Stock Assessment Form

Demersal species

Reference year: 2019

Reporting year: 2020

Following the last SAC meeting (Cairo, Egypt, 24–27 June 2019), the benchmark stock assessment of European hake was carried out assuming the stock in the boundaries of the Western Ionian Sea (GSA 19). M. merluccius represents one of the most important demersal species in terms of landing and income in GSA 19, especially for longlines (20% of the hake landing), gillnets and trammel nets (20% of the hake landing), but also for trawlers (60%). The benchmark assessment carried out in 2019 was updated, revising the catchability sub-model of the benchmark assessment, because showing instability signals. The catchability model was selected among the best performing during the benchmark. The results showed a decreasing pattern for the fishing mortality, that in 2019 is still well above the proxy of $F_{0.1}$ (F_{unique}= 0.143), with a value of 0.32. The SSB shows an increase in the recent years, while the recruitment is stable.

Stock Assessment Form version 1.0 (January 2014)

Uploader: Isabella Bitetto

Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
	European hake	32
1st Geographical sub-area:	2nd Geographical sub-area:	3rd Geographical sub-area:
GSA_19		
4th Geographical sub-area:	5th Geographical sub-area:	6th Geographical sub-area:
1st Country	2nd Country	3rd Country
Italy		
4th Country	5th Country	6th Country
Stock assessment method: Indirect (a4a)		
Authors:		
STECF EWG 20-15		

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

Following the last SAC meeting (Cairo, Egypt, 24–27 June 2019), the benchmark stock assessment of European hake was carried out in 2019 assuming the stock in the boundaries of the Western Ionian Sea (GSA 19). For this assessment the same hypothesis was made. *M. merluccius* represents one of the most important demersal species in terms of landing and income in GSA 19, especially for longlines (about 20% of the hake landing), gillnets and trammel nets (about 20% of the hake landing), but also for trawlers (about 60%).

2.1 Stock unit

2.2 Growth and maturity

Biological information on growth von Bertalanffy parameters, maturity at length, length-weight relationship were derived within DCF and are the same of the benchmark assessment of 2019.

The natural mortality vector was estimated as an average of different methods (Gislason, Prodbiom revised version with unique solution, Chen & Watanabe, Brodziak (2011 and 2012), Lorenz and Gulland), consistently with the approach used in the benchmark assessment of hake in Adriatic Sea in 2019. The same vector was here used.

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

Somatic magnitude measured (LT, LC, etc)			TL	Units	cm
Sex	Fem	Mal	Combined	Reproduction season	December-November
Maximum size observed	89			Recruitment season	
Size at first maturity	33-34	18		Spawning area	
Recruitment size to the fishery			4-5	Nursery area	On the shelf between Otranto and Santa Maria di Leuca, around the Amendolara Bank, in the Gulf of Squillace and offshore Siracusa (MEDISEH MAREA project).

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

Size/Age	Natural mortality	Proportion of matures
0	1.27	0.03
1	0.69	0.33
2	0.45	0.57
3	0.34	0.92
4	0.28	0.99
5	0.24	0.98
6	0.22	1.00
7+	0.20	1.00

Table 2-3: Growth and length weight model parameters

			Sex			
		Units	female	male	Combined	Years
Growth model	L_∞		111	73		2002-2018
	K		0.10	0.15		2002-2018
	t_0	cm	-0.60	-0.73		2002-2018
	Data source	DCF and benchmark assessment 2019				
Length weight relationship	a		0.0055	0.005		2002-2018
	b		3.1	3.04		2002-2018
	M (scalar)					
	sex ratio (% females/total)					

The natural mortality vector was derived as an average of different methods for estimating the natural mortality at age (Table 2.2-1 and Table 2.2-2). The revised version of Abella et al.,(1998), that is Martiradonna (2012) was used.

Table 2.2-1 Natural mortality vectors estimated with different models, and average M vector for females.

age	Gislason et al., 2010	Abella et al., 1998 (2009)	Chen & Watanabe, 1989	Brodziak et al., 2011	Brodziak et al., 2012	Gulland, 1987
0.5	2.69	1.71	0.96	1.01	0.43	1.20
1.5	1.19	0.88	0.68	0.61	0.26	0.56
2.5	0.63	0.60	0.44	0.41	0.18	0.31
3.5	0.45	0.46	0.33	0.34	0.14	0.22
4.5	0.34	0.38	0.27	0.28	0.12	0.17
5.5	0.27	0.32	0.23	0.25	0.10	0.14
6.5	0.23	0.28	0.21	0.22	0.09	0.12
7.5	0.20	0.25	0.19	0.20	0.09	0.10
8.5	0.18	0.23	0.17	0.19	0.08	0.09
9.5	0.16	0.21	0.16	0.18	0.08	0.09
10.5	0.15	0.20	0.15	0.17	0.07	0.08
11.5	0.14	0.18	0.15	0.16	0.07	0.07
12.5	0.13	0.17	0.14	0.16	0.07	0.07
13.5	0.12	0.16	0.14	0.15	0.06	0.07
14.5	0.12	0.16	0.13	0.14	0.06	0.06
15.5	0.11	0.15	0.13	0.14	0.06	0.06
16.5	0.11	0.14	0.13	0.14	0.06	0.06
17.5	0.10	0.14	0.12	0.14	0.06	0.06
18.5	0.10	0.13	0.12	0.13	0.06	0.05
19.5	0.10	0.13	0.12	0.13	0.06	0.05
20.5	0.09	0.13	0.12	0.13	0.05	0.05

Table 2.2-2 Natural mortality vectors estimated with different models, and average M vector for males.

age	Gislason et al., 2010	Abella et al., 1998 (2009)	Chen & Watanabe, 1989	Brodziak et al., 2011	Brodziak et al., 2012	Gulland, 1987
0.5	2.08	1.71	0.89	0.55	0.24	1.35
1.5	0.99	0.88	0.65	0.34	0.14	0.62
2.5	0.61	0.60	0.44	0.23	0.10	0.33
3.5	0.42	0.46	0.35	0.18	0.08	0.24
4.5	0.33	0.38	0.29	0.15	0.07	0.19
5.5	0.29	0.32	0.26	0.13	0.06	0.15
6.5	0.25	0.28	0.23	0.12	0.05	0.13
7.5	0.22	0.25	0.22	0.11	0.05	0.11
8.5	0.20	0.23	0.20	0.10	0.04	0.10
9.5	0.19	0.21	0.19	0.10	0.04	0.09
10.5	0.18	0.20	0.18	0.09	0.04	0.08
11.5	0.17	0.18	0.18	0.09	0.04	0.08
12.5	0.16	0.17	0.17	0.08	0.04	0.07
13.5	0.15	0.16	0.17	0.08	0.03	0.07
14.5	0.15	0.16	0.16	0.08	0.03	0.07
15.5	0.15	0.15	0.16	0.08	0.03	0.06
16.5	0.15	0.14	0.16	0.08	0.03	0.06
17.5	0.15	0.14	0.16	0.07	0.03	0.06
18.5	0.15	0.13	0.16	0.07	0.03	0.06
19.5	0.15	0.13	0.15	0.07	0.03	0.06
20.5	0.15	0.13	0.15	0.07	0.03	0.05

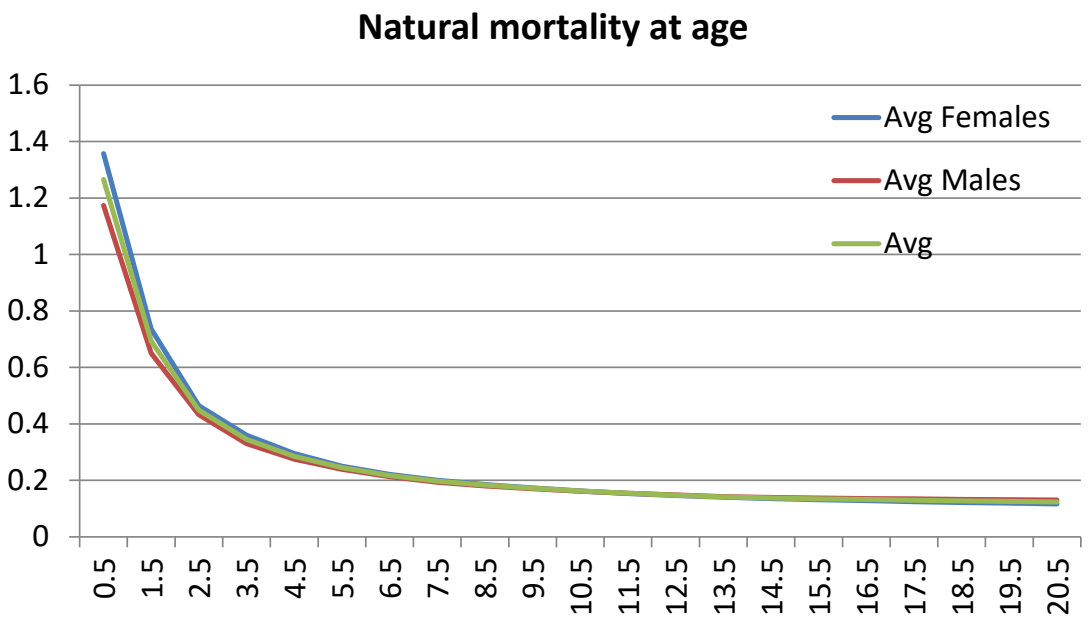


Figure 2.2-1 Natural mortality vectors for females (average of the different methods in Table 2.2-1), males (average of the different methods in Table 2.2-2) and average between the two sexes.

3 Fisheries information

3.1 Description of the fleet

As an average along the years, the longlines represent about the 20% of the hake landing, the gillnets and trammel nets around the 20% (together), while the trawlers about the 60%.

