Stock Annex: White anglerfish (*Lophius piscatorius*) in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters)

Stock specific documentation of standard assessment procedures used by ICES

**Stock:** White anglerfish

**Working Group:** Working Group for the Bay of Biscay and the Iberic waters Ecoregion (WGBIE)

**Created:**

**Authors:**

**Last updated:** 19 May 2016

**Last updated by:** Paz Sampedro (WGBIE2016)

---

A. General

A.1 Stock definition

The two species of anglerfish (the white, *Lophius piscatorius*, and the black, *L. budegassa*) are North-eastern Atlantic species; however black anglerfish has a more southerly distribution. White anglerfish is distributed from Norway (Barents Sea) to the Strait of Gibraltar (and including the Mediterranean and the Black Sea) and black anglerfish from the British Isles to Senegal (including the Mediterranean and the Black Sea). Anglerfish occur in a wide range of depths, from shallow waters to at least 1000 m. Information about spawning areas and seasonality is scarce, therefore the stock structure remains unclear. This lack of information is due to their particular spawning behaviour. Anglerfish eggs and larvae are rarely caught in scientific surveys.

ICES gives advice for the management of several anglerfish spp. stocks in European waters: one stock on the Northern Shelf area, that includes anglerfish from the Northern Shelf, Division 3.a, Subarea 4 and Subarea 6, and the stocks on the Southern Shelf area, one in Divisions 7.b–k and 8.a,b and d and the Southern stocks in Divisions 8.c and 9.a. The stock under this Annex is called Southern White Anglerfish and is defined as white anglerfish in Divisions 8.c and 9.a. The boundaries of anglerfish in Divisions 7.b–k and 8.a,b and d and Southern Anglerfish stocks were established for management purposes and they are not based on biological or genetic evidences (GESSAN, 2002; Duarte *et al.*, 2004; Fariña *et al.*, 2004).

Although the stock assessment is carried out separately for each species, white and black anglerfish are caught and landed together, due to that, the advice is given for individual and the combined species. There is a unique TAC for both species.

A.2 Fishery

Anglerfish in ICES Divisions 8.c and 9.a is exploited by Spanish and Portuguese vessels, since 2000 the Spanish landings being more than 81% for both anglerfish total reported landings. International catches for these two stocks have increased since the beginning of the 1980s, until a maximum was reached in 1988 (10 021 t). They have decreased to 1801 t–1802 t in 2001–2002. In the 2005–2011 period the catches were between 1774 t and 4500 t. Both species are caught on the same grounds by the same fleets and are marked together.
White and black anglerfish are caught together by Spanish and Portuguese bottom trawlers and gillnet fisheries. Spanish and Portuguese bottom trawlers are mixed fisheries. The Spanish bottom-trawl fleet predominantly targets hake, megrim, Norway lobster and anglerfish. Since 2003 the alternative use of a trawl gear with High Vertical Opening (HVO) has taken place in larger proportion relative to previous years. This gear targets horse mackerel and mackerel with very few anglerfish catches. Since 2002, the Spanish landings were on average 45% from the trawl fleet and 54% from the gillnet fishery. The Spanish gillnet fishery can use different artisanal gears, but most catches come from “Rasco” that is a specific gear targeting anglerfish.

Anglerfish are caught by Portuguese fleets in trawl and artisanal mixed fisheries. Portuguese landings were on average, from 2002, 11% from trawlers and 89% from artisanal fisheries. The trawl fleet has two components, the trawl fleet targeting demersal fish and trawl fleet targeting crustaceans. Since 2005, Portuguese combined species landings were TAC constrained and very low landings were registered during the 4th quarter since then.

Discarding in white anglerfish is considered low for the trawl fishery, based on estimated data for Spanish trawl fleet (ICES, 2011) and information from Portuguese trawl fleet (ICES, 2012a).

Each year, the European Union sets a combined TAC and quota for white and black anglerfish. There is no minimum landing size for anglerfish, but in order to ensure marketing standards a minimum landing weight of 500 g was fixed in 1996 by the Council Regulation (EC) No.2406/96.

As part of the Recovery Plan for the Southern hake and Iberian Nephrops stocks (Council Regulation (EC) No.2166/2005), in force since January of 2006, the fishing effort regulations are affecting the Spanish and Portuguese mixed trawl fisheries. As anglerfish are taken in these mixed trawl fisheries, these stocks are also affected by the recovery plan effort limitation.

