Stock Assessment Form

Demersal species

MUT GSA25

Reference year: 2020

Reporting year: 2020

Based on the recognised need to overcome data gaps and survey timing in abundance index a transitional assessment was contacted moving from previous XSA setups to a Statistical Catch At Age model. Due to inherit qualities of State Space methodologies to work around the data issues SAM model was selected over other options. The assessment was carried out using data from official landings and biological data collected under the Cyprus National Data Collection Program. The time-series covers the period 2005-2019 for catch and MEDITS survey data for the years 2005-2020 as tuning index. In previous assessment iterations various configurations were implemented using XSA platform, to overcome the gap of survey data in year 2014 (survey was not performed). In order to prove the validity of SAM and be consistent and/or directly compared with previous practises two configuration of XSA were also implemented and compared with SAM. Additionally two length based methods (LBSPR, LBB) and an Empirical indicator were employed as auxiliary analysis and comparison. Yield per recruit analysis was performed using original SAM code for the estimation of the reference point $F_{0.1}$ as proxy of $F_{MSY.}$ The results of the validated SAM assessment suggest that the stock is in low overfishing status with current F_{bar} (0.35) being higher than $F_{0.1}$ (0.25).

Stock Assessment Form version 2.0 (February 2021)

Uploader: *Ioannis Thasitis*

Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Mullus barbatus	Red mullet	33
1st Geographical sub-area:	2nd Geographical sub-area:	3rd Geographical sub-area:
GSA25		
4th Geographical sub-area:	5th Geographical sub-area:	6th Geographical sub-area:
1st Country	2nd Country	3rd Country
Cyprus		
4th Country	5th Country	6th Country
Stock assessment method: (direct, indirect, combined, none)		
SAM (State Space Stock Assessment), XSA (2 configurations), Y/R analysis, Short term prediction, LBSPR, LBB, Empirical indicator		
Authors:		
Thasitis I., Charilaou C.		
Affiliation:		
Department of Fisheries and Marine Research (DFMR), Ministry of Agriculture, Rural Development and Environment, Cyprus		

2 Stock identification and biological information

2.1 Stock unit

The assessment covers a complete stock unit under the effective control of Cyprus Republic; it is assumed that the stock limits of the assessed *Mullus barbatus* are in agreement with the limits of GSA 25 (Figure 2.1-1).

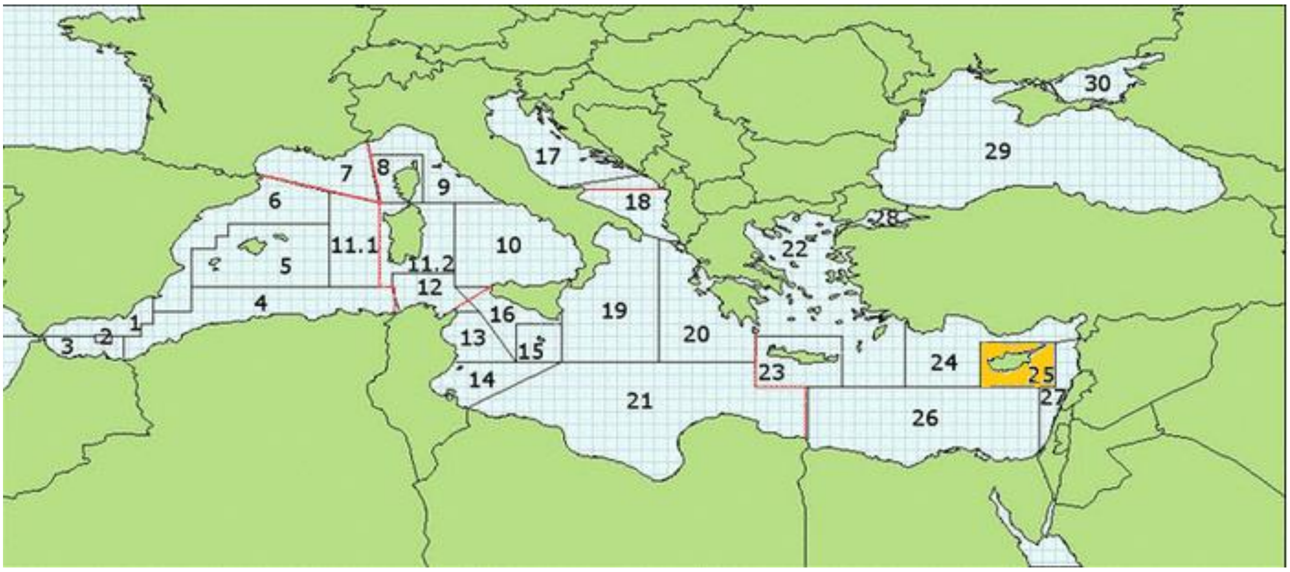


Figure 2.1-1: *Geographical location of GSA25.*

2.2 Growth and maturity

The following tables provide growth and maturity information on the stock, based on combined data from commercial catches and fisheries-independent survey. All information is based on data collected under the Cyprus National Data Collection Programme.

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

Somatic magnitude measured (LT, LC, etc)				**Units**	cm
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	April - July
Maximum size observed			26	**Recruitment season**	Summer – early autumn
Size at first maturity			10.9	**Spawning area**	Shelf
Recruitment size to the fishery				**Nursery area**	Shelf

Table 2.2-2: M vector and proportion of matures by age (Combined sex)

Age	Natural mortality	Proportion of matures
0	*0.85*	*0.2*
1	*0.39*	*0.9*
2	*0.29*	*1.00*
3	*0.25*	*1.00*
4+	*0.23*	*1.00*

As shown in Table 2.2-2, an M vector at age is used, calculated from Caddy (1991) equation using the PRODBIOM Excel spreadsheet (Abella et al., 1997)[1]. The growth parameters and the length weight relationship used for the estimation of M are those provided in Table 2.2-3. The proportion of matures at age were estimated using the estimated maturity ogive at length, converted to age by ALK and weighted by length distribution. Data used cover the period 2006-2015.

Different length weight relationships were applied along the years; the one provided in Table 2.2-3 refers to 2015.

Table 2.2-3: *Growth and length weight model parameters*

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**	cm			24.208	2011-2015
	K	Years -1			0.413	
	t_0	years			-0.314	
	Data source	Cyprus National Data Collection Programme under EU Data Collection Framework.				
Length weight relationship	**a**				0.006	2015
	b				3.197	2015
	M (scalar)					
	sex ratio (% females/total)					

[11] Abella, A., Caddy, J.F., Serena F. (1997). Do natural mortality and availability decline with age? An alterantive yield paradigm for juvenile fisheries, illustrated by the hake *Merluccius merluccius* fishery in the Mediterranean. IFREMER Aquatic Living Resources. 10: 257-269

3 Fisheries information

3.1 Description of the fleet

As indicated in Table 3.1-1, the stock is exploited by two Operational Units, the trawlers (18-24m) and polyvalent vessels operating with passive gears with length below 12m (for the majority of the vessels).

For the trawlers fishing in territorial waters a fixed number of 2 licenses is issued every year since 2012. Additionally, an extended 6 months closed season is employed from May to 7 of November since 1982. Since 2012 the trawlers operating in territorial waters are limited to two. Further information on the restrictions applied on this fleet is provided in Section 3.3.

The small-scale artisanal fleet operates mainly with bottom set nets and bottom longlines, targeting demersal species. Vessels under this fleet represent the large majority of the fishing vessels in the Cyprus Fleet Register (96%). Most vessels have length 6-<12m and are allowed to operate every day all year round, with a number of restriction measures on the use of fishing gears and minimum landing sizes, according to the national and community law (see Section 3.3). Since 2016 332 licenses are allowed.

Polyvalent vessels over 12m are mainly involved in the large pelagic fishery, but may also target demersal shelf species using nets and bottom longlines.

As shown in Table 3.1-2, red mullet in GSA25 is exploited with a number of other demersal species for all operational units.

Table 3.1-1: *Description of operational units exploiting the stock*

	Country	GSA	Fleet Segment	Fishing Gear Class	Group of Target Species	Species
Operational Unit 1	CYP	GSA25	F – Trawlers (>24 metres)	03 - Trawls	33 – Demersal shelf species	*Mullus barbatus* (MUT)
Operational Unit 2	CYP	GSA25	C-Polyvalent small-scale vessels with engine (6-12 metres)	07 – Gillnets and Entangling Nets	33 – Demersal shelf species	*Mullus barbatus* (MUT)
Operational Unit 3	CYP	GSA25	B – Polyvalent small-scale vessels with engine (<6 metres)	07 – Gillnets and Entangling Nets	33 – Demersal shelf species	*Mullus barbatus* (MUT)
Operational Unit 4	CYP	GSA25	M – Polyvalent vessels (>12 metres)	07 – Gillnets and Entangling Nets	33 – Demersal shelf species	*Mullus barbatus* (MUT)

Table 3.1-2: Catch, bycatch, discards and effort by operational unit in 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)
Trawlers	2	14.4 T	*Boops boops* (12t), *Spicara smaris* (49t), *Pagellus erythrinus* (5t), P. acarne (9 t) *Mullus surmuletus* (3t), Serranus cabrilla (4T), *Merluccius merluccius* (0.7t), *Octopus vulgaris* (1T)	0.015 t, (included in Catch)	*Boops boops, Pagellus erythrinus, P. acarne, Spicara smaris, Serranus cabrilla, Merluccius merluccius*	375 (days)
Polyvalent small-scale vessels (6-12 metres)		7.3 T	*Boobs boops* (88T), *Mullus surmuletus* (27 T), *Pagellus erythrinus (5.8T), Sparisoma cretense (22 T), Pagellus acarne* (15.4T), *Siganus rivulatus (13.2T), Spicara maena (49 T), Serranus cabrilla* (67.6 T), *Diplodus sargus* (10.8T), *Spicara smaris (40.3 T), Octopus vulgaris (20 T), Sepia officinalis (13.4T), Loligo vulgaris (3.5T)*	No discards	*Lagocephalus* spp.	20341 (days)
Polyvalent small-scale vessels (0-6m)		0.2 T	*Boobs boops* (5.5T), *Mullus surmuletus* (1 T), *Pagellus erythrinus (0.06 T), Siganus rivulatus (1.2T), Sparisoma*	No discards	*Lagocephalus* spp.	1240 (days)

			cretense (2.5 T), Diplodus sargus (0.8 T), *Spicara smaris (2.6 T), Spicara maena (3 T), Pagellus acarne* (0.01T), *Serranus cabrilla* (3.1 T), *Octopus vulgaris (2T), Sepia officinalis (3.4T), Loligo vulgaris (0.2T)*			
Polyvalent vessels (>12 metres)	26	0.3 T	*Boobs boops* (8.1T), *Mullus surmuletus* (0.66 T), *Spicara smaris (0.6 T)*	No discards	*Lagocephalus* spp.	515
Total		22.2				

3.2 Historical trends

Table 3.2.1 provides the catches of *M. barbatus* from both fisheries for the reference period of the current stock assessment study, 2005-2019. The catches are estimated as sum of products of numbers at age multiplied with weight at age. Discards data from the bottom trawlers are included in the catches.

Table 3.2-1*:* Red mullet GSA 25. Total annual catches (t) in 2005-2019.

Total landing (tonnes)	Cyprus		
	Net fishery	OTB fishery	Total
initial year			
2005	25.3	18.2	43.5
2006	18.2	15.5	33.7
2007	24.3	23	47.3
2008	12.6	20.2	32.8
2009	10.3	14.5	24.8
2010	9.9	16.3	26.2
2011	9.55	7.56	17.1
2012	8.5	6.7	15.2
2013	12	11.7	23.7
2014	8.3	11.6	19.9

2015	7.8	14.4	22.2
2016	6.5	13.6	20.1
2017	3	9.6	12.6
2018	3	8.9	11.9

The trends in cumulative landings for the period 1975-2019 are presented in Figure 3.2-1 shows coupled with managerial and/or other relevant info. As shown in Figure 3.2-1, the historical highest catches picked a little bit over 160 tons in the years 1988 and 1989 and ever since a declining trend occurs reaching the historically lowest catches in 2012. From 2005 onwards a series of managerial regulations took place that shaped considerably effort, gear and spatial characteristics of the fleets.

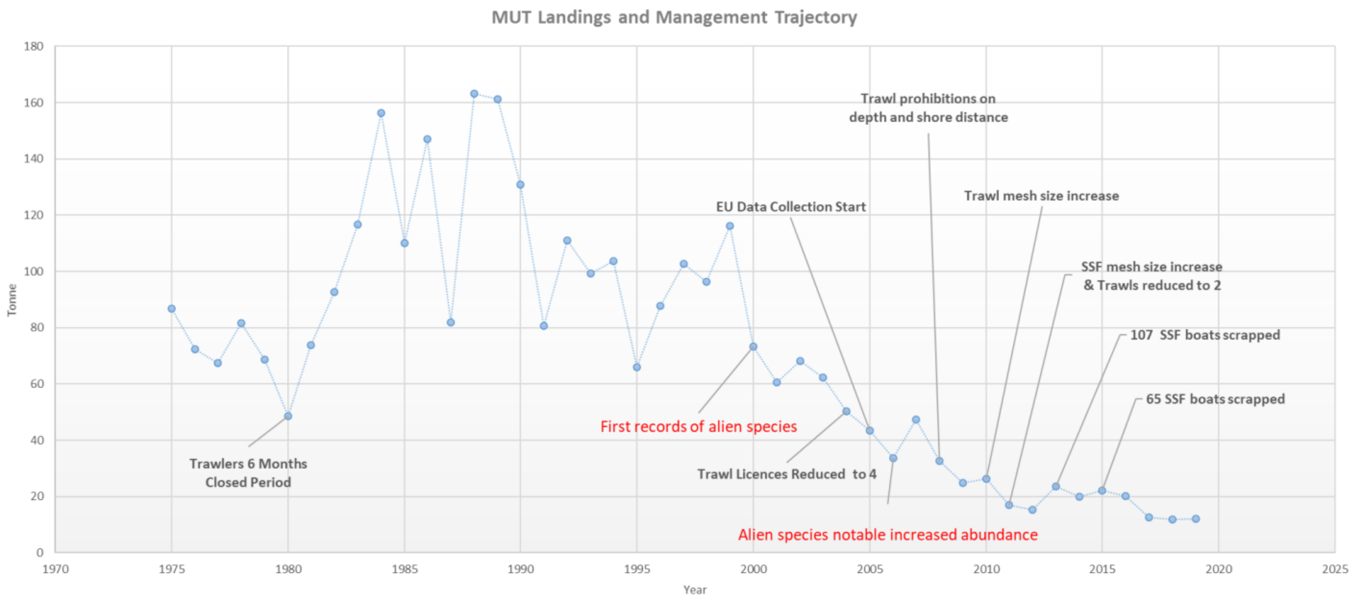
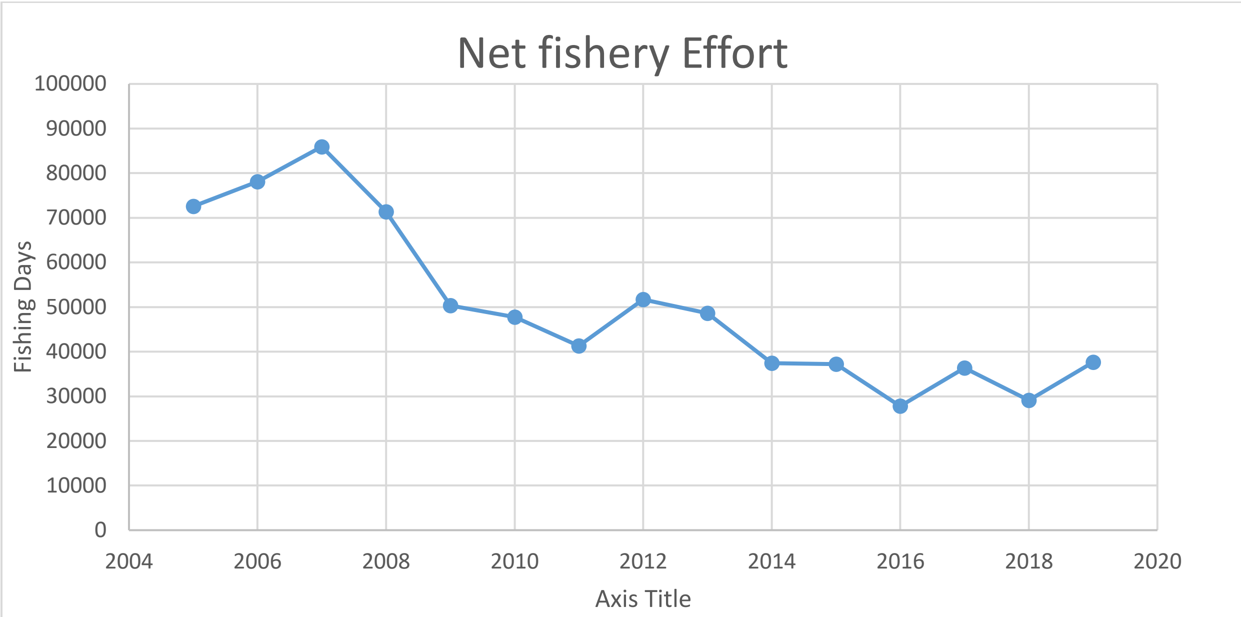


Figure 3.2-1: Landings of red mullet and managerial trajectories in GSA25 for the period 1975-2019.

