
# Stock Assessment Form

# Demersal species

## Reference year:2019

## Reporting year:2021

European hake (*Merluccius merluccius*) is one of the target species in the trawl fishery developed by around 30 vessels off Balearic Islands (GFCM-GSA05), mainly exploited on the deep shelf and upper slope, whose annual landings oscillating between 50 and 190 tons during the last decades. This stock has been assessed using data from the trawl on a time series covering 40 years (1980-2019). The assessment has been carried out applying tuned virtual population analysis (Extended Survivor Analysis, XSA) and a4a on the cohorts present during 1980-2019 and a Y/R analysis based on the exploitation pattern resulting from the a4a model and population parameters for the period 2017-2019. These approaches were performed using monthly size composition of catches and official landings. The models were tuned with bottom trawl surveys (2001–2019). The vector of natural mortality by age was calculated from Caddy´s formula, using the PROBIOM Excel spreadsheet. The software used was FLR in R.

# Stock Assessment Form version 1.0 (January 2014)

Uploader: *Marc Farré*

## Stock assessment form

# 1 Basic Identification Data

| Scientific name: | Common name: | ISCAAP Group: |
|---|---|---|
| *Merluccius merluccius* | European hake | 32 |
| 1st Geographical sub-area: | 2nd Geographical sub-area: | 3rd Geographical sub-area: |
| GSA05 – Balearic Islands | [GSA_2] | [GSA_3] |
| 4th Geographical sub-area: | 5th Geographical sub-area: | 6th Geographical sub-area: |
| [GSA_4] | | |
| 1st Country | 2nd Country | 3rd Country |
| Spain | [Country_2] | [Country_3] |
| 4th Country | 5th Country | 6th Country |
| | | |
| **Stock assessment method: (direct, indirect, combined, none)** | | |
| Trawl survey, Indirect method (XSA, a4a and Y/R) | | |
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The ISSCAAP code is assigned according to the FAO 'International Standard Statistical Classification for Aquatic Animals and Plants' (ISSCAAP) which divides commercial species into 50 groups on the basis of their taxonomic, ecological and economic characteristics. This can be provided by the GFCM secretariat if needed. A list of groups can be found here:

http://www.fao.org/fishery/collection/asfis/en

Direct methods (you can choose more than one):

- Trawl survey

Indirect method (you can choose more than one):

- XSA
- A4a
- Y/R

# 2 Stock identification and biological information

## *2.1 Stock unit*

GSA05 has been pointed as an individualized area for assessment and management purposes in the western Mediterranean (Quetglas *et al.*, 2013) due to its main specificities. These include: 1) Geomorphologically, the Balearic Islands (GSA05) are clearly separated from the Iberian Peninsula (GSA06) by depths between 800 and 2000 m, which would constitute a natural barrier to the interchange of adult stages of demersal resources; 2) Physical geographically-related characteristics, such as the lack of terrigenous inputs from rivers and submarine canyons in GSA05 compared to GSA06, give rise to differences in the structure and composition of the trawling grounds and hence in the benthic assemblages; 3) Owing to these physical differences, the faunistic assemblages exploited by trawl fisheries differ between GSA05 and GSA06, resulting in large differences in the relative importance of the main commercial species; 4) There are no important or general interactions between the demersal fishing fleets in the two areas, with only local cases of vessels targeting red shrimp in GSA05 but landing their catches in GSA06; 5) Trawl fishing exploitation in GSA05 is much lower than in GSA06; the density of trawlers around the Balearic Islands is one order of magnitude lower than in adjacent waters; and 6) Due to this lower fishing exploitation, the demersal resources and ecosystems in GSA05 are in a healthier state than in GSA06, which is reflected in the population structure of the main commercial species (populations from the Balearic Islands have larger modal sizes and lower percentages of small-sized individuals), and in the higher abundance and diversity of elasmobranch assemblages.

## *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)** | | | | **Units** | cm |
|---|---|---|---|---|---|
| **Sex** | **Fem** | **Mal** | **Combined** | **Reproduction season** | All year, but mainly concentrated in spring, the end of summer and winter |
| **Maximum size observed** | | | 82* | **Recruitment season** | |
| **Size at first maturity** | | | 33** | **Spawning area** | Deep shelf and upper slope |
| **Recruitment size to the fishery** | | | 5*** | **Nursery area** | Deep shelf |

* Maximum length obtained taking into account both catches from the commercial fleet and surveys.
** García-Rodríguez and Esteban (1995).
*** Minimum length found in catches from the commercial fleet.

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

| Size/Age | Natural mortality | Proportion of matures |
|---|---|---|
| 0 | 1.89 | 0 |
| 1 | 0.79 | 0.297 |
| 2 | 0.47 | 0.986 |
| 3 | 0.35 | 0.990 |
| 4 | 0.29 | 1 |
| +5 | 0.23 | 1 |

*Table 2-3: Growth and length weight model parameters*

| | | | Sex | | | |
|---|---|---|---|---|---|---|
| | | Units | female | male | Combined | Years |
| **Growth model** | **$L_\infty$** | | | | 110 | |
| | **K** | | | | 0.178 | |
| | **$t_0$** | | | | | |
| | **Data source** | Mellon-Duval et al. 2010 | | | | |
| **Length weight relationship** | **a** | | | | 0.00677 | |
| | **b** | | | | 3.035097 | |
| | **M** (scalar) | | | | | |
| | **sex ratio** (% females/total) | | | | | |

# 3 Fisheries information

## 3.1 Description of the fleet

In the Balearic Islands (western Mediterranean), commercial trawlers develop up to four different fishing tactics, which are associated with the shallow shelf, deep shelf, upper slope and middle slope (Guijarro and Massutí 2006; Ordines et al. 2006), mainly targeted to: (i) *Spicara smaris*, *Mullus surmuletus*, *Octopus vulgaris* and a mixed fish category on the shallow shelf (50-80 m); (ii) *Merluccius merluccius*, *Mullus* spp., *Zeus faber* and a mixed fish category on the deep shelf (80-250 m); (iii) *Nephrops norvegicus*, but with an important by-catch of big *M. merluccius*, *Lepidorhombus* spp., *Lophius* spp. and *Micromesistius poutassou* on the upper slope (350-600 m) and (iv) *Aristeus antennatus* on the middle slope (600-750 m). The European hake, *M. merluccius* is one of the target species from the deep shelf, although it is also an important by-catch in the upper slope and, in a lower level, in the middle slope.

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

| | Country | GSA | Fleet Segment | Fishing Gear Class | Group of Target Species | Species |
|---|---|---|---|---|---|---|
| **Operational Unit 1*** | ESP | 05 | E-Trawl (12-24 meters) | 03 - Trawls | 33 – Demersal shelf species | HKE |
| **Operational Unit 2** | ESP | 05 | E-Trawl (12-24 meters) | 03 - Trawls | 34 – Demersal slope species | HKE |

*Table 3.1-2: 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) |
|---|---|---|---|---|---|---|
| Trawl | 37* | 110** | See below | 4%*** | See comments | Fishing trips |
| **Total** | 37 | 110 | | 4% | | |

*Number of boats in 2020 (22 Mallorca, 6 Menorca and 9 Ibiza-Formentera).
** Catch is the average landings, in tons, 1980-2019.
*** From bottom trawl fleet monitoring (EU DCF).

