Stock Assessment Form of DPS (*P. longirostris*) in combined GSA 12-16

Reference year: 2007-2015

Reporting year: 2016

Parapenaeus longirostris, is the main target species of bottom otter trawling in the outer shelf upper slope of the Strait of Sicily. It is caught together with hake (*M. merluccius*) and Norway lobster (*N. norvegicus*). Scientific data available indicates that exploitation by the fishing fleets of Tunisia, Malta, Libya and Italy is targeting a single shared stock. Sicilian coastal trawlers (LOA between 12 and 24 m) fishing deep water rose shrimp are based in seven harbors along the southern coasts of Sicily. These trawlers operate mainly on short -distance with trips ranging from 1 to 2 days at sea. Sicilian trawlers over 24 m LOA have longer fishing trips, which may have a duration of up to 4 weeks. They operate offshore, in both Italian and international waters of the Central Mediterranean. In the Maltese Islands small vessels measuring 12 to 24 m in length target rose shrimp on fishing grounds located to the north and north -west of Gozo. Tunisian trawl vessels targeting rose shrimp measure around 24 m in length, and operate primarily in Northern Tunisia where 90% of the country's total *P. longirostris* catches originate. The great majority of these catches are landed in the ports of Bizerte and Kelibia. The assessment, performed by Extended Survivors Analysis (XSA) integrated with trawl survey data, showed a state of overfishing with low level of relative stock abundance.

Stock Assessment Form version 1.0 (January 2014)

Uploader: *Vita Gancitano*

Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Parapenaeus longirostris	[deep water rose shrimp]	[45]
1st Geographical sub-area:	**2nd Geographical sub-area:**	**3rd Geographical sub-area:**
[GSA12]	[GSA_13]	[GSA_14]
4th Geographical sub-area:	**5th Geographical sub-area:**	**6th Geographical sub-area:**
[GSA_15]	[GSA_16]	
1st Country	**2nd Country**	**3rd Country**
[Tunisia]	[Italy]	[Malta]
4th Country	**5th Country**	**6th Country**
Stock assessment method: (direct, indirect, combined, none)		
Indirect method (XSA) tuned by trawl survey data		
Authors:		
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Affiliation:		
[1]Institute National des Sciences et Technologies de la Mer (INSTM), Tunisia; [2]National Research Council (CNR) – Institute for Coastal Marine Environment (IAMC) of Mazara del Vallo, Via L. Vaccara 61, 91026, Mazara del Vallo (TP), Italy; [3]MSDEC – DFA Malta; [4]Food and Agriculture Organization of the United Nations (FAO), MedSudMed Project, Viale delle Terme di Caracalla, 00153 Rome, Italy.		

The ISSCAAP code is assigned according to the FAO 'International Standard Statistical Classification for Aquatic Animals and Plants' (ISSCAAP) which divides commercial species into 50 groups on the basis of their taxonomic, ecological and economic characteristics. This can be provided by the GFCM secretariat if needed. A list of groups can be found here:

http://www.fao.org/fishery/collection/asfis/en

Direct methods (you can choose more than one):

- Acoustics survey
- Egg production survey
- Trawl survey
- SURBA
- Other (please specify)

Indirect method (you can choose more than one):

- ICA
- VPA
- LCA
- AMCI
- XSA
- Biomass models
- Length based models
- Other (please specify)

Combined method: you can choose both a direct and an indirect method and the name of the combined method (please specify)

2 Stock identification and biological information

2.1 Stock unit

The deep water rose shrimp (DPS) *Parapenaeus longirostris* (Lucas 1846) is distributed throughout the SE Atlantic Ocean and the Mediterranean basin. The studies on stock structure of the species in the Strait of Sicily is still in progress. Concerning the connectivity between spawning and nursery areas, Levi et al. (1995) hypothesised that there is a flux of eggs, larvae and juvenile of *P. longirostris* from east to west due to an intermediate water current present in the region. The existence of at least two sub-populations in the northern side of the area (GSA 15 and 16) connected by the Atlantic Ionian Stream (AIS) were reported by Fortibuoni et al. (2010) (fig. 2.1.1). According to the multidimensional definition of stock followed in the STOCKMED project (Fiorentino et al., 2015), the deep water rose shrimp of the Strait of Sicily would belong to a single a stock unit, extending from the central –southern Tyrrhenian Sea (GSA 10) to eastern Ionian (GSA19) and southern Adriatic (GSA 18).

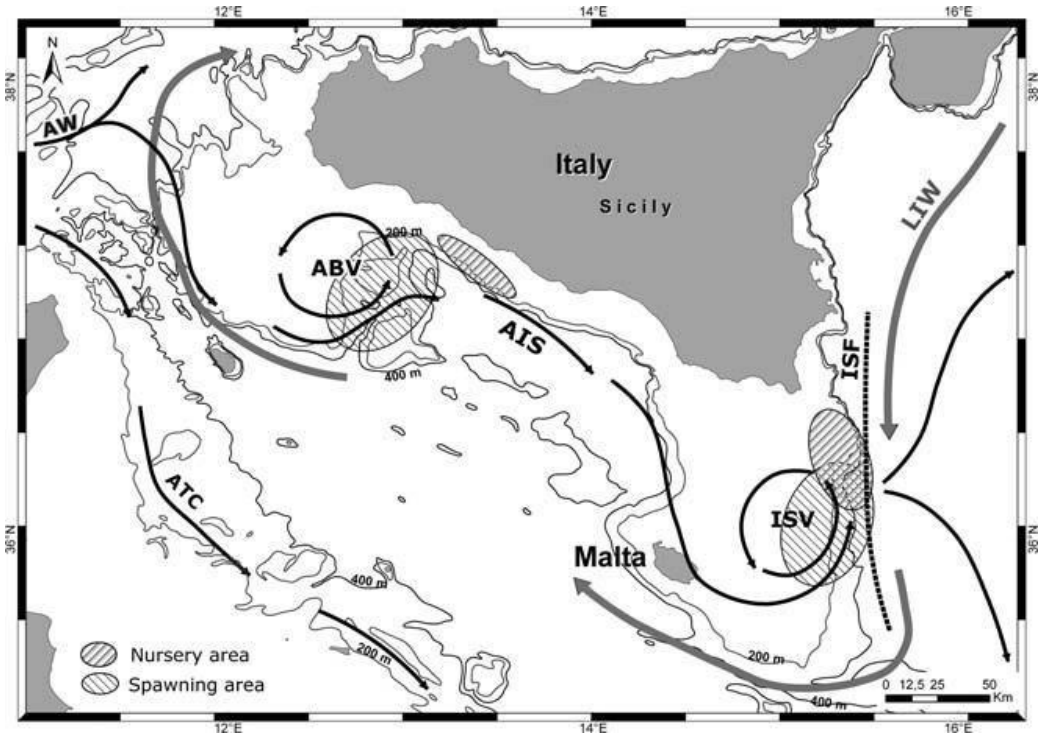

Figure 2.1.1 - Location of stable nurseries and spawning areas of *Parapenaeus longirostris* in the northern sector of the Strait of Sicily.The main hydrological characteristics of the area are also shown. ABV: Adventure Bank Vortex; ATC: Atlantic Tunisian Current; AIS: Atlantic Ionian Stream; ISV: Ionian Shelf-break Vortex; ISF: Ionian Slope Front; LIW: Levantine Intermediate Water; AW: Atlantic Water (from Fortibuoni et al., 2010).

2.2 Growth and maturity

P. longirostris is a short-lived species characterized by fast growth, high mortality rates (Abellò *et al*., 2002) and continuous spawning throughout the year (Levi et al. 1995, Ben Mariem *et al.*, 2001). It is distributed mostly on sandy - muddy bottoms between 100 and 400m, although the species has a bathymetric distribution

range of 20 – 750 m. Deep water rose shrimp have a size-dependent depth distribution, with the highest concentration of small individuals found at the edge of the continental shelf. This size related depth segregation is reflected in commercial catches, where smallest specimens are caught mainly on the outer continental shelf (50–200 m), and larger specimens along the slope (>200 m) .

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

Somatic magnitude measured (CL mm)					
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	Peak summer/fall
Maximum size observed	42	38		**Recruitment season**	All year
Size at first maturity	20.85	13.65	15	**Spawning areas**	Identified in northern sector
Recruitment size to the fishery			5 to 8	**Nursery areas**	Identified in northern sector

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

Size/Age	Natural mortality	Proportion of matures
0	*1.42*	*0.03*
1	*1.09*	*0.98*
2	*1.05*	*1.00*
3	*1.03*	*1.00*

Table 2-2.3: Growth and length weight model parameters

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**	mm	42.70	33.56	44.59	

	K		0.67	0.73	0.6	
	t_0	year	-0.208	-0.13	-0.118	
	Data source	Average SAMED (2002) / Ben Meriem (unpubl.)				
Length weight relationship	**A**		0.0029	0.0034	0.0033	
	B		2.48	2.41	2.46	
	M (scalar)					
	sex ratio (% females/total)					

3 Fisheries information

3.1 Description of the fleet

Trawlers targeting *P. longirostris* operate on the outer shelf and upper slope of the Central Mediterranean throughout the year, and catches often include hake (*Merluccius merluccius*), Norway lobster (*Nephrops norvegicus*), scorpionfish (*Helicolenus dactylopterus*), greater forkbeard (*Phicys blennioides*) and

monkfish (*Lophius* spp.). Scientific data available indicates that fishing fleets of Tunisia, Malta, Libya and Italy target a single shared stock (Camilleri *et al.*, 2007).

