



Stock Assessment Form

Demersal species

Reference year: 2020

Reporting year: 2021

The musky octopus, *Eledone cirrhosa*, is a commercially important species in the South Adriatic. It is caught by demersal gears, mostly Italian bottom trawlers. The catch statistics in the past may have misreported the species with its congeneric *E. moschata*. The stock was assessed for GSA 18 in 2021 using the CMSY-BSM method. For the current assessment, the same assessment methods is applied, with changes to the model setup and parameterisation. Sensitivity analyses and alternative assessment approaches using the Length-based methods LBB and LBSPR are also reported.

Stock Assessment Form version 1.0 (January 2014)

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Stock assessment form

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1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
<i>Eledone cirrhosa</i>	Horned octopus	57
1st Geographical sub-area:	2nd Geographical sub-area:	3rd Geographical sub-area:
18		
4th Geographical sub-area:	5th Geographical sub-area:	6th Geographical sub-area:
1st Country	2nd Country	3rd Country
Italy	Montenegro	Albania
4th Country	5th Country	6th Country
Stock assessment method: (direct, indirect, combined, none)		
indirect		
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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):

- Acoustics survey

- Egg production survey
- Trawl survey
- SURBA
- Other (please specify)

Indirect method (you can choose more than one):

- ICA
- VPA
- LCA
- AMCI
- XSA
- Biomass models
- Length based models
- Other (please specify)

Combined method: you can choose both a direct and an indirect method and the name of the combined method (please specify)

2 Stock identification and biological information

2.1 Stock unit

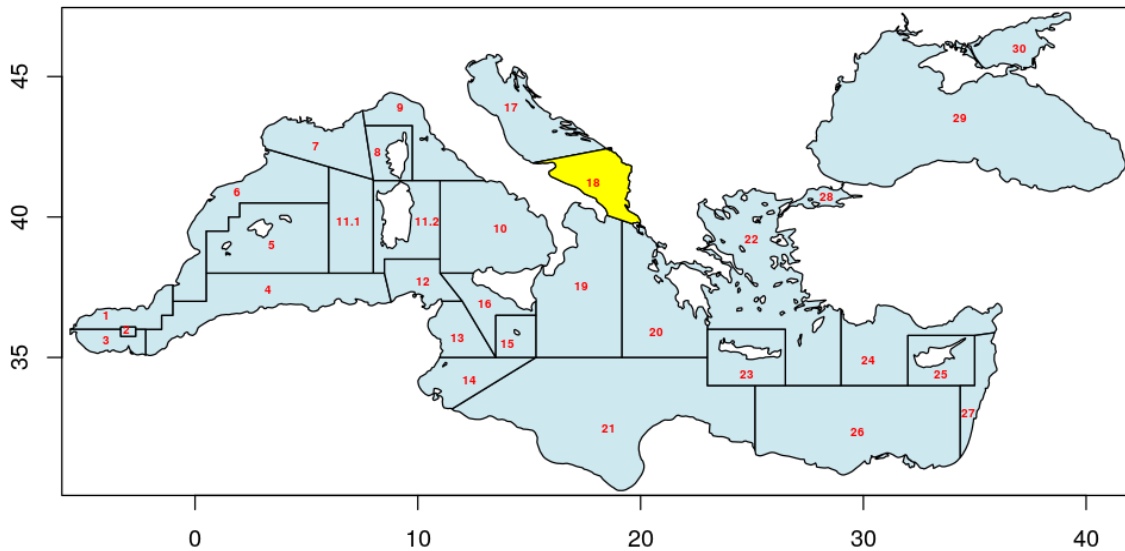


Figure 2.1. The study area GSA 18 is highlighted in yellow.

The Horned octopus *Eledone cirrhosa* can be found throughout the Mediterranean Sea and in the north-eastern Atlantic. The northern limit of distribution is about 66-67 °N, while the southern limit is in the latitudes of the Moroccan coast.

In the southern Adriatic, it is more abundant than the congeneric *E. moschata* (while the opposite is observed in the North Adriatic). The distribution area of these two species partly overlaps, and they are often commercialised together. The horned octopus lives in depths from 25 to 400 m, but it is most abundant over 75 m (Casali et al., 1998). In the southern Adriatic, it is found on muddy sediments in the depth range from 40 to 200 m along the Montenegrin coast (Mandić, 1984) and in a similar range along the Italian coast (Pastorelli et al., 1998).

The stock structure of this species in the Mediterranean is not clear. The STOCKMED project assessed the stock structure of *E. cirrhosa*, among other species, to identify plausible stock units. Although the methods suggested subdivision into six units at Mediterranean level, the results were considered not robust enough for proposing new reliable stock units. This assessment focuses on GSA 18 (Figure 2.1), assumed to be a unitary stock.

2.2 Growth and maturity

The horned octopus is a semelparous species, reproducing only once during its lifetime and dying shortly after. Belcari et al (2002) and Orsi Relini et al (2006) identify multimodal length frequency distributions and, therefore, relatively long life span up to three years of life.

The spawning peak takes place in summer (Donnalioia et al., 2010), while during autumn there are few mature and large specimens defined as “late spawners” (Cuccu et al., 2003; Orsi Relini et al., 2006). The appearance of the recruits of *E. cirrhosa* was recorded in January. The recruits shared coastal bottoms with

a cohort of adults for 6 months. After June the adults disappear moving to spawning grounds (Relini and Orsi Relini, 1984).

In the Adriatic, the proportion of young specimens (under 6 cm of mantle length, ML) is highest in the autumn period (Pastorelli et al., 1998).

Donnaloia et al., (2010) estimated the size at first maturity of both sexes and analysed the maturity cycle in the South Adriatic, observing that immature individuals were predominant during the autumn-winter period (62-100% from October to May for females; 66-95% from October to January for males), while in spring-summer the occurrence of mature or maturing individuals was higher (89-100% from June to August for females; 74-97% from March to August for males). The lengths at first maturity of females and males (Figure 2.2.) were respectively 9.7 ± 0.06 (MR= 1.5 ± 0.07 cm) and 7.8 ± 0.05 cm (MR= 1.4 ± 0.07 cm).

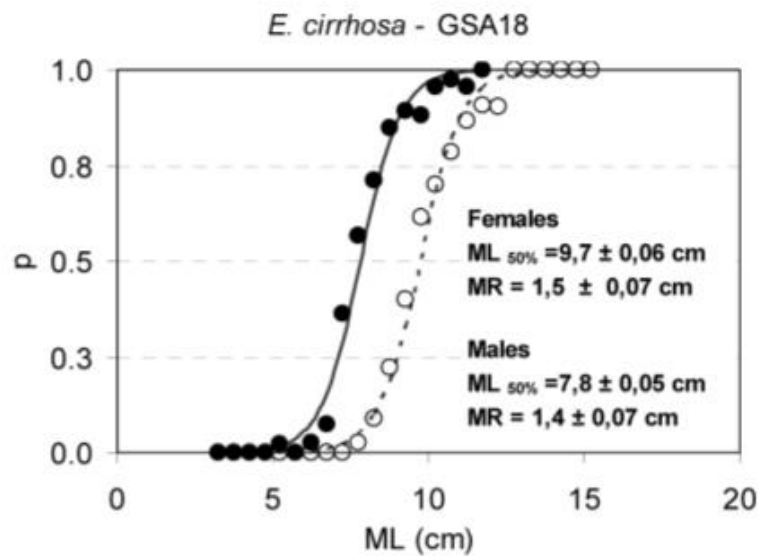


Figure 2.2. Maturity ogives of females (open circles) and males (closed circles) in GSA 18. Source: Donnaloia et al., 2010.

Table 2.1. Maximum size, size at first maturity and size at recruitment.

Somatic magnitude measured				Units	Cm
Mantle Length (ML)					
Sex	Fem	Mal	Combined	Reproduction season	summer
Maximum size observed				Recruitment season	Autumn
Size at first maturity	9.7(\pm 0.06)	7.8(\pm 0.05)		Spawning area	
Recruitment size to the fishery			2	Nursery area	

Table 2.2. Growth and length weight model parameters.

		Sex				
		Units	female	male	Combined	Years
Growth model	ML $_{\infty}$	cm	21	15.6		
	K		0.387	0.422		
	t ₀		-0.028	-0.071		
	Data source					
Length weight relationship	a	cm/g	0.3277	0.2903		
	b		2.8684	2.9009		
	M (scalar)	cm/g				
	sex ratio (% females/total)					

3 Fisheries information

3.1 Description of the fleet

The horned octopus is a commercially important species. It is fished mainly with bottom trawl nets. Catch from gillnets and other artisanal gears are minor. The gillnet and set net catch recorded in DCF Italian 2020 data accounts for 0.25%, while demersal trawlers account for 99.75%. In 2021, 100% of Italian landings come from demersal trawlers. The CPUE shows a distinct seasonality with the biggest catches occurring in spring months (Pastorelli et al., 1995). On the market, horned octopus often appears mixed with *E. moschata*, therefore misreporting between the two species cannot be excluded.

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*	Italy	GSA18	T10-T11-T12	OTB	57	Horned octopus
Operational Unit 2	Italy	GSA18	P05-P06-P07-P08	GNS	57	Horned octopus
Operational Unit 3	Italy	GSA18	P05-P06-P07-P08	GTR	57	Horned octopus
Operational Unit 4	Montenegro	GSA18	T10-T11	OTB	57	Horned octopus
Operational Unit 5	Albania	GSA18	T10-T11	OTB	57	Horned octopus

Table 3.2. Catch, bycatch, discards and effort by operational unit in the reference year

Operational Units*	Fleet (n° of boats)*	Catch (T or kg of the species assessed)	Other species caught (names and weight)	Discards (species assessed)	Discards (other species caught)	Effort (units)
[Operational Unit1]		293.7		0		
[Operational Unit2]		0		0		
[Operational Unit3]		0		0		
[Operational Unit4]		0		0		
[Operational Unit5]		62.88		0		
Total		456.5		0		

3.2 Historical trends

Landing records of the horned octopus GSA 18 from Italy (DCF data), Montenegro (Fishstat data) and Albania (from national statistics) are available (Figure 3.1).

For the Italian fleets, landings are available from DCF from 2004 to 2021. Discards recorded for the Italian fleet was only available for one year and one fleet segment, and in negligible amount (0.8% of catch). Catches were thus assumed identical to landings. Historical landing (1972-1999) for the Italian fleet were obtained from ISTAT for GSA18. These landing values were recorded as *E. cirrhosa* however are, with all likelihood, a mixture of the two species of *Eledone*. As such, the landing for *E. cirrhosa* were reconstructed based on the reported landings, downweighted with a ratio of the catches of *E. cirrhosa*/*E. spp.* This ratio was calculated using DCF landing data in GSA 18 for the two species, averaging across the closest five years (2004-2009). The ratio was fairly stable in the years for which both species are available (2004-2019). The ratio is thus likely to reflect well the historical proportion of the two species in the landing. The ratio in the catches was considered to be a better proxy of proportion in the catches compared with the ratio of biomass from the survey, as the survey is considered to capture *E. moschata* less efficiently than *E. cirrhosa*. For the years 2000-2003 for which no landing data are available, the missing values were estimated using a 5-year moving average (Figure 3.2).

Montenegrin catch data in Fishstat are available only as aggregate *Eledone spp.* between 2006 and 2021. To estimate the proportion in the catch, the median 2006-2019 proportion of *E. cirrhosa* over the two species (47%) in the Italian DFC landings was used to extrapolate catch of *E. cirrhosa* in Montenegrin data. Novel data for the years 2018-2021 were obtained, replacing the assumption of constant catches used in the previous years' assessment. Landings for 2004 and 2005 were assumed identical to the values in 2006. No information about discards was available for Montenegro.

Albania recorded landing information for this species only for 2019, 2020 and 2021. The declared catches, reported as *Eledone spp.*, are likely to be a mixture of the two species, thus the same criteria for estimating catches for *E. cirrhosa* as for Montenegrin data was applied.

Table 3.3. Landings in tons from Italian fleet (DCF data) for Italian gillnets (GNS), set net (GTR) and demersal trawler (OTB) with respective fisheries.

Gear	GTR	-1	GNS	OTB					Total
Fishery			DEF	-1	DEMSP	DWS	MDD	Total OTB	
2004					9.55		190.18	199.73	199.73
2005					20.78		509.92	530.70	530.70
2006		0.56			209.82		443.87	653.69	654.26
2007			0.14	842.69				842.69	842.83
2008				648.13				648.13	648.13
2009				758.90				758.90	758.90
2010					610.30	0.07	133.90	744.28	744.28
2011					609.88		45.69	655.58	655.58
2012					447.65		16.61	464.26	464.26
2013			0.41		904.50		12.84	917.34	917.75
2014					646.06		31.66	677.72	677.72
2015					441.78		28.35	470.13	470.13
2016			2.88		482.17	0.04	4.22	486.43	489.32
2017			0.09		838.84		80.94	919.78	919.87
2018			0.09		1440.86	1.96	42.66	1485.47	1485.56
2019			0.0443		1073.187	4.714	54.983	1132.883	1132.928
2020	0.989		0.002		386.06	0.46	5.18	391.7	392.7
2021					289.5388	0.008	4.1945	293.7413	293.7413

Table 3.4. Reconstructed landings (tons) from Montenegro from aggregated landing of *E. cirrhosa* and *E. moschata* (data from Fishstat), reconstructed to landing of *E. cirrhosa* based on proportion between the two species in Italian DCF landing data. Values underlined and in italics (2004-2005) were assumed identical to closest reconstructed values. Values in **bold font** (2018-2021) have been updated.