A.3 Ecosystem aspects

White anglerfish is a benthic species that occur on muddy to gravelly bottoms. It attains a maximum size of around 163 cm corresponding to a weight of approximately 51 kg. Historically white anglerfish has been considered a slow growing species, with a late maturation (Duarte et al., 2001). Nevertheless, new evidences from mar-recapture experiments indicate that the anglerfish growth could be faster (Landa et al., 2008).

The ovarian structure of anglerfish differs from most other teleosts. It consists of very long ribbons of a gelatinous matrix, within individual mature eggs floating in separate chambers (Afonso-Dias and Hislop, 1996). The spawning of the Lophius species is very particular, with eggs extruded in a buoyant, gelatinous ribbon that may measure more than 10 m and contain more than a million eggs (Afonso-Dias and Hislop, 1996; Hislop et al., 2001; Quincoces, 2002). Eggs and larvae drift with ocean currents and juveniles settle on the seabed when they reach a length of 5–12 cm. This particular spawning leads to highly clumped distributions of eggs and newly emerged larvae (Hislop et al., 2001) and favourable or unfavourable ecosystem conditions can therefore have major impacts on recruitment.

Due to their particular reproduction aspects (that shows a high parental investment in the offspring) the population dynamics of these species is expected to be highly sensitive to external biological/ecosystem factors.
Vertical displacements of immature and mature white anglerfish from the seabed to the near surface have been recorded in the Northeast Atlantic (Hislop et al., 2001) and are suggested to be related to spawning or feeding.

Improvement of knowledge regarding growth, spawning behaviour, migratory behaviour and juvenile drift are essential to present and future assessment and management of both Southern Anglerfish stocks.

B. Data

B.1 Commercial catch

Landings data are provided by National Government and research institutions of Spain and Portugal. Quarterly landings by country, gear and ICES Division are available from 1978. There were unrecorded landings in Division 8.c between 1978 and 1979, and it was not possible to obtain the total landings in those years. Portuguese landings were TAC constrained since 2005. Very low landings have been registered during the 4th quarters since then. The Portuguese landings were relatively stable during the first two years, but have decreased substantially from 2004 to 2010. In 2010 Portuguese landings were at its minimum value of the series.

The two species are not usually landed separately, for the majority of the commercial categories, and they are recorded together in the ports’ statistics. Therefore, estimates of each species in Spanish landings from Divisions 8.c and 9.a and Portuguese landings of Division 9.a are derived from their relative proportions in market samples.

For white anglerfish the maximum landing of the available series was recorded in 1986 at 6870 t. After that, a general decline to 788 t in 2001 was observed, reaching the minimum of the available series. From 2002-2005 landings increased reaching 3644 t. Since 2005 landings have slowly decreased to 1140 t in 2011.

Discards

Since 1994 a Spanish Discard Sampling Programme is being carried out for trawl fleets operating in the ICES Divisions 8.c and 9.a. However, the time-series is not complete and years with discard data are 1994, 1997, 1999, 2000 and from 2003-2015. The raising procedure used to estimate discards was based on effort. The Portuguese Discard Sampling Programme recorded anglerfish data from 2004. The frequency of occurrence of white anglerfish in discard samples is very low and its discard is considered negligible.

B.2 Biological

Landing numbers—at–length

Since 2009 the quarterly Spanish and Portuguese sampling for length compositions is by métier and ICES Division. Length data from sampled vessels are summed and the resulting length composition is applied to the quarterly landings of the corresponding métier and ICES Division. The sampled length compositions were raised for each country and SOP corrected to total landings on a quarterly or half yearly basis (when the sampling levels by quarter were low). The average lengths of trawl caught anglerfish are lower compared to the artisanal fleets.

Catch numbers—at–age

No catch numbers-at-age are provided to the Working Group. At the WGHMM 2007 meeting (ICES, 2007), age–length keys, based on illicia readings, were used to obtain
catch number-at-age for each species. The exploratory analysis of estimates indicated that the biased age reading criterion does not allow following cohorts along years in either of the two species. The last research about white anglerfish ageing, White Anglerfish Illicia and Otoliths Exchange 2011 (ICES, 2012b), highlighted that neither illicia nor otolith age readings have been validated and, in the case of illicia studies, the agreement among readers and the precision were not acceptable. Therefore it was concluded that the available age reading criteria for white anglerfish southern stock is not valid to build an ALK.

