Stock Assessment Form of MUT *(M. barbatus)* in combined GSA 15-16

Reference year: 2015

Reporting year: 2006-2015

Red mullet, Mullus barbatus, is an important species commercial for demersal fisheries in the Strait of Sicily (GFCM-GSAs12-16, south-central Mediterranean Sea). It is fished almost exclusively by bottom trawling on shelf grounds. Based on available knowledge red mullets inhabiting the continental shelf of GSA 15 and 16 are considered as a stock unit with average annual landings for the period 2006-2015 of about 774 tons. Italian trawlers catch about 95% of the total production of red mullet in the area, being a yield of Maltese trawlers about 5%. Trawl fishery data for the period 2006-2015 have been used to assess the *Mullus barbatus* stock in the combined GSA 15 and 16. The assessment was performed by extended survivor analysis (XSA) using commercial catch at age tuned with MEDITS data and FLR routines. The stock resulted in overfishing ($F_{curr}>F_{0.1}$), with the survey data (MEDITS) time series indicated a relative low biomass of the stock in 2015.

Stock Assessment Form version 1.0 (January 2014)

Uploader: *Giacomo Milisenda*

Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Mullus barbatus	[Red mullet]	MUT[33]
1st Geographical sub-area:	**2nd Geographical sub-area:**	**3rd Geographical sub-area:**
[GSA15]	[GSA_16]	
4th Geographical sub-area:	**5th Geographical sub-area:**	**6th Geographical sub-area:**
1st Country	**2nd Country**	**3rd Country**
[Malta]	[Italy]	
4th Country	**5th Country**	**6th Country**
Stock assessment method: (direct, indirect, combined, none)		
Indirect method (XSA)		
Authors:		
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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

Red mullet is a benthic species, frequently found on muddy bottoms at depths between 5 and 250 m (Voliani, 1999). It is also found on gravel, maerl and sandy bottoms. On the northern side of the Strait of Sicily (SoS) (GSAs 15 and 16), this species was found almost exclusively over the shelf (44 to 69% of the hauls) (SAMED, 2002).

The presence of different red mullet stock units in the SoS has been widely debated in the past decades. Levi *et al.,* (1992), comparing growth curves of *M. barbatus* in the Mediterranean, found significant differences between red mullet growth on the Sicilian side of the SoS (GSAs 15 and 16) and in the Gulf of Gabès (GSA 14). Other evidence supporting the existence of separate stocks of red mullets in the central Mediterranean comes from parasitological observations. A large infestation by a trematode of the genus *Stephanostomum* seriously affected the red mullet fishery in Tunisian waters for several months in 1990. No such occurrence was noted in the fish landed at the Sicilian base-ports of the SoS (Levi *et al.,* 1993). Levi *et al.,* (1995) reproposed the hypothesis on the existence of separate stock units of red mullet on the basis of the independence of the water masses and the circulation on the Sicilian and African sides of the SoS. Due to the occurrence of discrete spawning and nursery areas (Garofalo *et al.,* 2004, 2008) distributed along the European and African shelves of the SoS, coupled with separate currents systems (Beranger *et al.,* 2004), the existence of different sub-units of the red mullet population is considered highly probable by Fiorentino *et al.,* 2008. More recently the simulation of larval dispersal between the different spawning and recruitment areas laying on the northern and southern side of the area found a weak connectivity between the Sicilian–Maltese and the African sides of the SoS (Gargano *et al.,* in press). This result strongly support the existence of different subpopulations in the northern (GSA 15 and 16) and southern side (GSA 12, 13 and 14) of the Strait of Sicily.

2.2 Growth and maturity

In the northern sector (GSAs 15 and 16) the observed maximum length is 25 cm TL for both sexes. Red mullet reproduction in GSA 13 occurs near the coast, from May to June–July (Gharbi and Ktari, 1981; Cherif *et al.,* 2007b). According to Levi (1991) spawning of red mullet in GSAs 15 and 16 takes place mainly in May.

Eggs, larvae and post-larvae up to 30–35 mm, of *M. barbatus*, are pelagic and live in the surface waters. According to Sabatés and Palomera (1987), larvae are found only in surface waters (0–1.5 m depth), mainly in areas influenced by river outflow. Larvae were found in the Mediterranean mainly between June and July (Lago de Lanzos, 1980; Sabatés and Palomera, 1987).

Juveniles up to 4–5 cm TL are pelagic, have a blue livery and may be collected several miles off the coast. Above this size, juveniles move to the coastal areas and become demersal. Their livery gradually changes from the juvenile to the adult colors (Voliani, 1999). Although recruits exhibited a widespread distribution throughout the coastal waters, four main areas showing high abundance and the almost exclusive presence of recruits were found within GSA 16 (southwestern coast of Sicily), between 20 and 50 m depth.

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

Somatic magnitude measured (LT)				**Units**	
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	Spring-summer
Maximum size observed	25	25	25	**Recruitment season**	Late summer - Autumn
Size at first maturity	14.16	13.85	14.0	**Spawning area**	Continental shelf
Recruitment size to the fishery			7	**Nursery area**	Coastal areas

Table 2-2.3: Growth and length weight model parameters

			Sex			
		Units	female	male	Combined	Years
Growth model	**L_∞**	cm			24.1	
	K				0.42	
	t_0	year			-0.8	
	Data source	Fiorentino F., (Unpubl)				
Length weight relationship	**A**				0.001	
	B				3.0421	
	M (scalar)					
	sex ratio (% females/total)	0.50				

3 Fisheries information

3.1 Description of the fleet

Red mullet is one of the main coastal demersal resources in the Mediterranean. It is fished by otter trawls, trammel nets and gillnets (Voliani, 1999; Griffiths *et al.*, 2007). Red mullet is caught together with other important species, such as *Mullus surmuletus* (striped red mullet), *Merluccius merluccius* (European hake), *Pagellus spp*. (seabreams, pandoras), *Uranoscopus scaber* (stargazer), *Raja spp*. (rays), *Trachinus spp.* (weevers), *Octopus vulgaris* (common octopus), *Sepia officinalis* (common cuttlefish), *Eledone spp.* (horned and musky octopuses), and *Lophius spp*. (anglerfish). Red mullet is fished almost exclusively by trawling on shelf bottoms. Based on available knowledge red mullets inhabiting the continental shelf of GSA 15 and 16 are considered as a stock unit with an average annual landings for the period 2006-2015 of about 774 tons. Italian trawlers catch about 95% of the total production of red mullet in the area, while amounting yield of Maltese trawlers is about 5%.

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*	ITA	16	E - Trawl (12-24 metres)	03 - Trawls	34 - Demersal slope species	MUT
Operational Unit 2	ITA	16	F - Trawl (>24 metres)	03 - Trawls	34 - Demersal slope species	MUT
Operational Unit 3	MLT	15	E - Trawl (12-24 metres)	03 - Trawls	34 - Demersal slope species	MUT

Table 3.1-3: Catch, and effort by operational unit in the 2015.

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)
ITA 99 E 03 34 - MUT	394	372.9				
ITA 99 F 03 34 - MUT	14	99.1				
MLT 99 E 03 34 - MUT	22	21				
Total		493		No discard		

3.2 Historical trends

Trend in catch of red mullet of the Italian and Maltese trawl fleets since 2006 is shown in Fig. 3.2.1. The nominal effort (KW*days at sea) shows a decreasing of the two segments of the Italian trawl fleet (LOA<24m and LOA >24m) since 2004 (Fig. 3.2.2).