Year	MTN horned octopus landing reconstructed
2004	<u>8.64</u>
2005	<u>8.64</u>
2006	8.64
2007	6.24
2008	10.08
2009	7.2
2010	10.56
2011	6.24
2012	5.76
2013	4.8
2014	4.8
2015	4.32
2016	4.32
2017	1.44
2018	0
2019	0
2020	2.126
2021	0

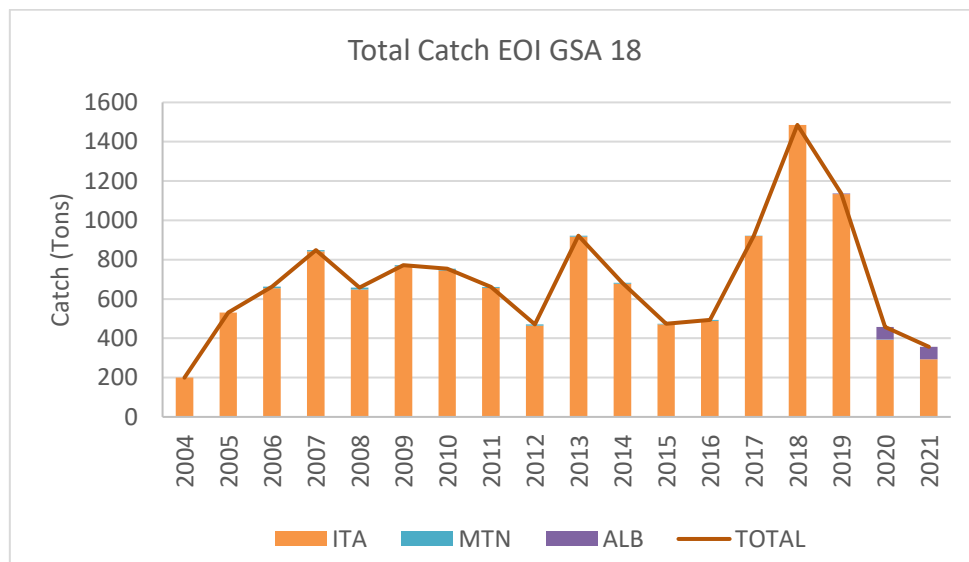


Figure 3.1. Catches (tons) by country (stacked bars) and total (line) for *E. cirrhosa* in GSA 18

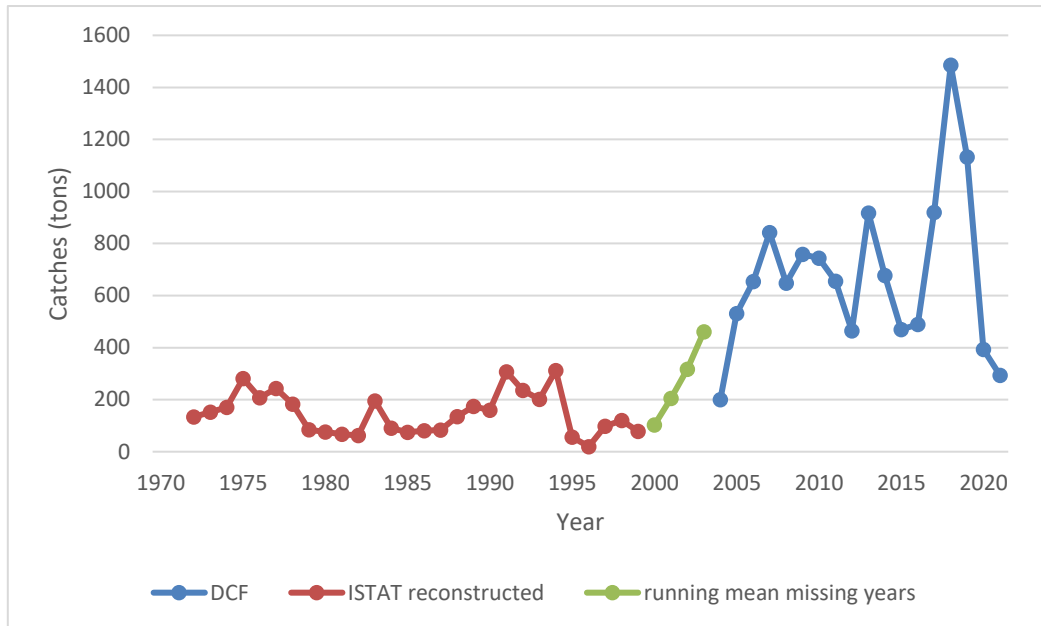


Figure 3.2. Reconstructed historical landings of Horned octopus *E. cirrhosa* (GSA 18) from ISTAT data (1972-1999), with running means for missing years (2000-2003), for Italian fleets.

The length frequency distributions in the catch (Figure 3.3) were obtained from DCF data (for Italian landings) for the years 2008-2021. No LFD data were available before 2008 as this species was not a DCF target species until that year.

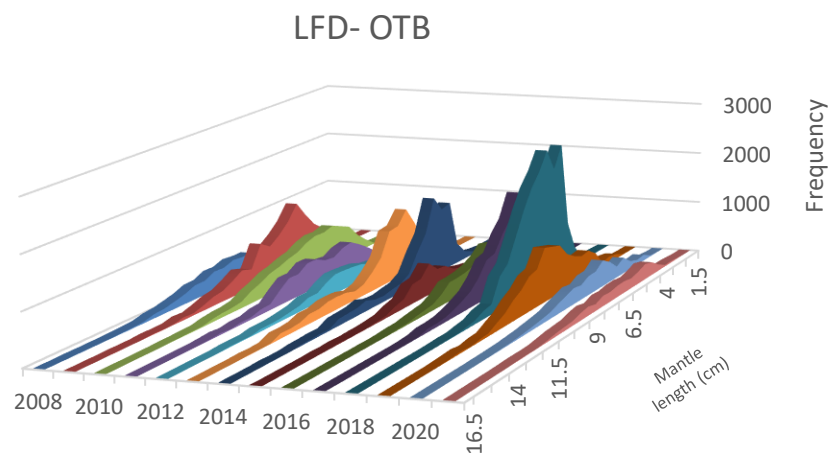


Figure 3.3. Length Frequency Distribution in the Italian landings per year. Length expressed as mantle length, in cm.

3.3 Management regulations

In Italy management regulations are based on technical measures, closed number of fishing licenses for the fleet and area limitation (distance from the coast and depth). In order to limit the over-capacity of fishing fleet, the Italian fishing licenses have been fixed since the late '80s and the fishing capacity has been gradually reduced. Other measures on which the management regulations are based regard technical measures (mesh size), minimum landing sizes (EC 1967/06) and seasonal fishing ban, that in southern Adriatic has been mandatory since the late '80s. Regarding small scale fishery management regulations are based on technical measures related to the height and length of the gears as well as the mesh size opening, minimum landing sizes and number of fishing licenses for the fleet. In 2008 a management plan was adopted, that foresaw the reduction of fleet capacity associated with a reduction of the time at sea. Two biological conservation zone (ZTB) were permanently established in 2009 (Decree of Ministry of Agriculture, Food and Forestry Policy of 22.01.2009; GU n. 37 of 14.02.2009) along the mainland, offshore Bari (180 km², between about 100 and 180 m depth), and in the vicinity of Tremiti Islands (115 km² along the bathymetry of 100 m) on the northern border of the GSA where a marine protected area (MPA) had been established in 1989. In the former only the professional small scale fishery using fixed nets and long-lines is allowed, from January 1st to June 30th, while in the latter the trawling fishery is allowed from November 1st to March 31 and the small scale fishery all year round. Recreational fishery using no more than 5 hooks is allowed in both the areas. Since June 2010 the rules implemented in the EU regulation (EC 1967/06) regarding the cod-end mesh size and the operative distance of fishing from the coasts are enforced.

In Montenegro, management regulations are based on technical regulations, such as mesh size (Official Gazette of Montenegro, 8/2011), including the minimum landing sizes (Official Gazette of Montenegro, 8/2011), and a regulated number of fishing licenses and area limitation (no-fishing zone up to 3 NM from the coastline or 8 NM for trawlers of 24+ m LOA). Currently there are no MPAs or fishing bans in Montenegrin waters.

In Albania, a new law "On fishery" has now been approved, repealing the Law n. 7908. The new law is based on the main principles of the CFP, it reflects Reg. 1224/2009 CE ; Reg.1005/2008 CE; Reg. 2371/2002 CE; Reg. 1198/2006 CE; Reg. 1967/2006 CE; Reg. 104/2000; Reg. 1543/2000 as well as the GFCM recommendations. The legal regime governing access to marine resources is being regulated by a licensing system. Regarding conservation and management measures, minimum legal sizes and minimum mesh sizes is those reflected in the CE Regulations. Albania has already an operational vessel register system. It is forbidden to trawl at less than 3 nautical miles (nm) from the coast or inside the 50m isobath when this distance is reached at a smaller distance from the shore.

3.4 Reference points

Reference points were calculated in the assessment performed in 2021, with FMSY=0.491 and BMSY=1.89.

4 Fisheries independent information

4.1 MEDITS

MEDITS survey was carried out in GSAs 18 since 1994 in the Italian area, since 1996 in Albania and since 2008 in Montenegro. Based on the DCF data call, abundance and biomass indices were calculated for

GSA18 using the ad hoc script. The survey takes place in the summer months with some variability in few years (Figure 4.1).



Figure 4.1. Timing of the MEDITS survey in GSA 18 through the years.

4.1.1 Spatial distribution of the resources

4.1.2 Historical trends

The survey takes place since 1994 and the biomass index are available from 1994 to 2021. The indices show large oscillations and no apparent trend in time. There is an increase in biomass in 2018 and 2019 compared to previous years, however this does not reach the historical peak biomass and is followed by a decline in 2020 and 2021. The standardized biomass index was used in the analysis. The raw and standardized index figures are provided (Figure 4.2).

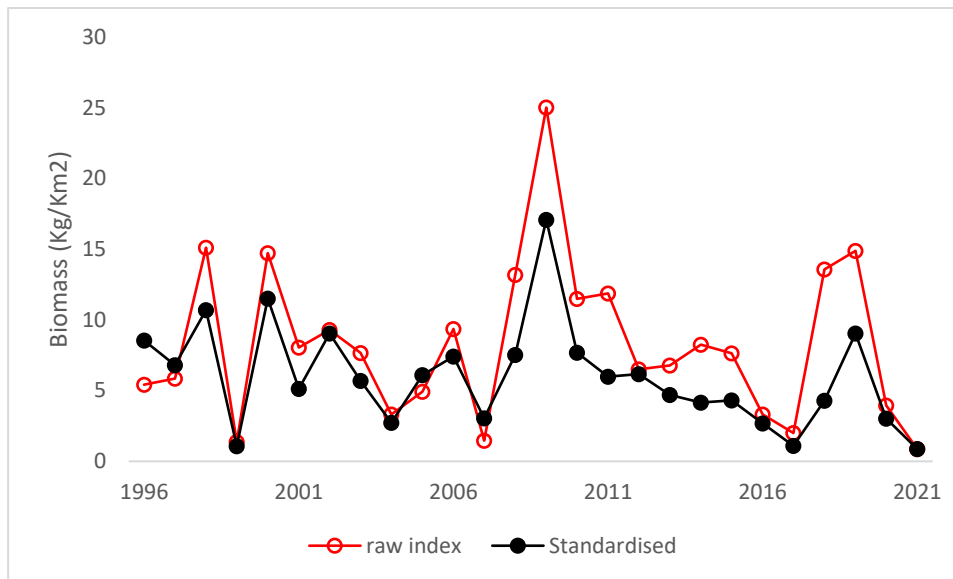


Figure 4.2. MEDITS biomass index of *E. cirrhosa* in GSA 18, raw data (red) and standardized indices (black).

5 Ecological information

5.1 Protected species potentially affected by the fisheries

This analysis has not been carried out.

5.2 Environmental indexes

No environmental indices used in this assessment.

6 Stock Assessment

6.1 CMSY

CMSY is a Monte-Carlo method that estimates fisheries reference points (MSY, F_{msy} , B_{msy}) as well as relative stock size (B/B_{msy}) and exploitation (F/F_{msy}) from catch data and broad priors for resilience or productivity (r) and for stock status (B/k) at the beginning and the end of the time series. Part of the CMSY package is an advanced Bayesian state-space implementation of the Schaefer surplus production model (BSM). The main advantage of BSM compared to other implementations of surplus production models is the focus on informative priors and the acceptance of short and incomplete (= fragmented) abundance data. The CMSY version used in the present assessment (CMSY++_16.R) is newer than the one used in Froese et al. (2017). The main differences are (i) the use of a full Bayesian approach with MCMC (Markov chain Monte Carlo) modelling also for the catch-only (i.e. CMSY) analysis, (ii) faster execution, (iii) the use of an AI (Artificial Intelligence) neural network to predict default biomass priors from catch, and (iv) more emphasis on graphical outputs including various analytical plots. A major improvement for both CMSY and BSM is the introduction of multivariate normal priors for r and k in log space, replacing the previous uniform prior distributions. This allowed also for a simplified determination of the 'best' r - k pair in CMSY and faster run times, as reported in the User Guide for CMSY++ (Froese et al., 2021)

6.1.1 Model assumptions

The CMSY model utilizes parameter estimation through Monte-Carlo. The Bayesian production model can also include CPUE or biomass data. These are not utilized by the CMSY model. The two models are run in parallel to provide a benchmark of the parameter estimates. The user decides whether the final management reference points should be calculated using CMSY or BSM. Based on the fact that the CPUE time series is based on MEDITS survey, which is known to sample the species assessed efficiently, the BSM model was chosen for this assessment.

6.1.2 Scripts

The model script was downloaded from the GEOMAR repository (<http://oceanrep.geomar.de/52147/>).

