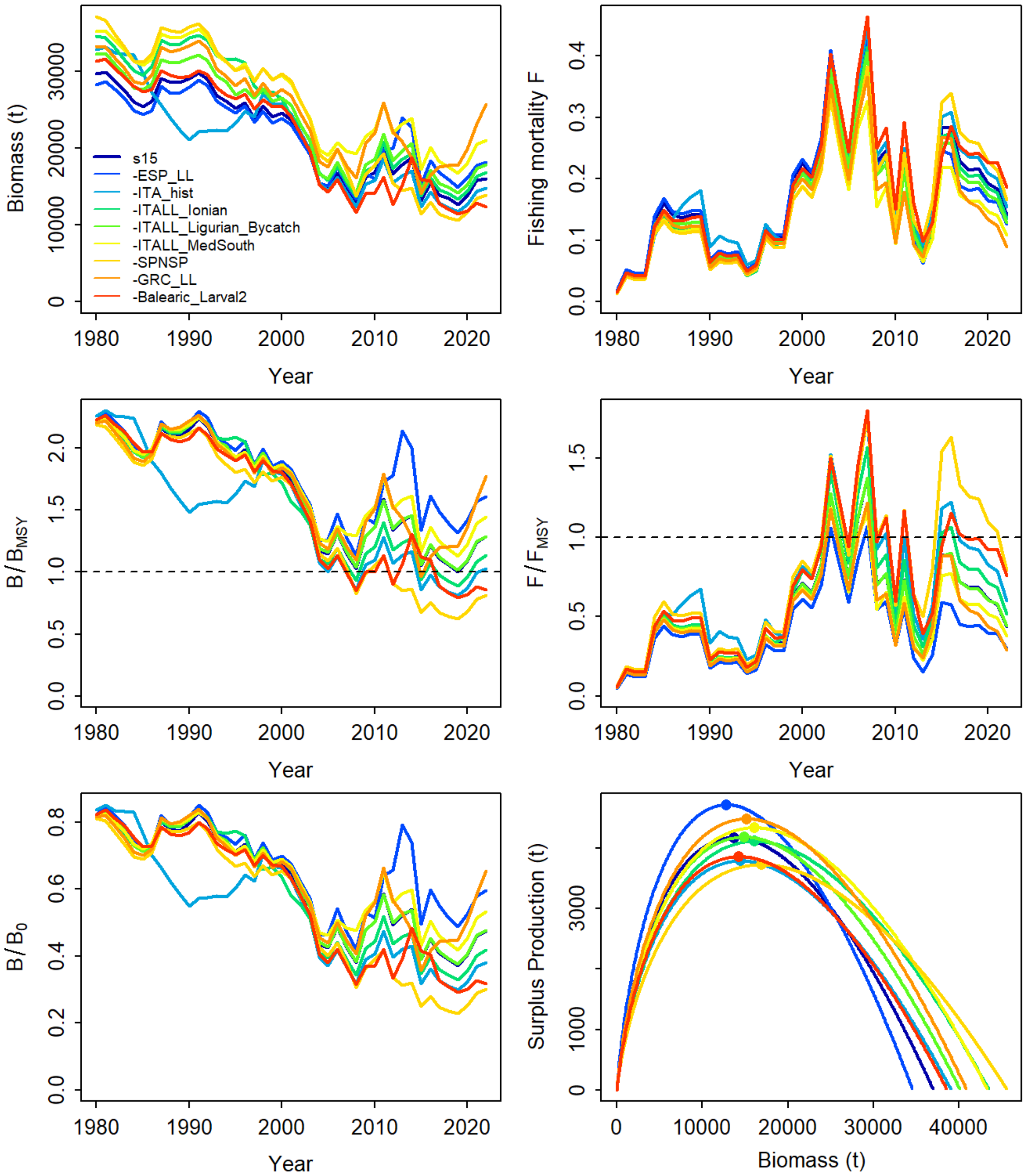
Appendix Figure 9. Prior and posterior distributions of various model and management parameters for the scenario S15 model for Mediterranean albacore. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.



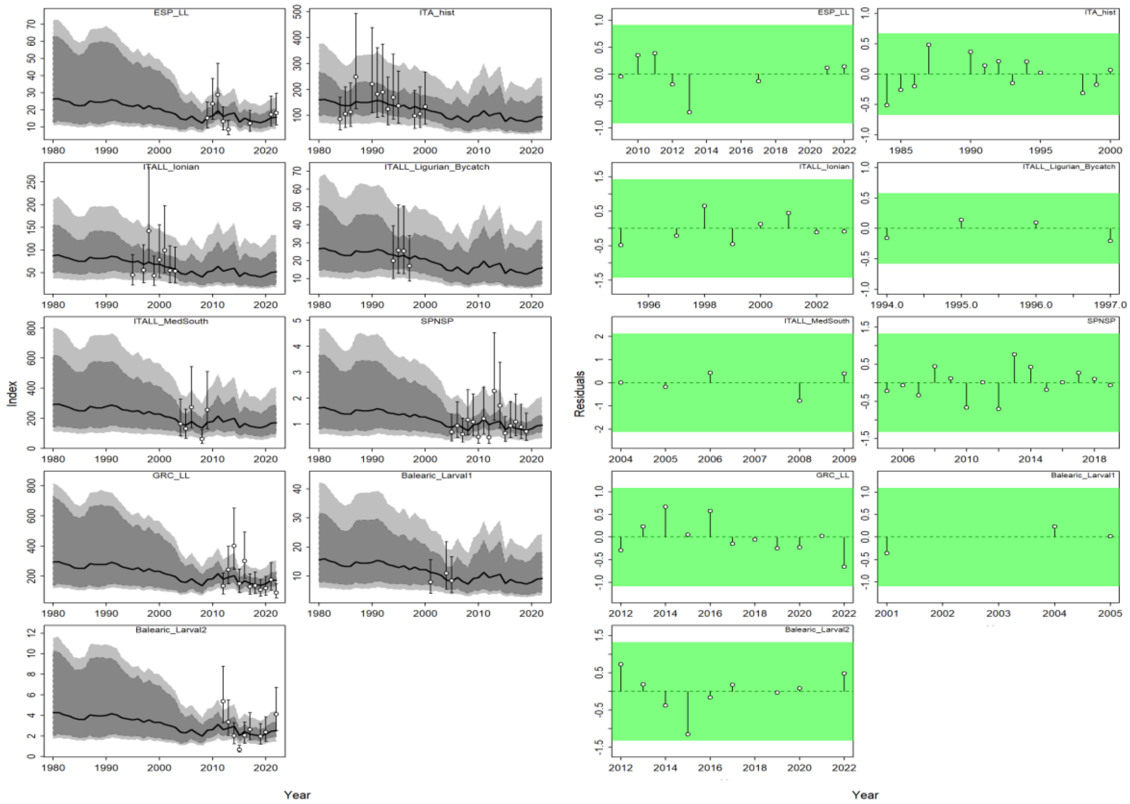
Appendix Figure 10. Comparison stock trajectory estimates for the Mediterranean albacore scenarios S12 and S15, showing trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).



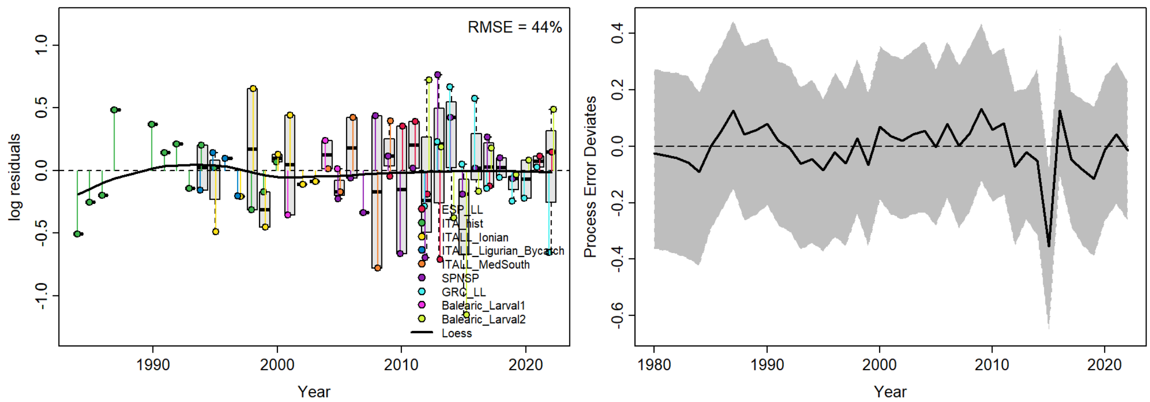
Appendix Figure 11. Retrospective analysis performed for the ALB-Med scenario S15, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.