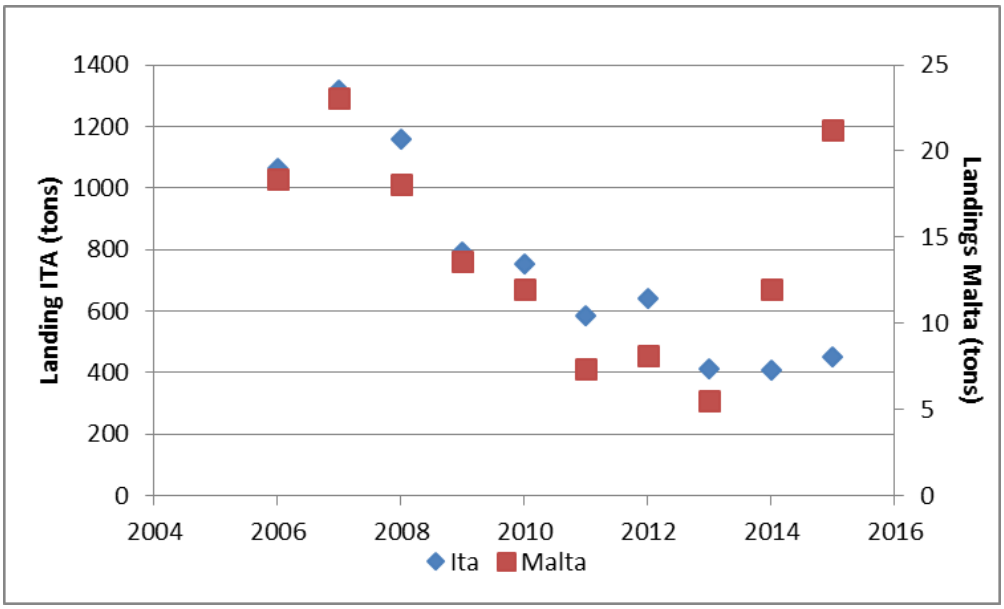


Figure 3.2.1 - Catch of MUT from 2005 to 2014 in the Strait of Sicily, Central Mediterranean (GSA 15 and 16) by fleet (Italian and Maltese trawlers).

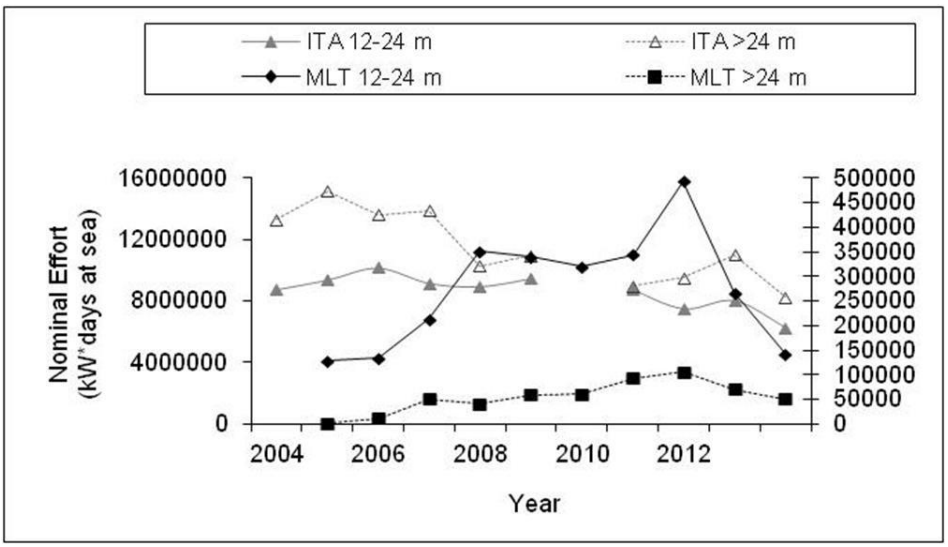


Figure 3.2.2 – Fishing effort from 2004 (Italy) – 2005 (Malta) to 2014 in the Strait of Sicily, Central Mediterranean (GSA 15 and 16) by fleet distinguished by country and LOA.

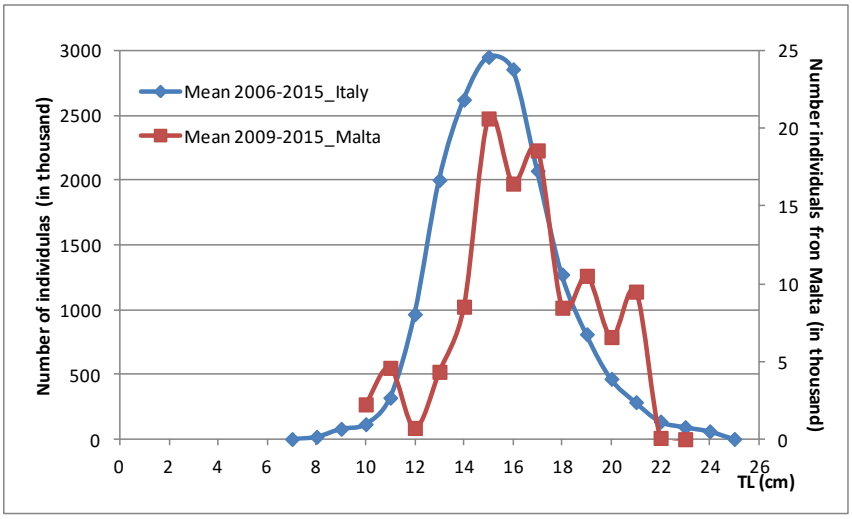


Figure 3.2.3 – Length frequency distributions mean (LFD) by fleet and country, combined sex.

3.3 Management regulations

As in other areas of the Mediterranean, the stock management of Italian fleet is based on control of capacity (number of fishing licenses), fishing effort (days at sea, number of trawls), and technical measures (cod-end mesh size, area closures and fish-size limits). A medium term management plan for 2008-2013 has been agreed for Italian trawlers in the Strait of Sicily. the plan was mainly based on a fleet reduction of 25% of the capacity obtained in two steps. The first (12.5%) from 2008 to 2010, and the second (12.5%) from 2011 to 2013. A trawling ban of 30 day per year oriented to retard the recruitment to fishery of red young of the year is adopted in late summer early autumn.

In addition, the Mediterranean Regulation EC 1967 of 21 December 2006 fixed a minimum harvest size of 11 cm TL for *Mullus spp*. and a minimum mesh size of 40 mm square or 50 mm diamond for EU bottom trawling vessels (i.e. Italian and Maltese trawlers).

In 2015, Malta had 14 trawlers that operated on a full-time basis. A preliminary analysis of the capacity of the fleet in the Sub-regional Committee report for the Central Mediterranean (SRC_CM) showed that there was a 39% reduction from 2011 to 2015 (7 permanent and 2 temporary). Fishing effort and capacity in the 25 nautical miles fisheries management zone are being managed by limiting vessel sizes, as well as total vessel engine powers (EC 813/2004; EC 1967/2006). Trawling is allowed within this designated conservation area, however only by vessels not exceeding an overall length of 24m and only within designated areas. Such vessels fishing in the management zone hold a special fishing permit in accordance with Article 7 of Regulation (EC) No 1224/2009, and are included in a list containing their external marking and vessel's Community fleet register number (CFR) to be provided to the Commission annually by the Member States concerned (EC 813/2004).

3.4 Reference points

Table 3.4-1: List of reference points and empirical reference values in 2015.

Indicator	Limit Reference point/empirical reference value	Value	Target Reference point/empirical reference value	Value	Comments
B					
SSB					
F			$F_{0.1}$	0.45	
Y					
CPUE					
Index of Biomass at sea	12.2	4.2	24.6		

4 Fisheries independent information

4.1 MEDITS TRAWL SURVEY

In order to collect fisheries independent data, which is a requirement of the EU DCF (Council Regulation 199/2008, Commission Regulation 665/2008, Commission Decision EC 949/2008 and Commission Decision 93/2010), the MEDITS international trawl survey is carried out in GSAs 15 & 16 on an annual basis.

