



Stock Assessment Form

Demersal species

Reference year:2012

Reporting year:2014

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% of catches come from the Italian side. Landings fluctuated between 1,000 and 2,300 t in the period 1996-2012.

XSA and Statistical Catch at Age assessments 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 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 2012 the fishing mortality appears much higher than $F_{0.1}$ (proxy of F_{MSY}) 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. 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 1.0 (January 2014)

Uploader: *Giuseppe Scarcella*

Stock assessment form

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1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
<i>Solea solea</i>	Common sole	31
1st Geographical sub-area:	2nd Geographical sub-area:	3rd Geographical sub-area:
17		
4th Geographical sub-area:	5th Geographical sub-area:	6th Geographical sub-area:
1st Country	2nd Country	3rd Country
Italy	Croatia	Slovenia
4th Country	5th Country	6th Country
Stock assessment method: (direct, indirect, combined, none)		
Indirect: XSA - SCAA		
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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 started in 2011, confirmed the previous evidences about the genetic differentiation between the stocks in GSA 17 and GSA 18. 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-Tyrrhenian 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-frequency distributions obtained from surveys.

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

Somatic magnitude measured (LT, LC, etc)				Units	
Sex	Fem	Mal	Combined	Reproduction season	Fall – Winter
Maximum size observed	40	38		Recruitment season	Fall
Size at first maturity			25.8	Spawning area	*
Recruitment size to the fishery			18-20	Nursery area	**

* 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: M vector and proportion of matures by size or age (Males+Females)

Age	Natural mortality	Proportion of matures
0	0.7	0
1	0.35	0.16
2	0.28	0.76
3	0.25	0.96
4	0.23	0.99
5+	0.22	1

Table 2-3: Growth and length weight model parameters

		Sex				
		Units	female	male	Combined	Years
Growth model	L_{∞}				39.6	
	K				0.4	
	t_0				-0.46	
	Data source	SoleMon project				
Length weight relationship	a				0.007	
	b				3.0638	
	M (scalar)					
	sex ratio (% females/total)	53				

3 Fisheries information

3.1 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 species for 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 3-1: Description of operational units exploiting 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 (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 3.1-2: Catch, bycatch, discards and effort by operational unit in the reference year

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

Spatial distribution of rapido trawl fishing effort

Figure 1 shows the fall rapido-trawl effort of Italian vessels over the years 2006–2011 in GSA 17. The first zone of effort concentration is inshore between 3 and 9 nautical miles from the Italian coast, between 43° and 44° latitude, and is mainly exploited by vessels belonging to Ancona and Rimini Harbours. The second zone is between Po river mouth and Venice lagoon and is concentrated at the same distance from the coast as the first region. This region is mainly exploited by the Chioggia rapido trawl fleet. The third area of effort concentration is offshore, near Istria peninsula and is exploited by both Chioggia and Rimini rapido trawl fleets. As expected, the area is characterised by a low abundance of sole, as suggested by survey data in Grati et al. (2013), and has a relatively low fishing effort. The area southward of this last region is not exploited by rapido trawlers mainly due to the high concentrations of debris and benthic communities that are dominated by holothurians (Despalatović et al., 2009). The data presented in the Figure 6.12.2.4.2 are quite important in order to explain the population selectivity curves used in the SS3 model in order to carry out the Statistical Catch at Age analysis (see discussion below).

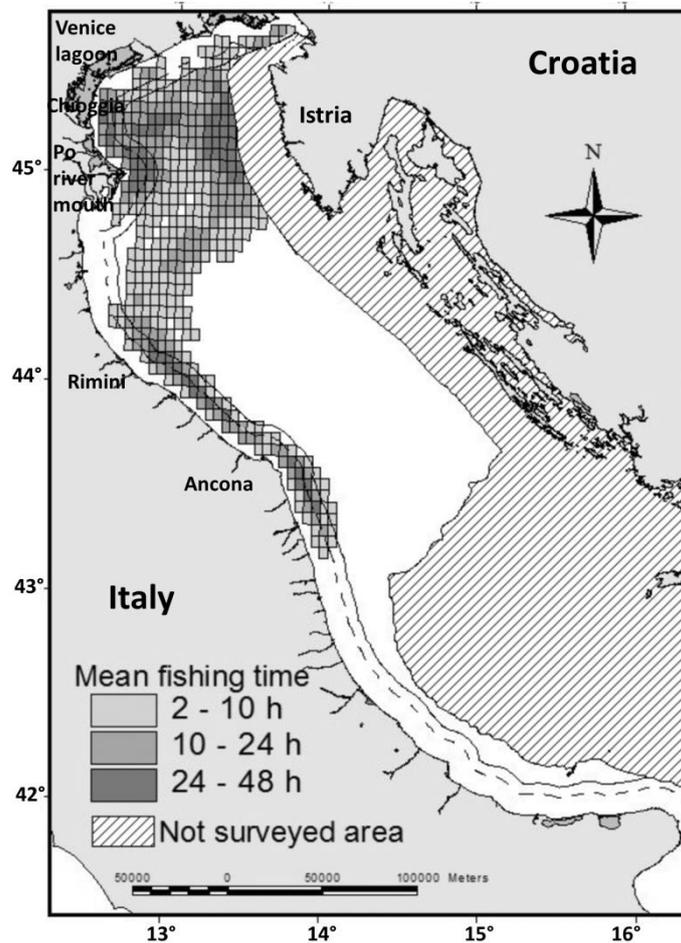


Figure 1 – Spatial distribution of Italian rapido trawl fishing effort

3.2 Historical trends

Common sole landings estimated in respectively from the FishStat – GFCM database and in the framework of Italian and Slovenia Official Data Collection submitted in the data call 2013 are showed in figure 2, together with Croatian data provided in the Croatian Primo Project.

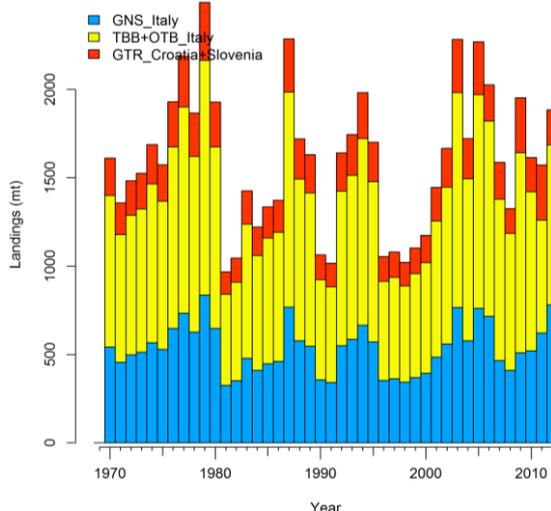


Figure 2 – Landings of common sole in GSA 17

3.3 Management regulations

Italy and Slovenia :

- In Italy and Slovenia the main rules in force are based on the applicable EU regulations (mainly EC regulation 1967/206):
- Minimum landing sizes: 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 have been 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.
- Set net minimum mesh size: 16 mm stretched.
- Set net maximum length x vessel x day: 5,000 m

Croatia

Since the accession of Croatia to the EU the 1st of July 2013, the same regulations of Italy and Slovenia are implemented. Furthermore the following regulation are applied:

- Beam trawl ("*rapido*"), according to the Fishing acts (Narodne novine, 148/2010, 25/2011), is gear for catching only shellfish, 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 wide up to 4 meters.
- 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 only one fisherman present on the vessel, the maximum allowed length is 4,000 m; for each additional fisherman an extra 1,000 m of net is allowed, up to 6000 m of total length per vessel. Maximum height of the nets is 4 m. Trammel nets can only be used only in the period from 10 September to 15 January.

3.4 Reference points

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

Indicator	Limit Reference point/empirical reference value	Value	Target Reference point/empirical reference value	Value	Comments
B					
SSB					
F			F0.1	0.31	Different from the previous year (F0.1= 0.26) because the input data used for the Y/R are coming from SCAA
Y					
CPUE					
Index of Biomass at sea					

4 Fisheries independent information

4.1 SoleMon

Ten *rapido* trawl fishing surveys were carried out in GSA 17 from 2005 to 2012: 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. 4.1.1).

Tab. 4.1.1 Number of hauls per year and depth stratum in GSA 17, 2005-2012

Depth strata	Spring 2005	Fall 2005	Spring 2006	Fall 2006	Fall 2007	Fall 2008-2012
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, spawning females and juveniles. 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:

$$Y_{st} = \sum (Y_i * A_i) / A$$

$$V(Y_{st}) = \sum (A_i^2 * s_i^2 / n_i) / A^2$$

Where:

A=total survey area

A_i=area of the i-th stratum

s_i=standard deviation of the i-th stratum

n_i=number of valid hauls of the i-th stratum

n=number of hauls in the GSA

Y_i=mean of the i-th stratum

Y_{st}=stratified mean abundance

V(Y_{st})=variance of the stratified mean

The variation of the stratified mean is then expressed as the 95 % confidence interval: Confidence interval = $Y_{st} \pm t(\text{student distribution}) * V(Y_{st}) / n$

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 4.1-1: Trawl survey basic information

Survey	SoleMon	Trawler/RV	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 4.1-2: Trawl survey sampling area and number of hauls

Stratum	Total surface (km²)	Trawlable surface (km²)	Swept area (km²)	Number of hauls
1	11512		1.32	39
2	8410		0.55	17
3	22466		0.41	11

