Stock Assessment Form
Demersal species

Reference Year:2016

Reporting Year: 2017

Stock Assessment of mantis shrimp in GSA 17

Although in the Italian landings of GSA 17, S. mantis ranks first among the crustacean landed in the Adriatic ports, mantis shrimp it is not the target of a specialized fishery, but it is only an important component of local multispecies trawl and gill net fishery. The Italian annual landing for 2016 was due for 81% to bottom trawl (2531 tons), for 13% gillnet (408 tons) and for 6% to rapido trawl (195 tons). Moreover it is not presenting the list of shared stock of S. mantis GFCM. Considering the results of the Assessment carried out using Stock Synthesis model (last version SS3.3); the mantis shrimp in the GSA 17 is subjected high overfishing being the current F (2016) estimates with SS3 model of 0.99, higher than the proposed reference point ($F_{0.1}$=0.51).

Stock Assessment Form version 1.0 (January 2014)

Uploader: *Francesco Masnadi*

Stock assessment form

Contents

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Squilla mantis	Spottail mantis shrimp	47
1st Geographical sub-area:	2nd Geographical sub-area:	3rd Geographical sub-area:
GSA_17		
4th Geographical sub-area:	5th Geographical sub-area:	6th Geographical sub-area:
1st Country	2nd Country	3rd Country
Italy	Slovenia	
4th Country	5th Country	6th Country
Stock assessment method: (direct, indirect, combined, none)		
Trawl survey, XSA, Stock Synthesis (SS3)		
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2 Stock identification and biological information

The spot-tail mantis shrimp (*Squilla mantis)* is widespread in the Eastern Atlantic, from the Iberian peninsula to Angola, including the Mediterranean Sea, but is absent from the Black Sea. It occupies the continental shelf to the maximum recorded depth of 247 m (Manning, 1997), but it usually digs burrows on soft bottoms to a depth of 100 m. The highest densities of mantis shrimp in the Adriatic Sea are usually found on bottoms characterised by fine sand or sandy mud at depths of less than 50 m (Froglia *et al*., 1996). The species is more frequent in the Western side of the basin while it is quite rare in the Eastern side where the sediment features are not as suitable for their borrowing behavior (Scarcella, pers. comm.).

The burrows of *S.mantis* are commonly U-shaped, large and distinctive with two circular openings, one bigger than the other, that sometimes are more than a metre apart (Atkinson *et al*., 1997). Unfortunately, genetic studies to support the identification of different stocks in the Mediterranean are missing. However, considering its territorial behavior, it is reasonable to assume that the population inhabiting the Adriatic Sea is divided in 2 sub-populations characterized by a low rate of mixing and the sub-populations distributions loosly align with the two Adriatic GSAs (GFCM - WGSADS, 2012).

2.1 Stock unit

2.2 Growth and maturity

The growth has been studied in GSA 17, by Froglia et al. (1996) using indirect method. The length frequency distributions for males and females recorded during experimental trawls carried in the central area of the GSA 17 in 1994 and 1995 (Froglia et al., 1996) showed similar size ranges for both sexes. The largest specimens (39 mm Carapace Length both for males and females) were collected in September 1994, and the smallest specimens were observed in the November 1994 (5 mm CL for males and females) and probably represent the new generation which larvae settled on the bottom in late summer and early autumn. The results of the analyses indicate that the growth is quite similar for males and females. Both sexes reach around 18 mm CL at the end of the first year of life and around 32 mm cl at the end of the third of life. Species life span seems not to exceed five or six years. The Von Bertalannfy (VBGF) parameters were computed on the above data and are presented in Table 2-3.

In the GSA 17 females reach maturity in their second year of life. Females with mature ovaries and active (white) cement glands are observed in late winter in the Central Adriatic (Piccinetti and Piccinetti Manfrin, 1970; Froglia et al., 1996). Spent females, with still whitish glan, are usually observed from April to September, when the sex ratio (M/F) is strongly in favour of males (Piccinetti and Piccinetti Manfrin, 1971; Froglia et al., 1996). The mean size of mature females was around 29 mm CL.

The maturity vector used in the assessment is shown in table 2-2.2 as reported in the DCF database for *S. mantis* in GSA 18.

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

Somatic magnitude measured (LC)				Units	
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	
Maximum size observed			53	**Recruitment season**	Autumn
Size at first maturity	29			**Spawning area**	
Recruitment size to the fishery				**Nursery area**	

Table 2-2.2: M vector and proportion of matures by size or age (Combined)

Size/Age	Natural mortality	Proportion of matures
0	1.20	0.003
1	0.70	0.809
2	0.60	1
3	0.52	1
4+	0.50	1

Table 2-3: Growth and length weight model parameters

			Sex			
		Units	female	male	Combined	Years
Growth model	L_∞	mm	41.88 (± 4.7 8)	41.18 (± 2.99)	41.53	1996
	K		0.448 (± 0.122)	0.532 (± 0.102)	0.49	1996
	t_0		0.038 (± 0.110)	-0.059 (± 0.154)	-0.0105	1996
	Data source	Froglia et al. (1996)				
Length weight relationship	a				0.00133	
	b				3.045	
	M * (scalar)	0	1	2	3	4+
		1.2	0.7	0.6	0.52	0.5
	sex ratio (% females/total)	50				

*Natural mortality as obtained from PRODBIOM model (Abella *et al.*, 1998).

Fisheries information

2.3 Description of the fleet

Although in the Italian landings of GSA 17, *S. mantis* ranks first among the crustacean landed in the Adriatic ports, mantis shrimp it is not the target of a specialized fishery, but it is only an important component of local multispecies trawl and gill net fishery. The Italian annual landing for 2016 was due for 81% to bottom trawl (2531 tons), for 13% to gillnet (408 tons) and for 6% to rapido trawl (195 tons). Moreover *S. mantis* it is not present in the list of shared stock of GFCM.

The species is absent from the landings statistic of Croatia (FAO -FISHSTAT J – GFCM Database) and it accounted only for 1.8 tons in the Slovenian catches of 2016 (2016 DCF data). The species is not present in the list of shared stock of GFCM.

Catches show marked dial periodicity with significantly more animals caught at night (Froglia and Giannini,1989; Froglia and Gramitto, 1989). The burrowing behavior of *S. mantis* makes it vulnerable only when individuals are out of their burrows and this occurs mainly at night, between sunset and sunrise. Seasonal variations in catchability result from reduced out-of-burrow activity, because females rarely exit their burrow when they are incubating their egg mass in spring and early summer. Conversely, catches increases in winter, when mating takes place. Catches increase further in late autumn with the arrival of new recruits.

The reproductive behavior of the species also influences the relative proportion of males and females in the catches by season: females outnumber males only in winter (mating season), while the sex-ratio is biased towards males in spring and summer. Additionally, weather and sea conditions represent an important influence on the catchability of this species as catches increase after prolonged bad weather conditions probably because of disturbance of the burrow systems as a result of the high turbidity (Froglia et al., 1996).

Table 0-1: 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)	Otter trawl (OTB)	33 - Demersal shelf species	
Operational Unit 2	ITA	17	C - Minor gear with engine (6-12 metres)	07 - Gillnets and Entangling Nets (GNS)	33 - Demersal shelf species	
Operational Unit 3	ITA	17	E - Trawl (12-24 metres)	98 - Other Gear (rapido trawl; TBB)	33 - Demersal shelf species	
Operational Unit 4	SVN	17	E - Trawl (12-24 metres)	Otter trawl (OTB)	33 - Demersal shelf species	
Operational Unit 5	SVN	17	C - Minor gear with engine (6-12 metres)	07 - Gillnets and Entangling Nets (GNS)	33 - Demersal shelf species	

Table 0.1-2: 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)
Italian OTB		*Squilla mantis*	*Bolinus brandaris, Chelidonichthy s lucernus, Sepia officinalis, Solea solea, Pecten jacobeus, Melicertus kerathurus*		*Aporrhais pespelecani, Ostrea edulis, Liocarcinus depurator, Anadara inaequivalvis , Anadara demiri*	
Italian GNL		*Squilla mantis*	*Bolinus brandaris, Chelidonichthy s lucernus, Soela solea*		*Aporrhais pespelecan, Ostrea edulis, Liocarcinus vernalis, Astropecten* irregularis	
Italian TBB		*Squilla mantis*	*Bolinus brandaris, Chelidonichthy s lucernus, Sepia officinalis, Solea solea, Pecten jacobeus, Melicertus kerathurus*		*Aporrhais pespelecani, Ostrea edulis, Liocarcinus depurator, Anadara inaequivalvis , Anadara demiri*	
Slovenian OTB		*Squilla mantis*				
Slovenian GNS		*Squilla mantis*				
Total						

2.4 Historical trends

S. mantis is an important commercial species in the Adriatic. It is caught in trammel nets, otter trawls and beam trawls (Froglia and Giannini, 1989). According to the historical trend shown in the GFCM statistics, Adriatic landings for 66% of Mediterranean landings of this species FISHSTAT (gfcm 2008), and showed a general increasing trend from 1990 to 2007.