**Growth curve**

The most recent study about white anglerfish growth in Atlantic integrates results for different growth researches (tag–recapture study, length–frequency of catches, and microstructure analysis of hard parts) (Landa et al., 2008). A von Bertalanffy growth curve fitted to all data provided the parameter values $L_{\text{inf}} = 140$ cm and $K = 0.11$. This growth rate is faster than estimated recently using illicia for age estimation.

**Maturity–at-length**

Different estimates of maturity ogive based on macroscopic maturity staging are available for white anglerfish (Duarte et al., 2001; Landa et al., 2012). In these studies the difficulty of finding mature females in the field resulted in samplings with low coverage of mature individuals. Besides, the inadequacy in same instances of the macroscopic examination to determine maturity stage, let it to consider a maturity ogive of white anglerfish from other areas. The available study was carried out in ICES Divisions 8abd and determined microscopically the maturity stage (Quincoces, 2002). The parameters of maturity ogive are 50% maturity at 61.84 cm and a slope at 0.1001.

**Natural mortality**

No specific studies about natural mortality of white anglerfish were available. However, taking into consideration its growth rate and the high size that can attain, a constant annual instantaneous natural mortality rate ($M$) of 0.2 yr$^{-1}$, for all ages and years, is assumed.

**Length–weight relationship**

The weight at length relationship was calculated using data from an international project with a sampling that spatially covered a large proportion of the stock and which number of samples (BIOSDEF, 1998):

$$W = 2.70 \times 10^{-5} L^{2.839}$$

where $W$ = weight in kilograms and $L$ = length in centimetres.

**8.3 Surveys**

**SpGFS–WIBTS–Q4**

The Spanish Groundfish Survey aims to collect data on the distribution and relative abundance, and biological information of commercial fish in ICES Divisions 8.c and Northern 9.a. Since 1983 it is annually carried out in fourth quarter (September/October) of the years, except for 1987. Time-series of abundance indices, in weight and in number, and correspondent length composition are available for both anglerfish species. The full time-series of this survey is used in the assessment of white anglerfish since 2012.
PtGFS–WTBS–Q4
Portuguese Autumn Groundfish Survey has been carried out in Portuguese continental waters since 1979 in the fourth quarter of the years. Abundance indices for both anglerfish species are available from 1989 to 2011. The abundance values detected by this survey are very low for the whole time-series, being insignificant for some years.

This survey is not used in the assessment of white anglerfish.

B.4 Commercial cpue
Six commercial series of landing-effort are available to the WG. Four of them are Spanish fleets in the ICES Division 8.c and two Portuguese fleets in the ICES Division 9.a. The Portuguese trawl fleet was split into fish trawlers and crustacean trawlers (WD12, Duarte et al., 2007 in ICES, 2007) according to the fleet segmentation proposed by the IBERMIX project (WD06, Castro et al., 2007 in ICES, 2007).

SP–CORTR8C
A Coruña trawl fleet fishing in Division 8.c is available for years 1982–2012. Data provided for A Coruña trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 15% of international catches of white anglerfish along the time-series. A standardized series from 1994 to 2006 is also available for this fleet with annual effort data (in fishing days) and annual lpue.

Data from this commercial lpue series has been used in the white anglerfish assessment since 2007.

SP–CEDGNS8C
Cedeira gillnet fleet fishing in Division 8.c is available for years 1999–2011. Data provided for Cedeira gillnets comprise quarterly standardized effort (in soaking days), landings and length composition of landings. This fleet represents an average of 11% of international catches of white anglerfish since 1999. Due to the reduction in the number of vessels of Cedeira fleet, this tuning series could not be considered as a representative abundance index of the stock and since 2012 it is no longer recorded.

Data from this commercial lpue series has been used in the white anglerfish assessment since 2007.

Other available commercial series of lpues that have never been employed in the assessment are

PT–TRF9A
Portuguese trawlers targeting fish: years 1989–2012. Data provided for Portuguese trawlers targeting fish comprise quarterly effort (1000 hours trawling with occurrence of anglerfish), landings and length composition of landings. This fleet represents an average of 1% of international catches of white anglerfish along the time-series. A standardized series from 1989 to 2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual lpue.