Other species caught (Ordines *et al.*, 2006): Teleosts: *Lepidorhombus boscii*, *Lophius* spp, *Chelidonichthys. cuculus*, *Trachinus draco,…* Elasmobranchs: *Raja* spp.
Discards other species: Teleosts: *Capros aper*, *Macroramphosus scolopax*, *Synchiropus. phaeton*, *Boops boops*, *Lepidotrigla cavillone,…* Elasmobranchs: *Scyliorhinus canicula,…*

## 3.2 Historical trends

Catches show important oscillations along the data series, although the maximum values reached before 1995 have never been observed again (Fig. 3.2.1). Size composition ranged between 5-82 cm and most of the catches correspond to individuals aged 0 and 1, with age 0 highly variable among years (Fig. 3.2.2).

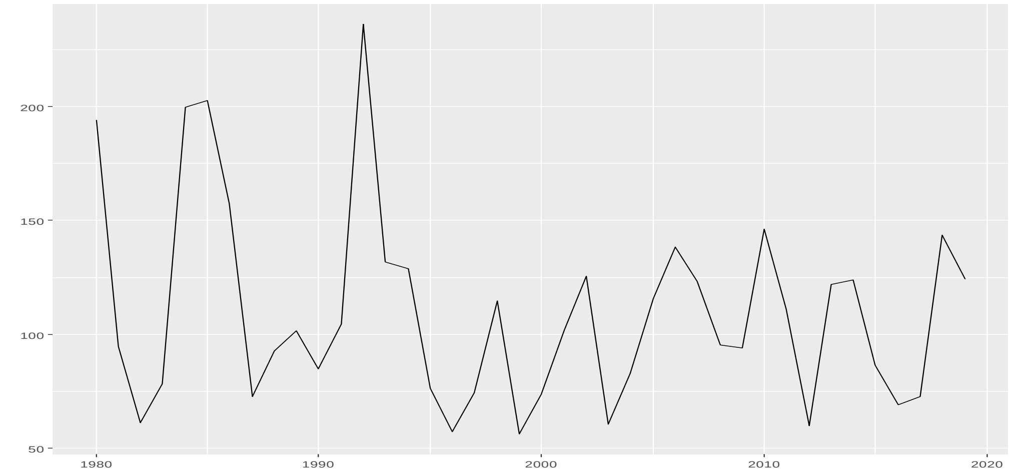


Fig. 3.2-1. *M. merluccius* GSA05: Annual landings of bottom trawl fleet from 1980 to 2018.

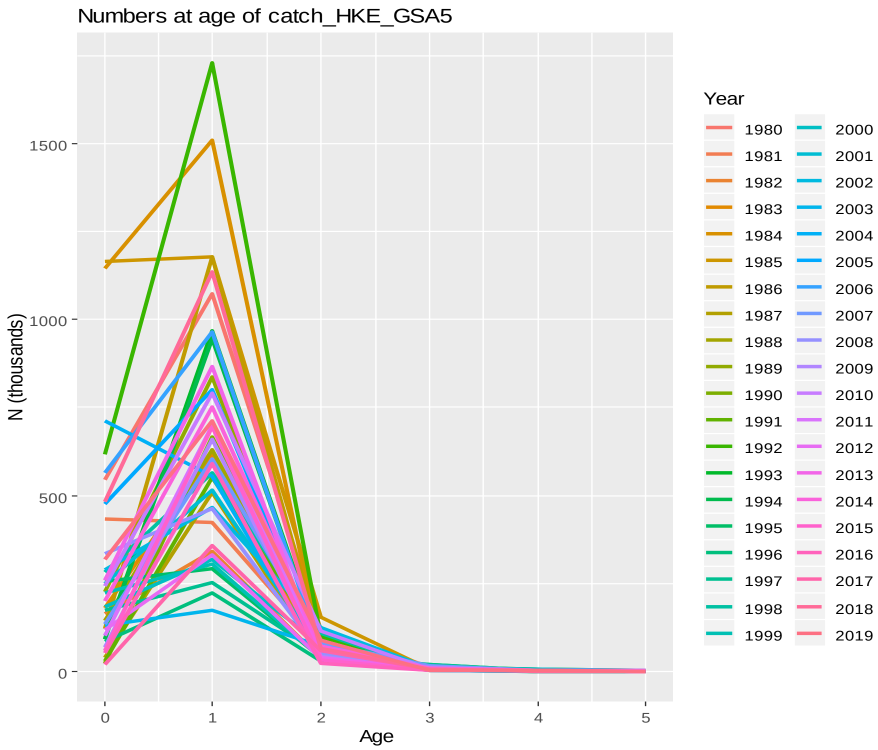


Figure 3.2.-2: Age composition from M. merluccius caught by the bottom trawl fishery.

## 3.3 Management regulations

<u>Trawl</u>

- Fishing license: fully observed

- Engine power limited to 316 KW or 500 CV: not observed

- Mesh size in the cod-end (before Jun 1st 2010: 40 mm diamond; from Jun 1st 2010: 40 mm square or 50 mm diamond -by derogation-): fully observed

- Fishing forbidden upper 50 m depth: not fully observed

- Time at sea (12 hours per day and 5 days per week): fully observed

- Weekly temporal bans (winter, for some years)

- Fishing reduction (2020) (number of days)

- Spatial-temporal closures (2020) (20% reduction juveniles)

## *3.4 Reference points*

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

| Indicator | Limit Reference point/empirical reference value | Value | Target Reference point/empirical reference value | Value | Comments |
|---|---|---|---|---|---|
| **B** | | | | | |
| **SSB** | | | | | |
| **F** | | | $F_{0.1}$ | 0.31 | |
| **Y** | | | | | |
| **CPUE** | | | | | |
| **Index of Biomass at sea** | | | | | |

# 4 Fisheries independent information

## *4.1 BALAR-MEDITS bottom trawl surveys*

### 4.1.1 Brief description of the direct method used

From 2001, the Spanish Institute of Oceanography has performed annual bottom trawl surveys following the same methodology and sampling gear described in the MEDITS protocol (BALAR surveys, Massutí and Reñones, 2005). Since 2007, this survey has been included in the MEDITS program (Bertrand *et al.*, 2002). Mean stratified abundances and biomasses by km$^2$ has been computed using the methodology described by Grosslein and Laurec (1982), with the following formula:

- Mean catch by stratum: $$\bar{Y}_{st} = \frac{1}{N_h} * \sum Y_h$$
- Variance by stratum: $$S^2(\bar{Y}_{st}) = \frac{1}{N_{h-1}} * \sum (Y_h - \bar{Y}_{st})^2$$
- Mean total catch: $$Y_t = \frac{1}{A} * \sum (\bar{Y}_{st} * A_h)$$
- Total variance: $$S^2(\bar{Y}_t) = \frac{1}{A^2} * \sum \frac{S^2(\bar{Y}_{st}) * A_h^{\,2}}{N_h}$$
- SE (standard error): $$SE = \sqrt{S^2(\bar{Y}_{st})}$$

Nh: number of hauls in each sub-stratum; Yh: mean catch by haul in each sub-stratum; A: total stratum area; Ah: sub-estratum area; $S^2(\bar{Y}_{st})$ variance in each sub-stratum.

