Institut Català de Recerca per a la Governança del Mar

State of fisheries in Catalonia 2024, Part 2:

Stock assessment

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Co-funded by the European Union

Generalitat de Catalunya

CSIC Consejo Superior de Investigaciones Científicas

Institut de Ciències del Mar

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How to cite this document
Institut Català de Recerca per a la Governança del Mar (ICATMAR). 2025. State of fisheries in Catalonia 2024, Part 2: stock assessment (ICATMAR, 25-06) 184 pp, Barcelona. DOI:10.20350/digitalCSIC/17394

https://doi.org/10.20350/digitalCSIC/17394

Published in August 2025.

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Section 5 (Alba Rojas)
References (Mireia G. Mingote)

Table of contents

Figures

Tables

Glossary

B_{curr}: Biomass current, in the period of time analyzed.

BKfrac: Ratio between biomass in the initial year relative to K. Stock depletion level at the beginning of the time series.

B_{lim}: Biomass limit, defined as the lowest biomass from which a recovery has been confirmed. 30% of Bmsy.

B_{th}: Biomass threshold. 50% of Bmsy.

B_{msy}: Biomass target

CPUE: Catch per unit of effort

DCF: Data Collection Framework

F: Fishing mortality

F_{msy}: Fishing mortality at a maximum sustainable yield.

F/M: relative fishing mortality.

F_{tgt}: Fishing mortality target.

F_{curr}: Fishing mortality current, in the period of time analysed.

GNS: Set gillnet

GSA: Geographic Sub-Area

k: Growth rate (Von Bertalanffy Growth Function)

LBSPR: Length-Based Spawning Potential Ratio.

LFD: Length Frequency Distribution

L_{inf}: Length infinity or asymptotic length at which growth is zero (Von Bertalanffy Growth Function)

LLS: Set longline

LLD: Drifted long liner

L_{mat50}: Length where 50% of individuals are mature

L_{mat95}: Length where 95% of individuals are mature

M: Natural mortality

OTB: Bottom otter trawl

PS: Purse seiner

SL50: Length where 50% of individuals are caught

SPR: Spawning Potential Ratio of a stock is defined as the proportion of the unfished reproductive potential left at any given level of fishing pressure.

SPR_{lim}: limit spawning potential ratio. Defined as 10% of SPR, below this value the population will not recover.

SPR_{tgt}: target spawning potential ratio. Defined as 40% of SPR remaining in the sea to achieve maximum sustainable yield.

SPiCT: Stochastic Production model in Continuous Time.

t_0: age at which the organisms would have had zero size (Von Bertalanffy Growth Function)

Executive summary

This report presents the stock assessment results obtained by ICATMAR for reference year 2024. Five demersal stocks (red mullet, European hake, deep-water rose shrimp, Norway lobster and blue and red shrimp) and two small pelagic fish stocks (European sardine and anchovy) were evaluated with length-based (LBSPR and LBB) and production (SPiCT) models under different scenarios. Additionally, red mullet, European hake and blue and red shrimp were also evaluated with integrated model MESTOCK (Canales et al. 2014). For LBSPR and LBB, data correspond to the continuous monitoring from ICATMAR in Catalonia (N GSA 6) for years 2019 to 2024. For MESTOCK and SPiCT, the report uses official data from the Data Collection Framework (DCF), the EU fleet register and the Spanish Government from the entire GSA 6, for different time spans specified in each corresponding section.

Each model provides different indicators which may lead to different perceptions of the stock status. LBSPR estimates the Spawning Potential Ratio (SPR), and LBB estimates the current exploited biomass in relation to the biomass in an unexploited state, whereas SPiCT and MESTOCK estimate Biomass and Fishing mortality. Length-based models (LBSPR and LBB) make use of the thorough length structure data available, but can deal with a high level of uncertainty, mainly due to their sensitivity to input data and biological assumptions. Key limitations include the exclusion of historical catch data and biomass indices. The surplus production model (SPiCT) can incorporate these data, but results are influenced by the lack of information on the length structure of the stock. Preliminary runs with MESTOCK integrate both sources of data, but still need further analysis including consideration of different scenarios, further data quality checks, and introduction of other factors such as different fleets.

For LBSPR, the results estimate that the SPR in 2024 for red mullet, European hake, Norway lobster and blue and red shrimp is under SPRlim (Figure 1). In contrast, SPR is near SPRlim for deep-water rose shrimp, clearly showing drops in the value corresponding to the species recruitment peaks in 2020 and 2024 (Figure 1). Trends are stable over the years in the case of red mullet, and Norway lobster, and relatively stable with fluctuations in for European hake, deep-water rose shrimp and blue and red shrimp. Finally, estimated SPR is above SPR_{lim} for European sardine, and around SPR_{tgt} for anchovy, placing this stock on sustainable exploitation levels according to this model (Figure 2). Trends for SPR are stable in both cases.

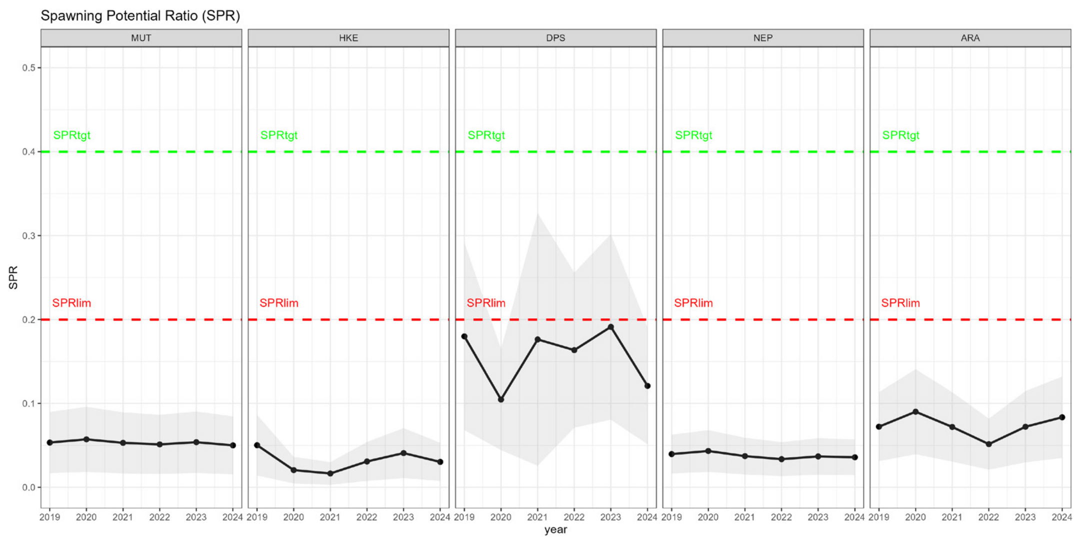

Figure 1. Spawning potential ratio (SPR) per year (2019 to 2024) for the five demersal stocks evaluated with LBSPR model. MUT: red mullet, HKE: European hake, DPS: deep-water rose shrimp, NEP: Norway lobster, ARA: blue and red shrimp, LBSPR: Length-Based Spawning Potential Ratio, $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio. The scenario selected for each species is explained in the corresponding section. The grey shade shows the standard deviation.

For LBB, estimates indicate that relative biomass (B/B0) are outside of sustainable levels for red mullet, European hake, Norway lobster, and blue and red shrimp, with minor improvements in the last few years in the case of European hake (Figure 3). Estimates are near sustainable levels for deep-water rose shrimp, with high fluctuations (Figure 3). In the case of small pelagic fish, estimates of relative biomass are out of sustainable levels and in a decreasing trend for European sardine, although the results require further analysis since other factors may be influencing the stock dynamics (Figure 4). For anchovy, estimates are near sustainable levels with a stable trend (Figure 4).

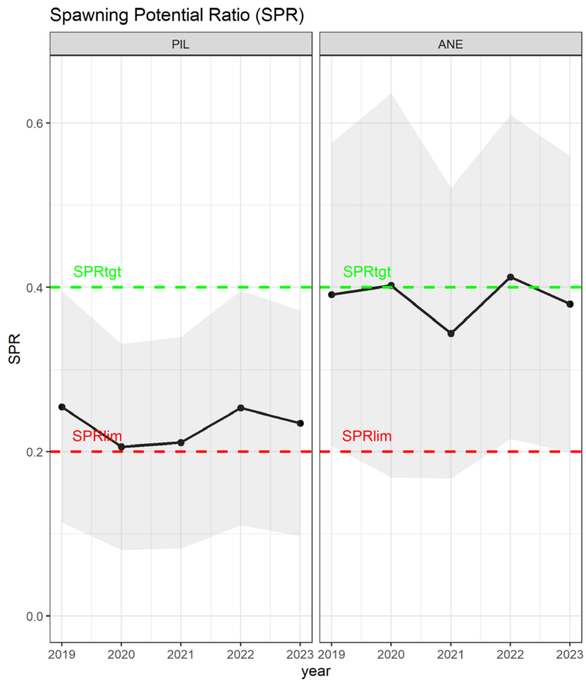

Figure 2. Spawning potential ratio (SPR) per year (2019 to 2024) for the two small pelagic stocks evaluated with LBSPR model. PIL: European sardine, ANE: anchovy, LBSPR: Length-Based Spawning Potential Ratio, $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio. The scenario selected for each species is explained in the corresponding section. The grey shade shows the standard deviation.

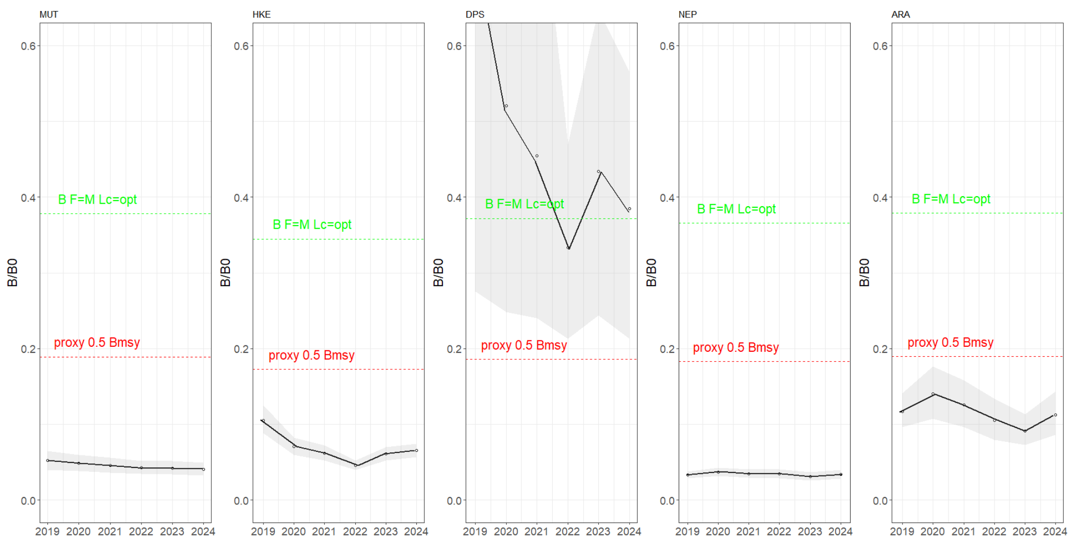

Figure 3. Exploited biomass relative to unexploited biomass (B/B0) for the five demersal stocks evaluated with LBB (Length-Based Bayesian) model. MUT: red mullet, HKE: European hake, DPS: deep-water rose shrimp, NEP: Norway lobster, ARA: blue and red shrimp. Green line indicates a biomass reference point where fishing mortality equals natural mortality and average catch length equals optimal catch length. Red line indicates a biomass reference point where B/B0 equals half of the target biomass (B_{msy}). The grey shade shows the standard deviation.

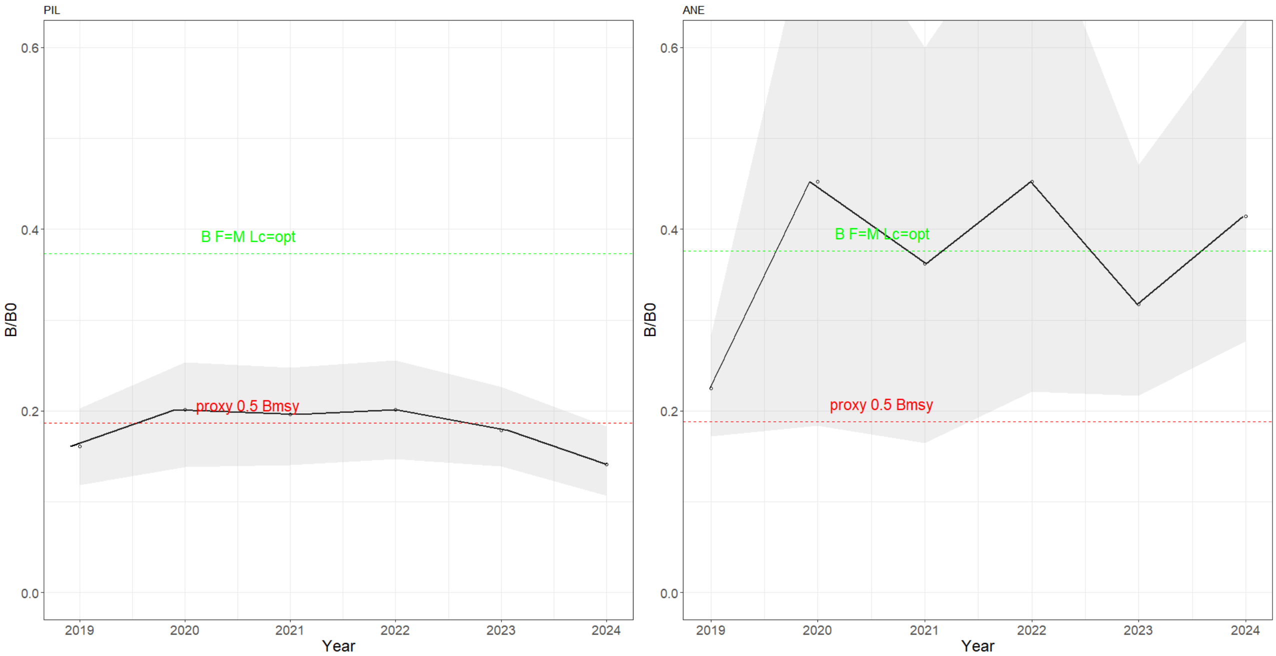

Figure 4. Exploited biomass relative to unexploited biomass (B/B0) for the two small pelagic fishes evaluated with LBB (Length-Based Bayesian) model. PIL: European sardine and ANE: anchovy. Green line indicates a biomass reference point where fishing mortality equals natural mortality and average catch length equals optimal catch length. Red line indicates a biomass reference point where B/B0 equals half of the target biomass (B_{msy}). The grey shade shows the standard deviation.

For SPiCT, biomass estimates for 2024 are above B_{msy} for red mullet, deep-water rose shrimp and blue and red shrimp, in line with the previous studied years (Figure 5). Estimated biomass is stable around B_{lim} for European hake, and around B_{thr} for Norway lobster (Figure 5a). In terms of fishing mortality, it is estimated below F_{msy} for red mullet and blue and red shrimp (Figure 5b). Estimates are around F_{msy} for Norway lobster, and above F_{msy} for European hake and deep-water rose shrimp, although trends differ showing stability over time in the first case, fluctuations in the second case, and a rising trend in the latter (Figure 5b). Progression of the stock over the years falls into three categories: according to this model, red mullet and blue and red shrimp stocks started in unsustainable exploitation and have made their way into sustainable exploitation at present (Figure 6). Other stocks have progressed either through increase of the biomass (deep-water rose shrimp) or decrease of fishing mortality (Norway lobster) but still have room for improvement. Lastly, the European hake stock is still being unsustainably exploited, despite slow progress in fishing mortality reduction over the last years. For small pelagic fish, biomass is estimated below B_{lim} for European sardine, and above B_{msy} for anchovy (Figure 7a). For European sardine, fishing mortality is below F_{msy} for 2023, confirming a steady decreasing trend over the studied years, and remains stable below F_{msy} for anchovy (Figure 7b). Progression of the stocks indicate room for improvement in biomass levels for European sardine, and might sustainable exploitation status if trends continue (Figure 8). For anchovy, estimates suggest that the stock has never left sustainable exploitation status, and is expected to continue to do well if trends continue.

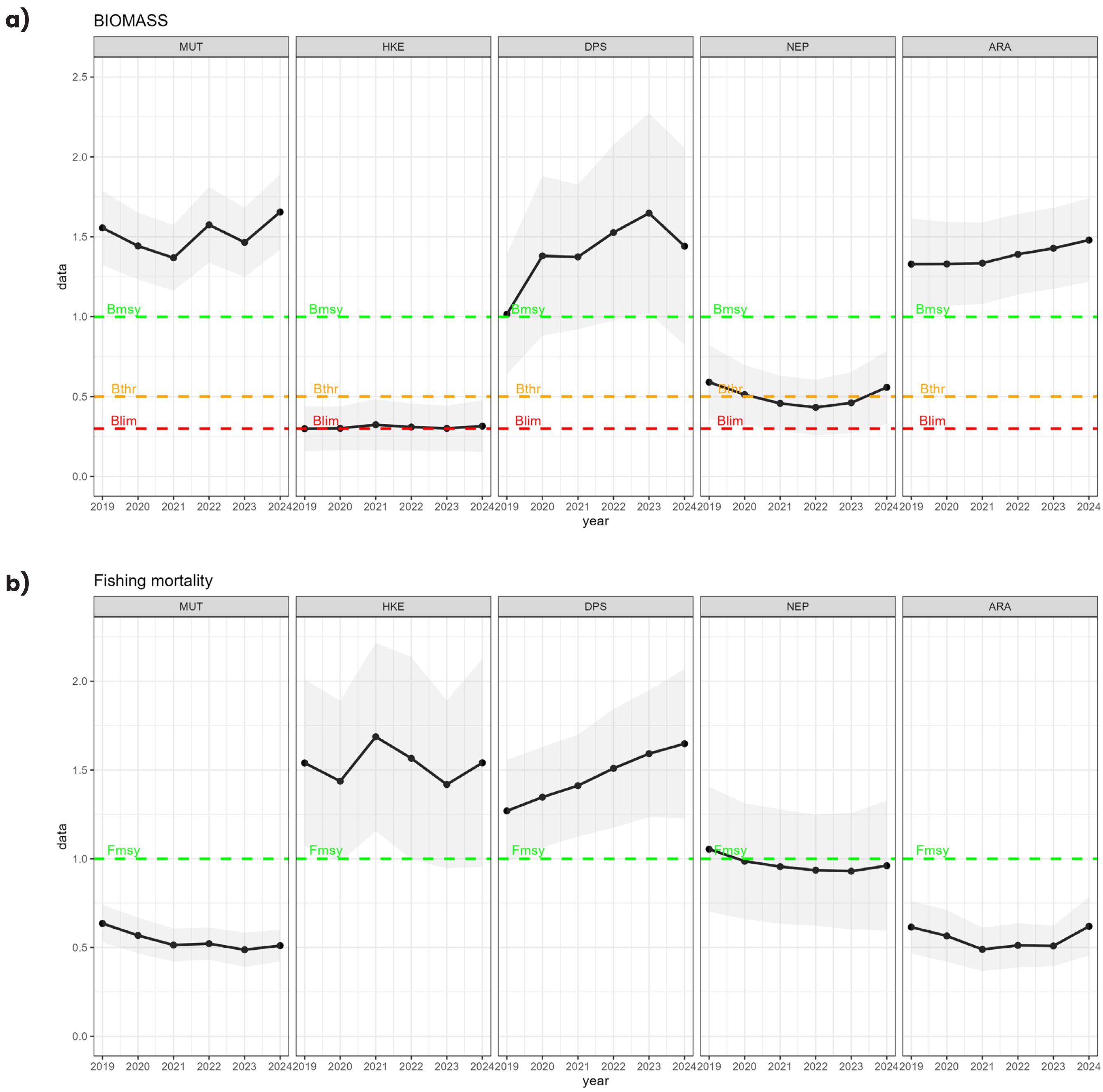

Figure 5. (a) Relative biomass (B_{curr}/B_{msy}) and (b) relative fishing mortality (F_{curr}/F_{msy}) per year (2019 to 2024) for the five demersal stocks evaluated with SPiCT model. MUT: red mullet, HKE: European hake, DPS: deep-water rose shrimp, NEP: Norway lobster, ARA: blue and red shrimp. SPiCT: Stochastic Production model in Continuous Time. $F_{msy:}$ Fishing mortality at a maximum sustainable yield, $B_{lim:}$ Biomass limit, $B_{thr:}$ Biomass threshold, $B_{msy:}$ Biomass target.

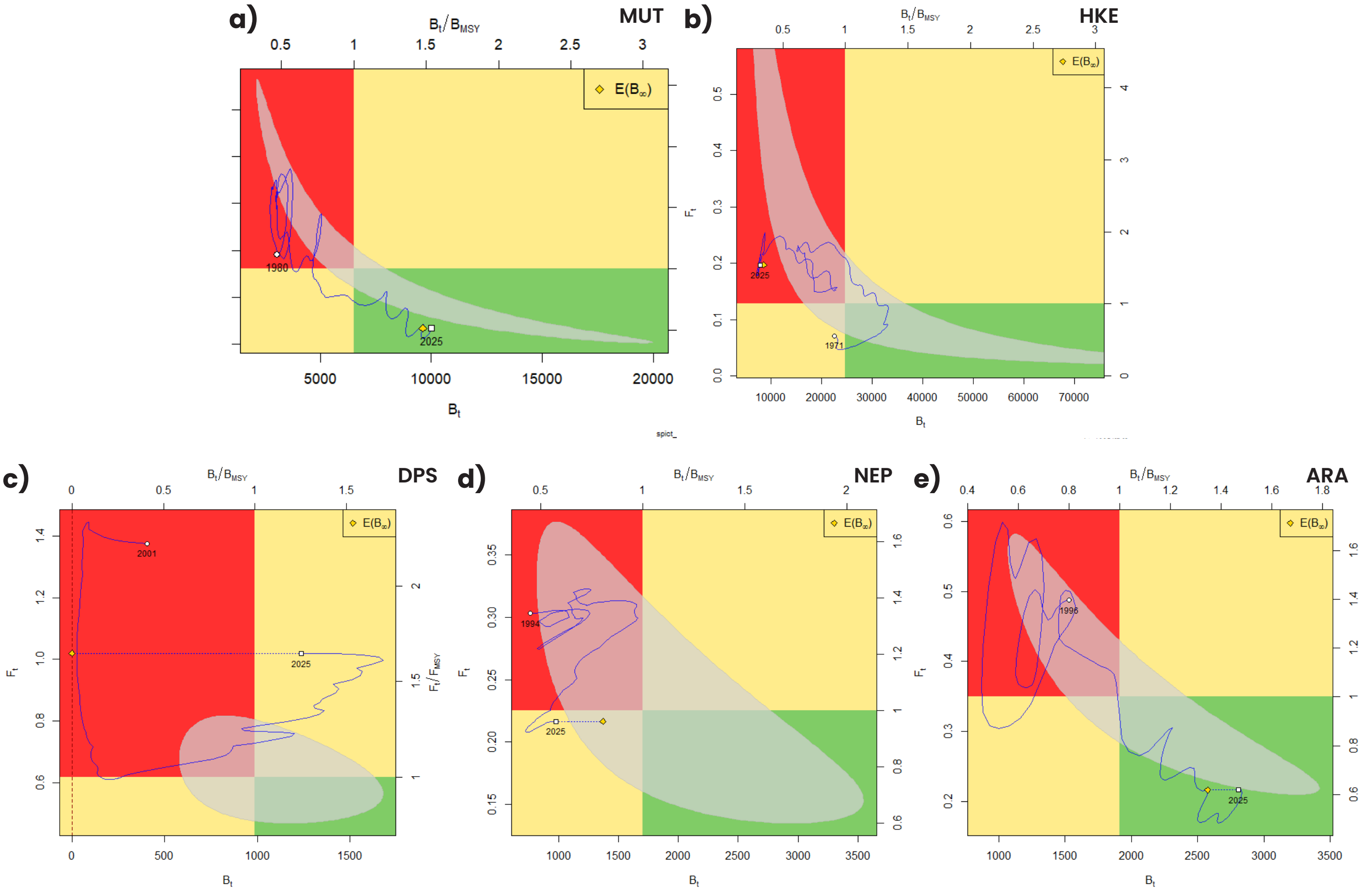

Figure 6. Kobe plots for the five demersal stocks evaluated with SPiCT showing the results for the final scenarios. MUT: red mullet, HKE: European hake, DPS: deep-water rose shrimp, NEP: Norway lobster, ARA: blue and red shrimp. SPiCT: Stochastic Production model in Continuous Time. F_{msy}: Fishing mortality at a maximum sustainable yield, B_{lim}: Biomass limit, B_{thr}: Biomass threshold and B_{msy}: Biomass target. The grey shade shows the uncertainty.

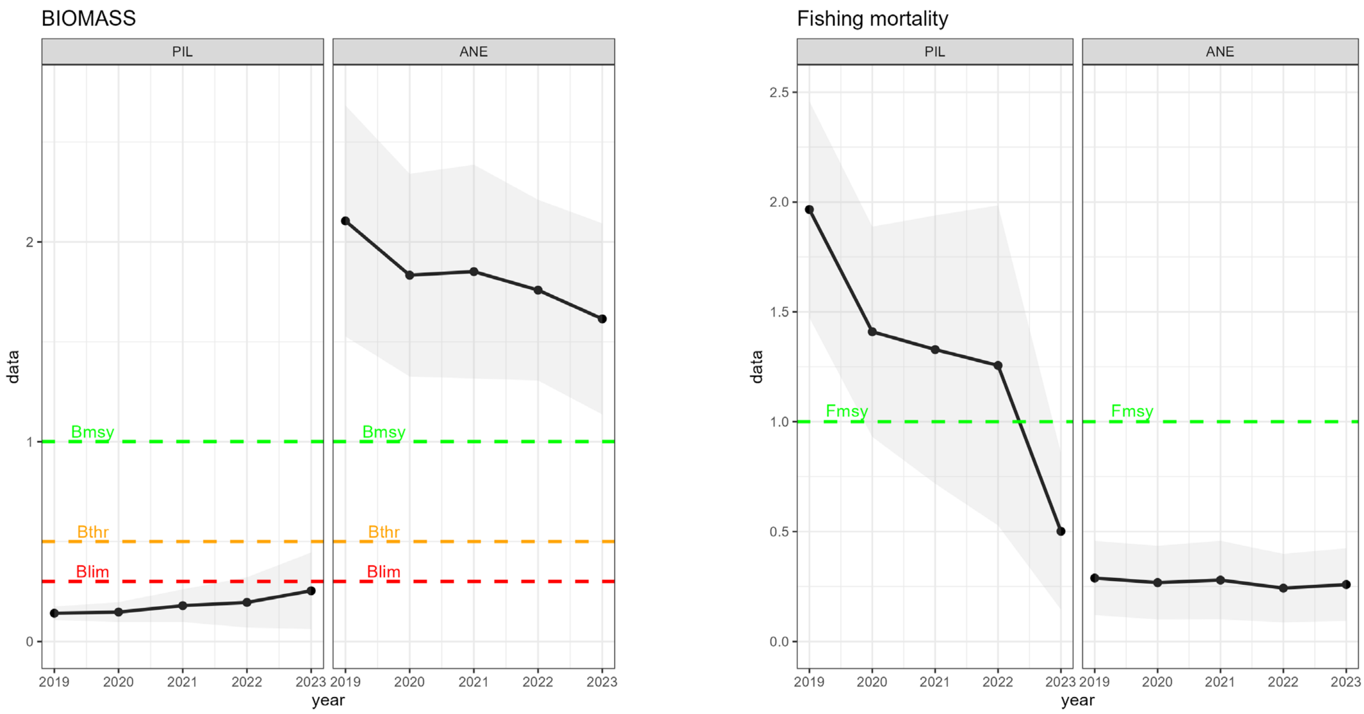

Figure 7. (a) Relative biomass (B_{curr}/B_{msy}) and (b) relative fishing mortality (F_{curr}/F_{msy}) per year (2019 to 2024) for the two small pelagic stocks evaluated with SPiCT model. PIL: European sardine, ANE: anchovy. SPiCT: Stochastic Production model in Continuous Time. F_{msy}: Fishing mortality at a maximum sustainable yield, B_{lim}: Biomass limit, B_{thr}: Biomass threshold, B_{msy}: Biomass target.

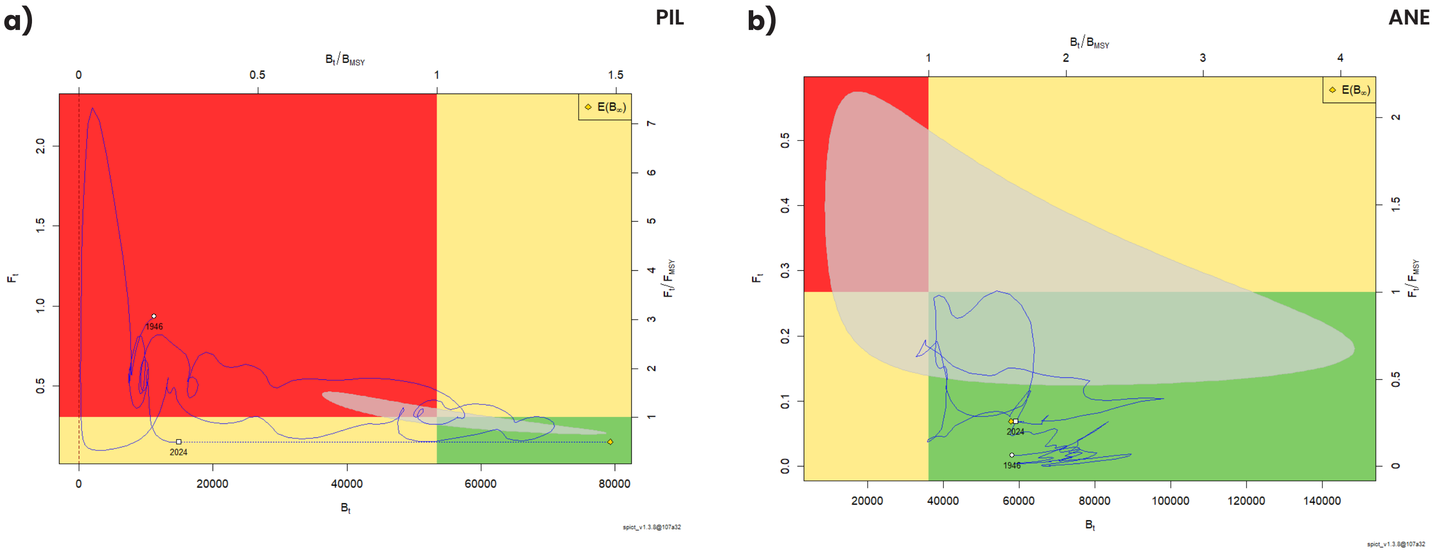

Figure 8. Kobe plots for the two small pelagic stocks evaluated with the SPiCT model. a) PIL: European sardine and b) ANE: anchovy. SPiCT: Stochastic Production model in Continuous Time. F_{msy}: Fishing mortality at a maximum sustainable yield, B_{lim}: biomass limit, B_{thr}: biomass threshold, and B_{msy}: biomass target. The grey shade shows the uncertainty.

For MESTOCK, biomass estimates (B/B_{msy}) for 2023 are slightly above B_{lim} for European hake, and above B_{msy} for red mullet (Figure 9). Estimates below B_{lim} for blue and red shrimp could be related to outdated biological parameters that condition the model to interpret a low spawning stock biomass, and so give a more pessimistic assessment. For European hake, estimated biomass shows a stable trend around B_{lim} over the last two decades. The progress of the stock over the years goes from sustainable exploitation in the 1970s and 1980s, declining until 2003, and progressing towards reduction of fishing mortality with no change to the biomass until present (Figure 10). For red mullet, estimated biomass is in a clear increasing trend since the beginning of the time series (2001), with the stock progressing from and unsustainable exploitation until 2020, through a slow but steady fishing mortality decrease and biomass increase, onto a sustainable level of exploitation in the last year studied (2023). For blue and red shrimp, progress of biomass over time is not in line with abundance indices or field observations, and is probably limited by model input data such as L_{inf} or growth parameters.

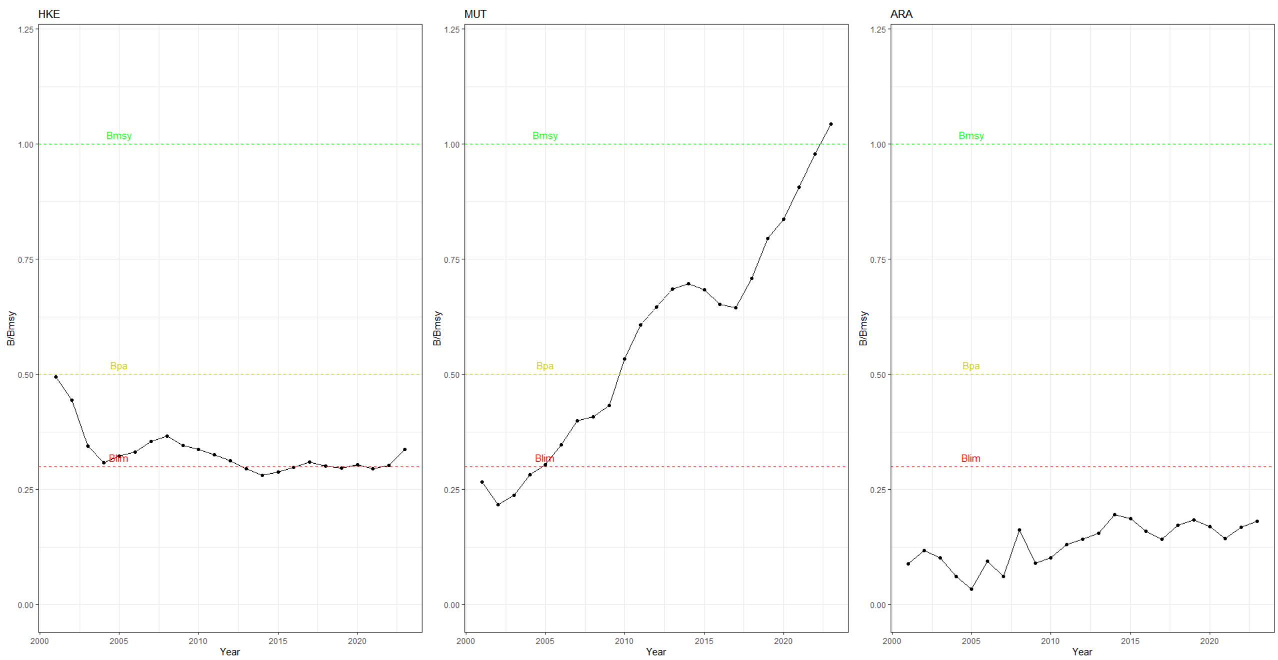

Figure 9. Biomass estimates (B/B_{msy}) per year (2019 to 2024) for the three demersal stocks evaluated with MESTOCK integrated model (Canales et al. 2014). MUT: red mullet, HKE: European hake and ARA: blue and red shrimp.

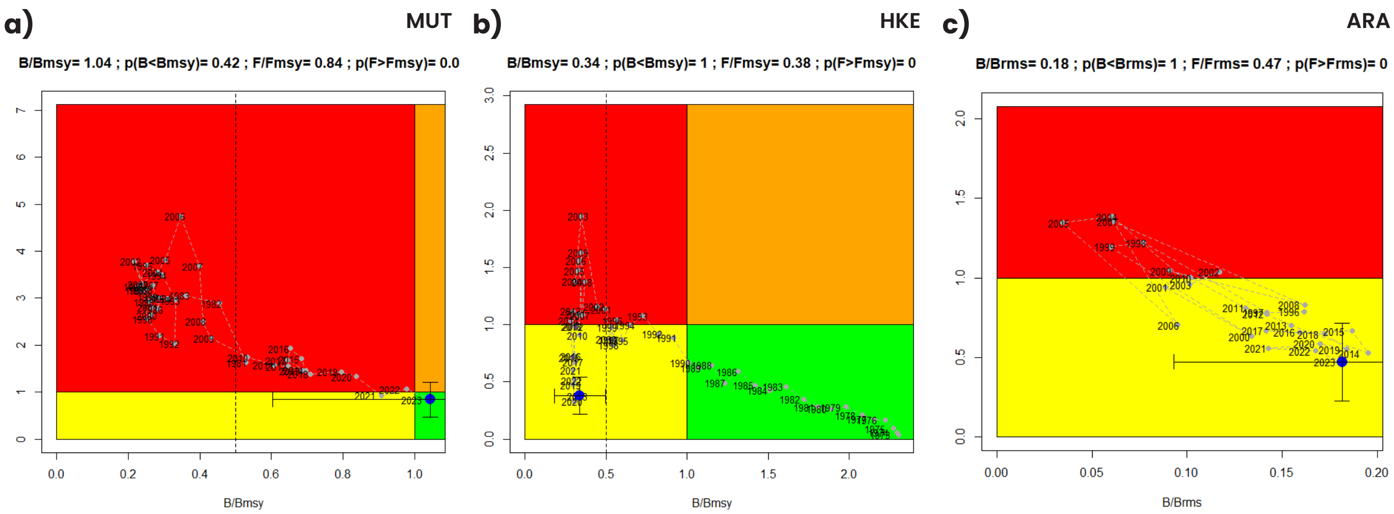

Figure 10. Kobe plots for the three demersal stocks evaluated with MESTOCK integrated model (Canales et al. 2014). (a) MUT: red mullet; (b) HKE: European hake; (c) ARA: blue and red shrimp. F_{msy}: Fishing mortality at maximum sustainable yield, and B_{msy}: biomass at maximum sustainable yield.

The advice drawn from these models should be considered as qualitative in all cases. Moreover, there are some discrepancies between models. For example, results for red mullet seem contradictory. While LBSPR and LBB estimate that SPR and biomass values are below limit reference points, SPiCT and MESTOCK show an increasing biomass trend coupled with a decreasing fishing mortality, placing this stock in sustainable exploitation. Conversely, results for blue and red shrimp with the different models are also not in line with each other, and are worth mentioning even when the spatial extensions are different. LBSPR, LBB and MESTOCK indicate that the SPR and biomass are below the limit reference points (Figure 1), while SPiCT estimates that the biomass is improving and the fishing mortality decreases (Figure 3). In both cases, this second estimation seems to be more in agreement with our observations from the monitoring program and also with landings and MEDITS (Figure 24 and Figure 120), highlighting that one model may not be suitable for evaluating the stocks of all species. Some models are more sensitive to different biological parameters and the lack of information for some species could produce misleading results.

A summary Table 1 is provided to understand, in a glance, the results obtained from the stock assessment models.

Table 1. Stock assessment outputs from LBSPR (Length-Based Spawning Potential Ratio), LBB (Length-Based Bayesian), SPiCT (Stochastic Production model in Continuous Time), and MESTOCK models. Official STECF assessments for the studied species have been included for comparison. A general commentary column is provided, bearing in mind that LBSPR and LBB results are from the N GSA 6 in 2024, MESTOCK results are from the entire GSA 6 in 2023, and SPiCT results are from the entire GSA 6 in 2024 (for demersal stocks) and 2023 (for small pelagic stocks). Up arrows indicate increasing trend; Down arrows indicate decreasing trend; Right arrows indicate stable trend; Up-and-down arrows indicate fluctuating trend. MUT: red mullet, HKE: European hake, DPS: deep-water rose shrimp, NEP: Norway lobster, ARA: blue and red shrimp, PIL: European sardine, ANE: anchovy, SPR: Spawning Potential Ratio, SPR0.4: SPR at 40%, B_{curr}: Biomass for the current year, B_{msy}: Biomass at maximum sustainable yield, F_{curr}: Fishing mortality for the current year, F_{msy}: Fishing mortality at maximum sustainable yield. *For LBSPR, indicator is SPR_{curr}/SPR_{tgt}.

Stock	Source	Assessment method	B Ref. Point	F Ref. Point	Ref. Year	Area	Trend B	Trend F	Bcurr/ Btgt*	Fcurr/F tgt	Comments
MUT	This report	LBSPR	SPR	F/M	2024	NGSA6	⇨	⇧	below	above	The MEDITS index indicates an increasing trend. The SPiCT model, which integrates historical data, provides a biomass estimate that aligns closely to this positive trend. Similarly, the MESTOCK model reflects comparable results, reinforcing the observed upward trend. In contrast, length-based models (LBSPR and LBB) do not reflect this increase. These models suggest stable biomass levels and may not fully capture recent changes in stock dynamics, possibly due to limitations in their reliance on length-frequency data. The a4a model presents a more pessimistic view, indicating a decline in biomass despite rising abundance indices and landings. Its reliability is limited and should be interpreted with caution. To improve the accuracy of future assessments, including those from MESTOCK, it is recommended that growth parameters be updated to reflect the current state of the stock better.
	This report	LBB	B/B0	F/M	2024	NGSA6	⇨	⇧	below	above	
	This report	SPiCT	B/Bmsy	F/Fmsy	2024	GSA6	⇧	⇩	above	below	
	This report	MESTOCK	B/Bmsy	F/Fmsy	2023	GSA6	⇧	⇩	above	below	
	STECF EWG 24-10	a4a	B/Bmsy	F/Fmsy	2023	GSA6	⇩	⇩	below	above	
HKE	This report	LBSPR	SPR	F/M	2024	NGSA6	⇳	⇳	below	above	Truncated size structure, with minor contribution of adults. Biomass indices show a decreasing trend over time. The MEDITS index suggests recent stability but only reflects smaller fish, while the CPUE indices for longliners and gillnets, which were a biomass indicator for larger individuals, show a drastic decreasing trend over the last few years, although the reasons remain unclear. Length-based models capture current size structure for the fishery but lack historical data and survey information. SPiCT includes historical context for the fishery but misses size and age structure, and results vary depending on the indices used (there is no way to inform the model about which index represents each part of the population). The a4a model, although data-rich, currently does not account for sexual dimorphism or the fishery's historical context, which limits its reliability. Improving the MESTOCK assessment would require high-quality length-frequency data by fleet and by sex. Overall, biomass is possibly near the limit reference point, and possibly in overexplotation, but with a reduced fishing mortality in recent years. However, the stock remains historically low and will likely take time to recover. Improved selectivity, realistic biological parameters, and fleet-specific historical data are key to rebuilding the stock.
	This report	LBB	B/B0	F/M	2024	NGSA6	⇧	⇩	below	above	
	This report	SPiCT	B/Bmsy	F/Fmsy	2024	GSA6	⇨	⇩	below	above	
	This report	MESTOCK	B/Bmsy	F/Fmsy	2023	GSA6	⇨	⇩	below	below	
	STECF EWG 24-10	a4a	B/Bmsy	F/Fmsy	2023	GSA1-5-6-7	⇨	⇨	below	above	
DPS	This report	LBSPR	SPR	F/M	2024	NGSA6	⇳	⇳	below	above	MEDITS index is reflected in models estimates of biomass increase. Given the rapid increase in catches and ability to sustain them, the status of the stock seems to be positive, but precaution is needed until MSY is identified. Sizes have decreased compared to previous years. SPiCT cannot be informed about the reason of low catches at the start of the time series (shift in species distribution driven by environmental factors) and interpretation that stock was possibly overexploited before 2015 must not be considered. a4a results may reflect a more realistic state of the fishery, since recruitment is not considered in the other models.
	This report	LBB	B/B0	F/M	2024	NGSA6	⇳	⇧	around	around	
	This report	SPiCT	B/Bmsy	F/Fmsy	2024	GSA6	⇳	⇧	above	above	
	STECF EWG 24-10	a4a	B/Bmsy	F/Fmsy	2023	GSA5-6-7	⇧	⇩	above	below	
NEP	This report	LBSPR	SPR	F/M	2024	NGSA6	⇨	⇳	below	above	Although biomass is relatively stable for the last 5 years, stock is at low biomass levels, even with the historic decrease of F, with no clear trend in MEDITS index and a decrease in landings in the last decade. SPiCT captures these trends and has no clear contrast to evaluate the biomass, so the stock status is possibly overexploited. For length-based models, lack of large individuals conditions the analysis and prevents a positive assessment. Environmental factors (e.g. increase of sea temperature) might be negatively conditioning the species development. Results from a4a are in line with length-based models if we acknowledge the size issue, bearing in mind spatial extension differences.
	This report	LBB	B/B0	F/M	2024	NGSA6	⇨	⇩	below	above	
	This report	SPiCT	B/Bmsy	F/Fmsy	2024	GSA6	⇧	⇨	below	below	
	STECF EWG 24-10	a4a	B/Bmsy	F/Fmsy	2023	GSA6	⇨	⇩	below	above	
ARA	This report	LBSPR	SPR	F/M	2024	NGSA6	⇳	⇳	below	above	MEDITS index is stable and at high levels of historical series, while catches and CPUE remain stable. SPiCT estimates increasing biomass and evaluates the stock as possibly sustainably exploited, with trends in line with indices and fisheries data. The status of the stock seems to be more sensitive to length frequency distribution than to the decrease in F. Models that use length frequency data (LBSPR, LBB, and MESTOCK) estimate low biomass levels, probably related to outdated biological parameters that drive the models to interpret a low spawning stock biomass, and so give a more pessimistic assessment. Bearing in mind the different spatial extensions of a4a and MESTOCK analyses, both models exhibit differences in fishing pressure status. MESTOCK includes data from 1996 to 2001, which a4a does not include. Environmental factors such as dense shelf water cascading are known to influence the stock dynamics.
	This report	LBB	B/B0	F/M	2024	NGSA6	⇳	⇳	below	above	
	This report	SPiCT	B/Bmsy	F/Fmsy	2024	GSA6	⇧	⇩	above	below	
	This report	MESTOCK	B/Bmsy	F/Fmsy	2023	GSA6	⇧	⇩	below	below	
	STECF EWG 24-10	a4a	B/Bmsy	F/Fmsy	2023	GSA6-7	⇳	⇩	below	above	
PIL	This report	LBSPR	SPR	F/M	2024	NGSA6	⇨	⇳	below	above	Assessment based on historical data from N GSA 6, assuming comparable MEDIAS biomass index trends. All models estimate that biomass is at the lowest levels in the time series for recent years, and F has decreased over time. The results are comparable to those from GSA 6.
	This report	LBB	B/B0	F/M	2024	NGSA6	⇩	⇧	below	above	
	This report	SPiCT	B/Bmsy	F/Fmsy	2024	NGSA6	⇧	⇩	below	below	
	GFCM WGSASP, 2024	a4a	-	F/F0.4	2023	GSA6	⇧	⇩	below	below	
ANE	This report	LBSPR	SPR	F/M	2024	NGSA6	⇨	⇳	above	above	Assessment based on historical data from N GSA 6, assuming comparable MEDIAS biomass index trends. All models estimate an increasing biomass since 2018, and a decrease in F. The results are comparable to those from GSA 6.
	This report	LBB	B/B0	F/M	2024	NGSA6	⇨	⇩	around	around	
	This report	SPiCT	B/Bmsy	F/Fmsy	2024	NGSA6	⇩	⇩	above	below	
	GFCM WGSASP, 2024	SPiCT	B/Bmsy	F/Fmsy	2023	GSA6	⇩	⇩	above	below	

*For LBSPR, indicator is SPRcurr/SPRtgt

SECTION 1
Introduction

Introduction

The European Union Data Collection Framework (DCF) establishes that the member states must collect, manage and annually report biological, environmental and socioeconomic data from fisheries to use as a base for scientific advice in management strategies (EU 2017/1004). In the Mediterranean and Black Seas, Geographical Sub-Areas (GSAs), as defined by the General Fisheries Commission for the Mediterranean (GFCM, Resolution GFCM/33/2009/2), are used to structure the data collection. The GSA 6 (Northern Spain) comprises the Spanish Mediterranean coast from Cartagena to the Spanish-French border.

The European Common Fisheries Policy (CFP) aims to ensure long-term sustainability for fisheries and regulates Mediterranean fisheries controlling fishing effort (fishing days) which, combined with specific technical measures such as gear regulation (Resolution GFCM/33/2009/2), the establishment of a minimum conservation reference size (EU Reg. 2019/1241) and the implementation of closure areas and closed seasons (EU Reg. 2022/1614), are the main management strategies adopted in the western Mediterranean Sea. Then, the CFP manages all fishing modalities including bottom trawling and purse seine. The bottom trawling fleet is currently regulated under the Western Mediterranean Multiannual Plan (WMMAP, EU reg. 2019/1022), which establishes a series of management measures. The bottom trawlers from the Spanish Mediterranean are allowed to fish between 50 and 1000 m depth or 3 miles far from shore when the seabed is shallow and five days per week with a maximum of 12 labour hours per day. The maximum power of the vessel may not exceed 500 hp and the vessel length is limited to a range between 12 and 24 meters (Real Decreto 1440/1999). In addition, the Ministry of Agriculture and Fisheries, Food and Environment may limit, by regulation, the number of days per year that a vessel may fish to regulate the total effort exerted in each of the fishing areas (EU Reg, 2019/1022). The purse seine fleet is regulated by the order (APA/1127/2023) approved by the Spanish Ministry of Agriculture, Fisheries and Food to comply with the CFP. This order aims to regulate the stocks for sardine and anchovy through spatial, temporal and catch fishing restrictions, including the increase of the minimum reference conservation size for both species.

Since 2000, the EU Member States have been collecting fisheries data to support CFP through fisheries-dependent and -independent methods. The fisheries-dependent samplings come from on-board samplings and occur monthly in some specific ports by on-board observers, whereas the fisheries-independent data is gathered once a year from the Mediterranean Trawl Survey (MEDITS). With the goal to obtain a more exhaustive data set to better manage marine resources, the monitoring program established by the DCF is complemented with a dataset obtained by the Institut Català de Recerca per a la Governança del Mar (ICATMAR). ICATMAR, promoted by the Directorate-General for Fisheries and Maritime Affairs of the Government of Catalonia and the Institut de Ciències del Mar (ICM-CSIC), is an autonomous organization whose main goal is to generate scientific advice for management purposes in the blue economy field. Since 2019, ICATMAR has developed and implemented a fisheries monitoring program in Catalonia, which constitutes the northern part of the GSA 6 (from the French border to the south of the Ebre delta). This program uses fisheries-dependent methods that also allow the collection of biological and stock parameters. The goal is to monitor the main target species of the Catalan commercial fleet of different fishing modalities, including bottom trawling and purse seining. In detail, bottom trawling is, economically, the most important fishing modality with a revenue of 53.79 M€ in 2024 (ICATMAR, 25-04). Moreover, bottom trawlers target demersal species, such as those defined by the WMMAP including red mullet, hake, deep-water rose shrimp, Norway lobster, and blue and red shrimp (EU reg. 2019/1022). Purse seine is the fishing modality that accounts for the highest biomass in catches, with a total value of 9 599 t in 2024 (ICATMAR, 25-04) and targets sardine and anchovy, species of special interest to manage for the CFP.

To provide scientific advice for management purposes in the northern GSA 6, different models were used for stock assessment evaluations for the five demersal species regulated by WMMAP and the two small pelagic fishes targeted by purse seine (Figure 7). First, two length-based models (LBSPR and LBB) with data gathered by ICATMAR during the period 2019 to 2024 were used for stock assessment evaluations in the northern GSA6. Second, a surplus production model (SPiCT), was applied to test the influence of a long-term data series, such as landings and biomass index, for the selected species in the whole GSA 6. Finally, exploratory runs were performed with integrated model MESTOCK (Canales et al. 2014) with both length data and historical data series. Each model is based on different assumptions and uses different input data, giving different perspectives of stock status and types of advice (Reference points for LBSPR: SPR, for SPiCT: Bmsy and Fmsy). SPiCT and MESTOCK reference points are comparable with the ones used for age-structured models (i.e., a4a) or other integrated models (i.e., SS3).

The long-term data collection from ICATMAR continuous and exhaustive monitoring program will allow, in the following years, the use of more complex integrated models, e.g. Stock Synthesis (SS3), which integrates species life-history and catch at length information with the time series of catch and fisheries-independent data.

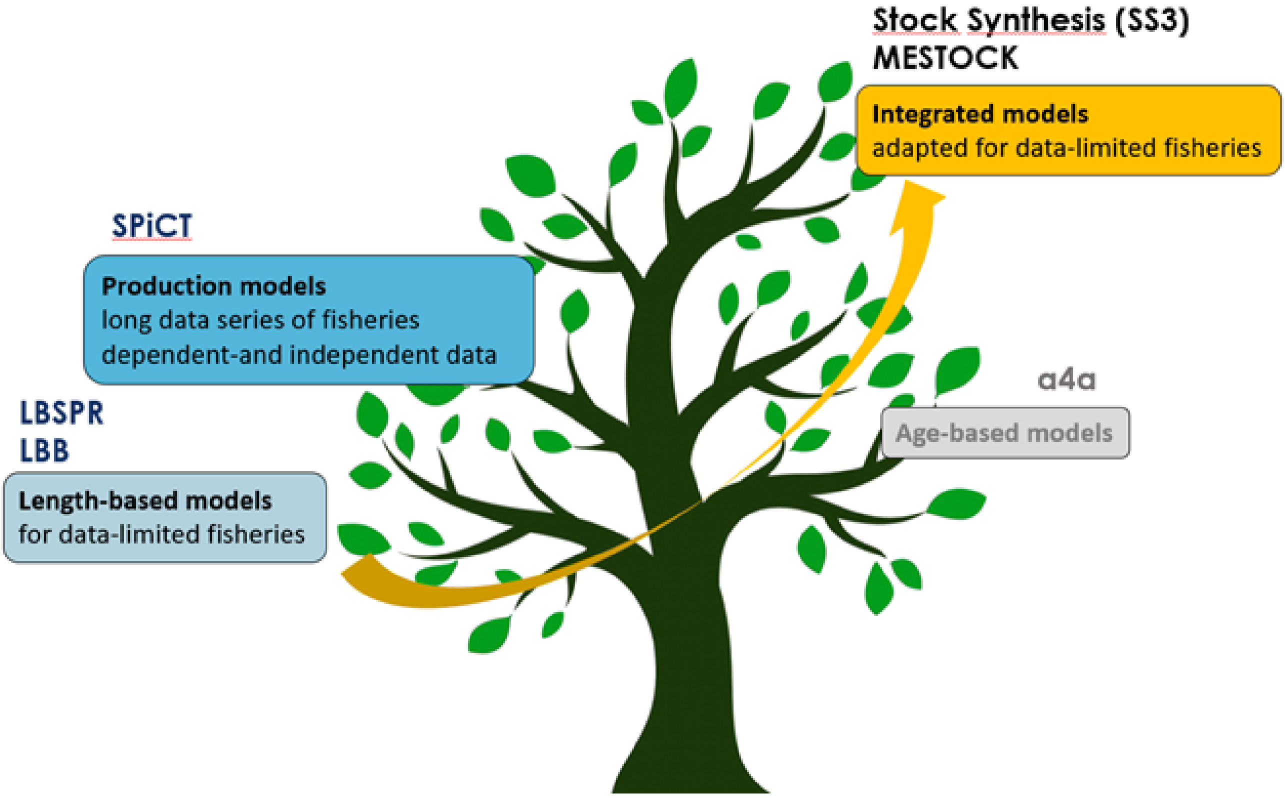

Figure 11. Different models used for fisheries stock assessment: LBSPR and LBB are length-based data-limited models, SPiCT is a Surplus production model, Stock Synthesis (SS3) and MESTOCK are integrated stock assessment models.

SECTION 2
Material and Methods

- **Machine learning for métiers assignation**

As explained in a previous report (ICATMAR, 22-04), the fishing fleet activity is defined by *métiers*. In short, a *métier* is defined as a "group of fishing operations targeting a similar assemblage of species, using similar gear, during the same period of the year and/or within the same area and which are characterized by a similar exploitation pattern" (Reg. (EC) N° 949/2008 and Commission Decision 2010/93/UE). In this study area, the daily fishing landings of a vessel correspond to one effective fishing day, as vessels land their catch daily. Therefore, as each sampling haul is allocated to a specific *métier*, the sampled length frequencies can be weighed and extrapolated to the fishing landings by *métier*.

Seven *métiers* are defined performing dendrograms and cluster analysis for the Catalan bottom trawling fleet (OTB). These *métiers* are related to different depths, areas and catch composition. All daily landings from 2002 to 2021 were classified according to these *métiers*.

For the for 2022 onwards, machine learning algorithms have been used to assign the corresponding *métier* to each daily trip (vessel + day). Machine learning is a branch of artificial intelligence that focuses on the training of algorithms and models to predict results based on data. In this case, random forests were the machine learning algorithms used because they are more suitable to classify the fishing trips in each different *métier*.

The applied process is described below:

- **Data preparation:**

Landings data from 2021 were selected, but only trips from 2021 had *métiers* assigned. The species considered for the analyses are those which biomasses contribute to the 95% of the daily trip. This filter allows to eliminate the species that rarely appear and have barely any influence on the *métier* assignation. The data were transformed to have one row per daily trip, area, *métier* and a column for each species that was caught with its percentage of biomass contribution to the daily trip.

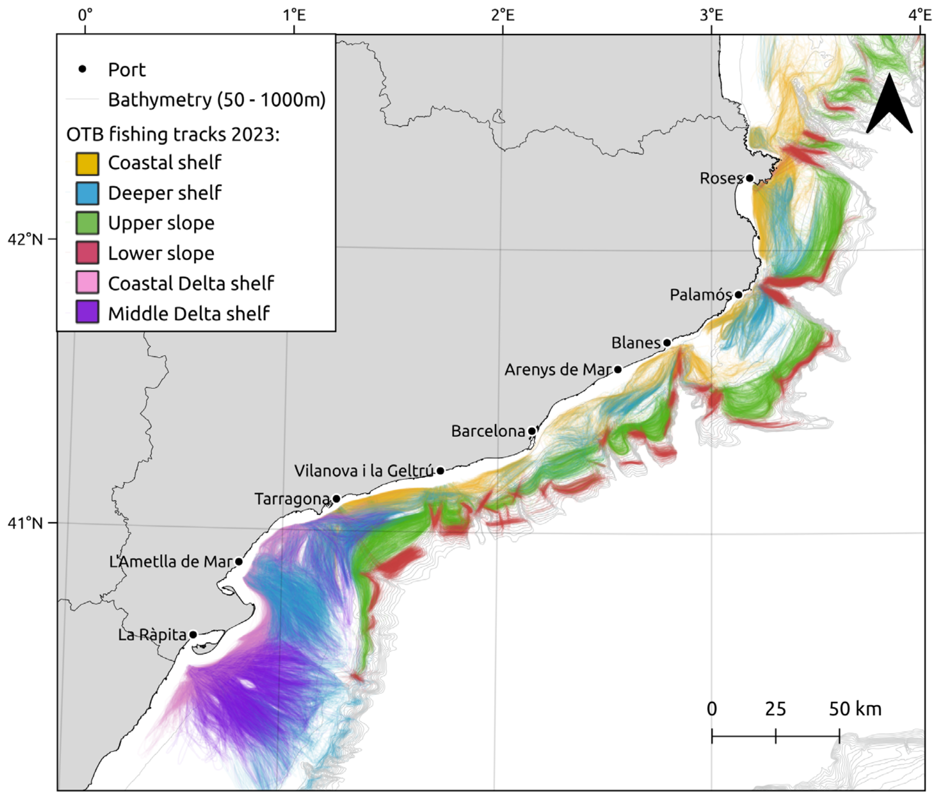

Figure 12. Spatial distribution of the bottom trawl fishery (OTB) tracks. Colors represent the different OTB métiers identified for the Catalan fishery in 2024.

- **Model execution:**

A process of model tuning was applied to test different combinations of the parameters and ways to split the data to find the most suitable model. To do this, 80% of the classified data from 2021 were used for model training and 20% for model validation. The model has a 95% of accuracy, which is obtained executing the model with the validation data. The trained model is used to predict the *métier* assignation for non-classified data for 2022 onwards. Besides the model execution with the validation data, the predicted *métiers* are combined with their corresponding VMS track to generate a map and perform a visual validation (Figure 12). Finally, the predicted *métiers* for 2022 onwards are imported to the database for the extrapolation of the data.

- **Data extrapolation**

To estimate the annual length-frequency distributions (LFD) of the target species in Catalonia (N GSA6), data from the ICATMAR monitoring program (trawling and purse seine) and from EU-DCF (GSA6, artisanal fisheries) were used. A three-step process was followed: 1) Raising of monitoring data, 2) inclusion of artisanal fisheries catch, and 3) validation of the estimated LFD using the sum of products (SOP) approach.

Raising of the monitoring data

Bottom trawling

The basic unit for the data raising were the fishing hauls, which were previously assigned to a *métier* according to its catch composition. The calculations for each area (North, Center, and Ebre delta) were made separately to keep the spatial resolution of the sampling and, within each area, fishing hauls were separated by port. Starting from this spatial aggrupation, the data raising also considered seasonal variations in catch, calculated according to the following steps:

Monthly LFD (sampled ports, by area, *métier* and month)

Seasonal LFD (sampled ports, by area, *métier* and season)

Seasonal LFD (all fleet, by area, *métier* and season)

Annual LFD (total for Catalonia)

This process is described below for each fraction of the catch (landed and discarded) and calculated independently for each target species. Note that the LFD were grouped by intervals of 1 cm for fish species and 1 mm for crustaceans. The extrapolation used two ICATMAR databases: monitoring data and commercial fishing landings.

Raising process for the landed catch

Monthly LFD (sampled ports, by area, *métier* and month)

For every fishing haul, the LFD and its total weight were extracted from the monitoring database. A ratio was calculated dividing the monthly landings by the total weight of each haul. The resulting monthly LFD was determined by multiplying the LFD of each fishing haul by the corresponding ratio.

Seasonal LFD (sampled ports, by area, *métier* and season)

In this step, the previous procedure is replicated, but now starting with the monthly LFD. The ratio was calculated dividing the seasonal landings of each port and *métier* by the corresponding monthly landings. The seasonal LFD was obtained by multiplying this ratio with the monthly size distribution.

Seasonal LFD (all fleet, by area, *métier* and season)

The previously calculated LFD of the sampled ports corresponding to the same season and *métier* were summed. The ratio was calculated dividing the total landings (considering all ports of each area) by the weight from the sum of the LFD of the sampled ports. The total LFD by area, season, and *métier* were obtained by the product of the LFD of the sampled ports by its ratio.

Annual LFD by area and totals for Catalonia

The annual LFD by area was obtained by the sum of the LFD of the different seasons and *métiers*. This process must be repeated for each year and area to obtain the estimated annual LFD of the landed individuals from the target species corresponding to all the trawling fishing fleet in Catalonia.

Raising process for the discarded catch

The raising of discards LFD follows the same structure as the raising of landings. The proportion of discards within the total catch was estimated from the monitoring database. This proportion was calculated for each year, area, season and *métier.* For those months when no sampling was available, the annual discard ratio was used. Then, the steps explained for landed size distributions can be replicated, considering that the commercial landings must be multiplied by the discard ratio beforehand.

Purse seine

The raising process of the purse seine sampling requires a simplified version of the method for trawling. In this case the spatial structure (area – port) is maintained but in the raising process only month and season were considered, as no *métiers* were available for purse seine.

Inclusion of the artisanal fisheries catch data for modelling

Our sampling includes both bottom trawling and purse seine. However, it does not include artisanal fisheries despite their catch may be important to be considered, especially for hake and red mullet. Then, for these two species, we employed data from the EU-DCF (GSA6) in order to obtain the LFD for our target species in Catalonia and add these data to our bottom trawling monitoring data. The ratio from the artisanal fisheries was calculated by dividing the catches from Catalonia by the total catches in the GSA6. The product of this ratio with the LFD of the GSA6 provides an estimate of the LFD corresponding to Catalonia. These LFD can be summed to the trawling (landing + discards) extrapolation to get the annual LFD for Catalonia considering all fishing gears.

- **SOP validation**

The sum of products (SOP) is computed by summing the number of individuals at each length class of the LFD multiplied by their corresponding weight, estimated with the species' growth parameters:

The results of the SOP validation for the landed catch must be similar to the reported landings.

- **Models settings**

1. **Length-Based Spawning Potential Ratio (LBSPR)**

LBSPR is classified as a data-limited stock assessment model which relies on a number of assumptions. In particular, the LBSPR models are equilibrium-based and assume that the length composition data is representative of the exploited population at a steady state. Also, selectivity is assumed to follow a logistic function.

To better fit the model, some facts should be considered such as:

The length structure of the harvested population raised by considering the main factors (time: monthly and annual catches; sample size; ports, fleets/gears and/or depth).

Local estimates of life-history parameters, including von Bertalanffy growth parameters, length of maturity (L_{mat50} and L_{mat95}) and M.

Information on the input data and methods used to estimate life history.

Sensitivity analysis

Different scenarios were carried out by stock to test the sensitivity of the model. In general, scenarios were chosen based on STECF or GFCM data inputs, available bibliography and ICATMAR data.

Uncertainty in life history parameters

To include uncertainty in the model computation, the following settings were applied for each stock and scenario (Table 2):

The main output of the model is the Spawning Potential Ratio (SPR) which is defined as a proportion of the unfished reproductive potential left in the population at any given level of fishing pressure.

The reference points were proposed for the length-based methods approach as: SPR_{tgt}=0.4, SPR_{pa}=0.2 and SPR_{lim}=0.1. Due to the model's instability regarding the stock's life history, the FM estimator is not considered a reference point.

Table 2. Settings used for model LBSPR computation uncertainty.

Number of random draws: nits=1000	
CVL_{inf}lower <- 0.075 CVL_{inf}upper <- 0.3 CVL_{inf}mid <- 0.15 CVL_{inf}vec <- rtriangle(nits, CVLinflower, CVLinfupper, CVLinfmid)	MKlower <- (M/K) *0.75 MKupper <- (M/K) *1.25 MKmid <- M/K MKvec <- rtriangle(nits, MKlower, MKupper, MKmid)

L_{inf}lower <- L_{inf}*0.75
L_{inf}upper <- L_{inf} *1.25
L_{inf}mid <- L_{inf}
L_{inf}vec <- rtriangle(nits, L_{inf}lower, L_{inf}upper, L_{inf}mid)
	L_{mat50}vec <- L_{inf}vec * (Lmat50/L_{inf}) # Assume constant Lmat50/L_{inf} ratio
	LHpars <- MyPars
	L_{mat95}vec <- L_{mat50}vec + (LHpars@L_{mat95} - LHpars@L_{mat50}) # assume constant L_{mat95}-L_{mat50}

2. Length-Based Bayesian Biomass (LBB)

Models settings

The Length-Based Bayesian biomass estimation (LBB) method, developed by (Froese et al., 2018), is a stock assessment approach specifically designed for data-limited fisheries. LBB requires length frequency distributions that are representative of the fishery. The core of LBB is the vBGF connecting fish age and body length. It uses the Bayesian approach to estimate growth and mortality parameters, relative exploitation level and stock size. In addition, LBB allows to obtain important parameters for fishery management such as the optimal length for the first capture Lc_opt and the length at maximum possible yield per recruit Lopt.

As with the LBSPR method, a sensitivity analysis was included to attain the uncertainty around life history parameters. Settings used were the same as LBSPR, except for the SPR reference points, since LBB does not estimate this value.

3. Stochastic Production model in Continuous Time (SPiCT)

Model assumptions and input data

SPiCT is classified as a data-moderate stock assessment model. To perform surplus production models for a certain stock, it is needed to have information on the time series of landings, effort, CPUE (ideally standardized), and/or fishery-independent biomass index. The catch data should be representative of both landings and bycatch. It is also possible to use a time series of landings, but the interpretation of the results varies in this case. When available, seasonal catches should be also used as input.

Stock size indices should be provided in terms of biomass and should be representative of the exploitable stock biomass. Given that the surplus production models require the comparison between the same fraction of the stock, to build the biomass index there should only be considered the range of lengths that are observed in the catches.

Biomass indices are assumed to be snapshots on given time points. Therefore, the timing of survey indices has to be given as decimal year, corresponding to the timing of the survey in the vector. Commercial CPUE indices should be associated to the midpoint of the interval of the corresponding catches, i.e. when CPUE indices are based on yearly aggregated catches and effort, the value in the mid-year should be considered.

The SPiCT model estimates reference points with associated uncertainties and accounts for both observation and process error.

4. Statistical catch-at-size model (MESTOCK)

MESTOCK is a statistical fisheries assessment model based on size composition data, developed by Canales et al. (2014). It has been used for the assessment of small pelagic fish populations in Ecuador and Panama, as well as marine decapod invertebrates like the pomada shrimp in Ecuador, and other invertebrate fisheries in Chile and Argentina (Canales, 2020; Canales et al., 2014, 2021; Canales & Jurado, 2024).

This model is implemented in ADMB and is conceptually similar to integrated models such as SS3 (Methot & Wetzel, 2013) and A-SCALA (Maunder & Watters, 2003). It models population dynamics by age but uses length composition data from catches as observations. It assumes a closed stock, where recruitment results from spawning within the species' distribution area, and larval survival is mainly influenced by environmental factors. Thus, recruitment is driven by stochastic processes, with a diffuse stock-recruitment relationship.

Recruitment occurs at the start of each year, following a normal length distribution. It is modeled using a Beverton & Holt stock-recruitment function with process error, with deviations represented as lognormal variables (mean 0, standard deviation σR). While there may be a link between spawners and recruits, this relationship is disturbed by random environmental factors.

Growth is modeled using the Von Bertalanffy growth curve, assuming normal distribution of length around the expected size for each age group. The model incorporates likelihood functions to represent observation error and includes priors or penalties for some key parameters.

SECTION 3
Results by stock

Demersal species

Stock assessment results for species in the GSA6

Red mullet (*Mullus barbatus*) MUT

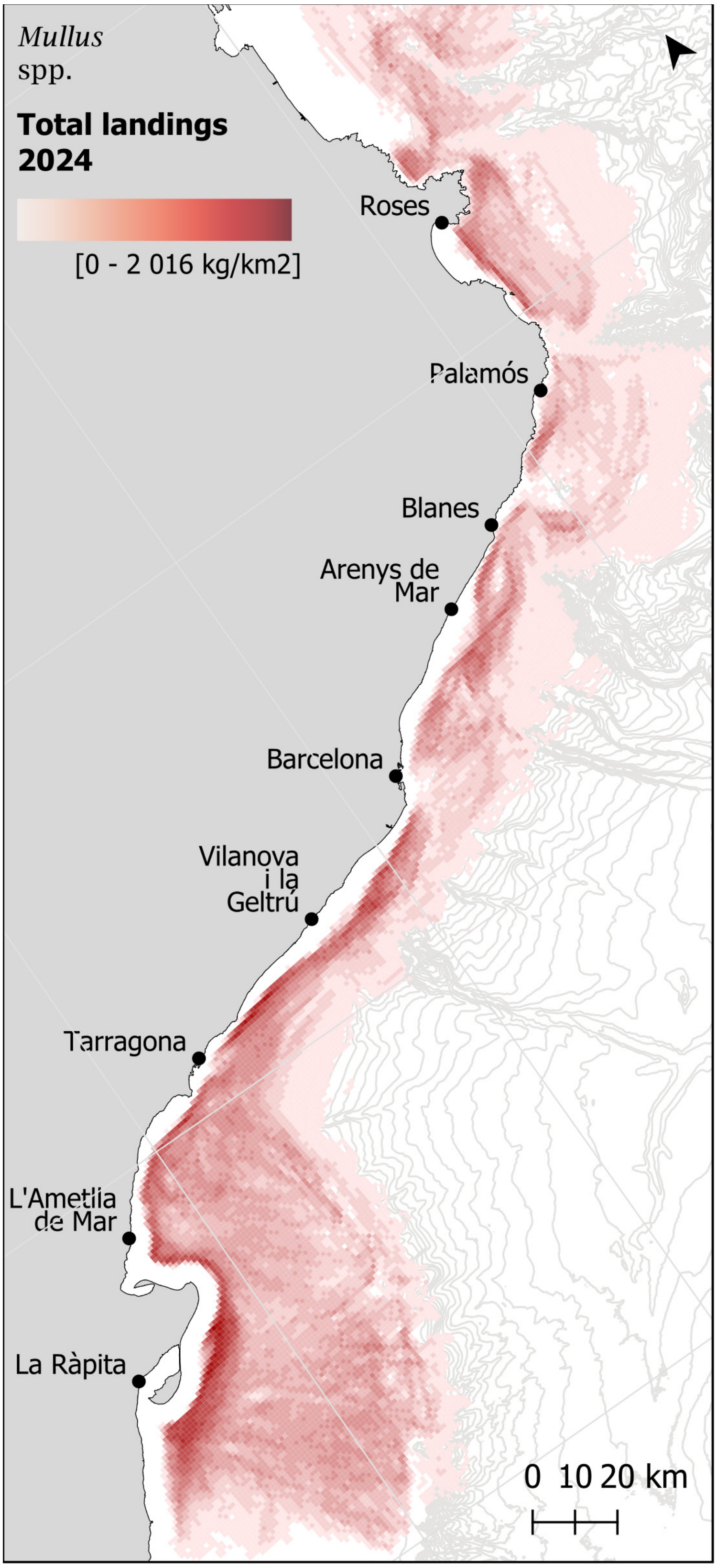

Figure 13. Spatial distribution of landings (kg/km²) for red mullet (*Mullus spp.)* in the Catalan fishing grounds (North GSA6) in the year analyzed.

The spawning area for red mullet is the continental shelf but the nursery zone is located on coastal areas. The recruitment season is between October and December (Lombarte et al. 2000).

Input data

The spatial distribution of total landings for red mullet in the Catalan fishing grounds (Figure 13) is located, mainly, in coastal areas considering bathymetry. However, in terms of total landings, red mullet is more abundant in the central and southern areas.

Historical red mullet landings in Catalonia since 2002 are shown in Figure 14. Landings increased throughout the time series until 2016, when the highest value was observed. Thereafter, landings were relatively stable. In 2024, red mullet landings returned to levels comparable to those observed in 2016.

Figure 15 shows red mullet landing distribution by métier from 2019 to 2024. Bottom trawlers have the highest landings for coastal delta shelf and the coastal shelf métiers. Lower landings are observed in the middle delta and deeper shelf métier. Artisanal fisheries have a small proportion of landings in all years.

Annual LFD

After raising the length frequencies obtained with the monitoring program, and considering discards and small-scale fisheries length frequency, the annual length frequency of red mullet in Catalonia is plotted in Figure 16. The SOP validation results are presented in Table 3, while the number of individuals sampled by the ICATMAR monitoring program is shown in Table 4. The shape of the plots varies among them, indicating different length-frequency distributions in time. An increase in smaller length classes was observed in 2021 and 2022, while in 2024 there was a notable rise in the number of individuals measuring 130–150 mm. It is also worth noting that the largest individuals are mainly caught with small-scale fisheries.

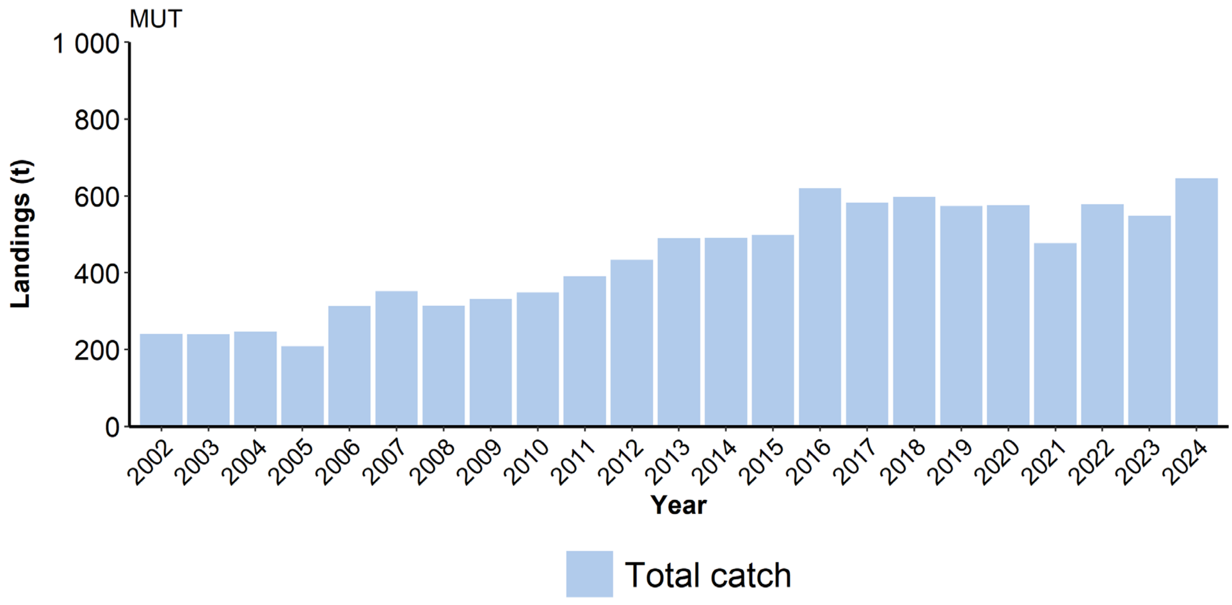

Figure 14. Historical landings (t) for red mullet in Catalonia.

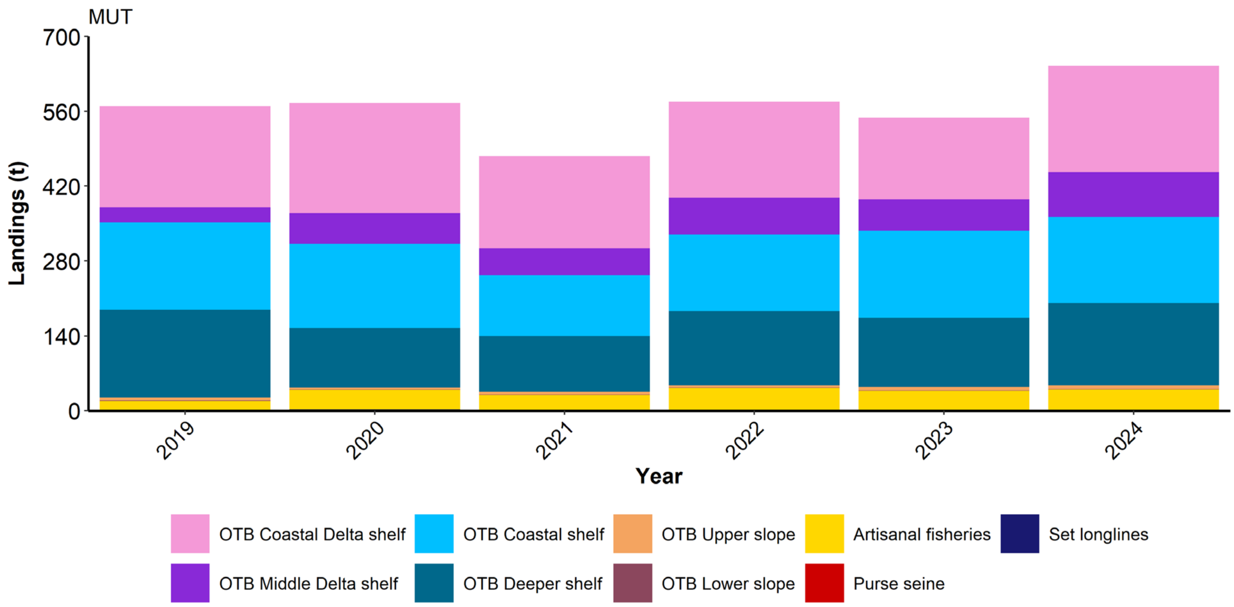

Figure 15. Landings (t) for red mullet by métier and fishing gear. OTB: bottom trawling.

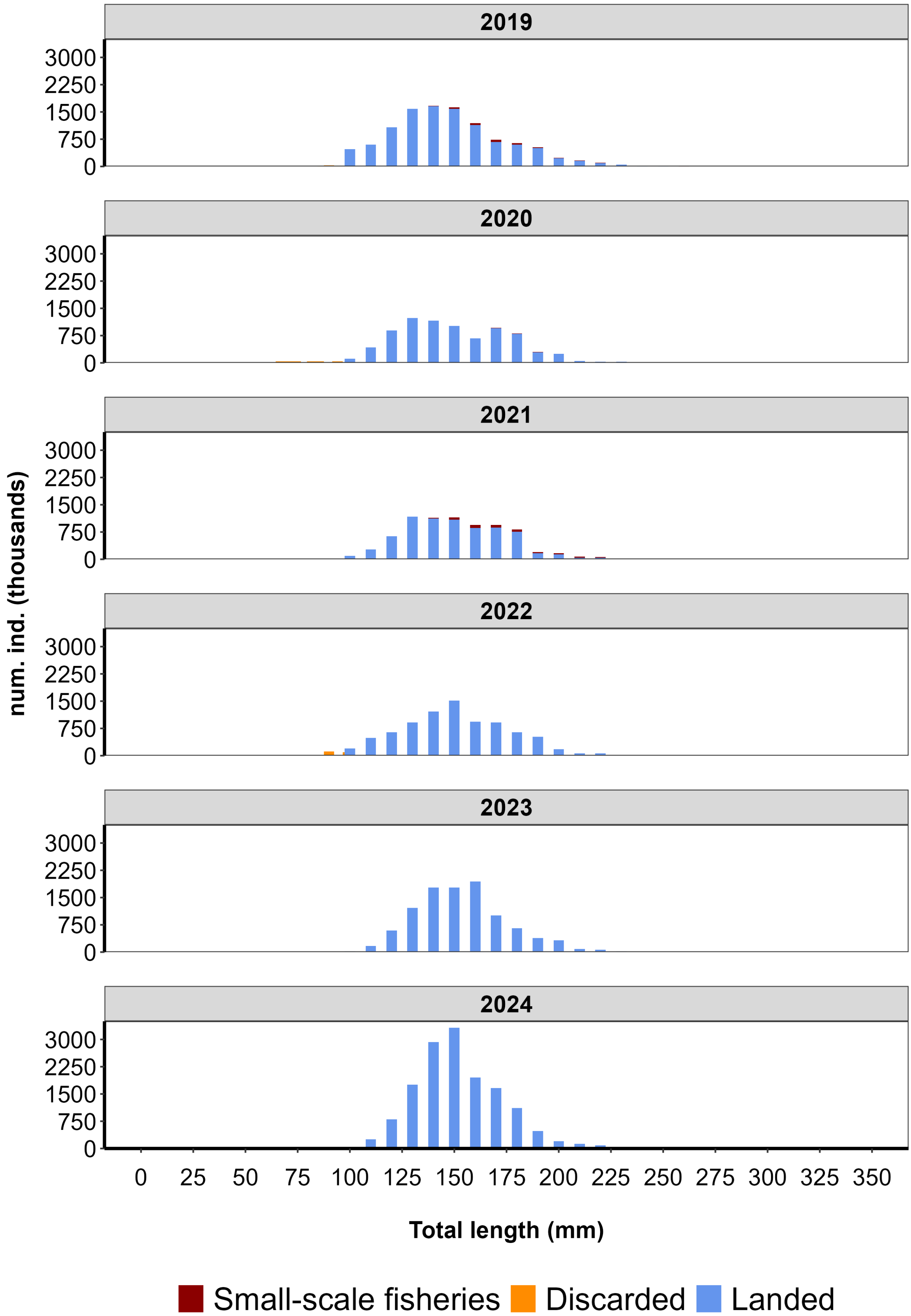

Figure 16. Annual length frequency distributions of red mullet from bottom trawling and small-scale fisheries. The data from bottom trawling is raised from ICATMAR data and details landed and discarded red mullet. The data from small-scale fisheries is obtained from DCF (Data Collection Framework) dataset.