Figure 3.2-2 shows the timeline of effort for the assessment period for each fleet. Net fishery, shows as steady declining trend 2006 onwards up until 2016 that there is a slightly increasing trend. Bottom trawl fishery effort shows a continues reduction from 2005 up until 2017 were it appears to retain a gradual increase close to 2012-2016 values.



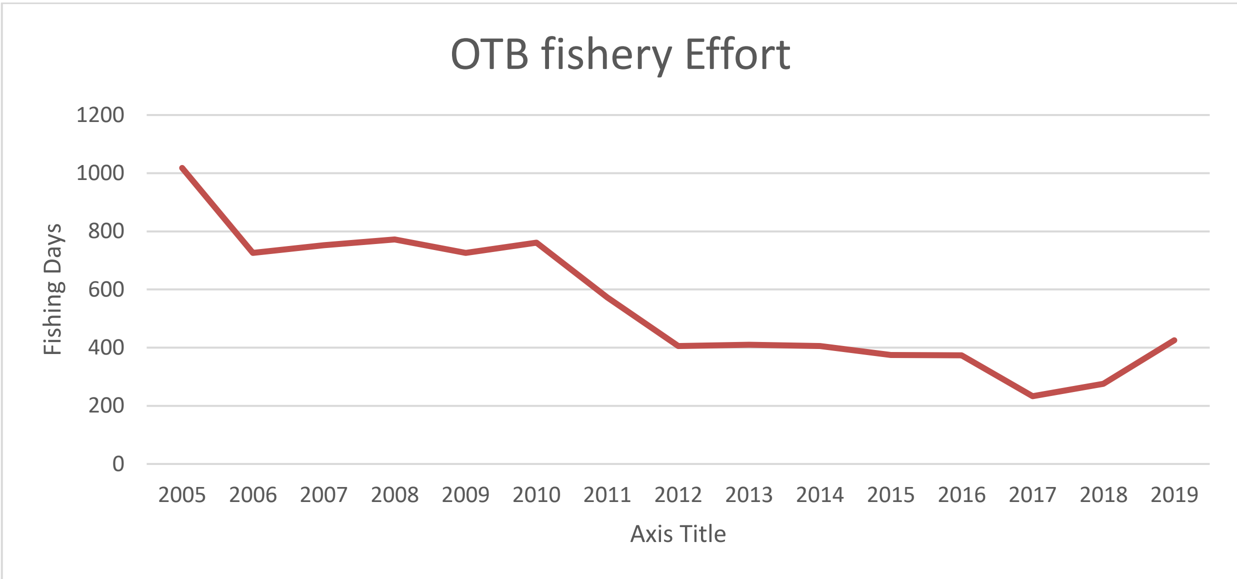


Figure 3.2-2: Landings per Unit Effort (LPUE) in terms of fishing days for red mullet in GSA25 (1985-2019).

Information on the length distribution of the catches from the two fisheries is provided in Figures 3.2-3 as derived from LBSPR model.

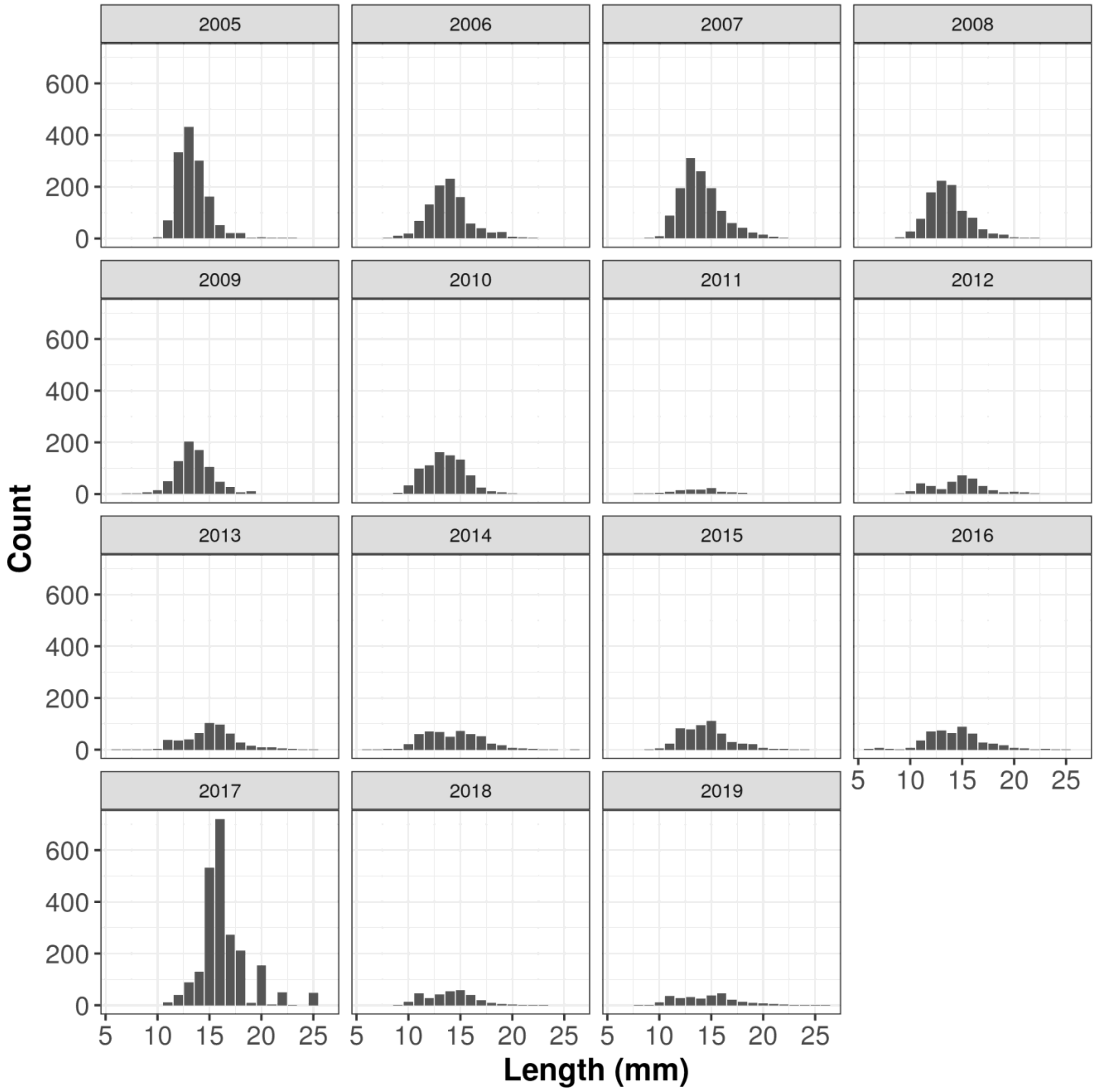


Figure 3.2-3: Length distribution of MUT catches from the net fishery in GSA25 (2005-2019)

Catches of the species from the trawl fishery are mainly represented by age 1 and also by age 2 as shown in Figure 3.2-4. A considerable number of Age 0 is also present in the catch. Net fishery catches include few Age 0 individuals with the highest proportion denoted to Age 1 and 2 although in the recent years there is reappearance of larger individuals.

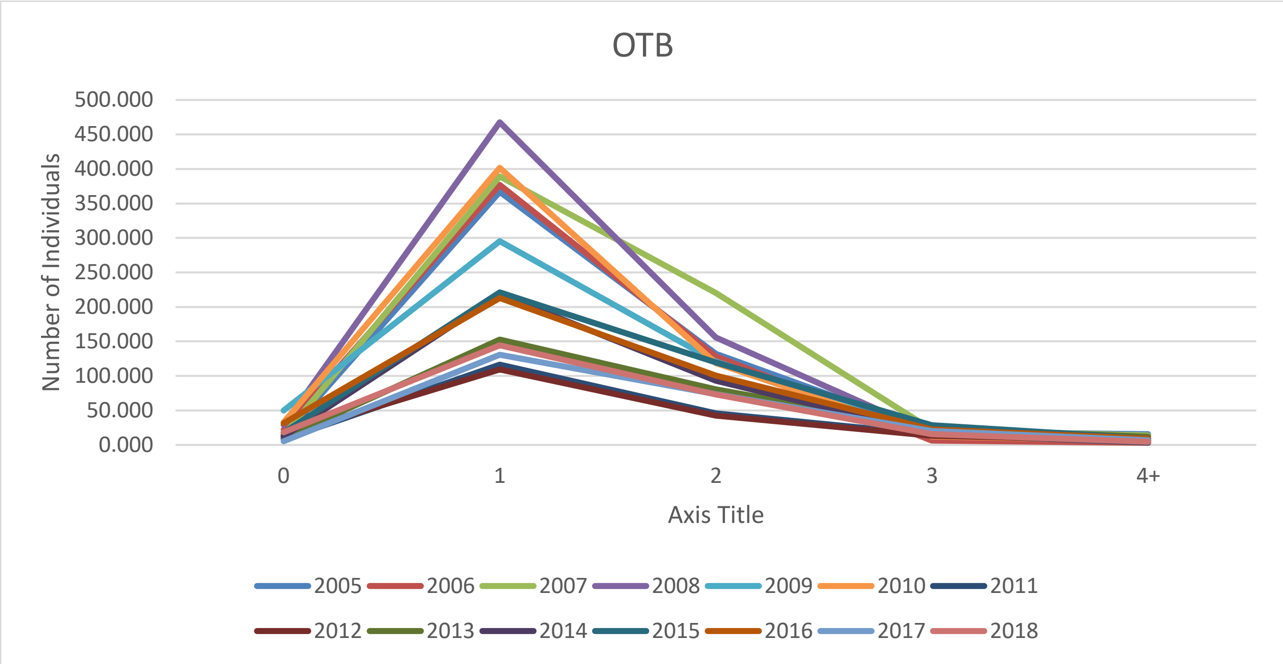


Figure 3.2-4: *Age composition of MUT catches from the net fishery in GSA 25 (2005-2018).*

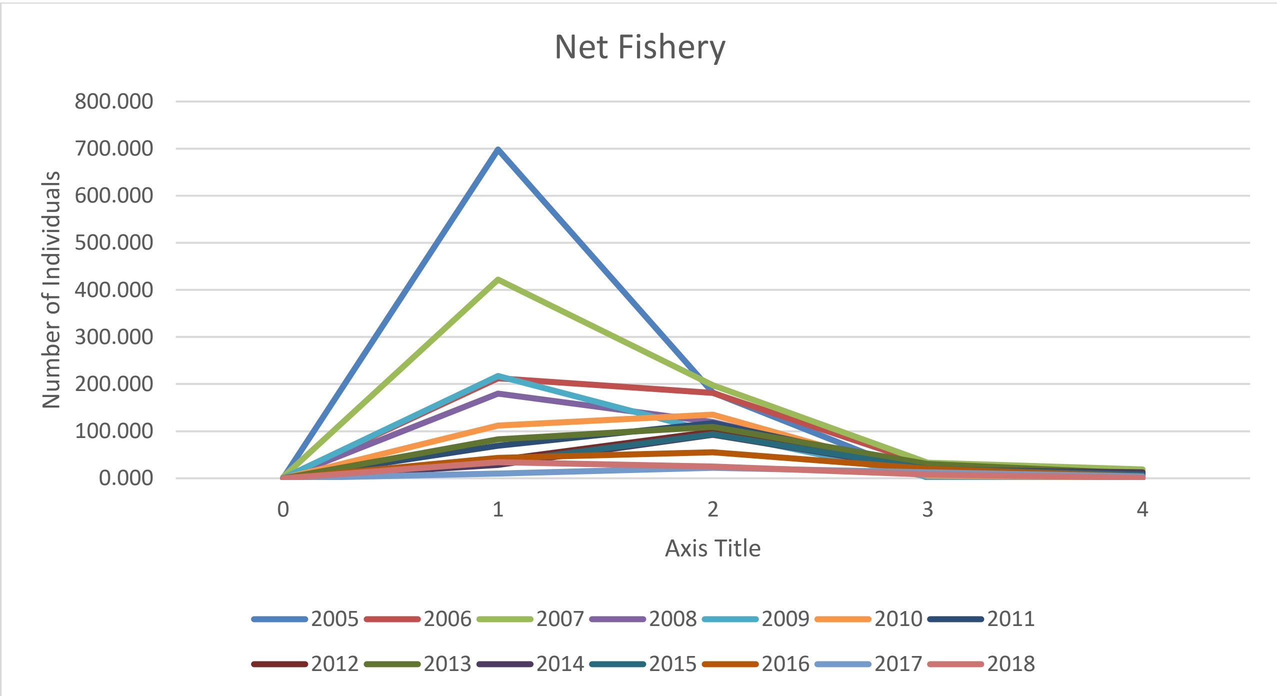


Figure 3.2-5: *Age composition of MUT catches from the trawl fishery in GSA 25 (2005-2018).*

3.3 Management regulations

Current and past management regulations:

1. Polyvalent small-scale vessels (0-6m, 6-12m)

- Restriction of the maximum number of licenses.

Historically small scale inshore vessel licenses (Category A&B) were restricted to 500 by legislation; however, the maximum number was further reduced in accordance with the number of vessels that were permanently removed from the fleet through adjustment schemes.

During 2013, 107 vessels were scrapped with public aid, in accordance with an effort adjustment plan based on Article 21 (a) of Regulation (EC) 1198/2006 on the *European Fisheries Fund* –EFF. In 2014 the maximum number of licenses was reduced accordingly to 393 licenses. During 2015 additional 66 vessels were scrapped with public aid, under the Operational Programme 2014-2020 of the European Marine and Fisheries Fund. From 2016 the maximum number of licenses has been reduced accordingly to 327 licenses.

- Restrictions on the use of fishing gears depending on the fishing license category.

  Until March 2011 minimum mesh size of nets was set at 32mm (open mesh size). From March 2011 minimum mesh size of nets is set at 38mm (open mesh size).

  Maximum length of nets: For boats with license A is 5000m, for boats with license B is 3000m.

  Maximum height of nets: 4m.

  Restrictions on the time and duration of fishing, depending on mesh sizes.

  Additional restrictions on the use of monofilament nets (mesh sizes, length of nets).

