# Stock Assessment Form version 0.1

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## Assessment form content for each stock

# 1 Basic Identification Data

| Scientific name: | Common name: | ISCAAP Group: |
|---|---|---|
| *Engraulis encrasicolus* | European anchovy | 35 - Herrings, sardines, anchovies |
| Geographical sub-area: | | |
| GSA 17 | | |
| Stock assessment method: (direct, indirect, combined, none) | | |
| Combined | | |
| Authors: Carpi P. (1), (*in alphabetical order)* Angelini S. (1), Belardinelli A. (1), Biagiotti I. (1), Campanella F. (1), Canduci G. (1), Cingolani N. (1), Čikeš Keč V. (2), Colella S. (1), Croci C. (1), De Felice A. (1), Donato F.(1), Leonori I. (1), Martinelli M. (1), Malavolti S. (1), Modic T. (3), Panfili M. (1), Pengal P. (3), Santojanni A. (1), Ticina V. (2), Vasapollo C. (1), Zorica B. (2), Arneri E (4). | | |
| | | |
| Affiliation: (1) CNR-ISMAR (Ancona, Italy), (2) Institute of Oceanography and Fisheries (Split, Croatia), (3) Fisheries Research Institute of Slovenia (Ljubjana, Slovenia), (4) FAO-Adriamed (Rome, Italy) | | |
| | | |

# 2 Stock identification and biological information.

## 2.1 Stock unit

Anchovy stock is shared among the countries belonging to GSA 17 (Italy, Croatia and Slovenia) and it constitutes a unique stock.

Many studies have been carried out regarding the presence of a unique stock or the presence of different sub populations living in the Adriatic Sea (GSA 17 and GSA 18). This has several implications for the management, i.e. differences in the growth features between subpopulations imply the necessity of ad hoc strategies in the management. The hypothesis of two distinct populations claims the evidence of morphometric differences between northern and southern Adriatic anchovy, such as color and length, and some variability in their genetic structure (Bembo et al., 1996). Nevertheless, many authors warns against the use of morphological data in studies on population structure (Tudela, 1999) and, a recent study from Magoulas et al. (2006), revealed the presence of two different clades in the Mediterranean, one of those is characterized by a high frequency in the Adriatic Sea (higher than 85%) with a low nucleotide diversity (around 1%). For this reason a joint assessment between GSA 17 and GSA 18 is advisable.

## 2.2 Growth and maturity

*Table 2: Maximum size, size at first maturity and size at recruitment.*

| | Somatic magnitude measured (LH, LC, etc)* | | | TL | Units* | cm |
|---|---|---|---|---|---|---|
| Sex | Fem | Mal | Both | Un-sexed | | |
| Maximum size observed | | | 18 | | Reproduction season | April - October |
| Size at first maturity | | | 8 | | Reproduction areas | Mainly western Adriatic. |
| Recruitment size | | | 9 | | Nursery areas | Mainly along western Adriatic coast, River Po delta, Manfredonia Gulf |

*Table 2: Growth and length weight model parameters*

| | | Units | Sex: female | male | both | | unsexed |
|---|---|---|---|---|---|---|---|
| Growth model | $L\infty$ | Cm | | | 19.4 | | |
| | K | $y^{-1}$ | | | 0.57 | | |
| | t0 | y | | | -0.5 | | |
| | Data source | Sinovcic, 2000 | | | | | |
| Length weight relationship | a | | | | 0.004 | | |
| | b | | | | 3.0 | | |
| | Age0 | Age1 | Age2 | Age3 | Age4 | Age5 | |
| M (vector by age) | 2.36 | 1.10 | 0.81 | 0.69 | 0.64 | 0.61 | |

| Gislason *et al*, 2010 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|

| sex ratio (% females/total) | 63.2 |
|---|---|

# 3 Fisheries information

## 3.1 Description of the fleet

*Table 3: Description of operational units in the stock*

| | Country | GSA | Fleet Segment | Fishing Gear Class | Group of Target Species | Species |
|---|---|---|---|---|---|---|
| Operational Unit 1* | Italy | 17 | Pelagic trawlers | Trawls | 35 - Herrings, sardines, anchovies | Engraulis encrasicolus |
| Operational Unit 2 | Italy | 17 | Purse Seiners | Surrounding Nets | 35 - Herrings, sardines, anchovies | Engraulis encrasicolus |
| Operational Unit 3 | Croatia | 17 | Purse Seiners | Surrounding Nets | 35 - Herrings, sardines, anchovies | Engraulis encrasicolus |
| Operational Unit 4 | Slove-nia | 17 | Purse Seiners | Surrounding Nets | 35 - Herrings, sardines, anchovies | Engraulis encrasicolus |
| Operational Unit 5 | Slovenia | 17 | Pelagic trawlers | Trawls | 35 - Herrings, sardines, anchovies | Engraulis encrasicolus |

*Table 3: Catch, bycatch, discards and effort by operational unit*

<table>
<tr><th>Operational Units*</th><th>Fleet (n° of boats) *</th><th>Kilos or Tons</th><th>Catch (species as-sessed)</th><th>Other species caught</th><th>Discards (species as-sessed)</th><th>Discards (other species caught)</th><th>Effort units</th></tr>
<tr><td>1</td><td>84</td><td>tons</td><td>17200</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>19</td><td>tons</td><td>2500</td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>NA</td><td>tons</td><td>13600</td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>5</td><td rowspan="2">tons</td><td rowspan="2">124</td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>1</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>122</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

*Table 3: Catches as used in the assessment*

| Classification (age, length, recruit/spawner) | Catch (tn) |
|---|---|
| 2000 | 29036 |
| 2001 | 28280 |
| 2002 | 23467 |
| 2003 | 25016 |
| 2004 | 31280 |
| 2005 | 42296 |
| 2006 | 43090 |
| 2007 | 47055 |
| 2008 | 41151 |
| 2009 | 44280 |
| 2010 | 39639 |
| 2011 | 35058 |
| Average | 35804 |

### 3.2 Historical trends

In figure 3.2.1 the trend in landings for Italy and Croatia are shown. From 2002 the trend is increasing with a maximum of 47055 tons in 2007. The Slovenian catches are included in the total landings but are not shown here since the quantities are really low (less than 150 tons in 2011):

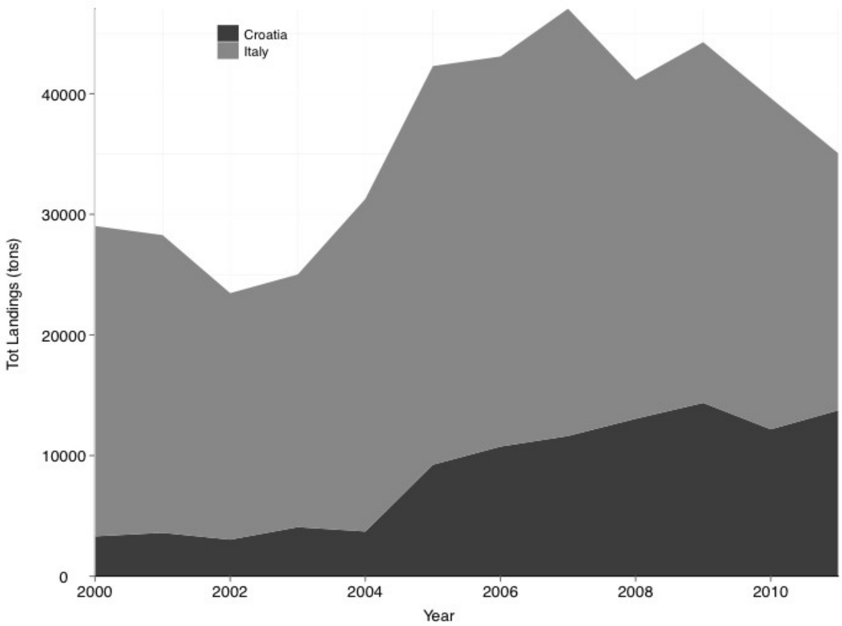


*Fig. 3.2. Total landings (in tons) by country for GSA 17 from 2000 to 2011*

The trend of the cohorts in the catches is shown in figure 3.2.2. Each plot represents the number of fish of each age born in the same year. Age 1 can be identified as the first fully recruited age.

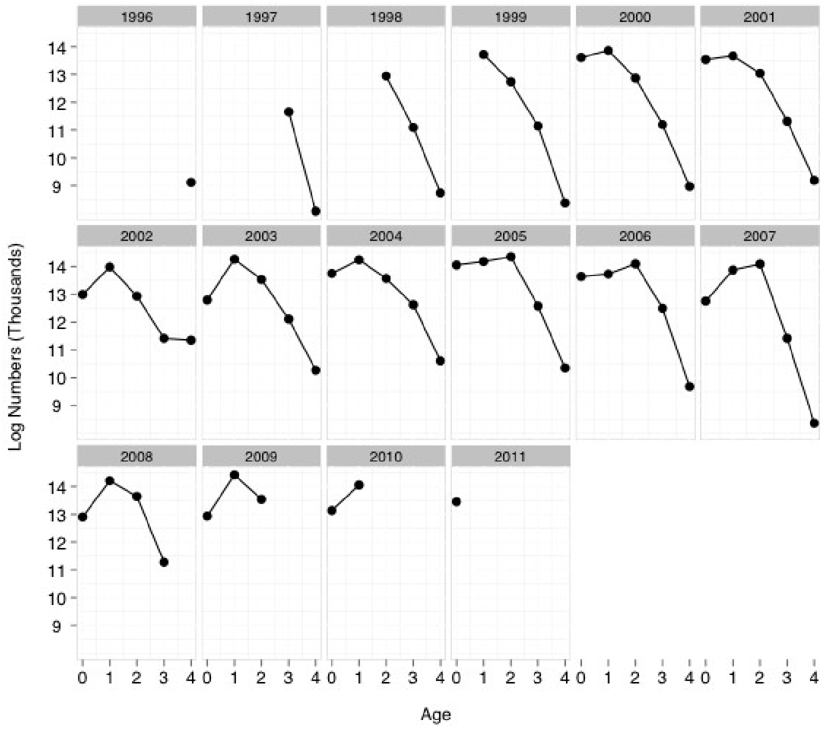


*Fig. 3..2 Log numbers at age (thousands) of the catch at age used in the assessment.*

The mean weight at age (in kg) as obtained by sampling of commercial catches is given in figure 3.2.3.