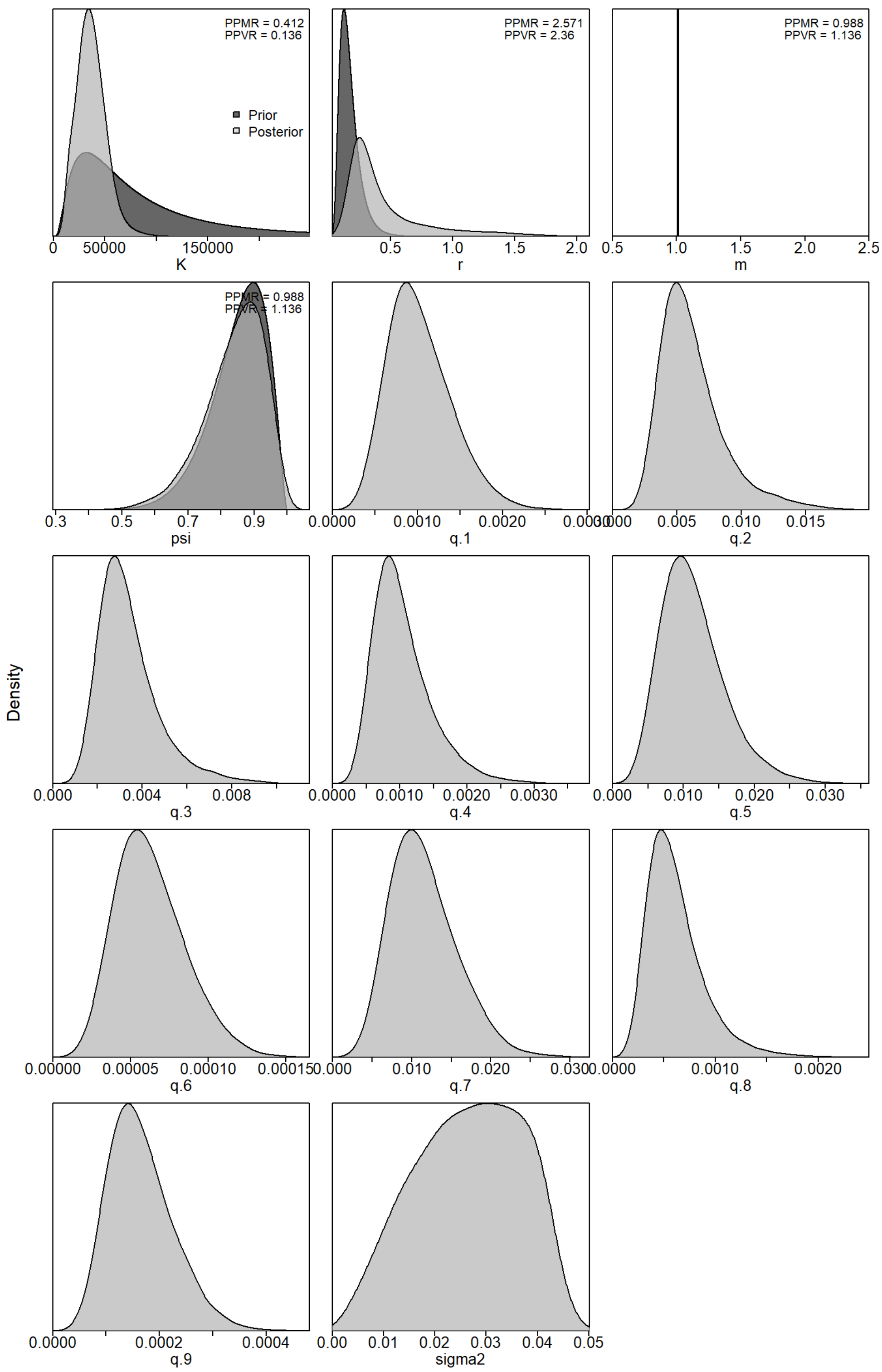
Appendix Figure 12. Jackknife index analysis performed on the ALB-Med scenario S15, by removing one index at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.



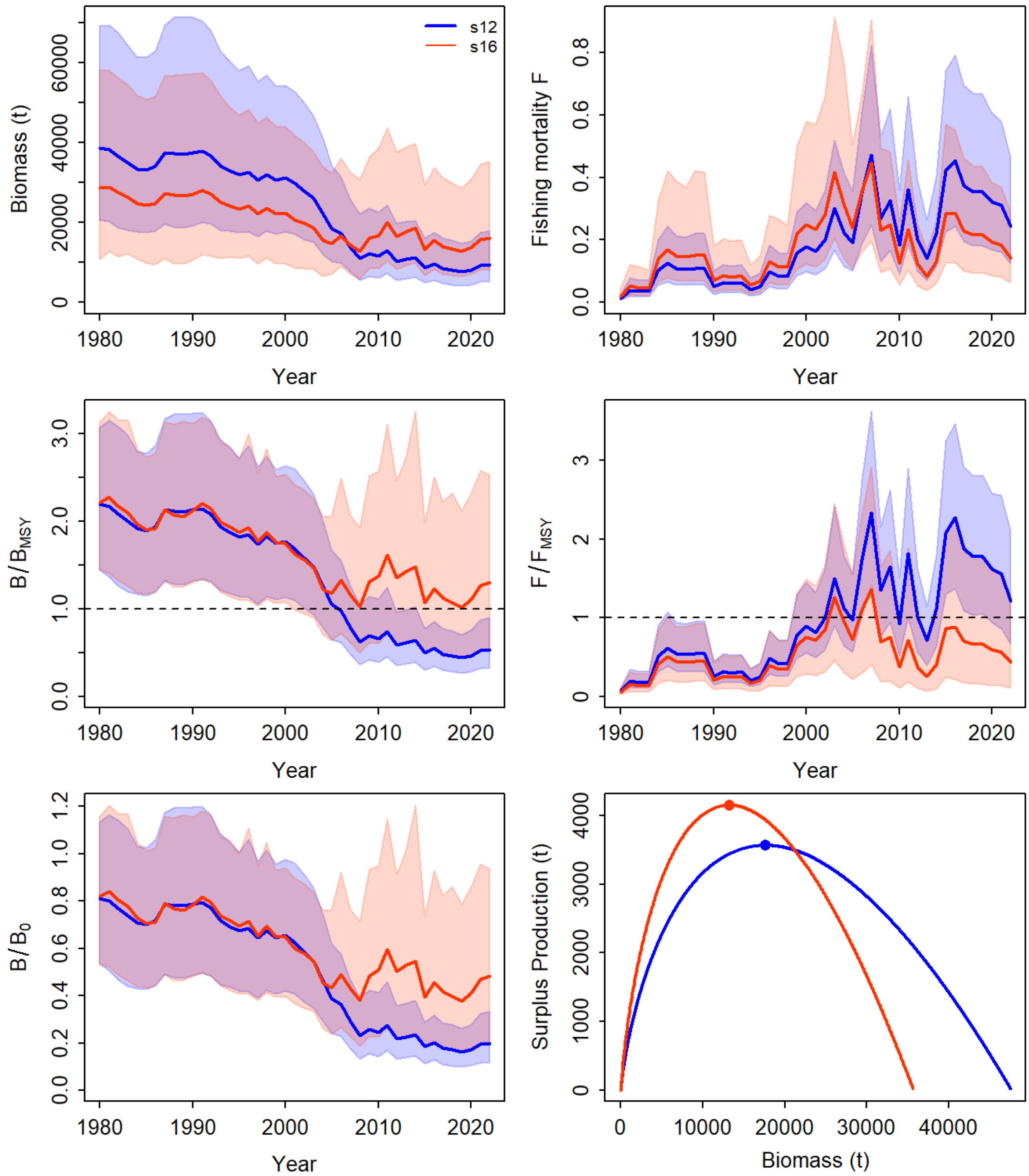
Appendix Figure 13. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line) CPUE (left) and Runs tests to quantitatively evaluate the randomness of the time series of index residuals (right) for the ALB-Med scenario S16 with 2024 catch and indices including Greek longline CPUE. On the left panel, the dark-shaded grey areas show 95% credibility intervals of the expected mean CPUE and light-shaded grey areas denote the 95% posterior predictive distribution intervals. On the right panel, green areas 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 (3- sigma rule).



