Stock Assessment Form
Demersal species

Mullus barbatus in GSA 7

Reference year: 2019

Reporting year: 2020

The status of the stock was assessed applying statistical catch at age (a4a) over the period 2002-2019. MEDITS index was used for tuning. The stock is at intermediate level of overfishing with relative high level of abundance. A deterministic short term forecast was carried out.

Stock Assessment Form version 1.0 (January 2014)

Uploader: *Please include your name*

Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
	Red mullet	33
1st Geographical sub-area:	2nd Geographical sub-area:	3rd Geographical sub-area:
[GSA_7]		
4th Geographical sub-area:	5th Geographical sub-area:	6th Geographical sub-area:
1st Country	2nd Country	3rd Country
France	Spain	
4th Country	5th Country	6th Country
Stock assessment method: (direct, indirect, combined, none)		
Indirect		
Authors:		
STECF EWG 20-09		
Affiliation:		
For more details please refer to https://stecf.jrc.ec.europa.eu/reports/medbs		

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

Red mullet (*Mullus barbatus*) in the Gulf of Lions (GSA 7) is a shared stock exploited by both Spanish and French trawlers, also since recent years by French gillnetters (2011, 2013-2017). The Gulf of Lions (GSA 7) is used as an individualized area for the assessment and management of red mullet in the western Mediterranean. However, recent studies stated that the red mullet of the Gulf of Lions could not be isolated from concomitant areas, for instance from GSAs 5 and 6 (STOCKMED, MAREA project, 2014).

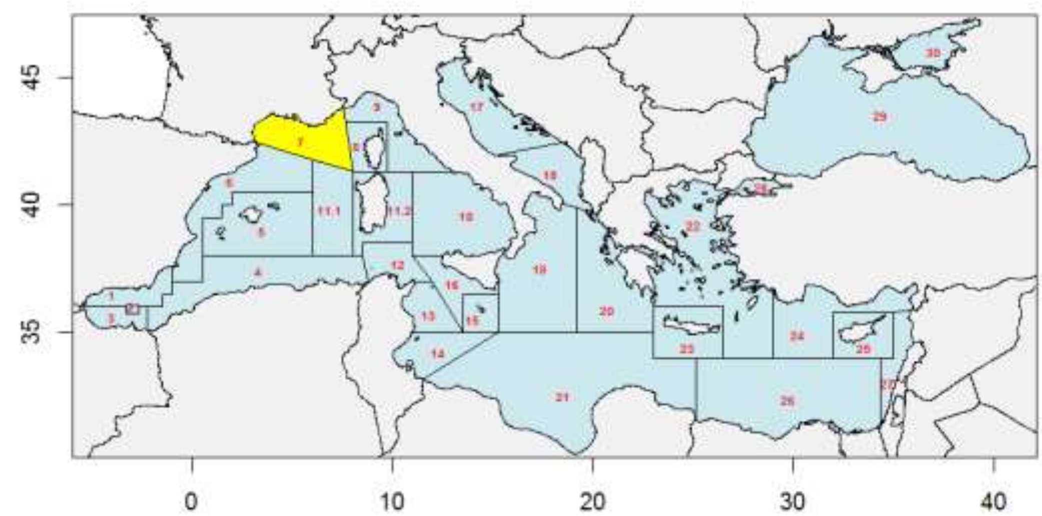


Figure 2-1: Geographical location of GSA 7 –Gulf of Lions

2.1 Stock unit

Assumed here that inside the GSA 7 boundaries inhabits a single, homogeneous red mullet stock that behaves as a single well-mixed and self-perpetuating population.

2.2 Growth and maturity

The process of age slicing is central to the data preparation of stock assessment. In previous assessment for this GSA, age slicing was based on a Von Bertalanffy growth curve estimated by Demestre et al. (1997), denoted “fast growth model” (FGM, with parameters Linf = 34.5cm, k = 0.34 years-1, and t0 = -0.14cm).

In the present assessment, we questioned the use of the FGM and compared its use with two alternatives, (1) fitting a Von Bertalanffy model to the age-reading data available for GSA 7; and (2) building a global Age-Length-Key directly from the data.

The fitted Von Bertalanffy growth model provided a slightly different set of parameters (Linf = 26.25cm, k = 0.5 years-1, and t0 = -0.55cm), and the comparison between both models suggested that the FGM was not well suited for Red Mullet in GSA 7. Cohort consistency is clearly improved when age slicing is performed with either the fitted growth model or the ALK. Between both, ALK provides a slightly better cohort consistency. We therefore chose to proceed with ALK to perform the assessment.

For the purpose of computing biomass and average weights at age from numbers at length, we used a length weight relationships fitted on individual DCF sample data – the same that were used to produce the ALK. The resulting relationships has parameters ln(a)=-4.55, and b=3.03.

Maturity was calculated assuming that spawning red mullet season is very short (May-June) and young individuals reach maturity when arrive to Age 1 on 1st of January. For ages >1 all individuals are considered adults.

Natural mortality was obtained from Rscript provided during the meeting and it is based on Chen Watanabe formula, with M=1.74, 0.8, 0.57, 0.48 and 0.43 at ages 0, 1, 2, 3 and 4+, respectively.

Table 2.2-1: Maximum size, size at first maturity and size at recruitment (SAFMUT_GSA_07_2017_ESP_FRA).

Somatic magnitude measured (LT, LC, etc)			**TL**	**Units**	cm
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	End of spring and summer
Maximum size observed			31	**Recruitment season**	End of summer, beginning of autumn
Size at first maturity			8.6	**Spawning area**	Shelf
Recruitment size to the fishery			5	**Nursery area**	Shelf

Table 2-3: Growth and length weight model parameters. Age-Length-Key directly from the data.

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**					
	K					
	t_0					
	Data source					
Length weight relationship	**ln(a)**				-4.55	
	b				3.03	
	M (scalar)					
	sex ratio (% females/total)					

3 Fisheries information

3.1 ***Description of the fleet*** *(SAF MUT_GSA_07_2017_ESP_FRA).*

In the Gulf of Lions (GSA 7), red mullet is exploited by both French and Spanish trawlers. Information on French gillnetters is only available for 2011 and 2013-2017, but although it is suspected that they have been fishing red mullet in the past, no data is available to quantify their catches. According to official statistics, during the first part of this period (2004-2012), the total annual landings have oscillated around an average value of 190 tons; since 2012, landings have shown a clear increasing trend until 2016 and are decreasing in 2017 (298 tons). French trawlers dominate the fishery, as they represent 83% of the catches (average 205 tons) for the entire period. After 2009, because of the large decline of small pelagic fish species in the area, the trawlers fishing small pelagic have diverted their effort on demersal species, which may partially explain the high levels of catches since 2010. Between 2004 and 2014, the number of French trawlers operating in the GSA 07 has decreased by 50%. From a maximum number of 121 trawlers in 2004, the French fleet catching red mullet is nowadays composed by 57 units. Catches from OTM represent less than 2% of the French trawl fleet, but the importance of OTT has increased during last years, from 5% in 2015, 29% in 2016 and 41% in 2017. The mean modal lengths in the catches of the French and Spanish trawlers are 14 and 15 cm, respectively and the length at first capture is about 5 cm. Catch is mainly composed by individuals of age 0, 1 and 2 (Figure 6.1.3-2), while the oldest age class (4+ group) is poorly represented. In GSA 07, the trawl fishery is a multi-specific fishery. In addition to *M. barbatus*, the following species can represent important catches: *Merluccius merluccius, Lophius* sp.*, Pagellus* sp.*, Trachurus* sp.*, Mullus surmuletus, Octopus vulgaris, Eledone* sp.*, Scyliorhinus canicula, G. melastomus, Trachinus* sp.*, Triglidae, Scorpaena* sp. and *Raja* sp.

