Stock Assessment Form

Demersal species

HAKE – GSA6

Reference year: 2002 - 2019

Reportingyear: 2021

José Luis Pérez Gil*, Antonio Esteban**, Encarnación García**, Miguel Vivas** and ***María José Meléndez****.

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European hake is a target demersal species of the Mediterranean fishing fleets. It is largely exploited in GSA6, mainly by trawlers on the shelf and slope (95% landings), but also by small-scale fisheries using long lines (2%) and gillnets and trammel nets (3%) (average percents estimated between 2016 and 2019). According to official statistics, around 1000 boats are involved in this fishery, with total annual landings oscillating around 1900 tons for the period 2016-2019 (1628 tons in 2019).

The trawler fleet is the largest in number of boats (419) and landings (1512 tons) in 2019. The assessment was carried out using official landings and data on the size composition of trawl, long lines and set gillnet catches for the years 2002-2019. Both extended Survivor Analysis (XSA) and a4a were used. Additionally, yield per recruit analysis was carried out. The final model considered for the assessment was a4a.

Total biomass (B) and yield (Y) showed a general decreasing trend from 2002 to 2019. Recruitment (R) showed a drastic decline from the maximum observed in 2002. Fishing mortality (F_{bar0-2}) shows a slight increase until 2013 and a decreasing trend until 2018, followed by a slight increase until 2019 when estimated F is 1.2.

Y/R analysis showed that the $F_{current}$= (1.2) exceeds the Y/R $F_{0.1}$ reference point = (0.14). The resulting ratio $F_{0.1}/F_{current}$ = 8.57, suggesting that for*Merlucciusmerluccius* stock in GSA6, the current exploitation level is in over exploitation and the stock size is overexploited (Relative low biomass).

Stock Assessment Form version 1.0 (January 2014)

Uploader: José Luis Pérez Gil*,María González*, Antonio Esteban**, Encarnación García**, Miguel Vivas** and María José Meléndez *.

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Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Merlucciusmerluccius - HKE	European hake	32 HKE
1st Geographical sub-area:	2nd Geographical sub-area:	3rd Geographical sub-area:
Northern Spain GSA_6		
4th Geographical sub-area:	5th Geographical sub-area:	6th Geographical sub-area:
1st Country	2nd Country	3rd Country
SPAIN		
4th Country	5th Country	6th Country
Stock assessment method: (direct, indirect, combined, none)		
XSA and a4a (tuned with MEDITS indices) and Y/R		
Authors:		
José Luis Pérez Gil*, María González*, Antonio Esteban**, Encarnación García**,Miguel Vivas** and María José Meléndez *.		
Affiliation:		
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2 Stock identification and biological information

2.1 Stock unit

The Northern Spain subarea (GSA06) is used as an individualized area for assessment and management purposes in the western Mediterranean. However no study currently allows to state that hake stock is isolated from neighboring areas, for instance from GSAs 01, 05 and 07.

2.2 Growth and maturity

Table 2.2.1: Maximum size, size at first maturity and size at recruitment.

Somatic magnitude measured (LT, LC, etc)			Total length (LT)	**Units**	cm
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	All year: Feb and June
Maximum size observed	90	61	90	**Recruitment season**	All year (higher picks in winter and spring)
Size at first maturity			26	**Spawning area**	Shelf and upper Slope
Recruitment size to the fishery			14.5	**Nursery area**	Continental Shelf

Table 2.2.2: M vector and proportion of matures by size or age (Combined Males-Females))

Age	Natural mortality **	Proportion of matures
0	*1.8*	*0*
1	*0.72*	*0.2965*
2	*0.41*	*0.9855*
3	*0.3*	*0.99*
4	*0.24*	*1*
5+	*0.18*	*1*

** It was decided to assume natural mortality (M) to be age-dependent and to derive the mortality vector applying the same procedure for all the age-based analytical assessments considered at the benchmark. Given the large uncertainty around the actual values of natural mortality, it was decided to derive this vector as an ensemble estimate (here a simple average) of different methods, similarly to what was done at the recent benchmark of European hake in the Adriatic Sea. The different methods selected are mostly based on life history invariants, linking mortality rates with different aspects of growth (i.e., von Bertalanffy growth parameters, longevity, mean weight and length at first maturity), and are those described in Gulland (1987), Chen and Watanabe (1989), Lorenzen (1996), the revised version of Abella *et al.* (1997) by Martiradonna (2012), Gislason *et al.* (2008) and Brodziak *et al.* (2011). The reviewers support the group decision to derive natural mortalities using this common rationale. It is important to note that, with this approach, uncertainties in ageing and estimation of growth also affect the value derived for M. (Benchmark session for the assessment of European hake in GSAs 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 19, 20, 22, 23 and 26, Rome, 2019).

Table 2.2.3: Growth and length weight model parameters

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**				110*	
	K				0.178*	
	t_0					
	Data source	*Mellon-Duval *et al.* (2010) (tagging surveys).**DCF-EU (Spain. 2012)				
Length weight relationship	**a**				0.00677**	
	b				3.035097**	
	M (scalar)				0.4 (Vector average)	
	sex ratio (% females/total)	0.36				

3 Fisheries information

3.1 Description of the fleet

European hake is a target demersal species of the Mediterranean fishing fleets. It is largely exploited in GSA6, mainly by trawlers on the shelf and slope (95% landings), but also by small-scale fisheries using long lines (2%) and gillnets and trammel nets (3%) (average percents estimated between 2016 and 2019).According to official statistics, around 1000 boats are involved in this fishery, with total annual landings oscillating around 1900 tons for the period 2016-2019 (1628 tons in 2019). The trawler fleet is the largest in number of boats (419) and landings (1512 tons) in 2019.

The total annual landings used in the assessment come from the official data.

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*	ESP	06	E-Trawl 12-24 m	03-Trawls	33 – Demersal shelf species	HKE
Operational Unit 2	ESP	06	M-Polyvalent 12-24 metres	07-Gillnets and Entangling Nets	33 – Demersal shelf species	HKE
Operational Unit 3	ESP	06	I-Long line 12-24 metres	09-Hooks and Lines	33 – Demersal shelf species	HKE

Table 3.1.2: Catch, bycatch, discards and effort by operational unit in the reference year

Operational Units	Fleet (n° of boats 2019)	Catch (average 2017-2019 species assessed) (tones)	Discards (species assessed) (tones)	Effort average 2017-2019 (days)	Effort 2019 (days)
03-Trawls	419	1829	78.7	73774	65100
07-Gillnets and Entangling Nets	339	59	-	5000	4387
09-Hooks and Lines	57	44	-	1434	1269
Total 2019	815	1512 OTB; 63 GNS; 52 LLS	78.7	70756	70756

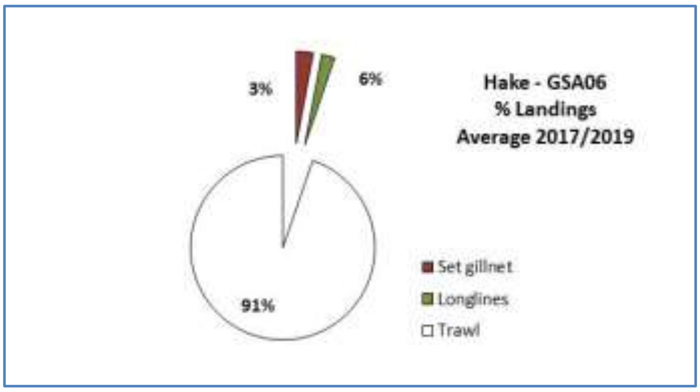


Figure 1.- Percentage landings by fleet in GSA 6 for hake (Average 2017-2019).

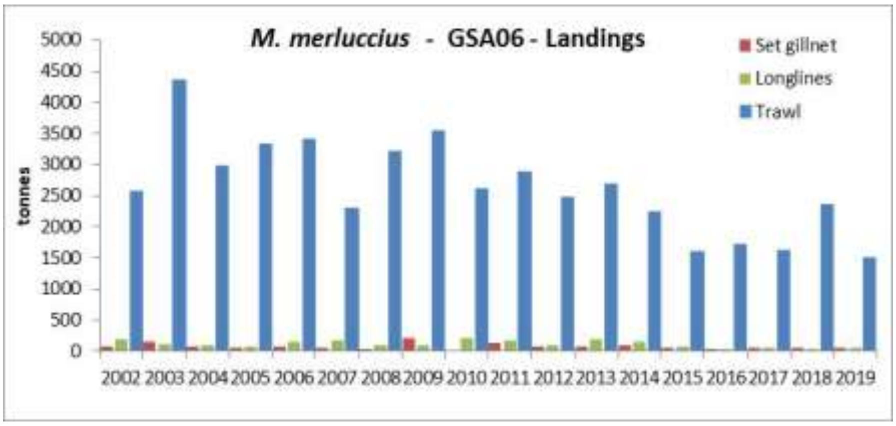


Figure 2.- Hake landings by fishing gear in tonnes.

3.2 Historical trends

Landings have shown important oscillations along the period of the data series. However, in the last years from 2009 onwards, a decreasing trend in landings is observed with the minimum values in the time series data.