## *Direct methods: trawl based abundance indices*

*Table 4.1-1: Trawl survey basic information*

| | | | |
|---|---|---|---|
| **Survey** | MEDITS_05_2019 | **Trawler/RV** | RV "Miguel Oliver" |
| **Sampling season** | End Spring (June) | | |
| **Sampling design** | MEDITS Handbook V.8 (2016) | | |
| **Sampler (gear used)** | G.O.C. 73 | | |
| **Cod –end mesh size as opening in mm** | 20 mm | | |
| **Investigated depth range (m)** | 50-750 m | | |

*Map of hauls positions*

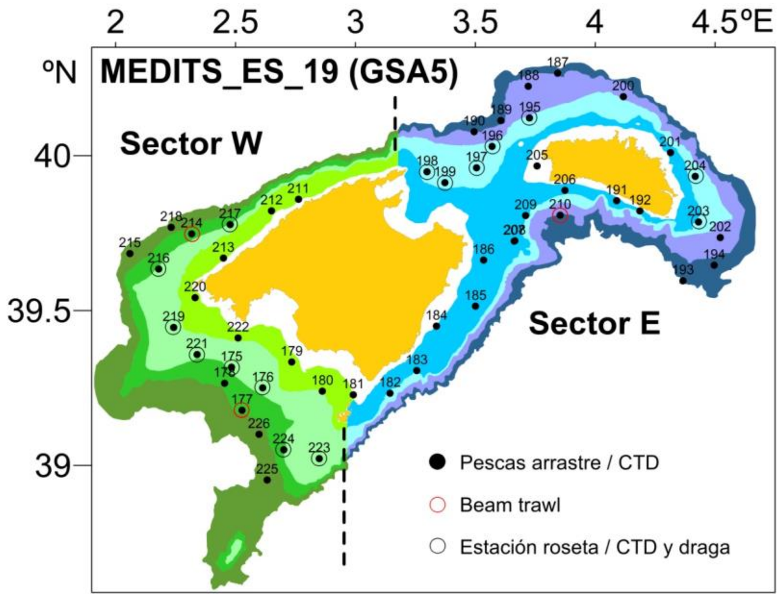


Figure 4.1-1: Map of the position of MEDITS survey trawls, beam trawls and CTD's in GSA 05.

### 4.1.2 Spatial distribution of the resources

*M. merluccius* is mainly distributed in the fishing grounds sited in the south of Mallorca and the Menorca channel (Fig 4.1.2.-1).

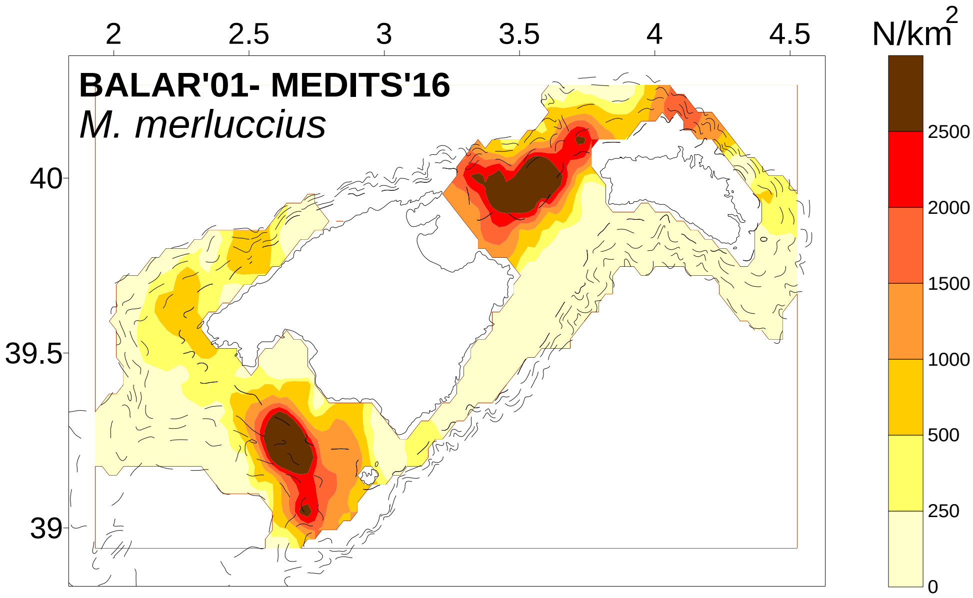


Fig 4.1.2-1. Spatial distribution of *M. merluccius* around the Balearic Islands using information obtained from surveys.

### 4.1.3 Historical trends

Abundance indices of *M. merluccius* in GSA 05 show oscillations along the data series without a clear trend (Fig 4.1.3-1).

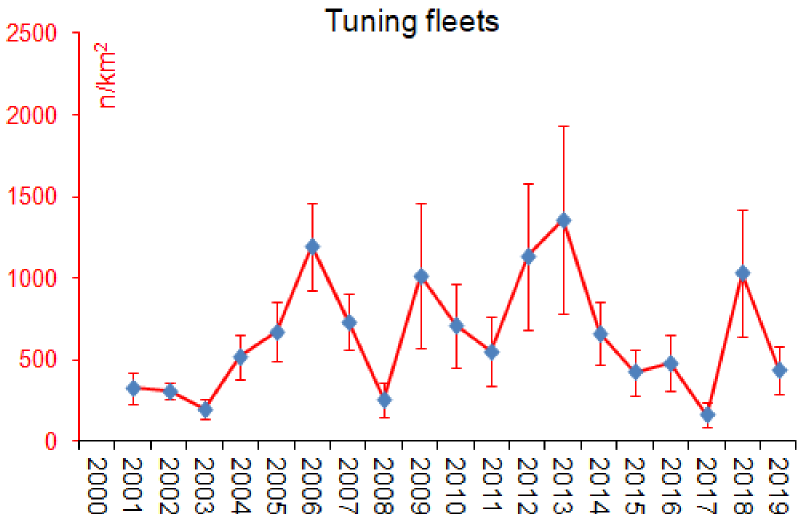


Fig 4.1.3-1. Abundance index of M. merluccius in GSA 05 from scientific surveys (including 2019).

