Stock Assessment Form

Demersal species

Reference year:2017

Reporting year:2018

STOCK ASSESSMENT OF CUTTLEFISH IN GSA17

The Italian, Croatian and Slovenian fleets exploit cuttlefish with several gears: otter trawl, rapido trawl and set gears (trammel nets, pots and fyke nets). Nearly 95% of catches come from the Italian side. Landings fluctuated between 2,000 and 9,000 t in the period 1972-2017.

Fishery independent data collected in the framework of SoleMon survey show a decrease of relative abundance and biomass from 2006 to 2010 followed by slight increasing trend up to 2017. The biomass index fluctuated above the empirical threshold of the 33rd percentiles from 2011 to 2016, whereas it fell slightly below in 2017.

CMSY production model showed that the exploitation is below FMSY and the biomass is below safe biological limits (BMSY). Therefore, the advice would be to avoid any increase of catches to improve the status of the stock in term of biomass.

Stock Assessment Form version 1.0 (November 2018)

Uploader: *Enrico Nicola Armelloni*

Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Sepia officinalis	Common cuttlefish	57
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: CMSY		
Authors:		
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2 Stock identification and biological information

Common Cuttlefish (*Sepia officinalis,* Linnaeus, 1758) is a demersal cephalopod species, more abundant in coastal waters on muddy and sandy bottoms covered with seaweed and phanerogams, but its distribution can be extended to a depth of about 200 m (Relini et al., 1999). It is particularly active during the night, whereas during the daytime it adopts a sedentary lifestyle, often burrowing into the sand. This species inhabits the entire coastal part of the Adriatic Sea, it migrates seasonally; in winter it resides mostly in circalitoral zone where it matures sexually, in spring, it migrates to the shallower infralitoral region to spawn (Mandić, 1984). In the central and northern Adriatic it occurs predominantly on sandy and muddy bottoms up to 100-150 m deep (Manfrin Piccinetti and Rizzoli, 1984; Soro and Piccinetti Manfrin, 1989). In the southern Adriatic, in the colder part of the year, the Common cuttlefish is most dense at depths from 50 to 60 m. During the warmer part of the year it migrates closer to the coast for spawning and forms dense settlements at 10 to 30 m depth. In autumn it withdraws into deeper waters and, in this part of the year, is most abundant at depths between 40 and 50 m. In spring, the population density is uniform up to 60 m, but it can be also found, in small quantities, up to 110 m (Mandic et al. 1981; Mandić, 1984).

2.1 Stock unit

A single population unit is probably present within the Adriatic stock. The seasonal migrations occurring for reproduction could determine admixture of different cohorts determining genetic disequilibrium and random genetic differentiation. Preliminary data show temporal genetic unstableness, suggest further analysis and recommend cautionary approach to the management (Garoia et al. 2004). Nevertheless, the mixing effect is reduced according to reproductive strategy of cuttlefish: in fact, eggs are attached to fixed substrates and the hatchlings are benthic (Boletzky and Villanueva 2014).

In the present assessment the stock has been considered confined in the GSA 17. However there is not any scientific evidence of such segregation.

2.2 Growth and maturity

As with most cephalopod species, the biological and ecological characteristics of common cuttlefish, and also the stock assessment, have been insufficiently investigated in the Adriatic Sea. This species can grow to a maximum of 35 cm (mantle length), but the usual length ranges between 15 to 20 cm. Longevity is 18 to 30 months (Fisher et al., 1987), although some male individuals may attain a greater age (Guerra 2006).

The spawning period of this species extends throughout the year, with peaks in spring and summer. In the northern and central Adriatic it reproduces in April and May, but females with mature eggs can be found even in June and July (Manfrin Piccinetti and Giovanardi, 1984). In the southern Adriatic, it spawns from February to September, but with a peak from April to June. The diameter of the eggs is from 6 to 8 mm (Mandić, 1984). The length of the mantle is about 10 cm at first sexual maturity. Cuttlefish, as most cephalopod species, die soon after breeding (Goff and Daguzan, 1991).

However, terminal reproduction be drawn out over a relatively long time during which the spawning female feeds regularly (Mangold, 1983). The common cuttlefish is an active predator. It feeds mostly on crustaceans, especially decapods, and fish. In the absence of this food, it can become cannibalistic (Fabi, 2001).

Table 2.2-1: Maximum size, size at first maturity and size at recruitment. (Manfrin Piccinetti and Giovanardi, 1984)

Somatic magnitude measured (LT, LC, etc)			ML	**Units**	mm
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	Spring - Summer
Maximum size observed			35	**Recruitment season**	Fall
Size at first maturity			10	**Spawning area**	
Recruitment size to the fishery			6-8	**Nursery area**	

Table 2.2-2: Growth and length weight model parameters (Manfrin Piccinetti and Giovanardi, 1984)

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**					
	K					
	t_0					
	Data source					
Length weight relationship	**a**				0.22041	
	b				2.773	
	M (scalar)					
	sex ratio (% females/total)	53				

3 Fisheries information

3.1 Description of the fleet

The common cuttlefish is an important commercial resource and one of the most appreciated cephalopod species. In the Adriatic Sea, cuttlefish is targeted by demersal trawl fleet (bottom trawl and rapido trawl nets), but Small Scale Fisheries, represented mainly by trammel nets, fyke nets and specific pots (Fabi & Sartor, 2001), represents a consistent part of landings. Trammel nets fyke nets and pots fish sexually mature individuals, going in coastal waters during reproductive period. In particular, pots are equipped with plastic materials used to attract spawning females for eggs clusters deposition. One possible impact of traps, though, may be the high mortality of the eggs attached inside (Blanc and Daguzan, 1998). Trawling gear are not selective for either recruits or spawners (Bettoso et al. 2015), and landings from those metiérs prevail during autumn-winter. After the temporary suspension (30 to 45 days) of bottom and mid-water trawling nets during summer, trawl gear were responsible for the capture of recruits during the summer-autumn period (Piccinetti et al., 2012).

Almost half of the production originates from the coastal regions of the northern Adriatic Sea: Veneto, Marche, Emilia Romagna and Friuli Venezia Giulia (IREPA, 2014).

Table 3.1-1: 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	
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 Traps	33 - Demersal shelf species	
Operational Unit 4	HRV	17	C - Minor gear with engine (6-12 metres)	07 - Gillnets and Entangling Nets	33 - Demersal shelf species	
Operational Unit 5	SVN	17	C - Minor gear with engine (6-12 metres)	07 - Gillnets and Entangling Nets	33 - Demersal shelf species	
Operational Unit 6	HRV	17	E - Trawl (12-24 metres)	Otter trawl	33 - Demersal shelf species	
	SVN	17		Otter trawl		

Operational Unit 7			E - Trawl (12-24 metres)		33 - Demersal shelf species	

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)
Operational Unit 1		503.2				
Operational Unit 2		879.22				
Operational Unit 3		1070.87				
Operational Unit 4		38.71				
Operational Unit 5		1.31				
Operational Unit 6		67.2				
Operational Unit 7		1.24				
Total		2561.75				

In Figure 1 are presented the length frequencies distributions of the Italian landings from 2007 to 2017. Also the data by gear are reported for 2017, showing a different exploitation pattern of the set gears if compared with trawls.

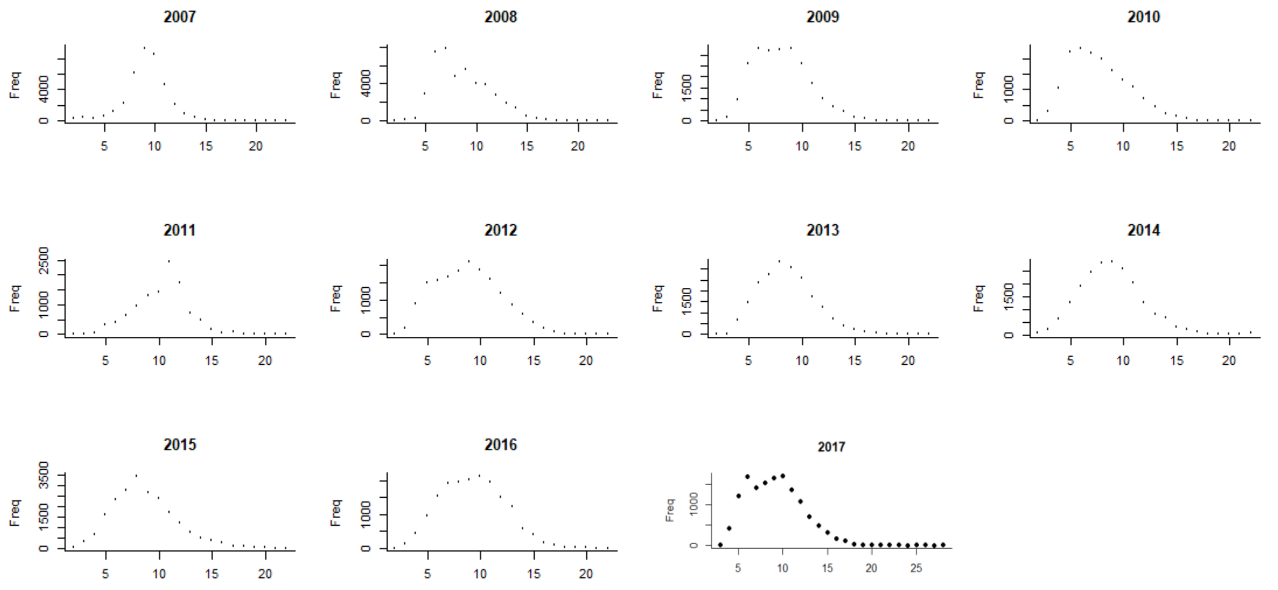

Figure 1 Length frequencies distributions of the Italian landings by year in GSA 17. Source: DCF 2018 Italian data call.

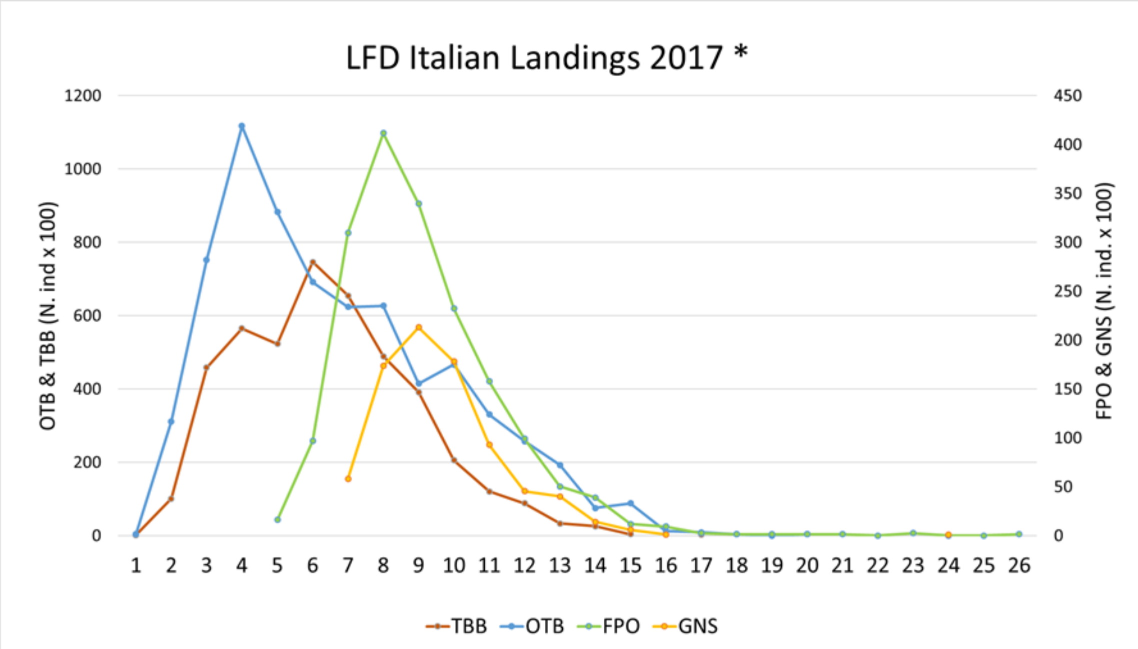

Figure 2 Length frequencies distributions of the Italian landings by gear from metièr sampled in DCF-EU 2017 framework in GSA 17, year 2017. Source: DCF 2018 Italian data call.

3.2 Historical trends

Common cuttlefish landings estimated by ISTAT-IREPA e FishStatJ – GFCM database and in the framework of Croatian, Italian and Slovenian Official Data Collection submitted in the data call 2018 are showed in figure 2.

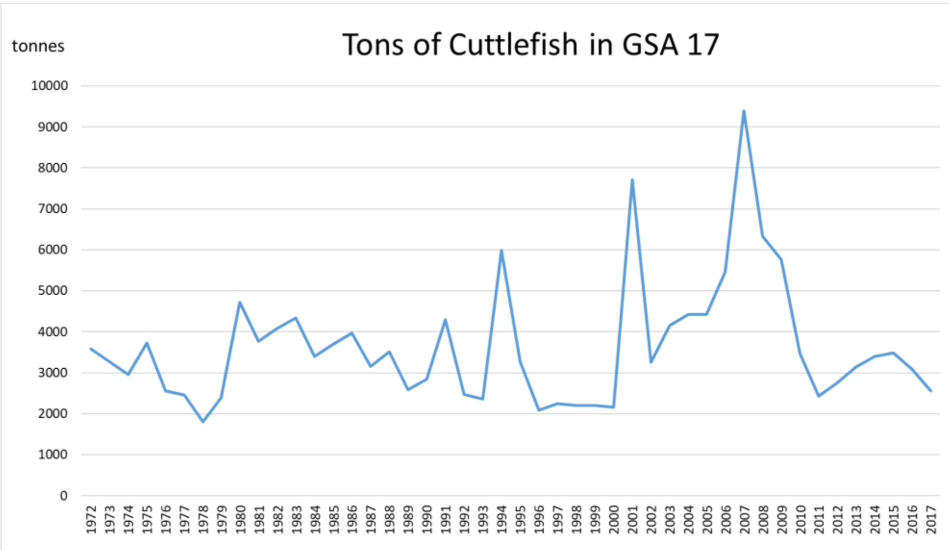

Figure 3 – Landings of common cuttlefish in GSA 17.