2. Bottom Trawlers in territorial waters

- Restriction of the maximum number of licenses. Before 2006 the maximum number of licenses was restricted to 8, while from 2006 until 2011 the maximum number was reduced to 4. From November 2011 maximum number of licenses is restricted to 2.
- Minimum mesh size: From June 2010 the 40mm diamond shape trawl net has been replaced by a diamond meshed net of 50mm at the cod-end. From November 2011 minimum mesh size of 50mm diamond implemented in any part of the net.
- Depth and distance from the cost restrictions: Prohibition of bottom trawling at depths less than 50m and at distances less than 0.7 nautical miles off the coast.
- Seasonal and Area restrictions:
  - Closed trawling period in territorial waters from 1st of June until the 7th of November (in force since the mid '80s).
  - Prohibition of bottom trawling in the Zygi coastal area, at a distance of 3 nautical miles from the coast.
  - Restriction of 2 areas from fishing with trawl nets, on a rotational basis (northwest part of Cyprus from 8 November – 15 February, southeastern part from 16 February – 31 May every year). Applied from November 2011.

3.4 Reference points

Table 3.4-1: *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					
Y					
CPUE					
Index of Biomass at sea					

4 Fisheries independent information

4.1 International Trawl Survey in the Mediterranean (MEDITS)

4.1.1 Brief description of the direct method used

The Medits survey is performed annually since 2005 between June – July, as part of the National Data Collection Programme under the EU Data Collection Framework (Regulations (EC) 199/2008, 665/2008 and Decision 2010/93/EU). In general the survey involves the collection of total weight and total number of individuals per species, as well as individual length and biological parameters (sex, maturity, individual weight and age), in accordance with the MEDITS reference list of target species groups. For *M. barbatus,* all the above parameters are collected.

The specificities of the MEDITS survey (sampling gear characteristics, design of survey, sampling methodology and processing of samples are described in the MEDITS manual (MEDITS-Handbook. Version n. 9, 2017, MEDITS Working Group: 177 pp.)

It is noted that the MEDITS survey was not carried out in 2014, while in 2005, 2015 and 2018 the survey was carried out in end of July to beginning of August.

The abundance indices used in the applied models derived from the Cyprus MEDITS trawl survey data, for the period 2005-2020.

Direct methods: trawl based abundance indices

Table 4.1-1: Trawl survey basic information

<table>
<tr><td>Survey</td><td colspan="2">MEDITS</td><td>Trawler/RV</td><td>Trawler</td></tr>
<tr><td colspan="2">Sampling season</td><td colspan="3">June - July</td></tr>
<tr><td colspan="2">Sampling design</td><td colspan="3">Depth stratified sampling with random drawing of the hauls (that remain stable through the years). The number of hauls in each stratum is proportional to stratum surface (taking into account trawlability). Details are provided in the MEDITS manual.</td></tr>
<tr><td colspan="2">Sampler (gear used)</td><td colspan="3">IFREMER reference GOC73</td></tr>
<tr><td colspan="2">Cod –end mesh size as opening in mm</td><td colspan="3">20mm.</td></tr>
<tr><td colspan="2">Investigated depth range (m)</td><td colspan="3">10-800m.</td></tr>
</table>

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

Stratum	Total surface (km^2)	Trawlable surface (km^2)	Swept area (km^2)	Number of hauls
10-50m	796			5
50-100m	717			9
100-200m	918			5
200-500m	2245			3
500-800m	6430			4
Total (10 – 800 m)	11106			26

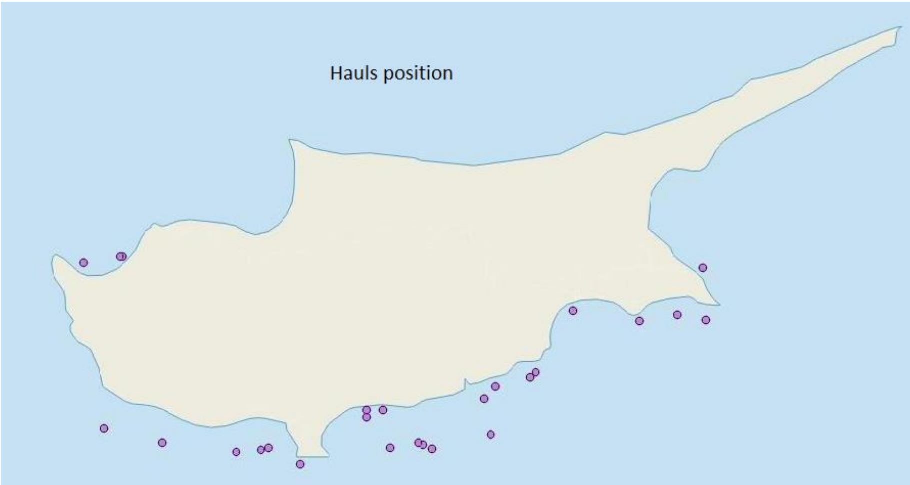


Figure 4.1-1: Cyprus (GSA 25) Medits survey - Distribution of sampling hauls.

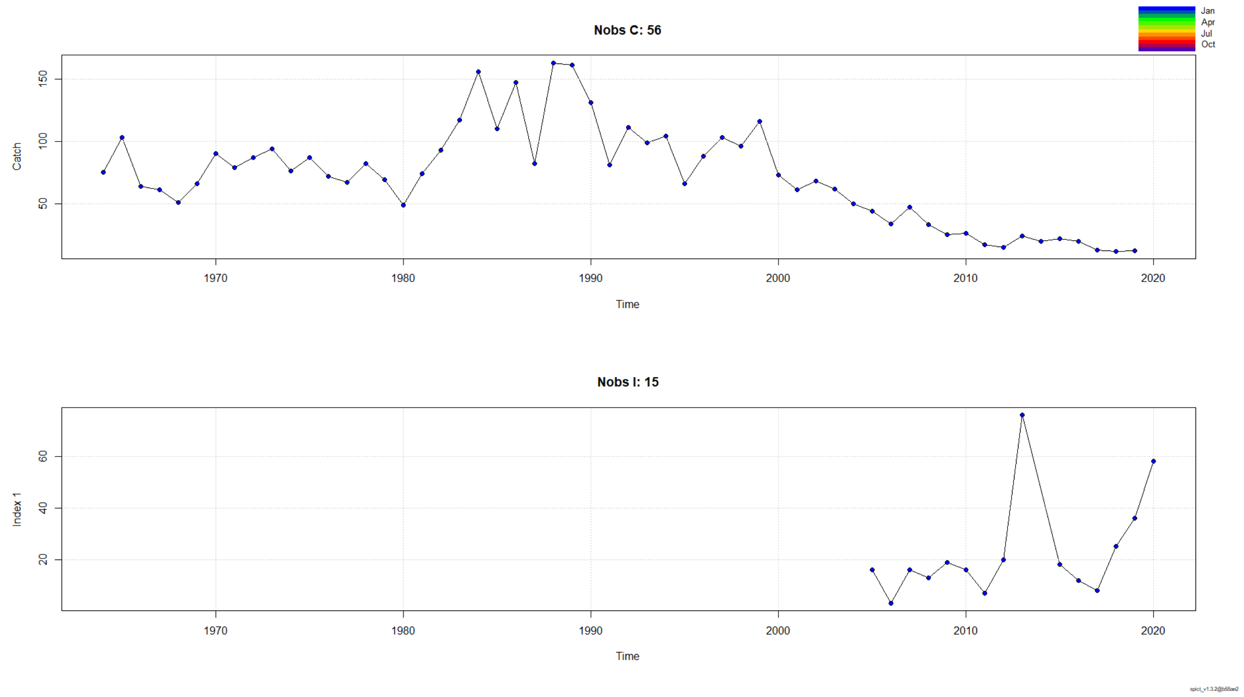


Figure 4.1-3: Trawl survey abundance and landings

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

The age structure of the red mullet population at sea, as recorded during the MEDITS survey, is provided in Table 4.1.-4. It is specified that numbers are provided per km^2. The age structure was estimated based on direct otolith readings and derived Age Length Key.

Table 4.1-4: Trawl survey results by age class (N/km2).

Age Class	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
0	761	5	41	8	291	865	34	9	64	NA	451	138	83	553	33	807
1	283	97	637	321	380	386	161	572	1531	NA	213	180	136	152	431	1786
2	113	15	168	68	124	94	52	109	654	NA	146	117	52	221	261	255
3	14	2	28	10	16	13	3	18	101	NA	28	10	11	43	50	46
4+	18	2	68	5	8	13	3	11	31	NA	13	9	13	35	88	42

Direct methods: trawl-based Recruitment analysis

No recruitment analysis was done.

Direct methods: trawl-based Spawner analysis

No spawner analysis was done.

4.1.2 Spatial distribution of the resources

The spatial distribution of *Mullus barbatus* in GSA25 was investigated and random examples of years are given as recorded during MEDITS survey in 2013 and in 2015 (Figure **4.1.2-1** and **4.1.2-2** respectively).

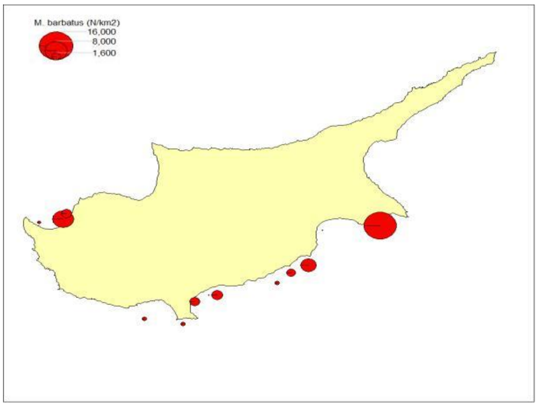


Figure 4.1.2-1. *Mullus barbatus* in GSA25 - Abundance distribution *(MEDITS 2013).*

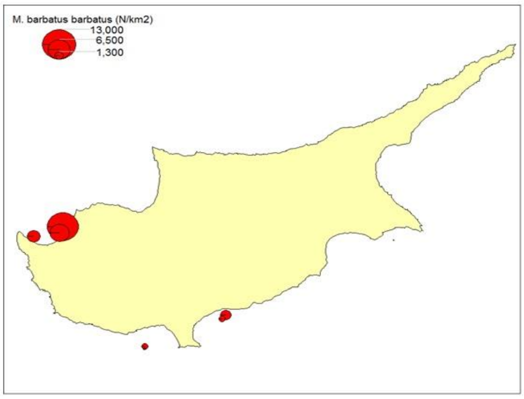


Figure 4.1.2-2. *Mullus barbatus* in GSA25 - Abundance distribution *(MEDITS 2015).*

4.1.3 Historical trends

MEDITS abundance and biomass indices (as seen in Figure 4.1-2) shows fluctuations up until a sharp increase to the historically highest values of in 2013. Steady decline followed the extremes of 2013 (although 2014 is missing) up until 2017. From 2017 onwards a rather rapid increase takes place through the remaining of timeseries.

5 Ecological information

5.1 Protected species potentially affected by the fisheries

The protected species that are potentially affected by the fisheries are the two turtle species (*Chelonia mydas*, *Caretta caretta)* encountered in Cyprus waters, and cetaceans (*Tursiops truncatus).* The interaction of the net fisheries with cetaceans involves mostly the damage of fishing gear and caught fish eaten by the dolphins.

In general, the catch of protected species (shark species, turtles, monk seal, cetaceans) is prohibited in accordance with international obligations (including relevant GFCM recommendations), and data on incidental catches are collected.

5.2 Environmental indexes

No environmental indices are used in the assessment.

6 Stock Assessment

Throughout the years a series of developments and upgrades in the implemented assessment methodologies were used following a parallel course with data collection development and timeseries build up. A summary of the assessment years and methodology evolution is given in Figure 6-1.

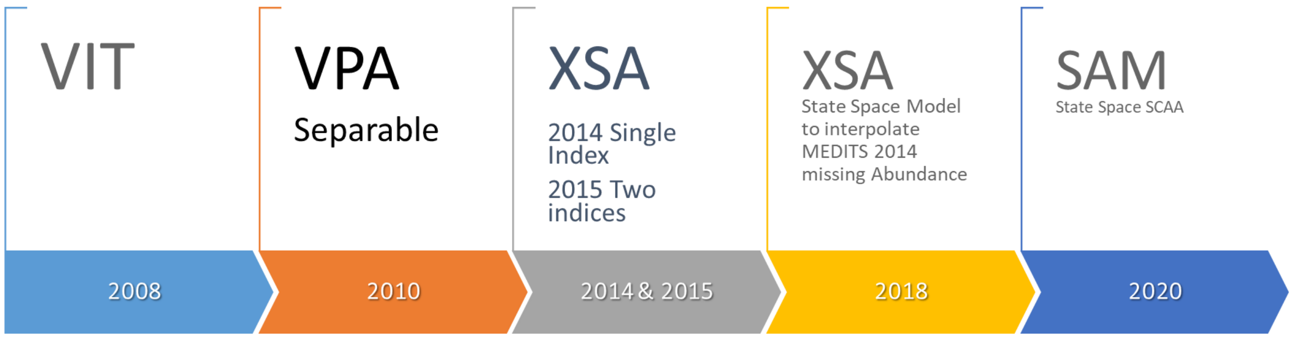


Figure 6-1: Assessment Methods Evolution for the subsequent assessment years.

In order to respect all past approaches and open room for a direct comparison between the previous XSA results, two XSA (VPA) models were built together with SAM (SCAA). The first XSA1 assessment was built as pure update of the 2018 validated XSA model with the addition of 2019 catch and abundance data. The second XSA2 model differed in the use of the newest (2020) and improved MEDITS survey numbers at age allocation which derived from better reprocessing and calculation of MEDITS data. The same numbers at age configuration that was implemented for XSA2 was used for SAM model. Another difference of SAM model was the utilization of the 2020 MEDITS survey abundance index as this analysis can work with data gaps contrary to XSA assessments.

Final outputs of the models (Table 6-1) did not differ dramatically however the various values trajectories had some deviations here and there.

Table 6-1: Assessment methods summary results

	$XSA1_{2019}$	$XSA2_{2019}$	SAM_{2020}
$F_{0.1}$	0.26	0.25	0.25
$F_{current}$	0.34	0.31	0.35
$F_{current}/F_{0.1}$	1.3	1.24	1.4

FLR libraries were employed in order to carry out the Extended Survivor Analysis (XSA) assessments (Darby and Flatman, 1994) and original SAM coding in R.

Length Based Spawning Potential Ratio (LBSPR) and a Length Based Bayesian Biomass Estimator (LBB) were implemented as auxiliary analysis in an external attempt to verify the derived stock status results. Additionally, a trend analysis of the 95th percentile of larger Individuals from MEDITS survey was performed.

6.1 Extended Survivor Analysis (XSA)

6.1.1 Model assumptions

Although different options were tested concerning catchability and shrinkage of the weighted estimates (Shrinkage weight - fse, Shrinkage ages "shk.ages", combinations on qage and rage) results presented to the group followed the same configuration as the one used in the 2018 validated assessment thus the final model settings that were implemented for the assessment are the following:

F_{bar}	fse	rage	qage	shk.yrs	shk.age
1-2	2	1	2	2	2

6.1.2 Scripts

The script has been uploaded on the GFCM sharepoint.

6.1.3 Input data and Parameters

The assessment by means of XSA was performed using the following input data and parameters for the period 2005-2019:

- Catch-at-age matrix
- Mean weight-at-age in the catch
- Mean weight-at-age in the stock
- Natural mortality at age
- Maturity ogive at age

The relevant files used for the assessment are available on the GFCM sharepoint.

6.1.4 Tuning data

The tuning data used in the assessment derived from the MEDITS survey and refer to the period 2005-2019.

6.1.5 Results

The results of the XSA assessments are shown in Figure 6.1.5-1.

