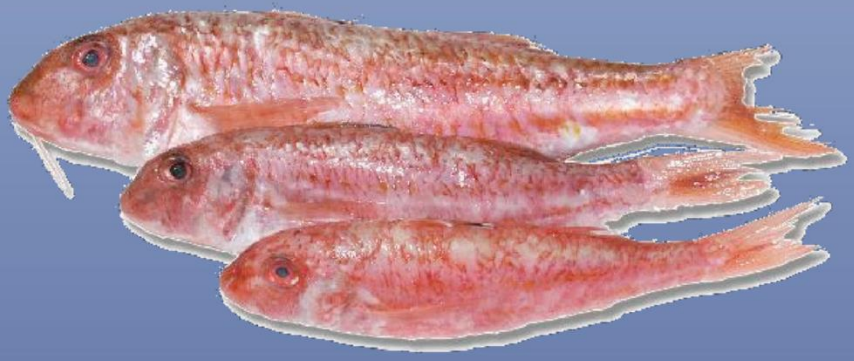

Stock Assessment Form of Red Mullet in GSA 22

Reference period: 1994-2016

Reporting year: 2017

[Red mullet (*Mullus barbatus*) is one of the main target species of the demersal fisheries, particularly the bottom trawlers, in the Aegean waters (GSA-22) and its annual landings in the reference period mostly varied between 1700-2800 tons. The stock status is assessed using FAO production data and abundance indices obtained from the MEDITS trawl surveys during the 1994-2016 period. The assessment was based on a surplus production model carried out with the SPiCT package under the R language environment, using custom made scripts. Results show that the stock is sustainably exploited and the current F is well below F_{msy} levels.

Stock Assessment Form version 1.0 (January 2014)

Uploader: *George Tserpes and Vasiliki Sgardeli*

Stock assessment form

Contents

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Mullus barbatus	[Red mullet]	[MUT]
1st Geographical sub-area:	**2nd Geographical sub-area:**	**3rd Geographical sub-area:**
[GSA_22]		
4th Geographical sub-area:	**5th Geographical sub-area:**	**6th Geographical sub-area:**
1st Country	**2nd Country**	**3rd Country**
Greece		
4th Country	**5th Country**	**6th Country**
Stock assessment method: (direct, indirect, combined, none)		
Indirect: Biomass model (SPICT)		
Authors:		
George Tserpes, Vasiliki Sgardeli		
Affiliation:		
Hellenic Centre for Marine Research (HCMR) - Institute of Marine Biological Resources and Inland Waters		

The ISSCAAP code is assigned according to the FAO 'International Standard Statistical Classification for Aquatic Animals and Plants' (ISSCAAP) which divides commercial species into 50 groups on the basis of their taxonomic, ecological and economic characteristics. This can be provided by the GFCM secretariat if needed. A list of groups can be found here:

http://www.fao.org/fishery/collection/asfis/en

Direct methods (you can choose more than one):

- Trawl survey

Indirect method (you can choose more than one):

- Biomass models

2 Stock identification and biological information

2.1 Stock unit

GSA 22 has been considered as a unique area for management purposes due to its specific geophysical characteristics and its separation from nearby areas, such as GSA 23 (Crete), through the Cretan Sea which is a deep (2500m) and large in volume particularly oligotrophic basin (Psarra et al., 1996; Lykousis et al., 2002). In addition, fishery exploitation patterns differ between the two nearby areas, with the trawling activities being much less intense in GSA 23 (Anonymous, 2013).

Anonymous, 2013. Management Plan for the Greek Bottom Trawl Fisheries. EU Ref. Ares(2013) 548016 05/04/2013, (https://tinyurl.com/kb6qfzv)

Lykousis V, Chronis G, Tselepides A, Price NB, Theocharis A, Siokou-Frangou I, et al. Major outputs of the recent multidisciplinary biochemical researches undertaken in the Aegean Sea. J Mar Syst. 2002; 33– 34: 313–334

Psarra S, Tselepides A, Ignatiades L, Dafnomili E. Primary production estimates in the Cretan Sea. In: Tselepides A, Papadopoulou K-N, Polychronaki T (eds) CINS: Pelagicbenthic coupling in the oligotrophic Cretan Sea, MAST-II Mediterranean Targeted Project. 1996; pp 46–56

2.2 Growth and maturity

Table 2.2- 1: Maximum size, size at first maturity and size at recruitment.