Table 3. Sum of Products (SOP) validation for red mullet (MUT): The column Calculated Weight in GSA6N (SOP) represents the biomass estimated through the raising process, while landings refer to the reported landings in NGSA6. The ratio between SOP and landings is known as the Sum of Products (SOP). Values close to 1 indicate that the raising process provides biomass estimates that closely match the reported landings, thereby validating the accuracy of the estimation method.

Species	Year	Catch classification	Gear	Calculated weight GSA6N (kg) (SOP)	Landings in GSA6N (kg)	SOP/Landings
MUT	2019	ASSF	Artisanal fisheries	16282	17332	0.94
MUT	2020	ASSF	Artisanal fisheries	2767	36769	0.08
MUT	2021	ASSF	Artisanal fisheries	26981	28790	0.94
MUT	2019	Discarded	Bottom trawl	336	-	-
MUT	2020	Discarded	Bottom trawl	1759	-	-
MUT	2021	Discarded	Bottom trawl	44	-	-
MUT	2022	Discarded	Bottom trawl	1783	-	-
MUT	2023	Discarded	Bottom trawl	172	-	-
MUT	2019	Landed	Bottom trawl	413483	555142	0.74
MUT	2020	Landed	Bottom trawl	323803	536623	0.60
MUT	2021	Landed	Bottom trawl	295497	447110	0.66
MUT	2022	Landed	Bottom trawl	347815	535696	0.65
MUT	2023	Landed	Bottom trawl	435548	510819	0.85
MUT	2024	Landed	Bottom trawl	616172	605741	1.02

Table 4. Number of red mullet individuals sampled by zone and season from ICATMAR monitoring data used to raise the length frequencies.

Fishery	Year	Zone	Winter	Spring	Summer	Autumn	N hauls
			Number individuals sampled				
Bottom trawl	2019	North	70	415	159	116	19
Bottom trawl	2019	Center	82	119	50	83	17
Bottom trawl	2019	South	301	217	206	391	25
Bottom trawl	2020	North	43	102	58	237	15
Bottom trawl	2020	Center	145	76	64	102	11
Bottom trawl	2020	South	114	67	264	142	18
Bottom trawl	2021	North	261	88	125	60	18
Bottom trawl	2021	Center	123	135	91	49	11
Bottom trawl	2021	South	33	46	221	211	20
Bottom trawl	2022	North	111	97	99	162	16
Bottom trawl	2022	Center	122	64	141	134	11
Bottom trawl	2022	South	88	188	272	359	21
Bottom trawl	2023	North	303	240	272	339	24
Bottom trawl	2023	Center	297	207	252	188	12
Bottom trawl	2023	South	297	141	285	122	20
Bottom trawl	2024	North	418	287	252	278	21
Bottom trawl	2024	Center	219	337	208	285	14
Bottom trawl	2024	South	245	319	270	477	24

Length-Based Spawning Potential Ratio (LBSPR)

Model setting and results

Scenarios

Four different scenarios were applied for the sensitivity analysis for red mullet (Table 5):

- **Scenario 1:** used growth parameters, natural mortality, and maturity data from the STECF and GFCM stock assessments**.**
- **Scenario 2:** applied growth parameters and natural mortality from the literature (Demestre et al., 1996), while using the same maturity data as in Scenario **1.**
- **Scenario 3:** used the same parameters as Scenario 1, but incorporated a preliminary estimate of length at first maturity from ICATMAR data.
- **Scenario 4:** also used the same growth parameters as the previous scenarios, but length at first maturity was sourced from Kokokiris et al. (2014).

Table 5. Biological parameters used in the different LBSPR scenarios for red mullet (MUT). $L_{inf:}$ asymptotic length at which growth is zero, k: growth rate, M: natural mortality, $L_{mat50:}$ length where 50% of individuals are mature, $L_{mat95:}$ length where 95% of individuals are mature.

Species	Scenario	L_{inf} (mm)	L_{mat50} (mm)	L_{mat95} (mm)	M/K
MUT	1	345	137	150.7	1.235
MUT	2	330	137	150.7	1.132
MUT	3	345	133	146.3	1.235
MUT	4	345	114	155.0	1.235

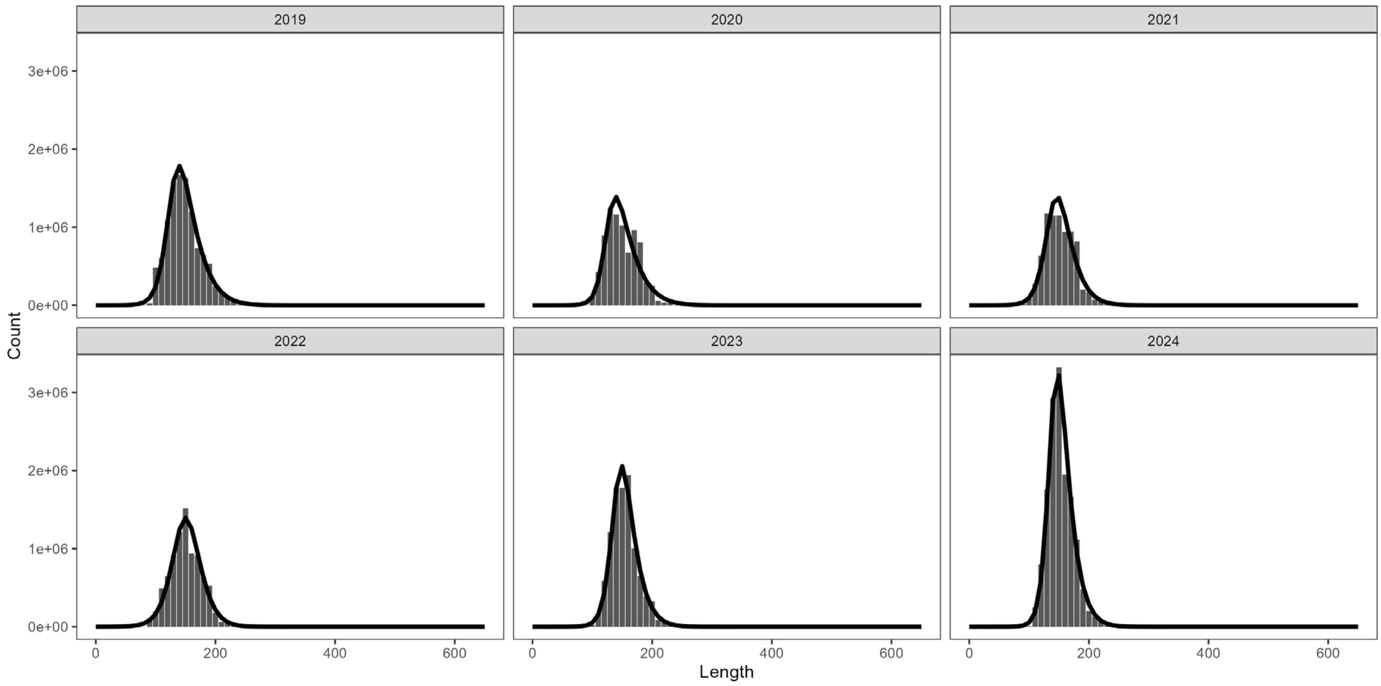

Figure 17. Fit of the data using the LBSPR model for red mullet for each studied year. Grey columns indicate length frequencies. Black lines indicate the fit of the model.

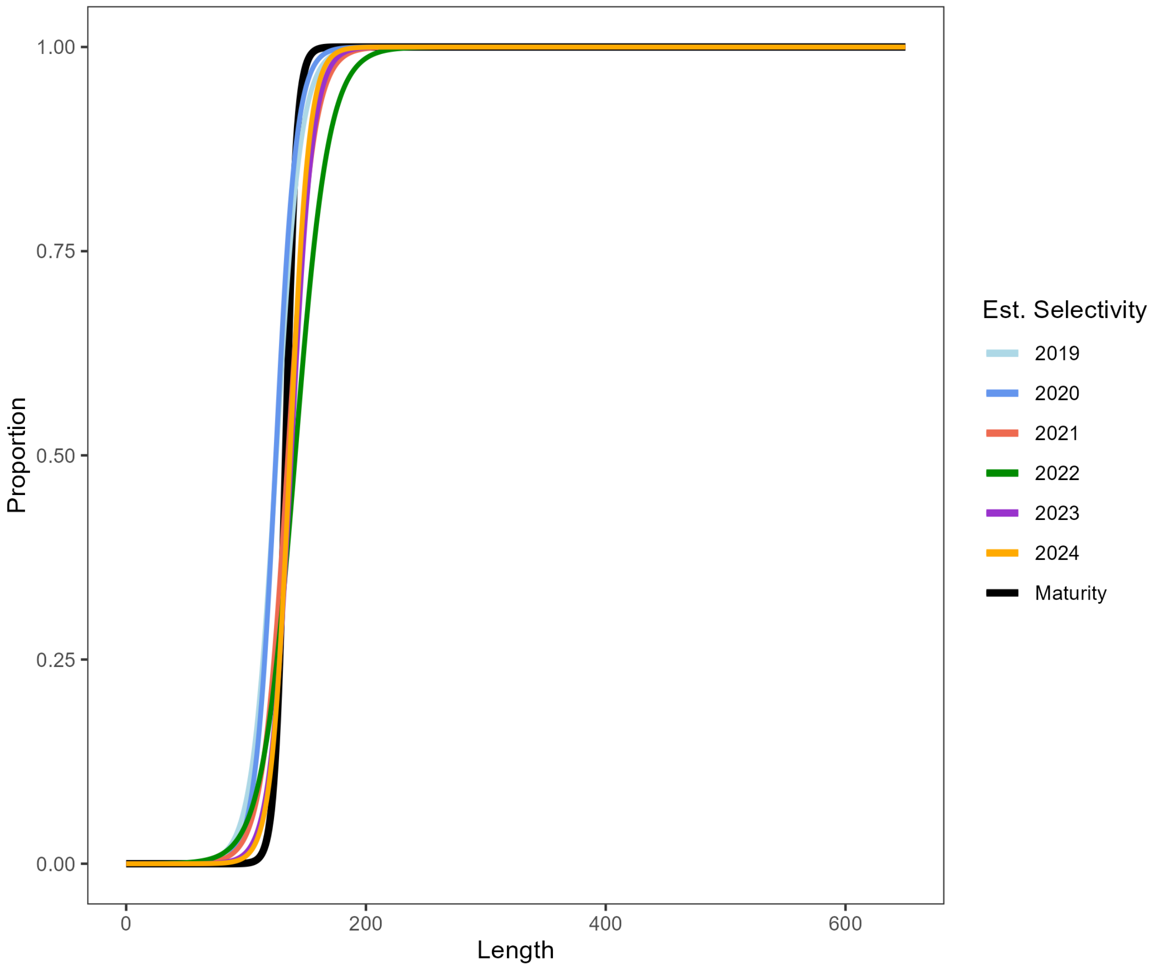

Figure 18. Length curves for red mullet. Black line shows the length curve at maturity. Color lines show the estimated selectivity at length curve predicted by the LBSPR model for each year in scenario 3 (the scenario selected).

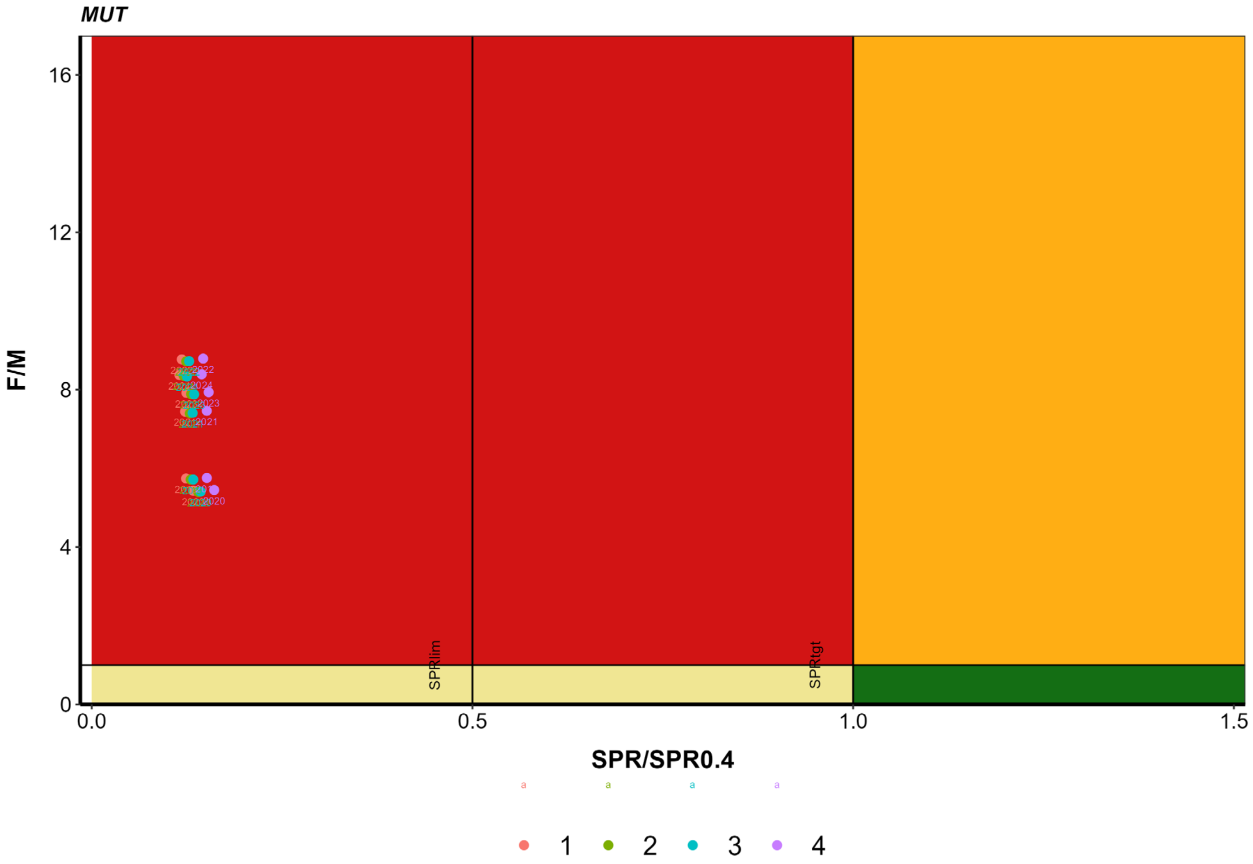

Figure 19. Kobe plot for red mullet by scenario (1-3) and year. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio, F: fishing mortality, M: natural mortality, and F/M: relative fishing mortality.

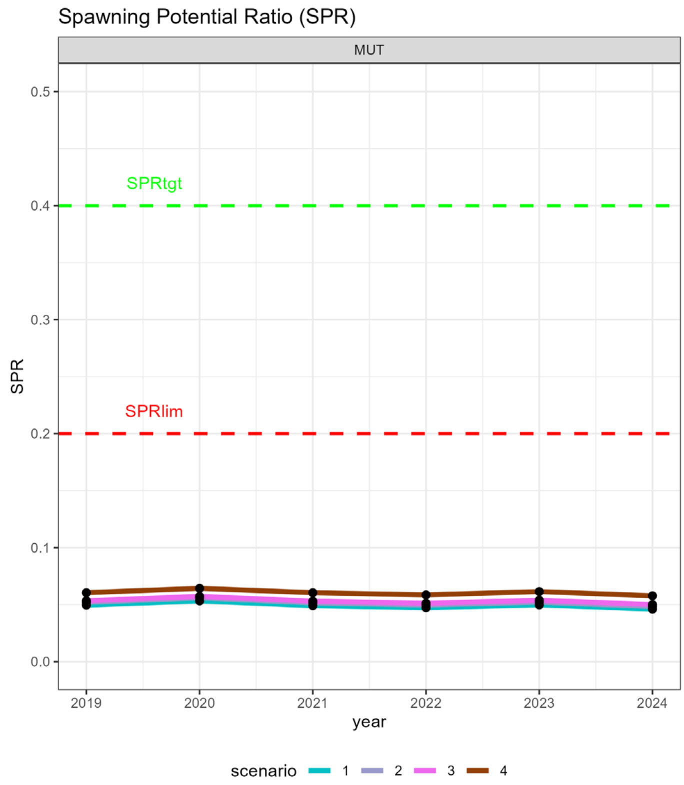

Figure 20. Spawning potential ratio (SPR) per year analyzed for red mullet evaluated with LBSPR model. LBSPR: Length-Based Spawning Potential Ratio. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio. Colored lines show the results for each scenario.

Table 6. LBSPR model results for red mullet with the different scenarios tested for each year analyzed. $SL5_{0:}$ Length where 50% of individuals are caught, SPR: spawning potential ratio and FM: fishing mortality. SD is the standard deviation calculated for each indicator. The selected scenario is highlighted in blue.

spp	scenario	year	SL_{50}	SD	SPR	SD	FM	SD
MUT	1	2019	127.30	1.63	0.05	0.03	5.74	1.52
MUT	1	2020	127.01	1.98	0.05	0.04	5.43	1.50
MUT	1	2021	137.87	2.29	0.05	0.03	7.45	2.04
MUT	1	2022	144.37	2.42	0.05	0.03	8.77	2.38
MUT	1	2023	139.61	1.34	0.05	0.03	7.92	2.03
MUT	1	2024	138.13	1.08	0.05	0.03	8.37	2.09
MUT	2	2019	126.99	1.87	0.05	0.04	5.72	1.57
MUT	2	2020	126.64	2.24	0.06	0.04	5.40	1.55
MUT	2	2021	137.54	2.61	0.05	0.04	7.40	2.12
MUT	2	2022	144.06	2.78	0.05	0.03	8.72	2.49
MUT	2	2023	139.45	1.54	0.05	0.04	7.89	2.10
MUT	2	2024	138.01	1.23	0.05	0.03	8.35	2.16
MUT	3	2019	127.27	1.74	0.05	0.04	5.71	1.55
MUT	3	2020	126.98	2.11	0.06	0.04	5.41	1.52
MUT	3	2021	137.82	2.43	0.05	0.04	7.41	2.06
MUT	3	2022	144.31	2.56	0.05	0.04	8.73	2.41
MUT	3	2023	139.58	1.43	0.05	0.04	7.88	2.06
MUT	3	2024	138.11	1.14	0.05	0.03	8.33	2.11
MUT	4	2019	127.30	1.69	0.06	0.04	5.75	1.52
MUT	4	2020	127.02	2.05	0.06	0.04	5.45	1.50
MUT	4	2021	137.86	2.37	0.06	0.04	7.46	2.03
MUT	4	2022	144.35	2.50	0.06	0.03	8.79	2.38
MUT	4	2023	139.60	1.39	0.06	0.04	7.94	2.02
MUT	4	2024	138.12	1.12	0.06	0.03	8.39	2.08

Fitted data

The length frequency distribution fit per year is shown in Figure 17. The model generally follows the mode for all years, slightly underestimating the number of individuals for some length classes.

Selectivity

The outputs of the model for the selectivity of the fishery are shown for each scenario in Table 6. The output of the selected scenario (3) is also plotted with L_{mat50} and SL_{50} in Figure 18. The model outputs reveal that the fishery is fishing similar to or above L_{mat50}.

Reference points

Even though the model is very sensitive to changes in growth parameters and maturity, the stock is below SPR_{lim} (=0.2) in all the scenarios (Table 6 and Figure 20). The Kobe plot for red mullet (Figure 19) shows the stock status throughout the different years, with a negative trend. The stock is, in all cases, located in the red zone meaning that it is overfished.

Final scenario

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBSPR model

Length-based Bayesian Biomass (LBB)

Scenarios

Four different scenarios were applied for the sensitivity analysis for red mullet (Table 7). The first scenario used growth parameters, natural mortality and maturity from STECF and GFCM stock assessment. The second one used growth parameters and natural mortality from literature (Demestre et al., 1996) and the same maturity as scenario one. The third scenario used the same parameters as scenario 1 but a preliminary length at first maturity from ICATMAR data. Finally, scenario four used the same growth parameters as scenario 1, 2 and 3, but length at first maturity from Kokokiris et al., 2014.

Table 7. Biological parameters used in the different LBB scenarios for red mullet (MUT). $L_{inf:}$ Asymptotic length, M/k: ratio between natural mortality and growth rate, $L_{mat50:}$ length where 50% of individuals are mature.

Specie	Scenario	Linf (cm)	M/k	Lmat50 (cm)
MUT	1	34.5	1.235	13.7
	2	33.0	1.132	13.7
	3	34.5	1.235	13.3
	4	34.5	1.235	11.4

As LFD and L_{mat} originated from ICATMAR data, scenario three was selected to provide final advice for the LBB model. The following graphics are based on Scenario 3.

Fitted data

The length frequency distribution fit per year is shown in Figure 21. The model generally follows the mode for all years, slightly underestimating the number of individuals for some length classes.

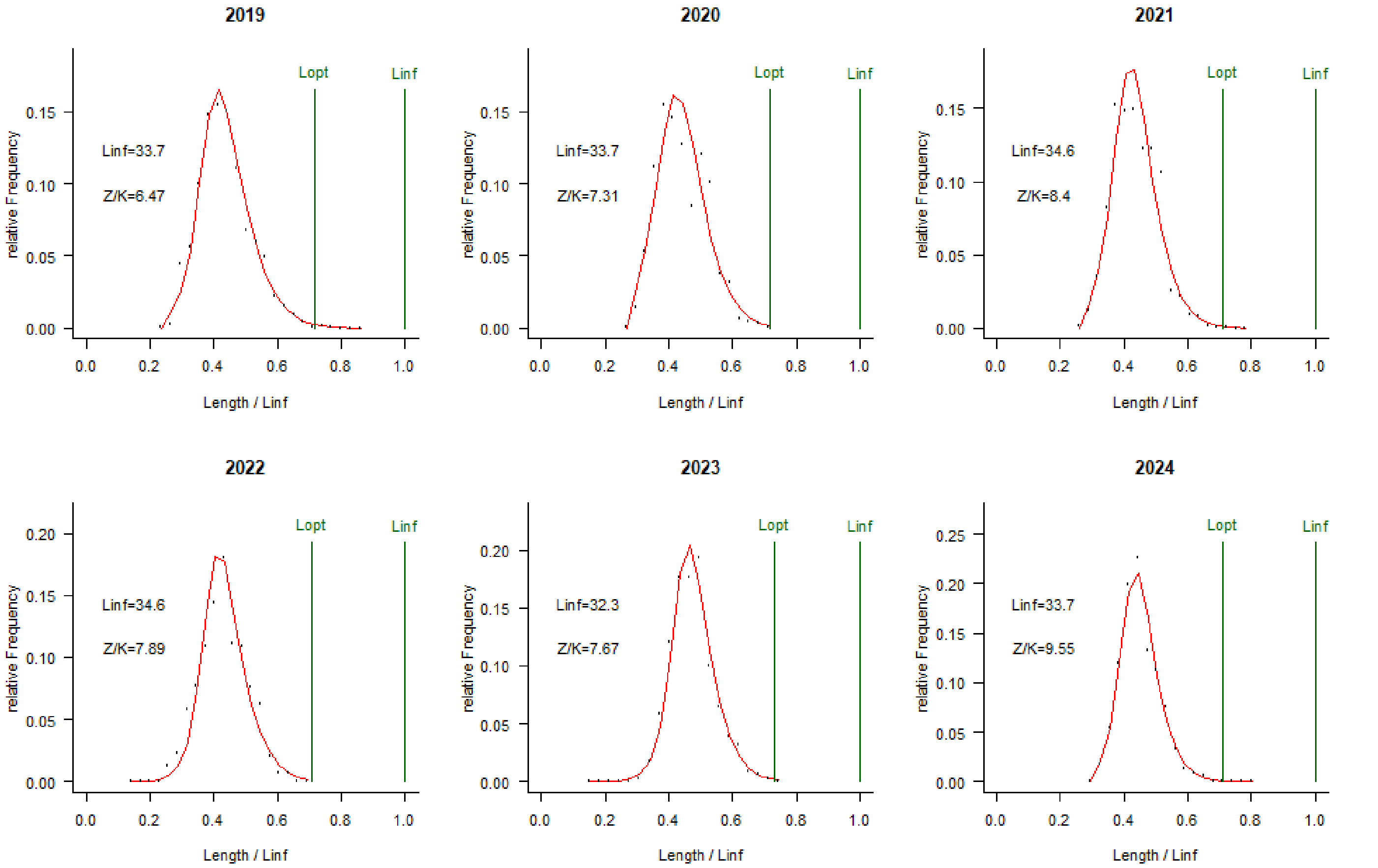

Figure 21. Fit of the data using the LBB model for MUT for each year in scenario 3. Red line indicates the fit of the model.

Reference points

Summary of the graphical results are in Figure 22. The upper left plot shows that the aggregated estimated length at first capture (L_c) is 12.5 cm, barely below the L_{mat} (13.3 cm) as seen in the left lower plot (L_c: dotted black line) for the majority of the series until the last years. The upper middle and right panels show that the L_{mean} is quite far from L_{opt}, which is also shown in the lower left plot (L_{mean}: bold black line). Lower middle and right plots show that the relative fishing pressure (F/M) and relative biomass (B/B_0) are outside of sustainable levels. More details related to these results are in Table 8.

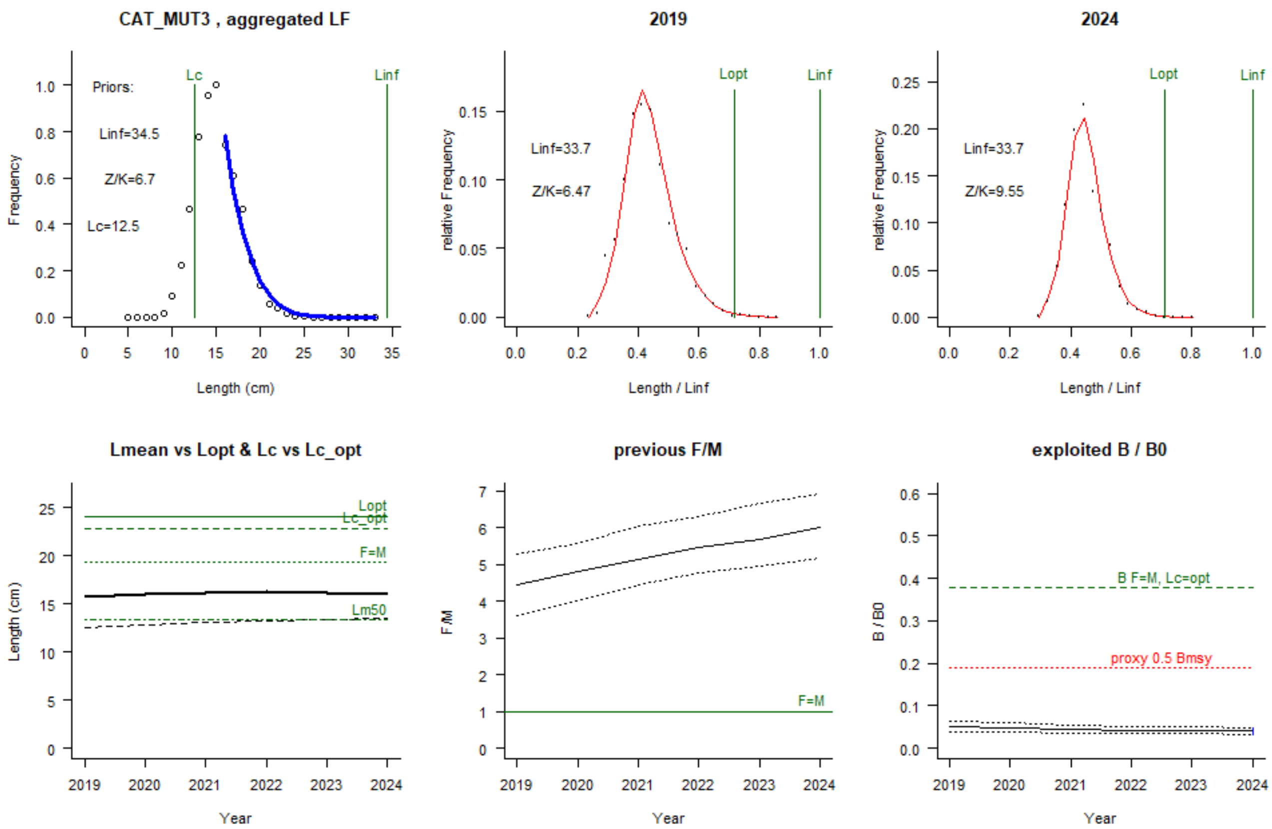

Figure 22. Summary output from LBB for MUT scenario 3.

Table 8. LBB model results for red mullet (MUT) with the different scenarios tested for each year analyzed. $L_{mean:}$ mean length of individuals, $L_{opt:}$ length at optimal yield, $Lc_{:}$ length at first capture, $L_{c\_opt:}$ length at first capture at optimal yield, L_{95th}/L_{inf}: ratio of the 95th percentile to asymptotic length , F/M: fishing mortality relative to natural mortality, $B/B0_{:}$ exploited biomass relative to unexploited biomass, $B/B_{msy:}$ exploited biomass relative to maximum sustainable yield biomass, $C_{mature:}$ proportion of mature individuals in the catch.

Specie	Scenario	Year	Lmean/Lopt	Lc/Lc_opt	L95th/Linf	F/M	B/B0	B/Bmsy	Cmature
MUT	1	2024	0.67	0.59	0.75	6.00	0.04	0.11	81%
	2	2024	0.68	0.60	0.77	6.00	0.04	0.11	81%
	3	2024	0.67	0.59	0.75	6.00	0.04	0.11	81%
	4	2024	0.67	0.59	0.75	6.00	0.04	0.11	98%

Stochastic Production model in Continuous Time (SPiCT)

For red mullet, data was taken from EU fleet register provided by the European Commission (Reg. EU 2017/218), GSA6 daily commercial fishing landings provided by the Spanish Ministry of Agriculture, Fisheries and Food, European Commission, Joint Research Centre (JRC) (2025), STECF-PLEN-25-01 background) and most recent available GFCM Stock Assessment Form (SAF) for MUT in GSA6 (RY2023) (Figure 23).

- Landings from 1971 to 2024 (Tons)
- Standardized CPUE (OTB): 2004 - 2024 (based on Henning Winker (GFCM) & Hoyle et al., 2024) -> Here assumes CPUE = LPUE
- Index: MEDITS survey data from 1994 to 2024 (Biomass, kg/km2)

As for the other species, a double-axis plot (Figure 24) was presented to compare trends between catches and indices (Biomass and LPUE).

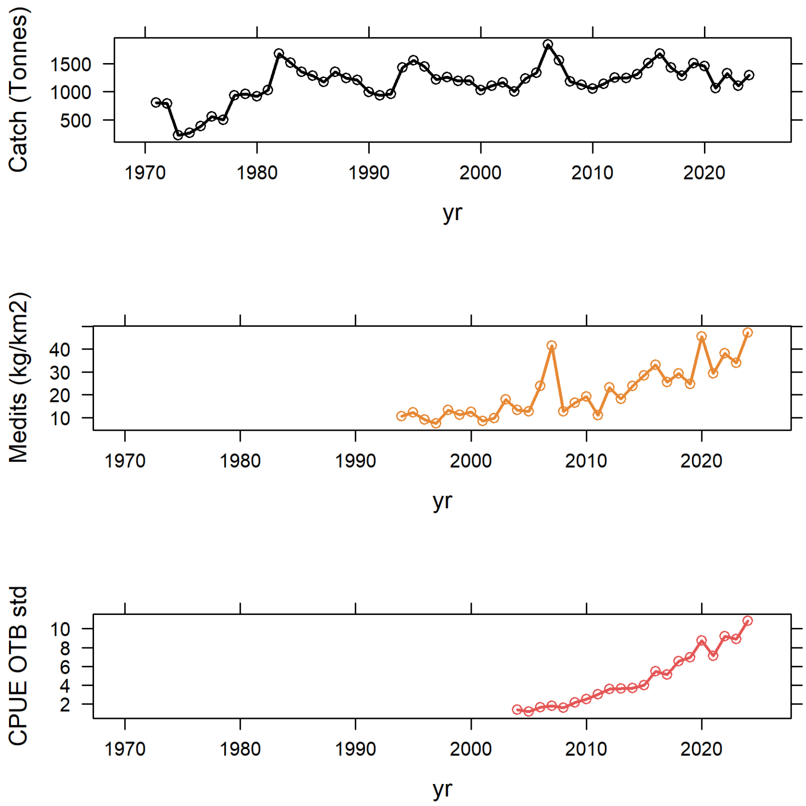

Figure 23. Data available for the assessment for red mullet in GSA6 to run SPiCT model. Top: catch data from 1971 to 2024. Centre: MEDITS survey data since 1994 to 2024. Bottom: CPUE standardized data since 2004 to 2024.

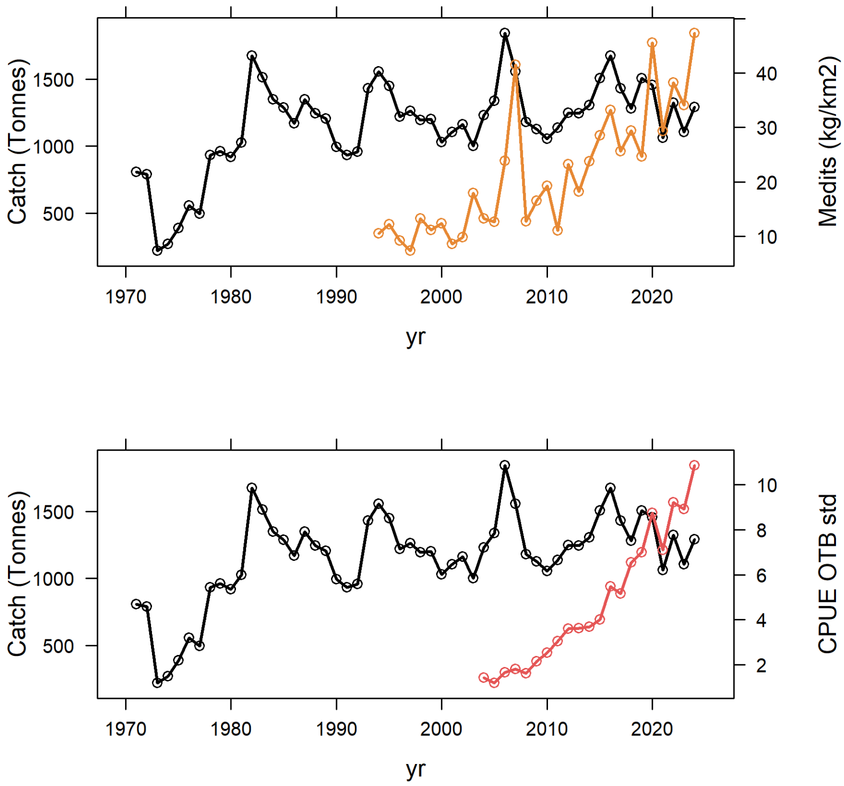

Figure 24. Double-axis plot to compare trends between catch and MEDITS index (top) and catch and CPUE standardized for OTB (bottom) for red mullet.

Although only the final scenario was presented, different scenarios were tested:

- Scenario 1: landings started in 1971, MEDITS 1994.
- Scenario 2: landings started in 1971, MEDITS 1994, CPUE std OTB.
- Scenario 3: landings started in 1990, MEDITS 1994.
- Scenario 4: landings started in 1971, MEDITS 1994, no rprior.

A final comparison of all scenarios is shown in Figure 25. Scenario 1 was chosen as the final because it performs better in diagnostics and more accurately reflects the current stock and fishery dynamics. Regarding scenario 2, the CPUE index is not informative for the model, and the diagnostics were also poor. Scenario 3 was tested to see if the model can estimate the stock status similarly, starting the time series in 1990. Since the trend is similar in both scenarios, scenario 1 was selected due to its longer time series. Finally, scenario 4 was tested to evaluate how the model performs without informing the r prior, as the sensitivity analysis for this prior was not satisfactory. Ultimately, the model estimates similar trends.

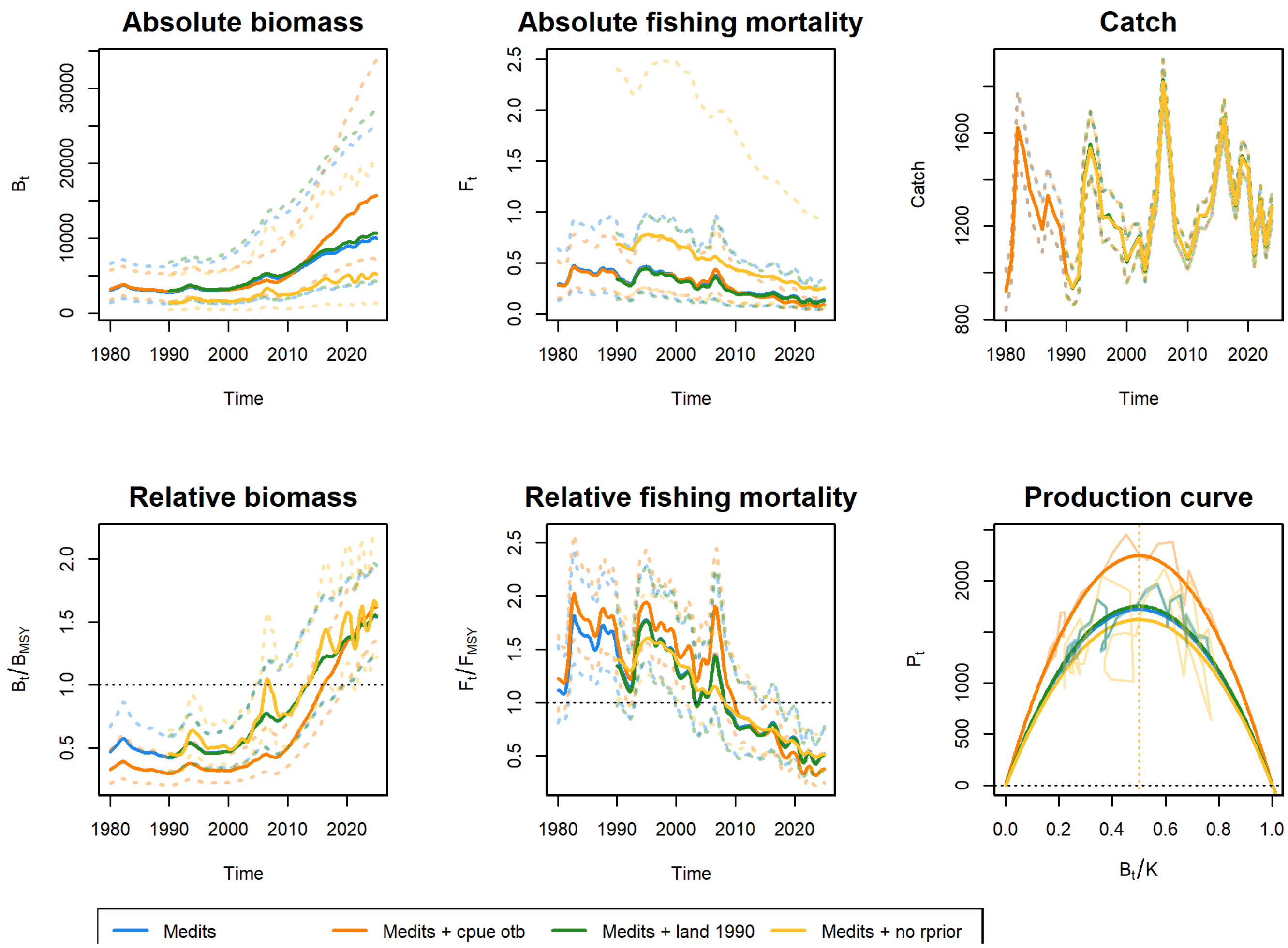

Figure 25. Scenarios comparison for red mullet in GSA6.

Final scenario

Type	Prior	Description	Assignment	Mean	Standard deviation	Comment
Fishery dynamic	logbkfrac	B/K fraction (depletion)	-	Log(0.5)	0.5	A prior for BKfrac is included because we already know that fisheries occurred before the beginning of the time series. A moderate depletion of 0.5 is used.
Relative standard deviation time series (input data)	stdevfacC	Standard deviation factor for catches	<2000	2	1	Landing data for years before 2002 were less reliable.
	stdevfacI	Standard deviation factor for indices		1	1	
Stock dynamic	logr	Population growth	-	Log(0.54)	0.49	Fishlife
	logn	Shape of production curve	-	Log(2)	-	Shaefer
Error	logsdc	Catch error	-	Log(0.025)	0.3	
	logsdf	Fishing mortality error	-	Log(4)	0.5	
	logsdb	Process error	-	Log(0.1)	0.5	
	logsdi	Observation error	-	Log(0.2)	0.3	Same for all indices

Table 9. Priors settings for red mullet in GSA 6 for final scenario.

Settings used for the final scenario are shown in Table 9. Among other settings, BK fraq prior was 0.5, which is a moderate value. Additionally, before 2002, a standard deviation factor of 2 was used because the data were less reliable than after that time.

The final scenario input data are shown in Figure 26, and the final summary assessment results are presented in Figure 27. The results show an increasing trend in biomass since 2000, with values above the reference point B_{msy} since 2012. For fishing mortality, the estimated values have been consistently below 1 since 2008, although they have remained relatively stable since 2020.

All diagnostics can be checked in Figure 28, Figure 29, Figure 30, Figure 31 and Figure 32. The chosen scenario met all of the model diagnostics, such as Mohnr values for the retrospective analysis and a MASE of 0.87. A sensitivity analysis for the final scenario was performed, testing r prior, bkfrac, process error, and observation error to assess the model's robustness within these priors. All these plots and results for the other scenarios will be available at

https://github.com/ICATMAR.

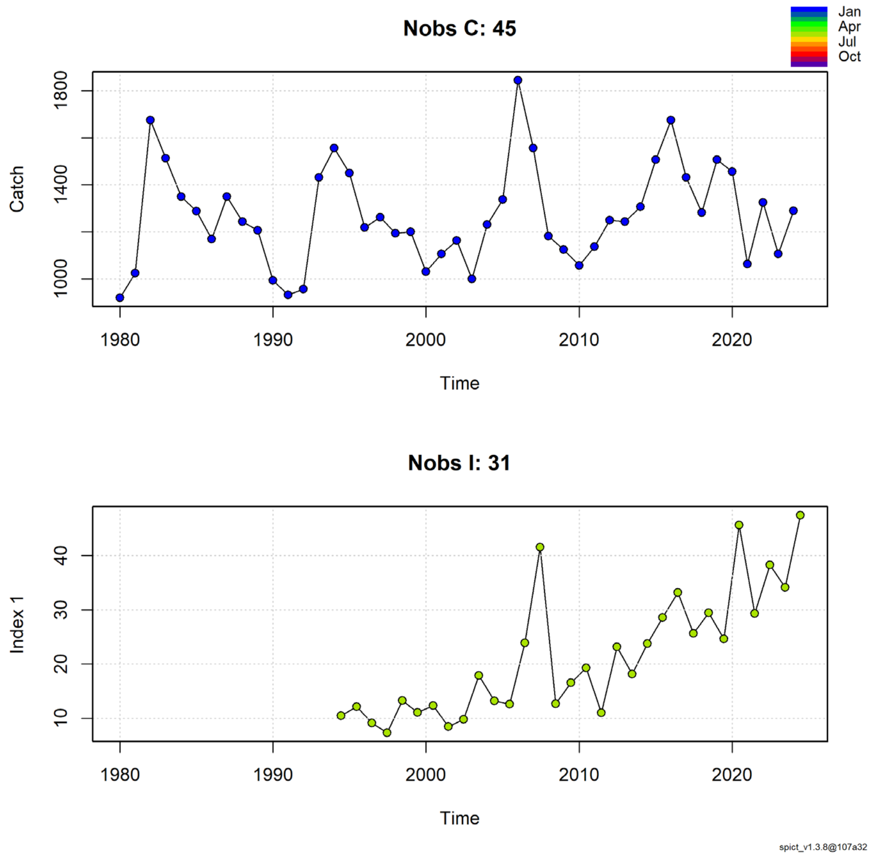

Figure 26. Input data for SPiCT model for red mullet in GSA6 for scenario 1. Top: catch in tons per year since 1971, bottom: index data of biomass derived from MEDITS since 1994.

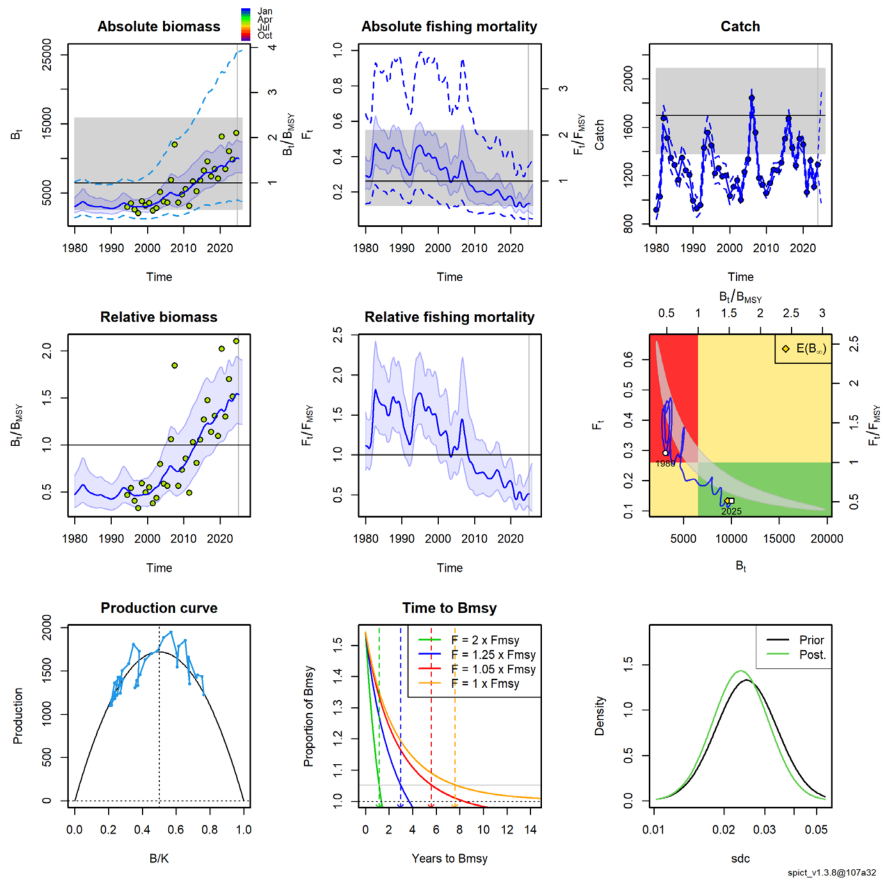

Figure 27. Stock assessment summary for SPiCT model for red mullet in GSA6 for final scenario.

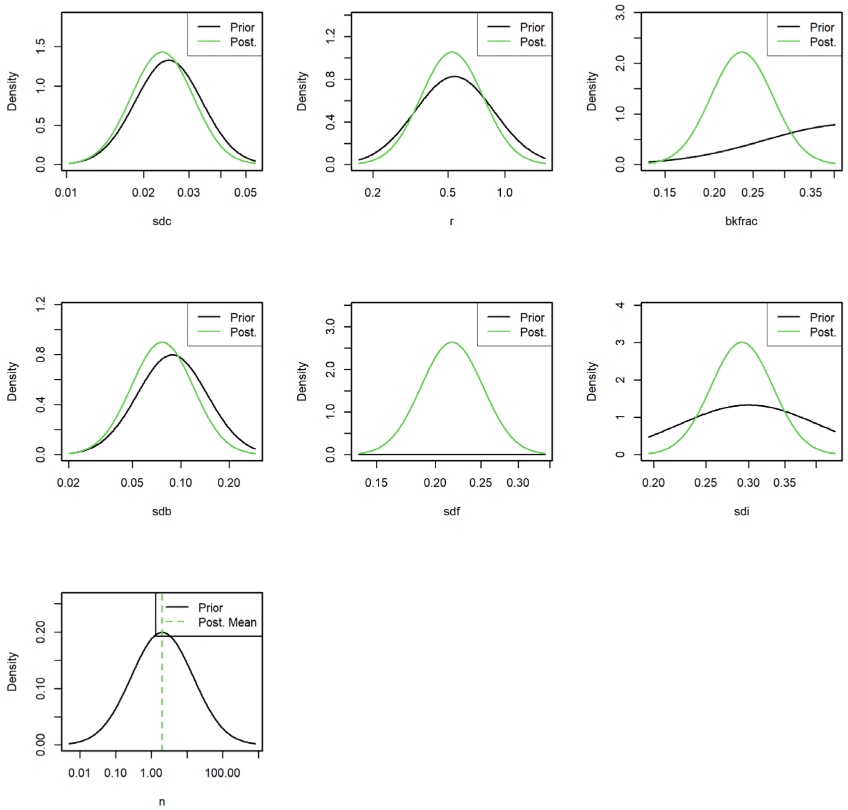

Figure 28. Estimated priors and posteriors for the updated assessment for red mullet in GSA6 for final scenario.

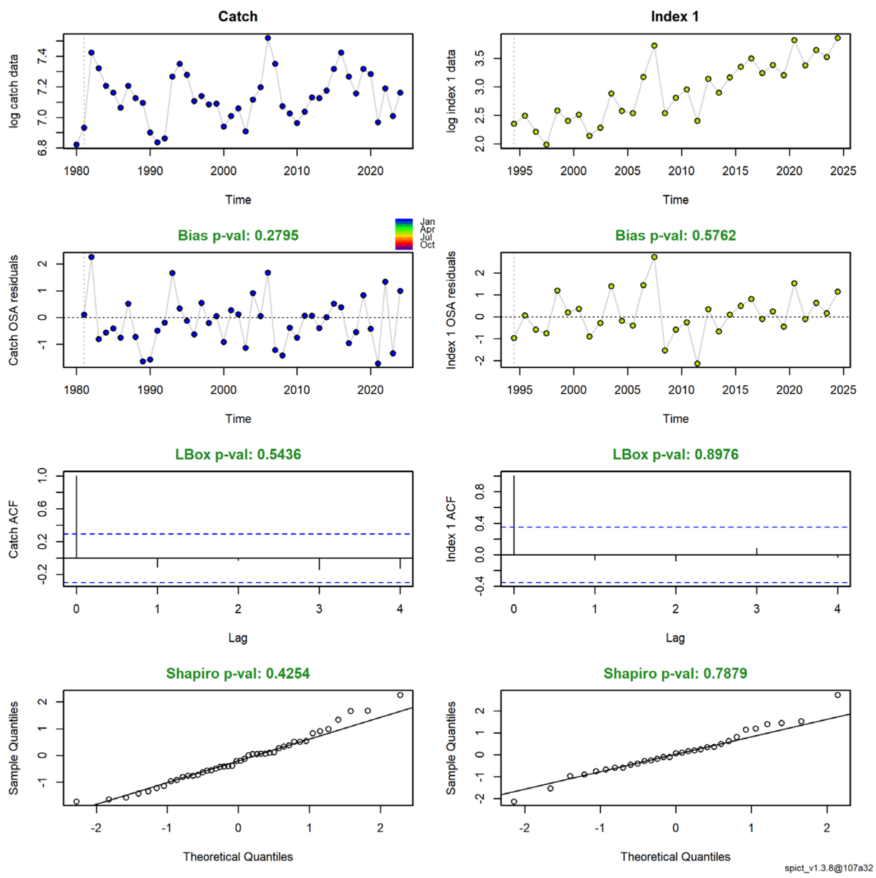

Figure 29. One-step-ahead residuals for the model for red mullet in GSA6 for final scenario.

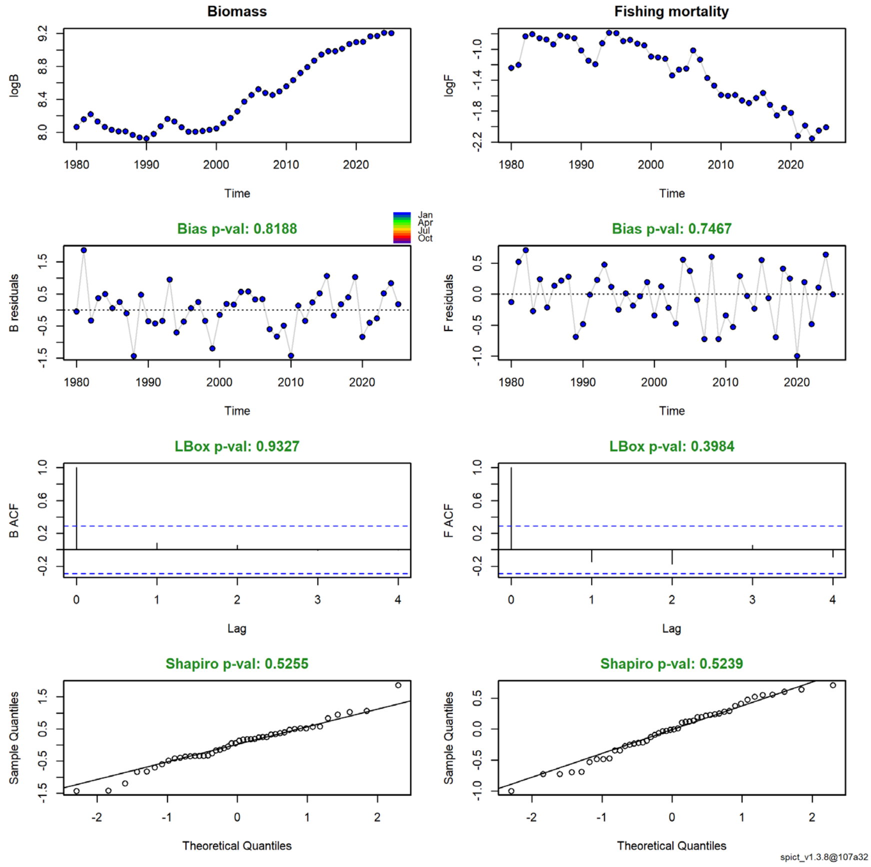

Figure 30. Process error deviations for the model for red mullet in GSA6 for final scenario.

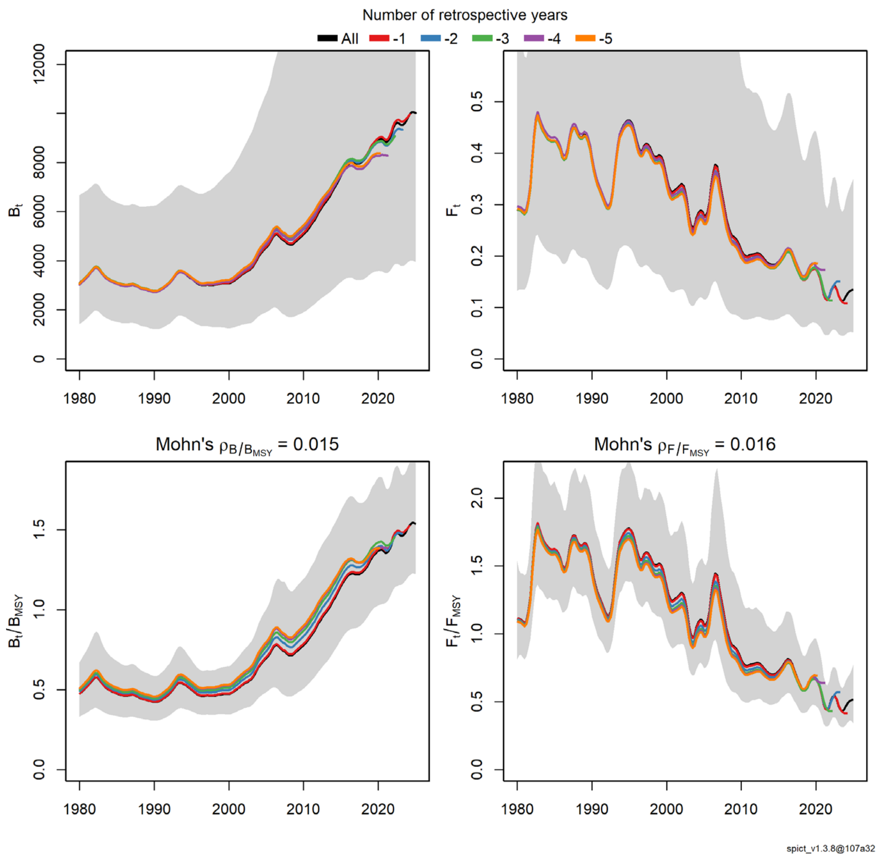

Figure 31. Retrospective analysis for red mullet in GSA6 for final scenario.

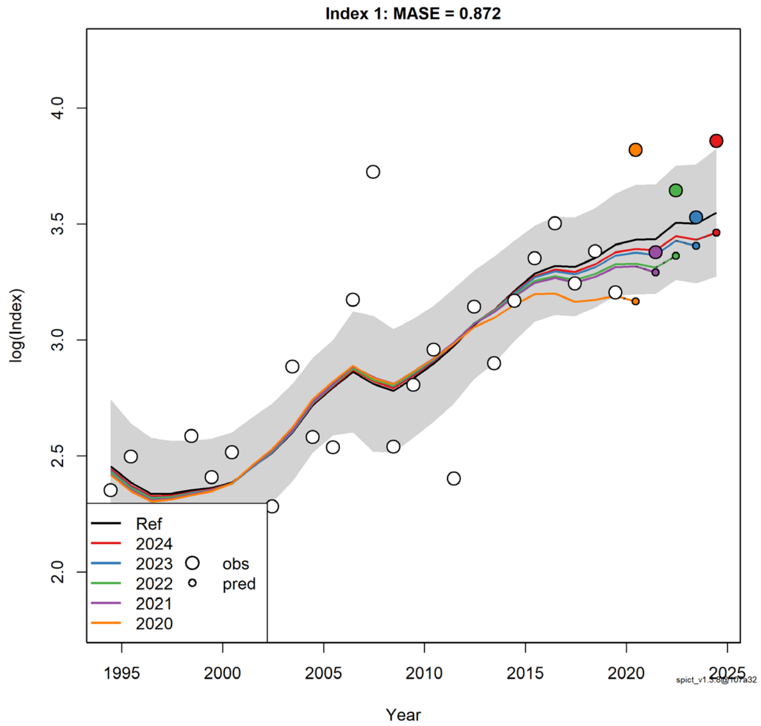

Figure 32. Hindcasting for the model for red mullet in GSA6 for final scenario.

Final scenario advice

Final scenario advice is presented in Figure 33 and in Table 10, which outlines the indicators for red mullet in GSA 6 in 2024, based on the GFCM advice framework. The assessment results should be considered qualitative, although the model results in good diagnostics. The sensitivity analysis and different scenarios result in similar stock status, indicating that the model is relatively stable and robust.

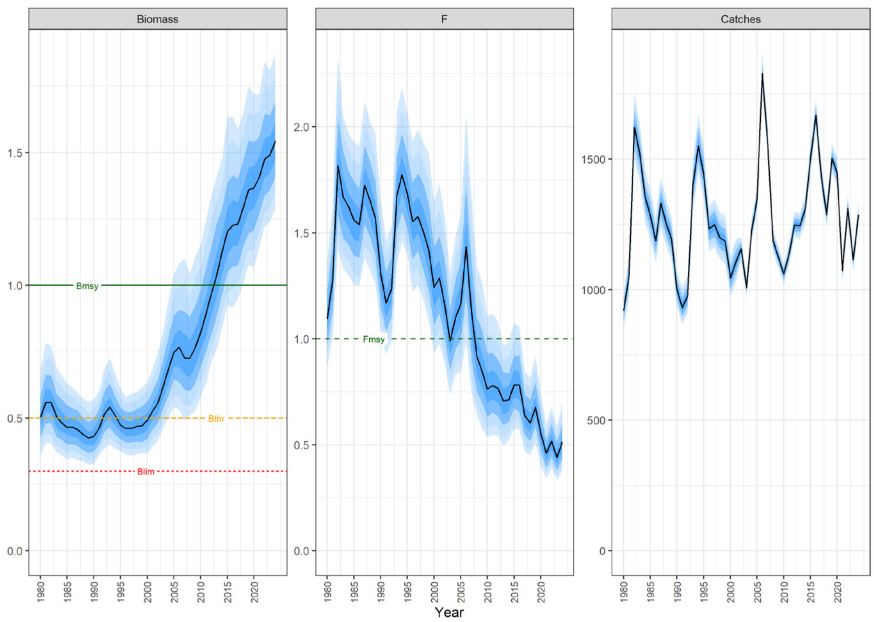

Figure 33. Advice for final scenario for red mullet in GSA6: Historical and current stock status regarding F_{msy}, B_{msy} and B_{lim}.

Table 10. Indicators in 2024 from SPiCT for red mullet in GSA6 final scenario.

Species	Year	Catch (t)	F/F_{msy}	B/B_{msy}	B/B_{pa}	B/B_{lim}
MUT	2024	1286.28	0.514	1.54	3.09	5.15

Statistical catch-at-size model (MESTOCK)

Model fits and associated variables from the assessment are presented in Figure 34, Figure 35, Figure 36 and Figure 37.

The model was experimentally applied using landing data (1981–2023), MEDITS survey data (2002–2023), CPUE standardized data for OTB, and length-frequency data from both landings (OTB, 2002–2023) and surveys (MEDITS, 2002–2023).

The model fits the CPUE data better than the index data. The model is not able to follow high peaks in biomass, for example, in 2006. The model shows some discrepancies in fitting the fleet and survey length frequencies, but generally follows similar shapes

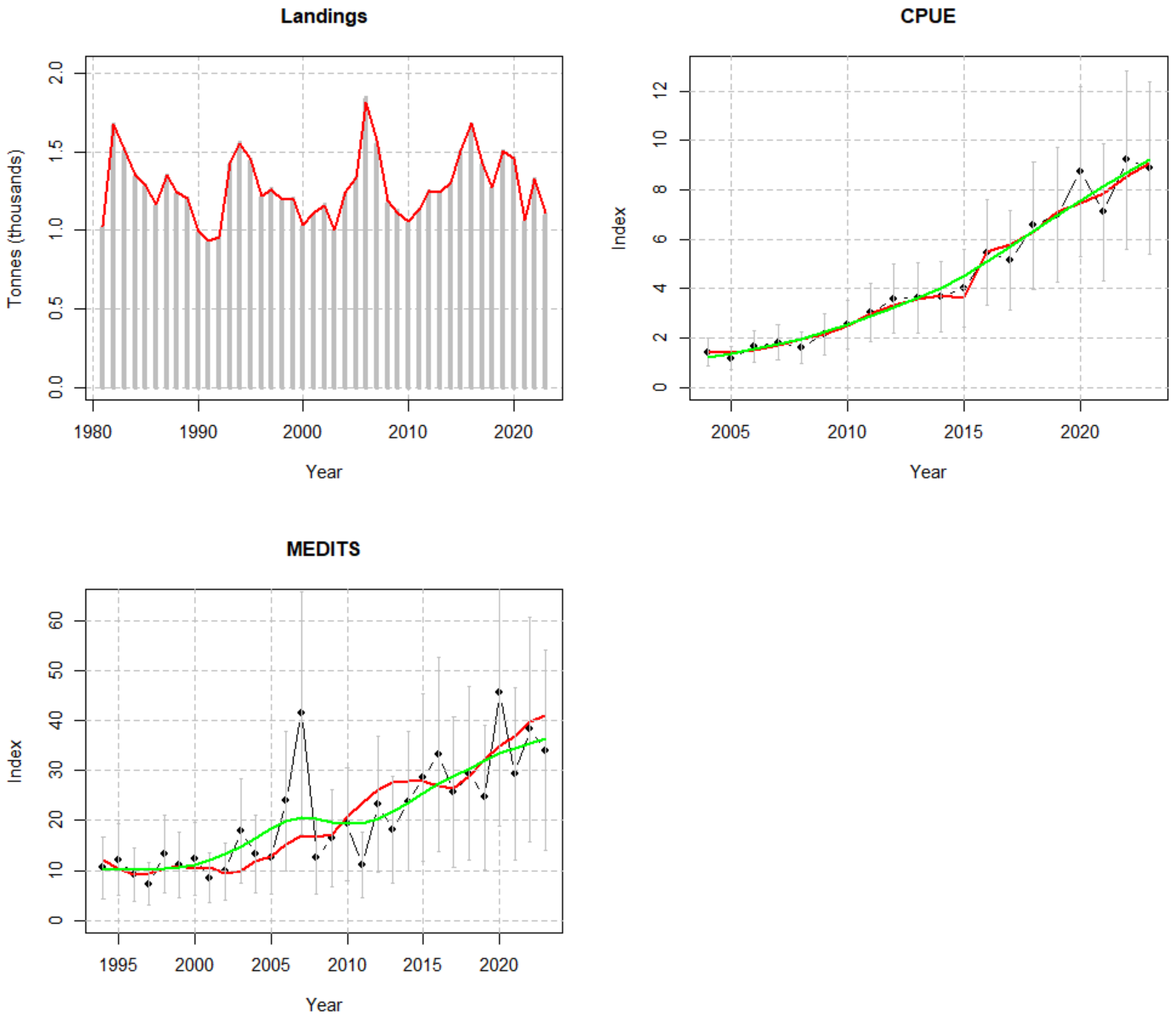

Figure 34. Fitting of the landing's series and abundance index for MUT in the GSA6. Red line corresponds to the model estimation.

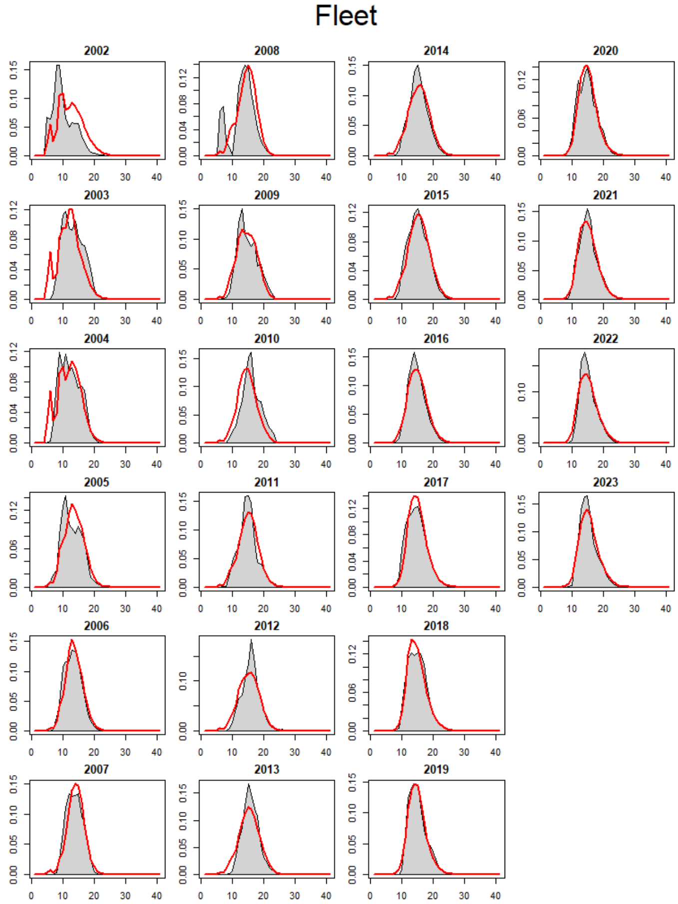

Figure 35. Fitting of the landings size compositions for MUT in the GSA6. Red line corresponds to the model estimation.

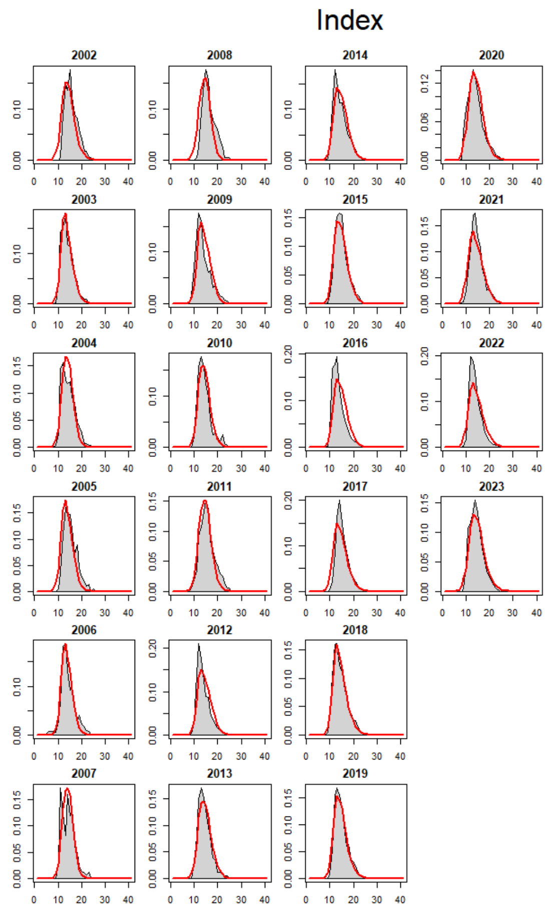

Figure 36. Fitt e compositions for MUT in the GSA6. Red line corresponds to the model estimation.

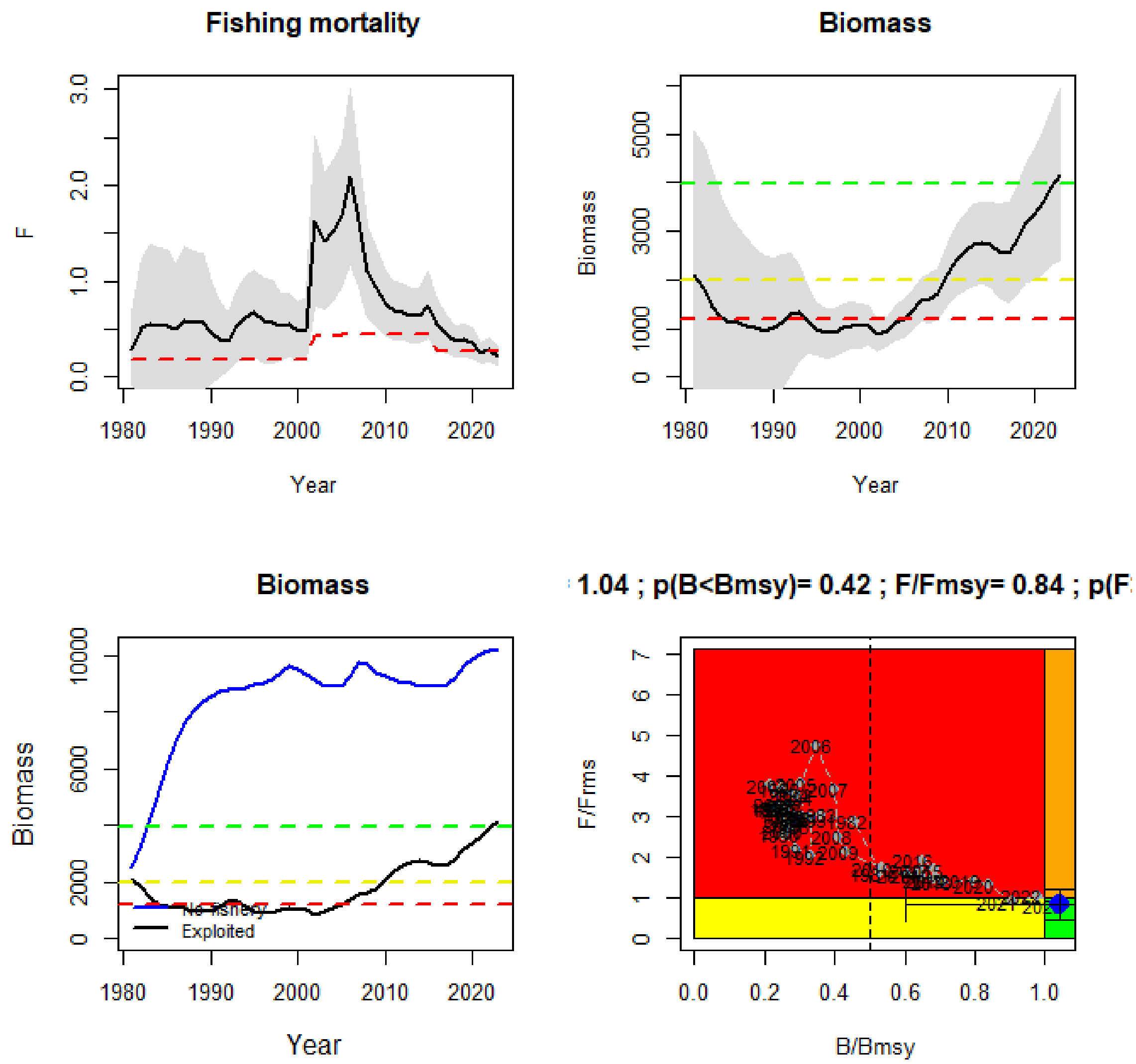

Figure 37. Biomass, fishing mortality, stock depletion and Kobe plot estimated for MUT in the GSA6.

Analysis of population variables indicates that the red mullet biomass has remained between B_{thr} and B_{msy} since 2010, although it has shown improvement from 2015 to the present.

It is estimated that fishing pressure on this resource has decreased to reach F_{msy} in recent years. Analyses indicate that the reduction in fishing pressure has led to a proportional increase in biomass. The Kobe diagram suggests that the stock is experiencing sustainable exploitation (B/B0 > 0.4) and is not currently subject to overfishing (F < F40%).

This is a preliminary assessment, and further analysis and scenarios should be conducted to refine the model, such as performing different sensitivity analyses on biological parameters, given the significant influence of this type of information on these models.

European hake (*Merluccius marluccius*) HKE

The spawning area for European hake is the continental shelf and upper slope but the nursery area is only on the continental shelf. Recruitment occurs all year round but peaks in winter and spring (Recasens *et al.* 2008, ICATMAR, 24-07).

Input data

The spatial distribution of total landings for European hake in the Catalan fishing ground is shown in Figure 38. The distribution is relatively homogeneous with respect to bathymetry; however, in terms of total landings per km², the northern and southern areas exhibit higher values.

Historical European hake landings in Catalonia, from 2002 to 2024, are shown in Figure 39. Landings decreased throughout the entire time series until 2020, when the lowest value was recorded. Subsequently, in 2021 and 2022, an increasing trend was observed. However, European hake landings declined again in 2023, and in 2024, the series reached a new minimum.

Figure 40 shows the distribution of European hake landings by métier from 2019 to 2024. Bottom trawlers account for the highest landings, especially for deeper shelf and upper slope métier. Artisanal fisheries and set longliners contribute less to total landings, and their European hake catches have declined in recent years.

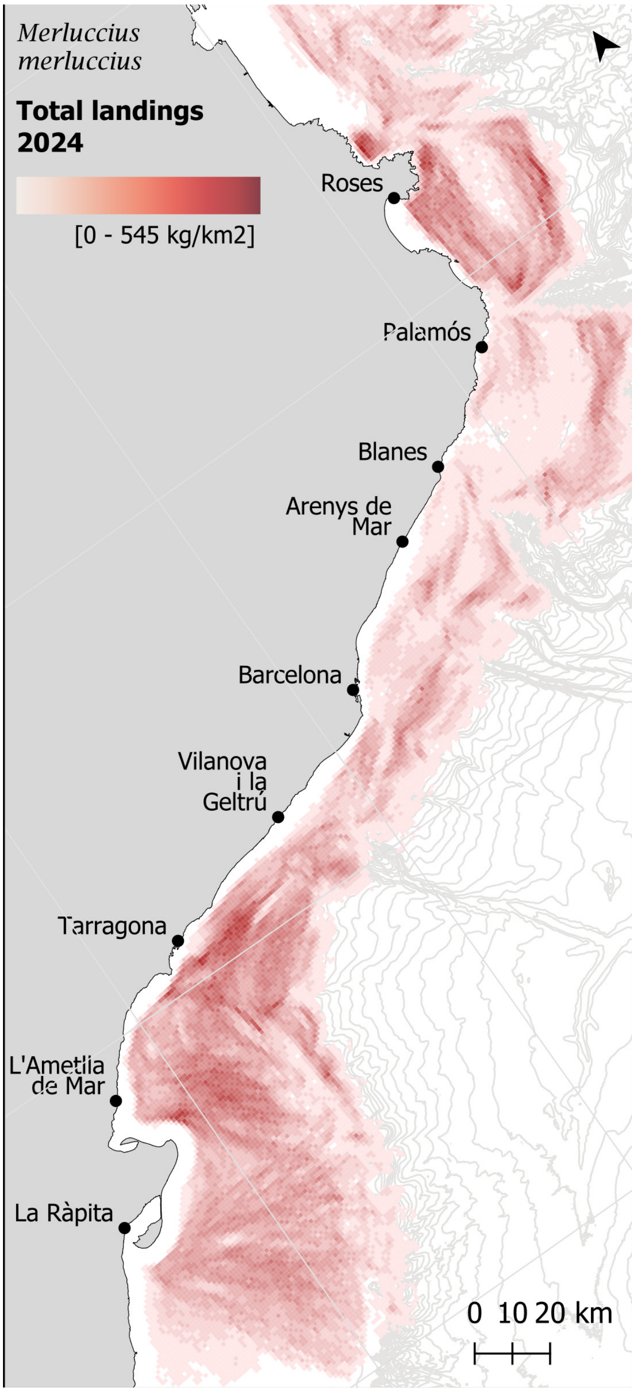

Figure 38. Spatial distribution of landings (kg/km²) for European hake in the Catalan fishing grounds (North GSA6) in the year analyzed.

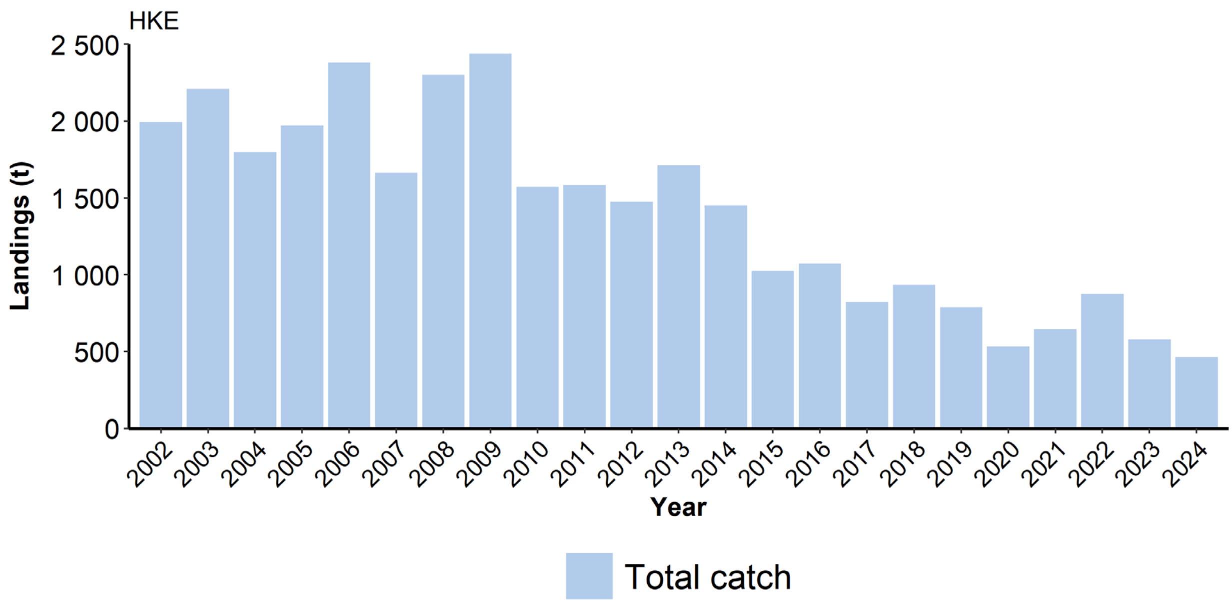

Figure 39. Historical landings (t) for European hake in Catalonia.

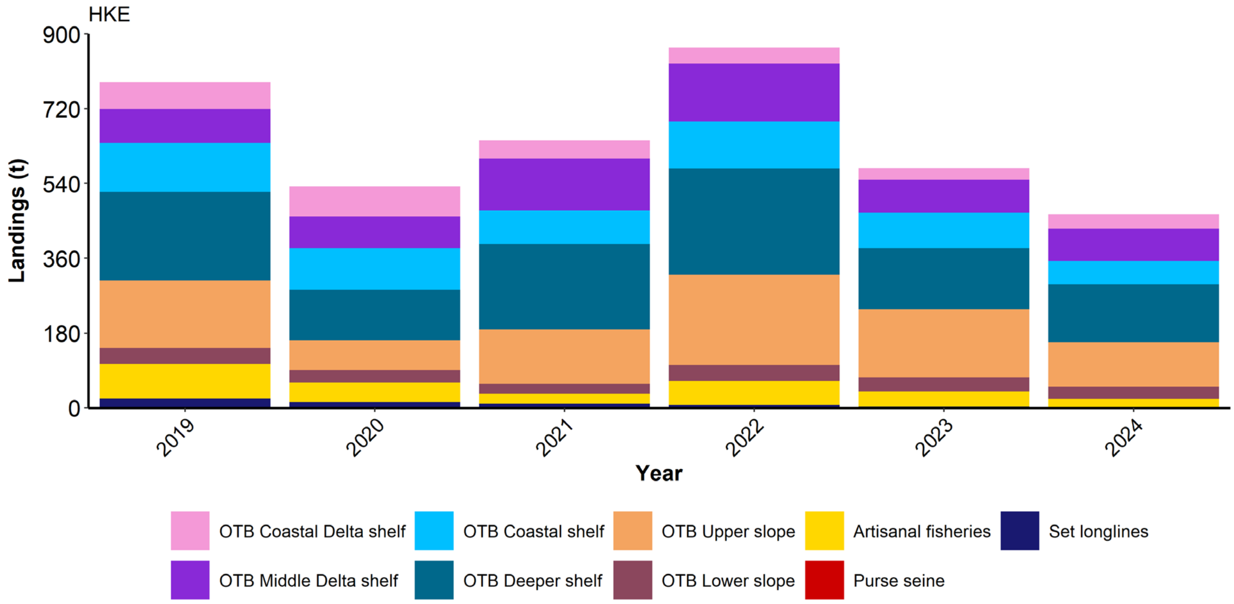

Figure 40. Landings (t) for European hake by métier and fishing gear. OTB: bottom trawling.