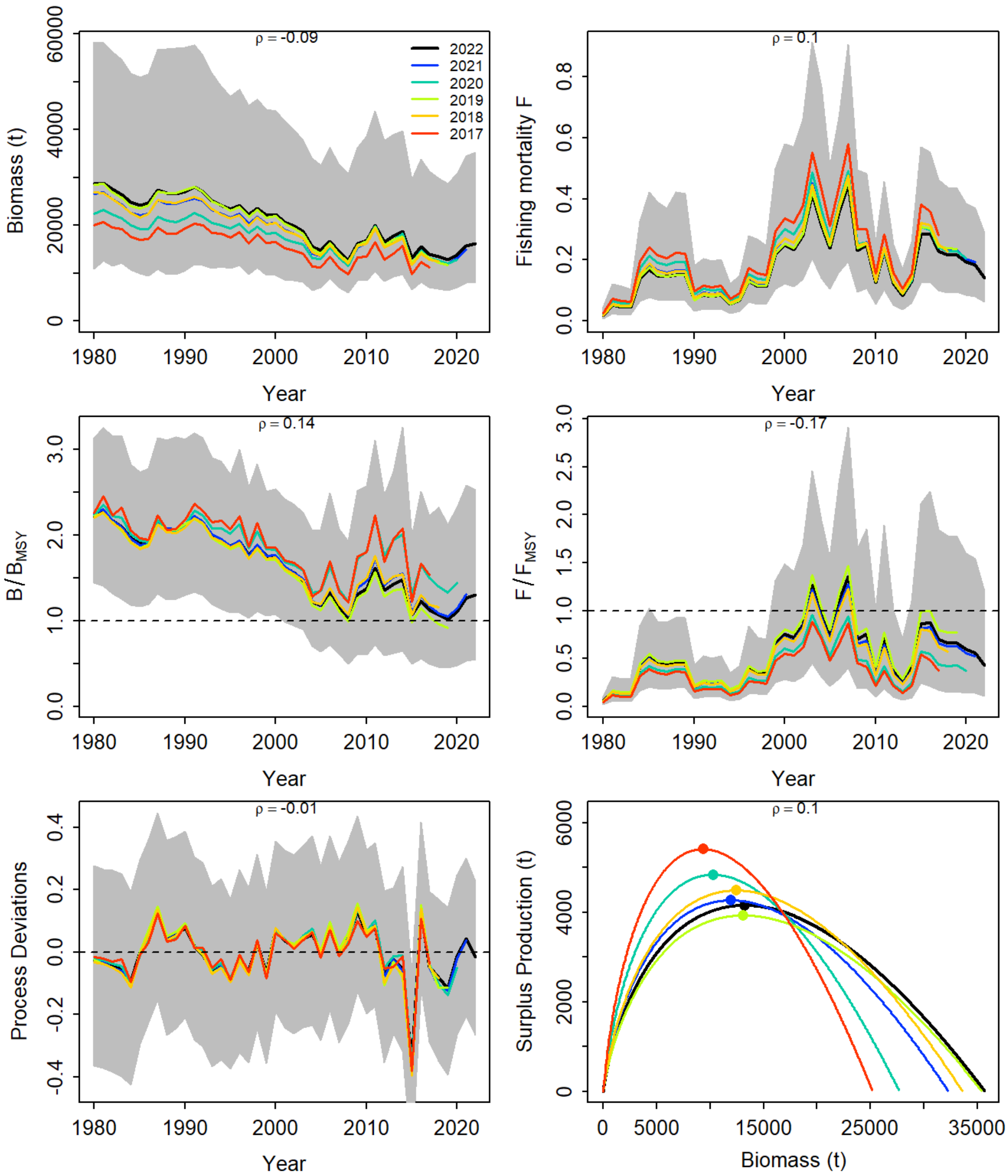
Appendix Figure 14. JABBA residual diagnostic plots of relative abundance indices (left panel) and process error deviation (right panel) for the ALB-Med scenario S16. Left panel: Boxplots indicating the median and quantiles of all residuals available for any given year, and solid black lines indicate loess smoother through all residuals. Right panel: Process error deviation (median: solid line) with a shaded grey area indicating 95% credibility intervals.



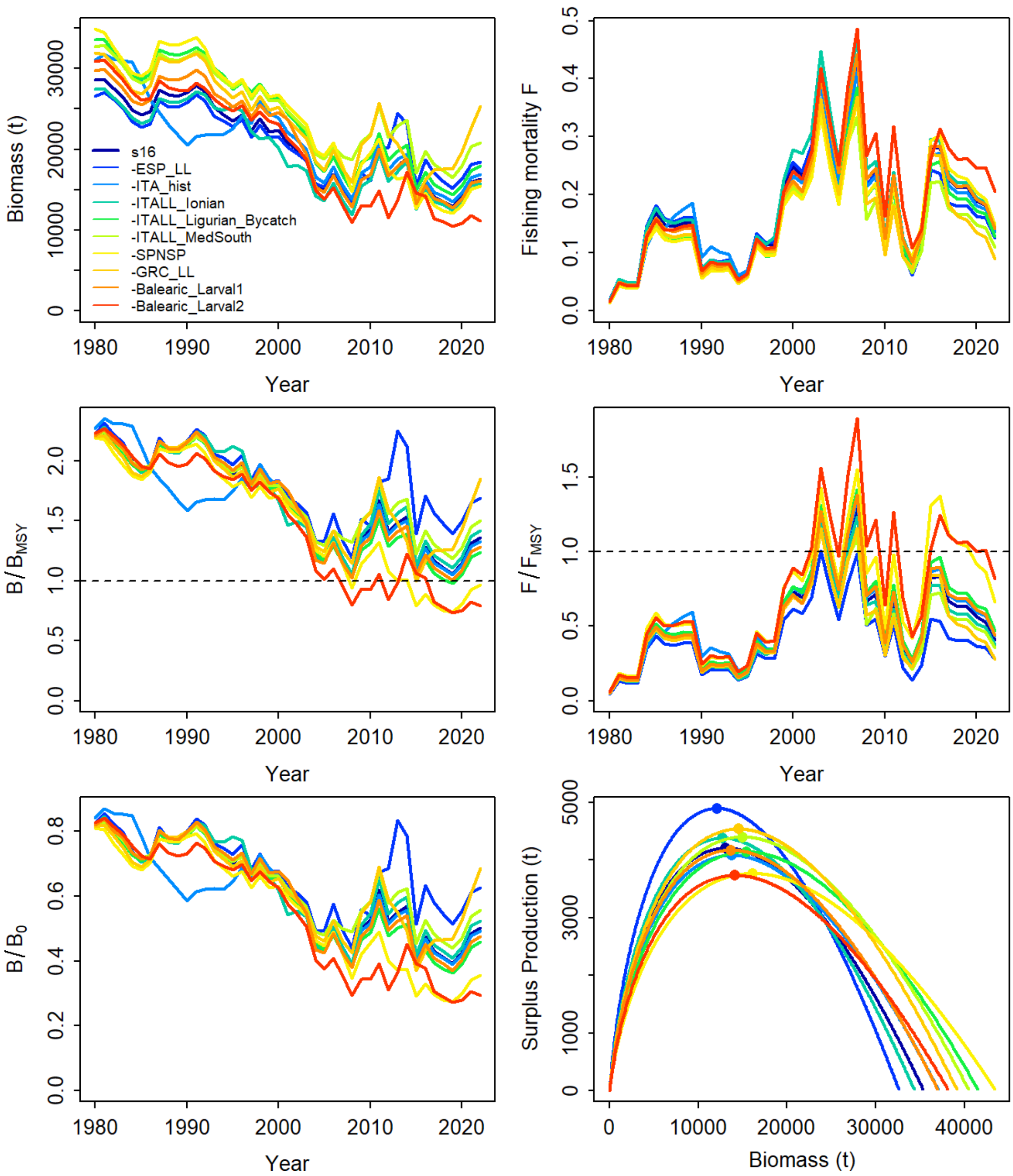
Appendix Figure 15. Prior and posterior distributions of various model and management parameters for the scenario S16 model for Mediterranean albacore. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.