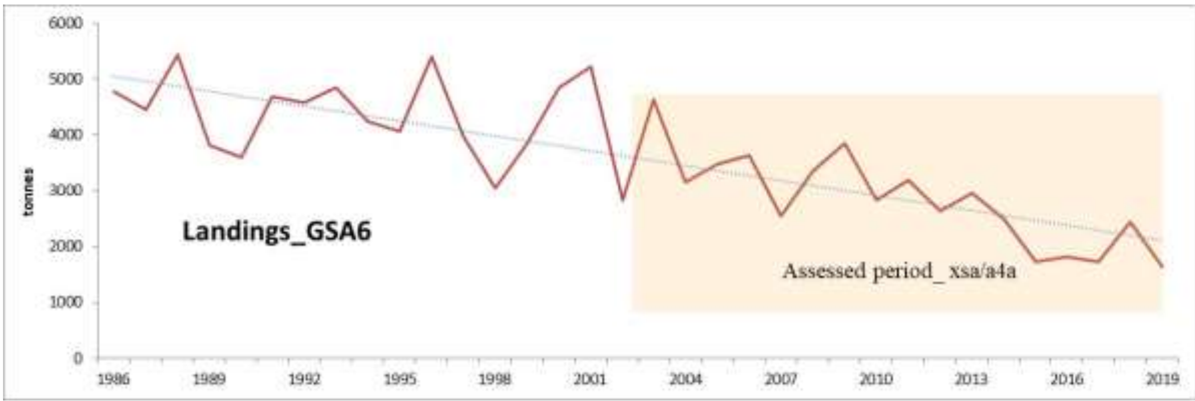


Figure 3.- Hake total landings 1986-2019 - GSA 6

Table 3.1.1: Catches as used in the assessment

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Catch (tonnes)	2835	4633	3151	3473	3627	2540	3341	3847	2822	3182	2641	2950	2489	1726	1810	1728	2443	1628
Minimumsize*	4	4	4	5	5	5	5	5	5	7	5	4	6	5	5	8	7	9
Averagesize *	11.5	15.3	14	16	16	16	15	17	16	22	21	22	22	22	20	22	23	26
Maximumsize*	72	77	90	74	89	85	72	88	77	82	69	87	72	64	69	77	71	79

**cm Total length*

Table 3.1.2: Fishing fleet in GSA 6.

Year / Fleet (nº of boats)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
OTB	559	538	512	484	472	461	453	438	437	418	419
LLS	215	209	169	155	190	162	156	250	88	82	57
GNS-GTR	307	314	310	250	320	210	303	483	385	297	339

Table 3.1.3: Selectivity

L25*	12.8
L50*	14.6
L75*	16.8
Selection factor	3.55

*It corresponds to 40 mm square mesh in the codend in force from 2012.

Data source: García-Rodriguez M. and Fernández A.M. 2005. Influencia de la geometría de la malla del copo en las captura,selectividad y rendimientos de algunas especies de peces comerciales en el Golfo de Alicante (SE de la península Ibérica). Inf.Tec.Ins.Esp.Oceanogr. 185.

3.3 Discards

Discards were not included in the assessment. There is only available discard data for the 2011-2019 period (Figure 4). The average percentage of discards (mainly caught by otter bottom trawlers) was ar 4.6% in this period (1.7 in 2019).

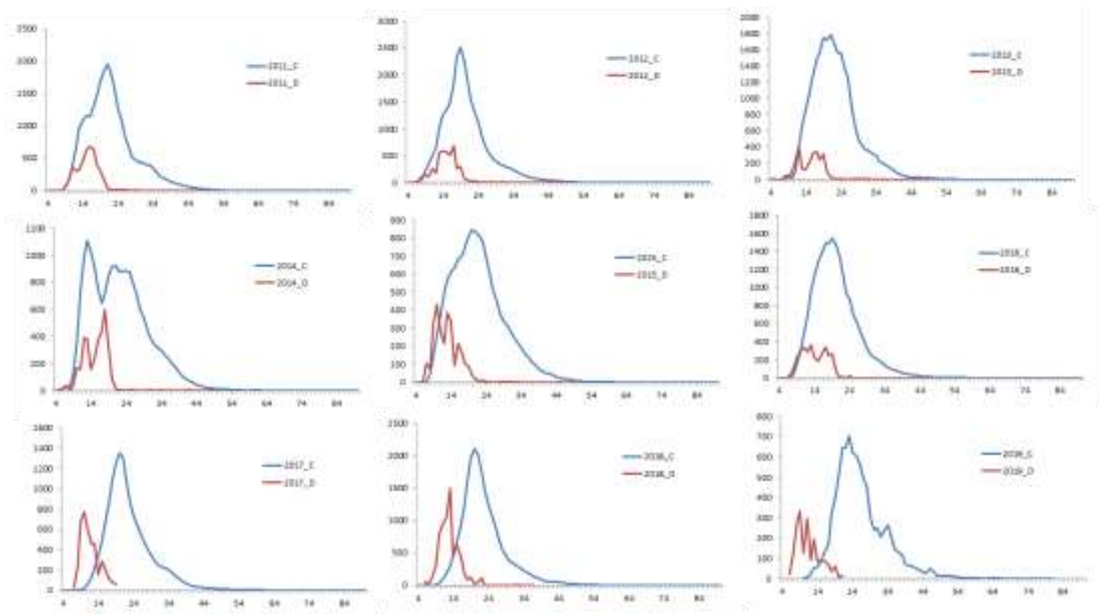


Figure 4.- Length frequency distribution (commercial and discard fraction) for the 2011-2019 period from commercial trawl fleet in the geographical sub-area 6 (Northern Spain).

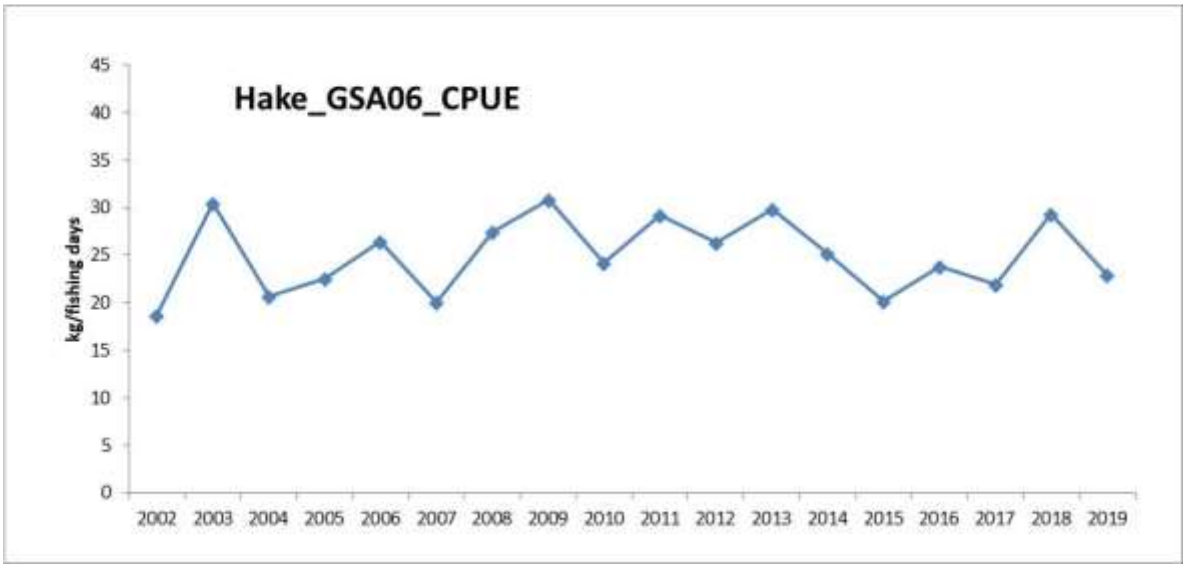


Figure 5.- CPUE (kg/day) for the GSA6 subarea. (Otter bottom trawl, Long lines and Set gillnet fleets)

3.4. Length/age composition.

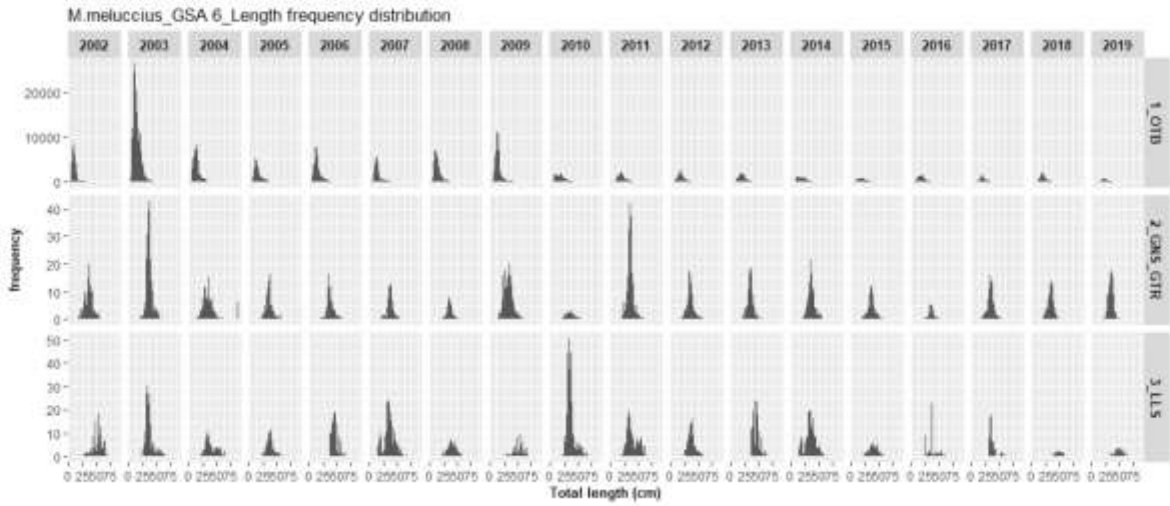


Figure 6.- Length frequency distribution of hake catches by gear in the GSA 6 area (2002-2019 period).