Most of the catches during the survey correspond to age 0 individuals (Fig 4.1.3-2).

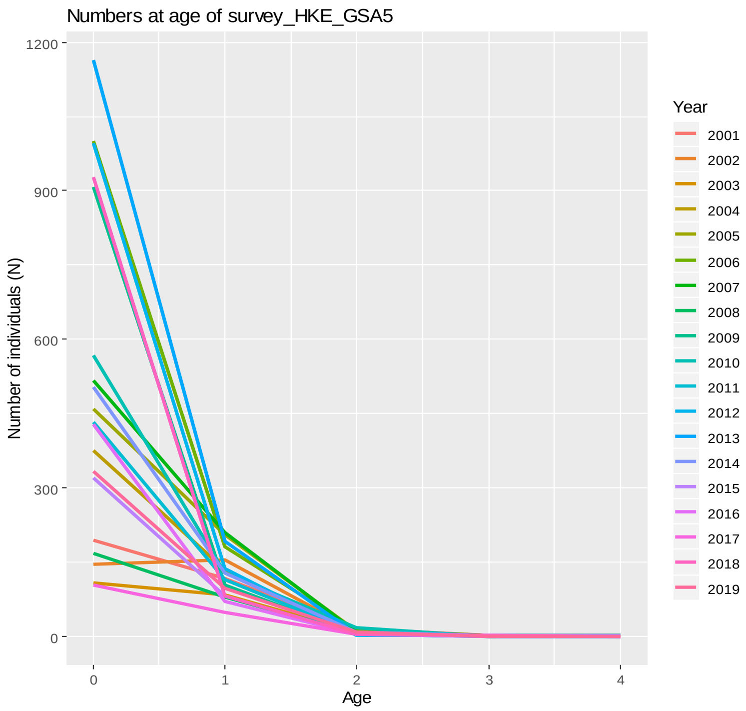


Fig 4.1.3-2. Age structure of of *M. merluccius* in GSA 05 from scientific surveys.

# 5 Ecological information

## 5.1 Protected species potentially affected by the fisheries

## 5.2 Environmental indexes

The study of the influence of environmental conditions on the population dynamics of *M. merluccius* in the Balearic Islands has been modeled using meso-scale (IDEA, Monserrat *et al*., 2008) and large-scale (NAO) indices (Massutí *et al*., 2008). IDEA index is used as a proxy for two oceanographic scenarios for the regional circulation around the Balearic Islands, while NAO index should have an impact on the climatic conditions on the areas where Western Intermediate Waters (WIW) are formed. The bathymetric range of these water masses coincides with those of hake population. Periods of low NAO and IDEA indices could produce an oceanographic scenario which increases productivity in the area, because of the major presence of cold intermediate WIW in the channels. In addition to its effect of reinforcement of the Northern and Balearic currents (Pinot et al., 2002; López-Jurado et al., 2008), it must also be considered that WIW has originated in a more productive area (Estrada, 1996) and during periods of high hydro-climatic dynamism (e.g. rainfall and increased wind strength, causing increasing river runoff and wind mixing; Lloret et al., 2001). These same authors have demonstrated that cold years (generally coincident with low NAO index) tend to be more productive in the western Mediterranean, partly because winter mixing may reach greater depths and in part because the formation of deep water in the Gulf of Lions may flow over a large area (Estrada et al., 1985). Also, periods of low NAO index result in favorable conditions for the productivity of exploited stocks in the Gulf of Lions (Lloret et al., 2001). These environmental conditions could benefit the recruitment of hake in the Balearic Islands.

# 6 Stock Assessment

In this section there will be one subsection for each different model used, and also different model assumptions runs should be documented when all are presented as alternative assessment options.

## 6.1 Statistical Catch-at-Age (a4a) model

### 6.1.1 Model assumptions

FLR libraries were employed in order to carry out a Statistical-Catch-at-Age (a4a) assessment. Several models were run with different configurations and the final model selected was the following:

```
f<- ~ factor(age) + s(year, k=11)

q <- list(~factor(replace(age,age>3,3)))

sr <- ~factor(year)
```

## 6.1.2 Scripts

## 6.1.3 Input data and Parameters

Catch data from the commercial fleet, by age, is shown in the following table (thousands individuals):

| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 584.9 | 471.6 | 174.5 | 196.5 | 1221.2 | 1265.9 | 133 | 41.8 | 155.9 | 248.5 |
| 1 | 1153.5 | 459.9 | 366.1 | 672.3 | 1611.6 | 1282.3 | 1302.3 | 547.1 | 675.8 | 921.4 |
| 2 | 125 | 78.9 | 36.6 | 29.8 | 64 | 167.4 | 88.3 | 42.2 | 59.3 | 42.8 |
| 3 | 13.4 | 6.7 | 4.5 | 2.2 | 5.3 | 4.5 | 9.9 | 4.5 | 4.6 | 2.7 |
| 4 | 0.3 | 3.1 | 0.7 | 0.1 | 0.2 | 0.3 | 1.1 | 1.7 | 0.1 | 0.9 |
| 5+ | 0.05 | 0.05 | 0.05 | 0.05 | 0.1 | 0.2 | 0.05 | 0.05 | 0.05 | 0.1 |
| | | | | | | | | | | |
| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
| 0 | 24.7 | 30.1 | 667.4 | 100 | 97.8 | 262.1 | 87 | 215.7 | 354.3 | 281.7 |
| 1 | 749.6 | 591 | 1874.7 | 1058.2 | 1035.1 | 300.2 | 232.4 | 316.9 | 714.7 | 388.1 |
| 2 | 47.9 | 87.6 | 107.3 | 74.7 | 73 | 37.8 | 30.7 | 60.5 | 136.3 | 48 |
| 3 | 5.2 | 13.8 | 13.5 | 8.2 | 8.1 | 19.2 | 11.7 | 22.5 | 6.3 | 7.4 |
| 4 | 0.5 | 2.1 | 5 | 1.6 | 1.6 | 2.6 | 4.5 | 4.2 | 1.2 | 1 |
| 5+ | 0.05 | 0.3 | 1.1 | 0.05 | 0.05 | 1.1 | 0.5 | 0.05 | 0.05 | 0.4 |
| | | | | | | | | | | |
| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| 0 | 229.4 | 321.5 | 366.9 | 169 | 776.9 | 590.9 | 701.5 | 145.7 | 372.1 | 80.2 |
| 1 | 401.9 | 660.1 | 588.8 | 227.4 | 606.3 | 996.2 | 1200.4 | 656 | 512.6 | 787.3 |
| 2 | 92.2 | 71.3 | 157.5 | 91.2 | 37.3 | 74.2 | 71.8 | 87.6 | 55.2 | 50 |
| 3 | 4 | 9.3 | 13.1 | 9.3 | 3.7 | 4.6 | 5.9 | 15.8 | 13.8 | 6.5 |
| 4 | 0.2 | 6.9 | 2.3 | 1.1 | 0.4 | 0.8 | 1 | 2.4 | 3.8 | 2.7 |
| 5+ | 0.05 | 1 | 1.1 | 0.2 | 0.05 | 0.05 | 0.3 | 0.5 | 0.6 | 0.2 |
| | | | | | | | | | | |
| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
| 0 | 272.7 | 113 | 123.8 | 272.9 | 210.3 | 62.7 | 52.9 | 20.9 | 514.4 | 286.4 |
| 1 | 887.1 | 781.6 | 347.2 | 918.8 | 794.5 | 743.3 | 626.7 | 375.6 | 1210.7 | 644.1 |
| 2 | 127.7 | 69.5 | 37.6 | 40.3 | 74.7 | 35.1 | 24.8 | 60.4 | 68.8 | 80.5 |
| 3 | 5 | 9 | 7.5 | 7 | 8.1 | 3.4 | 2.6 | 5.1 | 5.7 | 3.4 |
| 4 | 2.3 | 1.2 | 1.5 | 2.6 | 1.3 | 1.2 | 1.3 | 1.3 | 0.5 | 0.5 |
| 5+ | 0.1 | 0.3 | 0.2 | 1.3 | 0.3 | 0.05 | 0.05 | 0.1 | 0.3 | 0.05 |