Somatic magnitude measured (LT)				**Units**	cm
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	Late spring-early summer
Maximum size observed			31	**Recruitment season**	October-November
Size at first maturity	9			**Spawning area**	Continental shelf
Recruitment size to the fishery	8			**Nursery area**	Coastal areas

3 Fisheries information

3.1 Description of the fleet

Red mullet is exploited by bottom trawlers and various artisanal fisheries using gillnets. Most catches are coming from the Greek fleets exploiting the area and the majority originates from bottom trawlers. The Greek bottom trawl fishery has multi-species characteristics and similarly to most Mediterranean demersal trawl fisheries, captures more than 100 commercial species. However, few species, such as red mullets, hake and shrimps compose the main bulk of landings, with red mullet being one of the most important targets.

Table 3- 1: Description of operational units exploiting the stock

	Country	GSA	Fleet Segment	Fishing Gear Class	Group of Target Species	Species
Operational Unit 1*	GRC	22	E-Trawl (12-24 meters)	03 - Trawls	33 - Demersal shelf species	MUT
Operational Unit 2	GRC	22	F-Trawl (>24 meters)	03 - Trawls	33 - Demersal shelf species	MUT
Operational Unit 3	GRC	22	M - Polyvalent (12-24 metres)	07 - Nets	33- Demersal shelf species	MUT
Operational Unit 4	GRC	22	B - Minor gear with engine (<6 metres)	07 - Gillnets and entagling nets	34 - Demersal shelf species	MUT
Operational Unit 5	GRC	22	C - Minor gear with engine (612 metres)	07 - Gillnets and entagling nets	34 - Demersal shelf species	MUT

3.2 Historical trends

Landings in the reference period (1994-2016) are mostly between 1700-2800t (Table 3.2-1).

Table 3.2- 1: Total red mullet landings (tons) by year in GSA22 according to FAO statistics.

Year	Landings
1994	4422
1995	3414
1996	2770
1997	2705
1998	2164
1999	2339
2000	2167
2001	1933
2002	1741
2003	1464
2004	1781
2005	2211
2006	2565
2007	2280
2008	2052
2009	2321
2010	2411
2011	1933
2012	1764
2013	1920
2014	1790
2015	1705
2016	1700

3.3 Management regulations

As with all demersal fisheries in GSA 22, those catching red mullet are managed according to EU regulation 1967/2006 which include spatial fishery closures for the bottom trawlers, gear configuration specifications and minimum landing sizes. Additional national measures include a temporal (4.5 months) closure of the bottom trawl fisheries accompanied by certain localized spatio- temporal closures.

3.4 Reference points

Fishing mortality and biomass reference points based on the F/F_{msy} and B/B_{msy} ratios were adopted in the frame of the EU adopted Management plan for bottom trawlers (Anonymous, 2013). A rate equal to one was considered as a target for both ratios.

4 Fisheries independent information

4.1 MEDITS Trawl Survey

4.1.1 Brief description of the direct method used

The "MEDITS" bottom trawl surveys are accomplished in GSA 22 since 1994 on an annual basis. However, no surveys were accomplished in 2003, 2009-2013 and in 2015. Sampling includes sampling in 129 pre-defined stations following a standardized protocol. Trawling was made by means of a standard net GOC 73 having a cod-end mesh opening of 20 mm and selection of stations was based on a depth-stratified sampling scheme that included five depth zones: 10-50, 50-100, 100-200, 200-500 and 500-800 m. Collected data included number, weight, gonad maturation stage and total length measurements for a wide range of fish, cephalopod and crustacean species (MEDITS Handbook v9, 2017). From the collected data, standardized abundance indexes by year, expressed in terms of kg per square km of swept area (kg/km^2), were calculated for red mullet.