The script section with general settings for the analysis is reported below:

```
#-----  
# General settings for the analysis ----  
#-----  
CV.C      <- 0.15 #><>MSY: Add Catch CV  
CV.cpue   <- 0.2 #><>MSY: Add minimum realistic cpue CV  
sigmaR    <- 0.1 # overall process error for CMSY; SD=0.1 is the default  
cor.log.rk <- -0.76 # empirical value of log r-k correlation in 250 stocks analyzed with BSM (without r-k  
                correlation), used only in graph  
rk.cor.beta <- c(2.52,3.37) # beta.prior for rk cor+1  
nbk       <- 3 # Number of B/k priors to be used by BSM, with options 1 (first year), 2 (first & intermediate),  
                3 (first, intermediate & final bk priors)  
bt4pr     <- F # if TRUE, available abundance data are used for B/k prior settings  
auto.start <- F # if TRUE, start year will be set to first year with intermediate catch to avoid ambiguity  
                between low and high biomass if catches are very low  
ct_MSY.lim <- 1.21 # ct/MSY.pr ratio above which B/k prior is assumed constant  
q.biomass.pr <- c(0.9,1.1) # if btype=="biomass" this is the prior range for q  
n         <- 25000 # number of points in multivariate cloud in graph panel (b)  
ni        <- 3 # iterations for r-k-startbiomass combinations, to test different variability patterns; no  
                improvement seen above 3  
nab       <- 3 # recommended=5; minimum number of years with abundance data to run BSM  
bw        <- 3 # default bandwidth to be used by ksmooth() for catch data  
mgraphs   <- T # set to TRUE to produce additional graphs for management  
e.creep.line <- T # set to TRUE to display uncorrected CPUE in biomass graph  
kobe.plot <- T # set to TRUE to produce additional kobe status plot; management graph needs to be TRUE  
                for Kobe to work  
BSMfits.plot <- T # set to TRUE to plot fit diagnostics for BSM  
pp.plot   <- T # set to TRUE to plot Posterior and Prior distributions for CMSY and BSM  
rk.diags  <- T #><>MSY set to TRUE to plot diagnostic plot for r-k space  
retros    <- F # set to TRUE to enable retrospective analysis (1-3 years less in the time series)  
save.plots <- T # set to TRUE to save graphs to JPEG files  
close.plots <- T # set to TRUE to close on-screen plots after they are saved, to avoid "too many open devices"  
                error in batch-processing  
write.output <- T # set to TRUE if table with results in output file is wanted; expects years 2004-2014 to be
```

available

```
write.pdf <- F # set to TRUE if PDF output of results is wanted. See more instructions at end of code.  
select.yr <- NA # option to display F, B, F/Fmsy and B/Bmsy for a certain year; default NA  
write.rdata <- T #><>HW write R data file
```

6.1.3 Input data and Parameters

Following the previous year's assessment, priors were based on expert opinion and on the methods advised by Froese et al., 2017.

6.1.3.1 Resilience

Prior for Resilience (r) was set based on the carrying capacity of the Von Bertalanffy (using data reported above). The resilience can be assumed to approximate $3 \cdot K$. Using both male and female K provided, r values of 1.16-1.27 were assumed, corresponding to a high resilience according to the criteria provided by Froese et al. (2017) and CMSY user guide (Table 6.1).

Table 6.1. Ranges of prior r range and Resilience level to set in CMSY input file.

Resilience	prior r range
High	0.6 – 1.5
Medium	0.2 – 0.8
Low	0.05 – 0.5
Very low	0.015 – 0.1

6.1.3.2 Setting of initial, intermediate and final biomass:

The initial and final relative biomass compared to unexploited biomass (k) is required, based on the likely status of the stock: lightly fished, fully exploited or overfished. In addition, an intermediate year can also be set, and relative biomass for the intermediate year is set following the same criteria. Table 6.2 provides suggested ranges for relative biomass to be used as input parameters, depending on the depletion status of the stock.

Table 6.2. Prior relative biomass (B/k) ranges for CMSY.

Very strong depletion	Strong depletion	Medium depletion	Low depletion
0.01 – 0.2	0.01 – 0.4	0.2 – 0.6	0.4 – 0.8

Froese et al. (2017) provides rules for setting initial, intermediate and final year biomass priors:

Initial biomass:

According to these rules, initial biomass should be set at “medium depletion” (0.2-0.6) in all cases, except when the catch data start between 1950s and 1960s, when most fisheries were starting or re-starting after World War II. According to these rules, and based on the fact that our data starts in 2004 when the fishery was already developed, the initial biomass is set as **medium depletion (0.2-0.6)**.

Intermediate biomass:

For the setting of the intermediate biomass range, the years and amounts of minimum and maximum catch

are determined. Cases where minimum or maximum catch fall within 3 years of the beginning or the end of the time series are ignored, as it is deemed to make little sense to set intermediate prior biomass so close to start or end biomass. Instead, the next closest values were used for minimum and maximum catch.

Following these rules, year 1996 is the minimum (19.8 tons) when using the ISTAT data, and year 2004 (208.4 tons) when using the DCF data; and year 2018 the maximum (1487 tons) in the catch time series.

The following rules for the intermediate prior biomass range are applied in priority of sequence.

1. If overall contrast in catch data is low (overall min catch / overall max catch > 0.6), the intermediate year is set to the mid of the time series and biomass is assumed to be the same as the initial prior biomass.

In our case the contrast provides a value of 0.14 (short time series; 0.013 for the long time series), so we go to point 2.

2. If the minimum catch occurs after the maximum catch, the year before the minimum catch is used to set the intermediate prior biomass.

This is not our case as minimum catch is in 1996 (2004) and maximum in 2018 in our catches time series.

3. If the minimum catch occurs before the maximum catch, the year before the maximum catch is used as intermediate year. In our case, 2017 is thus set as the intermediate year.
 - a. If initial prior biomass is high and the maximum catch occurs in the first half of the time series then the intermediate prior biomass range is set to high.
 - b. If there is a steep increase in catches ((max catch - min catch) / max catch / (max year – min year) > 0.04), a developing or recovering fishery is assumed and the intermediate prior biomass range is set to high.
 - c. Else the intermediate prior biomass range is set to medium

In our case the increase in catch is steep (0.045 long time series; 0.06 short time series). We thus assume biomass in 2017 to be in a high state, and the intermediate biomass was set to **high (0.4-0.8)**.

Final catch:

If the last catch is high relative to overall maximum catch (last catch / overall max catch > 0.7) the final prior biomass range is set to high; if below 0.7 but above 0.3 the biomass range prior is set to intermediate; and if below 0.3, it is set to low. This is our case as last year (2021) divided by highest year (2018) gives a value of 0.24 (<0.3). Thus, we should set the final value to **low (0.01-0.4)**. However, the catch in the last two years are more indicative of reduced effort due to external factors (namely the COVID crisis) rather than the reduction of biomass caused by stock depletion. The MEDITS survey helps to outline the temporal pattern of biomass: the biomass trend declines constantly between 2009 and 2017, with an increase in biomass only in 2018, reaching about the average of the historical average biomass, and a third of the historical maximum. Accordingly, the biomass cannot be assumed to be in a low exploitation state, and prior values at medium level (0.2-0.6) are assumed realistic. However, the model was allowed to estimate freely the terminal biomass based on data, and no prior was set on the terminal B/k. The priors used in the main run are summarized in Table 6.3.

Table 6.3. Parameters used for the model. Endb.low and Endb.hi were not set and the model estimated the terminal biomass.

Species	Start year	End year	Resilience	Stb.low	Stb.hi	Int.yr	Intb.low	Intb.hi	Endb.low	Endb.hi	Model
<i>E. cirrhosa</i>	2004	2021	High	0.2	0.6	2017	0.4	0.8	-	-	BSM

Alternative settings are explored in sensitivity analysis in order to gauge the robustness of results to the model setup.

6.1.4 Results

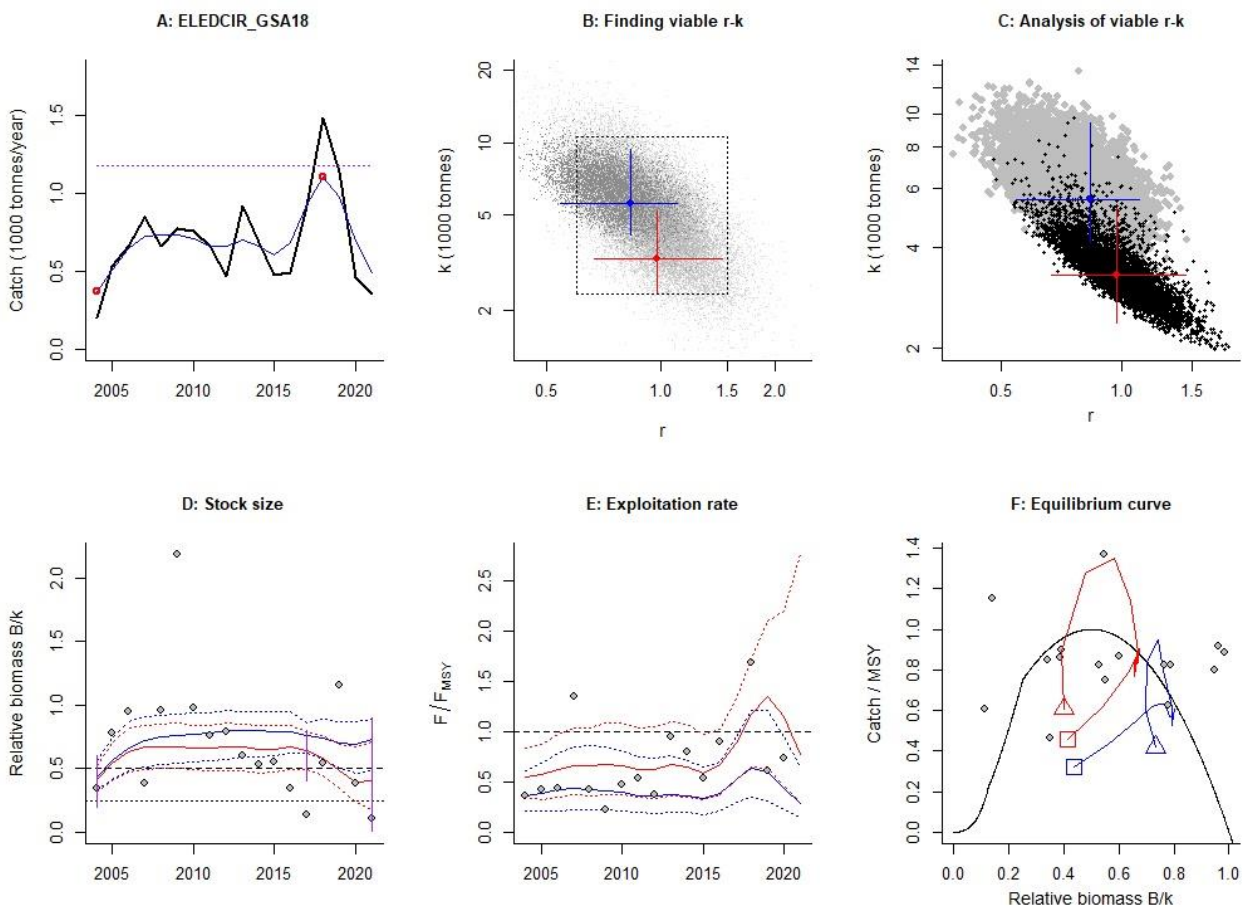


Figure 6.1. Diagnostics results of the final model run.

Figure 6.1 shows the CMSY assessment for horned octopus in GSA 18. The black curve in **A** shows the time series of catches and the blue curve shows the smoothed data with indication of highest and lowest catch in red, as used in the estimation of prior biomass by the default rules. Panel **B** shows the explored log r - k space and in dark grey the r - k pairs which were found by the model to be compatible with the catches and the prior information. The dotted rectangle indicates the range of the priors provided in the ID file. The point in the center of the blue cross is the most likely r - k pair predicted by CMSY and horizontal and vertical error bars approximate 95% confidence limits for r and k , respectively, which are again closer view in Panel **C**. The blue curve in **D** shows the median of the biomass trajectories estimated by CMSY. Dotted lines indicate the 2.5th and 97.5th percentiles. Vertical blue lines indicate the prior biomass ranges. Panel **E** shows median exploitation (F/F_{MSY}) as blue curve, with the dotted curves indicating 2.5th and 97.5th percentiles. The steep increase in the upper confidence limit in the last year results from catch relative to

the lower confidence limit of biomass in panel D. Panel F shows the Schaefer equilibrium curve of catch/MSY relative to B/k , indented at $B/k < 0.25$ to account for reduced recruitment at low stock sizes. The blue curve shows the predictions by CMSY, from first year (square) to last years (triangle).