Table 3.1-1 Composition of the fleet exploiting the stock according GFCM Fleet Segmentation http://www.fao.org/gfcm/activities/fisheries/fleet/segmentation/en/

Area	Country	Trawlers 6 - 12 m (T-10)	Trawlers 12 - 24 m (T-11)	Trawlers > 24 m (T-12)	Small scale vessel with engine using passive gears < 6 m (P-05)	Small scale vessel with engine using passive gears 6 - 12 m (P-06)	Small scale vessel with engine using passive gears 12- 24 m (P-07)	Longliners 12 - 24 m (L-03)	Total
GSA 19	Italy[1]	21	228	11	294	592	5	86	1237

[1] Fisheries and Maritime Affairs' Fleet Register, 2018

Table 3.1-1: Catch, bycatch, discards and effort by operational unit in the reference year

Operational Units*	Fleet (n° of boats)*	Catch (T or kg of the species assessed)	Other species caught (names and weight)	Discards (species assessed)	Discards (other species caught)	Effort (units)
T10+T11+T12	260			40**		
[P05+P06]	891			0		
L03	86			0		
Total	1237			40		

*Fisheries and Maritime Affairs' Fleet Register, 2018

** DCF discard data of the year 2019.

3.2 Historical trends

The time series of landings for hake in the area used in the assessment were from DCF and cover the years 2002-2019. Being the first two years quite different from the rest of the time series, and lacking the longliners in the same yeas, the assessment was carried out from 2004, consistently with the benchmark. The discard data were available for 2006, 2009-2019. In the years where the information on the discard was not available, it was derived multiplying the ratio between discard and landing on the years 2006 and 2009 to the landing of the lacking years (Figure 3.2.2). After the peak in 2006 and a decrease until 2012, the landing time series show a trend quite stable until 2018. Even the discard shows stability from 2010 ownards. The average proportion among the different gears is 40%, 20% and 20% respectively for OTB, GNS+GTR and LLS.

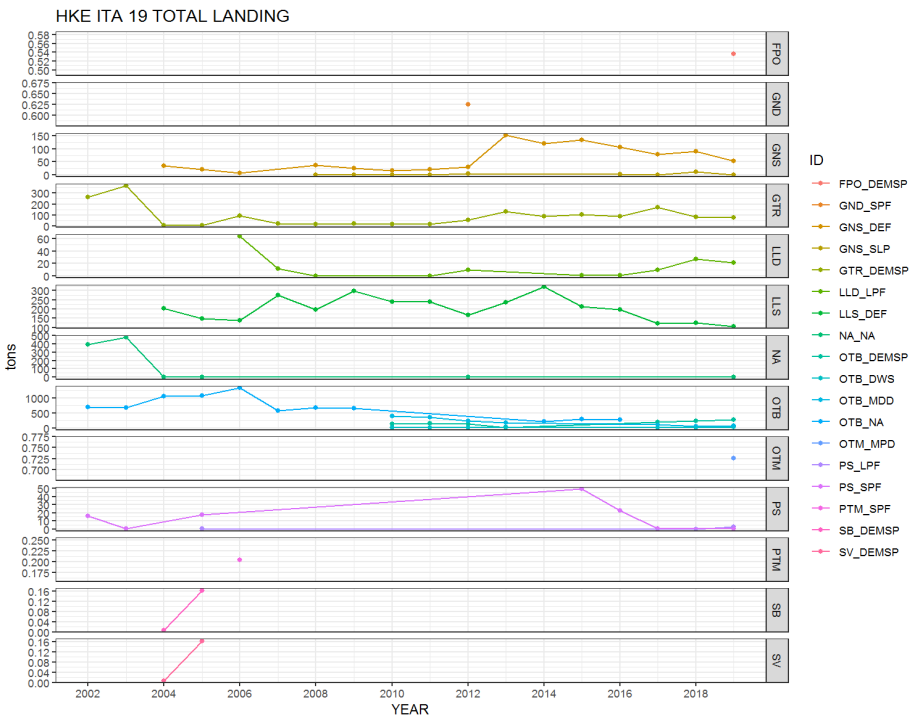


Figure 3.2.1 – Landing of M. merluccius in GSA 19 by gear (tons).

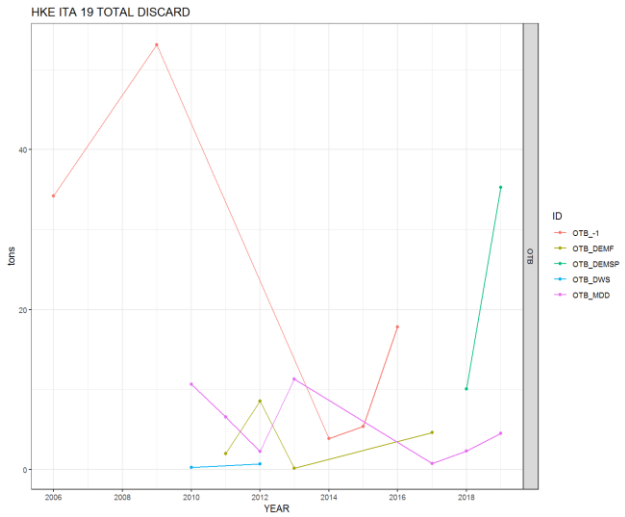


Figure 3.2.2 – Discard (trawlers) of M. merluccius in GSA 19 by gear (tons).

Figure 3.2.3 shows the different LFDs in the catch by gear. Longlines mean size in the catch is around 35-40 cm, the trawlers catches are more concentrated on smaller sizes (about 18-20 cm), while gillnets and trammel nets have their bulk around 20 cm.

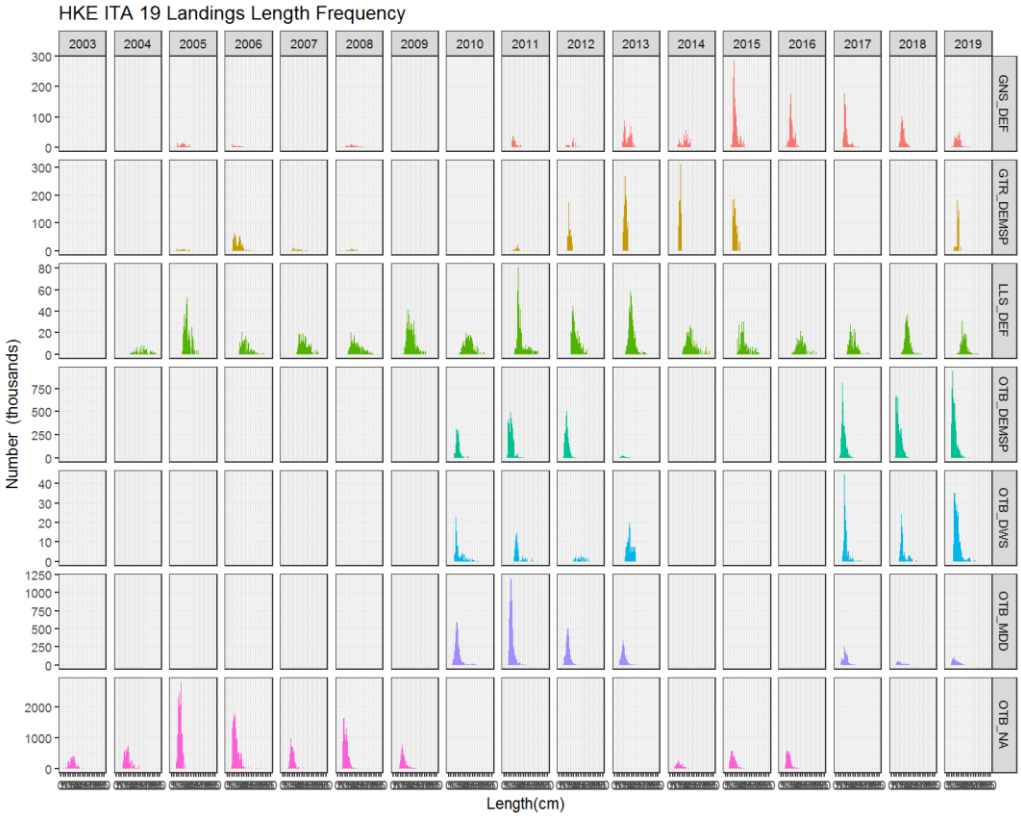


Figure 3.2.3 – Length-Frequency distributions of catch for *M. merluccius* in GSA 19 by gear.

3.3 Management regulations

In Italy management regulations are based on technical measures, closed number of fishing licenses for the fleet and area limitation (distance from the coast and depth). In order to limit the over-capacity of fishing fleet, the Italian fishing licenses have been fixed since the late eighties and the fishing capacity has been gradually reduced. Other measures on which the management regulations are based regards technical measures (mesh size), minimum landing sizes (EC 1967/06) and seasonal fishing ban. Regarding small scale fishery management regulations are based on technical measures related to the height and length of the gears as well as the mesh size opening, minimum landing sizes and number of fishing licenses for the fleet. In 2008 a management plan was adopted, that foresaw the reduction of fleet capacity associated with a reduction of the time at sea. The Protected Marine Area of Porto Cesareo, covering an area of 16,654 hectares (41 acres) (the third largest in Italy). *A* marine protected area (MPA) had been established in 1997. Recreational fishery using no more than 5 hooks is allowed**.** Since June 2010 the rules implemented in the EU regulation (EC 1967/06) regarding the cod-end mesh size and the operative distance of fishing from the coasts are enforced.

3.4 Reference points

Table 3.2-1: 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			0.13	$F_{0.1}$	GFCM benchmark in 2019
Y					
CPUE					
Index of Biomass at sea					

4 Fisheries independent information

4.1 MEDITS trawl survey

4.1.1 Brief description of the direct method used

The sampling design is random stratified with number of haul by stratum proportional to stratum surface.

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Hauls noted as valid were used only, including stations with no catches (zero catches are included).

The abundance and biomass indices by GSA were calculated through stratified means (Cochran, 1953; Saville, 1977). The variation of the stratified mean is then expressed as coefficient of variation respect to the mean.