PT–TRC9A
Portuguese trawlers targeting crustacean: years 1989–2012. Data provided for Portuguese trawlers targeting fish comprise quarterly effort (1000 hours trawling with occurrence of anglerfish), landings and length composition of landings. This fleet
represents an average of 1% of international catches of white anglerfish along the time-series. A standardized series from 1989 to 2008 is also available for this fleet with annual effort data (in 1000 hauls) and annual lpue.

**SP-AVTR8C**
Avilés trawl fleet fishing in Division 8.c is available for years 1986–2003. Data provided for Avilés trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 6% of international catches of white anglerfish along the time-series. The effort-series was interrupted in 2003.

**SP-SANTR8C**
Santander trawl fleet fishing in Division 8.c is available for years: years 1986–2010. Data provided for Santander trawlers comprise quarterly effort (fishing days per 100 horse power), landings and length composition of landings. This fleet represents an average of 7% of international catches of white anglerfish along the time-series. Effort data for 2008 was not provided to the WG.

**C. Assessment: data and method**
Until 2011 white anglerfish stock was assessed with a non-equilibrium production model (ASPIC software). Results from growth studies provide a growth pattern for this stock allowing the application of a length-based assessment model. Stock Synthesis is was considered a suitable model to assess this stock by WKFLAT (ICES, 2012a).

**Model**
Model used: Stock Synthesis 3 (SS3) (Methot, 2000)
Software used: Stock Synthesis v3.23b (Methot, 2011)

Stock Synthesis 3 (SS3) is an integrated assessment model. SS3 has been used for stock assessment all around the world. The area of highest used is on the US Pacific Coast. SS3 is coded in C++ using Auto-Differentiation Model Builder (http://www.admb-project.org) and available from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/SS3.html). SS3 has three main characteristics that differentiate it from classical assessment models:

- SS model structure allows for building of simple to complex models depending upon the data available. It is capable to build models with age and/or length structure and spatial structure.
- It is capable to use different sources of information.
- All parameters have a set of controls to allow prior constraints, time-varying flexibility, and linkages to environmental data.

The overall SS3 model is subdivided into three submodels. The first submodel simulates the population dynamics, where the basic abundance, mortality and growth functions create a synthetic representation of the true population. The second submodel is the observation submodel. This contains the processes and filters designed to derive expected values for the various types of data. The last submodel is the statistical that quantifies the magnitude of the difference between observed and expected data and employs an algorithm to find the set of parameters that maximizes the goodness-of-fit.
The SS3 model developed for white anglerfish during the WKFLAT 2012 has been designed for a particular set of data and specifications. White anglerfish is harvested by four fleets, and two commercial lpue series and one fishery-independent survey provide information about relative abundance. No discard information is considered. Length composition data are available from both the fisheries and surveys. No age information is available for this stock.

**Input data**


**Model structure:**

- Temporal unit: quarterly based data (landings, lpue and length–frequency) were used in SS3 calculations.
- Spatial structure: One area.
- Sex: Both sexes combined.

**Fleet definition:**

Four fleets were defined attending to the gear type and country:

- Spanish trawlers in ICES Division 8.c-9.a (SPTR8C9A)
- Spanish artisanal in ICES Division 8.c (SPART8C)
- Portuguese trawlers in ICES Division 9.a (PTTR9A)
- Portuguese artisanal in ICES Division 9.a (PTART9A)

**Landed catches:**

Quarterly landings entered the model as biomass (in weight) for the four fleets. Landings data for January 1980 to December 2015 were used to conduct the stock assessment of white anglerfish.

From 1980 to 1988 quarterly landings were estimated using the average proportion for the further five years (1989–1993) by fleet. In the case of SPART8C quarterly landings were estimated from 1980 to 1993 using the average proportion for the further five years (1994–1998).

**Abundance indices:**

- A Coruña trawlers (SPCORT8C): Quarterly lpue in weight from 1982 to 2012. It is entered as four separate indices, one index per quarter.
- Cedeira gillnetters (SPCEDGN8C): Quarterly lpue in weight from 1999 to 2011. It is entered as four separate indices, one index per quarter.