In the period from 1982 to 1991, in the central and northern Adriatic, the CPUE values from the "Pipeta" expedition showed distinct fluctuations without a clear trend (Piccinetti and Piccinetti Manfrin, 1994).

By analysing the total annual landings of this species in the Adriatic in the period from 1972 to 1997, Mannini and Massa (2000) observed distinct fluctuations in the catch. Nevertheless, a negative trend of the catches was found both in the northern and central Adriatic. During years 2000, landings sharply raised until 2008 and subsequently dropped until 2011. During recent years, landings raised again, however remained quite below that values observed during the period 2000-2008.

3.3 Management regulations

In Italy, Slovenia and Croatia the main rules in force are based on the applicable EU regulations (mainly EC regulation 1967/2006 and 1380/2013):

- Minimum landing sizes: NA
- Codend 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 codend with 40 mm (stretched) square meshes or a codend 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

Temporal bans for trawling gears (OTB, TBB and PTM):

- Minimum of 45 days of absolute ban during summer, whitin a period varying according to maritime compartments (Fully observed).
- In the period following the ban, for approximately 30 days, trawling gears are not allowed to operate whitin six nautical miles or at depth less than 60 m. (Not fully observed). Are excluded from this regulation those vessels operating in maritime compartments of Trieste and Monfalcone.

Numerous regulations have been adopted in Croatia to regulate fishing gears' technical characteristics and their use with regard to commercial, small-scale and sport fishing. An Ordinance of 1996 on commercial fishing (46/96) prescribes, according to the type of license granted to a vessel, the quantities and types of gear that can be carried on board and used from that vessel. Mesh sizes of nets and other fishing gears as well as their area and time of use have also been determined in Regulations on Commercial Fishing of 2000 (83/2000) and are summarized in Table 1.

Table 3.3-1 Specific characteristic for the trammel net used in Croatia to target common cuttlefish

	Allowed quantities per license in pieces or length (m)	**Minimum Mesh size in mm or number of hooks**	**Time of use (open season)**	**Area of use**
Trammel net for cuttle fish (*Sepia officinalis*)	800	32 - 38 mm (middle layer) and 150 – 170 mm (outer layer)	1/9 to 1/6	

3.4 Reference points

Table 3.4-1: 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			Bmsy	9.94 , 95% CL = 8.75 - 11.3	WGSAD 2017, CMSY model output
SSB					
F			Fmsy	0.481 , 95% CL = 0.412 - 0.5	WGSAD 2017, CMSY model output
Y					
CPUE					
Index of Biomass at sea					

4 Fisheries independent information

4.1 SoleMon

Thirteen *rapido* trawl fishing surveys were carried out in GSA 17 from 2005 to 2017: one systematic "pre-surveys" (fall 2005) and the rest random surveys (fall 2006 to fall 2017) 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 = 46). The following number of hauls was reported per depth stratum (Tab. 2).

Table 4.1-1 Number of hauls per year and depth stratum in GSA 17, 2005-2017

Depth strata	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0-30	30	35	32	39	39	39	39	35	37	39	39	39	38
30-50	12	20	19	18	18	18	18	18	18	18	18	18	16
50-120	15	8	11	10	10	10	10	10	10	10	10	10	10
HRV	5	4	0	0	0	0	0	0	0	0	0	7	6
Total	62	67	62	67	67	67	67	63	65	67	67	74	70

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:

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

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

Where:

A=total survey area

Ai=area of the i-th stratum

si=standard deviation of the i-th stratum

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

n=number of hauls in the GSA

Yi=mean of the i-th stratum

Yst=stratified mean abundance

V(Yst)=variance of the stratified mean

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

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

Direct methods: trawl based abundance indices

Table 4.1-2 Trawl survey basic information

Survey	SoleMon	**Trawler/RV**	Dallaporta
Sampling season	Fall		
Sampling design	Random stratified		
Sampler (gear used)	Rapido trawl		
Codend mesh size as opening in mm	46		
Investigated depth range (m)	5-120		

Table 4.1-3 Trawl survey sampling area and number of hauls 2017. Note that hauls in HRV stratum have been removed from the analyses.

Stratum	**Total surface (km^2)**	**Trawlable surface (km^2)**	**Swept area (km^2)**	**Number of hauls**
1	11512		1.343	38
2	8410		0.55	16
3	22466		0.36	10
HRV	6000		0.09	6

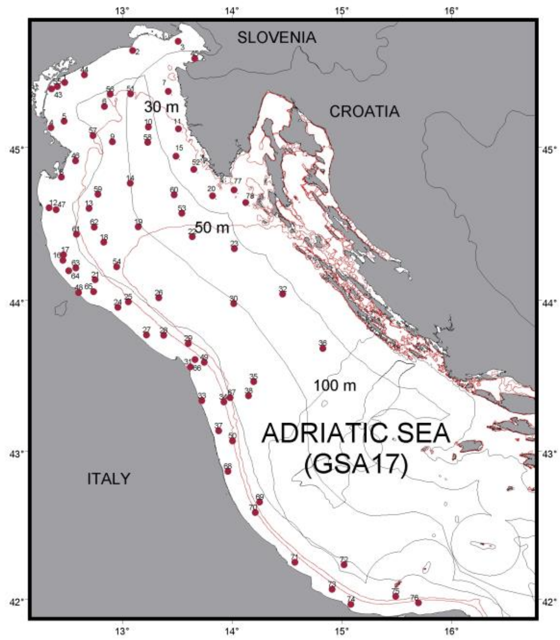

Figure 5 – Solemon map of hauls positions in 2017

Table 4.1-4 Trawl survey abundance and biomass results

Years	kg per km²	St Dev	Relative * biomass All age groups	CV or other	N per km²	St Dev	Relative * abundance All age groups	CV or other
2005	28.44	6.21			329.78	129.7		
2006	62.62	11.44			619.57	91		
2007	92.7	16.75			523.36	98.57		
2008	39.67	6.19			309.78	51.39		
2009	38.23	6.26			222.89	32.44		
2010	16.85	3			104.9	18.52		
2011	26.46	4.4			154.12	31.62		
2012	48.57	9.96			302.82	61.58		
2013	31.35	5.85			248.86	51.73		
2014	62.76	11.22			361.34	60.42		
2015	31.38	5.57			252.9	49.97		
2016	38.53	5.6			287.94	51.14		
2017	25.67	5.51			205.26	47.04		

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

Slicing method

No slicing method was used in the present assessment

Table 4.1-5 Trawl surveys; recruitment analysis summary

Survey	**SoleMon**	**Trawler/RV**	**Dallaporta**
Survey season		Fall	
Cod –end mesh size as opening in mm		46	
Investigated depth range (m)		0-120	
Recruitment season and peak (months)		September-October-November	
Age at fishing-grounds recruitment		0	
Length at fishing-grounds recruitment		7	

Table 4.1-6 Trawl surveys; recruitment analysis results

Years	**Area in km^2**	**N of recruit per km^2**	**St DEv**
2005		47.71	14.07
2006		224.91	32.41
2007		69.93	16.26
2008		104.37	23.21
2009		37.98	7.65
2010		17.34	4.65
2011		20.17	4.14
2012		64.86	14.37
2013		72.49	20.85
2014		61.37	12.08
2015		53.01	14.32
2016		86.26	23.68

2017		51.17	13.38

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 (0-8 cm; Fig. 6)

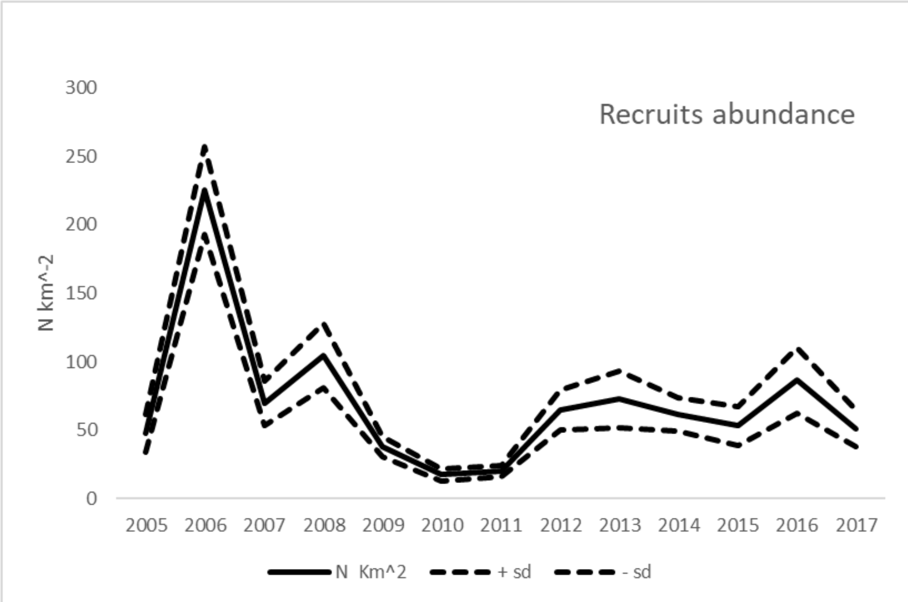

Figure 6 – Abundance indices (± s.d.) of cuttlefish recruits obtained from SoleMon surveys.

Direct methods: trawl based Spawner analysis

Table 4.1-7 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 4.1-8 Trawl surveys; spawners analysis results

Surveys	Area in km^2	N (N of individuals) of spawners per km^2	St Dev	SSB per km^2	St Dev	Relative SSB	CV or other
2005		49.21	13.75	0.39	0.32		
2006		165.92	38	0	0		

Surveys	Area in km²	N (N of individuals) of spawners per km²	St Dev	SSB per km²	St Dev	Relative SSB	CV or other
2007		295.27	60.91	1.82	1.47		
2008		118.39	21.65	11.81	6.15		
2009		132.38	20.47	0	0		
2010		57.92	10.17	2.38	0.95		
2011		99.5	20.1	8.23	3.35		
2012		144.9	31.58	31.15	6.34		
2013		97.31	18.69	18.49	3.37		
2014		209.16	35.61	49.57	10.49		
2015		93.72	16.69	18.86	3.38		
2016		110.43	15.11	25.07	3.8		
2017		69.82	14.55	14.94	2.98		

The spawners aggregates in the north sector of the sub-basin mainly in front of the Istria peninsula, the trend of spawners abundance are showed in figure 7 (> 10 cm).

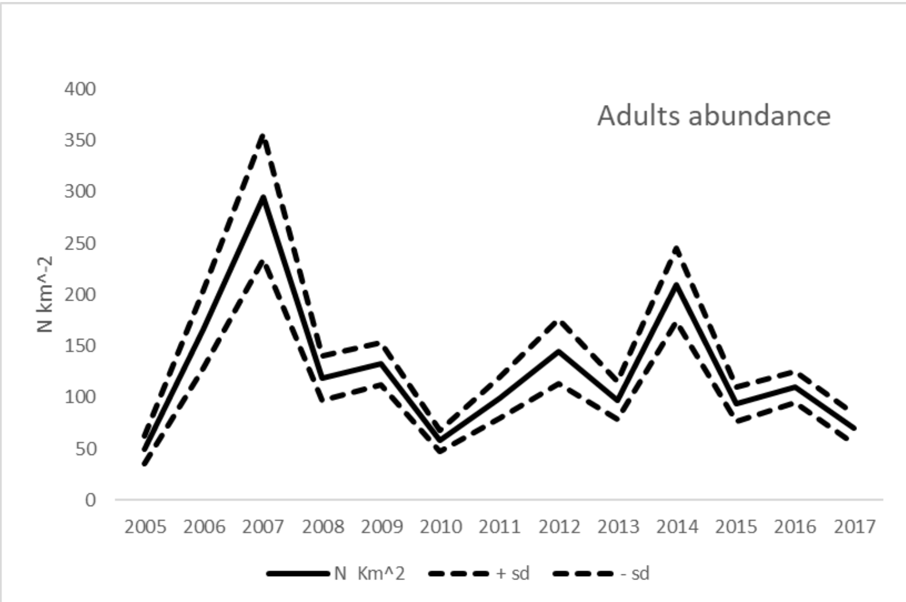

Figure 7 – Abundance indices (± s.d.) of cuttlefish adults obtained from SoleMon surveys.

4.1.1 Spatial distribution of the resources

According to data collected during SoleMon surveys (ADRIAMED, 2011), cuttlefish aggregates in the northern sector of GSA 17 (Figure 8).