The catchability is assumed equal to 1.

The survey time was quite stable along the years (varying from June to August), except in 2017 when the survey was carried out between October and December.

4.1.2 Direct methods: trawl based abundance indices

Table 4.1-1:MEDITS trawl survey basic information

Survey	**MEDITS GSA 19**	**Trawler/RV**	PEC
Sampling season	Summer		
Sampling design	Stratified sampling design with the number of hauls proportionate to the strata surface		
Sampler (gear used)	GOC 73		
Cod –end mesh size as opening in mm	20 mm		
Investigated depth range (m)	10 – 800 m		

Table 4.1-2: MEDITS trawl survey sampling area and number of hauls (2018)

Stratum	**Total surface (km²)**	**Trawlable surface (km²)**	**Swept area (km²)**	**Number of hauls**
10 – 50 m	2124			9
50 – 100 m	1701			8
100 – 200 m	2664			10

Stratum	Total surface (km^2)	Trawlable surface (km^2)	Swept area (km^2)	Number of hauls
200 – 500 m	4355			14
500 – 800 m	5503			29
Total (10 – 800 m)	16347			70

Figure 4.1.2 – 1 Map of hauls positions of MEDITS in GSA 19 *(2018)*.

The indices by stratum show that the species is more distributed in the area between 50 and 500 m.

Table 4.1-3: Trawl survey abundance and biomass results (2018)

Depth Stratum	Years	kg per km^2	CV	N per km^2	CV

10 – 50 m	2018	4.6	76.7	86.7	70.2
50 – 100 m	2018	29.5	65.7	775.3	59.7
100 – 200 m	2018	46.9	36.7	1618.3	57.2
200 – 500 m	2018	40.6	25.8	781.7	63.4
500 – 800 m	2018	8.9	22.0	11.0	21.7
Total 10-800m)	2018	25.1	17.9	567.6	36.4

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

The standardized LFDs from MEDITS trawl survey are shown in Figure 4.1.3-1; these LFDs were age sliced by the deterministic age slicing applying the parameters reported in the section 2.2. The maturity scale used for the maturity stages of this species is MEDITS scale (Medits Handbook 2017, version 9).

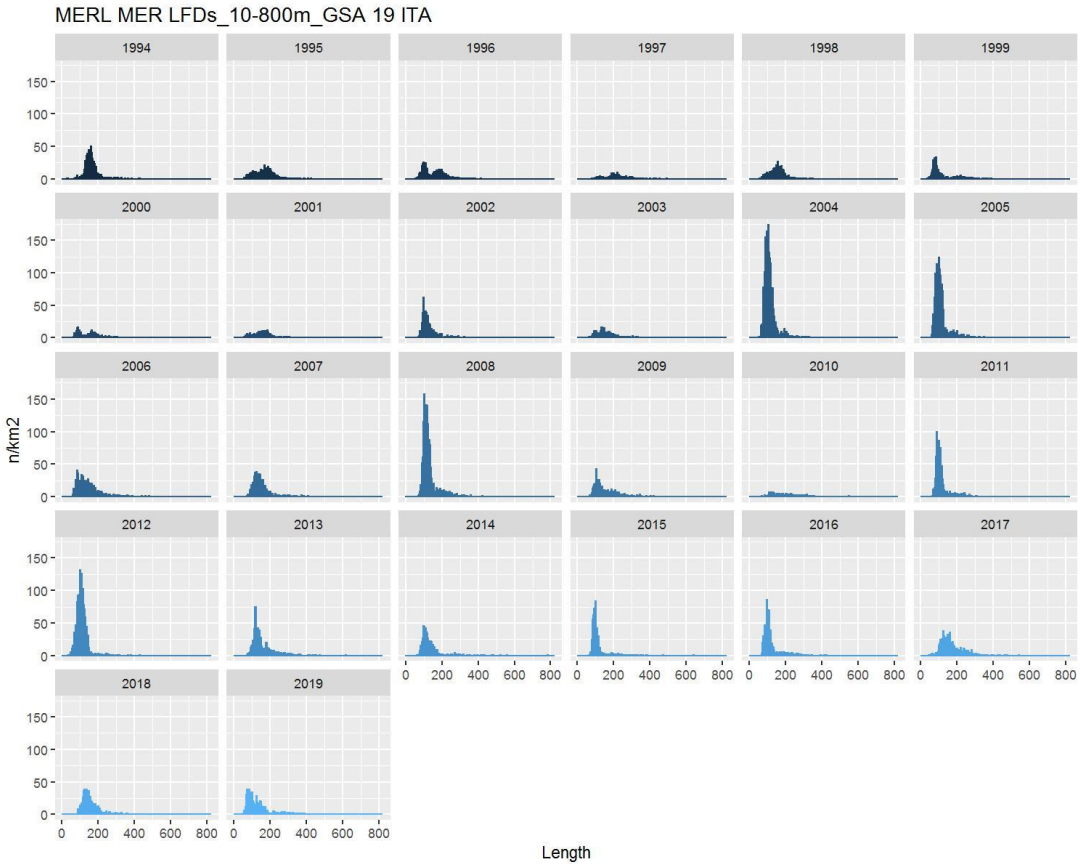


Figure 4.1.3-1: MEDITS survey indices (N/km²) by length. The catchability is

assumed equal to 1.

4.1.4 Direct methods: trawl based Recruitment analysis

The recruitment of *M. merluccius* is continuous. In MEDISEH project the recruitment threshold was estimated equal to 13.2 cm, using MEDITS data, while it was observed that the smallest individuals present in the catch are about 5 cm-sized. A recruitment index (N/km^2) was estimated and reported in Table 4.1.4-2 and Figure 4.1.4 1:, where the recruits are defined as the individuals smaller than 13 cm. Peaks in recruitment were observed in the years 2004, 2005, 2008 and 2012.

Table 4.1.4-1: MEDITS trawl surveys; recruitment analysis summary

Survey	MEDITS	Trawler/RV	PEC
Survey season		Summer	
Cod –end mesh size as opening in mm			
Investigated depth range (m)		10-800 m	
Recruitment season and peak (months)			
Age at fishing-grounds recruitment			
Length at fishing-grounds recruitment		4-5 cm first lengths in the fishery, 13 cm threshold for recruitment phase defined in MEDISEH project.	

Table 4.1.4-2: MEDITS trawl surveys; recruitment index.

Years	Area in km^2	N of recruit per km^2	CV
1994	16347	79.3	36.0
1995	16347	113.0	53.2
1996	16347	195.4	58.7
1997	16347	18.7	59.1
1998	16347	101.9	35.9
1999	16347	237.9	59.4
2000	16347	101.5	51.8
2001	16347	70.2	37.4

2002	16347	347.8	32.6
2003	16347	82.0	46.1
2004	16347	1373.7	46.9
2005	16347	1073.1	32.5
2006	16347	333.4	47.0
2007	16347	232.9	43.3
2008	16347	987.9	47.5
2009	16347	225.3	66.7
2010	16347	40.7	46.8
2011	16347	578.0	92.8
2012	16347	1132.9	44.8
2013	16347	283.1	55.9
2014	16347	324.2	62.6
2015	16347	442.7	65.1
2016	16347	506.6	51.4
2017	16347	197.1	46.1
2018	16347	185.2	58.5

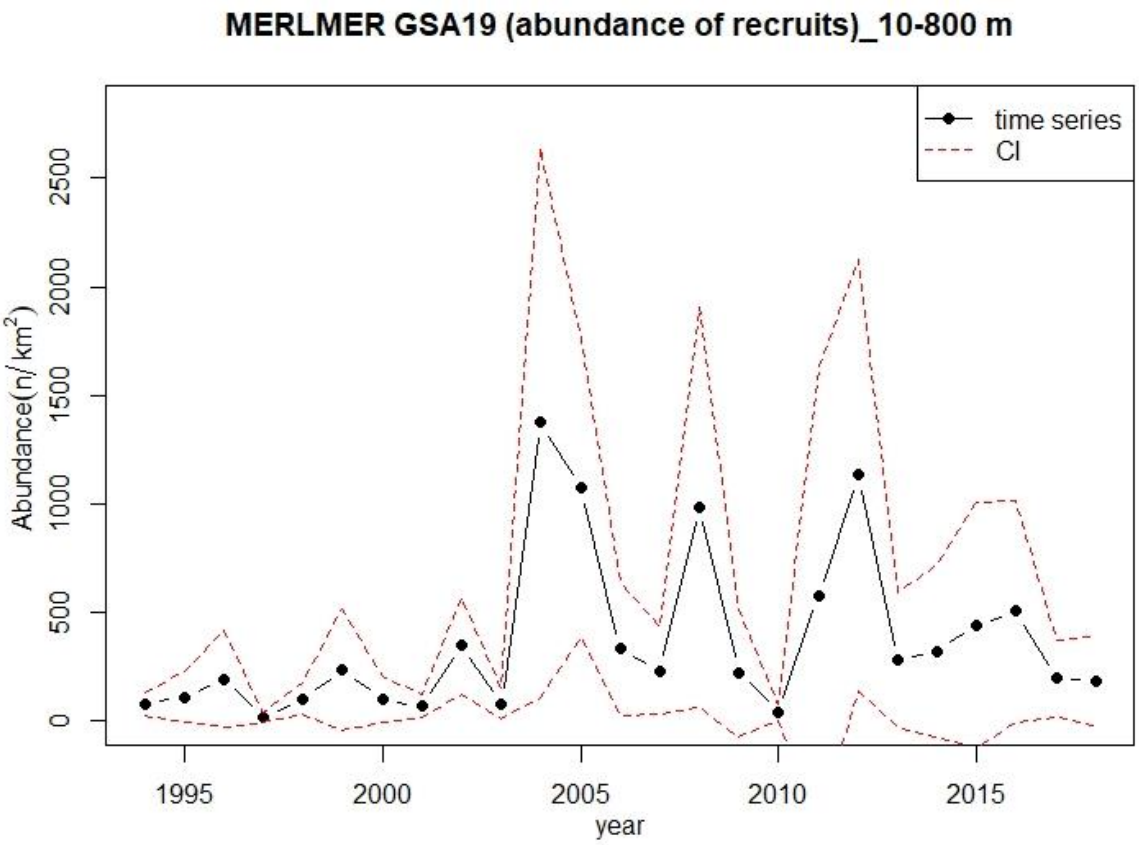


Figure 4.1.4-1: MEDITS trawl surveys; recruitment index with CI (red dotted lines).