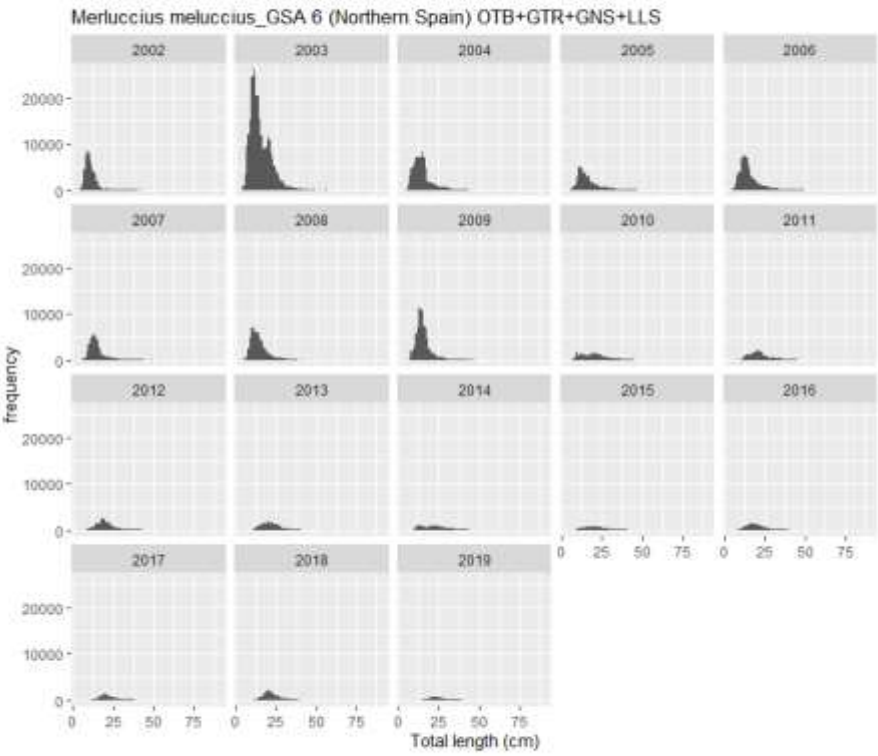


Figure 7.- Length frequency distribution (Total length) of Otter bottom traw, Long linesl and Gillnet (GTR+GNS) catches in the geographical sub-area 6 (Northern Spain) for the period (2002-2019).

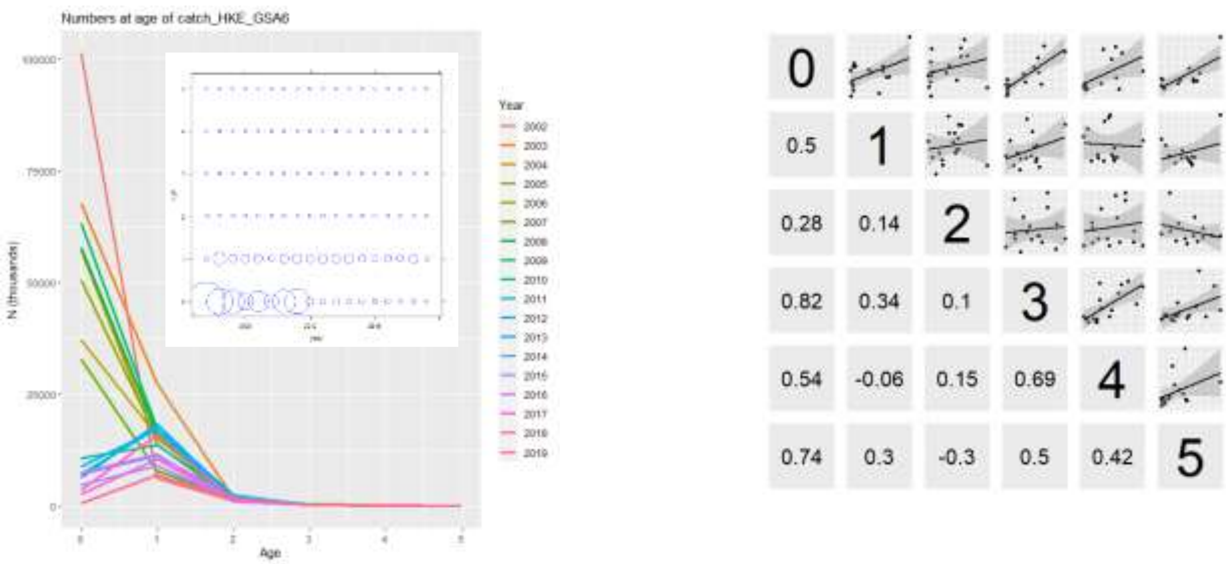


Figure 8.-Catch age matrix (left) and Consistency between cohorts (right) for Hake (All Fishing Gears) in the geographical sub-area 6 (Northern Spain) for the period (2002-2019).

Landings were largely composed of age 0 immature individuals from 2002 to 2009.However, this pattern changed from age 0 to age 1 from 2010 onwards.

Management regulations

- Fishing license: fully observed
- Engine power limited to 316 KW or 500 HP: not fully observed
- Mesh size in the codend (40 mm square or 50 mm rhomboidal): fully observed
- Fishing forbidden within upper 50 m depth: not fully observed
- Time at sea (12 hours per day and 5 days per week): fully observed
- Minimum landing size (20 mm CL), (EC regulation 1967/2006): mostly fully observed
- In force a multiannual plan for the fisheries exploiting demersal stocks in the western Mediterranean Sea and amending Regulation (EU) No 508/2014, in Spain from May 2020 (Orden APA, 423/2020).

4 Fisheries independent information

4.1 MEDITS_ES

4.1.1 Brief description of the direct method used

The Spanish Institute of Oceanography carries out two scientific surveys under the Data Collection Regulation: MEDITS and MEDIAS. Both are international coordinated surveys.

MEDITS is an international bottom trawl survey, the IEO is involved in it from 1994. The survey takes place in all EuropeanMediterranean countries and the main target species are the demersal species.

The Spanish Medits survey carries out about 170 – 180 hauls in spring. It samples 4 GSAs, including Balearic Islands, and the sampling procedure is based on the common methodology included in the MEDITS instruction manual. The GSAs sampled are: GSA1, GSA2, GSA5 and GSA6.

Direct methods: trawl based abundance indices

Table 4.1-1: Trawl survey basic information

Survey	MEDITS_ES	**Trawler/RV**	Trawler
Sampling season	MAY-JUN		
Sampling design	Random stratified with number of haul by stratum proportional to stratum surface		
Sampler (gear used)	GOC-73		
Cod –end mesh size as opening in mm	20		
Investigated depth range (m)	40-750		

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
A (-50m)	3026			9
B (50-100m)	11314			34
C (100-200m)	6889			22
D (200-500 m)	6719			17
E (+500m)	4558			8
Total (km^2)	32506			90

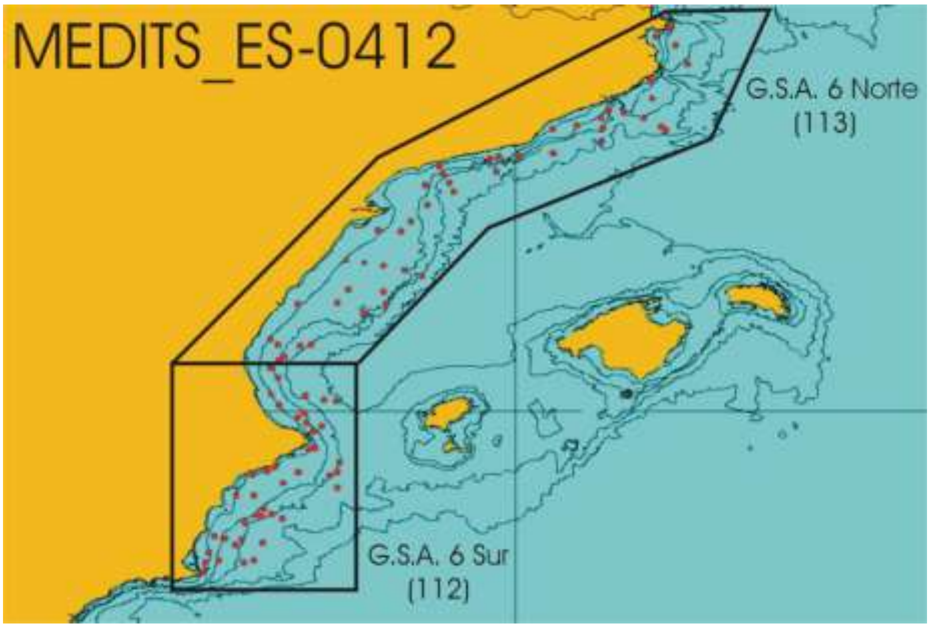


Figure 9.- MEDITS_ES in the GSA 6 "Northern Spain".Hauls.