4.1.1 Brief description of the direct method used

Distribution, abundance and demographic information of the stock at sea derived from data collected during the standard bottom trawl surveys carried out annually in the northern sector of the Strait of Sicily from 1994 to 2015 in spring/early summer within the MEDITS (MEDiterranean International Bottom Trawl-Surveys) program, included in the European Data Collection Framework (DCF). A total of 45 in GSA 15 and 120 hauls in GSA 16 were performed yearly. The bottom trawl surveys covered an area of about 22,395 km^2 in GSA 15 and 45,000 km^2 in GSA 16, within a water depth-range of 10-800 m. The sampling design is random stratified with allocation of hauls proportional to strata extension (depth strata: 10-50 m, 51-100 m, 101-200 m, 201-500 m, 501-800 m). Roughly the same haul positions were kept each year. The standardized GOC 73 gear is used with mesh size in the cod-end 20 mm opening and the vertical opening of the mouth of 2.4-2.9 m . More details on the the MEDITS protocol is reported in the MEDITS-Handbook, version n. 8 (2016).

Direct methods: trawl based abundance indices (GSA 15 &16)

Table 4.1-1: Trawl survey basic information

Survey	MEDITS	**Trawler/RV**	TRAWLER
Sampling season	MAY-JULY		
Sampling design	Stratified with number of haul by stratum proportional to stratum surface (see MEDITS-Handbook. version n. 8, April 2016, MEDITS Working Group : 120 pp.)		
Sampler (gear used)	Bottom trawl made of four panels (IFREMER reference GOC 73)		
Cod –end mesh size as opening in mm	10 mm mesh size, which corresponds to ~ 20 mm of mesh opening		
Investigated depth range (m)	10-800m		

Table 4.1-2: Trawl survey sampling area and number of hauls (GSA 15 & 16)

Stratum	**Total surface (km^2)**	**Trawlable surface (km^2)**	**Swept area (km2)**	**Number of hauls**
a	GSA 15=152 GSA 16=2979			GSA15=0 GSA 16=11
b	GSA 15=1473 GSA 16=5943			GSA 15=6 GSA16=23
c	GSA 15=3076 GSA 16=5565			GSA 15=13 GSA 16=21
d	GSA 15=3353 GSA 16=6972			GSA 15=15 GSA 16=27
e	GSA 15=2526 GSA 16=9927			GSA 15=11 GSA 16=38
Total	GSA 15=10428 GSA 16=31384			GSA 15=45 GSA 16=120

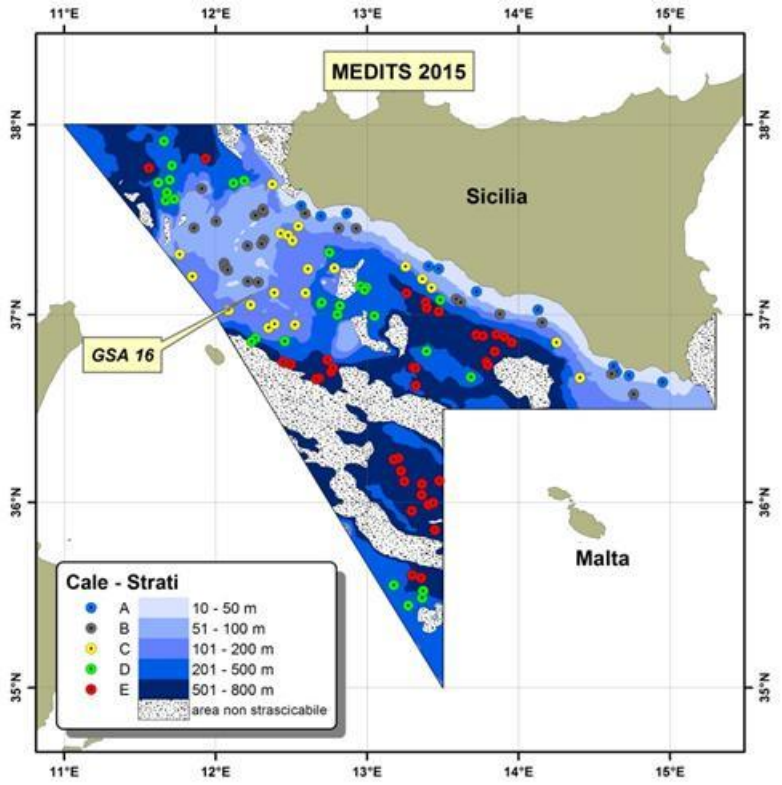


Figure 4.1 Map of hauls positions in the Strait of Sicily (GSA 16).

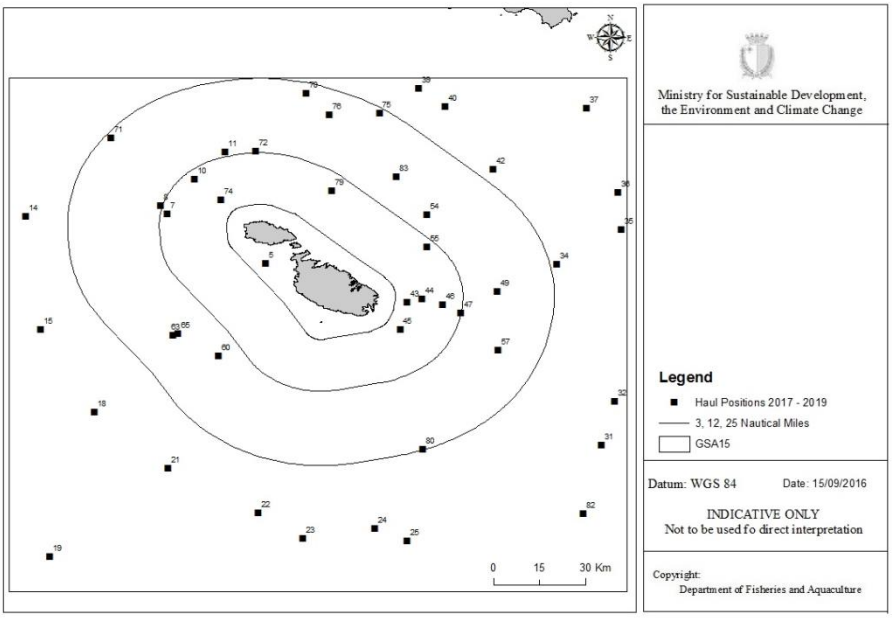


Figure 4.2 Map of hauls positions in GSA 15.

Assuming catchability equal to 1. In GSA 16 MEDTS in 2013 and 2014 was carried out in autumn for administrative reasons.

Table 4.1-3: Trawl survey abundance and biomass results in GSA 15 and 16

Depth Stratum	Years	Kg/km² GSA 16	CV	N/km² GSA 16	CV	Kg/km² GSA 15	CV	N/km² GSA 15	CV
10-200 m	1994	3.0	1.9	60.4	31.7	n.a	n.a	n.a	n.a
10-200 m	1995	5.2	2.5	122.5	59.3	n.a	n.a	n.a	n.a
10-200 m	1996	12.4	6.0	347.7	171.5	n.a	n.a	n.a	n.a
10-200 m	1997	7.2	2.7	198.8	72.8	n.a	n.a	n.a	n.a
10-200 m	1998	5.5	2.5	142.6	61.7	n.a	n.a	n.a	n.a
10-200 m	1999	10.0	5.8	240.4	147.6	n.a	n.a	n.a	n.a
10-200 m	2000	9.6	5.2	381.6	210.7	n.a	n.a	n.a	n.a
10-200 m	2001	26.6	19.8	579.2	420.6	n.a	n.a	n.a	n.a
10-200 m	2002	14.5	7.0	586.0	248.2	n.a	n.a	n.a	n.a
10-200 m	2003	23.7	10.3	5154.8	2832.5	n.a	n.a	n.a	n.a
10-200 m	2004	22.7	6.4	658.9	185.9	n.a	n.a	n.a	n.a
10-200 m	2005	24.8	13.9	1592.0	988.1	n.a	n.a	n.a	n.a
10-200 m	2006	22.0	13.0	564.4	318.2	23.0	33.3	562.0	33.6
10-200 m	2007	29.1	11.6	802.4	302.0	89.3	68.5	2934.2	70.3
10-200 m	2008	34.4	17.1	778.4	365.4	55.5	25.3	1418.9	23.5
10-200 m	2009	35.9	13.2	978.0	344.2	72.7	39.3	1694.5	39.4
10-200 m	2010	36.0	22.3	900.2	473.4	14.5	22.1	376.7	27.2
10-200 m	2011	25.5	10.1	1121.3	678.4	29.5	21.1	774.2	27.1
10-200 m	2012	21.9	8.3	650.1	262.2	25.7	45.3	691.4	44.8
10-200 m	2013	43.6	24.3	4062.1	3922.3	24.9	50.1	787.0	55.0
10-200 m	2014	39.9	14.9	2181.5	896.2	24.8	40.3	650.4	39.1
10-200 m	2015	8.3	2.5	208.8	69.0	18.0	26.4	431.6	28.6

Direct methods: trawl based length/age structure of population at sea

Length frequency distribution were sliced by knife edge approach by using the VBGF in table 2.3.