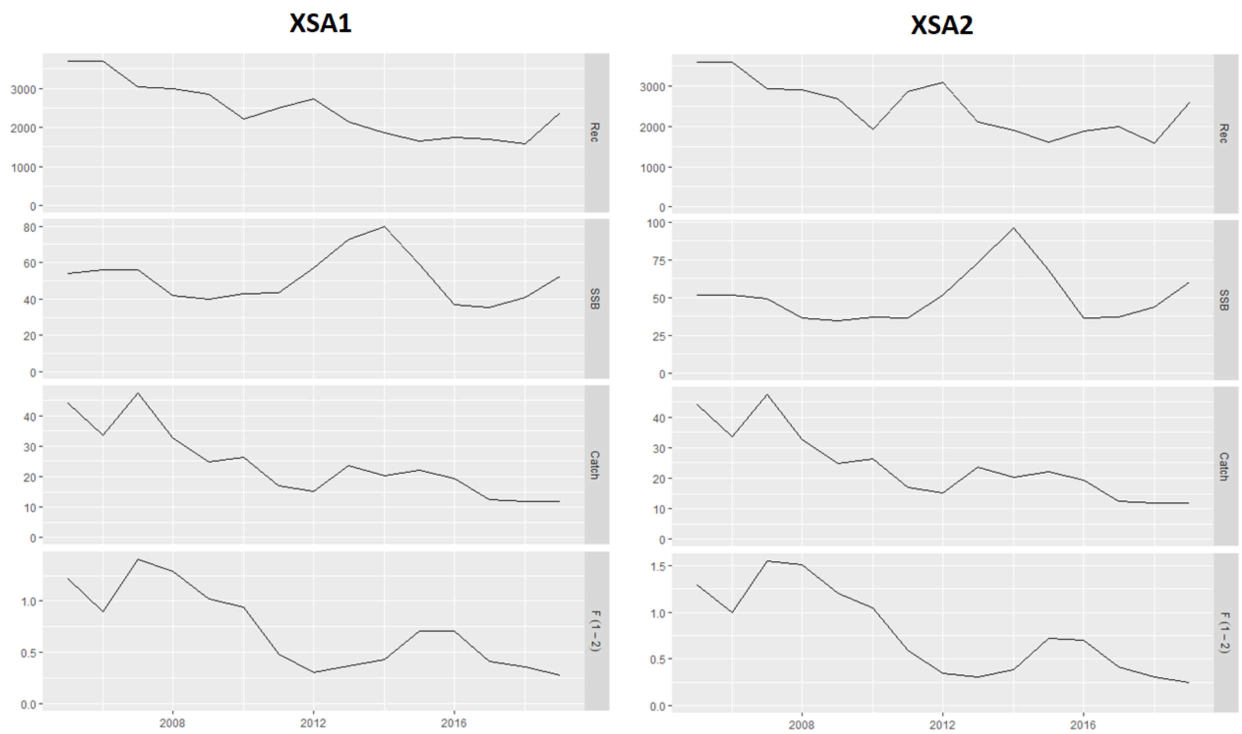


Figure 6.1.5-1: *Mullus barbatus* in GSA 25 - Results on recruitment, SSB, catch and fishing mortality for the two XSA models.

6.1.6 Robustness analysis

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

Sensitivity analysis was performed, testing different options concerning catchability and shrinkage. Residual patterns were also tested for verification of selected configuration.

Retrospective analysis of the final model generally showed a good agreement in the trend of recruitment (Rec), spawning stock biomass (SSB) and fishing mortality (Harvest), indicating that the assessments were consistent (Figures 6.1.7-1 for XSA1 and 6.1.7-2 for XSA2).

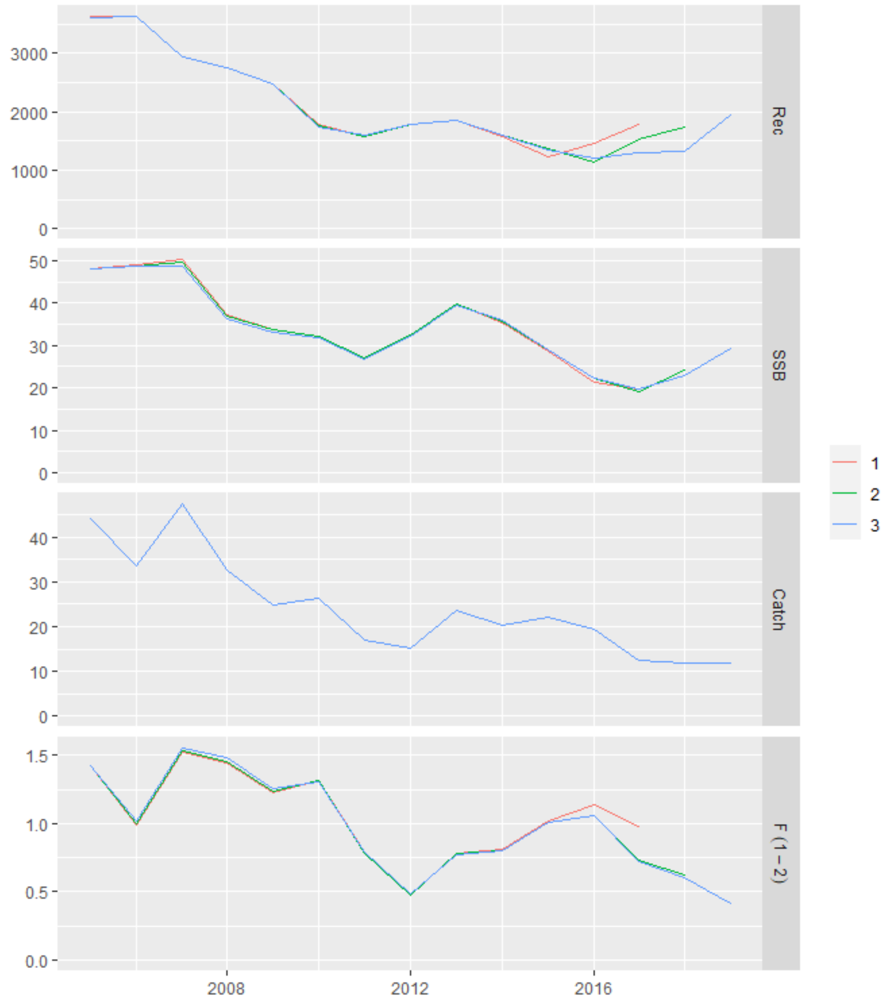


Figure 6.1.7-1: *Mullus barbatus* in GSA25- XSA1 retrospective analysis of the final selected scenario.

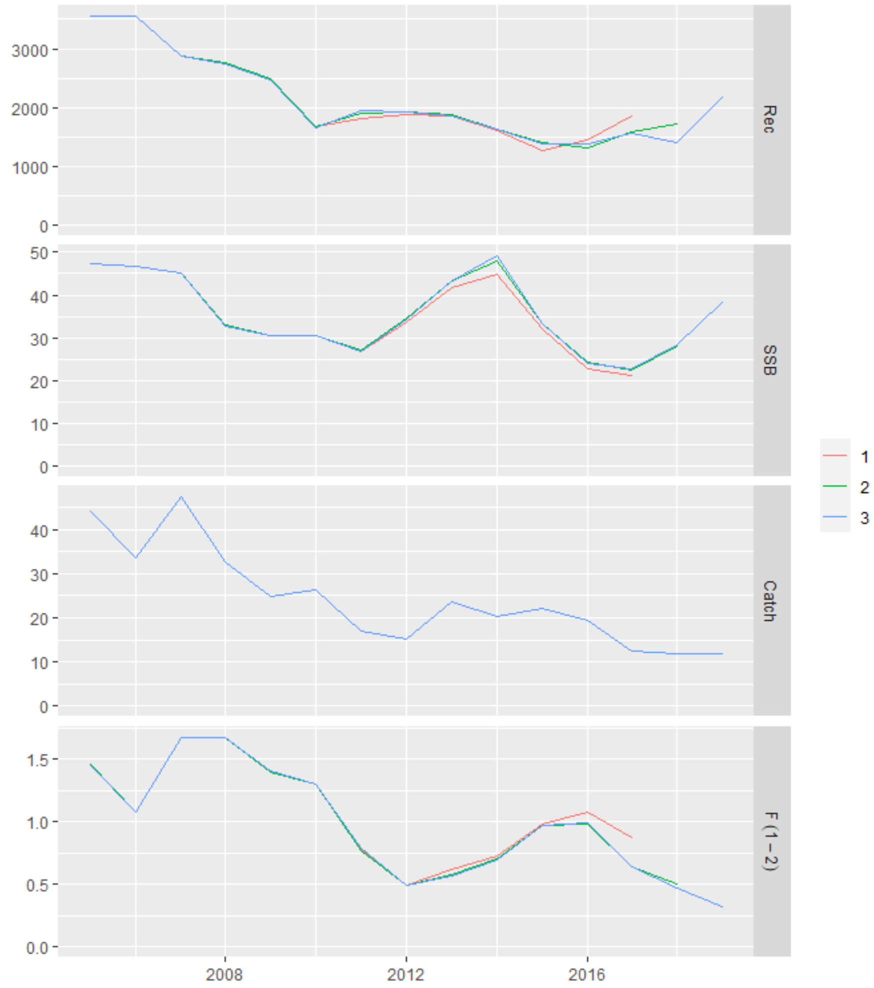


Figure 6.1.7-1: *Mullus barbatus* in GSA25- XSA2 retrospective analysis of the final selected scenario.

Concerning natural mortality (M), alternative methods to the ProdBiom method were used for estimating M vectors by age, specifically Gislason et al. (2010) and Chen & Watanabe (1989). The different estimations of the M vector are provided in Figure 6.1.7-3. M values resulting from Gislason method were rejected as unrealistic due to the very high value in 0 ages, and were not used in the model. Additional runs of the assessment models were made using the M vector resulting from Chen & Watanabe (1989) which provided similar trends on recruitment (R), spawning stock biomass (SSB) and fishing mortality (Fbar), though the values of R obtained with the Chen Watanabe M vectors were higher.

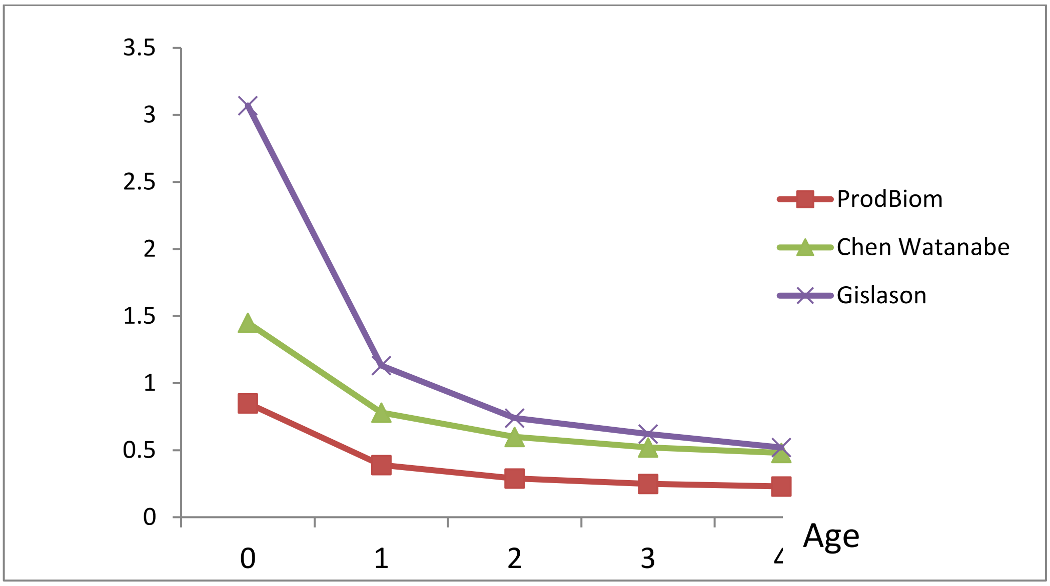


Figure 6.1.7-3: *Mullus barbatus* in GSA25 - Natural mortality vectors from ProdBiom, Gislason *et al.* (2010) and Chen & Watanabe (1989).

6.1.8 Assessment quality

Input data derive from the official landings and effort data collected by the Department of Fisheries and Marine Research, and from the biological data collected under the Cyprus National Data Collection Programme. It is considered that the best available data have been used.

The assumptions of the final model seem reliable.

6.1.9 Yield per Recruit Analysis

Yield per recruit analysis was carried out for the two XSA versions, using FLR Libraries. Current fishing mortality was considered as the mean F for ages 1-2 during the last 3 years (2013-2015).

The tuning data used in the assessment derived from the MEDITS survey and refer to the period 2005-2019. The script has been uploaded on the GFCM sharepoint.

6.2 SAM (State-Space Assessment Model), VALIDATED

6.2.1 Model assumptions

SAM model was selected as a means to work around the problem of data gap of 2014 in the provided abundance index derived from MEDITS survey. Additionally due to the fact that 2020 catch data were not officially available by the time that this work was carried out a data gap was inevitable for this year while 2020 abundance data were available.

SAM contains two parts were the first one (1) describes the process of unobserved states which in essence are log transformed stock sizes and mortalities and the second part (2) which describes the observations given the underlying states of log transformed catches and survey indices.

(1) $\alpha_y = T(\alpha_{y-1}) + \eta_y$ (2) $x_y = O(\alpha_y) + \varepsilon_y$

6.2.2 Scripts

The scripts chunk per analysis stage has been uploaded on the GFCM sharepoint.

6.2.3 Input data and Parameters

Input data for SAM model follow the same CEFAS format as the XSA analysis (data need summary is given in Table 6.2.3-1) with some room for slight modifications as concern formulation of surveys file, gaps in data and few additional files manipulation capabilities.

A simple (similar to XSA file) configuration was used in this work without many parameter estimation.

Table 6.2.3-1: Summary of SAM analysis data needs and sequence of importation.

Step No.	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11	Step 12
Contents	Total catches	Catch mean weights	Landing mean weights	Discard mean weights	Landing fraction	Surveys	Natural mortality	Maturity ogive	Stock mean weights	F before spawning	M before spawning	Extra files
Filename	cn.dat	cw.dat	lw.dat	dw.dat	lf.dat	survey.dat	nm.dat	mo.dat	sw.dat	pf.dat	pm.dat	

The relevant files used for the assessment are available on the GFCM sharepoint.

6.2.4 Tuning data

The tuning data used in the assessment derived from the MEDITS survey abundance and refer to the period 2005-2020.

6.2.5 Results

Catch predictions from the final validated run including point wise 95% confidence intervals are shown by line and shaded area in Figure 6.2.5-1. Confidence intervals appear higher in periods where noise in the data was higher as well as the terminal year of the assessment that catch observation was not provided. The yearly observed total catch weight (crosses) are calculated as Cy=sum(WayCay).An interesting aspect for the next assessment will be the implementation of COVID19 pandemic implications on effort and catches for 2020.

Spawning stock biomass (SSB) appeared in (Figure 6.2.5-2) follow a downward trend from the beginning of the assessment period up until 2009. A stabilization period with slight fluctuations of the biomass seems to occur in the years 2009 to 2016. Conditions seem to support an increasing biomass trend 2016 onwards up until 2020. Due to the lack of 2020 catch input confidence interval boundaries widen significantly.