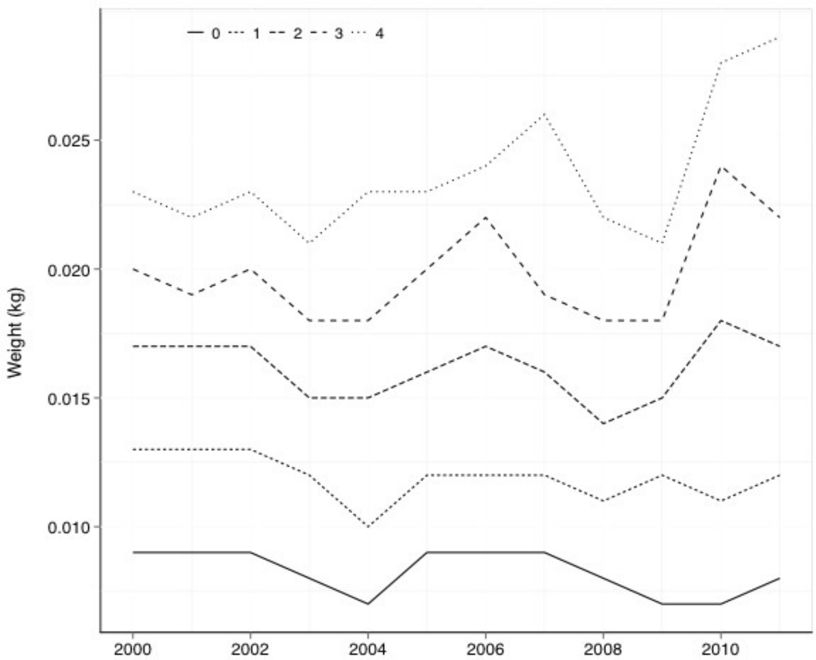


*Fig. 3.2.3. Mean weight at age (kg) in the catches*

# 4 Management regulations

A closure period is observed from the Italian pelagic trawlers on August, and from 15th December to 15th January from the Croatian purse seiners. In 2011 a closure period of 60 days (August and September) was endorsed by the Italian fleet.

## 4.1 Reference points

The present assessment has been considered as a benchmark assessment for biomass reference points. Up to now, the Patterson's reference point of E=0.4 has been adopted as fishing mortality reference point.

The reference points that were proposed during the working group are $B_{lim}$ and $B_{pa}$. The criterion adopted for $B_{lim}$ has been the minimum mid year biomass value of the assessed time series, which is of the same magnitude of the minimum value observed since 1976, so it seemed to be reasonable. $B_{pa}$ has been established in relation to Blim using an estimate or assumption on the coefficient of variance of the estimates (see general sections), and assuming that the confidence intervals for the estimate of the assessment model are estimate ± 2 * CV * estimate. In this case a CV of 20 % has been assumed, therefore $B_{pa}$ has been established as 40% above $B_{lim}$.

*Table 4: List of reference points*

| Crite-rion | Current value | Unit s | Reference Point | Trend | Comments |
|---|---|---|---|---|---|
| B | | | | | |
| SSB | | | | | |
| F | | | | | |
| Y | | | | | |
| CPUE | | | | | |
| E | 0.41 | | 0.4 | Stable | Patterson (1992) |
| Blim | 333404 | tons | 179000 | Sta-ble | |
| Bpa | 333404 | tons | 250600 | Sta-ble | |
| | | | | | |

# 5 Fisheries independent information

## *5.1 ECHOSURVEY (Acoustic survey)*

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

Echosurveys were carried out from 2004 to 2011 for the entire GSA 17. In the western part the acoustic survey was carried out since 1976 in the Northern Adriatic (2/3 of the area) and since 1987 also in the Mid Adriatic (1/3 of the area), and it is in the MEDIAS framework since 2009. The eastern part was covered by Croatian national pelagic monitoring program PELMON. The data from both the surveys have been combined to provide an overall estimate of numbers-at-age.

The survey methods for MEDIAS are given in the MEDIAS handbook (MEDIAS, March 2012).

Western Echosurvey:

- Length frequencies distribution available from 2004 onward (no LFD for Mid Adriatic in 2004, so the proportion of biomass at length in 2004 was assumed equal to the proportion of biomass at length in the 2005 Mid Adriatic survey).
- ALKs available for 2009-2010-2011;
- Numbers at age for 2004 to 2008 were obtained applying the sum of the 2009-2010-2011 ALKs to the numbers at length.

Eastern Echosurvey:

- Length frequencies distribution available from 2009.
- No ALKs available.
- Numbers at length from 2004 to 2008 were obtained applying the length frequency distribution from the 2009 survey to the total biomass.
- Numbers at age were obtained applying commercial ALK from the eastern catches to the eastern echosurvey length distribution.
- 2011 survey covered only the Northern part of the area (about 52% of the total area), so the estimated biomass was raised to the total using an average percentage from previous years (2004-2010).

### 5.1.2 Spatial distribution of the resources

Acoustic sampling transects and the total area covered are shown in figure 5.1.2.1.

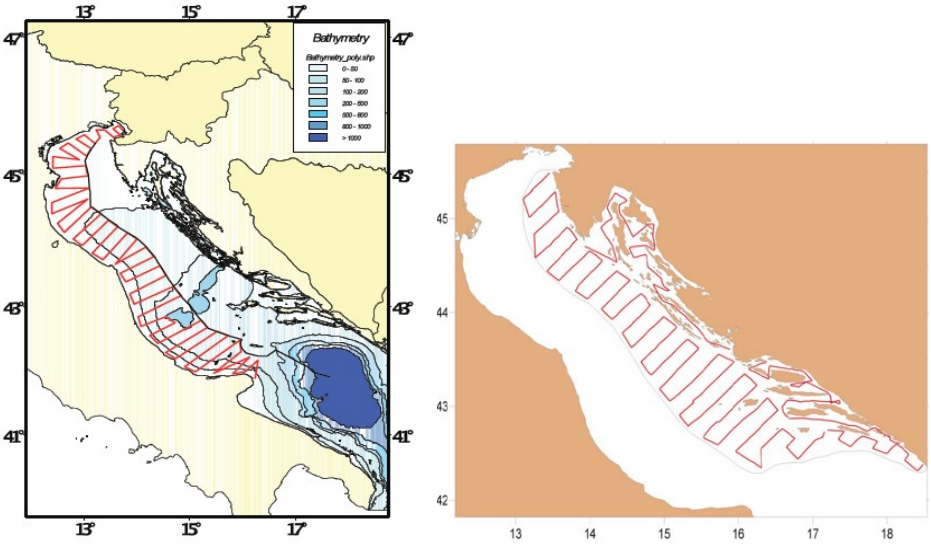


*Fig. 5..2.1. Acoustic transects for the western echosurvey (on the left) and the eastern echosurvey (on the right)*

### 5.1.3 Historical trends

Biomass estimates from the two surveys show a much higher occurrence of anchovy on the western side of the Adriatic. In 2008 the western survey contributed to more than 85% of the total estimated biomass.

Pooled total biomass in tons from eastern and western echosurvey (2004-2011) is given in table 5.1.3.1. and it is shown in figure 4.1.3.1.

*Tab. 5..3.1. Total biomass (tons) estimated by the acoustic surveys in GSA 17.*

| | Tons |
|---|---|
| 2004 | 302130 |
| 2005 | 335312 |
| 2006 | 627226 |
| 2007 | 533525 |
| 2008 | 858497 |
| 2009 | 486373 |
| 2010 | 642184 |
| 2011 | 474920 |

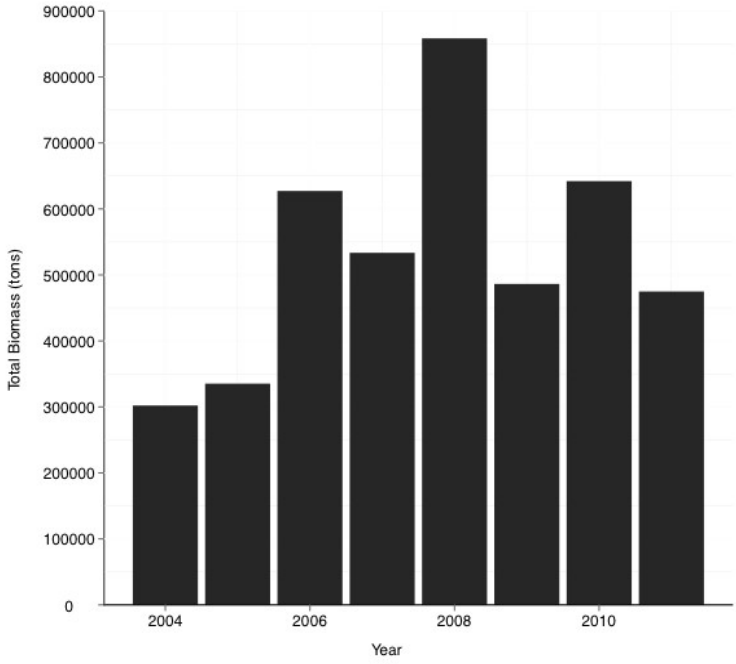


*Fig. 5.1.3.1. Total biomass (tons) estimated from the eastern and western echosurvey*

Figure 5.1.3.2 illustrates the proportion by year of each age class from the surveys. In 2008 a higher percentage of age 0 occurred. Age 3 and age 4 are scarcely represented in the estimation.