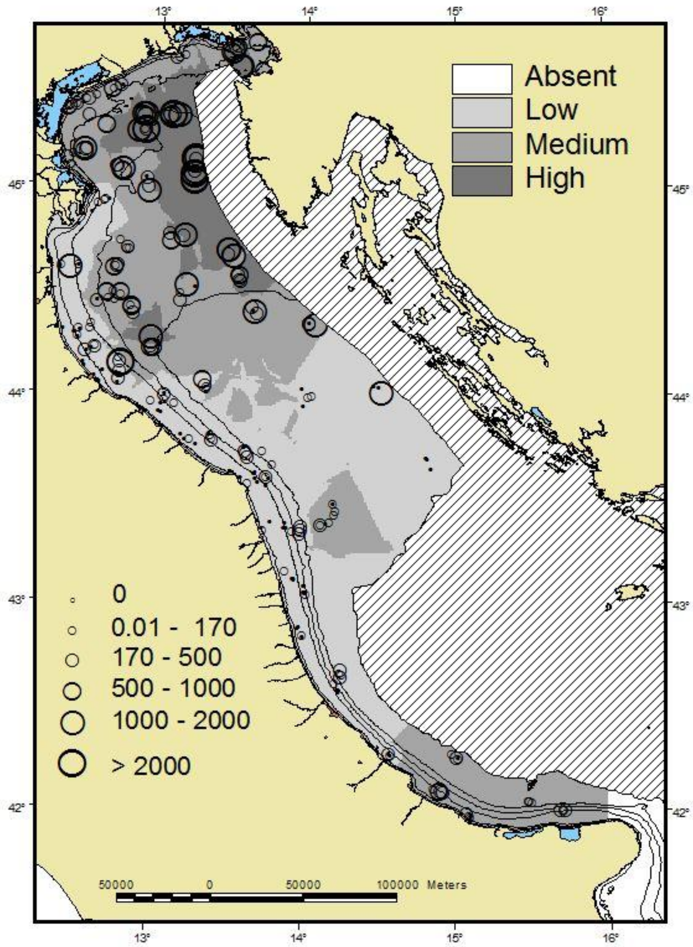

Figure 8 – Maps distribution of cuttlefish in GSA 17 (bubbles: N km^{-2}).

4.1.2 Historical trends

The SoleMon trawl surveys provided data either on cuttlefish total abundance and biomass as well as on important biological events (recruitment, spawning). Figure 9 shows the biomass indices of cuttlefish obtained from 2005 to 2017.

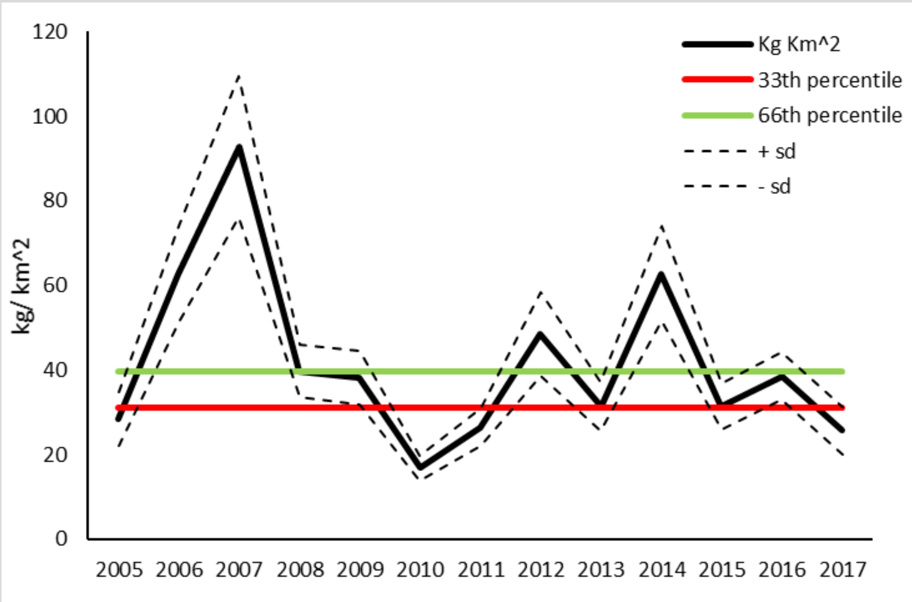

Figure 9 – Biomass indices (± s.d.) of cuttlefish obtained from SoleMon surveys.

Figures 10 and 11 displays the stratified abundance indices obtained in the GSA 17 in the years 2005-2017.

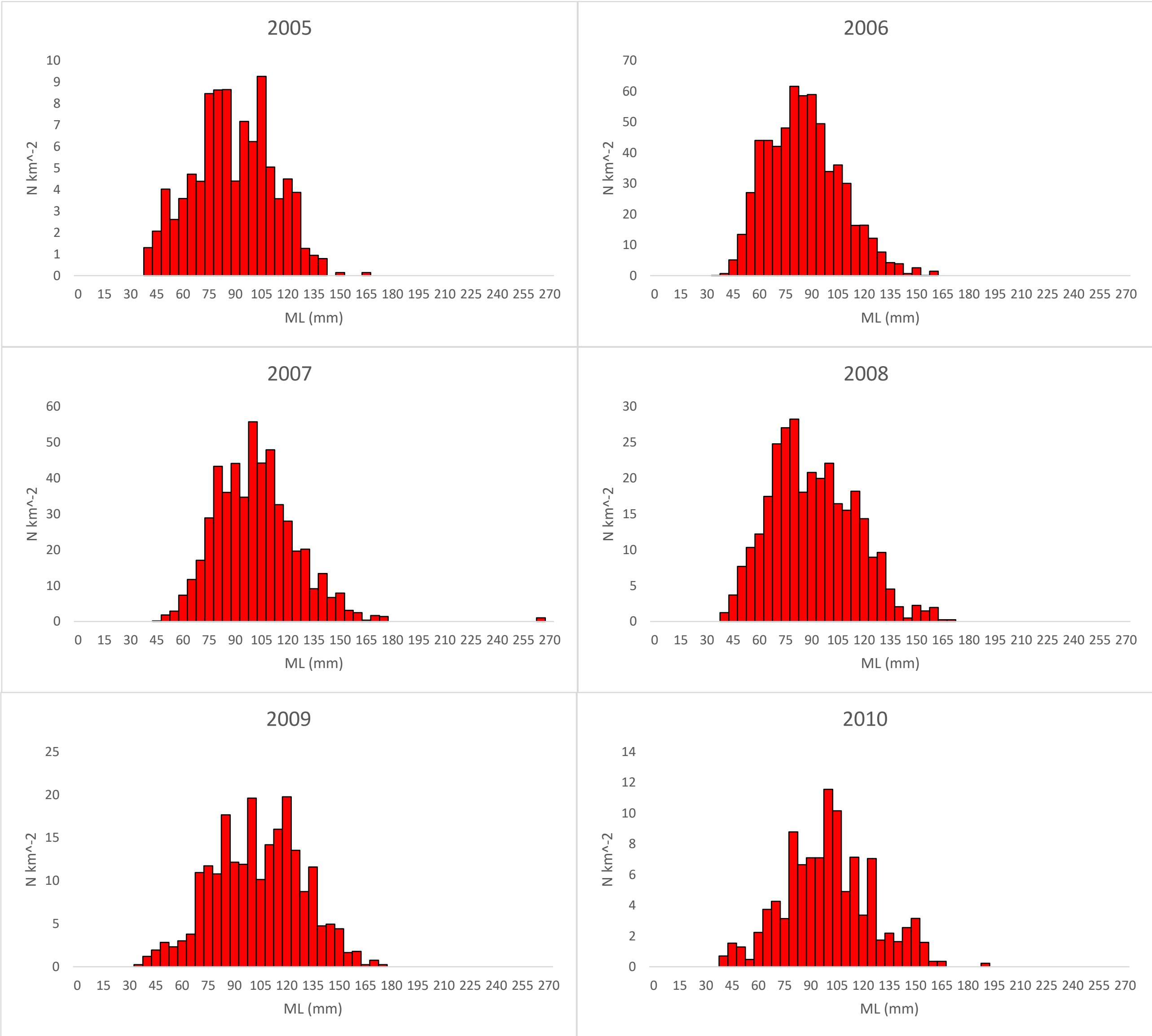

Figure 10 – Stratified abundance indices by size, 2005-2010.

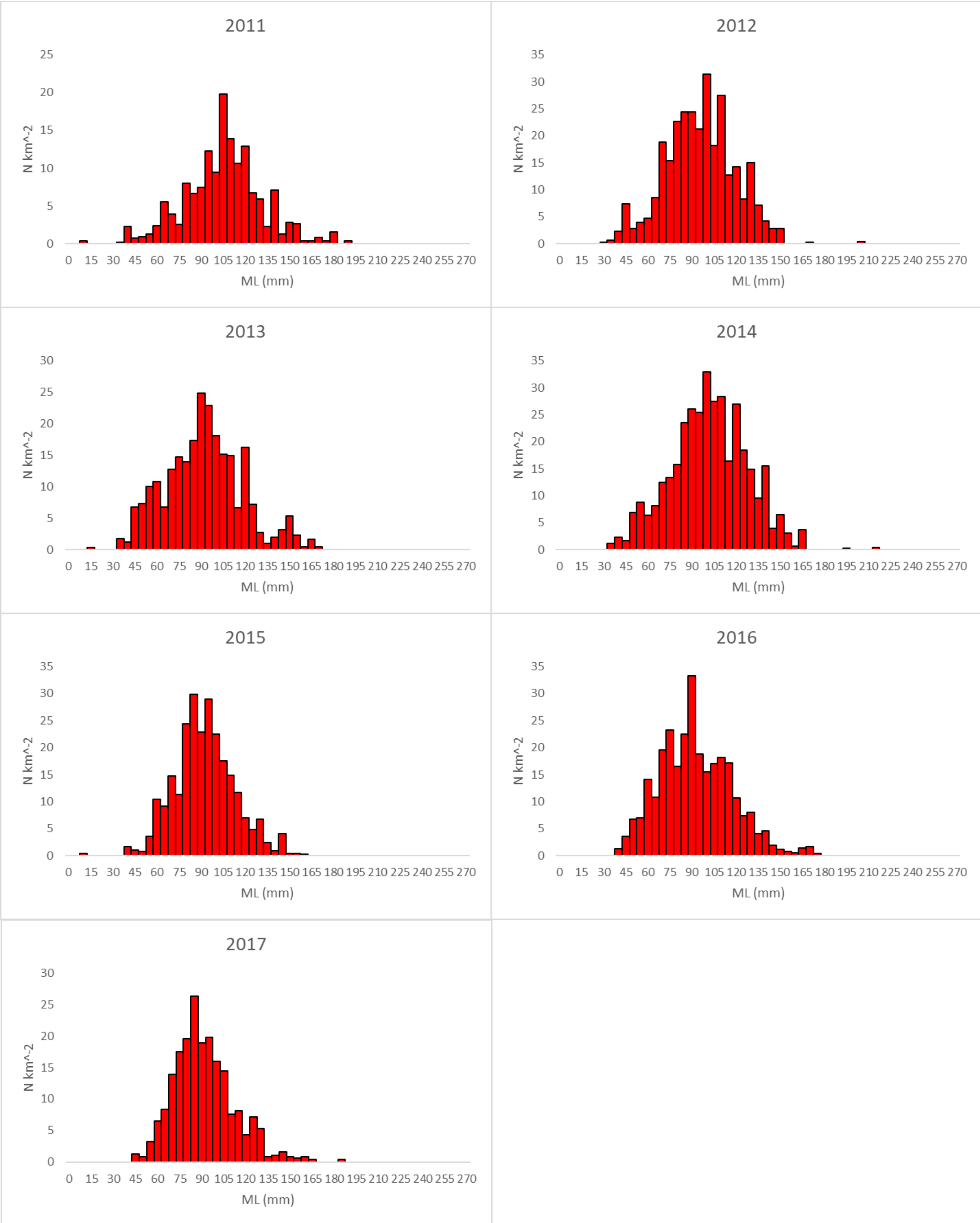

Figure 11 – Stratified abundance indices by size, 2011-2017.

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.

Table 5.1-1 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		
Aphrodite aculeata	0.096	4.706
Glycera spp	0.001	0.006
Polychaeta	0.248	0.027
Cnidaria		
Alcyonum spp		0.112
Calliactis parasitica	0.002	0.033
Unidentified anemone	0.019	0.600
Unidentified colonial hydroid		0.065
Virgularia mirabilis	0.018	3.405
Crustacea		
Alpheus glaber	0.002	0.001
Corystes cassivelaunus	0.023	
Goneplax rhomboides	10.385	16.042
Inachus comunissimus	0.030	
Inachus phalangium	1.979	0.004
Inachus spp	0.531	0.002
Liocarcinus depurator	8.292	178.664
Liocarcinus vernalis	9.168	0.609
Lysmata seticaudata		0.019
Medorippe lanata	4.375	2.979
Melicertus kerathurus	0.208	0.213
Nephrops norvegicus	0.006	0.044
Pagurus excavatus	0.019	0.045
Pagurus spp	0.364	0.299
Parapenaeus longirostris		0.154
Parthenope angulifrons	0.755	
Pilumnus hirtellus	0.033	
Squilla mantis	5.197	0.397
Echinodermata		
Astropecten irregularis	28.562	8.210
Holothuroidea	0.135	1.771
Marthasterias glacialis	0.174	4.511
Ophiura ophiura	2.592	
Schizaster canaliferus	0.413	0.020
Spatangoida	0.033	
Trachythyone elongata	0.238	2.194
Trachythyone spp	0.022	0.368
Trachythyone tergestina	0.125	3.270
Mollusca		
Acanthocardia paucicostata	0.238	0.072
Acanthocardia tubercolata	0.307	0.146
Aequipecten opercularis	0.136	
Alloteuthis media	0.025	0.003
Antalis dentalis	0.047	
Antalis inaequicostata	0.639	0.001
Antalis spp	0.168	
Aporrhais pespelecani	299.666	6.160
Atrina pectinata	0.190	0.909
Bolinus brandaris	11.135	0.625
Calliostoma spp	0.008	0.310
Cassidaria echinophora		0.784
Chamelea gallina	0.183	
Chlamys varia	0.082	0.004
Corbula gibba	43.145	0.030