Annual LFD

After raising the length frequencies obtained with the monitoring program, and incorporating discards and small-scale fisheries Figure 41 presents the annual length frequency of European hake in Catalonia from 2019 to 2024. The ICATMAR dataset also provides sex ratio information, which allow for sex-specific assessments, as certain biological parameters differ between females and males (Recasens et al., 1998). In general, females attain higher sizes and reach maturity later than males. The SOP validation results are shown in Table 11, while Table 12 summarizes the number of individuals sampled through the ICATMAR monitoring program. An important increase in small-length classes is observed, with more individuals appearing in the discards fraction than the commercial fraction in 2020 and 2022 (Table 11). These tend may indicate an increase in recruitment. It is also worth noting that the largest individuals are predominantly caught by small-scale fisheries (ICATMAR, 24-06)..

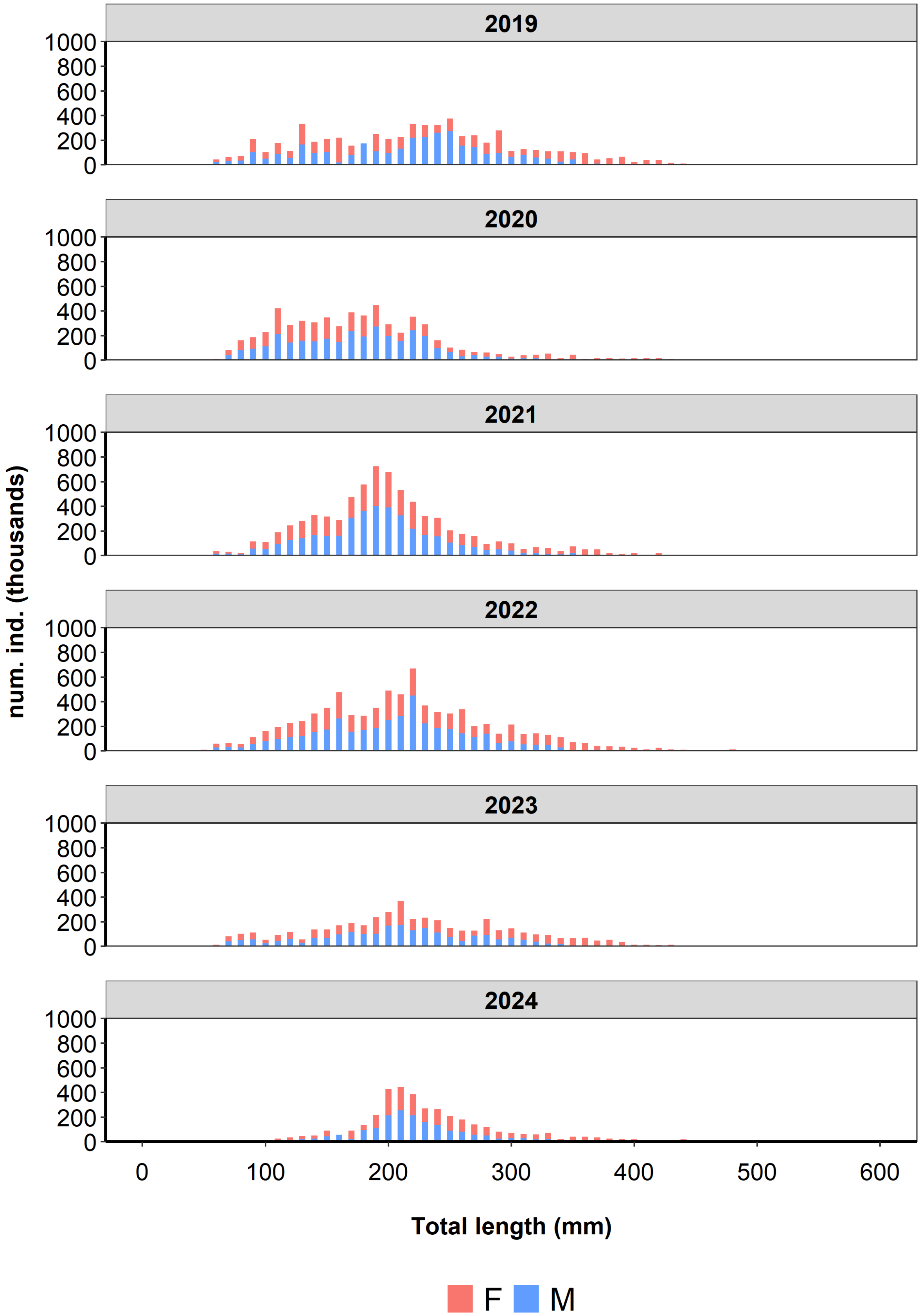

Figure 41. Annual length frequency distributions of European hake from bottom trawling and small-scale fisheries by sex. The data from bottom trawling is raised from ICATMAR data and details landed and discarded European hake. The data from small-scale fisheries is obtained from DCF (Data Collection Framework) dataset. Sex ration by each length is calculated from ICATMAR dataset.

Table 11. Sum of Products (SOP) validation for European hake (HKE): The column Calculated Weight in GSA6N (SOP) represents the biomass estimated through the raising process, while landings refer to the reported landings in NGSA6. The ratio between SOP and landings is known as the Sum of Products (SOP). Values close to 1 indicate that the raising process provides biomass estimates that closely match the reported landings, thereby validating the accuracy of the estimation method.

Species	Year	Catch classification	Gear	weight GSA6N (kg) (SOP)	Landings in GSA6N (kg)	SOP/Landings
HKE	2019	ASSF	Artisanal fisheries	75678	83483	0.91
HKE	2020	ASSF	Artisanal fisheries	11170	47599	0.23
HKE	2021	ASSF	Artisanal fisheries	11370	24410	0.47
HKE	2022	ASSF	Artisanal fisheries	49786	56425	0.88
HKE	2023	ASSF	Artisanal fisheries	32537	36875	0.88
HKE	2024	ASSF	Artisanal fisheries	18234	20666	0.88
HKE	2019	Discarded	Bottom trawl	33456	-	-
HKE	2020	Discarded	Bottom trawl	61849	-	-
HKE	2021	Discarded	Bottom trawl	69028	-	-
HKE	2022	Discarded	Bottom trawl	61985	-	-
HKE	2023	Discarded	Bottom trawl	25214	-	-
HKE	2024	Discarded	Bottom trawl	18054	-	-
HKE	2019	Landed	Bottom trawl	616547	680919	0.91
HKE	2020	Landed	Bottom trawl	285102	471789	0.60
HKE	2021	Landed	Bottom trawl	481352	609698	0.79
HKE	2022	Landed	Bottom trawl	620912	803304	0.77
HKE	2023	Landed	Bottom trawl	450674	537217	0.84
HKE	2024	Landed	Bottom trawl	408362	444366	0.92

Table 12. Number of European hake individuals sampled by zone and season from ICATMAR monitoring data used to raise the length frequencies.

Fishery	Year	Zone	Winter	Spring	Summer	Autumn	N hauls
			Number individuals sampled				
Bottom trawl	2019	North	19	636	216	201	42
Bottom trawl	2019	Center	474	417	211	446	32
Bottom trawl	2019	South	525	181	305	218	31
Bottom trawl	2020	North	104	87	253	227	30
Bottom trawl	2020	Center	208	130	466	310	29
Bottom trawl	2020	South	56	197	370	328	19
Bottom trawl	2021	North	320	390	487	293	43
Bottom trawl	2021	Center	190	528	751	325	27
Bottom trawl	2021	South	141	56	641	441	20
Bottom trawl	2022	North	181	449	755	643	41
Bottom trawl	2022	Center	464	216	507	394	31
Bottom trawl	2022	South	92	165	353	306	18
Bottom trawl	2023	North	632	536	330	427	45
Bottom trawl	2023	Center	427	169	279	254	34
Bottom trawl	2023	South	189	152	289	164	20
Bottom trawl	2024	North	383	283	263	553	40
Bottom trawl	2024	Center	164	217	494	177	32
Bottom trawl	2024	South	165	136	246	245	21

Length-Based Spawning Potential Ratio (LBSPR)

Model setting and results

Scenarios

Five different scenarios were applied for the sensitivity analysis for European hake (Table 13):

- **Scenario 1:** used growth parameters, natural mortality, and maturity data from the STECF and GFCM stock assessments**.**
- **Scenario 2:** used the same parameters but incorporated length at first maturity from the ICATMAR data**set.**
- **Scenario 3:** used growth parameters and natural mortality from the literature (Aldebert et al., 1993), while maintaining the same maturity data as in Scenario 2.
- **Scenarios 4 and 5:** considered sexes separately—females and males, respectively. Growth parameters were taken from Aldebert and Recasens (1996), and sex-specific length at first maturity values were obtained from the ICATMAR dataset (ICATMAR, 24-05).

Table 13. Biological parameters used in the different LBSPR scenarios for European hake (HKE). $L_{inf:}$ asymptotic length at which growth is zero, k: growth rate, M: natural mortality, $L_{mat50:}$ length where 50% of individuals are mature, $L_{mat95:}$ length where 95% of individuals are mature.

Species	Scenario	Linf (mm)	Lmat50 (mm)	Lmat95 (mm)	M/K
HKE (Combined)	1	1100	260	309.4	2.247
HKE (Combined)	2	1100	282	335.6	2.247
HKE (Combined)	3	802	282	335.6	2.247
HKE (Females)	4	802	319	407	2.247
HKE (Males)	5	558	246	316	2.247

Fitted data

The length frequency distribution fit per year is shown in Figure 42. The model generally follows the mode for all years, but tends to overestimate or underestimate the number of individuals in the middle-length classes.

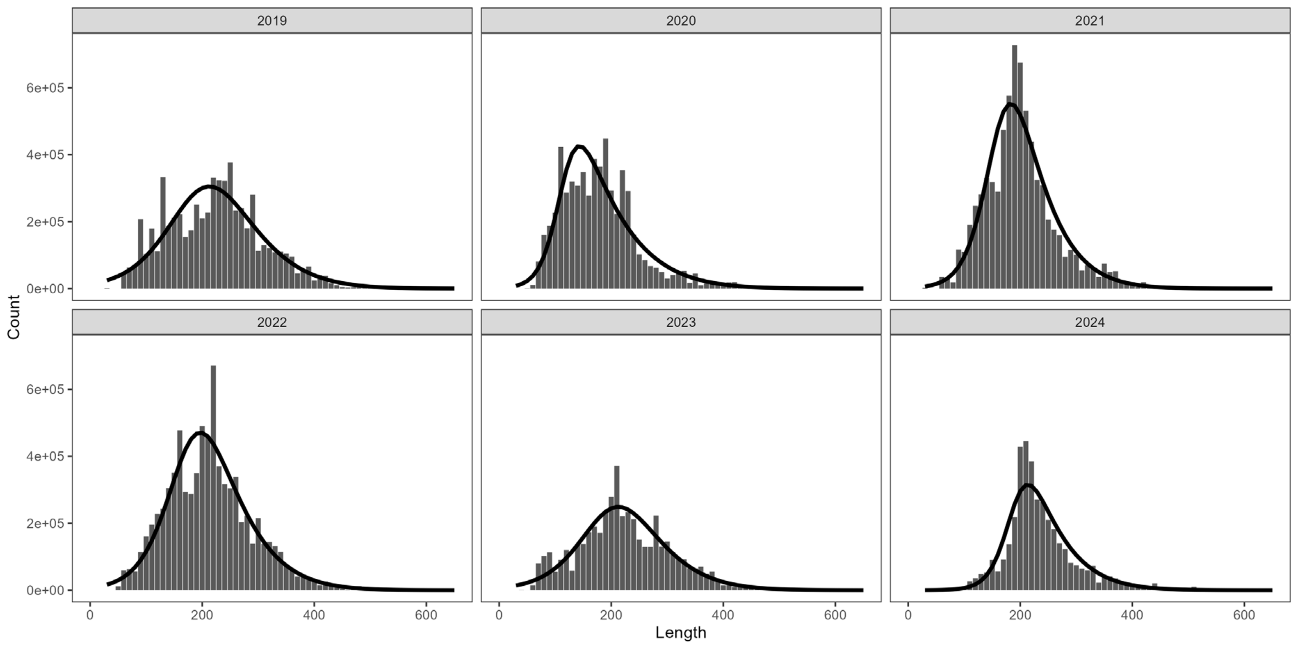

Figure 42. Fit of the data using the LBSPR model for European hake for each studied year. Grey columns indicate length frequencies. Black lines indicate the fit of the model.

Selectivity

The outputs of the model for the selectivity of the fishery are shown for each scenario in Table 14. The outputs of the selected scenario (3) are also plotted with L_{mat50} and SL_{50} in Figure 43. The model output reveal that the fishery is fishing below the SL_{50}.

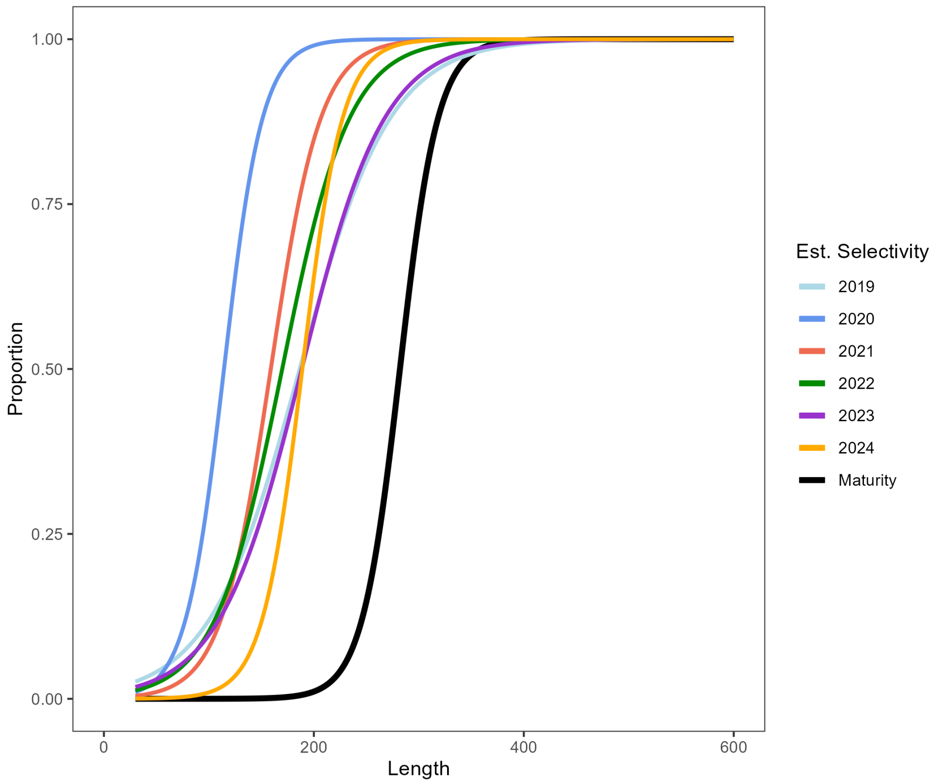

Figure 43. Length curves for European hake. Black line shows the length curve at maturity. Color lines show the estimated selectivity at length curve predicted by the LBSPR model for the scenario selected (3).

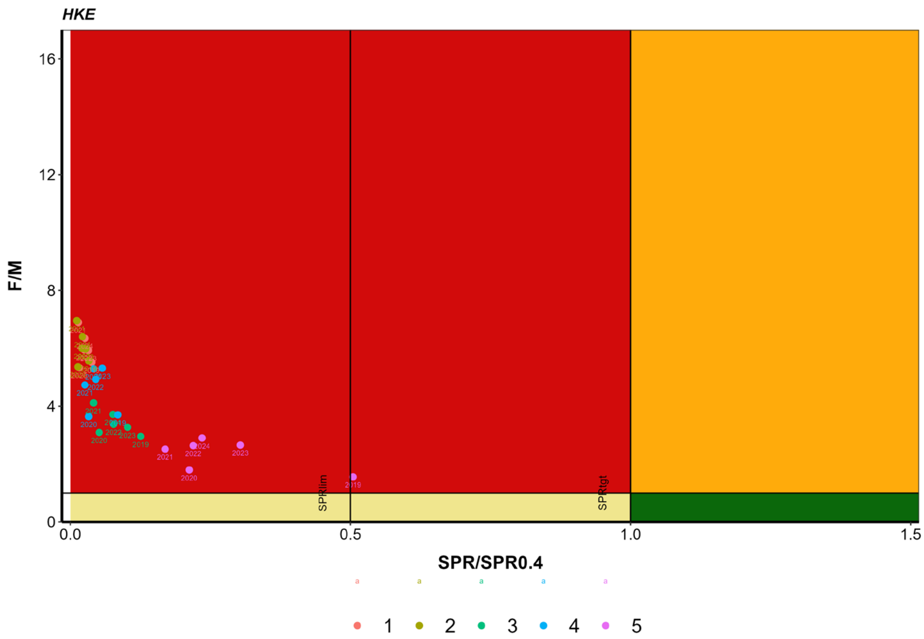

Figure 44. Kobe plot for European hake by scenario (1-3) and year. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio, F: fishing mortality, M: natural mortality, and F/M: relative fishing mortality.

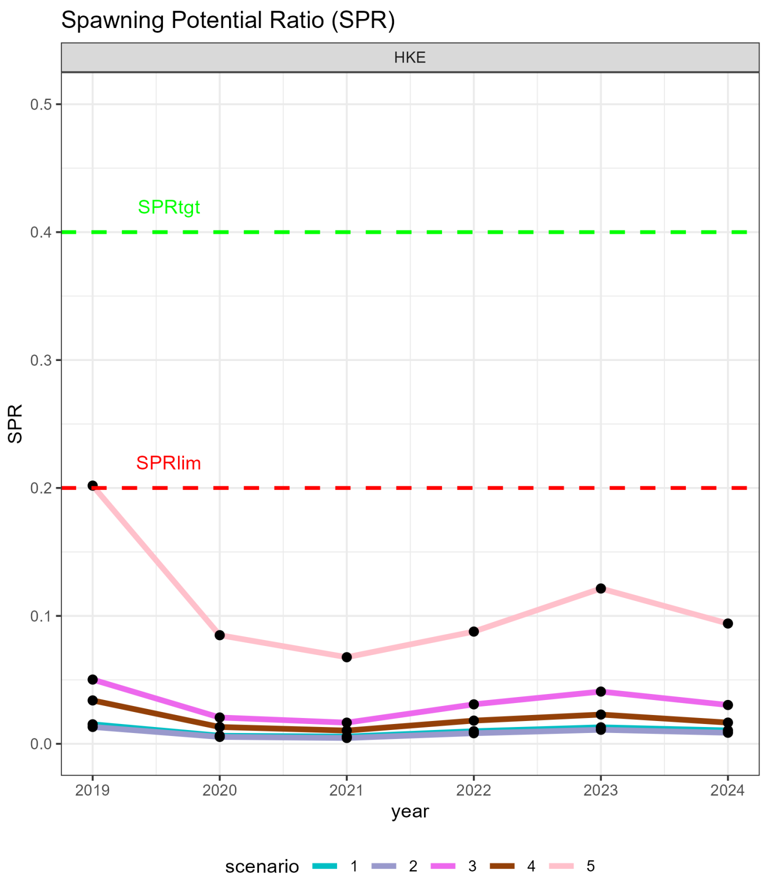

Figure 45. Spawning potential ratio (SPR) per year analyzed for European hake evaluated with LBSPR model. LBSPR: Length-Based Spawning Potential Ratio. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio. Colored lines show the results for each scenario.

Reference points

Although the model is highly sensitive to changes in growth and maturity parameters, the stock is below SPR_{lim} (= 0.2) in all the scenarios (Table 14 and Figure 45). When assessing the females (scenario 4) and male (scenario 5) population separately, different results are obtained: males reach a higher SPR than females, though both remain below SPR_{lim} (= 0.2). The Kobe plot for European hake (Figure 44) displays the stock status over time, with no clear trend. However, in all cases, the stock falls within the red zone, indicating that it is both overfished and subject to ongoing overfishing.

Final scenario

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBSPR model.

Table 14. LBSPR model results for European hake with the different scenarios tested for each year analyzed. $SL_{50:}$ Length where 50% of individuals are caught, SPR: spawning potential ratio and FM: relative fishing mortality. SD is the standard deviation calculated for each indicator. The selected scenario is highlighted in blue.

spp	scenario	year	SL_{50}	SD	SPR	SD	FM	SD
HKE	1	2019	203.36	5.62	0.02	0.01	5.52	1.20
HKE	1	2020	121.91	3.92	<0.01	<0.01	5.33	1.07
HKE	1	2021	163.68	1.88	<0.01	<0.01	6.90	1.32
HKE	1	2022	179.05	3.34	<0.01	<0.01	5.95	1.21
HKE	1	2023	200.42	4.26	0.01	<0.01	5.93	1.25
HKE	1	2024	192.11	1.27	0.01	<0.01	6.35	1.24
HKE	2	2019	203.29	5.80	0.01	<0.01	5.57	1.24
HKE	2	2020	121.54	6.02	<0.01	<0.01	5.36	1.12
HKE	2	2021	163.66	1.93	<0.01	<0.01	6.95	1.37
HKE	2	2022	178.94	4.03	<0.01	<0.01	6.00	1.26
HKE	2	2023	200.38	4.39	0.01	<0.01	5.98	1.30
HKE	2	2024	192.10	1.30	<0.01	<0.01	6.40	1.28
HKE	3	2019	195.74	7.97	0.05	0.04	2.96	0.83
HKE	3	2020	118.07	3.45	0.02	0.02	3.09	0.75
HKE	3	2021	162.03	2.39	0.02	0.01	4.11	0.93
HKE	3	2022	174.90	4.41	0.03	0.02	3.37	0.85
HKE	3	2023	194.95	5.59	0.04	0.03	3.27	0.87
HKE	3	2024	191.10	1.63	0.03	0.02	3.72	0.87
HKE	4	2019	209.98	16.77	0.03	0.03	3.70	1.27
HKE	4	2020	128.48	12.55	0.01	0.01	3.64	1.06
HKE	4	2021	166.43	5.91	0.01	0.01	4.73	1.29
HKE	4	2022	190.66	16.42	0.02	0.02	4.93	1.82
HKE	4	2023	223.12	22.67	0.02	0.03	5.31	2.07
HKE	4	2024	203.84	10.85	0.02	0.02	5.29	1.72
HKE	5	2019	202.82	14.11	0.20	0.15	1.56	0.70
HKE	5	2020	127.15	6.15	0.08	0.07	1.80	0.61
HKE	5	2021	166.70	3.21	0.07	0.05	2.52	0.74
HKE	5	2022	193.65	6.12	0.09	0.07	2.64	0.85
HKE	5	2023	224.75	10.56	0.12	0.09	2.66	0.98
HKE	5	2024	207.97	2.52	0.09	0.07	2.90	0.85

Length-based Bayesian Biomass (LBB)

Scenarios

Three different scenarios were applied for the sensitivity analysis for hake (Table 15). The first scenario used growth parameters, natural mortality and maturity data from STECF and GFCM stock assessment. The second one used the same parameters and included length at first maturity from ICAMAR data. Finally, the third scenario used growth parameters and natural mortality from the literature (Aldebert et al., 1993) and the same maturity as scenario two.

Table 15. Biological parameters used in the different LBB scenarios for European hake (HKE). $L_{inf:}$ Asymptotic length, M/k: ratio between natural mortality and growth rate, $L_{mat50:}$ length where 50% of individuals are mature.

Specie	Scenario	Linf (cm)	M/k	Lmat50 (cm)
HKE	1	110.0	2.247	26.0
	2	110.0	2.247	28.2
	3	80.2	2.247	28.2

As LFD and L_{mat} originated from ICATMAR data, scenario three was selected to provide final advice for the LBB model. The following graphics are based on Scenario 3.

Fitted data

The length frequency distribution fit per year is shown in Figure 46. The model generally follows the mode for all years, but tends to underestimate the number of individuals in the peaks.

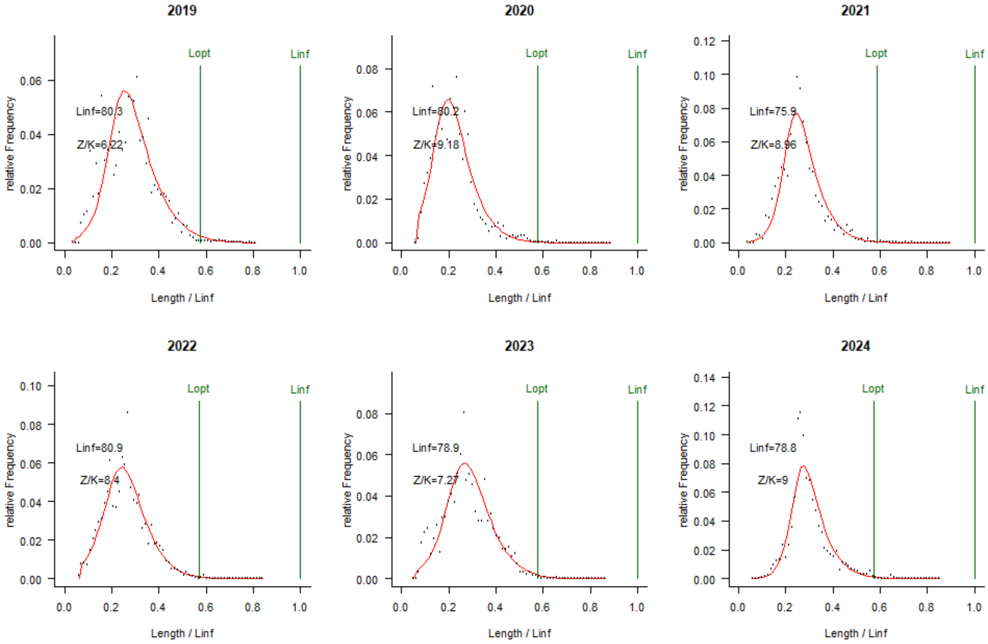

Figure 46. Fit of the data using the LBB model for European hake (HKE) for each year in scenario 3. Red line indicates the fit of the model.

Reference points

Summary of the graphical results are in Figure 47. The upper left plot shows that the aggregated estimated Length at first capture (L_c) is 13 cm, below the L_{mat} (28.2 cm) as seen in the left lower plot (L_c: dotted black line) for all the series. The upper middle and right panels show that the L_{mean} is far from L_{opt}, which is also shown in the lower left plot (L_{mean}: bold black line). Lower middle and right plots show that the relative fishing pressure (F/M) and relative biomass (B/B_0) are outside of sustainable levels, with minor improvements in last years. More details related to these results are in Table 16.

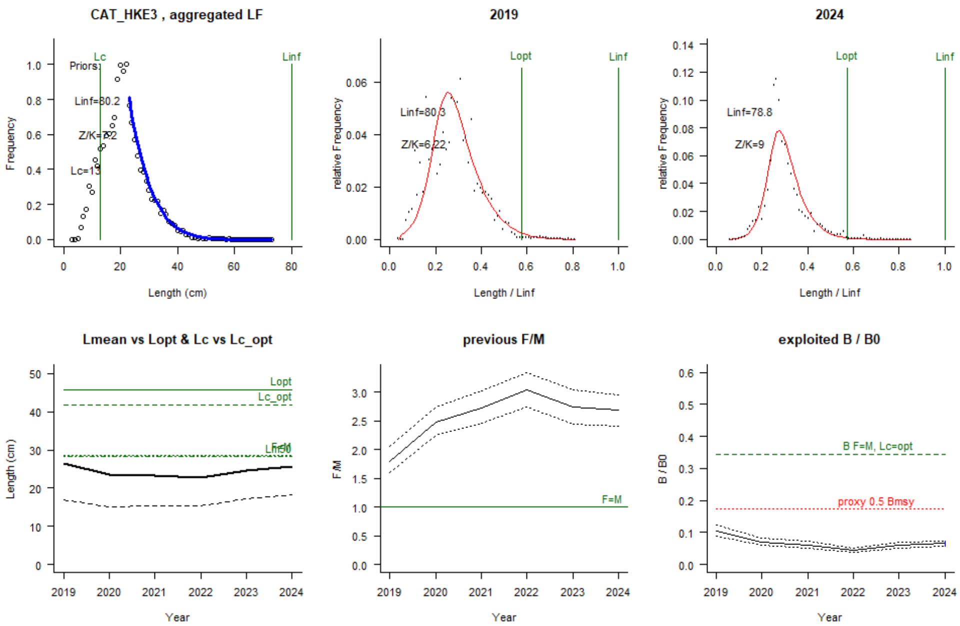

Figure 47. Summary output from LBB for European hake (HKE) scenario 3.

Table 16. LBB model results for European hake (HKE) with the different scenarios tested for each year analysed. $L_{mean:}$ mean length of individuals, $L_{opt:}$ length at optimal yield, Lc: length at first capture, $L_{c\_opt:}$ length at first capture at optimal yield, L_{95th}/L_{inf}: ratio of the 95th percentile to asymptotic length , F/M: fishing mortality relative to natural mortality, $B/B_{0:}$ exploited biomass relative to unexploited biomass, $B/B_{msy:}$ exploited biomass relative to maximum sustainable yield biomass, $C_{mature:}$ proportion of mature individuals in the catch.

Specie	Scenario	Year	Lmean/Lopt	Lc/Lc_opt	L95th/Linf	F/M	B/B0	B/Bmsy	Cmature
HKE	1	2024	0.41	0.32	0.62	5.20	0.02	0.05	24%
	2	2024	0.41	0.32	0.62	5.20	0.02	0.05	17%
	3	2024	0.56	0.44	0.85	2.70	0.07	0.19	17%

Stochastic Production model in Continuous Time (SPiCT)

Historical information from the fishery:

Catch Commercial data: the length structure removed by the commercial fishery from 1971 to 2009 represents catches. Since 2010, discards have been quantified, accounting for an average of 10% of the total catch, as the codend mesh size was changed from diamond to square 40 mm (DCF data on discards were used). Since 2010, the minimum conservation reference size (MCRS) for hake has been 20 cm.

- 1971-1994: Diamond codend mesh size 35.
- 1994-2009: Diamond codend mesh size 40.
- 2010-2023: Square codend mesh size 40 + MRSC > 20cm.

Input data

Data available for GSA6 is presented in Figure 48, Figure 49, Figure 50 and Figure 51 and described below:

<u>Commercial data:</u>

Landings, vessel characteristics and fishing days for GSA6 (for Catalonia (CAT), Valencia (VAL), and Murcia (MUR)) by year are available as follows:

Catch from 1971 to 2024 were estimated as follows:

- 1971-1987 (CAT+VAL) Paloma,1991.
- 1987-1999 (CAT *1.82 factor to GSA06) Laura Recasens data.
- 2000-2009 (GSA6 - Landings=catch) DCF data & Spanish Ministry of Agriculture, Fisheries and Food.
- 2010-2024 (GSA6 - Catch) DCF data & Spanish Ministry of Agriculture, Fisheries and Food.

CPUE:

- From 1990 to 2024: vessel data (EU fleet register provided by the European Commission (Reg. EU 2017/218)).
- From 2004 to 2024: GSA6 daily commercial fishing landings provided by the Spanish Ministry of Agriculture, Fisheries and Food.
- Standardized CPUE (LLS and GNS): 2004 - 2024 (based on Henning Winker (GFCM) & Hoyle et al., 2024) -> Here assumes CPUE = LPUE.

<u>Survey data:</u>

MEDITS data (1994-2024) - May-June (DCF-MED data)

(European Commission, Joint Research Centre (JRC) (2025) + STECF-PLEN-25-01 background)

- 1994-1996 -> High uncertainty

Codend mesh size is 20 mm (stretched mesh). In this exercise, it was assumed that MEDITS covers the same area as a commercial fleet and that the LFD removed by the MEDITS survey is the same as a commercial fleet. However, the MEDITS survey uses non-selective fishing gear, which can capture smaller individuals (20 mm codend mesh size).

As for the other species, a double-axis plot (Figure 52) was presented to compare trends between catches and indices (Biomass and CPUE indices).

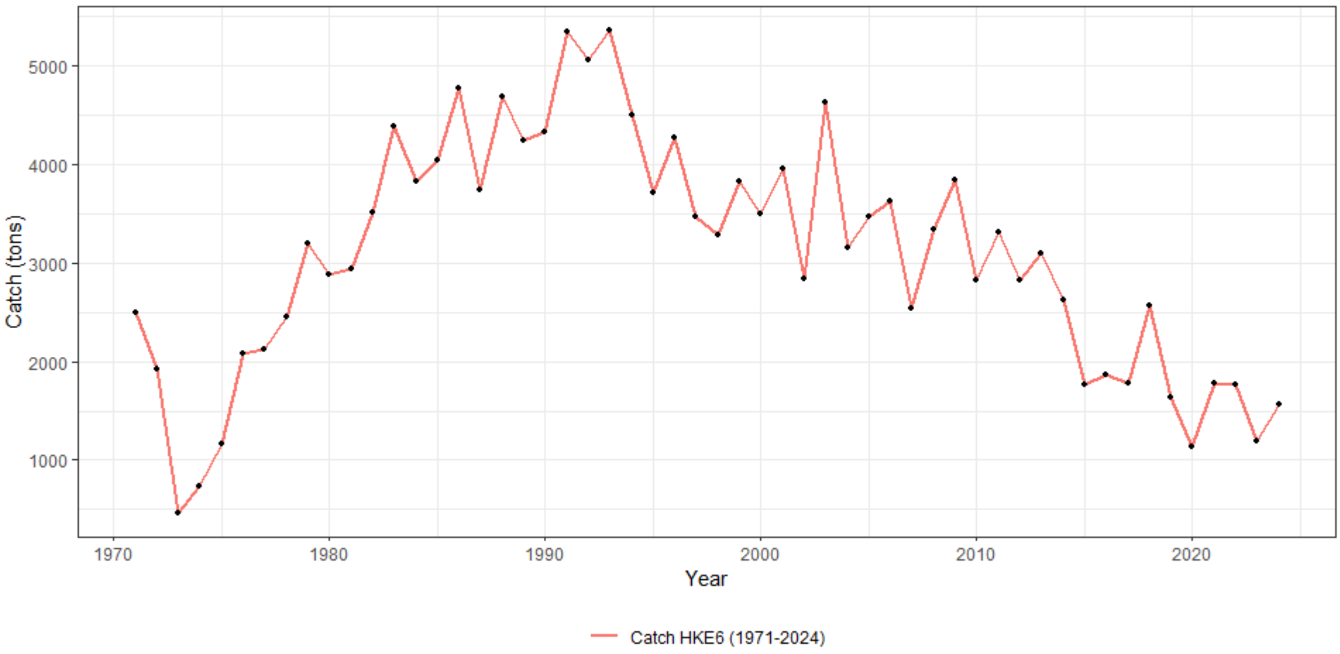

Figure 48. Data available for the assessment of European hake in GSA6 to run SPiCT model. Catch data from 1971 to 2024.

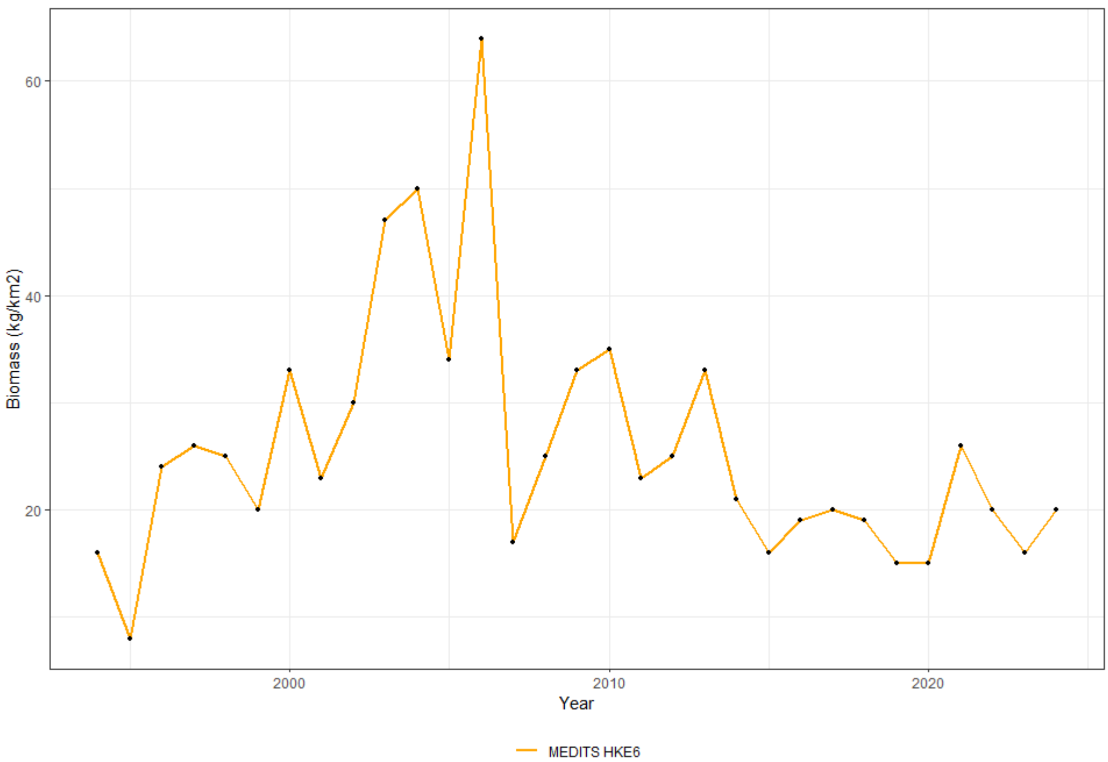

Figure 49. Data available for the assessment of European hake in GSA6 to run SPiCT model. Index data of biomass derived from MEDITS from 1997 to 2024.

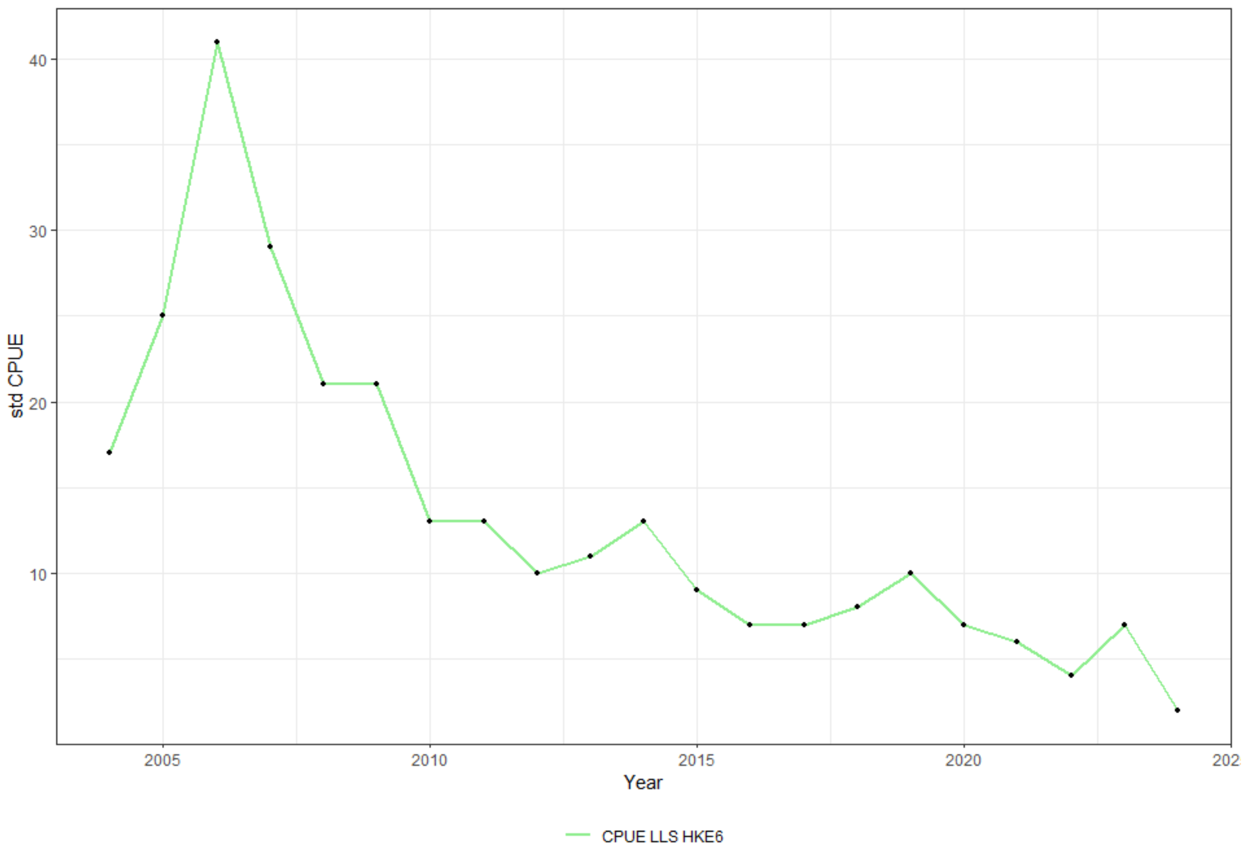

Figure 50. Data available for the assessment of European hake in GSA6 to run SPiCT model. Standardize CPUE for LLS from 2004 to 2024. CPUE: catch per unit of effort. LLS: longliners.

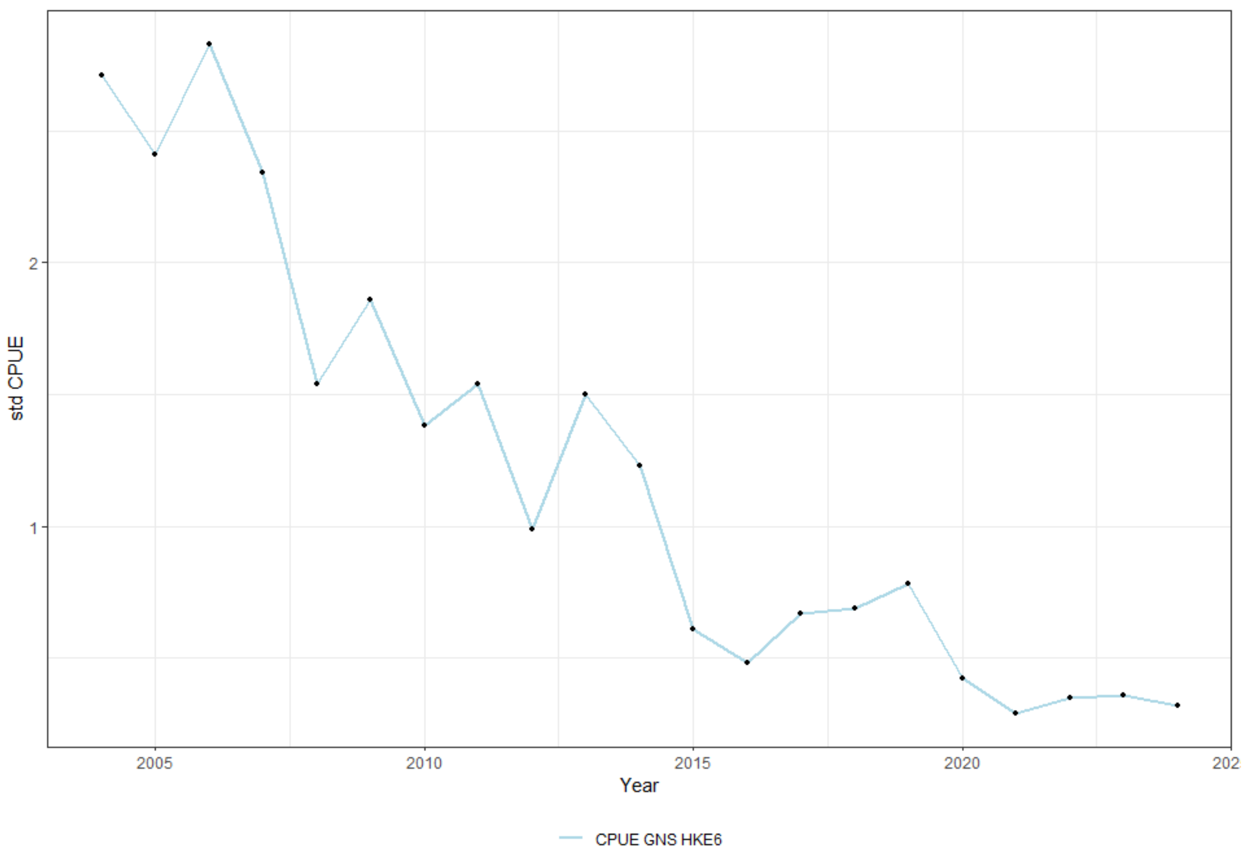

Figure 51. Data available for the assessment of European hake in GSA6 to run SPiCT model. Standardize CPUE for GNS from 2004 to 2024. CPUE: catch per unit of effort. GNS: gillnets.

Figure 52. Double-axis plot to compare trends between catch and MEDITS, CPUE LLS and CPUE GNS indices (top) and only the three indices for European hake in GSA6. CPUE: catch per unit of effort. LLS: longliners. GNS: gillnets.

Table 17. European hake in GSA6: Different SPiCT scenarios tested.

SCE	Idx data	Comments
1	medits	dteuler/rprior/bk0.4/Shaefer curve
1	LLS	dteuler/rprior/bk0.4/Shaefer curve
1	GNS	dteuler/rprior/bk0.4/Shaefer curve
2	medits	sce1 + (ce + pe + oe + F error + sdfactI)
2	LLS	sce1 + (ce + pe + oe + F error + sdfactI)
2	GNS	sce1 + (ce + pe + oe + F error + sdfactI)
3	medits + LLS	combine diff index
3	medits + LLS + GNS	combine diff index
3	LLS + GNS	combine diff index
3	medits	combine diff index
4	medits + LLS + GNS	Start Catches in 1997
5	medits	Start Catches in 1973
5	medits + LLS	Start Catches in 1973
5	medits + LLS + GNS	Start Catches in 1973
5	LLS + GNS	Start Catches in 1973
6	medits	bk frac = 0.6
6	medits + LLS	bk frac = 0.6
6	medits + LLS + GNS	bk frac = 0.6
6	LLS + GNS	bk frac = 0.6
7	medits + LLS + GNS	Sce6 + stdfactC for LLS and GNS (2021-2024)
8	medits + LLS	Sce7 but only Medits + LLS

Although only the final scenario was presented, different scenarios were tested (Table 17). The first two scenarios were based on the index used and the definitions of different settings and priors. Afterwards, scenario 3 involved the simultaneous use of different indices. For scenario 4, the objective was to test how the model performed when starting catches were made at the same time as the MEDITS indices. Then, for scenario 5, since catches between 1971 and 1973 seem to be very low, it was tested starting in 1973. From scenario 1 to 5, all scenarios used a bkfrack prior of 0.4, due to lower uncertainty when only using the MEDITS index. Finally, for scenario 6, the bk fraction was set to 0.6 because it is more reliable with the possible biomass available at the beginning of the time series. A final two scenarios, scenario 7 and 8 were done, where different parameters were adjusted, such as the standard deviation factor for the last years of the CPUE indices, to avoid possible uncertainty in the actual representativeness of adult and medium individuals at sea, considering the drastic decreases in vessels and the uncertainty about whether the reason is fewer fish or less interest in the species. Scenario 7 included MEDITS and CPUE for LLS and GNS, and scenario 8 only MEDITS and CPUE for LLS. Scenario 8 was run because MASE is higher than 1 for CPUE GNS in scenario 7. At the end, scenario 7 was selected as the final one because diagnostics for scenario 8 didn't improve sufficiently to avoid the CPUE index for GNS.

A final comparison of three main scenarios is shown in Figure 53. Main conclusions of this comparison were also presented in the GFCM *ad hoc* working group for European hake in March 2024:

- Small Scale Fisheries (SSF) data can help to have an overview of the largest individuals in the population: MEDITS biomass index needs to be complemented with CPUE stand for LLS and GNS. Also, historical data is important to understand the context of the stock.
- SPiCT has a different perception of stock status depending on input data, but tracks the trends comparably among different scenarios: The most optimistic stock status was obtained when SPiCT was fitted to MEDITS index only. The highest levels of both depletion and overexploitation were observed when SPiCT was fitted to only the gillnet and long-line CPUEs.

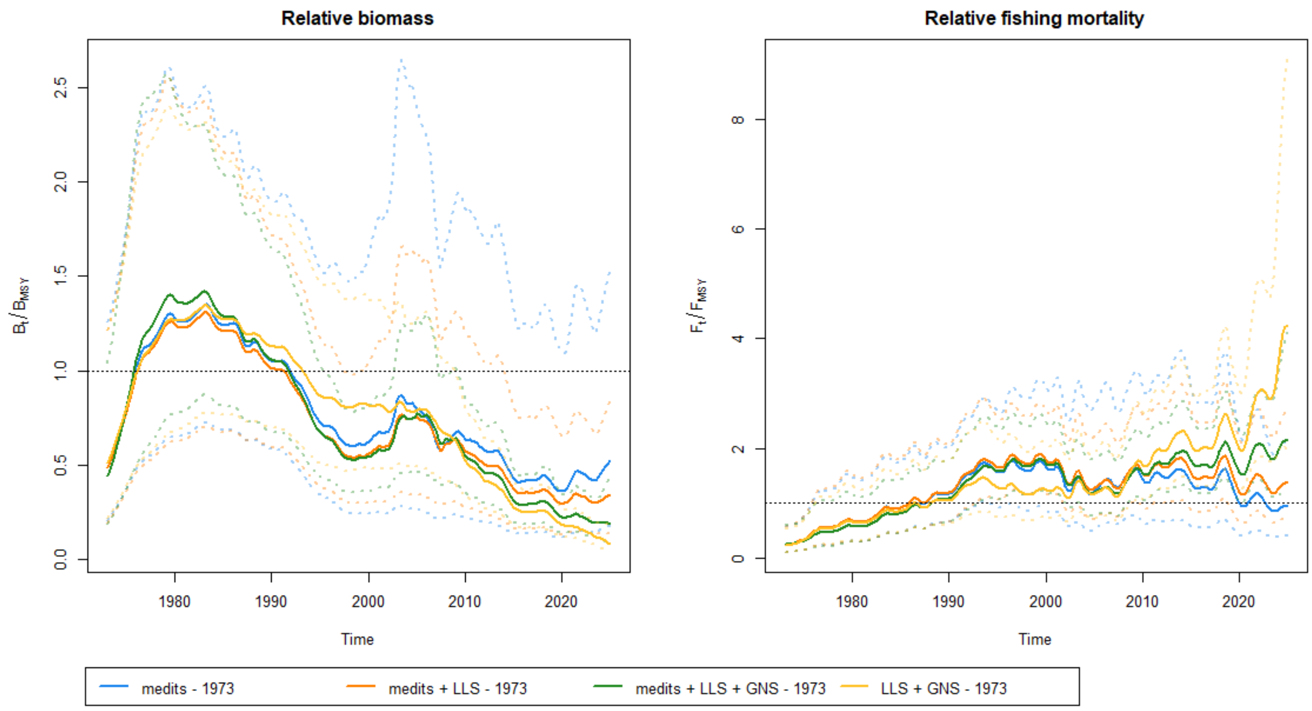

Figure 53. Scenarios comparison for European hake in GSA6.

Final scenario

The settings used for the final scenario are shown in Table 18, along with explanations of the assumptions made. Among other settings, the BK fraq prior was 0.6, which was selected because the biomass was higher at that time, after conducting different sensitivity analyses on this prior. Also, to reduce the possible effect of the high value in 2006 and that the last years of the time series index for LLS and GNS could be less representative of the adult biomass, a different standard deviation factor was applied to the different indices.

The final scenario input data are shown in Figure 54, and the final summary assessment results are presented in Figure 55. The results show a decreasing trend in biomass since 2005 but slight stability since 2015 in comparison with the historical time series. Since then, values have remained close to the reference point, B_{lim}. For fishing mortality, the estimated values have been consistently above 1 since 1980. Since 2020, F/F_{msy} has remained around 1.5, although these estimations should be considered a qualitative indicator.

All diagnostics can be checked in Figure 56, Figure 57, Figure 58, Figure 59 and Figure 60. The chosen scenario met all of the model diagnostics, such as Mohnr values for the retrospective analysis and a MASE less than 1 except for CPUE GNS index. A sensitivity analysis for the final scenario was performed, testing r prior, bkfrac, process error, and observation error to assess the model's robustness within these priors. All these plots and results for the other scenarios will be available at https://github.com/ICATMAR.

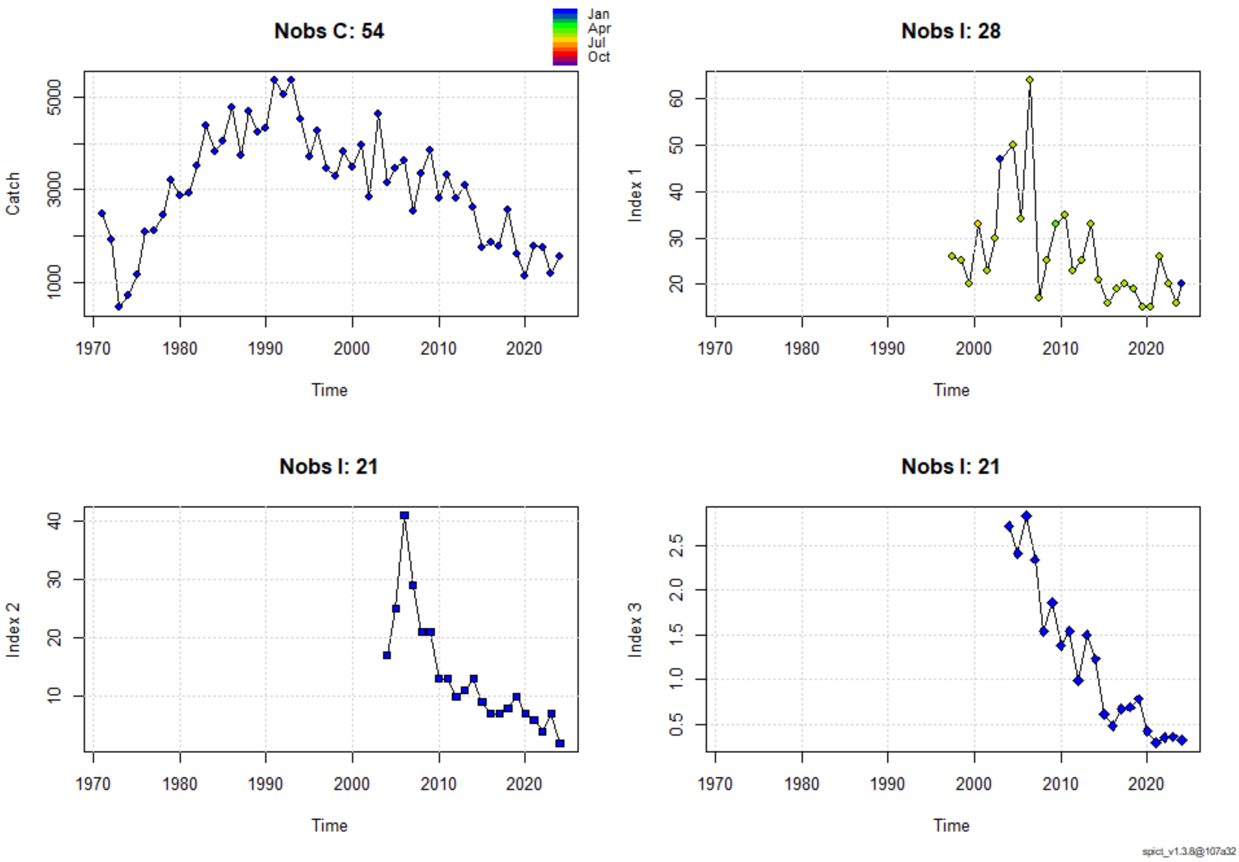

Figure 54. Input data for SPiCT model of European hake in GSA6 for final scenario. Top-left: catch in tons per year from 1971 to 2024; Top-right: index data of biomass derived from MEDITS from 1997 to 2024; bottom-left: Standardize CPUE for LLS from 2004 to 2024; bottom-right: Standardized CPUE for GNS from 2004 to 2024. CPUE: catch per unit of effort. LLS: longliners. GNS: gillnets.

Table 18. Priors settings for European hake in GSA 6 for final scenario.

<table>
<tr><th>Type</th><th>Prior</th><th>Description</th><th>Assignment</th><th>Mean</th><th>Standard deviation</th><th>Comment</th></tr>
<tr><td>Fishery dynamic</td><td>logbkfrac</td><td>B/K fraction (depletion)</td><td>-</td><td>Log(0.6)</td><td>0.5</td><td>A prior for BKfrac was included because we already know that fisheries occurred before the beginning of the time series. A value of 0.6 was selected as the biomass was higher at that time, and after conducting different sensitivity analyses on this prior.</td></tr>
<tr><td rowspan="4">Relative standard deviation time series (input data)</td><td>stdevfacC</td><td>Standard deviation factor for catches</td><td>1971-1973</td><td>3</td><td></td><td>Landings between 1971 and 1973 were the lowest and may have been less credible.</td></tr>
<tr><td rowspan="3">stdevfacI</td><td rowspan="3">Standard deviation factor for indices</td><td>Medits 2006</td><td>1.5</td><td></td><td>Reduce the possible effect of the high value in 2006.</td></tr>
<tr><td>LLS 2006 & 2021-2024</td><td>1.5 & 2</td><td></td><td>Reduce the possible effect of the high value in 2006. The last years of the time series index for LLS could be less representative of the adult biomass.</td></tr>
<tr><td>GNS 2006 & 2021-2024</td><td>1.5 & 2</td><td></td><td>Reduce the possible effect of the high value in 2006. The last years of the time series index for GNS may be less representative of the medium to adult biomass.</td></tr>
<tr><td rowspan="2">Stock dynamic</td><td>logr</td><td>Population growth</td><td>-</td><td>Log(0.17)</td><td>0.82</td><td>Fishlife</td></tr>
<tr><td>logn</td><td>Shape of production curve</td><td>-</td><td>Log(2)</td><td>-</td><td>Shaefer</td></tr>
<tr><td rowspan="5">Error</td><td>logsdc</td><td>Catch error</td><td>-</td><td>Log(0.05)</td><td>0.3</td><td></td></tr>
<tr><td>logsdf</td><td>Fishing mortality error</td><td>-</td><td>Log(4)</td><td>0.5</td><td></td></tr>
<tr><td>logsdb</td><td>Process error</td><td>-</td><td>Log(0.1)</td><td>0.5</td><td></td></tr>
<tr><td rowspan="2">logsdi</td><td rowspan="2">Observation error</td><td>Medits</td><td>Log(0.2)</td><td>0.3</td><td rowspan="2">Medits index was assumed to be more credible than CPUE indices</td></tr>
<tr><td>LLS & GNS</td><td>Log(0.3)</td><td>0.3</td></tr>
</table>

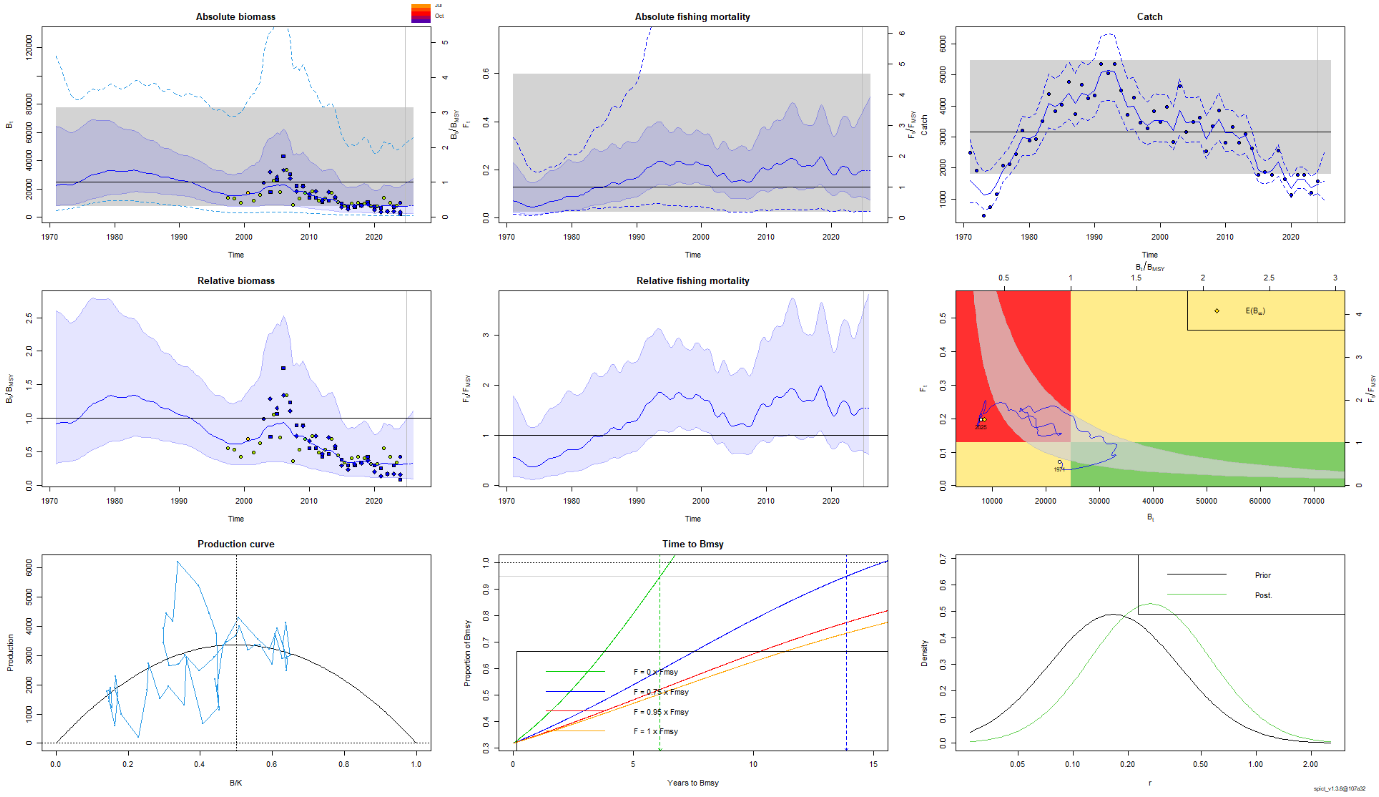

Figure 55. Stock assessment summary for SPiCT model for European hake in GSA6 for final scenario.

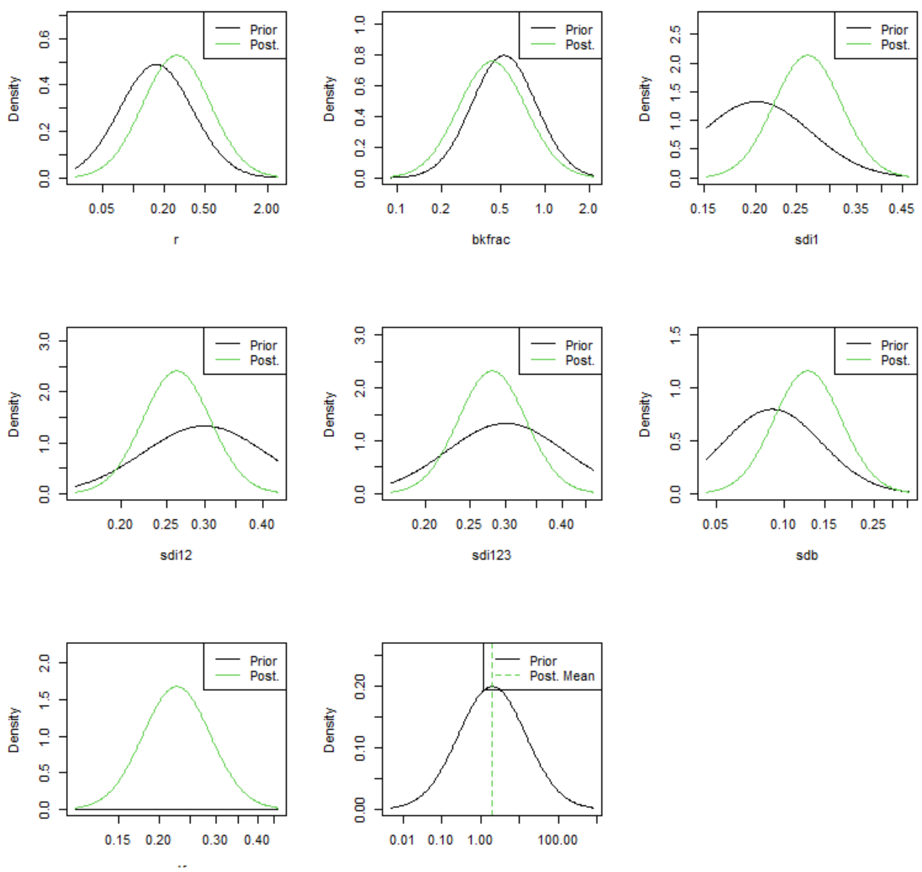

Figure 56. Estimated priors and posteriors for the updated assessment for European hake in GSA6 for final scenario.

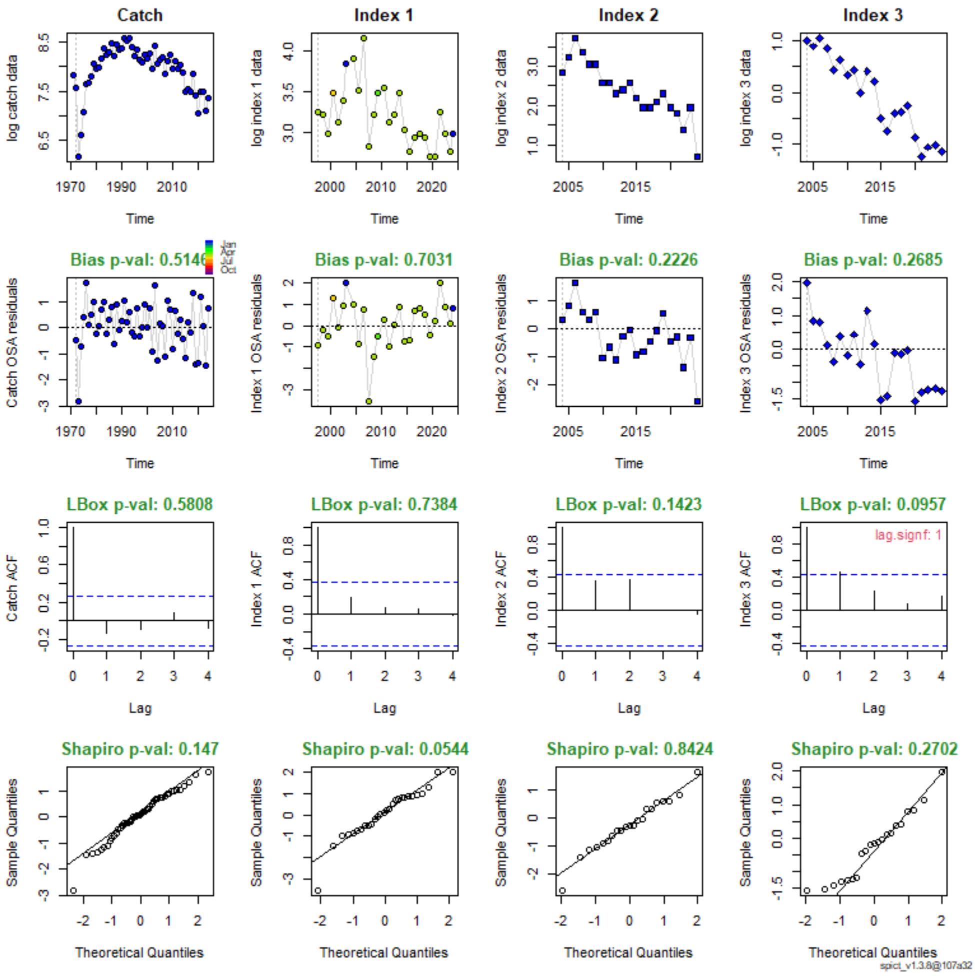

Figure 57. One-step-ahead residuals for the model for European hake in GSA6 for final scenario.

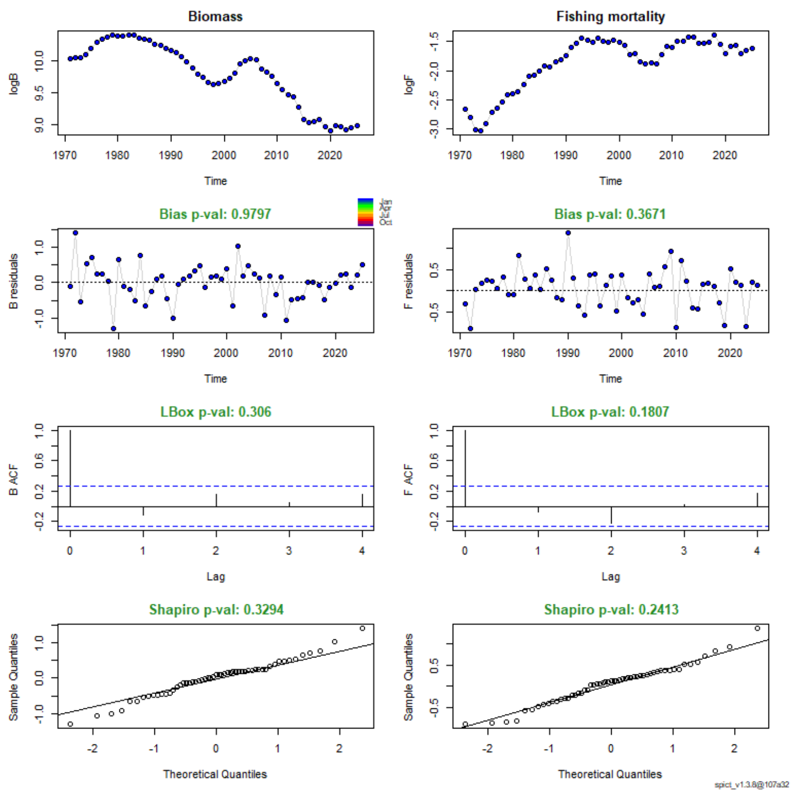

Figure 58. Process error deviations for the model for European hake in GSA6 for final scenario.

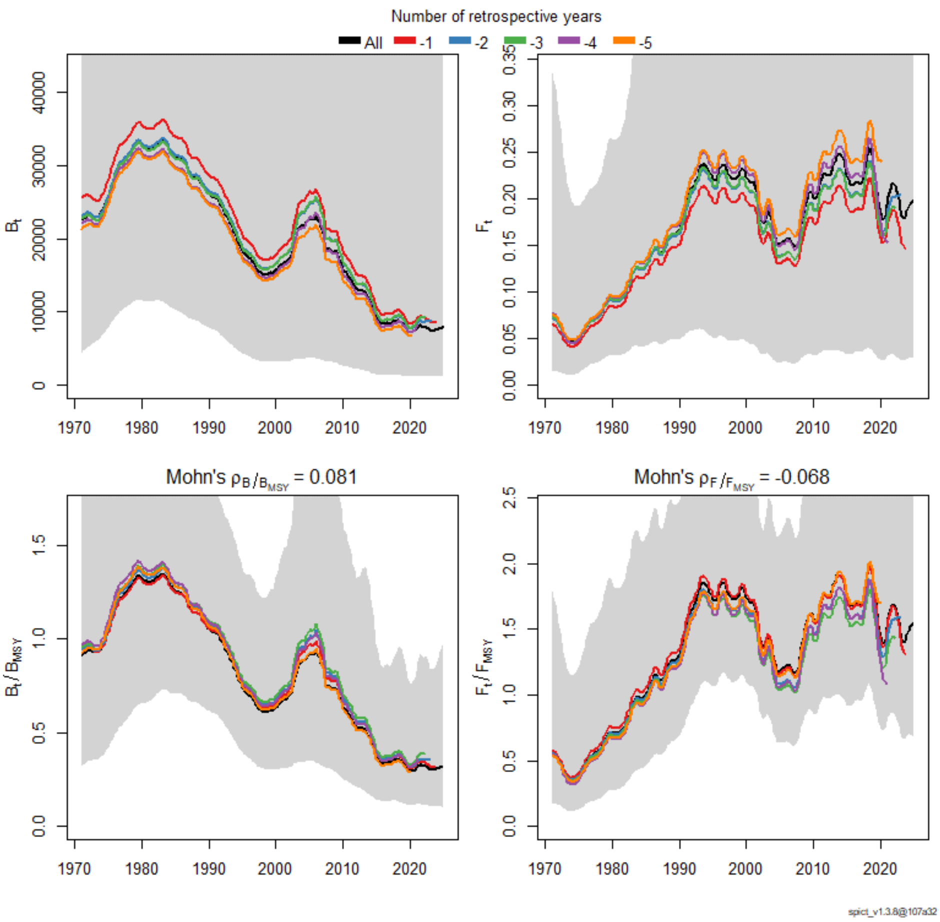

Figure 59. Retrospective analysis for European hake in GSA6 for final scenario.

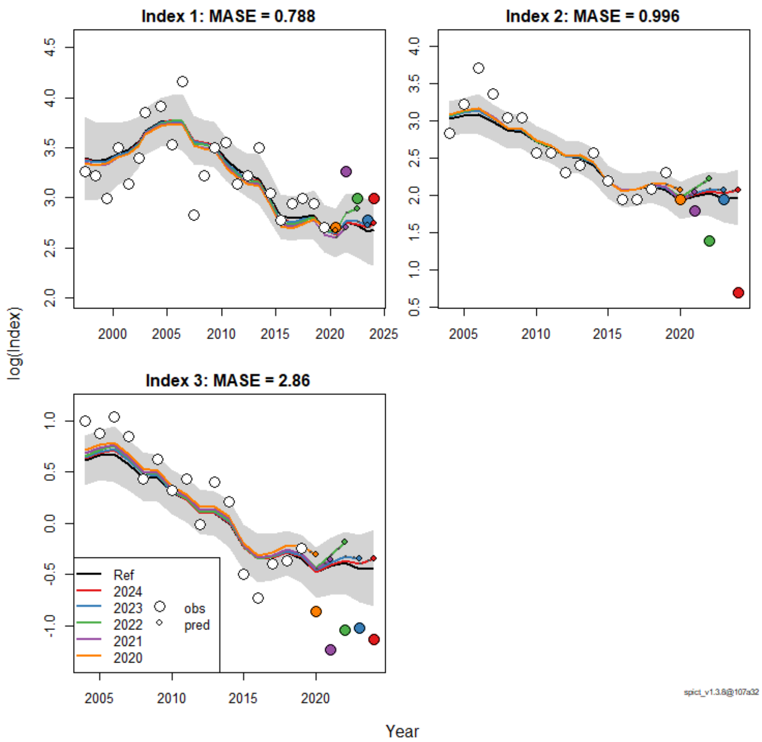

Figure 60. Hindcasting for the model for European hake in GSA6 for final scenario.

Final scenario advice

Final scenario advice is presented in Figure 61 and in Table 19, which outlines the indicators for European hake in GSA 6 in 2024, based on the GFCM advice framework. The assessment results should be considered qualitative, although the model results in good diagnostics. B/B_{msy} is close to B_{lim} but remains stable; more time is needed to see a recovery in Biomass indicator. F/F_{msy} is around 1.5, but this reference point is more variable depending on the biomass input (ad hoc WGHKE, GFCM 2025).

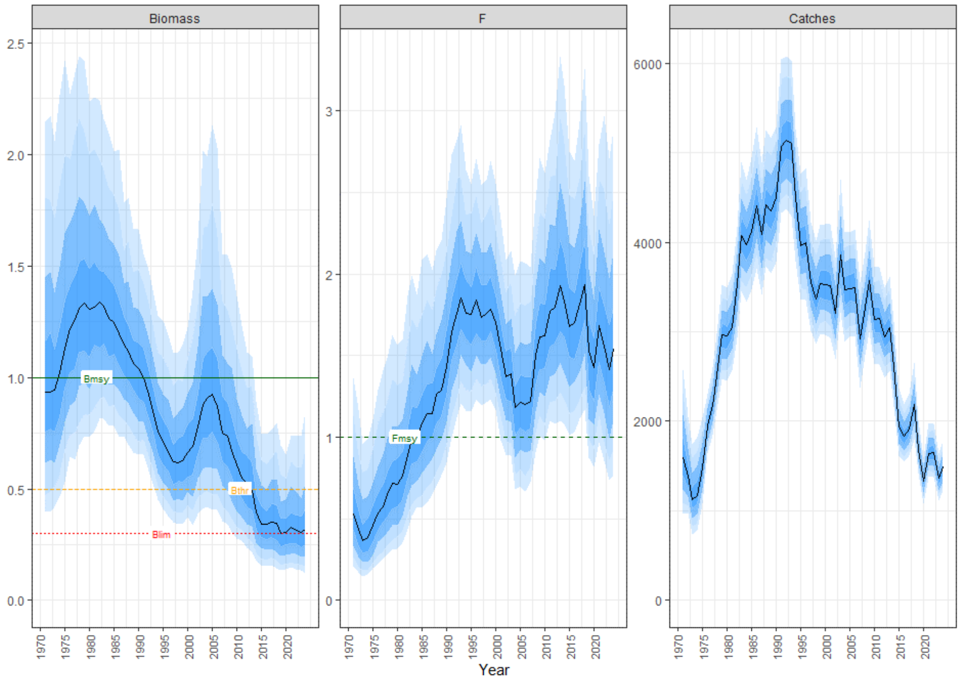

Figure 61. Advice for final scenario for European hake in GSA6: Historical and current stock status regarding F_{msy}, B_{msy} and B_{lim}.

Table 19. Indicators in 2024 from SPiCT for European hake in GSA6 final scenario.

Species	Year	Catch (t)	F/F_{msy}	B/B_{msy}	B/B_{pa}	B/B_{lim}
HKE	2024	1647.86	1.54	0.32	0.63	1.06

Statistical catch-at-size model (MESTOCK)

The Mestock model was applied in a simplified manner based on the evidence that throughout the history of the fishery, the trawler fleet (OTB) has had an almost absolute predominance (95% of landings). The sum of the three available vectors per fleet was considered the only landing vector, with the sum of the size compositions serving as a weighting factor for the landings per fleet. The CPUE of the trawler fleet (OTB) was considered representative. Model fits and associated variables from the assessment are presented in Figure 62, Figure 63, Figure 64 and Figure 65.

The model was experimentally applied using landing data (1971–2023), MEDITS survey data (2002–2023), CPUE for OTB, and length-frequency data from landings (OTB, 2002–2023) and surveys (MEDITS, 2002–2023).

The model better fits the CPUE data than the index data. It struggles to capture high peaks in biomHoass, such as in 2006. The model shows some discrepancies when fitting the fleet and survey length frequencies, underestimating the mean length in certain years, but generally aligns well with the shape of the actual data.

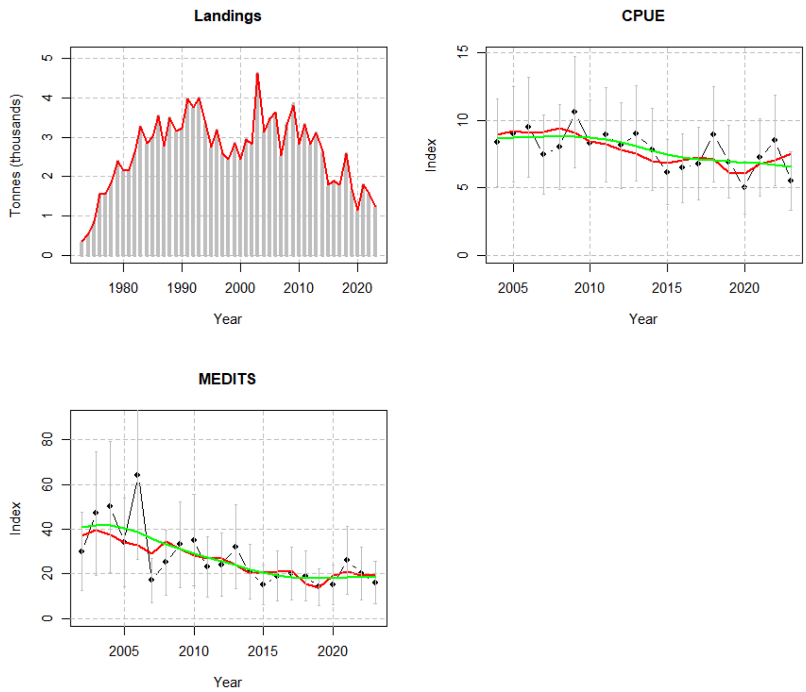

Figure 62. Fitting of the landing's series and abundance index for European hake (HKE) in the GSA6. Red line corresponds to the model estimation.