Sicilian coastal trawlers (LOA between 12 and 24 m) targeting deep water rose shrimp are based in seven harbours along the southern coasts of Sicily. These trawlers operate mainly on short-distance fishing trips, which range from 1 to 2 days at sea, and fishing taking place on the outer shelf and upper slope. With 290 registered vessels, this is the largest component of the fleet fishing deep water rose shrimp in 2015. Sicilian trawlers over 24 m in length have longer fishing trips, which may have a duration of up to 4 weeks. These vessels operate offshore, in both Italian and international waters of the Central Mediterranean. Due to the progressive shift in target species of such trawlers from deep water rose shrimps and Norway lobster to red shrimps, about 75 out 114 can be considered as targeted on *P. longirostris* in 2015.

In the Maltese Islands small vessels measuring 12 to 24 m in length target rose shrimp very close to land (around 6 km from the coast) at a depth of around 200m. The number of trawlers targeting rose shrimp decreased from 13 in 2011 to 10 in 2015. The activity is mainly carried out in winter, when the weather does not allow to fish in deeper waters.

Tunisian trawl vessels which target rose shrimp measure around 24 m in length, and operate primarily in Northern Tunisia where 90% of the country's total *P. longirostris* catches originate. The great majority of these catches are landed in the ports of Bizerte and Kelibia. The number of Tunisian trawlers targeting rose shrimp has increased from 40 in 1996 to around 70 in 2009.

The main fishing ground areas of *P. longirostris* for distant (coloured) and coastal (black) Sicilian trawlers in the Strait of Sicily are shown in fig.3.1.12.

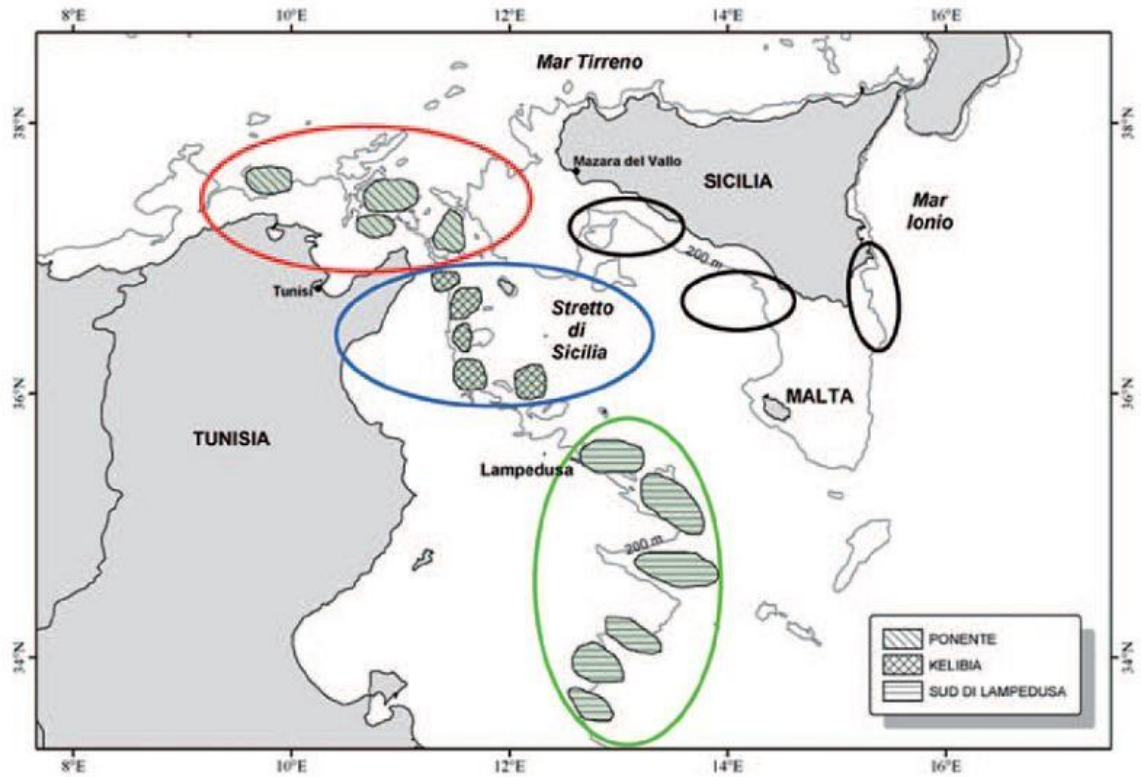

Figure 3.1.1 - The main fishing ground areas of *P. longirostris* for distant (coloured) and coastal (black) Sicilian trawlers in the Strait of Sicily.

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	99	E - Trawl (1224 metres)	03 - Trawls	34 - Demersal slope species	DPS
Operational Unit 2	ITA	99	F - Trawl (>24 metres)	03 - Trawls	34 - Demersal slope species	DPS
Operational Unit 3	TUN	99	F - Trawl (>24 metres)	03 - Trawls	34 - Demersal slope species	DPS
Operational Unit 4	MLT	99	E - Trawl (1224 metres)	03 - Trawls	34 - Demersal slope species	DPS

Table 3.1-2: Catch, and effort by operational unit in the 2015

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)
OU 1: ITA 99 E 03 34 - DPS	394	3783.7		73		
OU 2: ITA 99 F 03 34 - DPS	74	2375.8				
OU 3: TUN 99 F 03 34 - DPS	70	1931				
OU 4: MLT 99 E 03 34 - DPS	14	15.48				
Total		8106		73		

3.2 Historical trends

Trend in catch of deep-water rose shrimp (DPS) of the Italian, Tunisian and Maltese trawl fleets since 2007 is shown in Fig. 3.2.1. The nominal effort (KW*days at sea) shows a decreasing of the two segments of the Italian trawl fleet (LOA<24m and LOA >24m) since 2004 (Fig. 3.2.2).

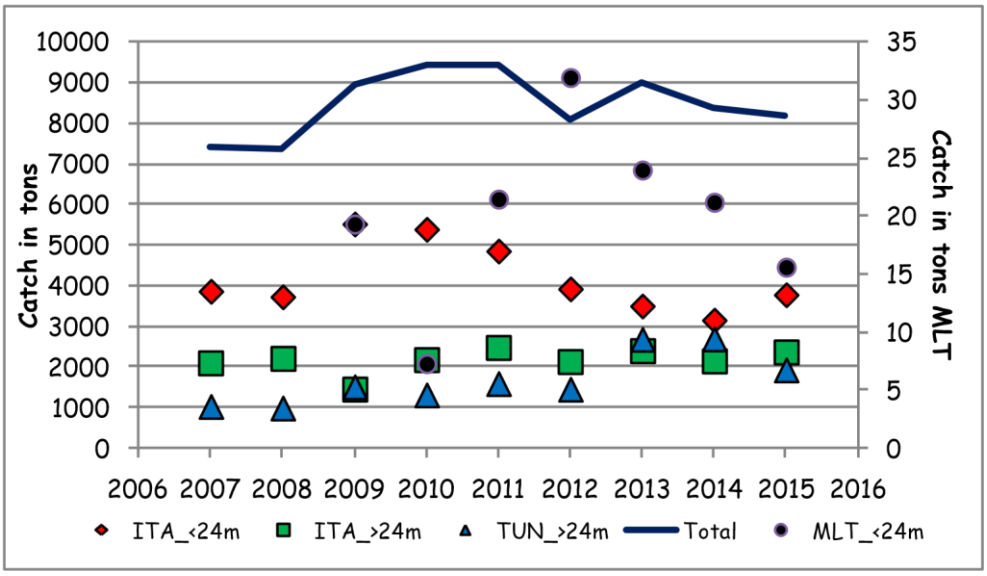

Figure 3.2.1 - Catch of DPS from 2005 to 2014 in the Strait of Sicily, Central Mediterranean (GSA 12 - 16) by country and LOA.

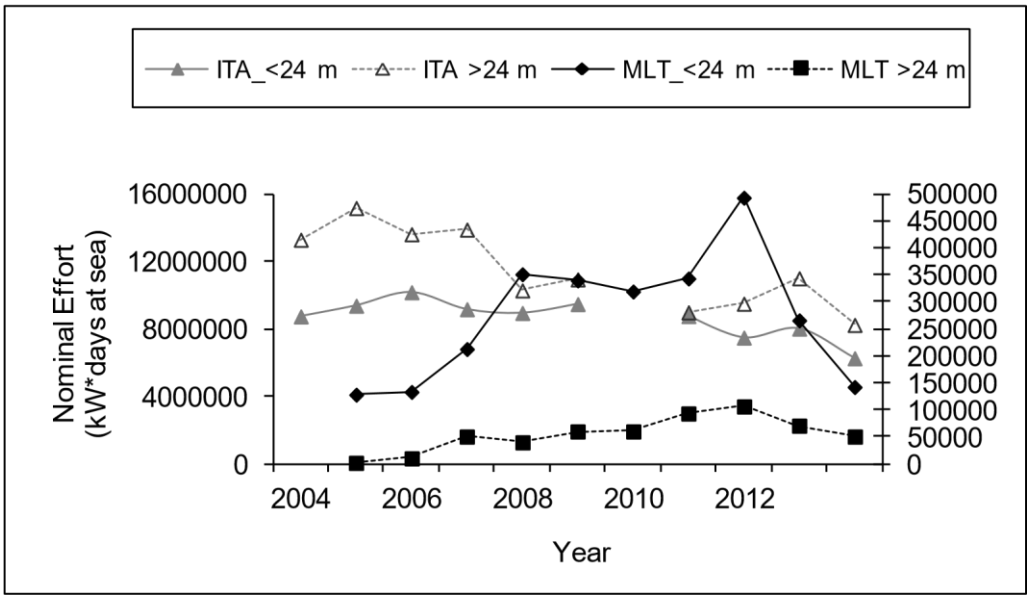

Figure 3.2.2 – Fishing effort from 2005 to 2014 in the Strait of Sicily, Central Mediterranean (GSA 15 and 16) by country and LOA.