4.1.2 Spatial distribution of the resources

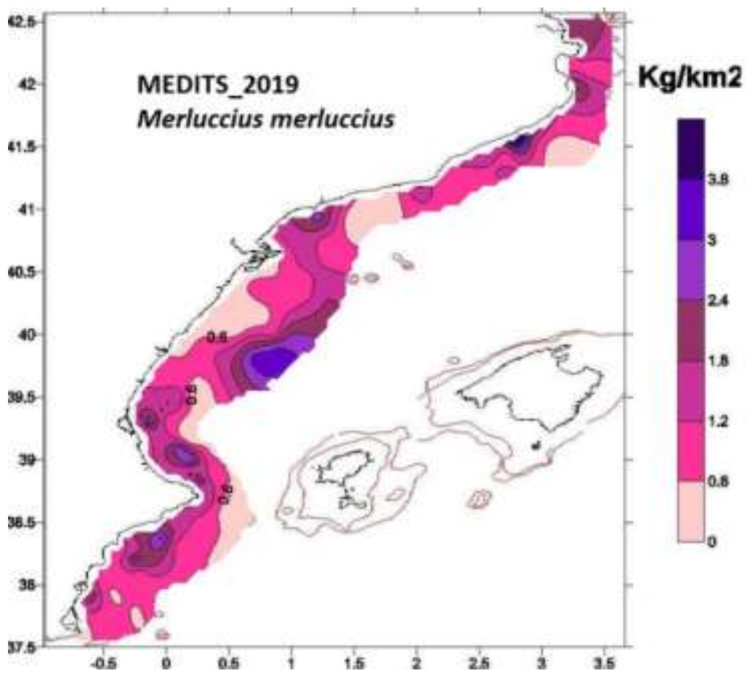


Figure 10.- MEDiTS_ES trawl survey 2018. Spatial distribution of estimated abundances.

4.1.3 Historical trends

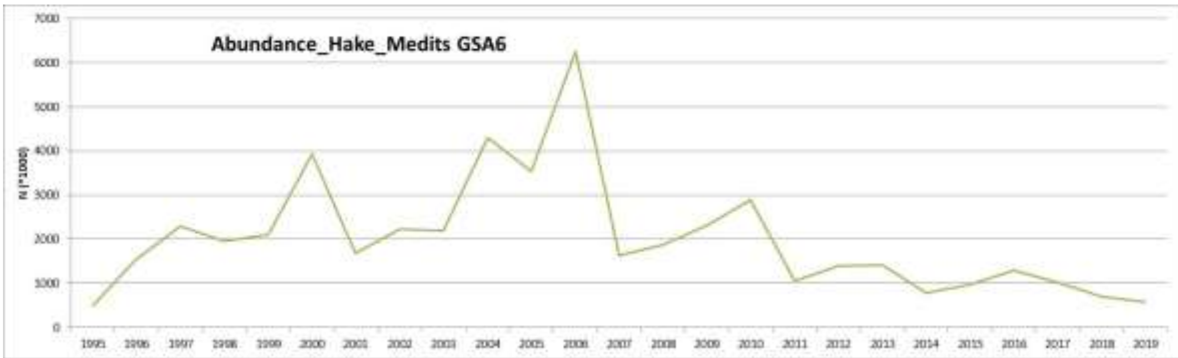


Figure 11.- MEDITS_ES survey indices. Trends in abundance indices by age for the assessed period (N/km^2) for 1995-2019 period.

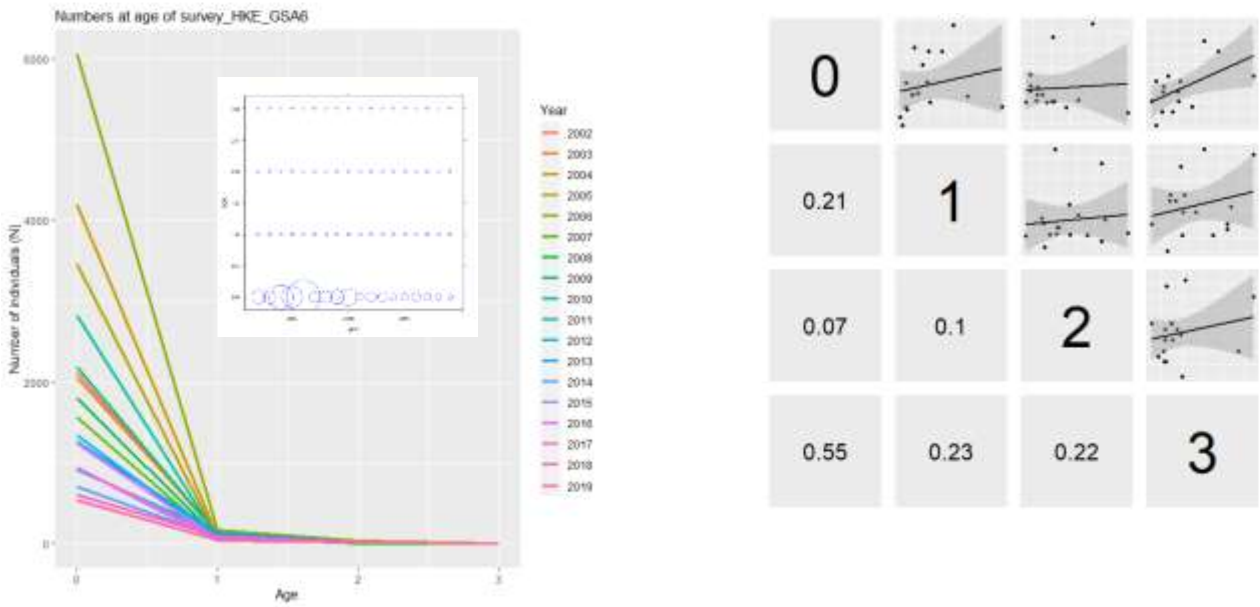


Figure 12- Survey abundance age matrix (left) and Consistency between cohorts (right) for Hake (Medits survey) in the geographical sub-area 6 (Northern Alboran Sea) for the period (2002-2019).

5 Ecological information

5.1 Protected species potentially affected by the fisheries

5.2 Environmental indexes

6 Stock Assessment

An **Extended Survivor Analysis (XSA)** tuned with MEDITS survey data was carried out over the period 2002-2019, considering age classes from 0 to 5+. The **statistical catch at age model a4a**, (non-linear model implemented in R/FLR/ADMB, (flr-project.com)), was also used to model the stock (2002-2019 period).The results obtained including the quality indicators of the adjustment using a4a, as well as the comparison with the XSA results, can be found in the section 6.

6.1 Extended Survivor Analysis (XSA)

Ad hoc methods for tuning single species VPA's to fleet catch per unit effort (CPUE) data are sensitive to observation errors in the final year because they make the assumption that the data for that year are exact. In addition, the methods fail to utilize all of the year class strength information contained within the catches taken from a cohort by the tuning fleets.

Extended Survivors Analysis (XSA), (Shepherd, 1992,1999), an extension of Survivors Analysis (Doubleday, 1981), is an alternative approach which overcomes these deficiencies. In general, the algorithms used within the *ad hoc* tuning procedures, exploit the relationship between fishing effort and fishing mortality.

XSA focuses on the relationship between catch per unit effort and population abundance, allowing the use of a more complicated model for the relationship between CPUE and year class strength at the youngest ages. (Darby and Flatman, 1994).

The XSA assessments can be performed using the Lowestoft VPA Suite stock assessment software package (Darby and Flatman, 1994) and the open-source framework FLR (Fisheries Library for R) (Kett*et al*, 2007). FLR packages were also can used to perform Exploratory Data Analysis, Sensitivity Analysis, Retrospective Analysis, Reference Points Estimation and Short Term Projections.

Shepherd J. G., 1999. Extended survivors analysis: An improved method for the analysis of catch-at-age data and abundance indices. ICES J. Mar. Sci 56: 584–591.

Darby, C. D., and S. Flatman. "1994. Virtual population analysis: version 3.1 (Windows/DOS) user guide." *Info.Tech. Ser. MAFF Direct.Fish. Res., Lowestoft* 1: 85.

Kell L.T., Mosqueira I., Grosjean P., Fromentin J-M., Garcia D., Hillary R., Jardim E., Pastoors M., Poos J.J., Scott F. & Scott R.D. 2007. FLR: an open-source framework for the evaluation and development of management strategies. *ICES J. of Mar. Sci. 20: 289-290*.

6.1.1 Model assumptions

✓ *Imput Parameters*

- Landings time series 1995-2019 (official landings).
- Length distributions 2002-2019 (monthly onboard and port sampling).
- Catch-at-Length data converted to Catch-at-Age data using cohort slicing.
- Growth Parameters from Mellon et al, 2010 and DCF-Spain (2012).
- Biological sampling 2002-2019 for Maturity and Length-Weight relationships.
- M vector by age using PROBION spreadsheet *(Abella et al, 1997*).
- Tuning data 2002-2019 from MEDITS survey and commercial fleet.

✓ *Main Settings*

- Ages 0 to 5+ (Age 5 is a Plus Group)
- Fbar 0-2.
- Catchability independent of size and age for ages older than 1 (-1) and 2 (3) respectively.
- Survivor estimates shrunk towards the mean F of the final 4 yrs or the 1 oldest ages.
- S.E. of the mean to which the estimates are shrunk = 1.5.
- Minimum standard error for population estimates derived from each fleet = 0.3.