Flexopecten glaber glaber	1.389	0.007
Glossus humanus		0.710
Hexaplex trunculus	0.712	0.089
Illex coindetii	0.012	0.004
Mytilus galloprovincialis	2.774	0.907
Nassarius lima	0.068	0.010
Nassarius mutabilis	0.577	0.002
Nassarius reticulatus	0.748	0.001
Naticarius hebraea	0.025	
Naticarius stercusmuscarum	2.219	
Neverita josephinia	0.030	
Nucula nitidosa	0.002	0.004
Nucula nucleus	0.006	0.021
Nucula sulcata	0.003	0.203
Ostrea edulis	94.311	3.043
Pectinidae	0.112	0.060
Polinices nitida	0.001	
Scapharca demiri	30.051	0.009
Scapharca inaequivalvis	137.864	0.290
Scaphodopa	0.077	
Sepia elegans	0.026	0.122
Sepia officinalis	0.465	0.367
Solecurtus strigilatus	0.217	
Turritella communis	0.808	2.758
Unidentified nudibrancs	0.553	
Venerupis aurea	2.552	
Osteichthyes		
Arnoglossus laterna	0.820	1.101
Blennius ocellaris		0.152
Boops boops	0.291	0.033
Buglossidium luteum	0.150	0.110
Cepola macrophthalma		0.487
Chelidonichthys lucernus	3.727	1.214
Citharus linguatula	0.005	0.083
Diplodus annularis	0.130	
Engraulis encrasicolus	0.032	0.019
Eutrigla gurnardus	0.002	0.239
Gobius niger	1.114	0.675
Lesueurigobius friesii	0.005	0.048
Merluccius merluccius	0.129	0.256
Mullus barbatus barbatus	0.234	0.095
Pagellus erythrinus	0.150	0.104
Sardina pilchardus	0.039	0.046
Sardinella aurita	1.081	0.635
Scorpaena notata	0.005	0.239
Serranus hepatus	0.010	0.200
Solea solea	0.128	0.004
Spicara maena	0.058	0.046
Spicara smaris		0.017
Trachurus mediterraneus	0.051	0.007
Porifera		
Unidentified sponge	0.017	0.376
Tunicata		
Ascidiacea		0.189

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

6 Stock Assessment

6.1 C-MSY

6.1.1 Model assumptions

CMSY (Froese et al., 2016) is a Monte-Carlo method that estimates fisheries reference points (MSY, Fmsy, Bmsy) as well as relative stock size (B/Bmsy) and exploitation (F/Fmsy) from catch data and broad priors for resilience or productivity (r) and for stock status (B/k) at the beginning and the end of the time series. Probable ranges for the maximum intrinsic rate of population increase (r) and for unexploited population size or carrying capacity (k) are filtered with a Monte Carlo approach to detect 'viable' r-k pairs. Part of the CMSY package is an advanced Bayesian state-space implementation of the Schaefer surplus production model (BSM). The main advantage of BSM compared to other implementations of surplus production models is the focus on informative priors and the acceptance of short and incomplete (= fragmented) abundance data.

The CMSY version referred in the present assessemnt (CMSY_O_7q.R, available at http://oceanrep.geomar.de/33076/) is newer than the one used in Froese et al. (2016). The main differences are faster execution because of parallel processing and more emphasis on management than on evaluating CMSY. In addition, estimation of priors has been improved and some labels in the input files have changed, as indicated below.

Table 10 reports a set of questions that can help to set the CMSY input parameters. Please note that priors can also be derived with other stock assessment tools, such as length frequency analysis or catch per unit of effort.

Table 6.1.1-1 Example of questions to be put to experts to establish priors for CMSY analysis.

Prior	Question to experts
Start year for catch time series	From what year onward are catch data deemed reliable?
Relative start and end biomass B/B_0	What is the most likely stock status for the beginning and end of the time series: lightly fished, fully exploited, or overfished?
Relative intermediate biomass B/B_0	Is there an intermediate year where biomass is considered to have been particular low or high, e.g., exploitation changed from light to full, or where an extraordinary large year class entered the fishery?
Resilience prior r	What is your best guess for the range of values including natural mortality of adults (M)? Consider the empirical relationship $r \approx 2\ M$
Resilience prior r	What is your best guess for the range of values including maximum sustainable fishing mortality (F_{msy})? Considering the relationship $r \approx 2\ F_{msy}$ *Use this question to reinforce or change the answer to previous question*

Alternatively, it is possible to get preliminary estimates of r from the following empirical relations:

$$r \approx 2\ M \approx 2\ Fmsy \approx 3\ K \approx 3.3/tgen \approx 9/tmax$$

where r is the intrinsic rate of population increase, M is the rate of natural mortality, Fmsy is the maximum sustainable fishing mortality, K is the somatic growth rate (from the von Bertalanffy growth equation), tgen is generation time, and tmax is maximum age. If point estimates are very close to each other, assume a range of uncertainty of +/- 50%. Give more weight to traits giving low estimates of r, as these will act as bottle neck for population growth. Consider that low annual fecundity (<100) will further reduce r. This is already considered in prior r estimates available from FishBase.

Table 11 suggests ranges for relative biomass to be used as input parameters, depending on the depletion status of the stock.

Very strong depletion	Strong depletion	Medium depletion	Low depletion
0.01 – 0.2	0.01 – 0.4	0.2 – 0.6	0.4 – 0.8

Table 6.1.1-2 Prior ranges for parameter r, based on classification of resilience.

Resilience	prior *r* range
High	0.6 – 1.5
Medium	0.2 – 0.8
Low	0.05 – 0.5
Very low	0.015 – 0.1

When setting an intermediate biomass, it often improves the CMSY analysis if the end of a period with low biomass is indicated by setting the intermediate year to the last year with low biomass, and indicating a respective relative range, e.g. as 0.01 – 0.3. Similarly, indicate a period of large biomass by setting the intermediate year to the last year with high biomass and indicate a respective range, e.g. as 0.4 – 0.8. In general, the width of relative biomass windows should not be less than 0.4, unless the stock is known to be very strongly depleted, in which case ranges of 0.01-0.3 or 0.01 – 0.2 are appropriate. Setting a range of 0 to 1 is also possible, and would indicate no information at all about stock status, which is, however, unlikely. If a stock is fished it must be smaller than 1. If it is delivering decent catches, it must be larger than 0.01. See Table 10 for guidance on how to get priors from interviews with fishers or experts (or yourself).

6.1.2 Scripts

```
library(R2jags)  # Interface with JAGS
library(coda)
library("parallel")
library("foreach")
library("doParallel")
library("gplots")
# Some general settings
# set.seed(999) # use for comparing results between runs
rm(list=ls(all=TRUE)) # clear previous variables etc
options(digits=3) # displays all numbers with three significant digits as default
graphics.off() # close graphics windows from previous sessions
FullSchaefer <- F    # initialize variable; automatically set to TRUE if enough abundance data are available
n.chains     <- ifelse(detectCores() > 2,3,2) # set 3 chains in JAGS if more than 2 cores are available
ncores_for_computation=detectCores() # cores to be used for parallel processing of CMSY
cl           <- makeCluster(ncores_for_computation)
registerDoParallel(cl, cores = ncores_for_computation)
```

6.1.3 Input data and Parameters

Italian data are available for the time series 1972-2007 from ISTAT and IREPA statistics, while Croatian and Slovenia data are available from FAO-FISTATJ database for years respectively from 2005-2011 and 1992-2007. DCF data were used in the remaing periods (Fig. 12).

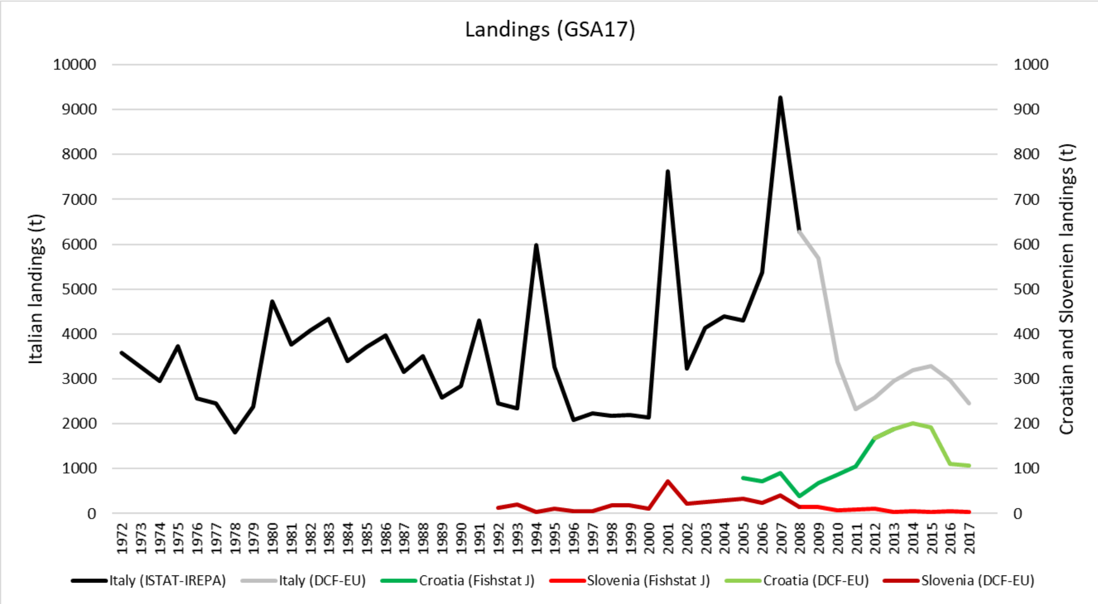

Figure 12 – Landings data in tons and their sources used in C-MSY model.

Biomass data were provided by SoleMon surveys, carried out in fall for the years 2005-2017.

CMSY was run using the following settings:

Table 6.1.3-1 Model settings

Species	Min of year / Start year	Max of year / End year	Resilience	Stb.low	Stb.hi	Int.yr	Intb.low	Intb.hi	Endb.low	Endb.hi	btype
Common cuttlefish	1972	2017	High	0.2	0.6	NA	NA	NA	0.1	0.4	CPUE

The resilience has been set as high taking into account the high spawning potential of this species as well as the fast somatic growth.

The prior for the relative biomass (B/k) range has been set as medium depletion (0.2-0.6) at the begin of the series, taking into account the high population density observed in the eighties in the central and northern Adriatic along the Italian coast in the biocenosis of *Turritella communis* by Casali et al. (1998). Conversely, the relative biomass (B/k) range at the end of the catch time series has been set between strong and strong-to-medium depletion (0.1-0.4) taking into account both the decrease of catches from year 2007 onward and the trend observed in SoleMon survey from 2005 to 2017.

In the following box is reported the screen output of the final run of CMSY for cuttlefish in GSA 17.

```
Species: Sepia officinalis , stock: Sepi_off_AD
 Cuttlefish in Adriatic Sea
 Source: NA
 Region: Mediterranean , Adriatic Sea
 Catch data used from years 1972 - 2017 , abundance = CPUE
 Prior initial relative biomass = 0.2 - 0.6 expert
 Prior intermediate rel. biomass= 0.5 - 0.9 in year 2008 default
 Prior final relative biomass   = 0.1 - 0.4 expert
 Prior range for r = 0.6 - 1.5 default , prior range for k  = 4.78 - 47.8
 Prior range of q = 0.00609 - 0.0193

 Results of CMSY analysis with altogether 2085 viable trajectories for 981 r-k pairs
 r = 1.19 , 95% CL = 0.948 - 1.48 , k = 16.8 , 95% CL = 12.7 - 22.2
 MSY = 4.97 , 95% CL = 4.41 - 5.61
 Relative biomass last year = 0.309 k, 2.5th = 0.116 , 97.5th = 0.396
 Exploitation F/(r/2) in last year = 0.835

 Results from Bayesian Schaefer model using catch & CPUE
 r = 0.953 , 95% CL = 0.817 - 1.11 , k = 19.8 , 95% CL = 17.3 - 22.5
 MSY = 4.71 , 95% CL = 4.35 - 5.09
 Relative biomass in last year = 0.323 k, 2.5th perc = 0.175 , 97.5th perc = 0.465
 Exploitation F/(r/2) in last year = 0.842
 q = 0.00772 , lcl = 0.00594 , ucl = 0.01

 Results for Management (based on BSM analysis)
 Fmsy = 0.476 , 95% CL = 0.409 - 0.556 (if B > 1/2 Bmsy then Fmsy = 0.5 r)
 Fmsy = 0.476 , 95% CL = 0.409 - 0.556 (r and Fmsy are linearly reduced if B < 1/2 Bmsy)
 MSY  = 4.71 ,  95% CL = 4.35 - 5.09
 Bmsy = 9.88 ,  95% CL = 8.67 - 11.3
 Biomass in last year  = 6.38 , 2.5th perc = 3.45 , 97.5 perc = 9.2
 B/Bmsy in last year   = 0.646 , 2.5th perc = 0.349 , 97.5 perc = 0.931
 Fishing mortality in last year = 0.401 , 2.5th perc = 0.279 , 97.5 perc = 0.742
 F/Fmsy  = 0.842 , 2.5th perc = 0.585 , 97.5 perc = 1.56
 Comment: NA
 ----------------------------------------------------------
```

Figure 13 shows assessments for cuttlefish in GSA 17. Panel A shows in black the time series of catches and in blue the three-years moving average with indication of highest and lowest catch, as used in the estimation of prior biomass by the default rules. Panel B shows the explored r-k log space and in dark grey the r-k pairs which were found by the CMSY model to be compatible with the catches and the prior information. Panel C shows the most probable r-k pair and its approximate 95% confidence limits in blue. The black dots are possible r-k pairs found by the BSM model, with a red cross indicating the most probable r-k pair and its 95% confidence limits. Panel D shows the available abundance data in red, scaled to the BSM estimate of Bmsy = 0.5 k, and in blue the biomass trajectory estimated by CMSY. Dotted lines indicate the 2.5th and 97.5th percentiles. Vertical blue lines indicate the prior biomass ranges. Panel E shows in red the harvest rate (catch/abundance) scaled to the r/2 estimate of BSM, and in blue the corresponding harvest rate from CMSY. Panel F shows the Schaefer equilibrium curve of catch/MSY relative to B/k, here indented at B/k < 0.25 to account for reduced recruitment at low stock sizes. The red dots are scaled by BSM estimates and the blue dots are scaled by CMSY estimates.