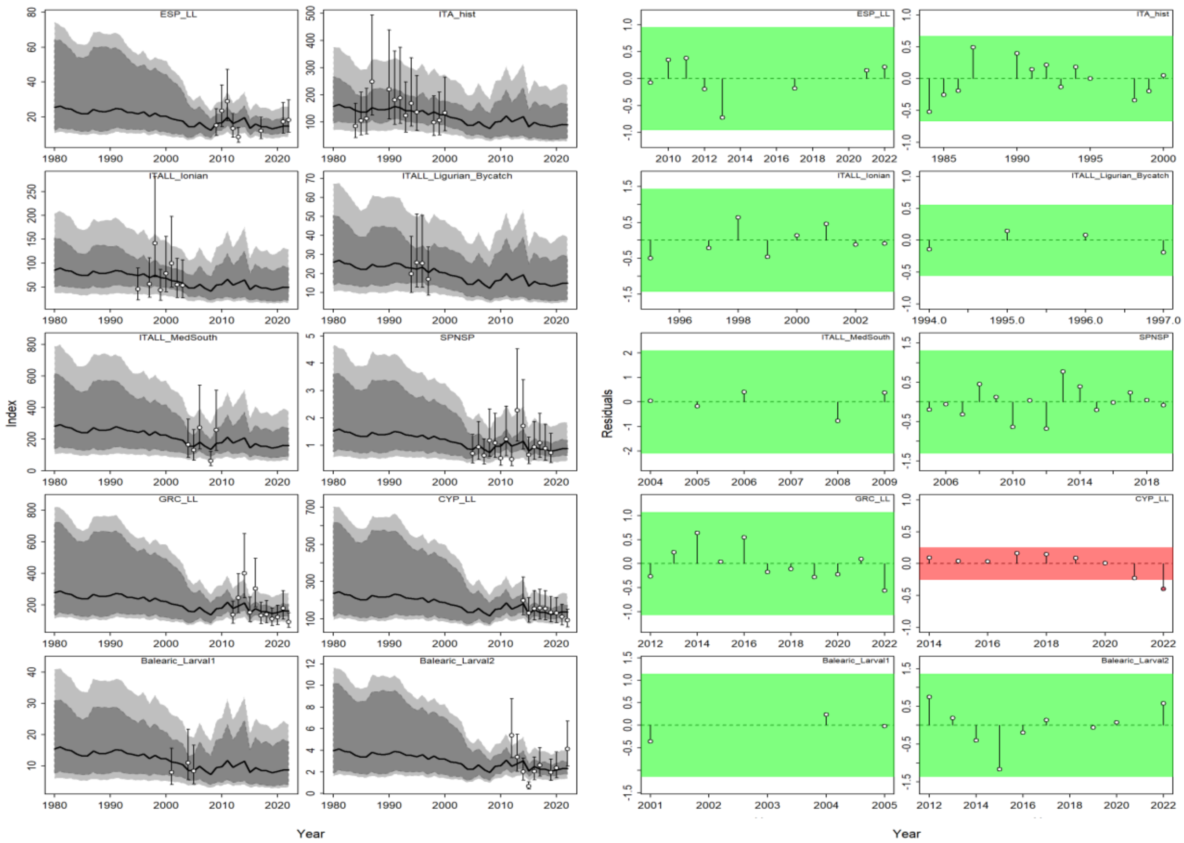
Appendix Figure 16. Comparison stock trajectory estimates for the Mediterranean albacore scenarios S12 and S16, showing trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).



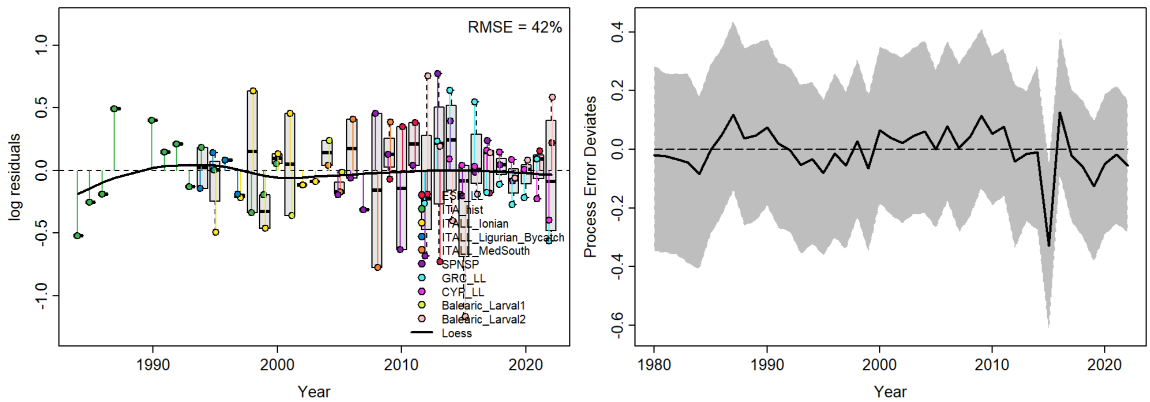
Appendix Figure 17. Retrospective analysis performed for the ALB-Med scenario S16, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.



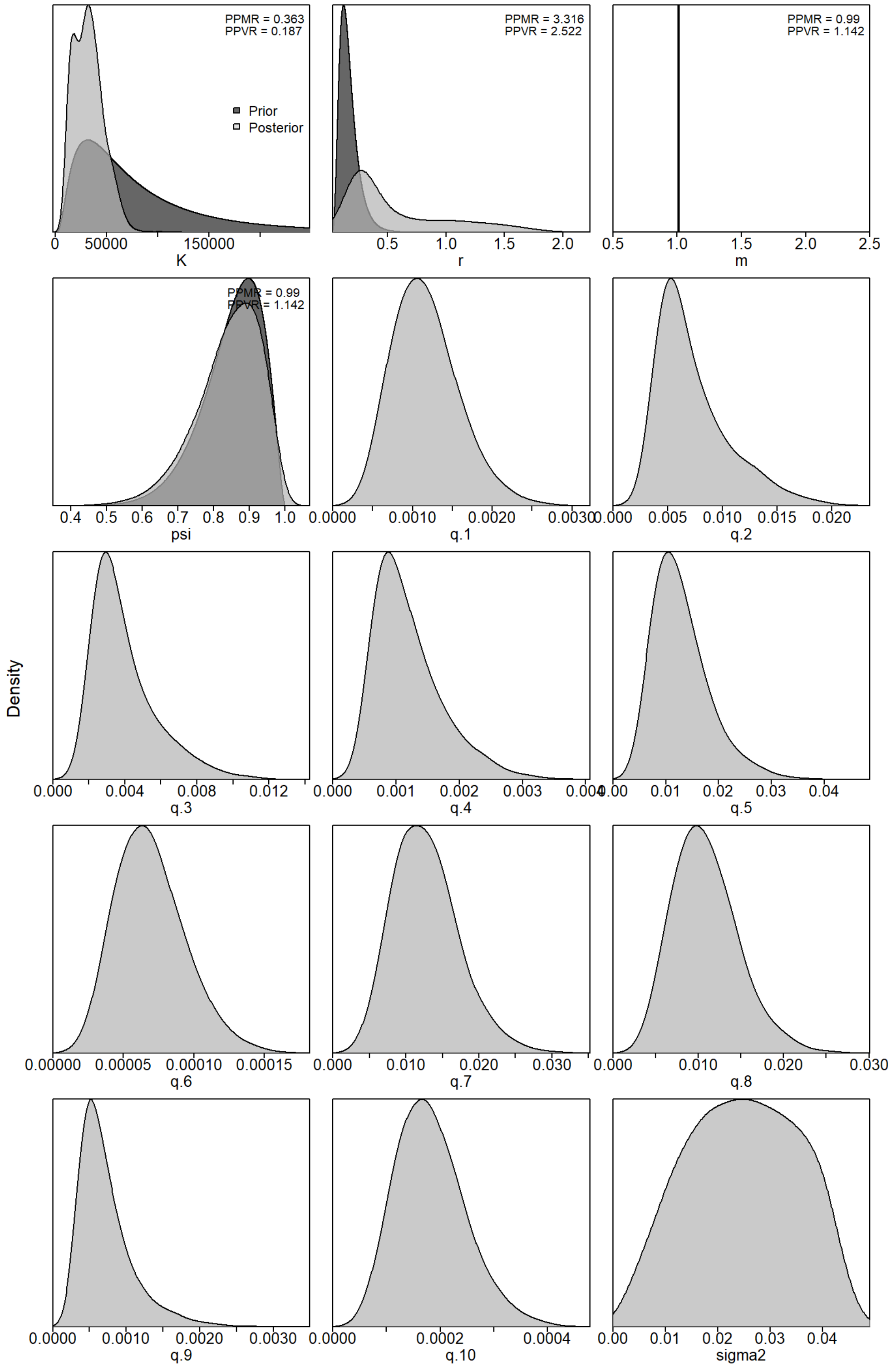
Appendix Figure 18. Jackknife index analysis performed on the ALB-Med scenario S16, by removing one index at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.