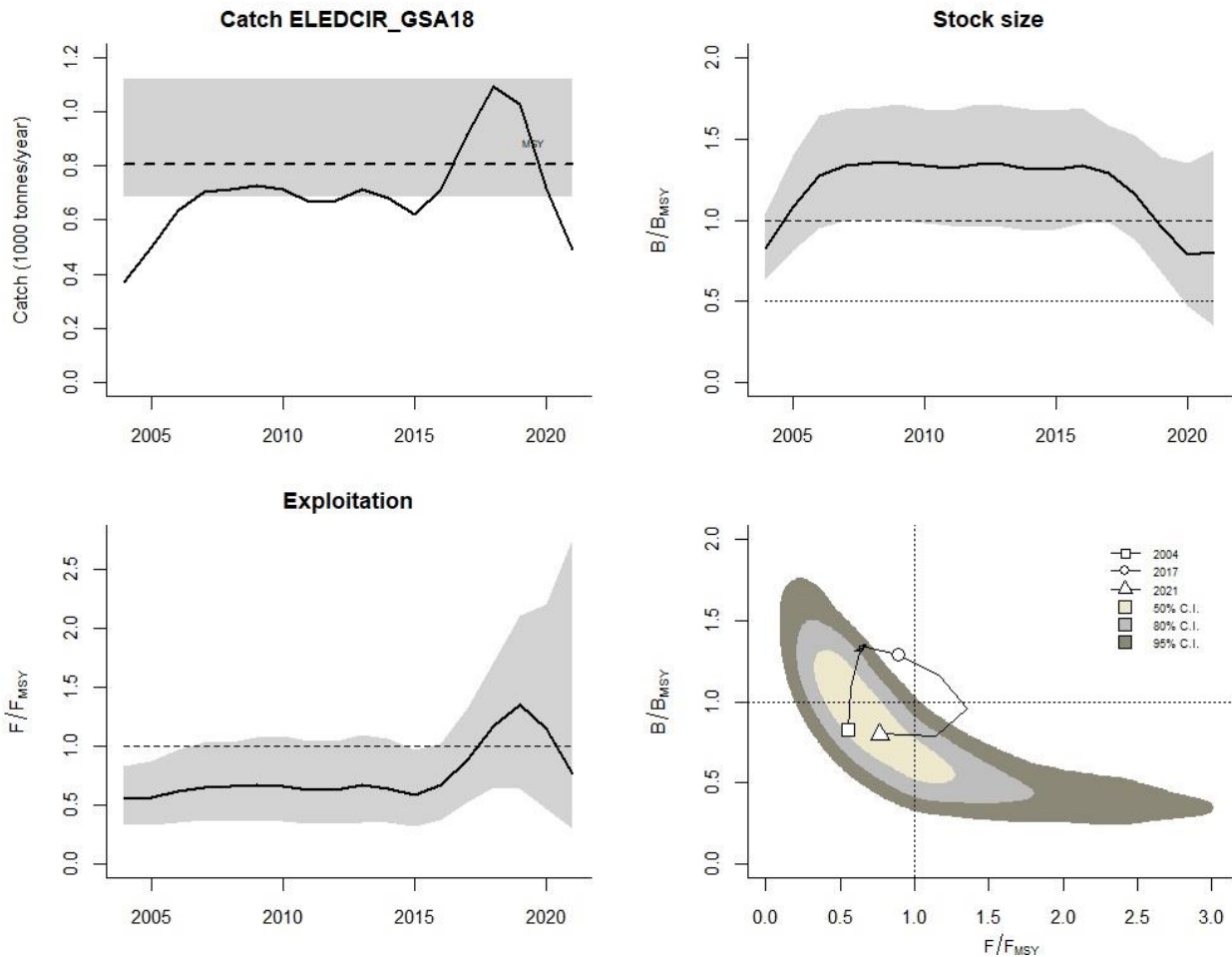


Figure 6.2. Results of the final model run.

Figure 6.2 shows the summary information relevant for management. The upper left panel shows catches relative to the BSM estimate of MSY, with indication of 95% confidence limits in grey. The upper right panel shows the development of relative total biomass (B/B_{msy}), with the grey area indicating uncertainty. The horizontal dashed lines in the Catch graph indicate MSY and the fine dotted line indicates the lower confidence limit of MSY. The lower left graph shows relative exploitation (F/F_{msy}). The lower right panel shows a KOBE plot indicating current and past state of the stock compared to reference points F/F_{MSY} and B/B_{MSY} . The “banana” shape around the assessment of the final year triangle indicates uncertainty with beige for 50%, grey for 80% and dark grey for 95% confidence levels.

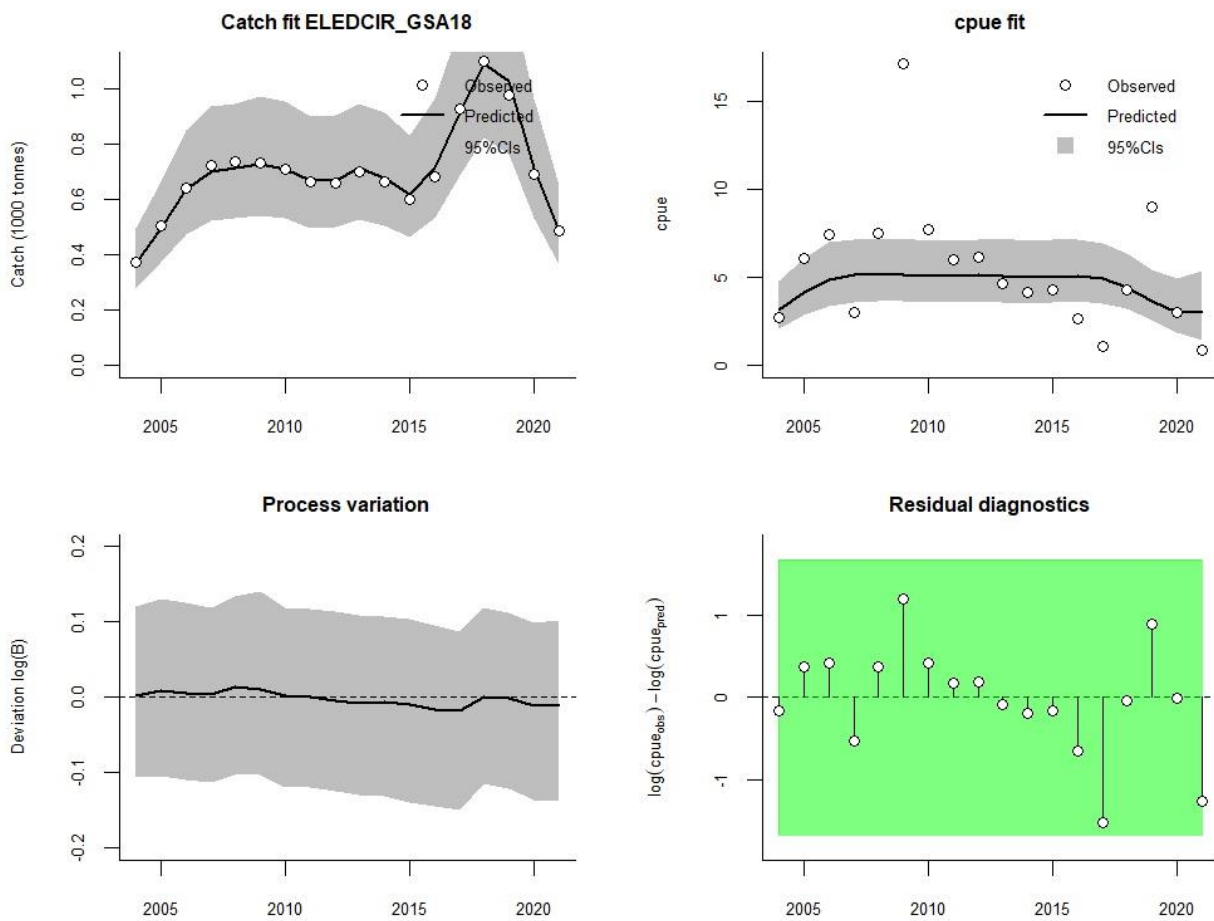


Figure 6.3. Analytical Results of the final model run.

Figure 6.3 shows the analytical results. The upper left panel shows the fit represented by the median of predicted catch posterior, with 95% confidence limits (grey shaded area), compared to the observed catch (points). The upper right panel shows a similar graph for predicted versus observed CPUE. The lower left panel shows the deviation between deterministic expectation (surplus production minus catch) and the stochastic realization (after adding process error), where a strong deviation of the bold curve from the dashed line would indicate that changes in biomass diverge from the Schaefer model expectations due to, e.g., (1) strong environmental variation, (2) CPUE not properly describing the abundance or (3) the priors are mis-specified and require re-evaluation. The lower right graph shows an analysis of the log-CPUE residuals, with a white or green background if autocorrelation of residuals is deemed negligible (and red otherwise), as judged by a non-parametric Runs test for testing randomness in time series. In our case, all values are within the limits of the autocorrelation for residuals.

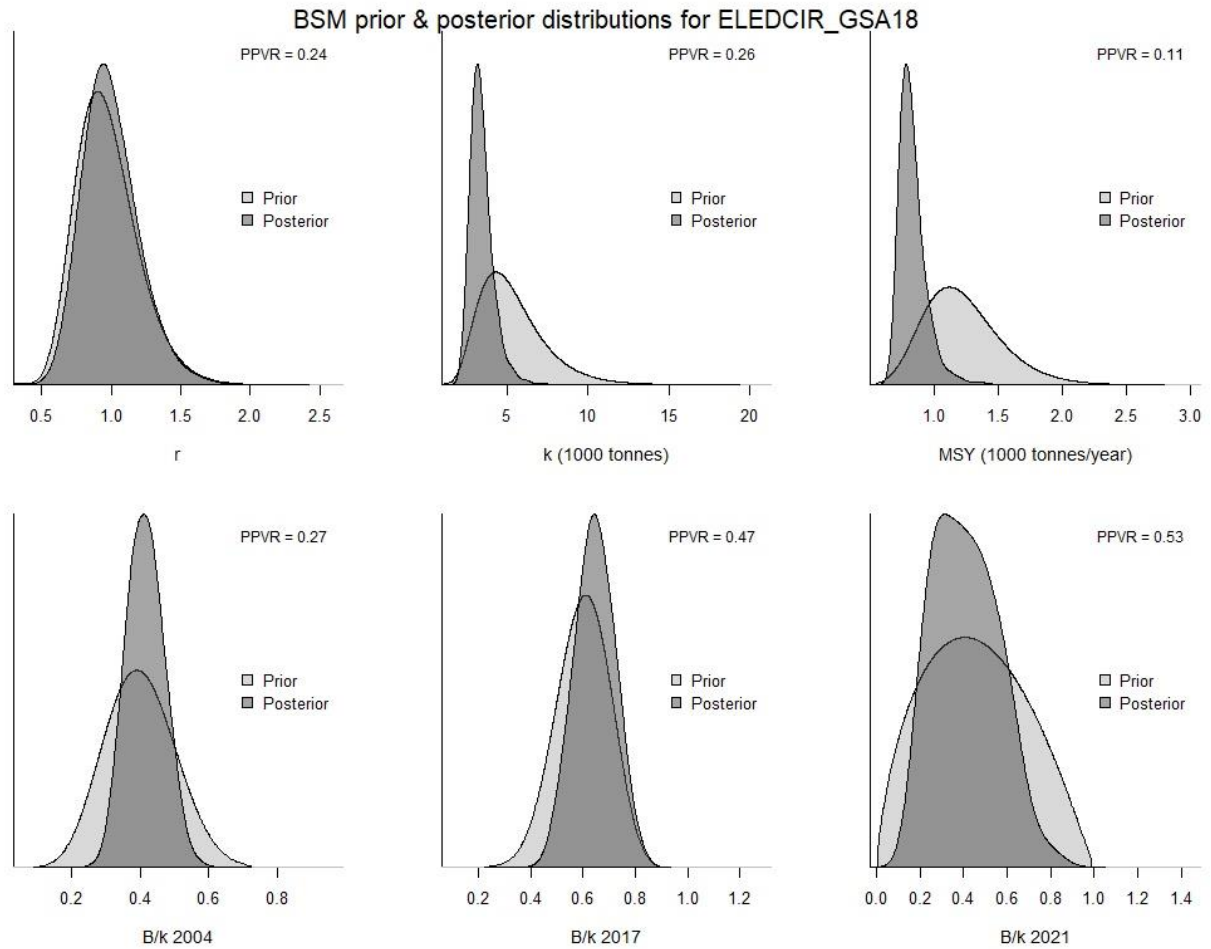


Figure 6.4. Prior-posterior densities comparison for final model run.

Figure 6.4 shows the comparison of prior and posterior densities (same area under curves) for productivity (r , top-left), maximum stock size (k , top-central), maximum sustainably yield (MSY, top-right), and relative stock size (B/k) at the beginning, the end, and an intermediate (bottom left, central and right panels) year of the available time series of catch data. The priors (light grey) inform the results, with posterior understanding (dark grey) of the stock clearly improved compared to prior perceptions. The lower the prior-posterior variance ratio (PPVR), the more the posterior knowledge is improved relative to prior knowledge.

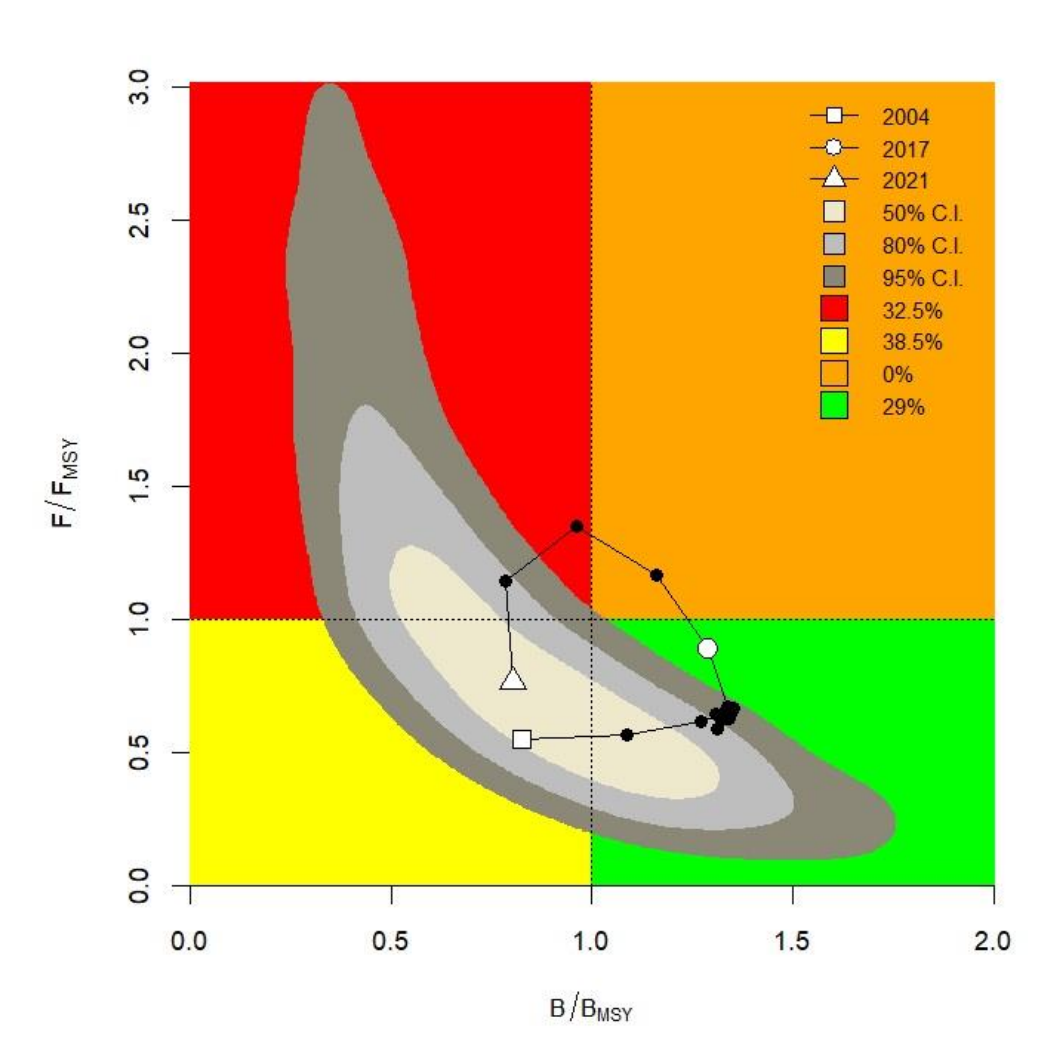


Figure 6.5. KOBE plot of the final model run. Current (triangle) and past position of the stock relative to reference points B/B_{MSY} and F/F_{MSY} , with intervals of confidence (grey areas).