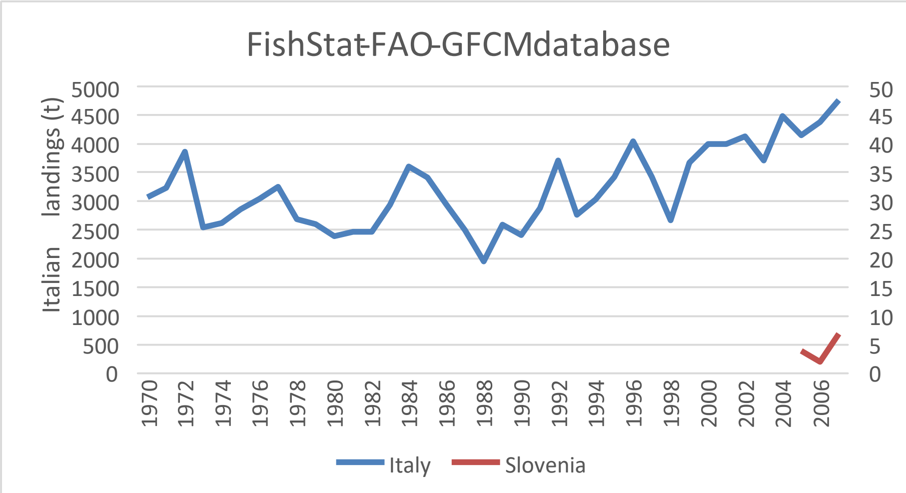


Fig. 1- Landings from FishStat database-Adraitic Sea.

In the period (2007-2016) the landings show a slight increase in the first part of the time series, followed by a strong decrease between 2010 and 2013. From 2014 to 2016 a new slight increase has been registered (due mostly to OTB fleet). A sudden drop in the landings of Italian GNS occurs in 2013, and the GNS contribution remains low in 2014-2016 period as well. This event might be connected to a general decrease in effort of GNS (nominal effort, gt per days and number of vessels) observed in 2013. Italian OTB on the other hand, show a decrease in landings starting in 2010 until 2013, and then rise again to more than 2,000 tonnes in the period 2014-2016. Landings of Slovenian OTB show a constant decreasing trend from the beginning of the time series, which from 2011 is correlated with a general decrease of effort. The trend, with a maximum value in 2010 (4565 tons) and a minimum in 2013 (2128 tons), is shown in table 3.1-3 and figure 2.

Table 3.1-3: Annual total landings (t) by fleets in the period 2007-2016 for Italy and Slovenia.

Fleet	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
OTB Italy	2969	2859	3167	3163	2399	1681	1682	2326	2477	2531
GNL Italy	936	831	872	961	1136	1141	205	296	325	408
TBB Italy	NA	309	490	440	251	283	240	184	262	195
OTB Slovenia	6.1	3.7	2.2	3.2	2.2	0.4	0.1	0.3	0.6	1.7
GNL Slovenia	0.9	2.1	1.1	1.3	0.6	0.3	0.1	0.1	0.2	0.1
Total	3912	4004	4533	4569	3789	3106	2128	2806	3064	3136

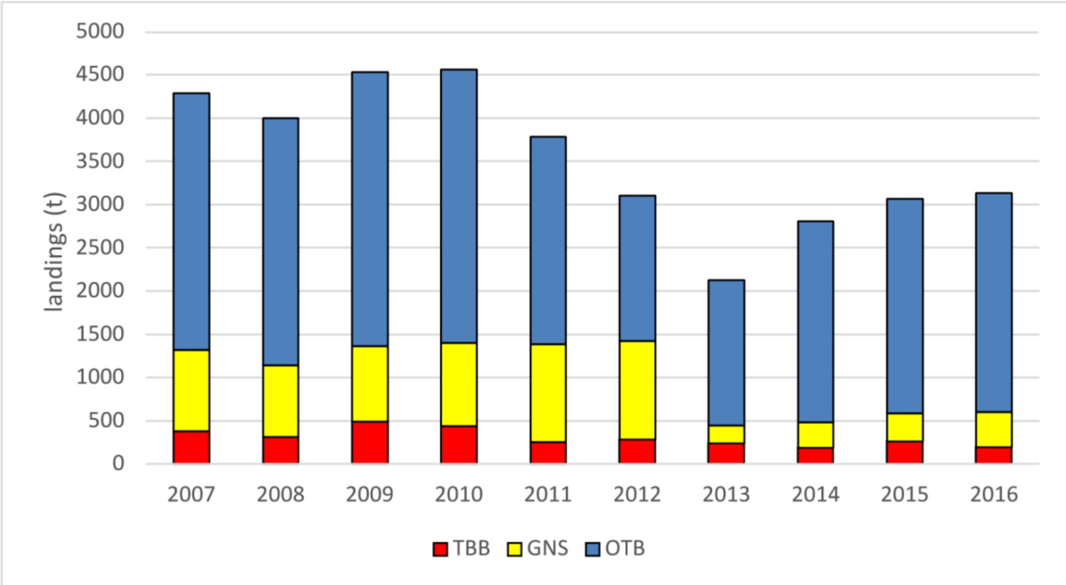


Fig. 2 – Annual total landings by gears in the period 2007-2016. GNS: gillnets; TBB: beam trawl (rapido trawl); OTB: demersal trawling.

Catch data are available for Italy since 2007 and for Slovenian starting in 2005. No fishery is reported for Croatia. Catch from Slovenia are negligible compared to the ones from Italy, therefore the data used goes from 2007 to 2014. No size structure of the catch was available for Slovenia. After exploring the Length Frequency Distribution (LFD) of the landings, it was agreed in discarding the 2007 data, since a clear difference in the shape of the distribution is observed (Fig. 3). This might have been caused by different measurements methodology (e.g. inclusion or not of the rostral plate). This issue should be further investigated.

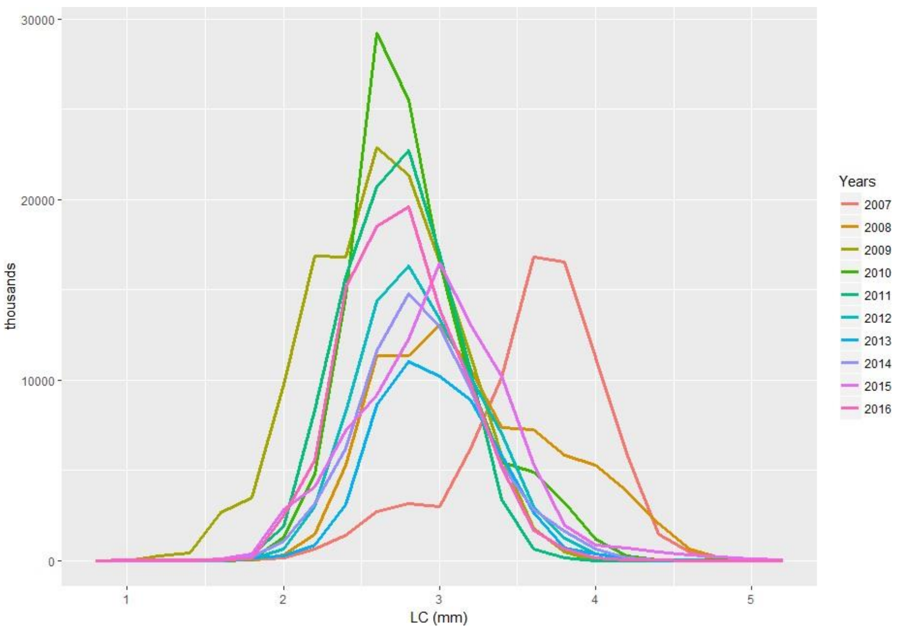


Fig. 3 - Length Frequency Distribution of catches from 2007 to 2016.

2.5 Management regulations

Italy and Slovenia

- Minimum landing sizes: none.
- Fishing closure for trawling: 30-45 days in late summer (not every year the same).
- 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. However, towed gears are always forbidden inside 1.5 miles from the coast with the exception of some areas of the GSA 17 that have benefited from the derogation according by the EC Regulation 1967/2006 for the Mediterranean Sea.
- Minimum mesh size for gill net (16 mm stretched). The mesh size used by set netters targeting sole and squilla range from 32 mm, hence larger than the legal minimum mesh size.
- Maximum length of nets x vessel x day (5,000 m).