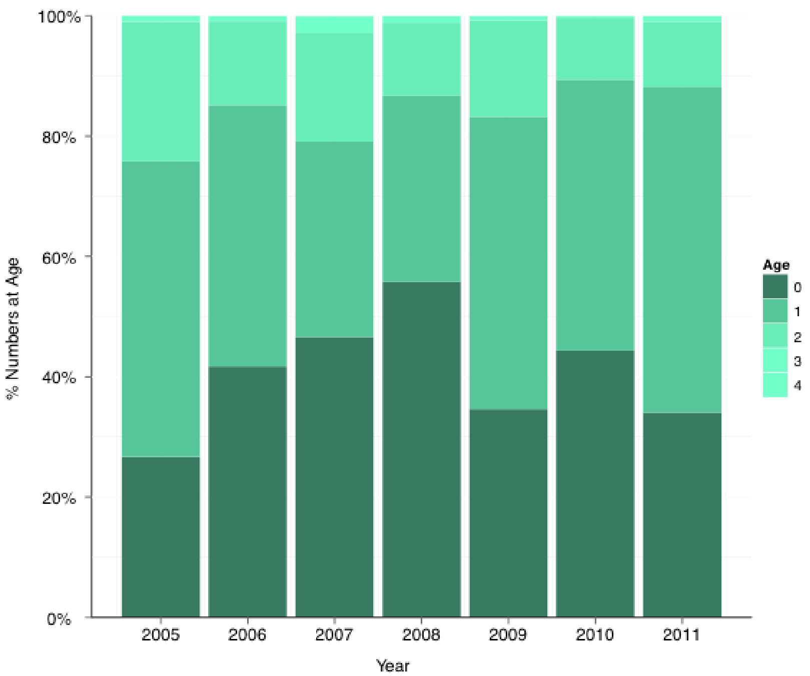


*Fig 5.1.3.2. Total proportion of age classes for the two surveys*

In figure 5.1.3.3 the trend of the cohorts in the acoustic survey is shown. Each plot represents the number of fish of each age born in the same year:

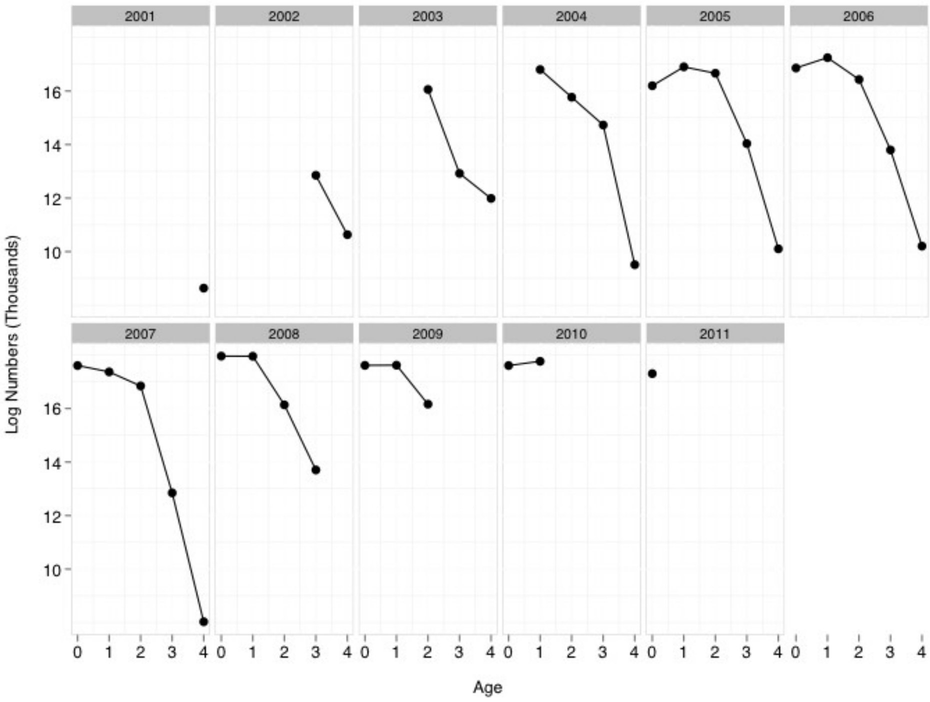


*Fig. 5.1.3.3. Log numbers at age (thousands) of the echosurvey index used in the assessment*

## *5.2 MEDITS*

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

The MEDITS bottom trawl survey started in 1994 and it has been carried out every year since. It takes place during the summer months (June-July) and it provides indices of fish abundance in the deepest part of water column (i.e. within layer up to 3 m above sea bed). Although this survey is targeted to investigate species living near the bottom, the characteristics of the net employed (high vertical opening of the mouth) allow to regularly catch species living in the water column, as small pelagics (Sbrana *et al.,* 2010).

The survey methodology is given in the MEDITS handbook (MEDITS, April 2012).

### 5.2.2 Spatial distribution of the resources

The spatial distribution of the Medits stations during the 2010 trawl survey is illustrated in figure 5.2.2.1.

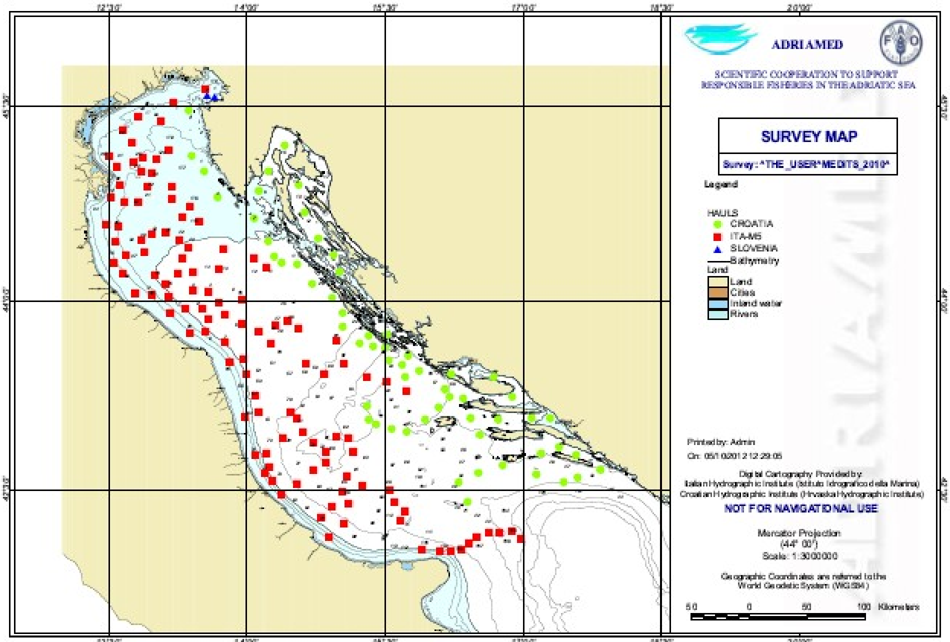


*Fig. 5..2.1. Spatial distribution of the MEDITS stations in GSA 17.*

### 5.2.3 Historical trends

The biomass index (kg/km$^2$) (table 5.2.3.1) shows an overall decreasing trend up to 2009, followed by a steep increase in the last couple of years.

*Tab. 5..3.1. MEDITS index of biomass (kg/km$^2$) from 2000 to 2011.*

| MEDITS biomass index | |
|---|---|
| Year | kg/km$^2$ |
| 2000 | 37.42 |
| 2001 | 86.00 |
| 2002 | 72.37 |
| 2003 | 71.57 |
| 2004 | 55.00 |
| 2005 | 58.92 |
| 2006 | 56.54 |
| 2007 | 32.27 |
| 2008 | 48.42 |
| 2009 | 27.06 |
| 2010 | 51.77 |
| 2011 | 116.56 |

The comparison between the acoustic series of total biomass and the trawl survey biomass index shows a general agreement between the two indices (figure 5.2.3.1). The only exceptions are 2006 and 2011: in 2006 MEDITS saw a slightly decreasing biomass while acoustic surveys showed a strong increase and in 2011 acoustic surveys saw a decreasing biomass and MEDITS showed the opposite.

The weight given in the assessment to the MEDITS trawl survey is much lower to the weight given to the acoustic survey (see section 7.1.1).

The 2011 data for both the indices didn't enter in the analysis (due to the split year assumption).

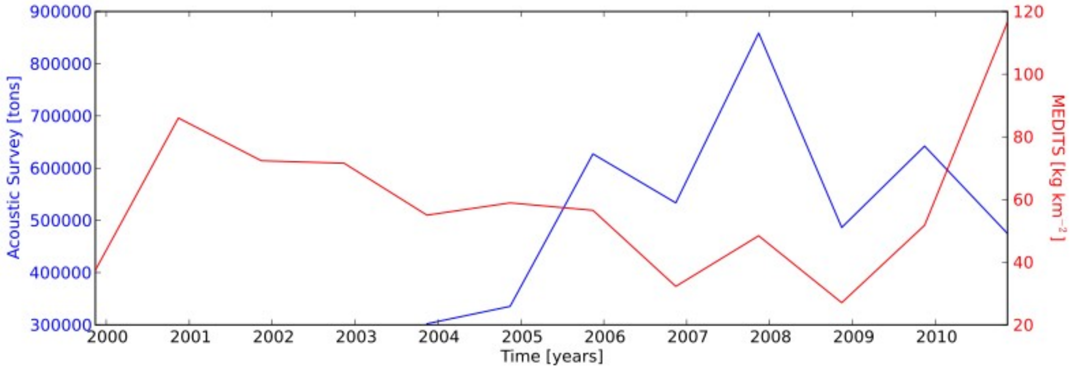


*Fig. 5.2.3.1. Comparison between biomass index from the acoustic survey (axis on the left, blue line) and the bottom trawl survey (axis on the right, red line).*

# 6 Ecological information

N/A

## *6.1 Protected species potentially affected by the fisheries*

N/A

## *6.2 Environmental indexes*

N/A

# 7 Stock Assessment

Integrated Catch Analysis (ICA) and Virtual Population Analysis (VPA) have been performed from 2000 to 2011.

Acoustic and bottom trawl survey were available for the assessment of anchovy in GSA 17. The weight given to the bottom trawl survey was decided equal to 0.3, in comparison to weight 1 given to the acoustic survey.