Figure 6.5 shows a Kobe phase plot, representing the time series of pressure (F/F_{MSY}) on the Y-axis and of state (B/B_{MSY}) on the X-axis. The plot is divided into four quadrants, defined for the stock biomass and fishing mortality relative to B_{MSY} and F_{MSY} , respectively. Panel colors follow a traffic-light approach. Shades of grey indicate levels of confidence. The “banana” shape around the assessment of the final year triangle indicates uncertainty with beige for 50%, grey for 80% and dark grey for 95% confidence levels. In the legend, percentage probability of the current year to fall under the four panels (indicated by respective colours) is shown. Here, the model estimates a probability of 38.5% to fall in the yellow area, 29% in the green area, and 32.5% in the red area.

State of exploitation: Exploitation varied without any trend in the years between 2004 and 2015, with an increase between 2016 and 2018, and in particular since 2017. In 2019, it reached the historical high level in terms of F/F_{MSY} , with a decline in the last two years, with a value of 0.767 (95% CI:0.298-2.75).

State of the biomass: The biomass was stable until 2016, to then decrease rapidly until 2020, with values for 2021 being very similar to those of 2020. Biomass has been above B_{MSY} throughout the time series

(except the first year) until 2018 to then drop below this threshold in 2019. In the terminal year, B/BMSY is estimated at 0.802 (95% CI: 0.349-1.43).

Results of the CMSY and BSM analyses are reported below:

Results of CMSY analysis

$r = 0.836$, 95% CL = 0.545 - 1.11 , $k = 5.58$, 95% CL = 4.13 - 9.41
MSY = 1.17 , 95% CL = 0.806 - 1.81
Relative biomass in last year = 0.735 k , 2.5th perc = 0.482 , 97.5th perc = 0.885
Exploitation $F/(r/2)$ in last year = 0.286 , 2.5th perc = 0.149 , 97.5th perc = 0.649

Results from Bayesian Schaefer model (BSM) using catch & CPUE

$q = 2.37$, $lcl = 1.24$, $ucl = 3.66$ (derived from catch and CPUE)
 $r = 0.975$, 95% CL = 0.669 - 1.45 , $k = 3.31$, 95% CL = 2.38 - 5.22 , $r-k$ log correlation = -0.798
MSY = 0.806 , 95% CL = 0.685 - 1.12
Relative biomass in last year = 0.401 k , 2.5th perc = 0.174 , 97.5th perc = 0.713
Exploitation $F/(r/2)$ in last year = 0.767 , 2.5th perc = 0.298 , 97.5th perc = 2.75

Results for Management (based on BSM analysis)

$F_{msy} = 0.487$, 95% CL = 0.334 - 0.725 (if $B > 1/2 B_{msy}$ then $F_{msy} = 0.5 r$)
 $F_{msy} = 0.487$, 95% CL = 0.334 - 0.725 (r and F_{msy} are linearly reduced if $B < 1/2 B_{msy}$)
MSY = 0.806 , 95% CL = 0.685 - 1.12
 $B_{msy} = 1.65$, 95% CL = 1.19 - 2.61
Biomass in last year = 1.28 , 2.5th perc = 0.57 , 97.5 perc = 3.38
 B/B_{msy} in last year = 0.802 , 2.5th perc = 0.349 , 97.5 perc = 1.43
Fishing mortality in last year = 0.383 , 2.5th perc = 0.139 , 97.5 perc = 0.911
Exploitation $F/F_{msy} = 0.767$, 2.5th perc = 0.298 , 97.5 perc = 2.75

6.1.5 Robustness analysis

6.1.6 Retrospective analysis, comparison between model runs, sensitivity analysis, etc.

Retrospective analyses of the model (Figure 6.6) show relatively similar patterns across runs for the whole time series, with absolute values being influenced by the terminal year but patterns being conserved, exhibiting relatively consistent dynamics among retrospective runs.

Retrospective analysis for ELEDCIR_GSA18

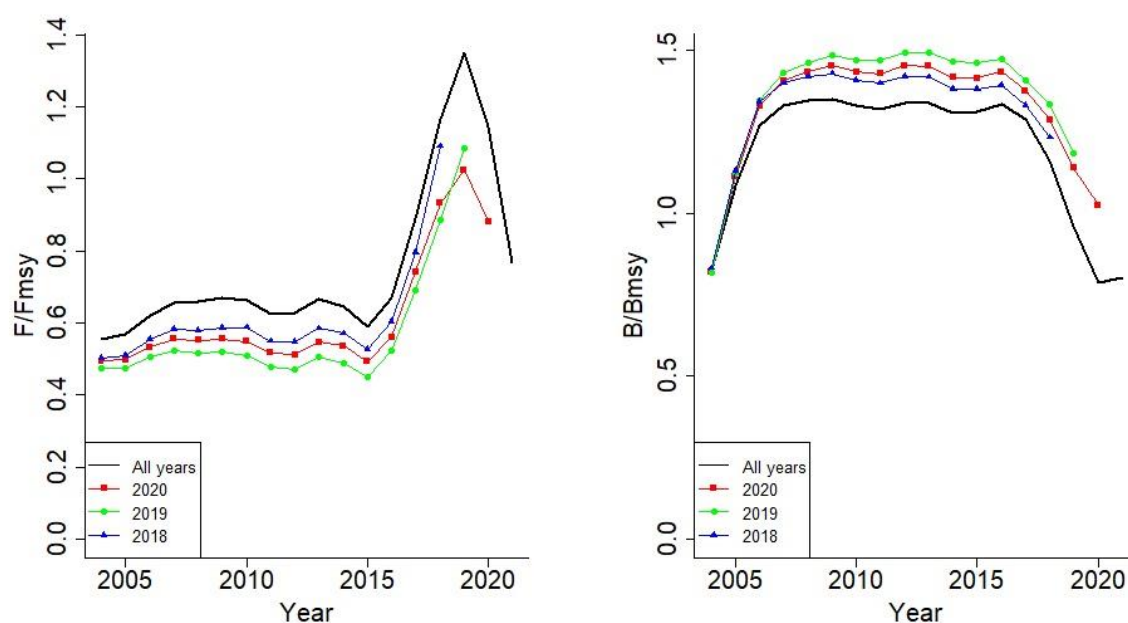


Figure 6.6. Retrospective analyses of the final model.

Multiple alternative model runs were performed to test the sensitivity of the model results to some of the key assumptions. In particular, five sensitivity runs are reported, modifying respectively: the length of time series, using reconstructed data of catch since 1972 and survey data since 1996; the setting for intermediate year and its Biomass prior, both of which are estimated by the model; and the prior for B/K at the final year, set at low depletion (0.4-0.8), strong depletion (0.01-0.4), and intermediate depletion level (0.2-0.6), respectively. A summary of these sensitivity runs (labelled S1 to S5) is reported in table 6.4.

Table 6.4. Summary of sensitivity model runs. In red, the parameters modified in each sensitivity run.

RUN	Start year	End year	Int. year	IntB.low	IntB.hi	Endb.low	Endb.hi
MAIN RUN	2004	2021	2017	0.4	0.8	estimated	estimated
S1	1972	2021	2017	0.4	0.8	0.2	0.6
S2	2004	2021	estimated	estimated	estimated	0.2	0.6
S3	2004	2021	2017	0.4	0.8	0.4	0.8
S4	2004	2021	2017	0.4	0.8	0.001	0.4
S5	2004	2021	2017	0.4	0.8	0.2	0.6

6.1.6.1 Sensitivity to length of time series

The sensitivity analysis using the year 1972 as starting year, based on a reconstructed time series of catches for the Italian fleet (as used in previous assessments), provided results similar to those of

the main run in terms of both B/B_{msy} and F/F_{msy} , with higher probability for the final year to fall in the yellow quadrant, and low probability to fall in the green or red quadrants compared to the main run. (Figure 6.7), but an overall consistent pattern in time.

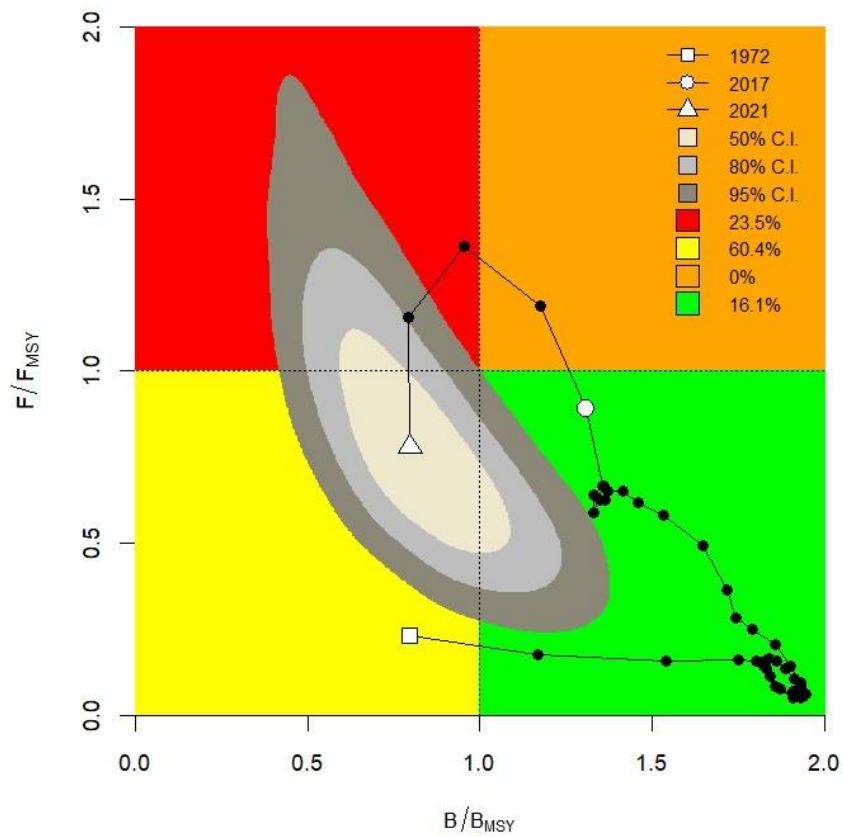


Figure 6.7. KOBE plot of the sensitivity run using a longer time series

6.1.6.2 Sensitivity to setting of intermediate year

The sensitivity analysis on the intermediate year, allowed to be determined by the model, shows not only a different temporal evolution, but also considerably worse outcomes for the final year compared to the main run. The KOBE plot (figure 6.8) shows higher probability that the final year falls in the red quadrant, and lower that falls in the green quadrant.

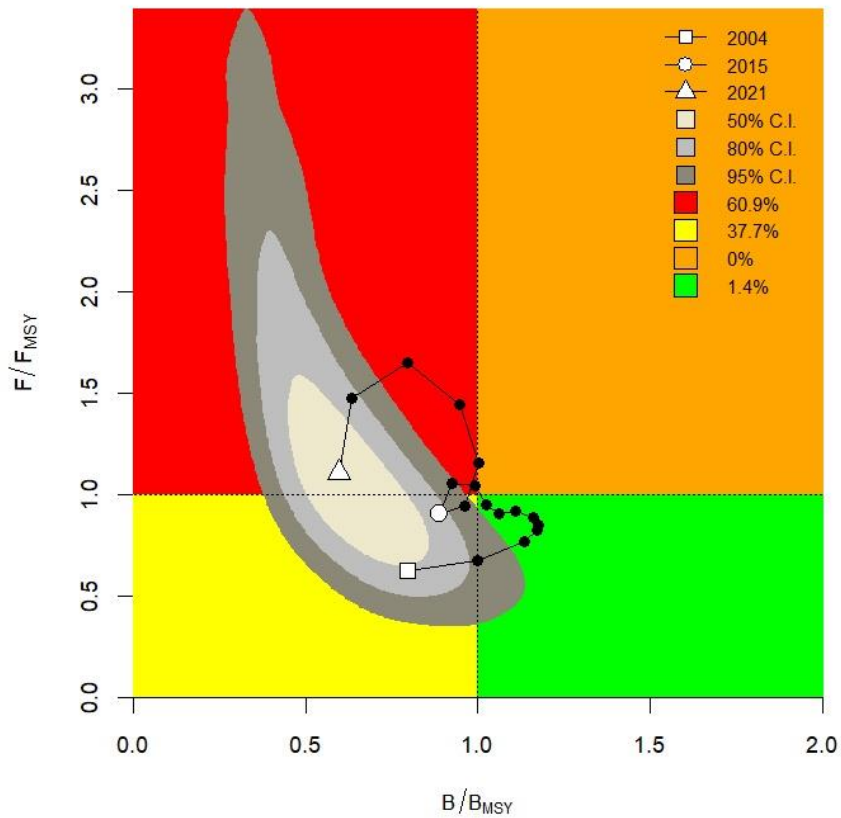


Figure 6.8. KOBE plot of horned octopus sensitivity run allowing the model to estimate the intermediate year.