2.6 Reference points

Table 0.3-1: 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=0.50	WGSAD 2012-Yield per Recruit analysis VIT model ($F_{0.1}$ as a proxy of F_{MSY})
Y					
CPUE					
Index of Biomass at sea					

3 Fisheries independent information

3.1 *SoleMon Survey*

3.1.1 Brief description of the direct method used

Fourteen *rapido* trawl fishing surveys were carried out in GSA 17 from 2005 to 2016: two systematic “pre- suveys” (spring and fall 2005) and twelve random surveys (spring and fall 2006, fall 2007-2016) stratified on the basis of depth (0-30 m, 30-50 m, 50-100m). Hauls were carried out by day using 2- 4 *rapido* trawls simultaneously (stretched codend mesh size = 40.2 ± 0.83). The following number of hauls was reported per depth stratum (Tab. 3.1.1).

Tab. 3.1.1 Number of hauls per year and depth stratum in GSA 17, 2005-2016

Depth strata	Spring 2005	Fall 2005	Spring 2006	Fall 2006	Fall 2007	Fall 2008-2016
0-30	30	30	20	35	32	39
30-50	14	12	10	20	19	17
50-100	24	15	8	8	11	11
HR islands	0	5	4	4	0	0
TOTAL	68	62	42	67	62	67

Abundance and biomass indexes from *rapido* trawl surveys were computed using ATrIS software (Gramolini *et al*., 2005) which also allowed drawing GIS maps of the spatial distribution of the stock, spawing females and juveniles. Underestimation of small specimens in catches due to gear selectivity was corrected using the selective parameters given by Ferretti and Froglia (1975). The abundance and biomass indices by GSA 17 were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum area in the GSA 17:

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

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

Where:

A=total survey area Ai=area of the i-th stratum

si=standard deviation of the i-th stratum ni=number of valid hauls of the i-th stratum n=number of hauls in the GSA Yi=mean of the i-th stratum

Yst=stratified mean abundance

V(Yst)=variance of the stratified mean

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

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

Direct methods: trawl based abundance indices

Table 3.1-1: Trawl survey basic information

Survey	SoleMon	**Trawler/RV**	G. Dallaporta
Sampling season	Fall		
Sampling design	Random stratified		
Sampler (gear used)	Rapido trawl		
Cod –end mesh size as opening in mm	40		
Investigated depth range (m)	5-100		

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

Stratum	**Total surface (km^2)**	**Trawlable surface (km^2)**	**Swept area (km^2)**	**Number of hauls**
0-30	11512		1.32	39
30-50	8410		0.55	17
50-100	22466		0.41	11
Total (5– 100 m)	42388		2.27	67

Table 3.1-3: Trawl survey abundance and biomass results

Depth Stratum	Years	kg per km^2	SD/CV	N per km^2	SD/CV
	Spring 2005	209.26	78.79	6.47	2.25
	Fall 2005	546.13	213.29	17.01	5.87
	Spring 2006	134.58	45.29	3.92	1.15
	Fall 2006	317.47	85.2	8.69	2.07
	2007	98.08	34.85	3.33	1.19
	2008	302.4	88.5	9.61	3
	2009	511.48	106.25	14.65	2.84
	2010	568.5	88.61	18.66	2.93
	2011	525.62	78.39	17.74	2.58
	2012	418.52	70.52	14.07	2.46
	2013	607.34	121.31	16.56	3.23
	2014	643.3	136.94	20.53	4.12
	2015	974.97	174.06	28.67	4.55
	2016	628.64	108.69	17.54	3.01

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

Slicing method

Report the maturity scale and age slicing method used

Table 3.1-4: Trawl survey results by length or age class

N (Total or sex combined) by Length or Age class	**Year**		
	....	**....**	**.....**
Total			

Sex ratio by Length or Age class	**Year**		
	....	**....**	**.....**
Total			

Comments

- Specify if numbers are per km^2 or raised to the area, assuming the same catchability .
- In case maturity ogive has not been estimated by year, report information for groups of years.
- Possibility to insert graphs and trends

Direct methods: trawl based Recruitment analysis

Table 3.1-5: Trawl surveys; recruitment analysis summary

Survey		Trawler/RV	
Survey season			
Cod –end mesh size as opening in mm			
Investigated depth range (m)			
Recruitment season and peak (months)			
Age at fishing-grounds recruitment			
Length at fishing-grounds recruitment			

Table 3.1-6: Trawl surveys; recruitment analysis results

Years	Area in km^2	N of recruit per km^2	CV or other

Comments

- Specify type of recruitment:
  - continuous and diffuse
  - discrete and diffuse - discrete and localised - continuous and localised.
- Specify the method used to estimate recruit indices
- Specify if the area is the total or the swept one
- Possibility to insert graphs and trends

Direct methods: trawl based Spawner analysis

Table 3.1-7: Trawl surveys; spawners analysis summary

Survey		**Trawler/RV**	
Survey season			
Investigated depth range (m)			
Spawning season and peak (months)			

Table 3.1-8: Trawl surveys; spawners analysis results

Surveys	**Area in km^2**	**N (N of individuals) of spawners per km^2**	**CV or other**	**SSB per km^2**	**CV or other**

Comments

- Specify type of spawner: -
  total spawner
  - sequential spawner
  - presence of spawner aggregations
- Specify if the area is the total or the swept one
- Possibility to insert graphs e trends

3.1.2 Spatial distribution of the resources

Include maps with distribution of total abundance, spawners and recruits (if available)

3.1.3 Historical trends

The SoleMon trawl surveys provided trend in abundance for *S. mantis.*
The trends in abundance index show a clear decrease of the stock in 2007 followed by an increase in the rest of the time series (Fig. 4).
Figure 5 displays the stratified abundance indices by size obtained in GSA 17 from 2011 to 2016 during fall survey.

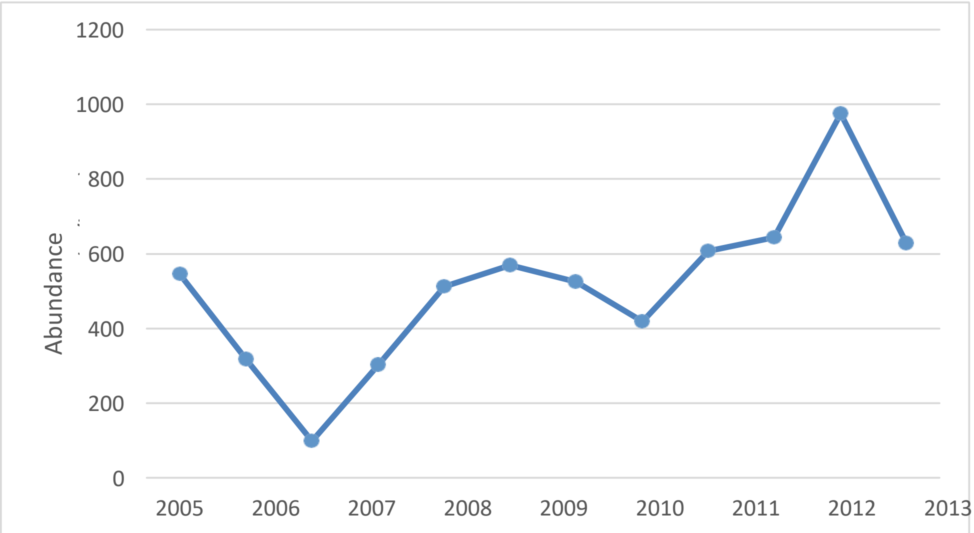


Fig. 4- Index of abundance from SOLEMON survey from 2005 to 2016.

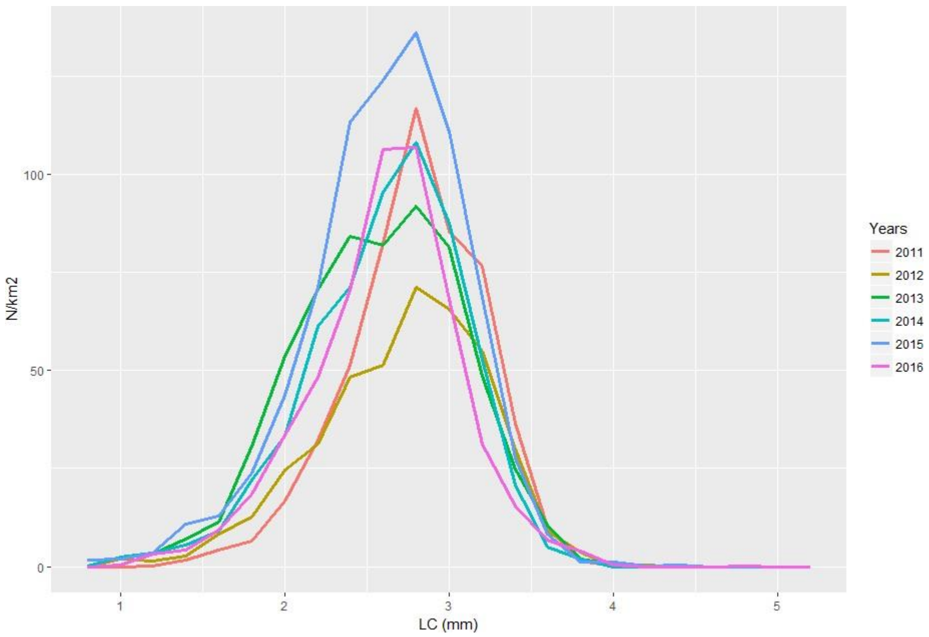


Fig. 5 - Stratified abundance indices by size from SOLEMON survey, 2011-2016.