## 6.1.4 Tuning data

Abundance index from the survey, by age, is shown in the following table (n/km$^2$):

| | 0 | 1 | 2 | 3 | 4 | 5+ |
|---|---|---|---|---|---|---|
| 2001 | 194 | 116.4 | 14.2 | 1.6 | 0.8 | 0.1 |
| 2002 | 145.3 | 154.8 | 10.3 | 1.4 | 0.5 | 0.3 |
| 2003 | 108.1 | 82.3 | 8.8 | 0.05 | 0.4 | 0.05 |
| 2004 | 374.5 | 135.1 | 7 | 1 | 0.3 | 0.05 |
| 2005 | 457.9 | 204.2 | 10.8 | 0.4 | 0.05 | 0.05 |
| 2006 | 1002 | 180.4 | 12.4 | 0.6 | 0.05 | 0.05 |
| 2007 | 516.8 | 209.4 | 8.5 | 0.3 | 0.6 | 0.05 |
| 2008 | 167.7 | 78.1 | 5.3 | 1.6 | 0.6 | 0.05 |
| 2009 | 908.1 | 103.3 | 4.7 | 0.3 | 0.05 | 0.05 |
| 2010 | 567.1 | 127.5 | 16.1 | 0.05 | 0.05 | 0.05 |
| 2011 | 432.4 | 115.3 | 5.2 | 0.7 | 0.05 | 0.05 |
| 2012 | 996.2 | 135.7 | 1.8 | 0.6 | 0.3 | 0.05 |
| 2013 | 1163 | 191.4 | 3.7 | 0.2 | 0.3 | 0.05 |
| 2014 | 504.1 | 126.7 | 8 | 1.2 | 0.8 | 0.05 |
| 2015 | 319.3 | 81.3 | 3.2 | 0.4 | 0.05 | 0.05 |
| 2016 | 427.9 | 70.3 | 3.4 | 0.2 | 0.05 | 0.05 |
| 2017 | 102.2 | 47.6 | 4.3 | 0.5 | 0.05 | 0.05 |
| 2018 | 926.9 | 81.1 | 4.7 | 1.1 | 0.2 | 0.05 |
| 2019 | 332.1 | 97 | 8.7 | 0.3 | 0.05 | 0.05 |

## 6.1.5 Results

3-D plots for the estimated fishing mortality and catchability from the survey are shown in Figure 6.2.5-1.

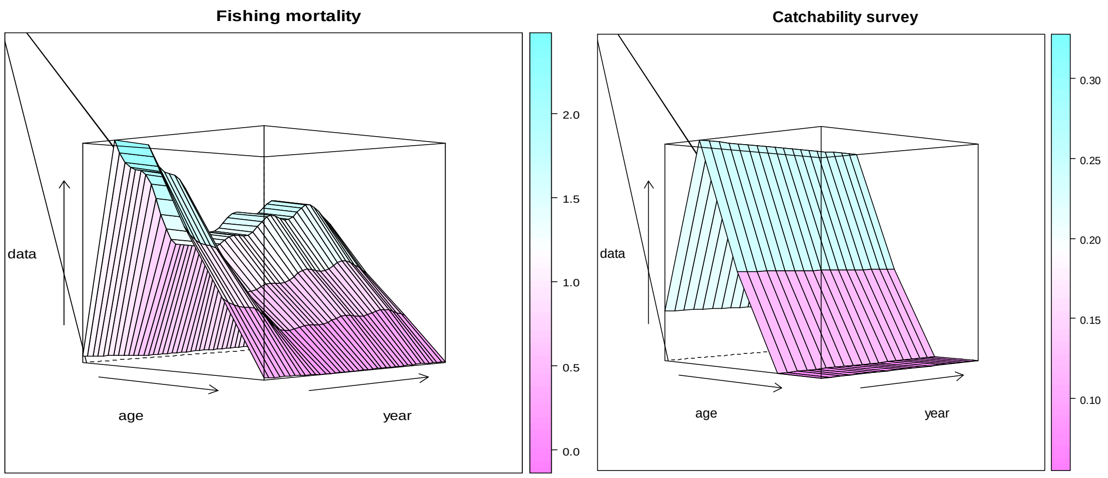


Figure 6.2.5-1. 3D contour plots of estimated fishing mortality and of estimated catchability at age and year for M. merluccius from GSA 05.

A4a results show important oscillations along the data series (Fig 6.1.5-1). For the last year, SSB and catch showed an increasing trend.

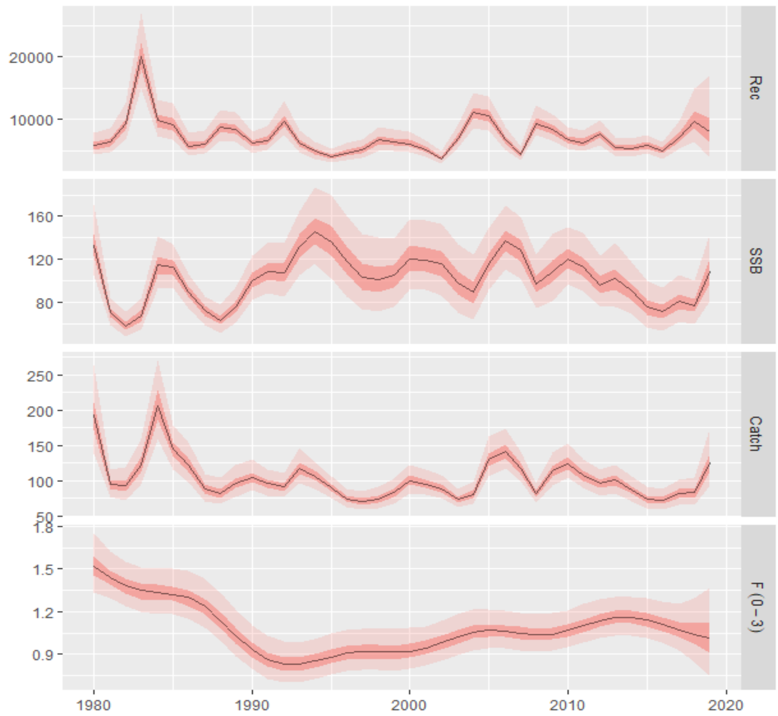


Fig 6.1.5-1. A4a results for *Merluccius merluccius* in GSA 05.

