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

Reference year: 2019

Reporting year: 2020

The deep-water rose shrimp is the main target species of bottom trawling in the outer shelf - upper slope of the Strait of Sicily. It is caught together with other important commercial species, such as hake (*M. merluccius*) and Norway lobster (*N. norvegicus*). Scientific data available indicates that exploitation by the fishing fleets of Tunisia, Malta, 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 the stock on fishing grounds located to the north and north-west of Gozo. Tunisian trawl vessels operate primarily in Northern Tunisia where 90% of the country's total *P. longirostris* catches originate. The great majority of these catches is landed in the ports of Bizerte and Kelibia. The overall annual landings in the period 2007-2019 ranged between 7000 and 10000 tons. The stock is assessed using data from Italy, Tunisia and Malta and applying both the Extended Survivors Analysis (XSA) tuned with MEDITS trawl survey data. Results showed the stock is in intermediate overfishing status with intermediate level of Spawing Stock Biomass.

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]	[GSA13]	[GSA14]
4th Geographical sub-area:	**5th Geographical sub-area:**	**6th Geographical sub-area:**
[GSA15]	[GSA16]	
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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2 Stock identification and biological information

2.1 Stock unit

Deep water rose shrimp (DPS) *Parapenaeus longirostris* (Lucas 1846) is distributed throughout the SE Atlantic Ocean and the Mediterranean basin. Studies on stock structure of the species in the Strait of Sicily are still in progress. Concerning the connectivity between spawning and nursery areas, Levi et al. (1995) hypothesised that might be a flux of eggs, larvae and juvenile of *P. longirostris* from east to west due to the 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 stock unit, extending from the central – southern Tyrrhenian Sea (GSA 10) to eastern Ionian (GSA19) and southern Adriatic (GSA 18). Very recently Quattrocchi et al. (2019) studied the connectivity between spawning areas laying in the northern sector of the Strait of Sicily and the nurseries in the whole strait. Ensembles scenarios derived by model outcomes displayed decadal changes in connectivity between spawning and nursery areas in the north side of the SoS. Expanding the area of investigation, the model results showed weak connectivity between spawning ground in the north side of SoS and nurseries on the African shelf break. However, according to the decision adopted in the benchmark assessment of 2015, DPS living in the GSAs 12, 13, 14, 15 and 16 were considered belonging to stock units.

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**	All year round with peaks summer/fall
Maximum size observed	42	38		**Recruitment season**	All year round
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	

Fisheries information

2.3 Description of the fleet

Trawlers targeting *P. longirostris* operate on the outer shelf and upper slope of the Central Mediterranean throughout the year. Catches often include European hake (*Merluccius merluccius*), Norway lobster (*Nephrops norvegicus*), Scorpionfish (*Helicolenus dactylopterus*), Greater forkbeard (*Phicys blennioides*) and Monkfish (*Lophius* spp.).

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 (270 registered vessels in 2018) operate mainly on short-distance fishing trips, which range from 1 to 2 days at sea, and fish e on the outer shelf and upper slope. Sicilian trawlers over 24 m in length (92 registered vessels in 2018), 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.

In the Maltese Islands, there were 13 trawlers operating in 2019. Small trawlers 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 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, from which the 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 based in GSAs 12 and 13 mainly targeting rose shrimp has increased from 40 in 1996 to about 77 in 2017. Overall, about 100 trawlers move seasonally from GSA 14 to fish DPS in GSAs 12 and 13.

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. 3.1.1.

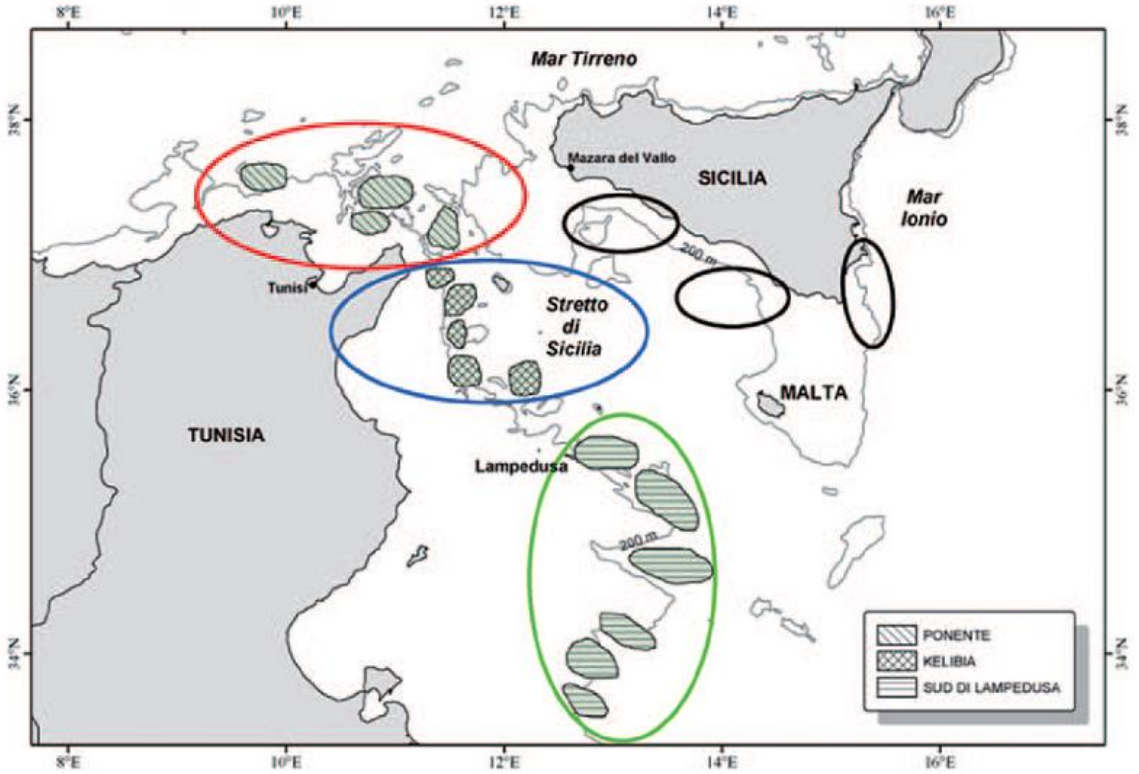


***Figure 2.3.1** - The main fishing ground areas of* P. longirostris *for distant (coloured) and coastal (black) Sicilian trawlers in the Strait of Sicily.*

Table 2.0.1: *Description of operational units exploiting the stock*

Operational Units*	Country	GSA	Fleet Segment	Fishing Gear Class	Group of Target Species	Species
Operational Unit 1	ITA	16	**T11 - Trawls**	**OTB**	**Demersal slope species**	DPS
Operational Unit 2	ITA	16	**T12 - Trawls**	**OTB**	**Demersal slope species**	DPS
Operational Unit 3	TUN	12-14	**T12 - Trawls**	**OTB**	**Demersal slope species**	DPS
Operational Unit 4	MLT	15	**T11&T12 - Trawls**	**OTB**	**Demersal slope species**	DPS

Table 2.3.2: *Catch, and effort by operational unit in the 2018.*

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 ITA16	270	2260.5 (t)		0.804 (t)		
OU 2 ITA 16	92	1157.1(t)				
OU 3 TUN 12-14	77+100*	3239.8 (t)				
OU 4 MLT 15	13	6.4 (t)				
Total	452+100	6663.8 (t)		0.804 (t)		

* refers to about 100 Tunisian trawlers move seasonally from GSA 14 to fish DPS in GSAs 12 and 13.

2.4 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 (GT*days at sea) shows a decreasing of the two segments of the Italian trawl fleet (LOA<24m and LOA >24m) in the last years (Fig. 3.2.2).