Table 3-1: Description of operational units exploiting the stock in 2017

	Country	GSA	Fleet Segment	Fishing Gear Class	Group of Target Species	Species
Operational Unit 1*	France	GSA 07	E – trawl (12-24m)	03 - Trawls	33 – Demersal shelf species	MUT
Operational Unit 2	Spain	GSA 07	E – trawl (12-24m)	03 - Trawls	33 – Demersal shelf species	MUT
Operational Unit 3	FRA	07	C - Minor gear with engine (6-12 metres)	07 - Gillnets and Entangling Nets	33 - Demersal shelf species	MUT

Table 3.1-2: Catch, bycatch, discards and effort by operational unit in 2017

Operational Units*	Fleet (n° of boats) *	Landings (T or kg of the species assessed)	Other species caught (names and weight)	Discards (species assessed)	Discards (other species caught)	Effort (units)
FRA 07 I 03 33 - MUT	56	251 tons	*M. merluccius, M. surmuletus, Solea spp., Lophius spp., S. aurata, D. labrax, Pagellus spp., M. poutassou, T. m. capelanus, Elasmobranchs, O. vulgaris and Eledone spp.*	7	unknown	unknown
ESP 07 I 03 33 - MUT	15	31 tons	*M. merluccius, M. surmuletus, Solea spp., Lophius spp., Pagellus spp., M. poutassou, T. m. capelanus, O. vulgaris and E. cirrhosa*	No	unknown	unknown
FRA 07 C 07 33 - MUT	286	9 tons	*Mainly Mullus surmuletus*	No	unknown	unknown
Total	357	291 tons		7 tons		

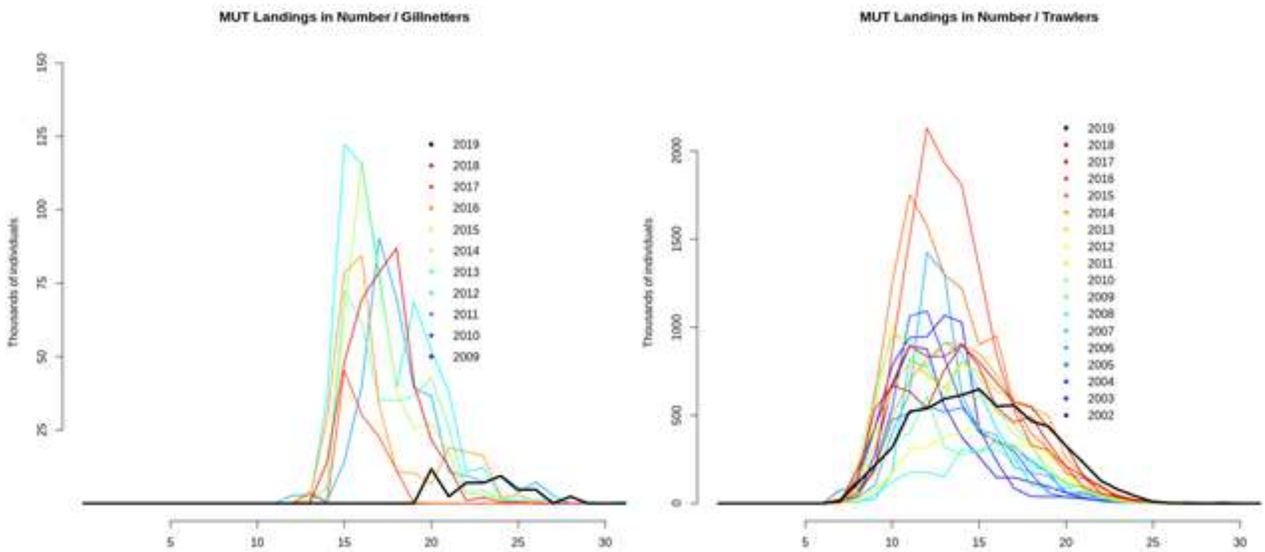
3.2 Historical trends

Year	ESP Gillnet	ESP Trammel	ESP Trawl	FRA Gillnet	FRA Other	FRA Trammel	FRA Trawl
2002	0	0	11.08	0	0	0	111.424
2003	0	0	11.87	0	0	0	164.141
2004	0	0	25.84	0	0	0	151.646
2005	0	0	27.48	0	0	0	148.086
2006	0	0	31.4	0	0	0	183.478
2007	0	0	36.16	0	0	0	171.526
2008	0	0	20.73	0	0	0	110.494
2009	0	0.12	26.01	0	0	0	122.555
2010	0	0.16	28.07	0	0	0	236.034
2011	0	0.07	28.06	15.924	0	18.878	206.881
2012	0	0	29.17	18.343	0	19.713	138.673
2013	0	0	37.53	13.57	0	7.388	239.465
2014	0	0	41.18	15.942	0	7.886	285.084
2015	0	0	33.05	0.041	0	0.025	335.315
2016	0	0	43.31	13.556	0	8.581	345.939
2017	0	0	31.09	3.444	0	2.47	255.45
2018	0	0	23.83	15.785	0	5.818	287.103
2019	0	0	22.168	6.335	0.363	2.878	269.039

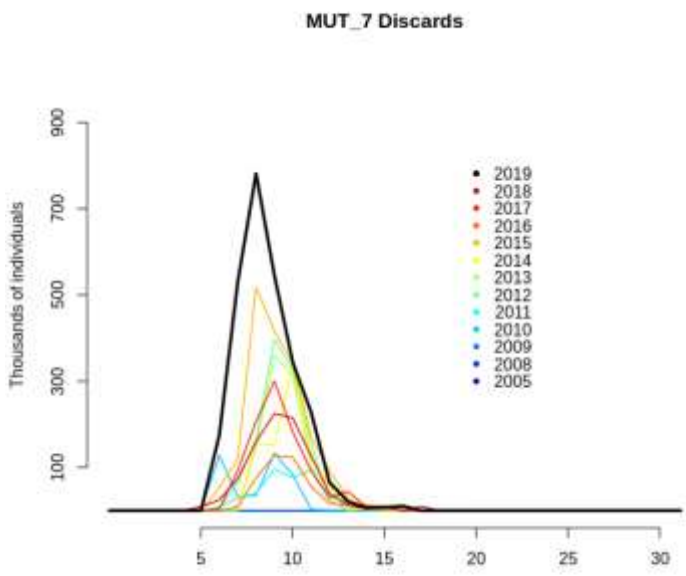
Year	Fra_GSA7	Spa_GSA7	Total landings	Discards	Catch
2002	111.424	11.08	122.504	0	122.504
2003	164.141	11.87	176.011	0	176.011
2004	151.646	25.84	177.486	0	177.486
2005	148.086	27.48	175.566	0	175.566
2006	183.478	31.4	214.878	0	214.878
2007	171.526	36.16	207.686	0	207.686
2008	110.494	20.73	131.224	0.18	131.404
2009	122.555	26.13	148.685	0	148.685
2010	236.034	28.23	264.264	2.505	266.769
2011	241.682	28.13	269.812	4.388	274.2
2012	176.729	29.17	205.899	12.176	218.075
2013	260.423	37.53	297.953	10.068	308.021
2014	308.912	41.18	350.092	9.359	359.451
2015	335.381	33.05	368.431	18.043	386.474
2016	368.077	43.31	411.387	6.457	417.844
2017	261.364	31.09	292.454	8.843	301.297
2018	308.705	23.83	332.535	9.543	342.078
2019	278.615	22.168	300.783	19.023	319.806

Landings in recent years vary around 300 tons with a maximum in 2016 and the minimum in 2002. The majority of the landings of red mullet comes from trawlers, and the other part are mainly nets. Landings of gears other than OTB, GNS and GTR are on average less than 1%. Since 2014, the French Trawl fleet is separated by OTB, OTM and OTT trawlers. The majority of landings are due to OTB, but OTT have an increasing importance on the last years.

Discards were regularly reported since 2010. They are mostly composed of small individuals and account for [1-5]% of the landed biomass, depending on year. In 2019, discards of small individuals have been particularly important.



Size-Class distribution of Red Mullet landings per year, for gillnets & trammel nets (left) and trawlers (right). The thick black line corresponds to the most recent year (2019).



Size-Class distribution of Red Mullet discards per year

3.3 ***Management regulations*** (SAF MUT_GSA_07_2017_ESP_FRA)

French trawlers

- Fishing license: fully observed. Important decrease in capacity since 2011, reducing the number of boats by 50% since the beginning of the series (2004)
- Engine power limited to 316 KW or 500 CV: Not full compliance
- Cod-end mesh size (bottom trawl: square 40 mm or 50 mm diamond. by derogation): not fully observed
- Fishing forbidden within 3 miles (France): not fully observed
- Time at sea: fully observed

Temporal bans depending on years

- 2011 and 2012. 1 month/year
- 2016 and 2017: 25 days/trawler between 17 April and 16 July

Biological ban.