Map of hauls positions

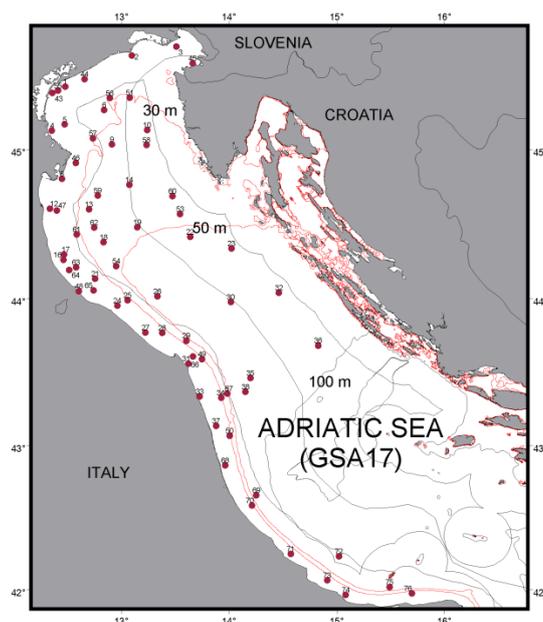


Table 4.1-3: Trawl survey abundance and biomass results

Stratum	Years	kg per km ²	CV	Relative * biomass All age groups	CV or other	N per km ²	CV	Relative * abundance 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		
	2012	42.85	12.77			438.01	17.02		

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

Slicing method

LFDA 5.0

Maturity at Age						
PERIOD	0	1	2	3	4	5+
2006-2012	0	0.16	0.76	0.96	0.99	1.00

Table 4.1-4: Trawl surveys; recruitment analysis summary

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

Table 4.1-5: Trawl surveys; recruitment analysis results

Years	Area in km²	N of recruit per km²	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
2012		199.23	28.12

The recruitment is mainly localised in the coastal close to Po river mouth. The recruits have been estimated on the base of the LFD observed from the survey (Fig. 3)

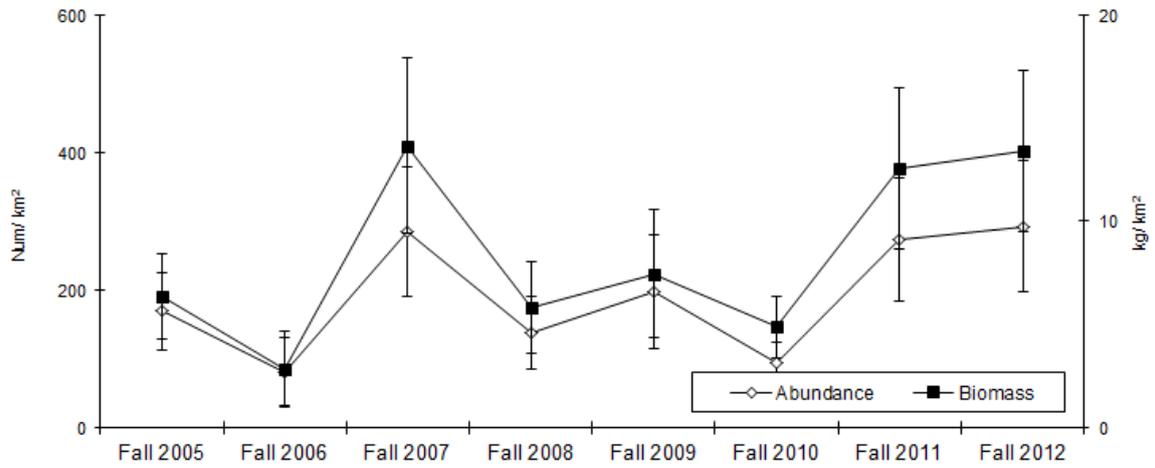


Figure 3 - Abundance and biomass indices of sole recruits obtained from SoleMon surveys.

Direct methods: trawl based Spawner analysis

Table 4.1-6: Trawl surveys; spawners analysis summary

Survey	SoleMon	Trawler/RV	Dallaporta
Survey season			Fall
Investigated depth range (m)			0-120
Spawning season and peak (months)			November-December

Table 4.1-7: Trawl surveys; spawners analysis results

Surveys	Area in km ²	N (N of individuals of spawners per km ²)	CV	SSB per km ²	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		
2012		103.64	13.15	20.18	13.3		

The spawners aggregates in the north sector of the sub-basin mainly in front of the Istria peninsula, the trend of spawners biomass and biomass are showed in figure 4.

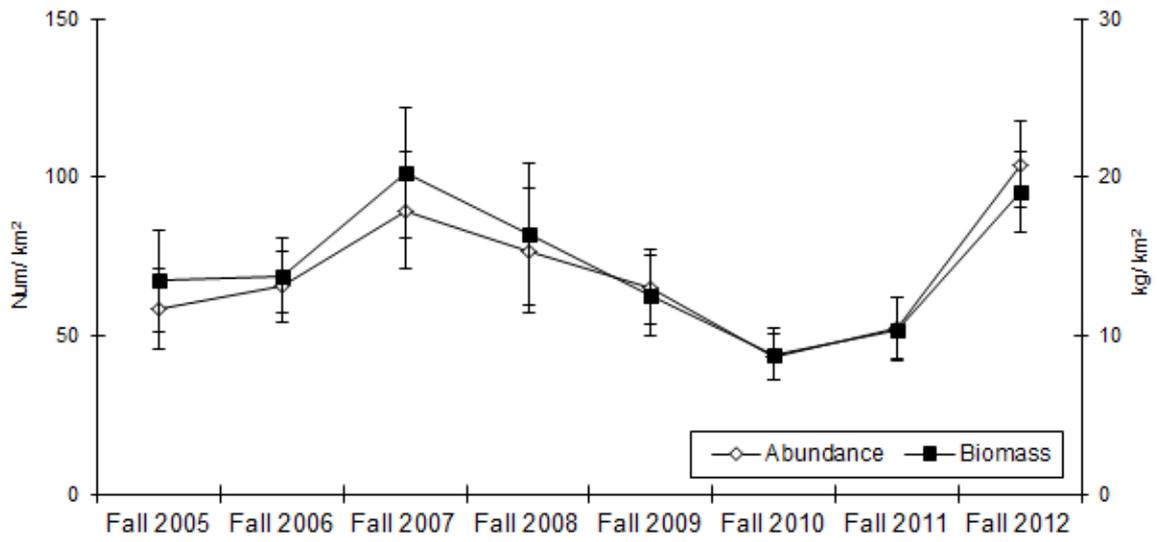


Figure 4 - Abundance and biomass indices of sole adults obtained from SoleMon surveys.

4.1.1 Spatial distribution of the resources

According to data collected during SoleMon surveys (Scarcella *et al.*, submitted), age class 0+ aggregates inshore along the Italian coast, mostly in the area close to the Po river mouth (Fig. 5). Age class 1+ gradually migrates off-shore and adults concentrate in the deepest waters located at South West from Istria peninsula (Fig. 5).

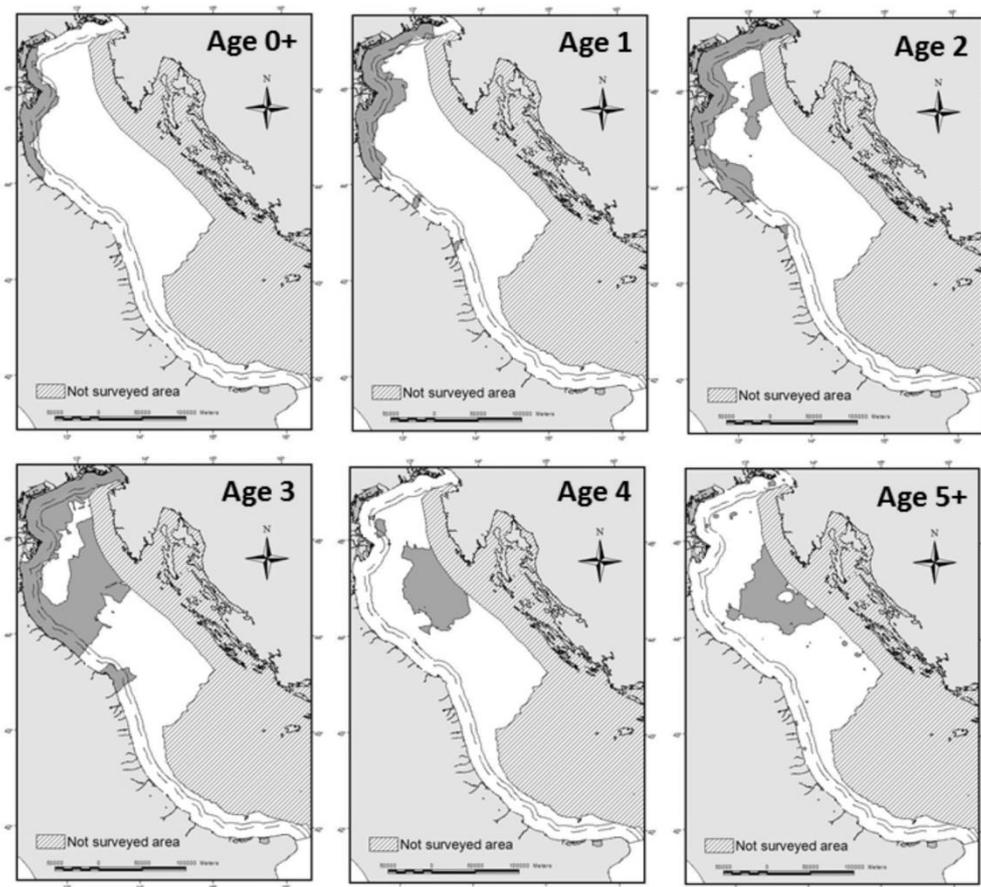


Figure 5 - Maps of hotspots calculated for the age classes of soles. The 6 and 9 nautical miles from the Italian coast are shown respectively by broken and continuous black lines (Scarcella *et al.*, submitted).

4.1.2 Historical trends

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

Figure 6 shows the abundance and biomass indices of sole obtained from 2005 to 2012; slightly increasing trends occurred till fall 2007, followed by a decrease in fall 2008-2009, and an increase in 2010-2012.