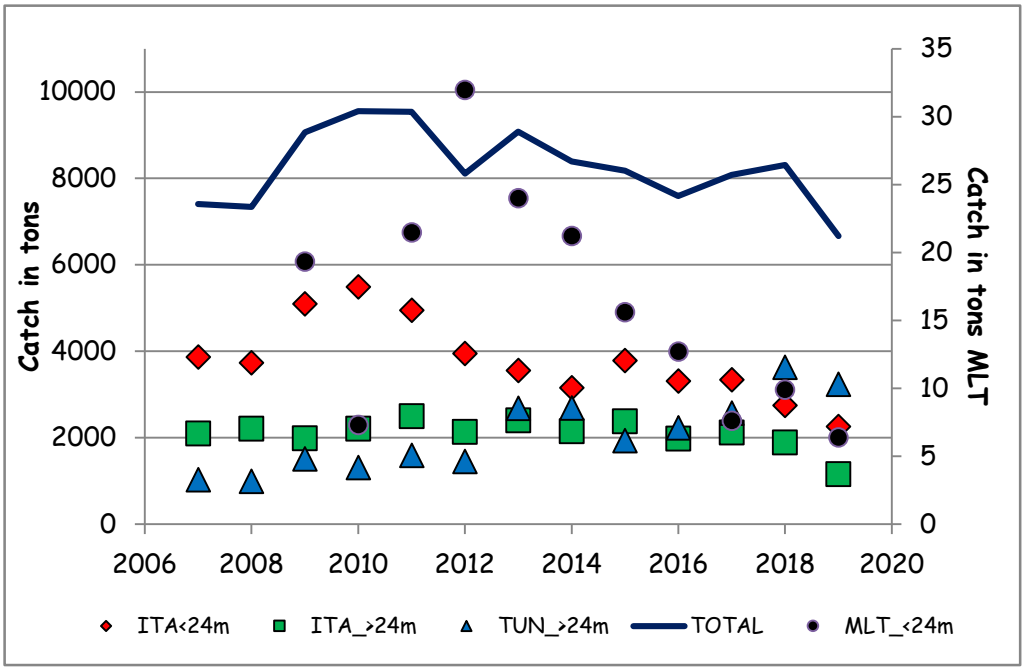


Figure 2.4.1 - Catch of DPS from 2007 to 2019 in the Strait of Sicily, Central Mediterranean (GSA 12 - 16) by country and LOA.

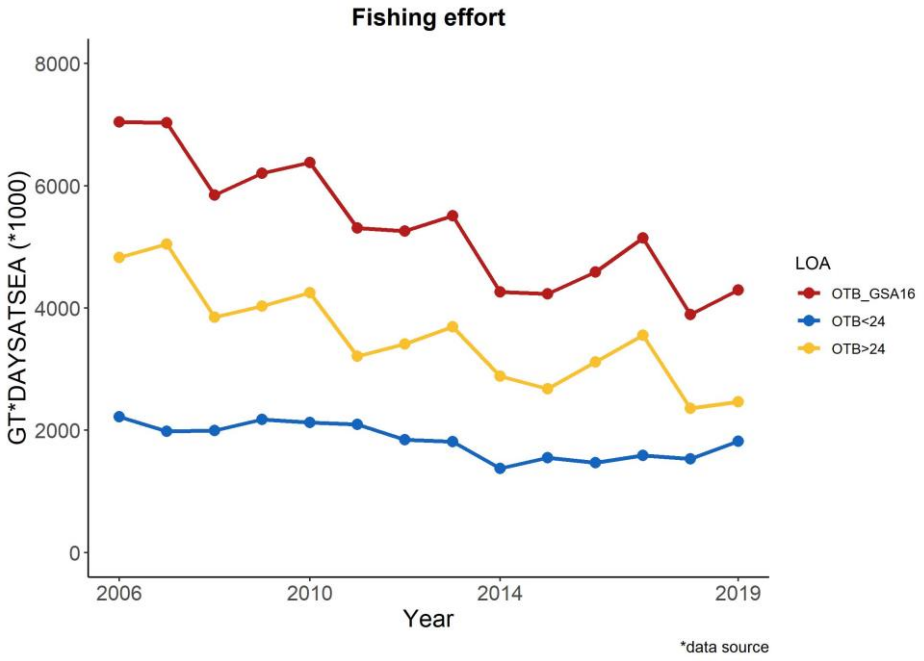


Figure 2.4.2 - Fishing effort of Italian trawlers in terms of GT (gross tonnage)*days at sea from 2006 to 2019.

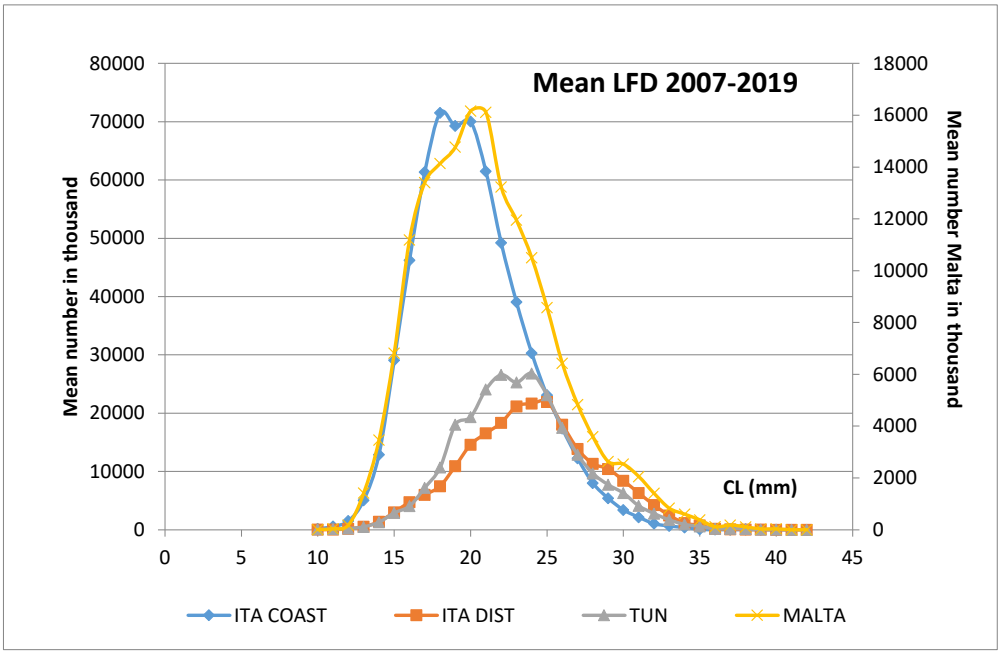


Figure 2.4.3 – Average length frequency distributions (2007-2019) of catch data by fleet and country (combined sex).

2.5 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). For the period 2008-2013, a multiannual management plan has been adopted in Italy (IMAP) for bottom trawlers operating in the Strait of Sicily.

The plan was mainly based on a fleet reduction of 25% of the capacity to be achieved in two steps. The first step (12.5% reduction) from 2008 to 2010, and the second step (12.5% reduction) from 2011 to 2013. The IMAP adopted also a trawling ban normally implemented in late summer early autumn every year. The IMAP foresees an interruption of fishing for 45 consecutive days, however the effective duration of the ban was 30 days per year.

The IMAP was updated in January 2018. The new IMAP based regulation mainly on reduction of fishing effort of 5 % in 2019 and 10 % in 2020 of fishing days occurred in 2018.In addition, the Regulation EC 1967/ 2006, amended by the Reg. EU 1241/2019, 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 2019, Malta had 13 trawlers that operated on a full-time basis. A preliminary analysis of the capacity of the fleet in the Sub-regional Committee for the Central Mediterranean (SRC-CM) showed that there was a 39% reduction from 2011 to 2015 (with 7 vessels permanent dismissed and 2 temporary inactive). 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 deep water 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. The minimum legal mesh size used by demersal trawlers in Tunisian waters is 20mm side.