Table 4.1- 1: Trawl survey basic information

Survey	MEDITS	**Trawler/RV**	
Sampling season	Summer		
Sampling design	Depth stratified random sampling		
Sampler (gear used)	GOC-73		
Cod –end mesh size as opening in mm	20		
Investigated depth range (m)	30-800		

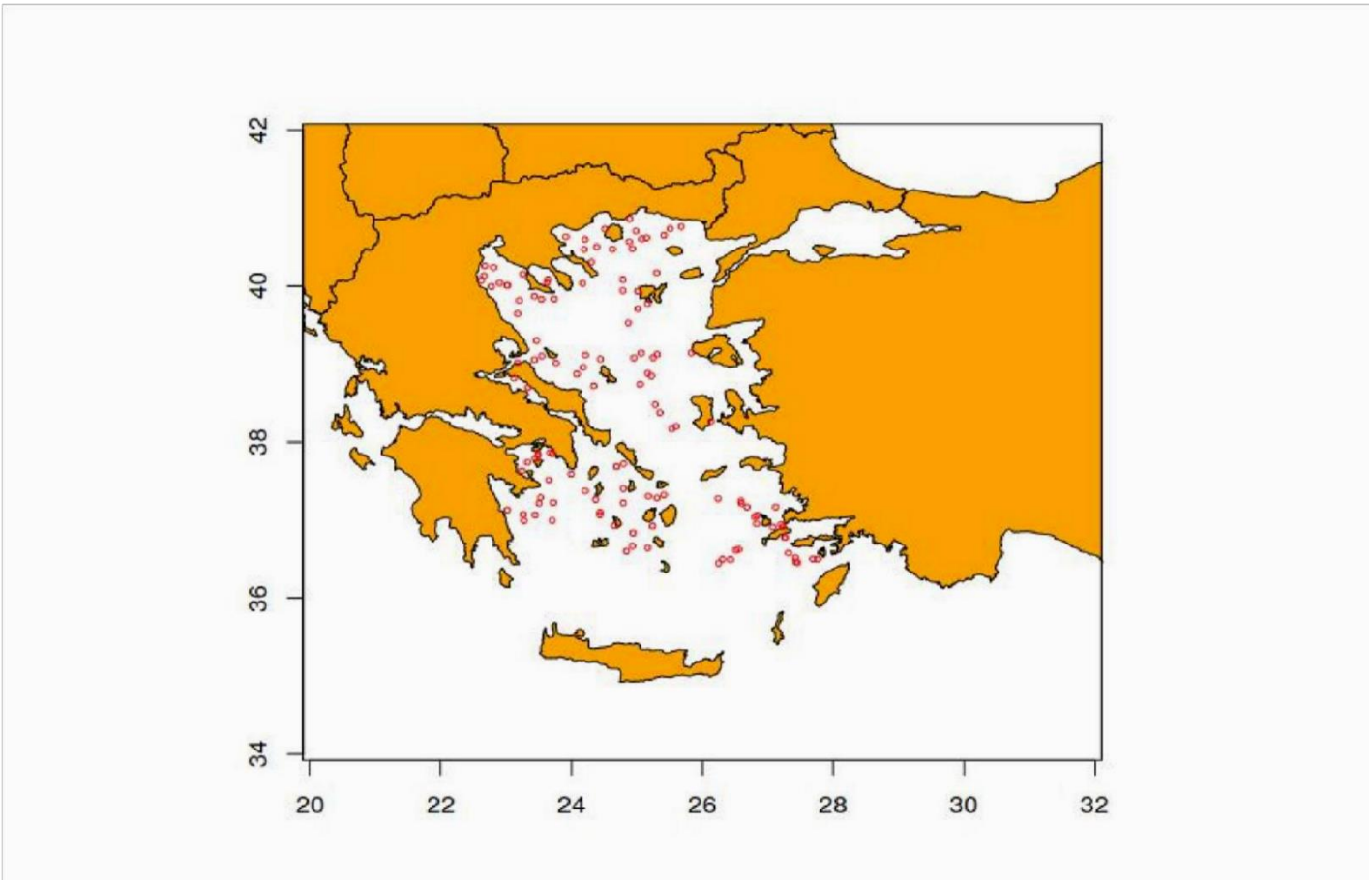

Fig. 4.1 -1 MEDITS stations in GSA 22

Table 4.1- 2: Trawl survey sampling area and number of hauls

Stratum	Total surface (km^2)	Trawlable surface (km^2)	Swept area (km^2)	Number of hauls
10-50	15318			11
50-100	12512			21
100-200	35373			36
200-500	41478			44
500-800	43650			17
Total	148331			129

5 Ecological information

5.1 Protected species potentially affected by the fisheries

5.2 Environmental indexes

6 Stock Assessment

In this section there will be one subsection for each different model used, and also different model assumptions runs should be documented when all are presented as alternative assessment options.