### *6.1.6 Robustness analysis*

Residuals from surveys by age and year were relatively low (Fig. 6.1.6-1).

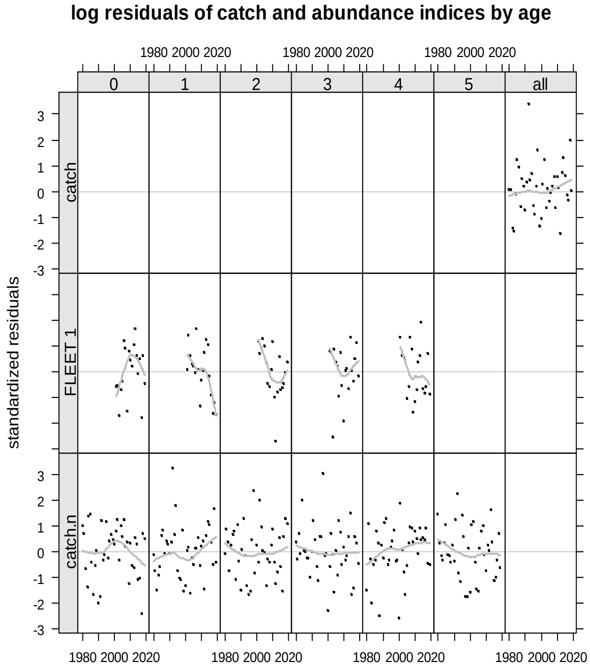


Figure 6.2.5-3. Residuals from the catches and the tuning fleet for M. merluccius from GSA 05.

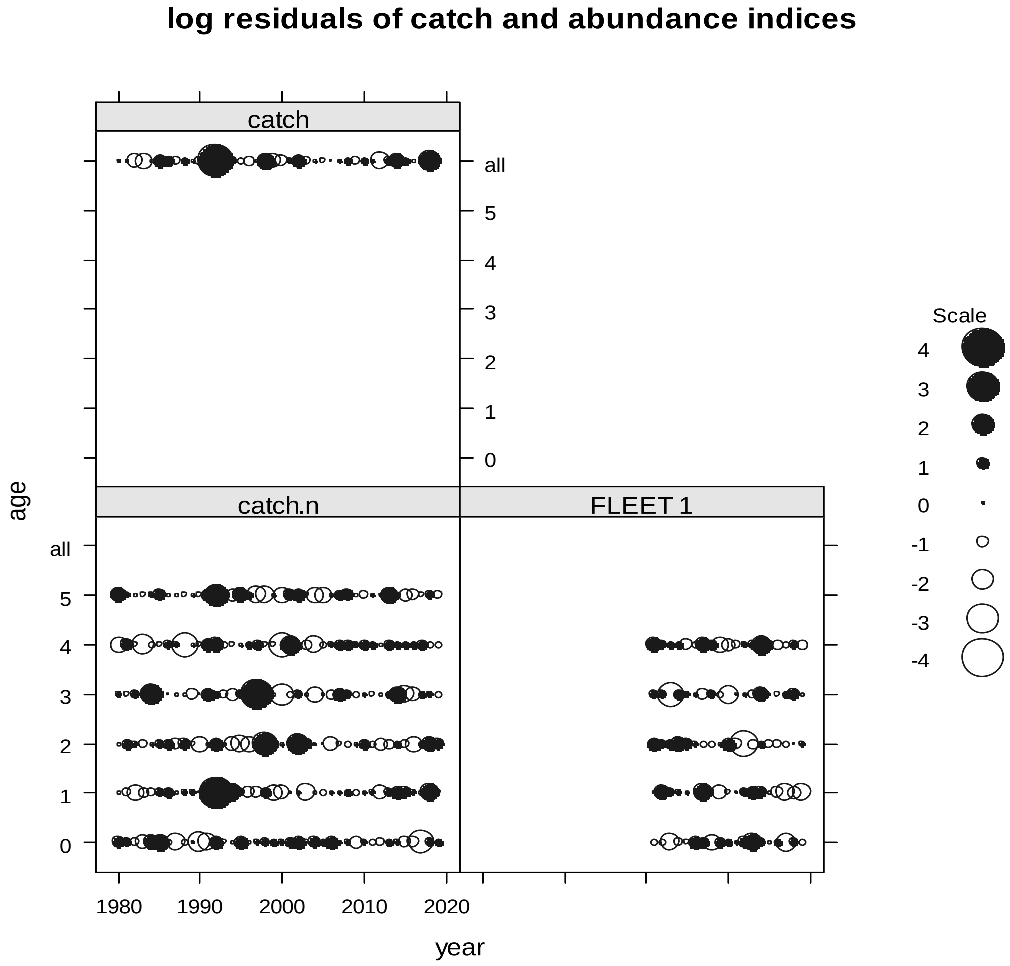


Fig. 6.1.6-1. *Merluccius merluccius* GSA05: Log residuals for the surveys and the commercial fleet.