Due to the importance of deep water rose shrimp fishery for the costal countries in the area, the CFGM adopted the Recommendation GFCM/40/2016/4 on 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 an international multiannual management plan.

In addition, owing to the importance of the deep water rose shrimp fishery for the costal countries in the area, the CFGM adopted a series of recommendations targeting deep water rose shrimp and hake fisheries: i) REC.CM-GFCM/39/2015/2 on 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; ii) REC.CM-GFCM/40/2016/4 establishing a multiannual management plan for the fisheries exploiting European hake and deep-water rose shrimp in the Strait of Sicily (GSA 12 to 16); and iii) REC.CM-GFCM/41/2017/8 on an international joint inspection and surveillance scheme outside the waters under national jurisdiction of the Strait of Sicily (geographical subareas 12 to 16).

In order to protect juveniles, three Fishery Restricted Areas (FRAs) in which bottom trawling is prohibited were established in the northern sector of the Strait of Sicily (GSA 15 and 16) based on the REC.CM-GFCM/40/2016/4. 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.

2.6 Reference points

Table 2.6.1: *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			$F_{0.1}$	0.84-0.93	Range of values obtained at the last benchmark assessment of DPS held in 2015
Y					
CPUE					
Index of Biomass at sea					

3. Fisheries independent information

3.1 {Medits survey}

Fisheries independent data were collected by MEDITS (MEDiterranean International Bottom Trawl-Survey, carried out in GSAs 15 & 16 on an annual basis within the EU Data Collection Regulation. In July 2011 an intercalibration experiment was carried out to standardize MEDITS indices from GSAs 15-16 with those of Tunisian surveys.

3.1.1 Brief description of the direct method used

Distribution, abundance and demographic information of the stock at sea are derived from data collected during the MEDITS surveys carried out in the northern sector of the Strait of Sicily from 1994 to 2017 in spring/early summer. A total of 45 hauls in GSA 15 and 120 hauls in GSA 16 were performed yearly. The area covered is of about 10600 in GSA 15 and 31400 km^2 in GSA 16 within the 10-800 m depth-range. 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 trawl net 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. 9 (2017).

Direct methods: trawl based abundance indices

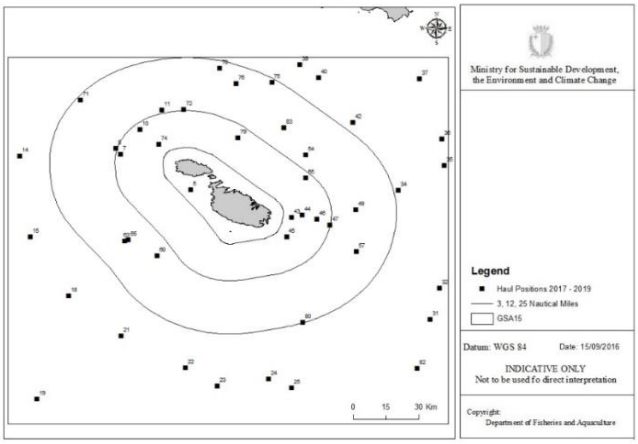
***Table 3.1.1**: Trawl survey basic information*

Survey	MEDITS	**Trawler/RV**	TRAWLER
Sampling season	MAY-JULY		
Sampling design	Stratified with number of hauls by stratum proportional to stratum surface (see MEDITS-Handbook. Version n. 9, 2017, MEDITS Working Group: 106 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 .3.1.2**: Trawl survey sampling area and number of hauls.*

Stratum	Total surface (km^2) GSA15	Total surface (km^2) GSA16	Trawlable surface (km^2) GSA16	Swept area (km^2) GSA16	Trawlable surface (km^2) GSA15	Swept area (km^2) GSA15	Number of hauls GSA 15	Number of hauls GSA 16
a	152	2979	2979	0.49	n.a	n.a		11
b	1473	5943	5943	1.06	n.a	n.a		23
c	3076	5563	5563	1.03	n.a	n.a		21
d	3353	6972	6972	2.79	n.a	n.a		27
e	2526	9927	9927	3.85	n.a	n.a		38
Total	**10580**	**31384**	**31384**	**9.23**			**45**	**120**

a)



b)

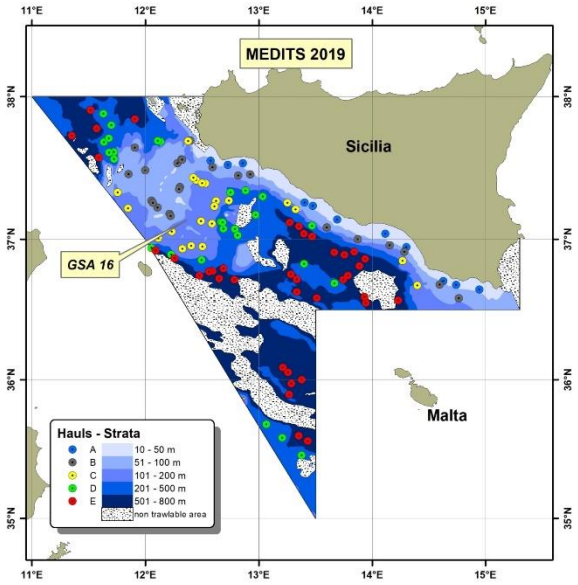


***Figure 3.1.1**-Map of hauls positions from Medits survey in GSAs 15(a) &16 (b).*

Table 3.1.3: *Trawl survey abundance and biomass results in GSAs 15 and 16.*

Depth Stratum	Years	kg/km² (GSA16)	CV (GSA16)	N/km² (GSA16)	CV (GSA16)	kg/km² (GSA15)	CV (GSA 15)	N/km² (GSA15)	CV (GSA 15)
10-800 m	1994	5.9	45.9	794	39.6	na	na	na	na
10-800 m	1995	5.1	34.2	785	27.2	na	na	na	na
10-800 m	1996	7.6	33.7	1523	29.6	na	na	na	na
10-800 m	1997	7.5	29.8	1462	29.2	na	na	na	na
10-800 m	1998	11.5	28.3	2448	28.3	na	na	na	na
10-800 m	1999	15.8	29.3	3190	27.5	na	na	na	na
10-800 m	2000	16	31.4	2869	29.6	na	na	na	na
10-800 m	2001	13	33.8	2548	29.5	na	na	na	na
10-800 m	2002	4.8	22	1572	30.8	na	na	na	na
10-800 m	2003	7.4	32.1	1433	31.3	na	na	na	na
10-800 m	2004	16.8	37.3	4565	41.4	na	na	na	na
10-800 m	2005	11.3	33.5	1858	35.2	7.3	na	1021	na
10-800 m	2006	12.4	47.5	1848	50.5	16.7	na	3192	na
10-800 m	2007	5.3	35.1	815	34.9	12.4	27.47	2237	32.2
10-800 m	2008	11.8	37	2287	37.6	22.3	24.34	4909	27.27
10-800 m	2009	23.9	42.2	3563	42.4	60.9	35.14	4483	23.86
10-800 m	2010	16.6	40.1	2718	41.4	14.3	32.51	2383	32.62
10-800 m	2011	13	42.7	2252	39.1	16.4	25.16	3206	25.97
10-800 m	2012	38.2	29.4	8012	29.5	17.2	23.24	3201	24.66
10-800 m	2013	21.8	28.7	4607	29.4	15.5	30.61	2225	33.16
10-800 m	2014	10.7	40.4	3245	59	11.6	23.23	2645	23.49
10-800 m	2015	5.4	33.8	948	34	4.1	11.73	937	10.45
10-800 m	2016	7.8	41.1	1640	42	10	17.59	2748	18.98
10-800 m	2017	6.8	24.3	1782	25	10.6	34.03	1050	14.63
10-800 m	2018	13.6	30.98	3300	35	3.8	23.0	1063	25.9
10-800 m	2019	13.0	35.5	2456	35	8.7	41.5	2396	44.3

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

Slicing method

Length structures were sliced using a knife edge approach.