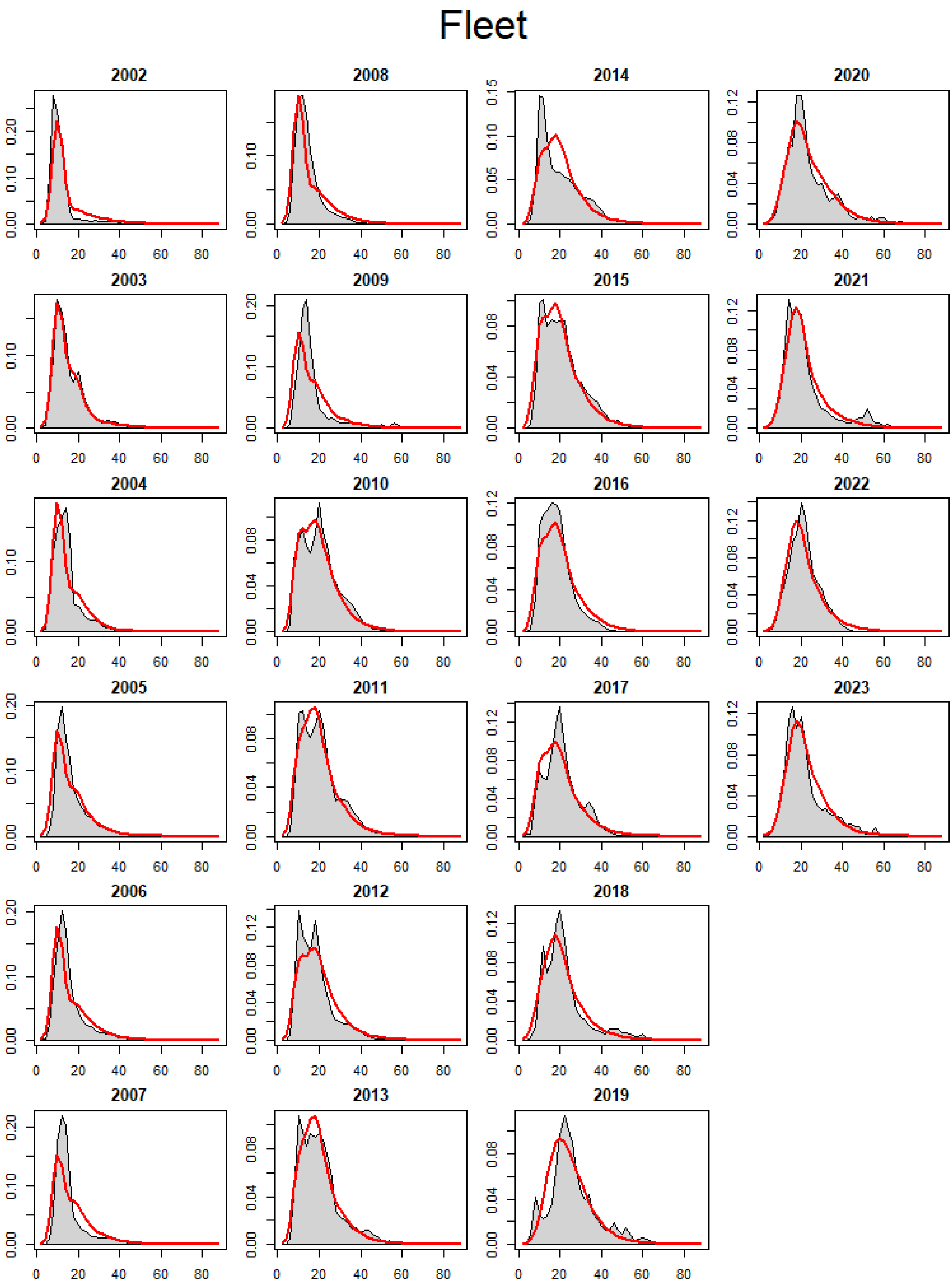

Figure 63. Fitting of the landings size compositions for European hake (HKE) in the GSA6. Red line corresponds to the model estimation.

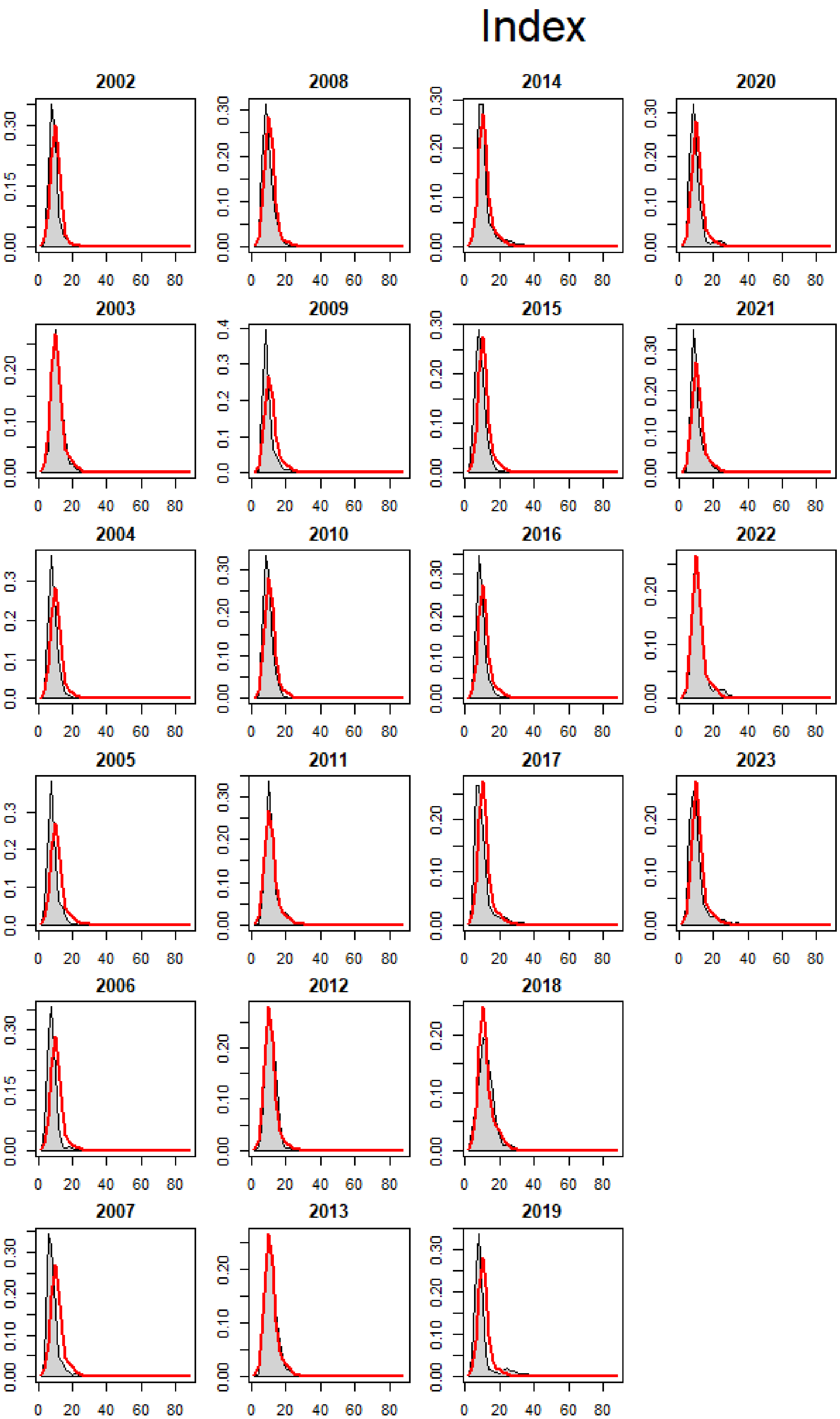

Figure 64. Fitting of the campaign size compositions for European hake (HKE) in the GSA6. Red line corresponds to the model estimation.

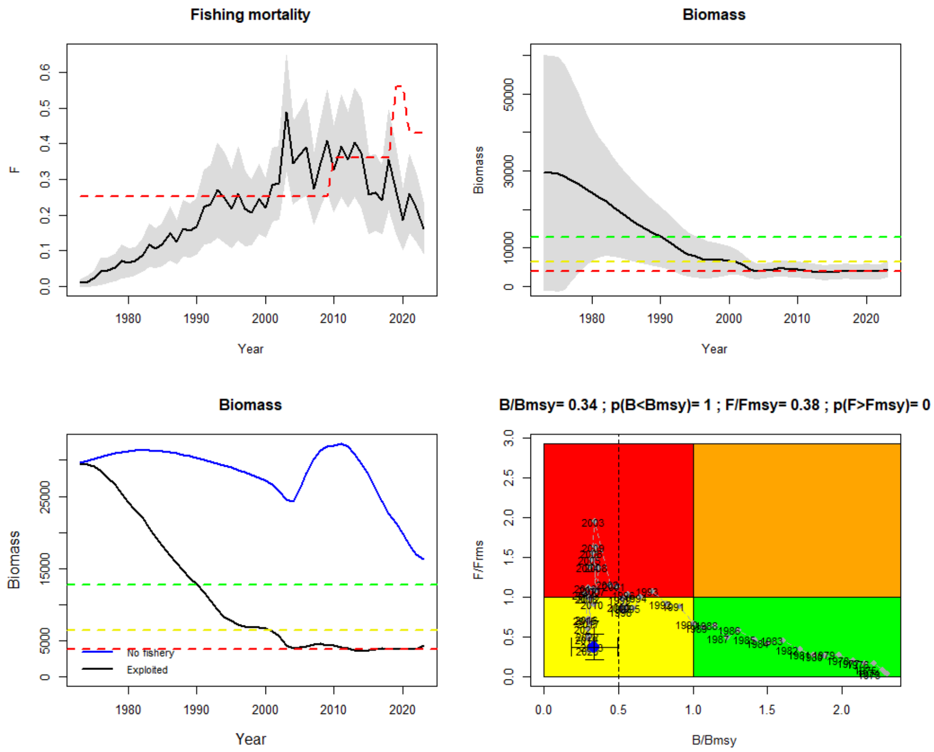

Figure 65. Biomass, fishing mortality, stock depletion and Kobe plot estimated for European hake (HKE) in the GSA6.

Analysis of population variables indicates that the European hake b iomass has remained relatively stable, with estimated values around B_{lim}, since 2002. However, this is when the model begins to incorporate length frequency distribution data.

It is estimated that fishing pressure on this resource has decreased to levels below F_{msy} since 2019. Analyses indicate that, despite a reduction in fishing pressure, there has not been a corresponding increase in biomass. The Kobe diagram suggests that the stock is experiencing overexploitation (B/B0 < 0.4), but is not currently subject to overfishing (F < F40%).

One possible explanation, as shown by the length-based model applied to the northern GSA6, is that the individuals in the population remain too small. This limits their spawning potential and the stock's ability to recover biomass. To explore this further, we tested a scenario with modified growth parameters (L_{inf} = 80.2 cm, as reported by Aldebert et al. (1993), instead of 110 cm, as used in STECF EWG24-10), using the same data in both cases. We believe that the L_{inf} = 80.2 cm value better represents the stock in the area; therefore, this scenario was chosen. In this case, the length distribution is closer to the L_{inf}, leading to a stock status nearer to B_{lim} (Figure 66). Additionally, different analyses were used to examine length frequencies by fleet (OTB, LLS, and GNS), but the data is not robust enough throughout the time series to fit the model properly, and the results were not acceptable.

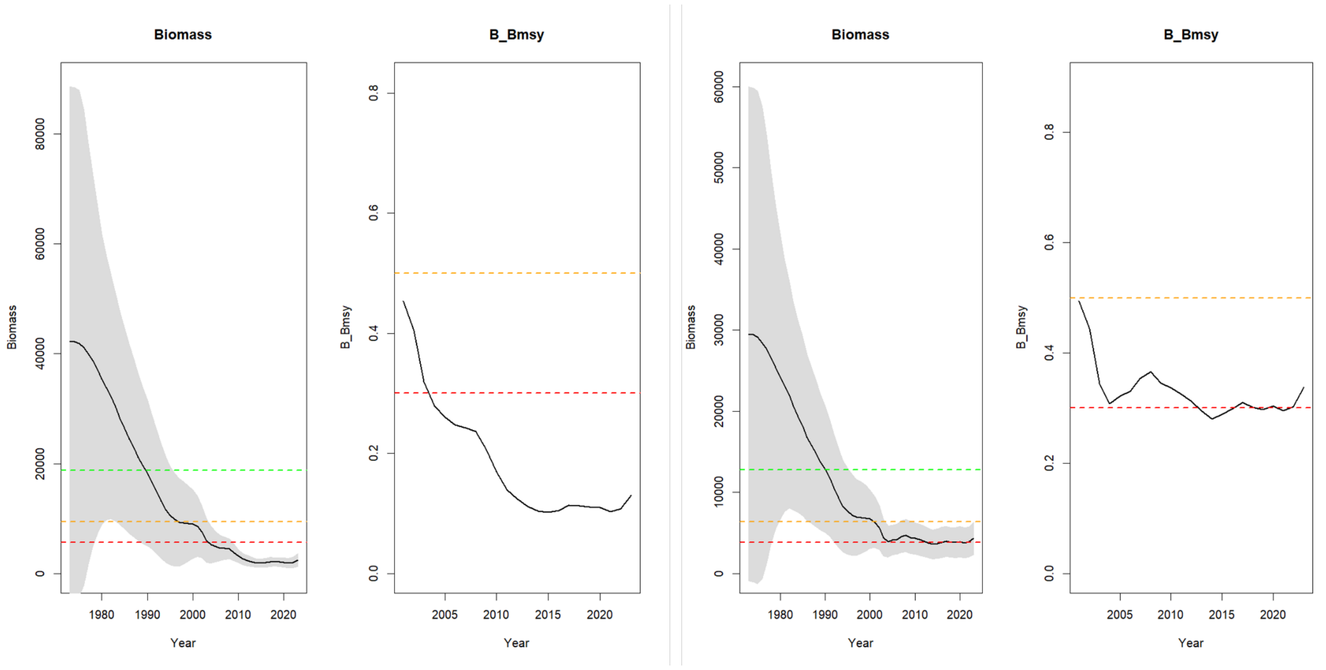

Figure 66. Biomass and B/B_{msy} ratio for European hake (HKE) in the GSA6 with modified growth parameters. Left: L_{inf}= 110 and k = 0.178 (STECF EWG24-10); right: L_{inf}= 80.2 and k = 0.113 (Aldebert et al., 1993).

In conclusion, the results should be considered as a reference and re-evaluated with a higher level of criticality regarding the data used. In this regard, it is recommended to review the usefulness of including unrepresentative size compositions, such as those of LLS. Similarly, it would be helpful to test different assessment scenarios considering possible ranges of European hake biological traits, or, if the data permits, evaluate the estimation of key parameters such as growth or the steepness of the stock-recruit relationship.

Deep-water rose shrimp (*Parapenaeus longirostris*) DPS

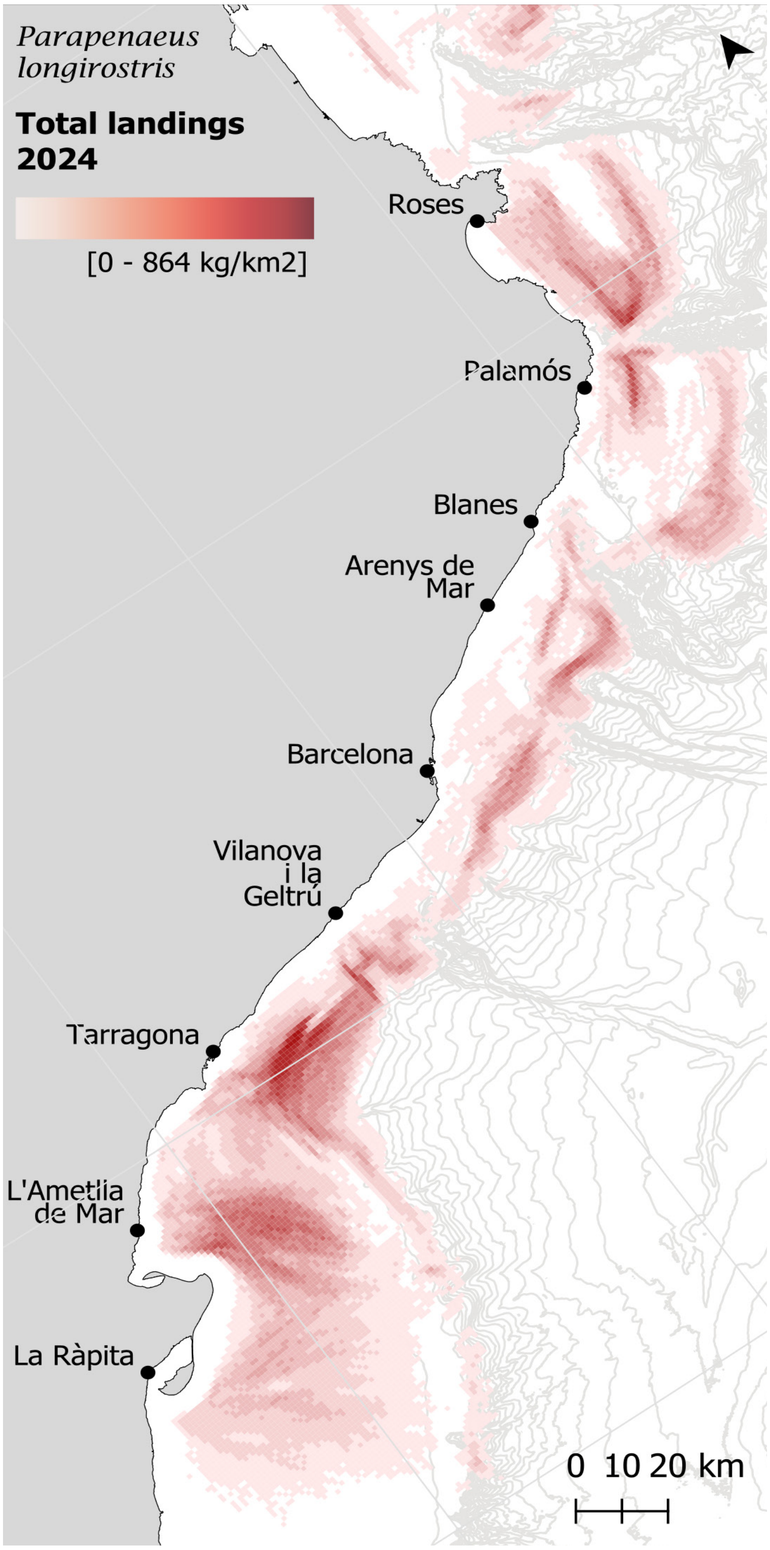

Figure 67. Spatial distribution of landings (kg/km²) for deep-water rose shrimp in the Catalan fishing grounds (North GSA6) in the year analysed.

The spawning season for deep-water rose shrimp occurs between January and November, with a peak between April and September (ICATMAR, 25-05); recruitment occurs afterwards.

Input data

The spatial distribution of total landings for deep-water rose shrimp in the Catalan fishing ground is shown in Figure 67. Considering bathymetry, the species has a main distribution in slope areas. However, in terms of total landings per km², it is more abundant in the central and southern areas.

Historical deep-water rose shrimp landings in Catalonia from 2002 to 2024 are shown in Figure 68. The species shows a clear increase in landings since 2016, with the highest value in 2021.

Figure 69 shows deep-water rose shrimp landing distribution by métier from 2019 to 2024. The highest landings are obtained with bottom trawlers, specifically for deeper shelf and upper slope métiers.

Annual LFD

After raising the length frequencies obtained with the monitoring program (Table 21), and considering discards, the annual length frequency of deep-water rose shrimp in Catalonia is plotted in Figure 41. The SOP validation results are shown in Table 20, while Table 21 summarizes the number of individuals sampled through the ICATMAR monitoring program. Small and medium length classes were more abundant in 2020 and 2021, associated with higher discard rates. The abundance of small individuals decreased in 2022 and 2023 but showed an increased in 2024.

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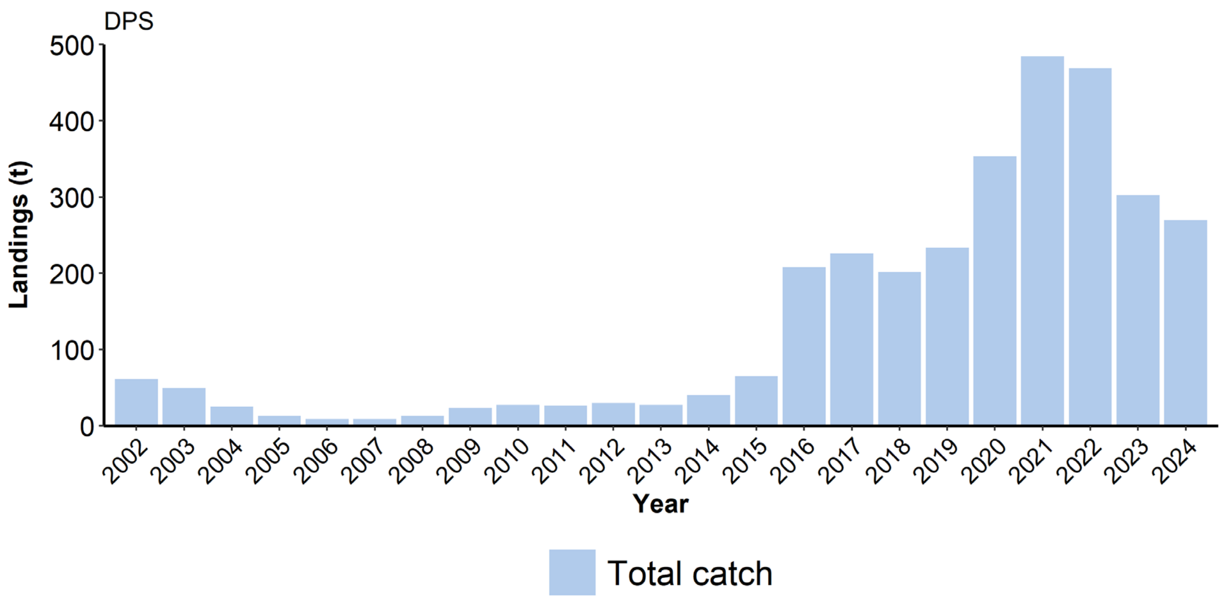

Figure 68. Historical landings (t) for deep-water rose shrimp in Catalonia.

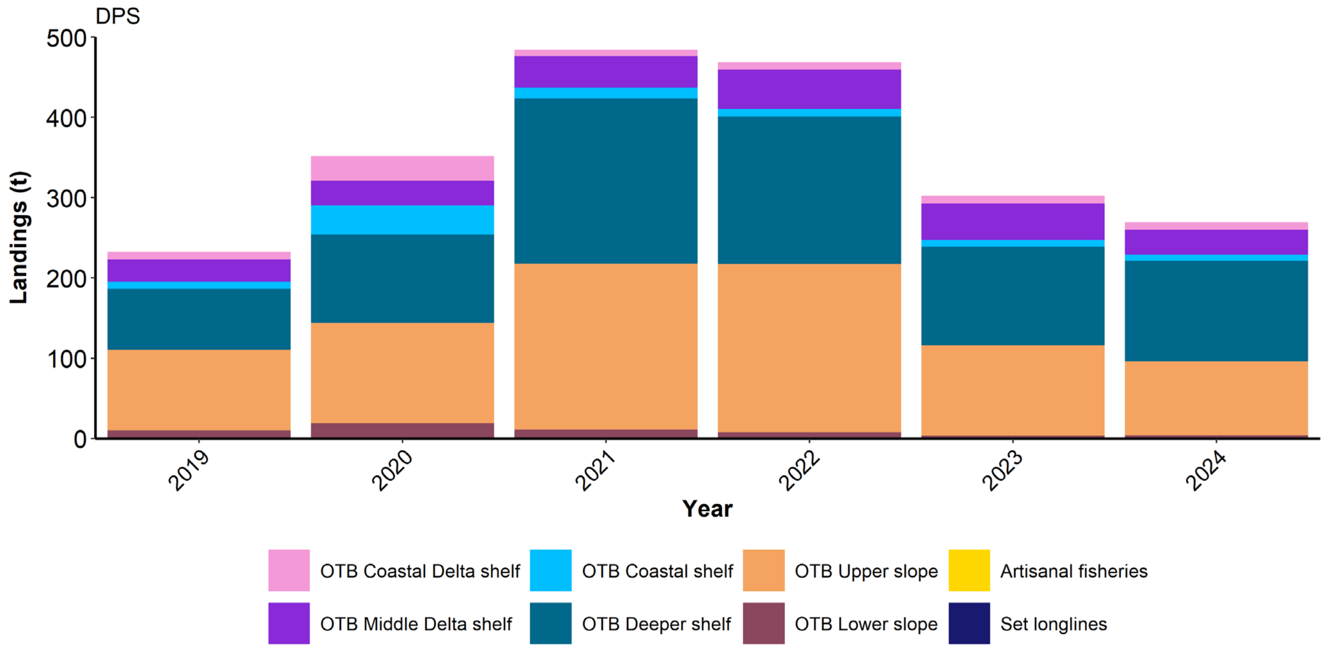

Figure 69. Landings (t) for deep-water rose shrimp by métier and fishing gear. OTB: bottom trawling.

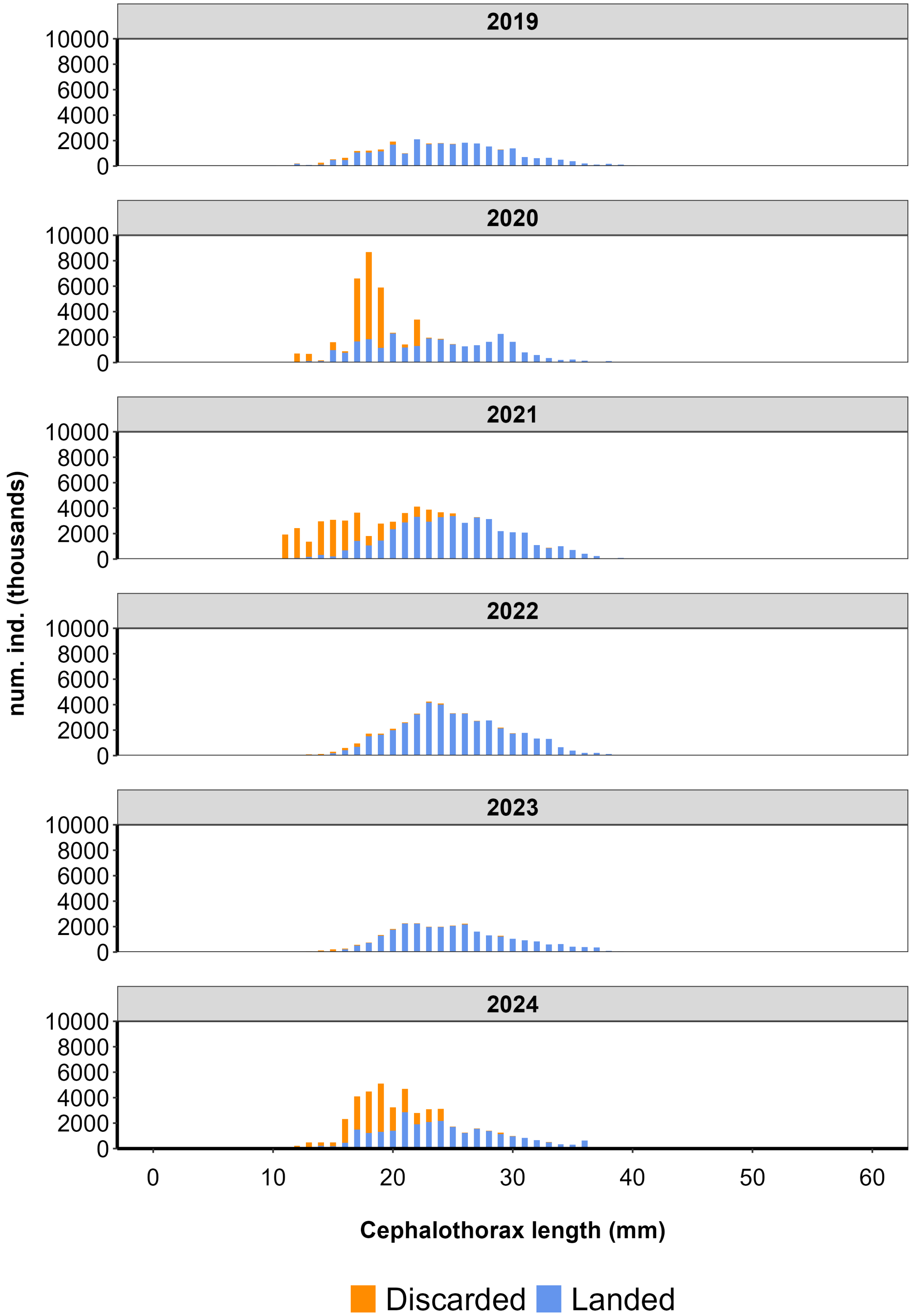

Figure 70. Annual length frequency distributions of deep-water rose shrimp from bottom trawling and small-scale fisheries. The data from bottom trawling is raised from ICATMAR data and details landed and discarded deep-water rose shrimp.

Table 20. Sum of Products (SOP) validation for deep-water rose shrimp (DPS): The column Calculated Weight in GSA6N (SOP) represents the biomass estimated through the raising process, while landings refer to the reported landings in NGSA6. The ratio between SOP and landings is known as the Sum of Products (SOP). Values close to 1 indicate that the raising process provides biomass estimates that closely match the reported landings, thereby validating the accuracy of the estimation method.

Species	Year	Catch classification	Gear	Calculated weight GSA6N (kg) (SOP)	Landings in GSA6N (kg)	SOP/Landings
DPS	2019	Discarded	Bottom trawl	5676	-	-
DPS	2020	Discarded	Bottom trawl	89726	-	-
DPS	2021	Discarded	Bottom trawl	116131	-	-
DPS	2022	Discarded	Bottom trawl	13501	-	-
DPS	2023	Discarded	Bottom trawl	18596	-	-
DPS	2024	Discarded	Bottom trawl	107497	-	-
DPS	2019	Landed	Bottom trawl	254227	233472	1.09
DPS	2020	Landed	Bottom trawl	253000	353327	0.72
DPS	2021	Landed	Bottom trawl	441827	484386	0.91
DPS	2022	Landed	Bottom trawl	424784	468905	0.91
DPS	2023	Landed	Bottom trawl	271831	302555	0.90
DPS	2024	Landed	Bottom trawl	250720	269391	0.93

Table 21. Number of deep-water rose shrimp individuals sampled by zone and season from ICATMAR monitoring data used to raise the length frequencies.

Fishery	Year	Zone	Winter	Spring	Summer	Autumn	N hauls
			Number individuals sampled				
Bottom trawl	2019	North	206	459	212	328	30
Bottom trawl	2019	Center	204	263	157	553	21
Bottom trawl	2019	South	402	170	285	272	23
Bottom trawl	2020	North	206	236	405	532	24
Bottom trawl	2020	Center	292	308	364	425	23
Bottom trawl	2020	South	368	77	156	340	15
Bottom trawl	2021	North	518	676	818	591	34
Bottom trawl	2021	Center	402	404	387	214	19
Bottom trawl	2021	South	297	41	204	224	16
Bottom trawl	2022	North	397	419	931	983	32
Bottom trawl	2022	Center	311	239	1197	659	19
Bottom trawl	2022	South	186	242	380	753	13
Bottom trawl	2023	North	1245	880	1012	565	25
Bottom trawl	2023	Center	585	369	591	207	18
Bottom trawl	2023	South	895	517	449	311	14
Bottom trawl	2024	North	830	742	627	936	26
Bottom trawl	2024	Center	322	657	1001	889	20
Bottom trawl	2024	South	576	282	611	1227	17

Length-Based Spawning Potential Ratio (LBSPR)

Table 22. Biological parameters used in the different LBSPR scenarios for deep-water rose shrimp (DPS). $L_{inf:}$ asymptotic length at which growth is zero, k: growth rate, M: natural mortality, $L_{mat50:}$ length where 50% of individuals are mature, $L_{mat95:}$ length where 95% of individuals are mature.

Species	Scenario	L_{inf} (mm)	L_{mat50} (mm)	L_{mat95} (mm)	M/K
DPS	1	45	25.60	43.60	1.07
DPS	2	44	25.60	43.60	1.13
DPS	3	44	17.05	29.00	1.13
DPS	4	44	17.05	29.00	1.50

Model setting and results

Scenarios

Four different scenarios were applied for the sensitivity analysis for deep-water rose shrimp (Table 22):

- **Scenario 1:** used growth parameters and natural mortality from the STECF stock assessment, along with maturity data from the GFCM.
- **Scenarios 2:** applied growth, maturity and mortality parameters from the GFCM stock assessment.
- **Scenario 3:** applied growth and mortality parameters from the GFCM stock assessment and incorporated maturity data from the ICATMAR dataset.
- **Scenario 4:** used the same growth parameter and length at first maturity values as Scenario 3, but applied a different M/k ratio to test the model's sensitivity to this parameter, it was based on (Froese et al., 2018; Hordyk et al., 2015; Jensen, 1996).

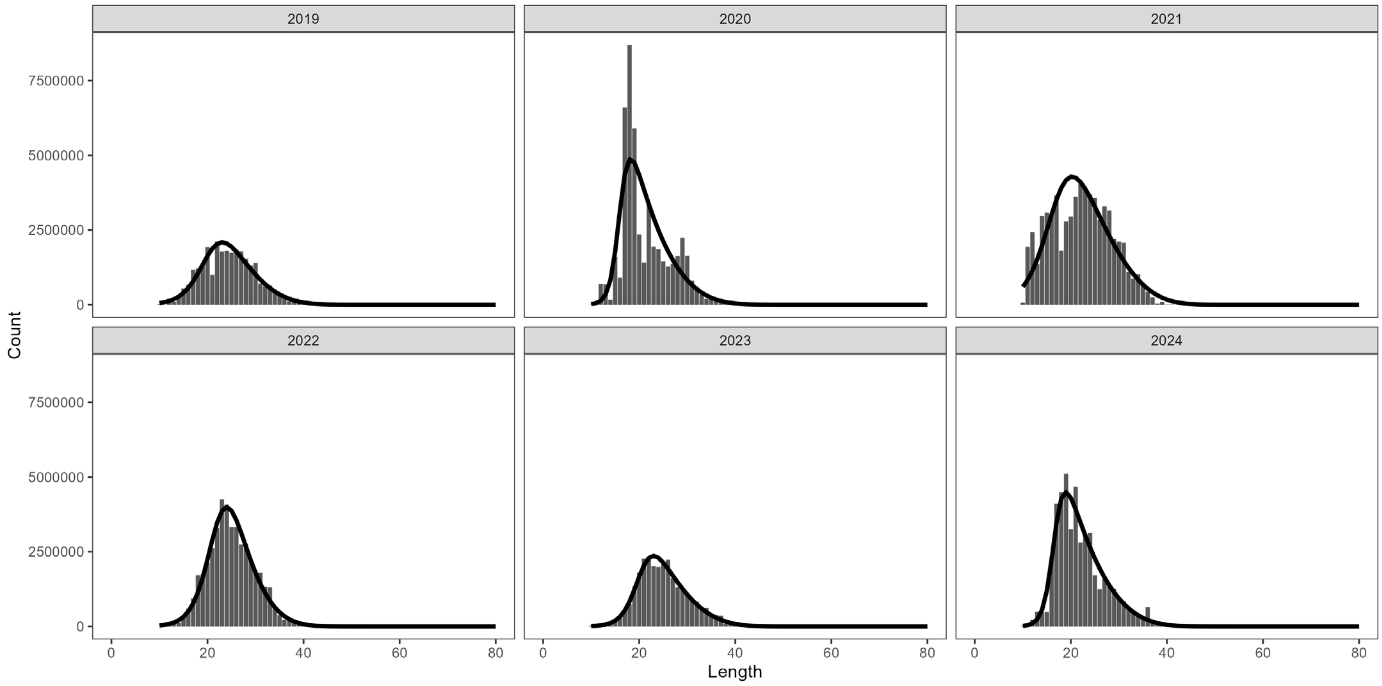

Figure 71. Fit of the data using the LBSPR model for deep-water rose shrimp for each studied year. Grey columns indicate length frequencies. Black lines indicate the fit of the model.

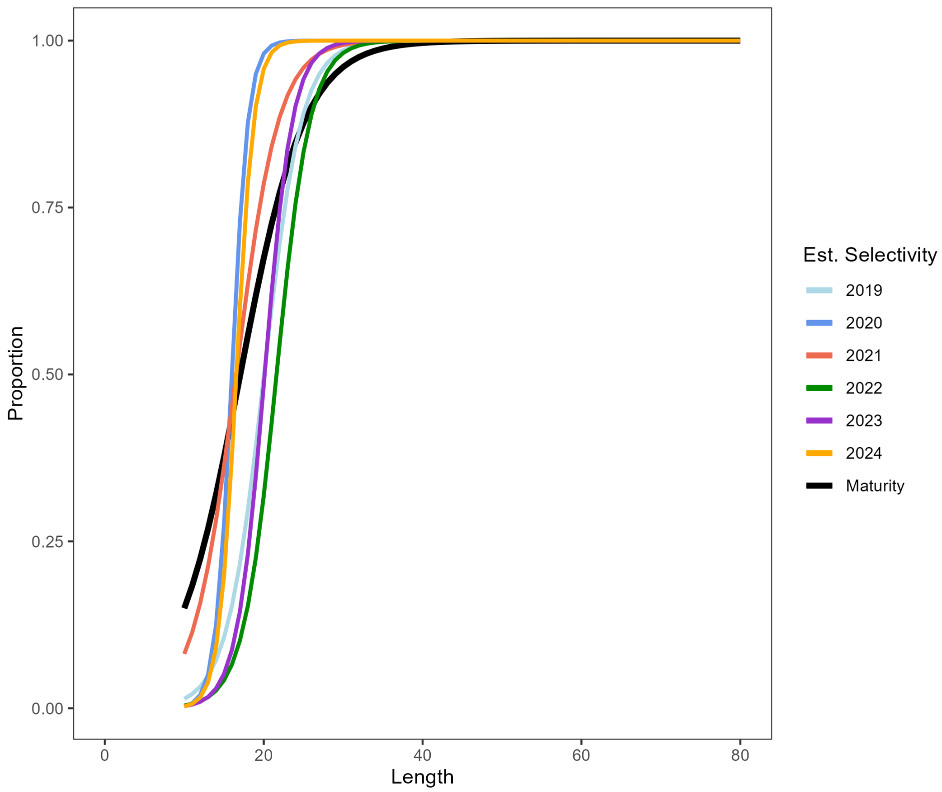

Figure 72. Length curves for deep-water rose shrimp. Black line shows the length curve at maturity. Color lines show the estimated selectivity at length curve predicted by the LBSPR model selected (3).

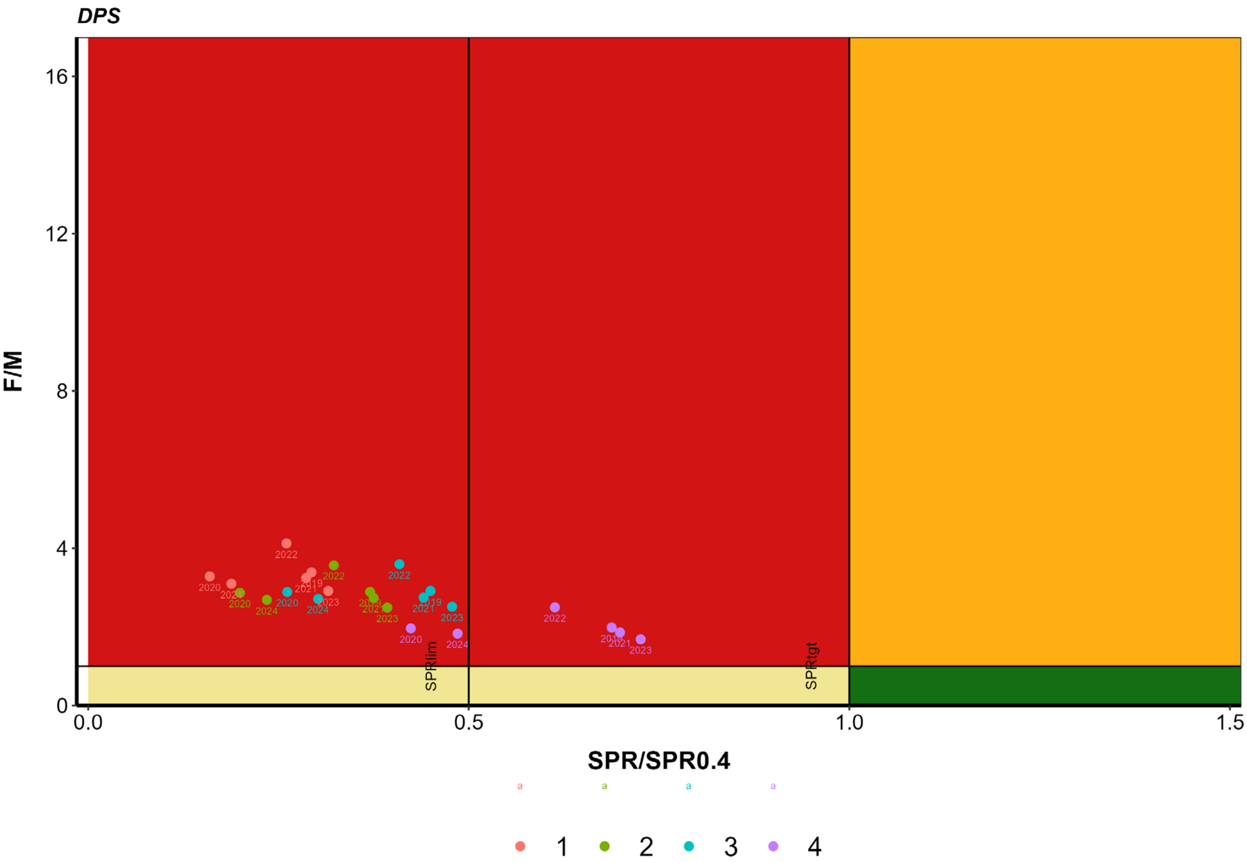

Figure 73. Kobe plot for deep-water rose shrimp by scenario (1-3) and year. SPR_{lim}: limit spawning potential ratio, SPR_{tgt}: target spawning potential ratio, F: fishing mortality, M: natural mortality, and F/M: relative fishing mortality.

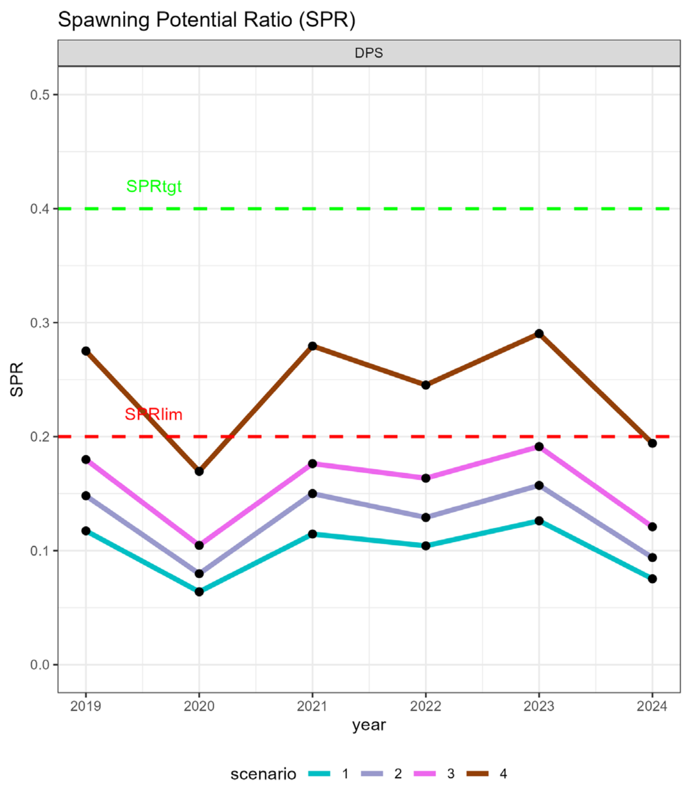

Figure 74. Spawning potential ratio (SPR) per year analyzed for deep-water rose shrimp evaluated with LBSPR model. LBSPR: Length-Based Spawning Potential Ratio. SPR_{lim}: limit spawning potential ratio, SPR_{tgt}: target spawning potential ratio. Colored lines show the results for each scenario.

Table 23. LBSPR model results for deep-water rose shrimp with the different scenarios tested for each year analysed. SL_{50}: Length where 50% of individuals are caught, SPR: spawning potential ratio and FM: fishing mortality. SD is the standard deviation calculated for each indicator. The selected scenario is highlighted in blue.

spp	scenario	year	SL_{50}	SD	SPR	SD	FM	SD
DPS	1	2019	21.36	1.15	0.12	0.09	3.38	1.42
DPS	1	2020	16.13	0.13	0.06	0.05	3.28	0.97
DPS	1	2021	18.76	2.69	0.11	0.12	3.24	1.65
DPS	1	2022	22.49	0.68	0.10	0.08	4.12	1.53
DPS	1	2023	20.75	0.55	0.13	0.09	2.91	1.12
DPS	1	2024	16.77	0.20	0.08	0.05	3.10	0.96
DPS	2	2019	21.23	1.23	0.15	0.13	2.89	1.34
DPS	2	2020	16.12	0.14	0.08	0.06	2.86	0.90
DPS	2	2021	18.43	2.85	0.15	0.16	2.73	1.54
DPS	2	2022	22.42	0.72	0.13	0.10	3.57	1.44
DPS	2	2023	20.69	0.58	0.16	0.12	2.49	1.05
DPS	2	2024	16.75	0.21	0.09	0.07	2.69	0.90
DPS	3	2019	21.25	1.17	0.18	0.11	2.91	1.31
DPS	3	2020	16.12	0.13	0.10	0.06	2.89	0.89
DPS	3	2021	18.43	2.80	0.18	0.15	2.75	1.52
DPS	3	2022	22.43	0.69	0.16	0.09	3.59	1.41
DPS	3	2023	20.70	0.56	0.19	0.11	2.51	1.02
DPS	3	2024	16.76	0.20	0.12	0.07	2.71	0.88
DPS	4	2019	21.33	1.12	0.28	0.17	1.98	1.01
DPS	4	2020	16.15	0.12	0.17	0.10	1.96	0.70
DPS	4	2021	18.60	2.72	0.28	0.23	1.86	1.16
DPS	4	2022	22.47	0.64	0.25	0.14	2.50	1.09
DPS	4	2023	20.74	0.53	0.29	0.17	1.68	0.80
DPS	4	2024	16.78	0.19	0.19	0.11	1.83	0.69

Fitted data

The length frequency distribution fit per year is shown in Figure 71. The model generally follows the mode for all years, except for 2020, when the model does not fit the data properly due to the presence of different pics with no normal distribution of the observed data.

Selectivity

The outputs of the model for the selectivity of the fishery are shown for each scenario in Table 23. The output for scenario selected (3) is also plotted with L_{mat50} and SL_{50} in Figure 72. The model outputs reveal that the fishery is fishing similar or above L_{mat50} in scenario 3

Reference points

Although the model shows sensitivity to changes in growth and maturity parameters, the stock remains between SPR (= 0.1) and SPR_{lim} (= 0.2) under scenarios 1 to 3. However, the model is highly sensitive to changes in mortality parameters (M/k). When M/k is increased to 1.5, as in scenario 4, the estimated SPR rises to near or above SPR_{lim} (= 0.2), indicating a more favorable stock status under this assumption (Figure 74). The Kobe plot for deep-water rose shrimp (Figure 73) shows the stock status throughout the different years, with a no clear trend. In all cases, the stock status is located in the red zone, meaning that it is overfished and under overfishing.

Final scenario

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBSPR model.

Length-based Bayesian Biomass (LBB)

Scenarios

Three different scenarios were applied for the sensitivity analysis for deep-water rose shrimp (Table 24). Scenarios 1 used growth parameters and natural mortality from STECF whereas scenarios 2 and 3 used GFCM stock assessment data. Scenario 1 used maturity data from GFCM stock assessment but 3 used that from ICATMAR.

Table 24. Biological parameters used in the different LBB scenarios for deep-water rose shrimp (DPS). $L_{inf:}$ Asymptotic length, M/k: ratio between natural mortality and growth rate, $L_{mat50:}$ length where 50% of individuals are mature.

Specie	Scenario	Linf (cm)	M/k	Lmat50 (cm)
DPS	1	4.5	1.070	2.6
	2	4.4	1.340	2.6
	3	4.4	1.340	1.7

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBB model. The following graphics are based on Scenario 3.

Fitted data

The length frequency distribution fit per year is shown in Figure 75. The model generally follows the mode for all years, except for 2020, 2021 and 2024, when the model does not fit the data properly due to the presence of different peaks with no normal distribution of the observed data.

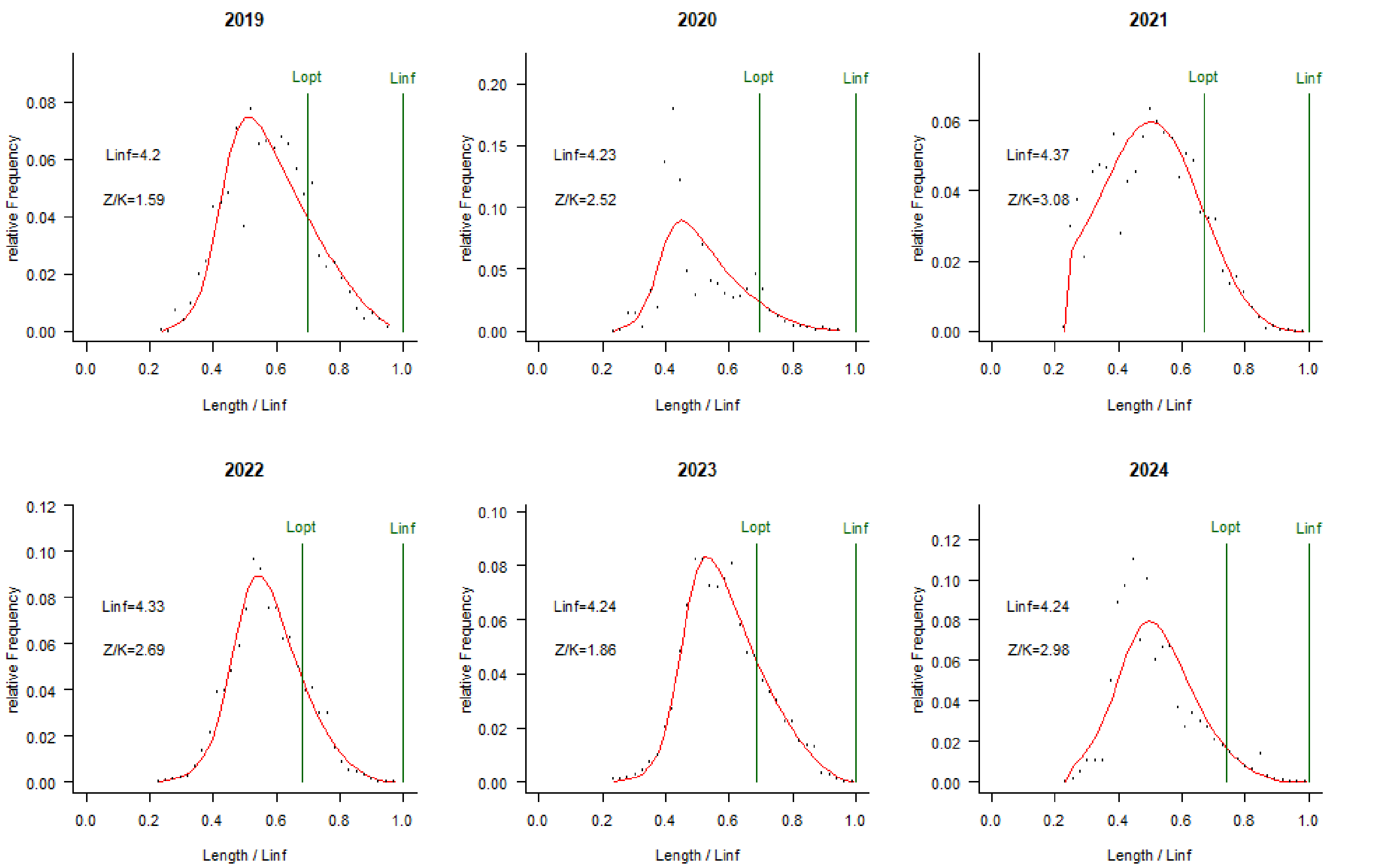

Figure 75. Fit of the data using the LBB model for DPS for each year in scenario 3. Red line indicates the fit of the model.

Reference points

Summary of the graphical results are in Figure 76. The upper left plot shows that the aggregated estimated Length at first capture (L_c) is 1.5 cm, below the L_{mat} (1.7 cm), but in the left lower plot it can be seen that is above in each year (L_c: dotted black line). The upper middle and right panels show that the L_{mean} is not far from L_{opt}, which is also shown in the lower left plot (L_{mean}: bold black line). Lower middle and right plots show that the relative fishing pressure (F/M) and relative biomass (B/B_0) are near sustainable levels. More details related to these results are in Table 25.

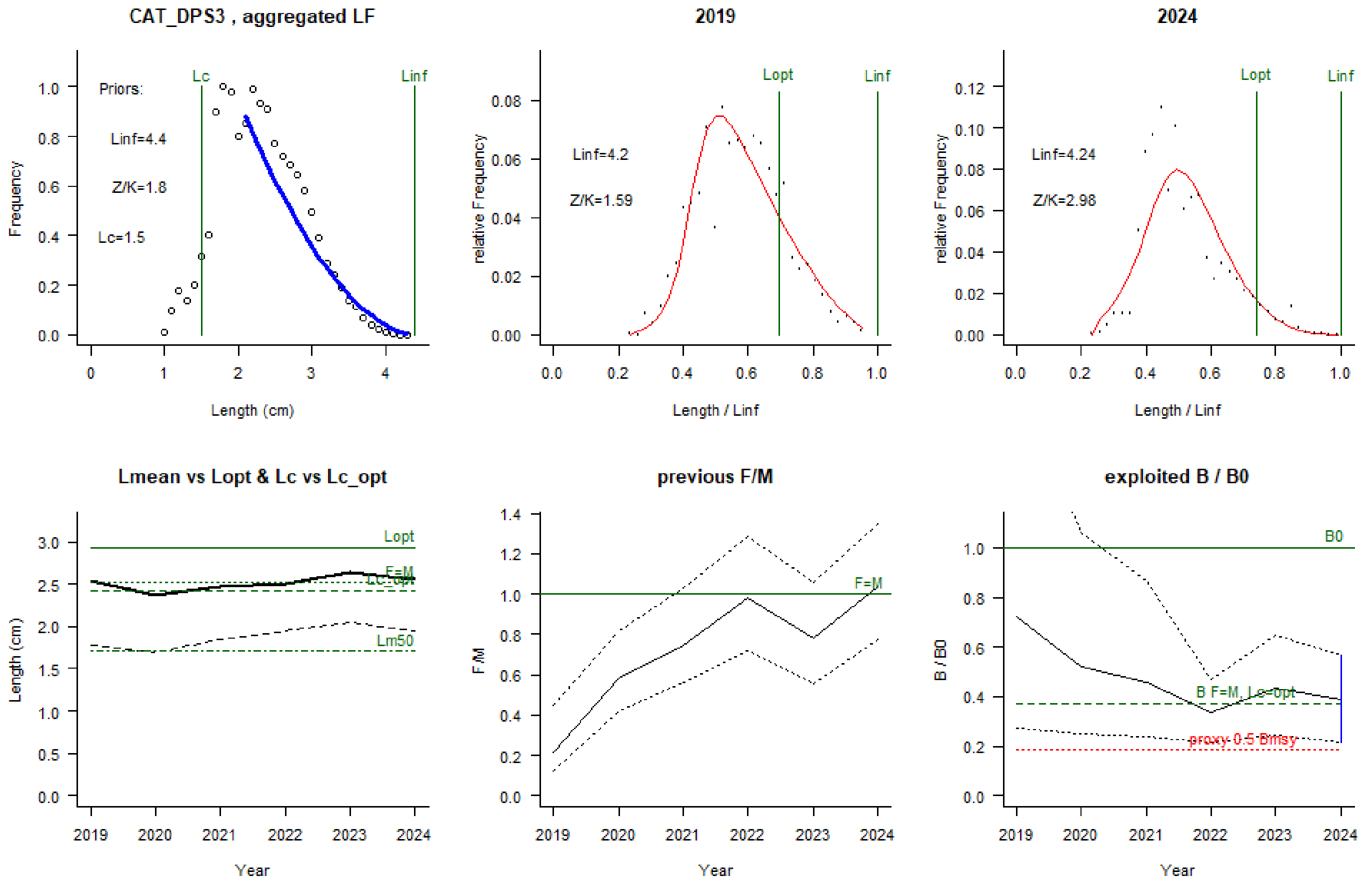

Figure 76. Summary output from LBB for DPS scenario 3.

Table 25. LBB model results for deep-water red shrimp (DPS) with the different scenarios tested for each year analyzed. $L_{mean:}$ mean length of individuals, $L_{opt:}$ length at optimal yield, $L_{c:}$ length at first capture, $L_{c\_opt:}$ length at first capture at optimal yield, L_{95th}/L_{inf}: ratio of the 95th percentile to asymptotic length , F/M: fishing mortality relative to natural mortality, B/B0: exploited biomass relative to unexploited biomass, $B/B_{msy:}$ exploited biomass relative to maximum sustainable yield biomass, $C_{mature:}$ proportion of mature individuals in the catch.

Specie	Scenario	Year	Lmean/Lopt	Lc/Lc_opt	L95th/Linf	F/M	B/B0	B/Bmsy	Cmature
DPS	1	2024	0.79	0.71	0.98	1.70	0.25	0.66	22%
	2	2024	0.85	0.80	0.98	1.00	0.39	1.00	22%
	3	2024	0.85	0.80	0.98	1.00	0.39	1.00	82%

Stochastic Production model in Continuous Time (SPiCT)

For deep-water rose shrimp, input data available for catches were from 1994 to 2024, while for the index we had MEDITS survey from 2001 to 2024 and CPUE data from 2009 to 2023 (Figure 77). This assessment reference year is 2024. A double-axis plot was presented to compare trends between catches and the indices (Figure 78).

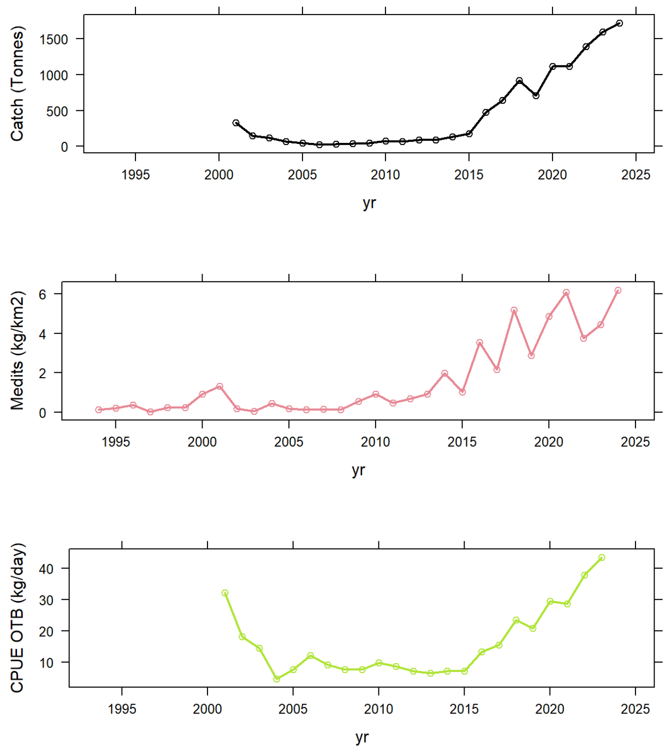

Figure 77. Data available for the assessment for deep-water rose shrimp in GSA6 to run SPiCT model. Top: catch data from 2001 to 2024. Centre: MEDITS survey data since 1994 to 2024. Bottom: CPUE data since 2009 to 2023.

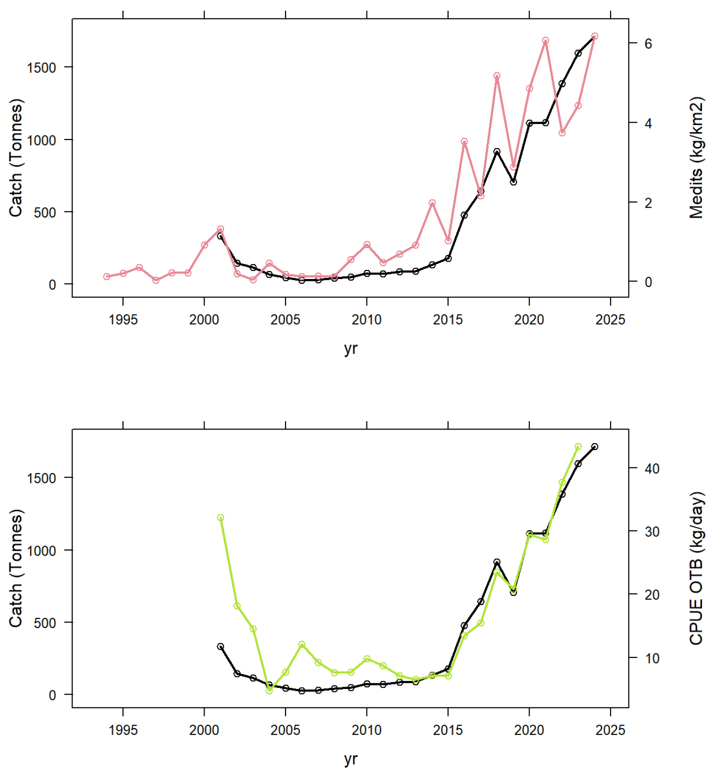

Figure 78. Double axis plot to compare trends between catch and MEDITS index (top) and catch and CPUE for OTB (bottom) for deep-water rose shrimp.

Data from catches prior to 2001 were not included in the assessments, as the earlier trials yielded unrealistic results and the diagnoses were not met. Further analysis is required to include this data.

Although only the final scenario is presented below, different scenarios were tested:

- **Scenario 1:** landings started in 2001, using MEDITS survey as index
- **Scenario 2:** landings started in 2001, using CPUE as index
- **Scenario 3:** landings started in 2001, using MEDITS survey and CPUE as indices

In Figure 79 is presented a comparison between the scenarios.

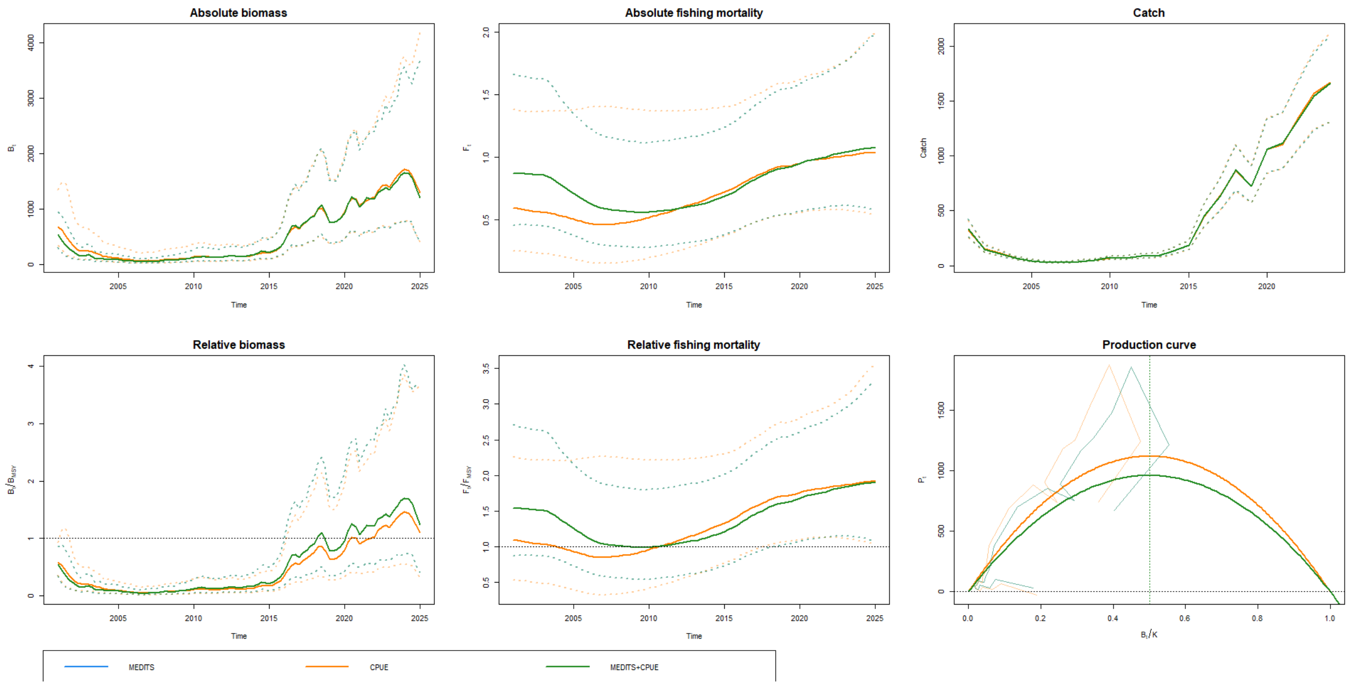

Figure 79. Scenarios comparison for deep-water rose shrimp in the GSA6.

Final scenario

Scenario 1 was chosen as the final scenario, since MEDITS survey gave better contrast information than CPUE, since the latter followed almost exactly the catches. The chosen scenario met most of the model diagnostics and provided good retrospective analysis and hindcasting diagnostics. (Figure 82, Figure 83, Figure 84, Figure 85 and Figure 86).

A sensitivity analysis for the final scenario was performed, testing r prior, bkfrac, process error, and observation error to assess the model's robustness within these priors. All these plots and results for the other scenarios will be available at https://github.com/ICATMAR.

The settings used for the final scenario are presented in Table 26. Is difficult to distinguish if at the beginning of the series, the stock was doing well or not, considering that the population growth should be the same from start to end. Given the complexity of the fishery and the difficult to estimate error sources, alpha and beta were established as 1.

Table 26. Priors settings for deep-water rose shrimp (DPS) in all scenarios.

Type	Prior	Description	Assignment	Mean	Standard deviation	Comment
Fishery dynamic	logbkfrac	B/K fraction (depletion)	-	Log(0.2)	0.2	Even when the fishery was not fully exploited during the beginning of the catch series, the model conflicts with higher values given the later fast increase in catches
Stock dynamic	logr	Population growth	-	Log(1.4)	0.1	Fishlife
	logn	Shape of production curve	-	Log(2)	-	Shaefer
Error	logalpha	Ratio between Observation error and Process error	-	Log(1)	0.001	
	logbeta	Ratio between Catch error and Fishing mortality error	-	Log(1)	0.001	

The final scenario input data is shown in Figure 80, and the final summary assessment results are shown in Figure 81.

Final scenario advice

Final scenario advice is presented in and Figure 87 and in Table 27, which outlines the indicators for deep-water rose shrimp in the GSA6 for the year 2024. The assessment results should be interpreted with caution, as the estimated biomass has shown a continuous increase since the beginning of the time series, without any sustained decline despite rising fishing mortality.

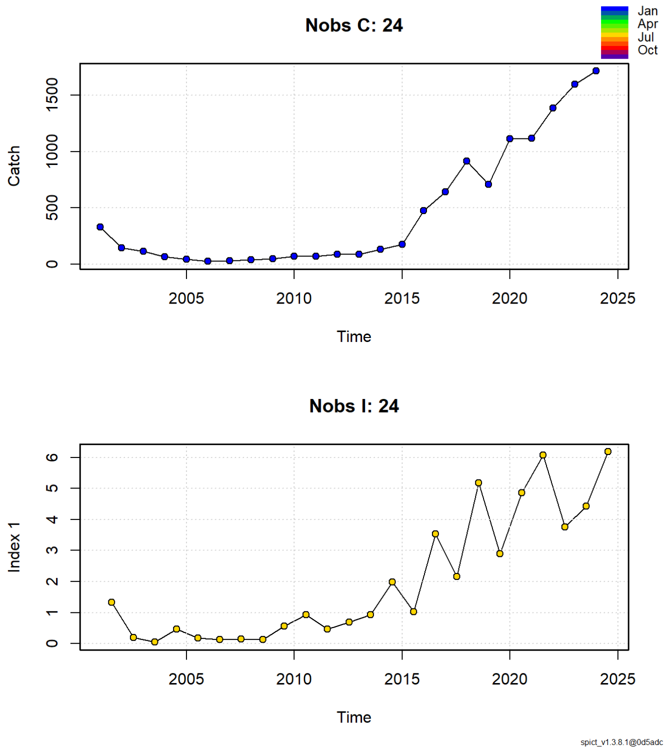

Figure 80. Input data for SPiCT model for deep-water rose shrimp in GSA6 for scenario 1. Top: catch in tons per year since 2002, bottom: index data of biomass derived from MEDITS since 2002.

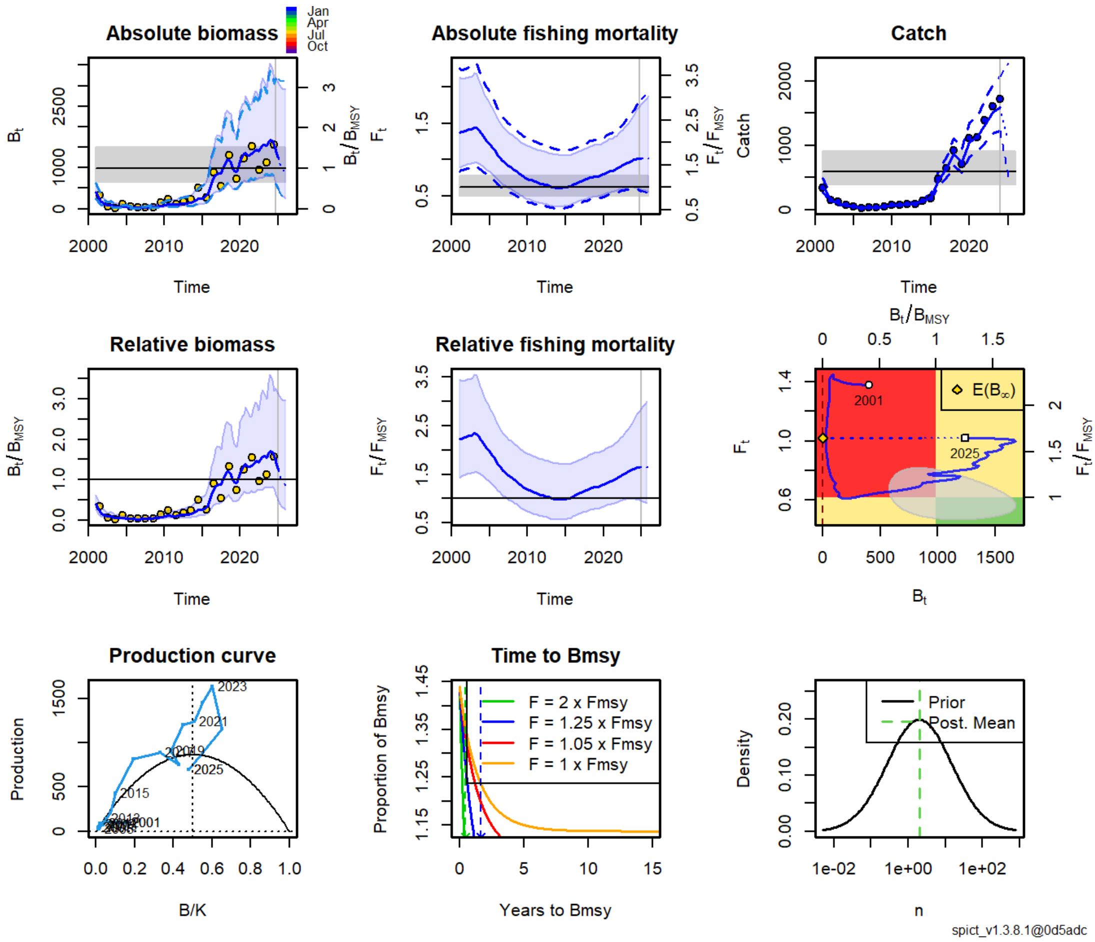

Figure 81. Stock assessment summary for SPiCT model for deep-water rose shrimp in the GSA6 for the final scenario.

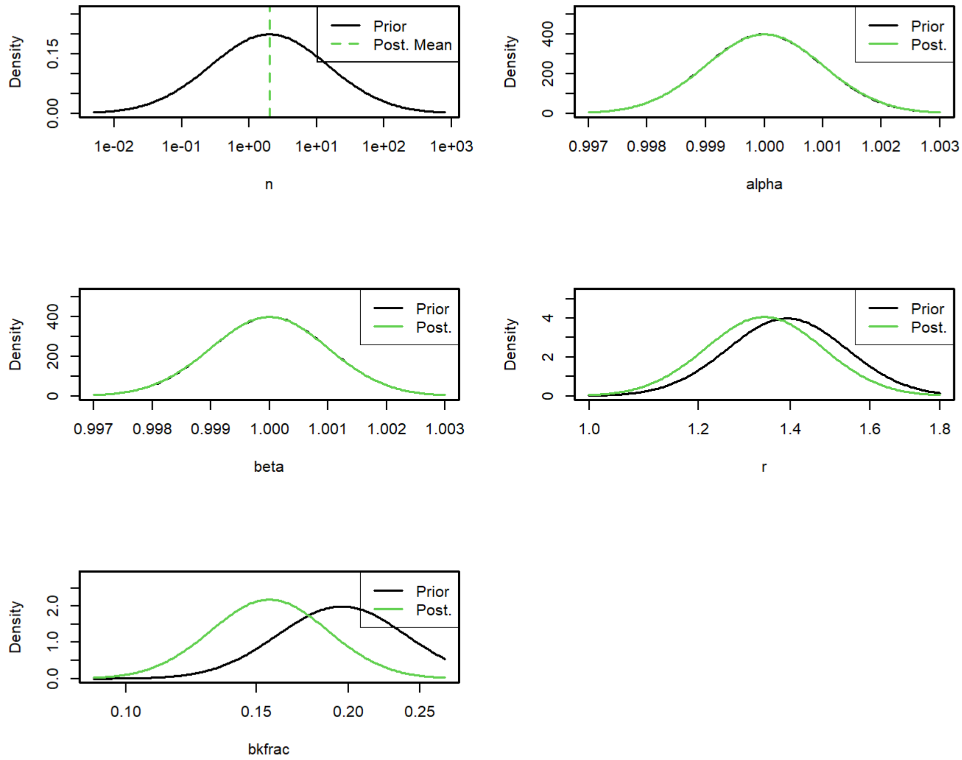

Figure 82. Estimated priors and posteriors for the updated assessment for deep-water rose shrimp in the GSA6 for the final scenario.

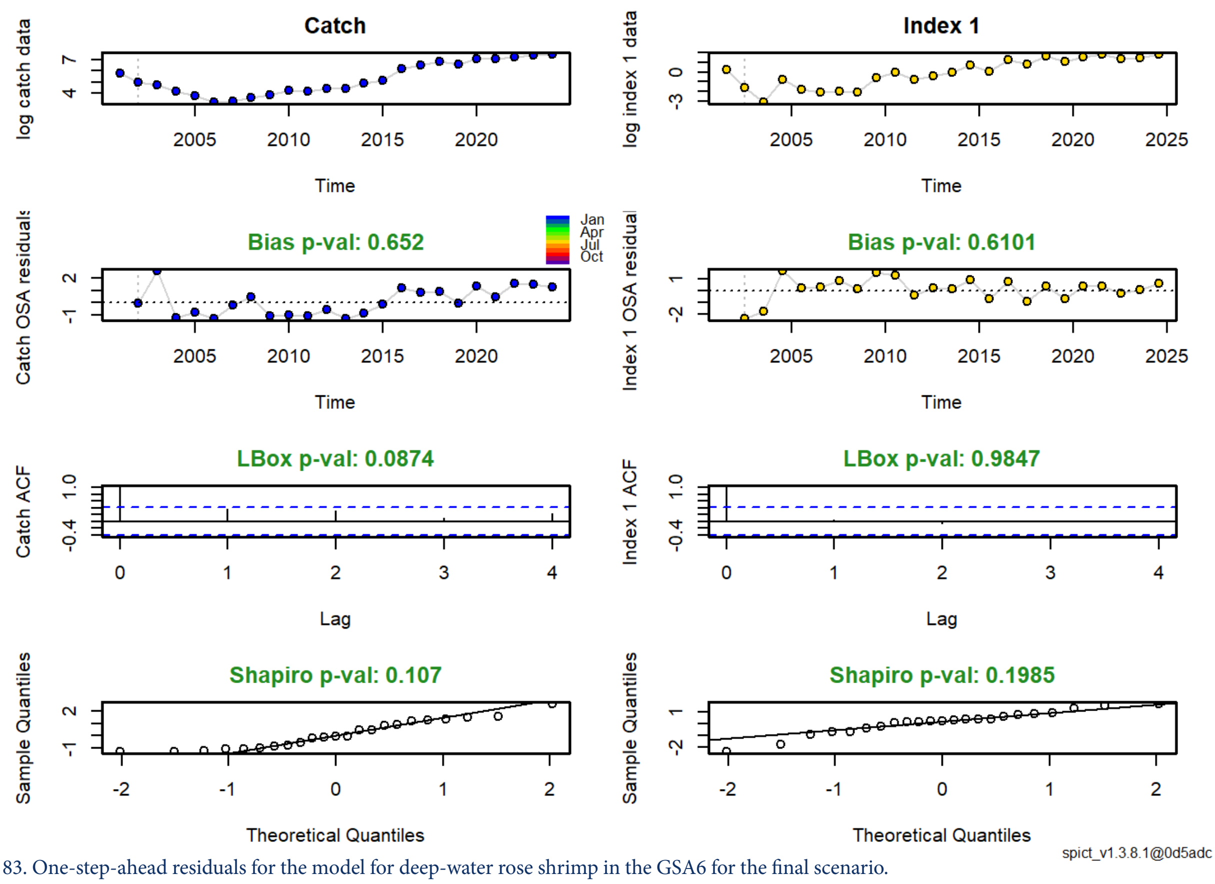

Figure 83. One-step-ahead residuals for the model for deep-water rose shrimp in the GSA6 for the final scenario.

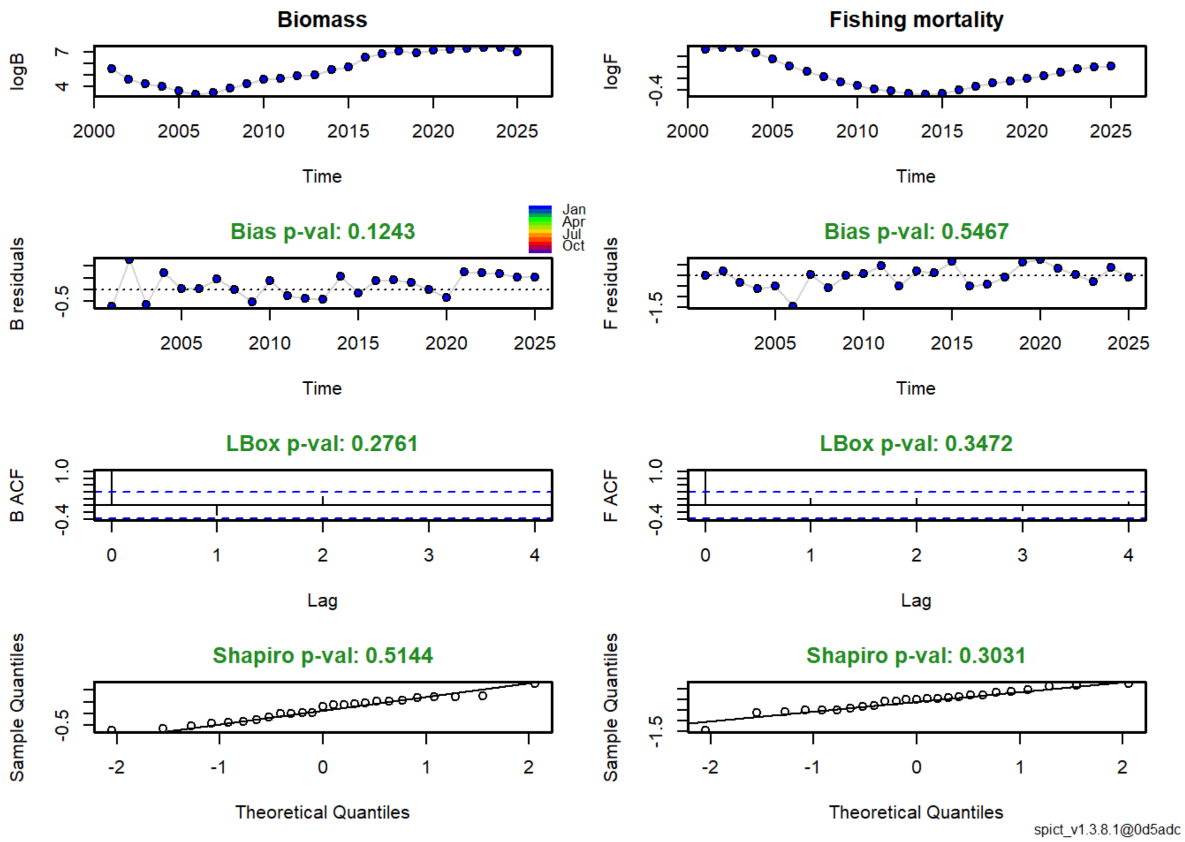

Figure 84. Process error deviations for the model for deep-water rose shrimp in the GSA6 for the final scenario.

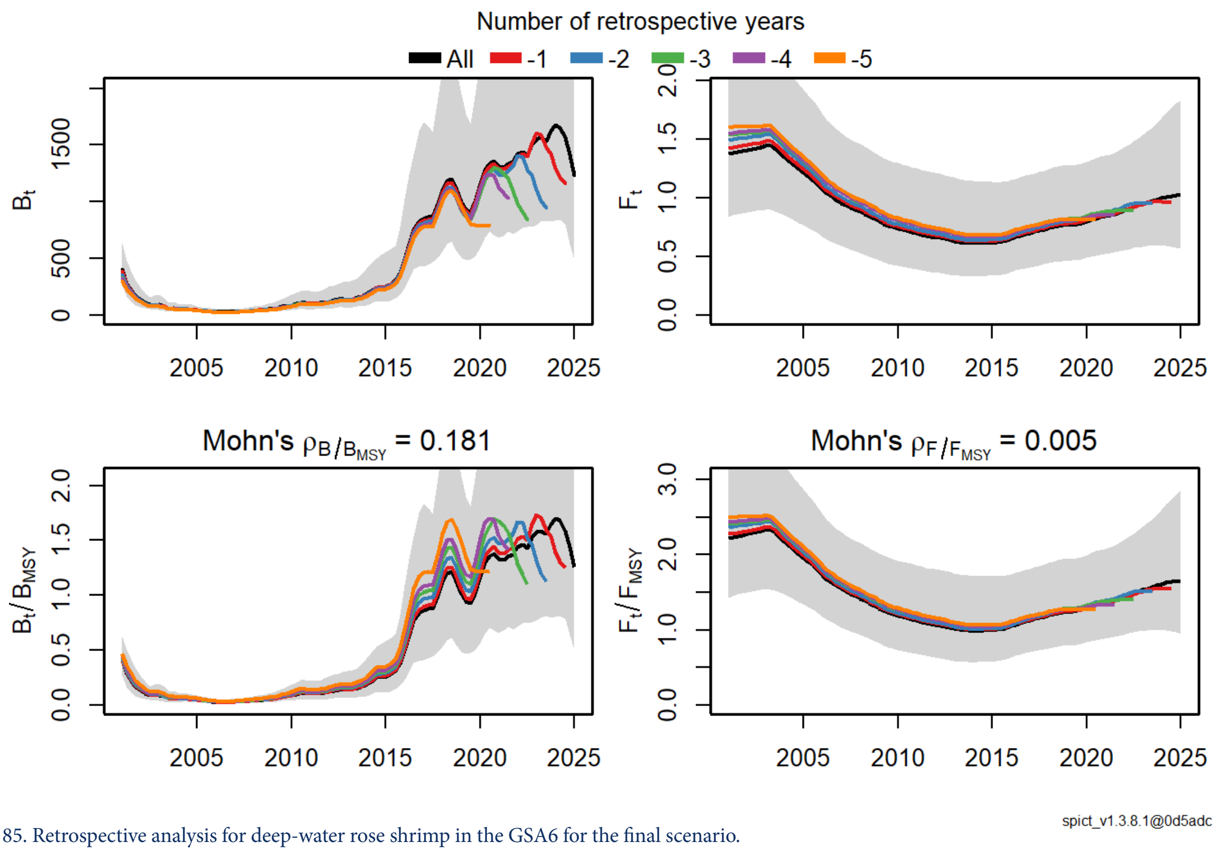

Figure 85. Retrospective analysis for deep-water rose shrimp in the GSA6 for the final scenario.