3.2 MEDITS Survey

3.2.1 Brief description of the direct method used

Fishery independent information regarding the state of the spottail mantis shrimp in GSA 17 was derived from the international survey MEDITS.

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to 60 minutes hauling duration. The abundance and biomass indices by GSA 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 areas in each GSA:

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

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

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, quasipoisson. Indeed, data may be better modeled 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 (subsamples raised to standardized haul abundance per hour) over the stations of each stratum. Aggregated length frequencies were then raised to stratum abundance * 100 (because of low numbers in most strata) 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.

The length frequency distributions of MEDITS survey shows some issues, in particular:

- 2010 is missing;
- Big shift in size between 2009 and 2011: the only explanation is that the observers changed the measuring methodology, from Carapace length (which is usually the common way of measuring crustaceans) to total length;
- The number of specimen measured in 2009, 2011 and 2013 is really low, maybe due to the paucity of individuals in the catches.

Direct methods: trawl based abundance indices

Table 3.2-1: Trawl survey basic information

Survey	MEDITS	**Trawler/RV**	Andrea
Sampling season	Spring		
Sampling design	Random stratified		
Sampler (gear used)	GOC73		
Cod –end mesh size as opening in mm	20		
Investigated depth range (m)	10-500		

Table 3.2-2: Trawl survey sampling area and number of hauls (2011 survey)

Stratum	**Total surface (km^2)**	**Trawlable surface (km^2)**	**Swept area (km^2)**	**Number of hauls**
Total (....... m)				

Table 3.2-3: Trawl survey abundance and biomass results

Depth Stratum	Years	kg per km^2	SD/CV	N per km^2	SD
	1994			14.65	4.08
	1995			16.64	5.23
	1996			29.87	10.39
	1997			83.05	41.44
	1998			17.84	5.89
	1999			143.98	40.45
	2000			33.91	9.29
	2001			38.86	15.26
	2002			87.28	28.23
	2003			40.73	11.47
	2004			106.53	29.67
	2005			126.13	59.91
	2006			143.28	41.51
	2007			47.08	17.25
	2008			38.37	13.24
	2009			16.27	4.64
	2010			30.94	5.01
	2011			27.75	8.24
	2012			21.61	6.28
	2013			9	2.66
	2014			105.26	27.15
	2015			23.46	7.01
	2016			174.47	43.68

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

Slicing method

Report the maturity scale and age slicing method used

Table 3.2-4: Trawl survey results by length or age class

N (Total or sex combined) by Length or Age class	**Year**		
	....	**....**	**.....**
Total			

Sex ratio by Length or Age class	**Year**		
	....	**....**	**.....**
Total			

Comments

- Specify if numbers are per km^2 or raised to the area, assuming the same catchability .
- In case maturity ogive has not been estimated by year, report information for groups of years.
- Possibility to insert graphs and trends

Direct methods: trawl based Recruitment analysis

Table 3.2-5: Trawl surveys; recruitment analysis summary

Survey		**Trawler/RV**	
Survey season			
Cod –end mesh size as opening in mm			
Investigated depth range (m)			
Recruitment season and peak (months)			
Age at fishing-grounds recruitment			
Length at fishing-grounds recruitment			

Table 3.2-6: Trawl surveys; recruitment analysis results

Years	**Area in km^2**	**N of recruit per km^2**	**CV or other**

Comments

- Specify type of recruitment:
  - continuous and diffuse
  - discrete and diffuse - discrete and localised - continuous and localised.
- Specify the method used to estimate recruit indices
- Specify if the area is the total or the swept one
- Possibility to insert graphs and trends

Direct methods: trawl based Spawner analysis

Table 3.2-7: Trawl surveys; spawners analysis summary

Survey		Trawler/RV	
Survey season			
Investigated depth range (m)			
Spawning season and peak (months)			

Table 3.2-8: Trawl surveys; spawners analysis results

Surveys	Area in km^2	N (N of individuals) of spawners per km^2	CV or other	SSB per km^2	CV or other

Comments

- Specify type of spawner: -
  total spawner
  - sequential spawner
  - presence of spawner aggregations
- Specify if the area is the total or the swept one
- Possibility to insert graphs e trends

3.2.2 Spatial distribution of the resources

Include maps with distribution of total abundance, spawners and recruits (if available)

3.2.3 Historical trends

Although mantis shrimp is not a target species in the MEDITS survey, data collected allowed to estimate the density of the population. The trends of the number of specimens indices estimated for the depth stratum 0-500 m is reported (Fig. 6).

The abundance index from 2009 to 2013 is really low maybe due to the paucity of individuals in the catches. For this reason, together with the length frequency distributions issues, MEDITS survey was therefore deemed inappropriate to be used as tuning index of mantis shrimp in GSA 17.

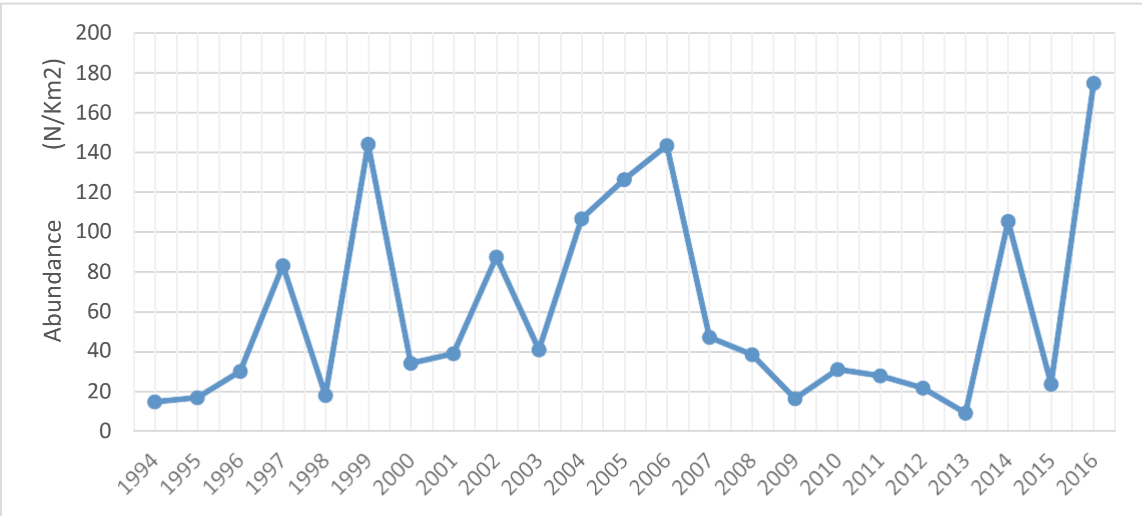


Fig. 6- Index of abundance from MEDITS survey from 1994 to 2016.

4 Ecological information

4.1 Protected species potentially affected by the fisheries 4.2 Environmental indexes

5 Stock Assessment

In this section, there will be one subsection for each different model used and also different model assumptions runs should be documented when all are presented as alternative assessment options.

5.1 XSA model

Scripts

```
##XSA SQUILLA
MANTIS 2017
####################
###### library(FLCore)
library(FLAssess)
library(FLXSA)
library(ggplotFL)
#load the stock (sqm.stk) and the tuning indices (indSol) for the
assessment load(file="SQM_indx_GSA172017.Rdata")
load(file="SQM_indx_GSA172017.Rdata") units(harvest(sqm.stk))<-"f" #
Set fbar in the stock range(sqm.stk)["minfbar"] <- 1
range(sqm.stk)["maxfbar"] <- 2 # Set the plus group in the stock sqm.stk
<- setPlusGroup(sqm.stk, 4)
#Running the assessments with the best setting found
FLXSA.control.22 <- FLXSA.control(fse=3, rage=1, qage=2,shk.yrs=3, shk.ages=2)
sqm.xsa22 <- FLXSA(sqm.stk, indSol, FLXSA.control.22)
#Add the results to the stock files
sqm.new_xsa22 <- sqm.stk + sqm.xsa22
summary(sqm.new_xsa22)
plot(sqm.new_xsa22) #final plot
#Retrospective sqm.stk.retro22 <-
tapply(retro.years,1:length(retro.years),function(x)
  return(window(sq.stkFinal22,end=x)+FLXSA(window(sq.stkFinal22,end=x),indSol,
                                          FLXSA.control.sqc)))
sqm.stk.retro22<- FLStocks(sqm.stk.retro22)
names(sqm.stk.retro22) <-
as.character(unique(retro.years)) plot(sqm.stk.retro22)
ggsave("retro_fse_3_1_2.png",last_plot())
```

5.1.1 Model assumptions

Data coming from DCF for the period 2008-2016 were used to perform an Extended Survivor Analysis (XSA) calibrated with fishery independent data and using FLR (www.r-project.org).