***Table 3.1.4**: Trawl survey indices of abundance (n/km2) by age group (in thousands) from GSAs 15&16.*

N (sex combined)	Year												
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
0	8777	35727	42942	36286	29318	130223	73322	51913	1422	7963	52157	6243	58314
1	9626	19087	44082	29844	24751	70010	37997	15764	1079	2125	12012	63986	33048
2	672	427	765	1117	485	450	719	576	24	14	142	1453	344
3	1	4	1	0	1	5	1	0	0	0	6	15	0

***Table 3.1.5:** Sex ratio (F/F+M) by length class in mm of deep water rose shrimp from MEDITS in GSA 16. All year combined.*

		CL (mm)	Sr
Sex ratio by Length class	1994-2019	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 3.1.5: *Trawl surveys; recruitment analysis summary in GSAs 15& 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		0+	
Length at fishing-grounds recruitment		10 mm CL	

Direct methods: trawl based Spawner analysis

No information was presented at the Working group

3.1.2 Spatial distribution of the resources

A first spatial distribution of Essential Fish Habitats of DPS based on trawl surveys (GRUND and MEDITS) information was given to Fortibuoni et al. (2010). The Authors related the position of spawning and nursery areas to the existence of stable oceanographical vortices and fronts on the eastern border of the Adventure and Malta Banks.

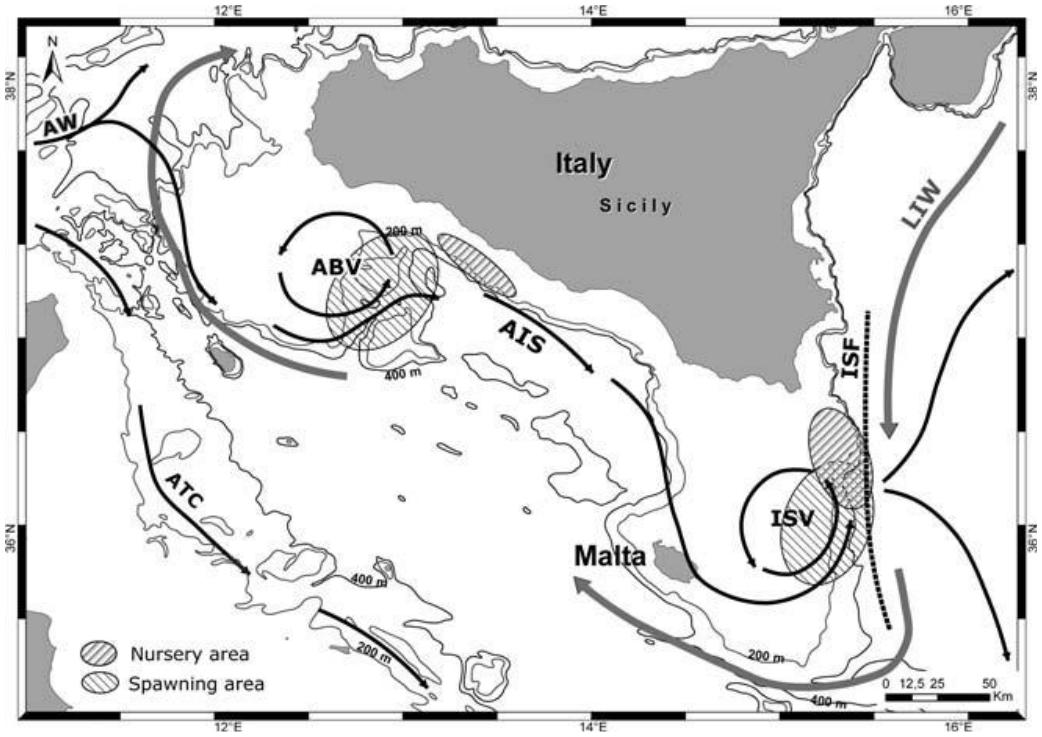


Figure 3.1.2.1 *- Location of stable nurseries and spawning areas of Parapenaeus longirostris in the northern sector of the Strait of Sicily. The main hydrological characteristics of the area are also shown. ABV: Adventure Bank Vortex; ATC: Atlantic Tunisian Current; AIS: Atlantic Ionian Stream; ISV: Ionian Shelf-break Vortex; ISF: Ionian Slope Front; LIW: Levantine Intermediate Water; AW: Atlantic Water (from Fortibuoni et al., 2010).*

A more recent mapping of stable nurseries and spawning grounds of the species around the coasts of Sicily, including GSA 15 and 16, are shown in Fig. 3.1.2.2 (Colloca et al., 2015).

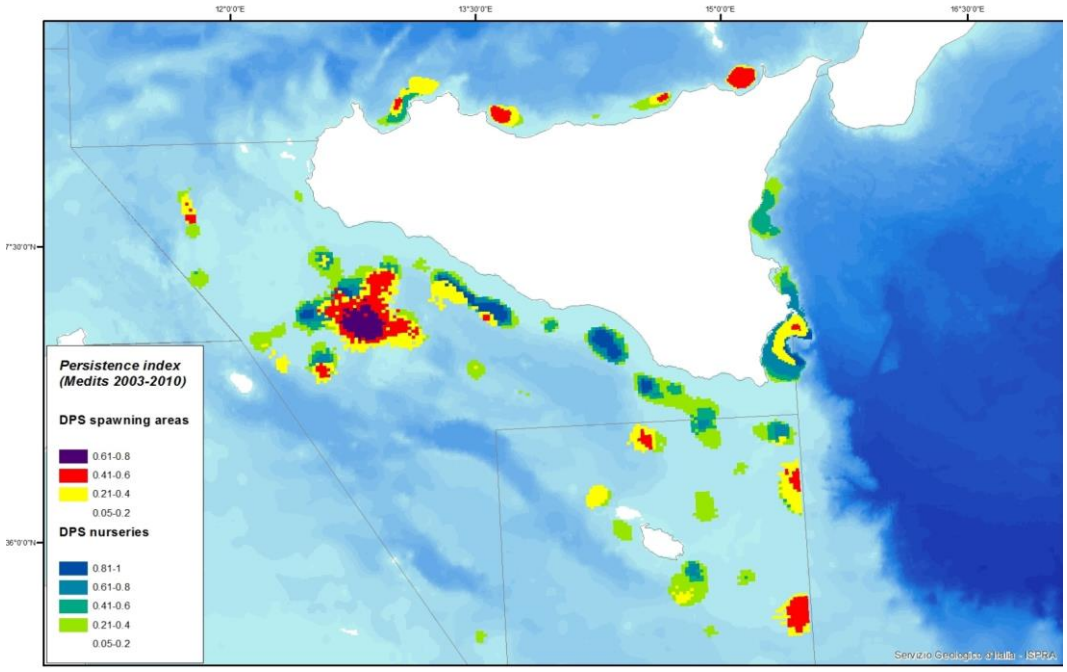
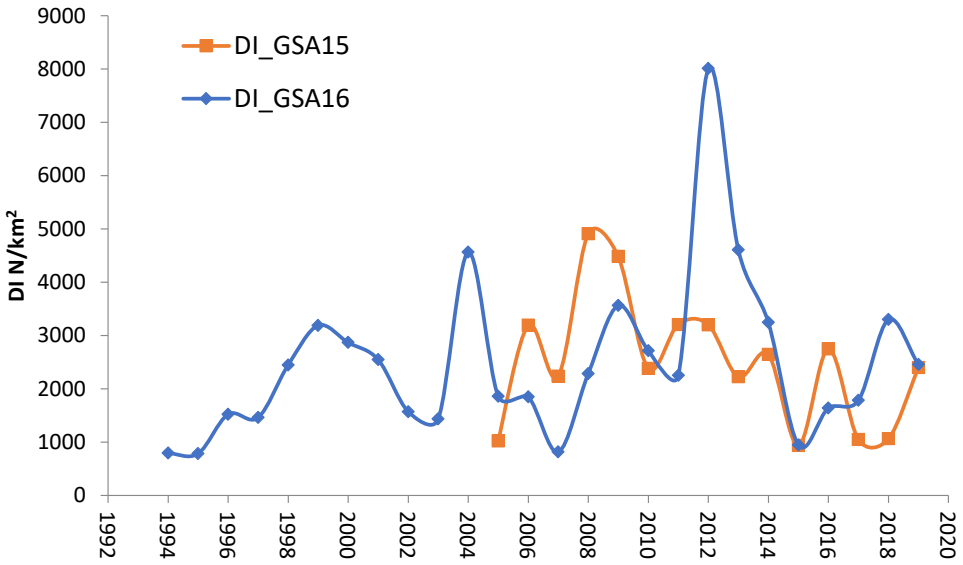