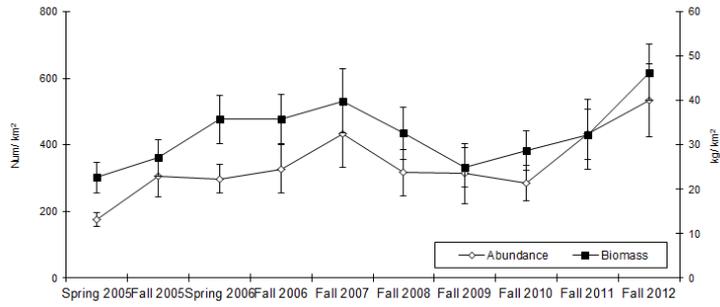
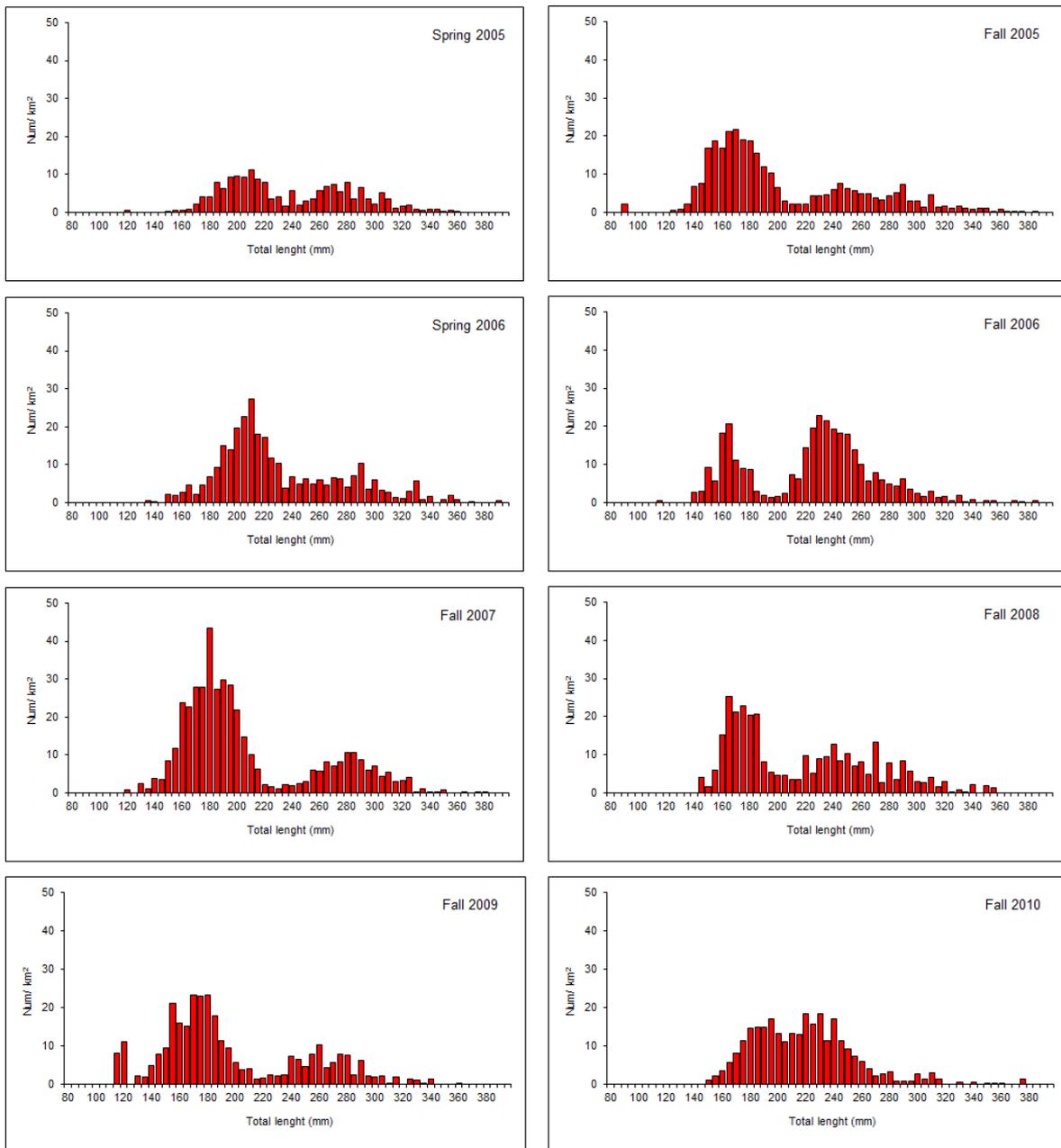


Figure 6- Abundance and biomass indices of sole obtained from SoleMon surveys.

Fig7 displays the stratified abundance indices obtained in the GSA 17 in the years 2005-2012.



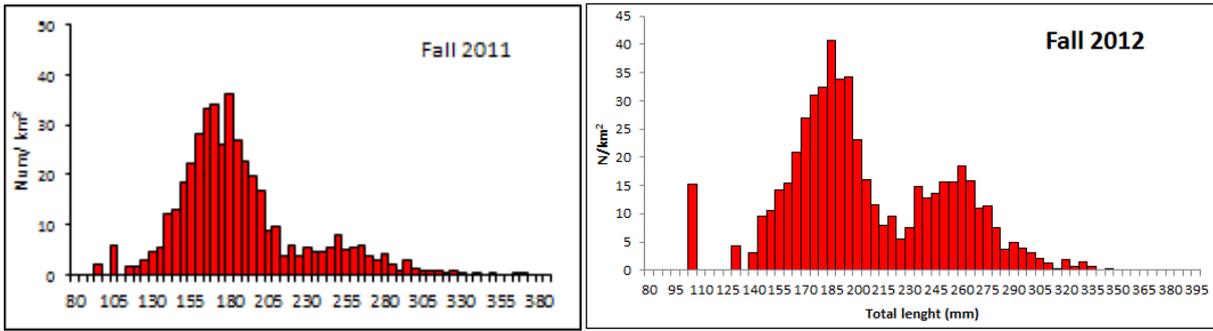


Figure 7 - Stratified abundance indices by size, 2005-2012.

5 Ecological information

5.1 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 rapido trawl fishery from Central Western Adriatic Sea

Taxa	Stratum 0-30 (kg km ⁻²)	Stratum 30-60 (kg km ⁻²)
Annelida		
<i>Aphrodite aculeata</i>	0.096	4.706
<i>Glycera</i> spp	0.001	0.006
Polychaeta	0.248	0.027
Cnidaria		
<i>Alcyonum</i> spp		0.112
<i>Calliactis parasitica</i>	0.002	0.033
Unidentified anemone	0.019	0.600
Unidentified colonial hydroid		0.065
<i>Virgularia mirabilis</i>	0.018	3.405
Crustacea		
<i>Alpheus glaber</i>	0.002	0.001
<i>Corystes cassivelaunus</i>	0.023	
<i>Goneplax rhomboides</i>	10.385	16.042
<i>Inachus comunissimus</i>	0.030	
<i>Inachus phalangium</i>	1.979	0.004
<i>Inachus</i> spp	0.531	0.002
<i>Liocarcinus depurator</i>	8.292	178.664
<i>Liocarcinus vernalis</i>	9.168	0.609
<i>Lysmata seticaudata</i>		0.019
<i>Medorippe lanata</i>	4.375	2.979
<i>Melicertus kerathurus</i>	0.208	0.213
<i>Nephrops norvegicus</i>	0.006	0.044
<i>Pagurus excavatus</i>	0.019	0.045
<i>Pagurus</i> spp	0.364	0.299
<i>Parapenaeus longirostris</i>		0.154
<i>Parthenope angulifrons</i>	0.755	
<i>Pilumnus hirtellus</i>	0.033	
<i>Squilla mantis</i>	5.197	0.397
Echinodermata		
<i>Astropecten irregularis</i>	28.562	8.210
Holothuroidea	0.135	1.771
<i>Marthasterias glacialis</i>	0.174	4.511
Ophiura ophiura	2.592	
Schizaster canaliferus	0.413	0.020
Spatangoida	0.033	
<i>Trachythyone elongata</i>	0.238	2.194
<i>Trachythyone</i> spp	0.022	0.368
<i>Trachythyone tergestina</i>	0.125	3.270
Mollusca		
<i>Acanthocardia paucicostata</i>	0.238	0.072
<i>Acanthocardia tuberculata</i>	0.307	0.146
<i>Aequipecten opercularis</i>	0.136	
<i>Alloteuthis media</i>	0.025	0.003
<i>Antalis dentalis</i>	0.047	
<i>Antalis inaequicostata</i>	0.639	0.001
<i>Antalis</i> spp	0.168	
<i>Aporrhais pespelecani</i>	299.666	6.160
<i>Atrina pectinata</i>	0.190	0.909
<i>Bolinus brandaris</i>	11.135	0.625
<i>Calliostoma</i> spp	0.008	0.310
<i>Cassidaria echinophora</i>		0.784
<i>Chamelea gallina</i>	0.183	
<i>Chlamys varia</i>	0.082	0.004
<i>Corbula gibba</i>	43.145	0.030

<i>Flexopecten glaber glaber</i>	1.389	0.007
<i>Glossus humanus</i>		0.710
Hexaplex trunculus	0.712	0.089
<i>Illex coindetii</i>	0.012	0.004
Mytilus galloprovincialis	2.774	0.907
<i>Nassarius lima</i>	0.068	0.010
Nassarius mutabilis	0.577	0.002
<i>Nassarius reticulatus</i>	0.748	0.001
<i>Naticarius hebraea</i>	0.025	
Naticarius stercusmuscarum	2.219	
<i>Neverita josephina</i>	0.030	
<i>Nucula nitidosa</i>	0.002	0.004
<i>Nucula nucleus</i>	0.006	0.021
<i>Nucula sulcata</i>	0.003	0.203
Ostrea edulis	94.311	3.043
Pectinidae	0.112	0.060
<i>Polinices nitida</i>	0.001	
<i>Scapharca demiri</i>	30.051	0.009
<i>Scapharca inaequalis</i>	137.864	0.290
Scaphodopa	0.077	
Sepia elegans	0.026	0.122
Sepia officinalis	0.465	0.367
<i>Solecurtus strigilatus</i>	0.217	
<i>Turritella communis</i>	0.808	2.758
Unidentified nudibrans	0.553	
<i>Venerupis aurea</i>	2.552	
Osteichthyes		
Arnoglossus laterna	0.820	1.101
<i>Blennius ocellaris</i>		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
<i>Lesueurigobius friesii</i>	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
Sardinella aurita	1.081	0.635
Scorpaena notata	0.005	0.239
<i>Serranus hepatus</i>	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		
Ascidacea		0.189

^a Commercially harvested groups are indicated in bold face.