4.1.5 Direct methods: trawl based Spawner analysis

Due to the poor presence of individuals longer than 40 cm in the MEDITS survey, MEDITS project could not identify a suitable threshold for spawners for this species in the area. A spawner index (N/km^2) was in any case estimated and reported in Table 4.1.5-2, defining as spawners the individuals > 33 cm, that is the size at first maturity of females from DCF biological data.

M. merluccius is a multiple spawner; the spawner index does not show any particular peak in the trend. Despite of this, it should be considered that individuals of length greater than 40 cm are poorly sampled, thus this index should be considered with caution.

Table 4.1.5-1: MEDITS trawl surveys; spawners analysis summary

Survey	MEDITS	Trawler/RV	PEC
Survey season			Survey season
Investigated depth range (m)			10-800 m
Spawning season and peak (months)			December-November

Table 4.1.5-2: MEDITS trawl surveys; spawner index.

Years	Area in km^2	N of recruit per km^2	CV
1994	16347	3.8	26.1
1995	16347	4.3	35.1
1996	16347	5.7	22.3
1997	16347	6.3	28.3
1998	16347	2.2	33.5
1999	16347	4.3	38.7
2000	16347	3.0	25.8
2001	16347	4.6	27.0
2002	16347	2.8	42.2
2003	16347	4.4	30.8
2004	16347	4.5	28.6
2005	16347	10.1	17.5
2006	16347	8.4	21.1
2007	16347	8.1	37.6
2008	16347	10.1	17.7
2009	16347	12.2	17.9
2010	16347	6.8	17.9
2011	16347	4.8	22.5
2012	16347	3.3	26.1

2013	16347	10.6	20.3
2014	16347	11.3	18.8
2015	16347	6.0	19.6
2016	16347	3.8	30.4
2017	16347	10.1	23.9
2018	16347	8.8	16.6

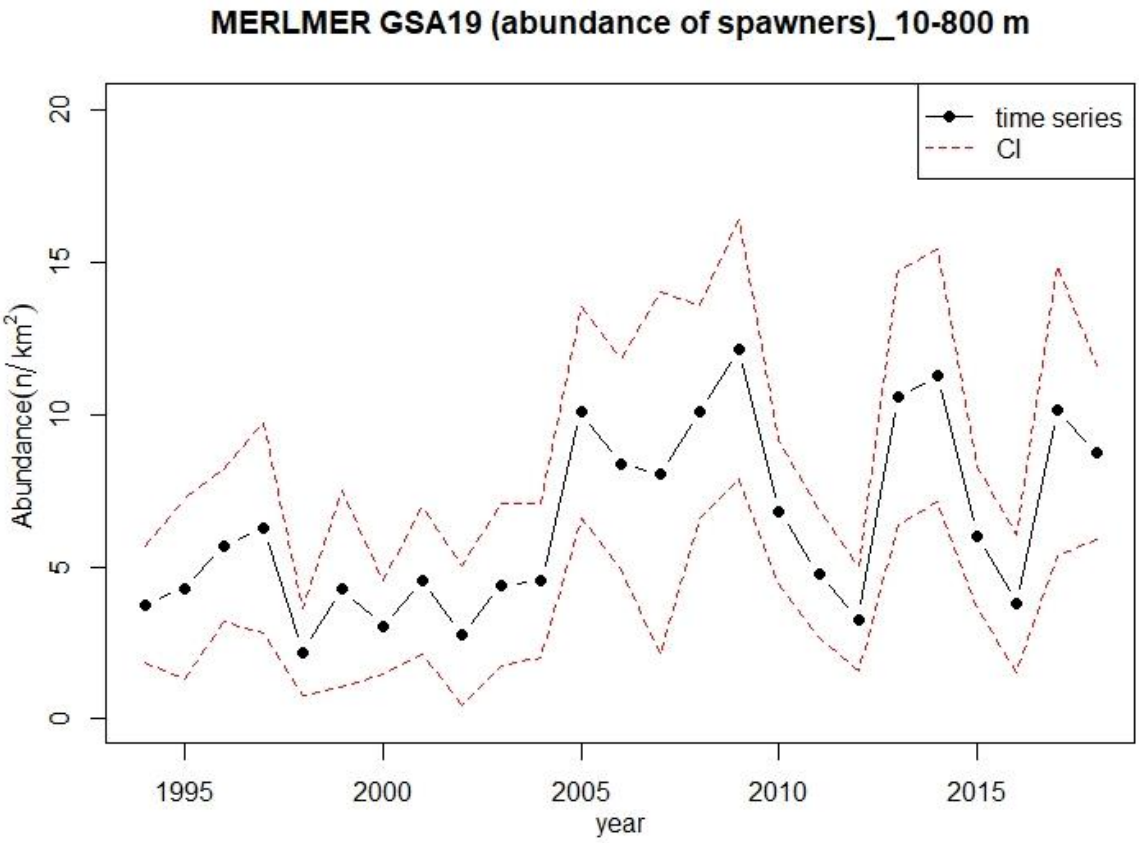


Figure 4.1.5-1: MEDITS trawl surveys spawners index.

4.1.6 Spatial distribution of the resources

MEDISEH project identified the main nurseries in the area, being located on the shelf between Otranto and Santa Maria di Leuca, around the Amendolara Bank, in the Gulf of Squillace and offshore Siracusa.

Spawning areas were not identified.

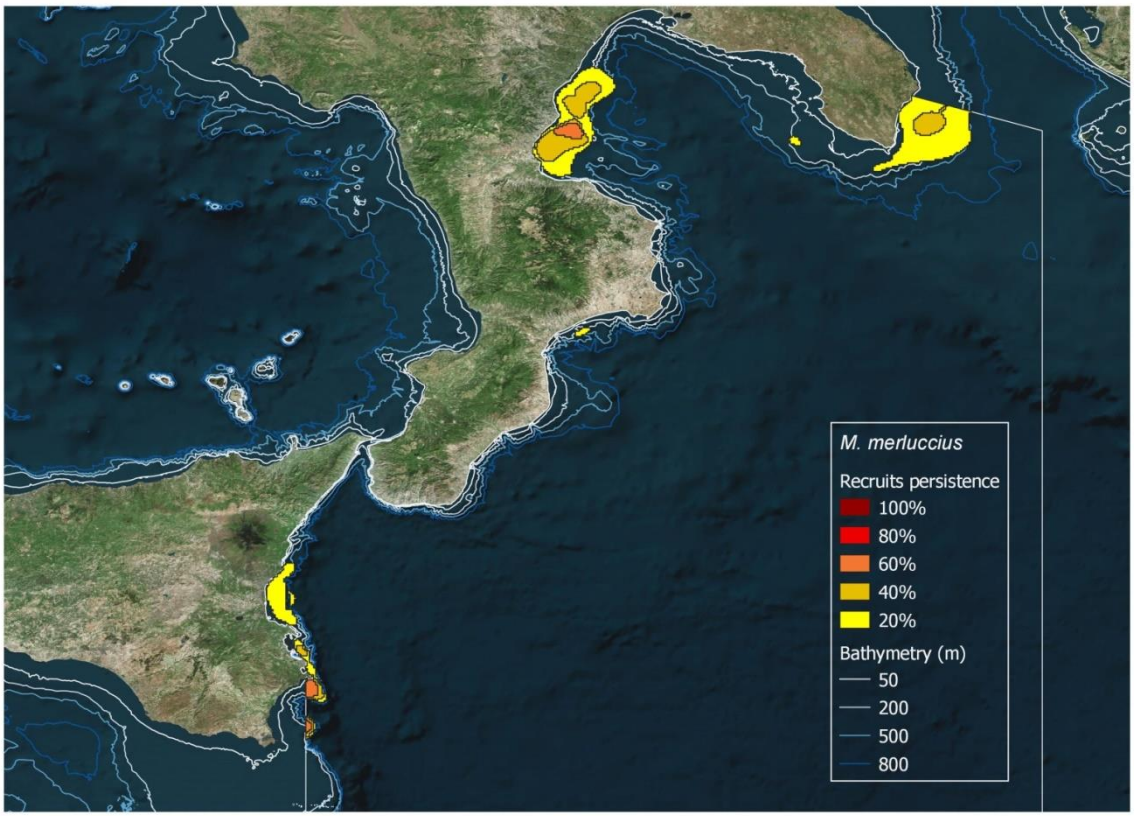


Figure 4.1.6-1 Nursery areas of *M. merluccius* GSA 19.

4.1.7 Historical trends

The density index shows an trend significantly increasing (Spearman's rho 0.455, pvalue<0.05), while the biomass index does not show any significant trend.