Figure 3.1.2.2 *- Temporal persistence of nursery and spawning areas of the deep water rose shrimp in GSAs 15-16, from MEDISEH - MAREA project (from Colloca et al., 2015).*

3.1.3 Historical trends

The trends in density and biomass of DPS during the MEDITS survey in GSA 15 and GSA 16 show cyclic pattern with relatively low values from 2015 onwards (Fig. 3.1.3.1). The length structures of the species in MEDITS 2007-2019 are shown in Fig. 3.1.3.2.

a)



b)

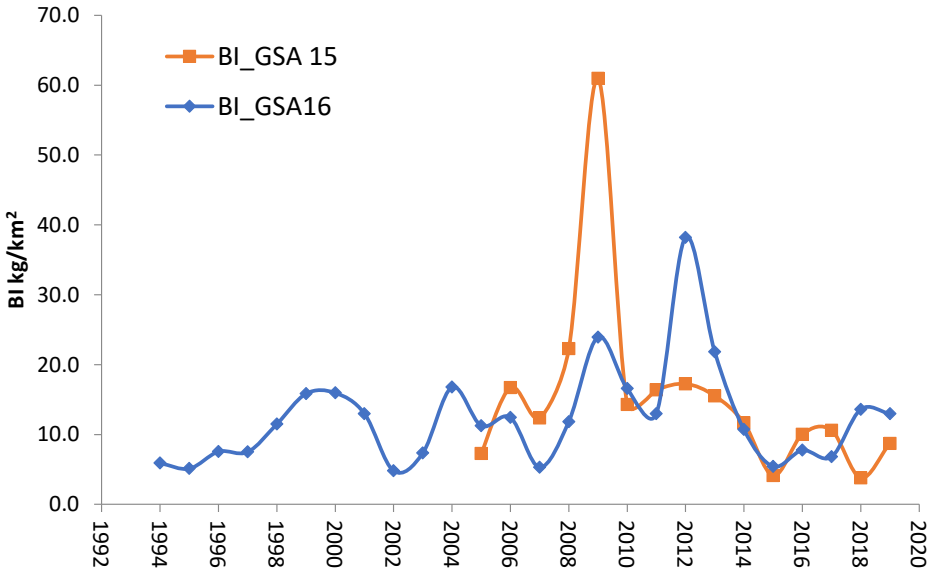
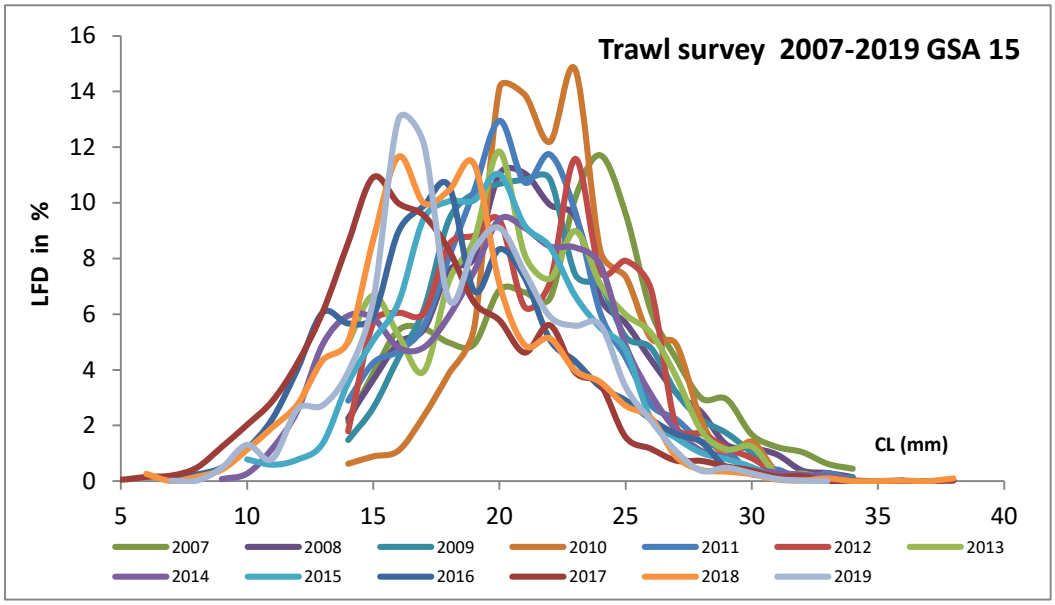


Figure 3.1.3.1 *– a) Medits density index (BI) in GSA 15 and GSA16. b) Medits biomass index (DI) in GSA 15 and GSA16.*

a)



b)

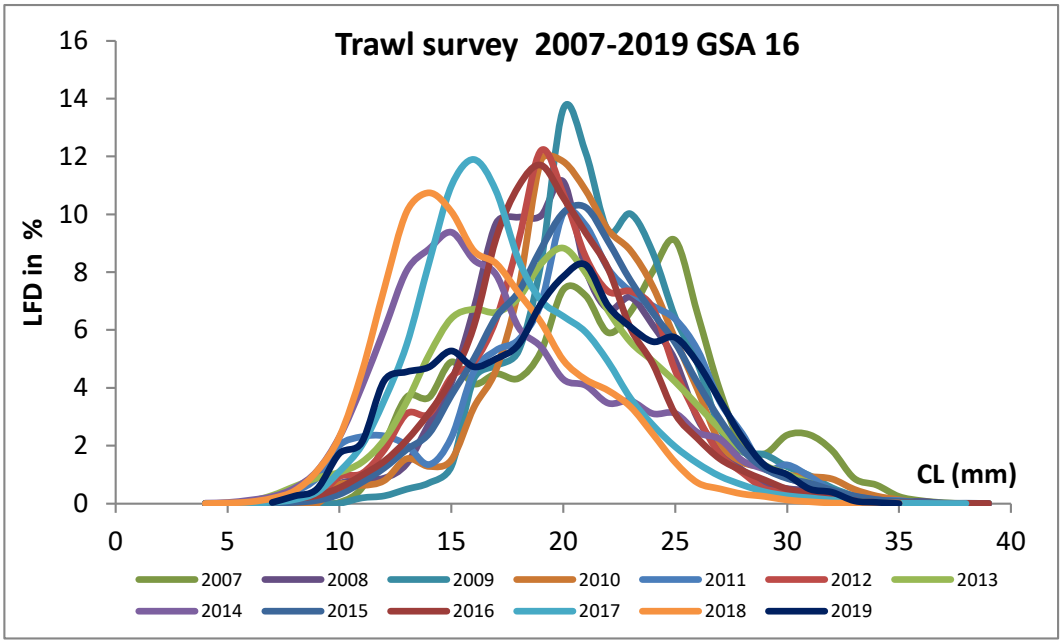


Figure 3.1.3.2 *– a) Length frequency distributions (LFD) in % from Medits survey in GSA 15. b) Length frequency distributions (LFD) in % from Medits survey in GSA 16. Sex combined.*