6.1.2 Scripts

FLR (Fisheries Libraries in R)

FLR Project -http://flr-project.org/

6.1.3 Input data and Parameters

6.1.4 Tuning data

6.1.5 Results. XSA

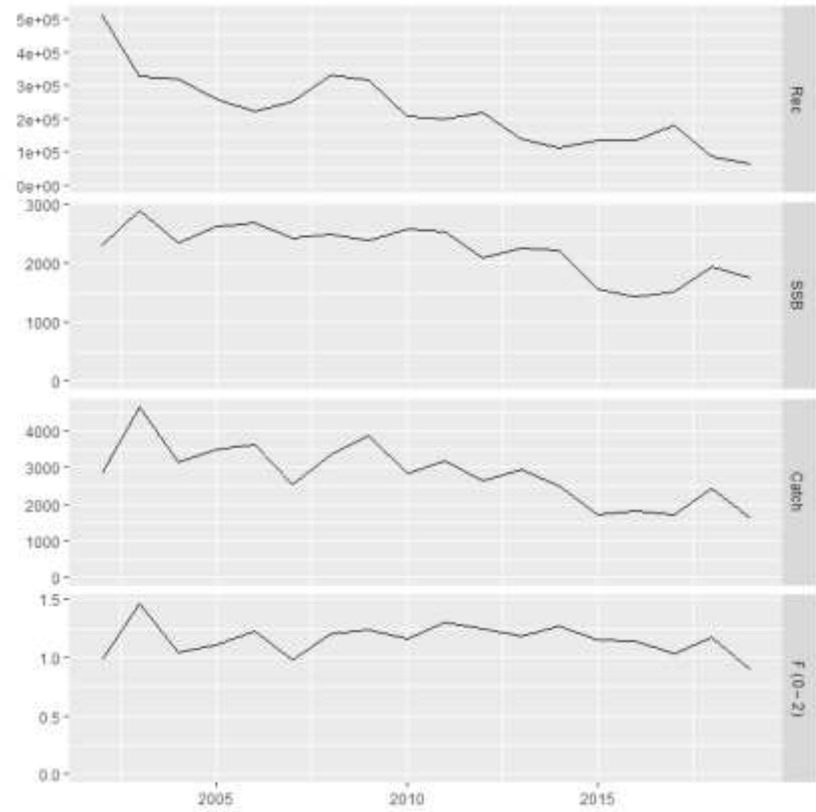


Figure 13.-XSA results.

Total spawning stock biomass (SSB) and yield (Y) showed a decreasing trend from 2009 to 2019. Recruitment (R) showed a drastic decline from the maximum observed in 2002.

Fishing mortality (F_{bar0-2}) shows an increasing trend from 2004 to 2012 and keeping in values close to 1.4 in the last years.

6.1.6 Robustness analysis

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

6.1.7.1 Retrospective analysis.

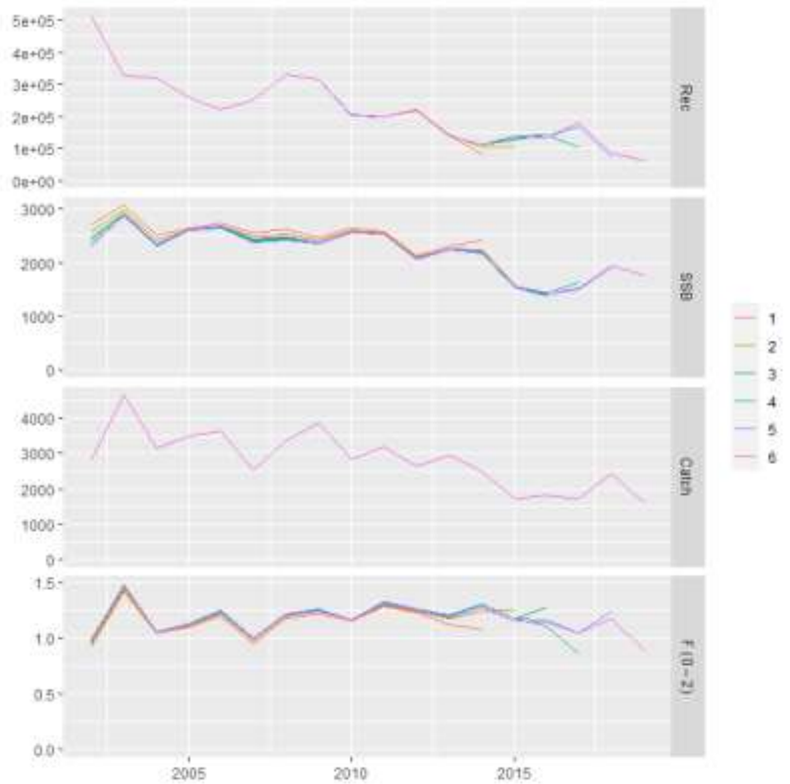


Figure 14.- Retrospective analysis was applied in the XSA model for hake in GSA 6 and the period 2002-2019 up to 6 years backward. Results show no particular retrospective bias in spawning biomass (SSB) and recruitment (R). Fishing mortality (F) seems to be slightly overestimated in 2017.

6.1.7.2 Sensitivity analysis.

Sensitivity analysis on different qage, fse and shk.ages values.

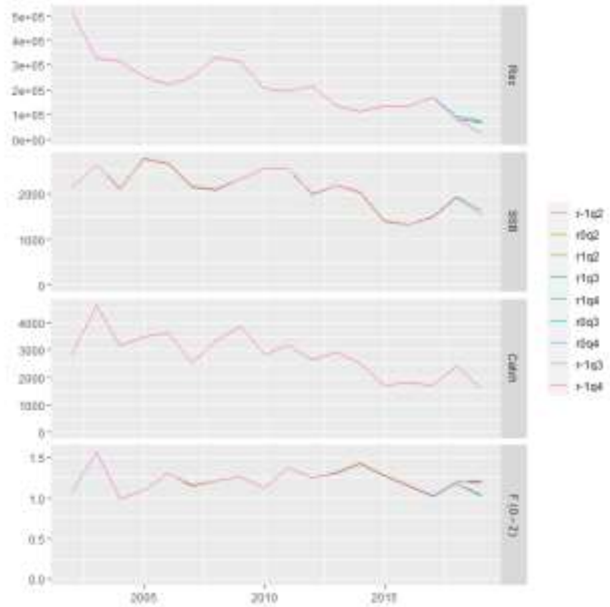


Figure 15.- Sensitivity analysis on different *catchability independent of "rage" and "qage"* values.

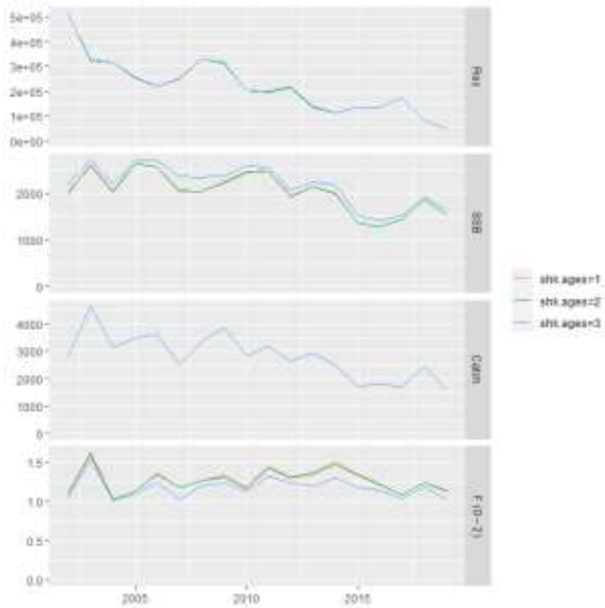


Figure 16.- Sensitivity analysis on different *shrinkage ages "shk.ages"*values.

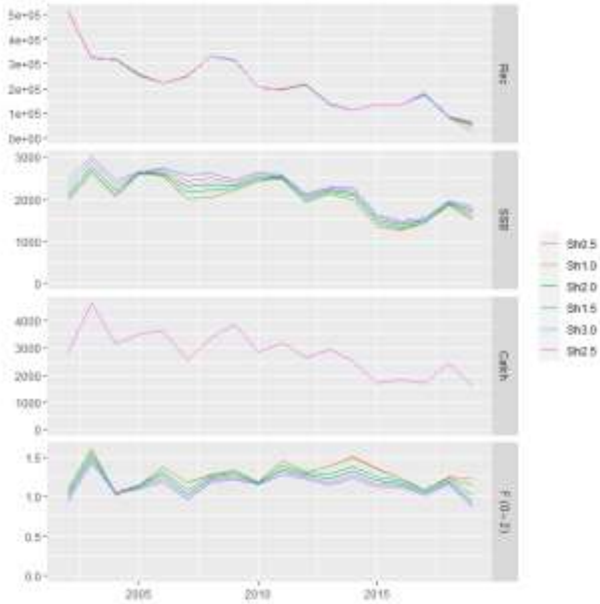


Figure 17- . Sensitivity analysis on different *shrinkage weight "fse" values.*

6.1.8 Assessment quality

Tunning Data analysis.

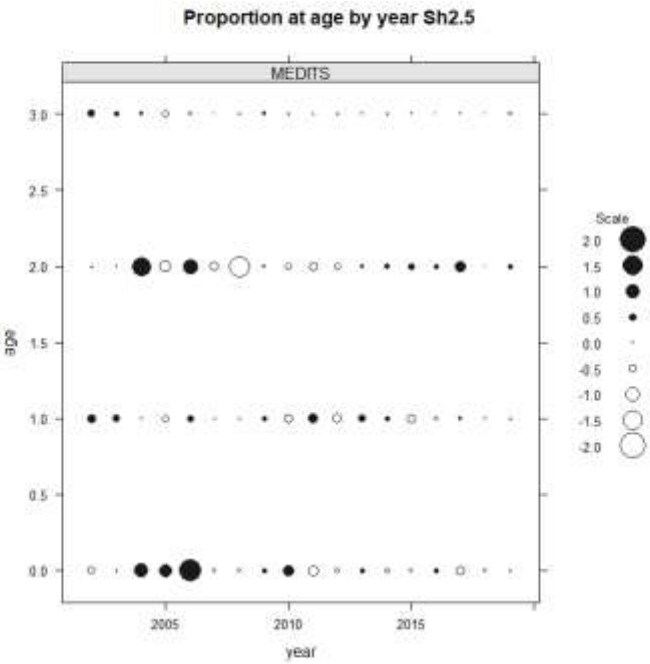


Figure 18.- Catchability residuals plots by fleet (MEDITS_ES Surveys in the GSA06 area.