Table 4.1-4: Trawl survey results. Number Km^{-1} by age class in the GSA 15 and 16.

N (sex combined) by Age class		Year								
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
0	1281	1763	592	1290	1773	3388	1948	22874	19565	511
1	3107	3833	4817	4980	3613	3438	5005	6017	5629	709
2	3370	3720	7055	6421	5926	2659	2868	3444	3401	1303
3	861	1090	2777	2112	2043	858	767	1047	1867	499
4	122	302	519	302	540	257	180	384	319	178
5+	17	14	62	46	74	54	21	87	43	31

Table 4.1-5 Sex ratio by length class in cm of red mullet from MEDITS in GSA 16.
All year combined.

Sex ratio by Length class	1994-2015	40	0.00
		80	0.00
		100	0.29
		120	0.30
		140	0.44
		160	0.56
		180	0.90
		200	0.98
		220	0.97
		240	1.00
		260	0.50
		300	1.0

4.1.2 Spatial distribution of the resources

As indicated by Garofalo *et al.,* (2004), two major and clearly separate spawning areas exist on the northern side of the Strait of Sicily (GSAs 15 and 16). They are located over the Adventure Bank, off the southwestern coast of Sicily (GSA 16) and over the Malta Bank, between Sicily and the Maltese Islands (GSA 15), respectively, on the outer shelf (100–150 m depth) (Figure 15). Recent research on the Marine Protected Area of Castellammare del Golfo (northwestern coast of Sicily – GSA 10), where trawling has been forbidden since 1990, has shown that the oldest spawners prefer deeper bottoms (100–200 m depth), whereas the young ones are found in shallower areas (<50m depth) (Fiorentino *et al.,* 2006b).

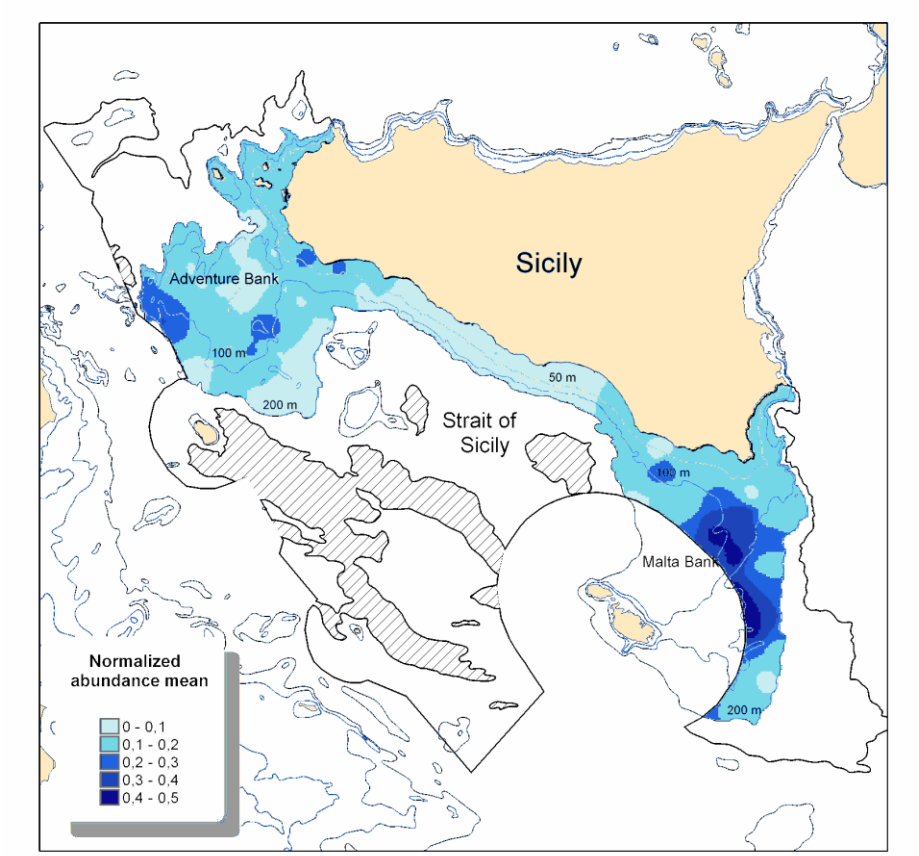


Figure 4.1.1. Map of the average distribution of *M. barbatus* spawners. The contour (solid black line) of the overall study area and the water depth of more than 800 m (hatched areas) are also shown (GSAs 15 and 16) (from Garofalo *et al.,* 2004).