6 Stock Assessment

6.1 XSA

6.1.1 Model assumptions

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

6.1.2 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####qage catchability =6 means that q is constant from age 6 , rage=1 q
independent 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=1,
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)
```

6.1.3 Input data and Parameters

Catch at age data series of the period 2006-2012 were provided by official statistics from the 2013 DCF data call (Fig. 8). Italian GNS and OTB catch at age data were missing from official statistics in 2008 and 2009,

and have thus been reconstructed on the basis of the mean catch composition available and landings provided by the DCF in 2013 (Fig. 8).

Croatian catch at age data were reconstructed in 2006-2012 on the base of the total landings suggested by Croatian colleagues and catch at age data composition observed for set netters (mainly using trammel nets).

The total catch numbers at age were rescaled based on the SOP correction observed between the reconstructed total catch and the total catch provided by 2013 Italian and Slovenia DCF official statistics and Croatian colleagues. The following analyses are carried out using rescaled catch numbers at age.

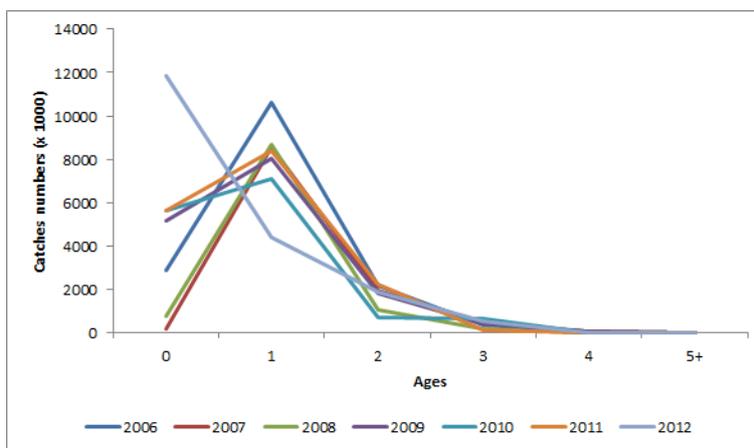


Figure 8 - Catch at age data used in the VPA and XSA runs.

Maturity at age, Length-Weight relationships, growth parameters were provided in the framework of SoleMon project.

Tuning data were provided by SoleMon surveys, carried out in fall for the years 2006-2012.

A vector of natural mortality rate at age was estimated using the PRODBIOM spreadsheet (Abella et al., 1997).

Input data and parameters.

Catch at age in numbers (x 1000)						
	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
2012	11864	4424	1892	531	26	10

Survey indexes (N. ind. km ⁻²)						
	0	1	2	3	4	5

2005	162	86	39	12	3	1.9
2006	91	174	49	9	2	1.2
2007	192	146	74	18	1	0.6
2008	128	114	58	11	5	0.6
2009	177	83	47	6	1	0.2
2010	55	200	23	5	0.2	1.3
2011	199	172	34	5	0.5	0.8
2012	206	248	74	6	0.33	0.1

Mean weight in catch (kg)						
	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
2012	0.08	0.151	0.204	0.267	0.453	0.522

Mean weight in stock (kg)						
PERIOD	0	1	2	3	4	5+
2006-2012	0.024	0.104	0.207	0.304	0.380	0.522

Maturity at Age						
PERIOD	0	1	2	3	4	5+
2006-2012	0	0.16	0.76	0.96	0.99	1.00

Natural mortality (M)						
PERIOD	0	1	2	3	4	5+
2006-2012	0.70	0.35	0.28	0.25	0.23	0.22

Sensitivity analyses were conducted to assess the effect of the main parameters, i.e. shrinkage (fse) and age above which q is independent from age (q_{age}). Values ranging from 0 to 2 (0.5 increasing) for the shrinkage and from 0 to 5 for the q_{age} parameter have been tested. As a result, the setting that minimized the residuals and showed the best diagnostics output both of the residuals and retrospective analyses were used for the final assessment.

On the base of the sensitivity analyses the XSA run were made using the following settings:

- Catchability dependent on stock size for ages = 0.
- Catchability independent of age for ages ≥ 4 .
- S.E. of the mean to which the estimates are shrunk = 1.
- Minimum S.E. for population estimates derived from each fleet = 0.30.
- Number of years used for the shrinkage = 5.

- Number of ages used for the shrinkage = 5.
- Ages used for tuning from the survey = 1-4.

The other setting employed were:

- $F_{bar} = 0-4$.
- Proportion of M before spawning = 0.5.
- Proportion of F before spawning = 0.5.

A separable VPA was run as exploratory analysis. Log catchability residual plots was produced (Fig. 9) and no major conflict between ages seems to appear, except for age 0/1 in 2010-2011.

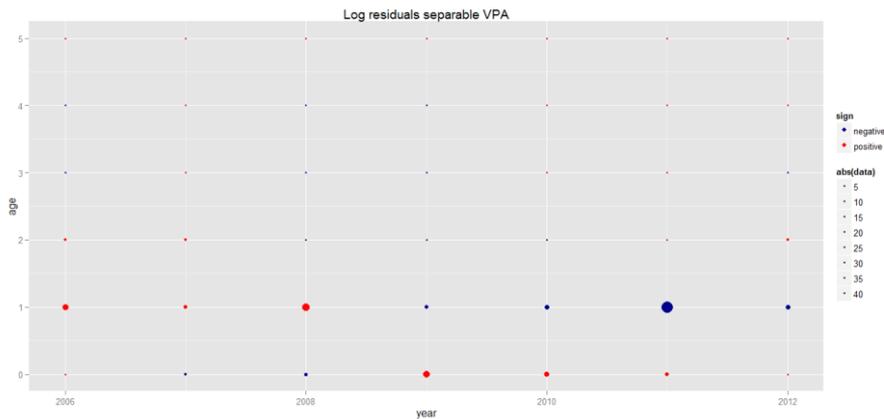


Figure 9 - Residual plot of the separable VPA. (Residuals = $\text{Log}(\text{Catch observed} - \text{Catch Hat})$; $\text{Catch Hat} = F/Z * N. \text{ind} * (1 - \exp(-Z))$)

The figure 10 presents the main results from the XSA run: fishing mortality F_{bar1-4} (harvest), spawning stock biomass (SSB), recruitment (in thousands) and catches (in tons).

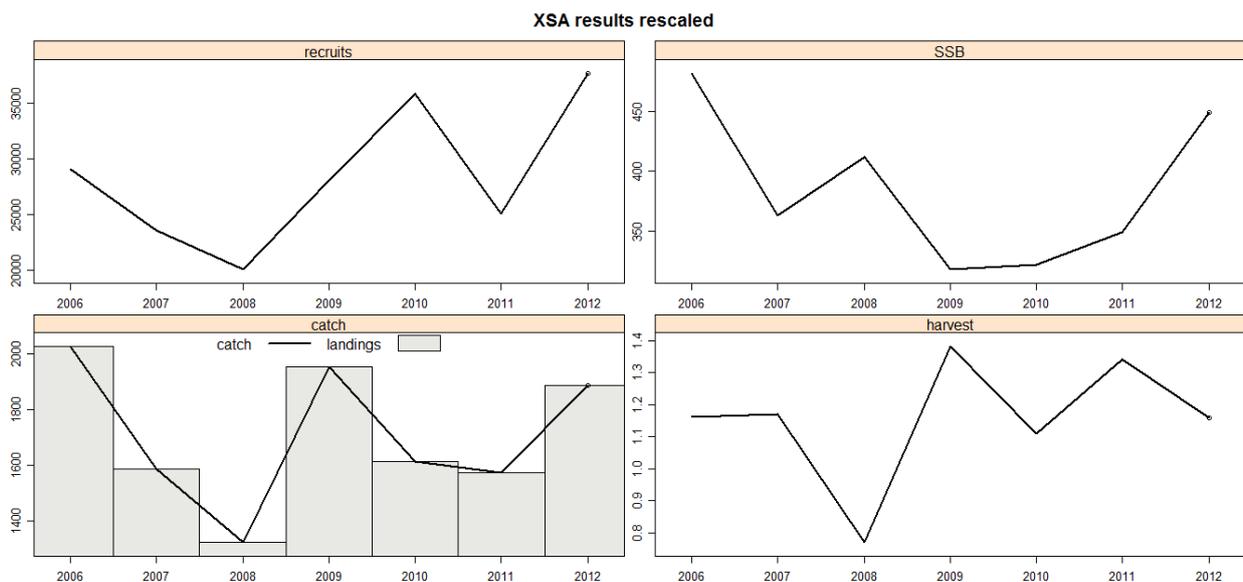


Fig. 10 - Final assessment results XSA run.

State of exploitation: Exploitation varied without any trend in the years 2006-2012, reaching a minimum in 2008. The most recent estimate of fishing mortality (F_{0-4}) is 1.16. As showed in Table the higher values of F are observed for the ages from 3 to 5+.