Spanish trawlers

- Fishing license: fully observed
- Engine power limited to 316 KW or 500 CV: Not full compliance
- Mesh size in the codend (before Jun 1st 2010: 40 mm diamond: after Jun 1st 2010: 40 mm square or 50 mm diamond. by derogation): fully observed
- Fishing forbidden <50 m depth: fully observed
- Time at sea: fully observed
- Temporal bans depending on years (for instance. 2015 and 2016. 1 month): fully observed

French gillnetters

- Fishing license: fully observed
- Maximum length of net: not fully observed

Spanish longliners:

- Fishing license: fully observed
- Number of hook per boat: not fully observed

Fishery Restricted Area: In 2009, GFCM proposed the creation of a High Sea Fishery Restricted Area (FRA. GFCM/33/2009/1) in which the fishing effort for demersal stocks of vessels using towed nets. bottom and mid-water longlines. bottom-set nets shall not exceed the level of fishing effort applied in 2008 in the fisheries restricted area of the eastern Gulf of Lions as bounded by lines joining the following geographic coordinates: 42°40'N. 4°20' E; 42°40'N. 5°00' E; 43°00'N. 4°20' E; 43°00'N. 5°00' E. In the article 4 from the EU Regulation No. 1343/2011 of the European Parliament and of the Council of 13 December 2011. this fisheries restricted area was established and in 2012 both French (Arrêté du 28 décembre 2012. NOR: TRAM1240493A) and Spanish (Orden AAA/1857/2012 de 22 de Agosto) governments published their own laws regulating this FRA.

Additional Spanish and French national measures have been endorsed in 201, considering the protection of demersal species:

- spatio-temporal temporal closure considering longliners, bottom trawlers and gillnetters, between 12th of October and 12th of December and between 150 and 275 meters in the zone defined following these coordinates:

Latitude	Longitude
42°26′ N	3°9′ E
43° N	3°2′ E
43° N	5° E
42°0,71′ N	5° E

- Permanent closure in 3 zones defined with the following geographical coordinates:

Zone 1

Latitud	Longitud
42°45,300′ N	3°37,050′ E
42°45,300′ N	3°41,086′ E
42°41,268′ N	3°41,086′ E
42°41,268′ N	3°37,050′ E

Zone 2

Latitud	Longitud
42°52,95′ N	4°2,95′ E
42°52,95′ N	4°7,32′ E
42°48,9′ N	4°7,32′ E
42°48,9′ N	4°2,95′ E

Zone 3

Latitud	Longitud
43° N	4°49,35′ E
43° N	4°53,7′ E
42°55,896′ N	4°53,7′ E
42°55,896′ N	4°49,35′ E

EU Multiannual Management plan for western Mediterranean region in place.

3.4 Reference points

Table 3.3-1: List of reference points and empirical reference values previously agreed (if any)

Indicator	Limit Reference point/empirical reference value	Value	Target Reference point/empirical reference value	Value	Comments
B					
SSB					
F			$F_{0.1}$	0.31	WGSAD 2018
Y					

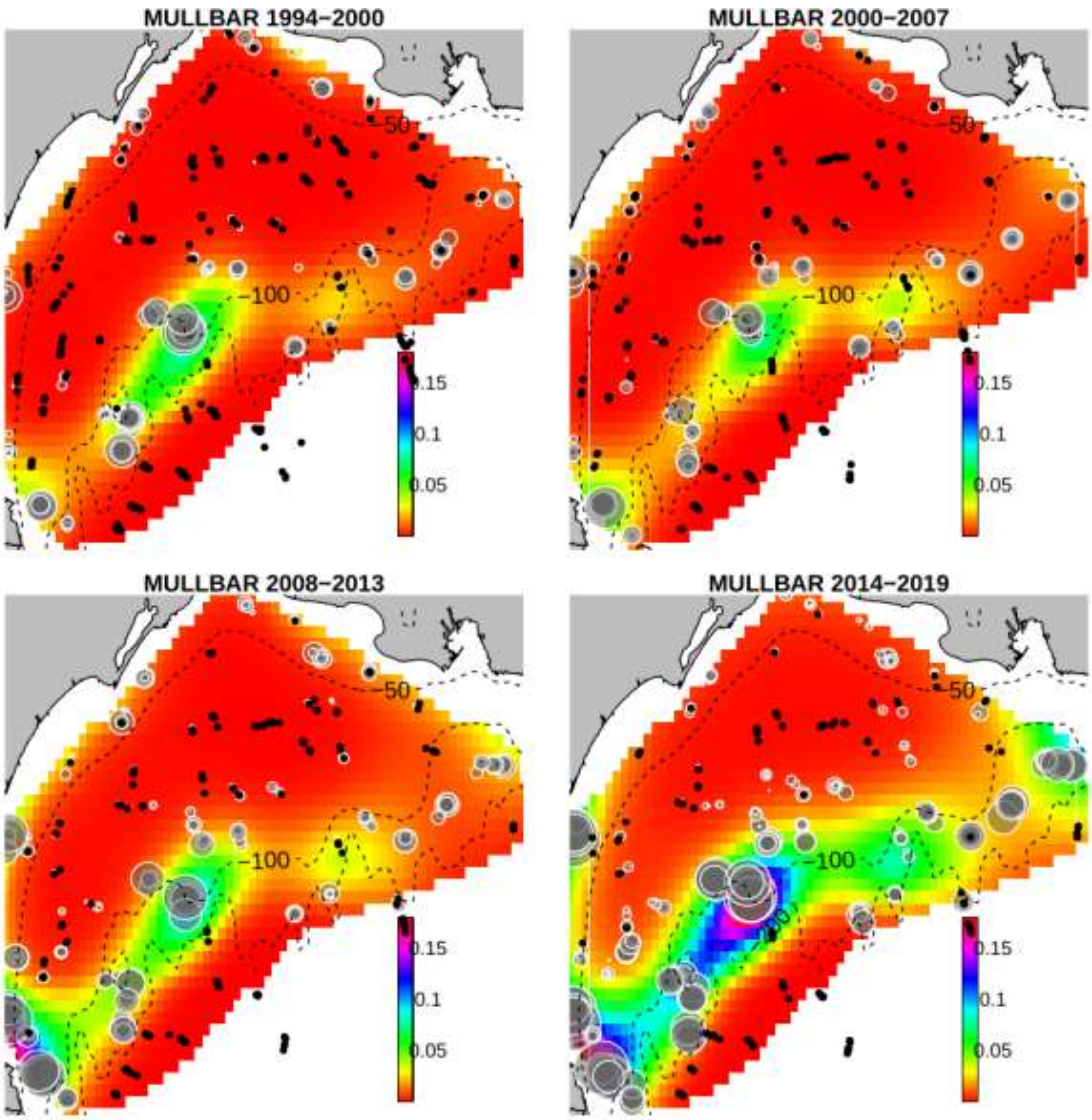
CPUE					
Index of Biomass at sea					

4 Fisheries independent information

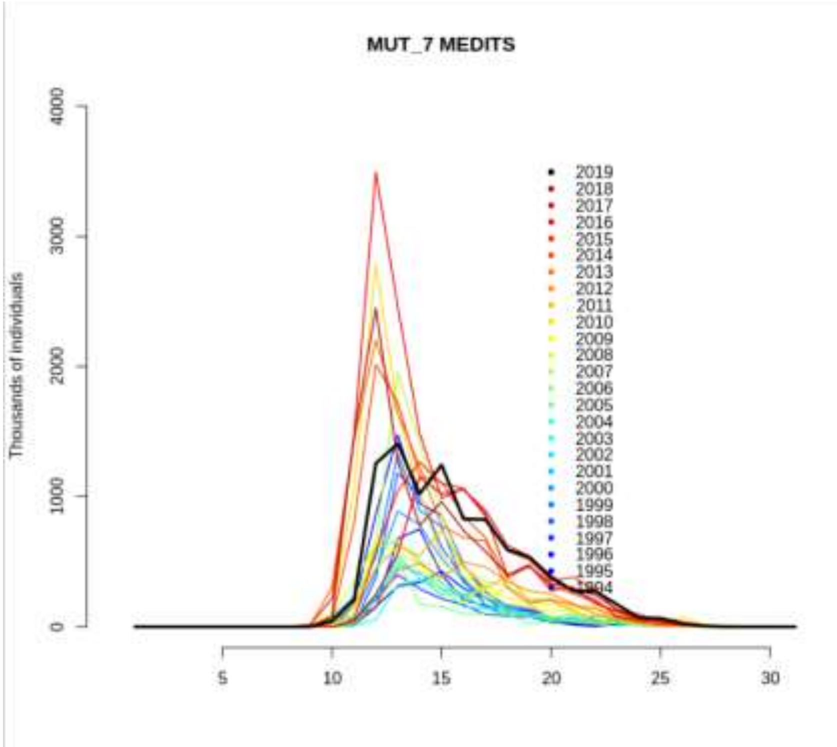
4.1 MEDITS bottom trawl surveys

According to the MEDITS protocol (Bertrand et al. 2002), trawl surveys were yearly carried out from end of May until end of June, applying a random stratified sampling by depth (5 strata with depth limits at: 50, 100, 200, 500 and 800 m; each haul position randomly selected in small sub-areas and maintained fixed throughout the time). Haul allocation was proportional to the stratum area. The same gear (GOC 73, by P.Y. Dremière, IFREMER-Sète), with a 20 mm stretched mesh size in the cod-end, was employed throughout the years. Detailed data on the gear characteristics, operational parameters and performance are reported in Dremière and Fiorentini (1996). Considering the small mesh size a complete retention was assumed. Abundances at trawl were standardized to square kilometre, using the swept area method, then MEDITS abundances (numbers of fish at length over the GSA 7 area) were computed.