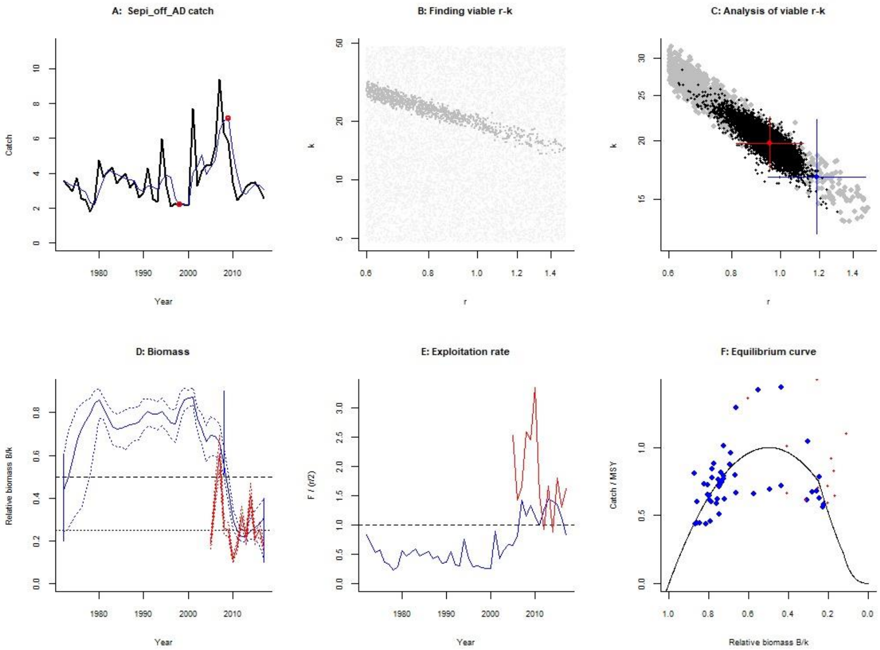

Figure 13 Diagnostics results of final C-MSY run.

Figure 14 shows the graphs meant to inform management. The upper left panel shows catches relative to the BSM estimate of MSY, with indication of 95% confidence limits in grey. The upper right panel shows the development of relative total biomass (B/Bmsy), with the grey area indicating uncertainty. The lower left graph shows relative exploitation (F/Fmsy), with Fmsy corrected for reduced recruitment below 0.5 Bmsy. The lower-right panel shows the trajectory of relative stock size (B/Bmsy) over relative exploitation (F/Fmsy).

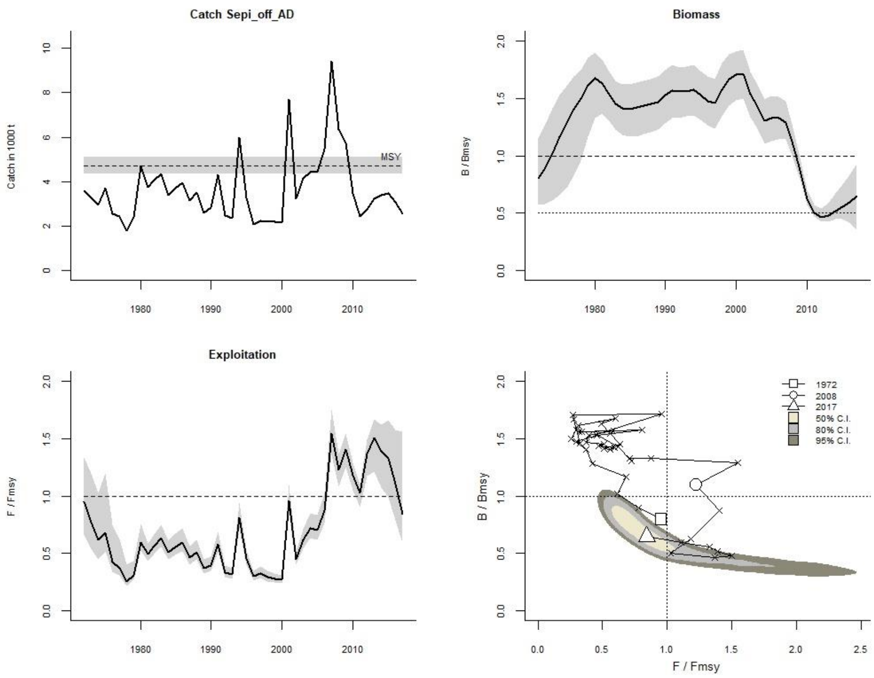

Figure 14 – Results of final C-MSY run.

6.1.4 Model results

Table 6.1.4-1 Summary table of model results

$F_{current}$ (2017)	0.401
Lower limit (95% c.i.)	0.279
Upper limit (95% c.i.)	0.742
F_{msy} (2017)	0.476 (±0.07)
$F_{current}/F_{msy}$	0.842
Lower limit F_{curr}/F_{msy} (95% c.i.)	0.585
Upper limit F_{curr}/F_{msy} (95% c.i.)	1.56
Current Biomass (thousand tonnes)	6.38
Lower limit biomass (95% c.i.)	3.45
Upper limit (95% c.i.)	9.2
B_{msy}	9.88 (±1.3)
Current Biomass / B_{msy}	0.646
L. limit Current Biomass/B_{msy}(95% c.i.)	0.349
U.limit Current Biomass/B_{msy}(95% c.i.)	0.931
MSY (thousand tonnes)	4.71 (±0.37)
Catches 2017 (thousand tonnes)	2.56

State of exploitation: Exploitation varied without any trend in the years 1972-2000, followed by an increase until 2007. In the last years, exploitation in term of F/FMSY ratio continued to decrease and in the last two years is below FMSY. However, wide ranges of uncertainties are observed in the last years from under exploitation to overexploitation levels of fishing pressure.

State of the biomass: The biomass showed a stable trend from 1972 to 2002, and decreased in 2003-2013. In the last 4 years, the biomass increased but is still below the BMSY.

Table 6.1.4-2 Summary table of model results

Year	**Recruitment ('000)**	**Upper limit**	**Lower limit**	**Biomass ('000)**	Upper limit	Lower limit	**F_{curr}**	Upper limit	Lower limit
2017				6.38	3.45	9.2	0.401	0.742	0.279

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

A sensitivity analysis was also carried out changing the priors. The initial priors do not have a great impact on the assessment results, while the priors set for the level of relative biomass (B/k) at the end of the series change the output results and the stock diagnosis (Figs. 15-29)

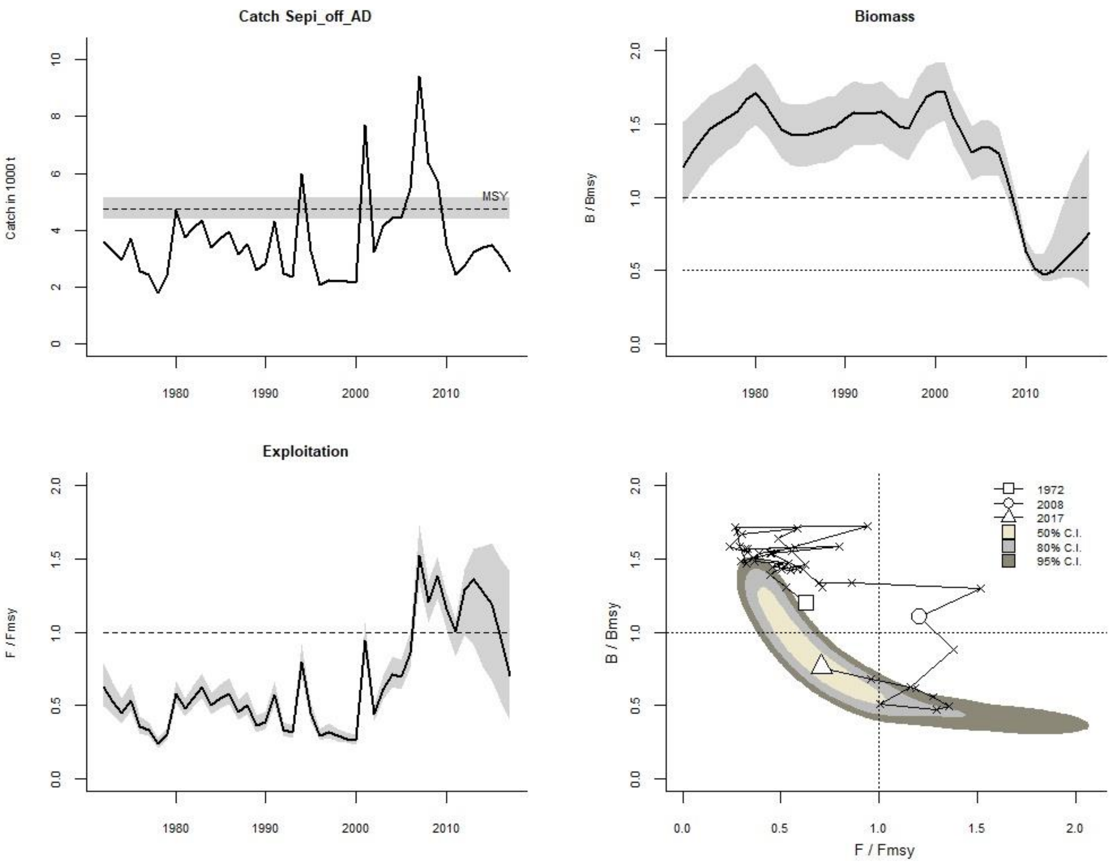

Figure 15 Sensitivity analyses on CMSY model using initial prior as low depletion and final as medium depletion.

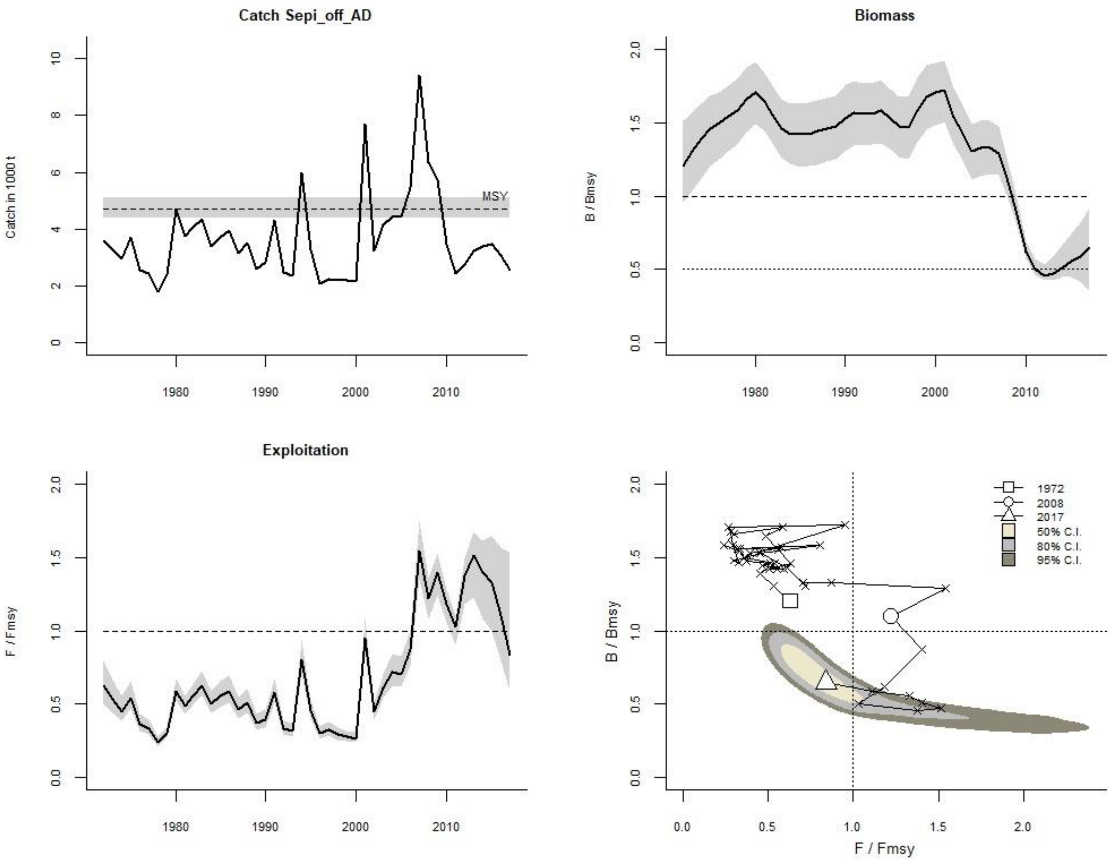

Figure 16 Sensitivity analyses on CMSY model using initial prior as low depletion and final as strong depletion.

