Stock Assessment Form

Demersal species

2012

**STOCK ASSESSMENT OF COMMON SOLE IN GSA17**

The Italian fleets exploit common sole with rapido trawl and set nets (gill nets and trammel nets), while only trammel net is commonly used in the countries of the eastern coast. Sole is an accessory species for otter trawling. More than 80-90% of catches come from the Italian side. Landings fluctuated between 1,000 and 2,300 t in the period 1996-2011.

XSA, SURBA and Statistical Catch at Age assessments, together with a steady state VPA using VIT-model were applied. Input data were provided by the Italian and Slovenian DCF official data call, estimations derived from the Croatian Primo Project, and tuning data were collected during the SoleMon survey. According to the XSA, SURBA and SCAA analyses a general decreasing trend of SSB is observed, while the recruitment fluctuated since 2006 without a clear trend. Based on the estimates of the current F, in 2011 the fishing mortality appears much higher than F0.1 (proxy of FMSY) and, hence, it can be concluded that the resource is exploited unsustainably.

A reduction of fishing pressure would be recommended, also taking into account that the exploitation is mainly orientated towards juveniles and the success of recruitment seems to be strictly related to environmental conditions. This could be achieved by a two–months closure for rapido trawling inside 11km (6 nm) offshore along the Italian coast, after the fishing ban of August. Moreover, information provided by VMS will be useful in order to quantify the fishing effort of rapido trawlers in such area and period.

Finally, specific studies on rapido trawl selectivity are necessary. In fact, it is not sure that the adoption of a larger mesh size would correspond to a decrease of juvenile catches. The same uncertainty regards the adoption of square mesh.

**Stock Assessment Form version 0.9**

Uploader: Luca Bolognini

## Stock assessment form

## 1 Basic Identification Data

| Scientific name: | Common name: | ISCAAP Group: |
|---|---|---|
| *Solea solea* | Common sole | 31 |
| 1st Geographical sub-area: | 2nd Geographical sub-area: | 3rd Geographical sub-area: |
| 17 | | |
| 1st Country | 2nd Country | 3rd Country |
| Italy | Croatia | Slovenia |
| **Stock assessment method: (direct, indirect, combined, none)** | | |
| **Trawl survey, LCA, XSA, Other: SCAA** | | |
| **Authors:** | | |
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## 2 Stock identification and biological information

Tagging experiments carried out on common sole in the northern Adriatic Sea, using the traditional mark-and-recapture procedure, showed that all individuals were re-captured within the sub-basin (Pagotto *et al.*, 1979). Local currents, eddies and marked differences of oceanographic features of this sub-basin with respect to those of southern Adriatic and Ionian Sea (Artegiani *et al.*, 1997) may prevent a high rate of exchange of adult spawners and the mixing of planktonic larval stages from nursery areas of adjacent basins (Magoulas *et al.*, 1996).Guarnieri *et al.* (2002), taking into account differences of sole specimens from five different central Mediterranean areas in the control region sequence marker, suggested that two near-panmictic populations of common sole could exist in the Adriatic Sea. The former population would inhabit the entire GSA 17 (northern Adriatic Sea). The second unit seems to be spread along the Albanian coasts (eastern part of the GSA 18). The hydrogeographical features of this semi-enclosed basin might support the overall pattern of differentiation of the Adriatic common soles.

The northern Adriatic Sea has a high geographical homogeneity, with a wide continental shelf and eutrophic shallow-waters. The southern Adriatic in contrast is characterized by narrow continental shelves and a marked, steep continental slope (1200 m deep; Adriamed, 2000). This deep canyon could represent a significant geographical barrier for *S. solea*.

On these bases, different actions for fishery management should be proposed for the Adriatic common sole stocks in GSA 17 and GSA 18. In the former area the stock is shared among Italy, Slovenia and Croatia, while in the latter one seems to be shared only between Montenegro and Albania.

A study supported by ADRIAMED-FAO (SoleDiff), about the population structure of common sole in the Adriatic Sea: genetic differentiation and stock boundaries in GSA17 and GSA18, has started in 2011, and is going to confirm the previous evidences. Capitalizing on an available dataset of 353 *S. solea* individuals sequenced in previous projects, additional sequences for 62 individuals of *S. solea* that were collected during the SOLEMON survey 2007 in the eastern side of GSA18 (Albania and Montenegro) and 9 from GSA17 have been generated. A total alignment of 615 bp of the mitochondrial cyt b gene in 424 specimens from a geographic range covering from the Gulf of Lion to the Levantine sea in order to better understand the phylogeographic relationships of the Mediterranean common sole populations have been produced. The results of the median joining network analysis showed the presence of three main phylogeographical clades, corresponding to the West-Central Mediterranean (Balearic-Tyrrenian samples), East-Central Mediterranean (Ionian and Aegean) and Levantine Sea. In the obtained pattern the specimens from the Adriatic sea *S. solea* populations showed both the Tyrrhenian and the Aegean most frequent haplotypes, suggesting the Adriatic sea as a contact zone. Moreover further analysis of the Adriatic populations showed a low but significant differentiation between GSA 17 and GSA 18 populations, with a stronger gene flow from the GSA 18 to the GSA 17. The additional specimens of *S. solea* that will be sampled in Neretva area in the framework of the SoleDiff project will be crucial in order to confirm such gene flow.

### *2.1 Stock unit*

### *2.2 Growth and maturity*

In the Mediterranean Sea, the reproduction of common sole occurs from December to May (Bini; 1968-70), Tortonese, 1975, Fisher *et al*., 1987). Within the framework of SoleMon project, it has been observed that in the central and northern Adriatic Sea the reproduction takes place from November to March. Data on the spatial distribution of spawners provided by the project show a higher concentration of reproducers outside the western coast of Istria (Fabi*et al.*, 2009).
Length at first maturity is 25 cm (Fisher *et al.*, 1987; Jardas, 1996; Vallisneri *et al.*, 2000); this value has been estimated at 25.8 using data from SoleMon project. Females having a weight of 300 g have about 150000 eggs, while those weighting 400 g have about 250000 eggs (Piccinetti and Giovanardi, 1984); eggs are pelagic. The male-female ratio is approximately 1:1 (Piccinetti and Giovanardi, 1984; Fabi*et al.*, 2009).
Hatching occurs after eight days and the larva measures 3 to 4 mm TL (Tortonese, 1975). Eye migration starts at 7 mm TL and ends at 10-11 mm TL. Benthic life begins after seven or eight weeks (15 mm) in coastal and brackish waters (Bini (1968-70); Fabi *et al*., 2009).
In the Adriatic sea, growth analyses on this species have been made using otoliths, scales and tagging experiments. A great variability in the growth rate was noted: some specimens had grown 2 cm in one month, while others, of the same age group, needed a whole year (Piccinetti and Giovanardi, 1984). Von Bertalanffy growth equation parameters have been calculated using various methods. Within the framework of SoleMon project, growth parameters of sole were estimated through the length-frequenzy distributions obtained from surveys.

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

| Somatic magnitude measured (LH, LC, etc)* | | | | | Units* | |
|---|---|---|---|---|---|---|
| Sex | Fem | Mal | Both | Unsexed | | |
| Maximum size observed | 40 | 38 | | | Reproduction season | Fall – Winter |
| Size at first maturity | | | 25.8 | | Reproduction areas | * |
| Recruitment size | | | 18-20 | | Nursery areas | ** |

* Northern Adriatic: within meridians 13°00' and 14°20' E and parallels 44°10' and 45°20' N

** Marine coastal areas, estuarine and lagoon systems along the Italian coast of the central and northern Adriatic Sea

*Table 2.2-2: Growth and length weight model parameters*

| | | | Sex | | | |
|---|---|---|---|---|---|---|
| | | Units | female | male | both | unsexed |
| Growth model | $L_\infty$ | cm | | | 39.6 | |
| | K | | | | 0.4 | |
| | $t_0$ | | | | -0.46 | |
| | Data source | SoleMon project | | | | |
| Length weight relationship | a | | | | 0.007 | |
| | b | | | | 3.0638 | |

| | 0 | 1 | 2 | 3 | 4 | 5+ |
|---|---|---|---|---|---|---|
| M *** | 0.7 | 0.35 | 0.28 | 0.25 | 0.23 | 0.22 |

| sex ratio (% females/total) | 53**** |
|---|---|

*** The vector of natural mortality by age was calculated from Caddy´s (1991) method, using the PROBIOM Excel spreadsheet (Abella et al., 1997):

**** SoleMon survey data 2011

Fisheries information

### 2.3 *Description of the fleet*

The common sole is a very important commercial species in the central and northern Adriatic Sea (Ghirardelli, 1959; Piccinetti, 1967; Jardas, 1996; Vallisneri *et al.*, 2000; Fabi *et al.*, 2009). Italian *rapido* trawlers exploit this resource providing more than 80% of landings. Sole is also a target species of the Italian and Croatian set netters, while it represents an accessory speciesfor otter trawlers.
From censuses carried out at the landing sites, the Italian rapido trawl fleet operating in GSA 17 was made of 155 vessels in 2005 and 124 vessels in 2006 ranging from 9 to 30 m in vessel length, GRT ranged from 4 to 100 and the engine power from 60 to 1000 HP. Each vessel can tow from 2 to 4 rapido trawls depending on its dimensions. The *rapido* trawl is a gear used specifically for catching flatfish and other benthic species (e.g. cuttlefish, mantis shrimp, etc.). It resembles a toothed beam-trawl and is made of an iron frame provided with 3-5 skids and a toothed bar on its lower side. These gears are usually towed at a greater speed (up to 10-13 km $h^{-1}$) in comparison to the otter trawl nets; this is the reason of the name “*rapido*”, the Italian word for “fast”. The mesh opening of the codend used by the Italian *rapido* trawlers is the same or larger (usually 50 mm stretched diamond mesh) than the legal one. The main Italian *rapido* trawl fleets of GSA17 are sited in the following harbours: Ancona, Rimini and Chioggia.
The Italian artisanal fleet in GSA 17, according to SoleMon project data (end of 2006), accounted for 469 vessels widespread in many harbours along the coast. They use gill net or trammel net especially from spring to fall and target small and medium sized sole (usually smaller than 25 cm TL).

*Table 2.3-1: Description of operational units in the stock*

| | Country | GSA | Fleet Segment | Fishing Gear Class | Group of Target Species | Species |
|---|---|---|---|---|---|---|
| **Operational Unit 1*** | ITA | 17 | E - Trawl (12-24 metres) | 98 - Other Gear<br>(rapido trawl) | 33 - Demersal shelf species | Sole |
| **Operational Unit 2** | ITA | 17 | E - Trawl (12-24 metres) | Otter trawl | 33 - Demersal shelf species | |
| **Operational Unit 3** | ITA | 17 | C - Minor gear with engine (6-12 metres) | 07 - Gillnets and Entangling Nets | 33 - Demersal shelf species | Sole |
| **Operational Unit 4** | HRV | 17 | C - Minor gear with engine (6-12 metres) | 07 - Gillnets and Entangling Nets | 33 - Demersal shelf species | Sole |
| **Operational Unit 5** | SVN | 17 | C - Minor gear with engine (6-12 metres) | 07 - Gillnets and Entangling Nets | 33 - Demersal shelf species | Sole |

*Table 2.3-2: Catch, bycatch, discards and effort by operational unit*

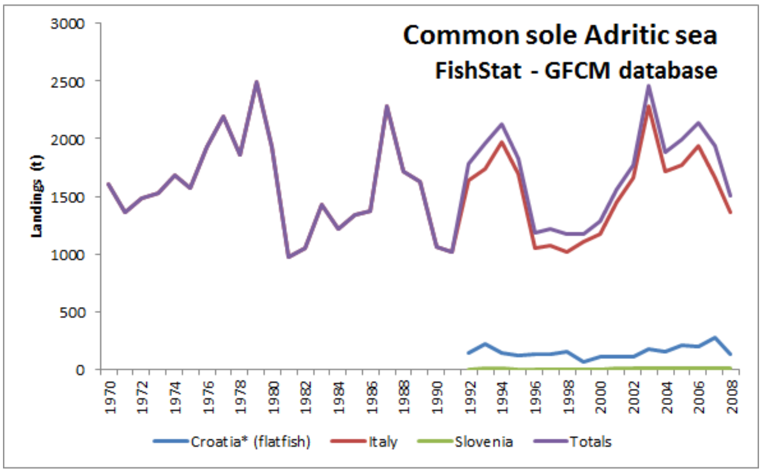
| Operational Units* | Fleet (n° of boats) * | Kilos or Tons | Catch (species assessed) | Other species caught | Discards (species assessed) | Discards (other species caught) | Effort units |
|---|---|---|---|---|---|---|---|
| ITA 17 E 98 33 - SOL | 124 | Tons | *Solea solea* | *Bolinus brandaris, Chelidonichthys lucernus, Sepia officinalis, Squilla mantis, Pecten jacobeus, Melicertus kerathurus* | | *Aporrhais pespelecani, Ostrea edulis, Liocarcinus depurator, Anadara inaequivalvis, Anadara demiri* | |
| ITA 17 E 98 33 - SOL | | Tons | *Solea solea* | *Bolinus brandaris, Chelidonichthys lucernus, Sepia officinalis, Squilla mantis, Pecten jacobeus, Melicertus kerathurus* | | *Aporrhais pespelecani, Ostrea edulis, Liocarcinus depurator, Anadara inaequivalvis, Anadara demiri* | |
| ITA 17 C 07 33 - SOL | 469 | Tons | *Solea solea* | *Bolinus brandaris, Chelidonichthys lucernus, Squilla mantis* | | *Aporrhais pespelecani, Ostrea edulis, Liocarcinus vernalis, Astropecten irregularis,* | |
| HRV 17 C 07 33 - SOL | | Tons | *Solea solea* | | | | |
| SVN 17 C 07 33 - SOL | | Tons | *Solea solea* | | | | |
| Total | | | | | | | |

*Table 2.3-3: Catches as used in the assessment (2011 – Data call)*

| Classification<br>2011 | Catch(tn) |
|---|---|
| **Gill net (Italy)** | 626 |
| **Otter Trawl (Italy)** | 289 |
| **Rapido Trawl (Italy)** | 418 |
| **Trammel net (Slovenia)** | 12 |
| **Trammel net (Croatia)** | 300 |
| **Total** | 1645 |

### 2.4 *Historical trends*

Common sole landings estimated in respectively from the *FAO Capture Production* (GFCM Area) 1970-2010 database and in the framework of Italian and Svolenia Official Data Collection submitted in the data call 2011 are showed in Figs. 1 and 2, together with Croatian data provided in the Croatian Primo Project.