3.3 Management regulations

As in other areas of the Mediterranean, the stock management of Italian fleet is based on control of capacity (number of fishing licenses), fishing effort (days at sea, number of trawls), and technical measures (cod-end mesh size, area closures and fish-size limits). A medium term management plan for 2008-2013 has been agreed for Italian trawlers in the Strait of Sicily. the plan was mainly based on a fleet reduction of 25% of the capacity obtained in two steps. The first (12.5%) from 2008 to 2010, and the second (12.5%) from 2011 to 2013. A trawling ban of 30 day per year is adopted, normally in late summer early autumn.

In addition, the Mediterranean Regulation EC 1967 of 21 December 2006 fixed a minimum harvest size of 20 mm CL and a minimum mesh size of 40 mm square or 50 mm diamond for EU bottom trawling vessels (i.e. Italian and Maltese trawlers).

In 2015, Malta had 14 trawlers that operated on a full-time basis. A preliminary analysis of the capacity of the fleet in the Sub-regional Committee report for the Central Mediterranean (SRC_CM) showed that there was a 39% reduction from 2011 to 2015 (7 permanent and 2 temporary). Fishing effort and capacity in the 25 nautical miles fisheries management zone are being managed by limiting vessel sizes, as well as total vessel engine powers (EC 813/2004; EC 1967/2006). Trawling is allowed within this designated conservation area, however only by vessels not exceeding an overall length of 24m and only within designated areas. Such vessels fishing in the management zone hold a special fishing permit in accordance with Article 7 of Regulation (EC) No 1224/2009, and are included in a list containing their external marking and vessel's Community fleet register number (CFR) to be provided to the Commission annually by the Member States concerned (EC 813/2004).

In Tunisia, no regulations targeted specifically at the rose shrimp fishery are currently in place. However, trawling is not permitted within 3 nautical miles of the coast and at less than 50m depth in GSAs 12-14. Moreover, in GSA 14 a closed season where trawling is prohibited extending from July-September is in place in order to protect recruits of a large number of species. Although minimum landing sizes exist for a number of crustacean species harvested by the Tunisian fleets, there is no minimum landing size for *P. longirostris*. The minimum legal mesh size used by demersal trawlers in Tunisian waters is 20mm.

Due to the importance of the deep water rose shrimp fishery for the costal countries in the area the CFGM adopted the Recommendation GFCM/40/2016/4on the establishment of a set of minimum standards for bottom trawling fisheries of demersal stocks in the Strait of Sicily, pending the development and adoption of a multiannual management plan.

The management plan targeted to deep water rose shrimp and hake fishery should include a first implementation period (about four years) during which an initial reduction of 20 percent of current fishing mortality would be implemented (i.e. F_{MSY} for shrimps should be established as a target fishing mortality during this first phase), concentrated as much as possible on reducing fishing mortality for hake juveniles (e.g. using spatial protection on hake nursery areas or reducing the effort of those parts of the fleet that have higher catches of small hake individuals) in order to maximize the potential positive effect on hake stocks. The effectiveness of this reduction should then be assessed and additional measures could be proposed if needed. Management measures that could help to achieve these targets include: i) spatial protection on hake nursery areas and ii) reducing fishing effort on hake juveniles.

Furthermore, the management plan should also include minimum and/or maximum landing sizes for elasmobranchs, as well as measures to mitigate incidental catches of such species.

In order to protect juveniles three Fishery Restricted Areas (FRAs) where bottom trawling is prohibited were adopted in the northern sector of the Strait of Sicily (GSA 15 and 16). These FRAs could be established for an initial testing phase of 2 years, with periodic scientific studies assessing the effectiveness of the measure. More

studies should be carried out to identify nursery areas of hake in GSAs other than 15 and 16, in order to evaluate the possibility of proposing additional FRAs to protect nursery areas throughout the subregion.

3.4 Reference points

Table 3.2-1: List of reference points and empirical reference values in 2015.

Indicator	Limit Reference point/empirical reference value	Value	Target Reference point/empirical reference value	Value	Comments
B					
SSB					
F			$F_{0.1}$	0.84-0.93	
Y					
CPUE					
Index of Biomass at sea					

4 Fisheries independent information

4.1 MEDITS Trawl Survey

In order to collect fisheries independent data, which is a requirement of the EU DCF (Council Regulation 199/2008, Commission Regulation 665/2008, Commission Decision EC 949/2008 and Commission Decision 93/2010), the MEDITS international trawl survey is carried out in GSAs 15 & 16 on an annual basis. In July 2011 an intercalibration experiment was carried out to standardize MEDITS indices from GSAs 15-16 with those of Tunisian surveys.

4.1.1 Brief description of the direct method used

Distribution, abundance and demographic information of the stock at sea derived from data collected during the standard bottom trawl surveys carried out annually in the northern sector of the Strait of Sicily from 1994 to 2015 in spring/early summer within the MEDITS (MEDiterranean International Bottom Trawl-Surveys) program, included in the European Data Collection Framework (DCF). A total of 45 haulsin GSA 15 and 120 hauls in GSA 16 were performed yearly. The bottom trawl surveys covered an area of about 10580 in GSA 15 and 45,000 km^2 in GSA 16 within a water depth-range of 10-800 m in both areas. The sampling design is random stratified with allocation of hauls proportional to strata extension (depth strata: 10-50 m, 51-100 m, 101-200 m, 201-500 m, 501-800 m). Roughly

the same haul positions were kept each year. The standardized GOC 73 gear is used with mesh size in the cod-end 20 mm opening and the vertical opening of the mouth of 2.4-2.9 m. More details on the MEDITS protocol is reported in the MEDITS-Handbook. Version n. 7 (2013).

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Direct methods: trawl based abundance indices

Table 4.1-1: Trawl survey basic information (GSA 16).

Survey	MEDITS	**Trawler/RV**	TRAWLER
Sampling season	MAY-JULY		
Sampling design	Stratified with number of haul by stratum proportional to stratum surface (see MEDITS-Handbook. Version n. 7, 2013, MEDITS Working Group : 120 pp)		
Sampler (gear used)	Bottom trawl made of four panels (IFREMER reference GOC 73)		
Cod –end mesh size as opening in mm	10 mm mesh size, which corresponds to ~ 20 mm of mesh opening		
Investigated depth range (m)	10-800m		

Table 4.1-2: Trawl survey sampling area and number of hauls (GSA 16).

Stratum	**Total surface (km^2)**	**Trawlable surface (km^2)**	**Swept area (km2)**	**Number of hauls**
a	2979			11
b	5943			23
c	5565			21
d	6972			27
e	9927			38
Total	31384			120

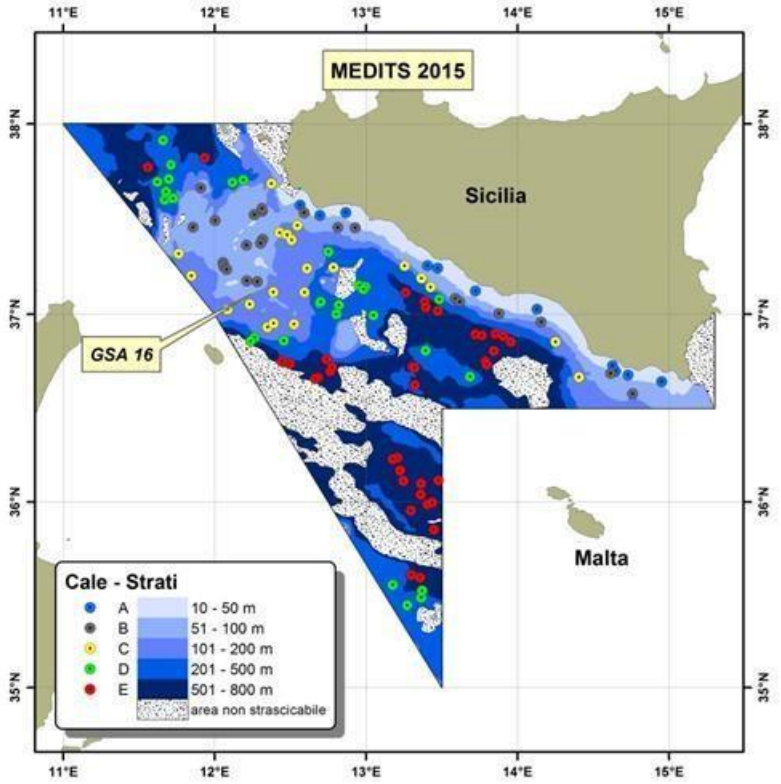


Figure 4.1.1 - Map of hauls positions in the Strait of Sicily (GSA 16).