The figure below shows MEDITS sampling and estimates of red mullet spatial distribution for 4 time periods, exemplifying quite well their core area of distribution in the Gulf of Lion in June in the South-Western upper slope, and their increased numbers since 1994.



. Colours: Biomasses of Red Mullet from MEDITS survey in t/km2 (ordinary kriging). Circles correspond to data points. Black dots locate trawls without red mullet.



Length distribution of MEDITS abundance index over the years. . The size range caught by the survey is quite constant [8 – 27cm] over the years, with a doubling of abundance of young individuals in the most recent years.

4.1.1 Brief description of the direct method used

Direct methods: trawl based abundance indices

Table 4.1-1: Trawl survey basic information

Survey		**Trawler/RV**	
Sampling season			
Sampling design			
Sampler (gear used)			
Cod –end mesh size as opening in mm			

Investigated depth range (m)	

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

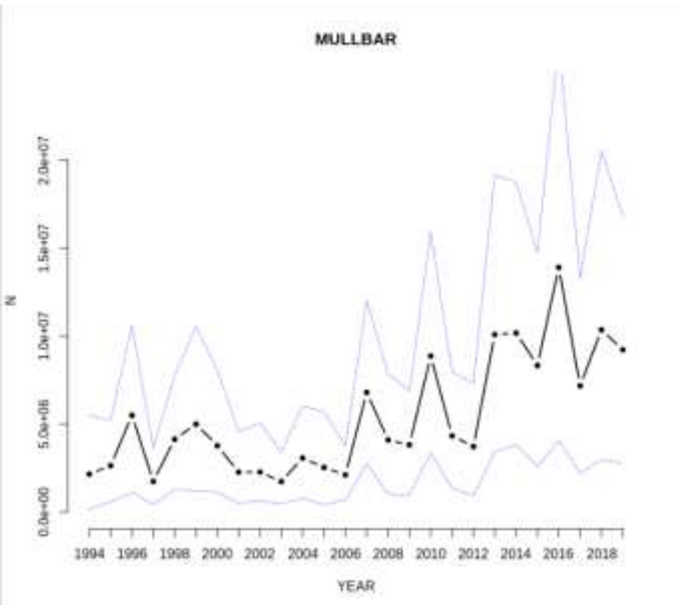
Stratum	Total surface (km^2)	Trawlable surface (km^2)	Swept area (km^2)	Number of hauls
Total (… – … m)				

Map of hauls positions

4.1.2 Spatial distribution of the resources

Include maps with distribution of total abundance, spawners and recruits (if available)

4.1.3 Historical trends



MEDITS abundance index (in number of individuals over the Gulf of Lion area). Dotted lines corresponds to 95% bootstrapped confidence intervals. Standardized abundances are computed from a stratified mean, with bootstrap-estimated confidence intervals, and displays an increasing trends in the recent years.

5 Ecological information

5.1 Protected species potentially affected by the fisheries

A list of protected species that can be potentially affected by the fishery should be incorporated here. This should also be completed with the potential effect and if available an associated value (e.g. bycatch of these species in T)

5.2 Environmental indexes

If any environmental index is used as i) a proxy for recruitment strength, ii) a proxy for carrying capacity, or any other index that is incorporated in the assessment, then it should be included here.

Other environmental indexes that are considered important for the fishery (e.g. Chl a or other that may affect catchability, etc.) can be reported here.

6 Stock Assessment

6.1 Statistical catch at age a4a (Jardim et al. 2015)

6.1.1 Model assumptions

6.1.2 Scripts

6.1.3 Input data and Parameters

Landings and discards at age have been recovered by combining landings and discards at length data, the Age-Length-Key and the length-weight relationship. SoP corrections to N at age in the catch were applied by year. The resulting numbers and average weight at age are summarized in the tables and figure below.

Year	0	1	2	3	4+
2002	809.73	3395.917	369.807	39.298	4.781
2003	1274.411	5387.557	363.285	33.813	5.543
2004	886.986	4802.032	499.869	53.809	7.105
2005	725.26	3433.611	695.798	87.715	30.538
2006	763.777	5390.863	666.692	75.775	12.354
2007	504.445	4723.495	702.504	87.591	14.378
2008	162.317	1758.901	728.367	83.983	9.857
2009	730.468	2619.198	696.102	87.89	11.9
2010	1492.944	5489.225	1010.569	135.53	24.101
2011	1235.718	5145.387	1120.604	156.815	36.904
2012	261.019	2700.563	1139.457	136.106	24.619
2013	860.234	5113.597	1411.999	166.345	23.768
2014	662.199	5473.461	1752.808	218.625	32.771
2015	1622.748	8164.393	1358.382	180.066	30.606
2016	1220.512	9462.887	1418.427	167.609	29.266
2017	1078.982	5206.711	1304.911	166.66	33.457
2018	1011.819	5015.077	1706.502	213.839	30.506
2019	605.768	3725.142	1569.267	265.788	52.27

. Landings at age (Thousands of individuals)

Year	0	1	2	3	4+
2002	0.013	0.024	0.071	0.095	0.123
2003	0.013	0.025	0.062	0.106	0.131
2004	0.014	0.026	0.064	0.101	0.142
2005	0.012	0.03	0.07	0.107	0.215
2006	0.016	0.027	0.07	0.103	0.152
2007	0.017	0.029	0.071	0.106	0.13
2008	0.015	0.037	0.075	0.093	0.118
2009	0.011	0.029	0.077	0.099	0.125
2010	0.011	0.029	0.071	0.111	0.153
2011	0.012	0.029	0.073	0.112	0.18
2012	0.015	0.036	0.076	0.098	0.206
2013	0.013	0.032	0.073	0.098	0.141
2014	0.015	0.033	0.075	0.102	0.135
2015	0.013	0.028	0.072	0.109	0.145
2016	0.016	0.029	0.069	0.108	0.164
2017	0.012	0.03	0.074	0.104	0.167
2018	0.011	0.033	0.076	0.101	0.131
2019	0.012	0.034	0.081	0.115	0.145