4 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 -2019 (collected since 2017 and 2018 within the framework of the FAO MedSudMed Project). The XSA was tuned using MEDITS data (2007-2019) from GSA 15 and GSA 16. The natural mortality M was estimated by Prodbiom's forced method with the adults' M similar to the scalar one (M=1). The annual number at size of the landings as well as MEDITS data were converted into number at age by knife edge slicing by using as mean length at age obtained by the VBGF reported in table 4-2.3. Data were processed firstly keeping sex separate and then summing the number in a sex combined age group.

4.1.1 XSA

4.1.2 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 fleet-based 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 fleet-derived 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.

4.1.3 Scripts

Scripts used were available to the WG.

4.1.4 Input data and Parameters

Catch matrix in ages included discard

Table 4.1.4.1 *- Catch matrix by year and age in thousand.*

Years	0	1	2	3
2007	676852	429484	19766	935
2008	528458	466487	23820	2017
2009	538292	624244	19529	692
2010	652641	606810	25165	17
2011	614769	665593	22091	87

2012	519415	557480	12818	29
2013	628310	646782	19901	0
2014	1032985	491032	4373	20
2015	794013	517912	17965	204
2016	644459	534484	13683	96
2017	385720	645959	18382	21
2018	529514	699802	28245	0
2019	427608	534739	14327	111

Table 4.1.4.2 *– Tuning data by year and age. Density indices were raised to the whole GSAs 15 and 16 areas assuming catchability equal to 1.*

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
2016	7963476	2125496	14211	113
2017	52156520	12012220	141822	5505
2018	6242543	63985994	1452533	14765
2019	58314362	33048100	344398	0

Table 4.1.4.3 *– Mean weight by year and age.*

Years	0	1	2	3
2007	0.0041	0.0089	0.0183	0.0257
2008	0.0043	0.0089	0.0184	0.0257
2009	0.0044	0.0093	0.0181	0.0259
2010	0.0046	0.009	0.0173	0.0245
2011	0.0045	0.0087	0.0173	0.0239
2012	0.0045	0.009	0.0176	0.0237
2013	0.0044	0.0085	0.0169	0
2014	0.0039	0.008	0.0169	0.0238
2015	0.0042	0.0086	0.0177	0.0242
2016	0.004	0.0089	0.0169	0.0243
2017	0.0042	0.0094	0.0178	0.0244
2018	0.0037	0.0084	0.0166	0.0205
2019	0.0037	0.0084	0.0166	0.0205

Table 4.1.4.4 *– Natural Mortality at age estimated by a modified Prodbiom's forced method (M equal to the scalar vakue after the age at full maturity).*

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

Table 4.1.4.5 *– Proportion of mature specimens at age.*

Age 0	Age 1	Age 2	Age 3
0.03	0.99	1.00	1.00

4.1.5 Results

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 settings of the best model are the followings:

The XSA run with shrinkage of 1.5 and catchability equal to 3 years, was adopted as final model (Fig. 4.1.5.1) based on both residuals and retrospective analysis. These settings reflect the settings adopted on occasion of the GFCM Benchmark assessment carried out in 2015.

Setting parameters of the best model

```
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)
```

In table 4.1.5.1 are reported the XSA results in terms of spawning stock biomass (SSB), total biomass (TB) and annual recruitment. Both SSB and recruitment does not show a clear trend. $F_{bar\ (0\text{-}2)}$ showed a decreasing trend from 2015 onwards.

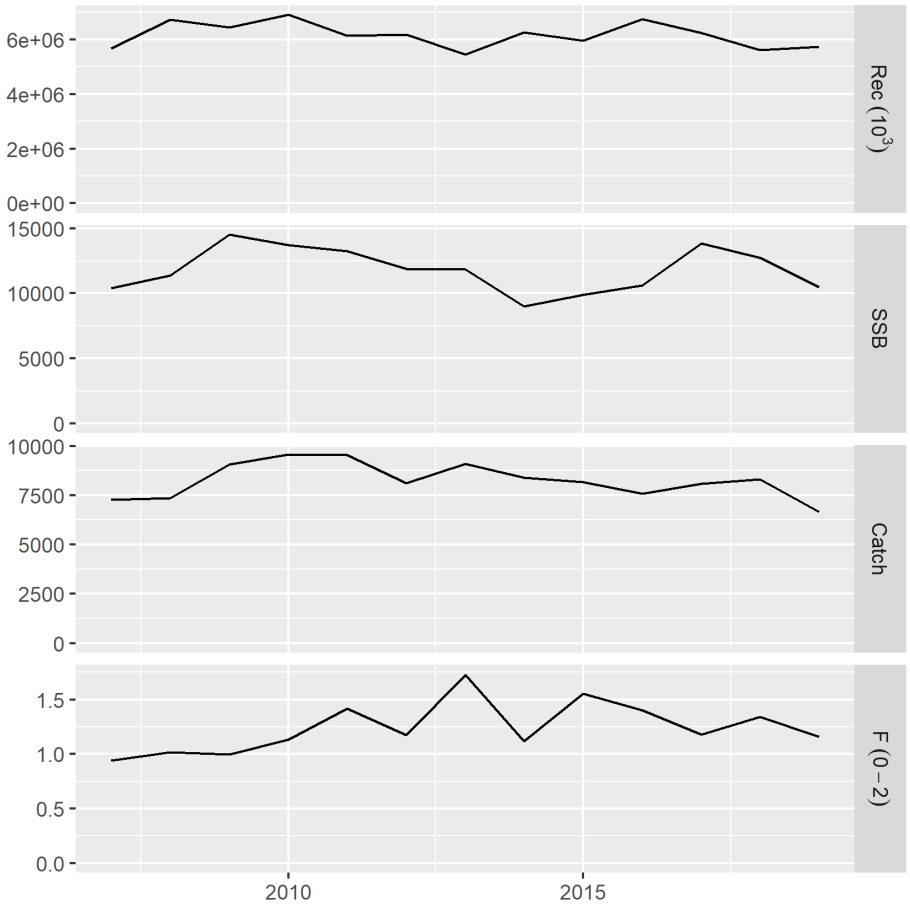


Figure 4.1.5.1. *Final XSA model for deep water rose shrimp in GSAs 12-16.*

Table 4.1.5.1 *– XSA estimates of spawning stock biomass (SSB), total biomass (TB), recruitment (REC) and* F_{bar}**.**

Years	SSB (in t)	TB (in t)	REC/10^6	F_{bar}
2007	10389	32969	5.67	0.94
2008	11364	39433	6.73	1.01
2009	14503	41860	6.45	1.00
2010	13693	44371	6.90	1.13
2011	13258	40182	6.15	1.42
2012	11875	38684	6.18	1.17
2013	11853	35181	5.45	1.73
2014	8987	32490	6.26	1.12

2015	9888	34027	5.96	1.55
2016	10610	36454	6.74	1.40
2017	13826	39469	6.23	1.18
2018	12719	33068	5.62	1.34
2019	10482	31209	5.74	1.16

The fluctuation of SSB (2007-2019) in GSA 12-16 estimated by XSA is showed in figure 5.1.4.3.