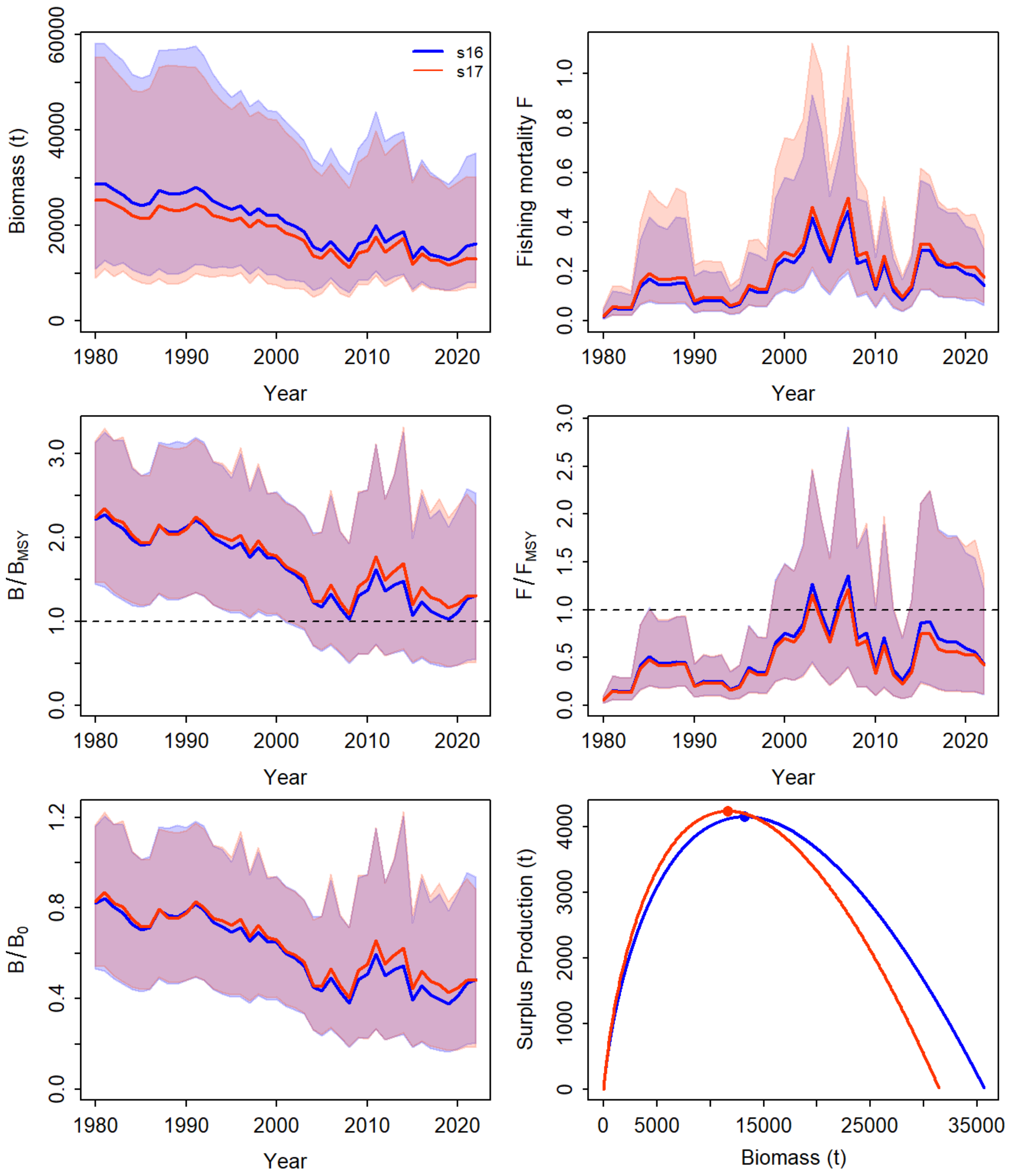
Appendix Figure 19. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line) CPUE (left) and Runs tests to quantitatively evaluate the randomness of the time series of index residuals (right) for the ALB-Med scenario S17 with 2024 catch and indices including Greek longline CPUE. On the left panel, the dark-shaded grey areas show 95% credibility intervals of the expected mean CPUE and light-shaded grey areas denote the 95% posterior predictive distribution intervals. On the right panel, green areas 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 (3- sigma rule).



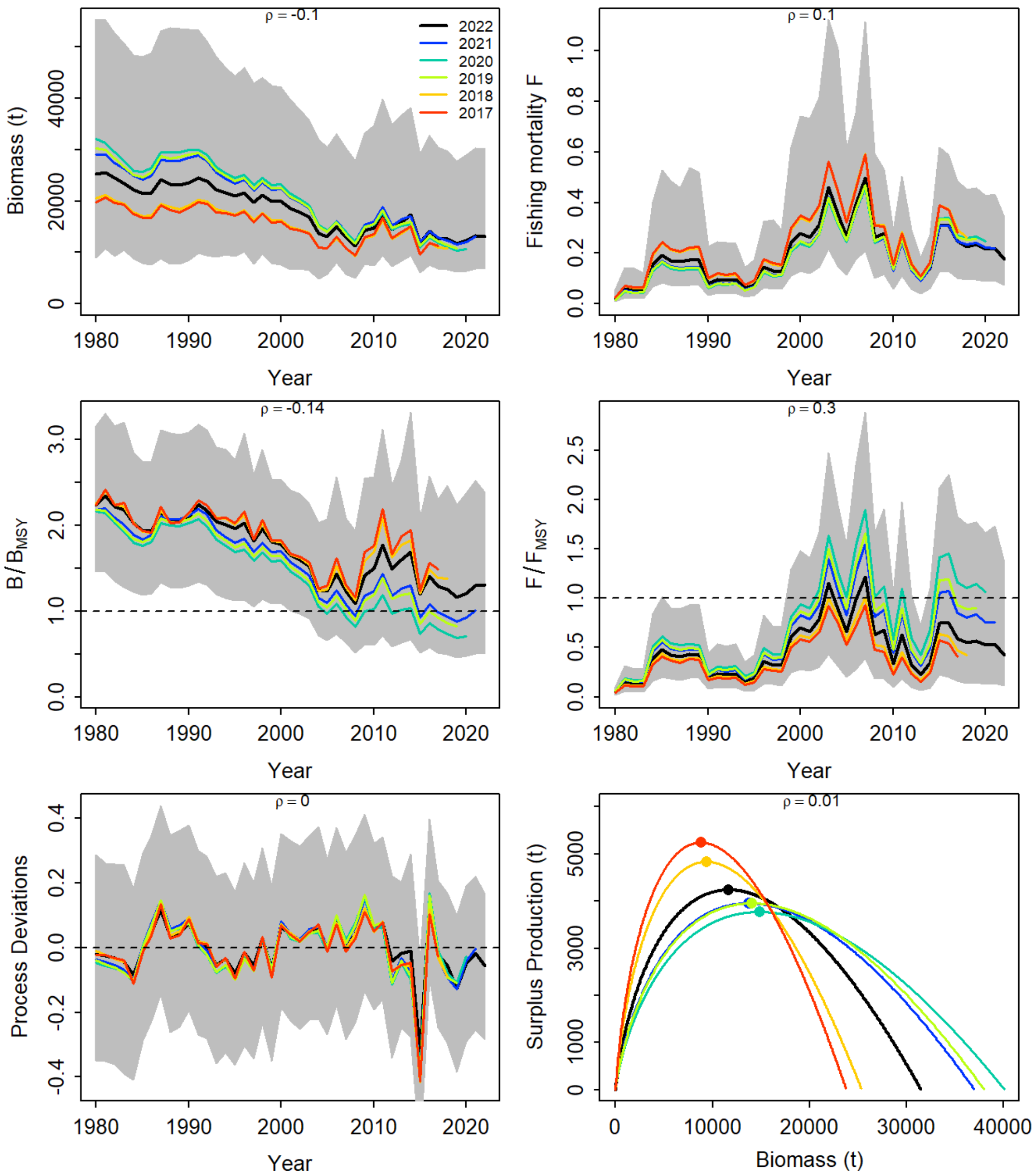
Appendix Figure 20. JABBA residual diagnostic plots of relative abundance indices (left panel) and process error deviation (right panel) for the ALB-Med scenario S17. Left panel: Boxplots indicating the median and quantiles of all residuals available for any given year, and solid black lines indicate loess smoother through all residuals. Right panel: Process error deviation (median: solid line) with a shaded grey area indicating 95% credibility intervals.