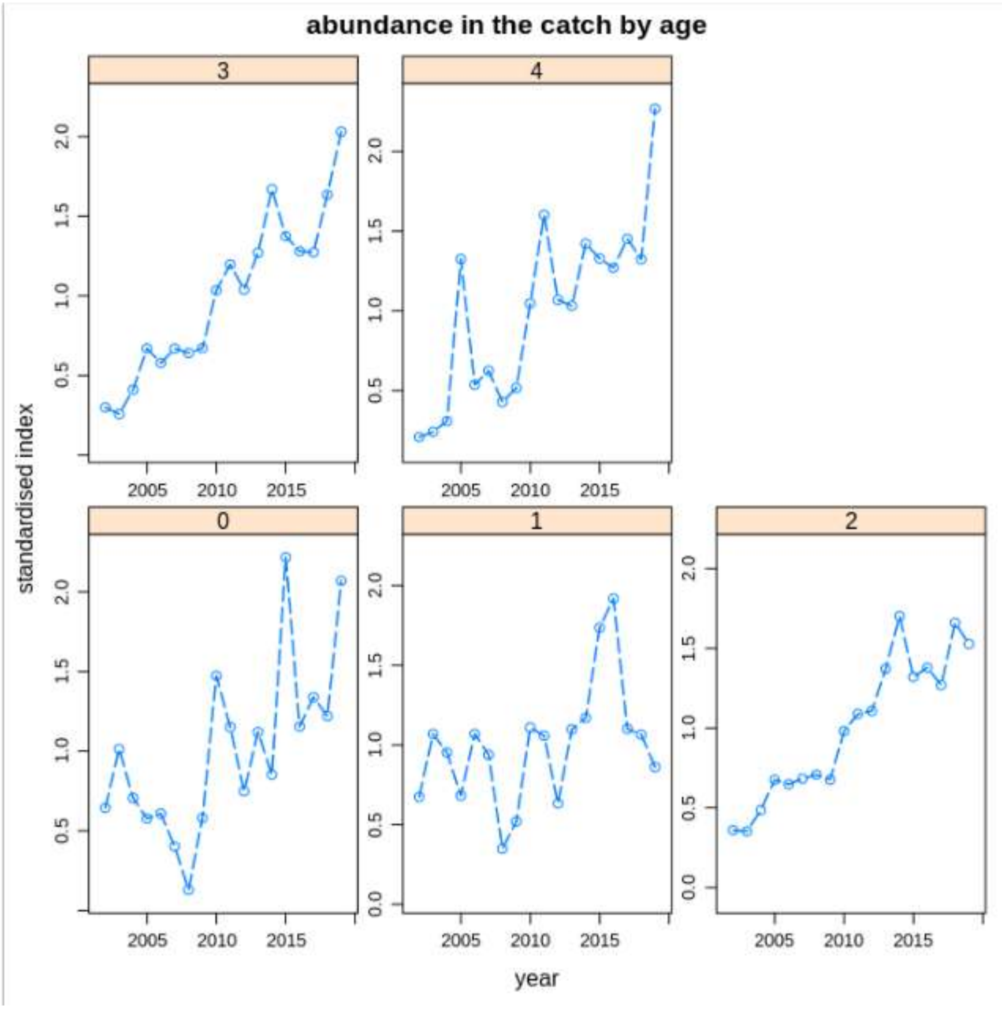
Average weight of landings at age (Kg)

Year	0	1	2	3	4+
2002	0	0	0	0	0
2003	0	0	0	0	0
2004	0	0	0	0	0
2005	0	0	0	0	0
2006	0	0	0	0	0
2007	0	0	0	0	0
2008	0	0	0	0	0
2009	0	0	0	0	0
2010	358.37	98.448	0	0	0
2011	211.065	189.221	0.48	0	0
2012	679.61	487.202	0.47	0.01	0
2013	547.566	418.21	1.104	0.035	0
2014	408.488	422.632	0.268	0	0
2015	1162.339	583.247	1.321	0.029	0
2016	230.636	202.463	2.118	0.009	0
2017	603.027	343.748	2.625	0.074	0
2018	521.458	352.56	4.374	0.281	0
2019	1995.538	615.184	3.2	0.083	0

Discards at age (Thousands of individuals)

Year	0	1	2	3	4+
2002	0.013	0.024	0.071	0.095	0.123
2003	0.013	0.025	0.062	0.106	0.131
2004	0.014	0.026	0.064	0.101	0.142
2005	0.012	0.03	0.07	0.107	0.215
2006	0.016	0.027	0.07	0.103	0.152
2007	0.017	0.029	0.071	0.106	0.13
2008	0.015	0.037	0.075	0.093	0.118
2009	0.011	0.029	0.077	0.099	0.125
2010	0.005	0.011	0.071	0.111	0.153
2011	0.008	0.014	0.032	0.112	0.18
2012	0.008	0.013	0.043	0.048	0.206
2013	0.008	0.013	0.043	0.048	0.141
2014	0.009	0.013	0.032	0.102	0.135
2015	0.007	0.014	0.041	0.048	0.145
2016	0.008	0.016	0.037	0.048	0.164
2017	0.007	0.015	0.046	0.069	0.167
2018	0.007	0.015	0.052	0.058	0.131
2019	0.006	0.014	0.043	0.048	0.145

Average weight of discards at age (Kg)



. Catch at age of Red Mulled in GSA 7. Y-axis is standardised.

6.1.4 Tuning data

Year	0	1	2	3	4
2002	78.639	1614.254	439.794	110.052	28.336
2003	38.677	1198.022	412.054	66.062	18.123
2004	168.266	2326.477	456.533	96.826	22.95
2005	91.695	1835.713	493.379	88.011	22.663
2006	164.518	1612.707	240.758	70.759	22.347
2007	272.386	5213.972	1088.391	172.527	54.106
2008	233.165	2852.414	800.903	168.678	42.116
2009	170.74	2411.65	896.397	250.727	88.309
2010	783.524	6921.276	851.761	219.618	90.225
2011	156.817	3004.863	1004.385	139.032	22.811
2012	67.87	2200.52	1188.019	206.457	58.025
2013	834.776	7686.893	1285.136	230.465	47.847
2014	601.813	7349.852	1849.54	306.247	67.186
2015	188.038	5315.959	2301.126	435.107	92.703
2016	1063.704	10437.178	1978.928	349.876	69.939
2017	104.996	4441.888	2194.776	360.581	70.666
2018	771.655	7236.566	1853.415	396.429	97.921
2019	347.856	6093.827	2234.239	446.775	101.853

MEDITS index at age (Numbers in thousands for the 13800 km^2 of the Gulf of Lion)

Year	0	1	2	3	4
2002	0.02	0.029	0.069	0.123	0.147
2003	0.02	0.029	0.066	0.099	0.161
2004	0.017	0.025	0.066	0.119	0.142
2005	0.018	0.029	0.064	0.11	0.152
2006	0.016	0.023	0.067	0.129	0.17
2007	0.019	0.026	0.062	0.105	0.157
2008	0.015	0.026	0.071	0.114	0.15
2009	0.019	0.028	0.078	0.124	0.169
2010	0.015	0.021	0.064	0.126	0.165
2011	0.016	0.029	0.063	0.091	0.114
2012	0.02	0.034	0.07	0.104	0.161
2013	0.014	0.023	0.067	0.109	0.132
2014	0.016	0.026	0.069	0.104	0.137
2015	0.018	0.031	0.068	0.103	0.128
2016	0.016	0.024	0.068	0.11	0.134
2017	0.019	0.034	0.066	0.1	0.13
2018	0.015	0.024	0.072	0.114	0.142
2019	0.016	0.027	0.065	0.104	0.129

MEDITS average weight at age.

6.1.5 Results

To select the final model for assessment, we investigated combinations of various options for the three submodels regarding fishing mortality, survey catchability and stock-recruitment inspired from previous assessment and other areas (notably GSA 5 & 6).

For fishing mortality, all investigated options considered age as a factor, but proposed different smoother for the year effect:

```
fmodel_list<-list(~ factor(age) + s(year, k = 3),
          ~ factor(age) + s(year, k = 4),
          ~ factor(age) + s(year, k = 5),
          ~ factor(age) + s(year, k = 6),
          ~ factor(age) + s(year, k = 7),
          ~ factor(age) + s(year, k = 8))
```