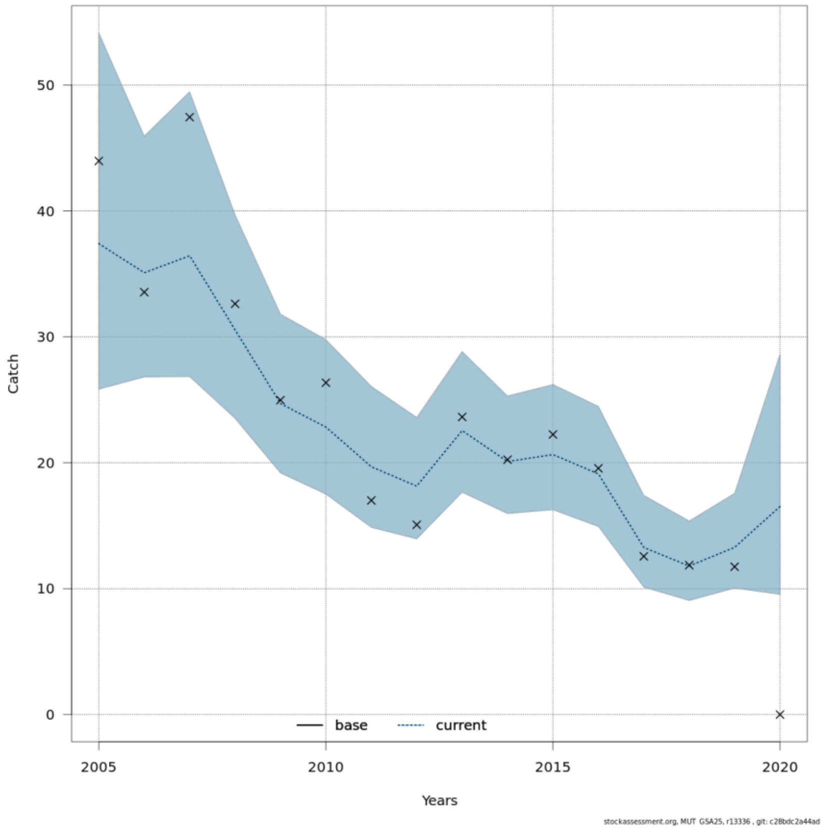


Figure 6.2.5-1: Total catch in weight predictions. The yearly observed total catch weight represented as crosses.

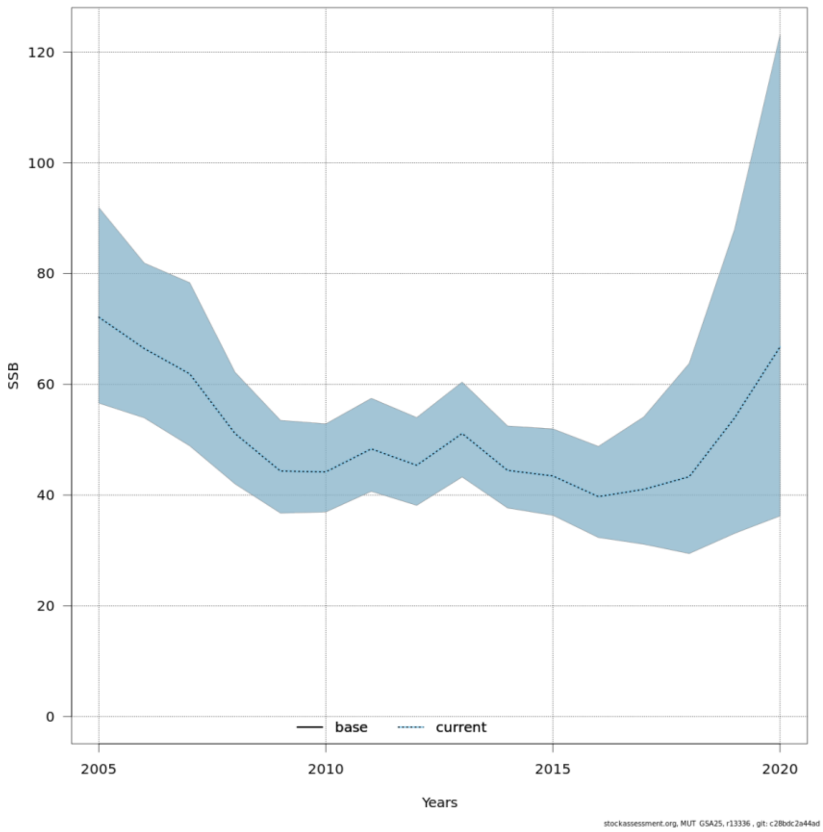


Figure 6.2.5-2: Spawning stock biomass. Estimates from the final run and point wise 95% confidence intervals are shown by line and shaded area.

Fishing mortality (F) was calculated as F_{bar} of ages 1 and 2 (Figure 6.2.5-3). Apart from a small increasing trend in the beginning of the assessment period, exploitation follows a declining trend with a slight increase in the years 2013 to 2015. The remaining period is characterized by a constant reduction in exploitation and what appears to be a stabilized condition in the last two years 2019 to 2020.

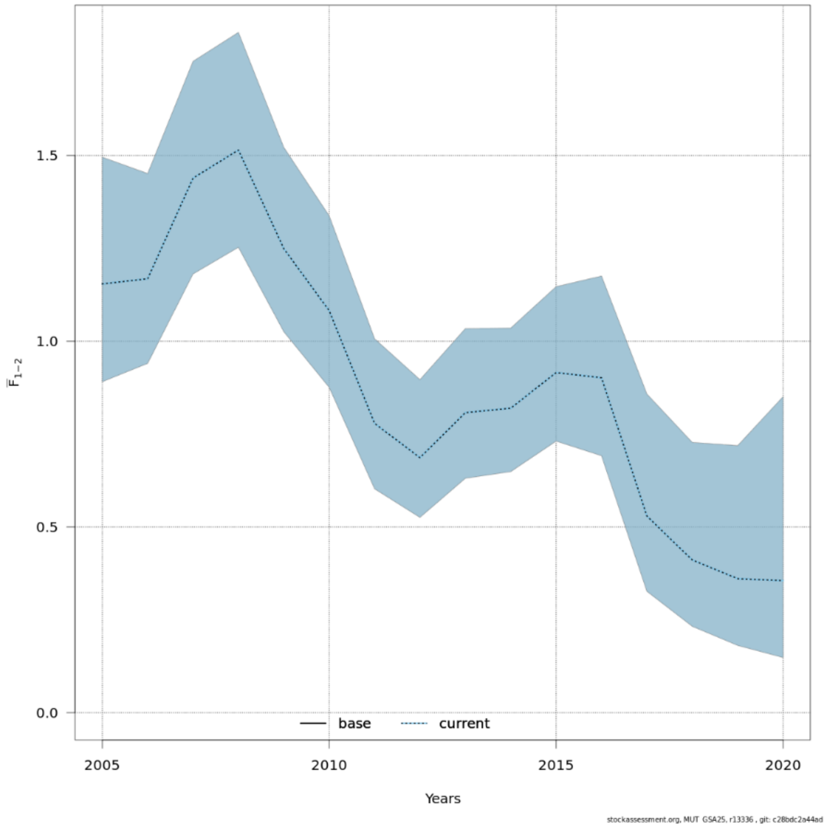


Figure 6.2.5-3: Average fishing mortality for the F1-2 age range. Estimates from the final run and point wise 95% confidence intervals are shown by line and shaded area.

Recruits of age 0 appear to follow similar to SSB shape with differences in magnitude and time (Figure 6.2.5-4). A downward trend from the beginning of the assessment period continues up until 2011. A plateau period occurs from in the years 2012 to 2017 before it start to steadily increase up until 2020.

A Spawner – Recruit computation in Figure 6.2.5-6 presents the relationship and trajectory of the two components among years. In year 2017 situation seems to clearly revert and improve although not at the magnitude of 2005.

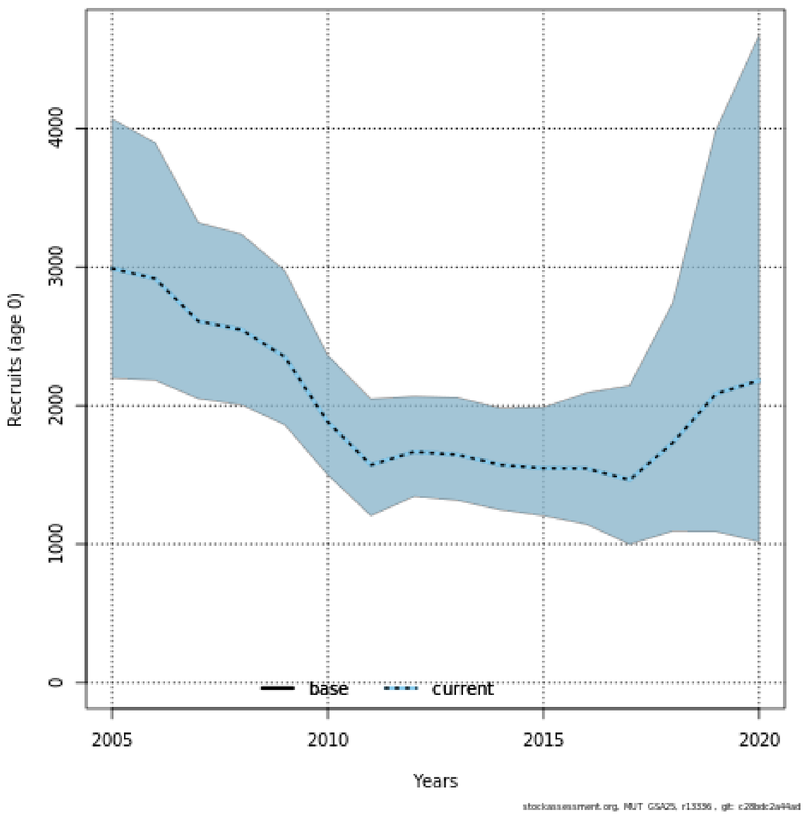


Figure 6.2.5-4: Yearly recruitment. Estimates from the final run and point wise 95% confidence intervals are shown by line and shaded area.

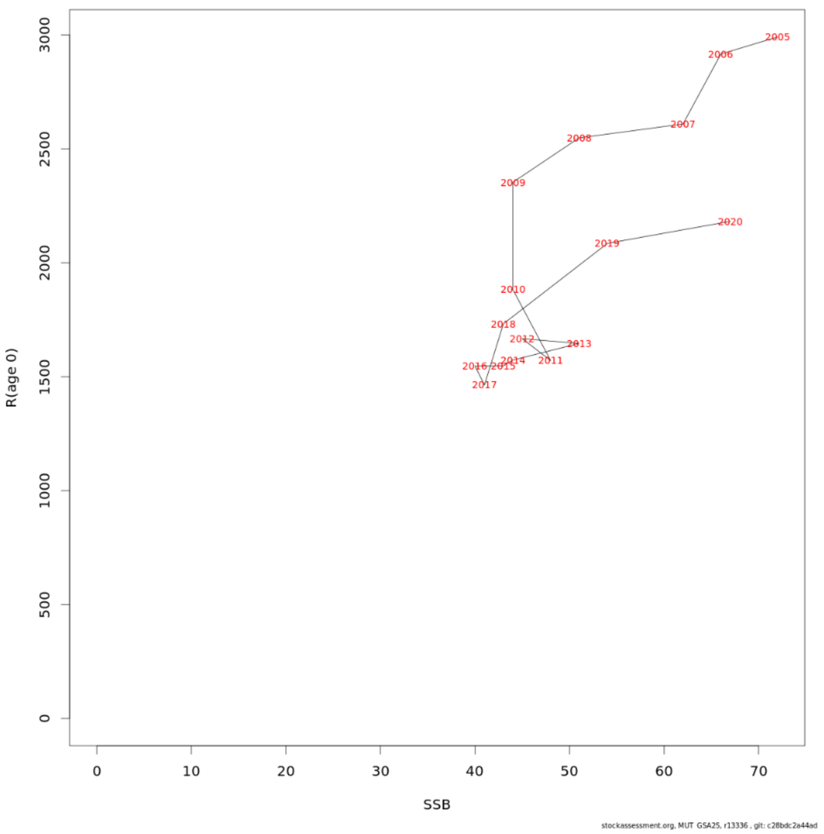


Figure 6.2.5-5: Estimated recruitment as a function of spawning stock biomass.

6.2.6 Retrospective analysis, comparison between model runs, sensitivity analysis, fit to data etc.

Apart from the initial fit to data examination, presented in Figures 6.2.6-1 and 6.2.6-2, a series of technics were followed based on SAM principles for model validation:

• Residuals (process residuals and one-observation-ahead)

• Retrospective patterns of key outputs

• Leave-out runs (to check consistency between data sources)

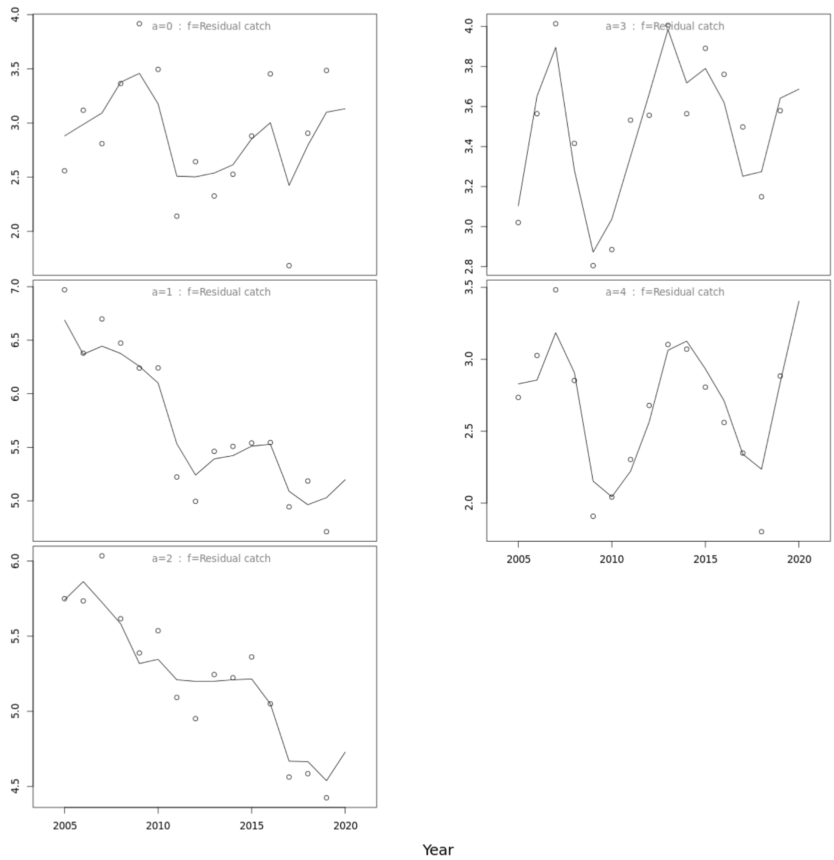


Figure 6.2.6-1: Fit to catch data. Predicted line and observed points (log scale).

In state-space assessment models residuals are calculated as:

$$ri = (yi - y\hat{}i)/\sigma\hat{}i$$

Although they supposed to be independent N(0, 1) they are not, even in perfectly correct models. Model process residuals are presenting in Figure 6.2.6-3. For this reason, a safer alternative can be derived from one-observation-ahead residuals $(y_i - \hat{y}_{i|i-1})/\hat{\sigma}_{i|i-1}$ which are shown in Figure 6.2.6-4.