## *7.1 Integrated Catch Analysis*

The final assessment of anchovy was carried out by fitting the integrated catch-at age model (ICA) with a separable constraint over a twelve-year period, tuned with the Acoustic survey (2004-2010) and bottom trawl survey biomass index (2000-2011).
ICA was performed using the Patterson's software (ICA, version 4.2 – Patterson and Melvin, 1996).

The model settings are presented in section 7.1.1.

### 7.1.1 Model assumptions

- Split year assumption
- Ages 0 to 5 (since the software doesn't accept less than 6 age class)
- M vector estimated using Gislason's equation (Gislason *et al.*, 2010):

| Age0 | Age1 | Age2 | Age3 | Age4 | Age5 |
|---|---|---|---|---|---|
| 2.36 | 1.10 | 0.81 | 0.69 | 0.64 | 0.61 |

- Maturity at age:

| Age0 | Age1 | Age2 | Age3 | Age4 | Age5 |
|---|---|---|---|---|---|
| 0.75 | 1 | 1 | 1 | 1 | 1 |

- 12 years for separable constraint
- Reference age for separable constraint = 1
- Constant selection pattern model
- S to be fixed on last age = 1.0
- $F_{bar}$: 1-3
- Catchability model = Linear
- Weight for surveys: Bottom trawl survey = 0.3; Acoustic surveys = 1.
- No shrinkage

### 7.1.2 Scripts

N/A

## 7.1.3 Results

The fishing mortality for age 1 (presented in figure 7.1.3.1., top-right) shows a constant decrease from 2000 up to 2007. Only in the last few years the F increased, remaining around F=0.4 and decreasing again in 2011 to the value of F=0.28. In 2011 the $F_{bar(1\text{-}3)}$ is equal to 0.61.

The mid year biomass (figure 7.1.3.1, bottom-right) is fluctuating around the value of 300 thousand tons, reaching the maximum in 2005 (B = 436000 tons). In 2011 the estimated biomass is B = 333000 tons.

The recruitment (age 0 – figure 7.1.3.1, bottom-left) is quite stable, with fluctuations between 52578000 and 129050000 thousands individuals.

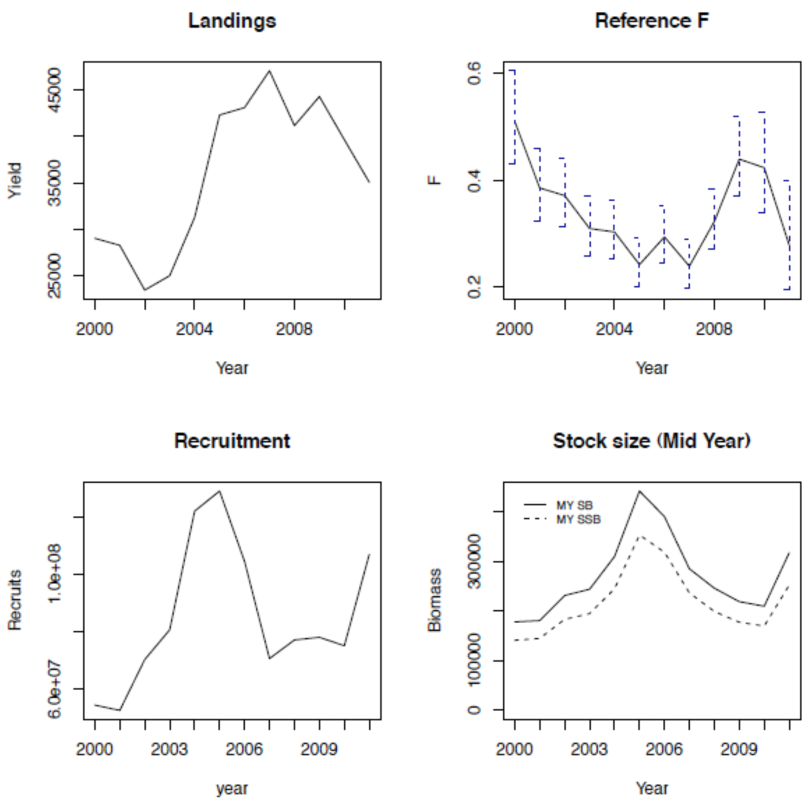


*Fig. 7.1.3.1. Total landings in tons (top-left); reference F (F for age 1) with the confidence interval for the separability period (top-right); recruitment (as thousands individuals)(bottom-left); mid year stock biomass and SSB in tons (bottom-right).*

Table 7.1.3.1 and 7.1.3.2 give respectively the stock numbers at age by year (in thousand) and the fishing mortality at age by year. In table 7.1.3.3 the mid year stock biomass and the spawning stock biomass in tons are presented.

*Tab. 7.1.3.1. Stock numbers at age by year (thousands)*

| | Age0 | Age1 | Age2 | Age3 | Age4 | Age5 |
|---|---|---|---|---|---|---|
| 2000 | 54428000 | 3882900 | 1070100 | 148860 | 30020 | 33 |
| 2001 | 52578000 | 4991800 | 776120 | 119240 | 17328 | 41 |
| 2002 | 70296000 | 4856500 | 1130000 | 121220 | 19822 | 42 |
| 2003 | 80670000 | 6498300 | 1115100 | 183440 | 20990 | 49 |
| 2004 | 12205000 | 7483500 | 1586600 | 213880 | 37875 | 50 |
| 2005 | 12905000 | 11326000 | 1839100 | 309760 | 44992 | 26160 |
| 2006 | 10457000 | 12018000 | 2958400 | 423610 | 77580 | 268900 |
| 2007 | 70659000 | 9708900 | 2980900 | 592220 | 91498 | 94682 |
| 2008 | 77143000 | 6581200 | 2543300 | 692030 | 149560 | 48 |
| 2009 | 78068000 | 7151000 | 1586100 | 470850 | 137650 | 37 |
| 2010 | 75126000 | 7188900 | 1534000 | 214080 | 67104 | 38 |
| 2011 | 10698000 | 6924200 | 1567000 | 216240 | 31939 | 54 |

*Tab. 7.1.3.2. Fishing mortality at age by year*

| | Age0 | Age1 | Age2 | Age3 | Age4 | Age5 |
|---|---|---|---|---|---|---|
| 2000 | 0.0291 | 0.5100 | 1.3844 | 1.4607 | 0.5100 | 0.5100 |
| 2001 | 0.0220 | 0.3856 | 1.0467 | 1.1043 | 0.3856 | 0.3856 |
| 2002 | 0.0212 | 0.3714 | 1.0081 | 1.0636 | 0.3714 | 0.3714 |
| 2003 | 0.0177 | 0.3099 | 0.8413 | 0.8876 | 0.3099 | 0.3099 |
| 2004 | 0.0173 | 0.3034 | 0.8236 | 0.8689 | 0.3034 | 0.3034 |
| 2005 | 0.0138 | 0.2425 | 0.6582 | 0.6945 | 0.2425 | 0.2425 |
| 2006 | 0.0168 | 0.2942 | 0.7985 | 0.8425 | 0.2942 | 0.2942 |
| 2007 | 0.0137 | 0.2396 | 0.6503 | 0.6862 | 0.2396 | 0.2396 |
| 2008 | 0.0184 | 0.3230 | 0.8767 | 0.9249 | 0.3230 | 0.3230 |
| 2009 | 0.0250 | 0.4394 | 1.1926 | 1.2583 | 0.4394 | 0.4394 |
| 2010 | 0.0241 | 0.4234 | 1.1493 | 1.2125 | 0.4234 | 0.4234 |
| 2011 | 0.0159 | 0.2790 | 0.7574 | 0.7991 | 0.2790 | 0.2790 |

*Tab. 7.1..3. Mid year Stock Biomass and Spawning Stock Biomass (tons)*

| | MidYear SB | Mid Year |
|---|---|---|
| 2000 | 179452 | 142313 |
| 2001 | 189980 | 151968 |
| 2002 | 234577 | 185927 |
| 2003 | 246451 | 196408 |
| 2004 | 311572 | 246560 |
| 2005 | 436249 | 349399 |
| 2006 | 396179 | 323426 |
| 2007 | 281252 | 233686 |
| 2008 | 251750 | 203721 |
| 2009 | 220013 | 177946 |
| 2010 | 221918 | 179277 |
| 2011 | 333404 | 264565 |

The exploitation rate (F/(F+M)) is shown in figure 7.1.1.2.

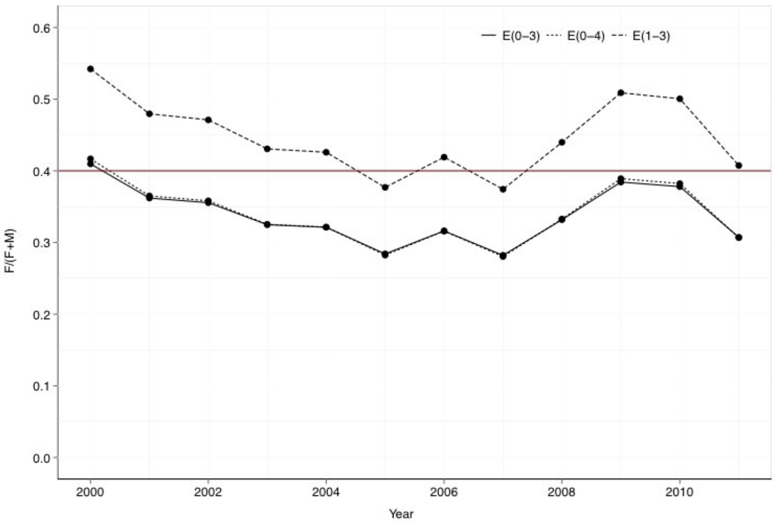


*Fig. 7.1.1.2. Exploitation rate (E = F/(F+M)) for age classes 0-3, 0-4 and 1-3 resulting from ICA analysis.*

In figure 7.1.1.3 the harvest rate, calculate as the ratio between the catches and the estimates from the ICA model, shows a drop in the last year. The harvest rate calculated on the acoustic biomass estimates shows instead a decrease from 2005 up to now. Both the time series are constantly below 0.2.