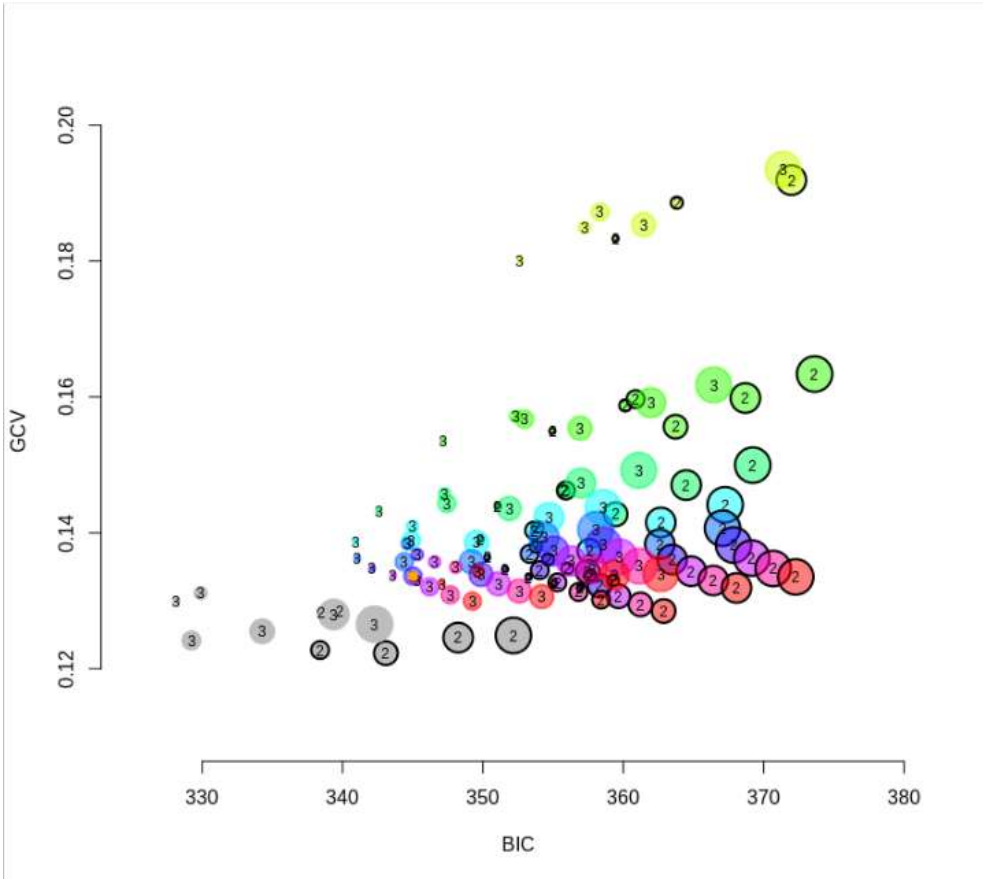
For catchability, two options allowed to test for a catchability threshold at age 2 or age 3:

```
qmodel_list<-list(list(~factor(replace(age,age>2,2))),
          list(~factor(replace(age,age>3,3))))
```

For stock recruitment, the default option (year as a factor) has been compared to forcing a geometric mean model, with different options corresponding to different variability (CV ranging from 0.1 to 0.5).

```
srmodel_list<-list(~factor(year),
           ~geomean(CV=0.1),
          ~geomean(CV=0.15),
          ~geomean(CV=0.2),
          ~geomean(CV=0.25),
          ~geomean(CV=0.3),
          ~geomean(CV=0.35),
          ~geomean(CV=0.4),
          ~geomean(CV=0.45),
          ~geomean(CV=0.5))
```

All combinations of options for the three submodels were tested, recovering BIC and GCV score for each combination. Model comparison regarding these two criterions is summarized in the next figure.



Performance of the different modelling options tested. Models are evaluated according to BIC (x-axis) and GCV-score (y-axis). Bubble size corresponds to the number of smoother knots in the fishing mortality submodel. Colours corresponds to the amount of variability in the stock-recruitment submodel (from yellow→ low variability, to red → high variability), with grey corresponding to stock recruitment being governed by factor (year); numbers represents the age threshold used for the survey catchability submodel. The orange dot corresponds to the final selected model.

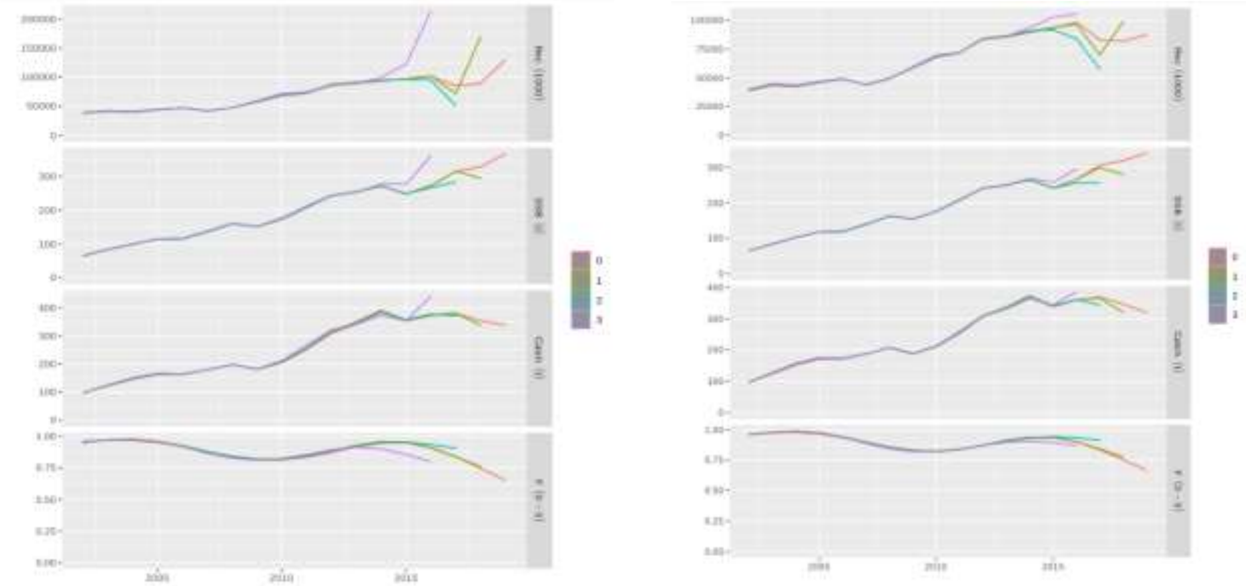
At first glance, models using stock recruitment factorized by years (grey bubbles) seemed to outperform the rest. However, retrospective analysis for these models led us to reject their use, as recruitment proved to be fairly unstable. Regarding the effect of the number of knots on the smoother of the fishing mortality model, models with low to intermediate number of knots (smaller bubbles) were favoured by both BIC and GCV, and especially k=5 appeared to be the best trade-off. Regarding the age threshold for survey catchability, models with threshold at age 3 systematically outperformed their counterpart with threshold at age 2, so age 3 was selected. Finally, regarding the amount of variability within the stock-recruitment geometric mean model (bubble colours), increasing variability decreased GCV, but BIC was minimized for intermediate variability. Therefore, geomean(CV=0.35) was selected.

The final model for stock assessment was therefore the following:

fmodel = ~ factor(age) + s(year, k = 5)

qmodel = ~factor(replace(age,age>3,3))

srmodel = ~geomean(CV=0.35)



Retrospective analysis carried out for the selected model with stock recruitment factorized by year (left panel) and stock recruitment modelled as a geometric mean of previous years (right panel). Unstable retrospective on the recruitment estimates (upper-left) led to the rejection of the use of stock recruitment factorized by year.

FINAL RUN

Recruitment, SSB, catch and Fbar (ages 0-3) estimates from the final model, fishing mortality at age and the estimated stock abundance are provided in the following three tables.

year	rec	ssb	catch	fbar
2002	38498.39	64.63	97.079	0.96
2003	43186.58	83.324	124.382	0.972
2004	42123.24	101.556	152.084	0.976
2005	45665.58	117.767	171.22	0.964
2006	48679.63	118.629	171.252	0.936
2007	44080.7	138.444	187.604	0.897
2008	49756.48	163.293	208.329	0.859
2009	58412.94	154.838	190.688	0.832
2010	67820.13	175.184	210.795	0.824
2011	71616.29	206.403	253.018	0.837
2012	83535.86	241.602	305.776	0.866
2013	85516.76	250.394	332.633	0.903
2014	89440.43	265.023	368.233	0.93
2015	93273.93	241.899	337.783	0.932
2016	98472.65	265.24	359.01	0.9
2017	83072.71	305.43	368.986	0.835
2018	81741.65	317.93	346.022	0.752
2019	87734.8	339.787	320.365	0.668

Recruitment (rec, in thousands), spawning stock biomass (ssb, in tons), catch (in tons) and fbar estimated by the stock assessment model.