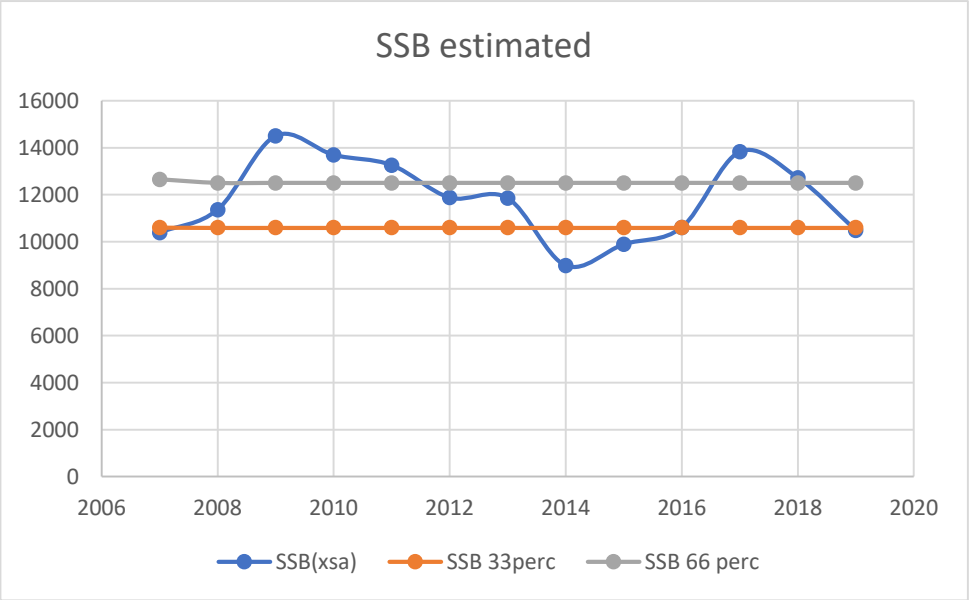


Figure 4.1.5.2 *- Trend of SSB (2007-2019) in GSA 12-16 estimated by XSA, the value in the last year is within the limit 66th percentile - Relative intermediate biomass.*

Fishing mortality values at age are reported in table 4.1.5.2. Current $F_{0\text{-}2}$ was estimated as mean over (2016-2019) being 1.24.

Table 4.1.5.2 *– XSA estimates of fishing mortality at age.*

age	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0	0.29	0.18	0.20	0.23	0.24	0.20	0.28	0.43	0.32	0.22	0.14	0.21	0.17
1	1.61	1.77	1.87	2.11	2.57	2.18	3.29	2.22	2.47	2.16	1.92	2.47	2.15
2	0.92	1.09	0.92	1.05	1.45	1.14	1.61	0.70	1.87	1.83	1.48	1.34	1.15
3	0.92	1.09	0.92	1.05	1.45	1.14	1.61	0.70	1.87	1.83	1.48	1.34	1.15
F_{bar0-2}	**0.94**	**1.01**	**1.00**	**1.13**	**1.42**	**1.17**	**1.73**	**1.12**	**1.55**	**1.40**	**1.18**	**1.34**	**1.16**

Yield per Recruit

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

4.1.6 Robustness analysis

Log residuals at age of the MEDITS survey are reported in Fig. 4.1.6.1.

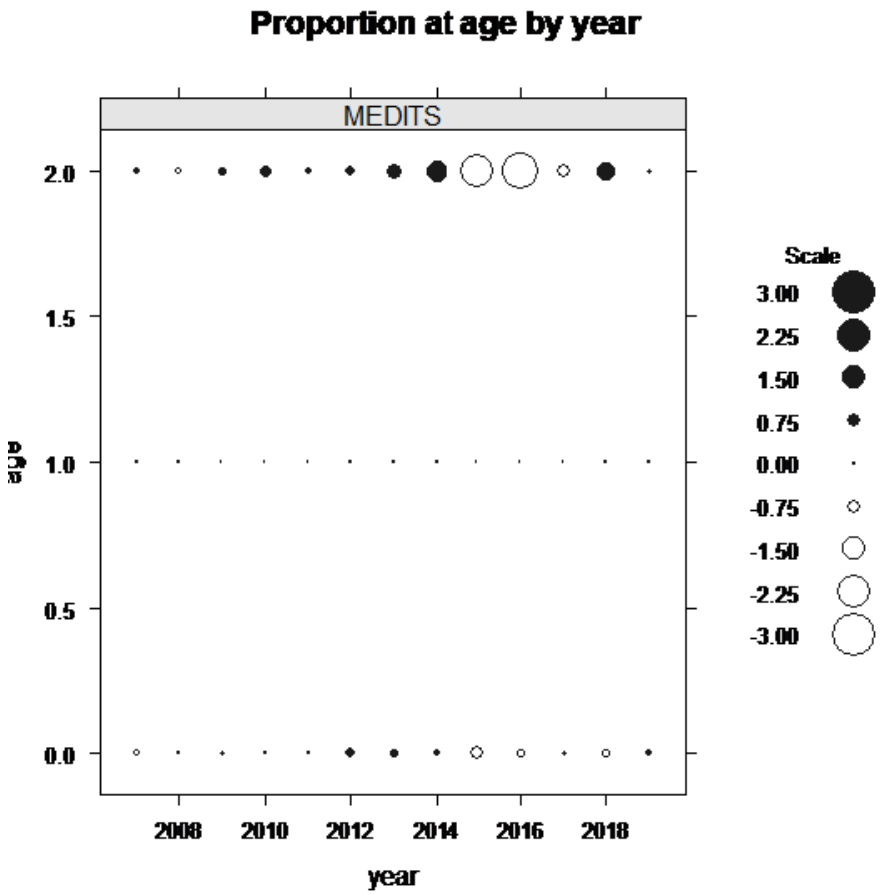


Figure 4.1.6.1 *- Log residuals of MEDITS survey.*

4.1.7 Retrospective analysis

Retrospective analyses showed rather consistent results with no major pattern in the data (Fig. 4.1.7.1).

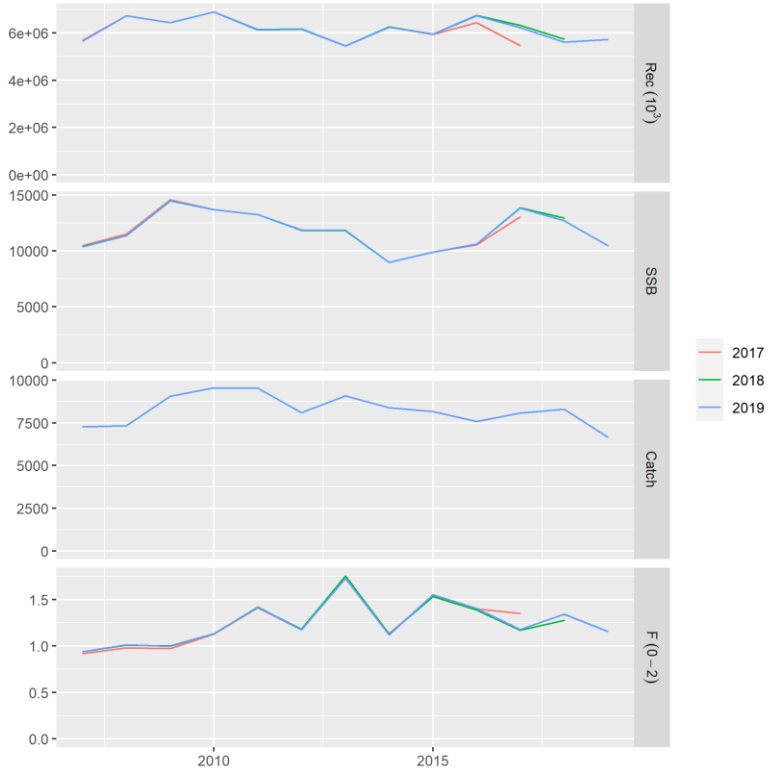


Figure 4.1.7.1 *- Retrospective analysis.*

4.1.8 Assessment quality

Based on MEDITS residuals and retrospective analysis, the XSA results appear consistent and in line with the XSA assessment carried out in 2019.