6.1 Surplus production model with SPiCT

Stock assessment was based on a surplus production model which was implemented with the SPiCT package in R environment. SPiCT does a state-space implementation of the Pella-Tomlinson surplus production model in continuous time, which assumes that both the biomass (process equation) and survey index equation (observation equation) are subject to errors. Additionally, SPiCT assumes that the catch equation is subject to error.

Pedersen MW and CW Berg (2017) A stochastic surplus production model in continuous time. *Fish and Fisheries*, **18**: 226–243.

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/

6.1.1 Model assumptions

Surplus production models aim to predict the biomass and exploitation level of stocks in cases where catch-at-age data are not available. The data required to fit the model are a time series of catches and a time series of effort or abundance indices. The model assumes that the rate of change of the total biomass is a function of the net biomass added or removed from the population through the processes of recruitment, growth and natural mortality (surplus production) and the biomass removed through fishing (the catch). The surplus production is the result of a constant density-independent growth rate, *r* (which incorporates recruitment, growth and natural mortality) and a density-dependent term that reduces the rate of growth when the biomass approaches the carrying capacity, K. The catch removed from the population is assumed to be proportional to the current biomass, B, and the fishing mortality, F. A second equation links the survey abundance index time series with the biomass equation, assuming that the abundance index is proportional to the biomass through a constant coefficient *q* that represents the catchability.

6.1.2 Scripts

The R scripts used are available for downloading from:
https://cloudfs.hcmr.gr/index.php/s/CeyrNcwpQiMJu2h

6.1.3 Input data and Parameters

The input data are the time series of FAO landings from 1994-2016 and the time series of abundance indices from the MEDITS trawl survey (1994-2016) (Table 6.1.3-1). The abundance index time series has a number of missing values, i.e. years when the sampling did not take place. Before providing the data to SPiCT, interpolation was used to fill in the gaps. This was done in R 3.4.2 with na.interpolation function and method "stine". The first 3 years of the time series (19901994) are omitted from the stock assessment because the data for these years are considered unreliable. The time series of landings and abundance indices are sufficient for SPiCT to run, however to improve convergence, prior distributions were provided for the growth rate, r and the relative biomass in 2009 (B/Bmsy), for which there are available information. A prior estimate of growth rate was determined using the demographic method of Krebs, utilizing literature data on fecundity, maturity and mortality (Table 6.1.3-2). The prior value for B/Bmsy in 2009 was taken from the Management Plan for the Greek Bottom Trawl Fisheries (https://tinyurl.com/kb6qfzv). All other SPiCT parameters were set to default.

Table 6.1.3-1 Landings and abundance index by year for red mullet in GSA 22.

Year	Landings (tones)	Abundance index	Interpolated Abund. index
1990	4422.2	NA	NA
1991	3414.3	NA	NA
1992	2769.6	NA	NA
1993	2705.3	NA	NA
1994	2163.7	7.307	7.307
1995	2338.8	7.841	7.841
1996	2166.6	7.428	7.428
1997	1933.3	11.637	11.637
1998	1740.5	15.456	15.456
1999	1463.8	10.765	8.958
2000	1781.0	24.695	24.695
2001	2211.5	7.128	7.128
2002	2564.7	NA	18.103
2003	2280.2	29.078	29.078
2004	2052.1	17.528	17.528
2005	2320.7	9.709	13.995
2006	2410.6	15.135	15.135
2007	1932.8	NA	14.250
2008	1764.2	9.216	13.365
2009	1920.1	NA	17.232
2010	1790.1	NA	21.139
2011	1705.1	NA	25.047
2012	1700.1	NA	28.955
2013	4422.2	NA	32.862
2014	3414.3	36.770	36.770
2015	2769.6	NA	40.679
2016	2705.3	44.590	44.590

Table 6.1.3-2 Input parameters and model settings for red mullet in GSA 22

	Parameter priors	
	r	B/K_2009
distribution	lognormal	lognormal
μ (mean of the log)	-0.249	0.438
σ (std of the log)	0.443	0.1

Moritz S. 2017. imputeTS: Time Series Missing Value Imputation. R package version 2.5. https://CRAN.Rproject.org/package=imputeTS

6.1.4 Results

The assessment indicates that the red mullet stock is exploited in a sustainable way and current (2016) F is well below F_{msy} (Table 6.1.4-1 and Fig. 6.1.4-2).