2007 was excluded from the assessment due to the problems in the LFD highlighted in the data section. The age classes considered range from 0 to 4: plug group was set at age 4. The SOLEMON trawl survey was used as tuning index of the assessment. The XSA runs were made using the following settings:

- Catchability dependent on stock size for ages = 1
- Catchability independent of age for ages >= 2
- S.E. of the mean to which the estimates are shrunk = 3
- Minimum standard error for population estimates derived from each fleet = 0.300 • The number of ages and years used for the shrinkage mean: 2 and 3
- Fbar: 1-2

5.1.2 Input data and Parameters

Catch at age were estimated from an age slicing of the length data series of the period 2008-2016 and using the combined growth parameters estimated by Froglia (Froglia *et al.,* 1996) reported in Table 2-3.

A vector of natural mortality rate at age was obtained from PRODBIOM model (Abella *et al*., 1998). The following set of parameters was used to perform the XSA:

Growth parameters (Von Bertalanffy)
Linf = 41.53 (mm, carapace length)
k = 0.49
t0 = -0.0105
L*W relationship
a = 0.00133
b = 3.045
Natural mortality
Age0=1.2, Age1=0.7, Age2=0.6, Age3=0.52, Age4+=0.5
L50 = 29.0 mm CL
Proportion of matures
Age0=0.003, Age1=0.809, Age2=1.00, Age3=1.00, Age4+=1.00

The following tables (from table 5.1.2-1 to table 5.1.2-4) show the input data used in the XSA assessment.

Table 5.1.2-1: Total catches in tons from 2008 to 2016.

Years	Tons
2008	3998.6
2009	4529.3
2010	4564.7
2011	3786.2
2012	3104.9
2013	2127.6
2014	2805.6
2015	3063.3
2016	3134.2

Table 5.1.2-2: Catch at age in numbers (thousands) from 2008 to 2016.

Age	0	1	2	3	4+
2008	4	7055	35734	17968	25102
2009	3325	46884	60731	17121	2213
2010	1	20734	71243	15282	9619
2011	0	26261	60402	13812	756
2012	0	18376	43174	13435	3046
2013	36	7770	31078	11784	2003
2014	3	15702	39316	11312	3657
2015	98	18449	40558	19935	6539
2016	114	32527	48544	10267	1424

Table 5.1.2-3: Mean weight at age (kg) from 2008 to 2016.

Age	0	1	2	3	4+
2008	0.0073	0.0271	0.0398	0.06	0.091
2009	0.0073	0.023	0.0392	0.0594	0.091
2010	0.0073	0.0268	0.0388	0.0596	0.091
2011	0.0073	0.0261	0.0394	0.0586	0.091
2012	0.0073	0.0264	0.0392	0.0592	0.091
2013	0.0088	0.0269	0.0396	0.0593	0.091
2014	0.0088	0.0257	0.0396	0.0589	0.091
2015	0.0088	0.0269	0.0396	0.0593	0.091
2016	0.0088	0.0257	0.0396	0.0589	0.091

Table 5.1.2-4: Stratified abundance indices by age from SOLEMON survey, 2011-2016.

Age	0	1	2	3	4+
2011	6.06	143.48	292.52	76.61	4.71
2012	14.36	143.75	189.71	59.17	10.36
2013	22.06	286.08	236.55	54.11	4.73
2014	20.97	235.58	272.01	48.46	3.49
2015	30.96	319.74	345.06	58.98	6.76
2016	17.05	228.39	242.09	33.28	6.4

Results

Fig. 7 presents the main results from the XSA model run: fishing mortality ($Fbar_{1-2}$ and by fleet), recruitment and spawning stock biomass (SSB).

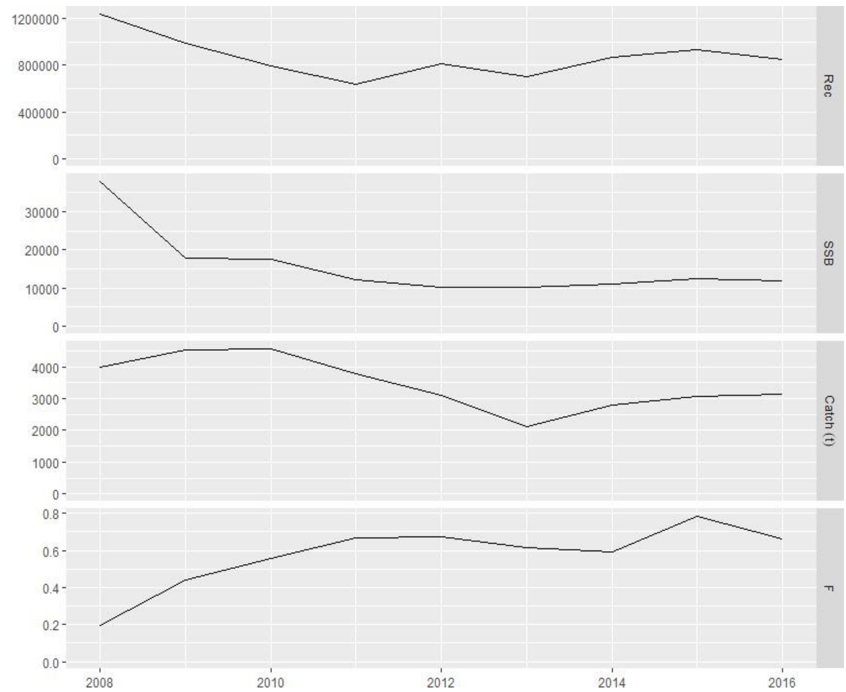


Fig. 7 – Final assessment results XSA run.

State of exploitation: for the exploitation pattern it was observed increasing trend 1with a maximum value in 2015 (0.78). In 2016 the value of mean fishing mortality (Fbar 1-2) was 0.66. The Fcurr (mean of the last three years) is 0.68.

State of the juveniles (recruits): Recruitment, after a decrease from 2008 to 2011, is quite stable in the last 5 years; in the last year estimate recruits are 851840 specimens.

State of the adult biomass: The SSB showed a decreasing trend in all the period analyzed; SSB decreases from a value of 37904 to a value of 12013 tons in 2016.

5.1.3 Robustness analysis

5.1.4 Retrospective analysis, comparison between model runs, sensitivity analysis, etc.

XSA Diagnostics in the form of residuals by survey and retrospective analyses are shown in Figures below. No particular trends are evidenced in residuals (Fig. 8) and the retrospective analyses is adequate (Fig. 9).

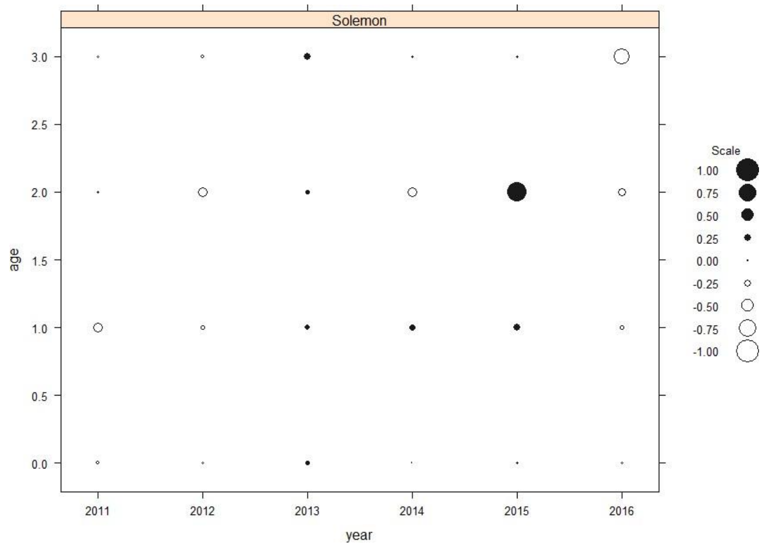


Figure 8 – Bubble plot of residuals

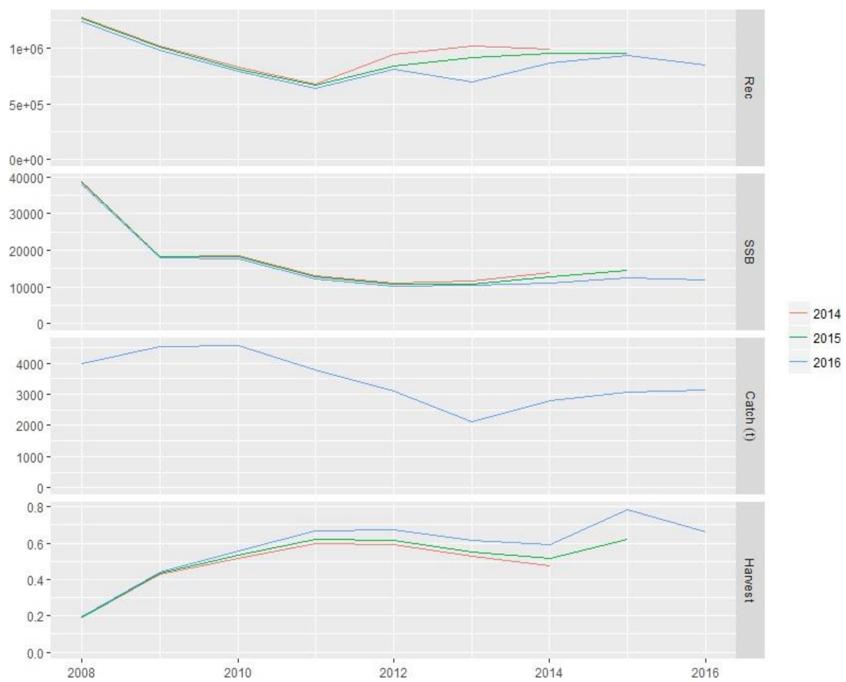


Figure 9 – Retrospective analyses

5.2 SS3 model

The fundamental idea of the stock assessment here presented is to use the integrated approach of SS3 model (last version SS3.3) to model the size structure data (not catch at age data) available for the mantis shrimp.