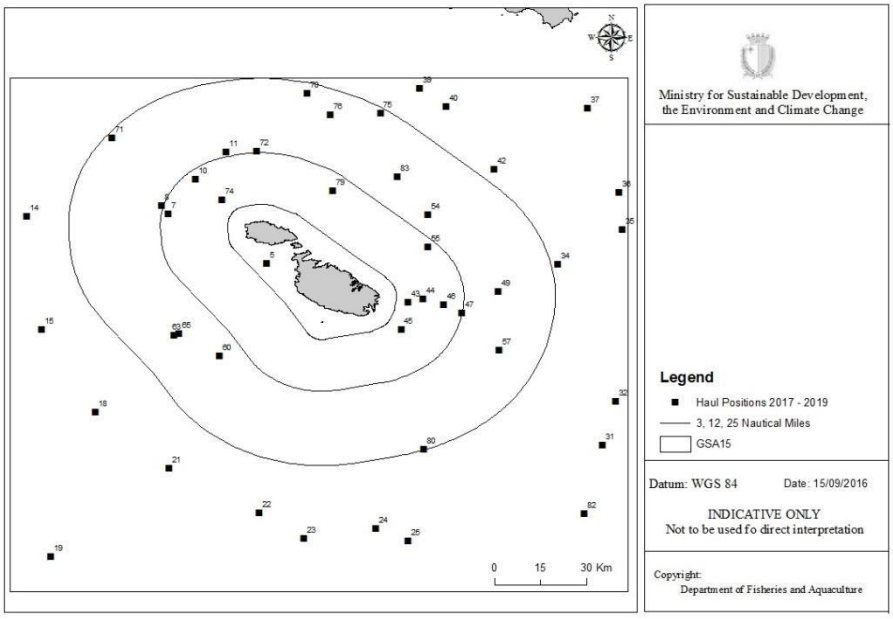


Figure 4.2 Map of hauls positions in GSA 15

Table 4.1-3: Trawl survey abundance and biomass results in GSA 15 and 16.

Depth Stratum	Years	kg per km² (GSA 16)	CV (GSA 16)	N per km² (GSA 16)	CV (GSA 16)	kg per km² (GSA 15)	CV (GSA 15)	N per km² (GSA 15)	CV (GSA 15)
10-800 m	1994	5.9	45.9	793.8	39.6				
10-800 m	1995	5.1	34.2	785.2	27.2				
10-800 m	1996	7.6	33.7	1523.3	29.6				
10-800 m	1997	7.5	29.8	1461.8	29.2				
10-800 m	1998	11.5	28.3	2448.2	28.3				
10-800 m	1999	15.8	29.3	3190.3	27.5				
10-800 m	2000	16.0	31.4	2868.7	29.6				
10-800 m	2001	13.0	33.8	2548.0	29.5				
10-800 m	2002	4.8	22.0	1571.7	30.8				
10-800 m	2003	7.4	32.1	1433.3	31.3				
10-800 m	2004	16.8	37.3	4565.5	41.4				
10-800 m	2005	11.3	33.5	1858.1	35.2	7.27		1021	
10-800 m	2006	12.4	47.5	1848.4	50.5	16.72		3192	
10-800 m	2007	5.3	35.1	815.2	34.9	12.36		2237	
10-800 m	2008	11.8	37.0	2286.9	37.6	22.29		4909	
10-800 m	2009	23.9	42.2	3563.1	42.4	60.96		4483	
10-800 m	2010	16.6	40.1	2717.9	41.4	14.29		2383	
10-800 m	2011	13.0	42.7	2252.1	39.1	16.40		3206	
10-800 m	2012	38.2	29.4	8012.1	29.5	17.24		3201	
10-800 m	2013	21.8	28.7	4606.9	29.4	15.52		2225	
10-800 m	2014	10.71	40.4	3245	59.0	11.65		2645	
10-800 m	2015	5.44	33.84	948	34	4.12		937	

Total (10 – 800 m)									

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

Length structures were sliced using a knife edge approach.

Table 4.1-4: Trawl survey indices of abundance (n/km2) by age class.

N (sex combined) by Age class in thousand	**Year**								
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
0	8777469	35726857	42941649	36285584	29317637	1.3E+08	73321941	51912722	1421857
1	9625894	19086610	44082420	29844160	24751090	70009530	37997260	15763830	1078966
2	671734.3	426680.9	765236.9	1116631	484802.1	450225.9	718793.4	575668.8	23941.83
3	1416	3979.4	869	0	1393.1	4654.2	1423.5	0	334.3117
Total									

Table 4.1-5 Sex ratio by length class in mm of deep water rose shrimp from MEDITS in GSA 16. All year combined.

Sex ratio by Length class	1994-2015	6	0.77
		8	0.73
		10	0.70
		12	0.61
		14	0.47
		16	0.37
		18	0.30
		20	0.31
		22	0.55
		24	0.74
		26	0.83
		28	0.92
		30	0.98
		32	1.00
		34	1.00
		36	1.00
		38	1.00

Direct methods: trawl based Recruitment analysis

Table 4.1-6: Trawl surveys; recruitment analysis summary in GSA 16.

Survey		**Trawler/RV**	
Survey season		Spring-summer	
Cod –end mesh size as opening in mm		20	
Investigated depth range (m)		10-800	
Recruitment season and peak (months)		All the year around	
Age at fishing-grounds recruitment			
Length at fishing-grounds recruitment		10 mm CL	

Table 4.1-7: Trawl surveys; recruitment analysis results.

Years	Area in km^2	N of recruit per km^2	CV
1994		212	40.2
1995		356	26.9
1996		1013	28.7
1997		950	27.5
1998		1658	26.8
1999		1956	25.3
2000		1304	36.4
2001		1354	25.5
2002		880	32.4
2003		645	31.3
2004		2698	44.8
2005		744	42.7
2006		595	68.3
2007		247	42.3
2008		1021	40.2
2009		1113	49.1
2010		986	48.2
2011		816	35.6
2012		3812	32.0
2013		2184	31.3
2014		1584	41.1
2015		384	30

4.1.2 Spatial distribution of the resources

The temporal persistence of nurseries and spawning grounds of *Parapenaeus longirostris* (DPS) is shown in Fig. 4.2.1.

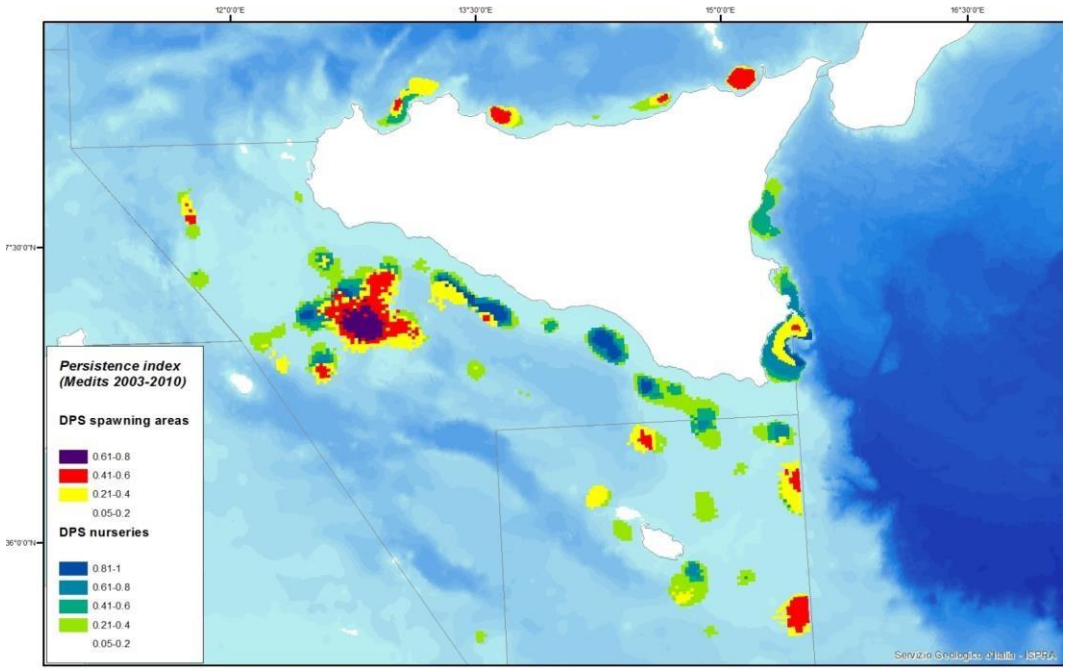
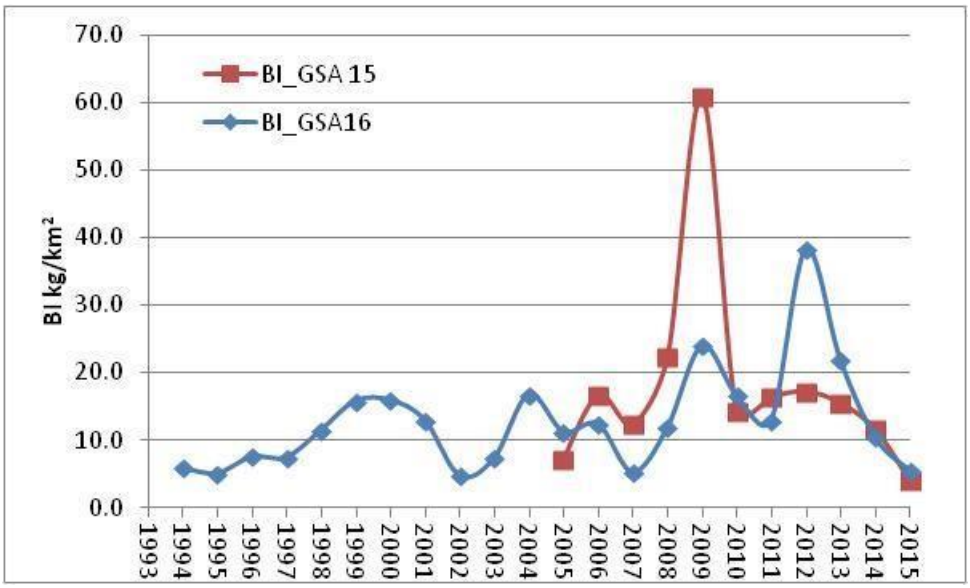