**Length composition of data:**

The length bin was set by 2 cm, from 4 to 100 cm, by 10 cm from 100 to 160 cm and by 40 cm from 160 to 200 cm. Length composition for the four fishing fleets and the three abundance indices were used. The available length data and their disaggregated level differ among fleets:

**Length composition of Fleets:**
• SPTR8C9A: 1986–2015, quarterly basis. From 1986 to 1988 quarterly length proportions were estimated from an annual proportion using the Data Super-Period approach available in SS3.
• SPART8C: 1986–2015, quarterly basis. From 1986 to 1994 quarterly length proportions were estimated from an annual proportion using the Data Super-Period approach available in SS3.
• PTTR9A: 1986–2009, quarterly basis. From 1986 to 1988 quarterly length proportions were estimated from an annual proportion using the Data Super-Period approach presented in SS3.
• PTART9A: 1986–2009, quarterly basis. From 1986 to 1988 quarterly length proportions were estimated from an annual proportion using the Data Super-Period approach present in SS3.

Length composition of Abundance Indices:
• SPCEDGN8C: 1999–2011, quarterly basis.

Model assumptions and parameters
• Natural mortality: $M=0.2$ for all ages and years.
• Growth: von Bertalanffy function: $K=0.11$ fixed, $L_{\infty}$ and mean length-at-age 0.75 are estimated.
• Maturity ogive: length-based logistic, $L_{50}=61.84$ and slope=-0.1001, constant over time.
• Weight-at-length: $a=2.70\times10^{-5}$ $b=2.839$, not estimated.
• Recruitment allocation in Quarter 3.
• Stock–recruitment relationship: Beverton–Holt model: steepness $h=0.999$, $\sigma_R=0.4$, $R_0$ estimated.
• Selectivity: For all fleets selectivity was only length-based and was modelled as a double normal function. Selectivity varies among fleets, but is assumed to be time-invariant.

D. Short-term projection

Model used: Stock Synthesis 3.
Software used: ad hoc R code.
Initial stock size: SS3 outputs in the last assessment year.
Natural mortality: Set to 0.2 for all ages in all years.
Growth model: von Bertalanffy function, with parameters estimated in the assessment model.
Maturity-at-length: The same ogive as in the assessment is used for all years.
Weight-at-length in the stock and in the catch: The same length–weight relationship as in the assessment model.
Exploitation pattern: Average of the final three assessment years (with the possibility of scaling to final year $F$).

Intermediate year assumptions: status quo $F$.

Recruitment: geometric mean of estimated recruitment from 1980 until the final assessment year. If trends in recruitment become evident a shorter range of years could be selected.

E. Medium-term projections

No medium-term projections are conducted for white anglerfish stock.

F. Yield and biomass per recruit/long-term projections

Yield-per-recruit calculations are conducted using the same input values as those used for the short-term forecasts.

Model used: yield and biomass-per-recruit over a range of $F$ values.

Software used: ad hoc R code.

G. Biological reference points

In the WKMSYREF4 (ICES, 2016) biological reference points were calculated for this stock. The following table shows the estimates that were obtained:

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
<th>Technical basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSY approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSY Btrigger</td>
<td>5400 t</td>
<td>5\text{th} percentile of SSB$_{2015}$ (WGBIE2015)</td>
</tr>
<tr>
<td>$F_{\text{MSY}}$</td>
<td>0.31</td>
<td>$F$ that maximises median equilibrium yield</td>
</tr>
<tr>
<td>$F_{\text{MSY}}$ ranges [Flower, Fupper]</td>
<td>0.18, 0.41</td>
<td>5% reduction in long-term yield compared with MSY</td>
</tr>
<tr>
<td>Precautionary approach</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blim</td>
<td>1900 t</td>
<td>Bloss (lowest observed SSB)</td>
</tr>
<tr>
<td>Bpa</td>
<td>2600 t</td>
<td>Blim * exp(1.645 * $\sigma$), where $\sigma$ = 0.2</td>
</tr>
<tr>
<td>Flim</td>
<td>0.60</td>
<td>Segmented regression with Blim as breakpoint</td>
</tr>
<tr>
<td>Fpa</td>
<td>0.43</td>
<td>Flim *exp (-$\sigma$1.645), where $\sigma$=0.2</td>
</tr>
</tbody>
</table>