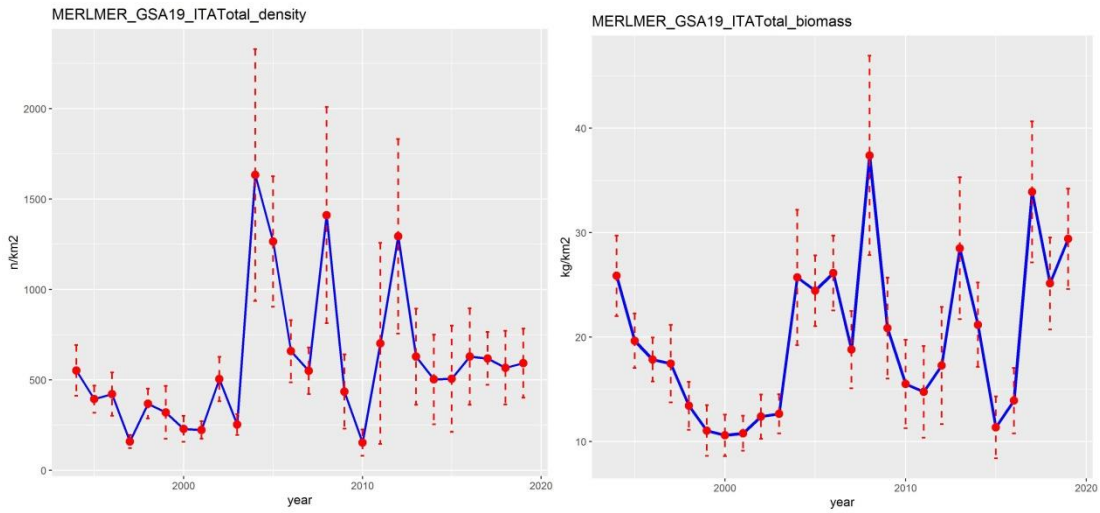


Figure 4.1.7 –1 Density (right) and biomass (left) indices from MEDITS trawl survey.

5 Ecological information

5.1 Protected species potentially affected by the fisheries

No analysis was carried out on this aspect.

5.2 Environmental indexes

No analysis was carried out on this aspect.

6 Stock Assessment

During the GFCM WGSAD 2020, the STECF EWG 20-15 presented the updated assessment, highlighting the impossibility to update the benchmark assessment using the same model used during the benchmark, due to the instability of the catchability sub-model. A similar model was used, among the scrutinized during the benchmark and giving comparable performance (see details below).

In addition, STECF EWG 20-15 found some discrepancies between the stock in weight estimated during the benchmark and the ones estimated during the EWG 20-15. During the STECF EWG 21-02 the possible reasons of this discrepancy were scrutinized. The main reason of this discrepancy was found in the age slicing of the catch LFDs, that was carried out using the growth parameters of females for both males and females. This was due to some rows erroneously omitted as they were commented out in the R code used to slice the LFDs (these were von bertalanffy function for males, located just before the slicing). This led to the inclusion of older males in younger age classes and, as a consequence, to increase the individual weight of the age classes from 2 years to 7+ (the ages where the sexual dimorphism in hake is more evident). A possible explanation for this is that those specific rows of code had been omitted when using the script to perform the slicing with sex combined. This error produced both differences in the catch at age matrix and in the stock in weight matrix; indeed, the latter was calculated weighing the individual weights by the numerosity of females and males in each age class. The differences were most pronounced in the ages 2-6.

Two other minor discrepancies were found: the use of the mean of DCF a and b of length-weight relationship from the years 2002-2018 in the benchmark, while the median 2002-2019 was used during the EWG 20-15; and the DCF sex ratio at length during the benchmark aggregated over years until 2018, while during the EWG 20-15 was used by year until 2019. This was due to a new submission of the data in 2020, that reported for this stock the same information, but by year.

The assessment was run with these settings is reported below, and a comparison between the main assessment results of EWG 20-15 and the new assessment shows no important differences in the status of the stock (Figure XX.3). The reference point F0.1 is now 0.143, instead of 0.135 (EWG 2015).

6.1 Statistical Catch at age (a4a)

A statistical catch-at-age assessment was carried out for this stock, using the Assessment for All Initiative (a4a) method (Jardim et al., 2015). The a4a method utilizes catch-at-age data to derive estimates of historical population size and fishing mortality. Model parameters estimated using catch-at-age analysis are done so by working forward in time and analyses do not require the assumption that removals from the fishery are known without error.

6.1.1 Model assumptions

The assessment was carried out using the period 2004-2019 for catch data and survey index for the ages 0 to 7+. Concerning the F_{bar}, the age range used was 0-4 age groups, being this the age range more represented in the catch and in the F at age.

During STECF EWG 21-02, the assessment was re-run with the corrected catch at age and

stock in weight matrices, both with the original catchability sub-model of the benchmark and the new catchability sub-model identified in EWG 20-15. The former returned results showing instability of the model, as obtained in EWG 20-15 (Figure 6.1.1.1 and Figure 6.1.1.2). Thus, the assessment was performed with the alternative catchability sub-model identified in the EWG 20-15. It should be noted that this model was selected as a candidate for among the models examined during the benchmark and had been found to be similar in main metrics to the unstable model previously selected. For this reason, the results of this revised model are reported thereafter.

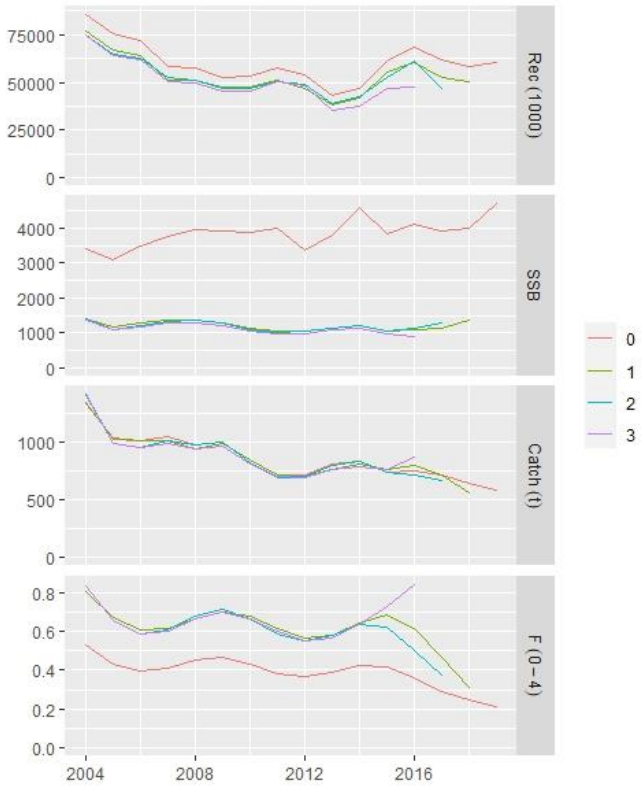


Figure 6.1.1.1 Retrospective with the corrected data using the original catchability benchmark sub-model.

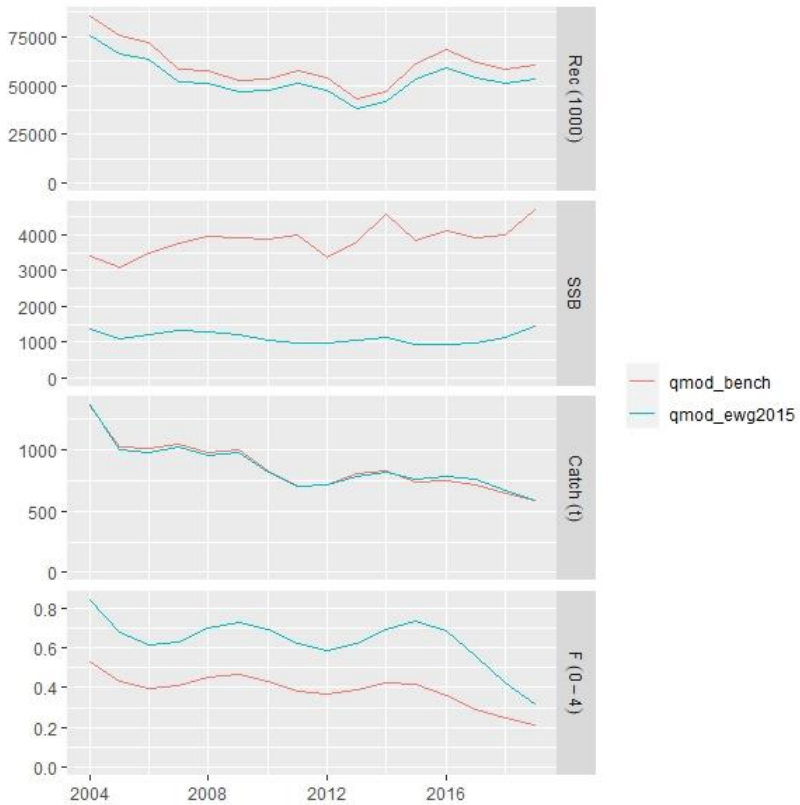


Figure 6.1.1.2 Comparison between the assessment with the corrected data , using the benchmark catchability sub-model and the one selected in EWG 20-15.

6.1.2 Scripts

During the benchmark, a model selection procedure was performed taking into account statistical measures (AIC, BIC) and model diagnostics (residuals, retrospective) and fitting.

The sub-models explored are:

F sub-models:

- `fmod1<-  ~ s(age, k=5) + s(year, k = 7) + te(age, year)`
- **`fmod2 <- ~ s(age, k=5)+s(year, k=7) + s(year, k=7, by=as.numeric(age==0))`**

Q sub-models:

- `qmod1 <-  list(~factor(replace(age,age>2,2))))`
- **`qmod2<- list(~factor(age))`**
- `qmod3<-list(~1)`

SR sub-models:

- `srmod1 <- ~factor(year)`
- `srmod2 <- ~s(year,k=7)`
- **`srmod3 <- ~geomean(CV=0.2)`**

In bold are reported the sub-models returning the best fit during the benchmark.

The underlined models are the one used in this revised assessment.

6.1.3 Input data and Parameters

The catch at age and the stock in weight have been re-estimated, after correcting the error in the R code for the slicing of catches. The assumptions made for natural mortality, maturity at age, F and M before spawning (=0) were maintained in line with what agreed during the benchmark. The reconstructed LFDs for GNS+GTR (nets) for the years 2004, 2009 and 2010 were carried out using the neighbouring years, as in the benchmark, but through R code, in order to be more easily replicable. The discard in volume was estimated in the years 2004, 2005, 2007 and 2008, using the information of the neighbouring years; analogously for the corresponding LFDs. This was also in line with the benchmark, but it was made by R code as well. MEDITS data have been mantained equal, because were already correctly sliced.
Input data in terms of catch numbers and mean weight at age are shown in **Figure 6.1.3.1**. Proportion of mature and M at age are shown in **Table 6.1.3.1**. The plus group in the catch data was set to age 7, and ages 0-4 in MEDITS survey data were used to tune the assessement model. The age range of Fbar was set to age 0-4 as the majority of the catches were represented by these age classes.