State of the juveniles (recruits): Recruitment varied without any trend in the years 2006-2012, reaching a minimum in 2011, followed by an increase in 2012, observed also in survey data.

State of the adult biomass: The SSB showed a general decrease from 2006 to 2010, increased in 2011 and 2012 (SSB_{2012} : 445 tons), as observed in the survey data.

Table 6.13 Fishing mortality by age estimated from the XSA.

age	2006	2007	2008	2009	2010	2011	2012
0	0.15	0.01	0.06	0.52	0.34	0.31	0.49
1	1.61	1.46	1.58	1.41	1.06	0.97	0.70
2	0.79	1.14	0.30	0.59	0.36	0.95	0.83
3	2.52	2.19	1.68	3.10	2.26	2.95	2.42
4	0.73	1.05	0.24	1.30	1.52	1.53	1.35
5+	0.73	1.05	0.24	1.30	1.52	1.53	1.35

6.1.4 Robustness analysis

6.1.5 Retrospective analysis, comparison between model runs, sensitivity analysis,

A retrospective analysis was also carried out. The retrospective analysis confirm the stability of the estimates of XSA (Fig. 11).

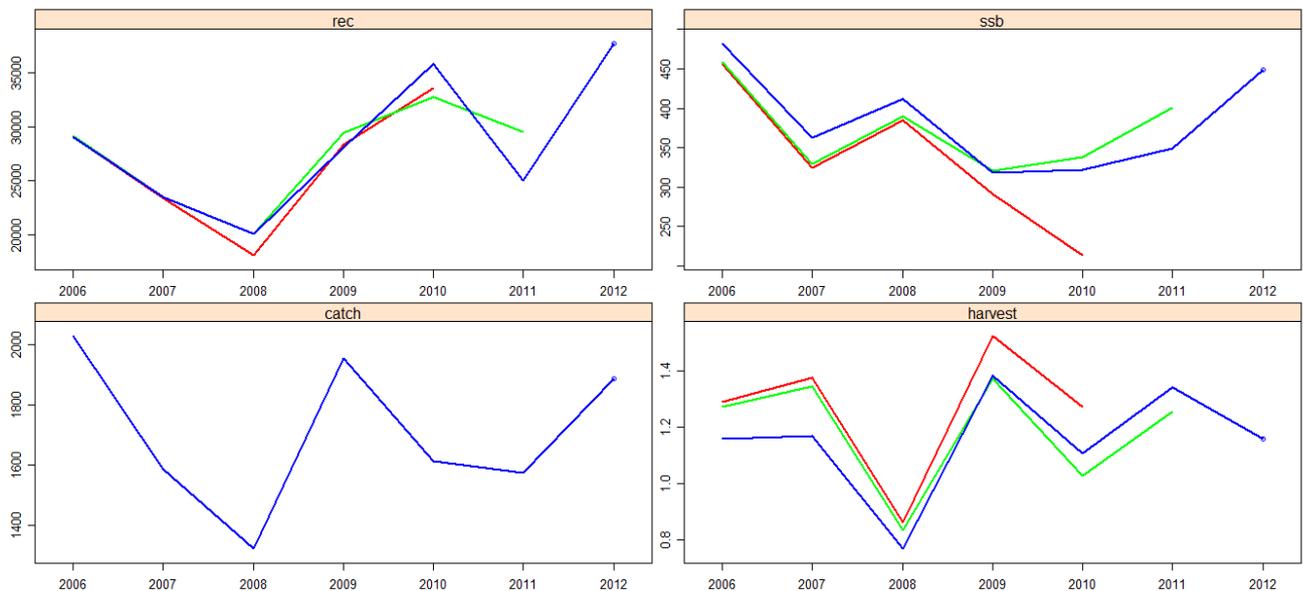


Figure 11- Retrospective analyses on rescaled data.

XSA Diagnostics in the form of residuals by survey data are shown in the figure 12.

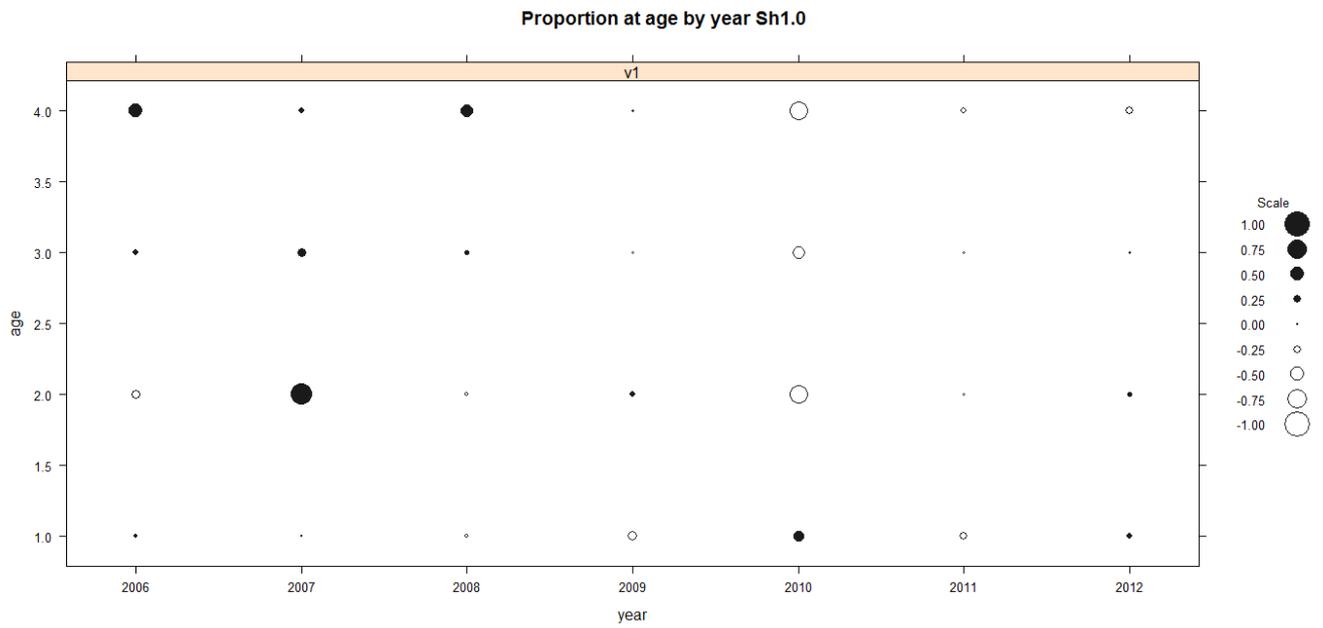


Figure 12 - Residuals by survey.

No trends in the residuals were observed.

6.1.6 Assessment quality

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

6.2 *Statistical catch at age (SS3 model)*

6.2.1 Model assumptions

Stock Synthesis 3 provides a statistical framework for the calibration of a population dynamics model using fishery and survey data. It is designed to accommodate both population age and size structure data and multiple stock sub-areas can be analysed. It uses forward projection of population in the “statistical catch-at-age” (hereafter SCAA) approach. SCAA estimates initial abundance at age, recruitments, fishing mortality and selectivity. Differently from VPA based approaches (e.g. by XSA) SCAA calculates abundance forward in time and allows for errors in the catch at age matrices. Selectivity has been generated as age-specific by fleet, with the ability to capture the major effect of age-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; in the present assessment such features are not summarized in the results. 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 methods. In the present assessment the variance is not shown for fishing mortality results, because the model outputs provide F values (called continuous F) within a year as standardized into selection coefficients by dividing each F value by the maximum value observed for any age class in the year (e.g., Derio et al., 1985; Sampson and Scott, 2011). For a better comparison with the results of previous assessments carried out both in the framework of STECF-EWGs and GFCM-WGs and with the outputs of the XSA carried out in the present assessment, the F values are standardized by dividing by the average (called F_{bar}) of the F values observed over a defined range of age classes (e.g., Darby and Flatman, 1994; Sampson and Scott, 2011).

The same SOP corrected data and parameters utilized in the XSA were employed, with the main difference that the catch at age matrix from the fishery has been extrapolated backwards until 2000, utilizing the same input data presented in the FAO-GFCM-WG of demersal held in Ancona in 2010 (http://151.1.154.86/meetingdocs/2009/SCSA_WG_Demersal_Species_Ancona/StockAssessmentForms, accessed July 2013). 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. The model allowed to specify the different source of data, providing different uncertainties estimates for each data set. Moreover also the total landings presented from 1970 to 2005 (FAO-FishstatJ source) 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. In order to facilitate the convergence of the model a higher number of ages has been employed for natural mortality, fecundity and weight at age. Moreover, for the same reason, the initial catch before 1970 has been assumed to be null (Fig. 14).

The SS3 analyses has been carried out considering the following three fleets:

1. Italian gill netters
2. Italian rapido and otter trawler
3. Croatian and Slovenian set netters.

The catch at age for the three fleets are summarized in figure 13.

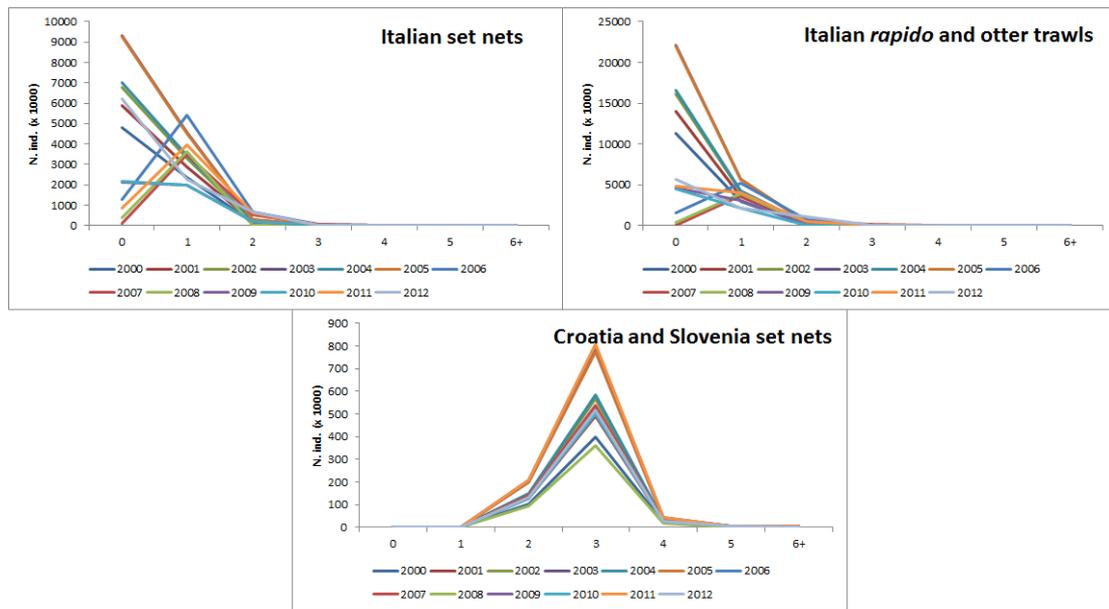