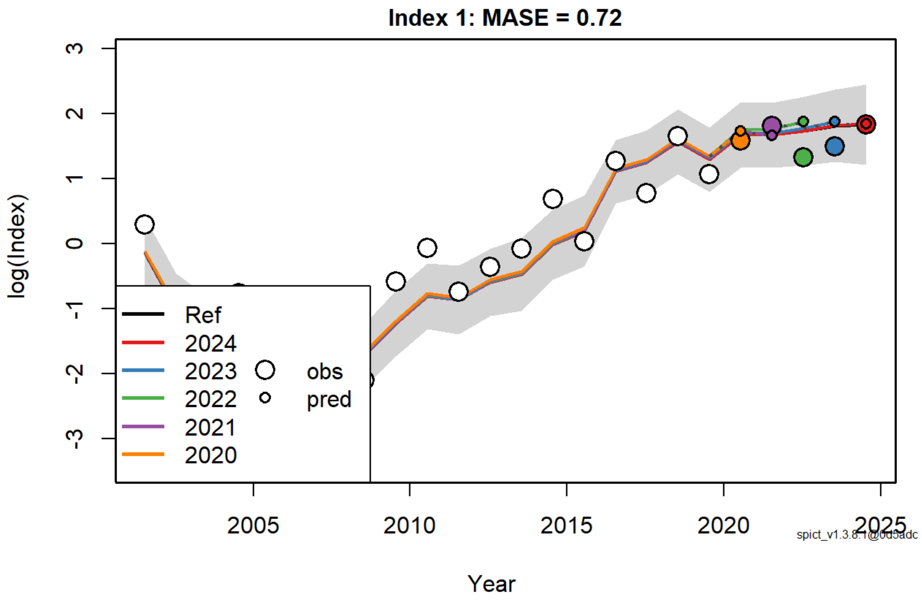

Figure 86. Hindcasting for the model for deep-water rose shrimp in the GSA6 for the final scenario.

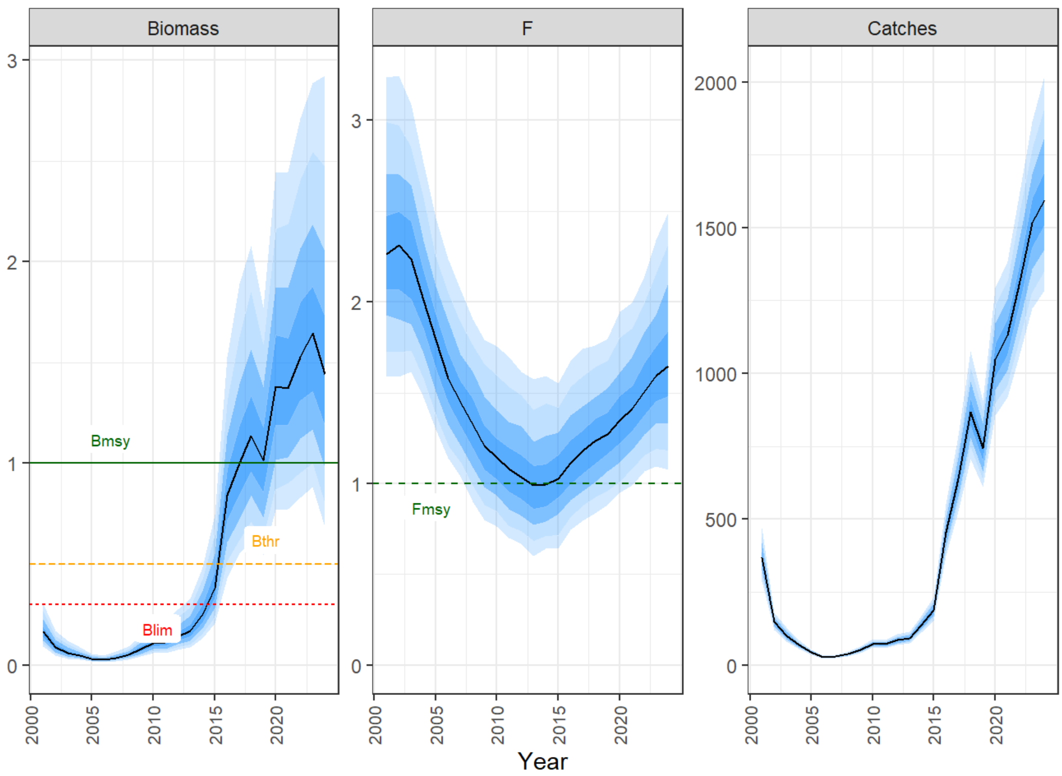

Figure 87. Advice for the final scenario for deep-water rose shrimp in the GSA6: Historical and current stock status regarding F_{msy}, B_{msy} and B_{lim}.

Table 27. Indicators in 2024 from SPiCT for deep-water rose shrimp (DPS) in GSA6.

Species	Year	Catch (t)	F/Fmsy	B/Bmsy	B/Bpa	B/Blim
DPS	2024	1587	1.65	1.44	2.9	4.80

Norway lobster (*Nephrops norvegicus*) NEP

The Norway lobster is known to have a dimorphic growth pattern, with males growing slower and reaching larger sizes than females. Reproduction occurs between April and September, and recruitment is observed afterwards, in fall and winter (ICATMAR, 25-05).

Input data

The spatial distribution of total landings for Norway lobster in the Catalan fishing ground is shown in Figure 88. The species is mainly distributed in upper slope areas (300-600 m) along the Catalan coast, with less occurrence in the Delta area (i.e. L'Ametlla de Mar and La Ràpita). Discards of Norway lobster are negligible.

Historical Norway lobster landings in Catalonia from 2002 to 2024 are shown in Figure 89. The species shows a decreasing trend in landings, especially since 2015, with the lowest value recorded in 2021. Since then, landings have shown a slight increase.

Figure 90 shows the Norway lobster landing distribution by métier from 2019 to 2024. The highest landings are obtained with bottom trawlers, specifically for upper slope métiers.

Annual LFD

After raising the length frequencies obtained with the monitoring program (Table 29), and considering discards, the annual length frequency of Norway lobster in Catalonia is plotted in Figure 91. The SOP validation results are shown in Table 28, while Table 29 summarizes the number of individuals sampled through the ICATMAR monitoring program.

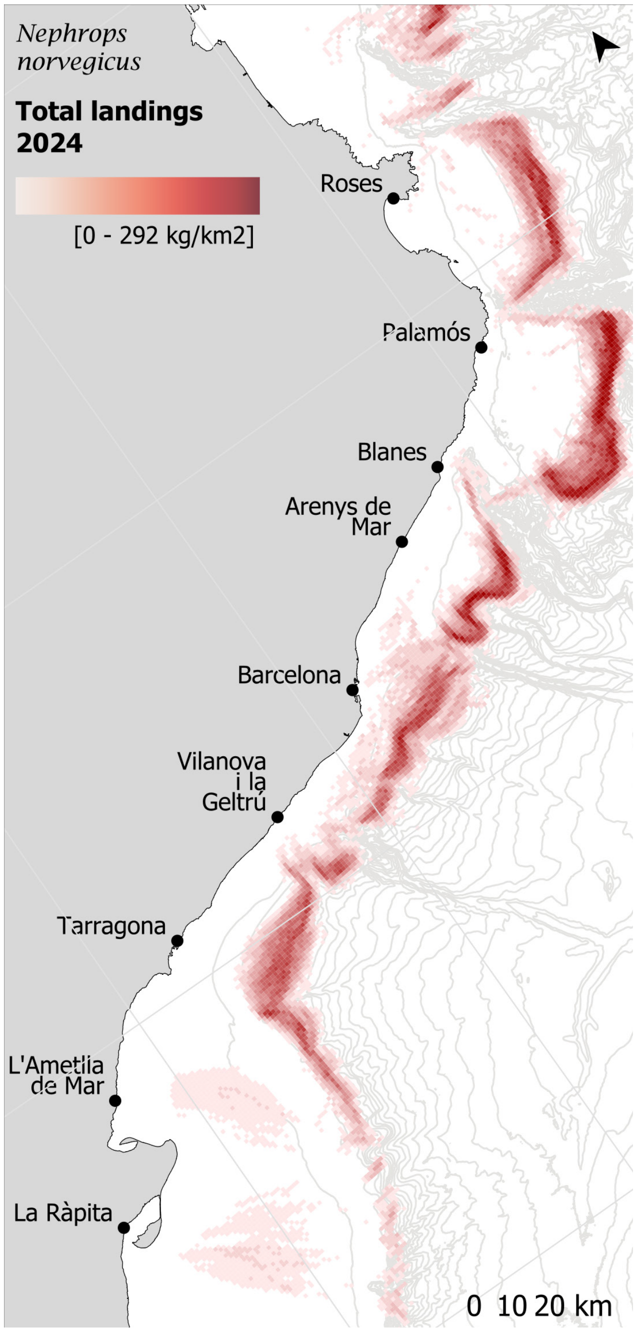

Figure 88. Spatial distribution of landings (kg/km^2) for Norway lobster in the Catalan fishing grounds (North GSA6) in the year analyzed.

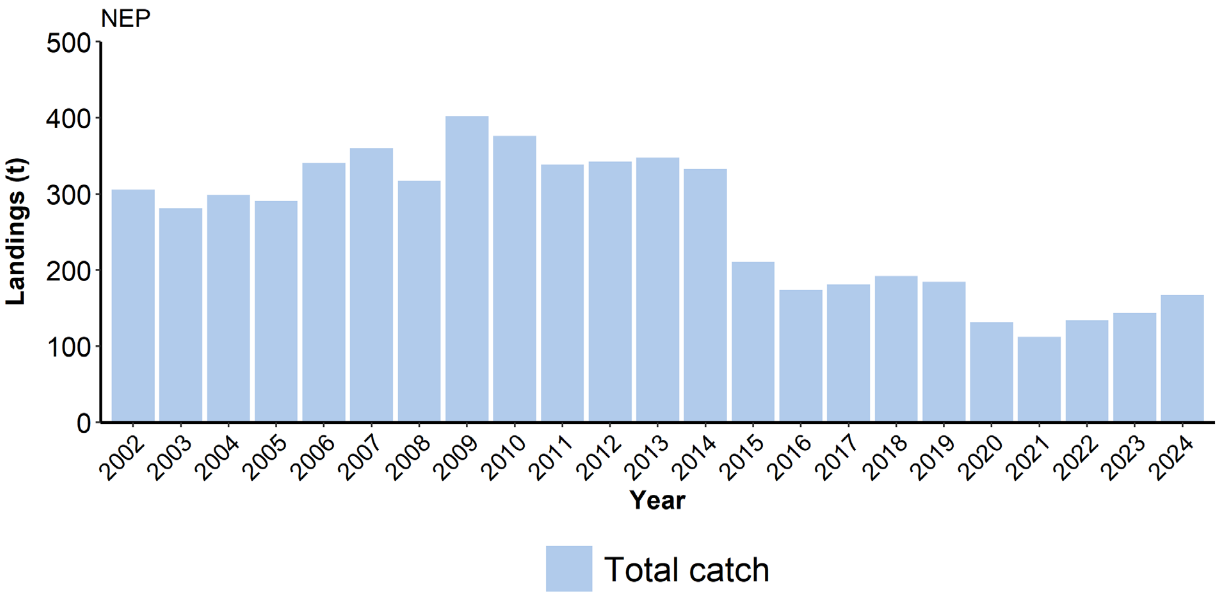

Figure 89. Historical landings (t) for Norway lobster in Catalonia.

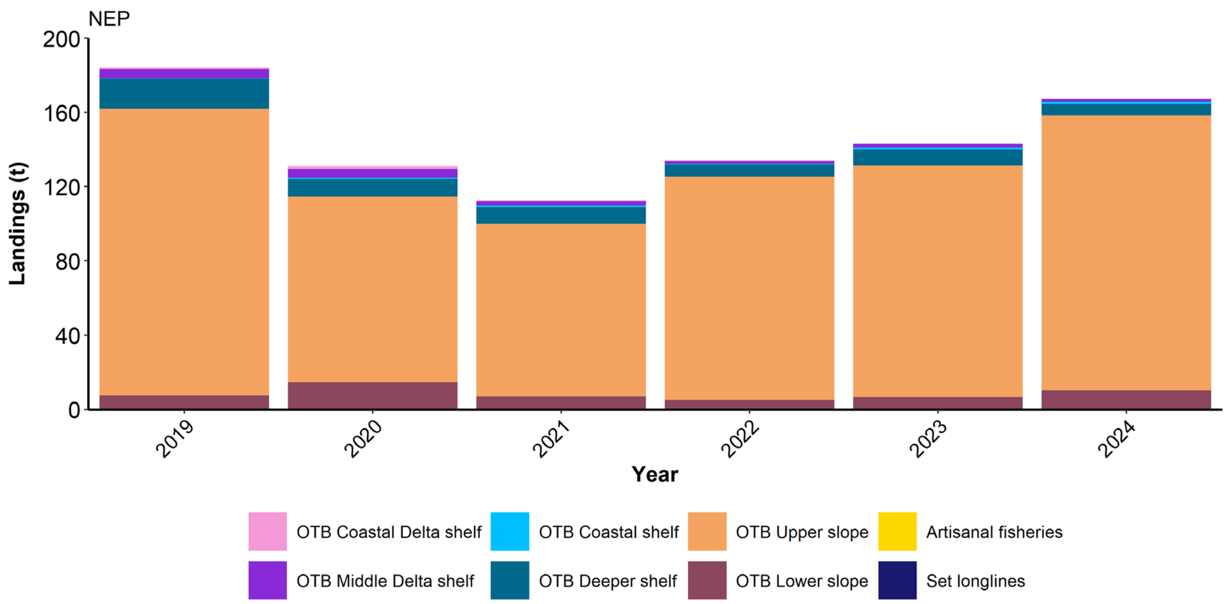

Figure 90. Landings (t) for Norway lobster by *métier* and fishing gear. OTB: bottom trawling.

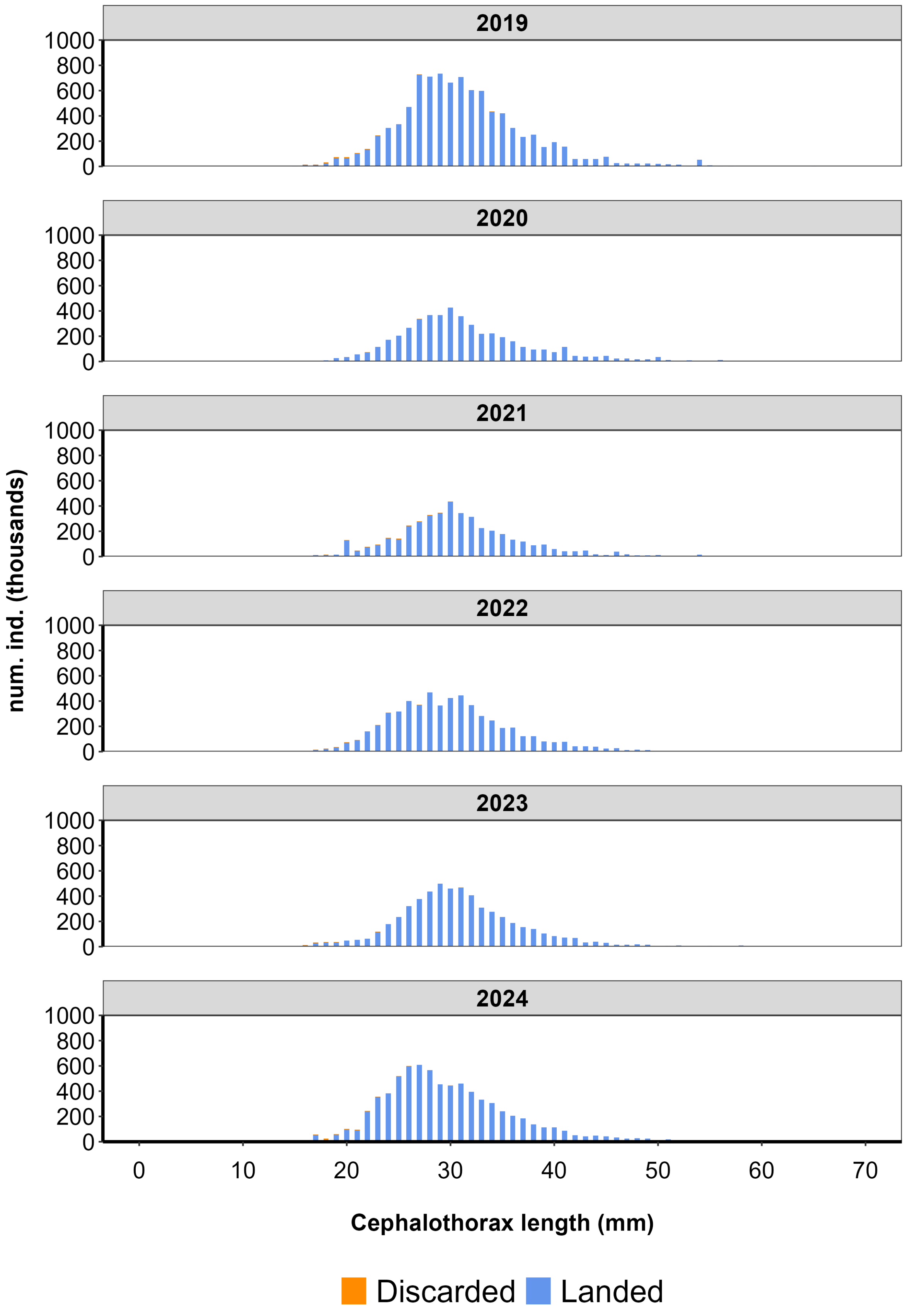

Figure 91. Annual length frequency distributions of Norway lobster from bottom trawling. The data from bottom trawling is raised from ICATMAR data and details landed and discarded Norway lobster.

Table 28. Sum of Products (SOP) validation for Norway lobster (NEP): The column Calculated Weight in GSA6N (SOP) represents the biomass estimated through the raising process, while landings refer to the reported landings in NGSA6. The ratio between SOP and landings is known as the Sum of Products (SOP). Values close to 1 indicate that the raising process provides biomass estimates that closely match the reported landings, thereby validating the accuracy of the estimation method.

Species	Year	Catch classification	Gear	Calculated weight GSA6N (kg) (SOP)	Landings in GSA6N (kg)	SOP/Landings
NEP	2019	Discarded	Bottom trawl	721	-	-
NEP	2020	Discarded	Bottom trawl	87	-	-
NEP	2021	Discarded	Bottom trawl	787	-	-
NEP	2022	Discarded	Bottom trawl	139	-	-
NEP	2023	Discarded	Bottom trawl	199	-	-
NEP	2024	Discarded	Bottom trawl	573	-	-
NEP	2019	Landed	Bottom trawl	247680	184329	1.34
NEP	2020	Landed	Bottom trawl	132042	131172	1.01
NEP	2021	Landed	Bottom trawl	113790	112438	1.01
NEP	2022	Landed	Bottom trawl	137221	133978	1.02
NEP	2023	Landed	Bottom trawl	148085	143155	1.03
NEP	2024	Landed	Bottom trawl	179753	167310	1.07

Table 29. Number of Norway lobster individuals sampled by zone and season from ICATMAR monitoring data used to raise the length frequencies.

Fishery	Year	Zone	Winter	Spring	Summer	Autumn	N hauls
			Number individuals sampled				
Bottom trawl	2019	North	16	1968	906	545	23
Bottom trawl	2019	Center	497	639	621	642	20
Bottom trawl	2019	South	183	23	187	6	12
Bottom trawl	2020	North	633	483	747	618	25
Bottom trawl	2020	Center	433	376	556	450	20
Bottom trawl	2020	South	75	1	12	2	9
Bottom trawl	2021	North	348	666	892	676	30
Bottom trawl	2021	Center	732	484	807	417	16
Bottom trawl	2021	South	15	1	6	2	8
Bottom trawl	2022	North	273	642	724	713	27
Bottom trawl	2022	Center	446	313	573	844	22
Bottom trawl	2022	South	1	1	2	0	4
Bottom trawl	2023	North	738	1017	1023	1044	27
Bottom trawl	2023	Center	414	803	662	450	24
Bottom trawl	2023	South	2	1	0	0	3
Bottom trawl	2024	North	636	1266	818	874	27
Bottom trawl	2024	Center	334	478	497	523	23
Bottom trawl	2024	South	3	9	1	3	8

Model setting and results

Scenarios

Three different scenarios were applied for the sensitivity analysis for Norway lobster (Table 30). All scenarios used the same growth and natural mortality parameters.

- **Scenario** 1: include maturity information from the STECF and GFCM stock assessments.
- **Scenario** 2: used maturity data from the literature (Vigo et al., 2023).
- **Scenar**io 3: applied maturity data from the ICATMAR dataset (ICATMAR, 25-05).

Fitted data

The length frequency distribution fit per year is shown in Figure 92. The model generally follows the modal length for all years; however, in some years, overestimated abundance at certain intermediate length classes where peaks are observed.

Selectivity

The model outputs for fishery selectivity under the scenarios tested are presented in Table 31. The output of the selected scenario (3) is also plotted with L_{mat50} and SL_{50} in Figure 93. For scenario 3 the fishery is fishing above $L_{mat50.}$

Reference points

Even though the model is very sensitive to changes in growth parameters and maturity, the stock is below SPR_{lim} (= 0.2) in all assessed scenarios (Table 31 and Figure 95). The Kobe plot for Norway lobster (Figure 94) illustrates the stock status over time, with no clear trend. However, the stock consistently falls within the red zone, indicating that it is both overfished and subject to ongoing overfishing.

Final scenario

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBSPR model.

Length-Based Spawning Potential Ratio (LBSPR)

Table 30. Biological parameters used in the different LBSPR scenarios for Norway lobster (NEP). $L_{inf:}$ asymptotic length at which growth is zero, k: growth rate, M: natural mortality, $L_{mat50:}$ length where 50% of individuals are mature, $L_{mat95:}$ length where 95% of individuals are mature.

Species	Scenario	Linf (mm)	Lmat50 (mm)	Lmat95 (mm)	M/K
NEP	1	86.10	32.50	36.00	3.97
NEP	2	86.10	25.60	28.40	3.97
NEP	3	86.10	24.80	19.70	3.97

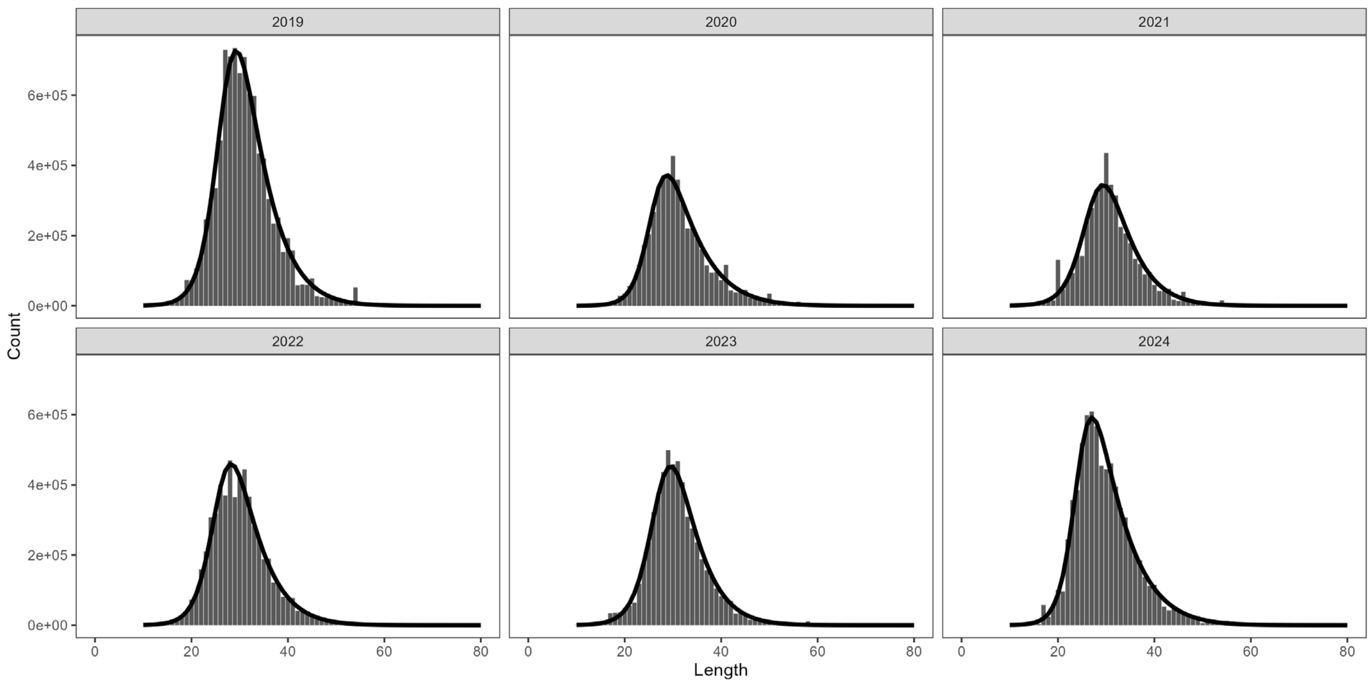

Figure 92. Fit of the data using the LBSPR model for Norway lobster for each studied year. Grey columns indicate length frequencies. Black lines indicate the fit of the model.

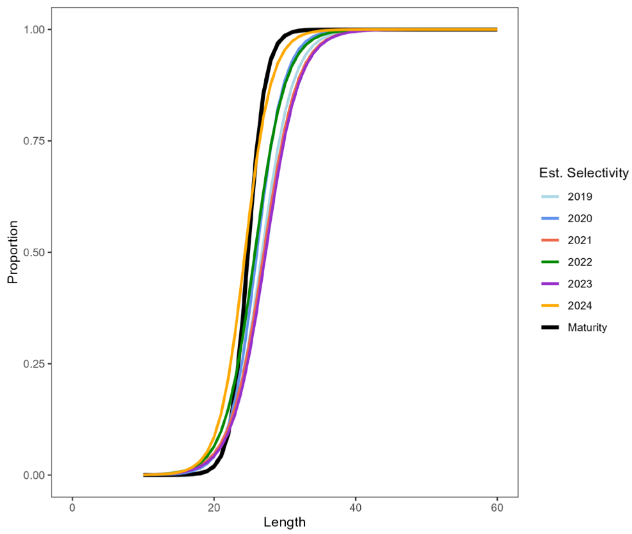

Figure 93. Length curves for Norway lobster. Black line shows the length curve at maturity. Color lines show the estimated selectivity at length curve predicted by the LBSPR model for each year in scenario 3 (the scenario selected)..

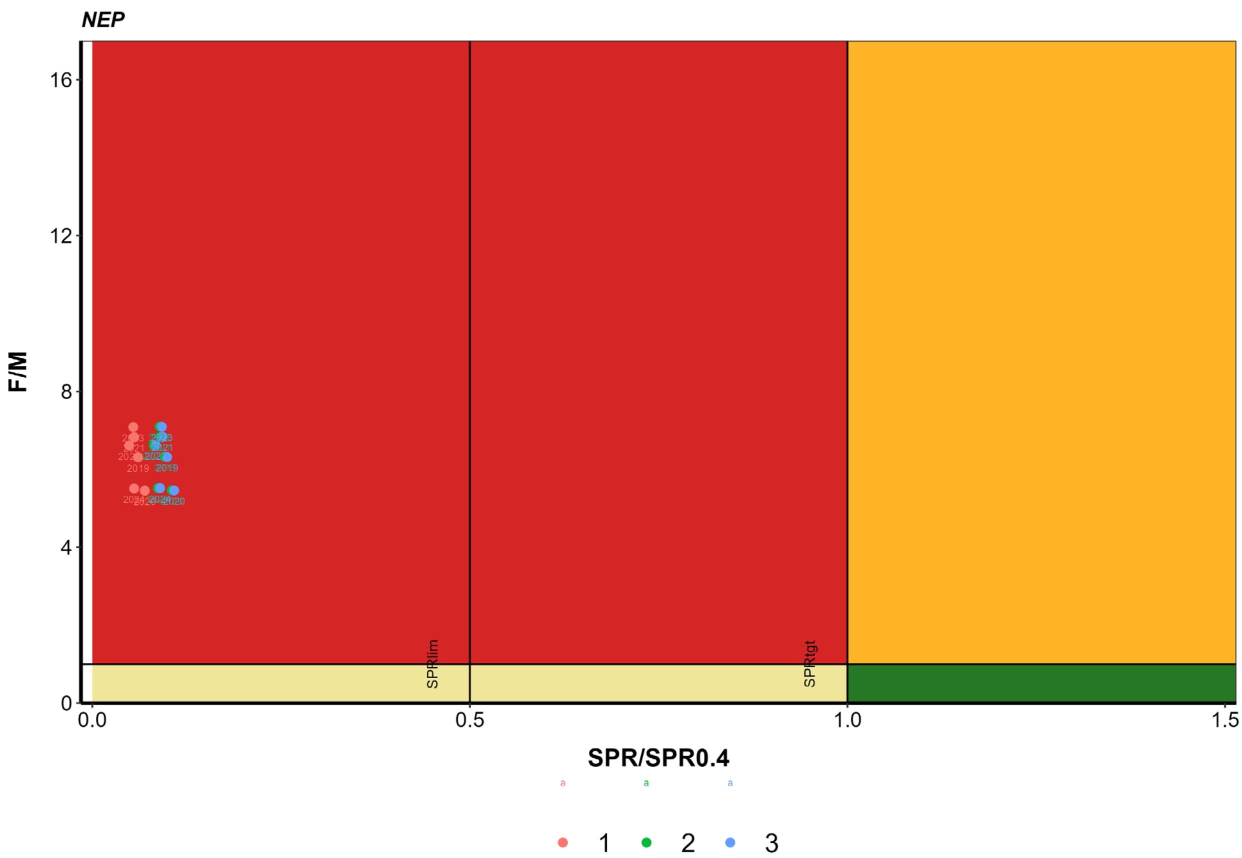

Figure 94. Kobe plot for Norway lobster by scenario (1-3) and year. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio, F: fishing mortality, M: natural mortality, and F/M: relative fishing mortality.

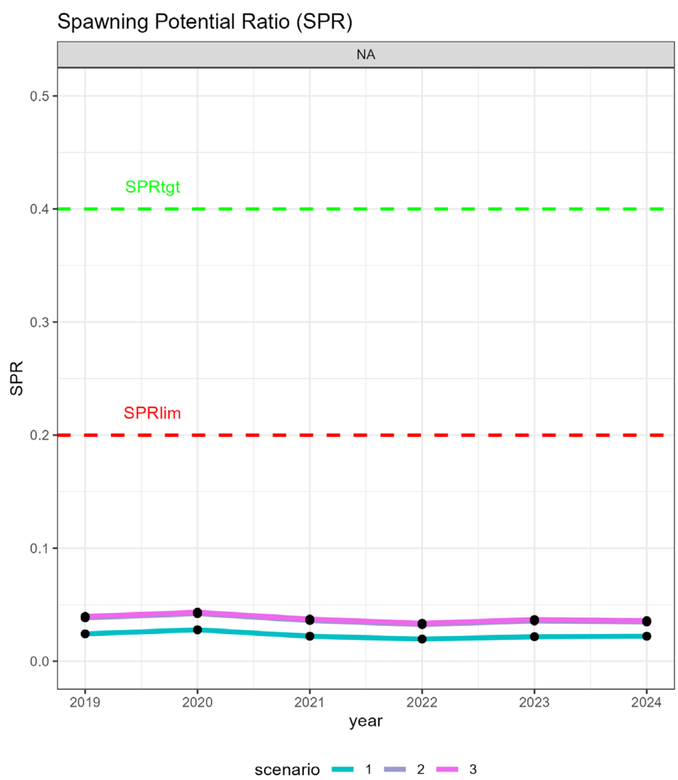

Figure 95. Spawning potential ratio (SPR) per year analyzed for Norway lobster evaluated with LBSPR model. LBSPR: Length-Based Spawning Potential Ratio. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio. Colored lines show the results for each scenario.

Table 31. LBSPR model results for Norway lobster with the different scenarios tested for each year analyzed. $SL_{50:}$ Length where 50% of individuals are caught, SPR: spawning potential ratio and FM: fishing mortality. SD is the standard deviation calculated for each indicator. The selected scenario is highlighted in blue.

spp	scenario	year	SL_{50}	SD	SPR	SD	FM	SD
NEP	1	2019	27.30	0.20	0.14	0.10	1.87	0.58
NEP	1	2020	26.50	0.18	0.16	0.11	1.54	0.51
NEP	1	2021	27.59	0.20	0.12	0.09	2.07	0.62
NEP	1	2022	26.28	0.22	0.12	0.09	1.98	0.60
NEP	1	2023	27.81	0.20	0.12	0.09	2.17	0.64
NEP	1	2024	24.78	0.18	0.14	0.10	1.55	0.50
NEP	2	2019	27.29	0.19	0.21	0.11	1.85	0.58
NEP	2	2020	26.49	0.17	0.24	0.12	1.53	0.50
NEP	2	2021	27.58	0.20	0.20	0.10	2.05	0.62
NEP	2	2022	26.27	0.21	0.19	0.10	1.96	0.59
NEP	2	2023	27.80	0.19	0.19	0.10	2.14	0.64
NEP	2	2024	24.78	0.17	0.21	0.11	1.54	0.50
NEP	3	2019	27.29	0.20	0.28	0.11	1.81	0.55
NEP	3	2020	26.49	0.18	0.30	0.12	1.49	0.49
NEP	3	2021	27.57	0.20	0.27	0.10	2.01	0.59
NEP	3	2022	26.27	0.22	0.25	0.10	1.91	0.57
NEP	3	2023	27.80	0.19	0.26	0.10	2.10	0.61
NEP	3	2024	24.77	0.18	0.27	0.11	1.50	0.48

Length-based Bayesian Biomass (LBB)

Scenarios

Three different scenarios were applied for the sensitivity analysis for Norway lobster (Table 32). All scenarios used the same growth and natural mortality parameters. For scenario 1, maturity information was obtained from STECF and GFCM stock assessment, for scenario 2, maturity data was obtained from the literature (Vigo et al. 2023) and for scenario 3, it was obtained from ICATMAR data (ICATMAR, 24-05).

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBB model.

Fitted data

The length frequency distribution fit per year is shown in Figure 96. The model generally fit well for all years.

Table 32. Biological parameters used in the different LBB scenarios for Norway lobster (NEP). $L_{inf:}$ Asymptotic length, M/k: ratio between natural mortality and growth rate, $L_{mat50:}$ length where 50% of individuals are mature.

Specie	Scenario	Linf (cm)	M/k	Lmat50 (cm)
NEP	1	8.6	1.500	3.3
	2	8.6	1.500	2.6
	3	8.6	1.500	2.5

Table 33. LBB model results for Norway lobster (NEP) with the different scenarios tested for each year analyzed. $L_{mean:}$ mean length of individuals, $L_{opt:}$ length at optimal yield, $L_{c:}$ length at first capture, $L_{c\_opt:}$ length at first capture at optimal yield, L_{95th}/L_{inf}: ratio of the 95th percentile to asymptotic length , F/M: fishing mortality relative to natural mortality, B/B0: exploited biomass relative to unexploited biomass, $B/B_{msy:}$ exploited biomass relative to maximum sustainable yield biomass, $C_{mature:}$ proportion of mature individuals in the catch.

Specie	Scenario	Year	Lmean/Lopt	Lc/Lc_opt	L95th/Linf	F/M	B/B0	B/Bmsy	Cmature
NEP	1	2024	0.55	0.46	0.70	5.00	0.03	0.09	28%
	2	2024	0.55	0.46	0.70	5.00	0.03	0.09	75%
	3	2024	0.55	0.46	0.70	5.00	0.03	0.09	82%

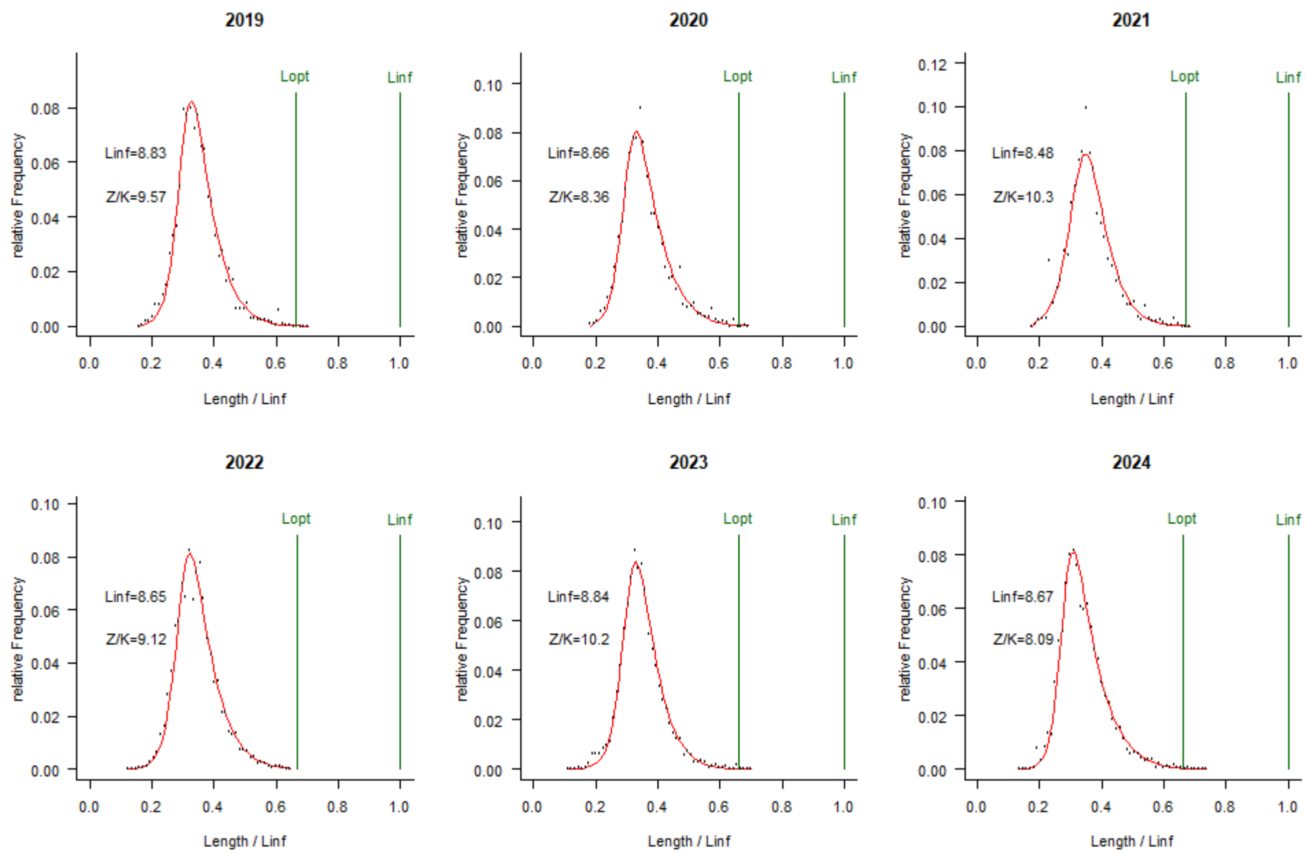

Figure 96. Fit of the data using the LBB model for Norway lobster (NEP) for each year in scenario 3. Red line indicates the fit of the model.

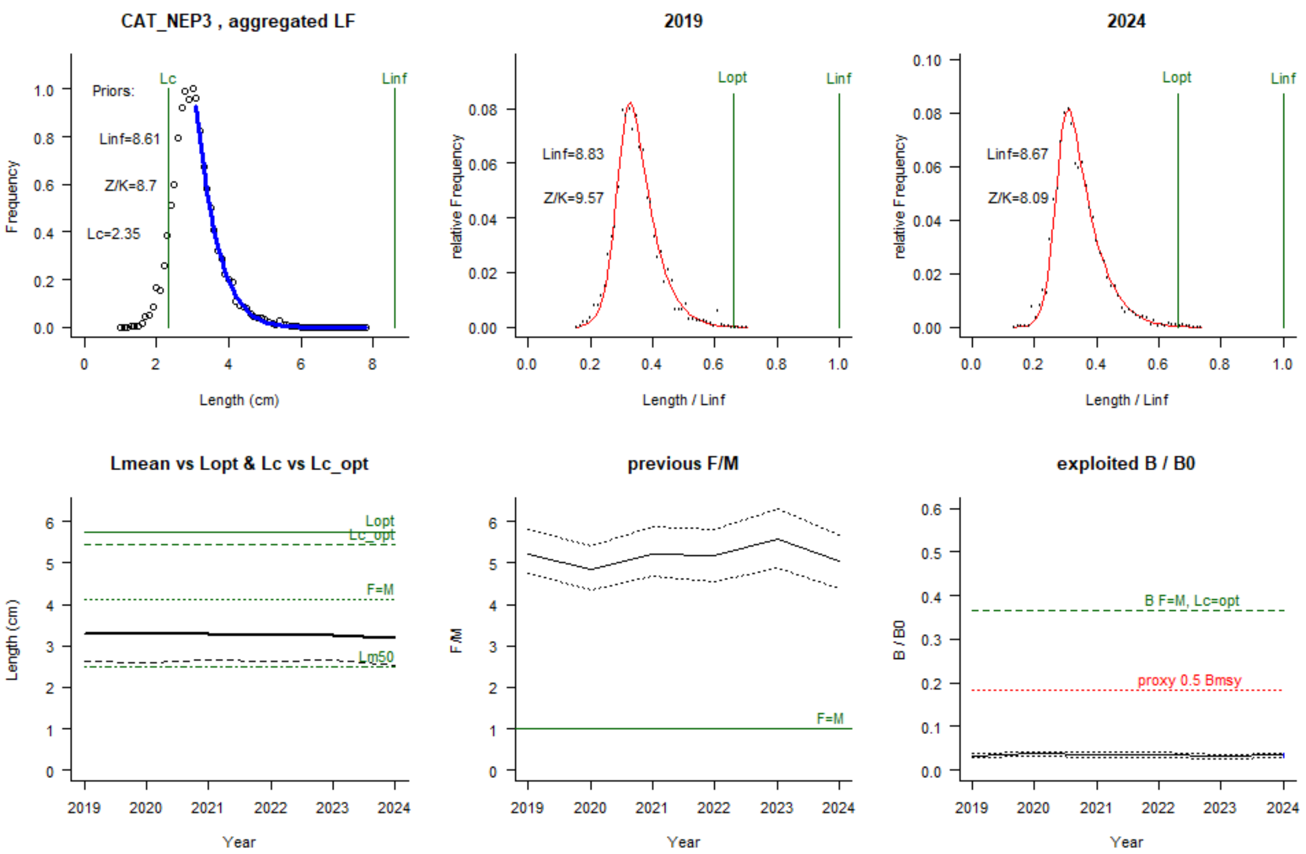

Figure 97. Summary output from LBB for Norway lobster (NEP) scenario 3.

Stochastic Production model in Continuous Time (SPiCT)

For Norway lobster, input data available for catches were from 1970 to 2024, while for the index we had MEDITS survey from 1994 to 2024 and CPUE data from 2004 to 2024 (Figure 98). This assessment reference year is 2024. A double-axis plot was presented to compare trends between catches and the indices (Figure 99).

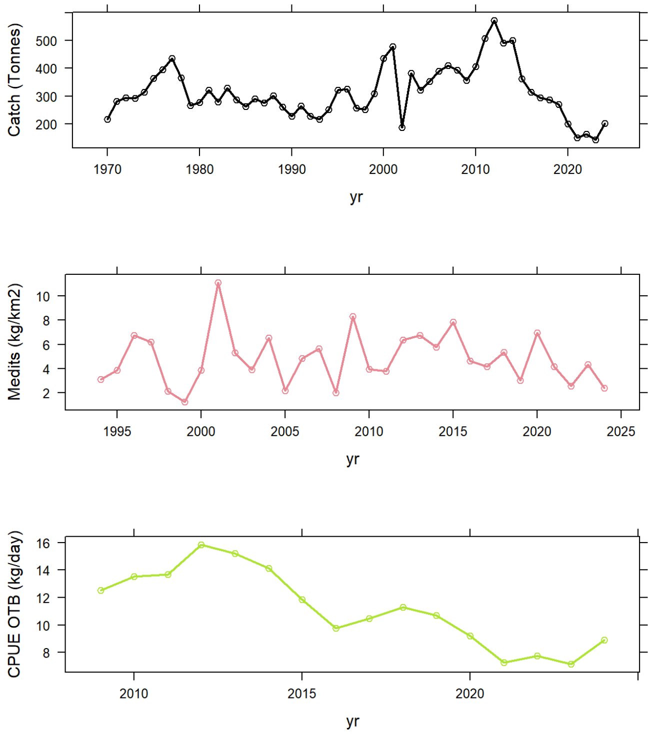

Figure 98. Data available for the assessment for Norway lobster in GSA6 to run SPiCT model. Top: catch data from 1970 to 2024. Centre: MEDITS survey data since 1994 to 2024. Bottom: CPUE data since 2009 to 2024.

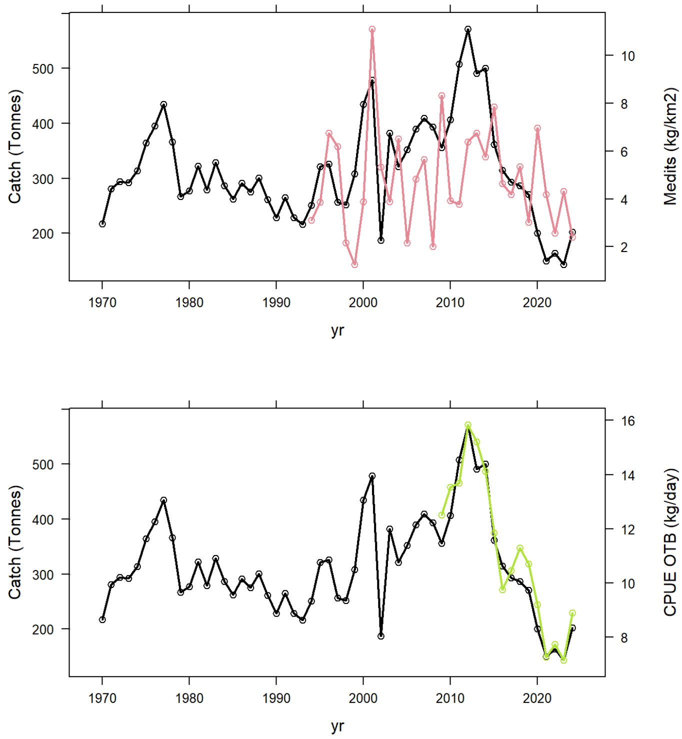

Figure 99. Double axis plot to compare trends between catch and MEDITS index (top) and catch and CPUE (bottom) for Norway lobster.

Data from catches prior to 1994 were not included in the assessments, as earlier trials yielded unrealistic results and the diagnoses were not met. Further analysis is required to include this data.

Although only the final scenario is presented below, different scenarios were tested:

- **Scenario 1:** landings started in 1994, using MEDITS survey as index
- **Scenario 2:** landings started in 1994, using CPUE as index
- **Scenario 3:** landings started in 1994, using MEDITS survey and CPUE as indices

In Figure 100 is presented a comparison between the scenarios..

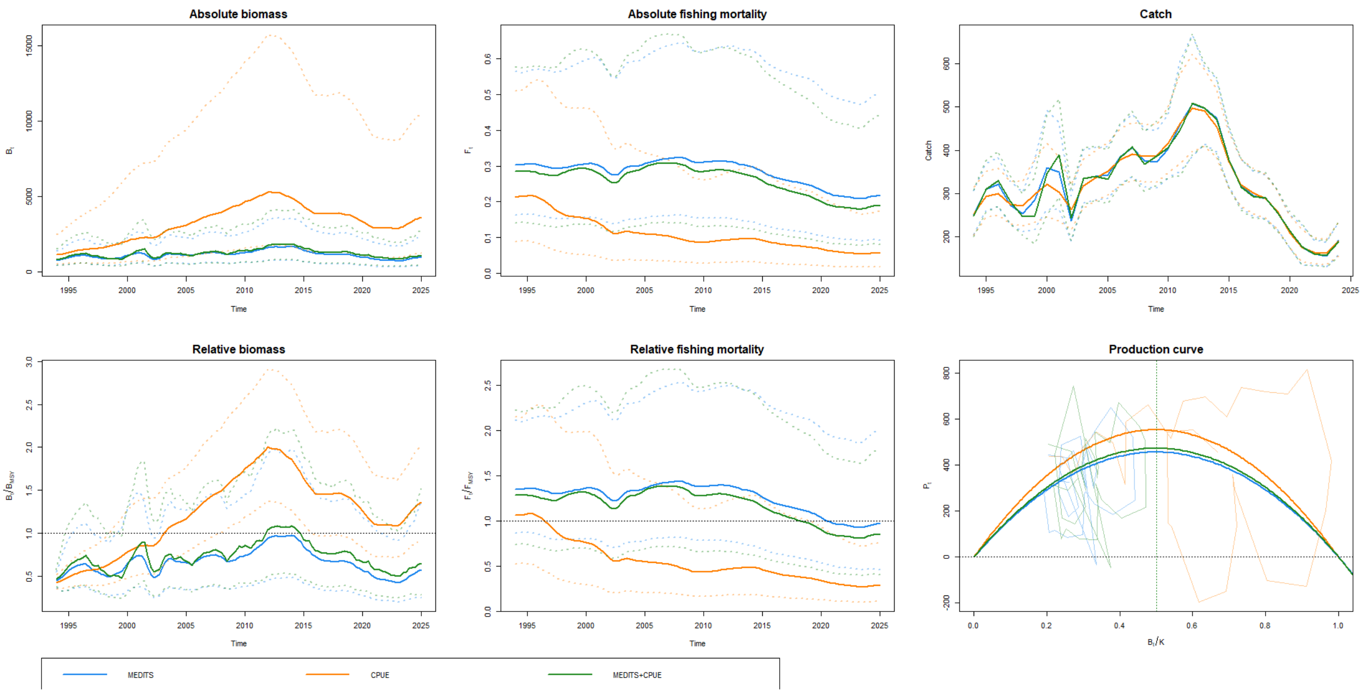

Figure 100. Scenarios comparison for Norway lobster in GSA6.

Final scenario

Scenario 1 was chosen as the final scenario, since MEDITS survey gave better contrast information than CPUE, since the latter followed almost exactly the catches. The chosen scenario met most of the model diagnostics and provided good retrospective analysis and hindcasting diagnostics. (Figure 103, Figure 104, Figure 105, Figure 106 and Figure 107).

A sensitivity analysis for the final scenario was performed, testing r prior, bkfrac, process error, and observation error to assess the model's robustness within these priors. All these plots and results for the other scenarios will be available at https://github.com/ICATMAR.

The settings used for the final scenario are presented in Table 34. The abundance index showed some stability that is not accompanied by the increase or decrease in catches, considering for example the sustained decrease in catches since 2010 and no increase in the abundance index is seen in the following years. Given the complexity of the fishery and the difficult to estimate error sources, alpha and beta were established as 1.

Table 34. Priors settings for Norway lobster (NEP) in all scenarios.

Type	Prior	Description	Assignment	Mean	Standard deviation	Comment
Fishery dynamic	logbkfrac	B/K fraction (depletion)		Log(0.2)	0.1	At the beginning of the catch series, the fishery exhibited an overexploited state
Stock dynamic	logr	Population growth		Log(0.5)	0.2	Fishlife
	logn	Shape of production curve		Log(2)	-	Shaefer
Relative standard deviation time series (input data)	stdevfacC	Standard deviation factor for catches	Years 1999, 2000, 2001, 2011, 2012, 2021 is 2	-	-	High inconsistency with the expected index value
	stdevfacI	Standard deviation factor for indices	Index 1994 – 2024 is 1.5. Years 1999, 2000, 2001, 2011, 2012, 2021 is 2	-	-	Relative stable index, even with high changes in historical catches. High inconsistency with the expected catch value for the selected years
Error	logalpha	Ratio between Observation error and Process error		Log(1)	0.001	
	logbeta	Ratio between Catch error and Fishing mortality error		Log(1)	0.001	

The final scenario input data is shown in Figure 101, and the final summary assessment results are shown in Figure 102.

Final scenario advice

Final scenario advice is presented in Figure 108 and Table 35, which outlines the indicators for Norway lobster in the GSA6 for the year 2024. The assessment results need to be considered with caution, since from the beginning of the time series the increases and decreases in catches are not reflected in the abundance index.

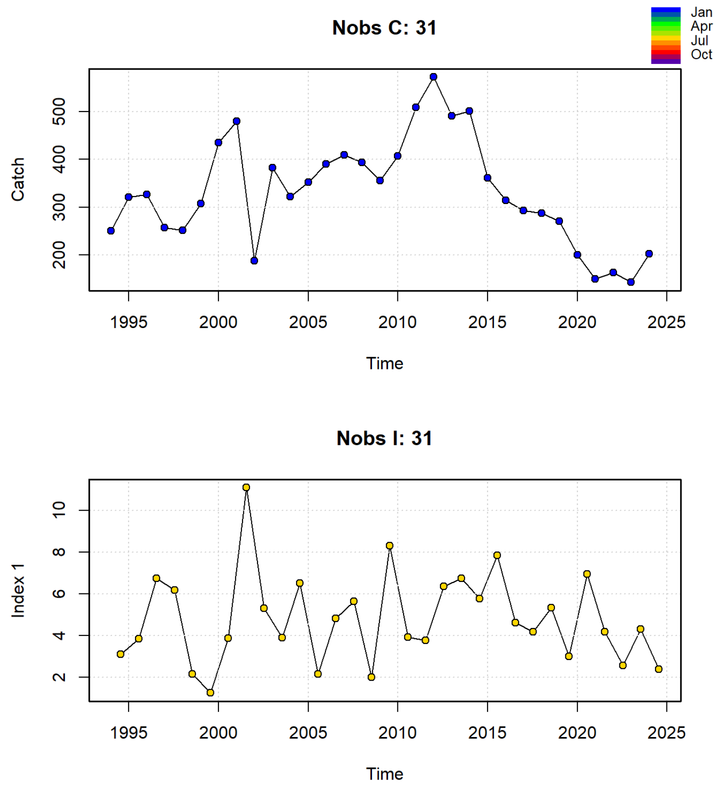

Figure 101. Input data for SPiCT model for Norway lobster in GSA6 for scenario 1. Top: catch in tons per year since 1994, bottom: index data of biomass derived from MEDITS since 1994.

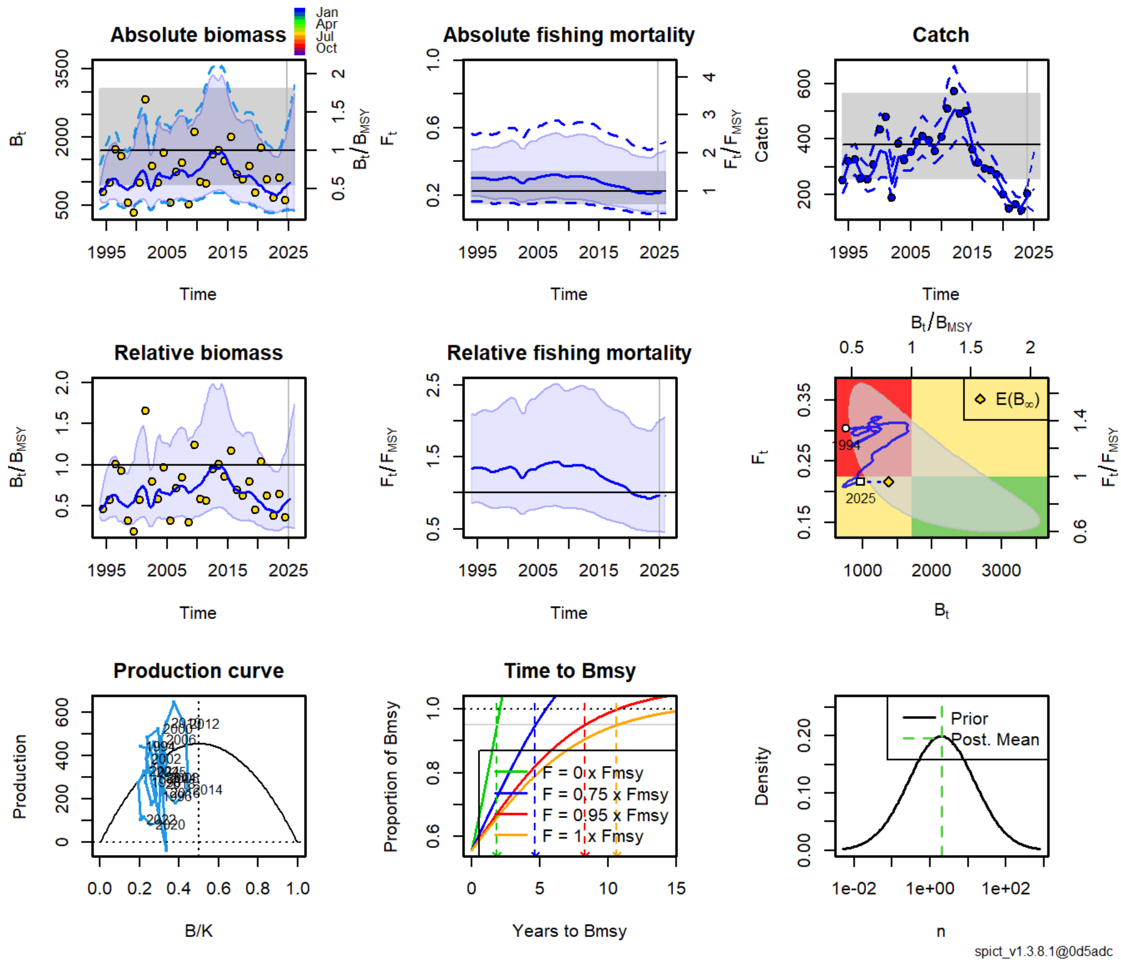

Figure 102. Stock assessment summary for SPiCT model for Norway lobster in GSA6 for the final scenario.

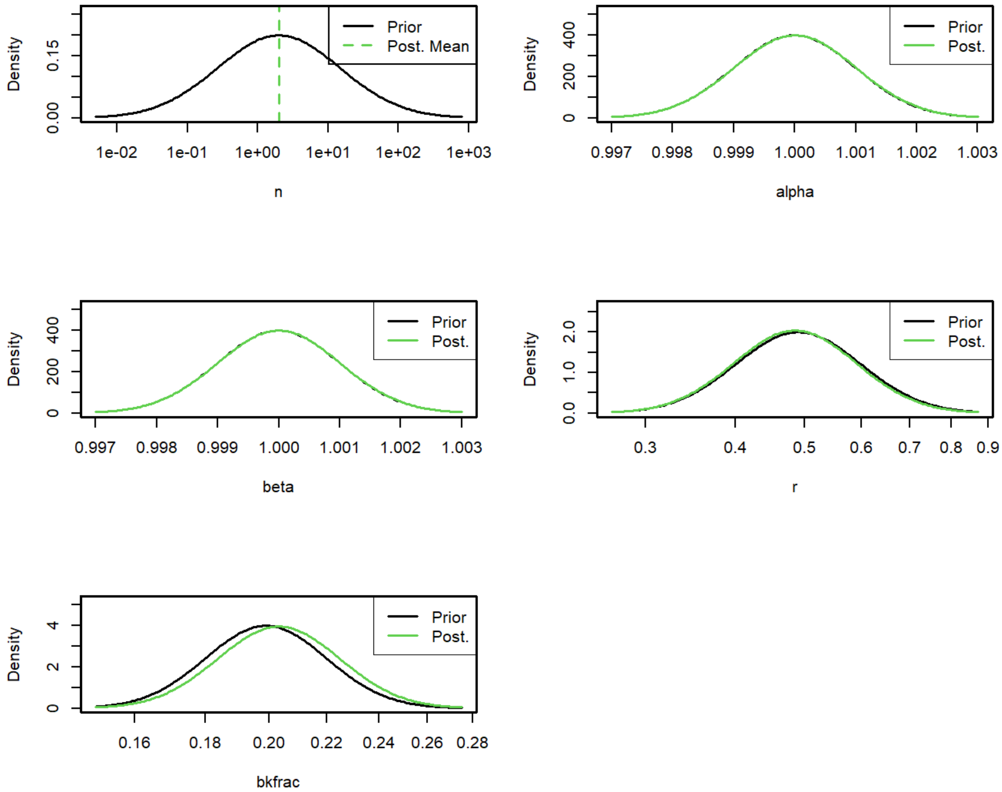

Figure 103. Estimated priors and posteriors for the updated assessment for Norway lobster in GSA6 for the final scenario.

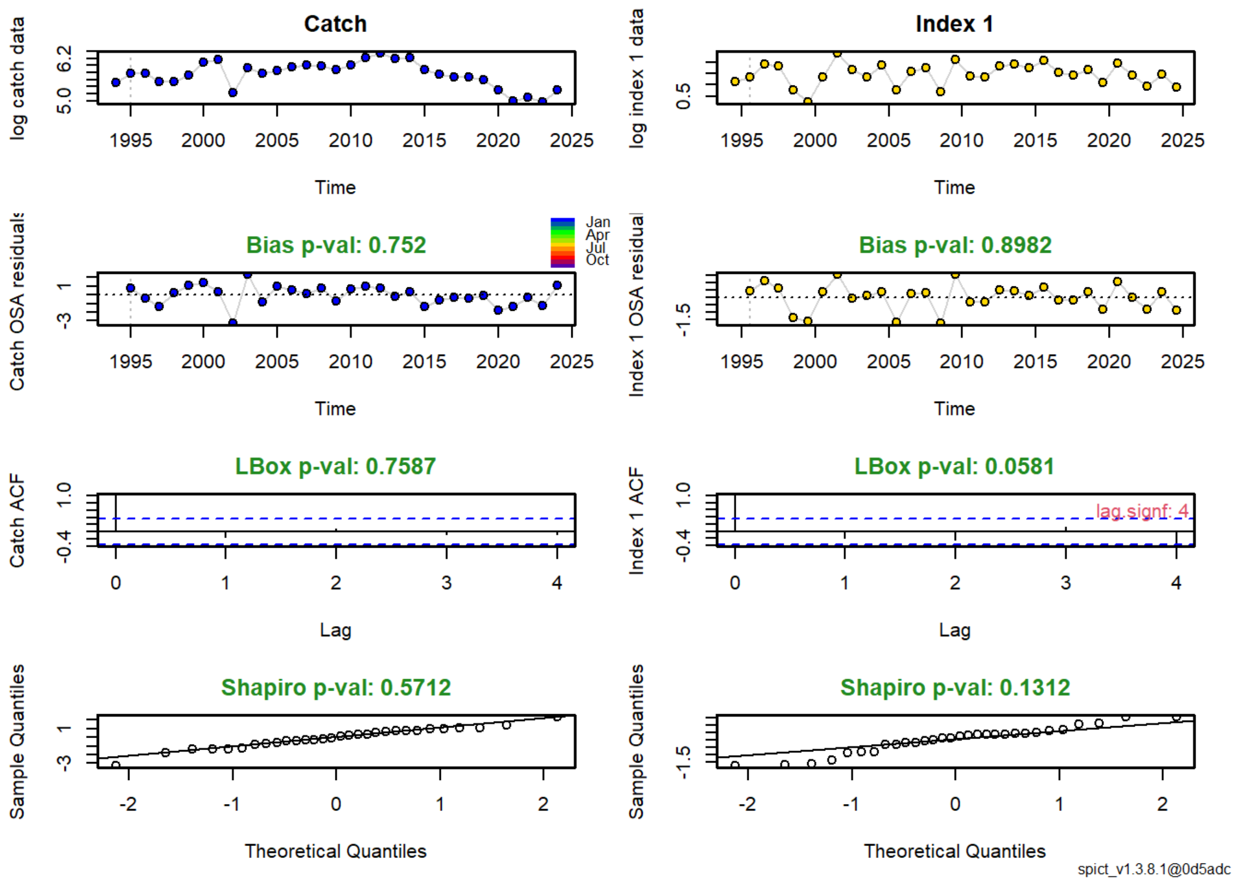

Figure 104. One-step-ahead residuals for the model for Norway lobster in GSA6 for the final scenario.

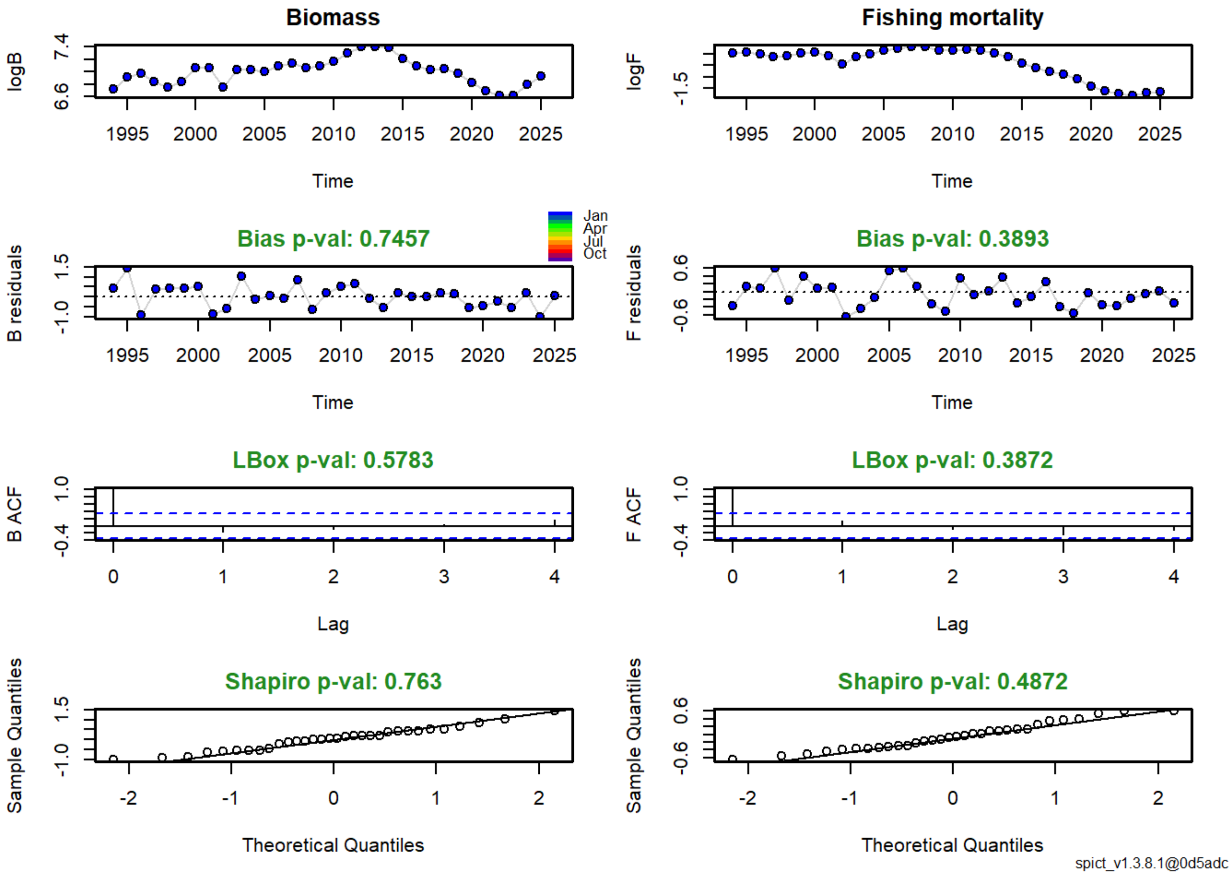

Figure 105. Process error deviations for the model for Norway lobster in GSA6 for the final scenario.

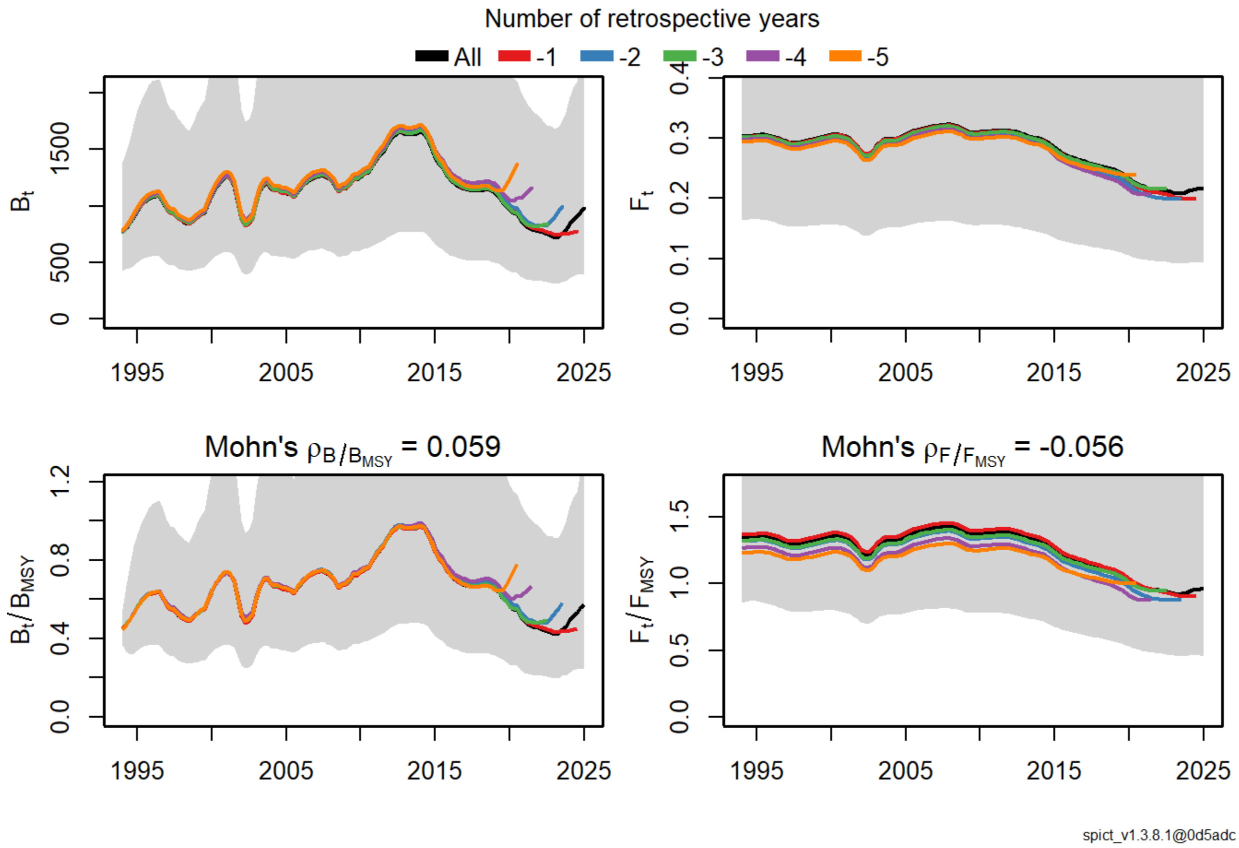

Figure 106. Retrospective analysis for Norway lobster in GSA6 for the final scenario.

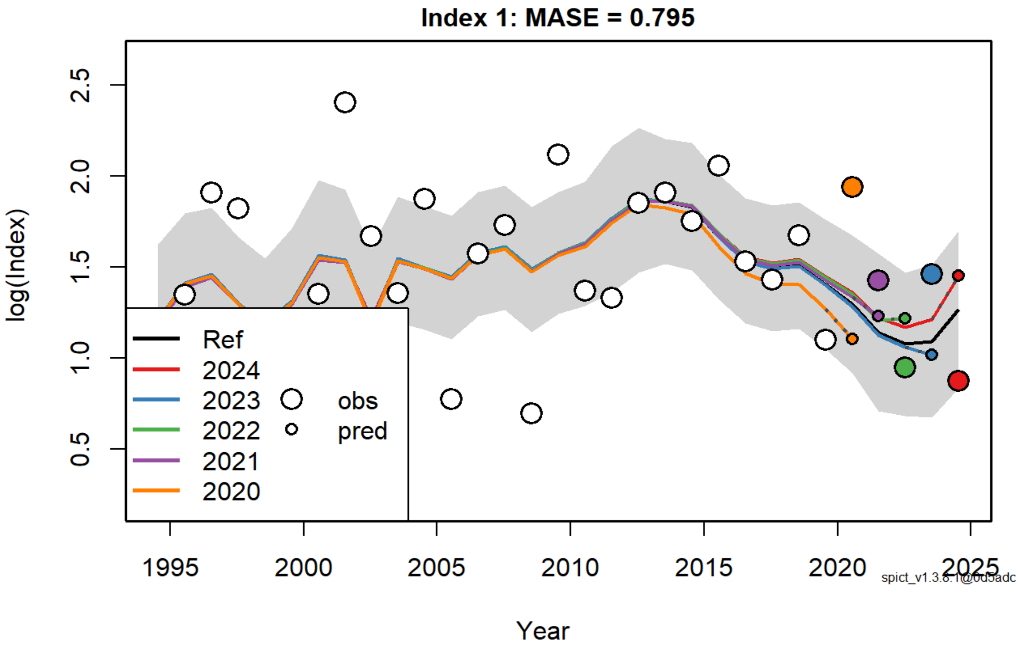

Figure 107. Hindcasting for the model for Norway lobster in GSA6 for the final scenario.

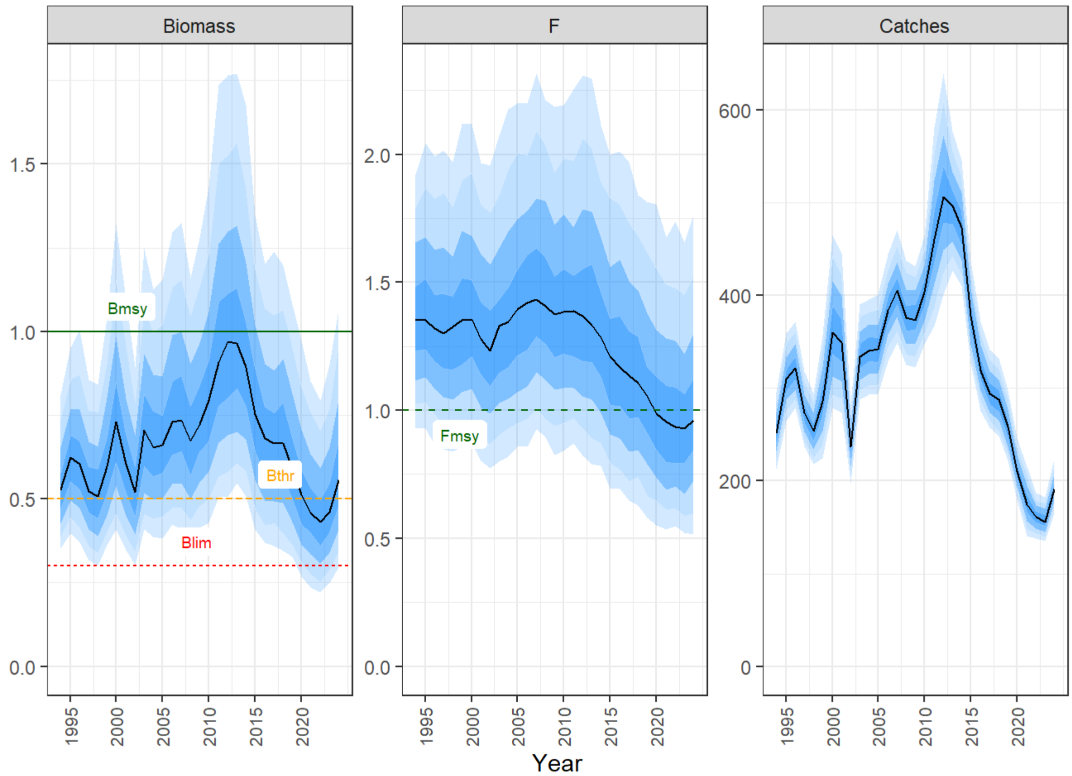

Figure 108. Advice for the final scenario for Norway lobster in GSA6: Historical and current stock status regarding F_{msy}, B_{msy} and B_{lim}.

Table 35. Indicators in 2024 from SPiCT for Norway lobster (NEP) in GSA6.

Species	Year	Catch (t)	F/Fmsy	B/Bmsy	B/Bpa	B/Blim
NEP	2024	192	0.96	0.56	1.1	1.86

Blue and red shrimp (*Aristeus antennatus*) ARA

The blue and red shrimp presents sexual dimorphism, with females reaching larger sizes than males. However, for the analysis, a combined set of growth parameters was used; thus, the length data available was a dataset with both male and female parameters. In addition, biological parameters were also considered separately by sex to assess whether sex-based differences could bias the assessment results. The reproduction of the blue and red shrimp occurs between April and September (ICATMAR, 24-05), and recruitment is observed afterwards, in autumn and winter. The blue and red shrimp is a deep-water species caught exclusively by bottom trawling. The species has a wide bathymetric distribution, between 80 and 3300 m depth (Sardà *et al.*, 2004), although commercial fishing grounds are located between 450 and 800 m depth.

Input data

The spatial distribution of total landings for blue and red shrimp in the Catalan fishing ground is shown in Figure 109. The species is mainly distributed in the lower slope along the Catalan coast, with less occurrence in the Delta area (i.e. L'Ametlla de Mar).

Historical blue and red shrimp landings in Catalonia from 2002 to 2024 are shown in Figure 110. The lowest value was observed in 2005. Following a peak in 2008, landings declined and have remained stable over the past five years.

Landings distribution for the blue and red shrimp by métier from 2019 to 2024 are presented in Figure 111, with the highest landings obtained with bottom trawlers, especially for lower slope métier.

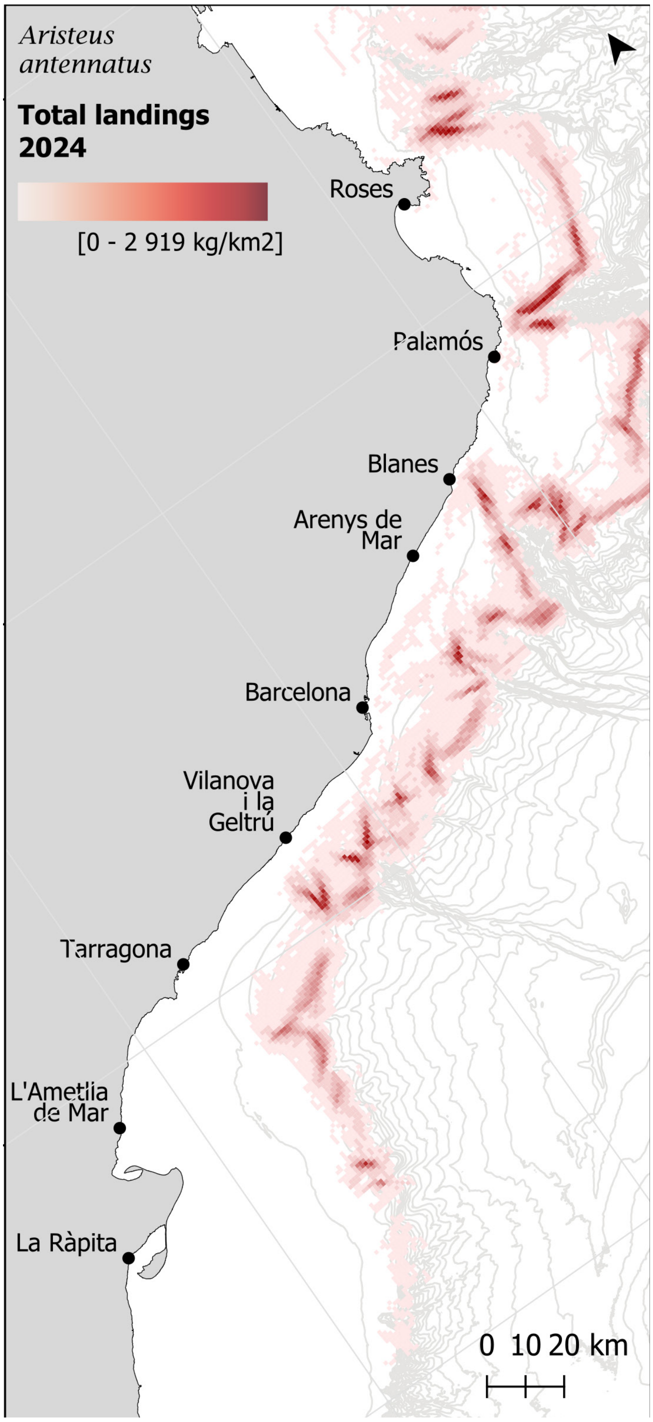

Figure 109. Spatial distribution of landings (kg/km²) for blue and red shrimp in the Catalan fishing grounds (North GSA6) in the year analyzed.

Annual LFD

After raising the length frequencies obtained with the monitoring program (Table 37), and accounting for sex-based differences, the annual length frequency of blue and red shrimp in Catalonia is shown in Figure 112. In general, females reach larger sizes and migrate to shallower depths (< 600 m) during summer (Company and Sardà, 2000; Sardà et al., 2004), coinciding with the reproductive period, when landings of blue and red shrimp where higher (ICATMAR, 25-04). In contrast, males are smaller and remain in deeper waters, making females more susceptible to capture by the bottom trawling fishery. The SOP validation results are shown in Table 36, while Table 37 summarizes the number of individuals sampled through the ICATMAR monitoring program.