Figuer 1. Landings from *FAO Capture Production* (GFCM Area) database

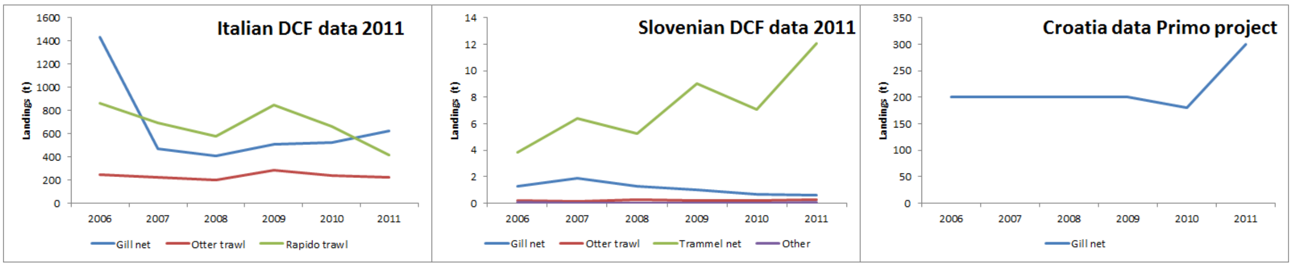



Figure 2 – Landings of common sole in GSA 17.

Discard data are negligible.

Effort data from DCF source are listed in the tables below.

| Italian nominal effort (kW * Days at sea/1000) DCF data call 2011 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|
| Gill nett | 3670 | 5034 | 4483 | 2540 | 2452 | 3281 | 3396 | 4643 |
| Trammel net | 1840 | 1311 | 1185 | 1502 | 893 | 1080 | 1261 | 1509 |
| Otter trawl | 24509 | 24435 | 20511 | 19142 | 20039 | 18890 | 18095 | 16572 |
| Rapido trawl | 4122 | 4006 | 5267 | 6626 | 4136 | 4386 | 3817 | 2585 |

| Slovenia nominal effort (kW * Days at sea/1000) DCF data call 2011 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|
| Gill nett | 542 | 501 | 561 | 1105 | 1199 | 1571 | 1217 |
| Trammel net | 656 | 637 | 1421 | 1896 | 2313 | 2214 | 3068 |
| Otter trawl | 730 | 952 | 1600 | 1842 | 1903 | 1878 | 1663 |

The eastern part of the basin contributes for about the 10-20% of the total landings, with on average 8 tons from Slovenia and 200 tons from Croatia. *Rapido* trawl landings were traditionally dominated by small sized specimens; they are basically composed by 1 and 2 year old individuals. Set net fishery lands mostly the same portion of the population, while the otter trawl fishery, exploiting wider fishing grounds, shows a different size distribution of the landings. In the eastern part of the basin common sole is exploited mainly by set netters (using trammel net), the catch composition, as suggested by preliminary data collection started in 2010 by Croatian colleagues in the framework of Primo Project, is dominated by adult.

### *2.5 Management regulations*

<u>Italy and Slovenia</u>

Minimum landing sizes: EC regulation 1967/2006: 20 cm TL for sole.
Cod end mesh size of trawl nets: 40 mm (stretched, diamond meshes) till 30/05/2010. From 1/6/2010 the existing nets will be replaced with a cod end with 40 mm (stretched) square meshes or a cod end with 50 mm (stretched) diamond meshes.
Towed gears are not allowed within three nautical miles from the coast or at depths less than 50 m when this depth is reached at a distance less than 3 miles from the coast.
Fishing ban for trawling: 1-2 months in summer.
Minimum mesh size for gill net (16 mm stretched). The mesh size used by set netters targeting sole range from 32 mm, hence larger than the legal minimum mesh size.
Maximum length of nets x vessel x day (5,000 m).

<u>Croatia</u>

In Croatian fisheries, the common sole is allowed to be caught by the following gears: trammel nets and bottom trawl net. Beam trawl ("rapido"), according to the Fishing acts (Narodnenovine, 148/2010, 25/2011), is a gear used to catch shellfish (not for sole as in Italy), and the rate of other species in the catches cannot exceed 20%. Allowed mesh size for rapido is 40 mm (from knots to knots), and it is allowed to use only two rapido per vessel. Each rapido can be up to 4 meters wide.

Only small quantities of sole are caught by bottom trawl, and allowed minimum mesh size for bottom trawl nets is 20 mm (from knot to knot).

The species is mainly caught with trammel nets, and minimum mesh size for trammel nets is 40 mm (inner nets) and 150 mm (outer nets). Maximum length of the nets allowed on the vessel is 6.000 m. If on the vessel is only one fisherman present, maximum allowed length is 4.000 m, and for additional one fishermen 1.000 m more is allowed, but total length of the nets on the vessel is 6.000 m. Maximum height of the nets is 4 m. Trammel nets could be used only in the period from 10$^{th}$ September to 15$^{th}$ January, and in the rest of the year are prohibited.

### *2.6 Reference points*

*Table 2.6-1: List of reference points*

| Criterion | Current value | Units | Reference Point | Trend | Comments |
|---|---|---|---|---|---|
| **B** | | | | | |
| **SSB** | | | | | |
| **F** | | | | | |
| **Y** | | | 0.26 | | Yield per Recruit analysis ($F_{0.1}$ as a proxy of $F_{MSY}$) |
| **CPUE** | | | | | |

## 3 Fisheries independent information

### *3.1 SoleMon Survey*

#### 3.1.1 Brief description of the chosen method and assumptions used

Nine *rapido* trawl fishing surveys were carried out in GSA 17 from 2005 to 2011: two systematic "pre-suveys" (spring and fall 2005) and four random surveys (spring and fall 2006, fall 2007-2011) stratified on the basis of depth (0-30 m, 30-50 m, 50-100m). Hauls were carried out by day using 2-4 *rapido* trawls simultaneously (stretched codend mesh size = 40.2 ± 0.83). The following number of hauls was reported per depth stratum (Tab. 3.1.1).

Tab. 3.1.1 Number of hauls per year and depth stratum in GSA 17, 2005-2011

| Depth strata | Spring 2005 | Fall 2005 | Spring 2006 | Fall 2006 | Fall 2007 | Fall 2008-2011 |
|---|---|---|---|---|---|---|
| 0-30 | 30 | 30 | 20 | 35 | 32 | 39 |
| 30-50 | 14 | 12 | 10 | 20 | 19 | 17 |
| 50-100 | 24 | 15 | 8 | 8 | 11 | 11 |
| HR islands | 0 | 5 | 4 | 4 | 0 | 0 |
| TOTAL | 68 | 62 | 42 | 67 | 62 | 67 |

Abundance and biomass indexes from *rapido* trawl surveys were computed using ATrIS software (Gramolini *et al*., 2005) which also allowed drawing GIS maps of the spatial distribution of the stock, spawing females and juveniles. Underestimation of small specimens in catches due to gear selectivity was corrected using the selective parameters given by Ferretti and Froglia (1975).

The abundance and biomass indices by GSA 17 were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum area in the GSA 17:

$Yst = \Sigma (Yi*Ai) / A$

$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$

Where:

A=total survey area
Ai=area of the i-th stratum
si=standard deviation of the i-th stratum
ni=number of valid hauls of the i-th stratum
n=number of hauls in the GSA
Yi=mean of the i-th stratum
Yst=stratified mean abundance
V(Yst)=variance of the stratified mean

The variation of the stratified mean is then expressed as the 95 % confidence interval: Confidence interval = Yst ± t(student distribution) * V(Yst) / n

It was noted that while this is a standard approach, the calculation may be biased due to the assumptions over zero catch stations, and hence assumptions over the distribution of data. A normal distribution is often assumed, whereas data may be better described by a delta-distribution, quasi-poisson. Indeed, data may be better modelled using the idea of conditionality and the negative binomial (e.g. O'Brien *et al.*, 2004). Length distributions represented an aggregation (sum) of all standardized length frequencies over the stations of each stratum. Aggregated length frequencies were then raised to stratum abundance and finally aggregated (sum) over the strata to the GSA. Given the sheer number of plots generated, these distributions are not presented in this report.

***Direct methods: trawl based abundance indices***

*Table 3.1-1: Trawl survey basic information*

| | | | | | |
|---|---|---|---|---|---|
| **Survey** | SoleMon | **Species** | Common sole | **Trawler/OV** | G. Dallaporta |
| **Sampling season** | Fall | | | | |
| **Sampling design** | Random stratified | | | | |
| **Sampler (gear used)** | Rapido trawl | | | | |
| **Cod –end mesh size as opening in mm** | 40 | | | | |
| **Investigated depth range (m)** | 5-120 | | | | |

*Table 3.1-2: Trawl survey sampling area and number of hauls(2011 survey)*

| **Stratum** | **Total surface ($km^2$)** | **Trawlable surface ($km^2$)** | **Swept area (km2)** | **Number of hauls** |
|---|---|---|---|---|
| **1** | 11512 | | 1.32 | 39 |
| **2** | 8410 | | 0.55 | 17 |
| **3** | 22466 | | 0.41 | 11 |
| **Total (5 – 120 m)** | 42388 | | 2.27 | 67 |

*Table 3.1-3: Trawl survey abundance and biomass results*

| Stratum | Years | kg per km² | CV | Relative * biomass<br><br>All age groups | CV or other | N per km² | CV | Relative * abundance<br><br>All age groups | CV or other |
|---|---|---|---|---|---|---|---|---|---|
| | **2005** | 27.13 | 15.23 | | | 305.05 | 19.97 | | |
| | **2006** | 35.82 | 15.75 | | | 327.14 | 22.06 | | |
| | **2007** | 39.34 | 18.23 | | | 433.37 | 23.75 | | |
| | **2008** | 29.59 | 18.14 | | | 244.74 | 18.92 | | |
| | **2009** | 29.11 | 19.85 | | | 479.48 | 35.3 | | |
| | **2010** | 28.72 | 15.61 | | | 285.85 | 18.86 | | |
| | **2011** | 32.39 | 17.58 | | | 430.87 | 24.76 | | |
| **Total (… – … m)** | …… | | | | | | | | |

* with catchability coefficient assumed =1

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

*Table 3.1-4: Trawl survey slicing method*

| **Survey** | SoleMon | **Species** | Solea solea | **Trawler/RV** | G. Dallaporta |
|---|---|---|---|---|---|
| **Total area ($km^2$)** | 42388 | | | | |
| **Age slicing method** | LFDA 5.0 | | | | |
| **Maturity scales (females and males)** | Nikolsky(1963) | | | | |

*Table 3.1-5: Trawl survey results by length or age class (Look Figure 6)*

| N (Total or sex combined) by<br>Length or age class | **Year** | | |
|---|---|---|---|
| | **….** | **….** | **…..** |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| **Total** | | | |

***Direct methods: Trawl based mortality rates***

*Table 3.1-6: Trawl survey methods for the estimation of mortality rates*

| **Survey** | | **Species** | | **Trawler/RV** | |
|---|---|---|---|---|---|
| **Z estimation** | | | | | |
| **F estimation** | | | | | |
| **M estimation** | | | | | |

Note: In case of average mortalities specify the age class, specify the age class included

*Table 3.1-7: Trawl survey; method for natural mortality estimates*

| M by age per Survey | **Report formula, or method and reference** | | | | |
|---|---|---|---|---|---|
| | **Age 0** | **Age 1** | **Age 2** | **Age 3** | **etc** |
| **Year** | | | | | |
| | | | | | |

Table 3.1-8: Trawl surveys; total mortality estimate

| Years | Total mortality rates (Z) | Years | Total mortality rates (Z) | years | Total mortality rates (Z) |
|---|---|---|---|---|---|
| Year | | | | | |
| | | | | | |
| | | | | | |

*Table 3.1-9: Trawl surveys; fishing mortality estimates*

| Years | Fishing mortality rates (F) | Survey | Fishing mortality rates (F) | Survey | Fishing mortality rates (F) |
|---|---|---|---|---|---|
| Year | | | | | |
| | | | | | |
| | | | | | |

*Table 3.1-10: Trawl surveys; total mortality estimates by age*

| Z by age per Survey | Age 0 | Age 1 | Age 2 | Age 3 | etc |
|---|---|---|---|---|---|
| year | | | | | |
| | | | | | |
| | | | | | |

*Table 3.1-11: Trawl surveys; fishing mortality estimates by age*

| F by age per Survey | Age 0 | Age 1 | Age 2 | Age 3 | etc |
|---|---|---|---|---|---|
| year | | | | | |
| | | | | | |
| | | | | | |

***Direct methods: trawl based Recruitment analysis***

*Table 3.1-12: Trawl survsys; recruitment analysis summary*

| Survey | SoleMon | Species | Solea solea | Trawler/RV | G. Dallaporta |
|---|---|---|---|---|---|
| Survey season | Fall | | | | |
| Cod –end mesh size as opening in mm | 40 | | | | |
| Investigated depth range (m) | 0-120 | | | | |
| Recruitment season and peak (months) | September-October-November | | | | |
| Age at fishing-grounds recruitment | 0 | | | | |
| Length at fishing-grounds recruitment | 17-20 | | | | |

*Table 3.1-13: Trawl surveys; recruitment analysis results*

| Years | Area in km$^2$ | N of recruit per km$^2$ | CV | Relative recruitment ( N of individuals) | CV or other |
|---|---|---|---|---|---|
| | | | | | |
| 2005 | | 201.05 | 29.92 | | |
| 2006 | | 99.85 | 57.91 | | |
| 2007 | | 299.8 | 31.98 | | |
| 2008 | | 90.57 | 35.56 | | |
| 2009 | | 379.87 | 43.94 | | |
| 2010 | | 119.31 | 29.56 | | |
| 2011 | | 316.29 | 31.55 | | |

Comments

| |
|---|
| Type of recruitment:continuous and localised.<br><br>The method used to estimate recruit indices: Bhattacharya |

**Direct methods: trawl based Spawner analysis**

*Table 3.1-14: Trawl surveys; spawners analysis summary*

| **Survey** | **SoleMon** | **Species** | **Solea solea** | **Trawler/RV** | **G. Dallaporta** |
|---|---|---|---|---|---|
| **Survey season** | | | Fall | | |
| **Investigated depth range (m)** | | | 0-120 | | |
| **Spawning season and peak (months)** | | | November-December | | |

*Table 3.1-15: Trawl surveys; spawners analysis results*

| **Surveys** | **Area in km²** | **N (N of individuals) of spawners per km²** | **CV** | **SSB per km²** | **CV** | **Relative SSB** | **CV or other** |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| **2005** | | 64.23 | 20.53 | 14.28 | 22.85 | | |
| **2006** | | 79.43 | 16.28 | 15.74 | 16.39 | | |
| **2007** | | 103.33 | 23.97 | 21.78 | 24.82 | | |
| **2008** | | 83.77 | 24.04 | 17.41 | 26.15 | | |
| **2009** | | 66.07 | 17.99 | 12.69 | 19.82 | | |
| **2010** | | 43.21 | 16.31 | 8.83 | 18.4 | | |
| **2011** | | 52.34 | 18.04 | 10.4 | 19.29 | | |

Comments

| |
|---|
| Specify type of spawner: presence of spawner aggregations |

### 3.1.2 Spatial distribution of the resources

According to data collected during SoleMon surveys (Fabi *et al.*, 2009), age class 0+ aggregates inshore along the Italian coast, mostly in the area close to the Po river mouth. Age class 1+ gradually migrates off-shore and adults concentrate in the deepest waters located at South West from Istria peninsula.