Figure 13 Catch at age data used in SCAA analysis.

6.2.2 Input data and Parameters

Input data and parameters.

Catch at age in numbers (x 1000) (GNS ITA + TBB ITA + GTR CRO-SLO)							
	0	1	2	3	4	5	6+
2000	1753	6681	1016	81	13	6	3
2001	1815	6919	1052	84	14	6	3
2002	1690	6444	980	78	13	5	3
2003	3599	13720	2086	166	27	11	3
2004	3185	12143	1847	147	24	10	3
2005	2190	12910	3120	138	11	8	3
2006	2858	10547	1618	702	26	5	3
2007	139	7224	1145	782	27	5	3
2008	738	7507	440	353	18	3	2
2009	4646	3120	359	793	40	7	4
2010	4508	2180	197	491	25	5	3
2011	5649	7948	1306	842	46	14	19
2012	11864	4424	1892	531	26	5	3

Mean weight in stock (kg)											
PERIOD	0	1	2	3	4	5	6	7	8	9	10
2006-2012	0.024	0.104	0.207	0.304	0.38	0.46	0.5	0.54	0.56	0.6	0.62

Fecundity at Age											
PERIOD	0	1	2	3	4	5	6	7	8	9	10
2006-2012	0	0.016	0.157	0.292	0.376	0.46	0.5	0.54	0.56	0.6	0.62

Natural mortality (M)											
PERIOD	0	1	2	3	4	5	6	7	8	9	10
2006-2012	0.70	0.35	0.28	0.25	0.23	0.22	0.21	0.2	0.2	0.2	0.2

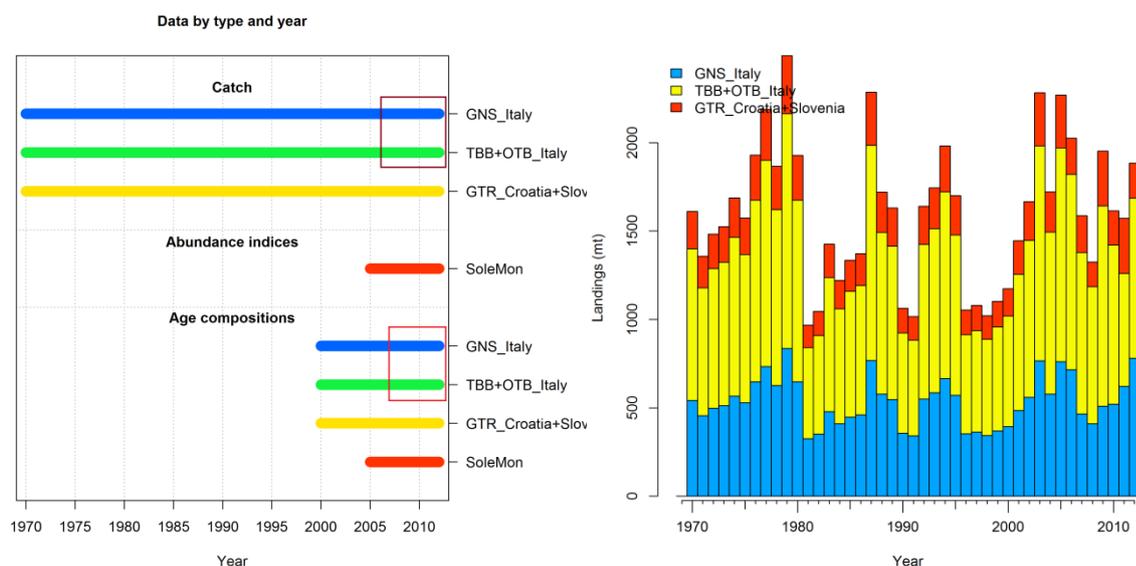


Figure 14 - Input data (the red squares represent DCF data) and landings imputed in the SS3 model.

Considering the information provided in Fig. 1 and 5 the selectivity patterns of the fleets and the survey have been rescaled as in the Fig. 15.

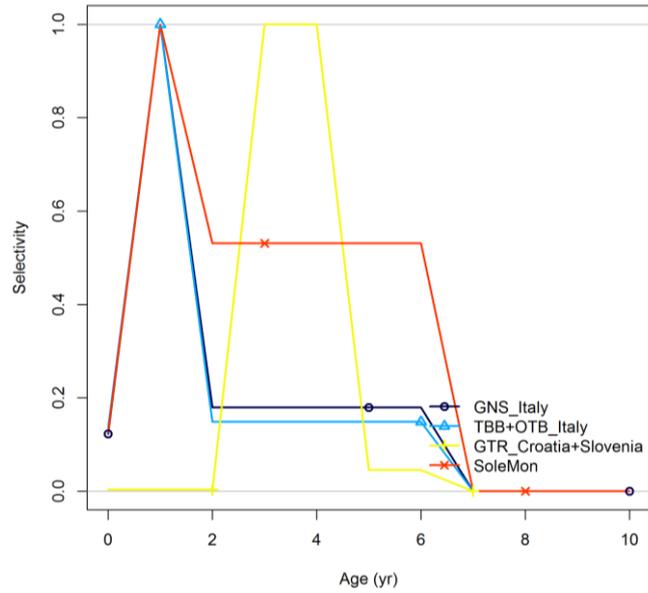


Figure 15 - Selectivity by age utilized in the SS3 model.

SCAA Diagnostics in the form of residuals by survey and fleet data are shown in Fig.16.

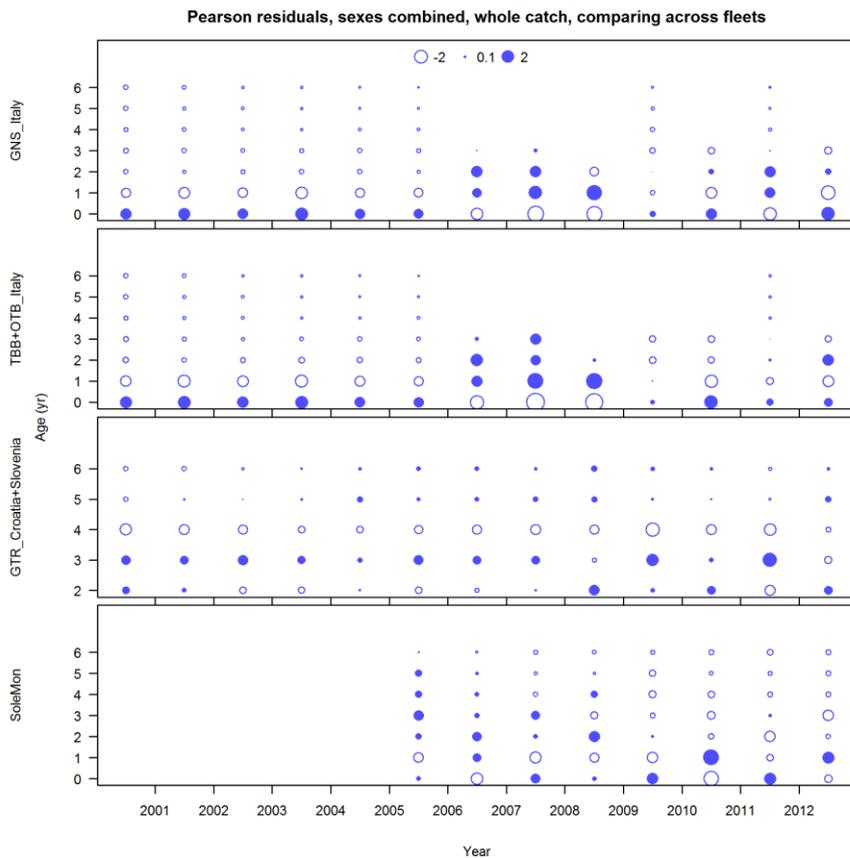


Figure 16 - Pearson residuals for SoleMon survey and the fleets.

No particular trends in the residuals were observed.

Fig. 17 presents the main results from the SCAA run: fishing mortality (Fbar0-4 and by fleet), total biomass, spawning stock biomass (SSB) and recruitment.

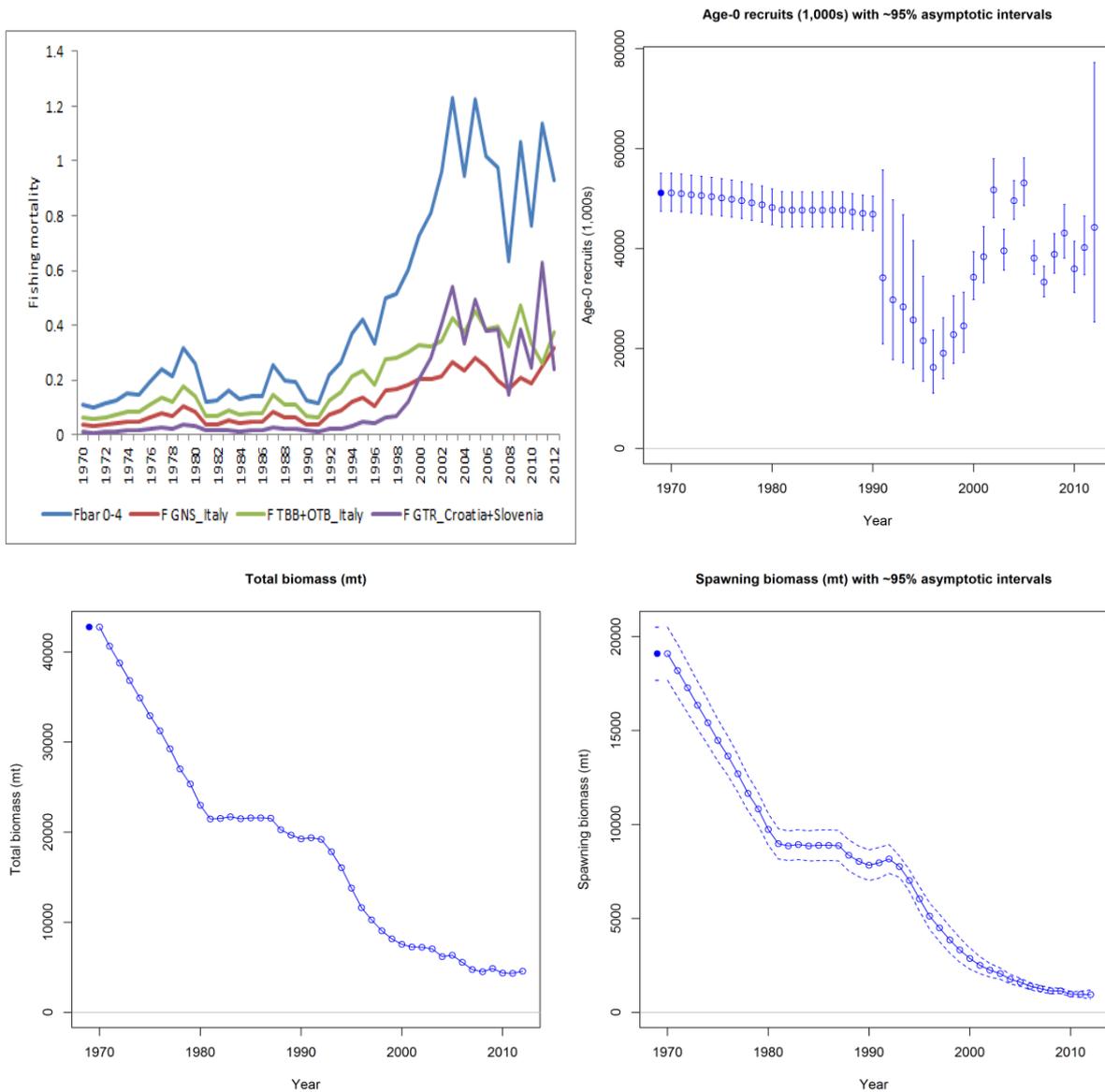


Figure 17 - Final assessment results SCAA run.

State of exploitation: Exploitation increased from the beginning of the time-series, with a more pronounced increase after 2000. In the period 2006-2012 the F_{bar} showed important oscillations around a value of 0.9. The most recent estimate of fishing mortality (F_{bar} 0-4) is 0.93, the partial F for each fleet is 0.37 for the Italian trawlers, 0.32 for the Italian gill netters and 0.24 for the Slovenian and Croatian set netters.

State of the juveniles (recruits): Recruitment varied without any trend in the years 1970-2012, reaching a minimum in 1998, followed by a general increase until 2012. The same trend was also observed in survey data.

State of the adult biomass: The SSB showed a strong decrease since the begin of the series. The last estimate of SSB in 2012 is around 1,900 tons.

7 Stock predictions

Due to the short time series it was not possible to estimate a stock recruitment relationship. As a consequence the biological reference point has been estimated using the Yield per Recruits approach, where $F_{0.1}$ is considered a proxy of F_{MSY} . Biological reference points have been estimated using the XSA and SCAA input data and selectivity patterns.

RPs suggest an overfishing situation for the *S. solea* stock both for the XSA and SCAA results (Figure 18).

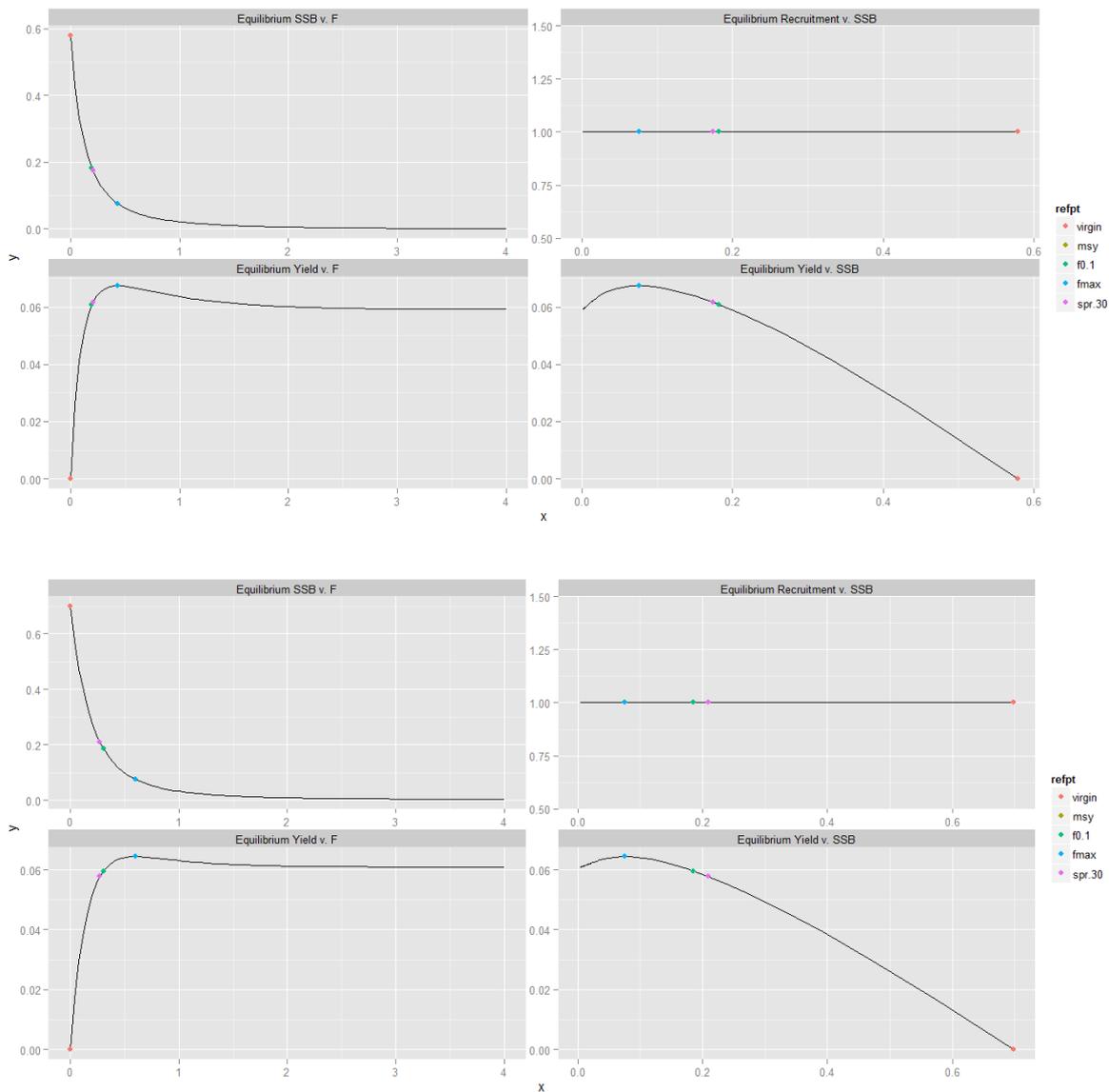


Figure 18 - Yield per Recruit analyses for XSA (above) and SCAA (below)

Table 7.1 - Yield per Recruit outputs for XSA and SCAA.

	Current F ($F_{BAR\ 0-4}$)	Reference Points	Harvest	Yield/R	SSB/R	Total biomass/R
XSA	1.16	$F_{0.1}$	0.19	0.059	0.17	0.239
		F_{max}	0.45	0.065	0.06	0.11
SCAA	0.93	$F_{0.1}$	0.31	0.05958	0.185	0.263
		F_{max}	0.60	0.06439	0.075	0.146

7.1 Short term predictions

Outlook until 2015 – SCAA results

Table 7.1.1 shows the short term forecast for different F scenarios computed for sole in GSA 17.

Table 7.1.1 - Basis: F(2013) = mean (Fbar 0-4, 2010-2012); R(2011) = GM (2010-2012) = 40,015 (thousands); F (2012) = 0.94; SSB (2012) = 1900 t; Catches (2012)= 1887.

Rationale	F scenario	F factor	Catch 2014	Catch 2015	SSB 2015	Change SSB 2014-2015 (%)	Change Catch 2012-2014 (%)
zero catch	0	0	0	0	3780.39	128.45	-100.00
High long-term yield (F _{0.1})	0.31	0.33	1179.69	1477.05	2753.22	66.37	-37.44
Status quo	0.94	1.00	2619.35	2614.05	1605.72	-2.97	38.90
Different scenarios	0.09	0.10	406.52	561.55	3420.57	106.70	-78.44
	0.19	0.20	769.36	1016.39	3104.28	87.59	-59.20
	0.28	0.30	1093.86	1385.48	2826.00	70.77	-41.99
	0.37	0.40	1384.71	1685.41	2580.90	55.96	-26.57