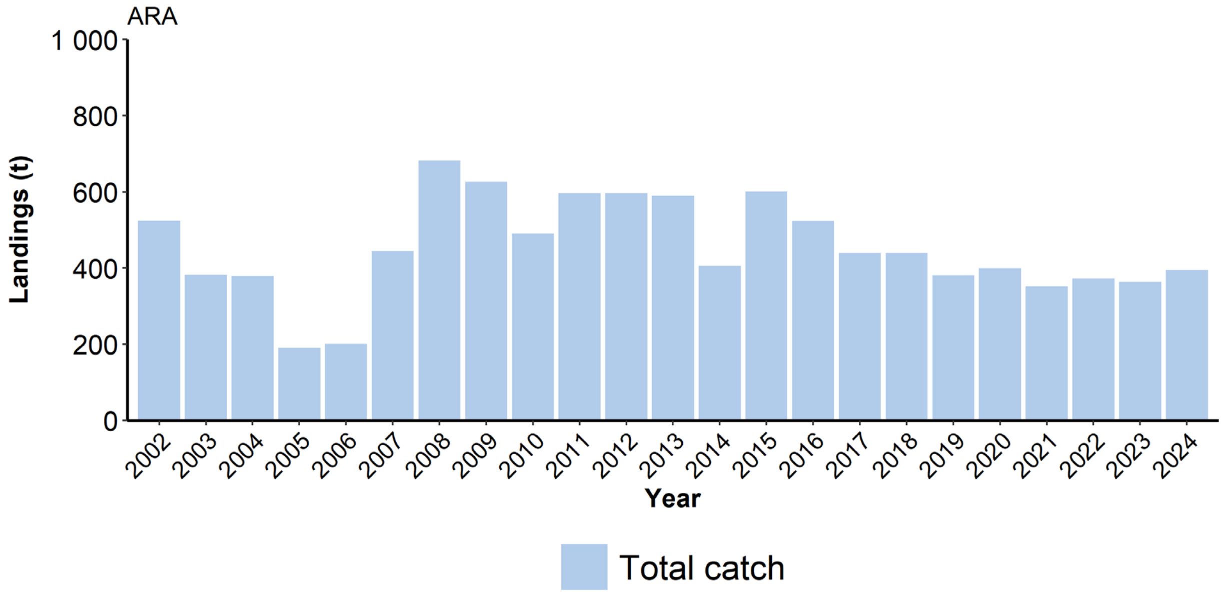

Figure 110. Historical landings (t) for blue and red shrimp in Catalonia.

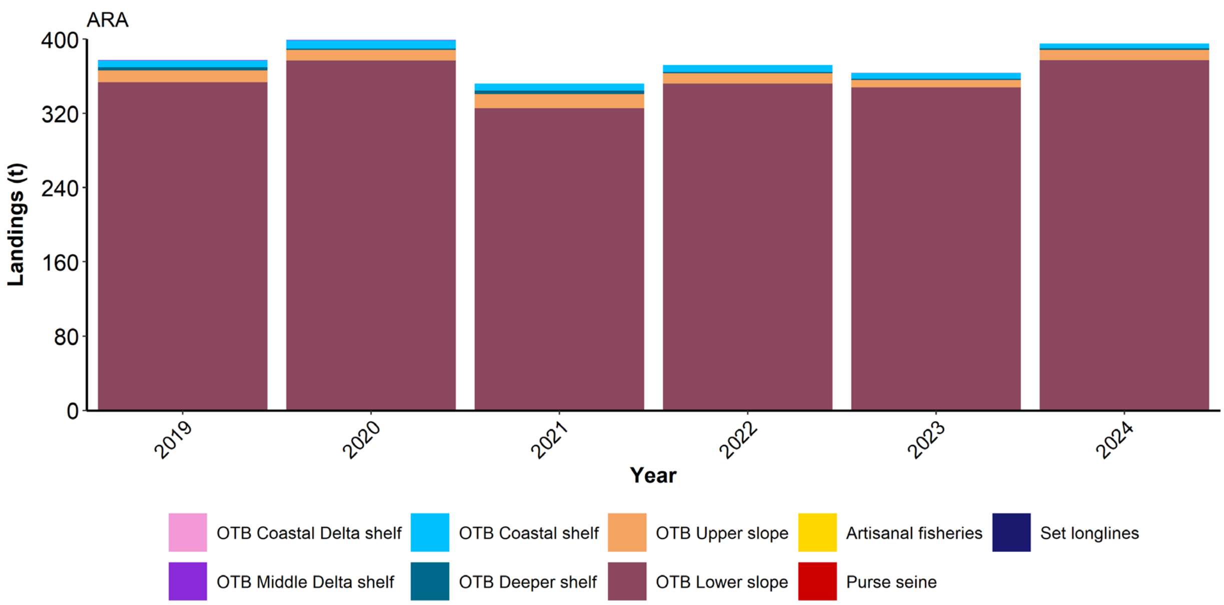

Figure 111. Landings (t) for blue and red shrimp by métier and fishing gear. OTB: bottom trawling.

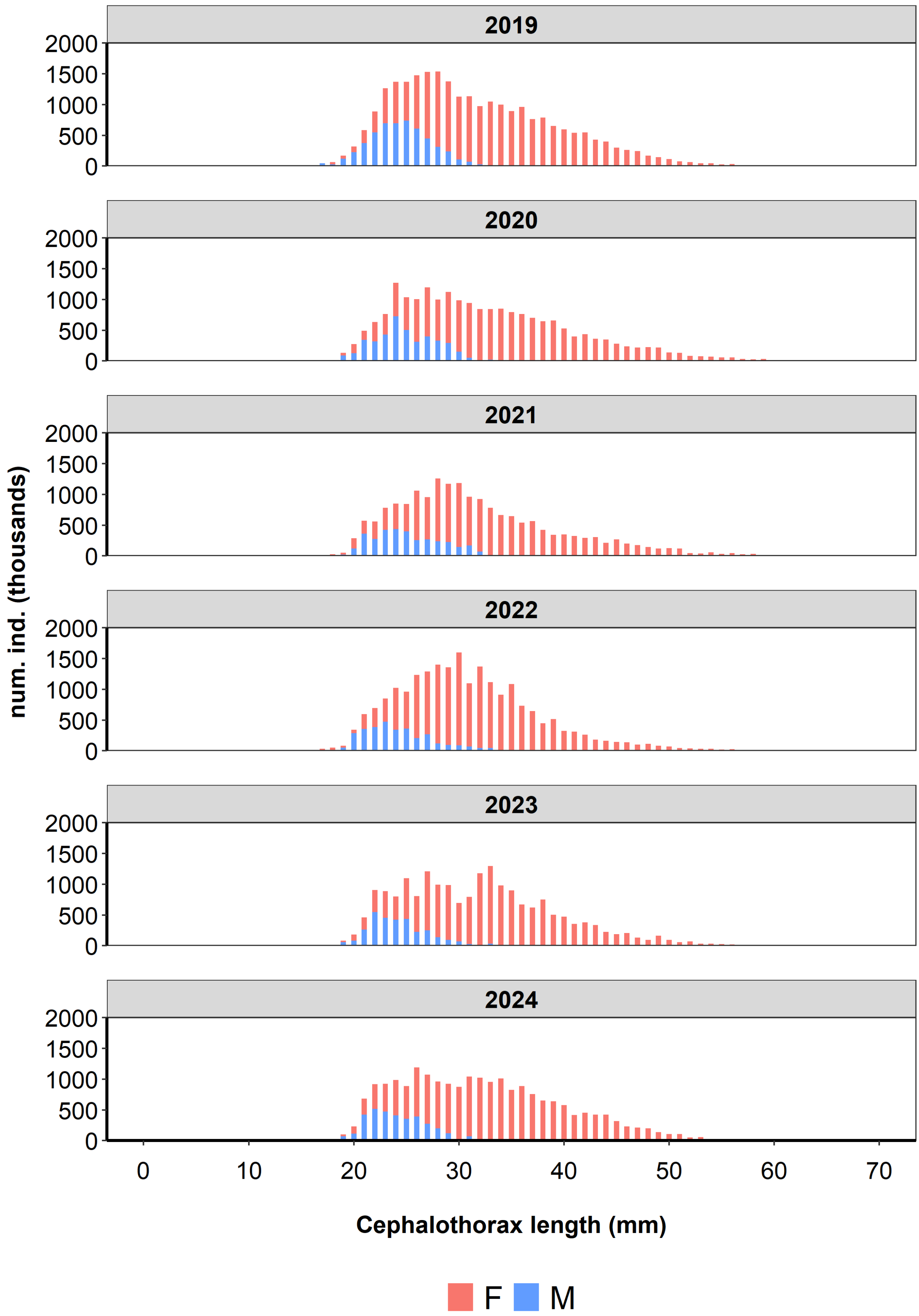

Figure 112. Annual length frequency distributions of blue and red shrimp from bottom trawling by sex. The data from bottom trawling is raised from ICATMAR data and details landed and discarded blue and red shrimp.

Table 36. Sum of Products (SOP) validation for blue and red shrimp (ARA): The column Calculated Weight in GSA6N (SOP) represents the biomass estimated through the raising process, while landings refer to the reported landings in NGSA6. The ratio between SOP and landings is known as the Sum of Products (SOP). Values close to 1 indicate that the raising process provides biomass estimates that closely match the reported landings, thereby validating the accuracy of the estimation method.

Species	Year	Catch classification	Gear	Calculated weight GSA6N (kg) (SOP)	Landings in GSA6N (kg)	SOP/Landings
ARA	2021	Discarded	Bottom trawl	45	-	-
ARA	2022	Discarded	Bottom trawl	9	-	-
ARA	2024	Discarded	Bottom trawl	31	-	-
ARA	2019	Landed	Bottom trawl	398551	380515	1.05
ARA	2020	Landed	Bottom trawl	357598	399302	0.90
ARA	2021	Landed	Bottom trawl	294870	352167	0.84
ARA	2022	Landed	Bottom trawl	315949	372080	0.85
ARA	2023	Landed	Bottom trawl	315294	363835	0.87
ARA	2024	Landed	Bottom trawl	350666	395314	0.89

Table 37. Number of blue and red shrimp individuals sampled by zone and season from ICATMAR monitoring data used to raise the length frequencies.

Fishery	Year	Zone	Winter	Spring	Summer	Autumn	N hauls
			Number individuals sampled				
Bottom trawl	2019	North	181	1796	1102	900	17
Bottom trawl	2019	Center	1005	848	483	1049	12
Bottom trawl	2019	South	490	0	898	433	5
Bottom trawl	2020	North	697	502	1040	1055	15
Bottom trawl	2020	Center	467	655	894	991	10
Bottom trawl	2020	South	537	0	477	335	3
Bottom trawl	2021	North	1053	979	1146	1100	16
Bottom trawl	2021	Center	1067	974	552	465	11
Bottom trawl	2021	North	889	921	934	746	15
Bottom trawl	2022	Center	835	532	663	431	11
Bottom trawl	2022	North	650	629	921	721	12
Bottom trawl	2022	Center	587	750	816	772	12
Bottom trawl	2023	North	924	964	859	881	14
Bottom trawl	2023	Center	556	895	931	1062	12
Bottom trawl	2023	North	697	502	1040	1055	15
Bottom trawl	2024	Center	467	655	894	991	10
Bottom trawl	2024	South	537	0	477	335	3
Bottom trawl	2024	North	1053	979	1146	1100	16

Length-Based Spawning Potential Ratio (LBSPR)

Model setting and results

Scenarios

Five different scenarios were applied in the sensitivity analysis for blue and red shrimp (Table 38):

- **Scenario 1:** used maturity, growth and mortality information from the STECF and GFCM stock assessment data**.**
- **Scenario 2:** incorporated maturity data from the literature (Sardà et al., 2004).
- **Scenario 3:** used maturity data from the ICATMAR dataset (ICATMAR, 25-05).
- **Scenarios 4 and 5:** applied sex-specific biological parameters, obtained from the literature (Company and Sardà, 2000), assessing females and males separately.

Fitted data

The length frequency distribution fit per year is shown in Figure 113. The model generally follows the mode for all years but overestimates some length classes in the middle mode part for all years.

Table 38. Biological parameters used in the different LBSPR scenarios for blue and red shrimp (ARA). L_{inf}: asymptotic length at which growth is zero, k: growth rate, M: natural mortality, L_{mat50}: length where 50% of individuals are mature, L_{mat95}: length where 95% of individuals are mature.

Species	Scenario	Linf (mm)	Lmat50 (mm)	Lmat95 (mm)	M/K
ARA (combined)	1	77.00	20.00	23.10	1.21
ARA (combined)	2	77.00	25.50	29.40	1.21
ARA (combined)	3	77.00	24.20	27.90	1.21
ARA (females)	4	76.00	23.16	26.60	1.60
ARA (males)	5	54.00	23.16	26.60	1.50

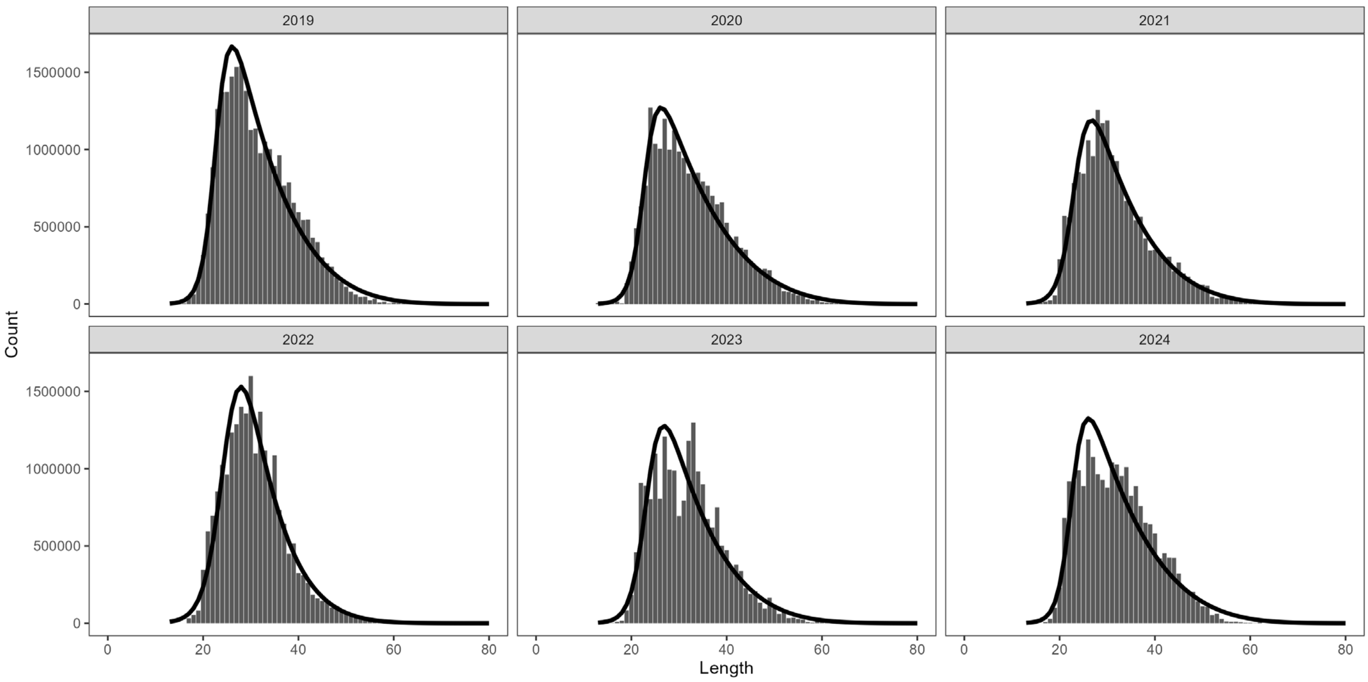

Figure 113. Fit of the data using the LBSPR model for blue and red shrimp for each studied year. Grey columns indicate length frequencies. Black lines indicate the fit of the model.

Selectivity

The outputs of the model for the selectivity of the fishery are shown for each scenario in Table 39. The output of the selected scenario (3) is also plotted with L_{mat50} and SL_{50} in Figure 114. Each scenario provides different results. In detail, for scenario 1, the model reveals that the fishery is fishing above L_{mat50}, for scenario 2 the fishing is below L_{mat50} and for scenario 3, it is around L_{mat50}.

Reference points

Although the model is very sensitive to changes in growth and maturity parameters, the stock is below SPR_{lim} (= 0.2) in all assessed scenarios (Table 39 and Figure 116). When comparing scenarios sex-specific scenarios, females (scenario 4) consistently show SPR values above 0.1, whereas males (scenario 5) reach the lowest SPR value, falling below 0.1. However, it is important to note that most blue and red shrimp—particularly males and immature females—inhabit depths beyond the reach of the bottom trawl fishery. The Kobe plot for blue and red shrimp (Figure 115) displays the stock status over time, with no clear trend. In all cases, the stock lies within the red zone, indicating that it is overfished and subject to ongoing overfishing.

Final scenario

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBSPR model.

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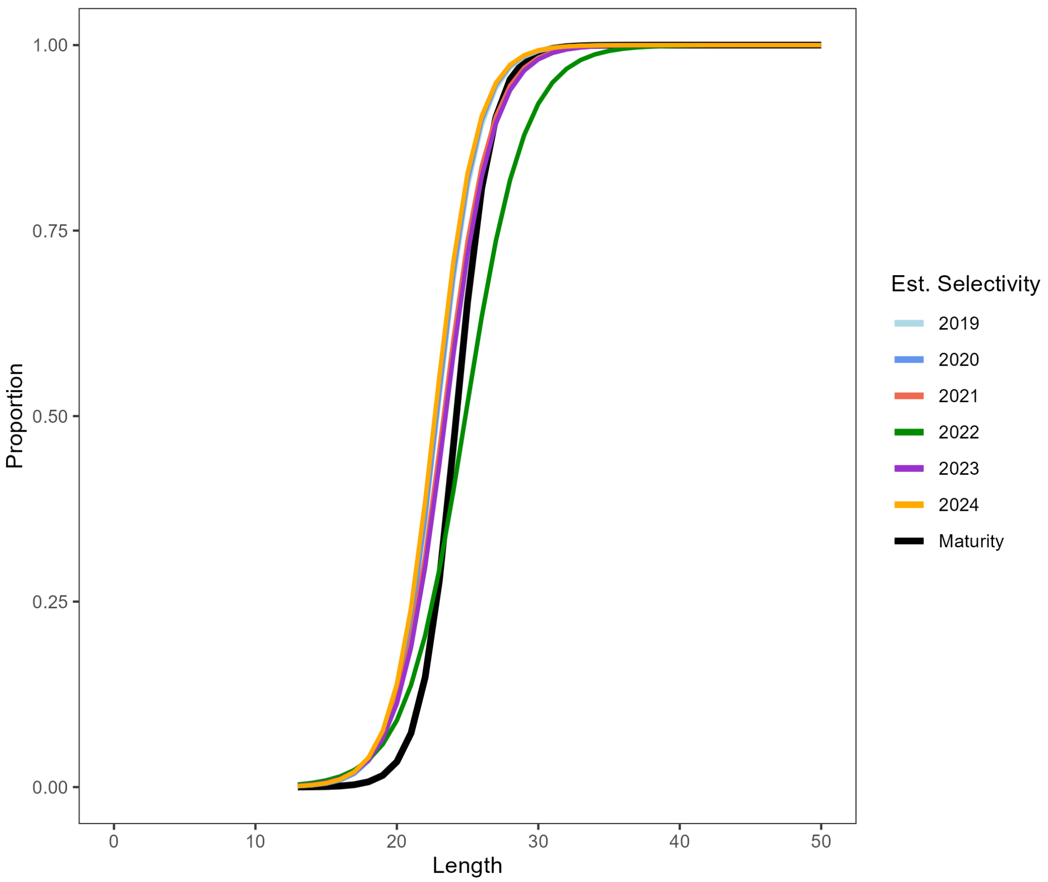

Figure 114. Length curves for blue and red shrimp. Black line shows the length curve at maturity. Color lines show the estimated selectivity at length curve predicted by the LBSPR model for the scenario selected (3).

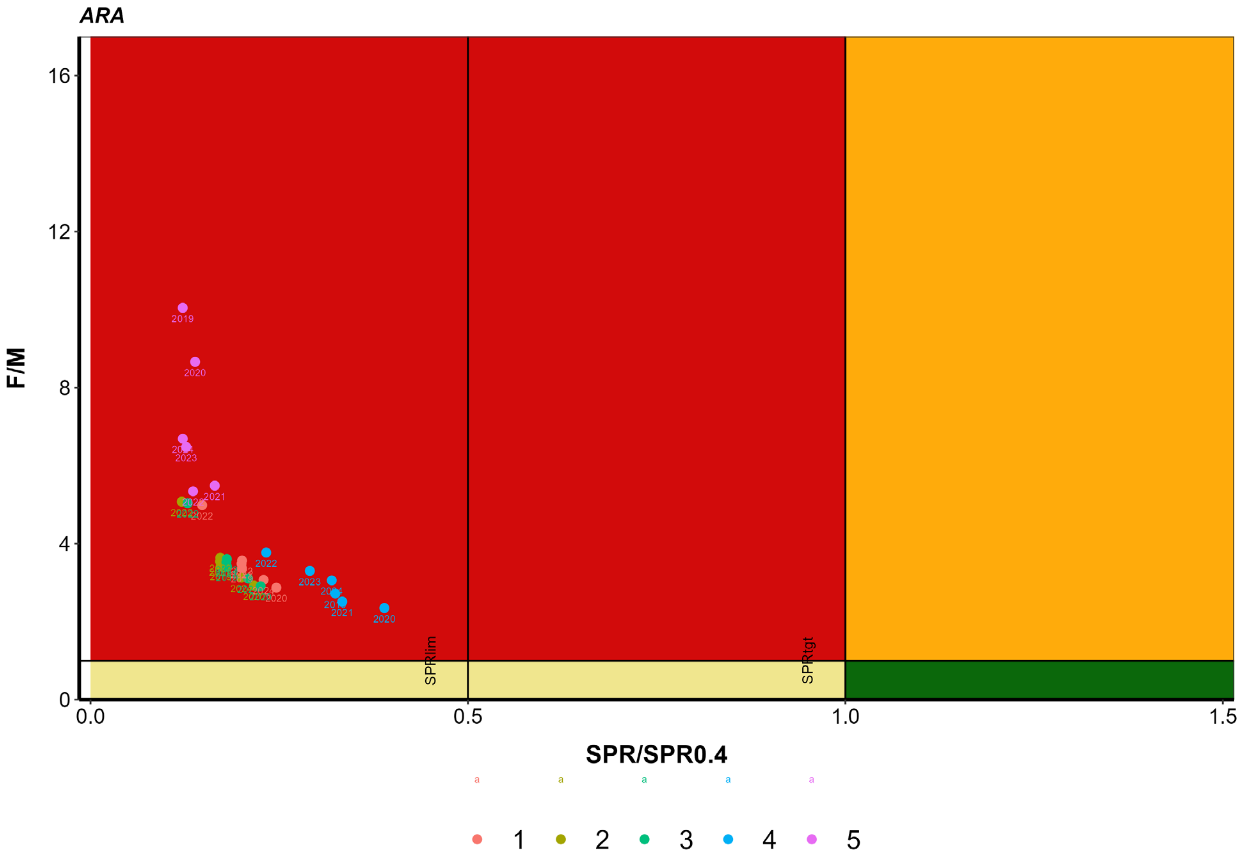

Figure 115. Kobe plot for blue and red shrimp by scenario (1-3) and year. SPR_{lim}: limit spawning potential ratio, SPR_{tgt}: target spawning potential ratio, F: fishing mortality, M: natural mortality, and F/M: relative fishing mortality.

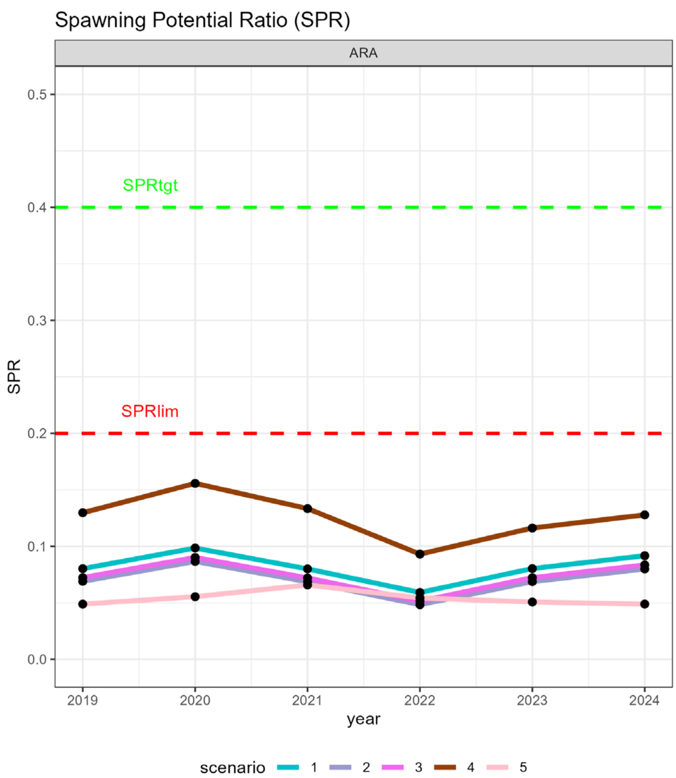

Figure 116. Spawning potential ratio (SPR) per year analyzed for blue and red shrimp evaluated with LBSPR model. LBSPR: Length-Based Spawning Potential Ratio. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio. Colored lines show the results for each scenario.

Table 39. LBSPR model results for blue and red shrimp with the different scenarios tested for each year analyzed. SL_{50}: Length where 50% of individuals are caught, SPR: spawning potential ratio and FM: fishing mortality. SD is the standard deviation calculated for each indicator. The selected scenario is highlighted in blue.

spp	scenario	year	SL_{50}	SD	SPR	SD	FM	SD
ARA	1	2020	23.06	0.31	0.10	0.05	2.87	0.86
ARA	1	2021	23.63	0.36	0.08	0.04	3.48	1.00
ARA	1	2022	25.29	0.42	0.06	0.03	4.99	1.34
ARA	1	2023	23.95	0.63	0.08	0.04	3.57	1.08
ARA	1	2024	23.10	0.57	0.09	0.05	3.07	0.95
ARA	2	2019	23.11	0.28	0.07	0.04	3.42	0.95
ARA	2	2020	23.09	0.31	0.09	0.05	2.92	0.86
ARA	2	2021	23.66	0.36	0.07	0.04	3.55	1.00
ARA	2	2022	25.34	0.42	0.05	0.03	5.08	1.35
ARA	2	2023	24.01	0.64	0.07	0.04	3.64	1.09
ARA	2	2024	23.15	0.58	0.08	0.05	3.13	0.96
ARA	3	2019	23.08	0.27	0.07	0.04	3.41	0.93
ARA	3	2020	23.06	0.31	0.09	0.05	2.91	0.84
ARA	3	2021	23.63	0.35	0.07	0.04	3.52	0.98
ARA	3	2022	25.29	0.41	0.05	0.03	5.04	1.31
ARA	3	2023	23.95	0.62	0.07	0.04	3.61	1.06
ARA	3	2024	23.10	0.56	0.08	0.05	3.11	0.94
ARA	4	2019	26.76	0.51	0.13	0.07	2.72	0.87
ARA	4	2020	27.17	0.63	0.16	0.09	2.35	0.81
ARA	4	2021	25.95	0.35	0.13	0.07	2.51	0.79
ARA	4	2022	26.94	0.33	0.09	0.05	3.77	1.06
ARA	4	2023	28.09	0.56	0.12	0.06	3.30	1.02
ARA	4	2024	28.33	0.71	0.13	0.07	3.06	1.00
ARA	5	2019	23.76	0.21	0.05	0.04	10.04	2.46
ARA	5	2020	23.75	0.24	0.06	0.04	8.66	2.20
ARA	5	2021	22.40	0.22	0.07	0.05	5.49	1.45
ARA	5	2022	21.10	0.15	0.05	0.04	5.34	1.34
ARA	5	2023	21.77	0.38	0.05	0.04	6.48	1.56
ARA	5	2024	21.79	0.39	0.05	0.04	6.69	1.59

Length-based Bayesian Biomass (LBB)

Scenarios

Three different scenarios were applied for the sensitivity analysis for blue and red shrimp (Table 40). All scenarios used the same growth and natural mortality parameters. For scenario 1, maturity information was obtained from STECF and GFCM stock assessment data, for scenario 2, these data were obtained from the literature (Sardà et al., 2004) and for scenario 3, from ICATMAR data (ICATMAR, 24-05).

Table 40. Biological parameters used in the different LBB scenarios for blue and red shrimp (ARA). $L_{inf:}$ Asymptotic length, M/k: ratio between natural mortality and growth rate, $L_{mat50:}$ length where 50% of individuals are mature.

Specie	Scenario	Linf (cm)	M/k	Lmat50 (cm)
ARA	1	7.7	1.211	2.0
	2	7.7	1.211	2.6
	3	7.7	1.211	2.4

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBB model.

Fitted data

The length frequency distribution fit per year is shown in Figure 117. The model generally follows the modal length across all years but consistently underestimates certain length classes in the mid-range of the distribution.

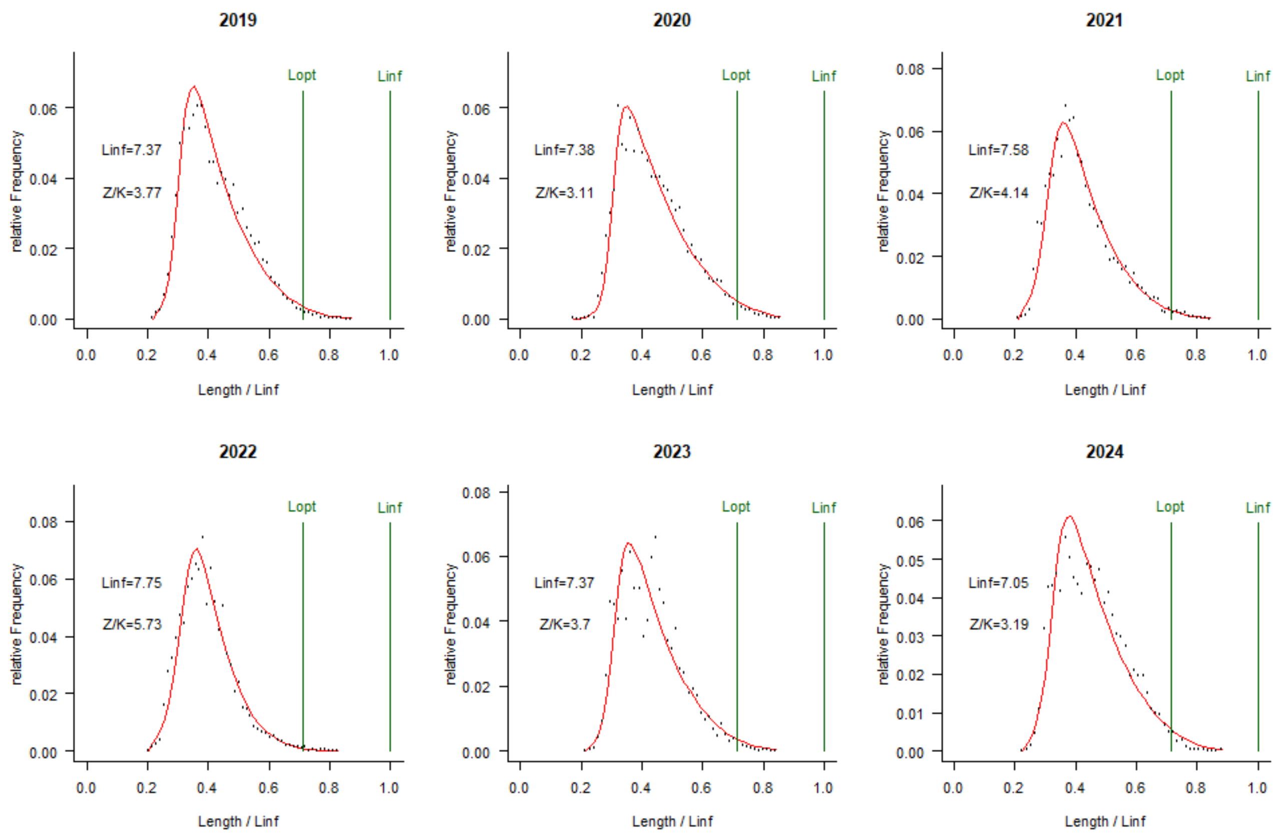

Figure 117. Fit of the data using the LBB model for ARA for each year in scenario 3. Red line indicates the fit of the model.

Reference points

Summary of the graphical results are in Figure 118. The upper left plot shows that the aggregated estimated length at first capture (L_c) is 2.3 cm, below the L_{mat} (2.42 cm). However, the lower left plot indicates that while L_c was initially below L_{mat} at the beginning of the time series, it gradually increases and eventually aligns with L_{mat} (L_c: dotted black line). The upper middle and right panels show that the mean length (L_{mean}) is far from L_{opt}, which is also shown in the lower left plot (L_{mean}: bold black line). Lower middle and right plots show that the relative fishing pressure (F/M) and relative biomass (B/B_0) are far from sustainable levels. More details related to these results are in Table 41.

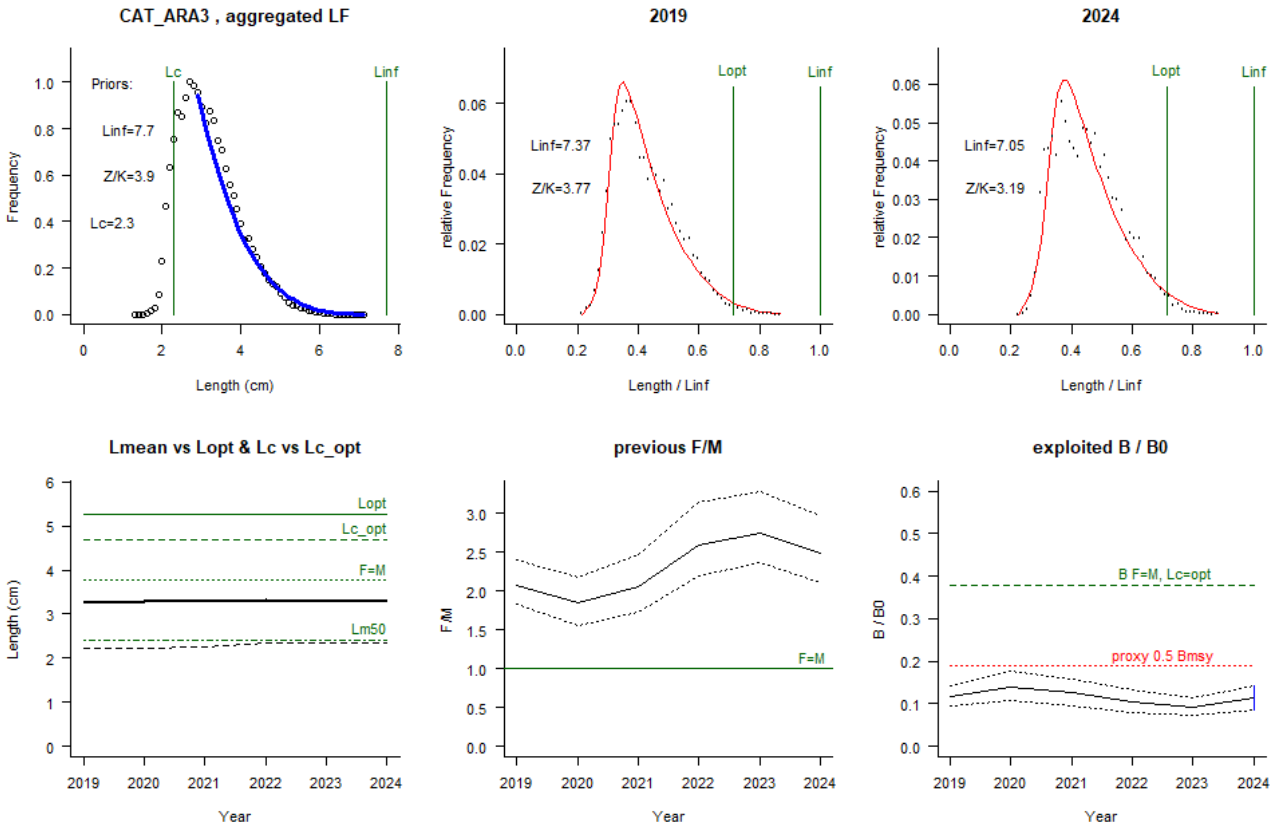

Figure 118. Summary output from LBB for ARA scenario 3.

Table 41. LBB model results for blue and red shrimp (ARA) with the different scenarios tested for each year analyzed. $L_{mean:}$ mean length of individuals, $L_{opt:}$ length at optimal yield, $L_{c:}$ length at first capture, $L_{c\_opt:}$ length at first capture at optimal yield, L_{95th}/L_{inf}: ratio of the 95th percentile to asymptotic length , F/M: fishing mortality relative to natural mortality, $B/B_{0:}$ exploited biomass relative to unexploited biomass, $B/B_{msy:}$ exploited biomass relative to maximum sustainable yield biomass, $C_{mature:}$ proportion of mature individuals in the catch.

Specie	Scenario	Year	Lmean/Lopt	Lc/Lc_opt	L95th/Linf	F/M	B/B0	B/Bmsy	Cmature
ARA	1	2024	0.62	0.50	0.85	2.50	0.11	0.30	98%
	2	2024	0.62	0.50	0.85	2.50	0.11	0.30	78%
	3	2024	0.62	0.50	0.85	2.50	0.11	0.30	82%

Stochastic Production model in Continuous Time (SPiCT)

For blue and red shrimp, input data available for catches were from 1996 to 2024, while for the index we had MEDITS survey from 1996 to 2024 and CPUE data from 1996 to 2023 (Figure 119). This assessment reference year is 2024. A double-axis plot was presented to compare trends between catches and the indices (Figure 120).

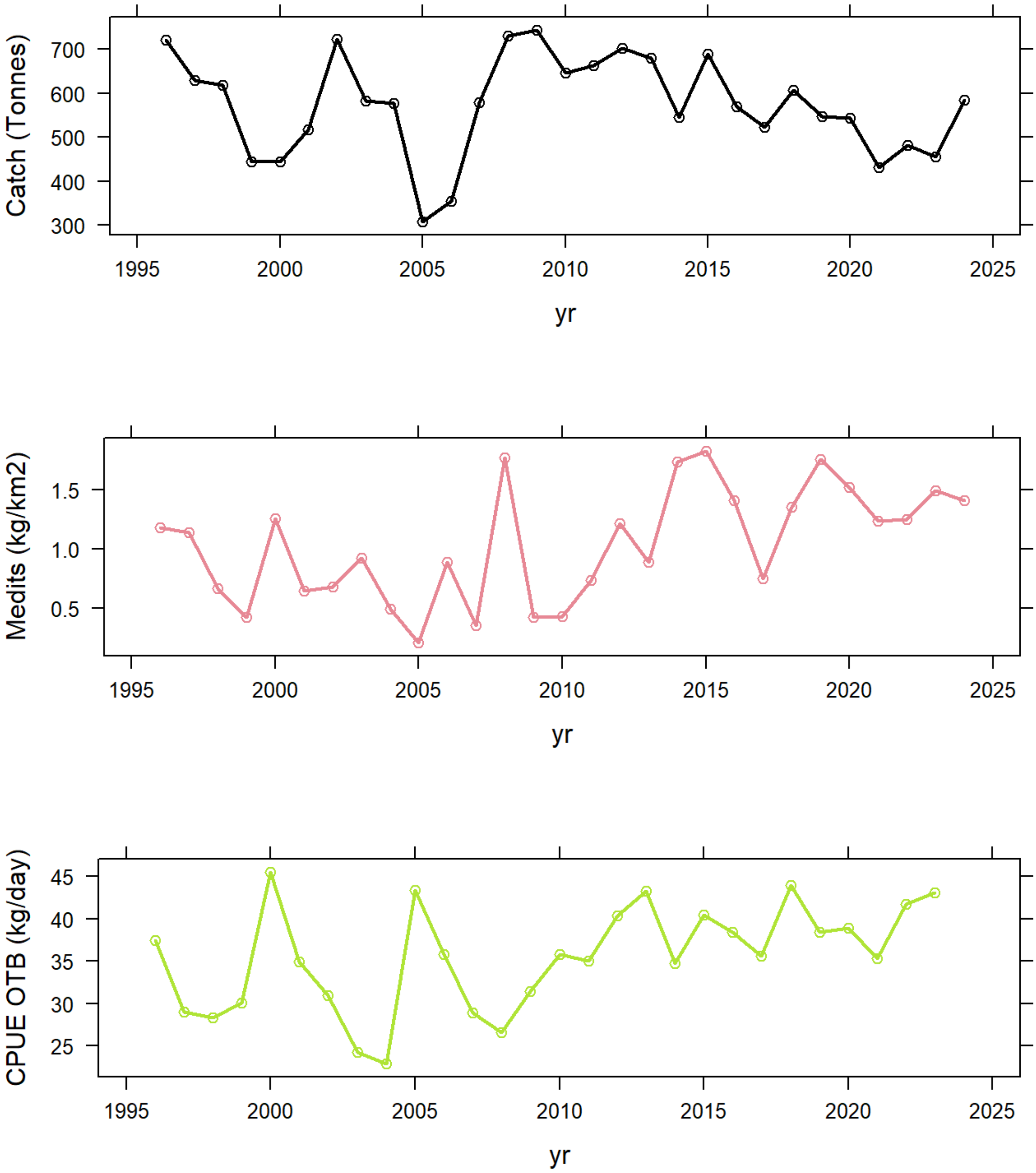

Figure 119. Data available for the assessment for blue and red shrimp in GSA6 to run SPiCT model. Top: catch data from 1996 to 2022. Centre: MEDITS survey data since 1996 to 2022. Bottom: CPUE for OTB data since 1996 to 2023.

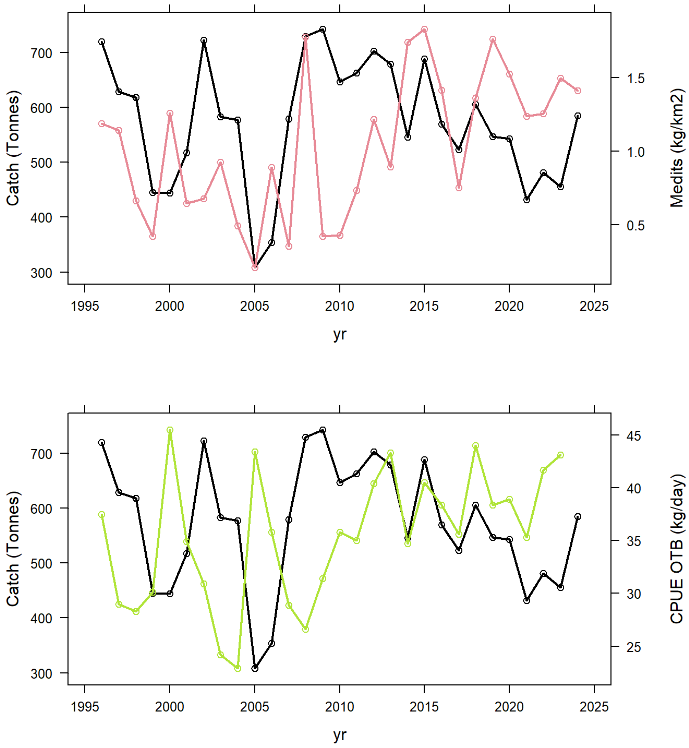

Figure 120. Double axis plot to compare trends between catch and MEDITS index (top) and catch and CPUE for OTB (bottom) for blue and red shrimp.

Although only the final scenario is presented below, different scenarios were tested:

- **Scenario 1:** landings started in 1996, using MEDITS survey as index
- **Scenario 2:** landings started in 1996, using CPUE as index
- **Scenario 3:** landings started in 1996, using MEDITS survey and CPUE as indices

In Figure 121 is presented a comparison between the scenarios.

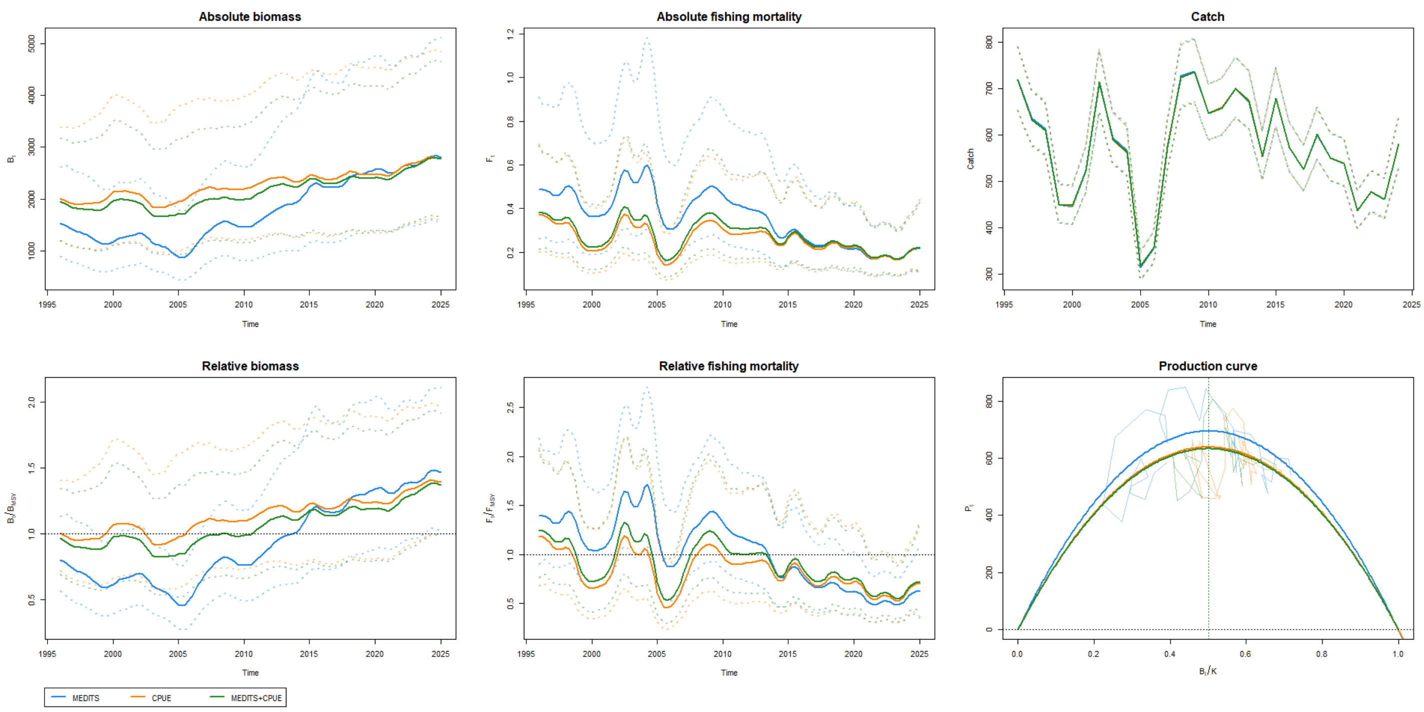

Figure 121. Scenarios comparison for blue and red shrimp in GSA6.

Final scenario

Scenario 1 was chosen as the final scenario, since diagnostics with MEDITS were better than those with CPUE. The chosen scenario met most of the model diagnostics and provided good retrospective analysis and hindcasting diagnostics (Figure 124, Figure 125, Figure 126, Figure 127 and Figure 128).

A sensitivity analysis for the final scenario was performed, testing r prior, bkfrac, process error, and observation error to assess the model's robustness within these priors. All these plots and results for the other scenarios will be available at https://github.com/ICATMAR.

The settings used for the final scenario is presented in Table 42.

Table 42. Priors settings for blue and red shrimp (ARA) in all scenarios.

Type	Prior	Description	Assignment	Mean	Standard deviation	Comment
Fishery dynamic	logbkfrac	B/K fraction (depletion)	-	Log(0.4)	0.2	Based on historic information and the high catches at the beginning of the catch series
Stock dynamic	logr	Population growth	-	Log(0.66)	0.2	Fishlife
	logn	Shape of production curve	-	Log(2)	-	Shaefer
Error	logsdc	Catch error	-	Log(0.05)	0.2	
	logsdf	Fishing mortality error	-	Log(4)	0.5	
	logsdb	Process error	-	Log(0.2)	0.5	
	logsdi	Observation error	-	Log(0.4)	0.5	

The final scenario input data is shown in Figure 122, and the final summary assessment results are shown in Figure 123.

Final scenario advice

Final scenario advice is presented in Figure 129 and Table 43, which outlines the indicators for blue and red shrimp in the GSA6 for the year 2024. The assessment results need to be considered with caution, since these are very contrary to what LBSPR or LBB showed, considering that those models consider the size frequency of the species (approximately 70% of the ARA catches come from the northern GSA6).

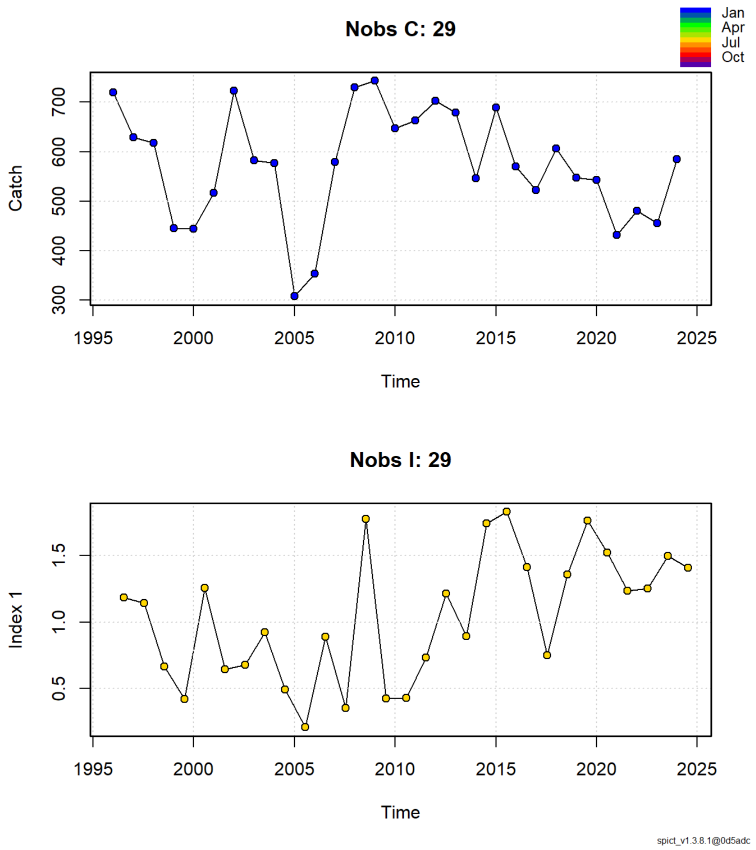

Figure 122. Input data for SPiCT model for blue and red shrimp in GSA6 for scenario 1. Top: catch in tons per year since 1996, bottom: index data of biomass derived from MEDITS since 1996.

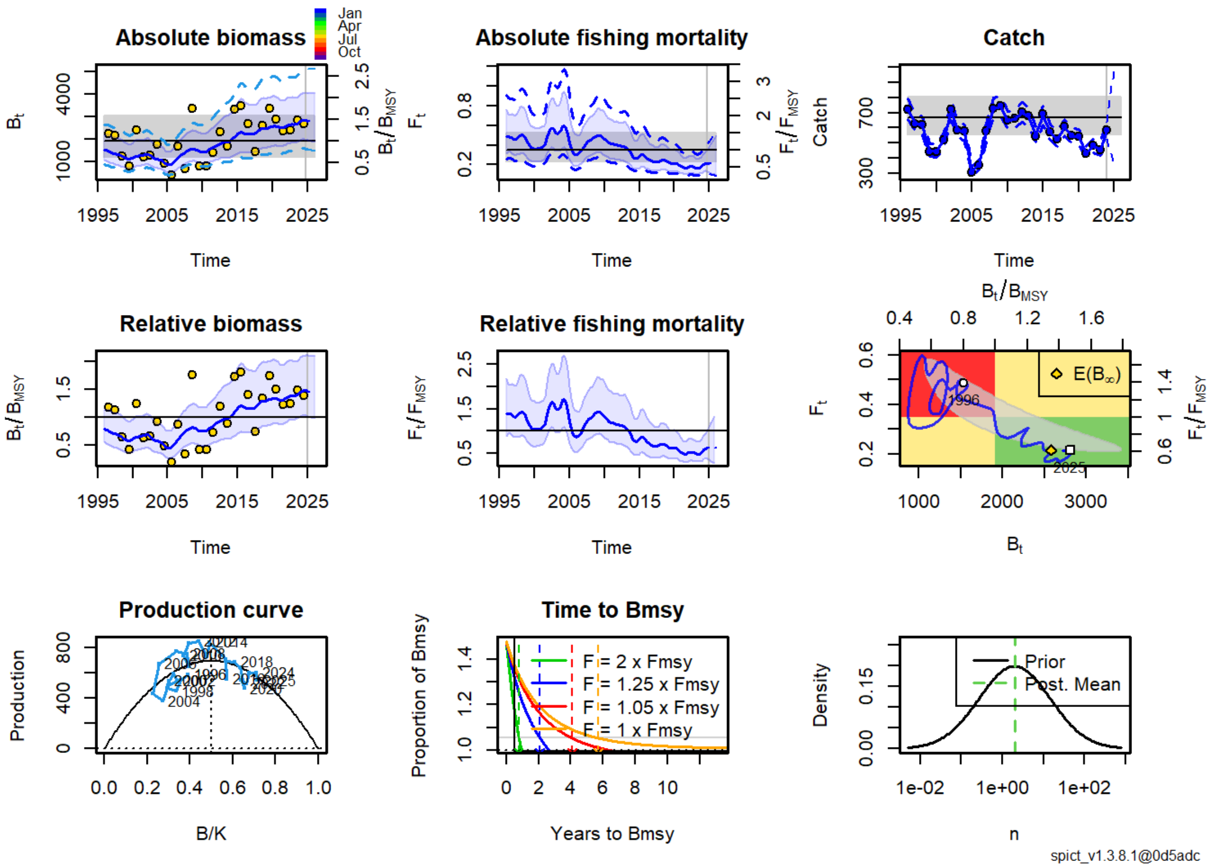

Figure 123. Stock assessment summary for SPiCT model for blue and red shrimp in GSA6 for the final scenario.

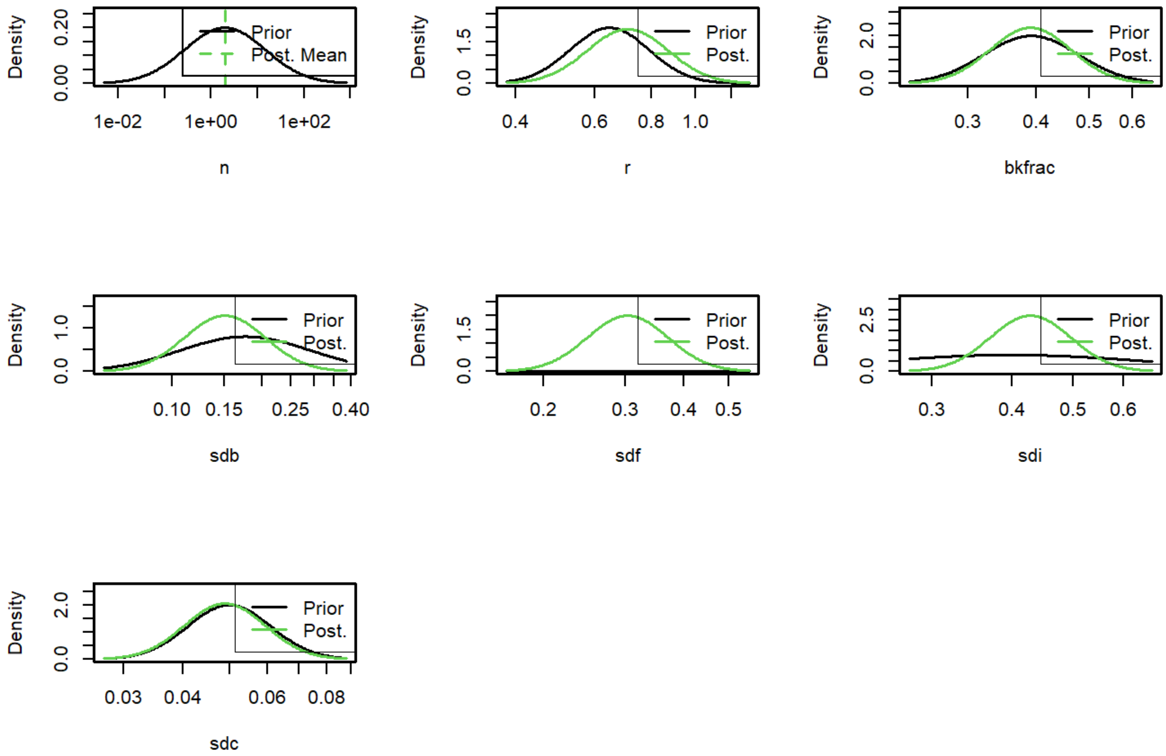

Figure 124. Estimated priors and posteriors for the updated assessment for blue and red shrimp in GSA6 for the final scenario.

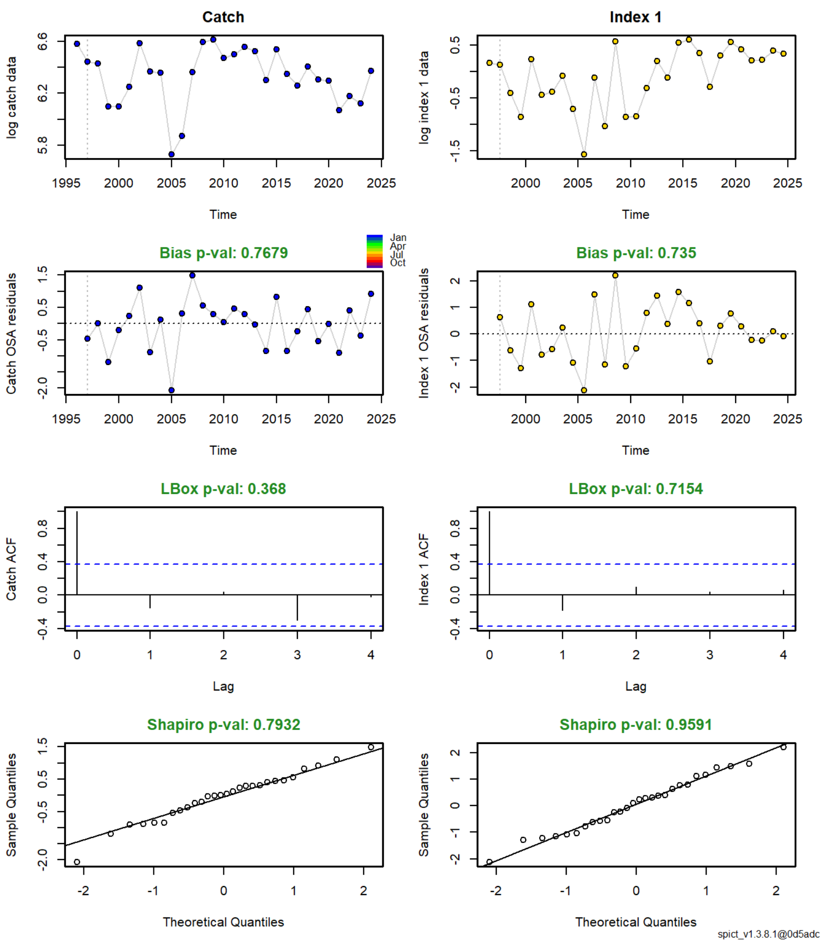

Figure 125. One-step-ahead residuals for the model for blue and red shrimp in GSA6 for the final scenario.

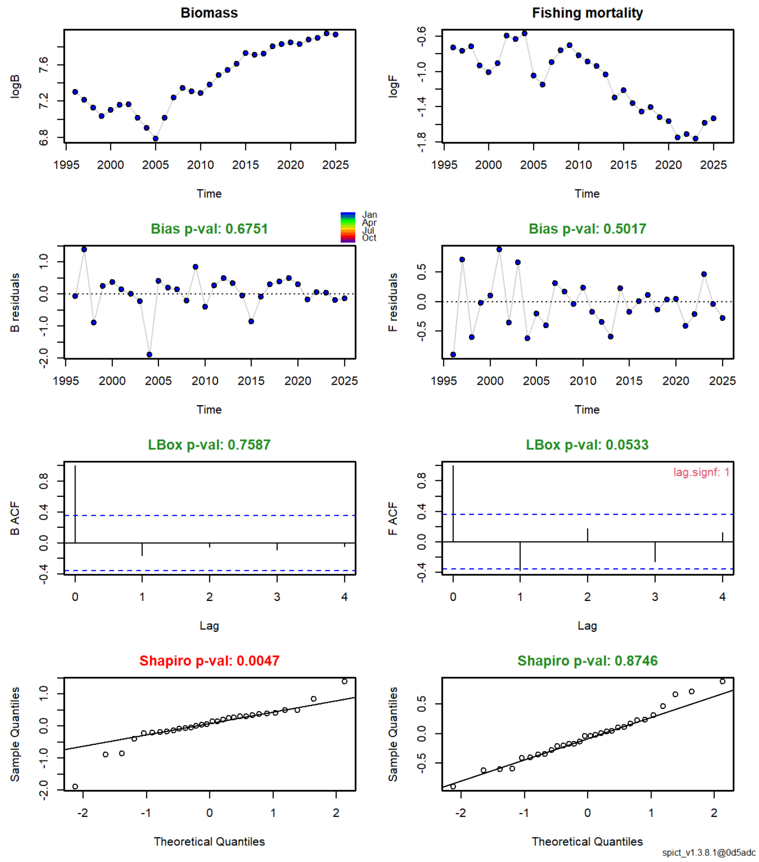

Figure 126. Process error deviations for the model for blue and red shrimp in GSA6 for the final scenario.

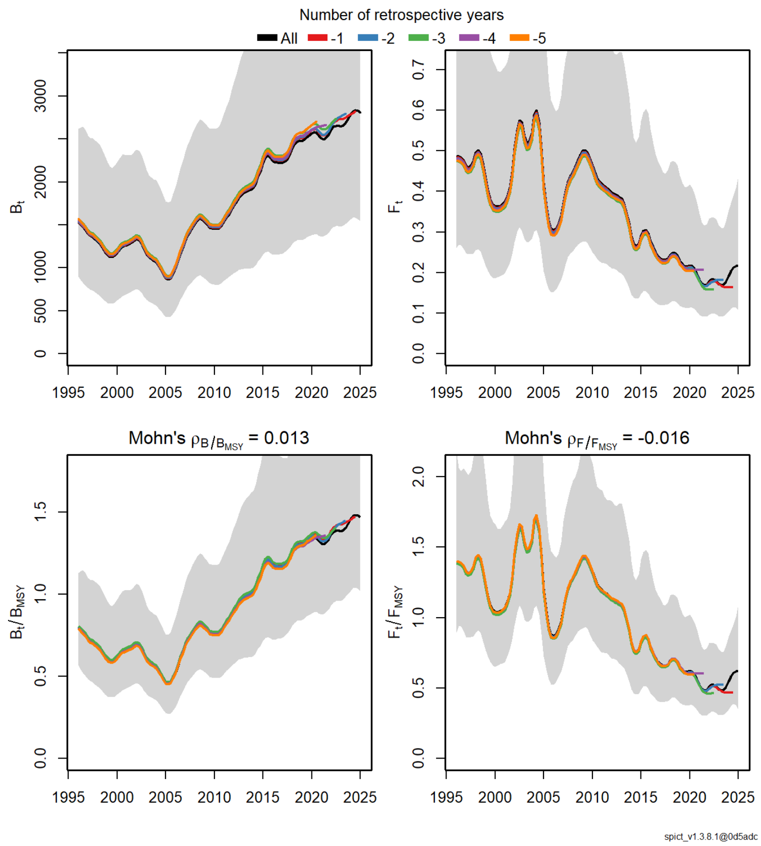

Figure 127. Retrospective analysis for blue and red shrimp in GSA6 for the final scenario.

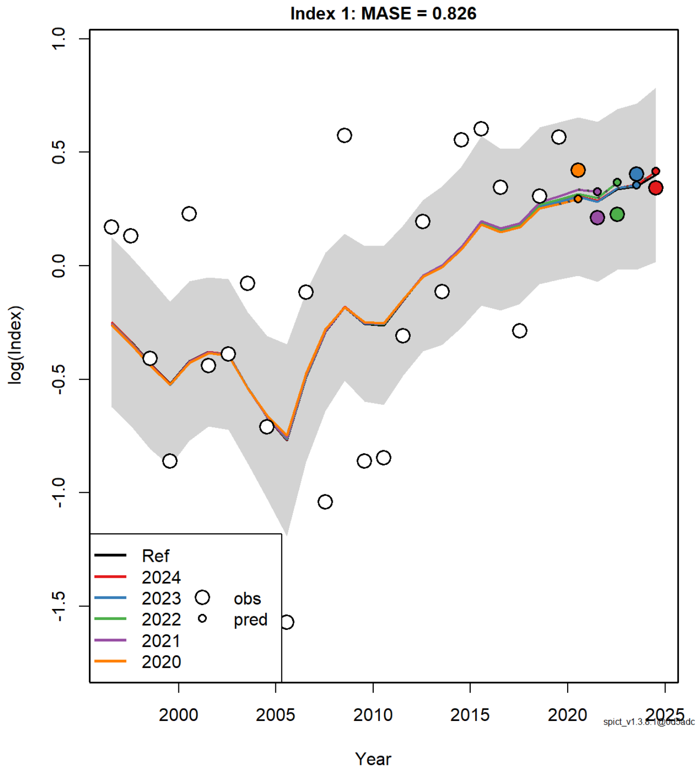

Figure 128. Hindcasting for the model for blue and red shrimp in GSA6 for the final scenario.

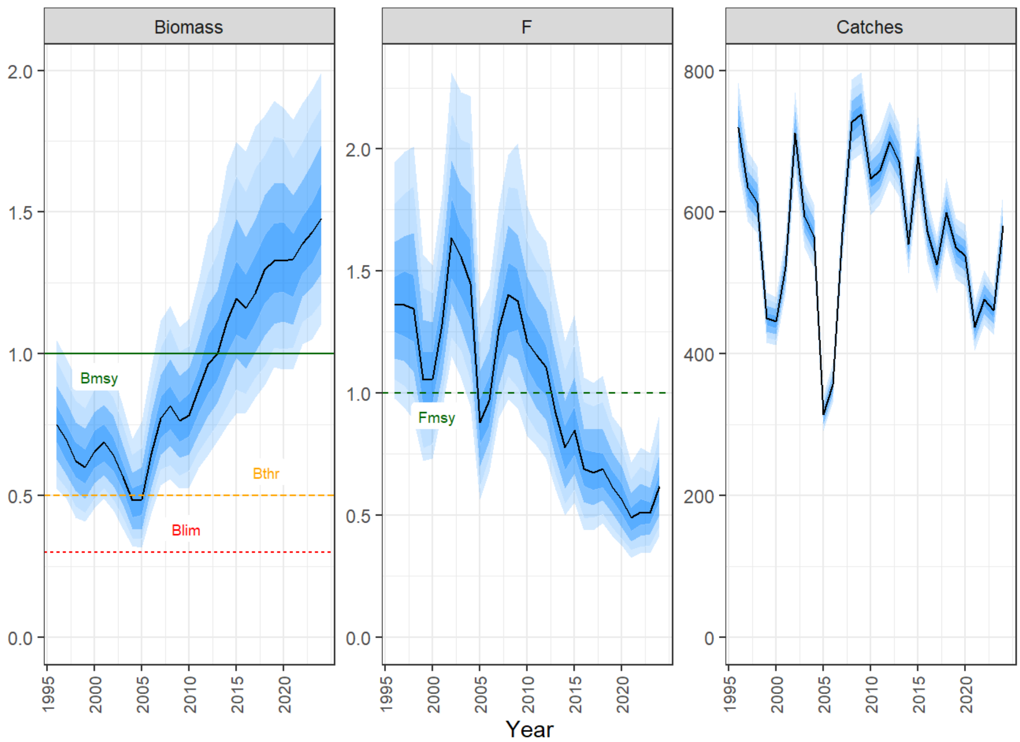

Figure 129. Advice for the final scenario for blue and red shrimp in GSA6: Historical and current stock status regarding F_{msy}, B_{msy} and B_{lim}.

Table 43. Indicators in 2024 from SPiCT for blue and red shrimp (ARA) shrimp in GSA6.

Species	Year	Catch (t)	F/Fmsy	B/Bmsy	B/Bpa	B/Blim
ARA	2024	579	0.62	1.48	3.0	4.93

Statistical catch-at-size model (MESTOCK)

The otter bottom trawl (OTB) fleet accounts for approximately 99% of ARA stock landings, making it the dominant fishing method for this specie. The MEDITS survey served as the abundance index for stock assessment, as it provides representative coverage of the population. Model fits and associated variables from the assessment are presented in (Figure 130, Figure 131, Figure 132 and Figure 133).

The model was experimentally applied using landing data (1996–2023), MEDITS survey data (1996–2023), and length-frequency data from both landings (OTB, 2002–2023) and surveys (MEDITS, 2002–2023).

The fleet fitting slightly overestimates mean sizes, primarily due to the increased prevalence of larger individuals in recent years compared to the beginning of the time series. While the model is able to reproduce the variability of the index, it shows some discrepancies in fitting the survey length frequencies. These discrepancies may be due to irregularities in the survey length frequency data, which could be associated with observation error, as data collection is limited to only one to two months (May–June) each year.

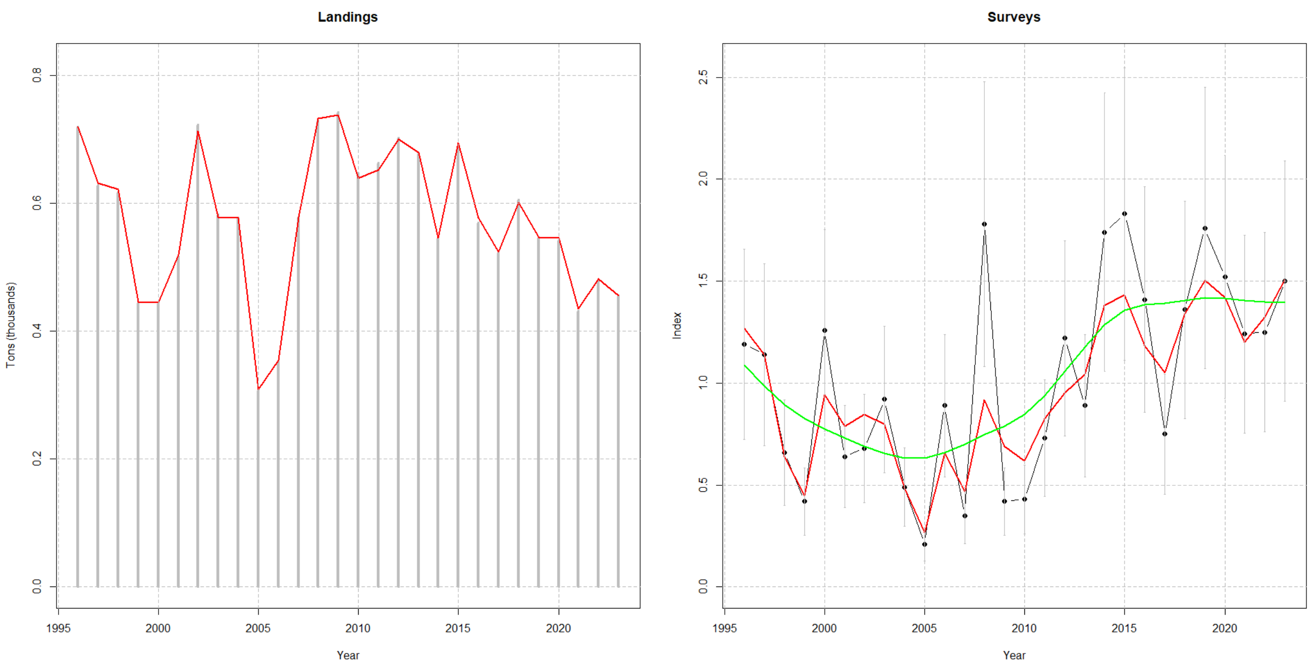

Figure 130. Fitting of the landing's series and abundance index for blue and red shrimp (ARA) in the GSA6. Red line corresponds to the model estimation.

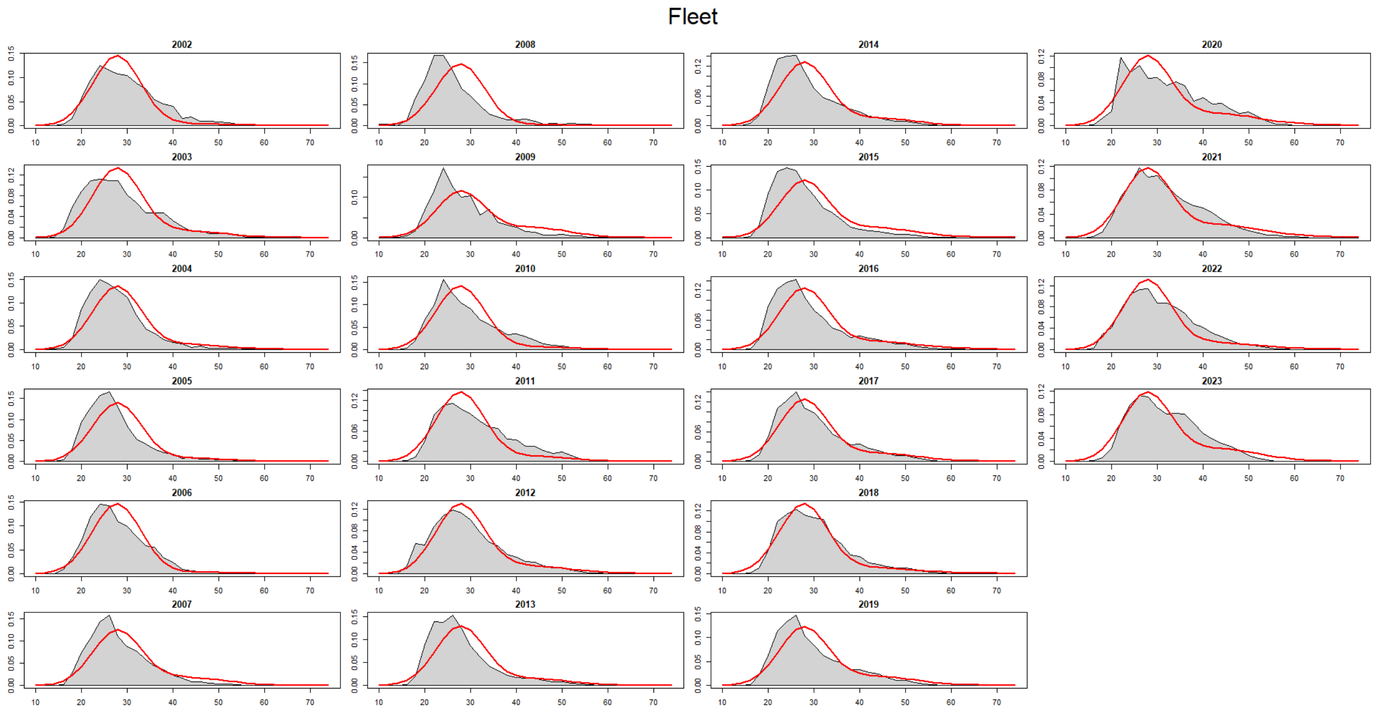

Figure 131. Fitting of the landings size compositions for blue and red shrimp (ARA) in the GSA6. Red line corresponds to the model estimation.

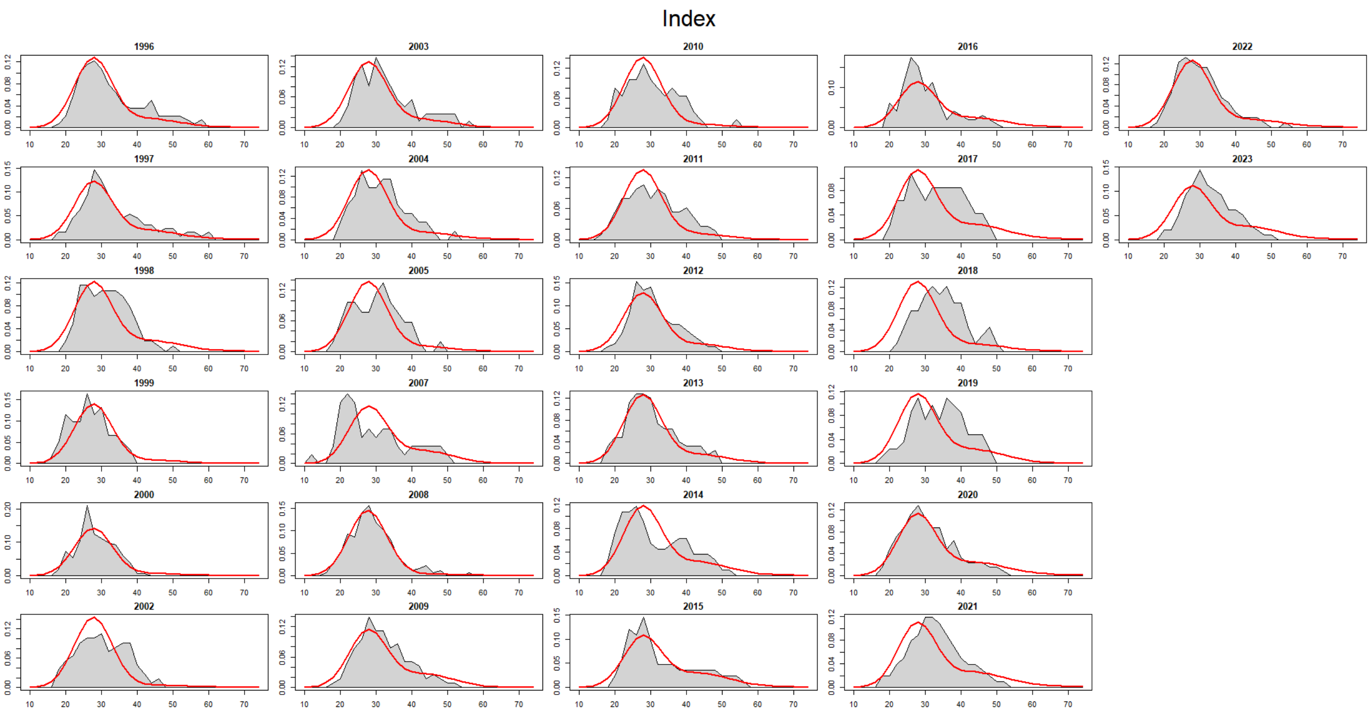

Figure 132. Fitting of the campaign size compositions for blue and red shrimp (ARA) in the GSA6. Red line corresponds to the model estimation.

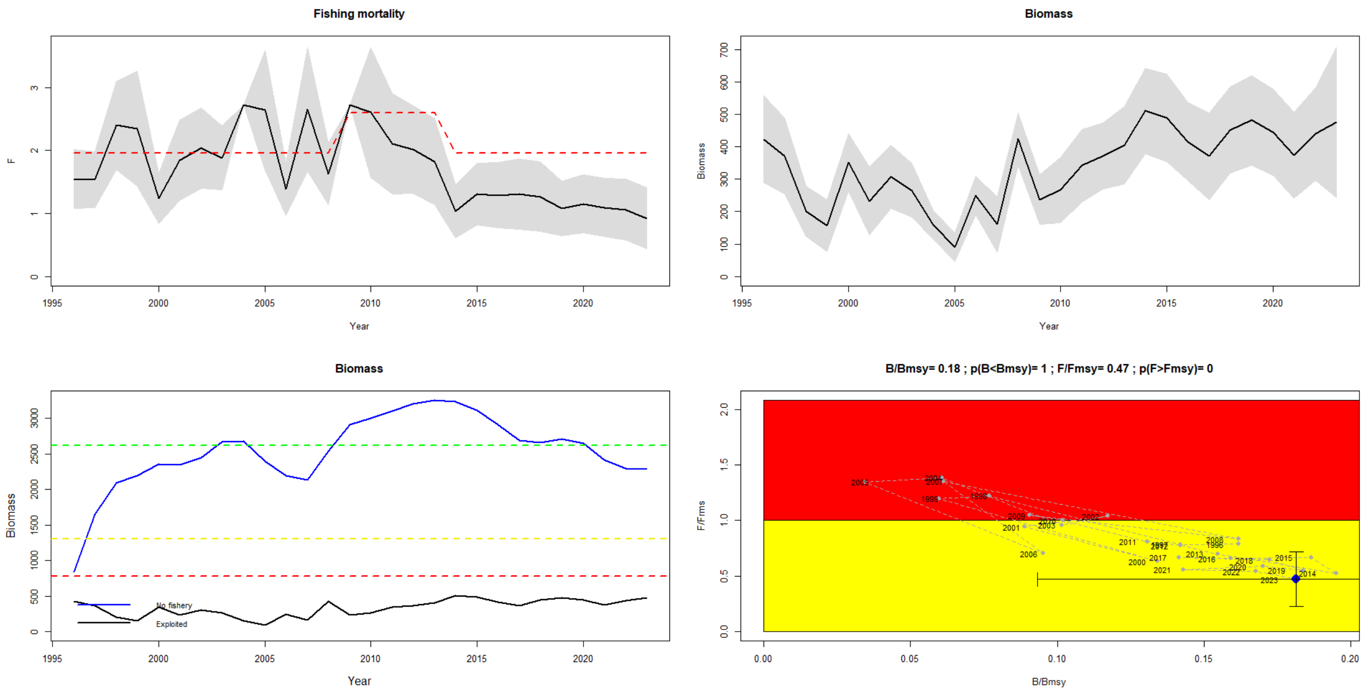

Figure 133. Biomass, fishing mortality, stock depletion and Kobe plot estimated for blue and red shrimp (ARA) in the GSA6 .

Analysis of population variables indicates that blue and red shrimp biomass has remained below B_{msy} throughout the entire time series, though showing improvement from 2020 to present. The reference biomass equivalent to 40% B0 was estimated at approximately 2,600 tons, while the average biomass for the most recent period is estimated at 474 tons.

It is estimated that fishing pressure on this resource has fluctuated around F_{msy}, and in recent years has remained below this threshold. However, analyses indicate that despite the reduction in fishing pressure, there has not been a proportional increase in biomass. The Kobe diagram suggests that the stock is experiencing overexploitation (B/B0 < 0.4), but is not currently subject to overfishing (F < F40%).

One possible explanation, as observed in the length-based model applied to the northern GSA6, is that the sizes of individuals in the population remain too small, limiting their spawning potential and the stock's capacity for biomass recovery. To explore this further, we tested a scenario with modified growth parameters (L_{inf} = 60 instead of 77), using the same data as before. In this scenario, the length distribution is closer to the new L_{inf}, resulting in a much-improved assessment in terms of B/B_{msy} (Figure 134): the value increased to 0.73, compared to 0.18 in the original assessment.