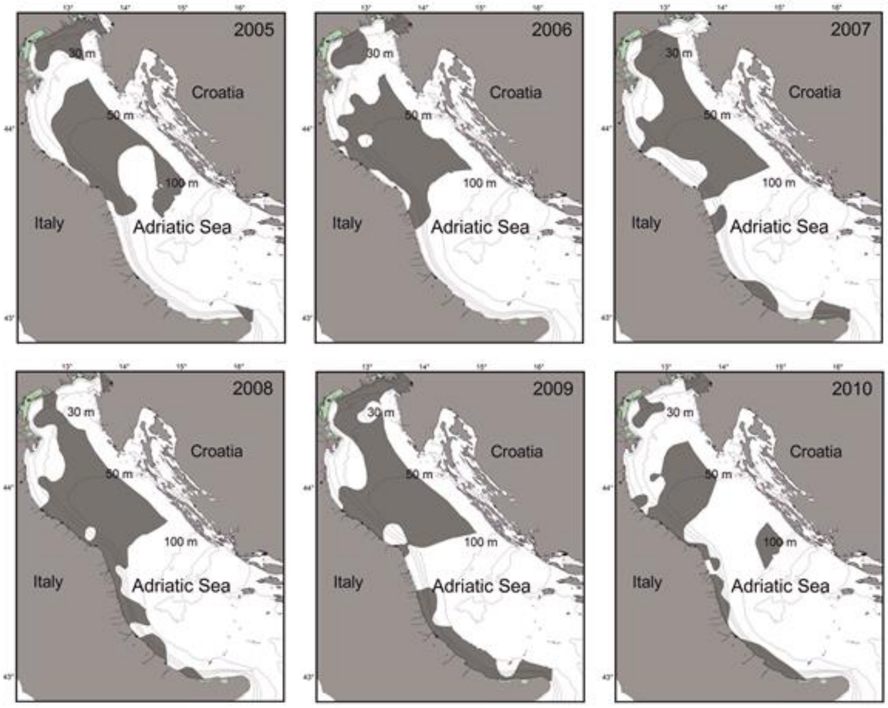



Fig. 4 Spatial distributions of  sole from SoleMon survey data carried out in GSA 17 and interpolated using Kriging.

### 3.1.3 Historical trends

### 3.1.4 Historical trends

The SoleMon trawl surveys provided data either on sole total abundance and biomass as well as on important biological events (recruitment, spawning).

Fig.5. shows the abundance and biomass indices of sole obtained from 2005 to 2011; slightly increasing trends occurred till fall 2007, followed by a decrease the rest of the period.

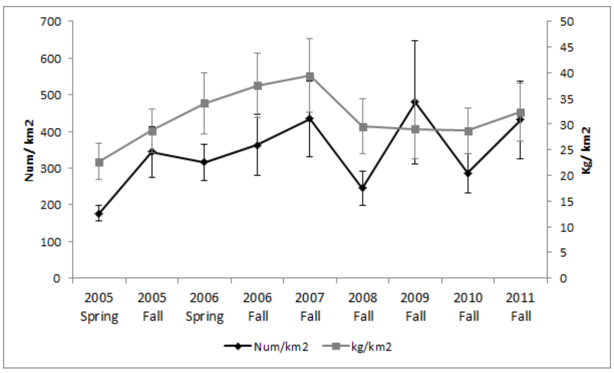



Fig.5 Abundance and biomass indices of sole obtained from SoleMon surveys

Fig. 6 displays the stratified abundance indices obtained in the GSA 17 in the years 2005-2008.

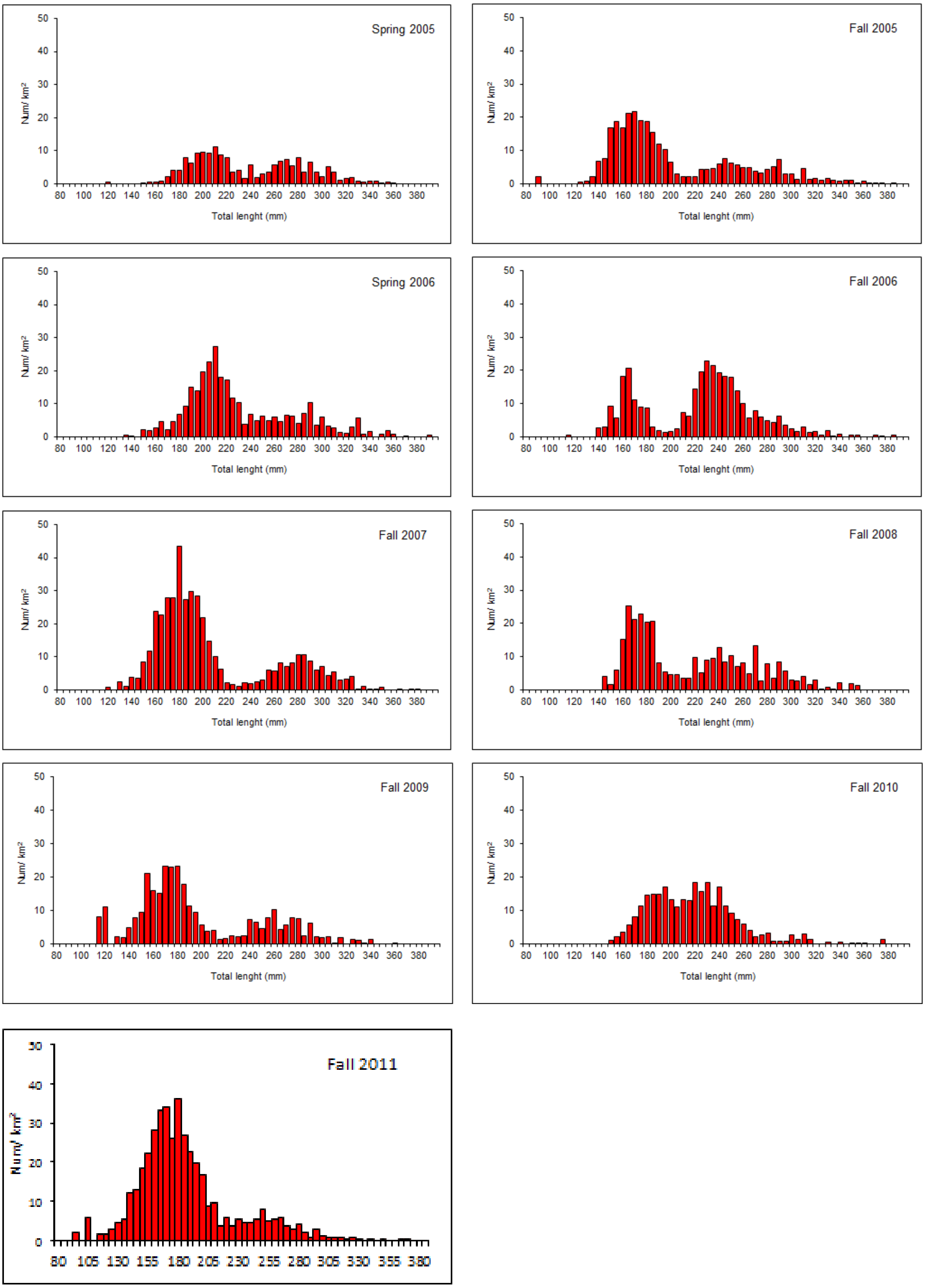



Fig. 6. Stratified abundance indices by size, 2005-2011.

# 4 Ecological information

## 4.1 Protected species potentially affected by the fisheries

Rapido trawl fishery has a deleterious effect on benthic habitat. The list of species discarded during the fishing operation is presented in the table below.

List of species/taxonomic groups and their mean biomass in Solea rapido trawl fishery from Central Western Adriatic Sea

| **Discarded Taxa** | **Stratum 0-30 (kg km$^{-2}$)** | **Stratum 30-60 (kg km$^{-2}$)** |
|---|---|---|
| Annelida | | |
| *Aphrodite aculeata* | 0.096 | 4.706 |
| *Glycera* spp | 0.001 | 0.006 |
| Polychaeta | 0.248 | 0.027 |
| Cnidaria | | |
| *Alcyonum* spp | | 0.112 |
| *Calliactis parasitica* | 0.002 | 0.033 |
| Unidentified anemone | 0.019 | 0.600 |
| Unidentified colonial hydroid | | 0.065 |
| *Virgularia mirabilis* | 0.018 | 3.405 |
| Crustacea | | |
| *Alpheus glaber* | 0.002 | 0.001 |
| *Corystes cassivelaunus* | 0.023 | |
| *Goneplax rhomboides* | 10.385 | 16.042 |
| *Inachus comunissimus* | 0.030 | |
| *Inachus phalangium* | 1.979 | 0.004 |
| *Inachus* spp | 0.531 | 0.002 |
| ***Liocarcinus depurator*** | 8.292 | 178.664 |
| *Liocarcinus vernalis* | 9.168 | 0.609 |
| *Lysmata seticaudata* | | 0.019 |
| *Medorippe lanata* | 4.375 | 2.979 |
| ***Melicertus kerathurus*** | 0.208 | 0.213 |
| ***Nephrops norvegicus*** | 0.006 | 0.044 |
| *Pagurus excavatus* | 0.019 | 0.045 |
| *Pagurus* spp | 0.364 | 0.299 |
| ***Parapenaeus longirostris*** | | 0.154 |
| *Parthenope angulifrons* | 0.755 | |
| *Pilumnus hirtellus* | 0.033 | |
| ***Squilla mantis*** | 5.197 | 0.397 |
| Echinodermata | | |
| *Astropecten irregularis* | 28.562 | 8.210 |
| Holothuroidea | 0.135 | 1.771 |
| *Marthasterias glacialis* | 0.174 | 4.511 |
| Ophiura ophiura | 2.592 | |
| Schizaster canaliferus | 0.413 | 0.020 |
| Spatangoida | 0.033 | |
| *Trachythyone elongata* | 0.238 | 2.194 |
| *Trachythyone* spp | 0.022 | 0.368 |
| *Trachythyone tergestina* | 0.125 | 3.270 |
| Mollusca | | |
| *Acanthocardia paucicostata* | 0.238 | 0.072 |
| *Acanthocardia tubercolata* | 0.307 | 0.146 |
| ***Aequipecten opercularis*** | 0.136 | |
| ***Alloteuthis media*** | 0.025 | 0.003 |
| *Antalis dentalis* | 0.047 | |
| *Antalis inaequicostata* | 0.639 | 0.001 |
| *Antalis* spp | 0.168 | |
| ***Aporrhais pespelecani*** | 299.666 | 6.160 |
| *Atrina pectinata* | 0.190 | 0.909 |
| ***Bolinus brandaris*** | 11.135 | 0.625 |
| *Calliostoma* spp | 0.008 | 0.310 |
| ***Cassidaria echinophora*** | | 0.784 |
| ***Chamelea gallina*** | 0.183 | |
| ***Chlamys varia*** | 0.082 | 0.004 |
| *Corbula gibba* | 43.145 | 0.030 |
| ***Flexopecten glaber glaber*** | 1.389 | 0.007 |
| *Glossus humanus* | | 0.710 |
| ***Hexaplex trunculus*** | 0.712 | 0.089 |
| ***Illex coindetii*** | 0.012 | 0.004 |
| ***Mytilus galloprovincialis*** | 2.774 | 0.907 |
| *Nassarius lima* | 0.068 | 0.010 |
| ***Nassarius mutabilis*** | 0.577 | 0.002 |
| *Nassarius reticulatus* | 0.748 | 0.001 |
| *Naticarius hebraea* | 0.025 | |
| ***Naticarius stercusmuscarum*** | 2.219 | |

| | | |
|---|---|---|
| *Neverita josephinia* | 0.030 | |
| *Nucula nitidosa* | 0.002 | 0.004 |
| *Nucula nucleus* | 0.006 | 0.021 |
| *Nucula sulcata* | 0.003 | 0.203 |
| ***Ostrea edulis*** | 94.311 | 3.043 |
| Pectinidae | 0.112 | 0.060 |
| *Polinices nitida* | 0.001 | |
| *Scapharca demiri* | 30.051 | 0.009 |
| *Scapharca inaequivalvis* | 137.864 | 0.290 |
| Scaphodopa | 0.077 | |
| ***Sepia elegans*** | 0.026 | 0.122 |
| ***Sepia officinalis*** | 0.465 | 0.367 |
| *Solecurtus strigilatus* | 0.217 | |
| *Turritella communis* | 0.808 | 2.758 |
| Unidentified nudibrancs | 0.553 | |
| *Venerupis aurea* | 2.552 | |
| Osteichthyes | | |
| ***Arnoglossus laterna*** | 0.820 | 1.101 |
| *Blennius ocellaris* | | 0.152 |
| ***Boops boops*** | 0.291 | 0.033 |
| ***Buglossidium luteum*** | 0.150 | 0.110 |
| ***Cepola macrophthalma*** | | 0.487 |
| ***Chelidonichthys lucernus*** | 3.727 | 1.214 |
| ***Citharus linguatula*** | 0.005 | 0.083 |
| ***Diplodus annularis*** | 0.130 | |
| ***Engraulis encrasicolus*** | 0.032 | 0.019 |
| ***Eutrigla gurnardus*** | 0.002 | 0.239 |
| ***Gobius niger*** | 1.114 | 0.675 |
| *Lesueurigobius friesii* | 0.005 | 0.048 |
| ***Merluccius merluccius*** | 0.129 | 0.256 |
| ***Mullus barbatus barbatus*** | 0.234 | 0.095 |
| ***Pagellus erythrinus*** | 0.150 | 0.104 |
| ***Sardina pilchardus*** | 0.039 | 0.046 |
| ***Sardinell aaurita*** | 1.081 | 0.635 |
| ***Scorpaena notata*** | 0.005 | 0.239 |
| *Serranus hepatus* | 0.010 | 0.200 |
| ***Solea solea*** | 0.128 | 0.004 |
| ***Spicara maena*** | 0.058 | 0.046 |
| ***Spicara smaris*** | | 0.017 |
| ***Trachurus mediterraneus*** | 0.051 | 0.007 |
| Porifera | | |
| Unidentified sponge | 0.017 | 0.376 |
| Tunicata | | |
| Ascidiacea | | 0.189 |

[a] Commercially harvested groups are indicated in bold face.