6.2. Stock assessment using statistical cacth at age model (a4a)

6.2.1. Results

In order to improve the stock assessment process by a reliability test, a statistical catch-at age model implemented in R (a4a), making use of the FLR platform (Kell*et al.*, 2007), was used using the XSA inputs data set (2002-2019 period).

The final model considered for the assessment was a4a.

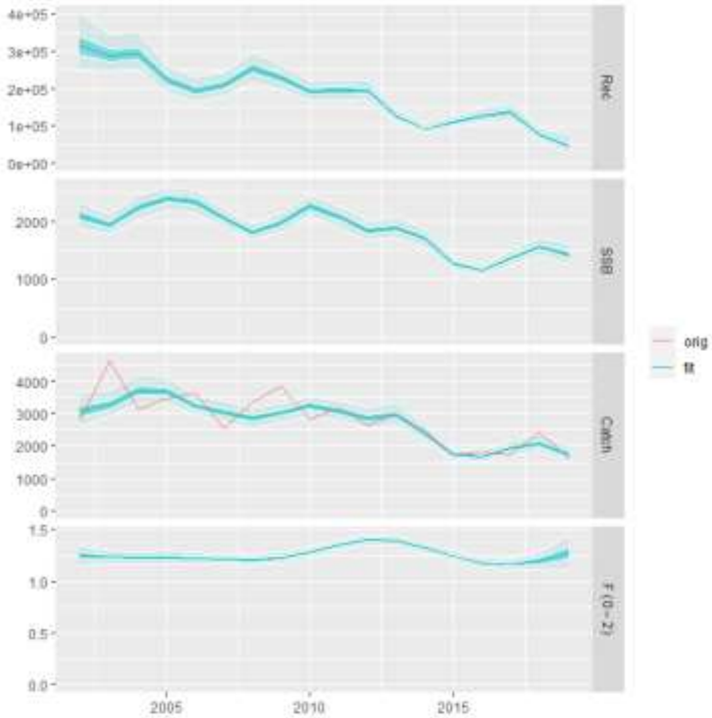
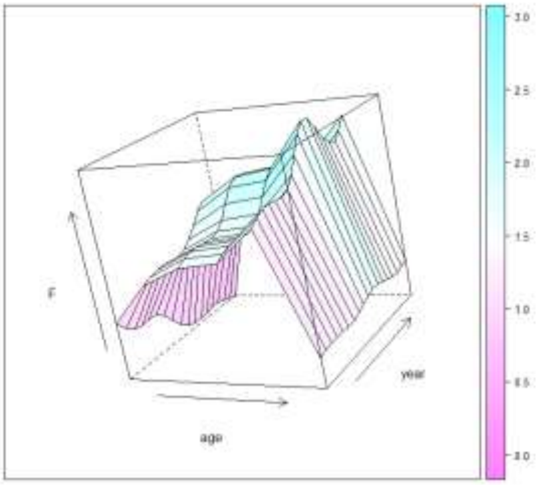
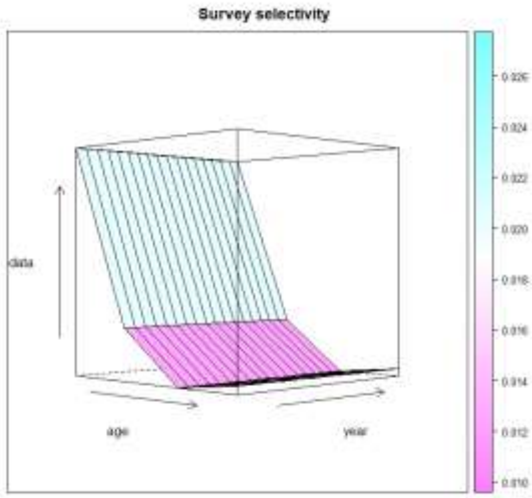


Figure 19.- Hake in GSA6. Stock summary results from a4a model.






```
fmod <- ~ factor(age) + s(year, k=6)+s(year, k = 6, by = as.numeric(age == 0))
srmod <- ~factor(year)
qmod <- list(~s(replace(age, age>3,2), k=2))
```

Fig. 20.- 3D contour plot of estimated fishing mortality (F) (separable model) at age and year (left); and population abundance by age and year. (Catchability smoother age model) for *Merluccius merluccius* in the GSA6 (Northern Spain). The table below shows the fishing mortality, catchability and recruitment models used in the analysis.

6.2.3. a4a diagnostic.

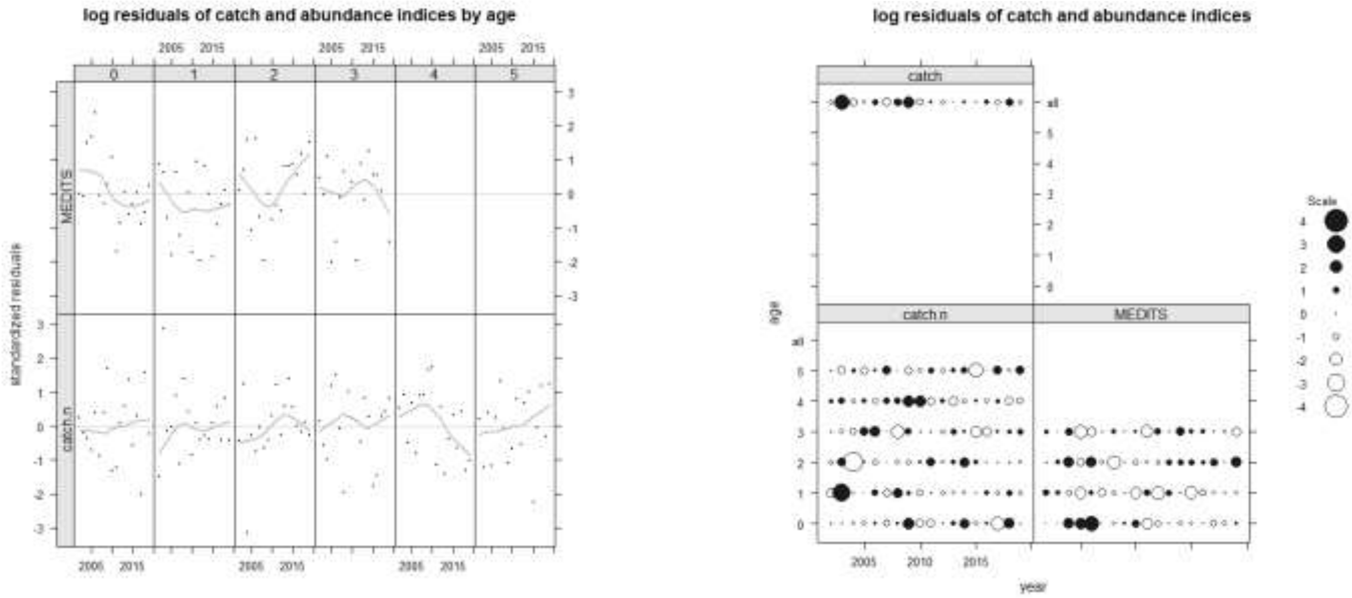


Figure 21.- Standardized residuals for abundance indices (MEDITS survey in GSA6) and for catch numbers for hake in GSA6 (left) and bubbles plot of standardized residuals for abundance indices and for catch numbers for hake in GSA6(right).

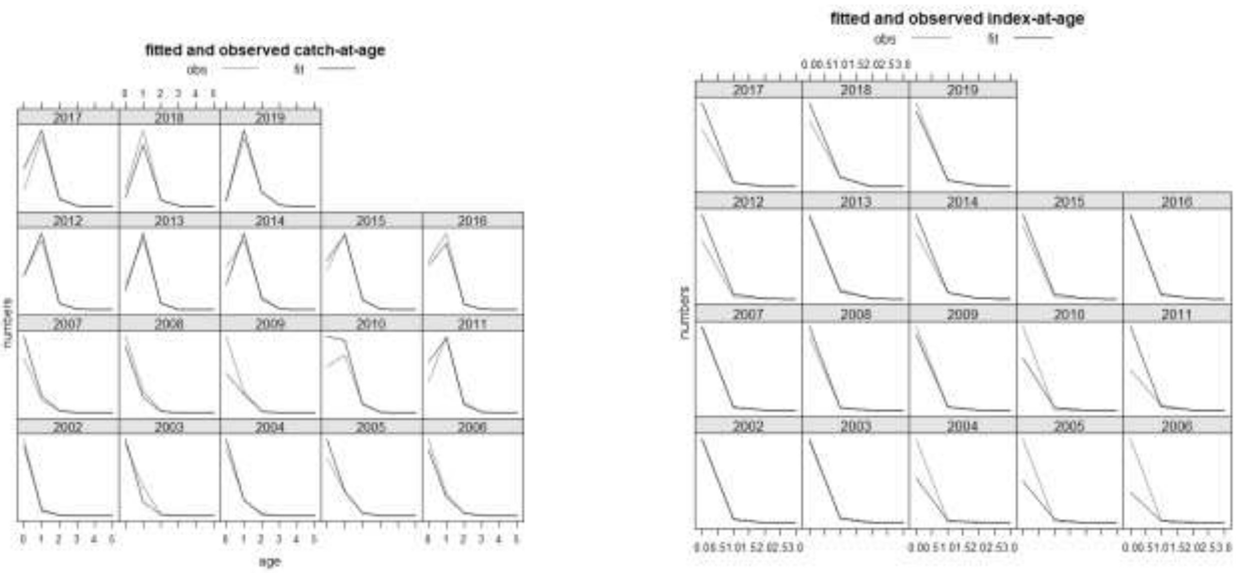


Figure 22.- Predict and observed catch-at-age (left) and abundance-at-age (right).