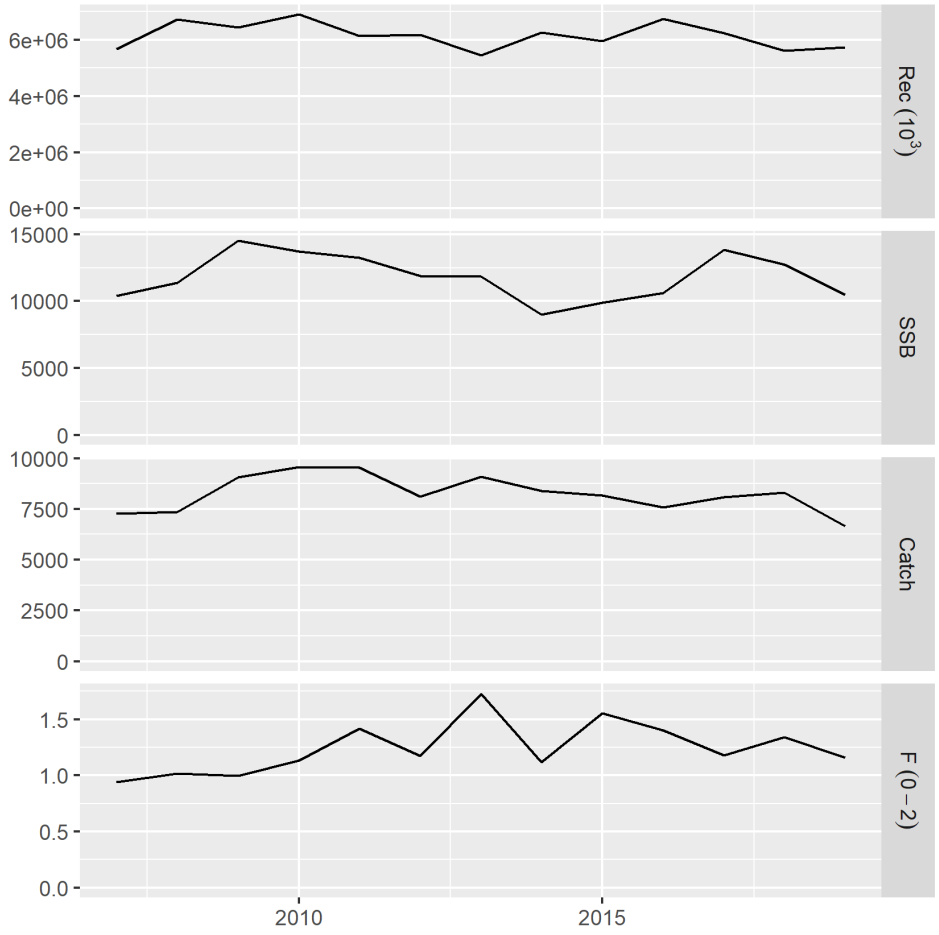


Figure 4.1.8.1. *Final XSA model for deep water rose shrimp in GSAs 12-16.*

5 Stock predictions

5.1 Short term forecast (XSA)

A deterministic short term forecast for the period 2020 to 2022 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 (about 5.8 billion individuals). To achieve F_{MSY} deep water rose shrimps catch in 2022 should not exceed 7913 tons.

	Ffactor	Fbar	Catch_2019	Catch_2020	Catch_2021	Catch_2022	SSB_2021	SSB_2022	Change_SSB 2021-2022(%)
1	0	0.0	6665	8907.2	0.0	0.0	11885.4	20076.3	68.9
2	0.1	0.1	6665	8907.2	1537.2	2128.0	11885.4	18503.0	55.7
3	0.2	0.2	6665	8907.2	2861.7	3762.4	11885.4	17197.5	44.7
4	0.3	0.4	6665	8907.2	4010.2	5030.9	11885.4	16108.4	35.5
5	0.4	0.5	6665	8907.2	5012.7	6026.7	11885.4	15194.3	27.8
6	0.5	0.6	6665	8907.2	5893.7	6818.1	11885.4	14421.7	21.3
7	0.6	0.7	6665	8907.2	6673.2	7455.6	11885.4	13763.9	15.8
8	0.7	0.9	6665	8907.2	7367.9	7976.0	11885.4	13199.0	11.1
9	0.8	1.0	6665	8907.2	7991.3	8406.9	11885.4	12709.8	6.9
10	0.9	1.1	6665	8907.2	8554.6	8768.8	11885.4	12282.1	3.3
11	1	1.23	6665	8907.2	9067.0	9076.7	11885.4	11904.6	0.2
12	1.1	1.3	6665	8907.2	9536.3	9342.3	11885.4	11568.1	-2.7
13	1.2	1.5	6665	8907.2	9968.7	9574.1	11885.4	11265.3	-5.2
14	1.3	1.6	6665	8907.2	10369.5	9778.8	11885.4	10990.1	-7.5
15	1.4	1.7	6665	8907.2	10743.1	9961.4	11885.4	10737.8	-9.7
16	1.5	1.8	6665	8907.2	11093.1	10125.7	11885.4	10504.5	-11.6
17	1.6	2.0	6665	8907.2	11422.6	10274.9	11885.4	10287.0	-13.4
18	1.7	2.1	6665	8907.2	11734.1	10411.3	11885.4	10082.8	-15.2
19	1.8	2.2	6665	8907.2	12029.9	10536.9	11885.4	9889.8	-16.8
20	1.9	2.3	6665	8907.2	12311.8	10653.1	11885.4	9706.4	-18.3
21	2	2.4	6665	8907.2	12581.2	10761.2	11885.4	9531.2	-19.8
22	0.69	0.84	6665	8907.2	7281.3	7913.5	11885.4	13268.3	11.6

6 Draft scientific advice

The ratio $F_{curr}/F_{0.1}$ ranged between 1.52 ($F_{0.1}$ = 0.84) and 1.37 ($F_{0.1}$ = 0.93). Accordingly, the stock status is assessed as **Intermediate Overfishing**. SSB from XSA on the whole stock resulted at Relative **Intermediate** level in the available time series (2007-2019), trend of MEDITS biomass indices in the GSA 15 showed a low level of standing stock in the last years while it is in increase in GSA 16. To improve the stock status a reduction of fishing mortality and catches of undersized shrimps is recommended.

Based on	Indicator	Analytic al reference point	Current value from the analysis	Empirical reference value	Trend (2007-2019)	Stock Status
Fishing mortality	Fishing mortality	$F_{0.1}$ = 0.84* $F_{0.1}$ = 0.93	F_{curr} =1.23 (mean 2017-2019)		I	O_I O_I
	Catch				N	
Stock abundance	SSB (tons)		$SSB_{current}$ =12342 (mean 2017-2019)	$SSB_{33_{th}\ percentile}$=10604 $SSB_{66_{th}\ percentile}$=12501	N	O_I
Recruitment		5.7 billion		Rec 2019		

Final Diagnosis	The ratio $F_{curr}/F_{0.1}$ was 1.46 ($F_{0.1}$ = 0.84). Accordingly, the stock status is assessed as Intermediate Overfishing. SSB_{curr} from XSA resulted at Relative Intermediatelevel.

**Value used in the assessment*

6.1 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)*