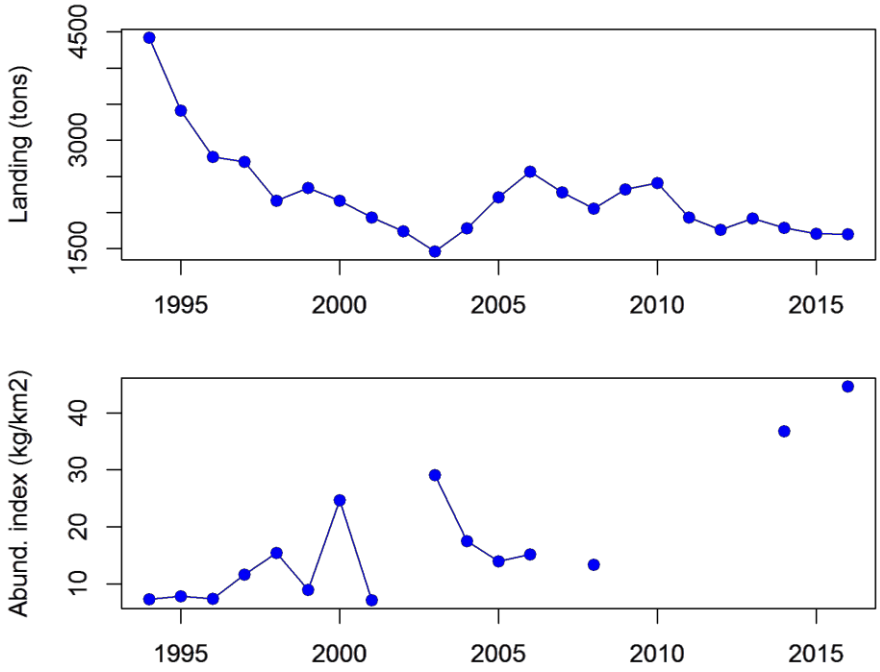

Fig. 6.1.4-1 Red mullet in GSA 22. Annual FAO landings and abundance indexes from the MEDITS surveys (including interpolated estimates).

Table 6.1.4-1. Average estimates of model parameters. The last two columns indicate relative biomass and fishing mortality levels in 2016.