6.2.4. Retrospective analysis.

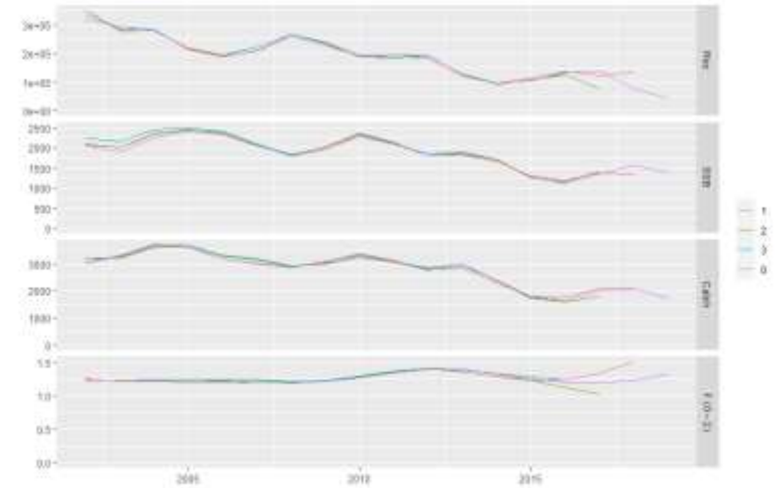


Figure 23.- Retrospective analysis was applied in the a4a model for hake in GSA 6 and the period 2002-2019 up to 3 years backward. Results show no particular retrospective bias in spawning biomass (SSB), recruitment (R).and Fishing mortality (F).

6.2.5 Comparative a4a/xsa

The results obtained using both models, showed relative good fit for most of the years and stock variables.(Fig 24).

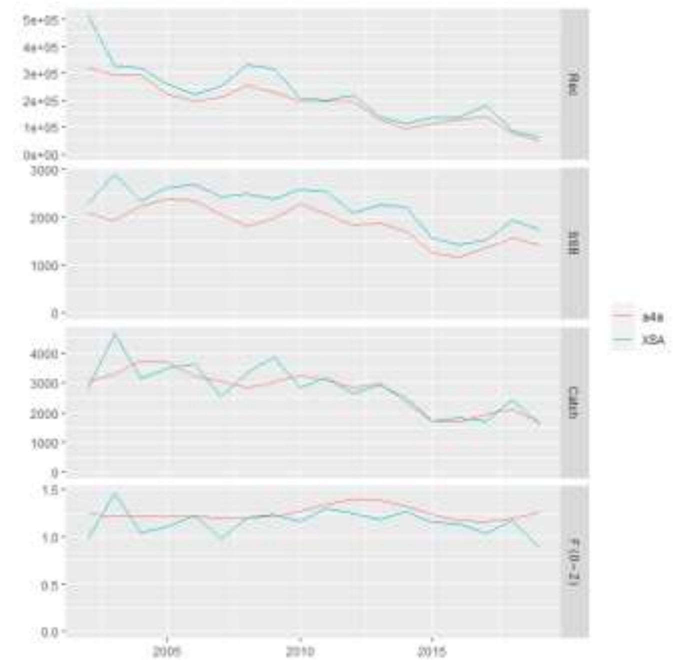
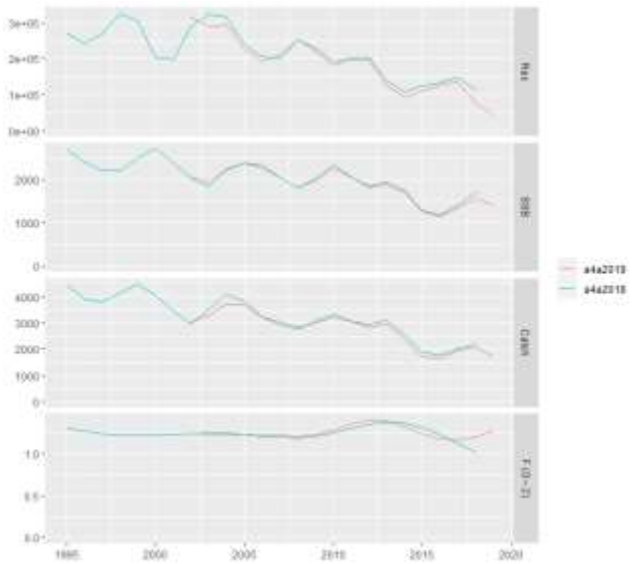


Figure 24.- Hake in GSA6. Comparative stock summary results from XSA and a4a.

6.2.5. Asessment quality.

The assessment was revised from previous assessment done in 2019 (Benchmark session for the assessment of European hake in GSAs 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 19, 20, 22, 23 and 26, Rome, 2019). Corrected inconsistencies observed in input data in 2019.



	A4a 2018	A4a 2019	XSA 2020	A4a 2020
$F_{0.1}$	0.2	NO ADVICE	0.13	0.14
$F_{current}$	1.4 (2015-2017,0-2)	NO ADVICE	1.03 (2017-2019,0-2)	1.2 (0.13) (2019, 0-2)
$F_c/F_{0.1}$	7	NO ADVICE	7.9	8.5

Figure 25.-a4a Stock summary of the assessment carried out in 2019 compared to the update made in 2020, including the reference points and exploitation levels obtained (right table). Note with The population was not rebuilt for the period 1995-2001 in the revised assessment.

7. Yield per recruit analysis.

Yield per recruit analyses was conducted based on the exploitation pattern resulting from the XSA model and population parameters. Minimum and maximum ages for the analysis were considered to be age group 0 and 4 stock weight at age, catch weight at age and maturity ogive was estimated as mean values between 2002 and 2019. Natural mortality vector values were applied per age group.. Fishing mortalities were the mean exploitation pattern F between 2017 and 2019. Reference F was considered to be F for ages 0 to 2 during the last year (2019).

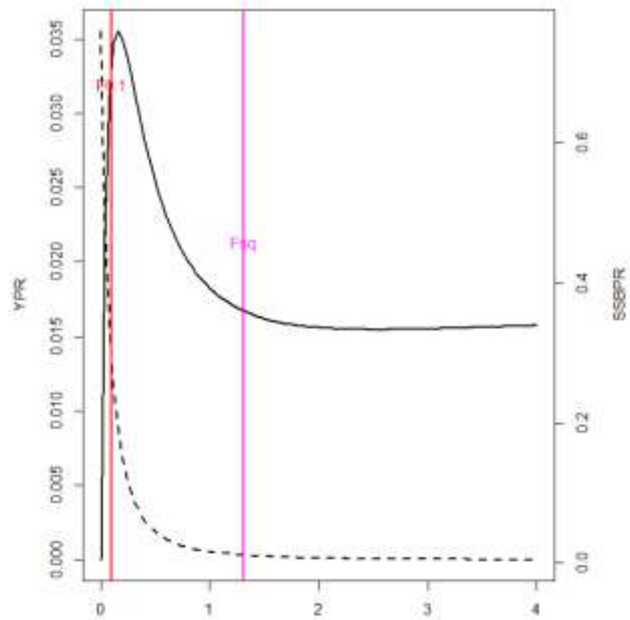


Figure 26.- Equilibrium Yield (t) vs F. Tables including the corresponding $F_{0.1}$ reference point calculated using a4a outputs.

Y/R analysis showed that the $F_{current}$= (1.2) exceeds the Y/R $F_{0.1}$ reference point = (0.14). The resulting ratio $F_{0.1}/F_{current}$ = 8.57, suggesting that for Hake stock in GSA6, the current exploitation level is in over exploitation and the stock size is overexploited (Relative low biomass).

7 Stock predictions

7.1 Short term predictions

Deterministic projections for three years (2020-2022) were produced. These projections are based on the arithmetic mean of recruitment, catches and weights at age of the last three years (2017-2019). F Status Quo is the $FBAR_{0\text{-}2}$ value from a4a analysis in the last year(2019).

To evaluate MSY ranges for stocks in this assessment, has been uses the values of F associated with $F=F_{0.1}$ which are given from the most updated assessments carried out on Mediterranean stocks assessment. Those values were then used in the formulas provided by STECF EWG 15-06 (STECF, 2015) to derive F_{MSY} range (F_{low} and F_{upp}). The empirical relationships used to estimate F_{MSY} range are the following: (F_{low} = 0.0029663+ 0.660214 x $F_{0.1}$), F_{upp} = 0.0078015 + 1.3494017 x $F_{0.1}$

Table 7.1.1: Short term prediction results.