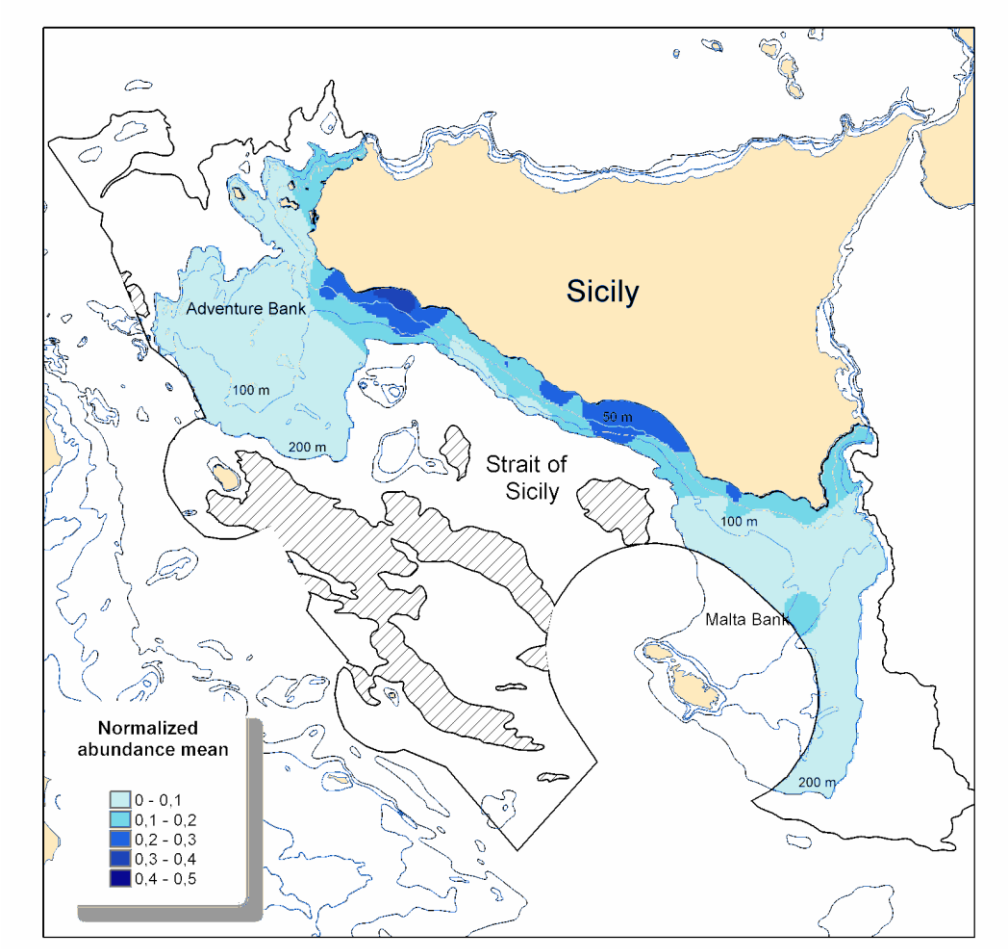


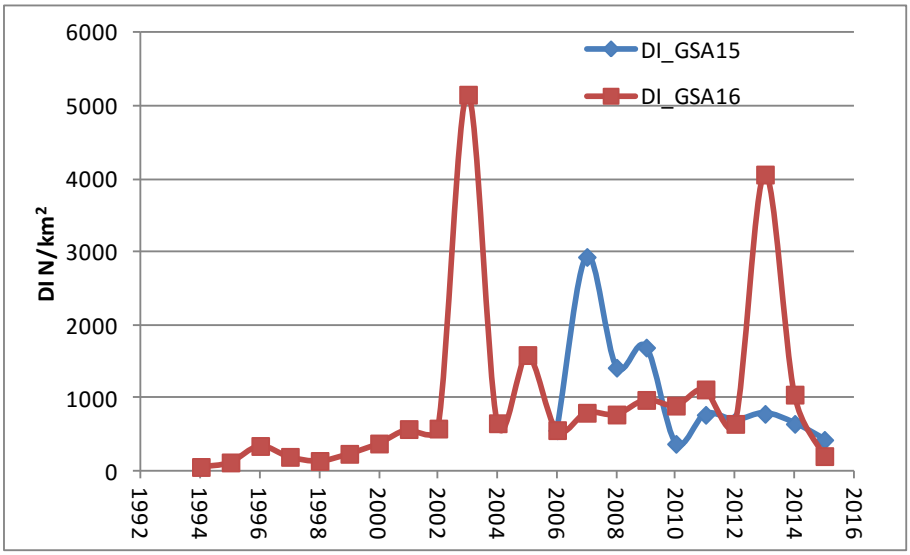
Figure 4.1.2. Map of the average distribution of *M. barbatus* recruits in GSAs 16 and 15, excluding the Maltese. Fisheries Management Zone (FMZ). The contour (solid black line) of the overall study area and the water depth of more than 800 m (hatched areas) are also shown (mainly GSA 16) (from Garofalo *et al.,* 2004).

The spatial distribution of the both Essential Fish Habitat in the northern side of SoS was repeatedly confirmed by Garofalo *et al.,* (2008); Garofalo *et al.,* (2011); Colloca *et al.,* (2013)

4.1.3 Historical trends

Considering the entire time series biomass and density of the red mullet (MUT) during the MEDITS survey in GSA 15 and GSA 16 show an increasing trend, but a reduction of abundance was observed in the last years (Fig. 4.1.3.1). The current relative stock biomass (kg/km-2) is below the 33rd percentile (Fig. 4.1.3.2). The length structures of MUT in MEDITS 2006-2015 are shown in Fig. 4.1.3.3.

a)



b)

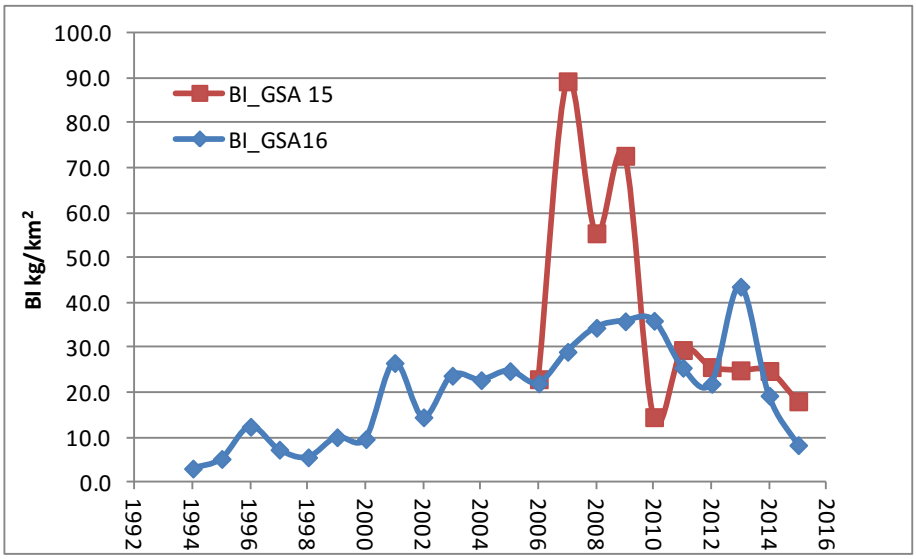


Fig. 4.1.3.1 – a) Medits Density Index (DI) in GSA 15&16. b) Medits Biomass Index (BI) in GSA 15&16. Sex combined.

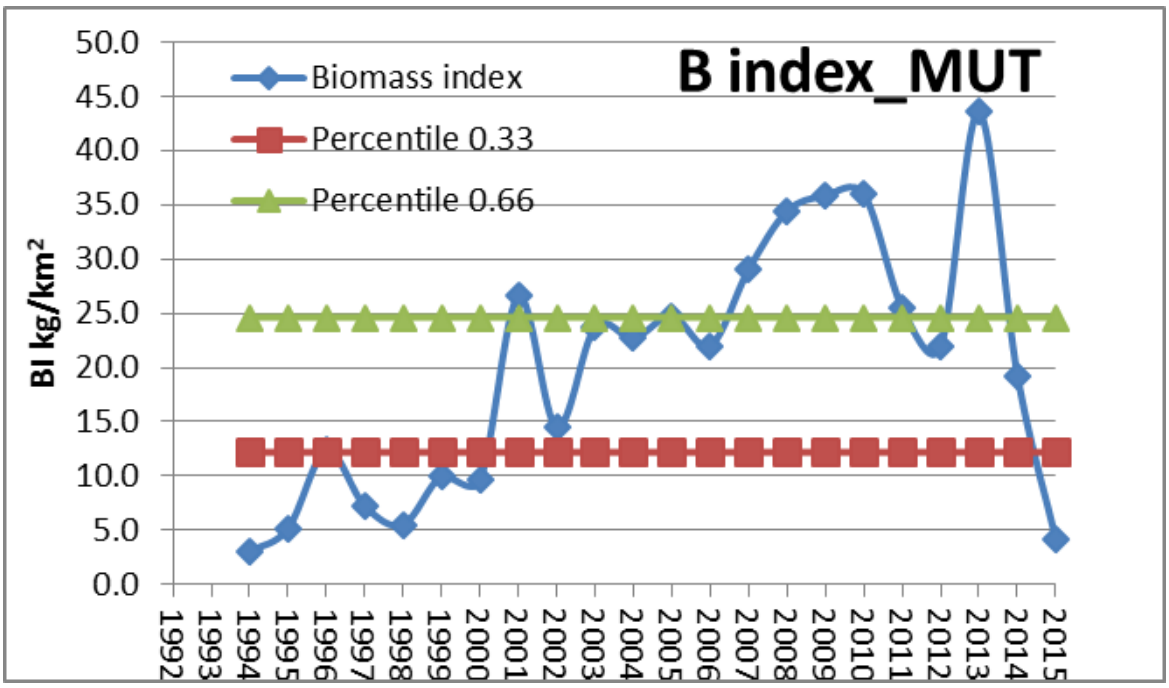
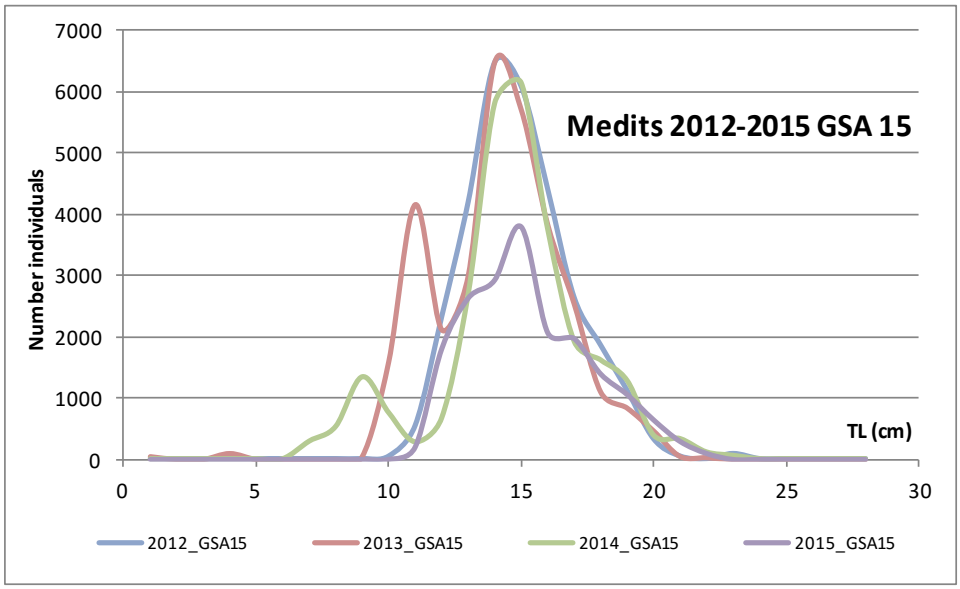