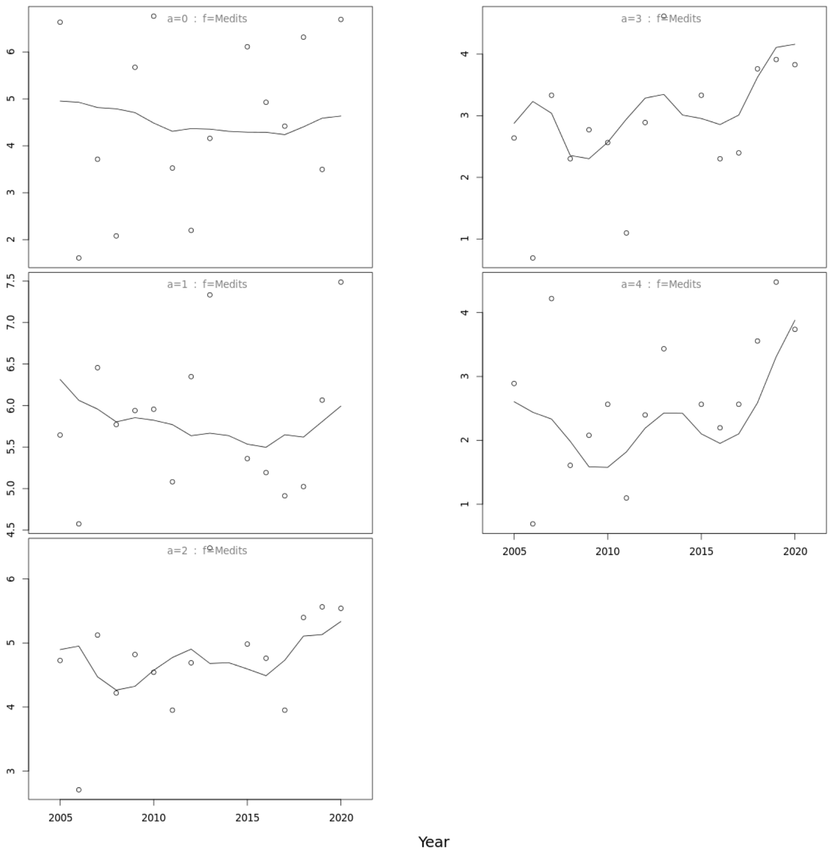


Figure 6.2.6-2: Fit to survey data. Predicted line and observed points (log scale).

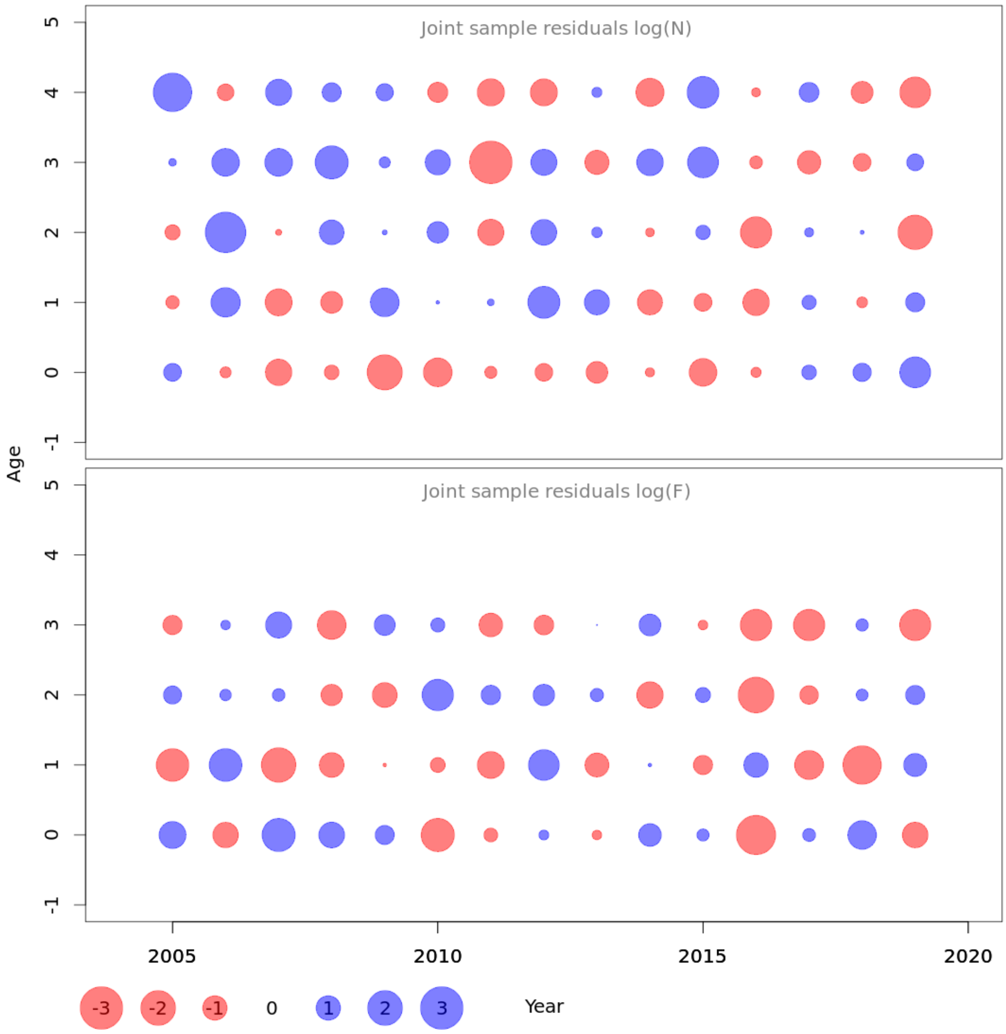


Figure 6.2.6-3: Standardized single-joint-sample residuals of process increments.

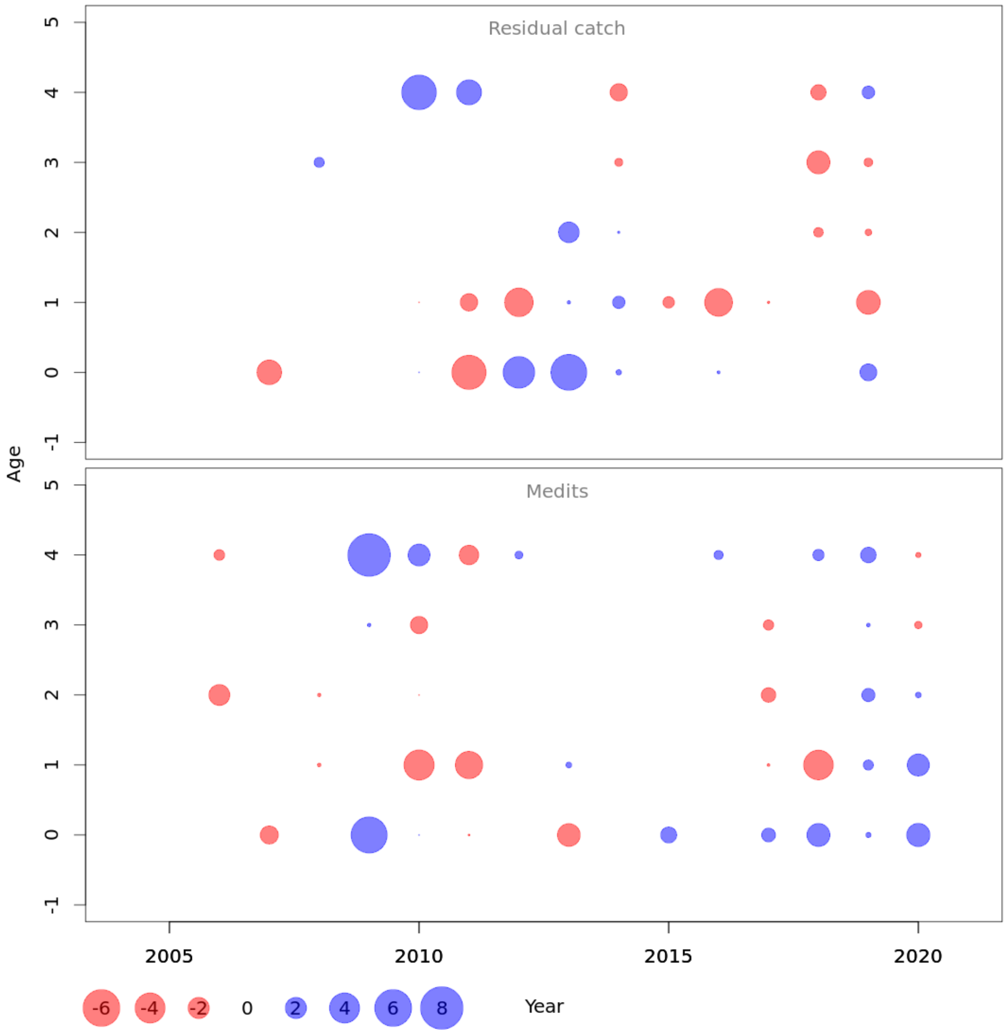


Figure 6.2.6-3: Standardized one-observation-ahead residuals for Catch and Survey.

Retrospective analysis which came after model verification via other diagnostics is a valuable terminal use validation tool. In doing so model was run with an extend of 3 years as per the agreed minimum standard of the WGSAD. All key estimates were compared to model run with all data and results are presented in Figures 6.2.6-4 to 6.2.6-7.

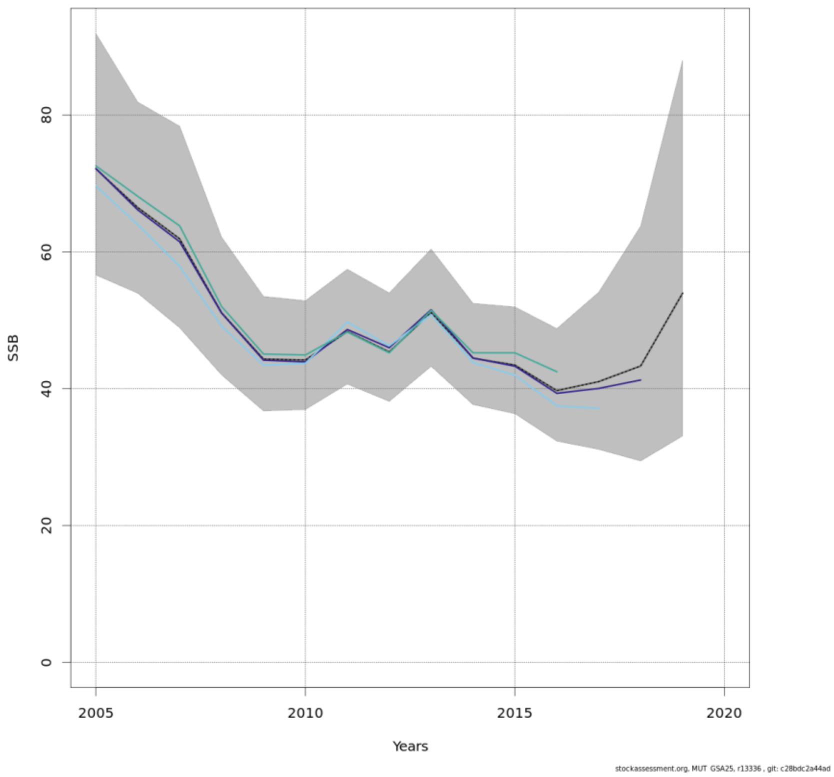


Figure 6.2.6-4: Retrospective analysis of Spawning Stock Biomass (SSB).

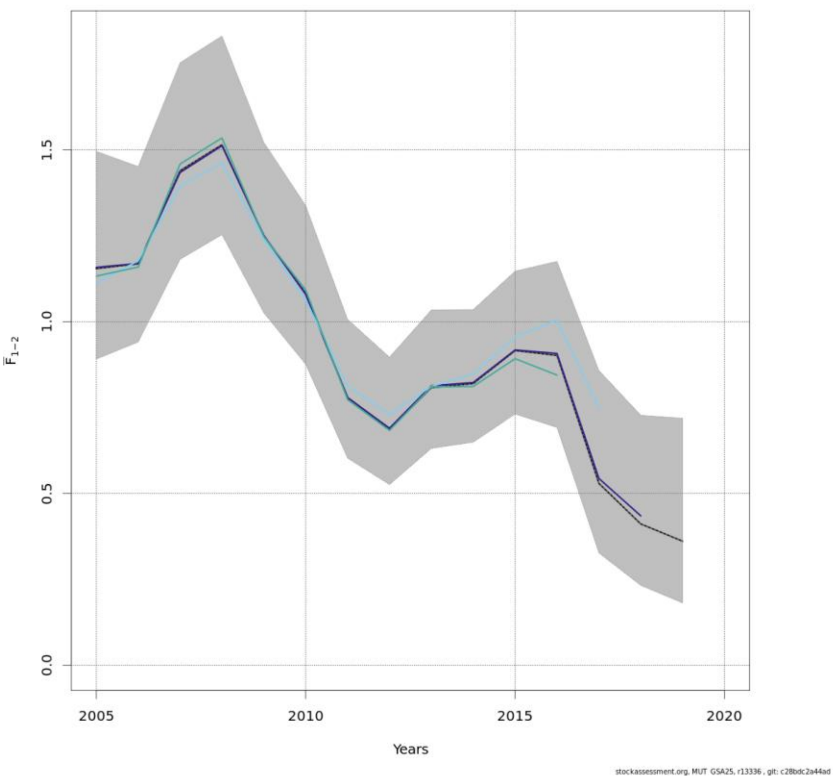


Figure 6.2.6-5: Retrospective analysis of average F.

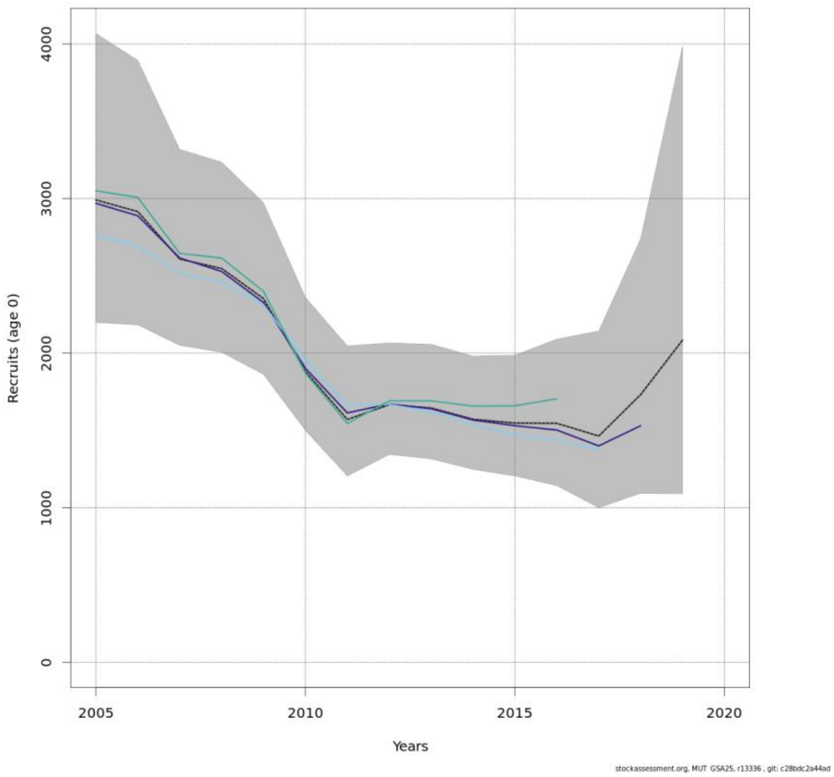


Figure 6.2.6-6: Retrospective analysis of Recruitment.