K	r	MSY	Bmsy	Fmsy	BBmsy	FFmsy
18024	0.530	2929	7763	0.38	1.78	0.33

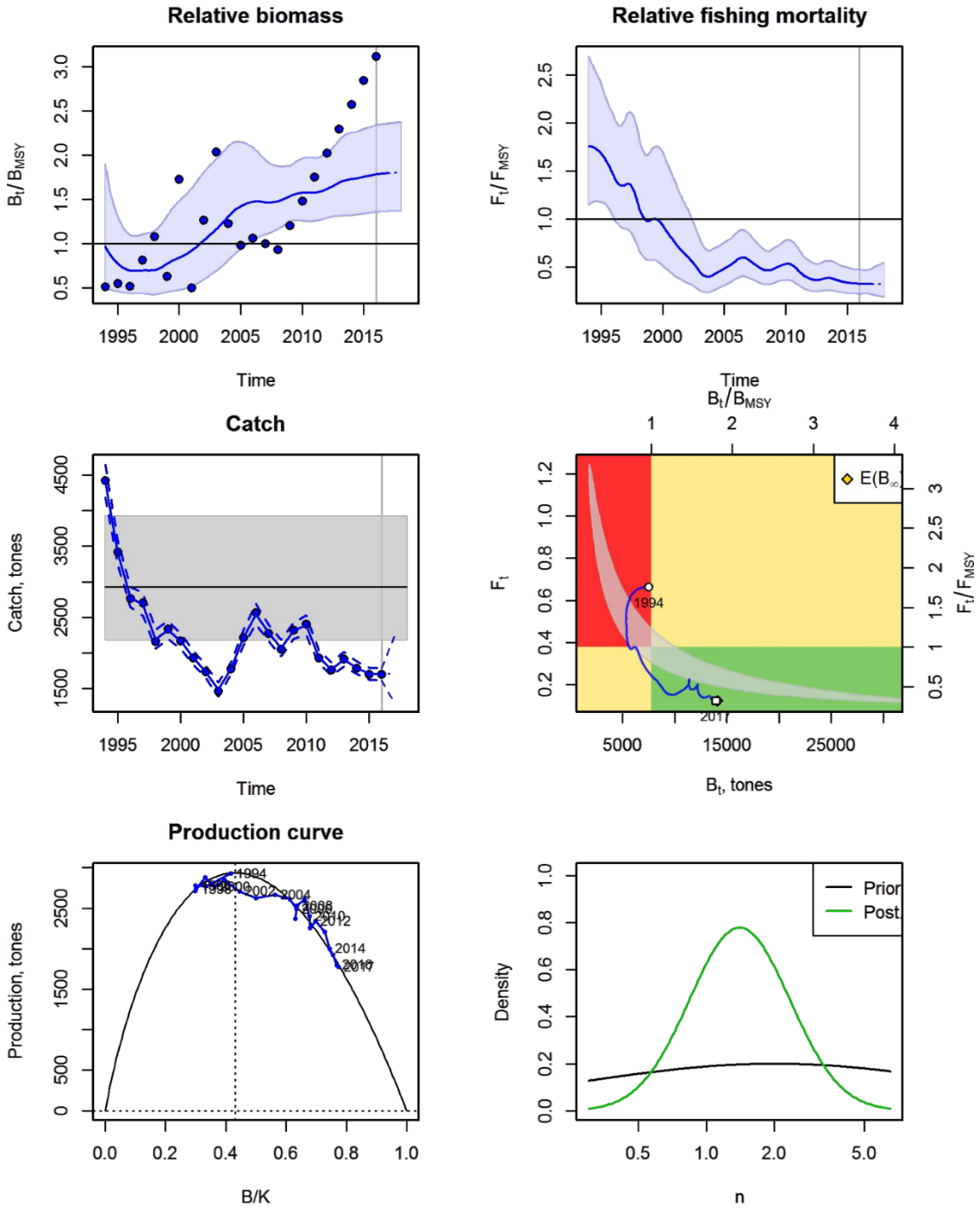

Fig. 6.1.4-2. Stock assessment results for red mullet in GSA-22. Upper row: Median (blue solid line) of relative biomass and relative fishing mortality with 95% CI (blue shaded area). Middle row: Observed (blue points) and estimated catch with 95% CIs (left) and Kobe plot of relative fishing mortality versus relative biomass (right). Bottom row:) Production curve (left) and comparison of prior and posterior distributions of the n parameter, which determines the shape of the production curve in the Pella-Tomlinson model (right).

6.1.5 Robustness analysis

6.1.6 Retrospective analysis

Retrospective plots show rather consistent trends of relative biomass and relative fishing mortality among the different runs. A deviation of 30% between the runs is present at the start of the time series for both relative biomass and fishing mortality, which reduces to almost zero deviation in recent years (Fig. 6.1.6-1). Apart from the uncertainty at the start of the time series, the retrospective analysis doesn't show any patterns suggesting model/data consistency and robustness of the results