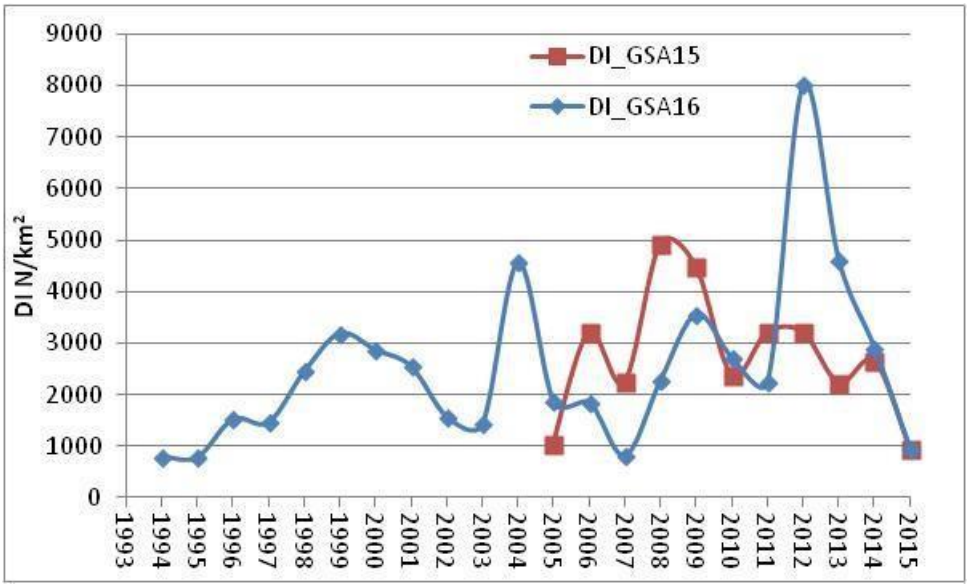
Figure 4.1.2.1 - Temporal persistence of nursery and spawning areas of the deep water rose shrimp in GSAs 15-16, from MEDISEH - MAREA project (from Colloca et al., 2015)

4.1.3 Historical trends

The trends in biomass and density of the deep water rose shrimp (DPS) during the MEDITS survey in GSA 15 and GSA 16 show large fluctuations without any clear temporal trend (Fig. 4.1.3.1). The current relative stock biomass (kg/km-2) is below the 33° percentile (Fig. 4.1.3.2).



a)



b)

Figure 4.1.3.1 – a) Medits biomass index (BI) in GSA 15 and GSA16. b) Medits density index (DI) in GSA 15 and GSA16.

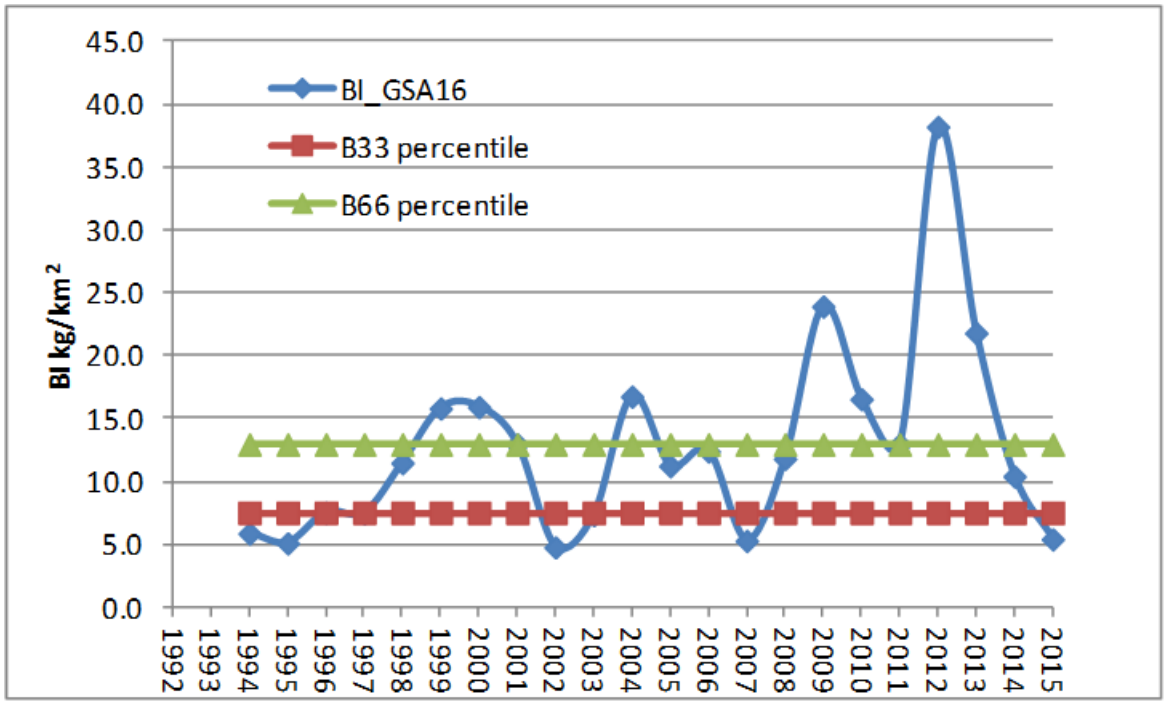
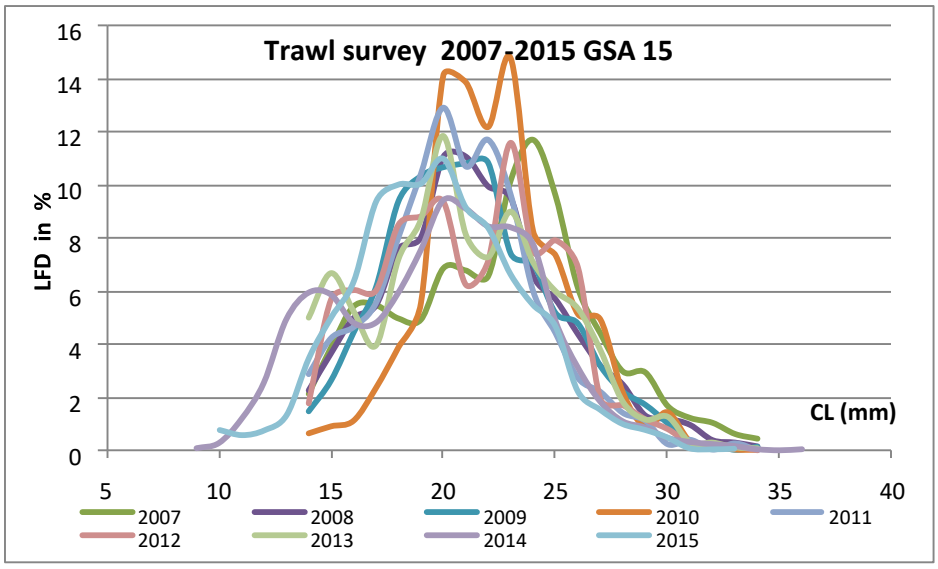


Figure 4.1.3.2 – a) Biomass index current (BI current), Biomass 33 and 66 percentile from Medits survey in GSA 16.

The length structures of DPS in MEDITS 2007-2015 are shown in Fig. 4.1.3.34

a)



b)

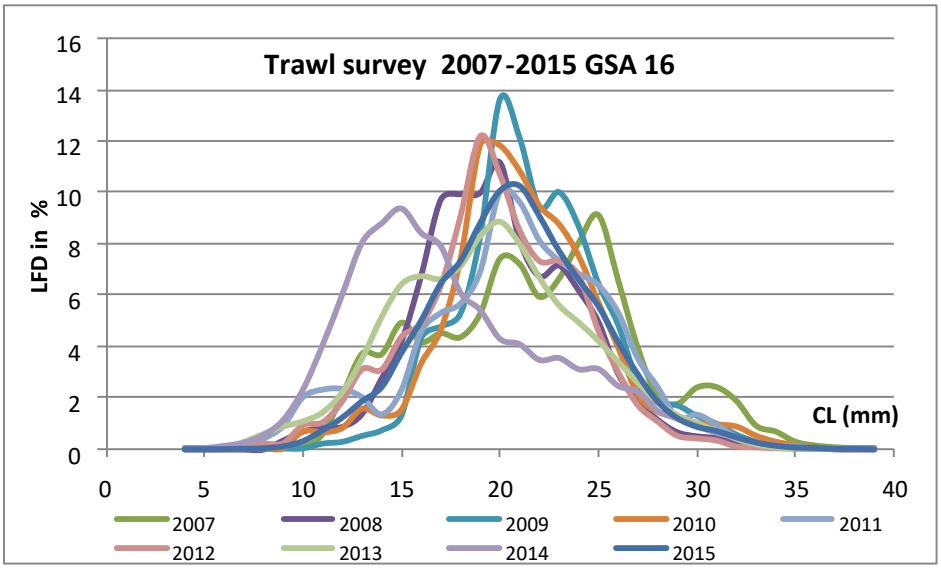


Figure 4.1.3.4 – a) Length frequency distributions (LFD) in % from Medits survey in GSA 15. b) Length frequency distributions (LFD) in % from Medits survey in GSA 16. Sex combined.

5 Stock Assessment

An XSA assessment was carried out using official trawl catch data (landings and discards, EU data collection framework) collected in GSAs 15-16 and GSAs 12-14 (Tunisia) in the period 2007 -2015. The XSA was tuned using Medits survey data (2007-2015) from GSA 15 and GSA 16. The natural mortality M was estimated by Prodbiom's method (forced). The annual size of the landings as well as Medits data were converted into the number at age by knife edge slicing. The status stock was also performed using Globally applicable Gadget (*A*rea *D*isaggregated *G*eneral *E*cosystem *T*oolbox) a parametric forward simulation model of an ecosystem, typically consisting of various fish populations, fleets and their interactions.