## 5 Stock Assessment

### *5.1 XSA*

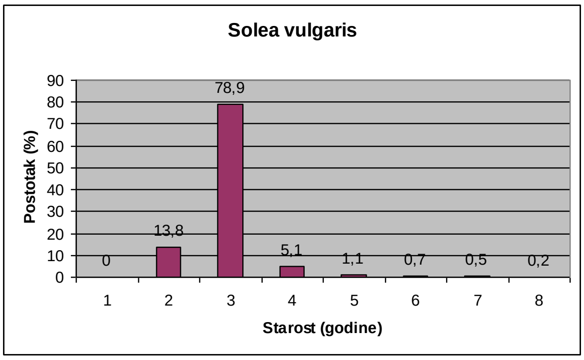
#### 5.1.1 Model assumptions

The errors associated with the measurement of catch at age matrixes are assumed as null.

The catches from the eastern side of the basin (Slovenia and Croatia) have been included in the catch numbers at age matrix considering the age distribution (Figure below) suggested by preliminary data collection started in 2010 by Croatian colleagues and assumed the same for all the period (2006-2011; Primo Project - 2010. Monitoring of Catches Fishery - R.C. - IOF Split).

Then XSA runs were made using the following settings:

- $F_{bar}$ 0-4.
- Catchability dependent on stock size for ages < 1.
- Catchability independent of age for ages >= 4.
- S.E. of the mean to which the estimates are shrunk = 0.50.
- Minimum S.E. for population estimates derived from each fleet = 0.30




Input data are listed in the tables below.

| **Catch at age (numbers x 1000): Italian and Slovenia DCF data and Croatian data** | | | | | | |
|---|---|---|---|---|---|---|
| Year / Age | 0 | 1 | 2 | 3 | 4 | 5+ |
| 2006 | 2858 | 10617 | 2154 | 371 | 46 | 18 |
| 2007 | 208 | 8574 | 1974 | 496 | 47 | 19 |
| 2008 | 799 | 8681 | 1058 | 171 | 32 | 12 |
| 2009 | 5180 | 8051 | 1840 | 395 | 70 | 28 |
| 2010 | 5614 | 7124 | 706 | 655 | 29 | 10 |
| 2011 | 5649 | 8364 | 2243 | 103 | 15 | 30 |

| **Survey indexes (N. ind. km$^{-2}$) for tuning** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **SoleMon survey** | | | | | | | |
| Year / Age | 0 | 1 | 2 | 3 | 4 | 5 | 6+ |
| 2006 | 91 | 174 | 49 | 9 | 2 | 1.2 | 91 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2007 | 192 | 146 | 74 | 18 | 1 | 0.6 | 192 |
| 2008 | 128 | 114 | 58 | 11 | 5 | 0.6 | 128 |
| 2009 | 177 | 83 | 47 | 6 | 1 | 0.2 | 177 |
| 2010 | 55 | 200 | 23 | 5 | 0.2 | 1.3 | 55 |
| 2011 | 199 | 172 | 34 | 5 | 0.5 | 0.8 | 199 |

| **Mean weight at age in the catches: DCF Italian data (kg)** | | | | | | |
|---|---|---|---|---|---|---|
| Year / Age | 0 | 1 | 2 | 3 | 4 | 5+ |
| 2006 | 0.066 | 0.125 | 0.186 | 0.356 | 0.453 | 0.522 |
| 2007 | 0.066 | 0.125 | 0.186 | 0.356 | 0.453 | 0.522 |
| 2008 | 0.077 | 0.133 | 0.211 | 0.356 | 0.453 | 0.522 |
| 2009 | 0.077 | 0.137 | 0.224 | 0.356 | 0.453 | 0.522 |
| 2010 | 0.079 | 0.156 | 0.254 | 0.356 | 0.453 | 0.522 |
| 2011 | 0.065 | 0.116 | 0.2 | 0.356 | 0.453 | 0.522 |

| **Mean weight at age in the stock (kg)** | | | | | | |
|---|---|---|---|---|---|---|
| Year / Age | 0 | 1 | 2 | 3 | 4 | 5+ |
| 2006-2011 | 0.024 | 0.104 | 0.207 | 0.304 | 0.38 | 0.522 |

| **Growth parameters: SoleMon Project** | | | |
|---|---|---|---|
| PERIOD | $L_\infty$ | k | $t_0$ |
| 2006-2011 | 39.6 cm | 0.44 $y^{-1}$ | -0.46 y |

| **Length-weight rel: SoleMon Project** | | |
|---|---|---|
| PERIOD | a | b |
| 2006-2011 | 0.0007 | 3.0638 |

| **Maturity at Age: SoleMon project (prop. mature)** | | | | | | |
|---|---|---|---|---|---|---|
| PERIOD | 0 | 1 | 2 | 3 | 4 | 5+ |
| 2006-2011 | 0 | 0.16 | 0.76 | 0.96 | 0.99 | 1.00 |

| **Natural mortality (M): probiom approach** | | | | | | |
|---|---|---|---|---|---|---|
| PERIOD | 0 | 1 | 2 | 3 | 4 | 5+ |
| 2006-2011 | 0.70 | 0.35 | 0.28 | 0.25 | 0.23 | 0.22 |

### 5.1.2 Scripts

```
library(FLCore)

library(FLEDA)

library(FLXSA)

library(FLAssess)

library(FLash)

#read stock file
```

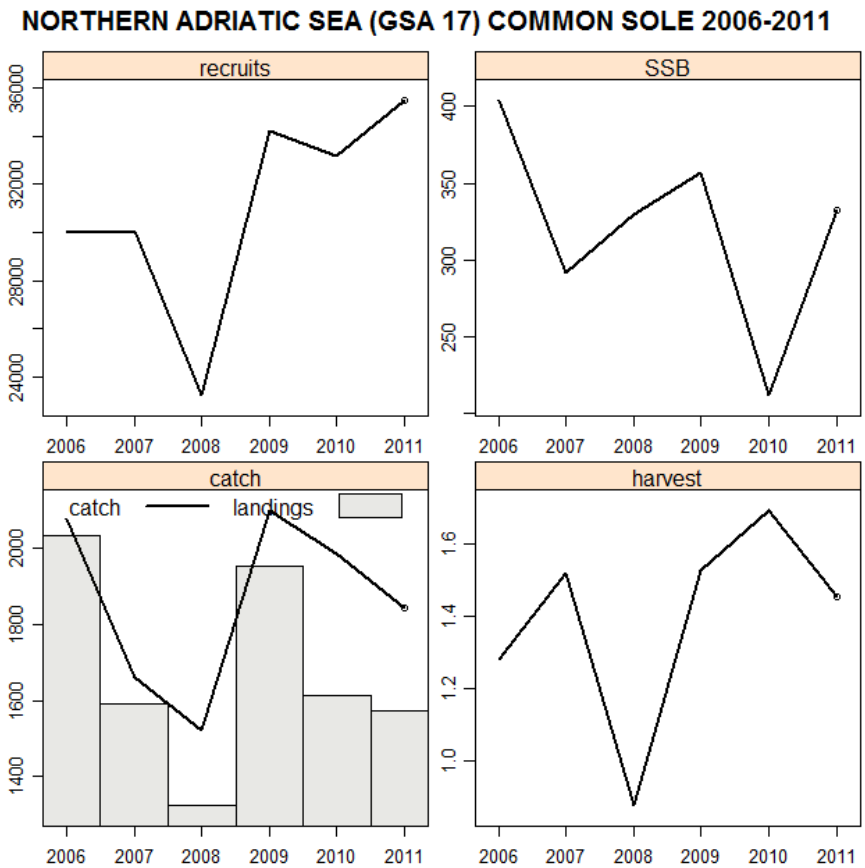
```
sole.stk<- readFLStock("SOLE17B.DAT", no.discards=TRUE)

#set up the stock (create the empty matrix)

units(harvest(sole.stk))<-"f"

range(sole.stk)["minfbar"] <- 0

range(sole.stk)["maxfbar"] <- 4

#Set the plus group

sole.stk<- setPlusGroup(sole.stk, 5)

#read index (tuning file)

sole.idx<- readFLIndices("SOLETUN.DAT")

###Set the control object####qagecatchability =6 means that q is constant from age 6 , rage=1 q
indipendent by stock size at age (=1 no constrains),

#shk.yrs=mortality of last 2 years dependent by the previous year mort.

FLXSA.control.sole<- FLXSA.control(x=NULL, tol=1e-09, maxit=30, min.nse=0.3, fse=0.5,

rage=0, qage=4, shk.n=TRUE, shk.f=TRUE, shk.yrs=3, shk.ages=3,

window=100, tsrange=20, tspower=3, vpa=FALSE)

###Final settings

#Running the assessments with different settings

sole.xsa<- FLXSA(sole.stk, sole.idx, FLXSA.control.sole)

#Add the results to the stock files

sole.stk<- sole.stk+sole.xsa

plot(sole.stk)
```

### 5.1.3 Results

State of exploitation: Exploitation decreased from 2005 to 2008, and increased in the next period. The most recent estimate of fishing mortality ($F_{0-4}$) is 1.43.

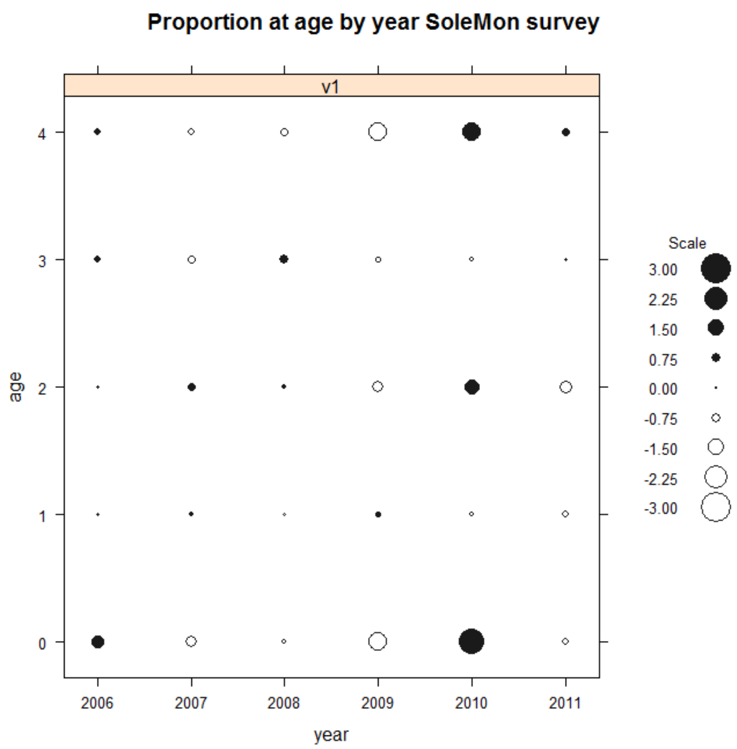
State of the juveniles (recruits): Recruitment decreased from 2005 to 2008, and increased in the next period.

State of the adult biomass: The SSB decreased from 2006 to 2010, and increased.



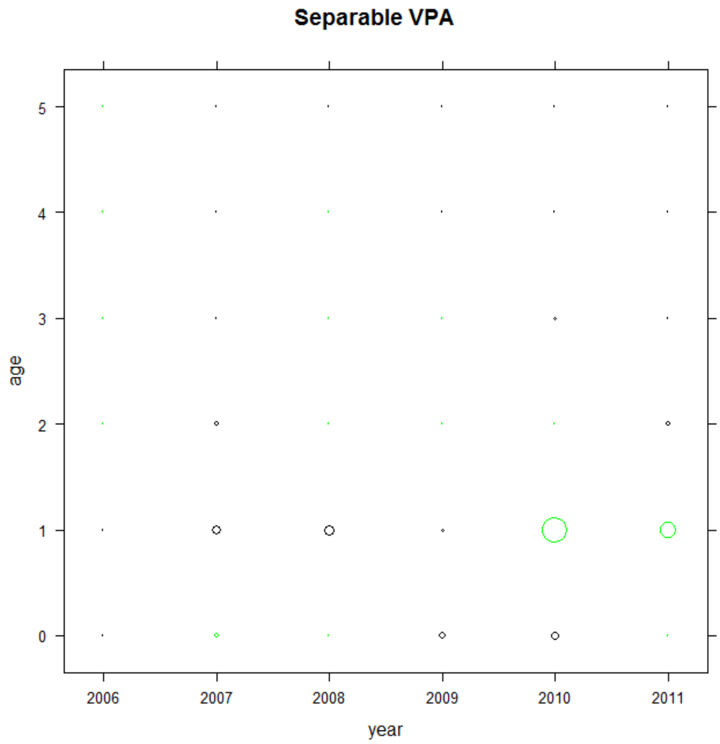

XSA outputs

No trends in the residuals were observed.