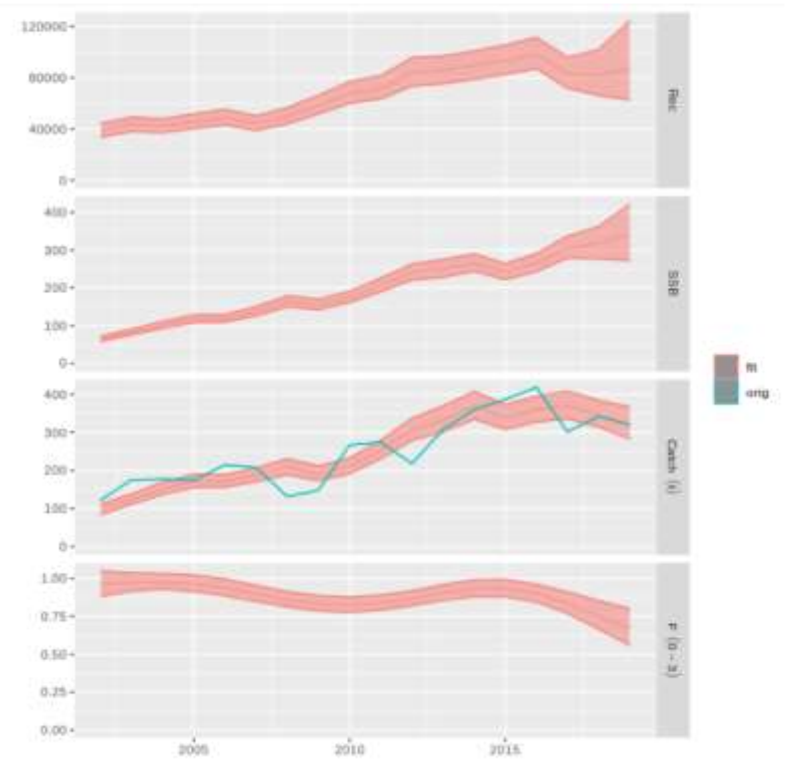
Year	0	1	2	3	4+
2002	0.039	1.089	1.475	1.237	0.66
2003	0.039	1.103	1.494	1.253	0.668
2004	0.04	1.107	1.5	1.258	0.671
2005	0.039	1.094	1.481	1.243	0.662
2006	0.038	1.061	1.438	1.206	0.643
2007	0.036	1.018	1.378	1.156	0.616
2008	0.035	0.974	1.32	1.107	0.59
2009	0.034	0.944	1.279	1.073	0.572
2010	0.033	0.935	1.267	1.062	0.566
2011	0.034	0.95	1.286	1.079	0.575
2012	0.035	0.983	1.331	1.117	0.595
2013	0.037	1.024	1.387	1.163	0.62
2014	0.038	1.055	1.429	1.198	0.639
2015	0.038	1.057	1.432	1.201	0.64
2016	0.036	1.021	1.382	1.159	0.618
2017	0.034	0.947	1.283	1.076	0.574
2018	0.03	0.853	1.156	0.97	0.517
2019	0.027	0.757	1.026	0.86	0.459

Fishing mortality at age resulting from the stock assessment model.

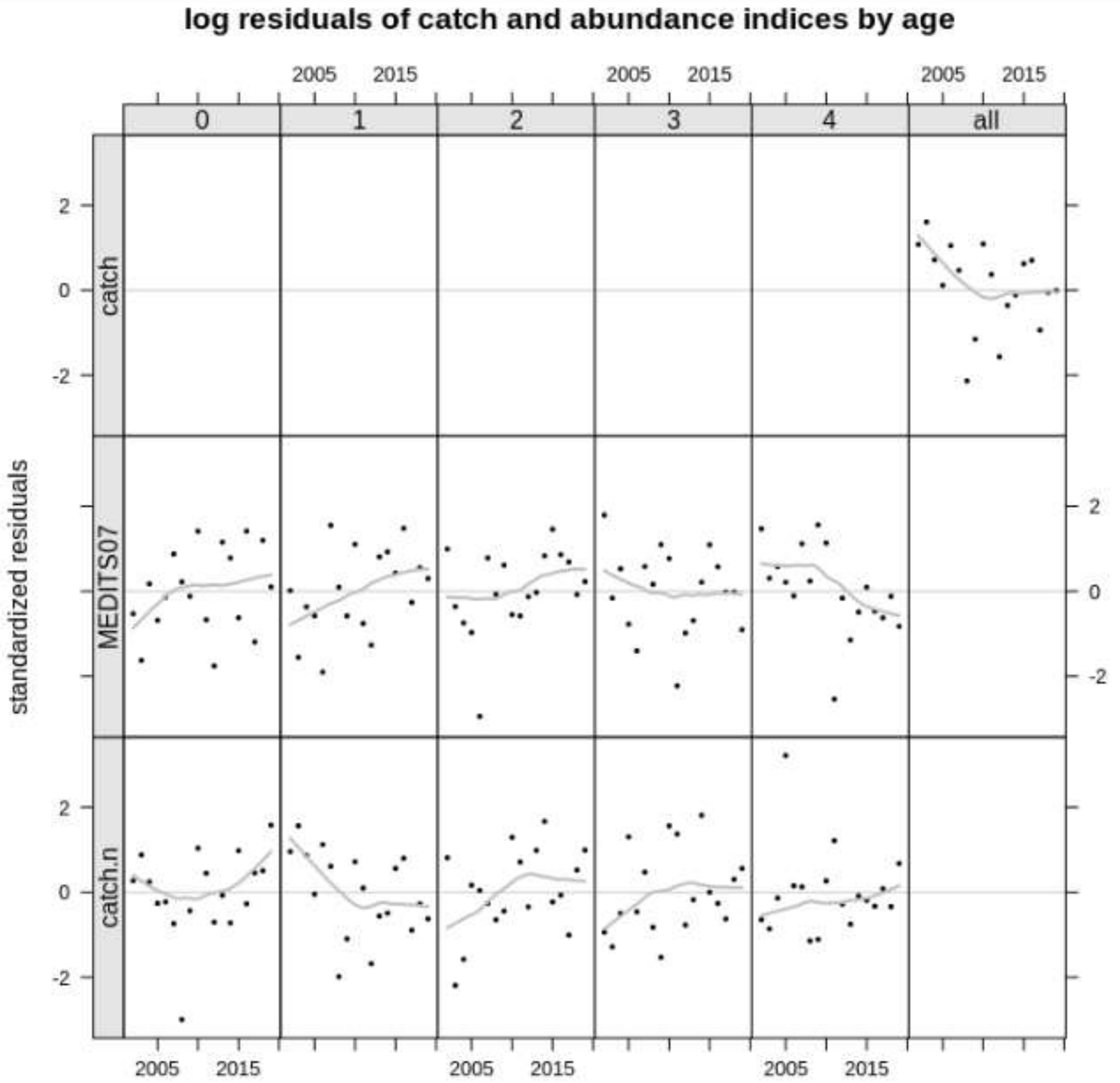
Year	0	1	2	3	4
2002	38498.39	5052.945	529.882	76.292	15.081
2003	43186.58	6499.396	764.138	68.562	18.774
2004	42123.24	7287.228	969.255	97.021	18.381
2005	45665.58	7106.735	1082.064	122.347	23.181
2006	48679.63	7708.075	1069.543	139.096	29.626
2007	44080.7	8226.279	1198.173	143.643	35.906
2008	49756.48	7460.81	1336.105	170.775	40.588
2009	58412.94	8434.419	1265.115	201.876	49.561
2010	67820.13	9912.488	1473.982	199.116	60.925
2011	71616.29	11512.62	1748.126	234.866	65.075
2012	83535.86	12150.822	2001.5	273.208	73.236
2013	85516.76	14156.231	2043.08	298.975	81.615
2014	89440.43	14470.744	2284.689	288.706	86.366
2015	93273.93	15117.923	2264.102	309.562	83.547
2016	98472.65	15764.506	2359.361	305.719	86.262
2017	83072.71	16665.028	2552.744	334.908	89.582
2018	81741.65	14095.656	2903.475	400.117	103.47
2019	87734.8	13916.473	2697.671	516.83	134.037

Stock abundance (in thousands) at age estimated by the model

Through the years, the fishing mortality at age has been quite constant on Red Mullet, and seems to follow a downward trend in the recent years that remains to be confirmed in the coming years. Such trend is probably not tied to a reduction of fishing effort, but is rather explained by increased productivity of the stock, as exemplified in the estimated recruitment, since 2012. Factors responsible for this high recruitment are up to know not identified.