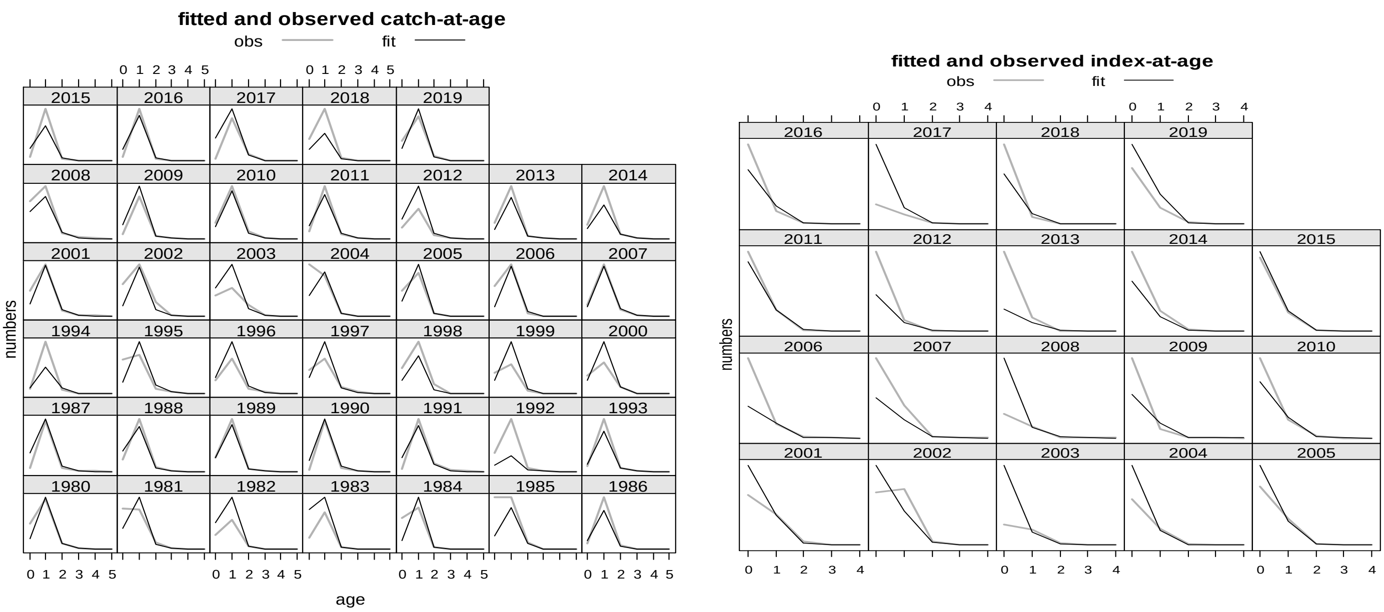


Figure 6.2.5-5. Model fit for *M. merluccius* for the commertial fleet and survey from GSA 05.

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

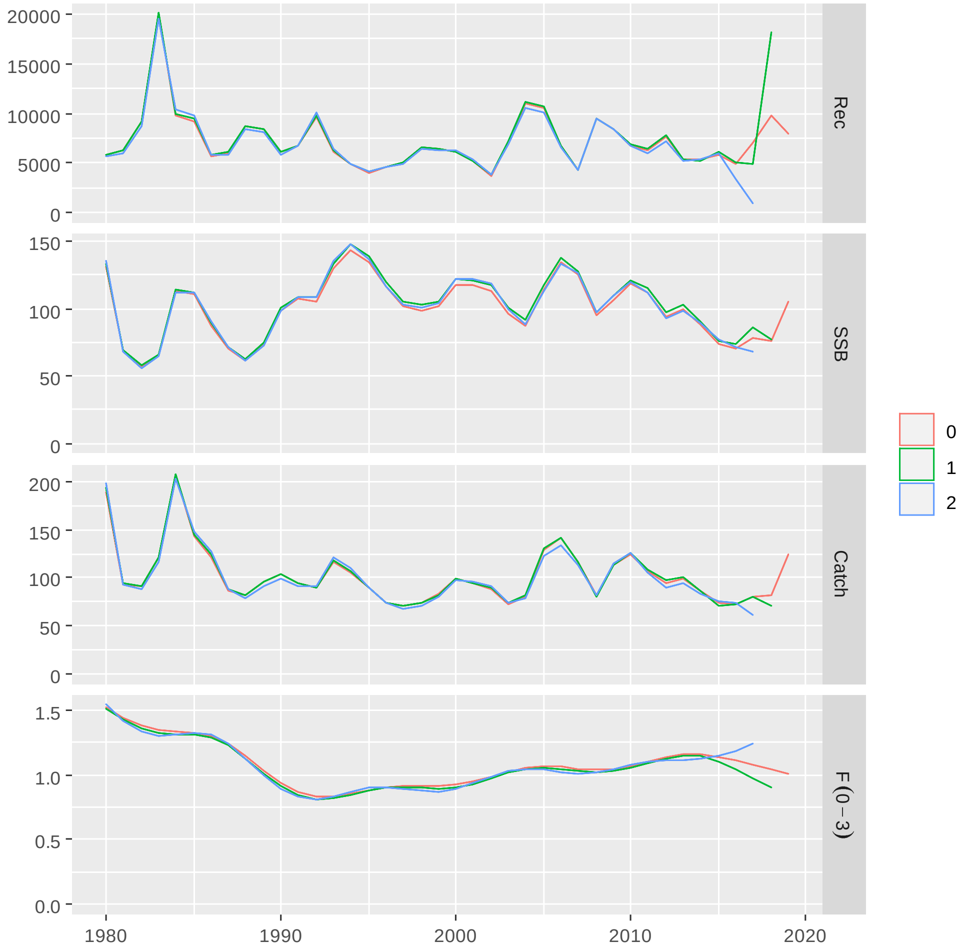


Figure 6.1.7-1. Retrospective analysis for M. merluccius from GSA 05.

### *6.1.8 Assessment quality*

Stability of the assessment, evaluation of quality of the data and reliability of model assumptions.

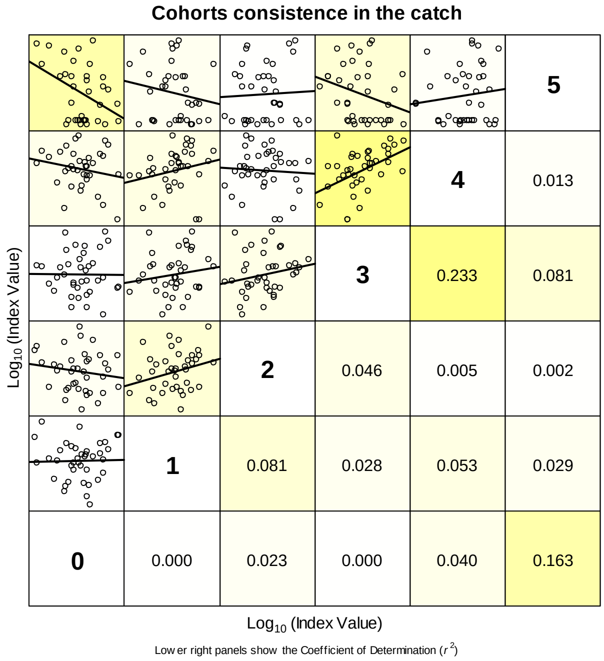


Figure 6.1.8.1. Internal consistency of the catch at age data, commercial fleet, for *Merluccius merluccius* from GSA5

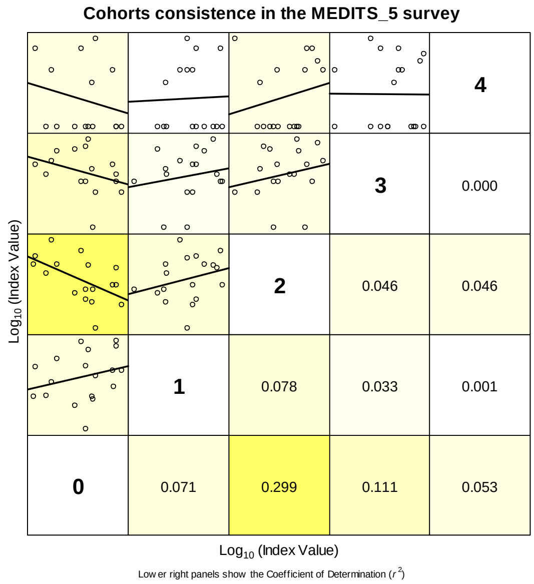


Figure 6.1.8.1. Internal consistency of the catch at age data, MEDITS survey, for *Merluccius merluccius* from GSA5

# 7 Stock predictions

## 7.1 Short term predictions

A deterministic short term prediction was performed using FLR routines, assuming an $F_{stq}$ of 1.04 and a recruitment as the geometric average 2017-2019). Table 7.1.1 shows the results of the predictions..