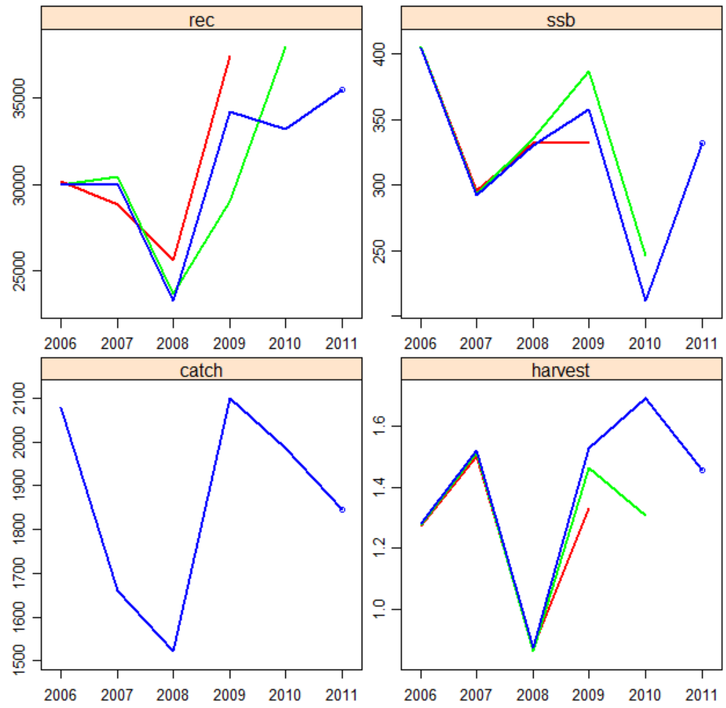
### 5.1.4 Robustness analysis

A separable VPA was run as exploratory analysis. Log catchability residual plots were produced and no major conflict between ages seems to appear.




### 5.1.5 Assessment quality

The retrospective analysis confirm the stability of the estimates of XSA.

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### *5.2 SURBA*

#### 5.2.1 Model assumptions

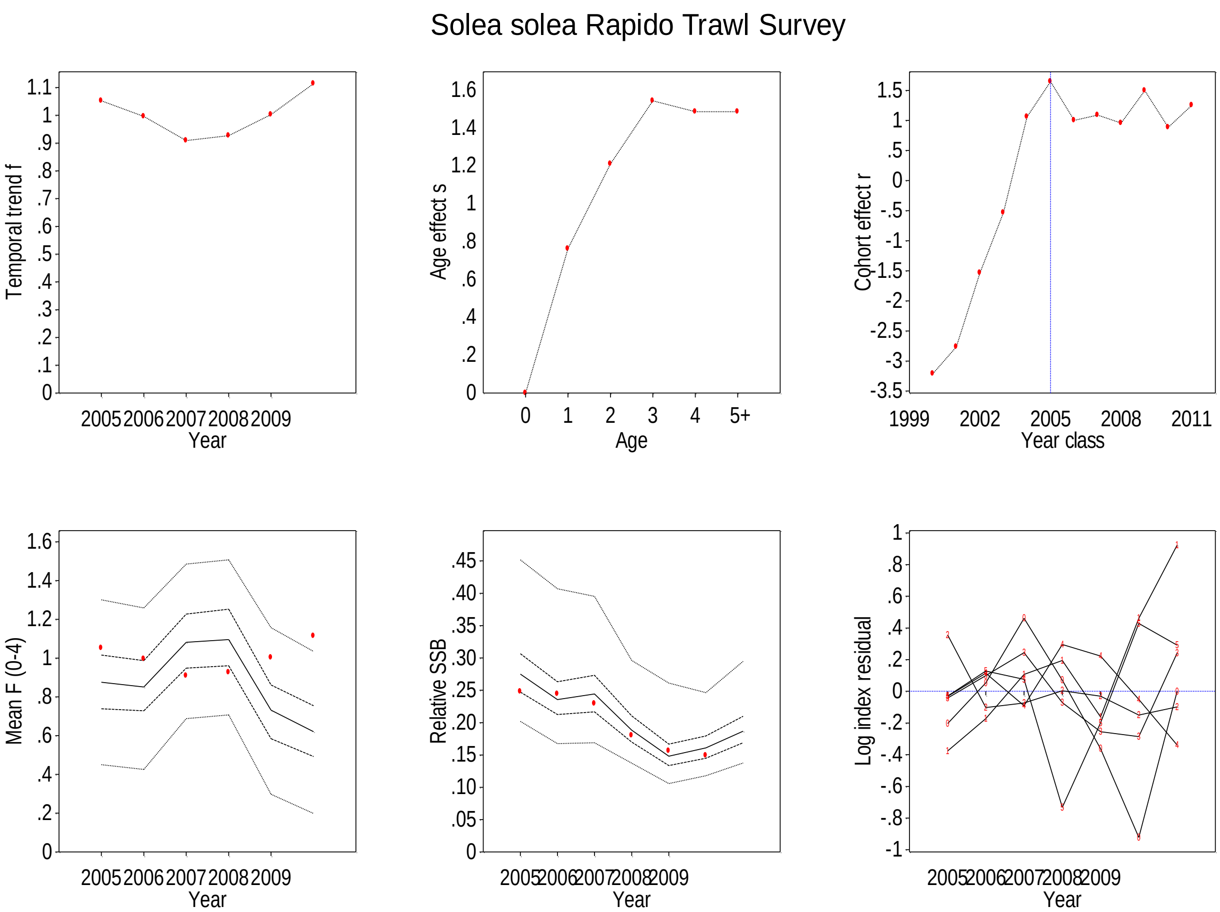
SURBA (survey-based assessment) is a recent development of RCRV1A, extending its functionality and flexibility. RCRV1A was an implementation by Robin Cook (FRS Marine Laboratory) of the separable survey model described by Cook (1997). In brief, it assumed that fishing mortality F = [Fa,y] is separable into an age effect s = [sa] and a year effect f = [fy], so that F = s × f. It estimates these s and f parameters, along with a year-class effect r, by minimizing the sum-of-squared differences between observed and fitted survey-derived abundance, using an assumed fixed vector of catchabilities-at-age q = [qa], which does not depend on year. Since these abundances are relative indices only, the model can only be used to estimate relative, rather than absolute population numbers. These, however, can be used to summarize population trends suggested by any particular survey. The model improvements implemented in SURBA in terms of estimable quantities include time-dependent weight, maturity and natural mortality data, catchability-estimation algorithms, and inverse-variance age-weighting.

The availability of a time series of data from SoleMon surveys allows the use of the SURBA assessment tool. Using the software, the evolution of fishing mortality rates of sole in the GSA 17 was reconstruct starting from the analysis of the length frequency distribution (LFD).

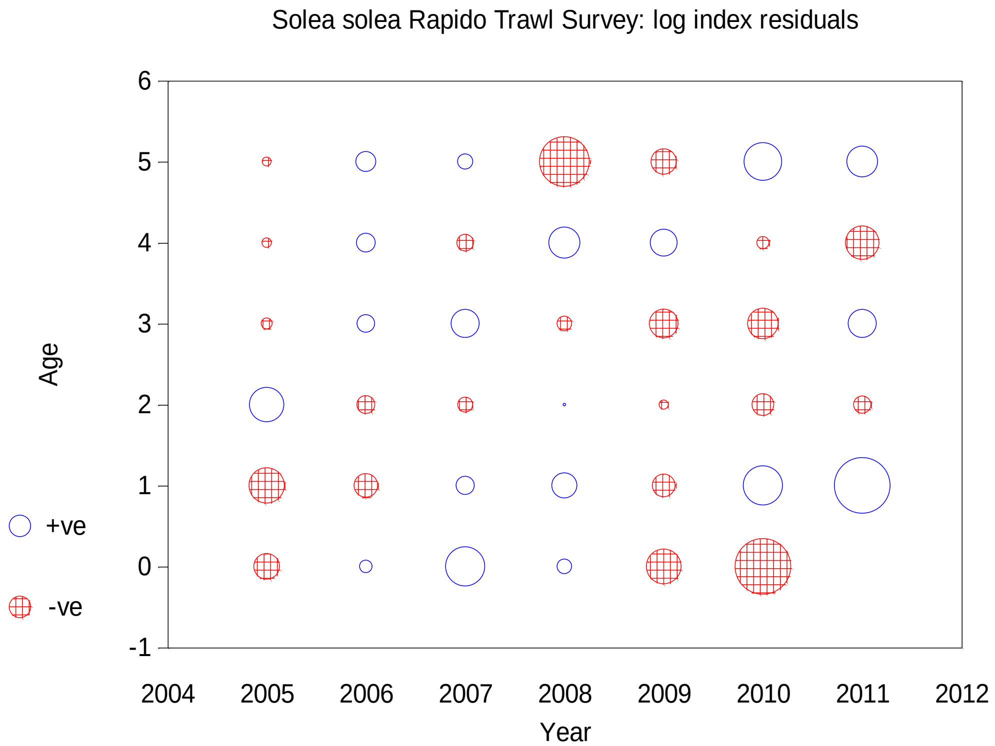
The main input parameters to run the SURBA-survey based stock analysis are abundances, natural mortality rates and catchability. The parameters used in this analysis were the same used in the XSA analysis.

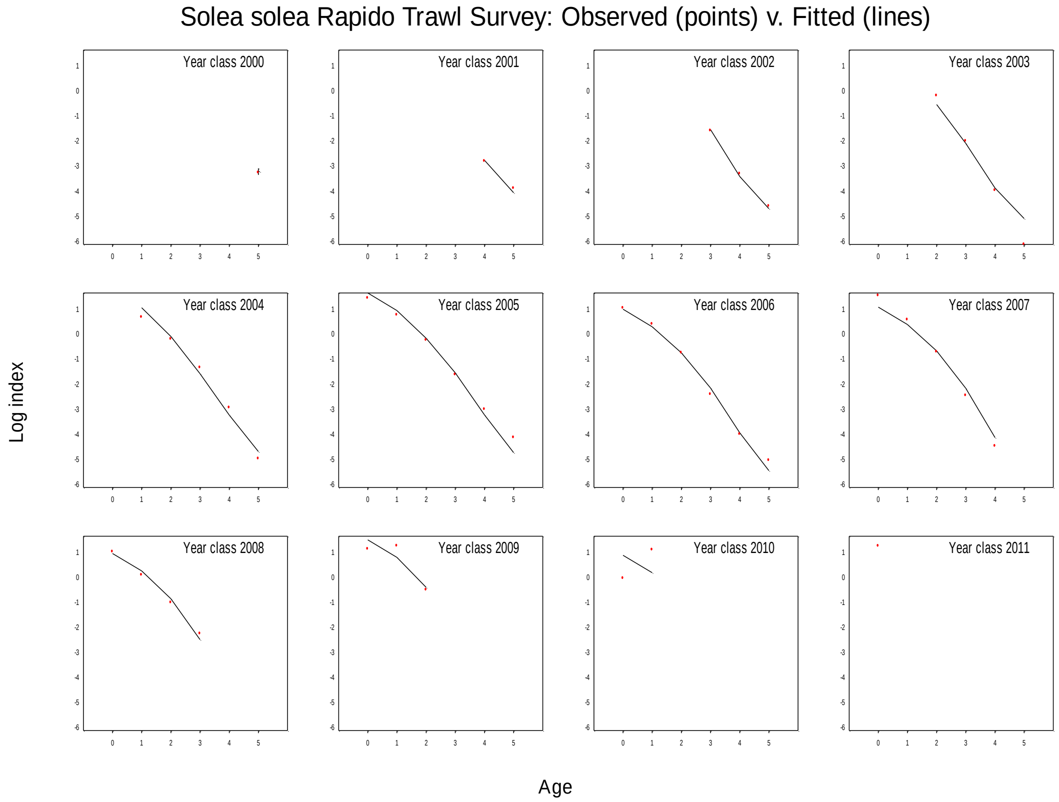
### 5.2.2 Results

The results and the diagnostic of the analyses are summarized in figures below. The results of the model are in general accordance with the previous method providing the same perception of the exploitation of the stock ($F_{0-4}$=1.15). Moreover a clear decreasing trend in SSB is showed. Diagnostic plots of SURBA models show an adequate fitting of the model in sole data in GSA 17 and absence of trends in the residuals.




Trends in stock parameters (SoleMon survey) in GSA 17 from SURBA.




Model diagnostic (SoleMon survey) in GSA 17 from SURBA.

Residuals trends; comparison between observed (points) and fitted (lines) of survey abundance indices, for each year; bubble plot of log-index residuals by age.

### *5.3 Statistical catch at age using Stock Synthesis 3 (SS3)*

#### 5.3.1 Model assumptions

Stock Synthesis 3 provides a statistical framework for calibration of a population dynamics model using a diversity of fishery and survey data. It is designed to accommodate both age and size structure in the population and with multiple stock sub-areas. It uses forward projection of population in the "statistical catch-at-age" (SCAA) approach. SCAA Estimates initial abundanceat age, recruitments, fishing mortality and selectivity. Differently from VPA based approach (XSA) SCAA calculates abundance forward in time and Allows error in the catch at age matrixes. Selectivity can be cast as age specific only, size-specific in the observations only, or size-specific with the ability to capture the major effect of size-specific survivorship. The overall model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various observed data, and quantify the magnitude of difference between observed and expected data. Some SS features include ageing error, growth estimation, spawner-recruitment relationship, movement between areas. SS is most flexible in its ability to utilize a wide diversity of age, size, and aggregate data from fisheries and surveys. The ADMB C++ software in which SS is written searches for the set of parameter values that maximize the goodness-of-fit, then calculates the variance of these parameters using inverse Hessian and MCMC methods.

In the present assessment the input same data and parameters utilized in the XSA and SURBA were employed, with the main difference that the catch at age matrix from the fishery has been backward extended until 2000 utilizing the same input data presented in the GFCM-WG 2010 of Ancona. The catch at age data from 2000 to 2005 has been provided in the framework of two different projects carried in 2000 and 2004 about the study of the Adriatic rapido trawl activity and sole exploitation in GSA 17. Differently the catch at age matrix from 2006 to 2011 has been provided in the framework of the Italian and Slovenian Official Data Collection submitted in the data call 2011 and Croatian data provided by the Croatian Primo Project. The model allowed specify the different source of data providing different uncertainties estimates for each data set. Moreover also the total landings presented before from 1970 to 2005 has been used in the model, together with the DCF and Croatian data for the period 2006-2011. Also in this case the model considered the different sources of the data sets and treated the error separately for each period.