5.2.1 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 length-specific by fleet, with the ability to capture the major effect of length-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 goodnessof-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, the F values are standardized by dividing by the average (called Fbar) of the F values observed over a defined range of age classes (e.g., Darby and Flatman, 1994; Sampson and Scott, 2011).

5.2.2 Input data and Parameters

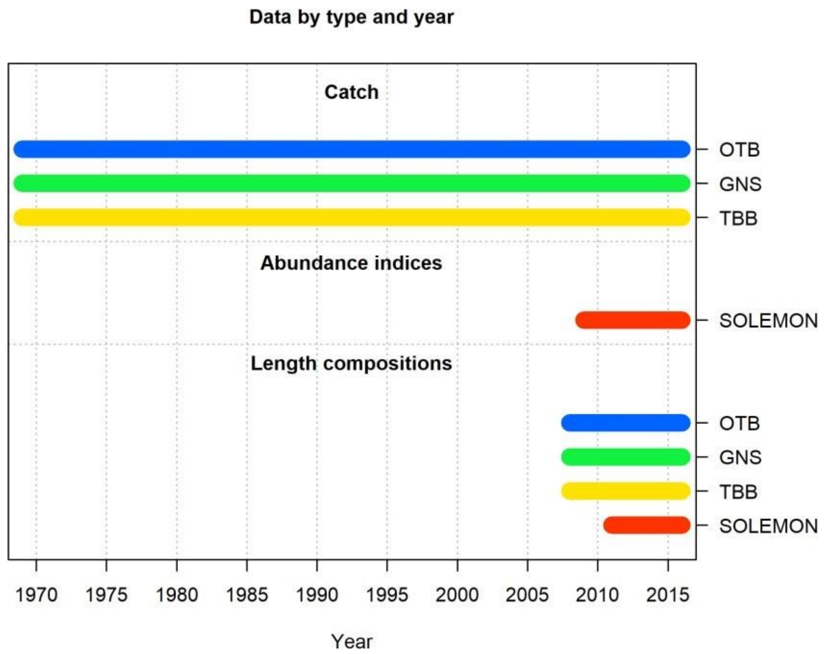


Fig. 10 – Summary of the input data of the SS3 model.

The model allowed to specify the different source of data, providing different uncertainties estimates for each data set. The total landings from 1970 to 2007, used in the model, come from FAO-FishStat source, after this year, for Italian and Slovenian from DCF. Catch from Slovenia are negligible compared to the ones from Italy, therefore Slovenian OTB and GNS catches era added respectively to Italian OTB and GNS.

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

1. OTB (ITA + SVN)
2. GNS (ITA + SVN)
3. TBB

The Stock Synthesis model used in this assessment is a size structure data model based on the separate fleet LFD from 2008 to 2016 (Tab 5.2.2-1-2-3); 2007 LFD was excluded from the assessment due to the problems highlighted in the data section.

The age classes considered range from 0 to 4: plug group was set at age 4.

Tuning data were provided by SOLEMON survey carried out in fall for the years 2008-2016 (Tab. 5.2.2-4) and the LFD of the survey from 2011 to 2016 were also used as an input data (Tab. 5.2.2- 5;Fig. 5).

Overall, the exploited size range is comprised between 8 and 52 mm carapace length (CL), corresponding to specimens between 0 and 4+ age classes.

Table 5.2.2-1: OTB numbers at length in the catches (thousands) from 2008 to 2016.

Length	2008	2009	2010	2011	2012	2013	2014	2015	2016
8	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	11
12	0	243	0	0	0	0	0	0	58
14	0	432	0	0	0	0	0	0	11
16	4	2645	0	0	0	36	3	98	34
18	25	3354	19	68	80	144	211	294	111
20	254	8954	888	598	392	203	1015	2235	2275
22	1168	14265	3757	5415	1798	631	2907	2788	5065
24	3688	11403	10248	9997	4260	2203	5377	5136	13520
26	6673	15174	20043	13889	6832	7045	10151	6394	15789
28	5379	14406	15725	14717	8488	8692	12148	9820	16620
30	6455	11046	10583	10078	7077	8077	10478	13732	11119
32	6250	7481	6527	6757	5940	7058	7430	10945	7496
34	5319	3728	3966	2425	4305	4759	4104	9056	3611
36	6537	1077	4500	460	1961	2209	2270	4863	1086
38	5837	340	3173	128	933	528	1460	1748	493
40	5296	0	1184	0	235	241	573	820	110
42	3877	0	237	0	36	78	134	695	7
44	2047	0	29	0	4	1	8	479	36
46	639	0	21	0	0	0	2	297	0
48	150	0	50	0	0	0	0	195	0
50	0	0	0	0	0	0	0	79	0
52	0	0	0	0	0	0	0	19	0

Table 5.2.2-2: GNS numbers at length in the catches (thousands) from 2008 to 2016.

Length	2008	2009	2010	2011	2012	2013	2014	2015	2016
8	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
18	0	0	0	234	0	4	0	0	0
20	30	113	116	1100	178	21	23	15	16
22	237	918	426	2417	786	142	88	119	43
24	1304	2259	2749	4776	2932	308	394	387	350
26	3672	4098	6013	5329	5843	499	700	1168	1125
28	4340	4239	6880	6140	6079	833	1291	1513	1825
30	4730	3314	3667	5716	4804	732	1377	1857	1932
32	2777	3035	2141	2927	3242	686	1429	1368	1749
34	1583	1718	939	889	2270	659	917	690	1345
36	603	526	339	156	885	312	480	266	521
38	0	82	16	6	261	167	167	100	137
40	0	0	0	0	126	91	60	26	28
42	0	0	0	0	93	4	4	8	0
44	0	0	0	0	42	0	0	9	0
46	0	0	0	0	28	0	0	2	0
48	0	0	0	0	0	0	0	1	0
50	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0

5.2.2-3: TBB numbers at length in the catches (thousands) from 2008 to 2016.

Length	2008	2009	2010	2011	2012	2013	2014	2015	2016
8	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
16	0	5	1	0	0	0	0	0	0
18	0	95	6	8	1	0	7	52	0
20	0	720	294	177	67	27	44	546	210
22	58	1665	605	513	426	97	130	1170	467
24	291	3138	1626	958	1047	563	442	1663	1243
26	990	3595	3150	1472	1701	1062	790	1586	1619
28	1631	2701	2894	1867	1779	1488	1328	970	1141
30	1864	2158	2288	1194	1474	1381	1086	899	865
32	1573	827	1155	764	984	1120	644	707	529
34	466	332	554	50	429	420	255	456	221
36	116	163	70	6	140	130	52	226	54
38	0	25	0	0	67	14	10	72	4
40	0	0	0	0	4	4	1	10	0
42	0	0	0	0	2	2	0	0	0
44	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0

Table 5.2.2-4: Abundance index (N/km2) from SOLEMON survey, 2008-2016.