Fig. 4.1.3.2 – Biomass index current (BI current), Biomass 33rd and 66th percentile from Medits survey in GSA 16.

a)



b)

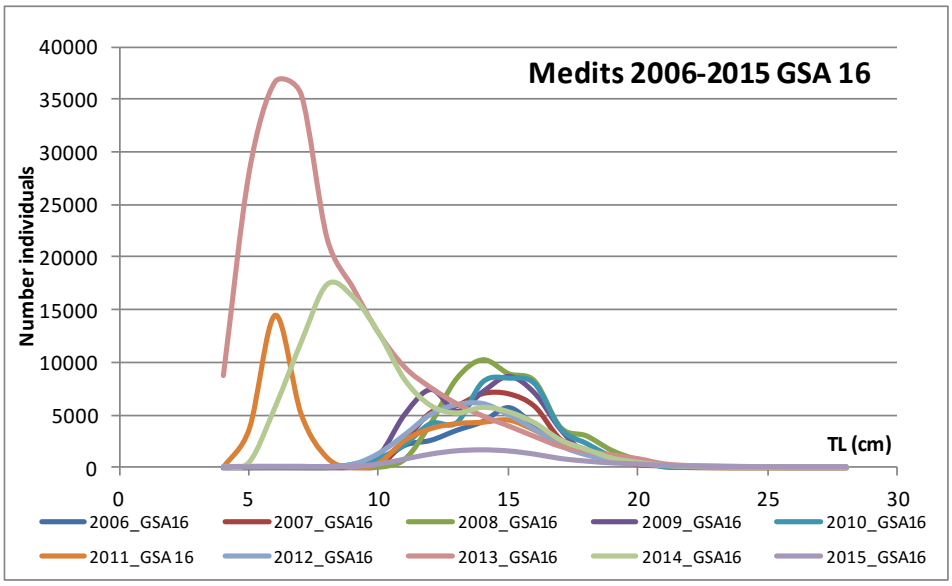


Figure 4.1.3.4 – a) Length frequency distributions (LFD) from Medits survey in GSA 15.

b) Length frequency distributions LFD from Medits survey in GSA 16. Sex combined.

5 Stock Assessment

An XSA assessment was carried out using catch data (landings and discards) EU data collection framework) collected in GSAs 15-16 in the period 2007 - 2015. For calibration (Tuning data) using survey data from GSA 15 and GSA 16 (MEDITS 2007-2015). The natural mortality M was estimated by Gislason's method. The annual size of the landings as well as Medits data were converted into the number at age by Length at age key method (ALK).

5.1 EXTENDED SURVIVOR ANALYSIS

5.1.1 Model assumptions

Darby and Flatman (1994) outline the XSA algorithm as performing the following steps: (1) a cohort analysis of the total catch-at-age data to produce estimates of population abundance-at-age, and total fishing mortalities; (2) adjustment of the CPUE values for the period of fishing defined using the alpha and beta parameters in the fleet tuning file, into CPUE values that would have been recorded if the fleet had fished only at the beginning of the year. The adjusted values are directly comparable with the population abundances at the beginning of the year; (3) calculation of fleet-based estimates of population abundance-at-age from the adjusted CPUE values and fleet catchabilities; (4) calculation of a least squares estimate (weighted mean) of the terminal population (survivors at the end of the final assessment year) for each cohort in the tuning range using the fleet-derived estimates of population abundance-at-age. These terminal populations are used to initiate the Cohort analysis in the next iteration. The process iterates until the convergence criteria described for *ad hoc* tuning are achieved. Various options are available for catchability analysis, time series weighting and shrinkage of the weighted estimates.

5.1.2 Scripts

5.1.3 Input data and Parameters

For analytical models: catch matrix in ages with discard included.

Table 5.1.3.1 - Catch matrix by years and age (GSA 15 & 16).

N (sex combined) by Age class		Year								
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
0	1432	946	515	482	1341	123	709	8	2146	573
1	5495	7446	9948	3409	4723	3428	4020	961	2101	1294
2	6311	15389	14165	8097	9996	5474	4805	3718	3142	4466
3	3724	5554	4653	4412	2813	1944	2333	1630	2422	2461
4	1654	1441	673	1156	602	662	1379	880	464	883
5+	1062	211	309	92	44	179	205	319	252	109

Table 5.1.3.2 – Tuning data by years and age (GSA 15 & 16).

N (sex combined) by Age class		Year								
	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
0	1281	1763	592	1290	1773	3388	1948	22874	19565	511
1	3107	3833	4817	4980	3613	3438	5005	6017	5629	709
2	3370	3720	7055	6421	5926	2659	2868	3444	3401	1303
3	861	1090	2777	2112	2043	858	767	1047	1867	499
4	122	302	519	302	540	257	180	384	319	178
5+	17	14	62	46	74	54	21	87	43	31

Table 5.1.3.3 – Catch weight matrix by year and age.

Age						
0	1	2	3	4	5	Year
0.01	0.029	0.053	0.08	0.107	0.141	2006
0.007	0.03	0.053	0.084	0.108	0.129	2007
0.006	0.03	0.052	0.081	0.103	0.126	2008
0.009	0.031	0.053	0.081	0.104	0.127	2009
0.01	0.033	0.054	0.082	0.105	0.128	2010
0.01	0.035	0.052	0.081	0.104	0.125	2011
0.01	0.033	0.052	0.082	0.105	0.128	2012
0.007	0.034	0.053	0.083	0.106	0.127	2013
0.009	0.03	0.055	0.082	0.106	0.134	2014
0.009	0.03	0.055	0.082	0.106	0.134	2015

Table 5.1.3.4 – Natural Mortality at age by Gislason's method.

Group 0	Group 1	Group 2	Group 3	Group 4	Group 5
1.71	0.87	0.65	0.53	0.44	0.38

5.1.4 Results

XSA was run with different shrinkage values, 0.5, 1.0, 1.5, 2.0 and 2.5. The results with the different settings produced similar estimates of recruitment and SSB. The model with shrinkage of 2 and catchability of 3 years was adopted as the final model, based on both residuals and retrospective analysis significant lower estimates of F current$_{(0\text{-}2)}$.

BEST MODEL:

xsa_control <- FLXSA.control (x=NULL, tol=1e-09, maxit=30,min.nse=0.3, fse=2, rage=1,qage=3,shk.n=TRUE,shk.f=TRUE, shk.yrs=2,shk.ages=2,window=100, tsrange=20, tspower=0, vpa=FALSE)

In the table 5.1.4.1 are reported the XSA results in terms of Spawning stock biomass (SSB), current F (F_{curr}) and Recruitment. In the last years the SSB and TB showed a decrease, whilst recruitment showed an increase.

Table 5.1.4.1 –XSA estimates of spawning stock biomass (SSB), current F (F_{curr}) and recruitment (REC).