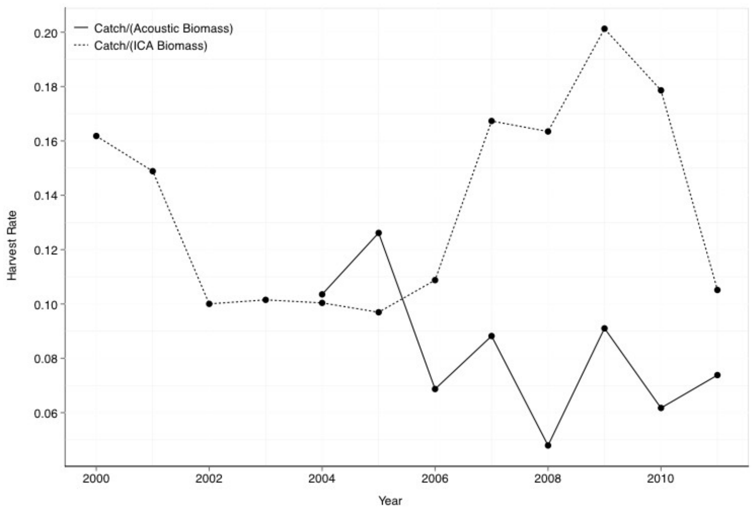


*Fig. 7.3.1.3. Harvest rate estimates (C/B) obtained from the mid year ICA biomass (dashed line) and the acoustic biomass (full line).*

The trend in biomass relatively to the proposed reference points is illustrated in figure 7.1.1.4.

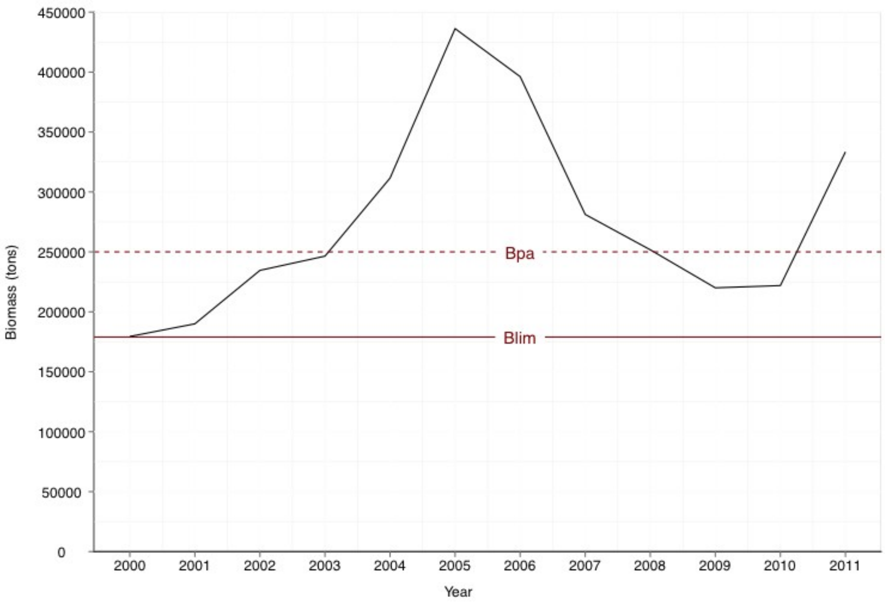


*Fig. 7.1.1.4. Mid year stock biomass from the ICA analysis with the relative reference points ($B_{lim}$ and $B_{pa}$).*

## 7.2 *Virtual Population Analysis*

VPA was carried out applying the Laurec-Shepherd tuning with the acoustic survey index. This tuning procedure derives estimates of fishing mortality at age in the final year from an analysis of the logarithms of fleet catchabilities.
The software used for the analysis is the Lowestoft VPA software (Darby and Flatman, Version 3.1).

### 7.2.1 Model assumptions

- Tuning method: Laurec-Shepherd
- Tuning index: Acoustic Survey
- Ages 0 to 4+
- Oldest age F = 1.600*average of 2 younger ages
- M vector estimated using Gislason's equation (Gislason *et al.*, 2010):

| Age0 | Age1 | Age2 | Age3 | Age4 | Age5 |
|---|---|---|---|---|---|
| 2.36 | 1.10 | 0.81 | 0.69 | 0.64 | 0.61 |

- Maturity at age:

| Age0 | Age1 | Age2 | Age3 | Age4 | Age5 |
|---|---|---|---|---|---|
| 0.75 | 1 | 1 | 1 | 1 | 1 |

- No shrinkage

## 7.2.2 Results

VPA estimations of mid year stock biomass, spawning stock biomass and trend in F by age are show in figures 7.2.2.1 and 7.2.2.2. The results are given in tables 7.2.2.1 and 7.2.2.2.

The biomass increases constantly up to a maximum in 2005 with about 450000 tons, then decreases until 2009 and then starts to increase again. The 2011 estimates is of 376500 tons.

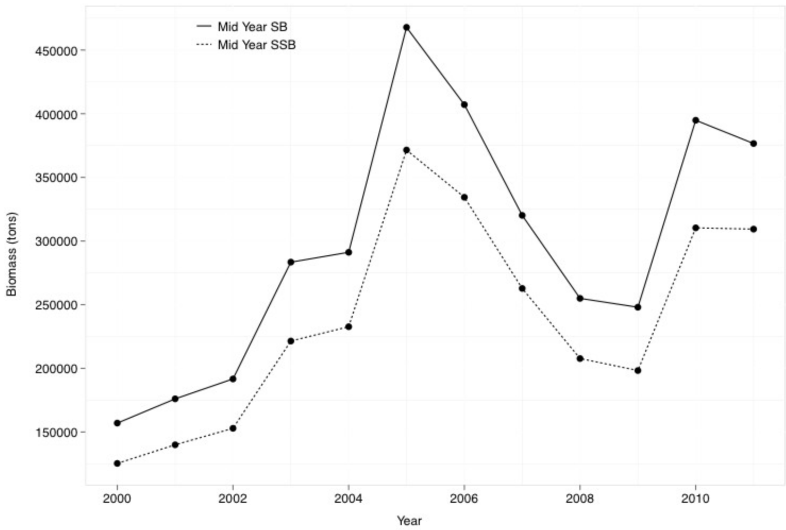


*Fig. 7..2.1. Mid year biomass (full line) and mid year SSB (dashed line) estimated by the means of the Laurec-Shepherd VPA.*

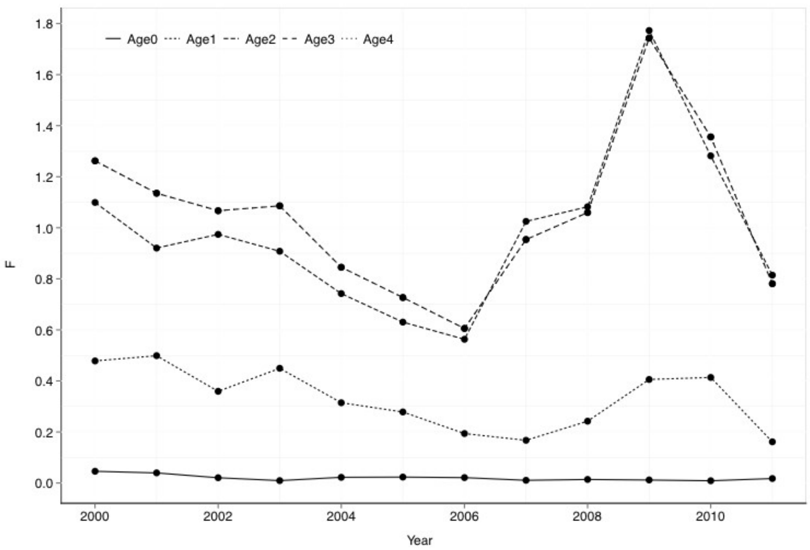


*Fig. 7.2.2.2. F by age estimated by the means of the Laurec-Shepherd VPA.*

*Tab. 7.2.2.1. Estimated numbers at age (in thousands).*

| | Age0 | Age1 | Age2 | Age3 | Age4 |
|---|---|---|---|---|---|
| 2000 | 46797100 | 3766500 | 849000 | 208000 | 16100 |
| 2001 | 50319700 | 4219900 | 777000 | 125800 | 6100 |
| 2002 | 56055300 | 4566800 | 853100 | 137700 | 12100 |

| | | | | | |
|---|---|---|---|---|---|
| 2003 | 99461900 | 5184700 | 1061400 | 143300 | 8400 |
| 2004 | 110057300 | 9302700 | 1101200 | 190400 | 17900 |
| 2005 | 143858300 | 10161600 | 2260700 | 233300 | 24700 |
| 2006 | 104769100 | 13271600 | 2560900 | 535500 | 245400 |
| 2007 | 85097600 | 9686100 | 3639400 | 648800 | 60500 |
| 2008 | 75709400 | 7949800 | 2727600 | 581000 | 79400 |
| 2009 | 91591500 | 7050100 | 2076900 | 411200 | 47200 |
| 2010 | 147736000 | 8546800 | 1563900 | 157000 | 27300 |
| 2011 | 104565900 | 13825200 | 1881200 | 193200 | 10300 |

*Tab. 7.2.2.2. Estimated F at age.*

| | Age0 | Age1 | Age2 | Age3 | Age4 |
|---|---|---|---|---|---|
| 2000 | 0.0460 | 0.4784 | 1.0993 | 1.2622 | 1.2622 |
| 2001 | 0.0396 | 0.4987 | 0.9206 | 1.1354 | 1.1354 |
| 2002 | 0.0206 | 0.3592 | 0.9742 | 1.0668 | 1.0668 |
| 2003 | 0.0095 | 0.4493 | 0.9079 | 1.0858 | 1.0858 |
| 2004 | 0.0224 | 0.3146 | 0.7420 | 0.8453 | 0.8453 |
| 2005 | 0.0232 | 0.2783 | 0.6303 | 0.7268 | 0.7268 |
| 2006 | 0.0211 | 0.1938 | 0.5631 | 0.6055 | 0.6055 |
| 2007 | 0.0107 | 0.1673 | 1.0249 | 0.9537 | 0.9537 |
| 2008 | 0.0139 | 0.2423 | 1.0821 | 1.0595 | 1.0595 |
| 2009 | 0.0118 | 0.4058 | 1.7725 | 1.7427 | 1.7427 |
| 2010 | 0.0089 | 0.4136 | 1.2814 | 1.3560 | 1.3560 |
| 2011 | 0.0175 | 0.1614 | 0.8144 | 0.7807 | 0.7807 |

## *7.3 Robustness analysis*

### 7.3.1 ICA

The diagnostic graph of the index SSQ against reference age F (age 1) from a separable VPA is plotted in figure 7.3.1.1. The curves should be U-shaped, with minima fairly close to each other on *x*-axis (Needle, 2000).