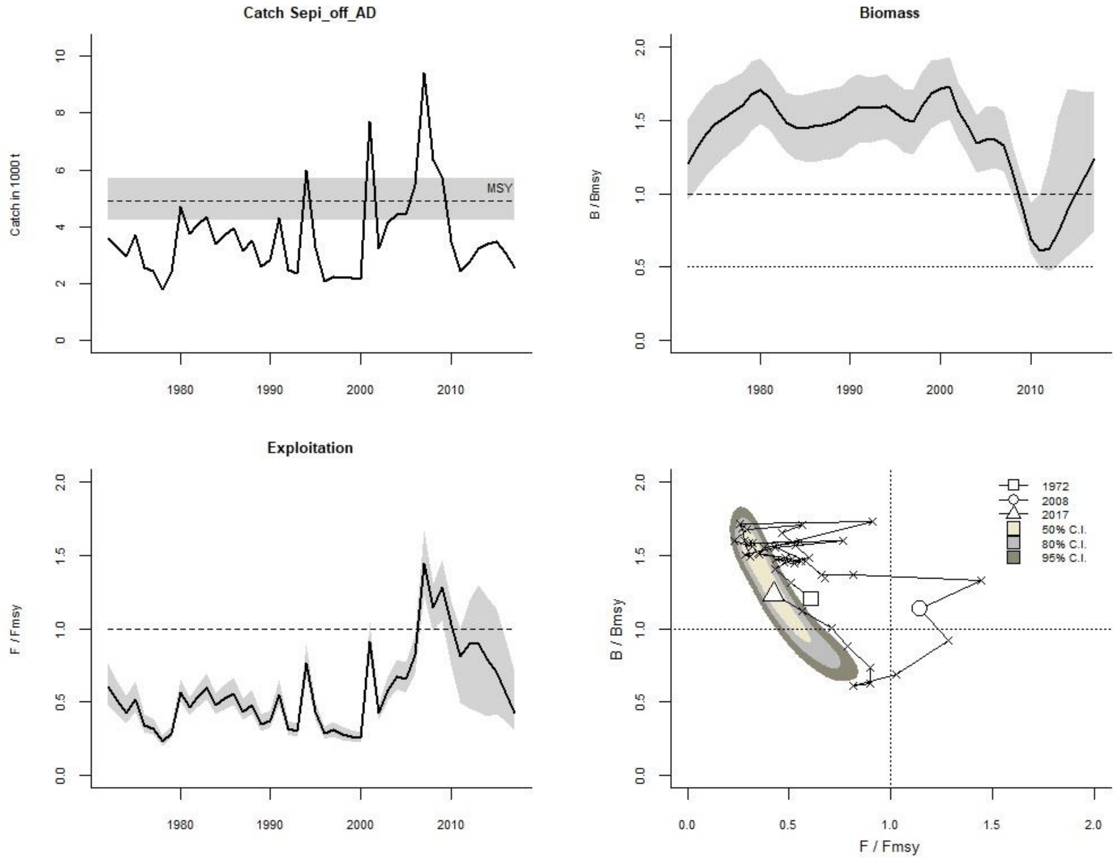

Figure 17 Sensitivity analyses on CMSY model using initial prior as low depletion and final as low depletion.

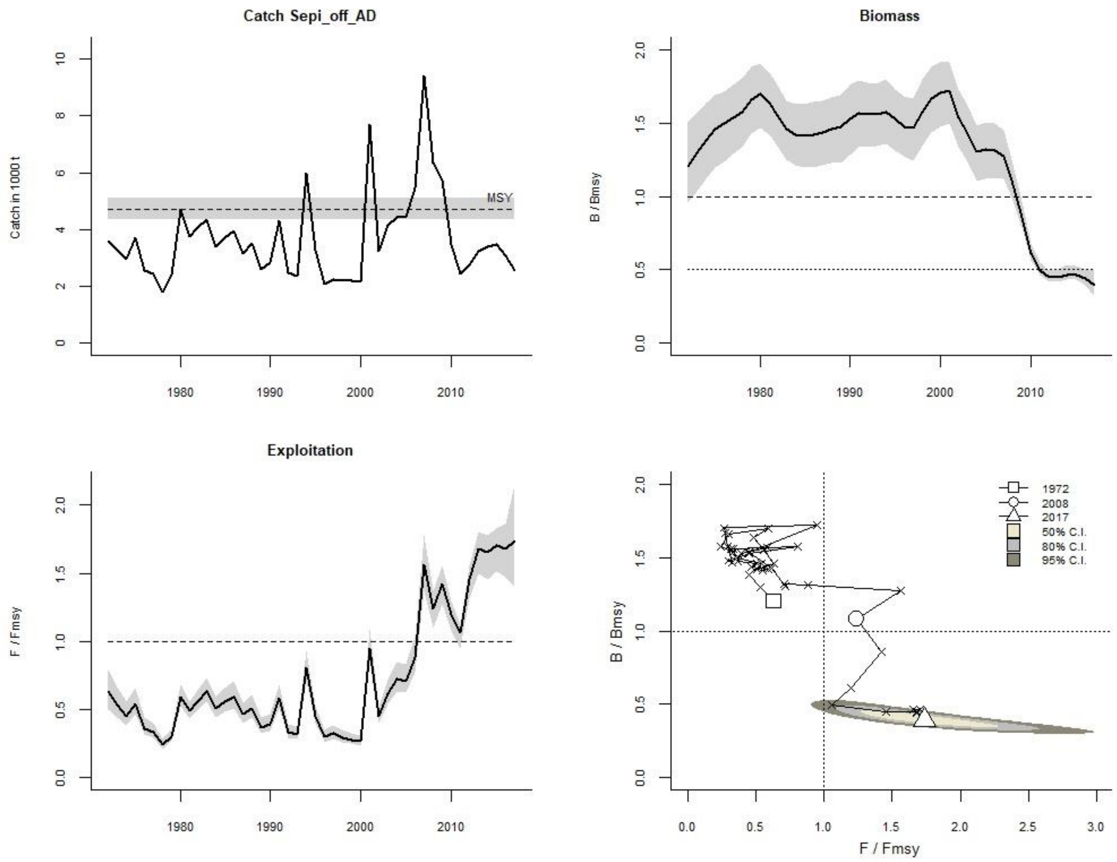

Figure 18 Sensitivity analyses on CMSY model using initial prior as low depletion and final as very strong depletion.

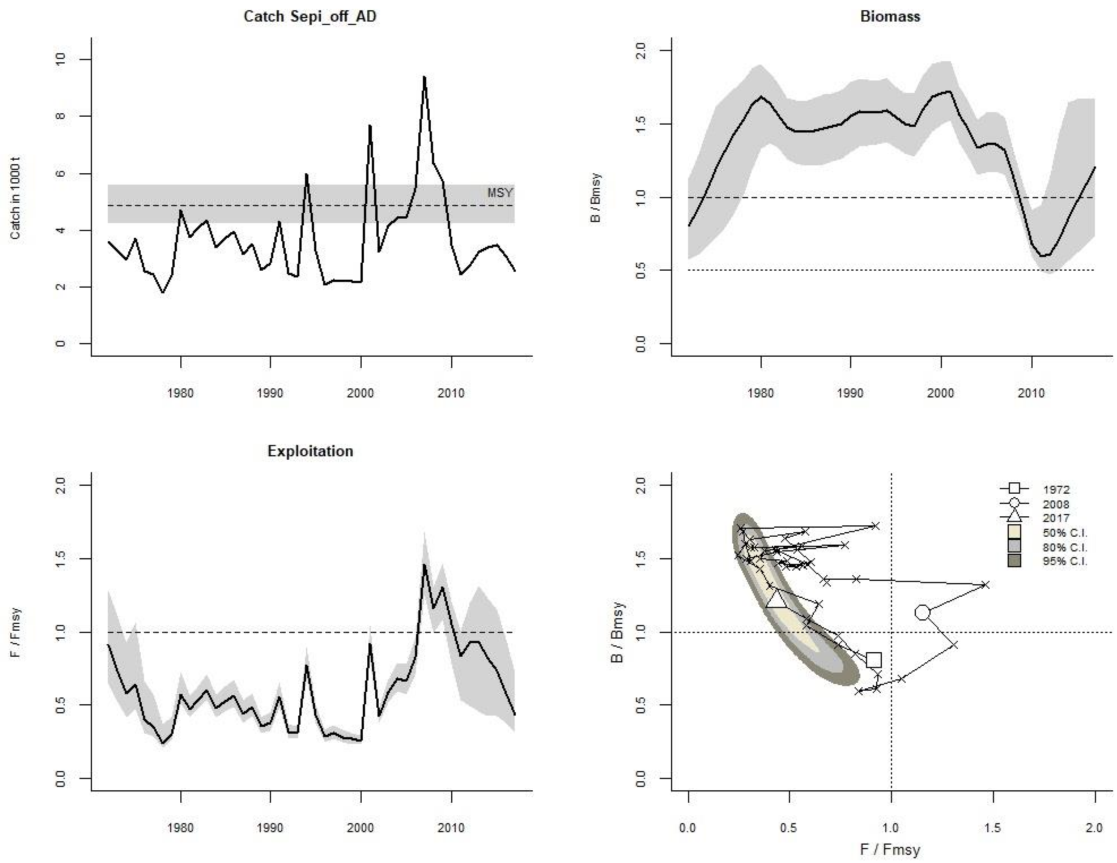

Figure 19 Sensitivity analyses on CMSY model using initial prior as medium depletion and final as low depletion.

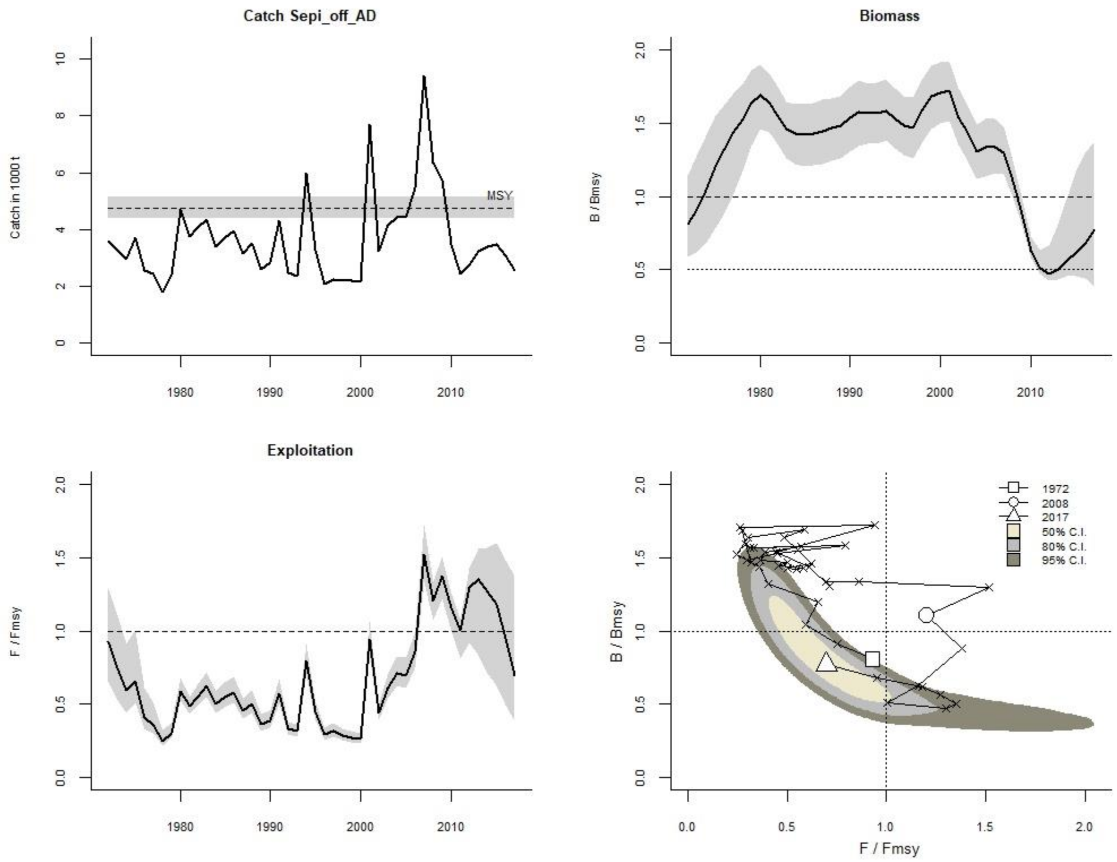

Figure 20 Sensitivity analyses on CMSY model using initial prior as medium depletion and final as medium depletion.

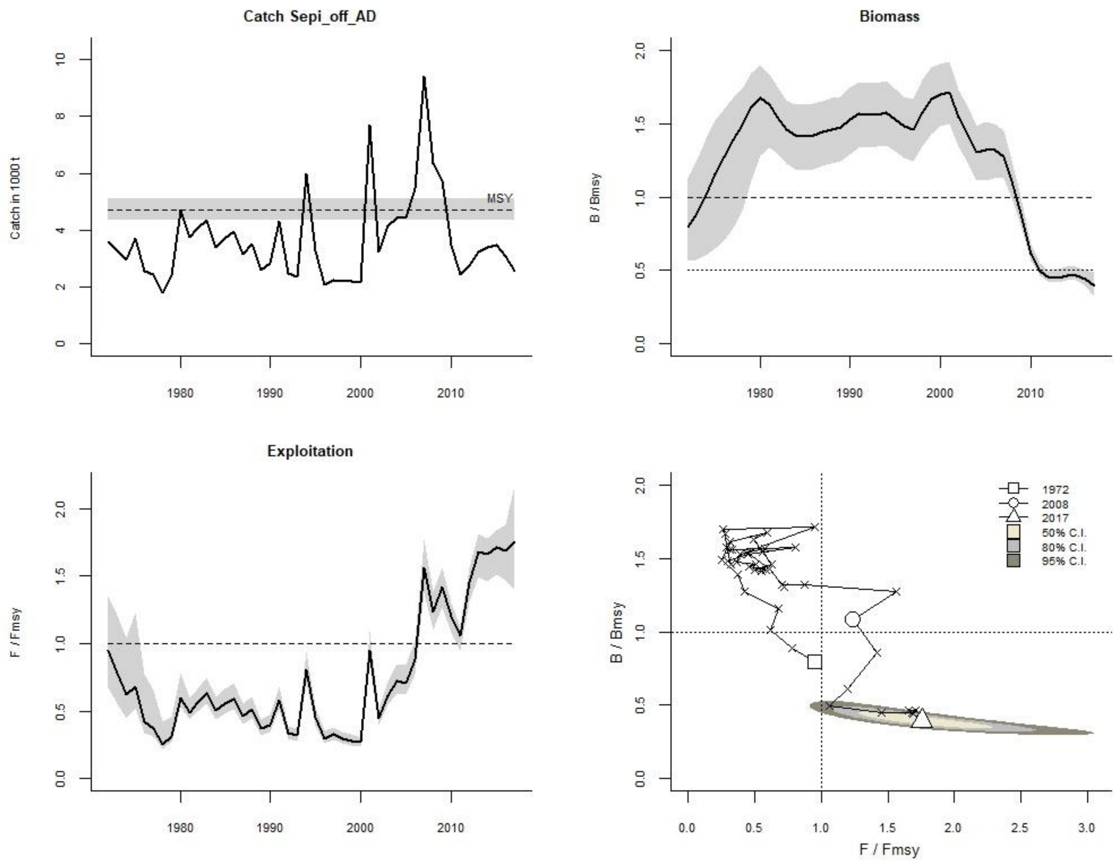

Figure 21 Sensitivity analyses on CMSY model using initial prior as medium depletion and final as very strong depletion.