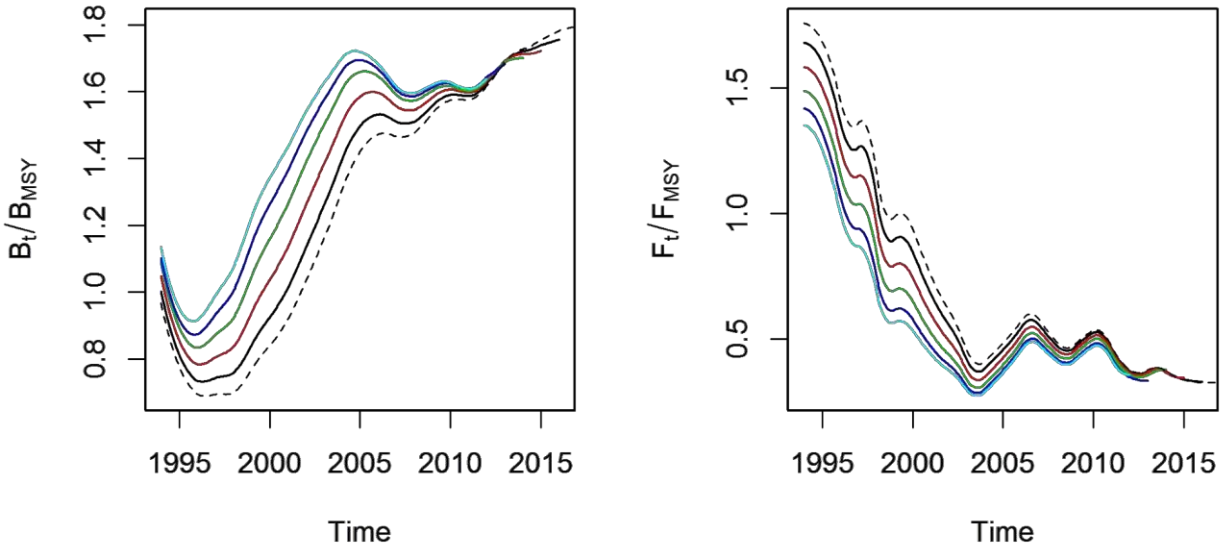

Fig.6.1.6-1 Retrospective plots of relative biomass and relative fishing mortality for red mullet, produced by repeating th stock assessment after excluding 1 (black line) to 5 (cyan line) final year observations of the catch and abundance index time series. The dotted black lines are the estimates when the full time series is considered.

6.1.7 Assessment quality

Residual analysis doesn't show any significant patters or bias and no significant deviation from normality (Fig. 6.1.7-1).