Catch data were SOP corrected using the ratio between total catch and SOPs at year **(Table 6.1.3.2).**

Relativily good consistency is observed between cohorts in the catch and survey data (**Fig. 6.1.3.1**).

Table 6.1.3.1 Hake in GSA 19. Proportion of mature specimens at age. Natural mortality (M) at age

Age	0	1	2	3	4	5	6	7+
Maturity	0.03	0.33	0.57	0.92	0.99	0.98	1.00	1.00
M	1.27	0.69	0.45	0.34	0.28	0.24	0.22	0.20

Table 6.1.3. 2 SOP correction applied to the catch at age.

Year	SOP
2004	0.996
2005	1.060
2006	1.064
2007	1.023
2008	1.036
2009	0.995
2010	0.993
2011	0.998
2012	1.000
2013	0.996
2014	0.994
2015	1.103
2016	1.181
2017	1.341

2018	1.233
2019	1.004

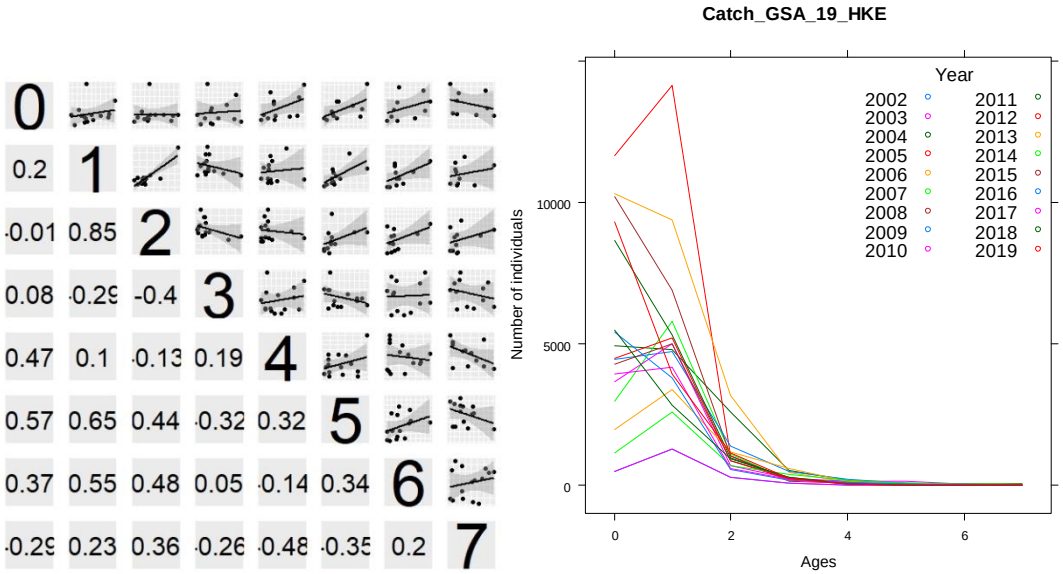


Figure 6.1.3.1 Hake in GSA 19. Hake number of individuals (thousands) at age of the catch in GSA 19. Data from DCF.

6.1.4 Tuning data

Table 6.1.4-1 Index at age matrix of survey derived using age slicing (the index until age 4 was used, because the other age classes are poorly represented).

Year/Age	2004	2005	2006	2007	2008	2009	2010	2011
0	1487	1089	442	395	1212	281	64	606
1	96	109	162	125	148	114	54	70
2	18	23	30	19	37	22	24	15
3	4	8	8	11	8	13	7	2
4	2	2	4	1	3	3	1	1
Year/Age	2012	2013	2014	2015	2016	2017	2018	2019
0	1193	430	422	459	541	340	363	466
1	27	146	49	31	65	203	163	67
2	12	36	17	7	16	55	27	34
3	3	11	6	6	2	10	11	17
4	1	3	4	2	2	4	1	4

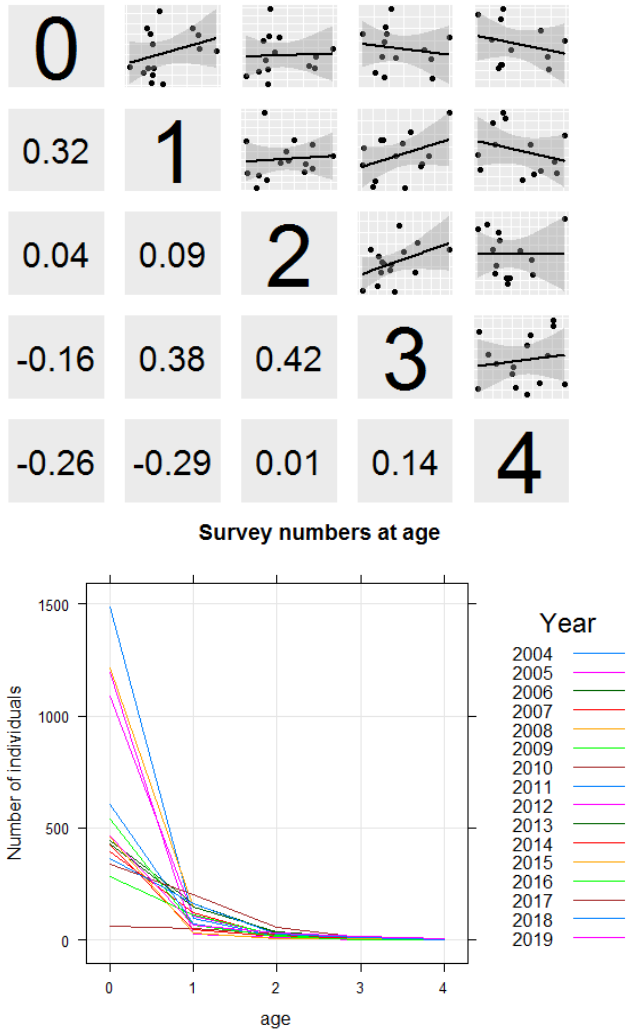


Figure 6.1.4-1 Comparison of the two methods for deriving the index at age, with consistency plots.

6.1.5 Results

The a4a models used in the hake GSA19 benchmark assessment (GFCM 2019) were tested with the new data added in 2019 and the corrected data until 2018. As the original submodels used for the benchmark assessment resulted in high instability of the present assessment, the survey catchability (originaly qmodel <- list(~factor(age), GFCM, 2019) was replaced by a model assigning equal catchability at ages >2**.** Fishing mortaliy and Stock-recruit sub-models remain the same as used for the benchmark assessment (GFCM, 2019).

Summary results and diagnostics from the a4a model are presented in **Figures 6.1.5.1** and **6.1.5.2.** Fishing mortality at age and catchabiity at age are presented in **Figure 6.1.5.1.**

The results and the diagnostics of the fitted model are very similar to those obtained at the benchmark assessment (GFCM 2019). The estimated catch follows the trend of the input catch data (except for 2006). The stock summary with simulated confidence intervals is presented at **Figure 6.1.5.4**. The SSB is increasing after 2016 while fishing mortality is decreasing. Estimated stock numbers and fishing mortality at age, as well as