	2006	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
SSB(tons)	4413	4183	3499	3033	2849	2550	2502	1886	1665	1580
Rec(Milions)	438	307	286	253	194	195	152	115	104	207
F_{curr}	0.82	0.66	0.55	0.61	0.46	0.45	0.70	0.47	0.44	0.77

Fishing mortality values at age are reported in table 5.1.4.2. Current F_{1-5} was estimated as average three previous years (2013-2015) and equal to 0.55. The results showing a decrease of value of $F_{bar(1-5)}$ in the last years.

Table 51.4.2 – Fishing mortality at age by XSA.

	year									
age	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
0	0.01	0.01	0.00	0.01	0.02	0.00	0.01	0.00	0.06	0.01
1	0.12	0.14	0.27	0.09	0.15	0.16	0.18	0.05	0.14	0.10
2	0.43	0.79	0.72	0.66	0.73	0.53	0.60	0.42	0.39	0.93
3	0.76	1.08	0.95	0.87	0.78	0.57	0.68	0.62	0.80	0.96
4	2.20	0.89	0.48	1.06	0.36	0.78	1.70	0.85	0.49	1.23
5+	2.20	0.89	0.48	1.06	0.36	0.78	1.70	0.85	0.49	1.23

Yield per Recruit

A yield per recruit analysis was carried using the FLBRP library (FLR) to calculate $F_{0.1.}$ The estimated F_{01} value was 0.45.

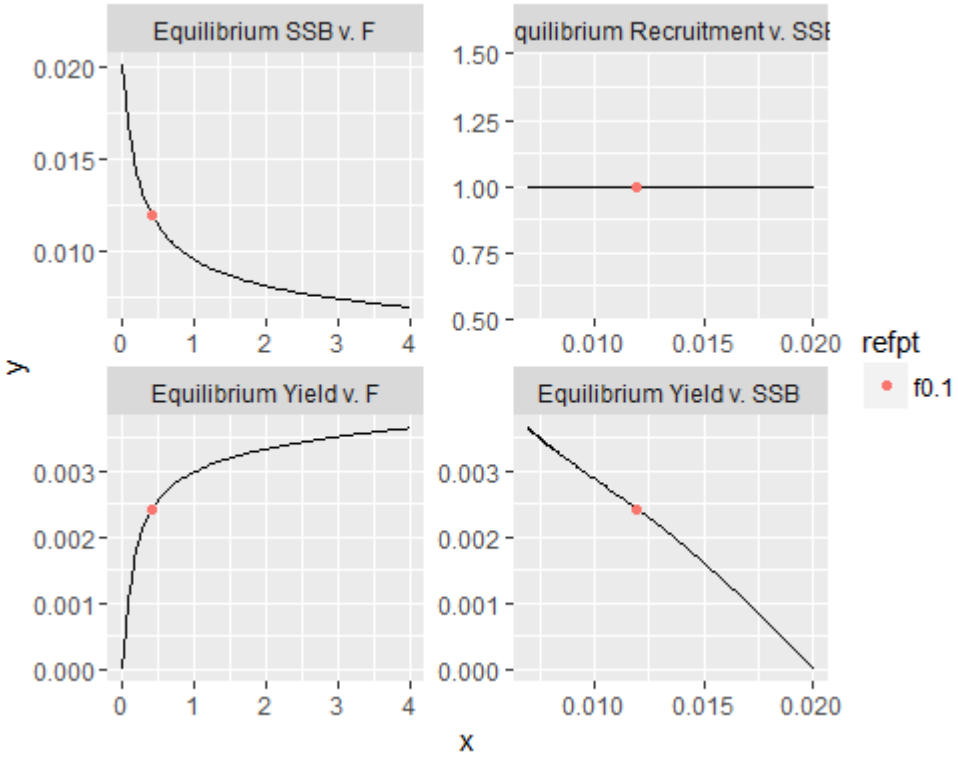


Figure 5.1.4.1 - Yield and biomass per recruit analysis.

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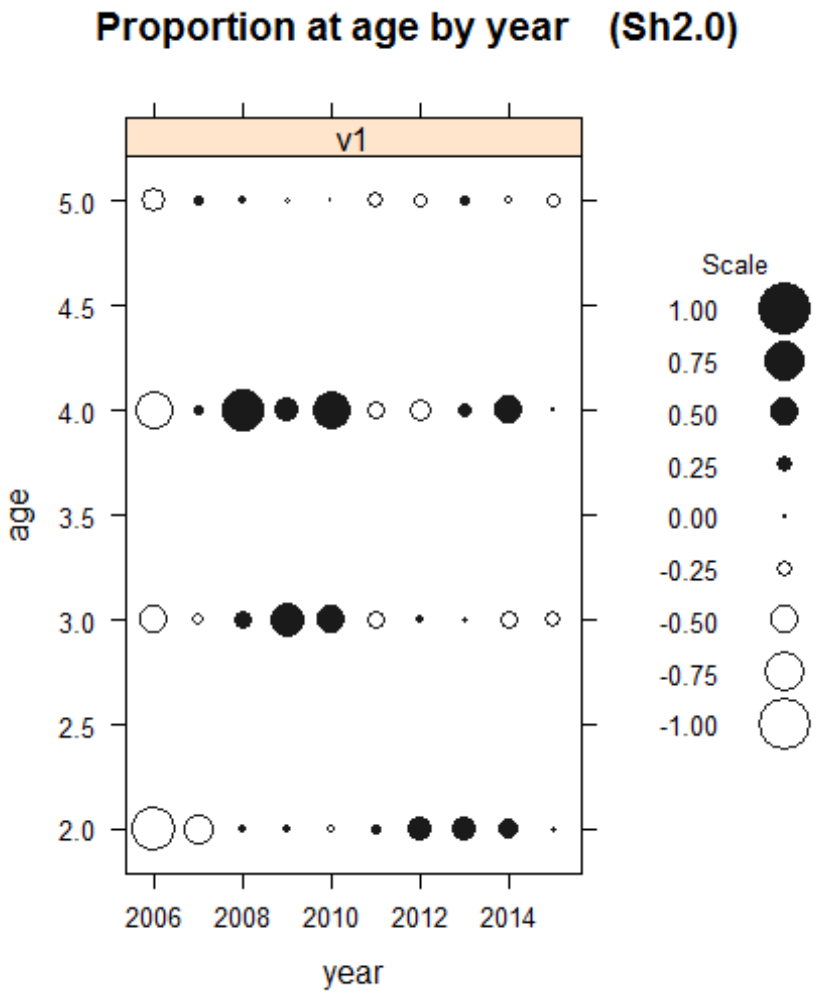
5.1.5 Robustness analysis

Log Residuals at age for survey analysis obtained with XSA models are reported below.



5.1.6 Retrospective analysis

Retrospective analyses showed rather consistent results with no major pattern in the data (Fig. 5.1.6.1.).