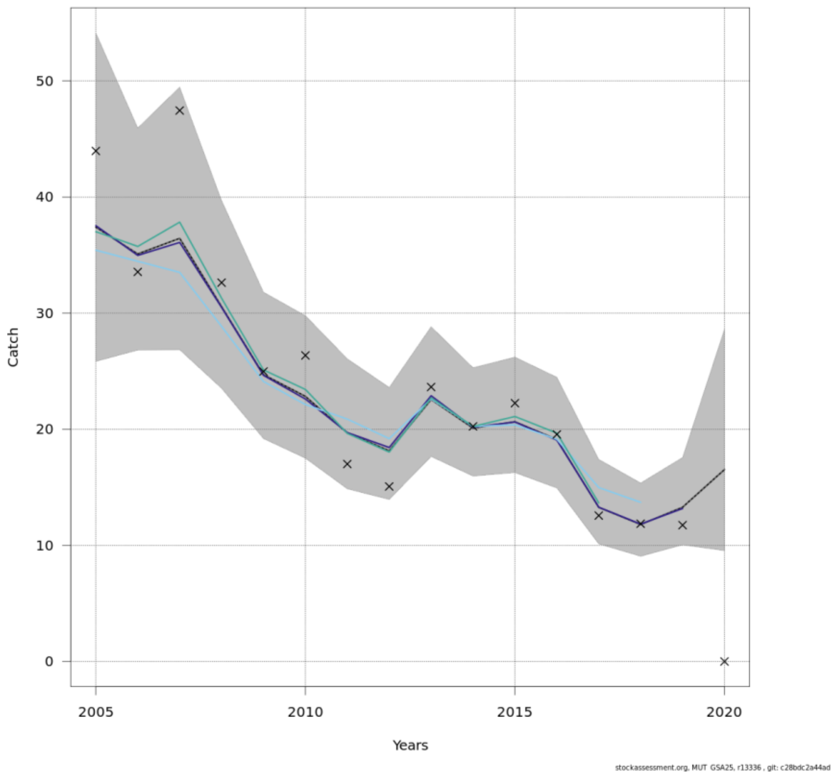


Figure 6.2.6-6: Retrospective analysis of Catch.

Leave out fleet run was another technique used as a final validation tool which is performed by leaving out individual data sets one at a time to observe if one of the components (fleet) is having an undue influence on the assessment results. Results of the analysis are given in Figures 6.2.6-7 to 6.2.6.10.

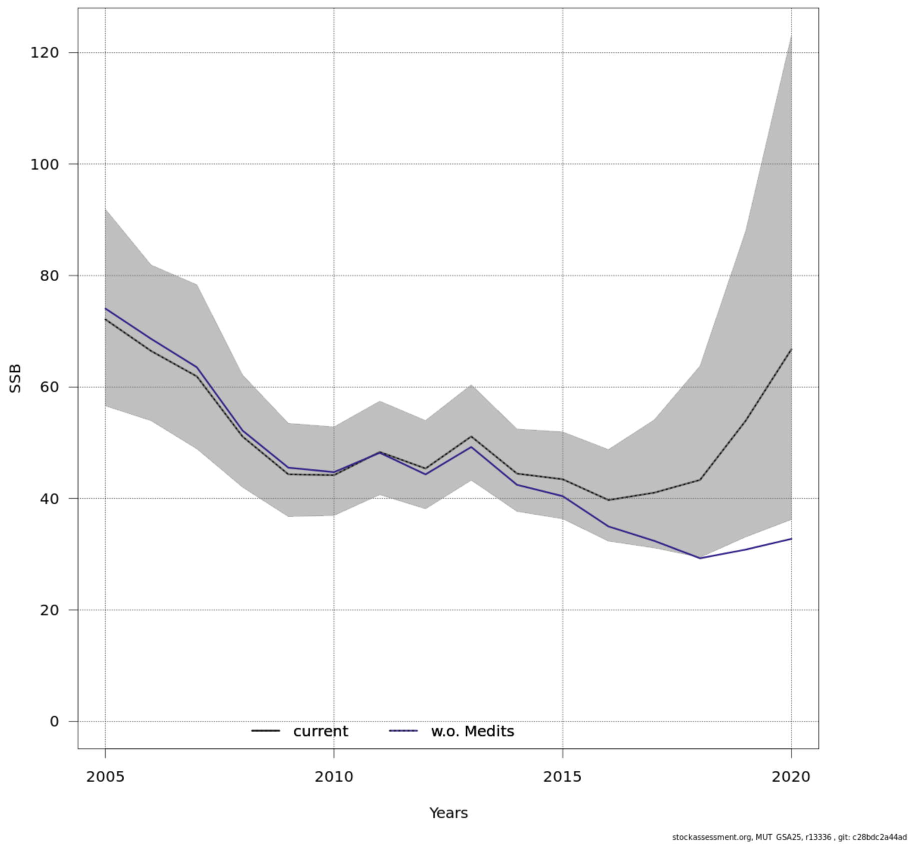


Figure 6.2.6-7: Leave out run on SSB.

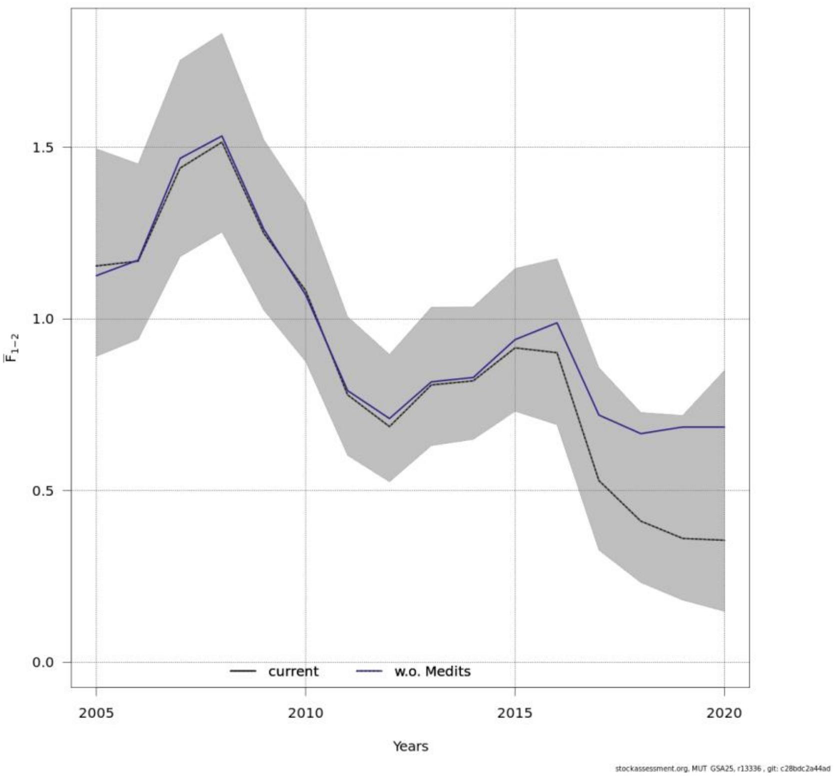


Figure 6.2.6-8: Leave out run on F.

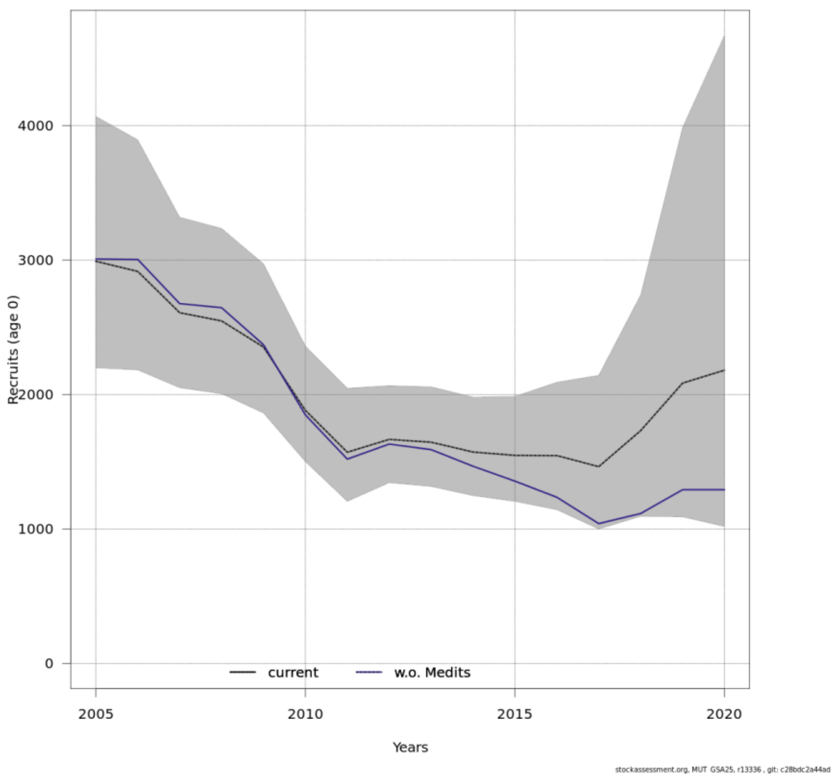


Figure 6.2.6-9: Leave out run on Recruitment.

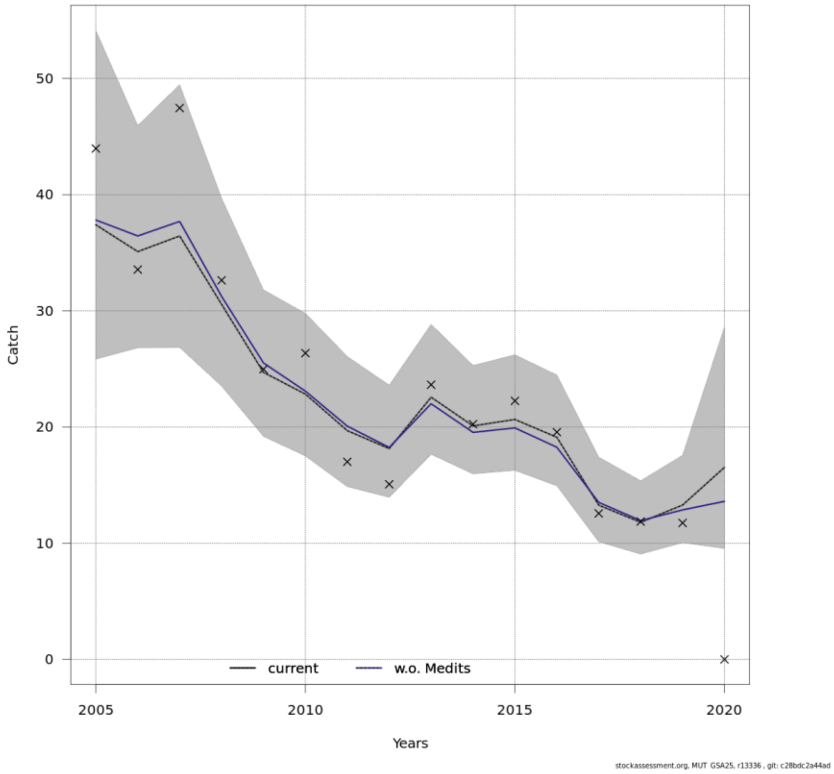


Figure 6.2.6-10: Leave out run on Catch.

6.2.7 Assessment quality

Input data derived from the official landings and effort data as collected by the Department of Fisheries and Marine Research, and from the biological data collected under the Cyprus National Data Collection Programme. It is considered that the best available data have been used.

The assumptions of the final model seem reliable.

6.2.8 Yield per Recruit Analysis

Yield per recruit analysis was carried using SAM library. Current fishing mortality was calculated as the mean F for ages 1-2 during the terminal year of the assessment. Results (Figure 6.2.8-1) show that current fishing mortality of $F_{current}$= 0.35 is exceeding the $F_{0.1}$= 0.25.