stock summary are presented at **Tables 6.1.5.1** to **6.1.5.6.**

A B

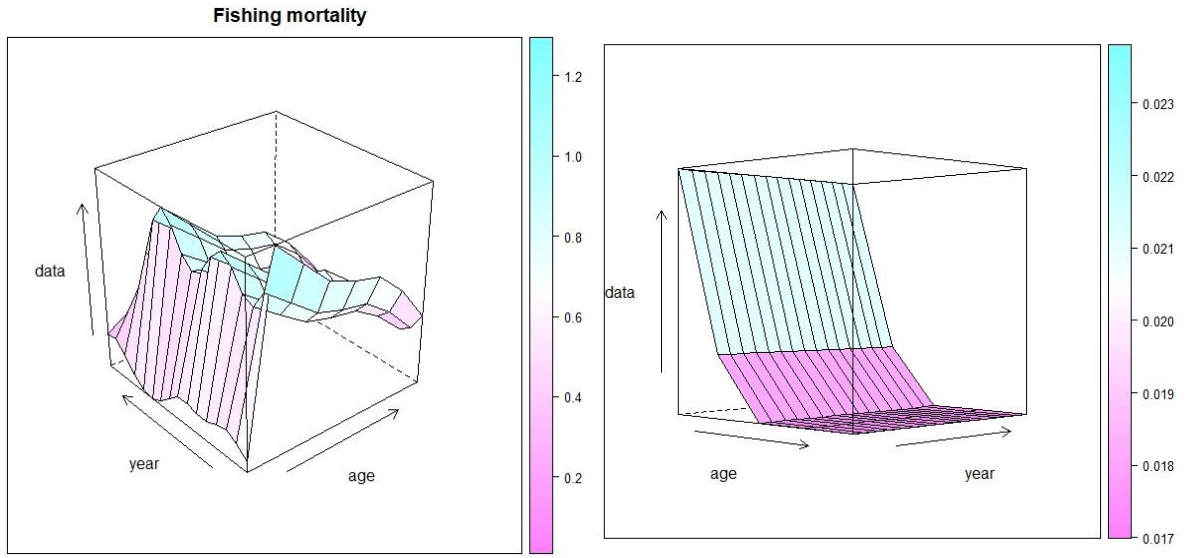
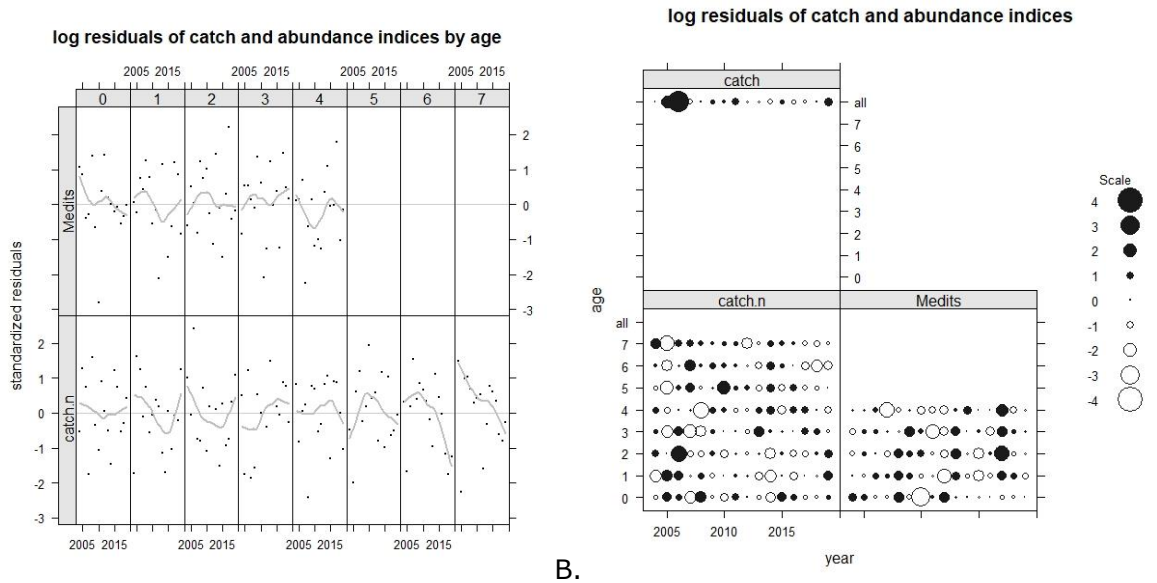
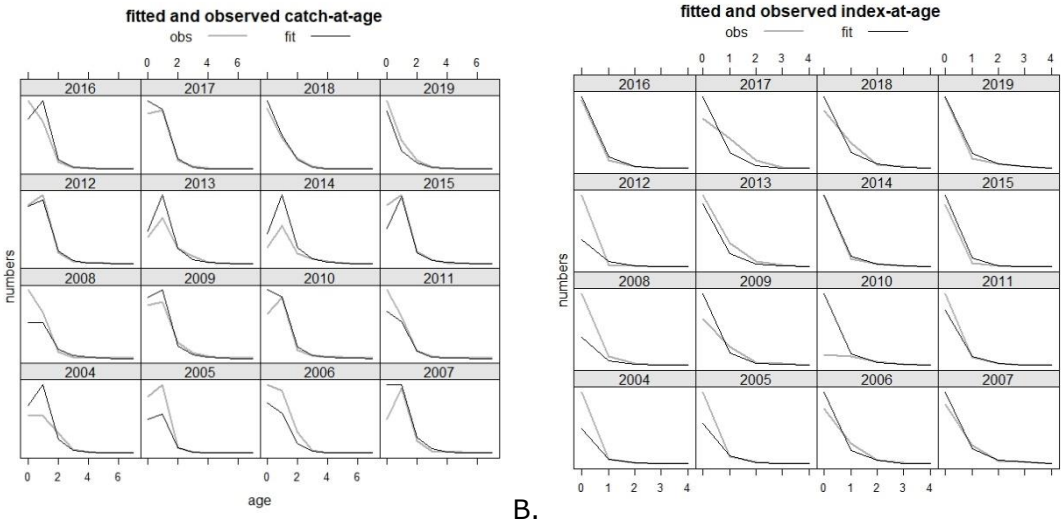


Figure 6.1.5.1 Hake in GSA 19. 3D plots of fishing mortality (A), and survey catchability (B) at age and year



A. B.

Figure 6.1.5.2 Hake in GSA 19. Standardized residuals for abundance indices (MEDITS) and catch at age data. Each panel present residuals by age and year.



A. B.

Figure 6.1.5.3 Hake in GSA 19. Fitted and observed catch (A.) and survey (B) numbers at age.

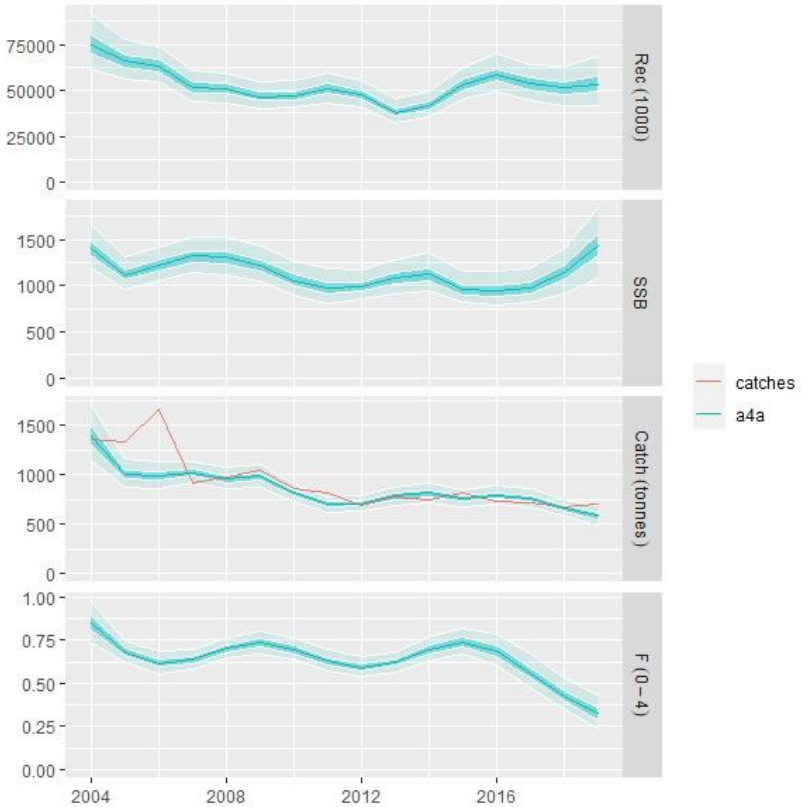


Figure 6.1.5.4 Hake in GSA 19. Stock summary for hake in GSA 19, recruits ('000), SSB (t), catch (t) and Fbar (age 0-4). Estimated catch is compared to recorded catch.

Table 6.1.5.1 Hake in GSA 19. Number of individuals per year by age group (ages 0-5) in the catch in GSA 19 (2004-2019). Data from DCF.

Year/Age	2004	2005	2006	2007	2008	2009	2010	2011
0	4933	11679	10329	2980	10216	4463	3668	8648
1	4811	14155	9376	5790	6919	4748	4998	5330
2	2598	1044	3182	1096	1039	1369	700	954
3	526	138	444	187	204	475	253	240
4	165	68	96	108	69	196	145	64
5	38	12	42	72	38	73	127	47
6	27	4	11	37	22	29	35	21
7+	46	1	24	28	23	18	19	24
Year/Age	2012	2013	2014	2015	2016	2017	2018	2019
0	4486	1957	1126	4271	5426	3947	5494	9335
1	5218	3400	2591	5021	3800	4178	2839	3924
2	862	1172	690	874	553	603	939	1157
3	203	580	383	288	161	212	281	248
4	73	129	167	64	100	55	46	56
5	39	25	71	24	51	14	11	20
6	13	7	32	18	11	4	2	3
7+	2	10	33	24	14	4	3	4

Table 6.1.5.2 Hake in GSA 19. Hake Weight of individuals at age in the catch in GSA 19 (2004-2019). Data from DCF.

Year/Age	2004	2005	2006	2007	2008	2009	2010	2011
0	0.023	0.019	0.018	0.023	0.016	0.022	0.020	0.017
1	0.069	0.055	0.056	0.060	0.055	0.061	0.054	0.049
2	0.163	0.144	0.170	0.145	0.150	0.166	0.160	0.172
3	0.355	0.338	0.329	0.349	0.367	0.362	0.387	0.327
4	0.661	0.599	0.614	0.632	0.619	0.625	0.653	0.632
5	0.930	0.872	0.952	0.958	0.999	0.941	0.987	1.030
6	1.360	1.266	1.407	1.423	1.445	1.379	1.400	1.449
7+	2.767	2.097	2.247	2.209	2.212	2.087	2.122	2.273

Year/Age	2004	2005	2006	2007	2008	2009	2010	2011
Year/Age	2012	2013	2014	2015	2016	2017	2018	2019
0	0.019	0.019	0.018	0.016	0.017	0.018	0.013	0.016
1	0.054	0.064	0.065	0.057	0.056	0.056	0.062	0.058
2	0.164	0.170	0.168	0.162	0.160	0.163	0.167	0.156
3	0.366	0.348	0.365	0.354	0.370	0.362	0.342	0.360
4	0.637	0.563	0.613	0.582	0.639	0.619	0.542	0.594
5	0.941	0.826	0.957	0.913	0.956	0.864	0.942	0.868
6	1.438	1.399	1.427	1.456	1.390	1.290	1.418	1.251
7+	1.511	1.967	2.745	2.146	2.440	2.133	1.854	2.080

Table 6.1.5.3 Hake in GSA 19. Number of individuals per year by age group (ages 0-4) according to MEDITS surveys.