5.1 XSA

5.1.1 Model assumptions

Darby and Flatman (1994) outlined the XSA algorithm as performing the following steps: (1) a cohort analysis of the total catch-at-age data to produce estimates of population abundance-at-age, and total fishing mortalities; (2) adjustment of the CPUE values for the period of fishing defined using the alpha and beta parameters in the fleet tuning file, into CPUE values that would have been recorded if the fleet had fished only at the beginning of the year. The adjusted values are directly comparable with the population abundances at the beginning of the year; (3) calculation of fleetbased estimates of population abundance-at-age from the adjusted CPUE values and fleet catchabilities; (4) calculation of a least squares estimate (weighted mean) of the terminal population (survivors at the end of the final assessment year) for each cohort in the tuning range using the fleetderived estimates of population abundance-at-age. These terminal populations are used to initiate the cohort analysis in the next iteration. The process iterates until the convergence criteria described for *ad hoc* tuning are achieved. Various options are available for catchability analysis, time series weighting and shrinkage of the weighted estimates.

5.1.2 Scripts

5.1.3 Input data and parameters

For analytical models: catch matrix in ages. It's included discards.

Table 5.1.3.1 - Catch matrix by year and age .

Years	0	1	2	3
2007	652357	489517	24976	1146
2008	351677	397528	26062	2331
2009	734964	842282	23882	825
2010	698082	527050	11892	6
2011	677125	600131	11290	31
2012	497600	409065	5929	0
2013	337626	318673	12229	0
2014	122979	41377	462	1
2015	912189	499935	16254	183

Table 5.1.3.2 – Tuning data by year and age.

Years	0	1	2	3
2007	8777469	9625894	671734	1416
2008	35726857	19086610	426681	3979
2009	42941649	44082420	765237	869
2010	36285584	29844160	1116631	0
2011	29317637	24751090	484802	1393
2012	130222916	70009530	450226	4654
2013	73321941	37997260	718793	1424
2014	51912722	15763830	575669	0
2015	1421857	1078966	23942	334

Table 5.1.3.3 – Catch in W by year and age.

Years	0	1	2	3
2007	0.002	0.012	0.021	0.029
2008	0.002	0.012	0.021	0.029
2009	0.002	0.012	0.021	0.029
2010	0.002	0.012	0.021	0.029
2011	0.002	0.012	0.021	0.029
2012	0.002	0.012	0.021	0.029
2013	0.002	0.012	0.021	0.029
2014	0.002	0.012	0.021	0.029
2015	0.002	0.012	0.021	0.029

Table 5.1.3.4 – Natural Mortality at age group estimated by a modified Prodbiom method (M constant after the age of full maturity).

Group 0	Group 1	Group 2	Group 3
1.42	1.09	1.05	1.03

Table 5.1.3.5 – Proportion of mature specimens by year and age.

Group 0	Group 1	Group 2	Group 3
0.03	0.99	1.00	1.00

5.1.4 Results (XSA)

XSA was run using different settings of shrinkage on fishing mortality (0.5, 1.0, 1.5 and 2.0), rage (0, 1, 2), qage (2, 3), shk.age (1, 2), shk.years (2, 3)The best model was:

xsa_control <- FLXSA.control (x=NULL, tol=1e-09, maxit=150,min.nse=0.3, fse=1.5, rage=1,qage=3,shk.n=TRUE,shk.f=TRUE,shk.yrs=3,shk.ages=2,window=100, tsrange=20, tspower=0, vpa=FALSE)

The XSA run with shrinkage of 1.5 and catchability equal to 3 years, was adopted as final model (Fig. 5.1.4.1) based on both residuals and retrospective analysis.

In table 6.2.2.1 are reported the XSA results in terms of spawning stock biomass (SSB), total biomass (TB) and annual recruitment.. The SSB and TB show a slight decline since 2009 an increase, whilst recruitment does not show a clear trend.

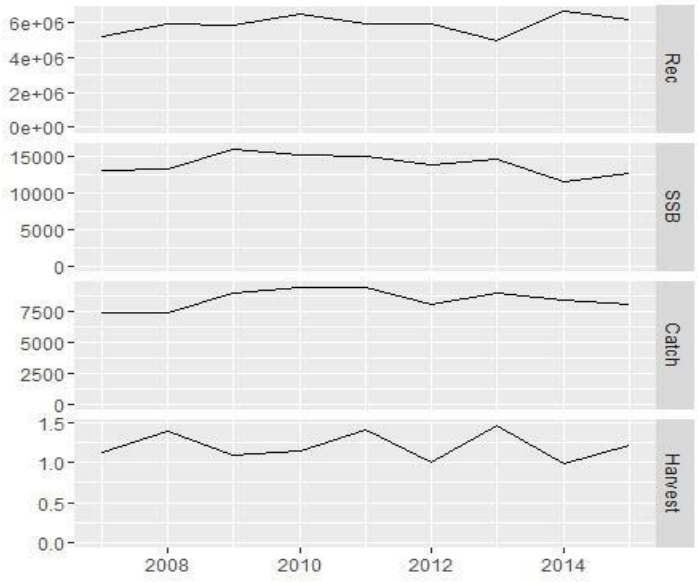


Figure 5.1.4.1. Final XSA model for deep water rose shrimp in GSAs 12-16

Table 5.1.4.1 – XSA estimates of spawning stock biomass (SSB), total biomass (TB) and recruitment (REC).

	2007	2008	2009	2010	2011	2012	2013	2014	2015
SSB (tons)	**13085**	**13126**	**15881**	**15122**	**14863**	**13789**	**14523**	**11489**	**12560**
TB (tons)	**20080.84**	**20058.66**	**24400.83**	**24020.3**	**23813.02**	**21334.98**	**23139**	**19513.94**	**20666.12**
Rec (in billions)	**5.23**	**5.94**	**5.86**	**6.51**	**5.97**	**5.94**	**4.97**	**6.68**	**6.17**

Fishing mortality values at age are reported in table 5.1.4.2. Current $F_{0\text{-}2}$was estimated as geometric mean three previous years (2013-2015) and equal to 1.21.

Table 5.1.4.2 – XSA estimates of fishing mortality at age at age .

F at age	2007	2008	2009	2010	2011	2012	2013	2014	2015
0	0.27	0.16	0.21	0.29	0.28	0.26	0.30	0.48	0.35
1	1.69	1.94	2.06	2.57	2.78	1.96	2.67	2.01	2.09
2	1.39	2.09	1.03	0.59	1.15	0.79	1.40	0.40	1.21
3	1.39	2.09	1.03	0.59	1.15	0.79	1.40	0.40	1.21
Fbar (0-2)	**1.12**	**1.40**	**1.10**	**1.15**	**1.41**	**1.00**	**1.46**	**0.99**	**1.21**

Yield per Recruit

A yield per recruit analysis was carried using the FLBRP library (FLR) to calculate $F_{0.1.}$ The estimated F_{01} value was 0.83.and in the range of the F_{01} values included in the GFCM management plan (F01 =0.84-0.93)

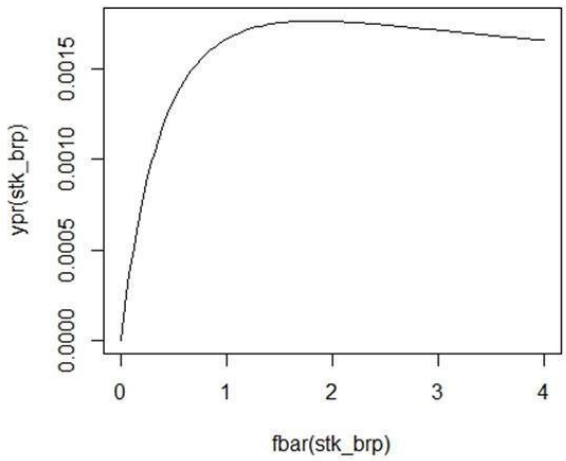


Figure 5.1.4.2 - Yield per recruit analysis.

5.1.5 Robustness analysis

Log residuals at age of the Medits survey are reported in Fig. 5.1.5.1

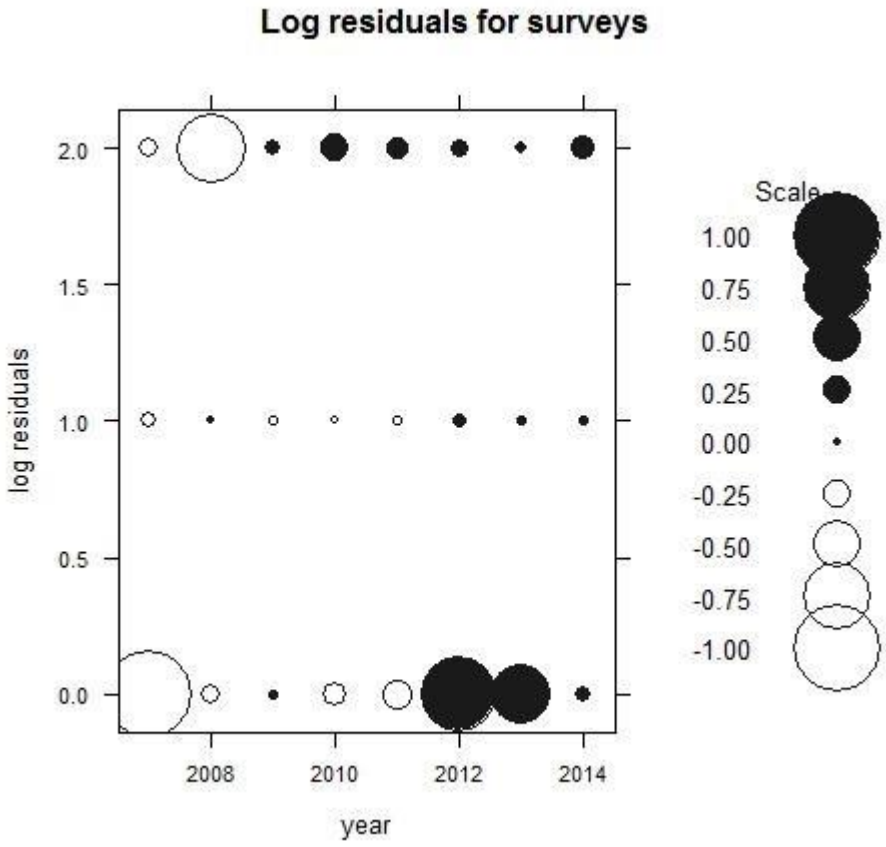


Figure 5.1.5.1 - Log residuals of Medits survey.