6.1.6.3. Sensitivity to the setting of B/k for the final year

The sensitivity of the model to using alternative setup of the prior for the final year, compared to letting the model estimating the parameter as in the main run, showed considerable sensitivity to this parameter. Setting the prior at low depletion resulted in very optimistic predictions for the terminal year (Figure 6.9). Conversely, predictions for terminal year when selecting a high depletion prior resulted in pessimistic outcomes, with very high probability of entering the red quadrant (Figure 6.10). The patterns shown in the run with prior set at intermediate level, instead, show a very consistent pattern with the main run (Figure 6.11).

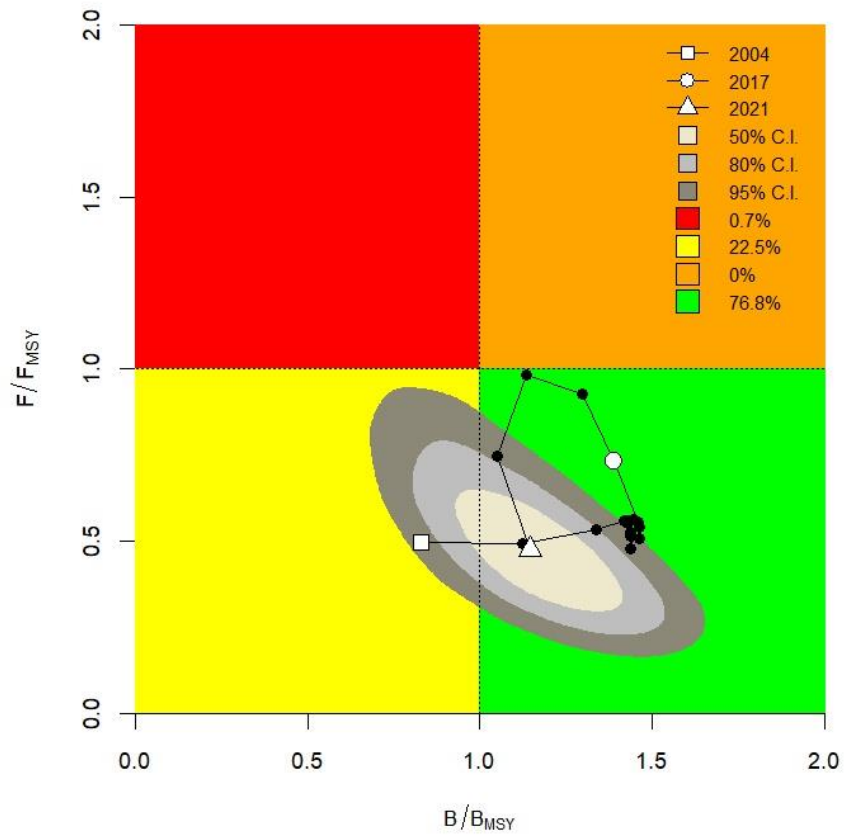


Figure 6.9. KOBÉ plot of the sensitivity analysis using a prior for B/k in the final year set at low depletion

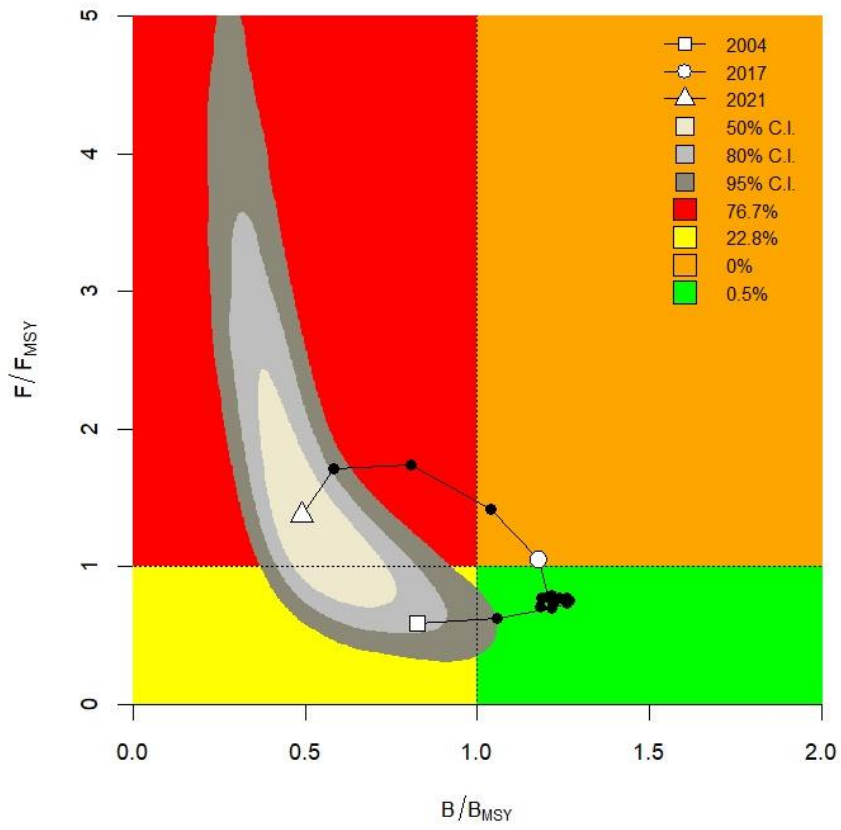


Figure 6.10. Kobe plot of the sensitivity analysis using a prior for B/k in the final year set at strong depletion

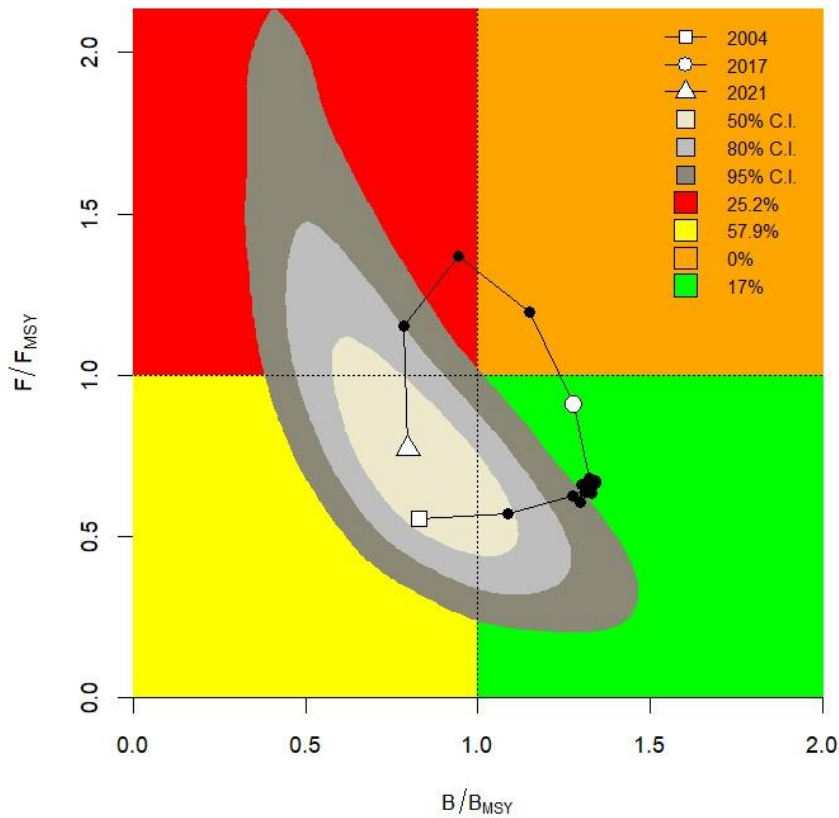


Figure 6.11. *KOBE plot of the sensitivity analysis using a prior for B/k in the final year set at intermediate depletion*

6.1.7 Assessment quality

The retrospective analyses show some patterns in the time series, which are however considered acceptable. There is an influence of the last year in the time series, which correspond to a year of changes in the catch patterns, plausibly due to the effects of the Covid pandemics. The sensitivity analyses confirm the robustness of the main model run, with consistent patterns observed in the last few years in the general trends. The absolute results are somewhat sensitive to the parameter settings. For example, the setting of intermediate and final year B/k priors influence the results. However, the intermediate year is set robustly based on the guidelines. The final year is estimated by the model, and yields a value and results strongly consistent with those obtained when setting a prior at intermediate depletion level. In fact the setting of intermediate level would be the setting of choice based on the rule-of thumb, and the model estimate in the main run yields a value for the terminal year around 0.35, consistent with the intermediate setting. These observations confirm the robustness of the main model.

Finally, the sensitivity analyses confirms the robustness of the choice of excluding the longer time series of reconstructed catches, which presents some uncertainty but does not influence substantially the outcome on the stock status at the terminal year. This represents a novelty compared to the assessments from previous years when the longer time series was included in the model, as it was considered to improve the model robustness.

6.2 LBB

6.2.1 Model assumptions

The length-based Bayesian biomass estimator (LBB) is a method for the analysis of length frequency data, preferably from the commercial fishery (Froese et al., 2018). LBB estimates asymptotic length (L_{inf}), length at first capture (L_c), relative natural mortality (M/K) and relative fishing mortality (F/M) over the age range represented in the length-frequency sample. With these parameters as input, standard fisheries equations are used to estimate depletion or current exploited biomass relative to unexploited biomass (B/B_0). In addition, these parameters allow the estimation of the length at first capture that would maximize catch and biomass for the given fishing effort (L_{c_opt}), and estimation of a proxy for the relative biomass capable of producing maximum sustainable yields (B_{msy}/B_0).

6.2.2 Scripts

The R-code (LBB_33a.R) was obtained from <http://oceanrep.geomar.de/43182/> and run in R.

6.2.3 Input data and Parameters

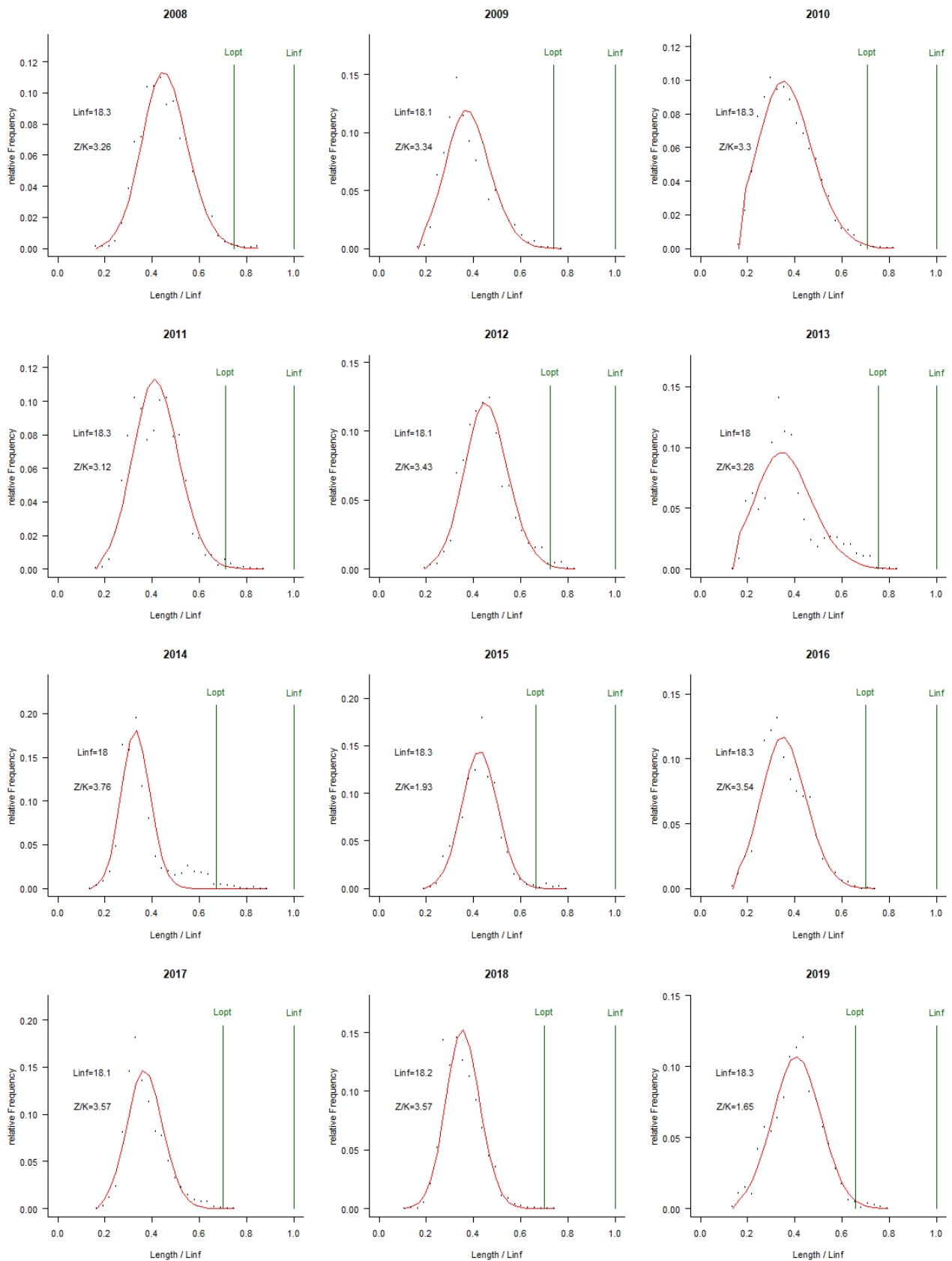
The length frequency distribution (2008-2021) from DCF was used as input values. The LBB model allows some parameters to be set according to the available knowledge. These include for example:

Linf.user: Linfinity or asymptotic length of the Von Bertalanffy growth function. The guidelines define that the method is very sensitive to this parameter. For our species, L_{inf} by sex is available from DCF information with 21 cm for females and 15.6 cm for males (mantle length). In comparison, the catch data report 15.2 cm as mean max length in the catch, and absolute max = 17 cm. For the main run the value chosen is the average of 18.3 cm.