stf_results	Fbar	Catch2019	Catch2020	Catch2021	Catch2022	SSB2021	SSB2022	SSB_20-22(%)	Catch_19-21(%)
	0	1737.7	1084.7	0	0	999.5	4952.6	395.5	-100.0
	0.13	1737.7	1084.7	312.5	821.7	999.5	4256.9	325.9	-82.0
F_ lower	0.11	1737.7	1084.7	262.8	706.7	999.5	4366.4	336.9	-84.9
F_0.1	0.14	1737.7	1084.7	375.7	959.9	999.5	4118.1	312.0	-78.4
F_upper	0.22	1737.7	1084.7	507.4	1218.6	999.5	3831.6	283.4	-70.8
	0.25	1737.7	1084.7	580.7	1346.1	999.5	3673.5	267.5	-66.6
	0.38	1737.7	1084.7	811.6	1673.0	999.5	3184.1	218.6	-53.3
	0.51	1737.7	1084.7	1011.0	1870.2	999.5	2773.3	177.5	-41.8
	0.63	1737.7	1084.7	1183.7	1983.0	999.5	2428.5	143.0	-31.9
	0.76	1737.7	1084.7	1333.8	2041.9	999.5	2138.8	114.0	-23.2
	0.89	1737.7	1084.7	1464.8	2067.3	999.5	1895.3	89.6	-15.7
	1.01	1737.7	1084.7	1579.4	2072.4	999.5	1690.5	69.1	-9.1
	1.14	1737.7	1084.7	1680.2	2066.1	999.5	1518.1	51.9	-3.3
F_current	1.27	1737.7	1084.7	1769.3	2054.0	999.5	1373.0	37.4	1.8
	1.39	1737.7	1084.7	1848.2	2039.6	999.5	1250.6	25.1	6.4
	1.52	1737.7	1084.7	1918.5	2024.9	999.5	1147.3	14.8	10.4
	1.65	1737.7	1084.7	1981.5	2011.3	999.5	1060.1	6.1	14.0
	1.77	1737.7	1084.7	2038.1	1999.3	999.5	986.2	-1.3	17.3
	1.90	1737.7	1084.7	2089.4	1989.3	999.5	923.7	-7.6	20.2
	2.02	1737.7	1084.7	2135.9	1981.3	999.5	870.6	-12.9	22.9
	2.15	1737.7	1084.7	2178.3	1975.1	999.5	825.5	-17.4	25.4
	2.28	1737.7	1084.7	2217.3	1970.7	999.5	787.0	-21.3	27.6
	2.40	1737.7	1084.7	2253.2	1967.7	999.5	754.1	-24.6	29.7
	2.53	1737.7	1084.7	2286.5	1966.1	999.5	725.9	-27.4	31.6

*$F_{0.1}$ is a proxy of F_{MSY}.

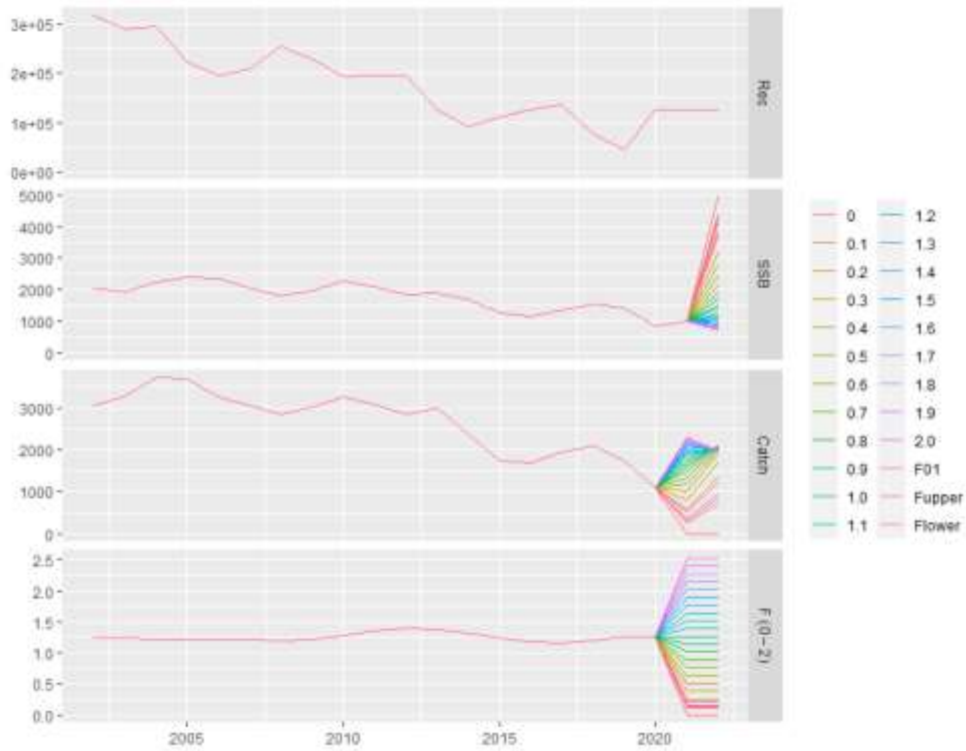


Figure 27.- Short term predictions results.

Fishing at $F_{current}$ from 2019 to 2021 would produce an increase in catches of 1.8% with an increase in SSB for the 2020-2022 period 37%).

Fishing at F0.1 from 2019 to 2021 would generate a decrease in catches of 78% of the catches and an increase of 312% in SSB for the 2020-2022period.

7.2 Medium term predictions

7.3 Long term predictions

Medium and long term forecast depends on having a reasonable Stock-Recruitment relationship (SSR). European hake *Merluccius merluccius* does not show a reasonable SRR (Fig 24) and therefore no medium or long term predictions were performed for this species.

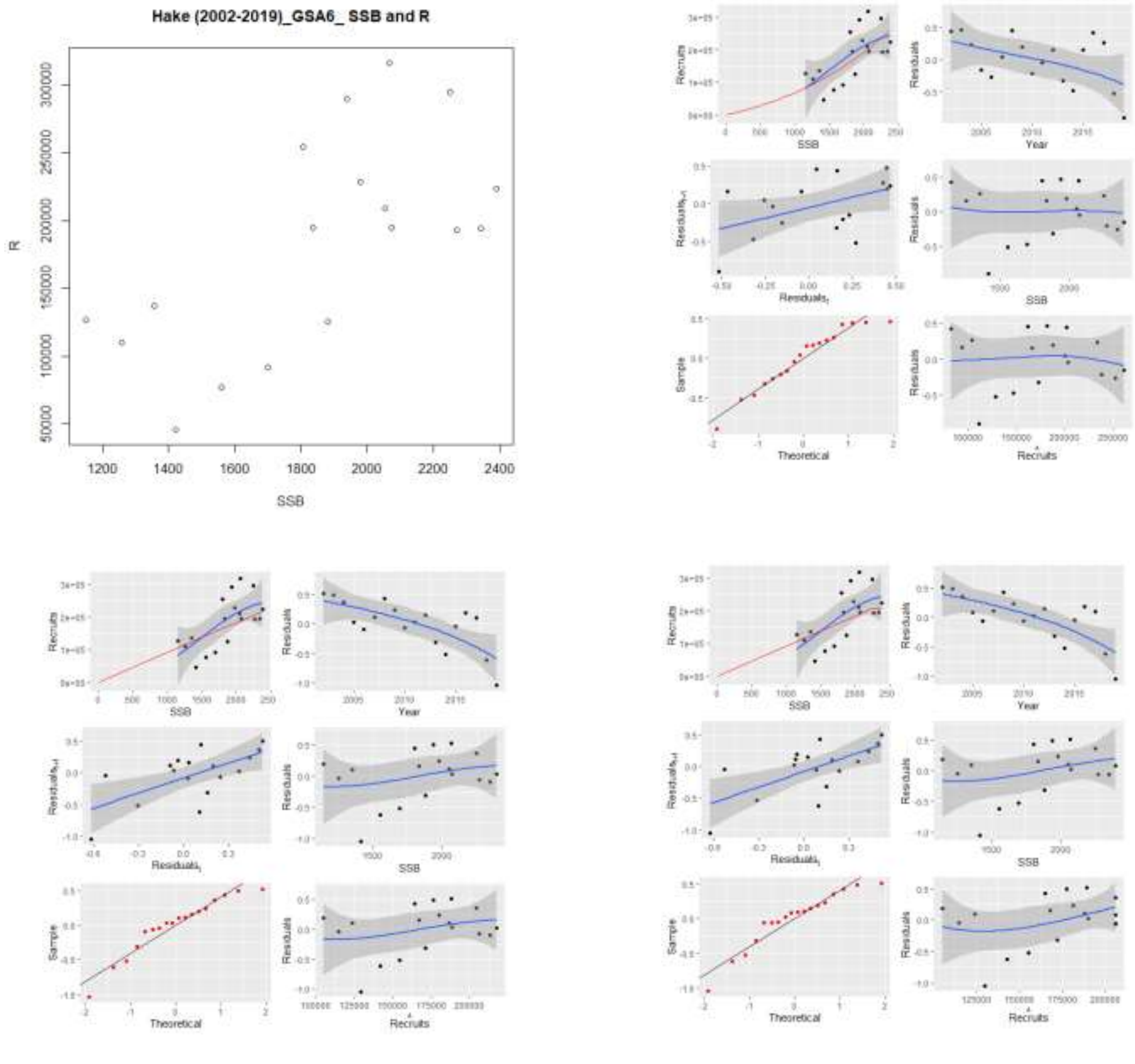


Figure 28.- Stock-Recruitment Relationship for Hake in the GSA6 (top left), showing different approaches (adjustement attempts) for this relation ship: Beverton& Holt model (top right), Ricker model (bottom left) and Segmented regression (bottom right).

Draft scientific advice. a4a results.

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 a4a analysis Fc= Last year	($F_{0.1}$ = 0.14) (Fc=1.2 (±0.13))	$Fc/F_{0.1}$=8.57		3	IO _O_h
	Catch (t) (2019)	1740		33% percentile, 2669 66% percentile,3077	18 18	
Stock abundance	SSB (t) (2019)		1423 (+/- 178)	33% percentile; 1745 66% percentile; 2029	18 18	O_ O_l
Recruitment	R(2019)	thousands	45663	33% percentile; 133026 66% percentile; 212320	18 18	
Final Diagnosis		- In overexplotation($F_{current}$>$F_{0.1}$) - Stock size is overexploited. Relative low biomass; $SSB_{current(2019)}$ = 1423 (t); SSB at 33rd percentile = 1745(t)				
Scientific advice for management		- Reduce fishing mortality - Complementary advice. Corrected inconsistencies observed in input data in 2019 Benchmark session				

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)*