5.1.6 Retrospective analysis

Retrospective analyses showed rather consistent results with no major pattern in the data (Fig. 5.1.6.1.).

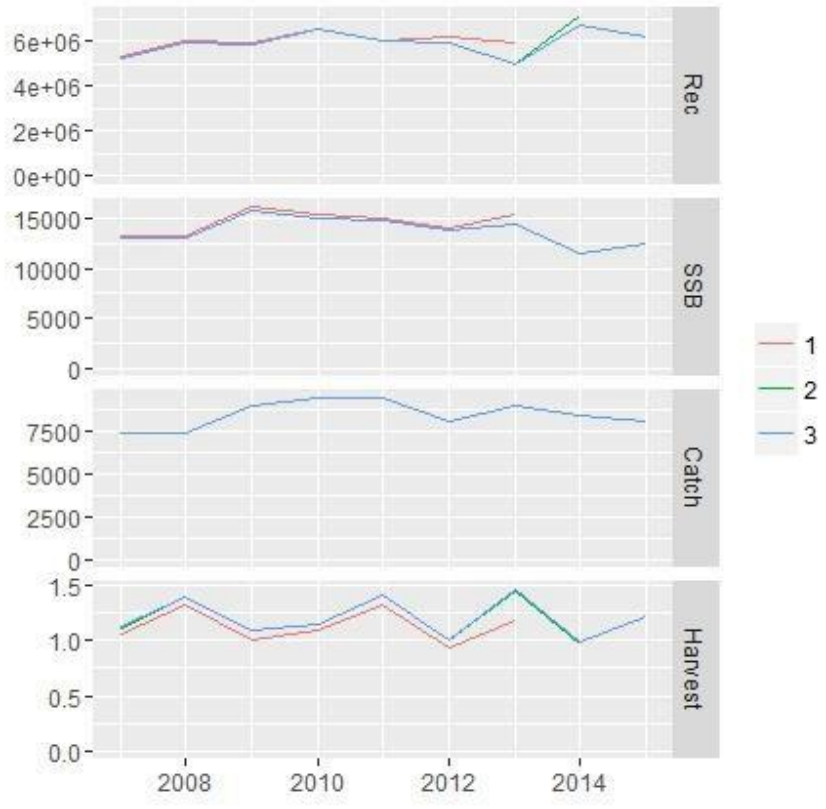
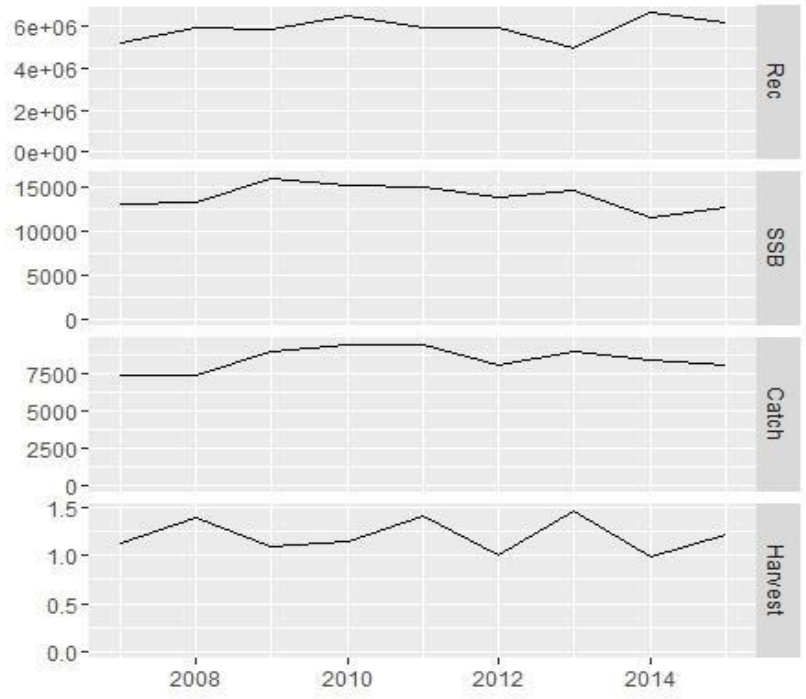
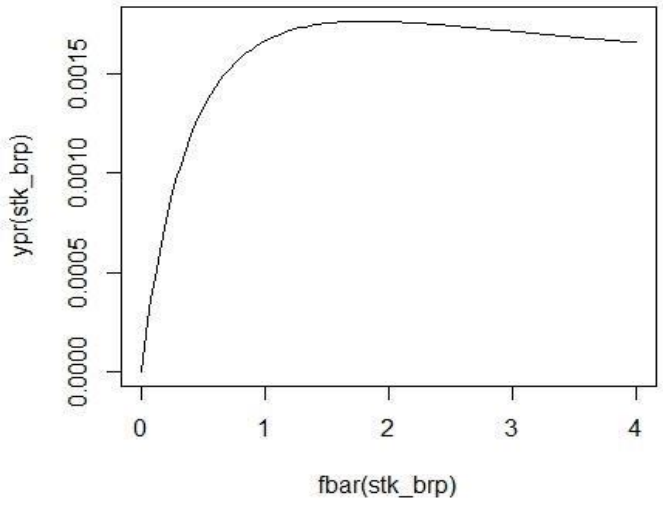


Figure 5.1.6.1 - Retrospective analysis.

5.1.7 *Assessment quality*

Based on Medits residuals and retrospective analysis the XSA results appear consistent and in line with the XSA assessment carried out in 2015.





5.2 Alternative models: GADGET

Gadget model (Beagley and Howell, 2004) is a parametric forward simulation model of an ecosystem, typically consisting of various fish populations, fleets and their interactions. In to the model the features of the ecosystem are:

- One or more species, each of which may be split into multiple components (stocks);
- - Multiple areas with migration between areas;
- - Predation between and within species;
- - Growth;
- - Maturation;
- - Reproduction and recruitment;

- - Multiple commercial and survey fleets taking catches from the populations.
- - Different fisheries selectivities.

The Gadget framework consists of three parts, a model to simulate the ecosystem, a statistical functions to compare the model output to data and search algorithms to optimize the model parameters.
Gadget works by running an internal forward projection model based on many parameters describing the ecosystem, and then comparing the output from this model to observed measurements to get a likelihood score. The model ecosystem parameters can then be adjusted, and the model re-run, until an optimum is found, which corresponds to the model with the lowest likelihood score. This iterative, computationally intensive process is handled within Gadget, using a robust minimization algorithm.

$$l = \sum_{\text{time}} \sum_{\text{age}} \sum_{\text{length}} (P_{tal} - \pi_{tal})^2,$$

It was already used in the Mediterranean (hake in GSA 9: Bartolino et al., 2011) and currently adopted for the assessment of hake (*Merluccius merluccius*) in Ices divisions 8.c and 9.a (Southern Stock of hake).

Deep water rose shrimp (DPS) population is defined by 2 mm carapace length groups. The year is divided into four quarters. DPS age range in between 0 and 4, this latter used as plus group. Recruitment take place in the second and third quarter. Parameters of VBGF are Linf=44 (fixed) and K=0.23 estimated. Natural mortality was assumed as a vector using the PRODBIOM approach (Abella et al., 1997) ad hoc implemented in R.

5.2.1 Input data and Parameters (Gadget)

The data included in the model:
• Length based
• Time: 2002-2014
• Two fleets: commercial trawlers ITA-MLT, commercial trawlers TUN
• Medits survey fleet
• Recruitment all year
• Fleet selectivity knife edge

Parameters:
• Linf=44.6 CL (fixed), K=0.26 (0.25-0.9) (estimated)
• M: 1.6 0.8 0.7 0.6
• Recruitments (estimated)
• Maturity: 0.03 0.98 1.0 1.0
• Selectivity parameters (estimated, Fig. 6.2.1)

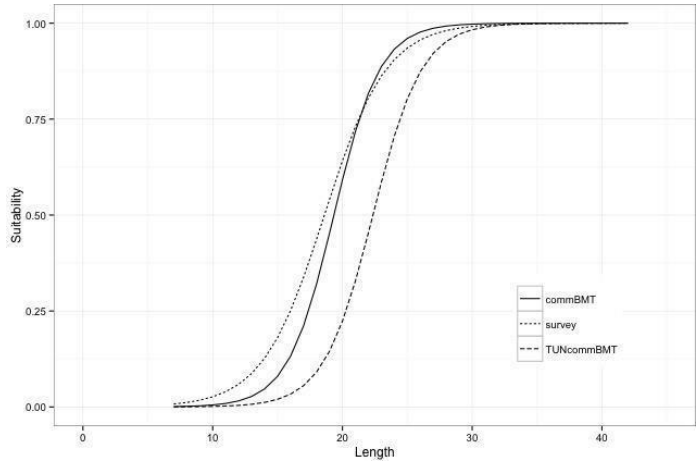
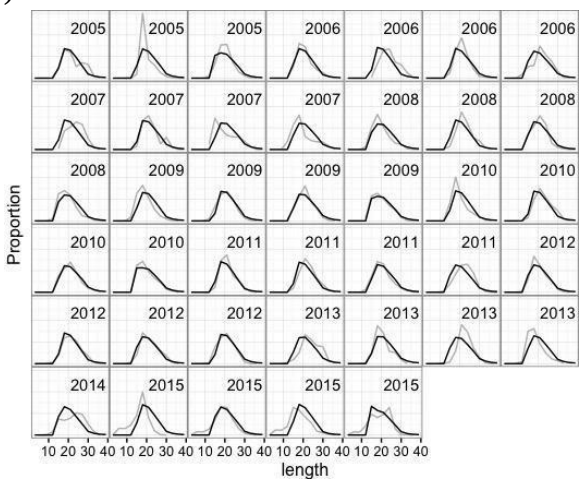


Figure 5.2.1.1 - DPS in GSAs 12-16. Fleets selectivity curves.