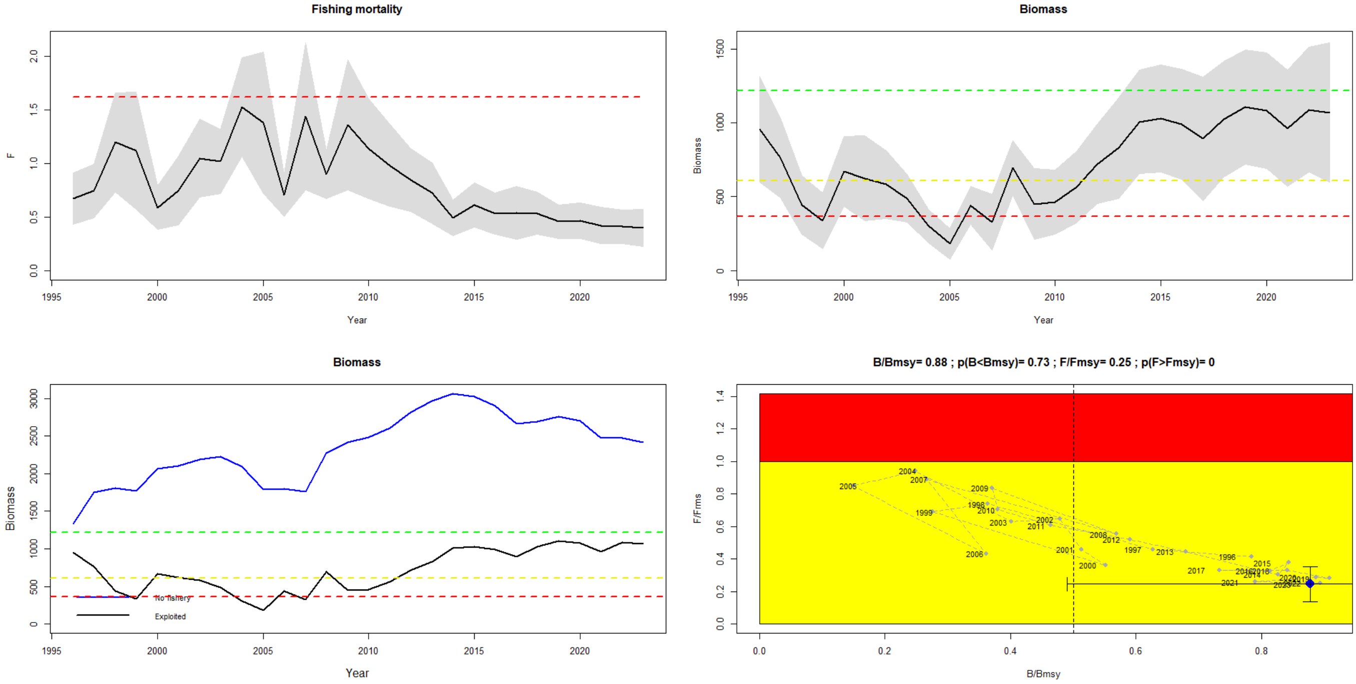

Figure 134. Biomass, fishing mortality, stock depletion and Kobe plot estimated for an especial case for blue and red shrimp (ARA) in the GSA6 with modified growth parameters.

SECTION 4
Results by stock
Small pelagic fishes
Stock assessment results for species in the GSA6

European sardine (*Sardina pilchardus*) PIL

The reproduction of the European sardine occurs between November and February (ICATMAR, 25-05), and recruitment is observed afterwards, in spring and summer.

Input data

The spatial distribution of total landings for European sardine in the Catalan fishing grounds (Figure 135) is located, mainly, in lower coastal areas along the Catalan coast, with no occurrence in the Delta area (the southernmost area of the coast).

Historical European sardine landings in Catalonia from 2002 to 2024 are shown in Figure 136. Landings peaked in 2007 with a great decrease from 2008 to 2010. The lowest recorded landings occurred in 2023, while in 2024, landings recovered to levels comparable to those of 2016—the highest within the last decade.

Annual LFD

After raising the length frequencies obtained with the monitoring program from commercial landings (Table 45), the annual length frequency of European sardine in Catalonia is plotted in Figure 137. The size classes with greater frequencies are about 120 - 130 mm in total length. Although for some bottom trawling métiers in the delta shelf discards of small pelagic fishes were important (Blanco et al. 2023) its biomasses were residual compared to purse seine landings. The SOP validation results are shown in Table 44, while Table 45 summarizes the number of individuals sampled through the ICATMAR monitoring program.

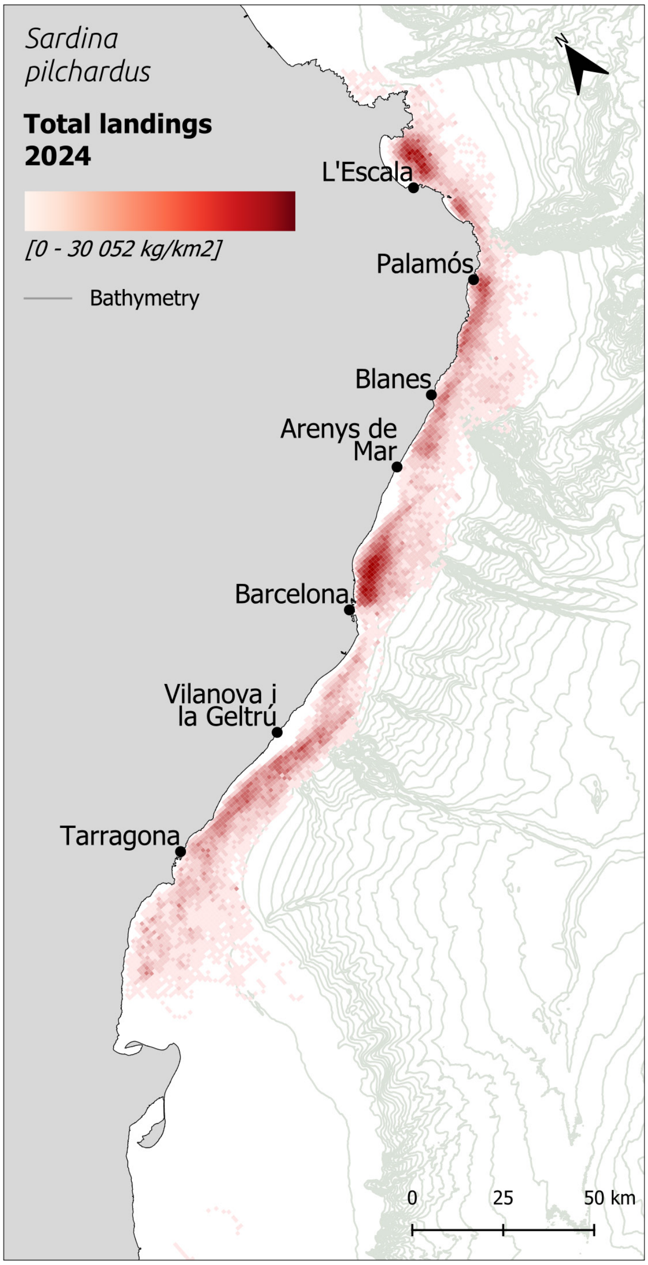

Figure 135. Spatial distribution of landings (kg/km²) for European sardine in the Catalan fishing grounds (North GSA6) in the year analyzed.

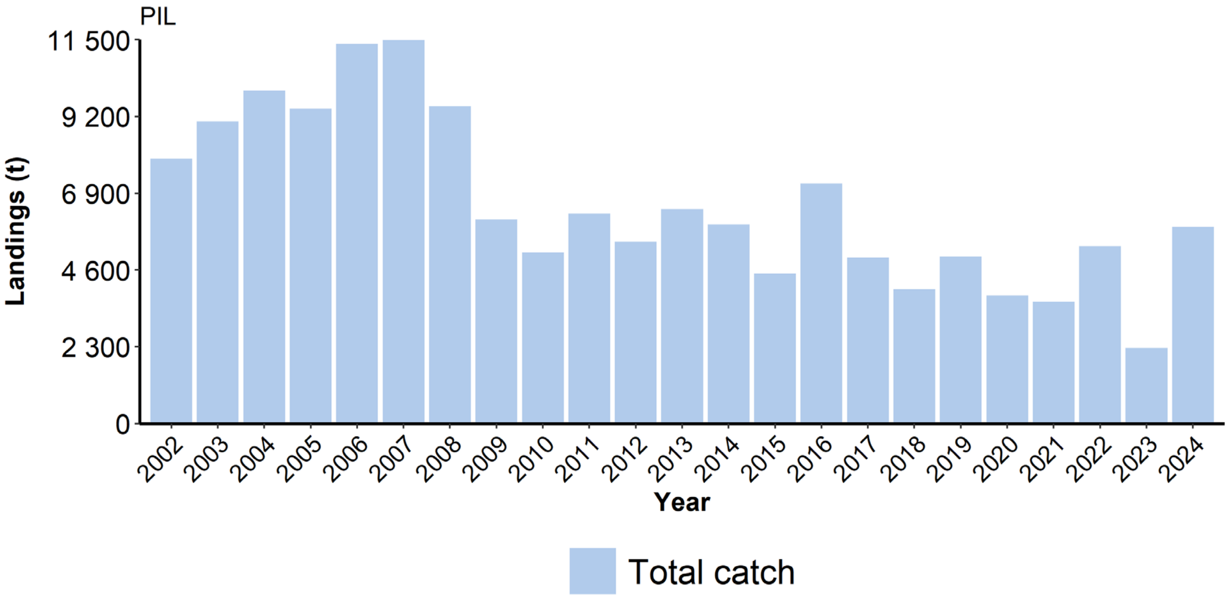

Figure 136. Historical landings (t) for European sardine in Catalonia.

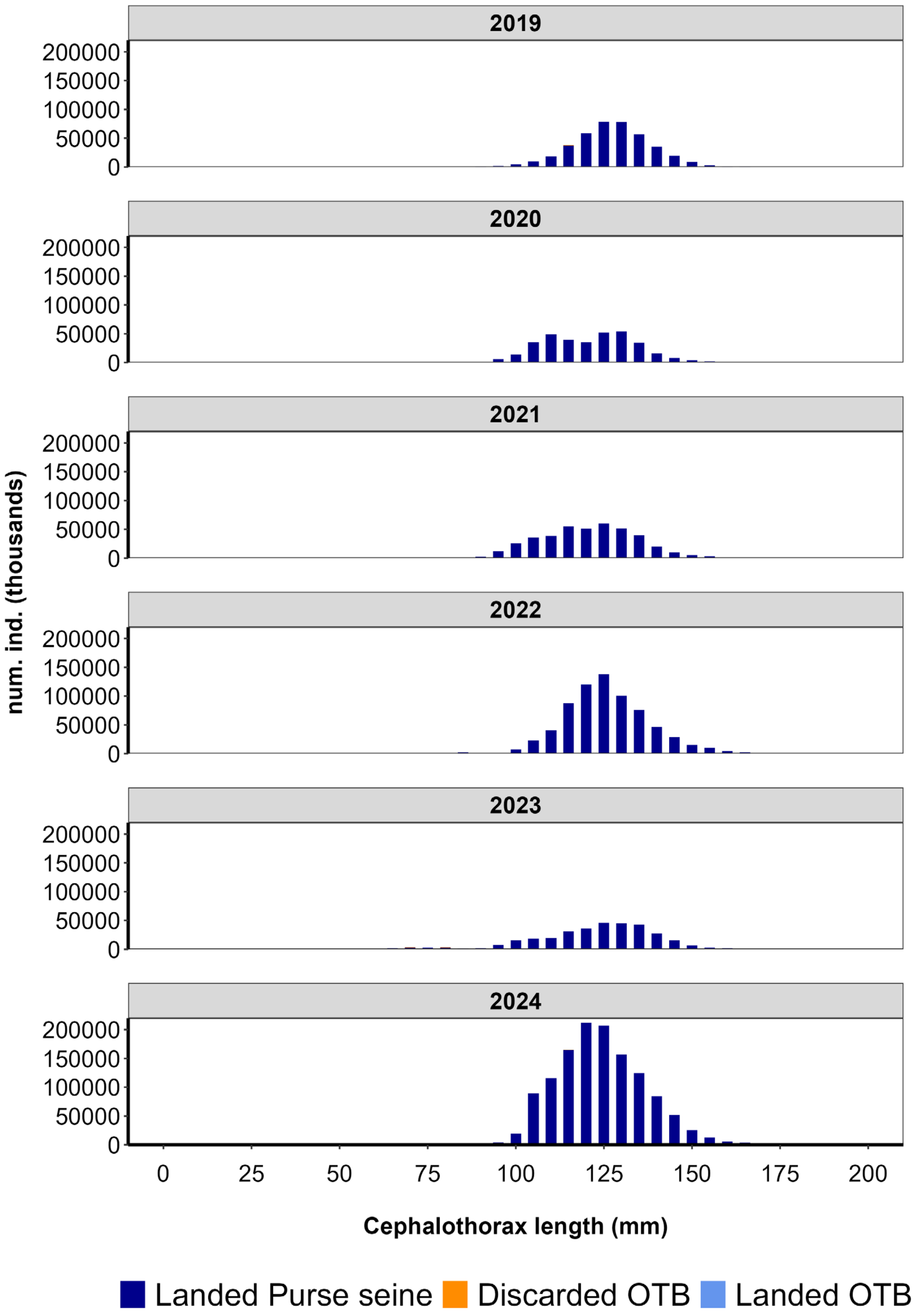

Figure 137. Annual length frequency distributions of European sardine from bottom trawling and small-scale fisheries. The data from purse seine and discards of bottom trawling is raised from ICATMAR dataset.

Table 44. Sum of Products (SOP) validation for European sardine (PIL): The column Calculated Weight in GSA6N (SOP) represents the biomass estimated through the raising process, while Landings refer to the reported landings in NGSA6. The ratio between SOP and landings is known as the Sum of Products (SOP). Values close to 1 indicate that the raising process provides biomass estimates that closely match the reported landings, thereby validating the accuracy of the estimation method.

Species	Year	Catch classification	Calculated weight GSA6N (kg) (SOP)	Gear	Landings in GSA6N (kg)	SOP/Landings
PIL	2021	Landed OTB	Bottom trawl	1802	7513	0.24
PIL	2022	Landed OTB	Bottom trawl	1520	6158	0.25
PIL	2023	Landed OTB	Bottom trawl	1336	6390	0.21
PIL	2024	Landed OTB	Bottom trawl	1178	8134	0.14
PIL	2019	Landed Purse seine	Purse seine	5866388	4974958	1.18
PIL	2020	Landed Purse seine	Purse seine	4295407	3818591	1.12
PIL	2021	Landed Purse seine	Purse seine	4988433	3646690	1.37
PIL	2022	Landed Purse seine	Purse seine	9753224	5302242	1.84
PIL	2023	Landed Purse seine	Purse seine	4324786	2258797	1.91
PIL	2024	Landed Purse seine	Purse seine	16811577	5888806	2.85

Table 45. Number of European sardine individuals sampled by zone and season from ICATMAR monitoring data used to raise the length frequencies.

Fishery	Year	Zone	Winter	Spring	Summer	Autumn	N sampling
			Number individuals sampled				
Artisanal fisheries	2019	North	0	0	1	0	1
Artisanal fisheries	2019	Center	32	3	0	0	2
Artisanal fisheries	2021	North	1	0	0	0	1
Artisanal fisheries	2024	North	2	0	0	0	1
Bottom trawl	2019	South	38	122	404	53	18
Bottom trawl	2020	North	0	0	3	1	2
Bottom trawl	2020	Center	0	0	30	1	2
Bottom trawl	2020	South	7	96	132	94	14
Bottom trawl	2021	North	4	0	4	0	4
Bottom trawl	2021	Center	9	1	15	11	6
Bottom trawl	2021	South	16	85	352	191	17
Bottom trawl	2022	North	0	5	2	1	4
Bottom trawl	2022	Center	4	0	0	38	2
Bottom trawl	2022	South	0	31	182	166	12
Bottom trawl	2023	North	0	8	2	3	3
Bottom trawl	2023	Center	0	70	31	0	2
Bottom trawl	2023	South	7	247	294	29	18
Bottom trawl	2024	North	0	5	1	0	3
Bottom trawl	2024	Center	2	16	89	0	3
Bottom trawl	2024	South	64	135	111	41	21
Purse seine (fish market)	2019	North	826	990	724	610	22
Purse seine (fish market)	2019	Center	800	861	725	690	19
Purse seine (fish market)	2020	North	722	393	936	681	18
Purse seine (fish market)	2020	Center	354	465	817	836	15
Purse seine (fish market)	2021	North	867	878	925	557	21
Purse seine (fish market)	2021	Center	623	370	921	526	17
Purse seine (fish market)	2022	North	979	785	500	407	17
Purse seine (fish market)	2022	Center	699	905	663	561	19
Purse seine (fish market)	2023	North	470	394	485	130	10
Purse seine (fish market)	2023	Center	570	463	598	431	15
Purse seine (fish market)	2024	North	314	425	416	164	9
Purse seine (fish market)	2024	Center	761	542	532	266	15
Purse seine (fishing trips)	2020	North	1800	0	0	0	5
Purse seine (fishing trips)	2020	Center	21	0	0	0	1
Purse seine (fishing trips)	2021	North	0	0	0	974	4
Purse seine (fishing trips)	2021	Center	0	0	219	149	2
Purse seine (fishing trips)	2022	North	581	497	750	11	17
Purse seine (fishing trips)	2022	Center	0	267	193	0	4
Purse seine (fishing trips)	2023	North	1058	942	970	144	23
Purse seine (fishing trips)	2023	Center	78	332	0	0	4
Purse seine (fishing trips)	2023	South	0	0	1	0	1
Purse seine (fishing trips)	2024	North	795	1274	951	683	28
Purse seine (fishing trips)	2024	Center	296	879	111	0	10

Length-Based Spawning Potential Ratio (LBSPR)

Table 46. Biological parameters used in the different LBSPR scenarios for European sardine (PIL). $L_{inf:}$ asymptotic length at which growth is zero, k: growth rate, M: natural mortality, $L_{mat50:}$ length where 50% of individuals are mature, $L_{mat95:}$ length where 95% of individuals are mature.

Species	Scenario	Linf (mm)	Lmat50 (mm)	Lmat95 (mm)	M/K
PIL	1	184	113	135.00	1.37
PIL	2	209	113	135.00	1.48
PIL	3	184	103	123.10	1.37
PIL	4	209	103	123.10	1.48

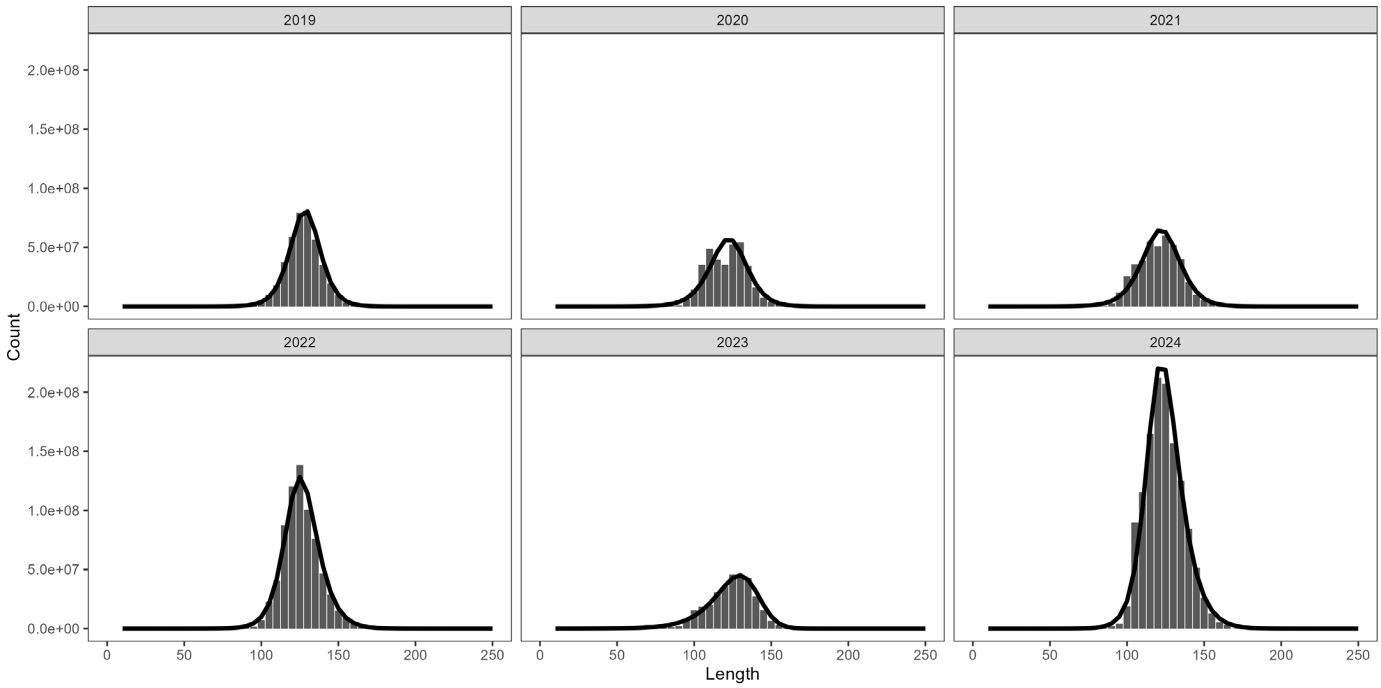

Figure 138. Fit of the data using the LBSPR model for European sardine for each studied year. Grey columns indicate length frequencies. Black lines indicate the fit of the model.

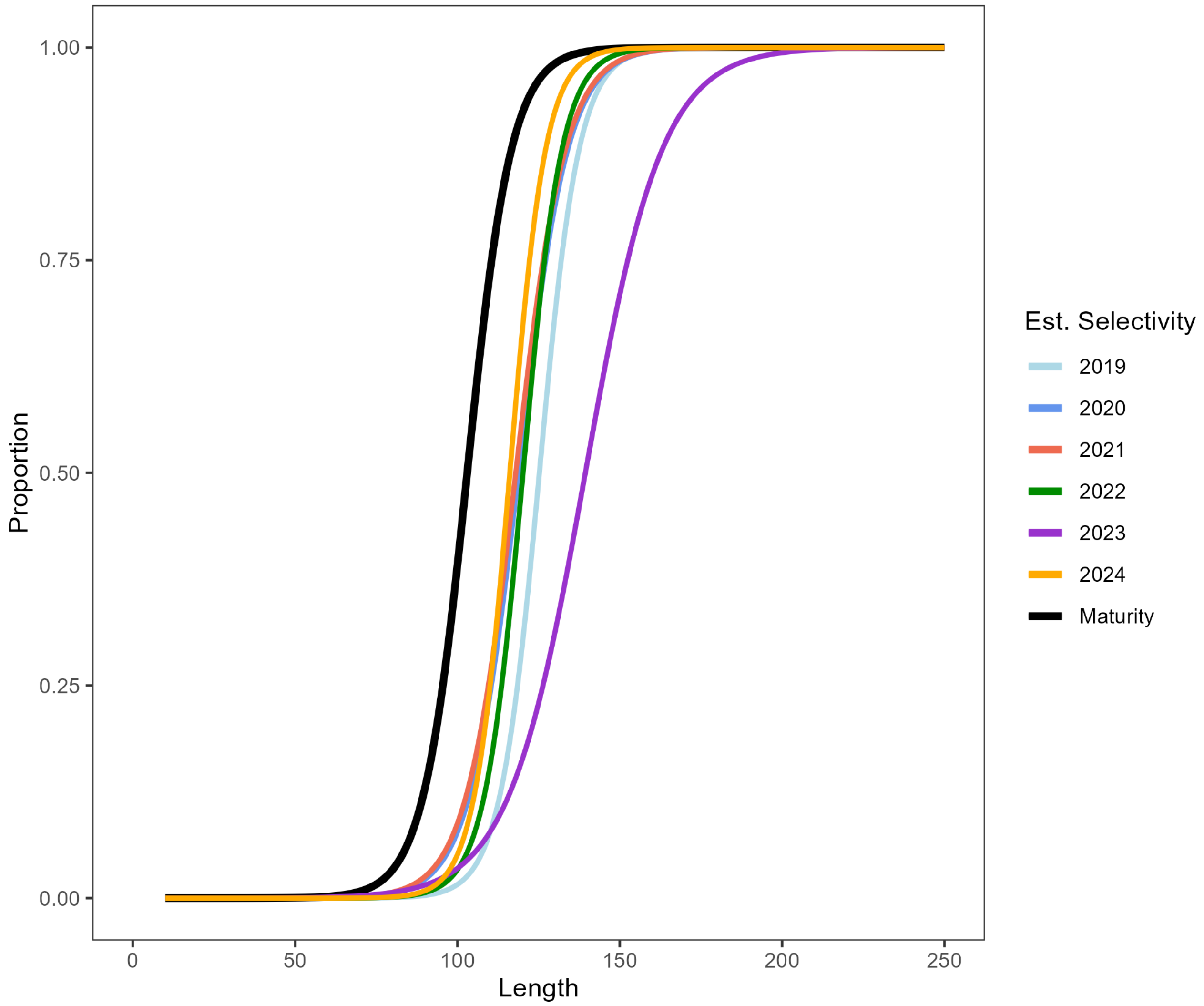

Figure 139. Length curves for European sardine. Black line shows the length curve at maturity. Color lines show the estimated selectivity at length curve predicted by the LBSPR model for selected scenario (3).

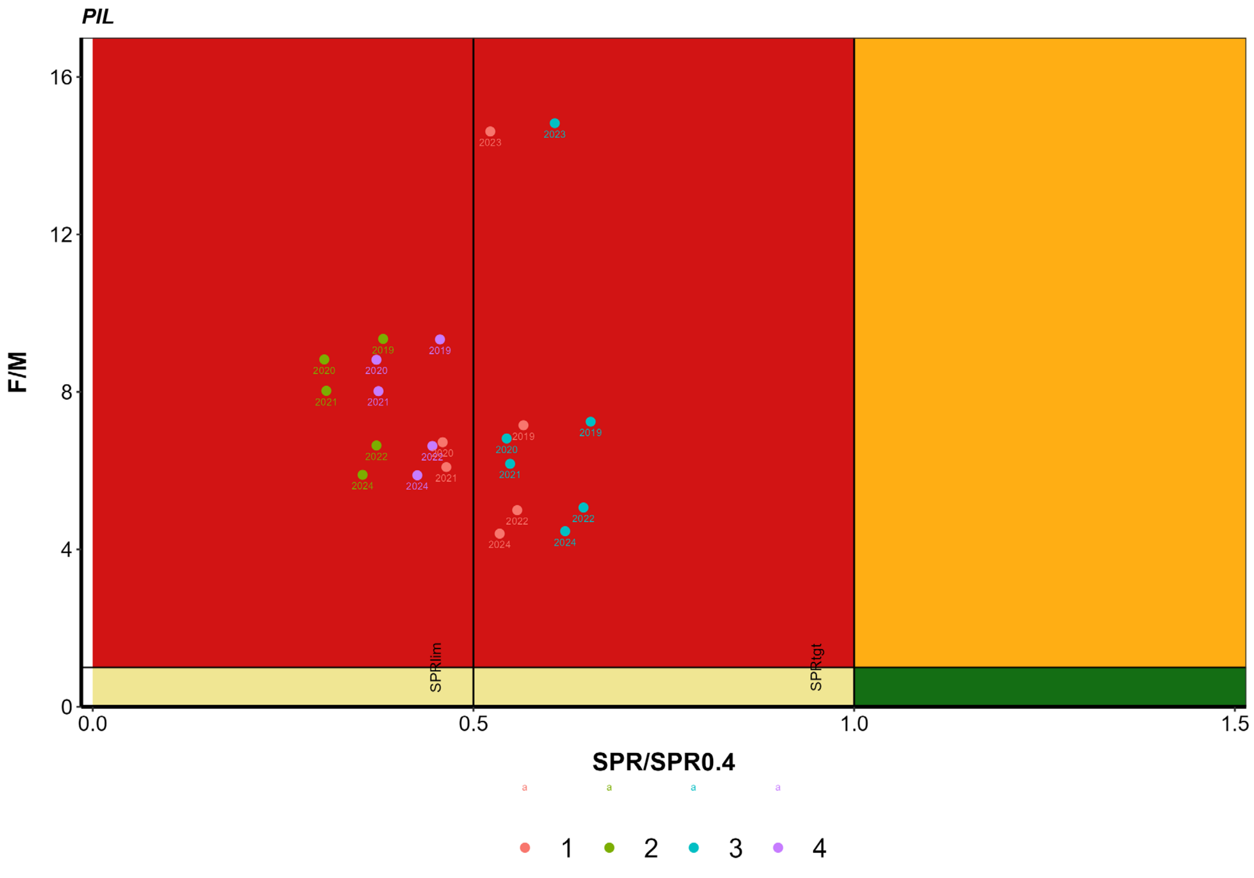

Figure 140. Kobe plot for European sardine by scenario (1-3) and year. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio, F: fishing mortality, M: natural mortality, and F/M: relative fishing mortality.

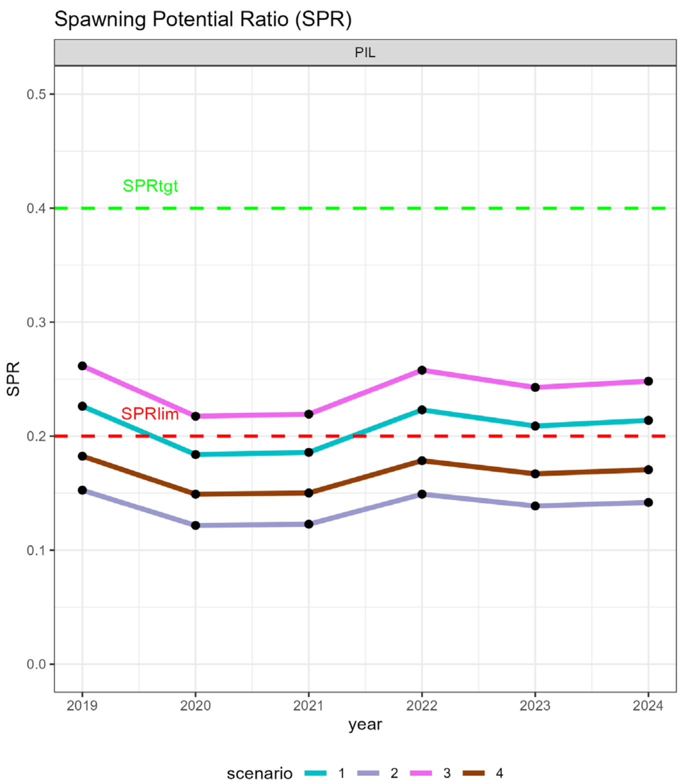

Figure 141. Spawning potential ratio (SPR) per year analyzed for European sardine evaluated with LBSPR model. LBSPR: Length-Based Spawning Potential Ratio. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio. Colored lines show the results for each scenario.

Table 47. LBSPR model results for European sardine with the different scenarios tested for each year analyzed. $SL5_{0:}$ Length where 50% of individuals are caught, SPR: spawning potential ratio and FM: fishing mortality. SD is the standard deviation calculated for each indicator. The selected scenario is highlighted in blue.

spp	scenario	year	SL_{50}	SD	SPR	SD	FM	SD
PIL	1	2019	127.12	0.95	0.23	0.14	7.15	2.75
PIL	1	2020	122.42	2.04	0.18	0.13	6.72	2.75
PIL	1	2021	121.33	1.92	0.19	0.13	6.09	2.49
PIL	1	2022	121.97	0.96	0.22	0.15	5.00	1.98
PIL	1	2023	142.86	2.22	0.21	0.14	14.62	6.50
PIL	1	2024	118.36	1.33	0.21	0.14	4.40	1.80
PIL	2	2019	127.11	0.86	0.15	0.10	9.35	2.98
PIL	2	2020	122.73	1.64	0.12	0.09	8.83	2.98
PIL	2	2021	121.64	1.57	0.12	0.09	8.03	2.70
PIL	2	2022	122.07	0.84	0.15	0.10	6.64	2.14
PIL	2	2023	143.26	1.74	0.14	0.09	19.28	6.99
PIL	2	2024	118.64	1.10	0.14	0.10	5.89	1.96
PIL	3	2019	127.13	0.97	0.26	0.15	7.24	2.81
PIL	3	2020	122.44	2.13	0.22	0.14	6.82	2.82
PIL	3	2021	121.36	1.98	0.22	0.14	6.18	2.54
PIL	3	2022	121.99	0.98	0.26	0.15	5.06	2.02
PIL	3	2023	142.85	2.31	0.24	0.15	14.83	6.65
PIL	3	2024	118.39	1.37	0.25	0.15	4.46	1.84
PIL	4	2019	127.13	0.84	0.18	0.11	9.33	2.94
PIL	4	2020	122.77	1.61	0.15	0.10	8.82	2.93
PIL	4	2021	121.68	1.54	0.15	0.10	8.02	2.65
PIL	4	2022	122.09	0.82	0.18	0.11	6.63	2.11
PIL	4	2023	143.29	1.70	0.17	0.10	19.27	6.86
PIL	4	2024	118.67	1.08	0.17	0.10	5.88	1.93

Model setting and results

Scenarios

Four scenarios were applied considering different growth parameters and natural mortality from GFCM working groups (Table 46). In scenarios 3, L_{mat50} correspond to ICATMAR dataset (ICATMAR, 25-05).

Fitted data

The length frequency distribution fit per year is shown in Figure 138. The model generally follows the mode for all years but it overestimates some length classes in the middle mode part and underestimates small individuals in 2020 and 2021. Also, in 2020, there was a decrease in the number of individuals, mainly for medium-length classes.

Selectivity

The outputs of the model for the selectivity of the fishery are shown for each scenario in Table 47. The output for the selected scenario is also plotted with L_{mat50} and SL_{50} in Figure 139. In all scenarios, the fishery is fishing above or similar to L_{mat50}.

Reference points

Although the model is very sensitive to changes in growth parameters and maturity, the stock is below or near SPR_{lim} (= 0.2) (Table 47 and Figure 141). For scenarios 2 and 4, the stock is below SPR_{lim}. For scenarios 1 and 3, the stock is around SPR_{lim}. The Kobe plot for European sardine (Figure 140) shows the stock status through the years, with no clear trend. The stock is, in all cases, located in the red zone, meaning that it is overfished and under overfishing.

Final scenario

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBSPR model.

Length-based Bayesian Biomass (LBB)

Scenario

Three scenarios were applied considering different growth parameters and natural mortality from GFCM working groups (Table 48). In scenarios 3, L_{mat50} correspond to ICATMAR data (ICATMAR, 24-05).

Table 48. Biological parameters used in the different LBB scenarios for European sardine (PIL). $L_{inf:}$ Asymptotic length, M/k: ratio between natural mortality and growth rate, $L_{mat50:}$ length where 50% of individuals are mature.

Specie	Scenario	Linf (cm)	M/k	Lmat50 (cm)
PIL	1	18.4	1.367	11.3
	2	20.9	1.483	11.3
	3	18.4	1.367	10.3
	4	20.9	1.483	10.3

As LFD and L_{mat} originated from ICATMAR data, scenario three was selected to provide final advice for the LBB model.

Fitted data

The length frequency distribution fit per year is shown in Figure 142. The model generally follows the mode for all years. Also, in 2020, there was a decrease in the number of individuals, mainly for medium-length classes.

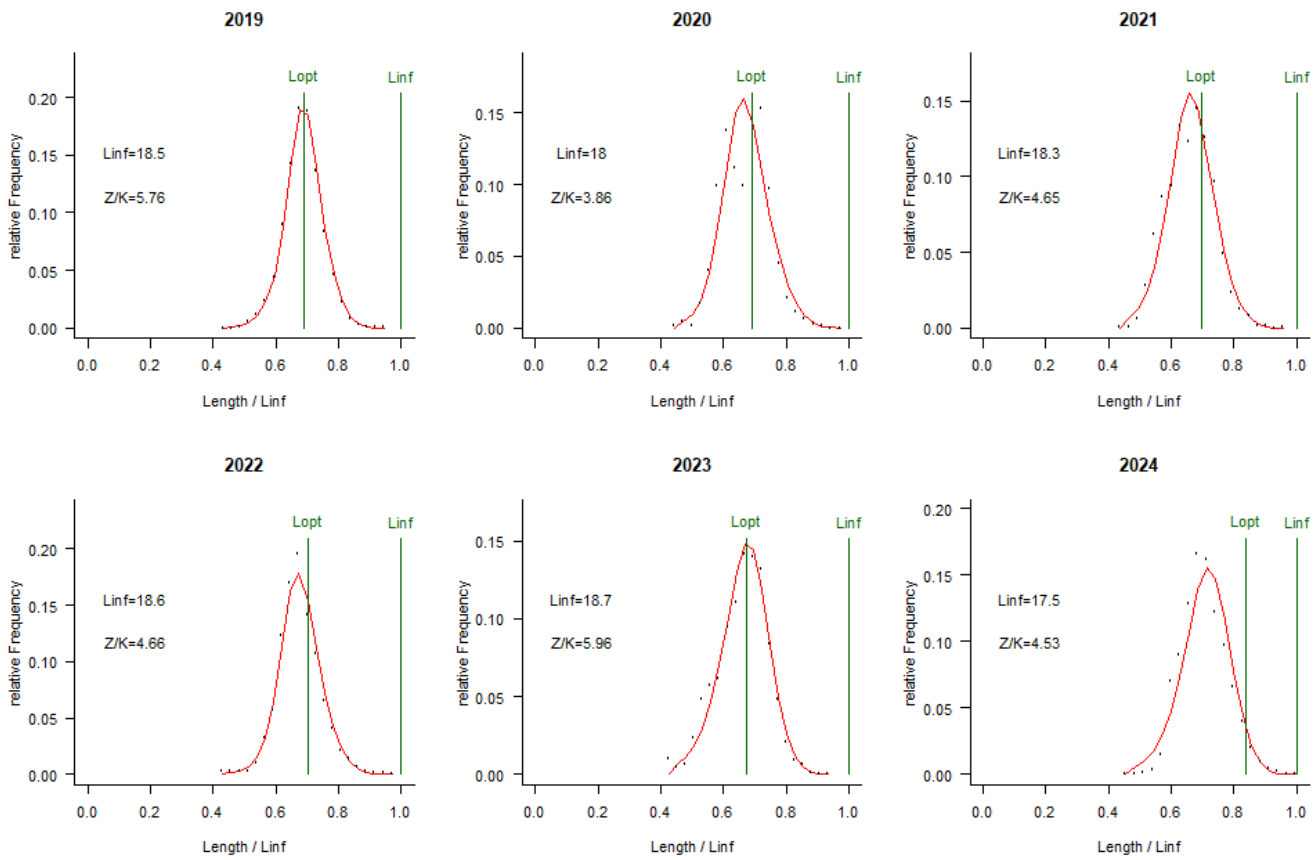

Figure 142. Fit of the data using the LBB model for European sardine (PIL) for each year in scenario 3. Red line indicates the fit of the model.

Reference points

Summary of the graphical results are in Figure 143. The upper left plot shows that the aggregated estimated length at first capture (L_c) is 11.2 cm, above the L_{mat} (10.3 cm) as seen in the left lower plot (L_c: dotted black line) for the whole series. The upper middle and right panels show that the L_{mean} is near from L_{opt}, which is also shown in the lower left plot (L_{mean}: bold black line). Lower middle and right plots show that the relative fishing pressure (F/M) and relative biomass (B/B_0) are far from sustainable levels. These results require further analysis, since other factors might be affecting the stock dynamics. More details related to these results are in Table 49..

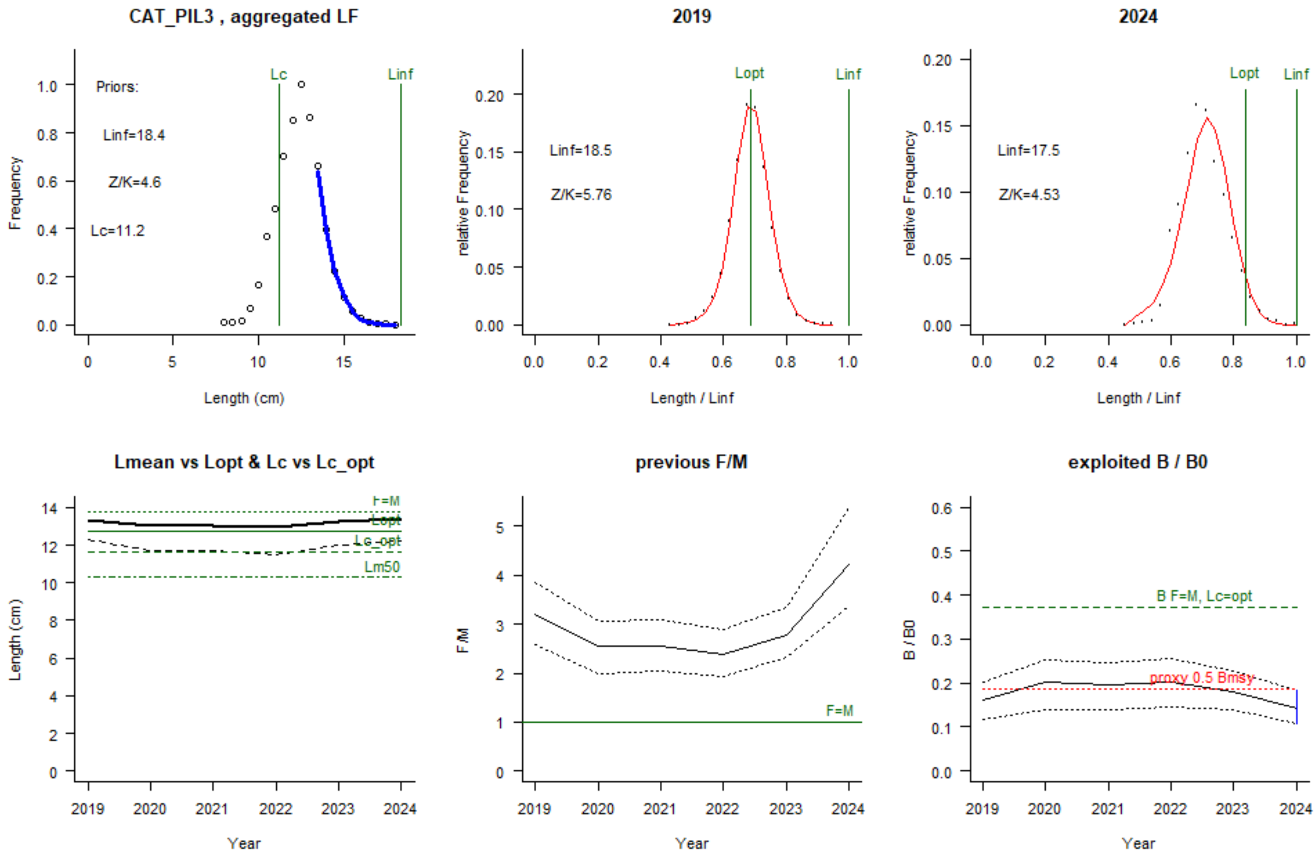

Figure 143. Summary output from LBB for European sardine (PIL) scenario 3.

Table 49. LBB model results for European sardine (PIL) with the different scenarios tested for each year analyzed. $L_{mean:}$ mean length of individuals, $L_{opt:}$ length at optimal yield, $L_{c:}$ length at first capture, $L_{c\_opt:}$ length at first capture at optimal yield, $L_{95th}/L_{inf:}$ ratio of the 95th percentile to asymptotic length, F/M: fishing mortality relative to natural mortality, $B/B_{0:}$ exploited biomass relative to unexploited biomass, $B/B_{msy:}$ exploited biomass relative to maximum sustainable yield biomass, $C_{mature:}$ proportion of mature individuals in the catch.

Specie	Scenario	Year	Lmean/Lopt	Lc/Lc_opt	L95th/Linf	F/M	B/B0	B/Bmsy	C%mature
PIL	1	2024	0.99	1.00	0.97	4.20	0.14	0.38	82%
	2	2024	0.94	0.93	0.89	5.00	0.10	0.26	82%
	3	2024	0.99	1.00	0.97	4.20	0.14	0.38	98%
	4	2024	0.94	0.93	0.89	5.00	0.10	0.26	98%

Stochastic Production model in Continuous Time (SPiCT)

The GFCM working group on small pelagics in 2024 has already completed the stock assessment for GSA6 for small pelagics. For this report, an effort was made for the first time to compile historical data on anchovy in Catalonia (Bas et al., 1955; Anuario de pesca del Mediterráneo Español, 1962-1970; Martin, 1991), and more recent data from EU fleet register provided by the European Commission (Reg. EU 2017/218), Catalan daily commercial fishing landings provided by the Spanish Ministry of Agriculture, Fisheries and Food and Catalan Government; European Commission, Joint Research Centre (JRC) (2025), and most recent available GFCM Stock Assessment Form (SAF) for PIL in GSA6 (RY2023). After that, a SPiCT model was run to estimate the stock status in the area and also compare the results with those in GSA6.

For European sardine, input data on catches were available from 1946 to 2022. Here, we assume that the total biomass trends for the time series are equivalent to those in GSA6, so two indices were used: ECOMED, an autumn acoustic survey from 1996 to 2009, and MEDIAS, a summer acoustic survey from 2009 to 2023 (Figure 144). Additionally, a landings per unit effort (LPUE) index was used (from 1990 to 2023), with units expressed in kg per vessel. This assessment reference year is 2023, so no available data for the biomass index in 2024 is available.

As for the other species, a double-axis plot (Figure 145) was presented to compare trends between catches and indices (Biomass and LPUE).

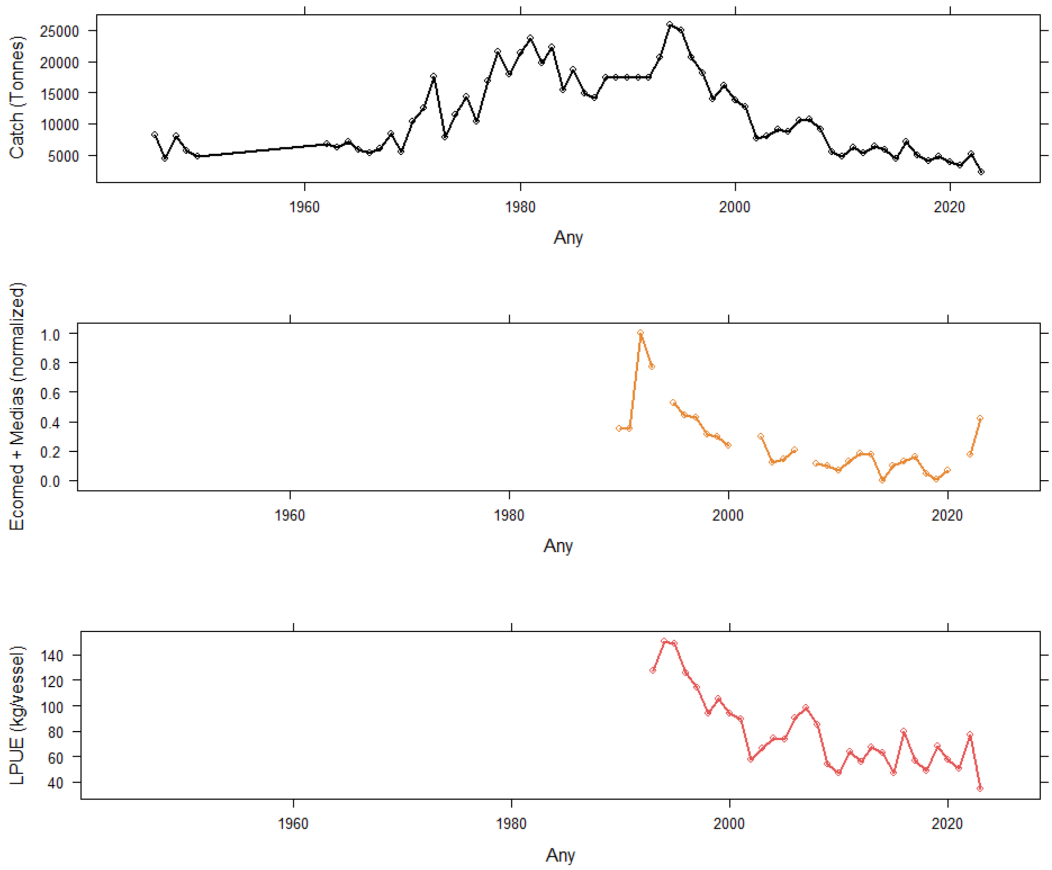

Figure 144. Data available for the assessment for European sardine in Catalonia to run SPiCT model. Top: Catch data from 1946 to 2023. Centre: Ecomed and MEDIAS acoustic surveys normalized from 1996 to 2008 and 2009 to 2023 respectively, and bottom LPUE index from 1990 to 2023.

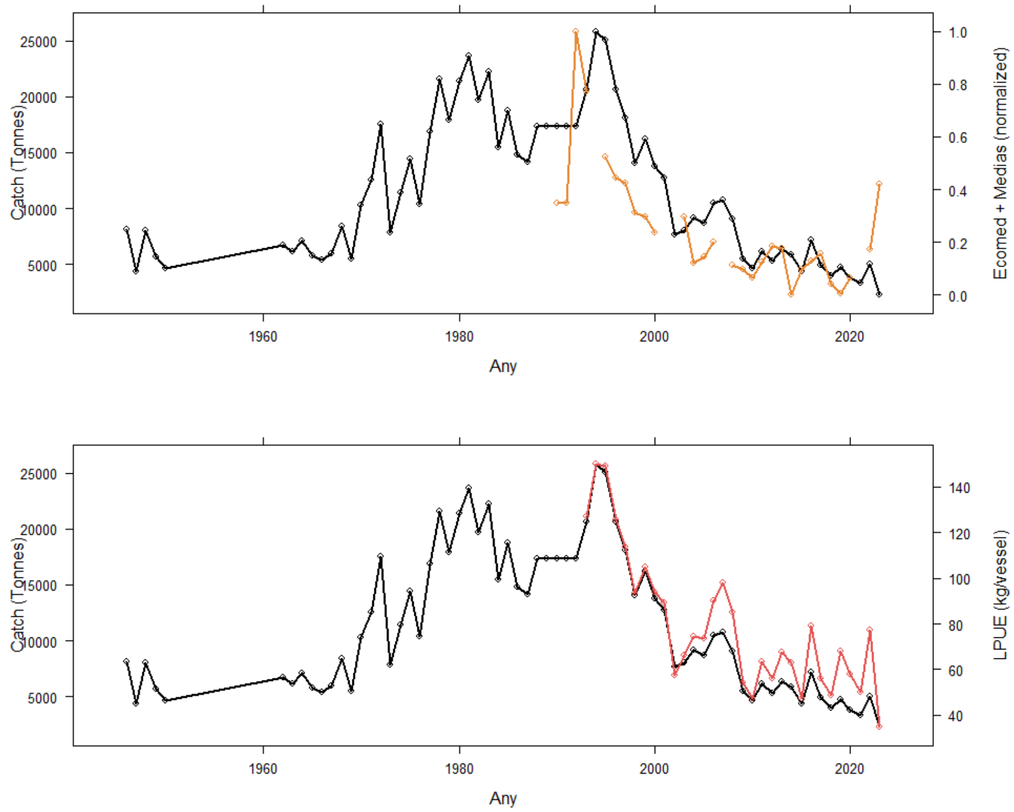

Figure 145. Double axis plot to compare trends between catch and Ecomed and MEDIAS index and catch (top) and LPUE index and catch (bottom) for European sardine in Catalonia.

Although only the final scenario was presented, different scenarios were tested:

- **Scenario 1:** landings started in 1946, using Ecomed, MEDIAS and LPUE as indices, and a BK prior of 0.5.
- **Scenario 2:** landings started in 1946, using Ecomed and MEDIAS as indices, and a BK prior of 0.5.
- **Scenario 3:** landings started in 1962, using Ecomed, MEDIAS and LPUE as indices, and a BK prior of 0.5.
- **Scenario 4:** landings started in 1946 and filling gaps between 1951-1961 with mean values (1951 and 1961), using Ecomed, MEDIAS and LPUE as indices, and a BK prior of 0.5.

A final plot comparison for scenarios 1 and 2, using the longest time series and considering or not considering the LPUE index, is shown in Figure 146. Scenario 2 was chosen as the final scenario, as Scenario 1 did not accurately represent the current status of this stock, and the uncertainty is greater. Additionally, it is not reliable that the stock is for the all-time series $B > B_{msy}$ and $F < F_{msy}$. For scenarios 3 and 4, the model did not pass the diagnostics.

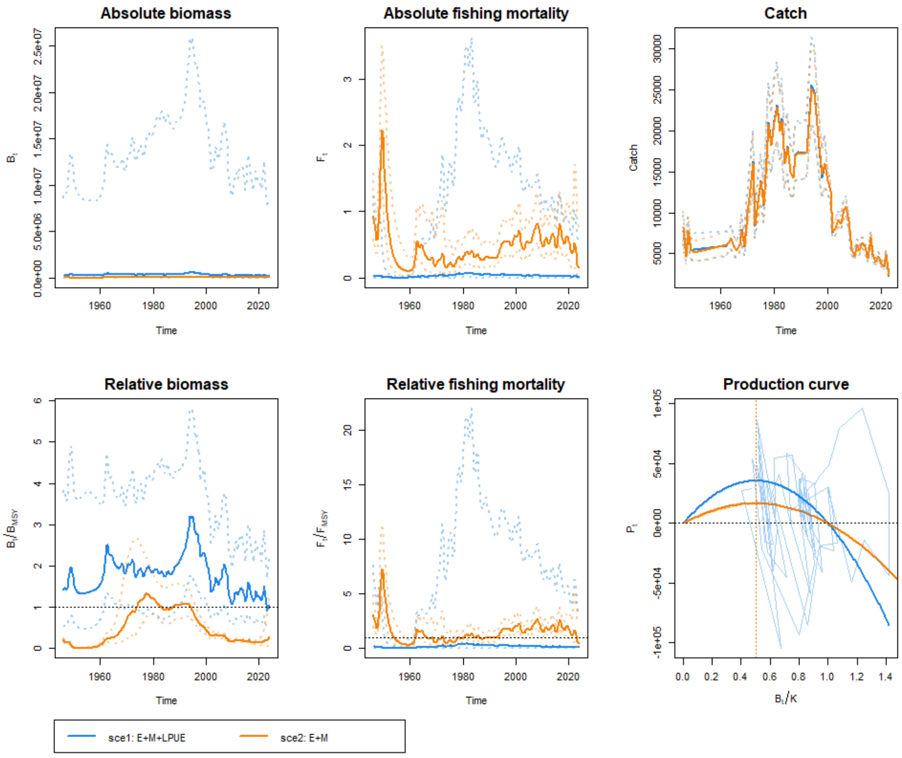

Figure 146. Scenarios comparison for European sardine in Catalonia.

Final scenario

Table 50 shows the settings used for the final scenario. Among other settings, BK fraq prior was 0.5 because at the beginning of the time series, European sardine was a target species for the fishery. Additionally, before 2000, a standard deviation factor of 2 was used because the data were less reliable than after that time.

Table 50. Priors settings for European sardine in Catalonia for final scenario.

Type	Prior	Description	Assignment	Mean	Standard deviation	Comment
Fishery dynamic	logbkfrac	B/K fraction (depletion)	-	Log(0.5)	0.5	Target species at the beginning of the time series. Same BK value as used for GSA6 (SAF, GFCM2024). A sensitivity analysis was done for this prior, resulting in a similar stock status in the current year.
Relative standard deviation time series (input data)	stdevfacC	Standard deviation factor for catches	<2000	2	1	Landing data for years before 2002 were less reliable.
	stdevfacI	Standard deviation factor for indices		1	1	
Stock dynamic	logr	Population growth	-	Log(0.46)	0.26	Fishlife
	logn	Shape of production curve	-	Log(2)	-	Shaefer
Error	logsdc	Catch error	-	Log(0.05)	0.3	
	logsdf	Fishing mortality error	-	Log(4)	0.5	
	logsdb	Process error	-	Log(0.15)	0.5	
	logsdi	Observation error	-	Log(0.2)	0.5	Same for all indices

The final scenario input data are shown in Figure 147 , and the final summary assessment results are presented in Figure 148. The results show a decreasing trend in biomass below the reference point since 1990, with a slight improvement since 2020, but still below B_{lim}. For fishing mortality, the estimated values have been below 1 since 2022, although they are pretty close to the F_{msy}.

All diagnostics can be checked in Figure 149, Figure 150, Figure 151, Figure 152 and Figure 153. The chosen scenario didn't meet all of the model diagnostics, such as high Mohnr values for the retrospective analysis and a MASE of 1.13, but the trends are similar to those in GSA6. Further analysis and scenarios will be needed to improve the final diagnostics of the SPiCT assessment for this stock. A sensitivity analysis for the final scenario was performed, testing r prior, bkfrac, process error, and observation error to assess the model's robustness within these priors. All these plots and results for the other scenarios will be available at https://github.com/ICATMAR.

Final scenario advice

Final scenario advice is presented in Figure 154 and Table 51, which outlines the indicators for European sardine in Catalonia in 2023, based on the GFCM advice framework. The assessment results need to be considered as qualitative, although they were in line with the ones in the GSA6 assessment, where European sardine Biomass < B_{msy} and Fishing mortality < F_{msy}.

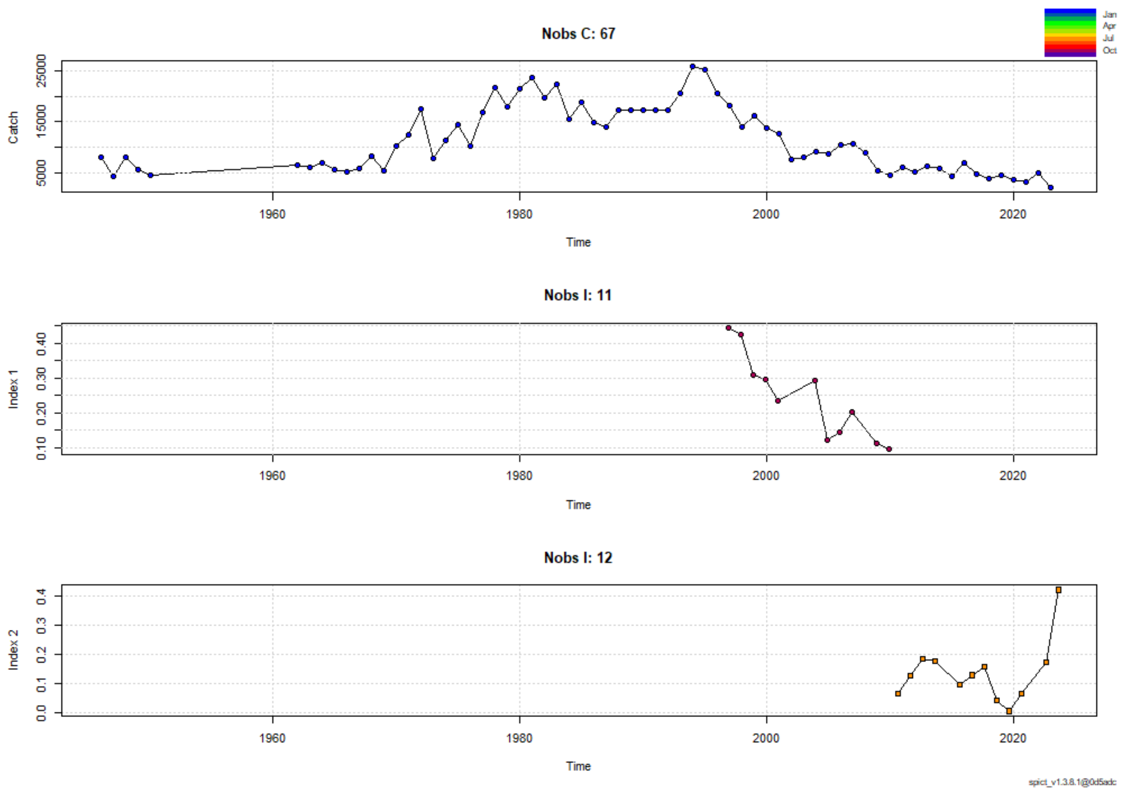

Figure 147. Input data for SPiCT model for European sardine in Catalonia. Top: catch in tons per year since 1946, center: biomass index derived from the Ecomed survey from 1994 to 2008 and the MEDIAS survey from 2009 to 2022.

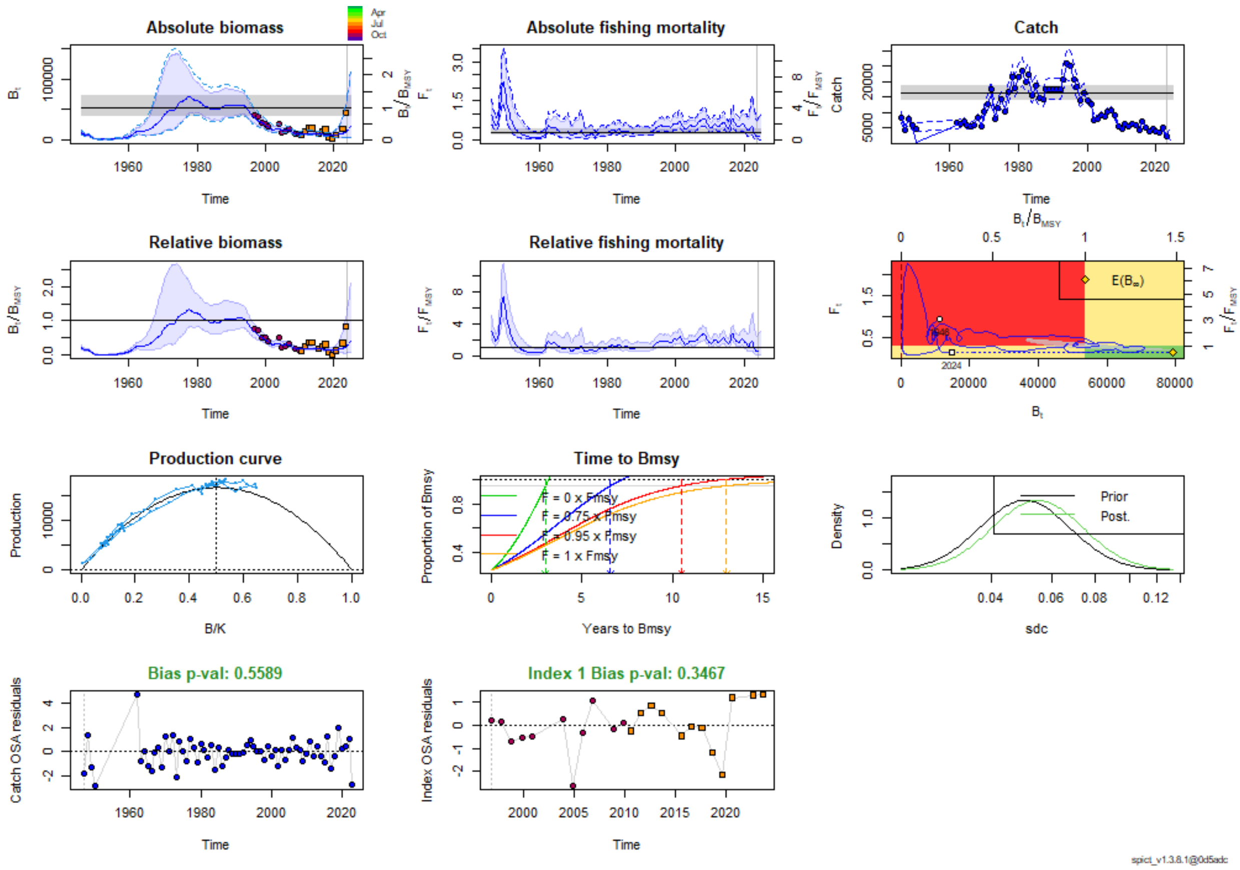

Figure 148. Stock assessment summary for SPiCT model for European sardine in Catalonia for the final scenario.

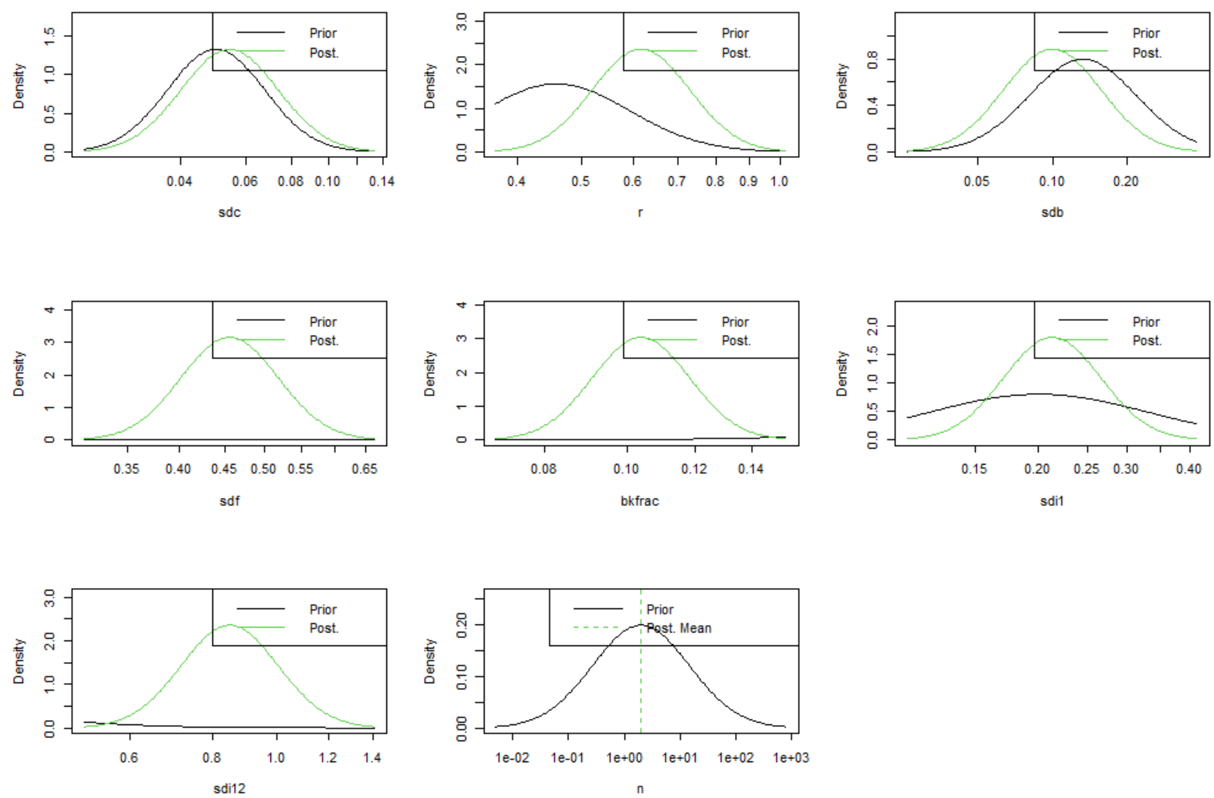

Figure 149. Estimated priors and posteriors for the updated assessment for European sardine in Catalonia for the final scenario.

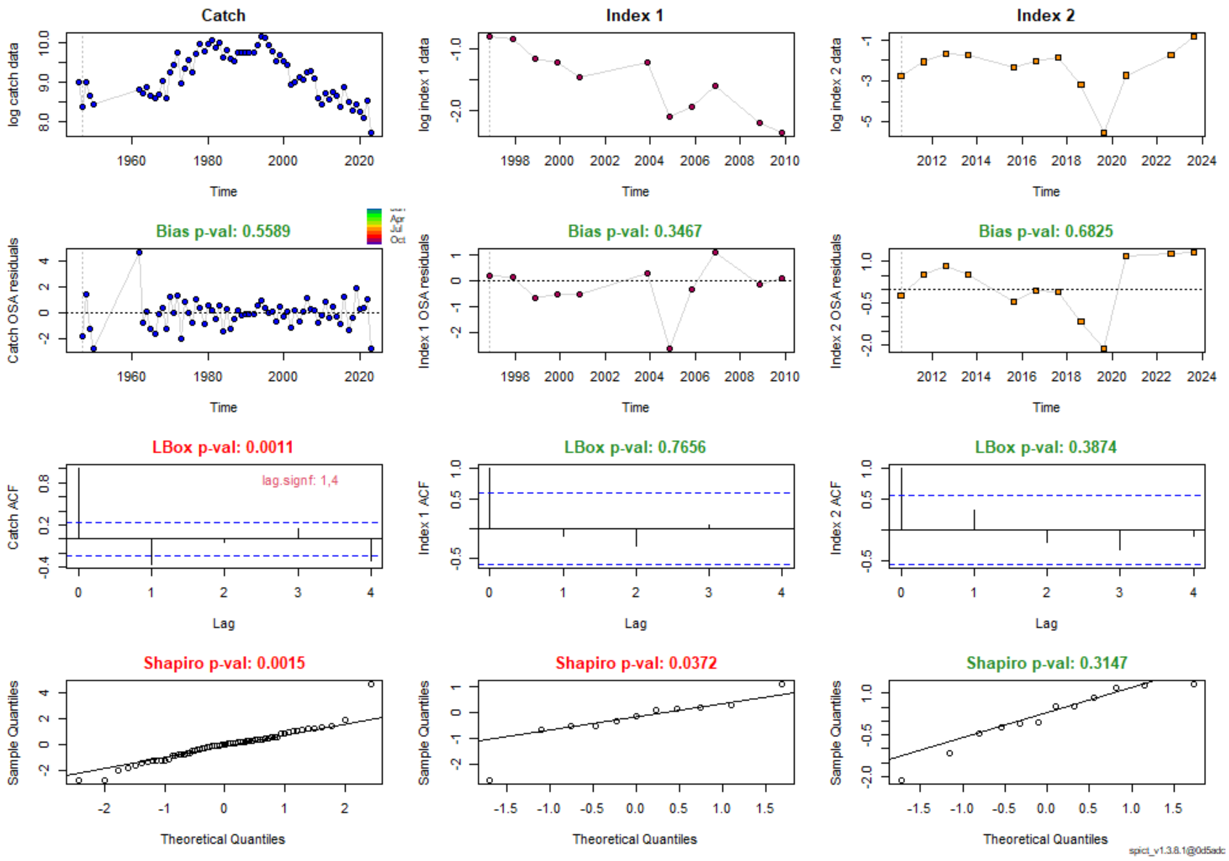

Figure 150. One-step-ahead residuals for the model for European sardine in Catalonia for the final scenario.

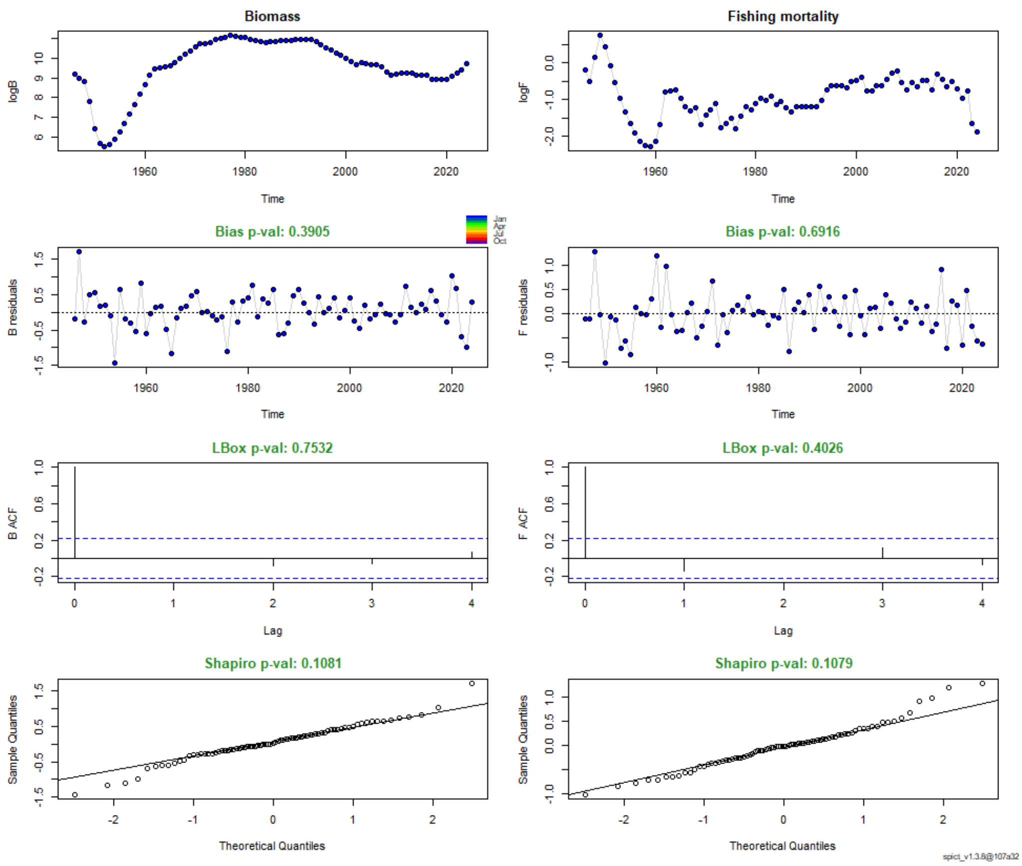

Figure 151. Process error deviations for the model for European sardine in Catalonia for the final scenario.

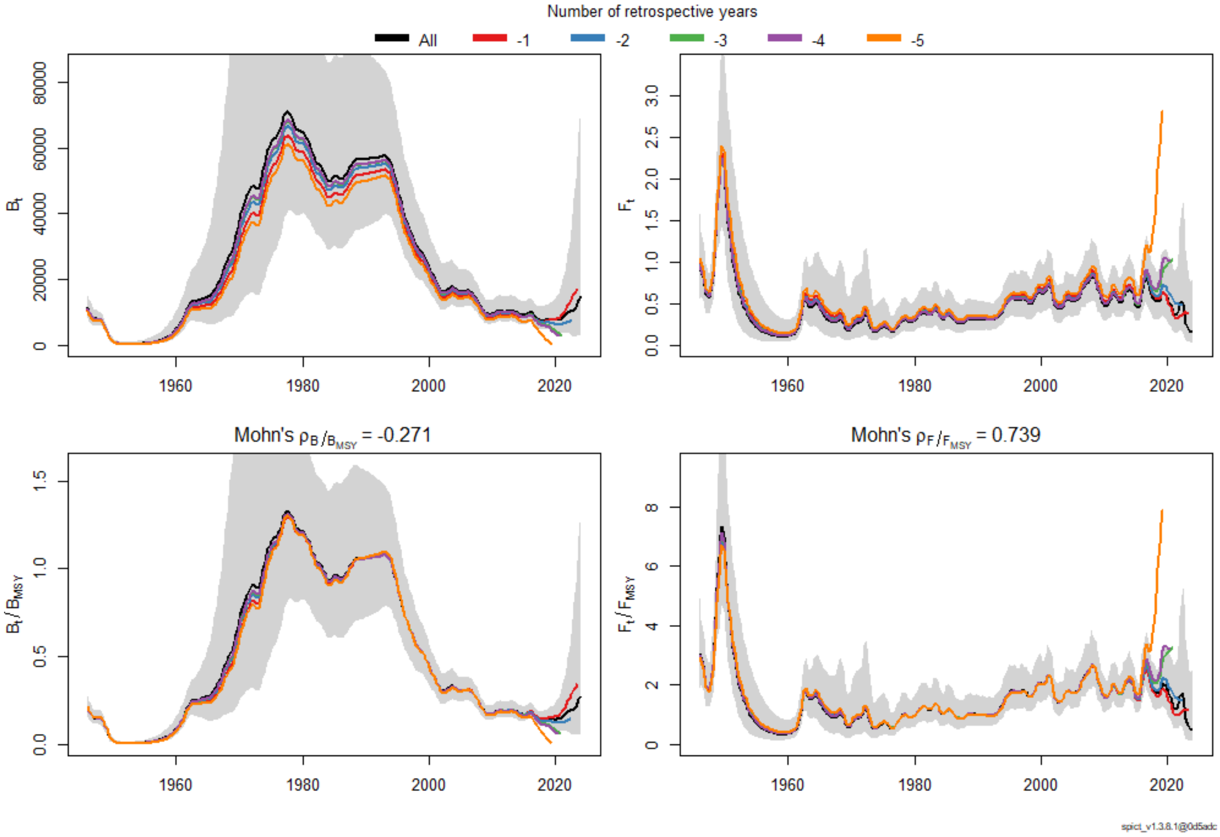

Figure 152. Retrospective analysis for European sardine in Catalonia for the final scenario.

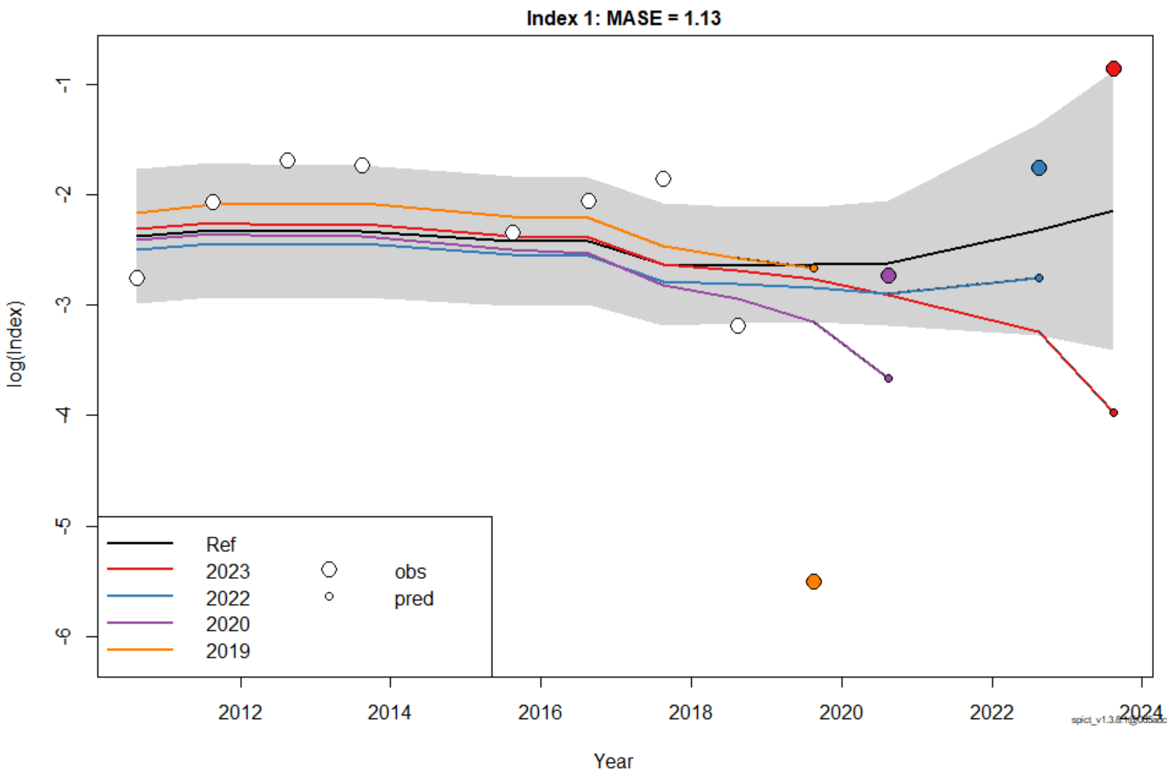

Figure 153. Hindcasting for the model for European sardine in Catalonia for the final scenario.

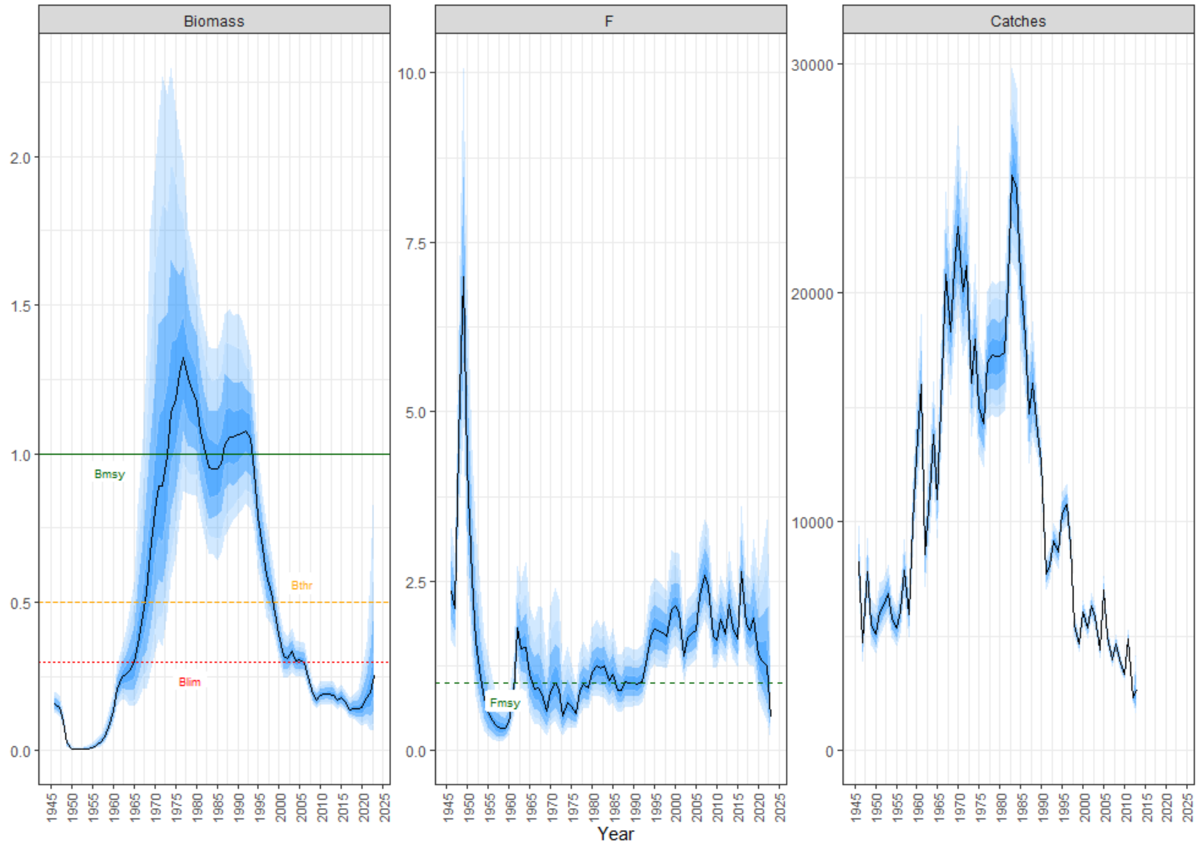

Figure 154. Advice for the final scenario for European sardine in Catalonia: Historical and current stock status regarding F_{msy}, B_{msy} and B_{lim}.