	0.47	0.50	1645.99	1929.40	2364.77	42.90	-12.71
	0.56	0.60	1881.27	2127.96	2173.95	31.37	-0.24
	0.65	0.70	2093.68	2289.55	2005.25	21.18	11.03
	0.75	0.80	2285.95	2420.95	1855.88	12.15	21.22
	0.84	0.90	2460.48	2527.64	1723.41	4.14	30.48
	1.02	1.10	2764.41	2683.79	1500.96	-9.30	46.60
	1.12	1.20	2897.26	2739.80	1407.53	-14.94	53.64
	1.21	1.30	3019.30	2784.47	1324.01	-19.99	60.11
	1.30	1.40	3131.77	2819.78	1249.18	-24.51	66.08
	1.40	1.50	3235.74	2847.34	1181.97	-28.57	71.59
	1.49	1.60	3332.18	2868.48	1121.44	-32.23	76.71
	1.58	1.70	3421.90	2884.31	1066.79	-35.53	81.46
	1.68	1.80	3505.64	2895.74	1017.30	-38.53	85.90
	1.77	1.90	3584.04	2903.52	972.34	-41.24	90.06
	1.86	2.00	3657.67	2908.28	931.38	-43.72	93.97

8 Draft scientific advice

Considering the results of XSA and SCAA analyses, it can be concluded that the resource is subjected to overfishing. A reduction of fishing mortality is recommended. SSB shows general stable trends in the XSA run, while the SCAA showed a clear decreasing trend of SSB. It is important to point out that the absolute values of XSA are underestimated due to the use of a constant catchability at the older ages. Differently, the SS3 model allows the assumption of a dome-shaped population selection curve, which determines more reliable values of SSB if compared with the historical yields. Nevertheless the clear decreasing pattern of SSB observed in the SCAA analysis since the begin of the series appears quite alarming, considering that at the moment the level of SSB is less than 20% of the SSB observed in the 90s.

According to the XSA and SCAA analyses the SSB was practically constant in the period 2006-2012, but the estimates made by the SS3 model with SCAA show a critical situation. The population is characterized by an SSB which is less than 20% of the 90s, and demonstrates a clear decreasing pattern of the older ages (Fig. 19). Nevertheless, it is unfeasible to fully evaluate the state of the spawning stock due to the absence of proposed or agreed management reference points.

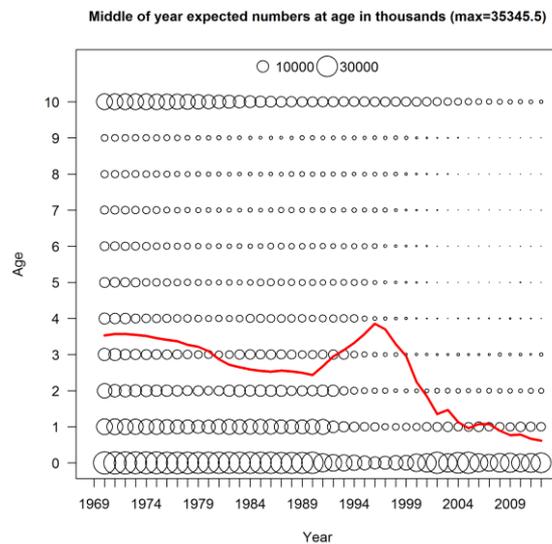


Figure 19 - Bubble plot showing the middle of year expected numbers at age in thousands (max bubble = 35,345) from SS3 model. Red line represents the mean age of the population.

According to the XSA and SCAA analyses the recruitment of sole in GSA 17 fluctuated since 2006 without a clear increasing or decreasing pattern. The SoleMon survey data show higher values in the last two years.

Based on the XSA and SCAA estimates, in 2012 the fishing mortality appears much higher than the respective estimates of $F_{0.1}$ (6 times in the XSA and 3 times in the SCAA) and, hence, it can be concluded that the resource is in high overfishing.

The group believes that, due to the reasons expressed in paragraph before, the more accurate methodology to assess the stock is the SCAA carried out with SS3. The calculation of reference point has been updated according to the new methodology applied and the value proposed is $F_{0.1} \leq 0.31$ as proxy for F_{MSY} . Such value is little bit higher than the historical value presented in the previous years ($F_{0.1} = 0.26$) and calculated with Yield software assuming a knife-edge selection pattern. Given the results of the present

analysis (current F is around 0.93), the stock appeared to be subject to overfishing. A considerable reduction is necessary to approach the reference point.

Considering the overexploited situation and the low values of SSB and biomass of the sole stock in GSA 17 a reduction of fishing effort and an improvement in exploitation pattern is advisable, especially of Italian rapido trawlers and gillnetters, which mainly exploit juveniles. The best option to reduce effort and improve the exploitation pattern for sole in GSA 17, would be to introduce a closure for rapido trawling within 17 km of the Italian coast during the summer-fall period (June- December). Moreover, it was noted that in the last years some Italian artisanal fleets fish with gill net in the main spawning area during periods when trawling is prohibited. Additional measures to restrict exploitation of sole in the spawning area are desirable, to afford further protection to the Adriatic sole stock.