Lm50: length at which 50% reach maturity. In the case of *E. cirrhosa*, Donnalioia et al (2010) found that in GSA18 the lengths at first maturity of females and males were respectively 9.7 ± 0.06 (MR = 1.5 ± 0.07 cm) and 7.8 ± 0.05 cm (MR = 1.4 ± 0.07 cm). A mean of 8.75 is used in the main run of the model.

In addition, the model allows to switch from a logistic selectivity curve (default) to a Gaussian. For our case, the Gaussian selectivity curve was chosen as the fishery is known to target intermediate size classes due to market demand. Additionally, preliminary analyses yielded more consistent results under this setting.

6.2.4 Results



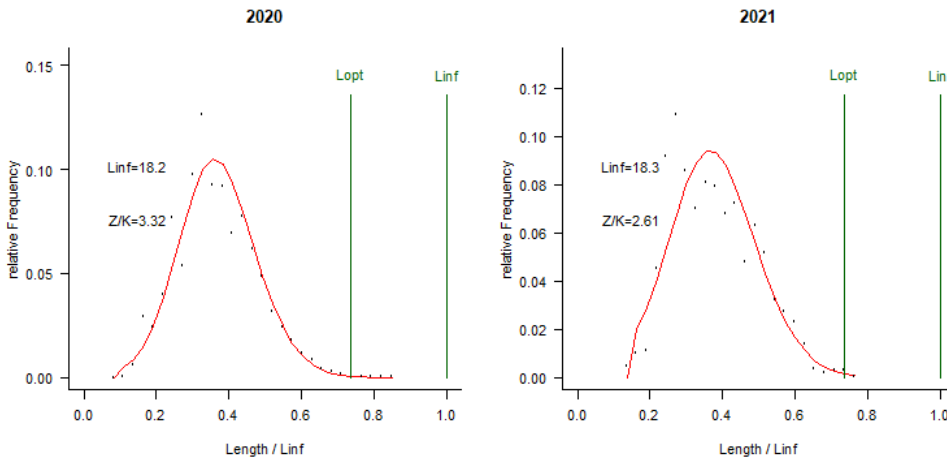


Figure 6.12. LBB fits (red lines) to length frequency data (black dots) per year.

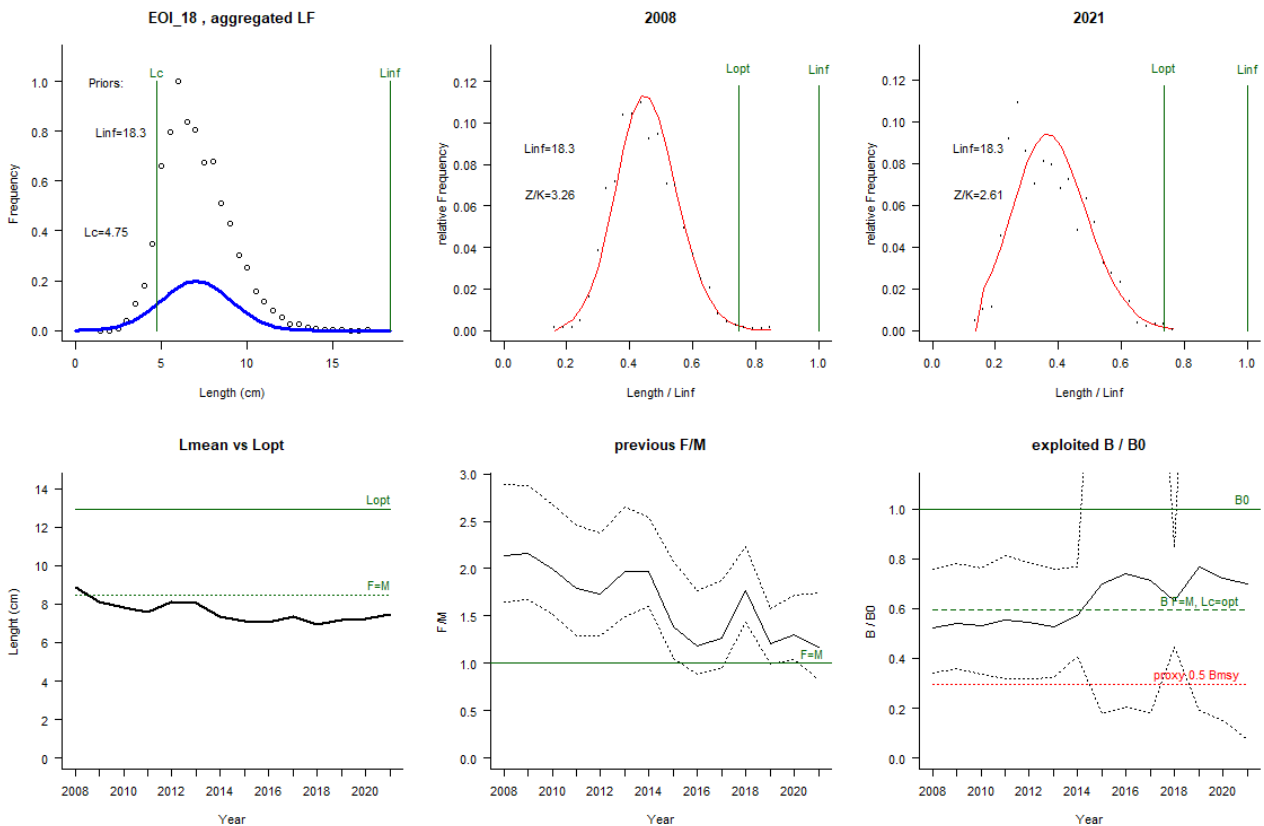


Figure 6.13. Graphical summary output produced by LBB. The upper left panel shows the accumulated LF data used to estimate priors for L_c , L_{inf} and Z/K . The upper middle and right panels show the LF data for the first and last year in the time series. The red curve shows the fit of the LBB master equation, which provides estimates of Z/K , M/K , F/K , L_c , and L_{inf} . From L_{inf} and M/K , L_{opt} is calculated and shown as reference. The lower left panel shows L_{mean} (bold black curve) relative to L_{opt} , and L_c (dashed black curve) relative to L_{c_opt} . The lower middle panel shows relative fishing pressure F/M (black curve), with approximate 95% confidence limits (dotted curves), with indication of the reference level where $F = M$ (green horizontal line). The lower right panel shows relative biomass B/B_0 (black curve) with approximate 95% confidence limits (dotted black curves), with indication of a proxy for B_{msy} (green dashed line) and a proxy for B_{pa} or $0.5 B_{msy}$ (red dotted line). The blue vertical line indicates the confidence limits of the selected year, here 2021.

The results (Figure 6.13) show a decreasing pattern of Length in time with a stabilization in the past three years, and a gradual reduction of F/M with an increase of B/B0, growing above the Bmsy proxy and maintaining above this threshold since 2015. However, the confidence interval for the B/B0 are very large, and the reliability of these results suffer of the very short time series. The estimate of B/Bmsy in the final year was = 1.2 (C.I.: 0.12-4.8)

The overall results output is reported below:

LBB results for Eledone cirrhosa, stock EOI_18, 2008-2021, Gaussian selection
Files:EOI_18_ID.csv, EOI_18_Dat.csv

Linf prior= 18.3, SD=0.18 cm (user-defined), Lmax=17, median Lmax=15.2
Z/K prior = 3.8, SD=0.17, M/K prior=1.5, SD=0.15

General reference points (median across years):

Linf = 18.3 (17.9-18.6) cm
Lopt = 13 cm, Lopt/Linf=0.71
Lc_opt = 11 cm, Lc_opt/Linf=0.62, Lmean if F=M 8.47 cm
M/K = 1.23 (0.968-1.47)
F/M = 1.75 (1.39-2.29), F/K=2.25 (2.04-2.31), Z/K=3.31 (3.05-3.62)
B/B0 = 0.58 (0.35-0.82), B/B0 F=M Lmean=Lopt 0.59
Y/R' = 0.023 (0.012-0.033), Y/R' F=M Lmean=Lopt 0.049

Estimates for 2021 (mean of last 3 years with data):

GLmean/Linf= 0.41 ,SD/Linf = 0.113
GLmean = 7.46 ,SD = 2.06
F/M = 1.2 (0.83-1.7), F/K=1.3 (1-1.6), Z/K=2.5 (2.2-2.9)
Y/R' = 0.016 (0.0086-0.027)
B/B0 = 0.7 (0.072-2.8), best LF fit year 2019=0.766 (0.19-2.8)
B/Bmsy = 1.2 (0.12-4.8)

6.2.5 Robustness analysis

6.2.6 Retrospective analysis, comparison between model runs, sensitivity analysis, etc.

Two sensitivity analyses are reported: the first checked the sensitivity of the model results to the setting of Linf, using the default value that allows the model to estimate this parameter; the second included an alternative value of L50Mat, using the value from females instead than the average by sex.

The sensitivity analyses, and their results in terms of estimated B/Bmsy in the terminal year, are compared to the values from the main run in the Table 6.5 below.

Table 6.5. Summary of main run and sensitivity model runs. In red, the parameters modified in each sensitivity run.

RUN	Linf	Lmat50	B/Bmsy
Main run	18.3	8.75	1.2 (0.28-4.2)
S1	Default	8.75	1.5 (0.32-5.2)
S2	18.3	9.7	1.2 (0.28-4.2)

6.2.6.1 Sensitivity to Linf parameter

This sensitivity analysis assessed the sensitivity of the model results to the setting of the parameter Linf, using the default value that allows the model to estimate this parameter. The results (Figure 6.14) show a similar pattern to that of the main run, but the B/Bmsy predictions are visibly more optimistic, with consistently $B/BO > BMSY$ proxy through the time series, but larger confidence intervals.

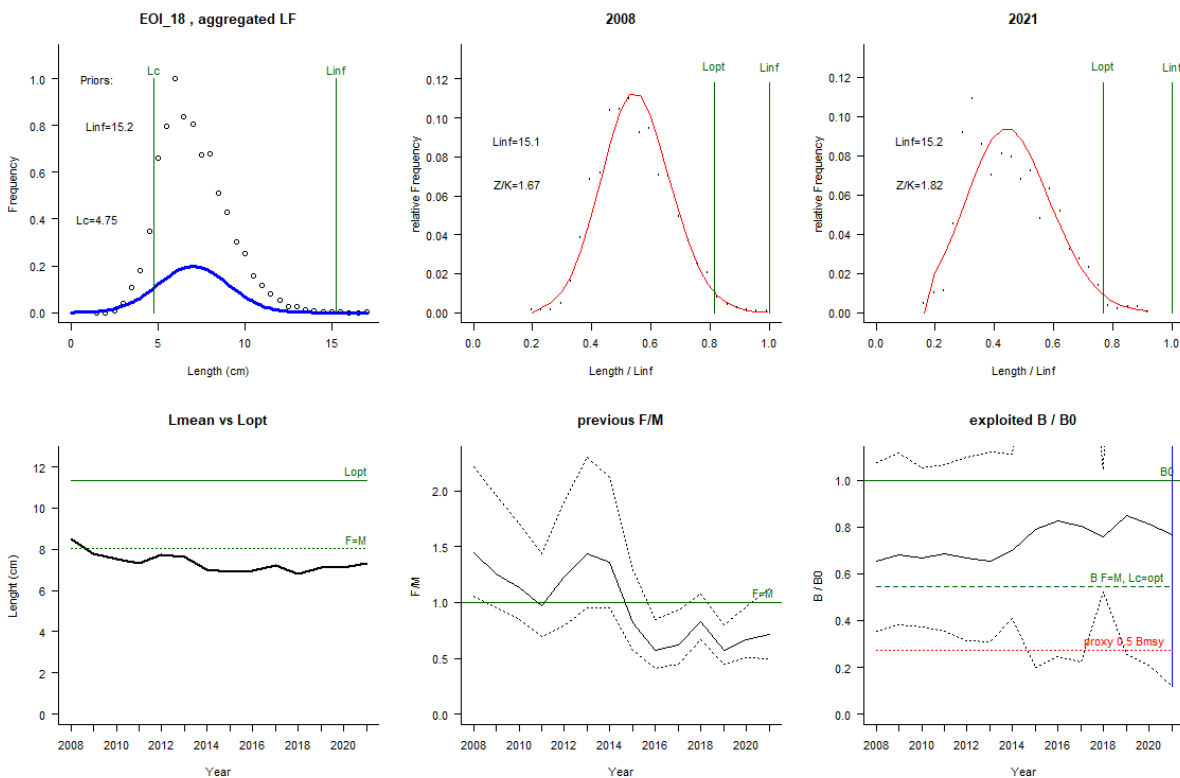


Figure 6.14. Graphical summary output produced by LBB for the sensitivity run with Linf parameter set at default value.

6.2.6.2 Sensitivity to Lmat50 parameter

This sensitivity run used an alternative value of L50Mat, using the value from females instead than the average by sex. The results (Figure 6.15) are very close to those of the main run, with almost identical patterns. This indicated a low sensitivity of the model to the setting of the length at maturity parameter.