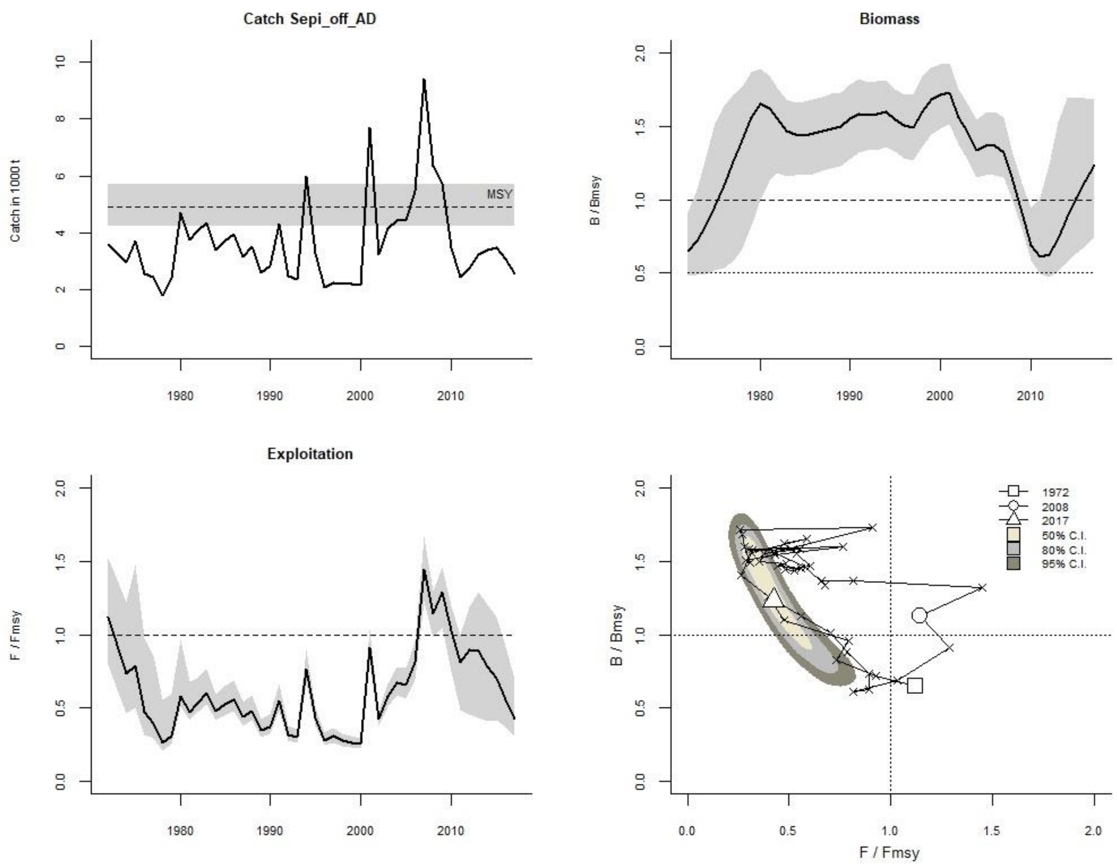

Figure 22 Sensitivity analyses on CMSY model using initial prior as strong depletion and final as low depletion.

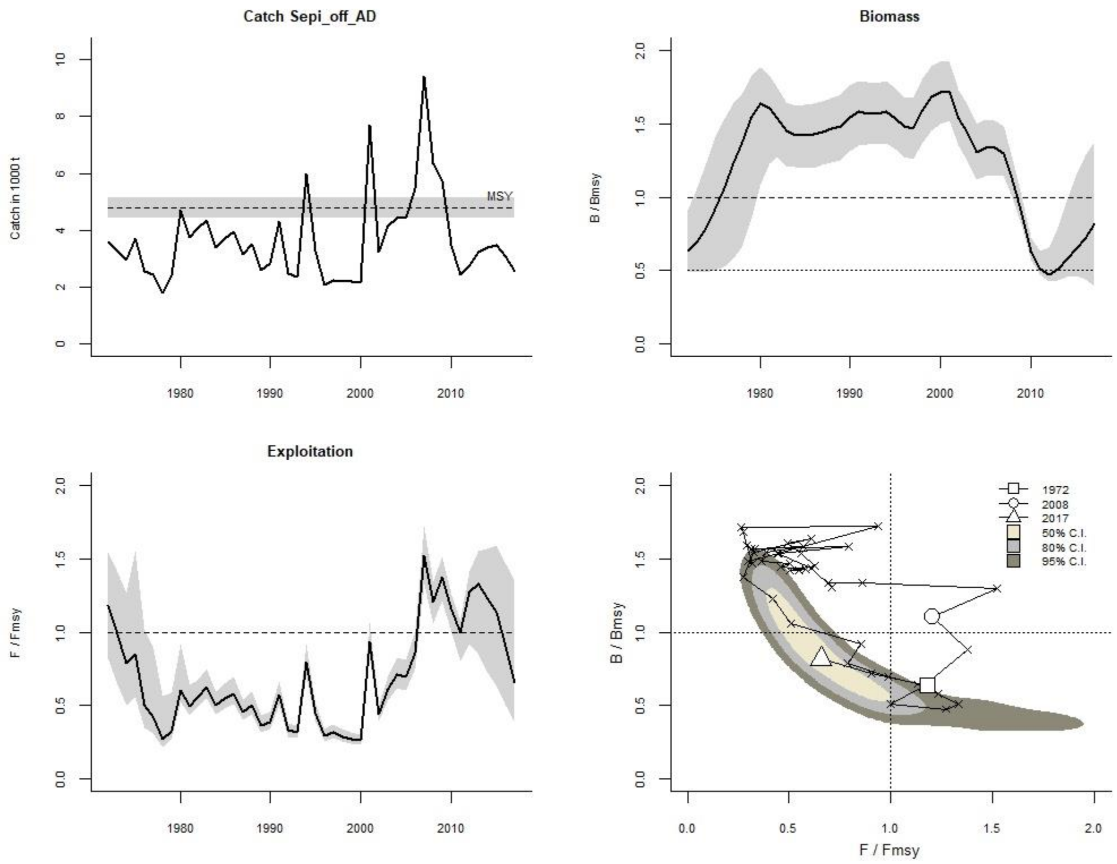

Figure 23 Sensitivity analyses on CMSY model using initial prior as strong depletion and final as medium depletion.

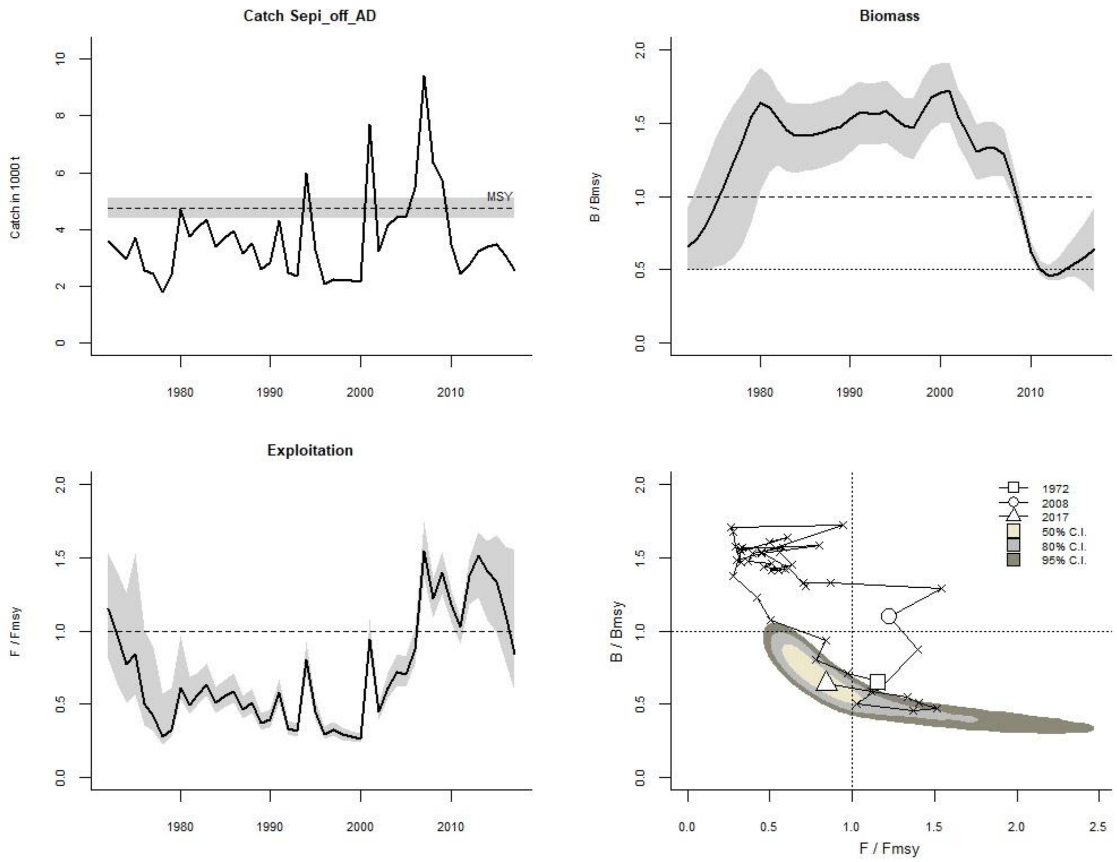

Figure 24 Sensitivity analyses on CMSY model using initial prior as strong depletion and final as strong depletion.

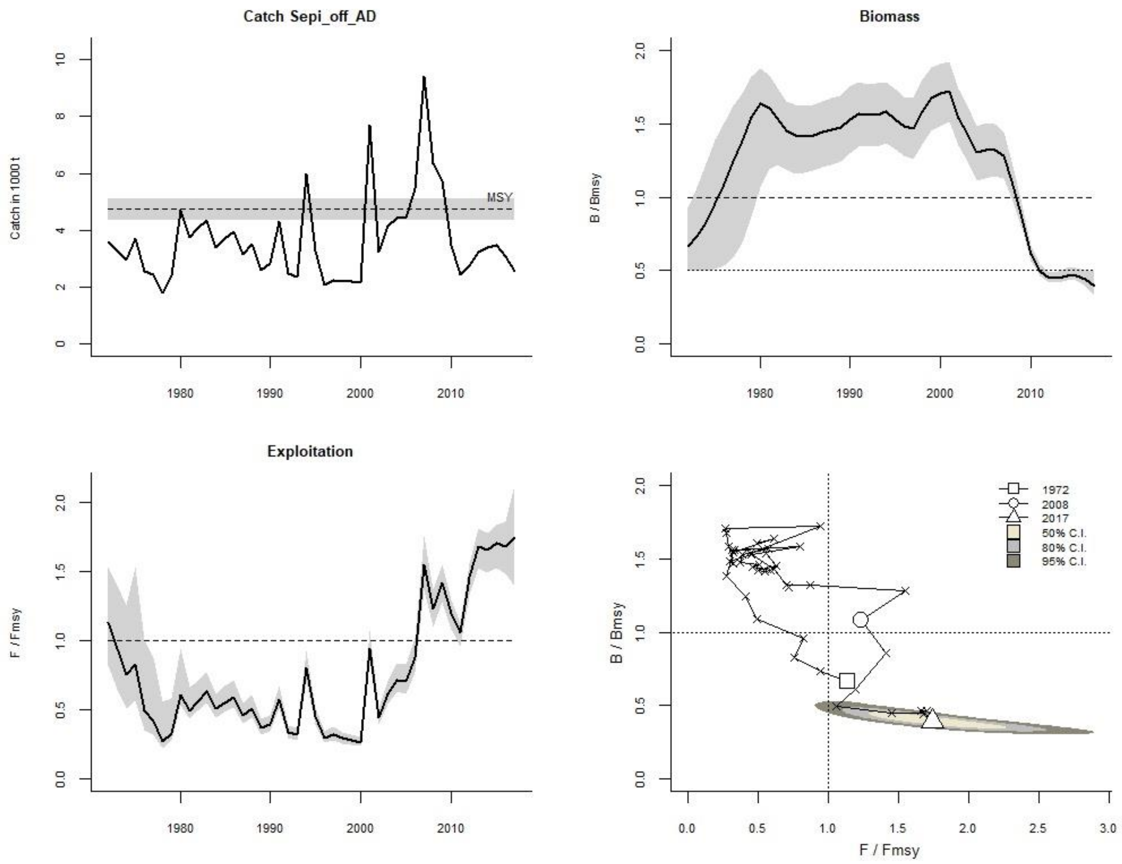

Figure 25 Sensitivity analyses on CMSY model using initial prior as strong depletion and final as very strong depletion.