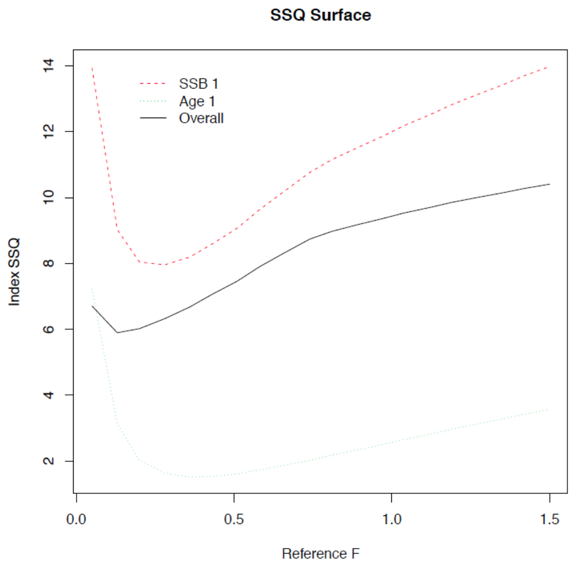


*Fig. 7.3.1.1. SSQ surface plot.*

The marginal totals of residuals between the catch and the separable model are overall small, as well as reasonably trend-free in the separable period (2000-2011) (see figure 7.3.1.2).

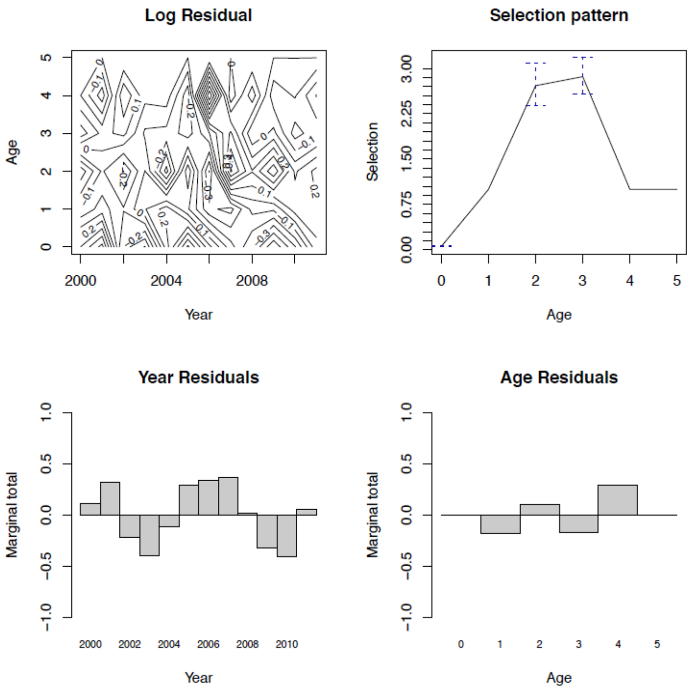


*Fig. 7.3.1.2. Diagnostics: log-residual contour plot (top-left); fitted selection pattern (top-right); year residuals for the catches (bottom-left); age residuals for the catches (bottom-right).*

The diagnostics tables for the final run are given below (tables 7.3.1.1 and 7.3.1.2).

*Tab. 7.3.1.1. Parameters estimates for the ICA run.*

| Separable model | | Maximum Likelh. Estimate | CV % | Lower 95% CL | Upper 95% CL | -s.e. | +s.e. | Mean of Param. Distrib. |
|---|---|---|---|---|---|---|---|---|
| 1 | 2000 | 0.51 | 16 | 0.3656 | 0.7116 | 0.4303 | 0.6045 | 0.5174 |
| 2 | 2001 | 0.3856 | 17 | 0.2744 | 0.5419 | 0.3241 | 0.4587 | 0.3914 |
| 3 | 2002 | 0.3714 | 17 | 0.2651 | 0.5202 | 0.3127 | 0.4411 | 0.3769 |
| 4 | 2003 | 0.3099 | 18 | 0.2171 | 0.4425 | 0.2584 | 0.3717 | 0.3151 |
| 5 | 2004 | 0.3034 | 18 | 0.2124 | 0.4335 | 0.2529 | 0.364 | 0.3085 |
| 6 | 2005 | 0.2425 | 18 | 0.1675 | 0.351 | 0.2008 | 0.2929 | 0.2468 |
| 7 | 2006 | 0.2942 | 18 | 0.2062 | 0.4196 | 0.2454 | 0.3526 | 0.299 |
| 8 | 2007 | 0.2396 | 18 | 0.1662 | 0.3454 | 0.1988 | 0.2887 | 0.2438 |
| 9 | 2008 | 0.323 | 17 | 0.2293 | 0.4548 | 0.2712 | 0.3846 | 0.3279 |
| 10 | 2009 | 0.4394 | 16 | 0.3156 | 0.6116 | 0.3711 | 0.5201 | 0.4457 |
| 11 | 2010 | 0.4234 | 22 | 0.2743 | 0.6536 | 0.3392 | 0.5284 | 0.4339 |
| 12 | 2011 | 0.279 | 35 | 0.1381 | 0.5637 | 0.1949 | 0.3995 | 0.2976 |
| Separable Model: Selection (S) by age | | | | | | | | |
| 13 | 0 | 0.057 | 15 | 0.0425 | 0.0765 | 0.049 | 0.0662 | 0.0576 |
| | 1 | 1 | Fixed: | Reference Age | | | | |
| 14 | 2 | 2.7145 | 12 | 2.1097 | 3.4927 | 2.3869 | 3.087 | 2.737 |
| 15 | 3 | 2.8639 | 10 | 2.3352 | 3.5124 | 2.5807 | 3.1782 | 2.8795 |
| | 4 | 1 | Fixed: | Last true Age | | | | |
| Separable model: Populations in year | | | | | | | | |
| 16 | 0 | 106982991 | 41 | 4766451 | 24012331 | 7082263 | 16160596 | 11648288 |
| 17 | 1 | 6924237 | 30 | 3841537 | 12480697 | 5126579 | 9352254 | 7244227 |
| 18 | 2 | 1566979 | 26 | 940359 | 2611157 | 1207579 | 2033345 | 1621073 |
| 19 | 3 | 216237 | 31 | 116826 | 400240 | 157946 | 296042 | 227174 |
| 20 | 4 | 31938 | 37 | 15388 | 66287 | 22004 | 46356 | 34233 |

Separable model: Populations

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 21 | 2000 | 30019 | 36 | 14607 | 61689 | 20787 | 43350 | 32116 |
| 22 | 2001 | 17327 | 30 | 9607 | 31250 | 12824 | 23410 | 18129 |
| 23 | 2002 | 19820 | 26 | 11731 | 33489 | 15167 | 25902 | 20543 |
| 24 | 2003 | 20988 | 26 | 12427 | 35448 | 16064 | 27422 | 21752 |
| 25 | 2004 | 37873 | 25 | 22960 | 62472 | 29338 | 48891 | 39128 |
| 26 | 2005 | 44990 | 25 | 27299 | 74146 | 34868 | 58052 | 46476 |
| 27 | 2006 | 77579 | 24 | 47960 | 125488 | 60699 | 99152 | 79949 |
| 28 | 2007 | 91496 | 25 | 56000 | 149493 | 71223 | 117541 | 94412 |
| 29 | 2008 | 149561 | 23 | 93615 | 238942 | 117762 | 189947 | 153896 |
| 30 | 2009 | 137645 | 24 | 85199 | 222375 | 107764 | 175812 | 141830 |
| 31 | 2010 | 67102 | 27 | 39155 | 114996 | 50977 | 88328 | 69685 |

Medits

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 32 | 1Q | 2.36E-04 | 20 | 1.93E-04 | 4.40E-04 | 2.36E-04 | 3.60E-04 | 2.98E-04 |

Age-structured index catchabilities (Acoustic
Linear model fitted. Slopes at age :

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 32 | 1Q | 9.84E-04 | 31 | 7.26E-04 | 2.52E-03 | 9.84E-04 | 1.86E-03 | 1.42E-03 |
| 33 | 2Q | 7.54E-03 | 30 | 5.60E-03 | 1.88E-02 | 7.54E-03 | 1.40E-02 | 1.08E-02 |
| 34 | 3Q | 1.16E-02 | 31 | 8.61E-03 | 2.94E-02 | 1.16E-02 | 2.18E-02 | 1.67E-02 |
| 35 | 4Q | 3.94E-03 | 33 | 2.87E-03 | 1.05E-02 | 3.94E-03 | 7.66E-03 | 5.81E-03 |
| 36 | 5Q | 2.60E-04 | 34 | 1.87E-04 | 7.22E-04 | 2.60E-04 | 5.18E-04 | 3.90E-04 |

*Tab. 7.3.1.2. Distribution statistics for the parameters.*

PARAMETERS OF THE DISTRIBUTION OF ln(CATCHES AT AGE)
Separable model fitted from 2000 to 2011

| | |
|---|---|
| Variance | 0.1592 |
| Skewness test stat. | 1.4958 |
| Kurtosis test statistic | 0.2223 |
| Partial chi-square | 0.3813 |
| Significance in fit | 0 |
| Degrees of freedom | 29 |

PARAMETERS OF DISTRIBUTIONS OF THE SSB INDICES (Medits)
Linear catchability relationship
Last age is a plus-

| | |
|---|---|
| Variance | 0.039 |
| Skewness test stat. | 0.6551 |
| Kurtosis test statistic | -0.5216 |
| Partial chi-square | 0.1002 |
| Significance in fit | 0 |
| Number of | 11 |
| Degrees of freedom | 10 |
| Weight in the analysis | 0.3 |

PARAMETERS OF THE DISTRIBUTION OF THE AGE-STRUCTURED INDICES
Acoustic Survey
Linear catchability relationship

| Age | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Variance | 0.1311 | 0.0938 | 0.062 | 0.0613 | 0.1618 |
| Skewness test stat. | -0.9472 | -0.3466 | 0.079 | -0.1107 | 0.8822 |
| Kurtosis test statisti | -0.28 | -0.8077 | 0.0215 | -0.6811 | -0.4493 |
| Partial chi-square | 0.0745 | 0.0532 | 0.0398 | 0.0553 | 0.3332 |
| Significance in fit | 0 | 0 | 0 | 0 | 0.0007 |
| Number of | 7 | 7 | 7 | 7 | 7 |
| Degrees of freedom | 6 | 6 | 6 | 6 | 6 |
| Weight in the analysis | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |

The restrospective analysis (figure 7.3.1.3) doesn't show any particular trend for the biomass estimations, while it shows some degree of variation on the absolute levels of F in the last 2 years. Future investigations will aim to solve this problem.