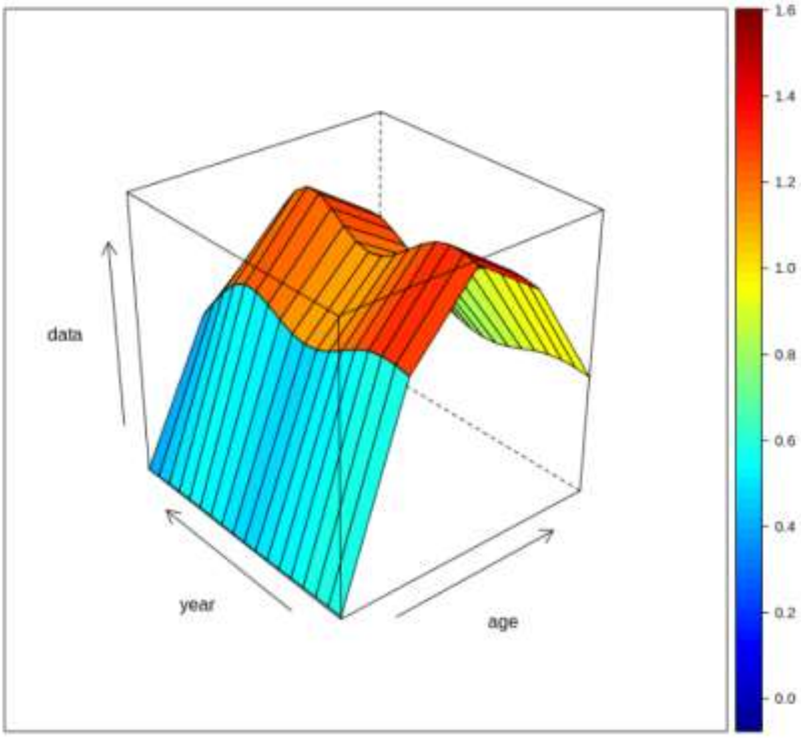
Time series and confidence intervals of Recruitment, SSB, Catch and Fbar estimated by the model, together with confidence intervals. The blue line corresponds to the observed catch.



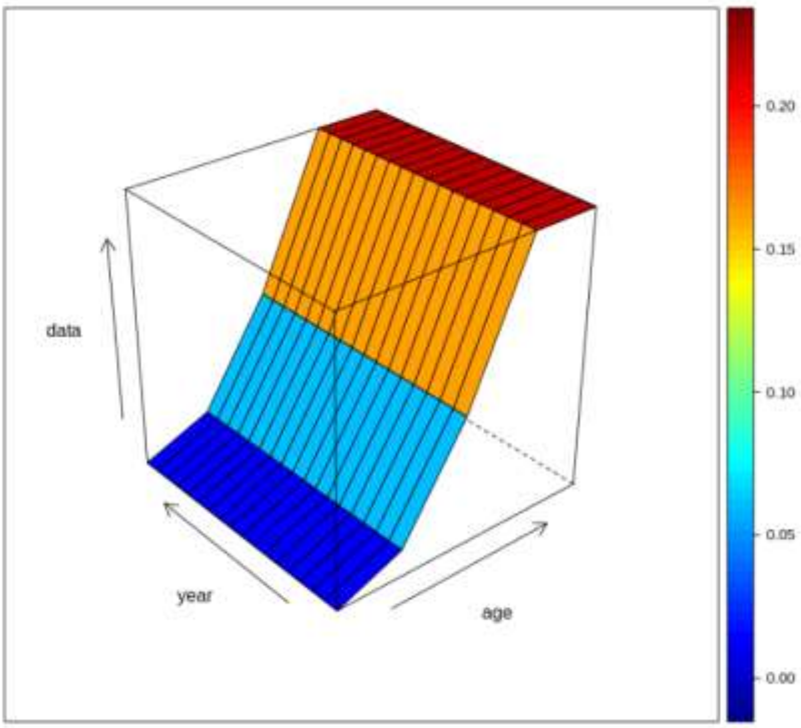
Log residuals from the stock assessment model.

Log-residuals exhibited few patterns, except for positive residuals at age 1 for the catch at the first half of the series (up to 2010). Despite our modelling efforts, this pattern could not be avoided. Further investigations should be carried out next year to solve this somewhat moderate issue if it remains.

Tri-dimensional representation of fishing mortality at age through the years suggests that fishing mortality is quite low at age 0 compared to other ages, and is also somewhat reduced at older ages. Survey catchability is assumed constant through the years, but increases with age up to age 3, in accordance with the catchability submodel specification.



Fishing mortality at age through the years



Survey catchability at age through the years

7 Stock predictions

Reference points

To define reference points F01 (as a proxy for FMSY) and Fmax a Yield per Recruit analysis (YPR) was carried out in R using FLBRP.

Input data

As input the same population parameters used for the stock assessment model and its output of the exploitation pattern for last three years of the assessment.

Results

F01 = 0.423; Fcurrent = 0.668 and the resulting ratio F01 / Fcurrent = 1.579, suggesting that the stock is currently over-harvested.

Reference points estimated in previous assessments, with $F_{bar(-2)}$ and XSA and a4a and for the last assessments (GFCM, 2017, STECF 14-17, 2014). The exploitation status ($F/F_{0.1}$) is similar for XSA or a4a.

	$F_{0.1}$	Fcurrent*	$F/F_{0.1}$
a4a	0.62	0.82	1.32
XSA	0.52	1.2	2.3
GFCM 2018	0.31	0.78	2.52
STECF 18-12 - a4a	0.64	1.30	2.03
STECF 18-12 - XSA	0.40	0.87	2.18

7.1 Short term predictions

Input parameters used in the stock assessment were used for the STF. Different scenarios of constant harvest strategy with Fbar calculated as the average of ages 0 to 3 and F status quo (Fstq = 0.668 based on F in 2019) were performed. Recruitment (class 0) has been estimated as the geometric mean of the stock assessment output since 2012 as it corresponds to the high-recruitment time period.

Assumptions made for the interim year and in the forecast.

Variable	Value	Notes
Biological Parameters	average 2017-2019	mean weights at age, maturation at age, natural mortality at age and selection at age, based average of 2017-2019
$F_{ages\ 1-3}$ (2020)	0.67	F2019 used to give F status quo for 2020
SSB (2020)	361.8	Stock assessment 1 January 2020
R_{age0} (2020,2021)	88300	mean of the years 2012-2019
Total catch (2020)	320	Assuming F status quo for 2020

Short-term forecast

Rationale	Ffactor	Fbar	Catch 2019	Catch 2021	SSB 2020	SSB 2022	SSB_change 2020-2022(%)	Catch_change 2019-2021(%)
High long term yield (F0.1)	0.63	0.423	320	252	362	516	42.6	-21.3
F upper	0.87	0.578	320	320	362	425	17.5	-0.3
F lower	0.42	0.282	320	181	362	621	71.6	-43.6
FMSY transition	0.88	0.586	320	323	362	421	16.4	0.7
Zero catch	0.00	0.000	320	0	362	923	155.2	-100.0
Status quo	1.00	0.668	320	354	362	382	5.6	10.4
Different Scenarios	0.10	0.067	320	48	362	838	131.6	-85.0
	0.20	0.134	320	93	362	762	110.6	-71.1
	0.30	0.200	320	134	362	694	91.8	-58.2
	0.40	0.267	320	173	362	633	75.1	-46.2
	0.50	0.334	320	208	362	579	60.1	-35.0
	0.60	0.401	320	242	362	531	46.8	-24.6
	0.70	0.467	320	273	362	488	34.8	-14.9
	0.80	0.534	320	302	362	449	24.0	-5.9
	0.90	0.601	320	328	362	414	14.3	2.5
	1.10	0.734	320	377	362	354	-2.3	17.7
	1.20	0.801	320	399	362	328	-9.4	24.6
	1.30	0.868	320	420	362	305	-15.8	31.0
	1.40	0.935	320	439	362	284	-21.6	37.0
	1.50	1.002	320	457	362	264	-26.9	42.6
	1.60	1.068	320	474	362	247	-31.8	47.9
	1.70	1.135	320	490	362	231	-36.2	52.9
	1.80	1.202	320	505	362	216	-40.2	57.6
	1.90	1.269	320	519	362	203	-43.9	62.0
	2.00	1.335	320	532	362	191	-47.3	66.1

Fishing at $F_{0.1}$ (0.42) generates a decrease of the catch of 21.3% from 2019-2021 and an increase of the spawning stock biomass of 42.63% from 2020 to 2022.

7.2 Medium term predictions

7.3 Long term predictions

8 Draft scientific advice

(Examples in blue)

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	$F_{0.1}$ = 0.42	0.67		D	IO_I
	Fishing effort					
	Catch In the last 3 yr				D	
Stock abundance	Biomass					
	SSB	340	143 246	33^{th} percentile 66^{th} percentile		O_H
Recruitment					I	
Final Diagnosis		In intermediate level of overfishing with relative high level of biomass.				

For more details please refer to

https://stecf.jrc.ec.europa.eu/reports/medbs

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 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 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)*