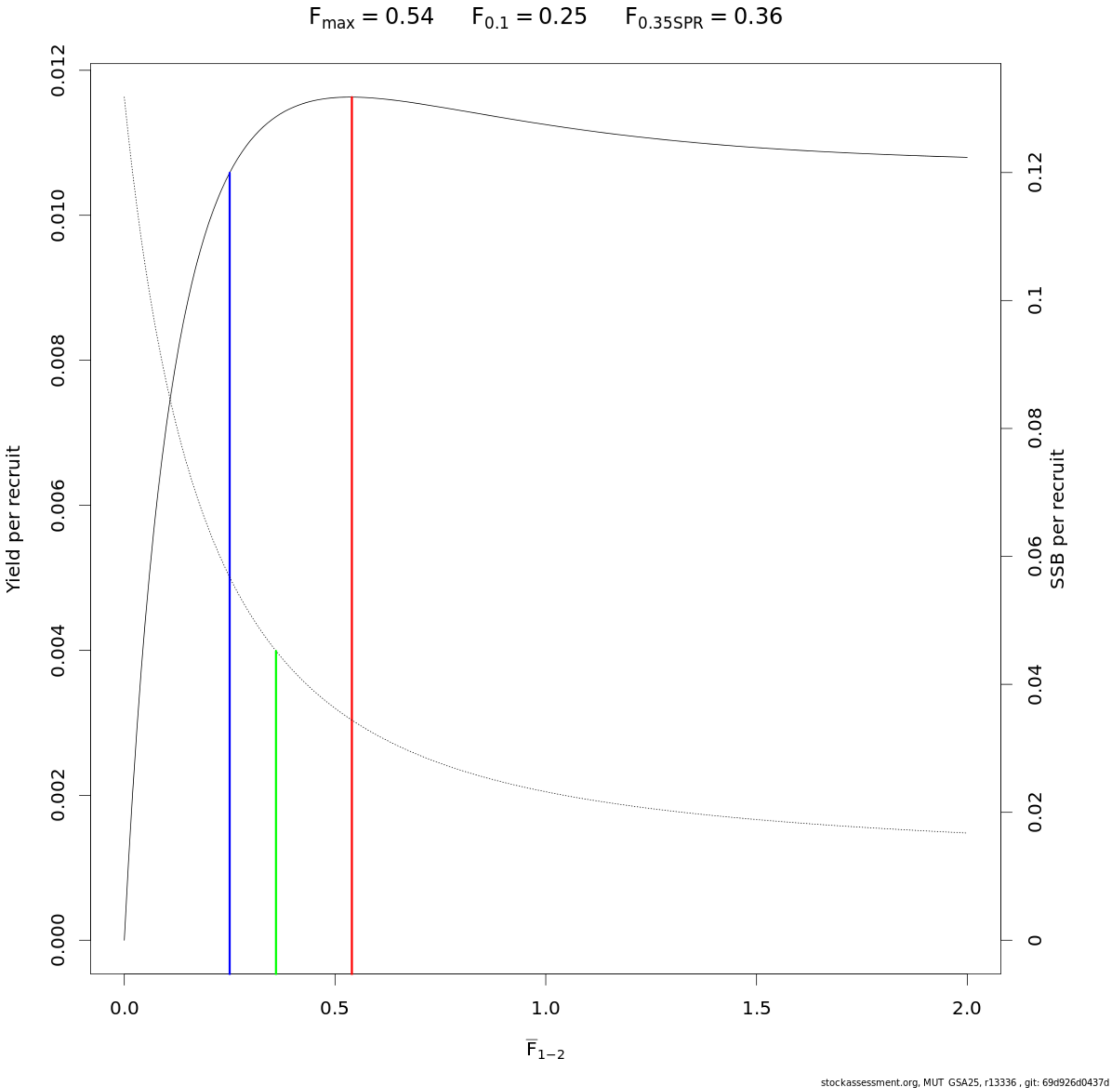
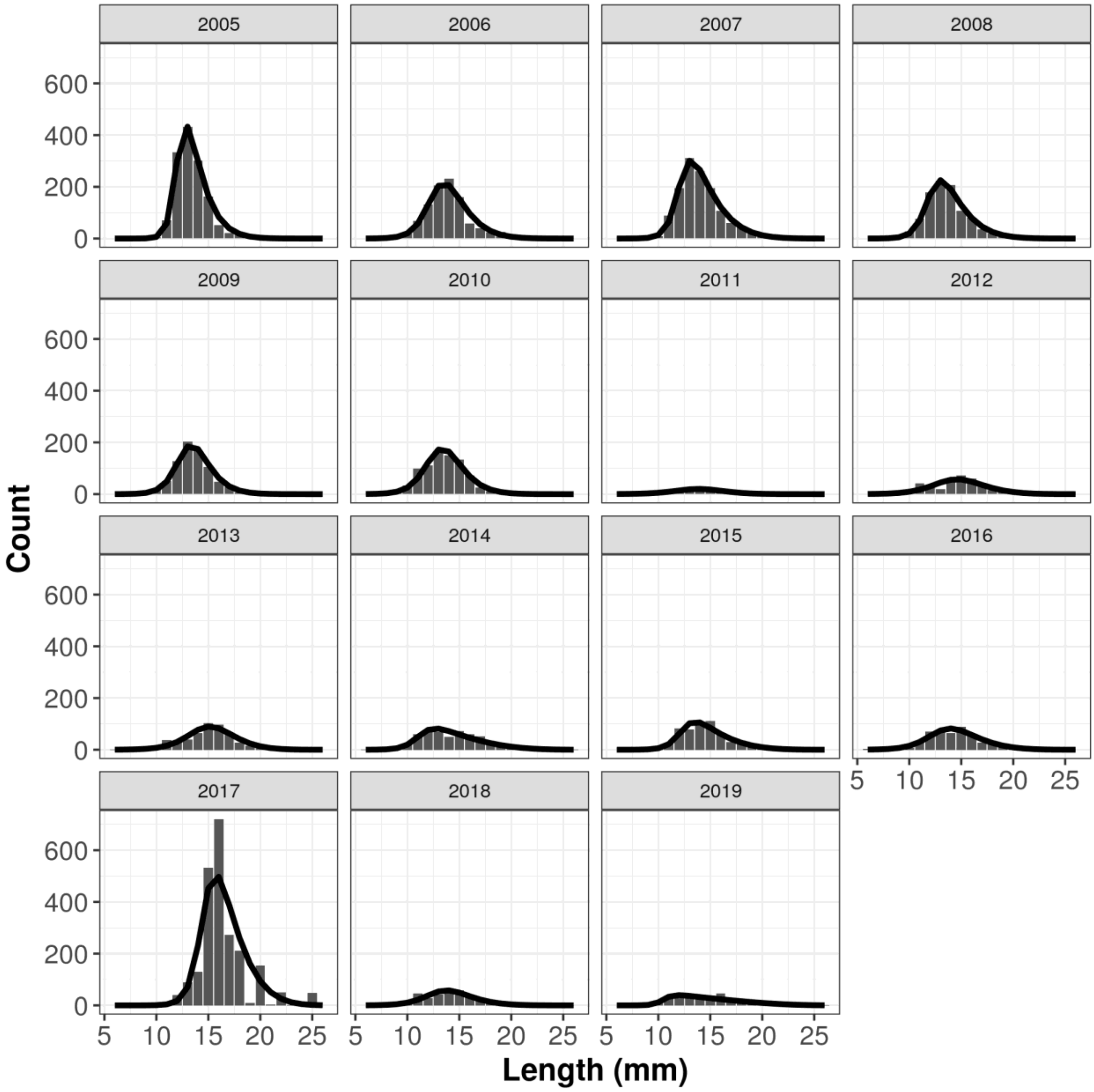
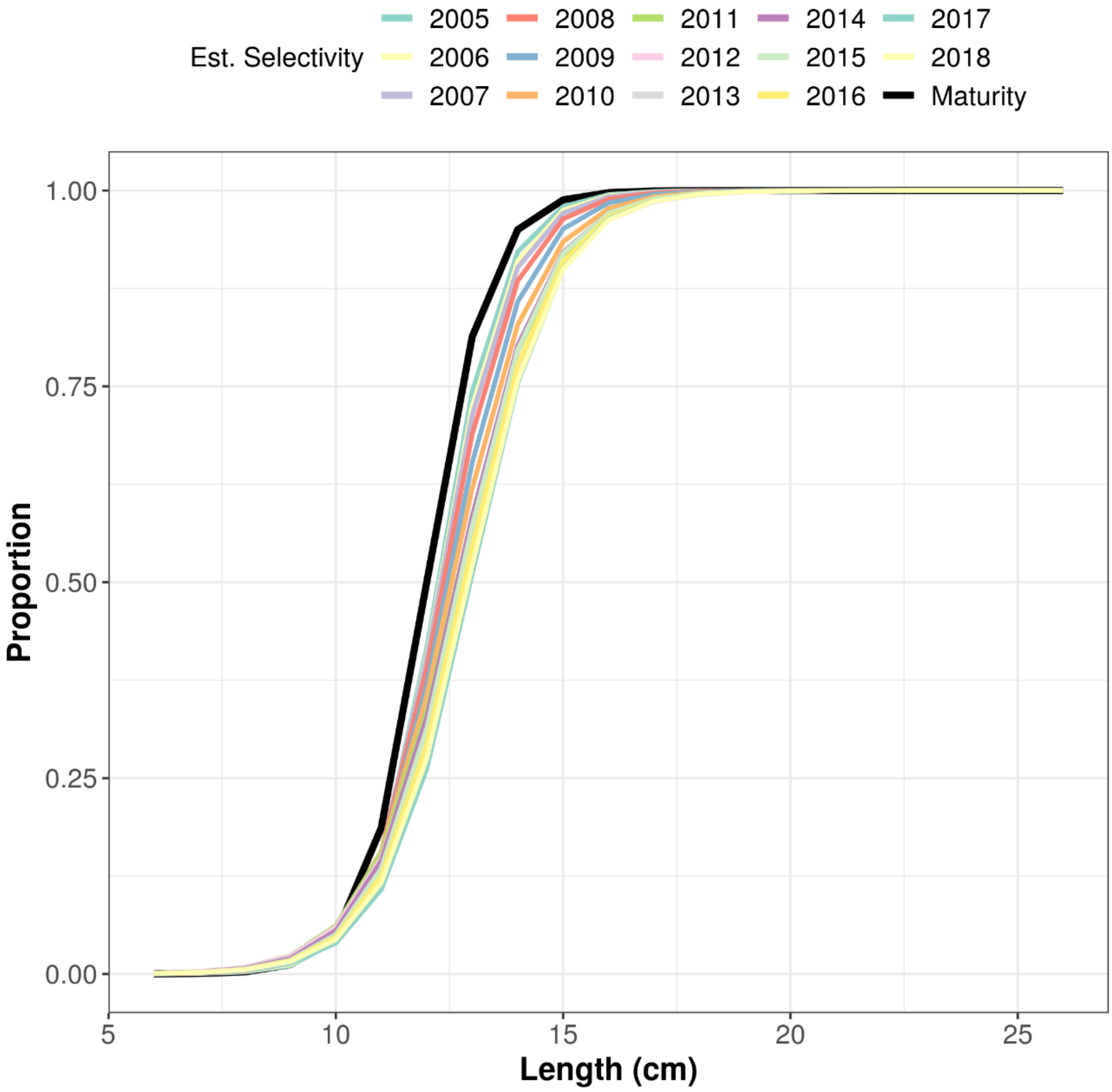


Figure 6.2.8-1: Yield per recruit (solid line) and spawning stock biomass plotted against different levels of fishing.

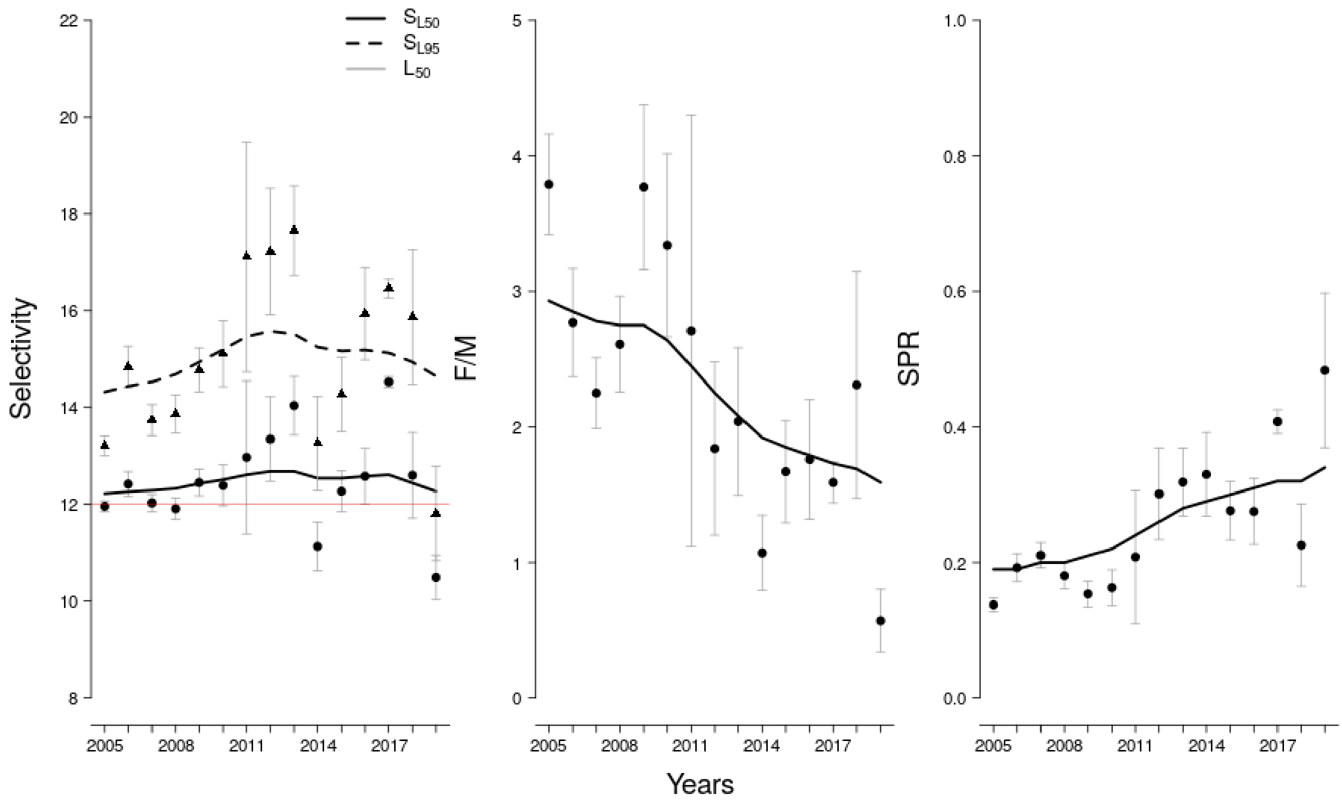
6.3 Auxiliary Analysis results

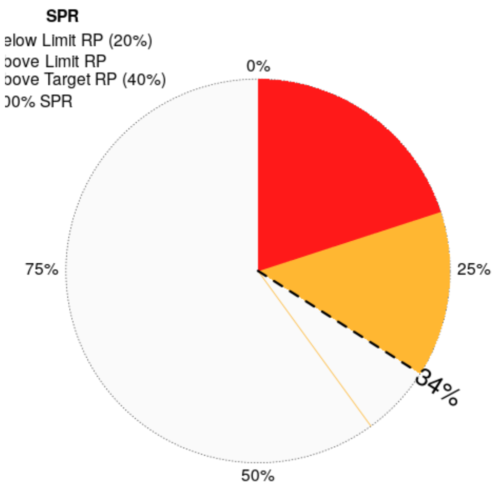
LBSPR



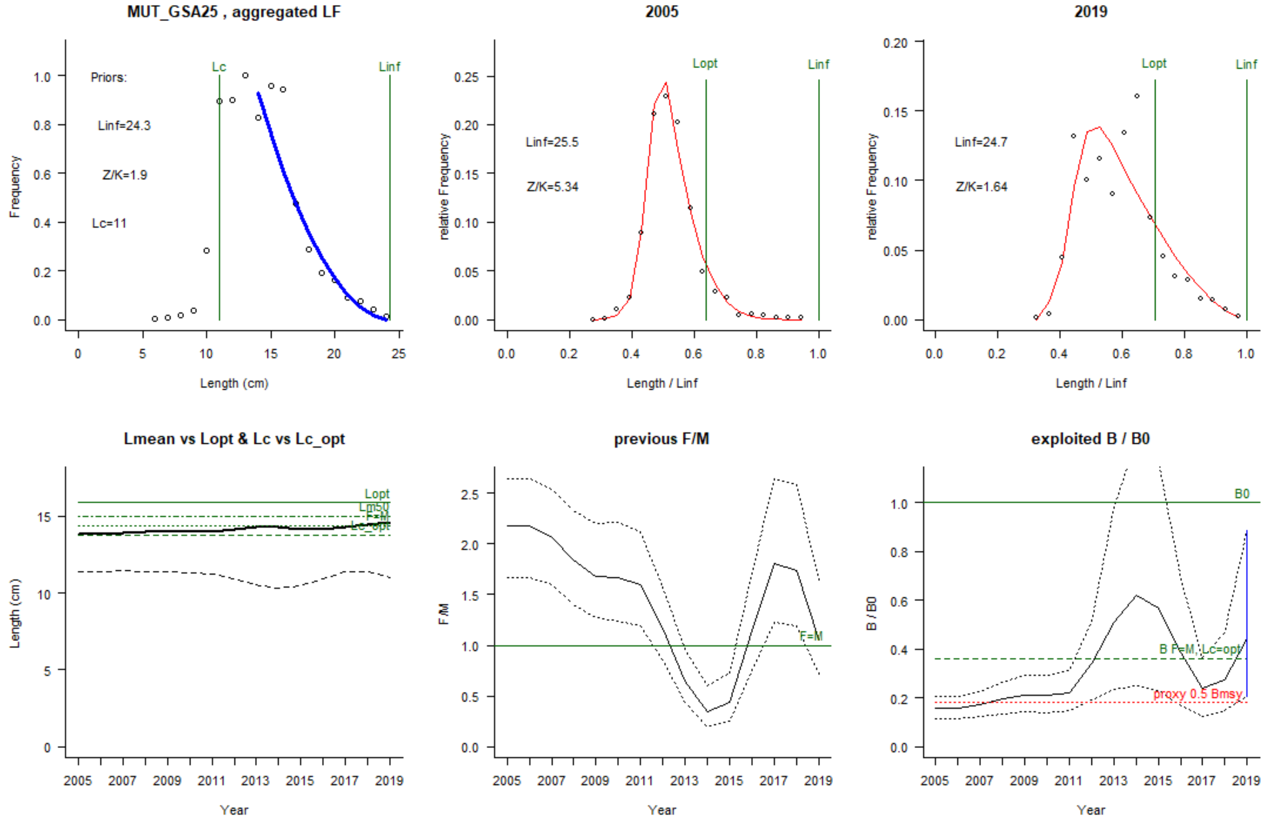


Est. Selectivity
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Maturity
Proportion
1.00
0.75
0.50
0.25
0.00
5
10
15
20
25
Length (cm)

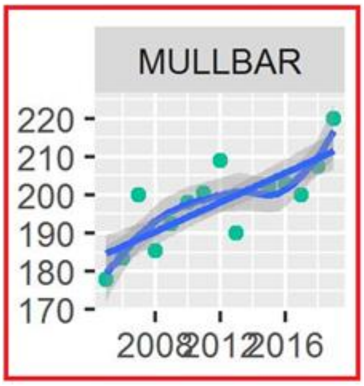

Selectivity
F/M
SPR
Years
S_{L50}
S_{L95}
L_{50}


SPR
elow Limit RP (20%)
oove Limit RP
oove Target RP (40%)
)0% SPR
0%
25%
50%
75%
34%

LBB



Empirical Indicator



7 Stock predictions

7.1 Medium term predictions

No medium term predictions were carried out for this stock.

7.2 Long term predictions

No long term predictions were carried out for this stock.

8 Draft scientific advice

Based on	Indicator	Analytic al reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (time period)	Stock Status
Fishing mortality	Fishing mortality	$F_{0.1}$ = 0.25	$F_{bar(1-2)}$ =0.35		D	O_L
Stock abundance						
	SSB $_{2020}$		SSB= 67 t	SSB_{33p}= 44 t SSB_{66p}= 51 t	I	
Recruitment						
Final Diagnosis		In low overfishing, with relative high biomass.				

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)*