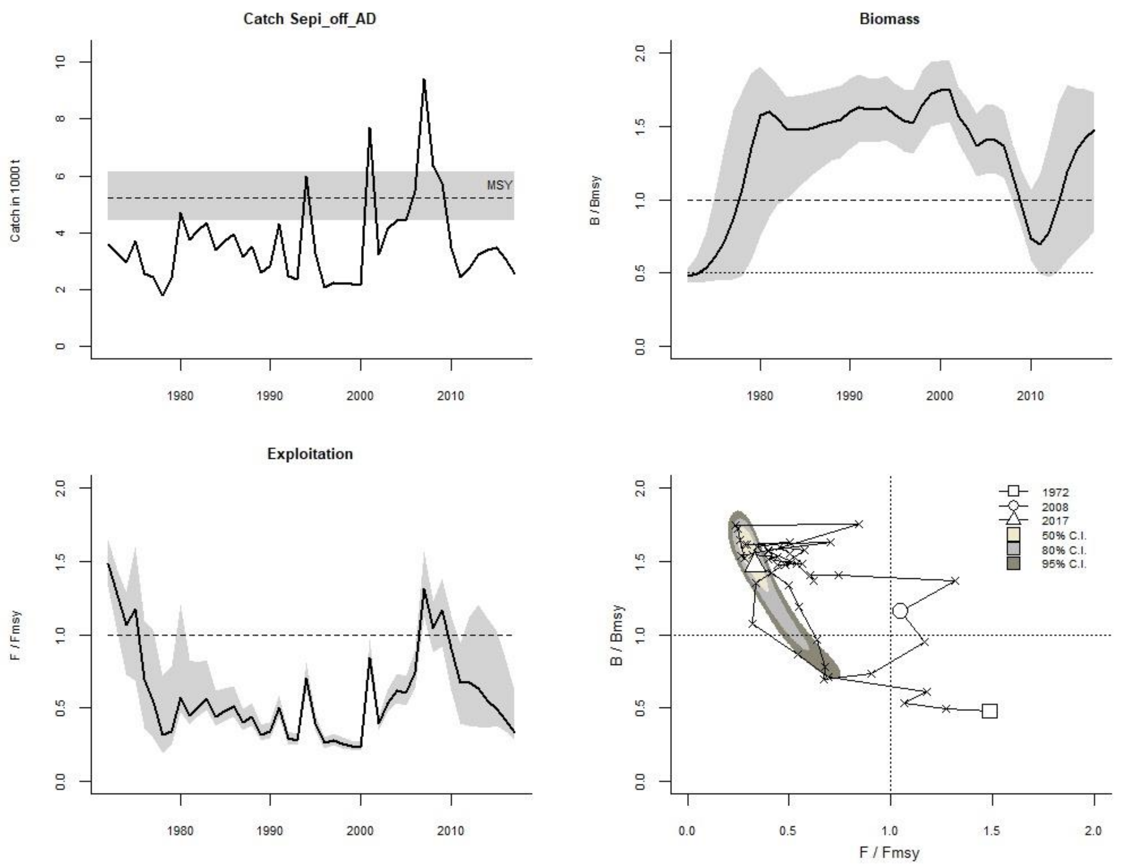

Figure 26 Sensitivity analyses on CMSY model using initial prior as very strong depletion and final as low depletion.

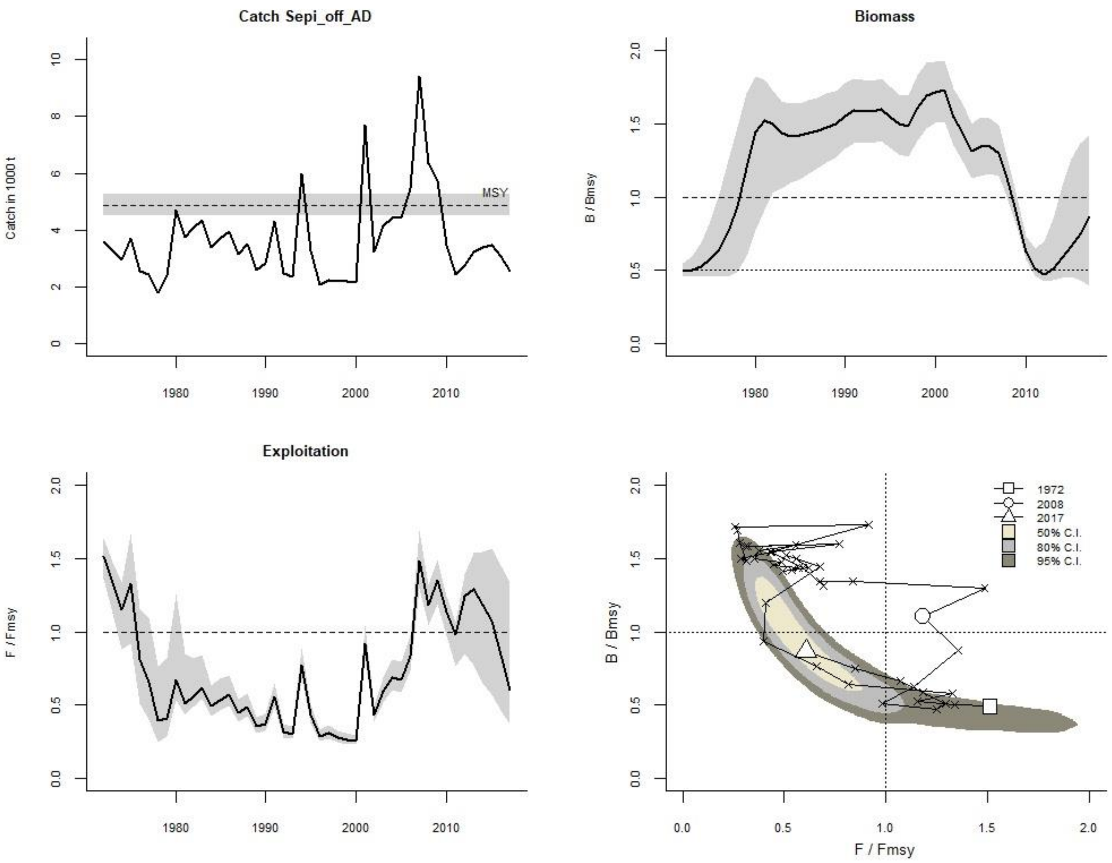

Figure 27 Sensitivity analyses on CMSY model using initial prior as very strong depletion and final as medium depletion.

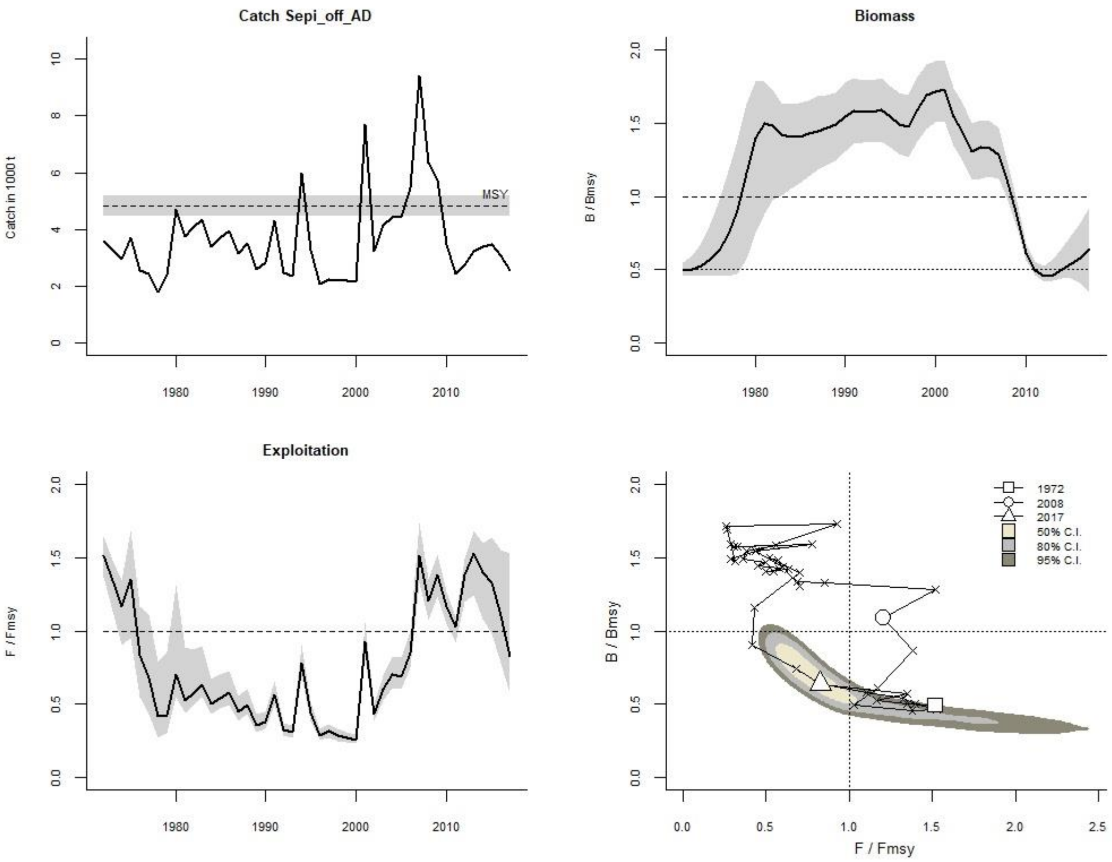

Figure 28 Sensitivity analyses on CMSY model using initial prior as very strong depletion and final as strong depletion.

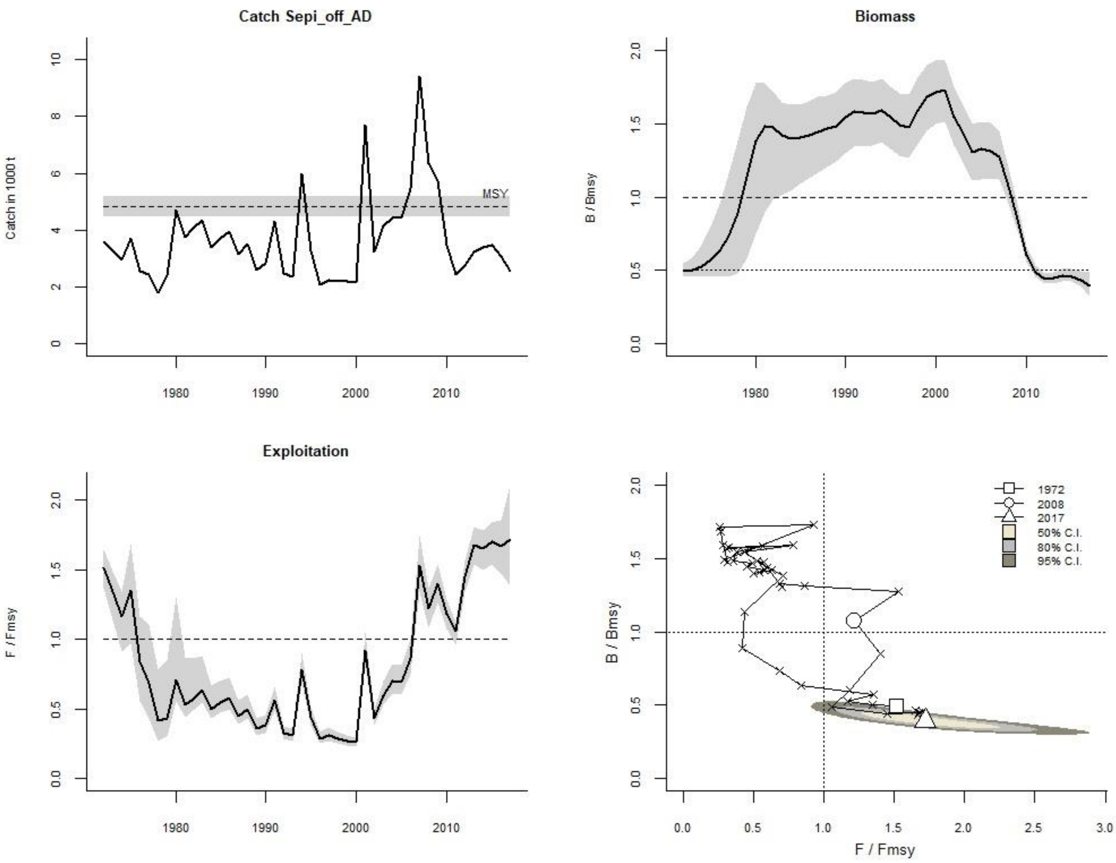

Figure 29 Sensitivity analyses on CMSY model using initial prior as very strong depletion and final as very strong depletion.

6.1.6 Assessment quality

The sensitivity analyses showed a changing pattern in the stock diagnosis. However the decision about the priors to be used for the advice seems supported by the evidence that the stock was in a condition of medium depletion at the begin of the series. The priors choice relative to the end state of biomass was supported by the fact that exploitation was very high until 2010 and then a reduction in number of vessels and catches has been observed. However, catches raised again in 2014 and in 2017 the biomass index from survey fell again below 33rd percentile. These evidence have supported the decision of setting as strong-strong to medium depletion at the end of the series.

7 Stock predictions

Draft scientific advice

The scientific advices in the following table are based on the BSM analysis using CMSY model results and on the Biomass index from Solemon survey.

Table 7-1 Draft scientific advice

Based on	Indicator	Analytic al reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (2014-2017)	Stock Status
Fishing mortality	Fishing mortality	Fmsy: 0.476	Fcurr: 0.401		D	S
Stock abundance	Biomass	Bmsy: 9.88	Bcurr: 6.38		I	R
	Biomass index from survey	33rd percentile: 31.23 kg/km^2	Biomass index: 25.67 kg/km^2		C	O_L
Recruitment					C	
Final Diagnosis		Avoid any increase of catches to improve the status of the stock in term of biomass.				

8 Explanation of codes

Trend categories

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

Stock Status

Based on Fishing mortality related indicators

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

Range of Overfishing levels based on fishery reference points

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

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

*Fc is current level of F

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

Based on Stock related indicators

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

Empirical Reference framework for the relative level of stock biomass index

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

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

Agreed definitions as per SAC Glossary

Overfished (or overexploited) *- A stock is considered to be overfished when its abundance is below an agreed biomass based reference target point, like B0.1 or BMSY. To apply this denomination, it should be assumed that the current state of the stock (in biomass) arises from the application of excessive fishing pressure in previous years. This classification is independent of the current level of fishing mortality.*

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

9 Literature cited

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