Input data are summarized in the tables below

| **Catch at age (numbers x 1000)** | | | | | | |
|---|---|---|---|---|---|---|
| Year / Age | 0 | 1 | 2 | 3 | 4 | 5+ |
| 2000 | 1753 | 6681 | 1016 | 81 | 13 | 6 |
| 2001 | 1815 | 6919 | 1052 | 84 | 14 | 6 |
| 2002 | 1690 | 6444 | 980 | 78 | 13 | 5 |
| 2003 | 3599 | 13720 | 2086 | 166 | 27 | 11 |
| 2004 | 3185 | 12143 | 1847 | 147 | 24 | 10 |
| 2005 | 1753 | 6681 | 1016 | 81 | 13 | 6 |
| 2006 | 2858 | 10617 | 2154 | 371 | 46 | 18 |
| 2007 | 208 | 8574 | 1974 | 496 | 47 | 19 |
| 2008 | 799 | 8681 | 1058 | 171 | 32 | 12 |
| 2009 | 5180 | 8051 | 1840 | 395 | 70 | 28 |
| 2010 | 5614 | 7124 | 706 | 655 | 29 | 10 |
| 2011 | 5649 | 8364 | 2243 | 103 | 15 | 30 |

| **Survey indexes (N. ind. km$^{-2}$) for tuning** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Year / Age | 0 | 1 | 2 | 3 | 4 | 5 | 6+ |
| 2005 | 162 | 86 | 39 | 12 | 3 | 1.9 | 0.3 |
| 2006 | 91 | 174 | 49 | 9 | 2 | 1.2 | 91 |
| 2007 | 192 | 146 | 74 | 18 | 1 | 0.6 | 192 |
| 2008 | 128 | 114 | 58 | 11 | 5 | 0.6 | 128 |
| 2009 | 177 | 83 | 47 | 6 | 1 | 0.2 | 177 |
| 2010 | 55 | 200 | 23 | 5 | 0.2 | 1.3 | 55 |
| 2011 | 199 | 172 | 34 | 5 | 0.5 | 0.8 | 199 |

| **Total catches (t) FISHSTA – GFCM FAO Database, DCF data, PRIMO project** | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1970 | 1611 | 1981 | 968 | 1992 | 1640 | 2003 | 2286 |
| 1971 | 1358 | 1982 | 1046 | 1993 | 1744 | 2004 | 1722 |
| 1972 | 1482 | 1983 | 1424 | 1994 | 1983 | 2005 | 2273 |
| 1973 | 1525 | 1984 | 1221 | 1995 | 1701 | 2006 | 2213 |
| 1974 | 1687 | 1985 | 1334 | 1996 | 1053 | 2007 | 1881 |
| 1975 | 1574 | 1986 | 1372 | 1997 | 1079 | 2008 | 2324 |
| 1976 | 1929 | 1987 | 2287 | 1998 | 1021 | 2009 | 2195 |
| 1977 | 2188 | 1988 | 1720 | 1999 | 1103 | 2010 | 1613 |
| 1978 | 1866 | 1989 | 1629 | 2000 | 1174 | 2011 | 1473 |
| 1979 | 2491 | 1990 | 1065 | 2001 | 1445 | | |
| 1980 | 1927 | 1991 | 1015 | 2002 | 1666 | | |

| **Mean weight at age in the catches and stock (kg)** | | | | | | |
|---|---|---|---|---|---|---|
| Year / Age | 0 | 1 | 2 | 3 | 4 | 5+ |
| 2000-2011 | 0.024 | 0.104 | 0.207 | 0.304 | 0.38 | 0.522 |

| **Growth parameters: SoleMon Project** | | | |
|---|---|---|---|
| PERIOD | $L_\infty$ | k | $t_0$ |
| 2000-2011 | 39.6 cm | 0.44 $y^{-1}$ | -0.46 y |

| **Length-weight rel: SoleMon Project** | | |
|---|---|---|
| PERIOD | a | b |
| 2000-2011 | 0.007 | 3.0638 |

| **Maturity at Age: SoleMon project (prop. mature)** | | | | | | |
|---|---|---|---|---|---|---|
| PERIOD | 0 | 1 | 2 | 3 | 4 | 5+ |
| 2000-2011 | 0 | 0.16 | 0.76 | 0.96 | 0.99 | 1.00 |

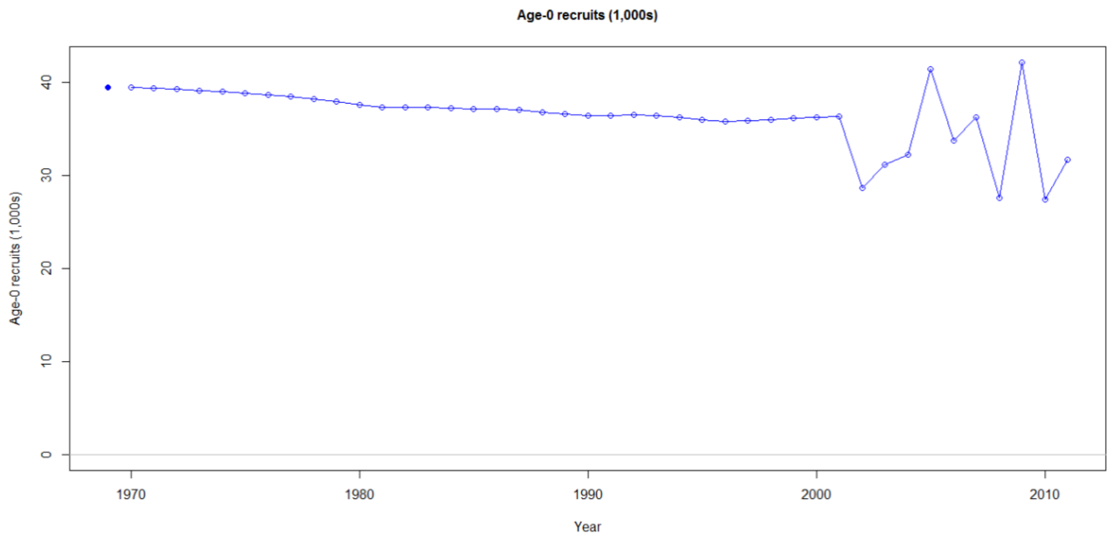
| **Natural mortality (M): probiom approach** | | | | | | |
|---|---|---|---|---|---|---|
| PERIOD | 0 | 1 | 2 | 3 | 4 | 5+ |
| 2000-2011 | 0.70 | 0.35 | 0.28 | 0.25 | 0.23 | 0.22 |

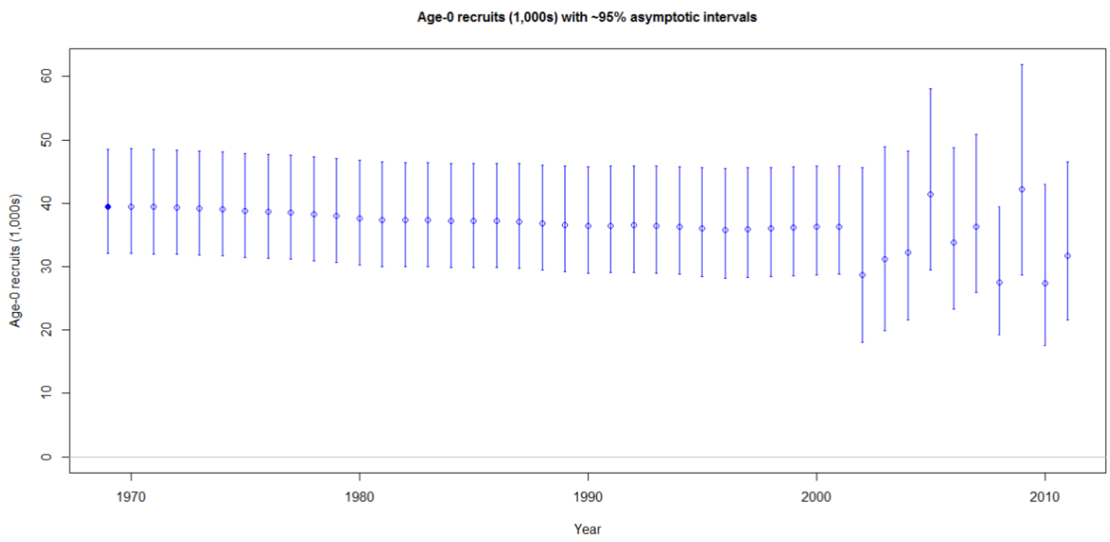
### 5.3.2 Results

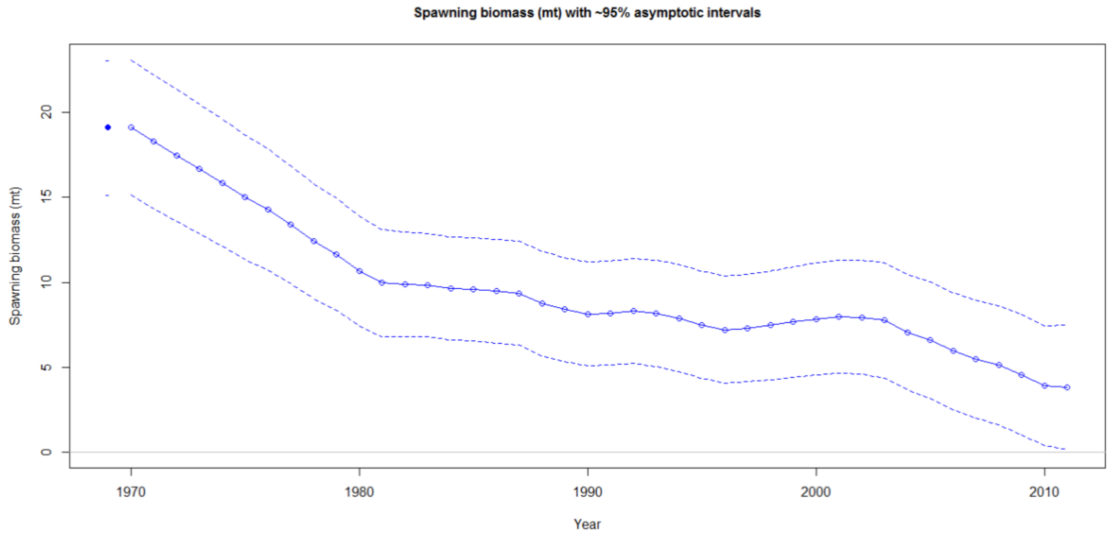
State of exploitation: Exploitation increased with big fluctuation from 1970 to 2009 and decreased in the following period. The most recent estimate of fishing mortality ($F_{0\text{-}4}$) is 0.73 with confidence limits of 0.32 and 1.26.

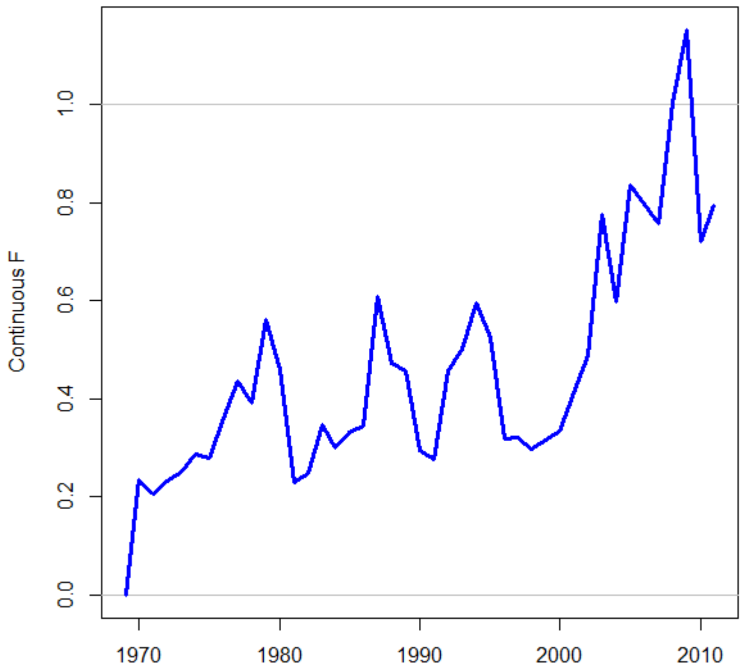
State of the juveniles (recruits): Recruitment showed a decreasing trend until 2000 and fluctuated without a clear trend in the next period.

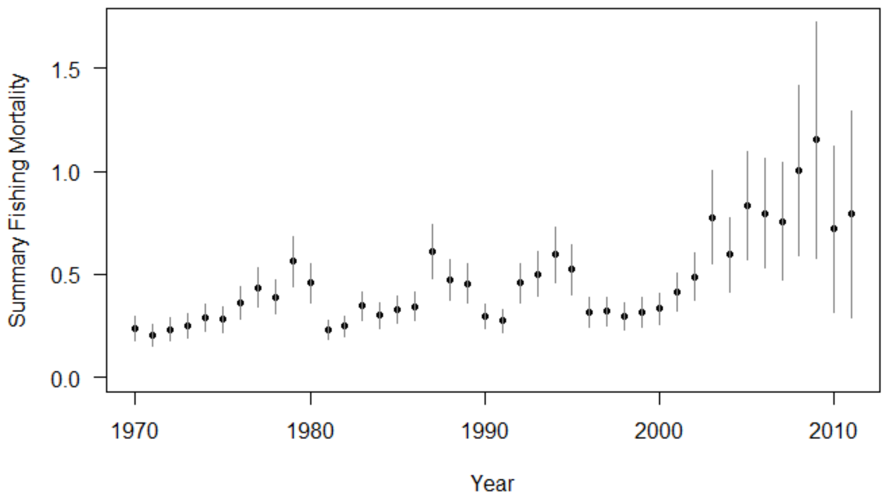
State of the adult biomass: The SSB decreased from 1970 to 2011.