Year	N/km2
2008	302.4
2009	511.48
2010	568.5
2011	525.62
2012	418.52
2013	607.34
2014	643.3
2015	974.97
2016	628.64

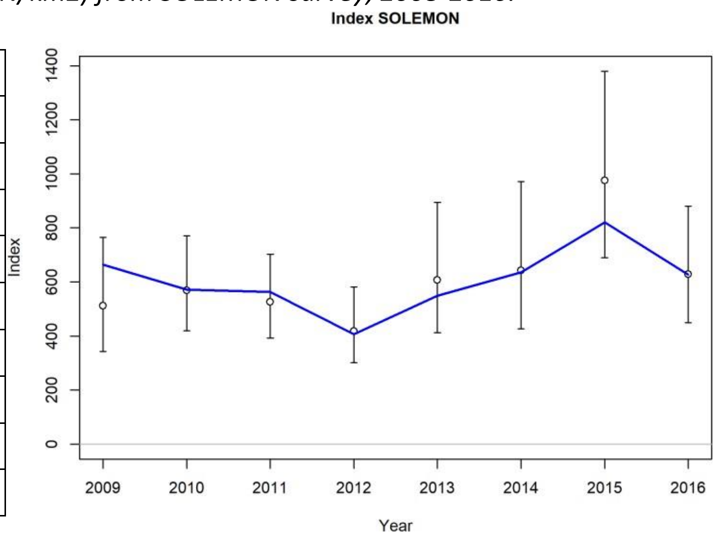


Table 5.2.2-5: Stratified abundance indices by size from SOLEMON survey, 2011-2016.

Length	2011	2012	2013	2014	2015	2016
8	0	0	0	0.25	1.71	0
10	0	1.91	0.37	2.57	2.01	0.4
12	0.21	1.44	3.21	3.44	3.49	3.16
14	1.6	2.62	7.11	5.53	10.96	4.24
16	4.25	8.39	11.37	9.18	12.79	9.25
18	6.52	12.64	30.64	21.98	23.96	18.42
20	16.81	24.54	53.67	33.14	43.79	33.47
22	32.32	31.18	70.76	61.38	71.15	48.35
24	51.42	48.36	84.19	71.31	113.12	70.41
26	82.48	51.3	82.02	95.46	124.03	106.48
28	116.8	71.17	91.96	108.09	136.09	106.87
30	85.48	65.73	81.44	87.52	110.91	68.14
32	76.68	54.92	48.66	52.97	68.64	31.17
34	36.53	29.98	24.81	20.81	27.57	15.54
36	10.17	9.04	10.66	5.01	8.19	6.84
38	1.48	3.64	2	1.87	1.26	3.87
40	0.21	0	0.66	0	1.2	0.4
42	0.42	0.49	0	0	0.21	0
44	0	0	0	0	0.42	0
46	0	0	0	0	0	0
48	0	0	0	0	0	0.2
50	0	0	0	0	0	0
52	0	0	0	0	0	0

Considering the information provided before the selectivity patterns of the fleets and the survey have been rescaled as in the Fig. 11, assuming a dome shaped selectivity for each fleet and the survey.

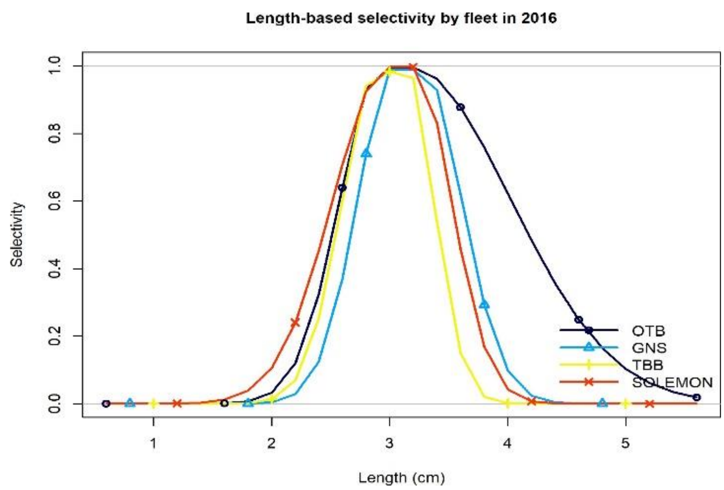


Fig. 11 – Selectivity by length and by fleet used in the SS3 model.

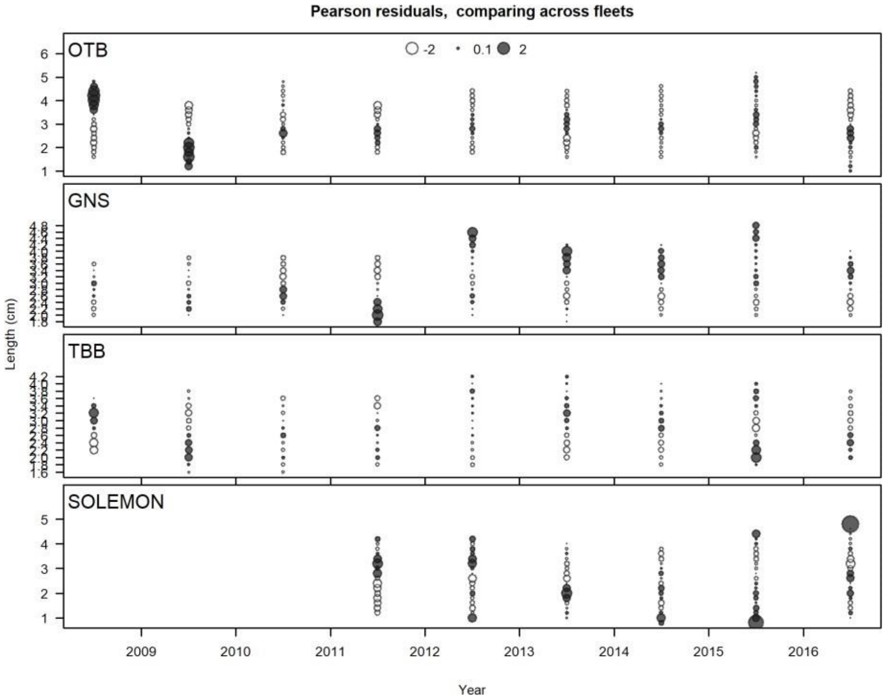


Fig. 12 – Pearson residuals for SoleMon survey and the fleets.

No particular trends in the residuals were observed (Fig. 12).
SS3 Diagnostics in the form of retrospective are shown in Fig. 13.

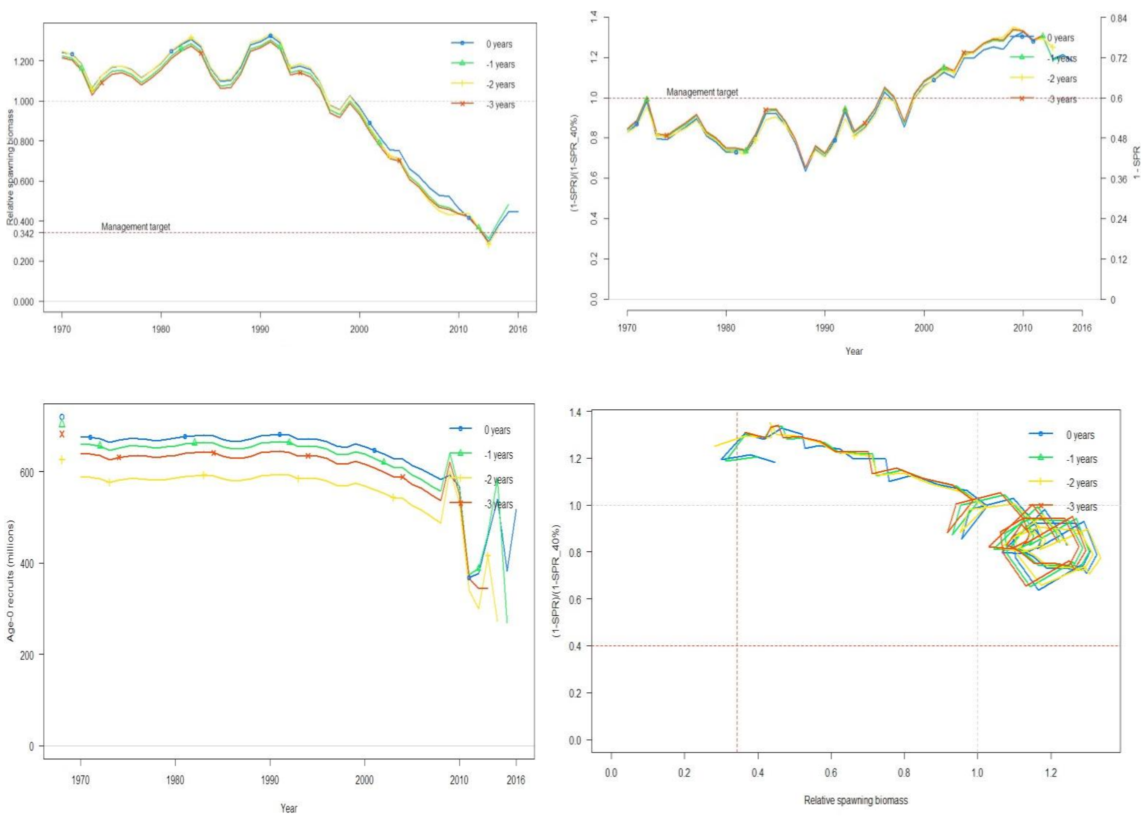


Figure 13 – Retrospective analyses

The number of active parameters estimated by the model is 30.