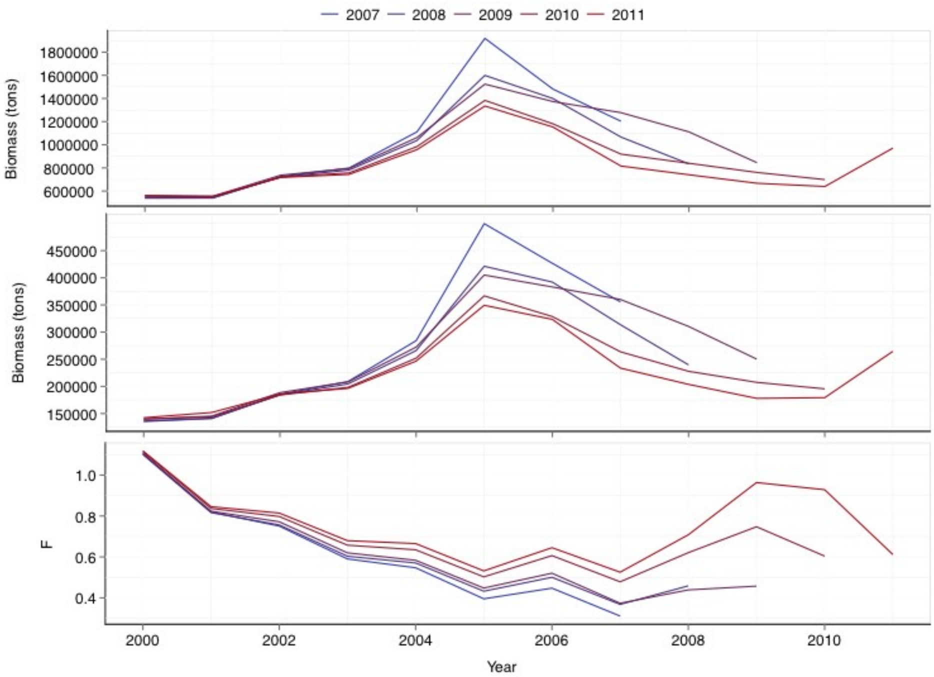


*Fig. 7..1.3. ICA Retrospective analysis for respectively total stock biomass at the beginning of the year (on top), mid year SSB (in the middle) and F (at the bottom).*

The fitting of the model estimates with the acoustic surveys is shown in figure 7.3.1.4. The predicted numbers at age fit quite well the observed data, except for some disagreement in the first ages, which can be expected.

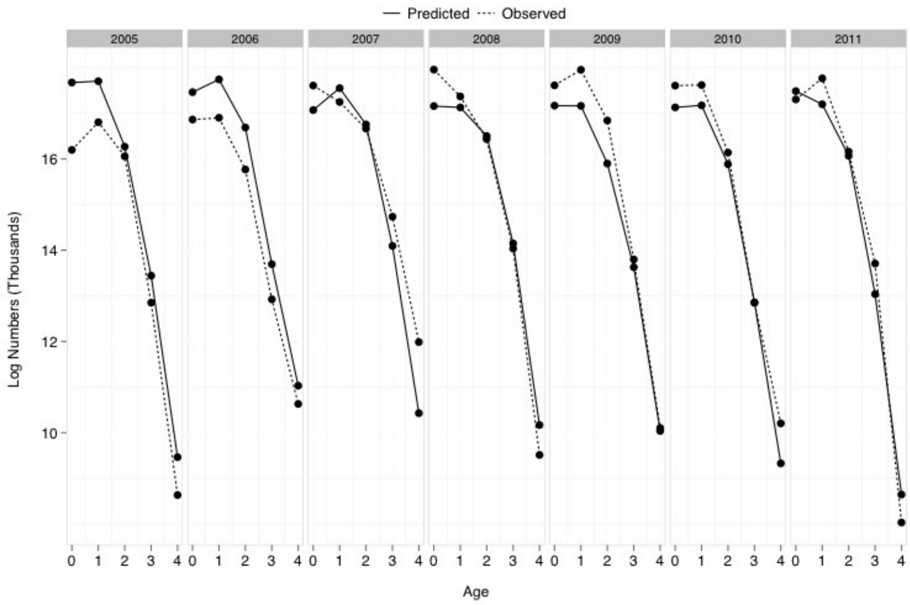


*Fig. 7.3.1.4. Predicted VS observed log numbers at age for the acoustic survey.*

### 7.3.2 VPA

The summary statistic for the VPA run is shown in table 7.3.2.1.

*Tab. 7.3.2.1. Summary statistic by age for the Laurec-Shepherd VPA.*

SUMMARY STATISTIC FOR AGE 0

| Fleet | Pred. Log q | se (log q) | Partial F | Raied F | Slope | se Slope | Intercept | se |
|---|---|---|---|---|---|---|---|---|
| 1 | -7.110 | 0.830 | 0.820 | 0.018 | 0.178 | 0.139 | -7.106 | 0.293 |

| Fbar | Sigma(int.) | Sigma(ext. | Sigma(over | Variance ratio |
|---|---|---|---|---|
| 0.017 | 0.830 | 0 | 0.830 | 0 |

SUMMARY STATISTIC FOR AGE 1

| Fleet | Pred. Log q | se (log q) | Partial F | Raied F | Slope | se Slope | Intercept | se |
|---|---|---|---|---|---|---|---|---|
| 1 | -5.020 | 0.646 | 6.616 | 0.162 | 0.194 | 0.090 | -5.018 | 0.228 |

| Fbar | Sigma(int.) | Sigma(ext. | Sigma(over | Variance ratio |
|---|---|---|---|---|
| 0.161 | 0.646 | 0 | 0.646 | 0 |

SUMMARY STATISTIC FOR AGE 2

| Fleet | Pred. Log q | se (log q) | Partial F | Raied F | Slope | se Slope | Intercept | se |
|---|---|---|---|---|---|---|---|---|
| 1 | -4.490 | 0.568 | ****** | 0.8144 | 0.153 | 0.086 | -4.49 | 0.201 |

| Fbar | Sigma(int.) | Sigma(ext. | Sigma(over | Variance ratio |
|---|---|---|---|---|
| 0.814 | 0.568 | 0 | 0.568 | 0 |

The restrospective analysis (figure 7.3.2.1) shows high variability of the estimates for all the parameters.

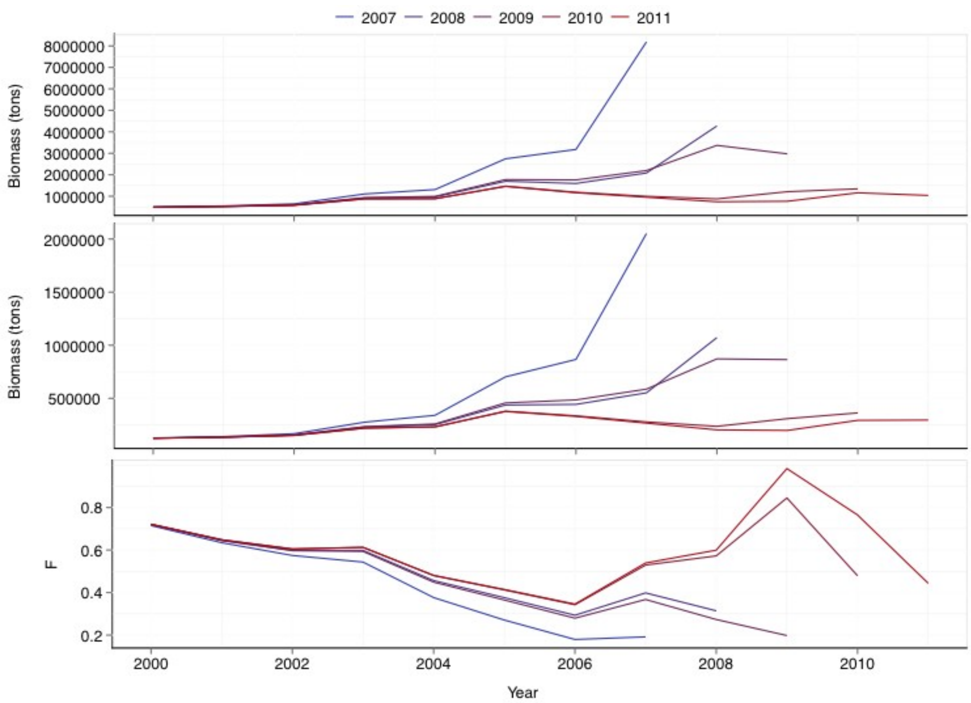


*Fig. 7.3.2.1. VPA Retrospective analysis for respectively total stock biomass at the beginning of the year (on top), mid year SSB (in the middle) and F (at the bottom).*

The residuals for ln(q) shows a clear trend throughout the years (see figure 7.3.2.2) that was not possible to reduce.