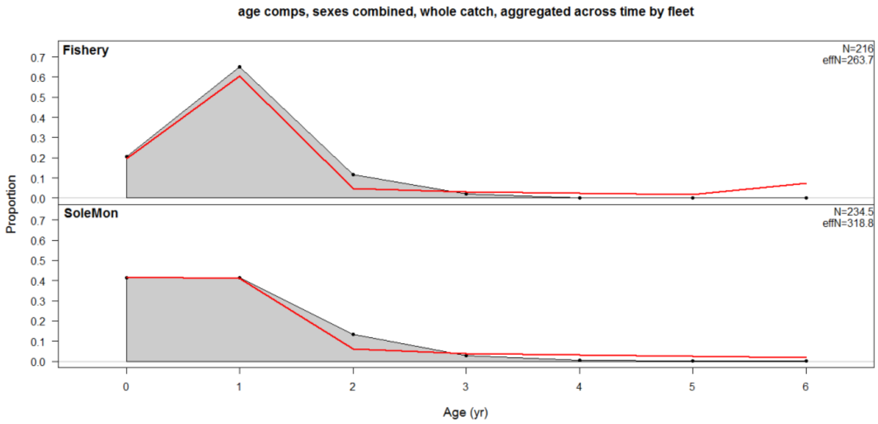

Spawning biomass (mt) with ~95% asymptotic intervals
Spawning biomass (mt)
0
5
10
15
20
1970
1980
1990
2000
2010
Year

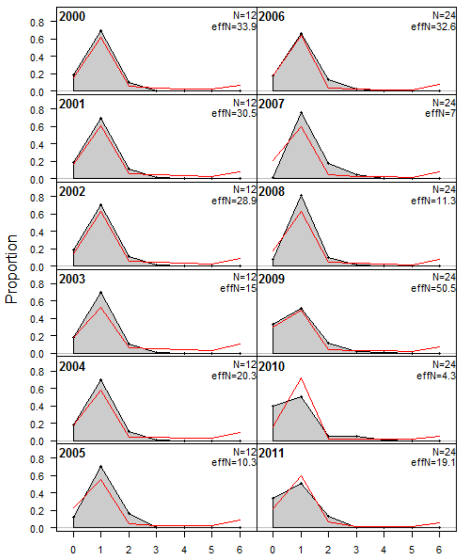

Continuous F
0.0
0.2
0.4
0.6
0.8
1.0
1970
1980
1990
2000
2010

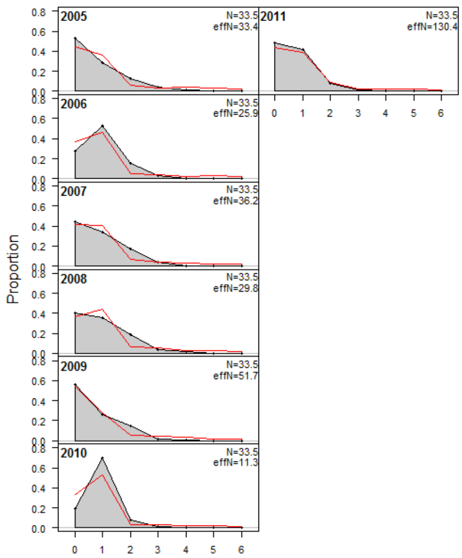

Summary Fishing Mortality
0.0
0.5
1.0
1.5
1970
1980
1990
2000
2010
Year

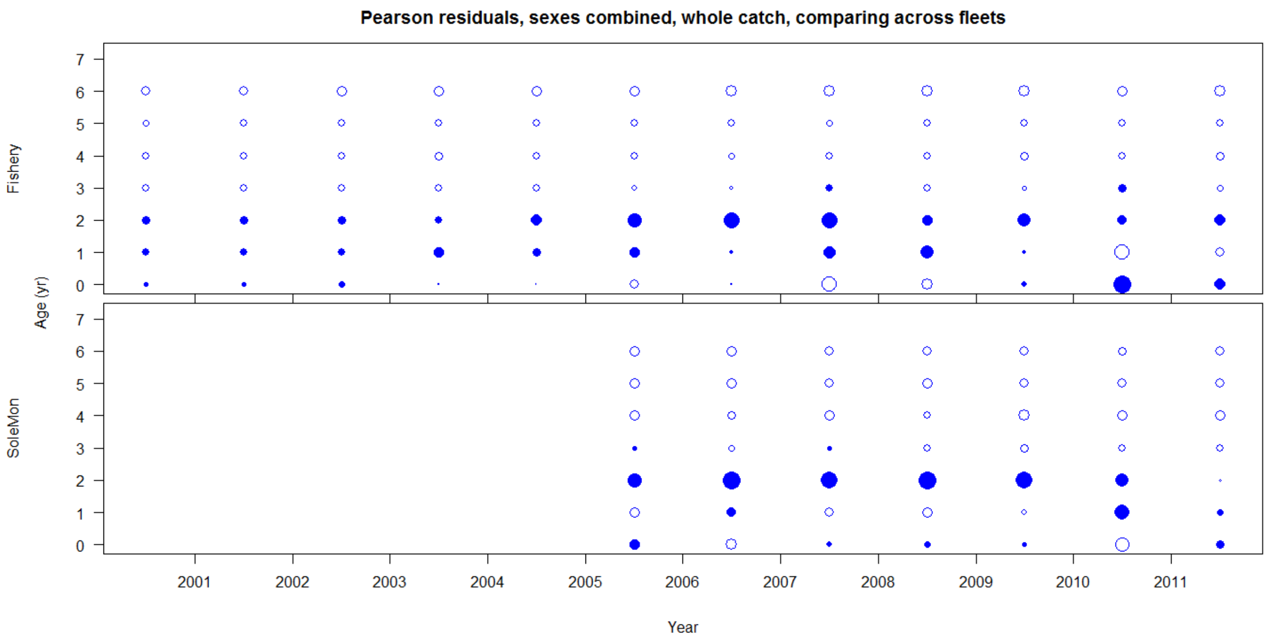
### 5.3.3 Robustness analysis

The selectivity patterns estimated by the model are showed in figures below, both for the fishery and the survey. It is possible to observe a general good agreement between observed and estimated data, both in the fishery and in the survey, overall and in each year. Moreover the residuals do not show particular trends.






## *5.4 Steady state VPA (VIT model)*

### 5.4.1 Model assumptions

The program VIT was designed to analyze exploited marine populations based on catch data, structured by ages or sizes, from one or several gears. The main assumption is that of steady state because the program works with pseudo-cohorts, therefore it is not suitable for historic series. From the catch data with some auxiliary parameters and using Virtual Population Analysis (VPA) the program rebuilds the population and mortality vectors.

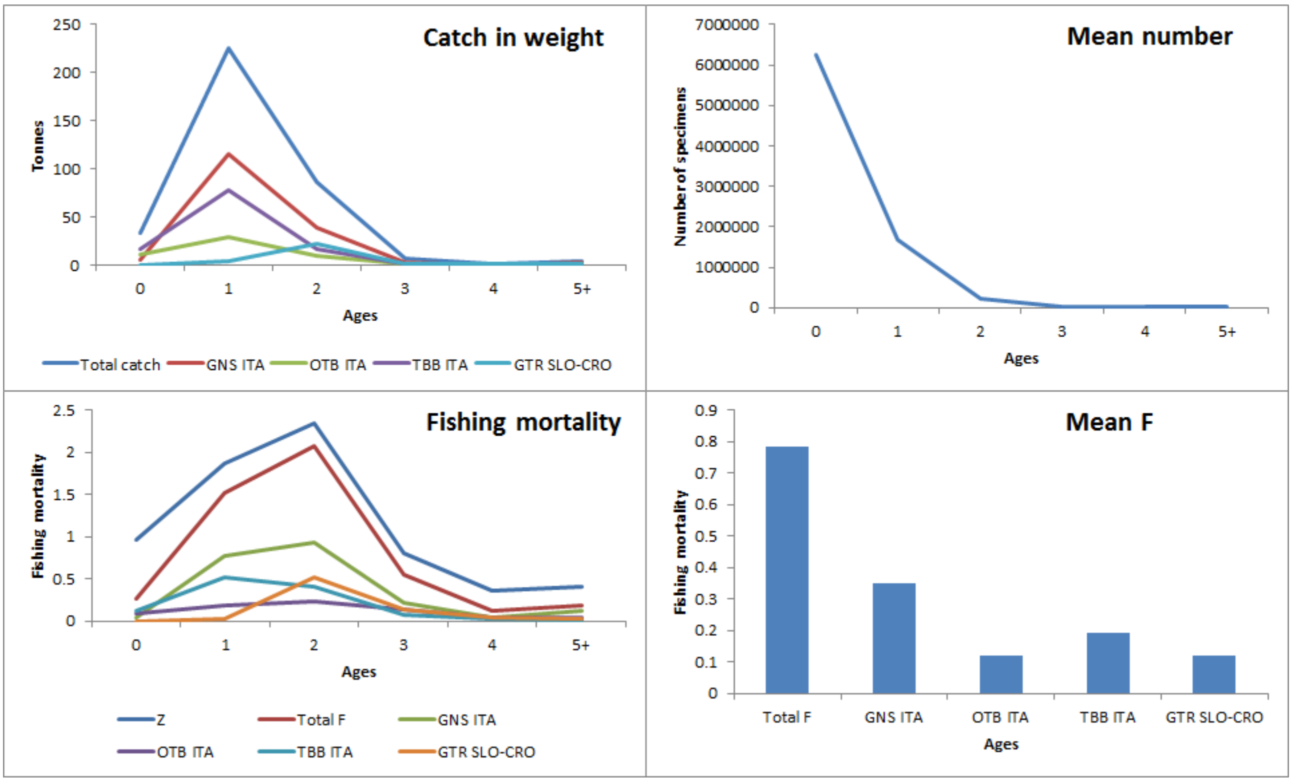
The data used for the analyses were catch at age data per gear in numbers of 2011. The same parameters of the previous analyses were employed and the F terminal (0.18) has been estimated using a catch curve applied at the older ages of the SoleMon survey data.

### 5.4.2 Results

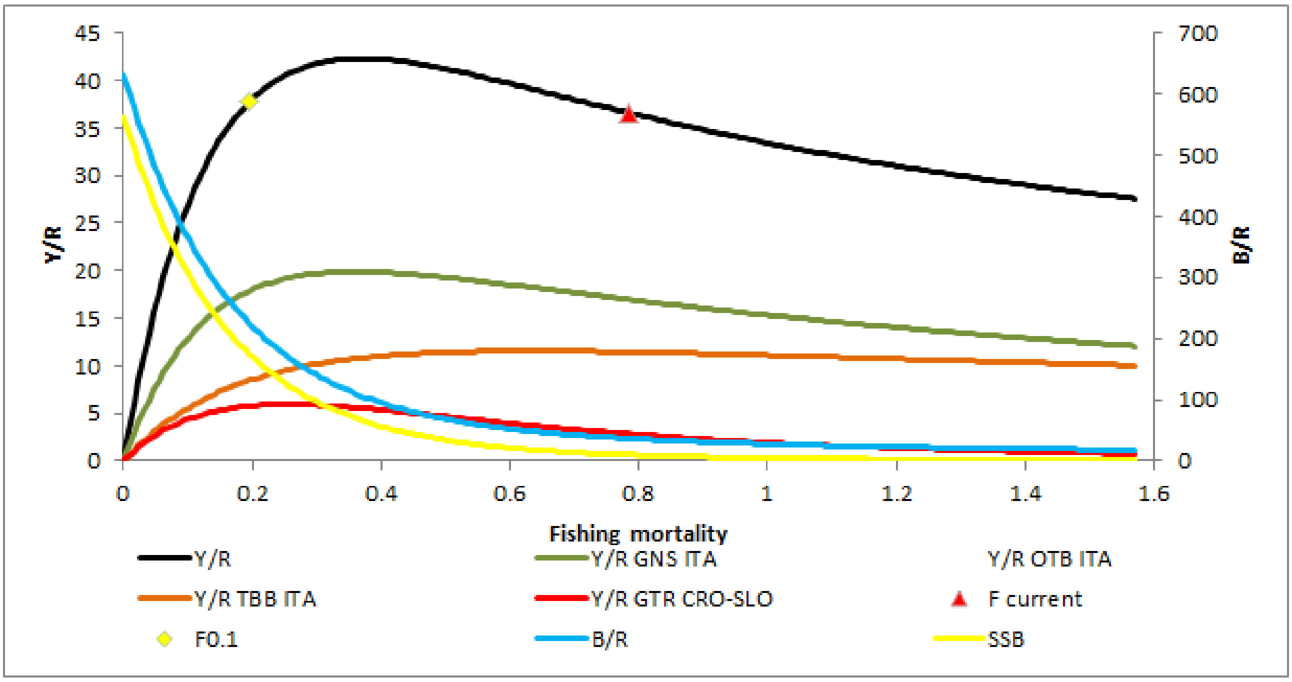
State of exploitation: The estimate of fishing mortality (mean F) is 0.79, with Italian gill netters and rapido trawler representing almost 80%. The catches are mainly represented by age 1.

State of the juveniles (recruits): Recruitment estimate is 6,236,656 of specimens (mean number).

State of the adult biomass: The SSB estimate is around 94 tons (mean weight).




The yield per recruit analysis showed a status of overfishing, being the F current (0.79) higher than the F0.1 (0.25).



## 7. Stock predictions

### *7.1 Short term predictions*

Short term prediction for 2013 were implemented in R (www.r-project.org) using the FLR libraries and based on the results of the Extended Survivor Analyses (XSA). Maturity, weight-at-age in the stock and weight-at-age in the catch were estimated as the mean of the last 3 years. Different scenarios of constant harvest strategy with variation of the mean F ($F_{bar}$ ages 0-4), calculated as the average of the last 3 years, were tested. No particular trend in F in the last years has been observed.

A short term projection (Table I), assuming an $F_{stq}$ of 1.43 in 2012 and a recruitment of 41,195 (thousand) individuals, shows that:

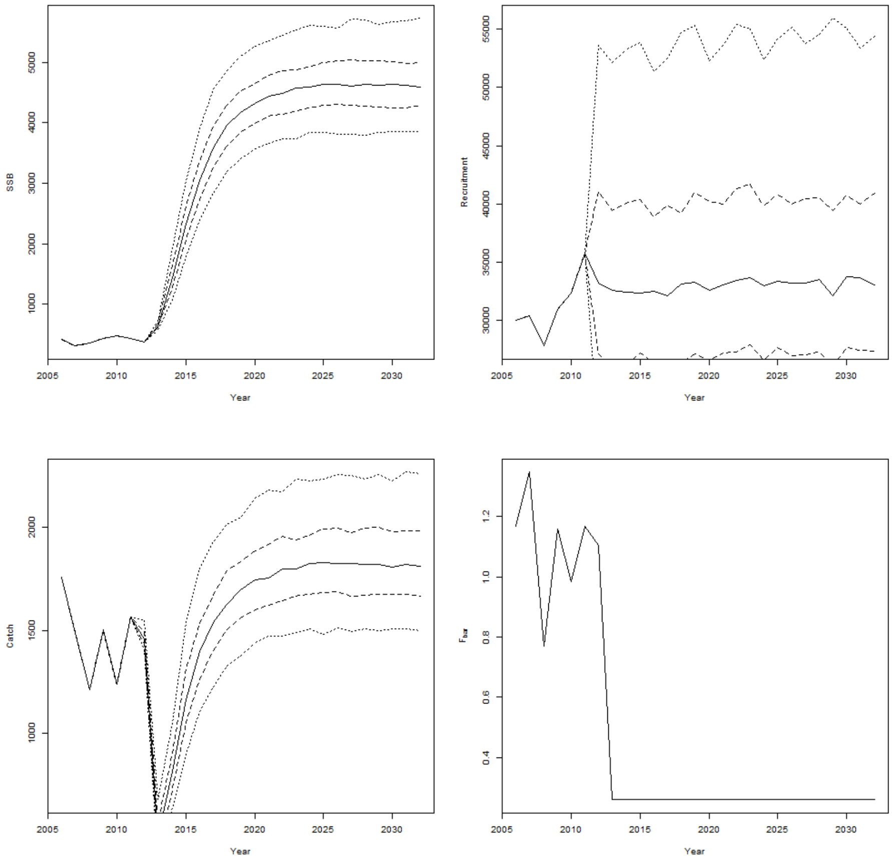
In order to reach the target point $F_{MSY}$, a decrease of $F_{stq}$ by 80% is needed. Keeping with the present analysis based on $F_{stq}$, and the use of $F_{MSY}$ as a target reference point, that catch for sole in the Northern Adriatic Sea (GSA 17) in 2013 should not exceed 494 t.