Fig. 14 presents the main results from the SS3 model run: fishing mortality (Fbar$_{1-2}$ and by fleet), recruitment and spawning stock biomass (SSB).

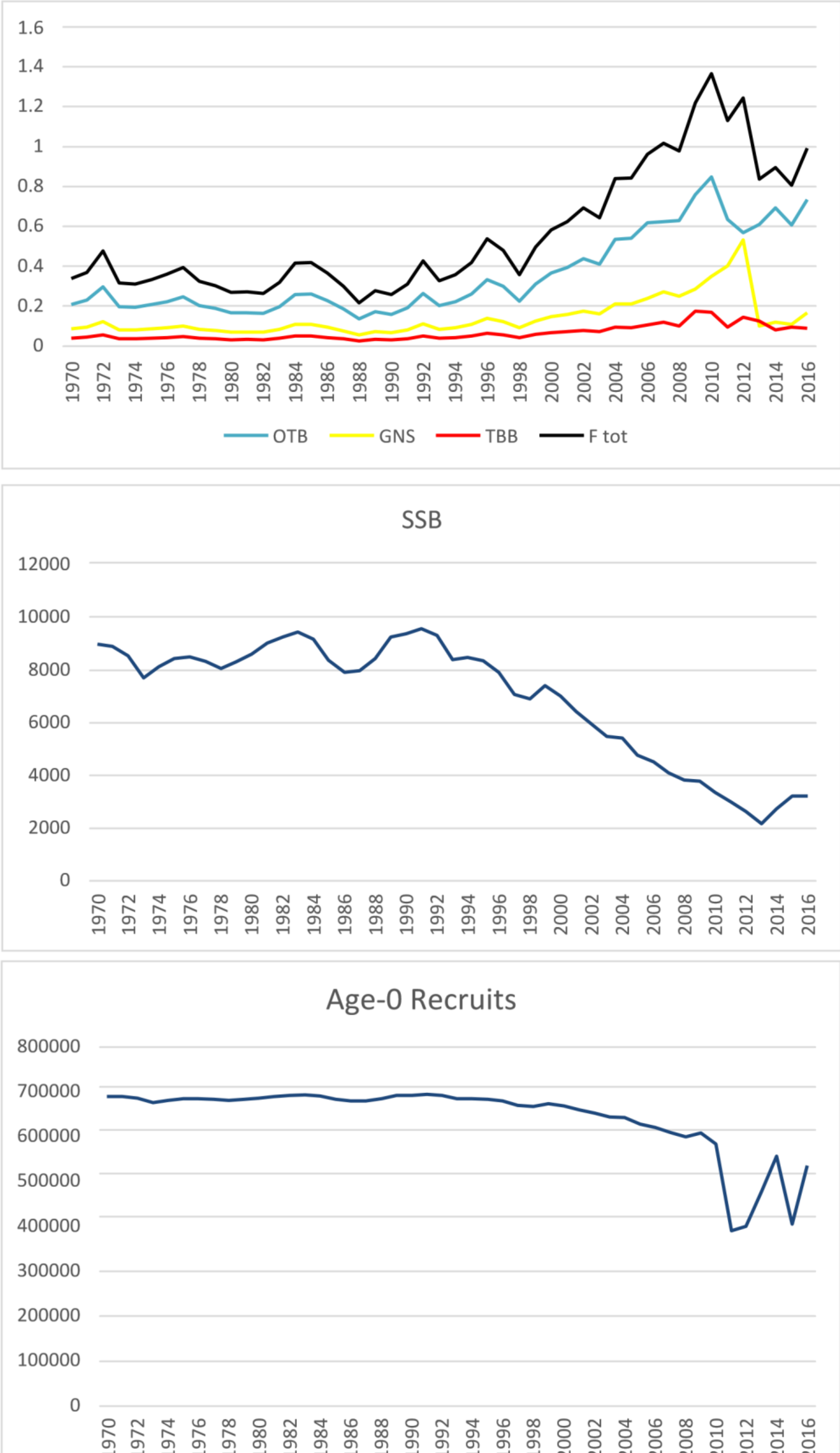


Fig. 14 – Final assessment results SS3 run.

State of exploitation: for the exploitation pattern it was observed a variable trend from the beginning of the time-series, with a more pronounced increase from 1990 to 2012; after this year a reduction occurred. In 2013 there was sudden drop of the partial F of GNS due to the general decrease in effort of GNS fishing fleet observed in 2013. In the last few years (2014-2016) the partial F remain constant for all the fleet. In 2016 the value of mean fishing mortality (Fbar 1-2) was 0.99.

State of the juveniles (recruits): Recruitment varied in the last period from 2010-2016, reaching a minimum in 2011 and a maximum in 2014; in the last year estimate recruits are 516813. State of the adult biomass: The SSB showed a decreasing trend in all the period analyzed (minimum in 2013) but, from 2014, the SSB returns to increase. The last estimate of SSB in 2016 is around 3218.52 tons.

5.2.3 Assessment quality

Several issues have been identified in the data for *S. mantis* in GSA 17.

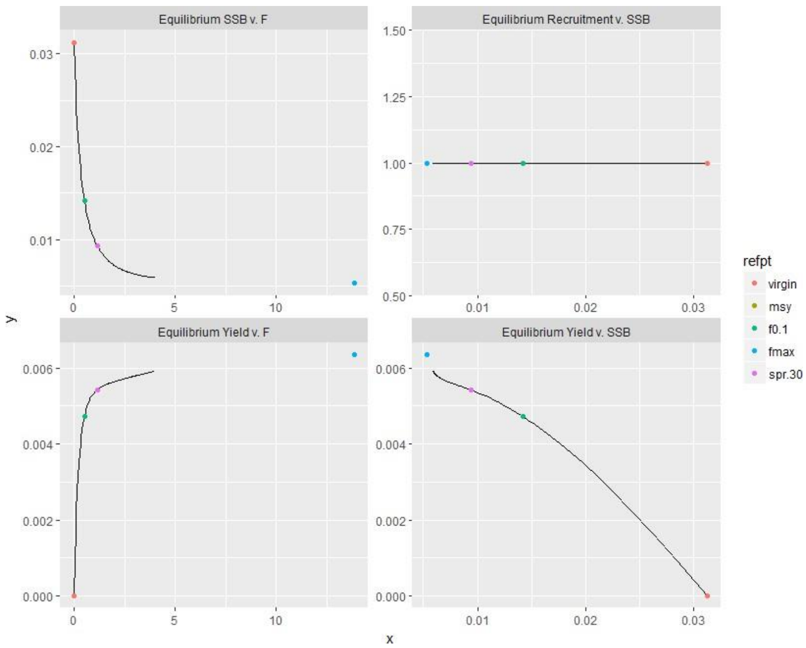
First of all, the available time series of complete commercial length data of landings is short (2007 – 2016) and shows some anomalous big lengths (far beyond the estimated L_{inf} by Froglia in 1996) which seem to highlight some differences in the measuring methodology in the commercial sampling maybe caused by the inclusion of the rostral plate in some sampling.

A data control is desirable for the next years.

Also, the sudden drop in GNS landings registered in 2013 should be further investigated. MEDITS data for this species are considered completely unreliable for several reasons: a change in the measuring methodology between 2009 and 2011, the few numbers of specimens measured and the huge temporal extension of the MEDITS survey in 2014 (from May to November).

Reference points

The yield per recruit (YpR) analysis was run using FLBRP routine. $F_{0.1}$ has been estimated equal to 0.51.



6 Stock predictions

6.1 Short term predictions

6.2 Medium term predictions

6.3 Long term predictions

7 Draft scientific advice

Considering the results of the analyses conducted the mantis shrimp in GSA 17 is subjected to high overfishing being the current F(1-2) estimates with SS3 model of 0.99, higher than the proposed reference point ($F_{0.1}$ = 0.51).

Base on the biomass level (SSB) the stock result in a state of relative low biomass being the current SSB estimated by the SS3 model 3218.52 tons; lower than 33rd percentile of biomass ($B33^{rd}$=6417.22).

<u>Stock Status</u> : Fcurr/$F_{0.1}$=1.94 →**(O_H): High overfishing**

Bcurr=3218.52 ($B33^{rd}$=6417.22 - $B66^{rd}$=8392.86) →**(O_L): Relative low biomass** A

reduction of fishing mortality towards $F_{0.1}$ would be recommended.

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 (1970-2012)	Stock Status
Fishing mortality	Fishing mortality	$F_{0.1}$ = 0.51	F_{curr} = 0.99		I (1970-2012) N (2013-2016)	O_H
	Fishing effort					
	Catch					
Stock abundance	Biomass					
	SSB		B_{curr}=3218.52	$B33^{rd}$=6417.22 $B66^{rd}$=8392.86	D (1970-2012) I (2013-2016)	O_L
Recruitment						
Final Diagnosis	In high level of overfishing and relative low biomass					

7.1 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 $Fc^*/F_{0.1}$ 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)*