As shown in figures before the main spawning area is only partially exploited by *rapido* trawlers and the Croatian artisanal fleet, considering the information gathered from Croatian colleagues about the fishing zones of set netters targeting sole. It is important to mention that in the last two-three years some Italian artisanal fleets are fishing with gill net in the main spawning area during the trawl fishing ban in August or during the week ends. Safeguarding this area (identified by the SoleMon trawl survey, Grati et al., 2013) to prevent a dramatic increase of the fishing pressure both of *rapido* trawlers and set netters might be crucial for the sustainability of the Adriatic sole stock. Moreover in order to have a more accurate estimation of the tuning data it is extremely important to extend the SoleMon survey also inside the Croatian waters.

The scientific advices in the following table are based on the SCAA using SS3 model results.

Based on	Indicator	Analytic al reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (time period)	Stock Status
Fishing mortality	Fishing mortality	($F_{0.1}$, = 0.31, F_{max} = 0.60)	0.93		I	IO_i
Stock abundance	Biomass	8925.533 (from SCAA)	4569.682 (Total biomass from SCAA)	33 th percentile:	D	O_L
Recruitment					C	
Final Diagnosis	High overfishing and low biomass					

8.1 *Explanation of codes*

Trend categories

- 1) N - No trend
- 2) I - Increasing
- 3) D – Decreasing
- 4) C - Cyclic

Stock Status

Based on Fishing mortality related indicators

- 1) **N - Not known or uncertain** – Not much information is available to make a judgment;
- 2) **U - undeveloped or new fishery** - Believed to have a significant potential for expansion in total production;
- 3) **S - Sustainable exploitation**- fishing mortality or effort below an agreed fishing mortality or effort based Reference Point;
- 4) **IO –In Overfishing status**– fishing mortality or effort above the value of the agreed fishing mortality or effort based Reference Point. An agreed range of overfishing levels is provided;

Range of Overfishing levels based on fishery reference points

In order to assess the level of overfishing status when $F_{0.1}$ from a Y/R model is used as LRP, the following operational approach is proposed:

- If $F_c/F_{0.1}$ is below or equal to 1.33 the stock is in (**O_L**): **Low overfishing**
- If the $F_c/F_{0.1}$ is between 1.33 and 1.66 the stock is in (**O_I**): **Intermediate overfishing**
- If the $F_c/F_{0.1}$ is equal or above to 1.66 the stock is in (**O_H**): **High overfishing**

* F_c is current level of F

- 5) **C- Collapsed**- no or very few catches;

Based on Stock related indicators

- 1) **N - Not known or uncertain**: Not much information is available to make a judgment
- 2) **S - Sustainably exploited**: Standing stock above an agreed biomass based Reference Point;
- 3) **O - Overexploited**: Standing stock below the value of the agreed biomass based Reference Point. An agreed range of overexploited status is provided;

Empirical Reference framework for the relative level of stock biomass index

- **Relative low biomass**: Values lower than or equal to 33rd percentile of biomass index in the time series (**O_L**)
- **Relative intermediate biomass**: Values falling within this limit and 66th percentile (**O_I**)
- **Relative high biomass**: Values higher than the 66th percentile (**O_H**)

- 4) **D – Depleted:** Standing stock is at lowest historical levels, irrespective of the amount of fishing effort exerted;
- 5) **R –Recovering:** Biomass are increasing after having been depleted from a previous period;

Agreed definitions as per SAC Glossary

Overfished (or overexploited) - A stock is considered to be overfished when its abundance is below an agreed biomass based reference target point, like $B_{0.1}$ or B_{MSY} . To apply this denomination, it should be assumed that the current state of the stock (in biomass) arises from the application of excessive fishing pressure in previous years. This classification is independent of the current level of fishing mortality.

Stock subjected to overfishing (or overexploitation) - A stock is subjected to overfishing if the fishing mortality applied to it exceeds the one it can sustainably stand, for a longer period. In other words, the current fishing mortality exceeds the fishing mortality that, if applied during a long period, under stable conditions, would lead the stock abundance to the reference point of the target abundance (either in terms of biomass or numbers)