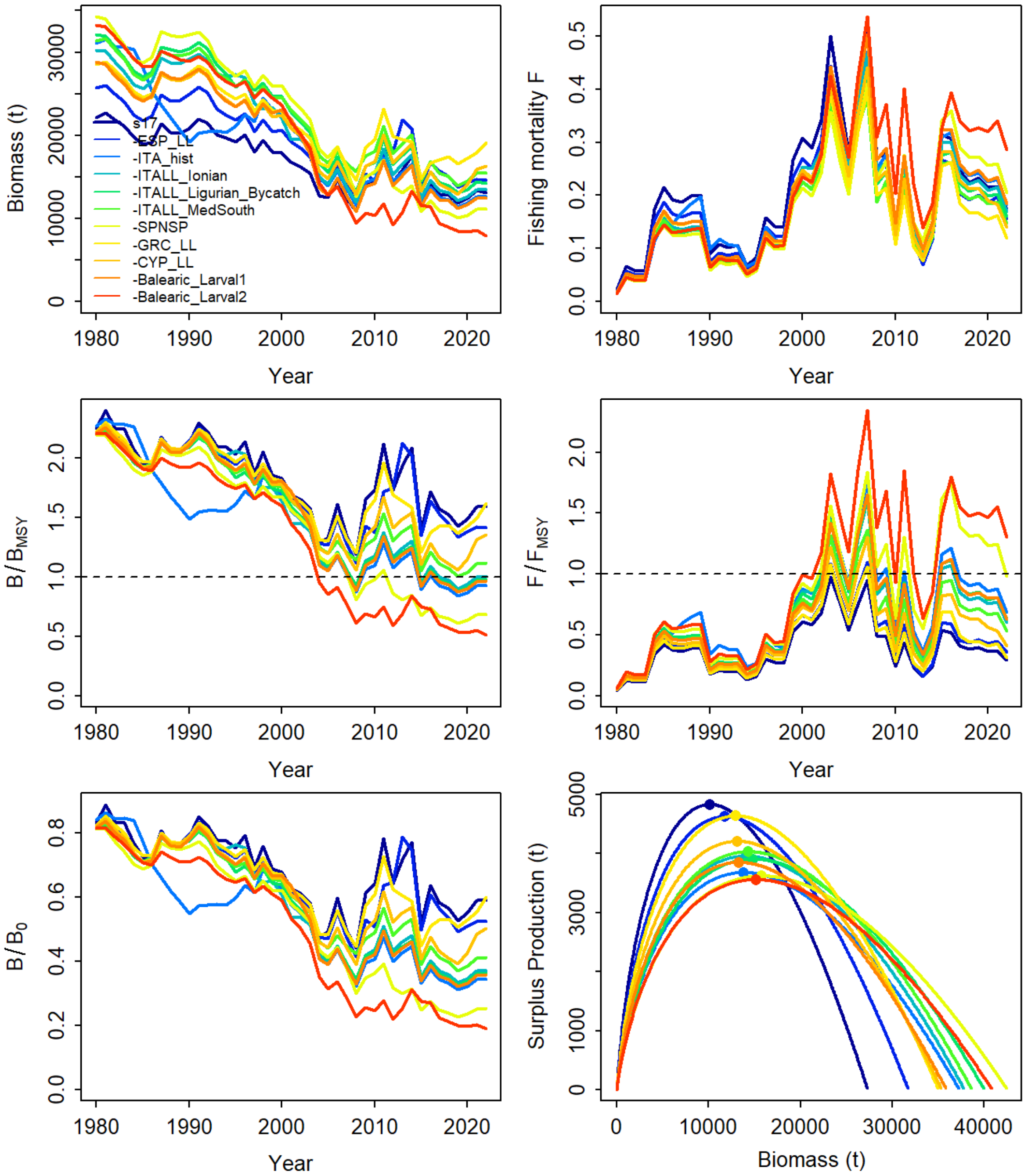
Appendix Figure 21. Prior and posterior distributions of various model and management parameters for the scenario S17 model for Mediterranean albacore. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.



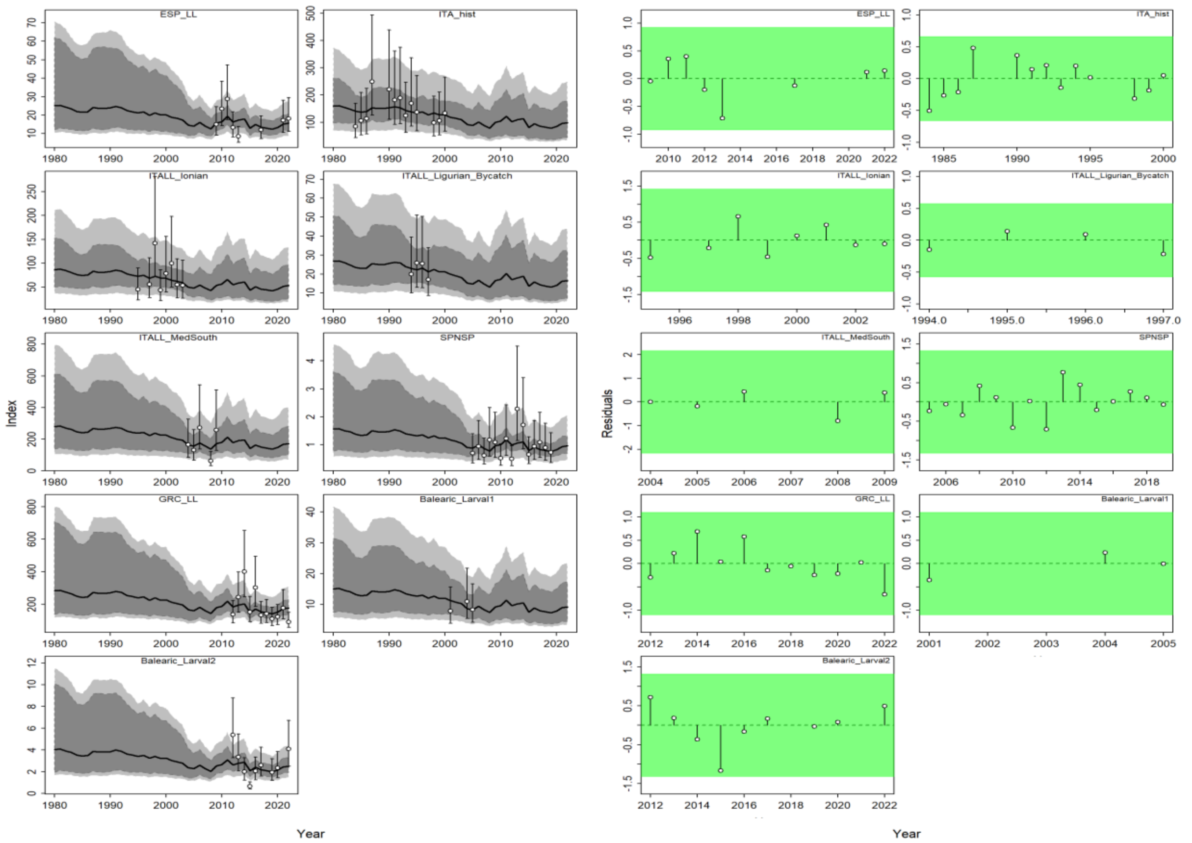
Appendix Figure 22. Comparison stock trajectory estimates for the Mediterranean albacore scenarios S16 and S17, showing trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels).



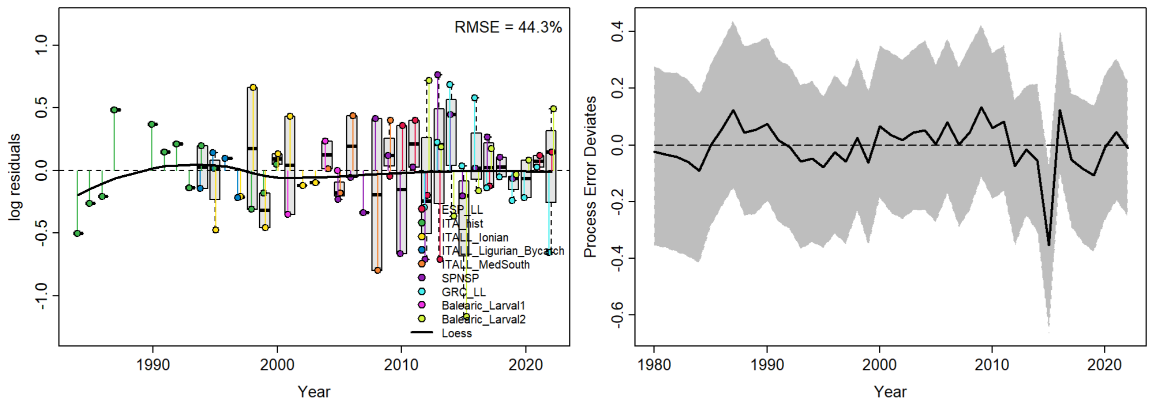
Appendix Figure 23. Retrospective analysis performed for the ALB-Med scenario S17, by removing one year at a time sequentially (n=5) and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.