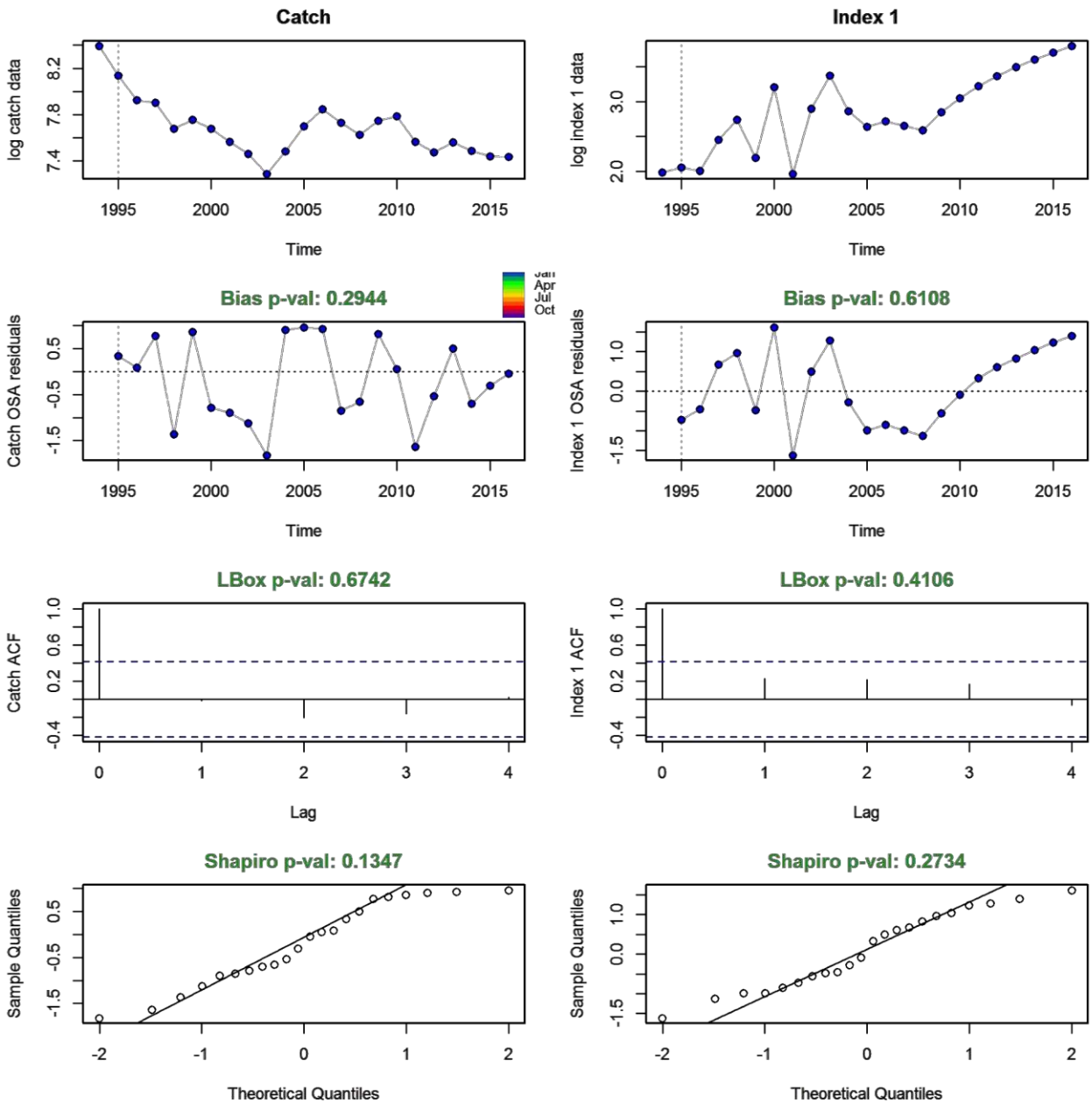

Fig. 6.1.7-1 Diagnostic test of the fit for the residuals of the catch and abundance index series. Log of input data series (first row), residuals plot (second row), autocorrelation of residuals (third row) and normality of residuals (fourth row). I the header is green the test is not significant, otherwise the header is red.

7 Stock predictions

7.1 Short term predictions

7.2 Medium term predictions

7.3 Long term predictions

8 Draft scientific advice

Based on	Indicator	Analytic al reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (time period)	Stock Status
Fishing mortality	Fishing mortality	$F/F_{msy}=1$	0.33		D	S
Stock abundance	Biomass	$B/B_{msy}=1$	1.78		I	S
Recruitment						
Final Diagnosis		The stock is exploited in a sustainable way				

8.1 Explanation of codes

Trend categories

1) N - No trend
2) I - Increasing
3) D – Decreasing 4) C - Cyclic

Stock Status Based on Fishing mortality related indicators

1) **N - Not known or uncertain** – Not much information is available to make a judgment;
2) **U - undeveloped or new fishery** - Believed to have a significant potential for expansion in total production;
3) **S - Sustainable exploitation**- fishing mortality or effort below an agreed fishing mortality or effort based Reference Point;
4) **IO –In Overfishing status**– fishing mortality or effort above the value of the agreed fishing mortality or effort based Reference Point. An agreed range of overfishing levels is provided; **Range of Overfishing levels based on fishery reference points**

   In order to assess the level of overfishing status when $F_{0.1}$ from a Y/R model is used as LRP, the following operational approach is proposed:

   - If $Fc^*/F_{0.1}$ is below or equal to 1.33 the stock is in **(O_L): Low overfishing**
   - If the $Fc/F_{0.1}$ is between 1.33 and 1.66 the stock is in **(O_I): Intermediate overfishing**
   - If the $Fc/F_{0.1}$ is equal or above to 1.66 the stock is in **(O_H): High overfishing** *Fc is current level of F

5) **C- Collapsed**- no or very few catches;

Based on Stock related indicators

1) **N - Not known or uncertain:** Not much information is available to make a judgment
2) **S - Sustainably exploited:** Standing stock above an agreed biomass based Reference Point;
3) **O - Overexploited**: Standing stock below the value of the agreed biomass based Reference
   Point. An agreed range of overexploited status is provided;

Empirical Reference framework for the relative level of stock biomass index

- **Relative low biomass:** Values lower than or equal to 33rd percentile of biomass index in the time series **(O_L)**
- **Relative intermediate biomass:** Values falling within this limit and 66th percentile **(O_I)**
- **Relative high biomass:** Values higher than the 66th percentile **(O_H)**

4) **D – Depleted**: Standing stock is at lowest historical levels, irrespective of the amount of fishing effort
5)
6)
7) Tables and graphs of Total biomass, SSB, Recruitment, F or other outcomes of the stock assessment model with comments on trends in stock size, recruitment and exploitation.
8) exerted;
9) **R –Recovering:** Biomass are increasing after having been depleted from a previous period;

Agreed definitions as per SAC Glossary

Overfished (or overexploited) *- A stock is considered to be overfished when its abundance is below an agreed biomass based reference target point, like B0.1 or BMSY. To apply this denomination, it should be assumed that the current state of the stock (in biomass) arises from the application of excessive fishing pressure in previous years. This classification is independent of the current level of fishing mortality.*

Stock subjected to overfishing (or overexploitation) *- A stock is subjected to overfishing if the fishing mortality applied to it exceeds the one it can sustainably stand, for a longer period. In other words, the current fishing mortality exceeds the fishing mortality that, if applied during a long period, under stable conditions, would lead the stock abundance to the reference point of the target abundance (either in terms of biomass or numbers)*