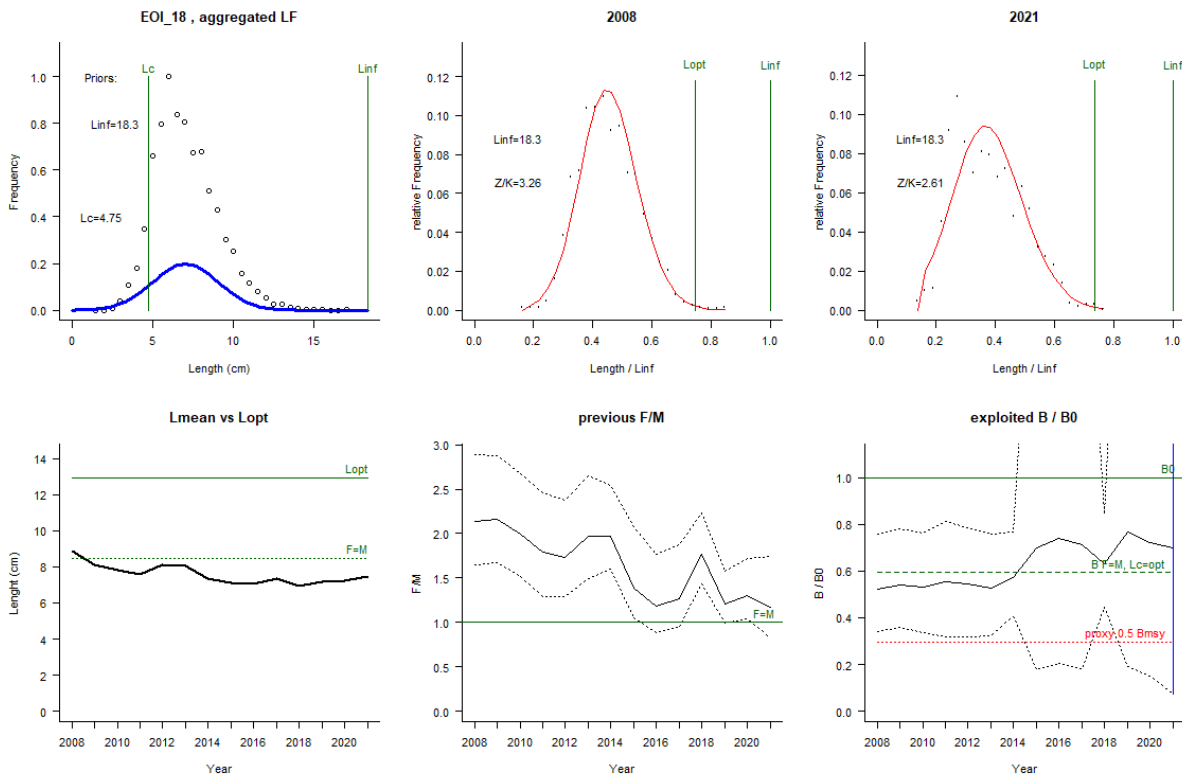


Figure 6.15. Graphical summary output produced by LBB for the sensitivity run with *Lmat50* parameter set using female L50.

6.2.7 Assessment quality

The LBB model results are influenced by the short time series with limited contrast, and their reliability is therefore impaired. The very large confidence intervals for the estimated B/B_0 confirm this consideration. The results must thus be interpreted with care.

6.3 LBSPR

The Length-Based Spawning Potential Ratio (LBSPR) method (Hordyk et al., 2016) has been developed for data-limited fisheries, where a representative sample of the size structure of the vulnerable portion of the population (i.e., the catch) as well as a basic understanding of the life history of the species are available.

6.3.1 Model assumptions

The LBSPR model relies on a number of simplifying assumptions. In particular, the LBSPR models are equilibrium based, and assume that the length composition data is representative of the exploited population at steady state. The LBSPR method does not require knowledge of the natural mortality rate (M), but instead uses the ratio of natural mortality and the von Bertalanffy growth coefficient (K) (M/K), which is believed to vary less across stocks and species than M .

6.3.2 Scripts

The R code for LBSPR was obtained from the URL <https://github.com/AdrianHordyk/LBSPR>

6.3.3 Input data and Parameters

The length frequency distribution (2008-2021) from DCF was used as input values. The LBSPR model requires setting some life-history parameters, which were set based on available information from DCF, such as a , b , L_{inf} , L_{mat50} and L_{mat95} (aggregated sexes), and M which calculated based on Then et al. (2015). The values used in the model are reported in table 6.6.

Table 6.6. Parameters and values used, based on DCF data for aggregated sexes.

Parameters	Values
a	0.486
b	2.683
L_{inf}	18.5
L_{mat50%}	8.75
L_{mat95%}	13
M/K	1.92

6.3.4 Results

The results (Figure 6.16) show a good fit of the model to data of length distribution per year. In particular, the model results in Fig. 6.17 shows that the selectivity pattern has remained fairly stable in time, while the F/M has increased, stabilized and, in the past three years, started decreasing. This shows that the fishing pressure is high, but tends to improve in the past few years. The stock is exploited below length at maturity ($SPR < 0.4$), a pattern that has been maintained through the time series (figure 6.18).

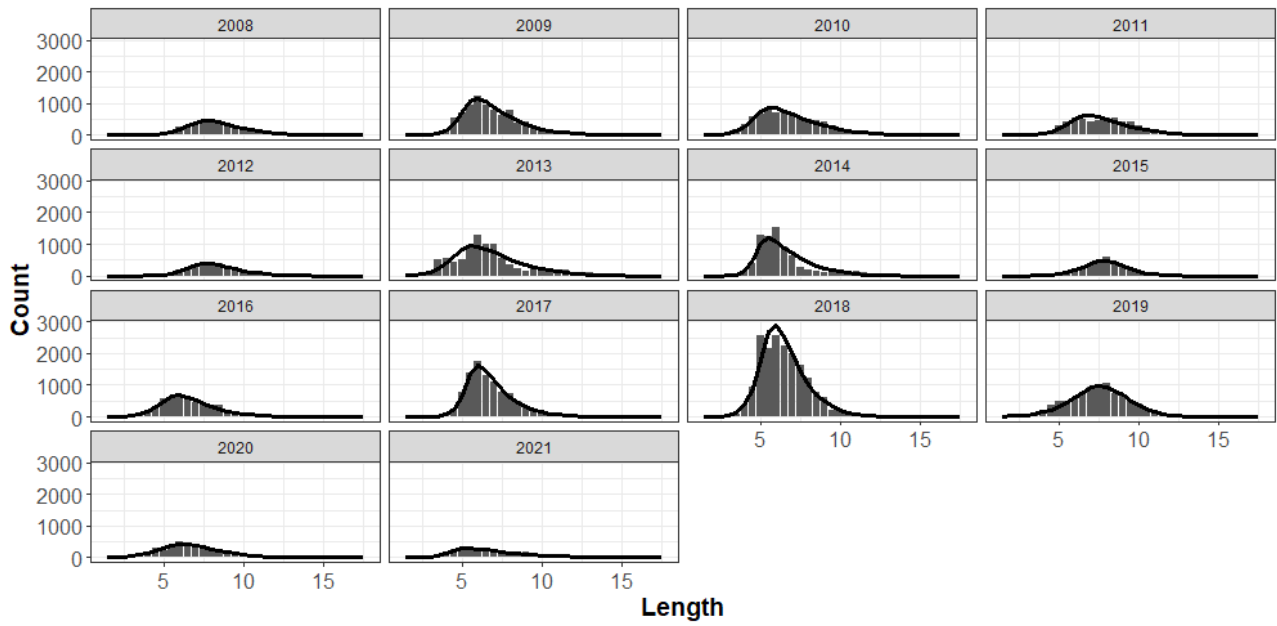


Figure 6.16. LBSPR model fits (black lines) to length frequency data (bars) per year.

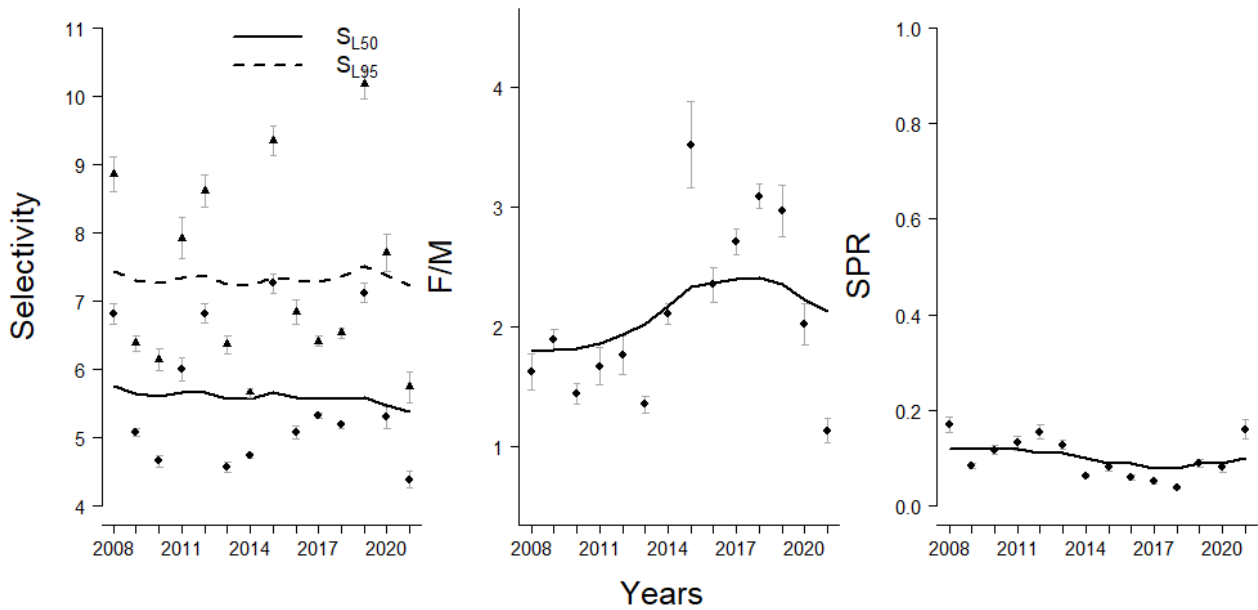


Figure 6.17. LBSPR model results (lines) and data (dots). Left: Selectivity (in cm, mantle length); Center: F/M ratio; right: Spawning Potential Ratio.

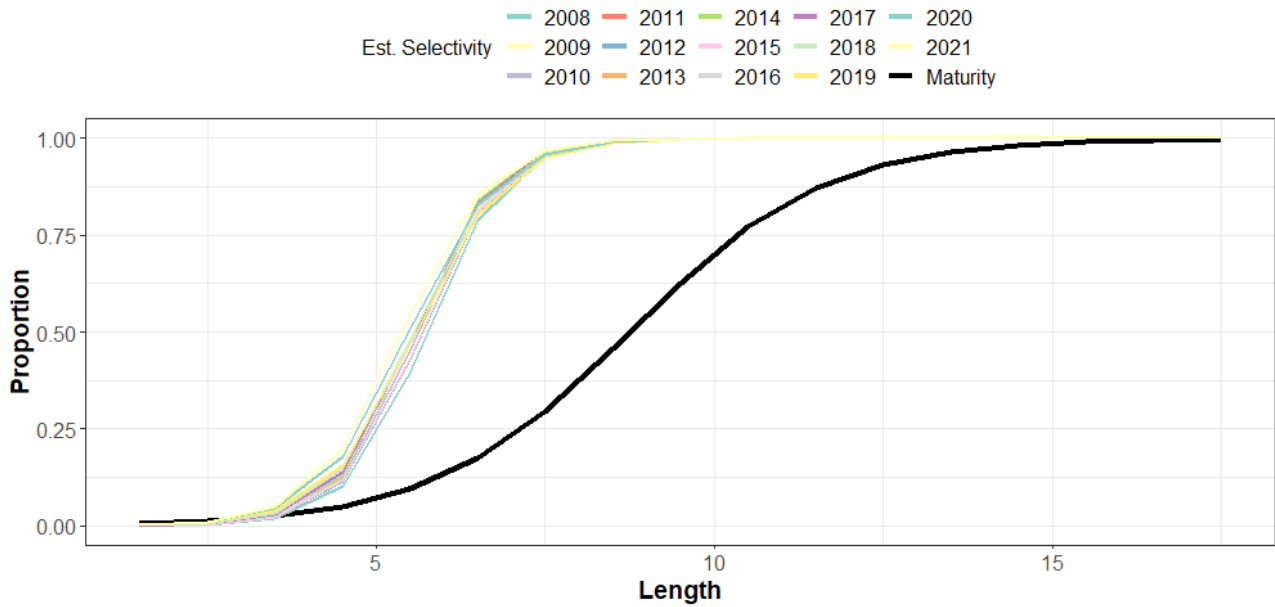


Figure 6.18. LBSPR model estimated selectivity per year compared to the maturity curve.

6.3.5 Robustness analysis

6.3.6 Retrospective analysis, comparison between model runs, sensitivity analysis, etc.

6.3.7 Assessment quality

The LBSPR model results are influenced by the short time series with limited contrast, however they clearly show a strong signal. The outcome is partially in line with the other models, namely showing the decrease in fishing pressure in the past few years. The assessment is used in a comparative way to support the conclusions of the other models.

7 Stock predictions

7.1 Short term predictions

These analyses were not performed.

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	FMSY=0.487	Fcurrent=0.383	Fcurrent/FMSY =0.79	N	S
	Fishing effort					
	Catch					
Stock abundance	Biomass	BMSY=1.65	Bcurrent=1.28	Bcurrent/BMSY =0.77		O
	SSB					
Recruitment						
Final Diagnosis	<ul style="list-style-type: none"> - Overexploited with a low fishing mortality. - Reduce fishing mortality and/or implement a recovery plan. 					

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

* F_c 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 exerted;
 - 5) **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 $B_{0.1}$ or B_{MSY} . 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)