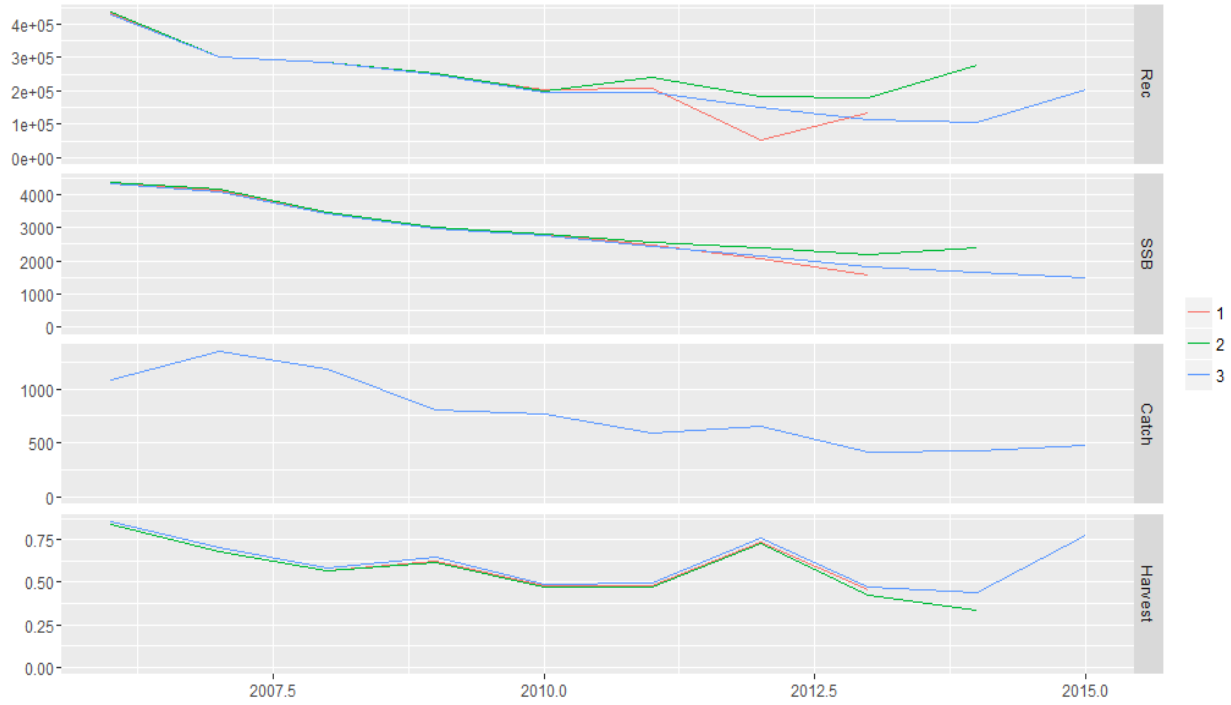
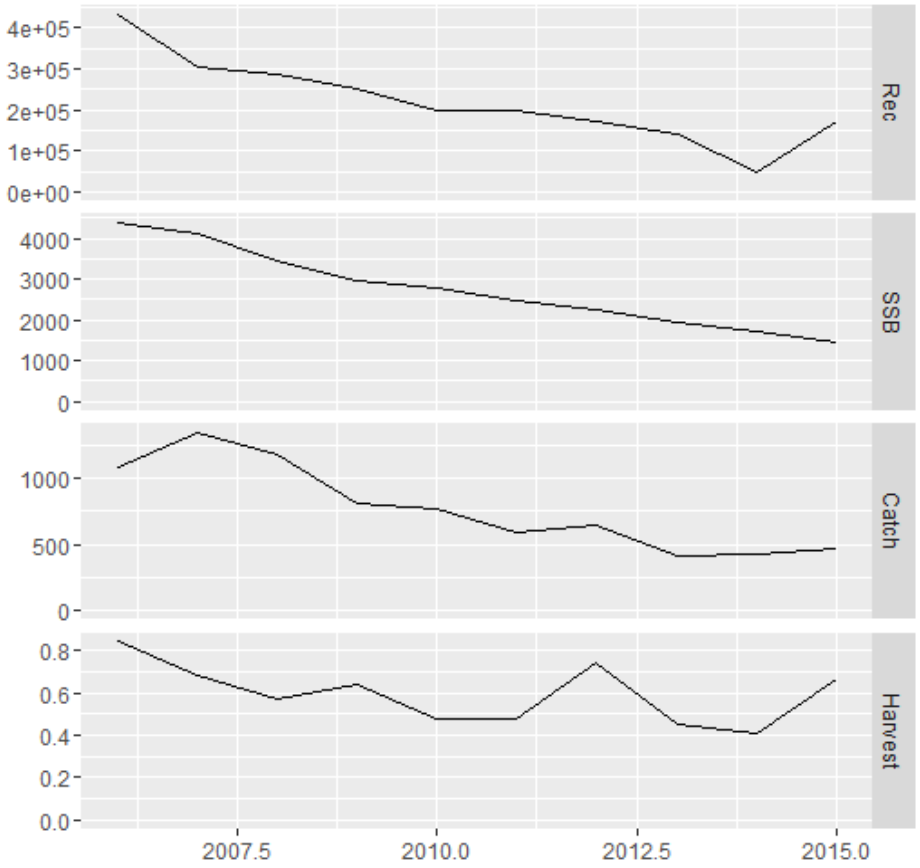


Figure 5.1.6.1- Retrospective analysis. Recruits must be multiply for 1000 to obtain data in millions.

5.1.7 Assessment quality

Based on Medits residuals and retrospective analysis the XSA results appear consistent.



6 Stock predictions

6.1 Short term forecast

A deterministic short term forecast for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the assessment performed during the GFCM WG. The input parameters were the same used for the XSA stock assessment. An average of the last three years has been used for weight at age, maturity at age and F at age. Recruitment (age 0) has been estimated from the population results as geometric mean of the last 3 years (143 millions).

Table 6.1.1 – GSA 15-16 MUT - Short term forecast in different F scenarios.

	Ffactor	Fbar	Catch_2015	Catch_2016	Catch_2017	Catch_2018	SSB_2017	SSB_2018	Change_SSB_2017-2018(%)	Change_Catch_2015-2017(%)
1	0	0	472	316.46	0	0	2522.23	3577.68	41.85	-100
2	0.1	0.05	472	316.46	57.33	107.97	2522.23	3520.08	39.56	-87.85
3	0.2	0.11	472	316.46	112.13	204.63	2522.23	3465.33	37.39	-76.24
4	0.3	0.16	472	316.46	164.55	291.31	2522.23	3413.26	35.33	-65.14
5	0.4	0.22	472	316.46	214.71	369.17	2522.23	3363.7	33.36	-54.51
6	0.5	0.27	472	316.46	262.76	439.25	2522.23	3316.52	31.49	-44.33
7	0.6	0.33	472	316.46	308.8	502.43	2522.23	3271.56	29.71	-34.58
8	0.7	0.38	472	316.46	352.95	559.51	2522.23	3228.7	28.01	-25.22
9	0.8	0.44	472	316.46	395.32	611.17	2522.23	3187.81	26.39	-16.25
10	0.9	0.49	472	316.46	436	658.03	2522.23	3148.78	24.84	-7.63
11	1	0.55	472	316.46	475.1	700.61	2522.23	3111.51	23.36	0.66
12	1.1	0.6	472	316.46	512.69	739.39	2522.23	3075.88	21.95	8.62
13	1.2	0.65	472	316.46	548.87	774.78	2522.23	3041.81	20.6	16.29
14	1.3	0.71	472	316.46	583.7	807.15	2522.23	3009.2	19.31	23.66
15	1.4	0.76	472	316.46	617.26	836.82	2522.23	2977.98	18.07	30.77
16	1.5	0.82	472	316.46	649.62	864.07	2522.23	2948.05	16.88	37.63
17	1.6	0.87	472	316.46	680.84	889.16	2522.23	2919.36	15.75	44.25
18	1.7	0.93	472	316.46	710.98	912.3	2522.23	2891.83	14.65	50.63
19	1.8	0.98	472	316.46	740.11	933.7	2522.23	2865.39	13.61	56.8
20	1.9	1.04	472	316.46	768.27	953.52	2522.23	2839.99	12.6	62.77
21	2	1.09	472	316.46	795.51	971.93	2522.23	2815.56	11.63	68.54
22	0.83	0.45	472	316.46	406.24	624.01	2522.23	3177.31	25.97	-13.93

7 Draft scientific advice

Based on	Indicator	Analytic al reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (time period)	Stock Status
Fishing mortality	Fishing mortality	$F_{0.1}$ = 0.45	F_{curr} =0.55	$F_C/F_{0.1}$=1.22	N	O_L
	Fishing effort				D	
	Catch					
Stock abundance	Biomass	12.2 25 4.22		33_{th} percentile 66_{th} percentile $B_{current}$	N	O_L
	SSB					
Recruitment		207 million			Rec 2015	
Final Diagnosis		The ratio $F_{curr}/F_{0.1}$ is equal to 1.22 ($F_{0.1}$ = 0.45), the stock is in low overexploitation with relative low biomass.				

8 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)*