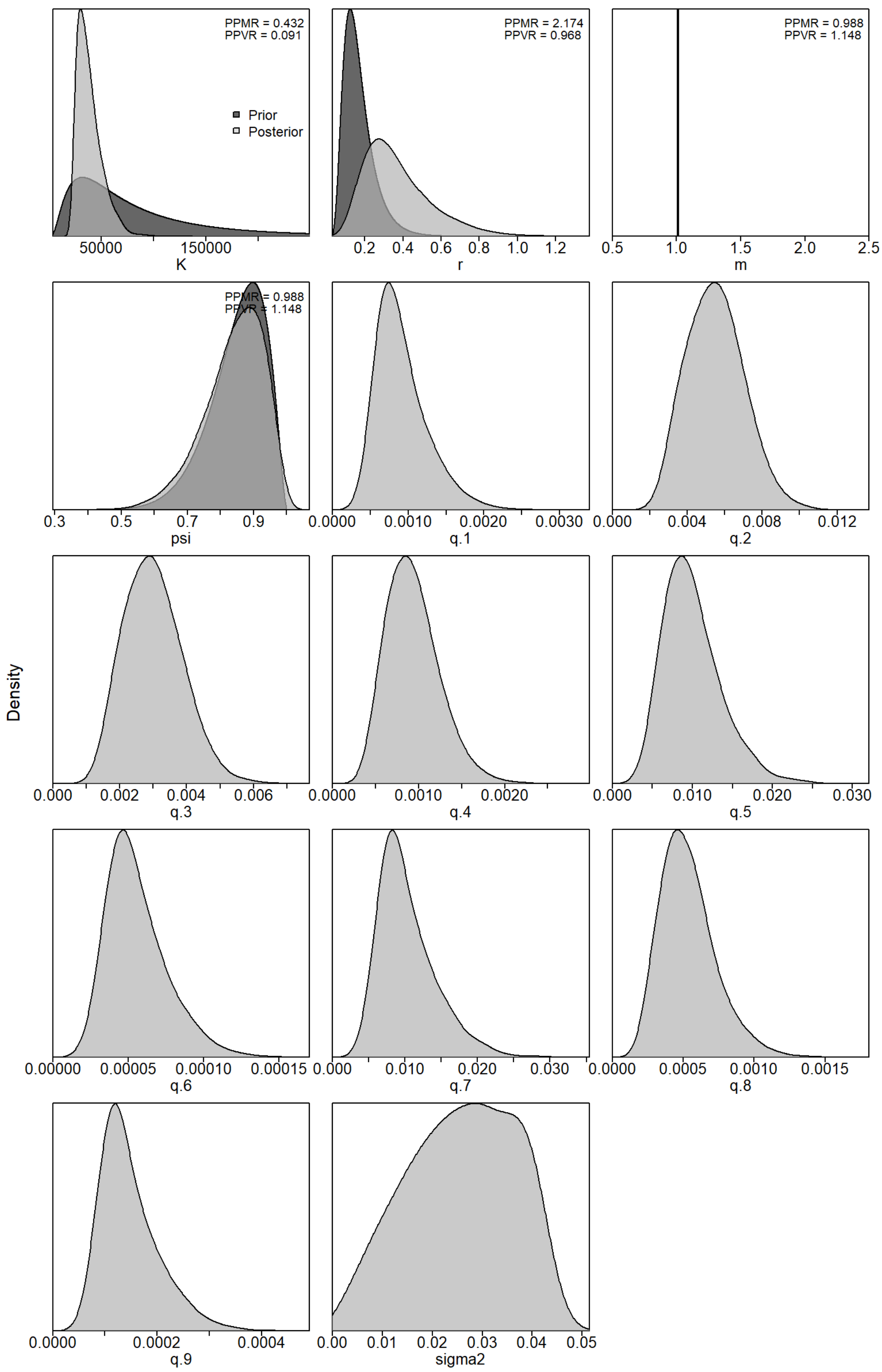
Appendix Figure 24. Jackknife index analysis performed on the ALB-Med scenario S17, by removing one index at a time and predicting the trends in biomass and fishing mortality (upper panels), biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (middle panels) and biomass relative to K (B/K) and surplus production curve (bottom panels) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.



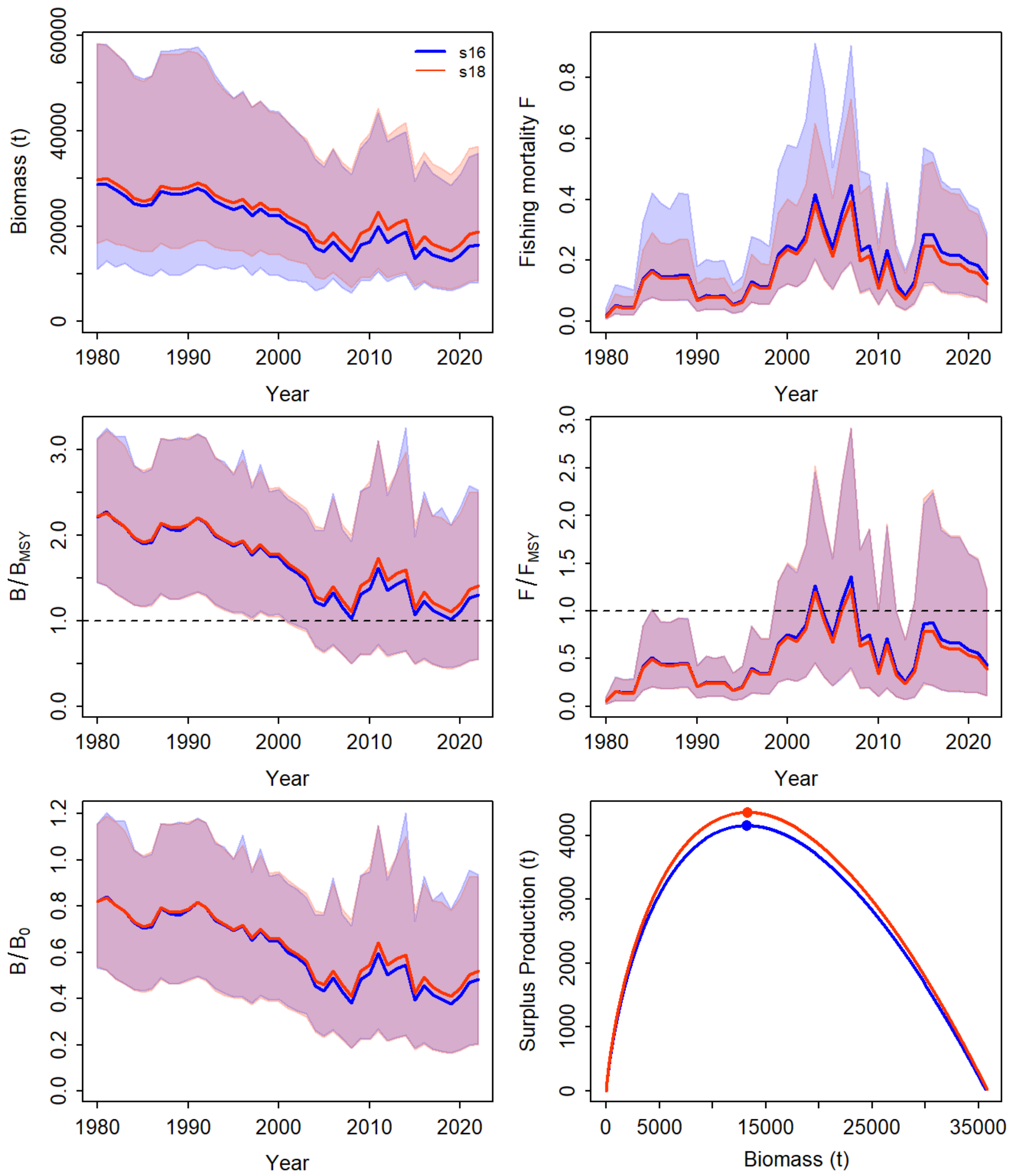
Appendix Figure 25. Time-series of observed (circle) with error 95% CIs (error bars) and predicted (solid line) CPUE (left) and Runs tests to quantitatively evaluate the randomness of the time series of index residuals (right) for the ALB-Med scenario S18 with 2024 catch and indices including Greek longline CPUE. On the left panel, the dark-shaded grey areas show 95% credibility intervals of the expected mean CPUE and light-shaded grey areas denote the 95% posterior predictive distribution intervals. On the right panel, green areas 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 (3- sigma rule).