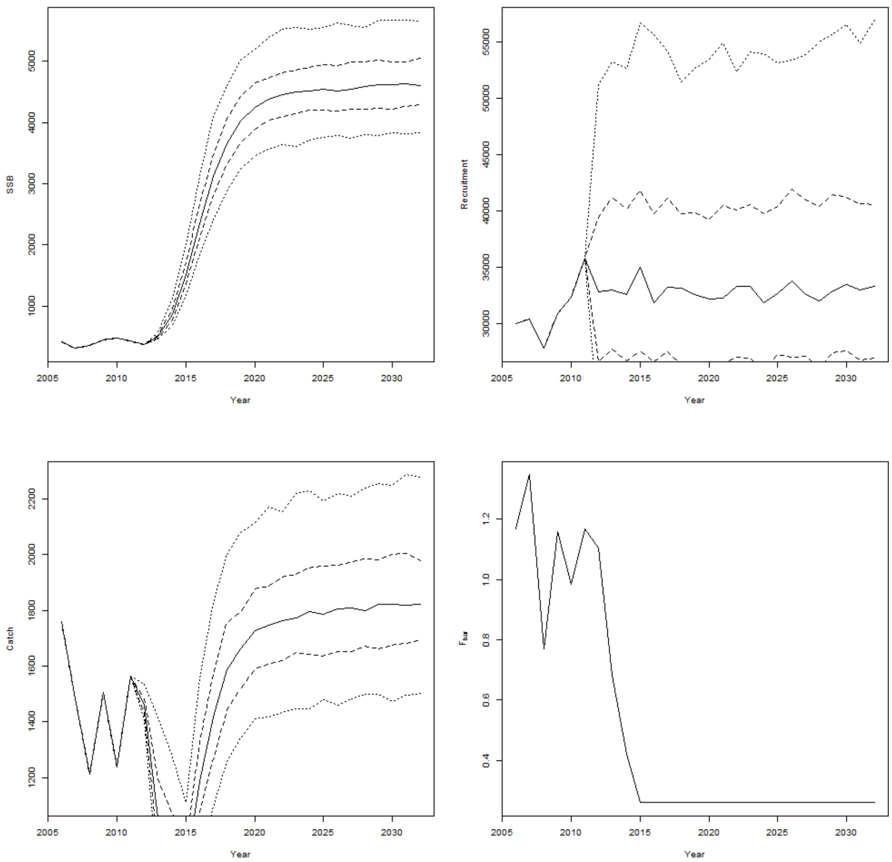
Short term predictions

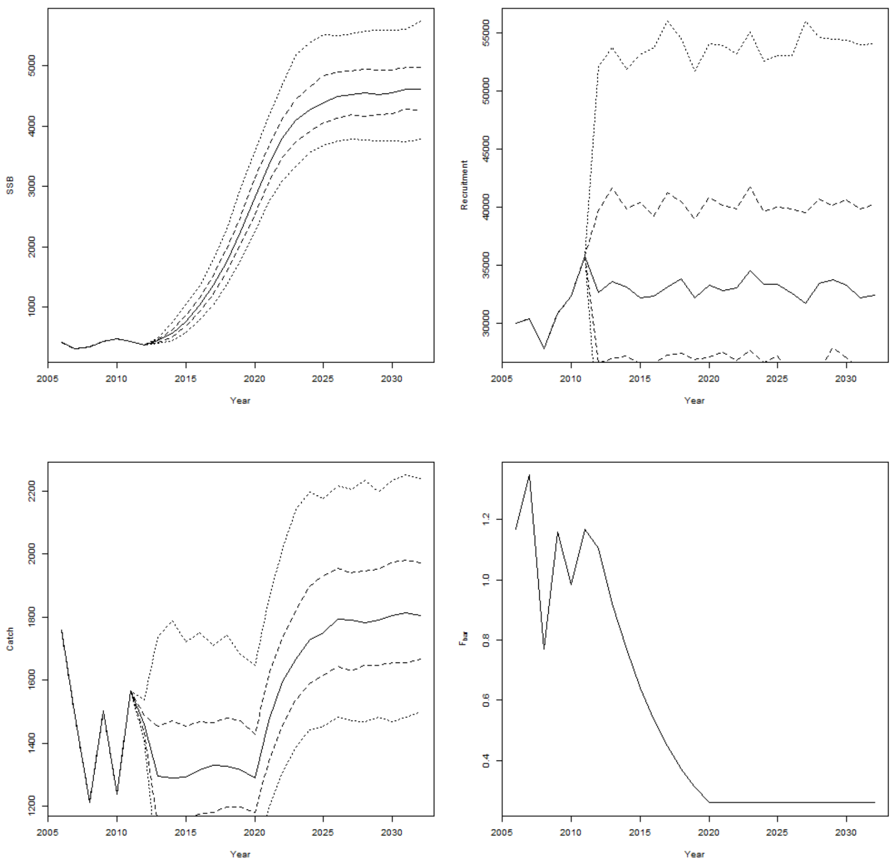
| Rationale | F scenario | F factor | Catch 2012 | Catch 2013 | SSB 2013 | Change SSB 2012-2013 (%) | Change Catch 2010-2012 (%) |
|---|---|---|---|---|---|---|---|
| zero catch | 0.00 | 0.00 | 1459 | 0.00 | 731.72 | 192.03 | -100.00 |
| High long-term yield ($F_{0.1}$) | 0.26 | 0.24 | | 494.17 | 633.59 | 123.98 | -68.42 |
| Status quo | 1.43 | 1.00 | | 1431.27 | 403.85 | -2.16 | -8.54 |
| Different scenarios | 0.11 | 0.10 | | 226.67 | 688.13 | 160.81 | -85.51 |
| | 0.22 | 0.20 | | 427.95 | 647.43 | 133.09 | -72.65 |
| | 0.33 | 0.30 | | 607.04 | 609.42 | 108.48 | -61.21 |
| | 0.44 | 0.40 | | 766.71 | 573.90 | 86.61 | -51.00 |
| | 0.55 | 0.50 | | 909.35 | 540.68 | 67.18 | -41.89 |
| | 0.66 | 0.60 | | 1037.05 | 509.61 | 49.90 | -33.73 |
| | 0.77 | 0.70 | | 1151.62 | 480.53 | 34.53 | -26.41 |
| | 0.88 | 0.80 | | 1254.62 | 453.29 | 20.86 | -19.82 |
| | 0.99 | 0.90 | | 1347.44 | 427.77 | 8.69 | -13.89 |
| | 1.21 | 1.10 | | 1507.14 | 381.41 | -11.82 | -3.69 |
| | 1.32 | 1.20 | | 1575.98 | 360.36 | -20.43 | 0.71 |
| | 1.43 | 1.30 | | 1638.57 | 340.60 | -28.12 | 4.71 |
| | 1.54 | 1.40 | | 1695.62 | 322.04 | -34.98 | 8.36 |
| | 1.66 | 1.50 | | 1747.75 | 304.59 | -41.10 | 11.69 |
| | 1.77 | 1.60 | | 1795.48 | 288.20 | -46.58 | 14.74 |
| | 1.88 | 1.70 | | 1839.29 | 272.78 | -51.48 | 17.54 |
| | 1.99 | 1.80 | | 1879.61 | 258.26 | -55.86 | 20.12 |
| | 2.10 | 1.90 | | 1916.79 | 244.60 | -59.79 | 22.49 |
| | 2.21 | 2.00 | | 1951.16 | 231.74 | -63.32 | 24.69 |

### *7.2 Medium term predictions*

Medium term prediction from 2011 to 2030 was implemented in R (www.r-project.org) using the FLR libraries and based on the results of the Extended Survivor Analyses (XSA, Darby and Flatman, 1994) used for the short term forecasts. The program used in the medium term projections (9 years) were assuming a decreasing trend of the $F_{stq}$ toward the $F_{MSY}$ in 9 years, 4 years, 1 year (2013). The stock-recruitment relationship used geometric mean recruitment over the observed SSB range from 2009 to 2011. Runs were made with 500 simulations per run to try projecting with stochastic recruitment, multiplying the recruitment by log-normally distributed noise with a mean of 1 and a standard deviation of 0.3.




SSB
Year
Recruitment
Year
Catch
Year
$F_{bar}$
Year


SSB
Year
Recruitment
Year
Catch
Year
$F_{bar}$
Year

### *5.5 Long term predictions*

Growth, length-weight relationship, natural mortality and maturity ogive were the same used in the previous paragraphs. Length at first capture was 16 cm TL (about 0.7 year old).

A guess estimate of uncertainty in terms of coefficient of variation (CV=0.2) was added to each parameter.

Beverton and Holt stock-recruit relationship commonly employed for North Sea flatfish (Kell *et al.*, 2005; Pilling *et al.*, 2008) was usedwith steepness of 0.9 and virgin SSB of 13000 t. The value of steepness represents a hypothesis based on the high resilience of the stocks at low spawning-stock size. The value of virgin SSB was estimated from previous analyses carried out by VIT package. The recruitment variability among years was estimated as CV=0.3 from recruit indices obtained in trawl surveys.

Estimation of Y and SSB per recruit are shown in Fig 8

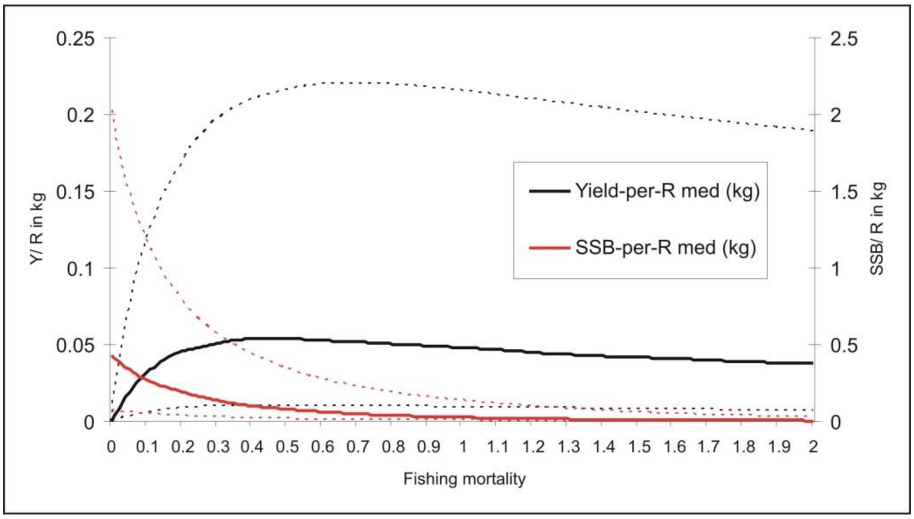



Fig 8. Yield and spawning stock biomass per recruit and corresponding uncertainty of sole in the GSA 17 according to the Yield Package.

Searching for BRP through 1000 simulation produced the median values reported in table 1.1.7.3.1. $Y/R_{max}$, $F_{max}$ and $Y/R_{ref}$, $F_{ref}$, the two latter corresponding to Y/R and F at SSB/initial SSB = 0.30, were assumed as limiting reference points. Whereas $Y/R_{0.1}$ and $F_{0.1}$, should be considered as target reference points.

RPs suggest an overfishing situation for the stock considering F current (1.43 from XSA) is much higher than the limit and target RPs F.

The effect of several bad recruitment years in a row has been evaluated using the transient analysis of SSB. A fishing mortality rate of 0.24 will result in a probability of 0.1 of the SSB falling below 0.2 of its unexploited level at least once in 20 years.

Tab. 2. Yield (kg) per recruit and fishing mortality based BRP of sole for GSA 17 according to the Yield package.

| **Yield based RP** | **value** | **F based RP** | **Value** |
|---|---|---|---|
| $Y/R_{max}$ | 0.054 | $F_{max}$ | 0.46 |
| $Y/R_{ref}$ | 0.051 | $F_{ref}$ | 0.32 |
| $Y/R_{0.1}$ | 0.048 | $F_{0.1}$ | 0.26 |

## 6 Draft scientific advice

Considering the results of the analyses conducted the common sole stock in GSA 17 is subjected tooverfishing, being the current F (2011) estimated with different model comprised between 0.73 and 1.43 and higher than the proposed reference point (F0.1 = 0.26).

A reduction of fishing pressure would be recommended, also taking into account that the exploitation is mainly orientated towards juveniles and the success of recruitment seems to be strictly related to environmental conditions. This could be achieved by a two–months closure for rapido trawling inside 11km (6 nm) offshore along the Italian coast, after the fishing ban of August. Moreover, information provided by VMS will be useful in order to quantify the fishing effort of rapido trawlers in such area and period.

Finally, specific studies on rapido trawl selectivity are necessary. In fact, it is not sure that the adoption of a larger mesh size would correspond to a decrease of juvenile catches. The same uncertainty regards the adoption of square mesh.

*Table 5.5-1: Unidimensional stock status*

| | |
|---|---|
| **Unidimnsional** | |
| | **Overexploited**. The fishery is being exploited at above a level which is believed to be sustainable in the long term, with no potential room for further expansion and a higher risk of stock depletion/collapse.<br><br>***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)* |

*Table 5.5-2: Bidimensional stock status*

| **Bidimensional** | **Exploitation rate** | **Stock Abundance** |
|---|---|---|
| | 0.8<br><br>(Fxsa = 1.43, Mean M = 0.35) | |