Model fit reasonably well the time series of catch and Medits survey data

a)



b)

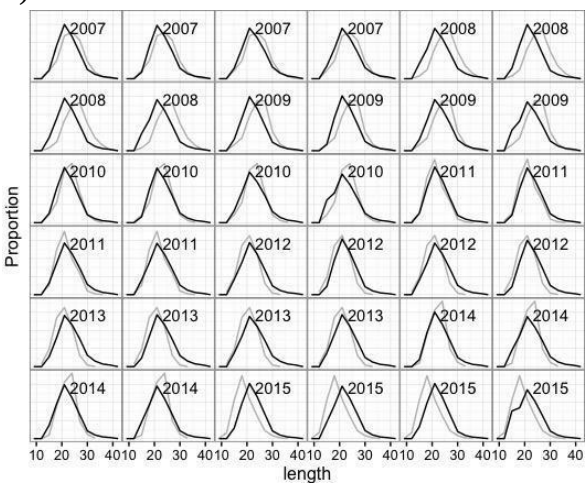


Figure 5.2.1.2 - DPS in GSAs 12-16. Model simulated (black line) and observed (grey line) size distributions of trawlers catch (a: Tunisian trawlers; b: Italian trawlers).

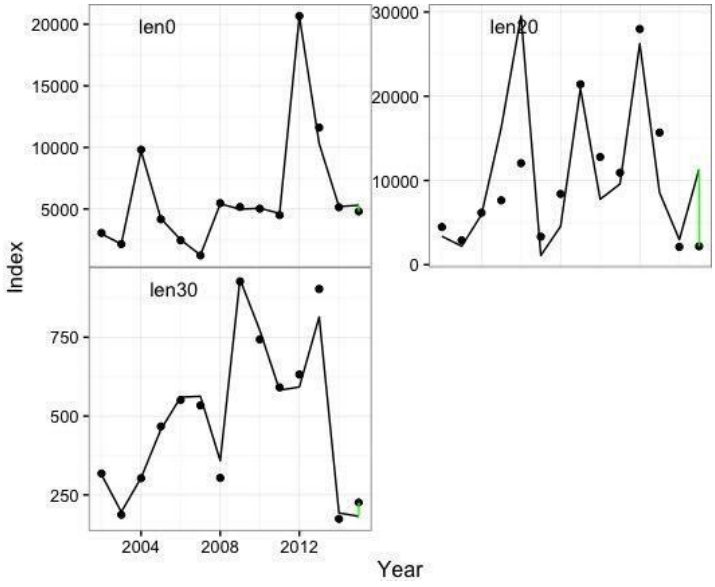


Figure 5.2.1.3 - DPS in GSAs 12-16. Medits index (n Km^{-2}) by length group: 0-20mm, 20-30mm, >30mm (—— Simulated; • Observed).

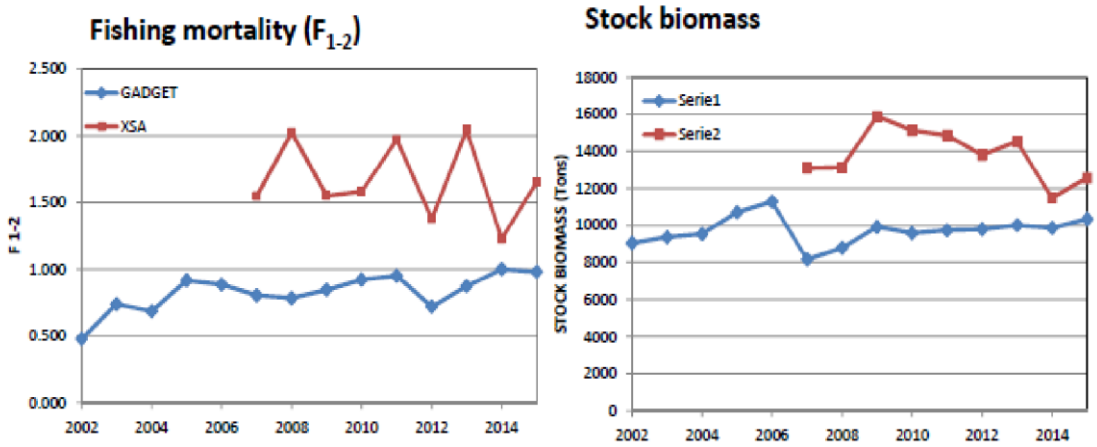


Figure 5.2.1.4 - Comparison fishing mortality and stock biomass from XSA (red line) and GADGET (blue line).

6 Stock predictions

6.1 Short term forecast (XSA)

A deterministic short term forecast for the period 2015 to 2017 was performed using the FLR routines provided by JRC and based on the results of the assessment performed during the GFCM WG. The input parameters were the same used for the XSA stock assessment. An average of the last three years has been used for weight at age, maturity at age and F at age. Recruitment (age 0) has been estimated from the population results as geometric mean of the last 3 years (6 billion individuals).

Table 6.1.1 – GSA 12-16 DPS - Short term forecast in different F scenarios.

	Ffactor	Fbar	Catch_2015	Catch_2016	Catch_2017	Catch_2018	SSB_2017	SSB_2018	Change_SSB_ 2017-2018(%)	Change_Catch_ 2015-2016(%)
Zero catch	0	0	8106.1	10817.06	0	0	12787.03	24333.28	90.3	-100
$F_{0.1}$	0.69	**0.83**	8106.1	10817.06	8203.64	9220.94	12787.03	14958.67	16.98	1.2
Status quo	1	**1.21**	8106.1	10817.06	10146.31	10120.41	12787.03	12723.55	-0.5	25.17
Different scenarios	0.1	0.12	8106.1	10817.06	1753.2	2621.56	12787.03	22313.86	74.5	-78.37
	0.2	0.24	8106.1	10817.06	3255.81	4608.73	12787.03	20592.91	61.05	-59.84
	0.3	0.36	8106.1	10817.06	4551.84	6115.88	12787.03	19114.68	49.48	-43.85
	0.4	0.48	8106.1	10817.06	5677.05	7258.96	12787.03	17834.45	39.47	-29.97
	0.5	0.6	8106.1	10817.06	6660.53	8125.2	12787.03	16716.34	30.73	-17.83
	0.6	0.73	8106.1	10817.06	7526.01	8780.36	12787.03	15731.5	23.03	-7.16
	0.7	0.85	8106.1	10817.06	8292.86	9274.13	12787.03	14856.75	16.19	2.3
	0.8	0.97	8106.1	10817.06	8976.92	9644.14	12787.03	14073.4	10.06	10.74

	0.9	1.09	8106.1	10817.06	9591.18	9918.97	12787.03	13366.39	4.53	18.32
	1.1	1.33	8106.1	10817.06	10651.09	10265.08	12787.03	12135.03	-5.1	31.4
	1.2	1.45	8106.1	10817.06	11112.79	10365.75	12787.03	11592.83	-9.34	37.09
	1.3	1.57	8106.1	10817.06	11537.4	10432.24	12787.03	11090.45	-13.27	42.33
	1.4	1.69	8106.1	10817.06	11929.92	10472.15	12787.03	10622.57	-16.93	47.17
	1.5	1.81	8106.1	10817.06	12294.51	10491.37	12787.03	10184.83	-20.35	51.67
	1.6	1.93	8106.1	10817.06	12634.64	10494.51	12787.03	9773.67	-23.57	55.87
	1.7	2.06	8106.1	10817.06	12953.23	10485.17	12787.03	9386.11	-26.6	59.8
	1.8	2.18	8106.1	10817.06	13252.74	10466.19	12787.03	9019.7	-29.46	63.49
	1.9	2.3	8106.1	10817.06	13535.25	10439.82	12787.03	8672.37	-32.18	66.98
	2	2.42	8106.1	10817.06	13802.53	10407.84	12787.03	8342.4	-34.76	70.27

7 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 (time period)	Stock Status
Fishing mortality	Fishing mortality	$F_{0.1}$ = 0.84 $F_{0.1}$ = 0.93	F_{curr} =1.21	$F_C/F_{0.1}$=1.44 $F_C/F_{0.1}$=1.30	N	O_I O_L
	Fishing effort				D	
	Catch					
Stock abundance	Biomass	7.6 13.0 **5.4**		33$_{th}$ percentile 66$_{th}$ percentile $B_{current}$	N	 O_L
	SSB					
Recruitment		6.17 billion		Rec 2015		
Final Diagnosis		The ratio $F_{curr}/F_{0.1}$ is equal to 1.44 ($F_{0.1}$ = 0.84) and equal to 1.30 if considering $F_{0.1}$ = 0.93, the stock is therefore between intermediate and low overfishing status with relative low biomass.				

The diagnoses, is based on analytical and empirical references.

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)*