Table 7.1.1 – Short term forecast in different F scenarios computed for M. merluccius in GSA 5.

| | Ffactor | Fbar | Catch_201 | Catch_202 | Catch_202 | Catch_202 | SSB_2020 | SSB_2021 | SSB_2022 | Change_S | Change_C |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F0.1 | 0.31 | 0.326 | 124.150 | 121.040 | 47.371 | 74.325 | 118.267 | 107.997 | 206.659 | 91.356 | -61.844 |
| F upper | 0.43 | 0.447 | 124.150 | 121.040 | 60.804 | 85.923 | 118.267 | 107.997 | 180.422 | 67.062 | -51.024 |
| flower | 0.21 | 0.218 | 124.150 | 121.040 | 33.737 | 58.441 | 118.267 | 107.997 | 234.096 | 116.762 | -72.826 |
| Zero catch | 0.00 | 0.000 | 124.150 | 121.040 | 0.000 | 0.000 | 118.267 | 107.997 | 304.753 | 182.186 | -100.000 |
| Status quo | 1.00 | 1.042 | 124.150 | 121.040 | 105.398 | 99.758 | 118.267 | 107.997 | 101.464 | -6.050 | -15.104 |
| Different | 0.10 | 0.104 | 124.150 | 121.040 | 17.260 | 33.403 | 118.267 | 107.997 | 268.166 | 148.308 | -86.098 |
| | 0.20 | 0.208 | 124.150 | 121.040 | 32.437 | 56.703 | 118.267 | 107.997 | 236.749 | 119.218 | -73.873 |
| | 0.30 | 0.313 | 124.150 | 121.040 | 45.810 | 72.721 | 118.267 | 107.997 | 209.761 | 94.228 | -63.101 |
| | 0.40 | 0.417 | 124.150 | 121.040 | 57.618 | 83.523 | 118.267 | 107.997 | 186.565 | 72.749 | -53.590 |
| | 0.50 | 0.521 | 124.150 | 121.040 | 68.069 | 90.614 | 118.267 | 107.997 | 166.616 | 54.278 | -45.172 |
| | 0.60 | 0.625 | 124.150 | 121.040 | 77.339 | 95.090 | 118.267 | 107.997 | 149.450 | 38.384 | -37.706 |
| | 0.70 | 0.729 | 124.150 | 121.040 | 85.583 | 97.746 | 118.267 | 107.997 | 134.669 | 24.697 | -31.065 |
| | 0.80 | 0.833 | 124.150 | 121.040 | 92.933 | 99.155 | 118.267 | 107.997 | 121.932 | 12.903 | -25.144 |
| | 0.90 | 0.938 | 124.150 | 121.040 | 99.505 | 99.728 | 118.267 | 107.997 | 110.946 | 2.731 | -19.851 |
| | 1.10 | 1.146 | 124.150 | 121.040 | 110.698 | 99.451 | 118.267 | 107.997 | 93.270 | -13.636 | -10.835 |
| | 1.20 | 1.250 | 124.150 | 121.040 | 115.479 | 98.952 | 118.267 | 107.997 | 86.183 | -20.199 | -6.984 |
| | 1.30 | 1.354 | 124.150 | 121.040 | 119.805 | 98.360 | 118.267 | 107.997 | 80.045 | -25.883 | -3.500 |
| | 1.40 | 1.459 | 124.150 | 121.040 | 123.733 | 97.741 | 118.267 | 107.997 | 74.722 | -30.811 | -0.336 |
| | 1.50 | 1.563 | 124.150 | 121.040 | 127.311 | 97.138 | 118.267 | 107.997 | 70.100 | -35.091 | 2.546 |
| | 1.60 | 1.667 | 124.150 | 121.040 | 130.580 | 96.577 | 118.267 | 107.997 | 66.080 | -38.813 | 5.179 |
| | 1.70 | 1.771 | 124.150 | 121.040 | 133.579 | 96.075 | 118.267 | 107.997 | 62.577 | -42.057 | 7.595 |
| | 1.80 | 1.875 | 124.150 | 121.040 | 136.338 | 95.639 | 118.267 | 107.997 | 59.520 | -44.888 | 9.817 |
| | 1.90 | 1.980 | 124.150 | 121.040 | 138.885 | 95.270 | 118.267 | 107.997 | 56.845 | -47.364 | 11.869 |
| | 2.00 | 2.084 | 124.150 | 121.040 | 141.245 | 94.967 | 118.267 | 107.997 | 54.501 | -49.535 | 13.769 |

## 7.2 Medium term predictions

No medium term prediction was carried out due to the lack of a reliable model fit for the spawning stock biomass-recruitment relationship

## 7.3 Long term predictions

A4a results were used as input data for the Y/R analysis, performed in R (FLBRP) using the last 3 years (2017-2019) in order to calculate the reference point ($F_{0.1}$ as a proxy of $F_{MSY}$) and the estimated reference fishing mortality ($F_{current}$). However, the $F_{0.1}$ considered for the final advice was those computed in 2019.

Yield per recruit analysis was used (FLBRP) to calculate the reference point ($F_{0.1}$ as a proxy of $F_{MSY}$) and the estimated reference fishing mortality ($F_{current}$).

| | |
|---|---|
| $F_{0.1\ (2019)}$ | 0.33 |
| $F_{current\ (0\text{-}3,\ 2019)}$ | 1.02 |

# 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 | $F_{0.1\ (2019)}$ =0.33 | $F_{(0\text{-}3,\ 2019)}$=1.02 | | | IO ($O_H$) |
| | Fishing effort | | | | | |
| | Catch | | | | | |
| | | | | | | |
| **Stock abundance** | Biomass | | | | | |
| | SSB | | 107.89 tons | $33_{th}$ percentile= 95.83<br>$66_{th}$ percentile= 113.02 | | |
| **Recruitment** | | 8.3 millions | 9705.3 | | | |
| **Final Diagnosis** | | In high level of overfishing and overexploited with intermediate level of biomass | | | | |

Ratio $F_{(0\text{-}3,\ 2019)}/F_{0.1(2019)}$= 3.09.

## 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)*