Table 51. Indicators in 2023 from SPiCT for European sardine in Catalonia for the final scenario.

Species	Year	Catch (t)	F/F_{msy}	B/B_{msy}	B/B_{pa}	B/B_{lim}
PIL	2023	2632	0.50	0.25	0.51	0.85

Anchovy (*Engraulis encrasicolus*) ANE

The reproduction of the anchovy occurs between May and September (ICATMAR, 24-05), and recruitment is observed afterwards, in fall and winter.

Input data

The spatial distribution of total landings for anchovy in the Catalan fishing grounds (Figure 155) is located, mainly, in lower coastal areas along the Catalan coast, with no occurrence in the Delta area (the southernmost area of the coast).

Historical anchovy landings in Catalonia from 2002 to 2024 are shown in Figure 156. From 2002 to 2008, there was a decrease in landings. Afterwards, the landings increased until 2018, when they inverted the trend and decreased again.

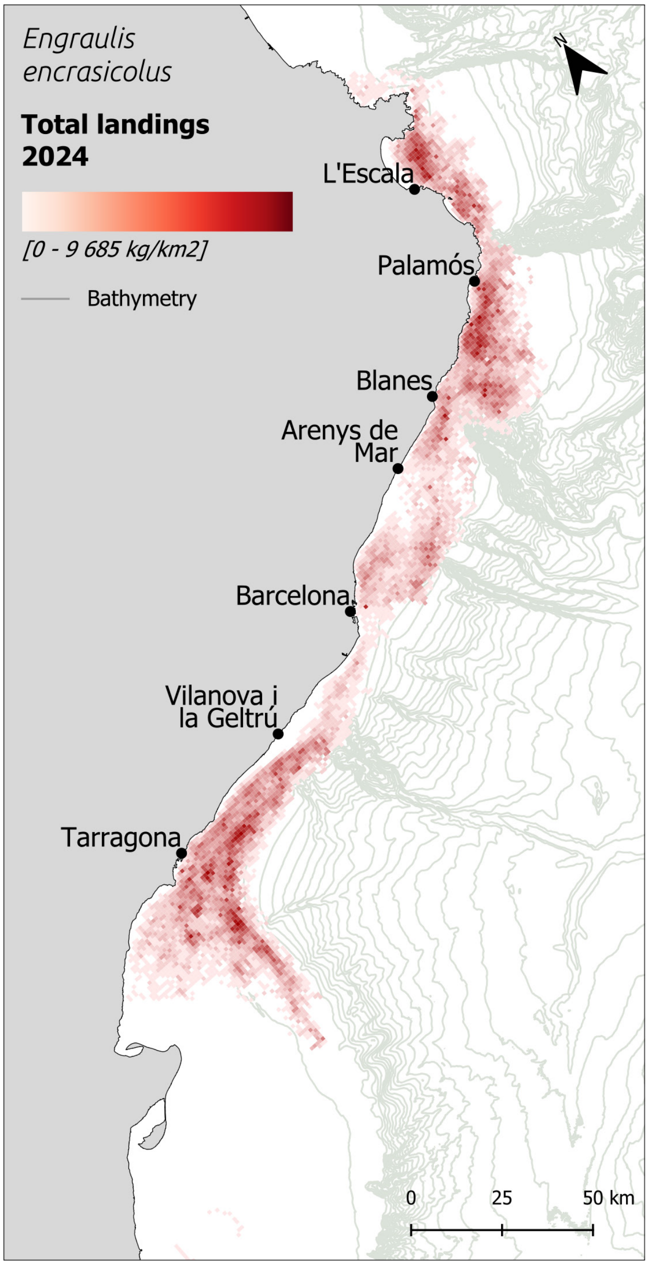

Figure 155. Spatial distribution of landings (kg/km^2) for anchovy in the Catalan fishing grounds (North GSA6) in the year analyzed.

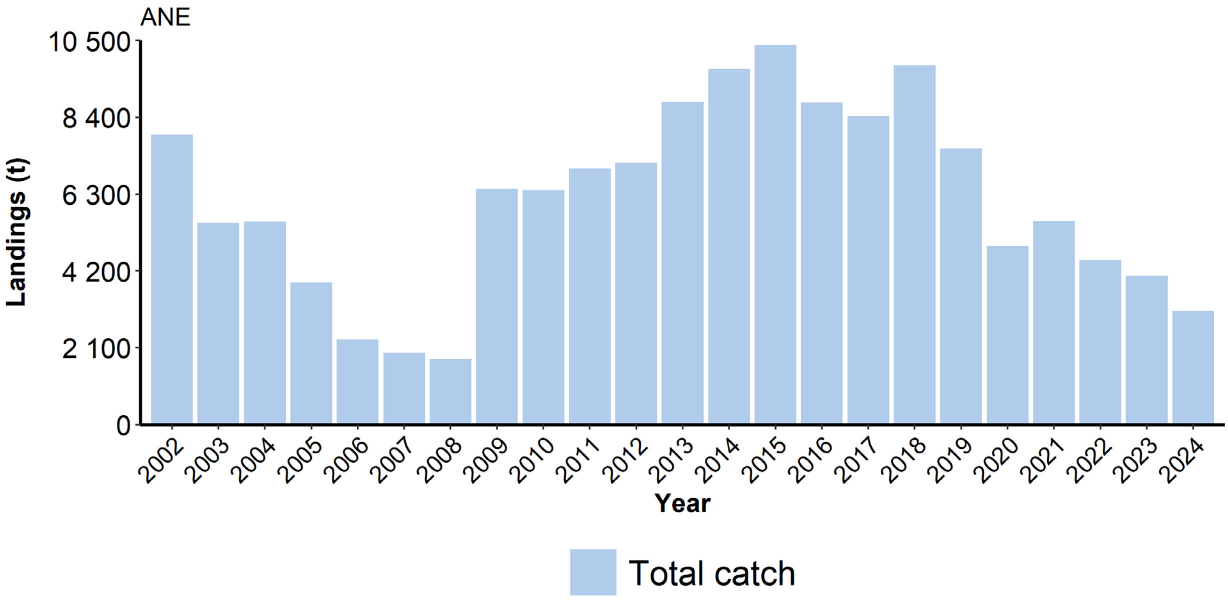

Figure 156. Historical landings (t) for anchovy in Catalonia.

Annual LFD

After raising the length frequencies obtained with the monitoring program from commercial landings, the annual length frequency of anchovy in Catalonia is plotted in Figure 157. There is no clear consistency in the length frequency of small and big individuals. Although for some bottom trawling métiers in the delta shelf discards of small pelagic fishes were important (Blanco et al. 2023) its biomasses were residual compared to purse seine landings. The SOP validation results are shown in Table 52, while Table 53 summarizes the number of individuals sampled through the ICATMAR monitoring program.

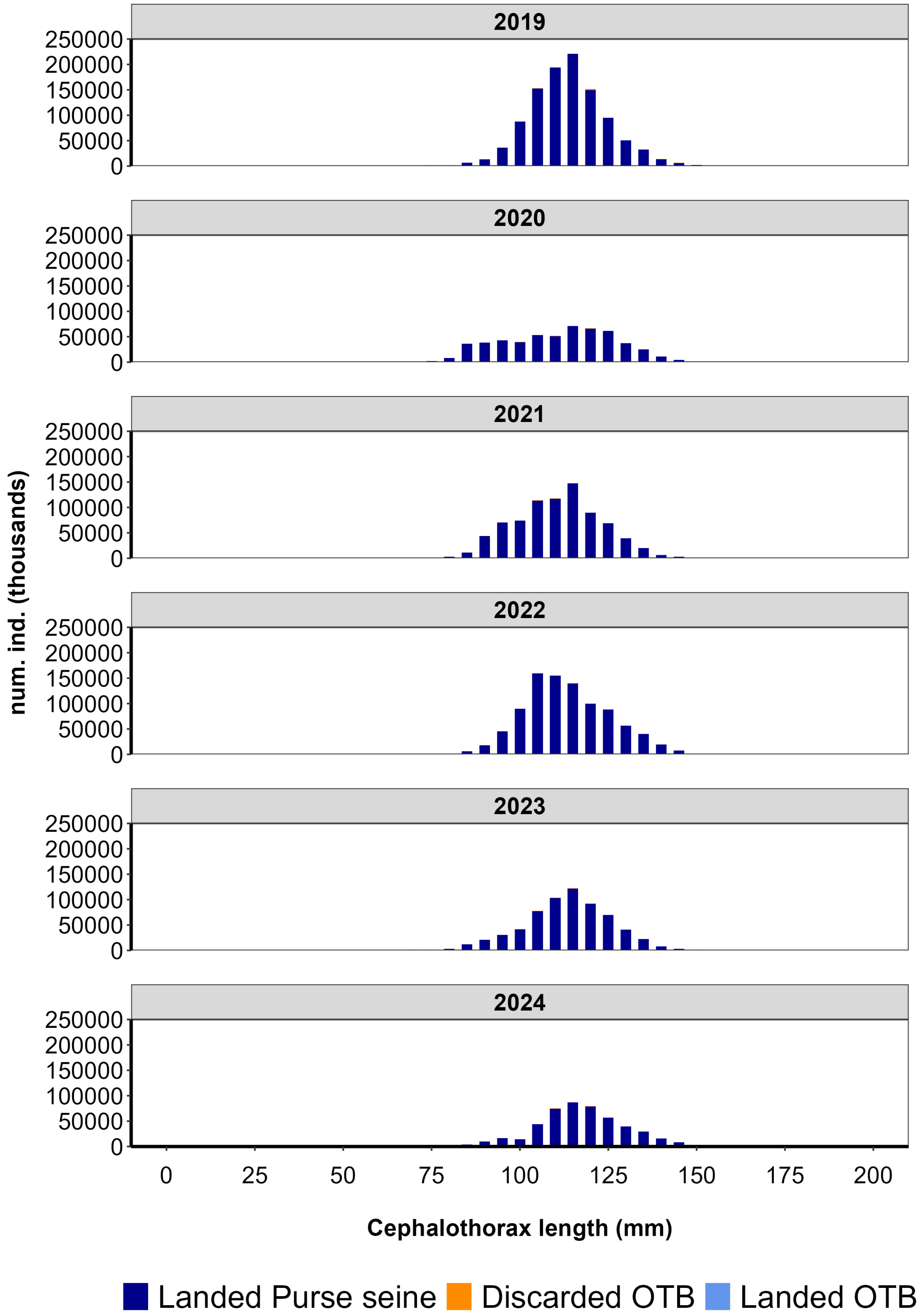

Figure 157. Annual length frequency distributions of anchovy from purse seine and discards of bottom trawling fisheries. The data from bottom trawling is raised from ICATMAR dataset.

Table 52. Sum of Products (SOP) validation for anchovy (ANE): The column Calculated Weight in GSA6N (SOP) represents the biomass estimated through the raising process, while landings refer to the reported landings in NGSA6. The ratio between SOP and landings is known as the Sum of Products (SOP). Values close to 1 indicate that the raising process provides biomass estimates that closely match the reported landings, thereby validating the accuracy of the estimation method.

Species	Year	Catch classification	Gear	Calculated weight GSA6N (kg) (SOP)	Landings in GSA6N (kg)	SOP/Landings
ANE	2019	Landed OTB	Bottom trawl	11616	25895	0.45
ANE	2020	Landed OTB	Bottom trawl	2460	18558	0.13
ANE	2021	Landed OTB	Bottom trawl	5941	14199	0.42
ANE	2022	Landed OTB	Bottom trawl	3877	8987	0.43
ANE	2023	Landed OTB	Bottom trawl	3088	6258	0.49
ANE	2024	Landed OTB	Bottom trawl	1991	11407	0.17
ANE	2019	Landed Purse seine	Purse seine	9970737	7517351	1.33
ANE	2020	Landed Purse seine	Purse seine	4953129	4856577	1.02
ANE	2021	Landed Purse seine	Purse seine	7061563	5541606	1.27
ANE	2022	Landed Purse seine	Purse seine	8714443	4484937	1.94
ANE	2023	Landed Purse seine	Purse seine	6140892	4057504	1.51
ANE	2024	Landed Purse seine	Purse seine	5061611	3089884	1.64

Table 53. Number of anchovy individuals sampled by zone and season from ICATMAR monitoring data used to raise the length frequencies.

Fishery	Year	Zone	Winter	Spring	Summer	Autumn	N samplings
			Number individuals sampled				
Artisanal fisheries	2019	Center	0	1	0	0	1
Artisanal fisheries	2020	North	0	0	0	19	1
Artisanal fisheries	2021	North	0	3	0	1	2
Artisanal fisheries	2021	Center	105	0	0	0	3
Artisanal fisheries	2022	Center	0	13	0	0	1
Artisanal fisheries	2023	North	0	0	0	30	1
Artisanal fisheries	2023	Center	39	0	0	0	1
Bottom trawl	2019	North	0	2	81	0	3
Bottom trawl	2019	Center	1	0	163	25	4
Bottom trawl	2020	North	0	0	5	0	3
Bottom trawl	2020	Center	0	1	1	51	3
Bottom trawl	2020	South	10	273	266	177	14
Bottom trawl	2021	North	3	52	5	0	8
Bottom trawl	2021	Center	56	6	30	47	4
Bottom trawl	2021	South	72	143	192	297	19
Bottom trawl	2022	North	3	40	91	0	4
Bottom trawl	2022	Center	0	13	0	0	1
Bottom trawl	2022	South	8	259	155	180	17
Bottom trawl	2023	North	0	2	1	0	2
Bottom trawl	2023	Center	0	31	0	0	1
Bottom trawl	2023	South	60	277	109	1	17
Bottom trawl	2024	North	0	5	3	0	3
Bottom trawl	2024	Center	0	20	40	0	3
Bottom trawl	2024	South	174	130	140	19	20
Purse seine (fish market)	2019	North	1052	1729	1282	929	20
Purse seine (fish market)	2019	Center	929	1278	944	1078	17
Purse seine (fish market)	2020	North	1333	649	1562	1129	17
Purse seine (fish market)	2020	Center	1008	496	804	854	14
Purse seine (fish market)	2021	North	1307	1100	1416	565	19
Purse seine (fish market)	2021	Center	778	1037	1083	968	18
Purse seine (fish market)	2022	North	576	1637	867	752	16
Purse seine (fish market)	2022	Center	710	1337	1135	399	16
Purse seine (fish market)	2023	North	986	551	697	387	12
Purse seine (fish market)	2023	Center	907	1327	384	269	13
Purse seine (fish market)	2024	North	396	579	343	240	8
Purse seine (fish market)	2024	Center	707	801	649	325	13
Purse seine (fishing trips)	2020	North	878	0	0	0	4
Purse seine (fishing trips)	2020	Center	77	0	0	0	1
Purse seine (fishing trips)	2021	North	0	0	0	211	3
Purse seine (fishing trips)	2022	North	1755	153	939	573	15
Purse seine (fishing trips)	2022	Center	430	383	471	834	9
Purse seine (fishing trips)	2023	North	967	185	887	525	13
Purse seine (fishing trips)	2023	Center	254	193	0	0	2

Length-Based Spawning Potential Ratio (LBSPR)

Model setting and results:

Scenarios

Three scenarios were applied considering different growth parameters and natural mortality from GFCM working groups (Table 54). In scenario 3, L_{mat50} correspond to ICATMAR data (ICATMAR, 25-05).

Fitted data

The length frequency distribution fit per year is shown in Figure 158. The model generally follows the modal lengths across all years; however, in some length classes, the observed data fall outside the range of the simulated estimates.

Selectivity

The outputs of the model for the selectivity of the fishery are shown for each scenario in Table 55. The output of the selected scenario (3) is also plotted with L_{mat50} and SL_{50} in Figure 159. In all scenarios, the fishery is fishing above L_{mat50}.

Reference points

For all scenarios assessed the stock's SPR remains above the SPR_{lim} (= 0.2) but below SPR_{tgt} (= 0.4), except for scenario 3, which exceeds SPR>0.4 in 2024 (Table 55 and Figure 161). The Kobe plot for anchovy (Figure 160) shows the stock status over time, with no clear trend. The stock is located in the red zone in most years, indicating overfishing condition, except in 2022 and 2024, when fishing mortality decreases and spawning potential increases. Although the stock appears to be moving toward a sustainable reference point, it remains in an overfished state.

Final scenario

As LFD and L_{mat} originated from ICATMAR data, scenario 3 was selected to provide final advice for the LBSPR model.

Table 54. Biological parameters used in the different LBSPR scenarios for anchovy (ANE). $L_{inf:}$ asymptotic length at which growth is zero, k: growth rate, M: natural mortality, $L_{mat50:}$ length where 50% of individuals are mature, $L_{mat95:}$ length where 95% of individuals are mature.

Species	Scenario	Linf (mm)	Lmat50 (mm)	Lmat95 (mm)	M/K
ANE	1	155	99	117.00	1.43
ANE	2	155	96	114.00	1.43
ANE	3	155	82	97.40	1.43

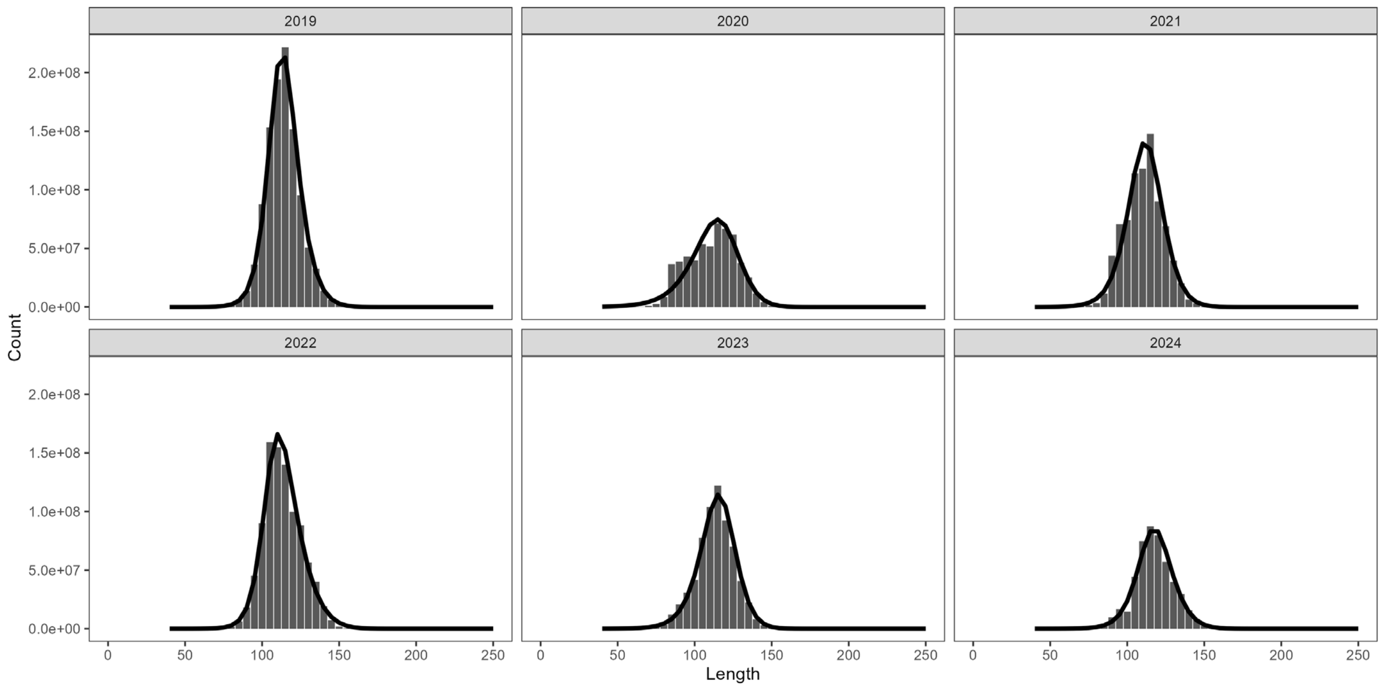

Figure 158. Fit of the data using the LBSPR model for anchovy for each studied year. Grey columns indicate length frequencies. Black lines indicate the fit of the model.

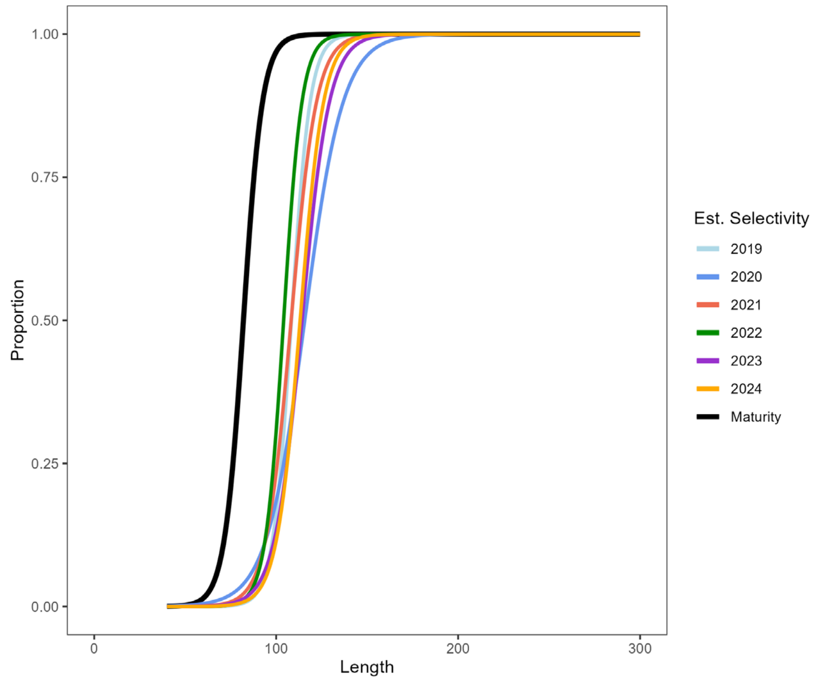

Figure 159. Length curves for anchovy. Black line shows the length curve at maturity. Color lines show the estimated selectivity at length curve predicted by the LBSPR model for selected scenario (3) .

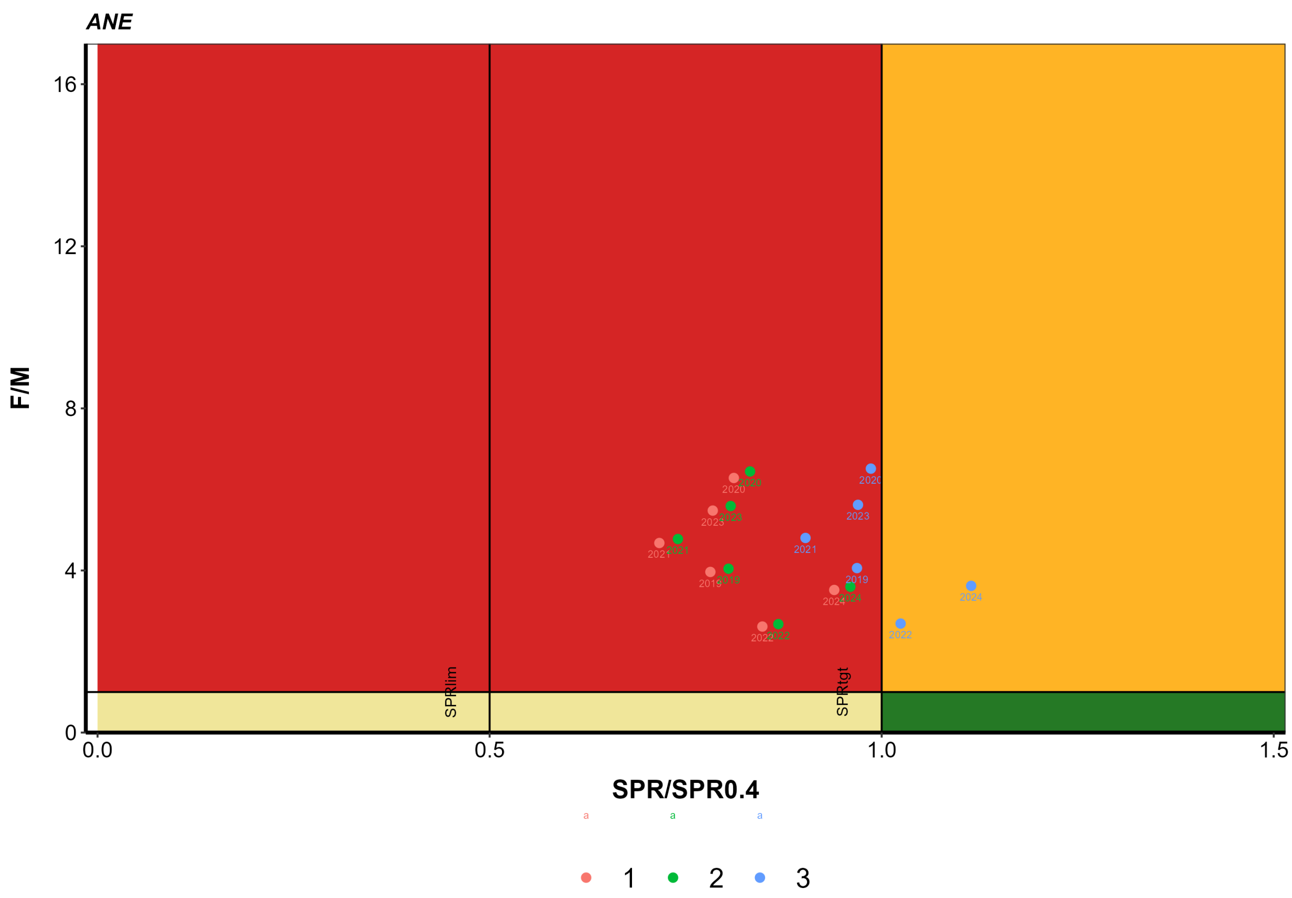

Figure 160. Kobe plot for anchovy by scenario (1-3) and year. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio, F: fishing mortality, M: natural mortality, and F/M: relative fishing mortality.

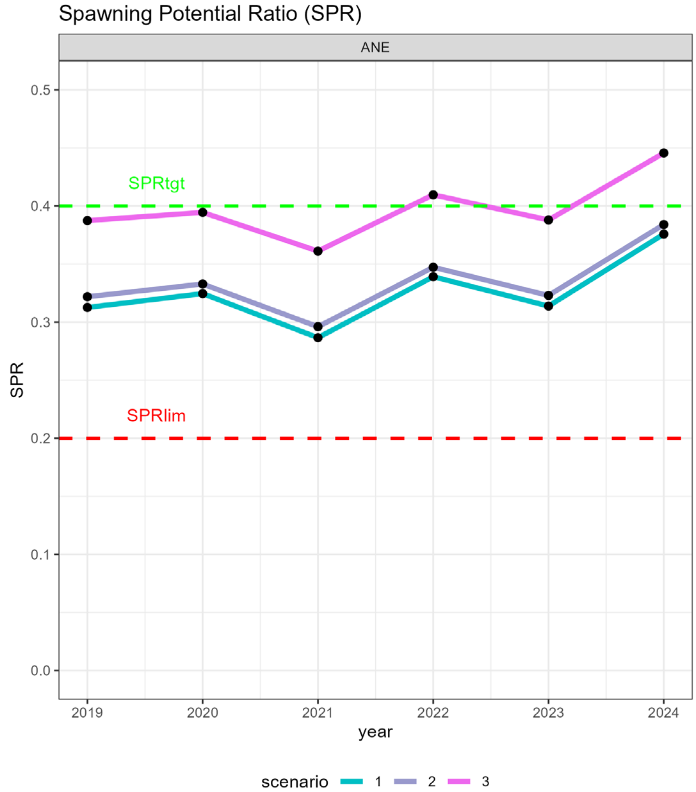

Figure 161. Spawning potential ratio (SPR) per year analyzed for anchovy evaluated with LBSPR model. LBSPR: Length-Based Spawning Potential Ratio. $SPR_{lim:}$ limit spawning potential ratio, $SPR_{tgt:}$ target spawning potential ratio. Colored lines show the results for each scenario.

Table 55. LBSPR model results for anchovy with the different scenarios tested for each year analyzed. $SL_{50:}$ Length where 50% of individuals are caught, SPR: spawning potential ratio and FM: fishing mortality. SD is the standard deviation calculated for each indicator.

spp	scenario	year	SL_{50}	SD	SPR	SD	FM	SD
ANE	1	2019	110.24	0.99	0.31	0.19	3.96	1.84
ANE	1	2020	122.49	5.24	0.32	0.21	6.28	3.96
ANE	1	2021	111.44	1.78	0.29	0.18	4.68	2.26
ANE	1	2022	106.31	1.37	0.34	0.21	2.62	1.37
ANE	1	2023	116.87	1.37	0.31	0.19	5.48	2.62
ANE	1	2024	115.70	1.42	0.38	0.21	3.52	1.86
ANE	2	2019	110.24	1.09	0.32	0.19	4.04	1.83
ANE	2	2020	122.56	5.46	0.33	0.21	6.44	3.95
ANE	2	2021	111.43	1.99	0.30	0.18	4.78	2.26
ANE	2	2022	106.33	1.47	0.35	0.21	2.68	1.37
ANE	2	2023	116.87	1.51	0.32	0.19	5.59	2.62
ANE	2	2024	115.71	1.51	0.38	0.21	3.60	1.86
ANE	3	2019	110.28	1.08	0.39	0.18	4.06	1.88
ANE	3	2020	122.63	5.47	0.39	0.20	6.51	4.08
ANE	3	2021	111.49	1.95	0.36	0.18	4.80	2.32
ANE	3	2022	106.39	1.45	0.41	0.20	2.69	1.40
ANE	3	2023	116.91	1.50	0.39	0.18	5.62	2.68
ANE	3	2024	115.79	1.62	0.45	0.20	3.62	1.90

Length-based Bayesian Biomass (LBB)

Scenarios

Three scenarios were applied considering different growth parameters and natural mortality from GFCM working groups (Table 56). In scenario 3, L_{mat50} correspond to ICATMAR data (ICATMAR, 24-05).

Table 56. Biological parameters used in the different LBB scenarios for anchovy (ANE). $L_{inf:}$ Asymptotic length, M/k: ratio between natural mortality and growth rate, $L_{mat50:}$ length where 50% of individuals are mature.

Specie	Scenario	Linf (cm)	M/k	Lmat50 (cm)
ANE	1	15.5	1.426	9.9
	2	15.5	1.426	9.6
	3	15.5	1.426	8.2

TAs LFD and L_{mat} originated from ICATMAR data, scenario three was selected to provide final advice for the LBB model.

Fitted data

The length frequency distribution fit per year is shown in Figure 162. The model generally follows the mode for all years, but in 2020 there are some underestimations for smaller sizes.

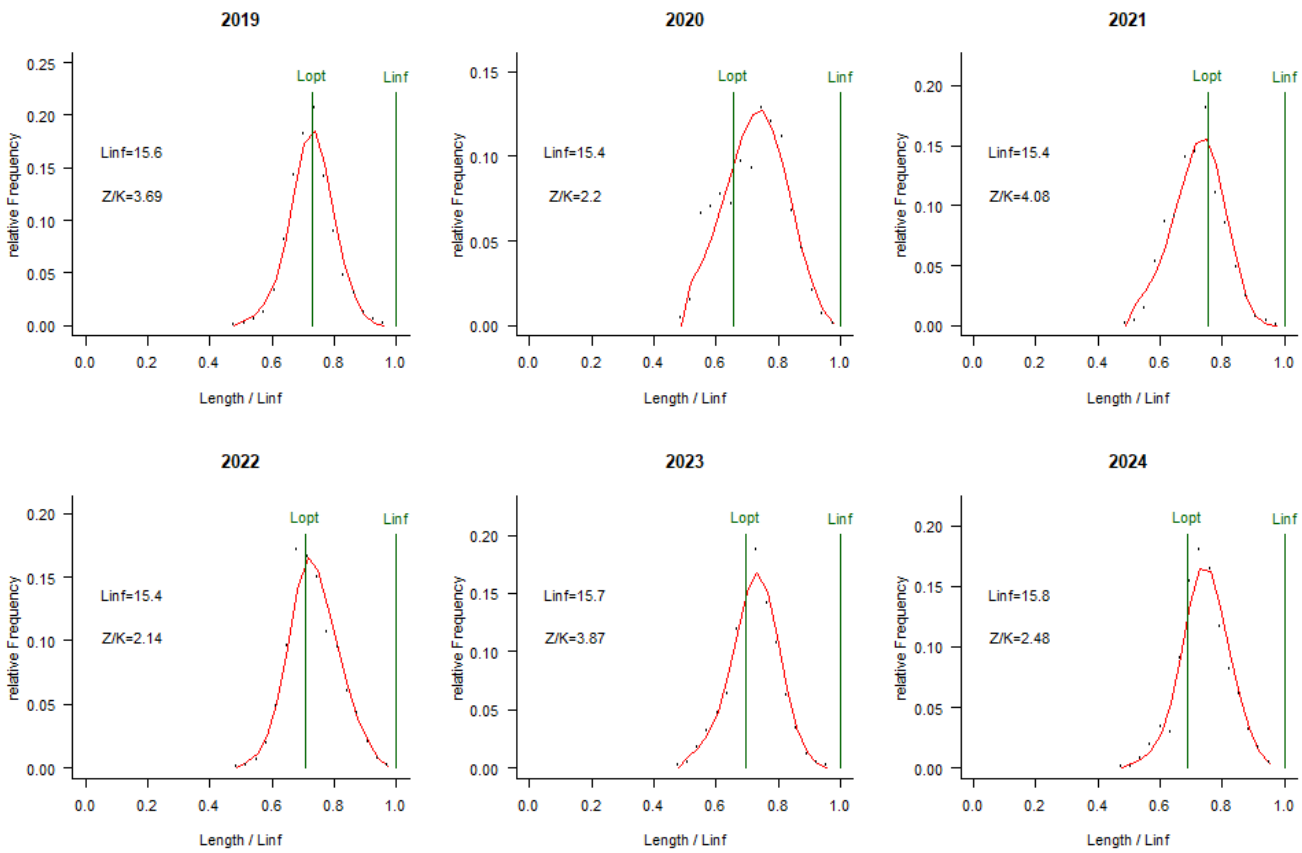

Figure 162. Fit of the data using the LBB model for ANE for each year in scenario 3. Red line indicates the fit of the model.

Reference points

Summary of the graphical results are in Figure 163. The upper left plot shows that the aggregated estimated Length at first capture (L_c) is 10 cm, above the L_{mat} (8.2 cm) as seen in the left lower plot (L_c: dotted black line) for the whole series. The upper middle and right panels show that the L_{mean} is above from L_{opt}, which is also shown in the lower left plot (L_{mean}: bold black line). Lower middle and right plots show that the relative fishing pressure (F/M) and relative biomass (B/B_0) is near sustainable levels. More details related to these results are in Table 57.

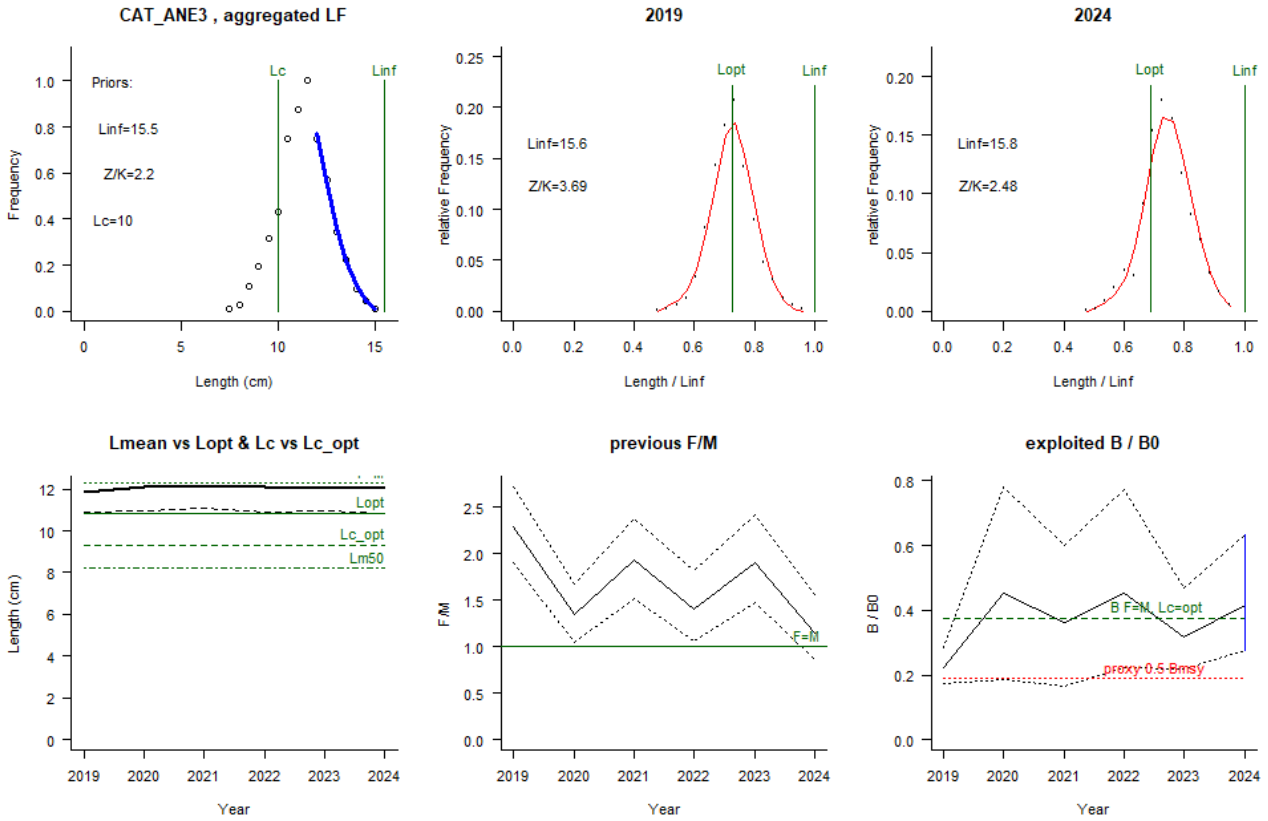

Figure 163. Summary output from LBB for ANE scenario 3.

Table 57. LBB model results for anchovy (ANE) with the different scenarios tested for each year analysed. $L_{mean:}$ mean length of individuals, $L_{opt:}$ length at optimal yield, $Lc_{:}$ length at first capture, $L_{c\_opt:}$ length at first capture at optimal yield, L_{95th}/L_{inf}: ratio of the 95th percentile to asymptotic length , F/M: fishing mortality relative to natural mortality, $B/B_{0:}$ exploited biomass relative to unexploited biomass, $B/B_{msy:}$ exploited biomass relative to maximum sustainable yield biomass, $C_{mature:}$ proportion of mature individuals in the catch.

Specie	Scenario	Year	Lmean/Lopt	Lc/Lc_opt	L95th/Linf	F/M	B/B0	B/Bmsy	C%mature
ANE	1	2024	1.10	1.20	0.96	1.10	0.41	1.10	93%
	2	2024	1.10	1.20	0.96	1.10	0.41	1.10	93%
	3	2024	1.10	1.20	0.96	1.10	0.41	1.10	100%

Stochastic Production model in Continuous Time (SPiCT)

The GFCM working group on small pelagic fishes in 2024 has already completed the stock assessment for GSA6 for small pelagic fishes. For this report, an effort was made for the first time to compile historical data on anchovy in Catalonia (Bas et al., 1955; Anuario de pesca del Mediterráneo Español, 1962-1970; Martin, 1991), and more recent data from EU fleet register provided by the European Commission (Reg. EU 2017/218), Catalan daily commercial fishing landings provided by the Spanish Ministry of Agriculture, Fisheries and Food and Catalan Government; European Commission, Joint Research Centre (JRC) (2025), and most recent available GFCM Stock Assessment Form (SAF) for ANE in GSA6 (RY2023). After that, a SPiCT model was run to estimate the stock status in the area and also compare the results with those in GSA6.

For anchovy, input data available for catches were from 1946 to 2022. Here, we assume that the total biomass trends for the time series are equivalent to those in GSA6, so two indices were used: ECOMED, an autumn acoustic survey from 1996 to 2009, and MEDIAS, a summer acoustic survey from 2009 to 2023 (Figure 77). Additionally, a landings per unit effort (LPUE) index was used (from 1990 to 2023), with units expressed in kg per vessel. This assessment reference year is 2023, so no available data for the biomass index in 2024 is available.

As for the other species, a double-axis plot (Figure 78) was presented to compare trends between catches and indices (Biomass and LPUE).

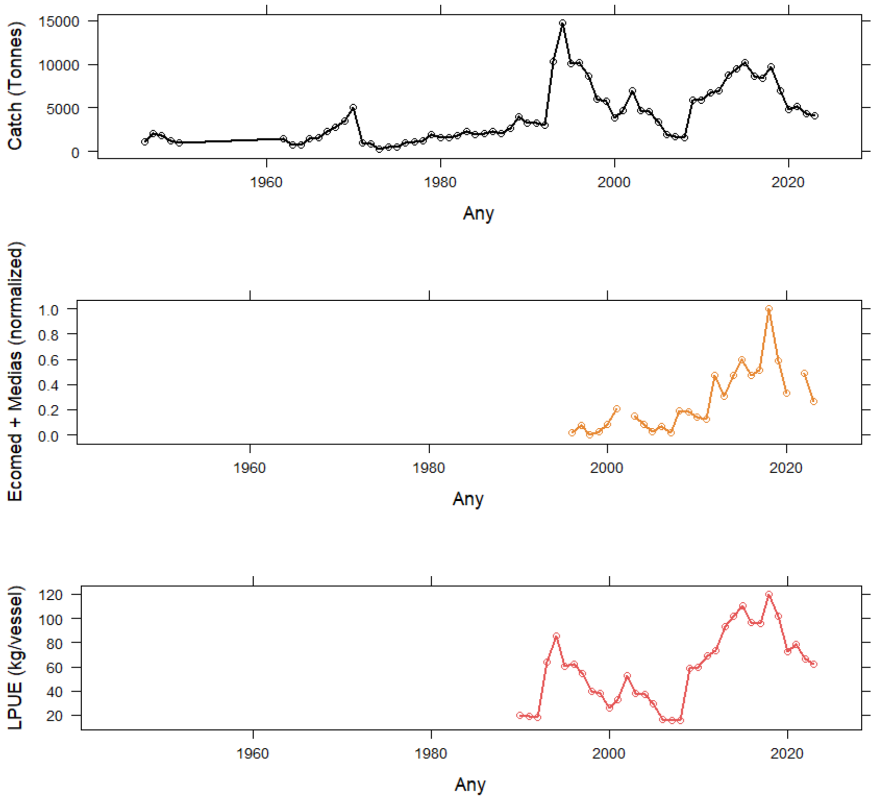

Figure 164. Data available for the assessment for anchovy in Catalonia to run SPiCT model. Top: Catch data from 1946 to 2023. Centre: Ecomed and MEDIAS acoustic surveys normalized from 1996 to 2008 and 2009 to 2023 respectively, and bottom LPUE index from 1990 to 2023.

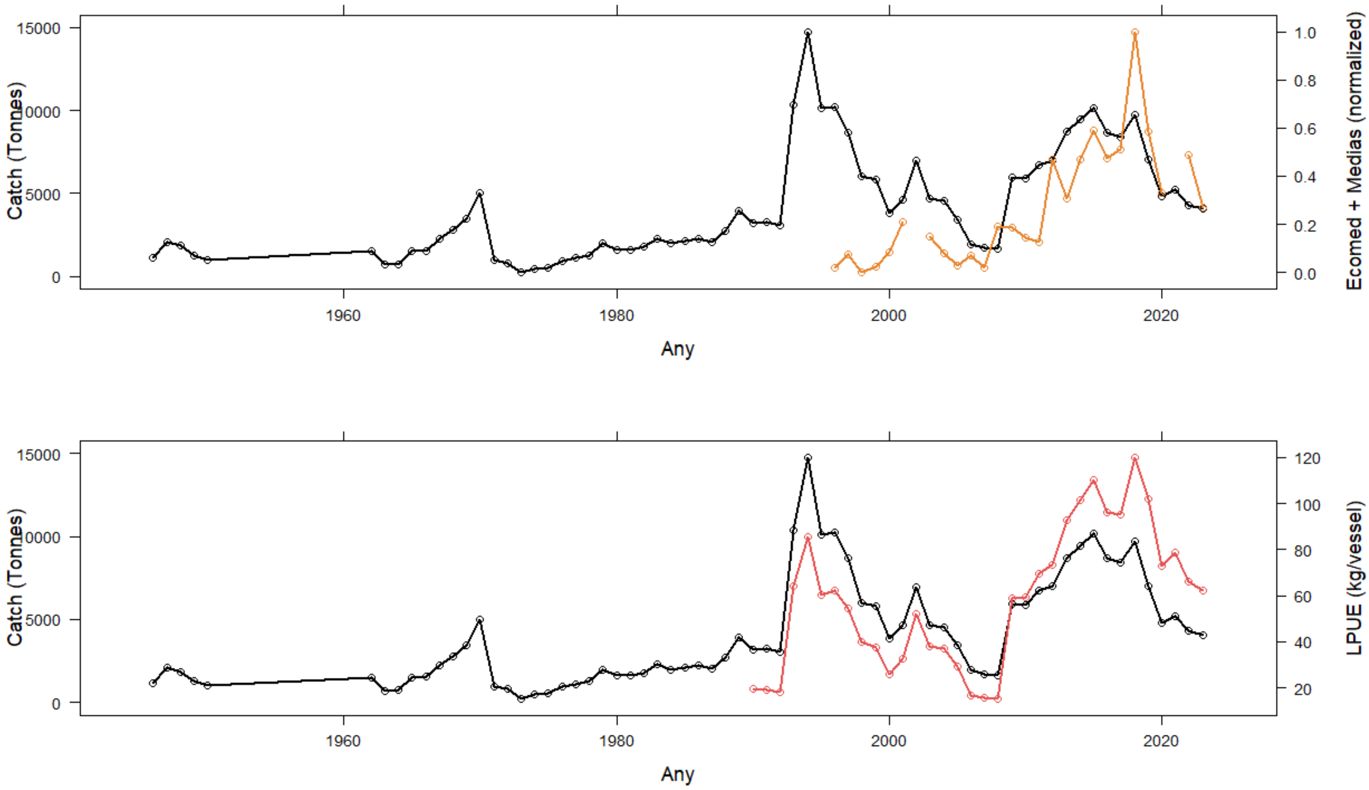

Figure 165. Double axis plot to compare trends between catch and Ecomed and MEDIAS index and catch (top) and LPUE index and catch (bottom) for anchovy in Catalonia.

Although only the final scenario was presented, different scenarios were tested:

- **Scenario 1**: landings started in 1946, using Ecomed, MEDIAS and LPUE as indices, and a BK prior of 0.8.
- **Scenario 2:** landings started in 1946, using Ecomed and MEDIAS as indices, and a BK prior of 0.8.
- **Scenario 3:** landings started in 1962, using Ecomed, MEDIAS and LPUE as indices, and a BK prior of 0.8.
- **Scenario 4:** landings started in 1946 and filling gaps between 1951-1961 with mean values (1951 and 1961), using Ecomed, MEDIAS and LPUE as indices, and a BK prior of 0.8.

A final plot comparison for scenarios 1 and 2, using the longest time series and considering or not considering the LPUE index, is shown in Figure 79. Scenario 1 was chosen as the final scenario, as Scenario 2 did not accurately represent the current status of this stock, and the uncertainty is greater. Additionally, it is not reliable that the stock is for the all-time series $_B > B_{msy}$ and $F < F_{msy}$. For scenarios 3 and 4, the model did not pass the diagnostics.

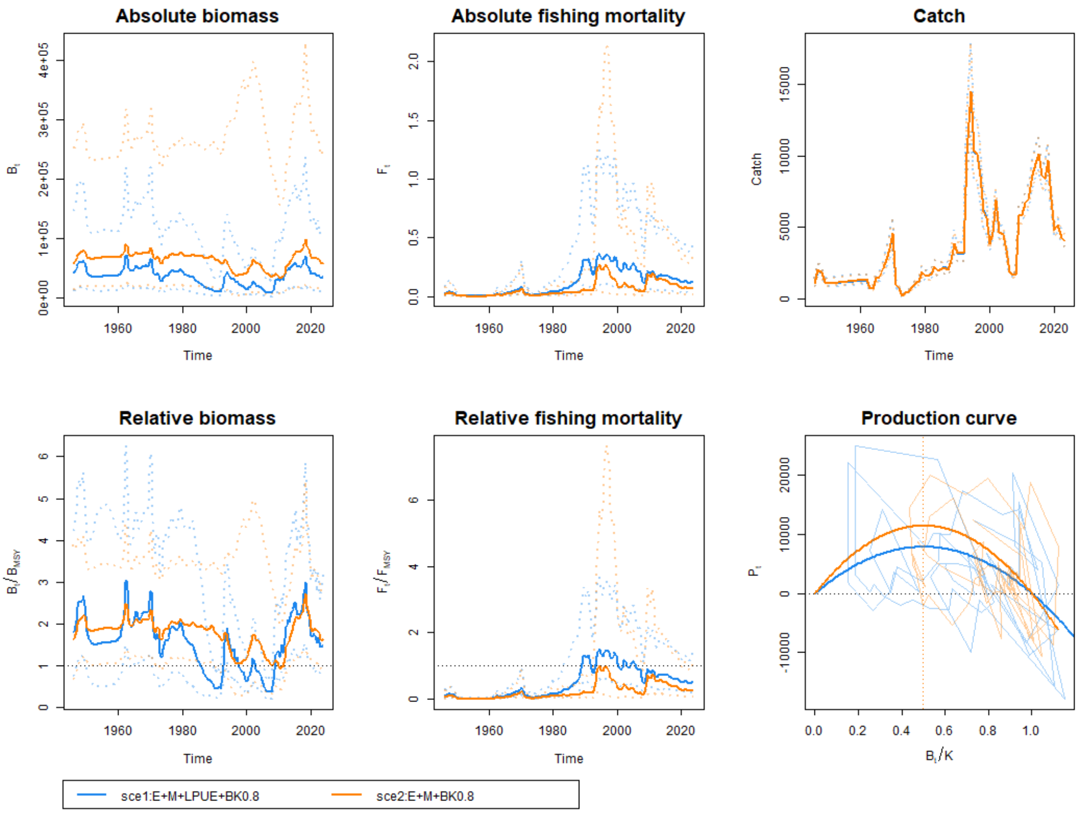

Figure 166. Scenarios comparison for anchovy in Catalonia.

Final scenario

The settings used for the final scenario are presented in Table 58. Among other settings, BK fraq prior was 0.8 because at the beginning of the time series, anchovy was not a target species for the fishery. Additionally, before 2000, a standard deviation factor of 2 was used because the data were less reliable than after that time.

Table 58. Priors settings for anchovy in Catalonia for final scenario.

Type	Prior	Description	Assignment	Mean	Standard deviation	Comment
Fishery dynamic	logbkfrac	B/K fraction (depletion)	-	Log(0.8)	0.5	At the beginning of the time series, anchovy was not the target species of the fleet, with the same value as GSA6 (SAF, GFCM 2023).
Relative standard deviation time series (input data)	stdevfacC	Standard deviation factor for catches	<2000	2	1	Landing data for years before 2002 were less reliable.
	stdevfacI	Standard deviation factor for indices		1	1	
Stock dynamic	logr	Population growth	-	Log(0.64)	0.3	Fishlife
	logn	Shape of production curve	-	Log(2)	-	Shaefer
Error	logsdc	Catch error	-	Log(0.05)	0.3	
	logsdf	Fishing mortality error	-	Log(4)	0.5	
	logsdb	Process error	-	Log(0.15)	0.5	
	logsdi	Observation error	-	Log(0.2)	0.5	Same for all indices

The final scenario input data is shown in Table 58, and the final summary assessment results are shown in Figure 81. The results show an increasing trend of biomass below the reference point since 2015. For fishing mortality, the estimated values have remained below 1 since 2005.

All diagnostics can be checked in Figure 82, Figure 83, Figure 84, Figure 85 and Figure 86. The chosen scenario met most of the model diagnostics and provided good retrospective analysis and hindcasting diagnostics. A sensitivity analysis for the final scenario was performed, testing r prior, bkfrac, process error, and observation error to assess the model's robustness within these priors. All these plots and results for the other scenarios will be available at https://github.com/ICATMAR.

Final scenario advice

Final scenario advice is presented in Figure 87 and in Table 59, which outlines the indicators for anchovy in Catalonia in 2023, based on the GFCM advice framework. The assessment results need to be considered as qualitative, although they were in line with the ones in the GSA6 assessment, where anchovy Biomass > B_{msy} and Fishing mortality < F_{msy}.

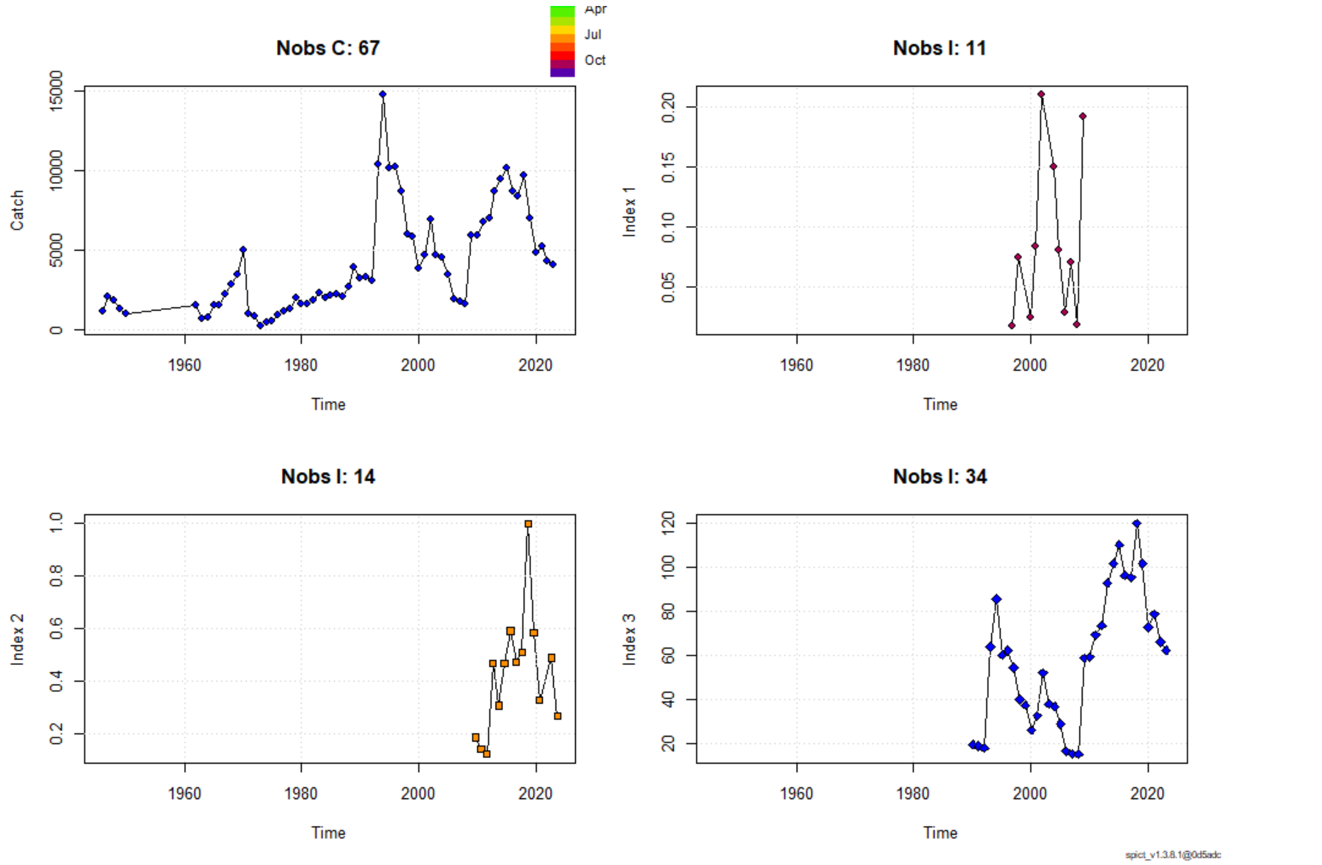

Figure 167. Input data for SPiCT model for anchovy in Catalonia. Top: catch in tons per year since 1946, centre: biomass index derived from the Ecomed survey from 1994 to 2008 and the Medias survey from 2009 to 2022.

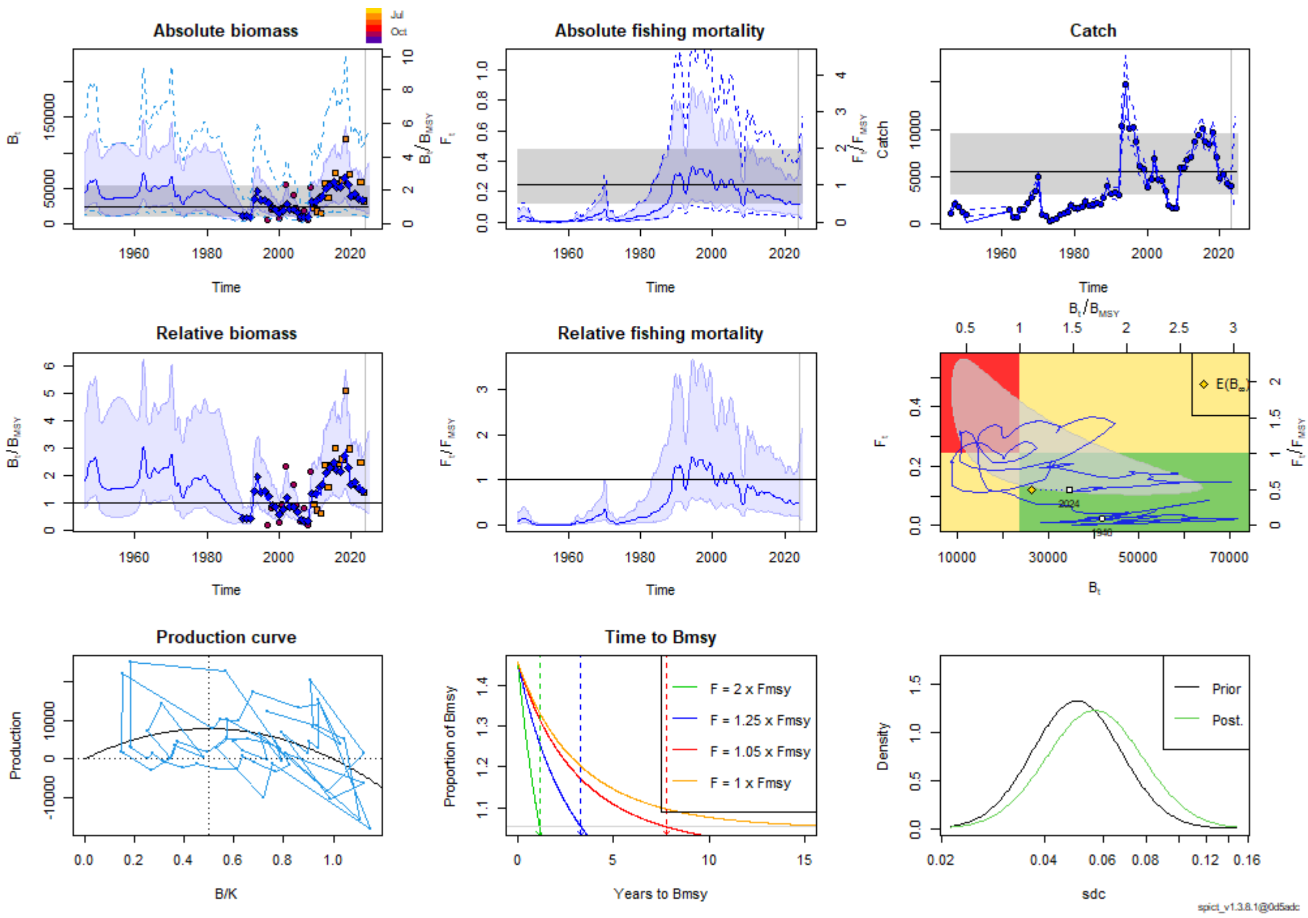

Figure 168. Stock assessment summary for SPiCT model for anchovy in Catalonia for the final scenario.

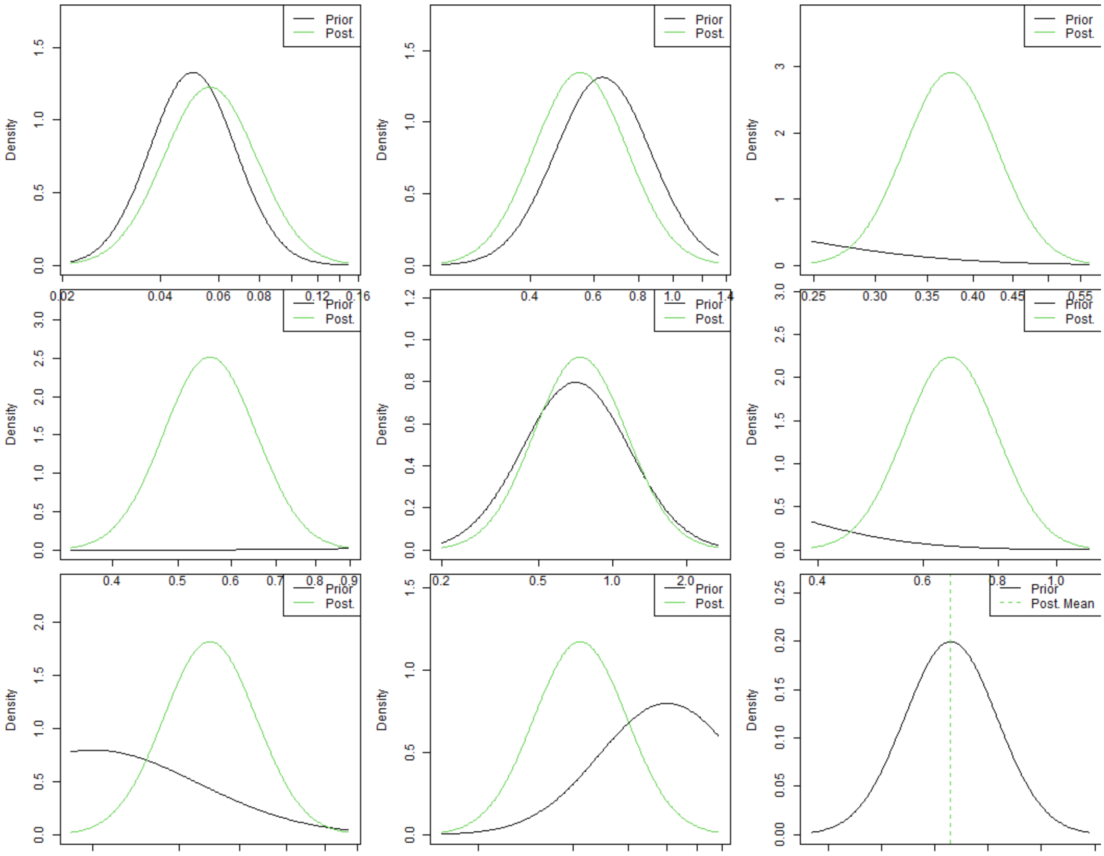

Figure 169. Estimated priors and posteriors for the updated assessment for anchovy in Catalonia for the final scenario.

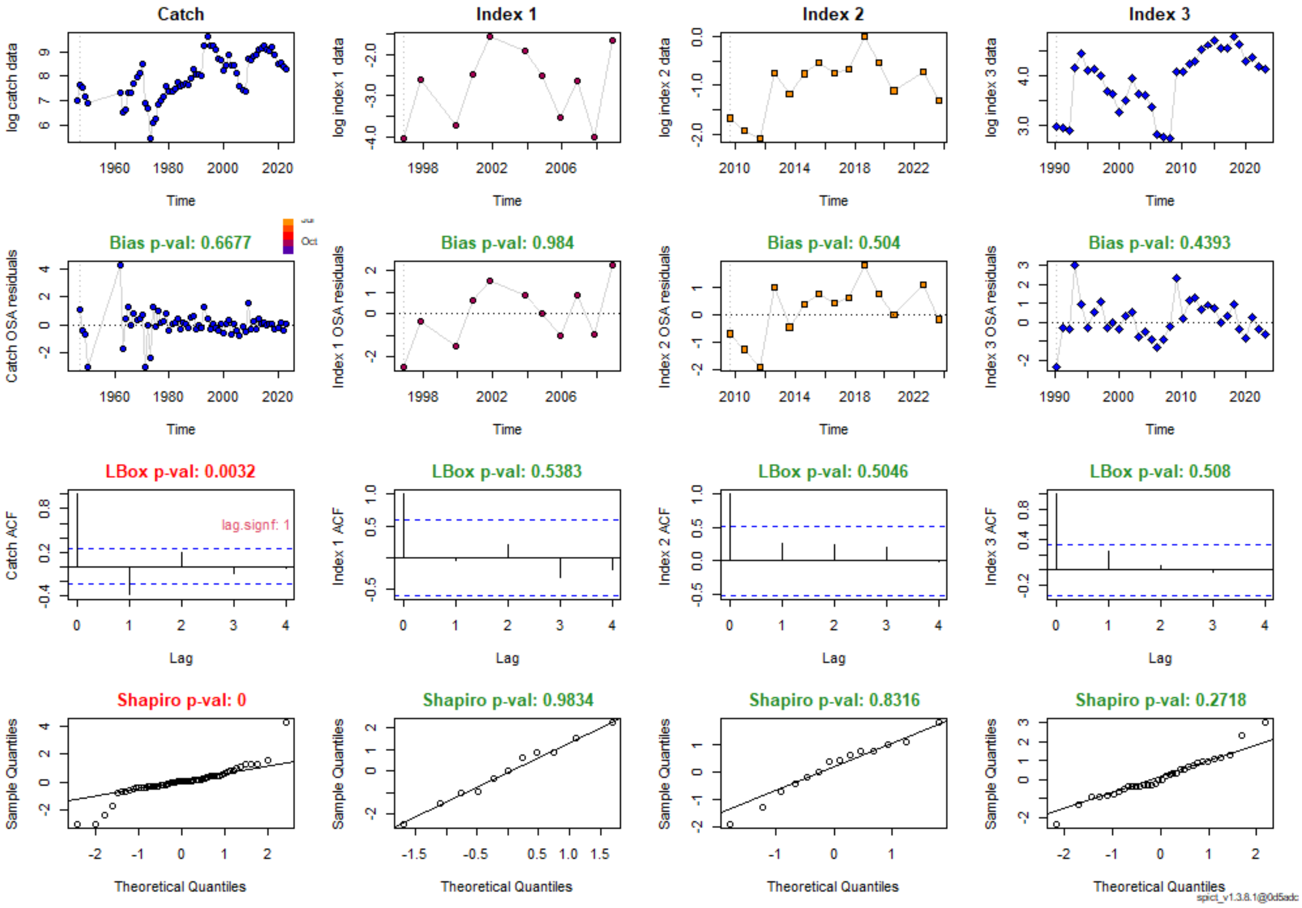

Figure 170. One-step-ahead residuals for the model for anchovy in Catalonia for the final scenario.

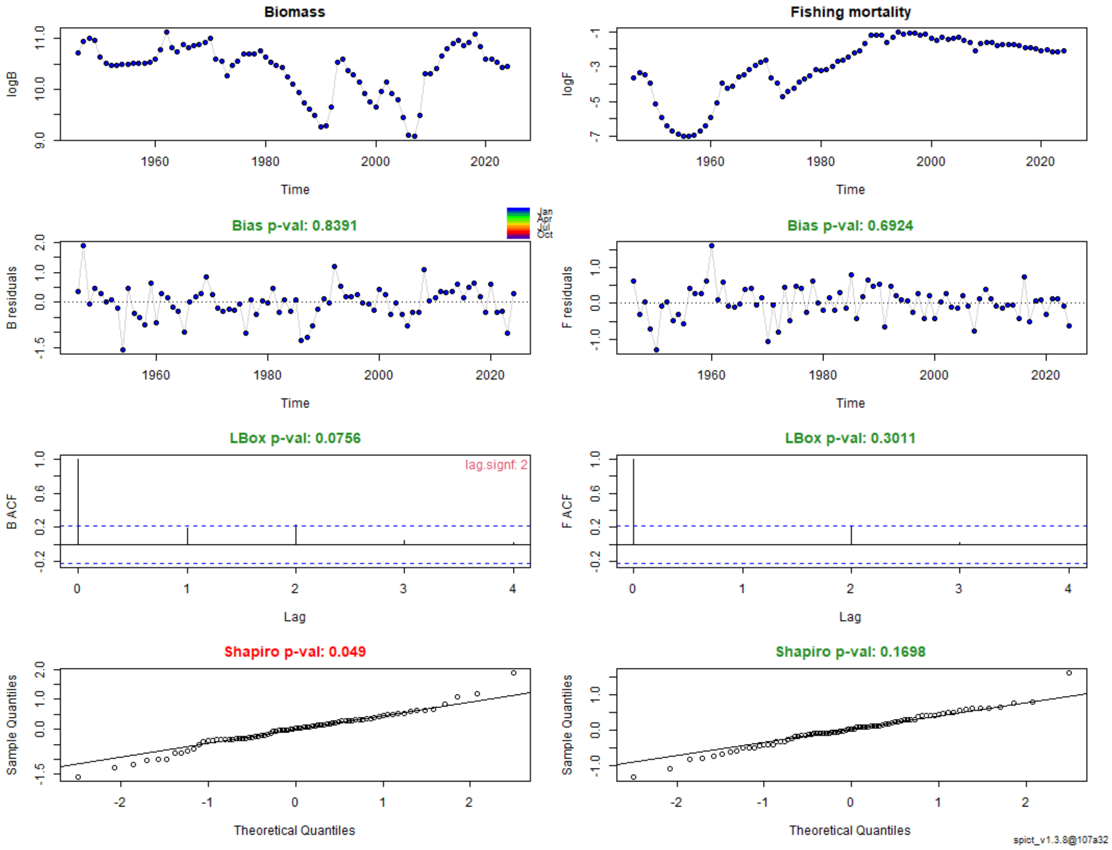

Figure 171. Process error deviations for the model for anchovy in Catalonia for the final scenario.

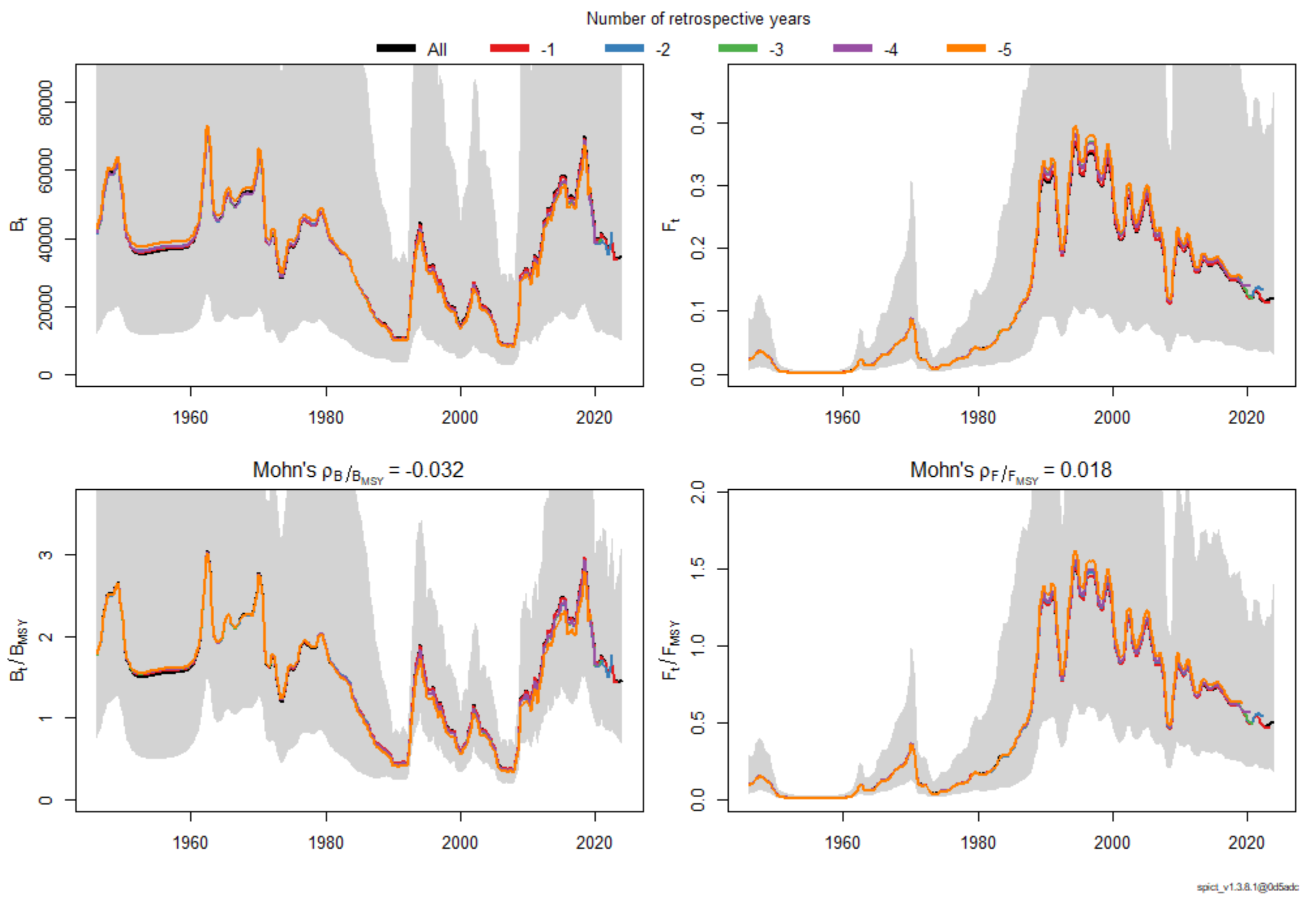

Figure 172. Retrospective analysis for anchovy in Catalonia for the final scenario.

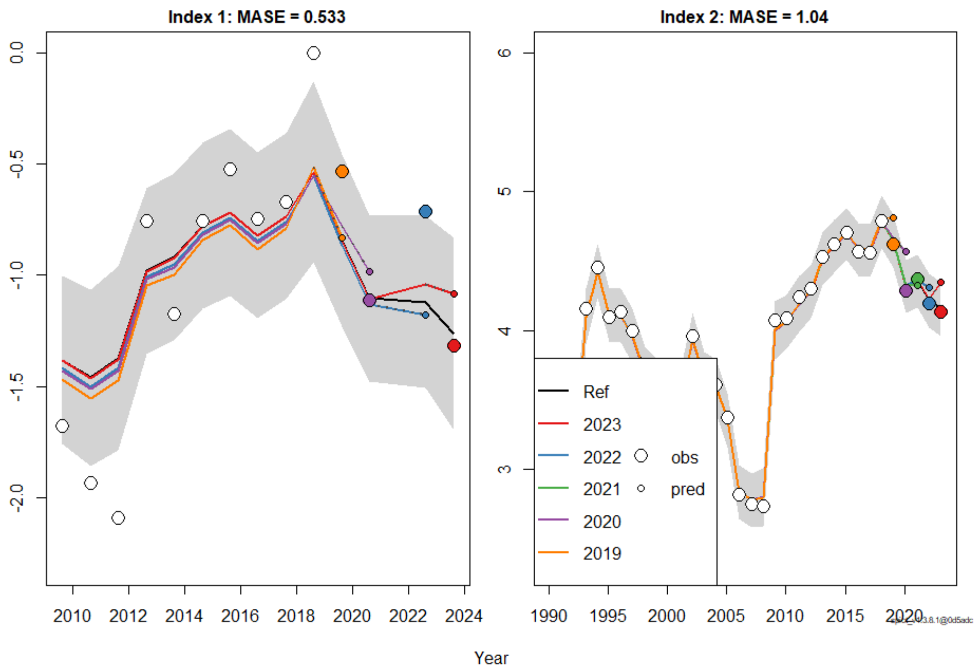

Figure 173. Hindcasting for the model for anchovy in Catalonia for the final scenario.

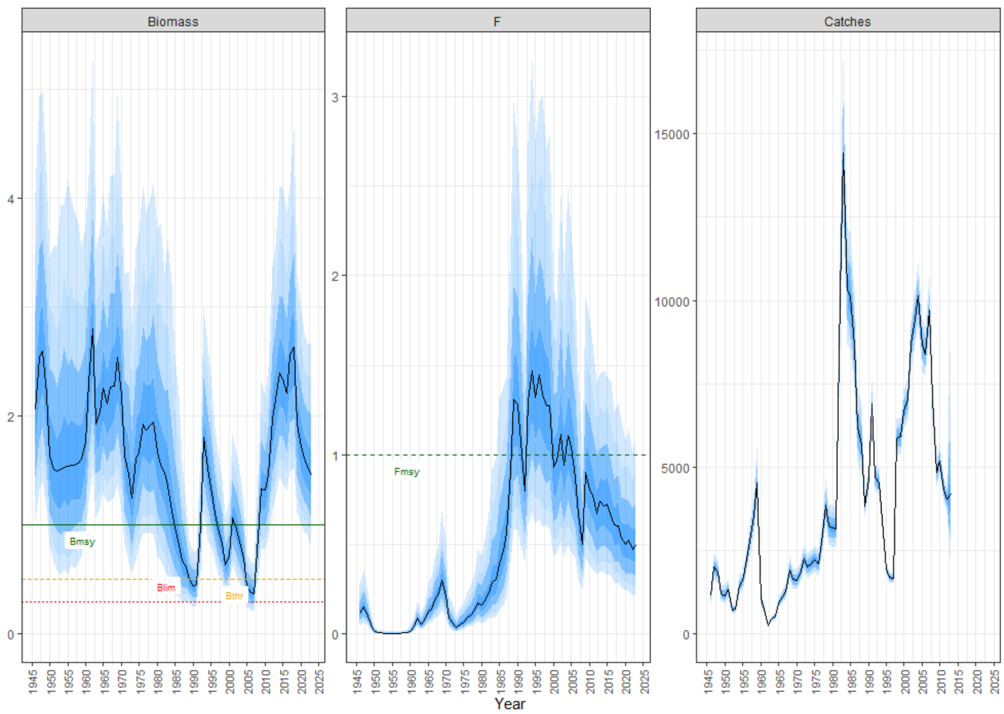

Figure 174. Advice for the final scenario for anchovy in Catalonia: Historical and current stock status regarding F_{msy}, B_{msy} and B_{lim}.

Table 59. Indicators in 2023 from SPiCT for anchovy in Catalonia for the final scenario.

Species	Year	Catch (t)	F/F_{msy}	B/B_{msy}	B/B_{pa}	B/B_{lim}
ANE	2023	4196	0.50	1.46	2.91	4.85

SECTION 5
Conclusions and comments

Conclusions

Five demersal stocks (red mullet, European hake, deep-water rose shrimp, Norway lobster and blue and red shrimp) and two small pelagic fish stocks (European sardine and anchovy) were evaluated with two length-based models (LBSPR and LBB), and a production model (SPiCT) considering a range of different scenarios. In addition, a preliminary evaluation was run for red mullet, European hake and blue and red shrimp with integrated model MESTOCK (Canales et al. 2014).

Length-based models make use of the thorough length structure data available, but can deal with a high level of uncertainty, mainly due to their sensitivity to input data and biological assumptions. Key limitations include the exclusion of historical catch data and biomass indices. The surplus production model can incorporate these data, but results are influenced by the lack of information on the length structure of the stock. Preliminary runs with MESTOCK integrate both sources of data, but still need further analysis including consideration of different scenarios, further data quality checks, and introduction of other factors such as different fleets.

For red mullet, length-based models concur in estimating low but stable levels of spawning potential ratio and biomass. In contrast, surplus production and integrated models place the stock at sustainable exploitation levels with increasing biomass and decreasing fishing mortality trends, in line with abundance index data and field observations.

For European hake, despite the different models used, the overall trend remains consistent: biomass is close to the limit reference point but shows a stable trajectory, along with a reduction in fishing mortality over the past five years. The stock needs time to recover and would benefit from management measures directed to recover large spawner individuals or improve selectivity, could help protect recruitment and support stock rebuilding.

For deep-water rose shrimp, LBB and SPiCT concur in estimating both biomass and fishing mortality levels above reference points. The results from LBB are based on the available portion of large size individuals from the length frequency (LF), which are near the optimal length (L_{opt}) and might reflect a healthy state of the fishery. SPiCT does not consider LF, but the constant increase in the abundance index, despite the constant increase in catches, indicates that the stock is doing well. On the contrary, LBSPR estimates SPR below 0.2, which is not possible due to the exploitation ratio that the fishery has sustained in recent years. Also, environmental factors such as the increase of sea temperature and salinity are known to affect the stock and are not currently being integrated by the models.

For Norway lobster, length-based and production models are in line in estimating the poor status in all reference points. In the case of SPiCT, the abundance index shows no major changes, even with the increases and decreases in catches. The lack of large individuals prevents length-based models from evaluating the stock in a positive status, despite the historical decrease of fishing mortality. Environmental factors such as the increase of sea temperature may be negatively conditioning the development of the population.

For blue and red shrimp, length-based models concur in estimating low but stable levels of spawning potential ratio and biomass. In contrast, SPiCT places the stock at possibly sustainable exploitation status considering the changes in catches and the abundance index, although without acknowledging the LFs. Preliminary runs with MESTOCK integrate LFs, catches, abundance index, in addition to other model parameterizations, and results show that the constant decrease in fishing mortality has not been translated in an increase in biomass. Biomass increases may be related to changes in selectivity, since stock status seems to be more sensitive to size distribution than to the decrease in fishing mortality. Overall, a possible explanation for these contrasting diagnoses may include outdated biological parameters.

Finally, it is clear that stock assessment models are useful tools that can give information on different parameters of populations, but the uncertainty that all models deal with should prevent decision-makers from taking output values as unquestionable attributes of the stocks. The roadmap for official assessments already considers strategy simulation tools such as Management Strategy Evaluation (MSE), which are able to predict the effect of different management measures in the catches, biomass and fishing mortality of a fishery. However, this is a long process that requires the cooperation of all stakeholders (fisheries scientists, policy makers, fishers, etc.). In the meantime, Mediterranean fisheries are in need of robust but comprehensive tools that can orient management decisions towards sustainable exploitation.

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Co-funded by the European Union

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