H. Other issues

H.1 Historical development of assessment

Southern Anglerfish stocks were assessed for the first time in the 1990 ICES WG meeting. Different assessment trials were performed during the subsequent eight years but analytical assessments indicated unrealistic results. The database (both biological and fisheries data) were improved along these years trying to apply an analytical assessment model. Since 1998 a non-equilibrium surplus production model ASPIC (Prager, 1994) was applied to each stock or to the combined stock data. These stock assessments were accepted by the ACFM and used to provide management advice. The assessment of white anglerfish as a separate stock has been carried out continuously from 2007. The history of white anglerfish assessment from 2007 to 2016 is presented in Table 1.
Table 1. History of southern white anglerfish assessment from 2007 to 2013.

<table>
<thead>
<tr>
<th>WG</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Assessment Model</td>
<td>Assessment Model</td>
<td>Assessment Model</td>
<td>Assessment Model</td>
<td>Stock Synthesis 3</td>
<td>Stock Synthesis 3</td>
<td>Stock Synthesis 3</td>
</tr>
<tr>
<td></td>
<td>No updated</td>
<td>No updated</td>
<td>No updated</td>
<td>No updated</td>
<td>Length based Quarterly based data</td>
<td>Length based Quarterly based data</td>
<td>Length based Quarterly based data</td>
</tr>
<tr>
<td>Software</td>
<td>ASPIC (v. 5.16)</td>
<td>ASPIC (v. 5.16)</td>
<td>ASPIC (v. 5.34)</td>
<td>ASPIC (v. 5.34.9)</td>
<td>Software</td>
<td>Software</td>
<td>Software</td>
</tr>
<tr>
<td></td>
<td>Fleets</td>
<td>Fleets</td>
<td>Fleets</td>
<td>Fleets</td>
<td>Fleets</td>
<td>Fleets</td>
<td>Fleets</td>
</tr>
<tr>
<td>Error Type</td>
<td>Condition on yield</td>
<td>Condition on yield</td>
<td>Condition on yield</td>
<td>Condition on yield</td>
<td>Abundance Index 3 (4rd quarter)</td>
<td>Abundance Index 3 (4rd quarter)</td>
<td>Abundance Index 3 (4rd quarter)</td>
</tr>
<tr>
<td>Number of bootstrap</td>
<td>500</td>
<td>500</td>
<td>1000</td>
<td>1000</td>
<td>Natural mortality</td>
<td>Natural mortality</td>
<td>Natural mortality</td>
</tr>
<tr>
<td>Maximum F</td>
<td>8.0 (y-1)</td>
<td>8.0 (y-1)</td>
<td>8.0 (y-1)</td>
<td>8.0 (y-1)</td>
<td>Growth</td>
<td>Growth</td>
<td>Growth</td>
</tr>
<tr>
<td>Statistical weight B1/K</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Maturity ogive</td>
<td>Maturity ogive</td>
<td>Maturity ogive</td>
</tr>
<tr>
<td>Statistical weight for fisheries</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
<td>Weight-at-length</td>
<td>Weight-at-length</td>
<td>Weight-at-length</td>
</tr>
</tbody>
</table>

Notes: 
- **Model Structure**
  - Stock Synthesis 3 (Methot, 2000)
  - Length based Quarterly based data

- **Cpue Series 1 (years)**
  - SP-CORUTR8c (1986–2006)
  - SP-CORUTR8c (1986–2008)
  - SP-CORUTR8c (1986–2009)
  - SP-CORUTR8c (1986–2010)

- **Index of Biomass (years)**
  - SP-CEDGSN8c (1999–2006)
  - SP-CEDGSN8c (1999–2008)
  - SP-CEDGSN8c (1999–2009)
  - SP-CEDGSN8c (1999–2010)

- **Error Type**
  - Condition on yield
  - Condition on yield
  - Condition on yield
  - Condition on yield

- **Number of bootstrap**
  - 500
  - 500
  - 1000
  - 1000

- **Maximum F**
  - 8.0 (y-1)
  - 8.0 (y-1)
  - 8.0 (y-1)
  - 8.0 (y-1)