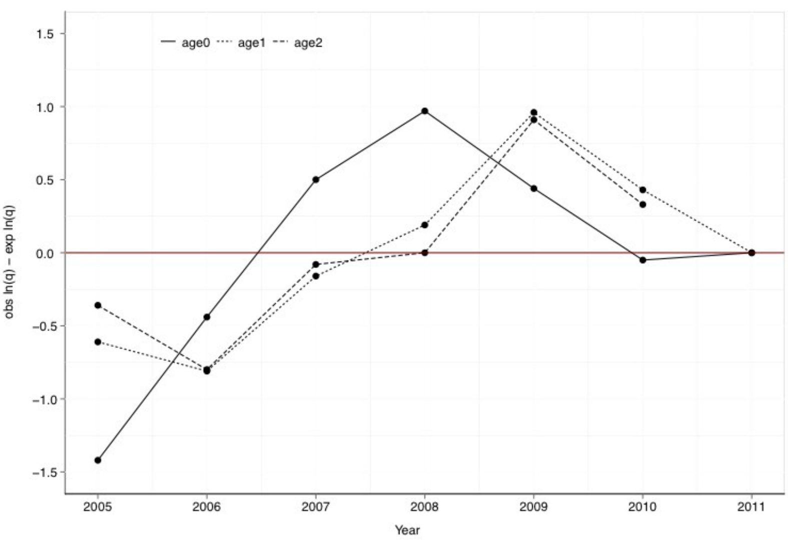


*Fig. 7.3.2.2. Observed log(q) – Expexted log(q) by age estimated by VPA analysis.*

## *7.4 Assessment quality*

The separable VPA performed well with the data available, reducing the retrospective pattern and improving the estimates of parameters, respect to the Laurec-Shepherd VPA.

The comparison between the resulting biomasses from the two models is shown in figure 7.4.1.

*Fig. 7.4.1. Mid year Stock Biomass from VPA (dashed line) and ICA (full line); split-year acoustic biomass estimates are shown as well in the form of background bars.*

An ICA run was performed without the bottom trawl survey to test how much the inclusion of this index influences the model results. Despite a slight increase in the SSQ minimization, the CVs of the parameters estimations got worst. Besides, the resulting trend in biomass and F are almost identical, which was expected due to the really low weight gave to the index in the model.

ICA with absolute catchability model for the acoustic survey was attempted, but there was no way to stabilize the results: the SSQ and the CVs were really high, the residuals showed clear trends in ages and years with high values and the fitting with the acoustic survey got much worst.

In the present assessment there is improved coherence between the biomass estimated from the model and the survey data respect to last year assessment, although absolute values from the survey remain about double the estimates from the assessment models.

# 8 Stock predictions

N/A

## *8.1 Short term predictions*

## *8.2 Medium term predictions*

## *8.3 Long term predictions*

# 9 Draft scientific advice

This year we will use the already approve reference point for F (Patterson) and another set of reference points for biomass.

The assessment shows an increase in the biomass trend starting in 2009 and the exploitation rate is around the reference point of E = 0.4 from Patterson ($E_{(1-3)}$ = 0.41). The 2011 total biomass (333404 tons) is above of both the proposed $B_{lim}$ (179000 tons) and $B_{pa}$ (250600 tons) reference points. The recruitment is increasing in the last year, and on the average it's quite stable, with little fluctuations compared to other small pelagic stocks.

The acoustic surveys show some fluctuations with no particular trend. The 2011 value is about 475000 tons.

It should be noted that Adriatic small pelagic fishery is multispecies and effort on anchovy cannot be separated from effort on sardine, so that most of the management decision have to be taken considering both species.

On the overall, the suggestion is not to increase the fishing mortality.

*Table : Bidimensional stock advice summary; Exploitation rate and Stock Abundance.*

| Exploitation rate | | Stock Abundance | |
|---|---|---|---|
| [STATE THE PERIOD] | | [STATE THE PERIOD] | |
| | No fishing mortality | | Virgin |
| | Low fishing mortality | | High abundance |
| X | Sustainable Fishing Mortality | X | Intermediate abundance |
| | High fishing mortality | | Low abundance |
| | Uncertain/Not assessed | | Depleted |
| | | | Uncertain / Not assessed |

*Table : Stock advice summary; Historical trends in biomass and recruitment.*

| Biomass trends | | Recruitment trends | |
|---|---|---|---|
| [2000-2011] | | [2000-2011] | |
| [179452 tons – 436249 tons] | | [52578000 - 129050000 thousands] | |
| X | Stable | X | Stable |
| | Increasing | | Increasing |
| | Decreasing | | Decreasing |

Add figures for SSB, Recruitment and $F_{bar}$

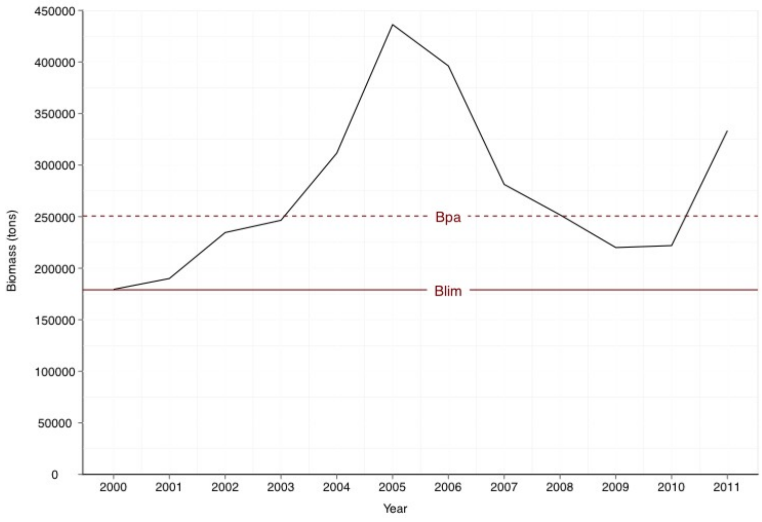


*Fig. 9.1. Mid year stock biomass and proposed reference points.*

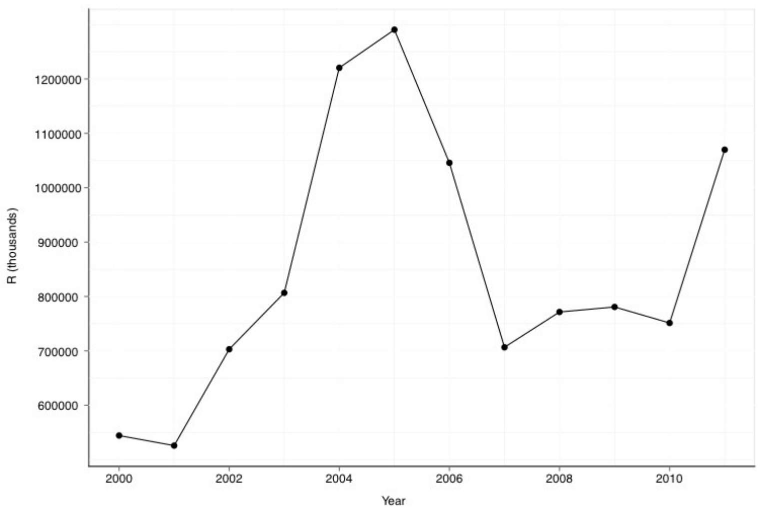


*Fig. 9.2. Recruitment estimates (in thousands).*

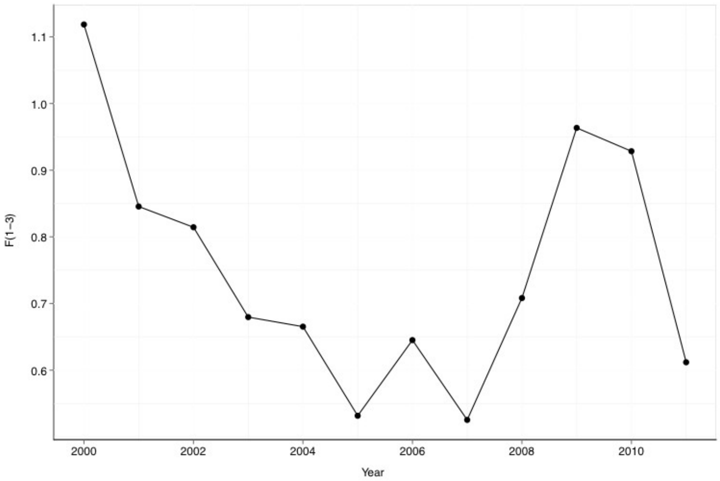


*Fig. 9.3. $F_{bar(1-3)}$ estimates.*

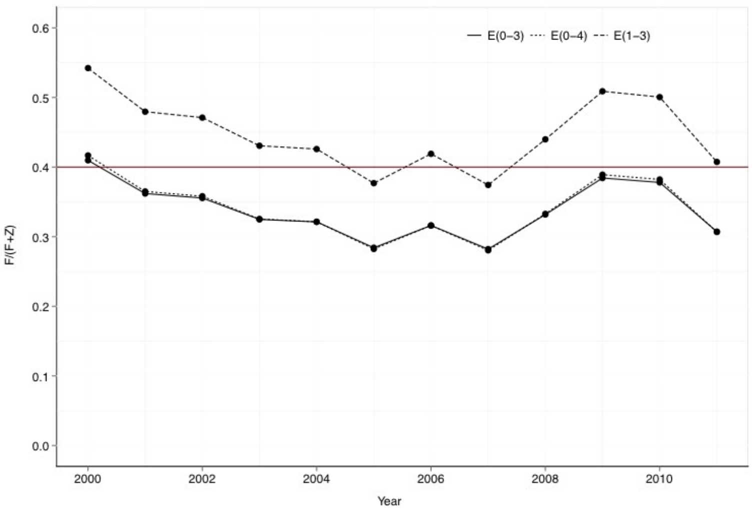


*Fig. 9.4. Exploitation rate (F/Z).*

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