Year/Age	2004	2005	2006	2007	2008	2009	2010	2011
0	1487	1089	442	395	1212	281	64	606
1	96	109	162	125	148	114	54	70
2	18	23	30	19	37	22	24	15
3	4	8	8	11	8	13	7	2
4	2	2	4	1	3	3	1	1
Year/Age	2012	2013	2014	2015	2016	2017	2018	2019
0	1193	430	422	459	541	340	363	466
1	27	146	49	31	65	203	163	67
2	12	36	17	7	16	55	27	34
3	3	11	6	6	2	10	11	17
4	1	3	4	2	2	4	1	4

Table 6.1.5.4 Hake in GSA 19. Hake number of individuals at age in the stock in GSA 19 (2004-2019)

Year/Age	2004	2005	2006	2007	2008	2009	2010	2011
0	75228	65948	63478	51813	51005	46831	47273	50909
1	16166	18209	15021	13978	11590	11694	10728	10609

Year/Age	2004	2005	2006	2007	2008	2009	2010	2011
2	3359	2396	3517	3236	2911	2176	2085	2036
3	795	738	664	1073	958	787	562	569
4	238	224	254	249	392	323	255	191
5	94	76	86	105	101	147	117	97
6	47	32	31	38	46	41	57	48
7+	27	33	34	35	39	43	42	50
Year/Age	2012	2013	2014	2015	2016	2017	2018	2019
0	47616	38084	41879	53238	58795	53653	51398	53431
1	11457	11284	9567	10807	13600	14257	11947	10812
2	2230	2502	2316	1739	1846	2558	3316	3446
3	608	688	731	608	433	500	835	1307
4	209	230	248	241	191	146	198	390
5	78	88	92	91	85	72	64	101
6	42	35	38	36	35	34	34	35
7+	53	52	47	43	39	38	41	47

Table 6.1.5.5 Hake in GSA 19. Hake fishing mortality at age (2004-2019)

Year/Age	2004	2005	2006	2007	2008	2009	2010	2011
0	0.153	0.213	0.247	0.232	0.207	0.208	0.228	0.226
1	1.216	0.951	0.842	0.876	0.979	1.031	0.968	0.867
2	1.068	0.835	0.739	0.769	0.860	0.906	0.850	0.761
3	0.920	0.720	0.637	0.663	0.741	0.781	0.733	0.656
4	0.860	0.672	0.595	0.619	0.692	0.729	0.685	0.613
5	0.823	0.644	0.570	0.593	0.663	0.698	0.656	0.587
6	0.687	0.537	0.475	0.494	0.553	0.582	0.547	0.489
7+	0.482	0.377	0.334	0.347	0.388	0.409	0.384	0.343
Year/Age	2012	2013	2014	2015	2016	2017	2018	2019
0	0.174	0.115	0.089	0.099	0.151	0.236	0.293	0.291
1	0.828	0.891	1.012	1.074	0.977	0.765	0.550	0.386
2	0.727	0.782	0.888	0.943	0.858	0.672	0.483	0.339

Year/Age	2004	2005	2006	2007	2008	2009	2010	2011
3	0.627	0.674	0.766	0.813	0.740	0.579	0.416	0.292
4	0.586	0.630	0.715	0.759	0.691	0.541	0.389	0.273
5	0.561	0.603	0.685	0.727	0.662	0.518	0.372	0.261
6	0.468	0.503	0.571	0.606	0.552	0.432	0.311	0.218
7+	0.328	0.353	0.401	0.426	0.387	0.303	0.218	0.153

Table 6.1.5.6 Stock summary: number of recruits, SSB, Fbar 0-4, estimated catch.

Year	Recruitment age 0, in thousands	SSB, t	Fbar 0-4	Catch, t
2004	75228	1371	0.84	1370
2005	65948	1102	0.68	1001
2006	63478	1206	0.61	982
2007	51813	1311	0.63	1023
2008	51005	1297	0.70	959
2009	46831	1216	0.73	980
2010	47273	1057	0.69	818
2011	50909	968	0.62	701
2012	47616	989	0.59	712
2013	38084	1072	0.62	787
2014	41879	1114	0.69	819
2015	53238	954	0.74	759
2016	58795	941	0.68	790
2017	53653	971	0.56	762
2018	51398	1132	0.43	665
2019	53431	1427	0.32	585

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

The retrospective analysis as well as the plot of residuals did not show any signal of instability or trend (Figures 6.1.7-1).

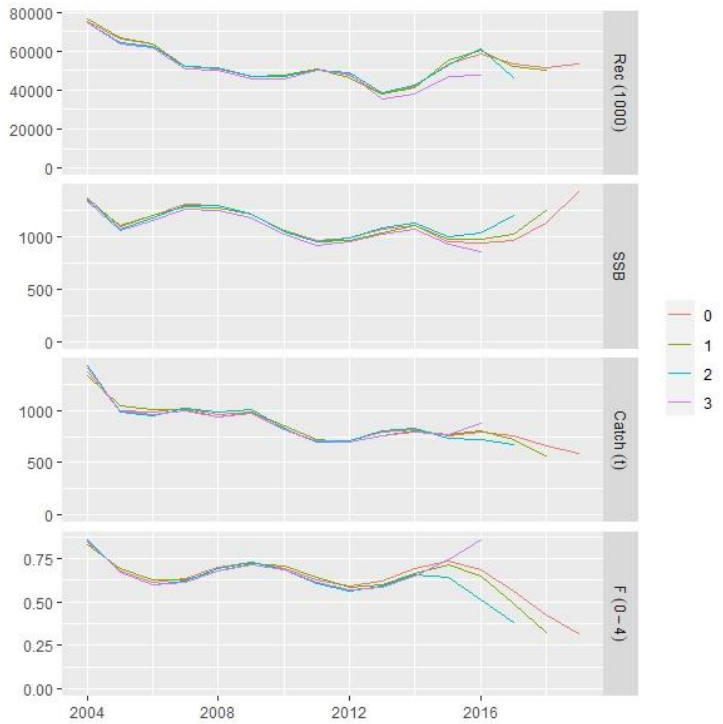


Figure 6.1.7-1 Retrospective analysis of the revised model.

6.1.7 Assessment quality

Considering the exploration of discrepancies in the input data, the retrospective analysis and the residuals diagnostic of the revised model, the assessment results, that are also n line with the benchmark results, can be considered quite reliable.

7 Stock predictions

7.1 Short term predictions

The library FLBRP available in FLR was used to estimate $F_{0.1}$ from the stock object. Current Fbar= 0.32 is higher than $F_{0.1}$ (0.143), chosen as proxy of F_{MSY} and as the exploitation reference point consistent with high long-term yields, which indicates that hake stock in GSA 19 is over-exploited.

A deterministic short term prediction for the period 2020 to 2022 was performed using the FLR libraries and scripts, and based on the results of the a4a revised stock assessment.

Table 7.1.1 Hake in GSA 19: Assumptions made for the interim year (2020) and in the STF forecast.

Variable	Value	Notes
Biological Parameters		mean weights at age, maturation at age, natural mortality at age and selection at age, based average of 2017-2019
$F_{ages\ 0\text{-}4}$ (2020)	0.32	F status quo (in the interim year 2020) is assumed Fbar in the last assessment year (2019)
SSB (2020)	1880 t	SSB projection based on stock assessment
R_{age0} (2020)	52455	Geometric mean of the whole time series
Total catch (2020)	689 t	Catch at F status quo in 2020

The results of the short term forecasts for hake (GSA 19) are shown in **Table 7.1.2**.

The F status quo = 0.32 (assumed Fbar in the last assessment year 2019) is larger than $F_{0.1}$ (0.143), which is a proxy of F_{MSY} and is used as the exploitation reference point consistent with high long term yields. This indicates that hake in GSA 19 is over exploited. The catch of hake in 2022, consistent with $F_{0.1}$ (0.143), should not exceed 486 tonnes, 17% less than the current estimated catch (585 t).

Table 7.1.2 Hake (HKE) in GSA 19 short term forecast. Annual catch scenarios and predictions of catch and SSB. Catch and SSB are in tonnes.

Rationale	Ffactor	Fbar	Catch2019	Catch2021	SSB2022	SSB_change_2020-2022(%)	Catch_change_2019-2021(%)
High long term yield (F0.1)	0.45	0.14	585	383	3121	66.0	-34.7
F upper	0.64	0.20	585	523	2950	56.9	-10.6
F lower	0.31	0.10	585	266	3264	73.6	-54.6
FMSY transition	0.82	0.26	585	655	2791	48.5	11.9
Zero catch	0.00	0.00	585	0	3592	91.1	-100.0
Status quo	1.00	0.32	585	781	2640	40.4	33.4
Different Scenarios	0.10	0.03	585	89	3482	85.3	-84.8
	0.20	0.06	585	175	3376	79.6	-70.1
	0.30	0.09	585	259	3273	74.1	-55.8
	0.40	0.13	585	340	3174	68.8	-42.0
	0.50	0.16	585	419	3077	63.7	-28.5
	0.60	0.19	585	495	2984	58.7	-15.4
	0.70	0.22	585	570	2894	53.9	-2.7
	0.80	0.25	585	642	2806	49.3	9.7
	0.90	0.28	585	712	2722	44.8	21.7
	1.10	0.35	585	847	2560	36.2	44.7
	1.20	0.38	585	912	2484	32.1	55.7
	1.30	0.41	585	974	2409	28.2	66.4
	1.40	0.44	585	1035	2337	24.3	76.9
	1.50	0.47	585	1095	2267	20.6	87.0
	1.60	0.51	585	1152	2200	17.0	96.8
	1.70	0.54	585	1208	2135	13.6	106.4
	1.80	0.57	585	1263	2071	10.2	115.7
	1.90	0.60	585	1316	2010	6.9	124.7
	2.00	0.63	585	1367	1951	3.8	133.5

7.2 Medium term predictions

7.3 Long term predictions

8 Draft scientific advice

(Examples in blue)

Based on	Indicator	Analytic al reference point	Current value from the analysis	Empirical reference value (name and value)	Trend (time period)	Stock Status
Fishing mortality	Fishing mortality	$F_{0.1}$ = 0.143	F current (2019) = 0.32		D	IO_I
Stock abundance	SSB		SSB(2019)= 1321 tons	33_{th} percentile	1054	O_H
				66_{th} percentile	1194	
Recruitment						
Final Diagnosis		In overexploitation and with relatively 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)