- **Statistical weight B1/K**
  - 1
  - 1
  - 1
  - 1

- **Statistical weight for fisheries**
  - 1.1
  - 1.1
  - 1.1
  - 1.1
<table>
<thead>
<tr>
<th>WG</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1-ratio (starting guess)</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>Recruitment allocation</td>
<td>Quarter 3</td>
<td>Quarter 3</td>
</tr>
<tr>
<td>MSY (starting guess)</td>
<td>5000 t</td>
<td>5000 t</td>
<td>5000 t</td>
<td>5000 t</td>
<td>Stock-Recruitment</td>
<td>Beverton–Holt model h=0.999 sigmaR=0.4 R0 estimated</td>
<td>Beverton–Holt model h=0.999 sigmaR=0.4 R0 estimated</td>
</tr>
<tr>
<td>K (starting guess)</td>
<td>50 000 t</td>
<td>50 000 t</td>
<td>50 000 t</td>
<td>50 000 t</td>
<td>Selectivity</td>
<td>All fleets: length-based double normal function Varies among fleets Time-invariant</td>
<td>All fleets: length-based double normal function Varies among fleets Time-invariant</td>
</tr>
<tr>
<td>q1 (starting guess)</td>
<td>1d-5</td>
<td>1d-5</td>
<td>1d-5</td>
<td>1d-5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>q2 (starting guess)</td>
<td>1d-6</td>
<td>1d-6</td>
<td>1d-6</td>
<td>1d-6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated parameter</td>
<td>All</td>
<td>All</td>
<td>All</td>
<td>All</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min and Max allowable MSY</td>
<td>2000 (t) – 10 000 (t)</td>
<td>2000 (t) – 10 000 (t)</td>
<td>2000 (t) – 11 500 (t)</td>
<td>2000 (t) – 11 500 (t)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min and Max K</td>
<td>5000 (t) – 500 000 (t)</td>
<td>5000 (t) – 100 000 (t)</td>
<td>5000 (t) – 112 000 (t)</td>
<td>5000 (t) – 112 000 (t)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random Number Seed</td>
<td>1 964 185</td>
<td>1 964 185</td>
<td>1 964 185</td>
<td>1 964 185</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>WG</strong></td>
<td><strong>2014</strong></td>
<td><strong>2015</strong></td>
<td><strong>2016</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
<td>----------</td>
<td>----------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model Structure</strong></td>
<td>Length based Quarterly based data</td>
<td>Length based Quarterly based data</td>
<td>Length based Quarterly based data</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Software</strong></td>
<td>SS3v23b</td>
<td>SS3v23b</td>
<td>SS3v23b</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fleets</strong></td>
<td>SPTR8C9A SPART8C PTT9A PTT9A</td>
<td>SPTR8C9A SPART8C PTT9A PTT9A</td>
<td>SPTR8C9A SPART8C PTT9A PTT9A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Abundance Index 1 (by quarter)</strong></td>
<td>SPCORUTR8c (1982-2012)</td>
<td>SPCORUTR8c (1982-2012)</td>
<td>SPCORUTR8c (1982-2012)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Natural mortality</strong></td>
<td>M=0.2 for all ages and years</td>
<td>M=0.2 for all ages and years</td>
<td>M=0.2 for all ages and years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Growth</strong></td>
<td>von Bertalanffy K=0.11 fixed Lmax estimated</td>
<td>von Bertalanffy K=0.11 fixed Lmax estimated</td>
<td>von Bertalanffy K=0.11 fixed Lmax estimated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maturity ogive</strong></td>
<td>length-based logistic L50=61.84 slope=-0.1001</td>
<td>length-based logistic L50=61.84 slope=-0.1001</td>
<td>length-based logistic L50=61.84 slope=-0.1001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weight-at-length</strong></td>
<td>a=2.70×10-5 b=2.839</td>
<td>a=2.70×10-5 b=2.839</td>
<td>a=2.70×10-5 b=2.839</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Recruitment allocation</strong></td>
<td>Quarter 3</td>
<td>Quarter 3</td>
<td>Quarter 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stock-Recruitment</strong></td>
<td>Beverton–Holt model h=0.999 sigmaR=0.4 R0 estimated</td>
<td>Beverton–Holt model h=0.999 sigmaR=0.4 R0 estimated</td>
<td>Beverton–Holt model h=0.999 sigmaR=0.4 R0 estimated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### I. References