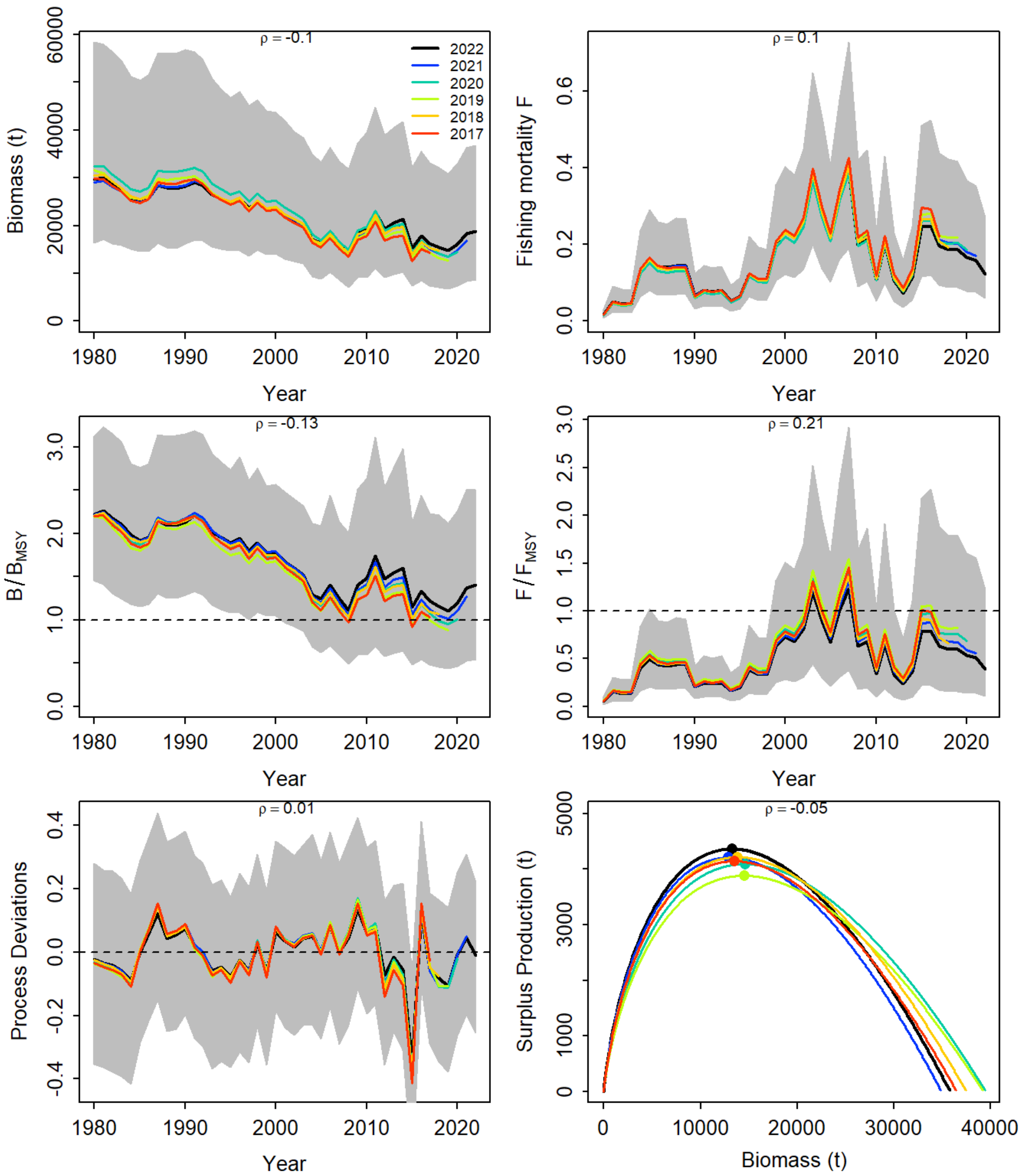
Appendix Figure 26. JABBA residual diagnostic plots of relative abundance indices (left panel) and process error deviation (right panel) for the ALB-Med scenario S18. Left panel: Boxplots indicating the median and quantiles of all residuals available for any given year, and solid black lines indicate loess smoother through all residuals. Right panel: Process error deviation (median: solid line) with a shaded grey area indicating 95% credibility intervals.



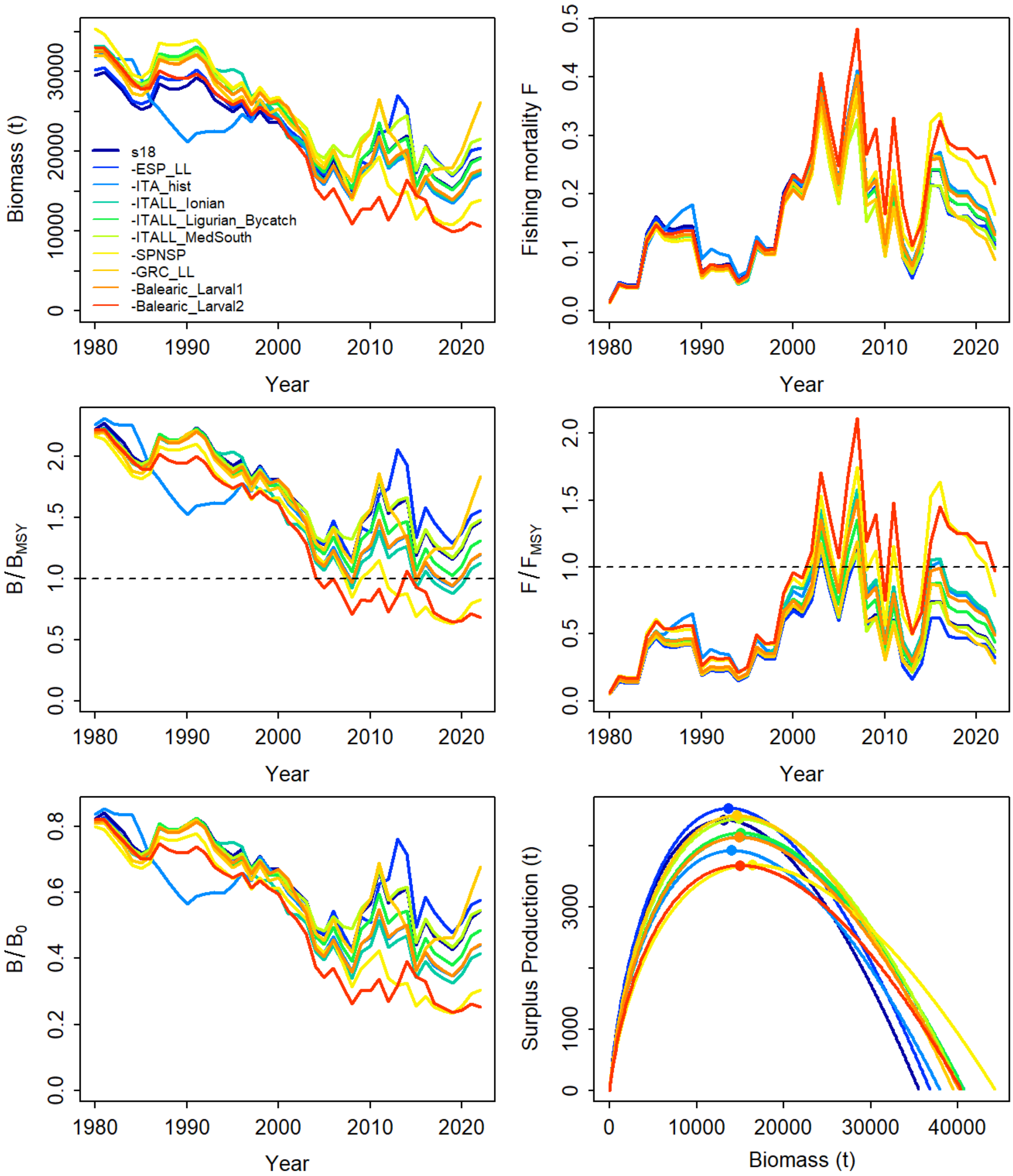
Appendix Figure 27. Prior and posterior distributions of various model and management parameters for the scenario S18 model for Mediterranean albacore. PPRM: Posterior to Prior Ratio of Means; PPRV: Posterior to Prior Ratio of Variances.



Appendix Figure 28. Comparison stock trajectory estimates for the Mediterranean albacore scenarios S16 and S18 showing 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).



Appendix Figure 29. Retrospective analysis performed for the ALB-Med scenario S18, 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) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.



Appendix Figure 30. Jackknife index analysis performed on the ALB-Med scenario S18, by removing one index 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) for each scenario from the Bayesian state-space surplus production model fits to Mediterranean albacore stock.