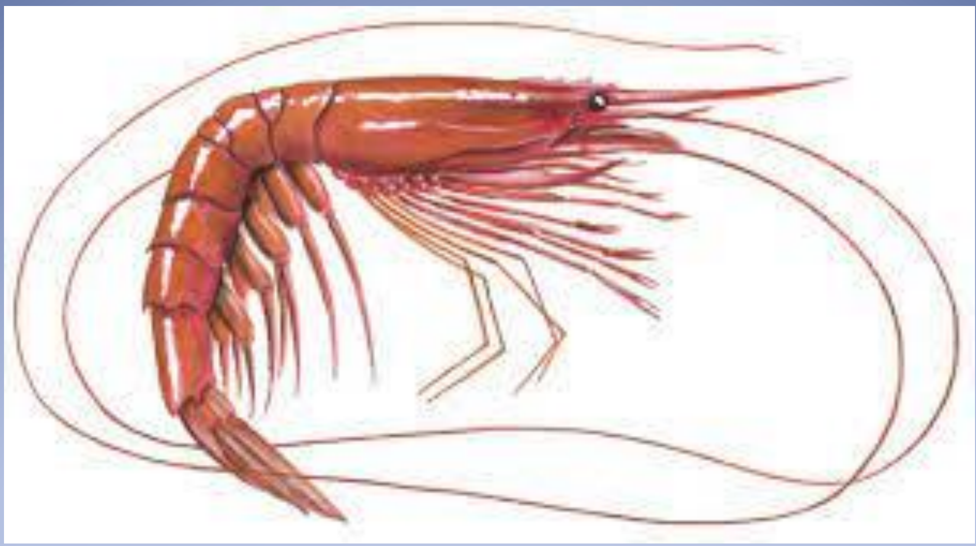

Stock Assessment Form

Demersal species

Reference year: 2021

Reporting year: 2022

STOCK ASSESSMENT OF GIANT RED SHRIMP IN GSA18 19 AND 20

SSB of Giant red shrimp show an increasing trend from 2003 to 2017. Then catches started to decline steadily until 2021, while SSB was declining until 2019 and then it stabilized around 400 tons. The assessment shows a general oscillating trend in the number of recruits, especially after 2012, with recent years indicating an increasing trend. Fbar (1-3) shows a slight continuous increase until 2017 while it starts declining until 2021 where it reached a value of F of 0.828.

Stock Assessment Form version 1.0 (March 2023)

Uploader: *Enrico Nicola Armelloni*

Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Aristaeomorpha foliacea	Giant red shrimp	
1st Geographical sub-area:	**2nd Geographical sub-area:**	**3rd Geographical sub-area:**
18	19	20
4th Geographical sub-area:	**5th Geographical sub-area:**	**6th Geographical sub-area:**
1st Country	**2nd Country**	**3rd Country**
Italy	Greece	Albania
4th Country	**5th Country**	**6th Country**
Montenegro		
Stock assessment method: (direct, indirect, combined, none)		
Indirect: a4a		
Authors:		
STECF ewg 22-16 revides by GFCM WGSAD		
Affiliation:		

2 Stock identification and biological information

The Giant red shrimp *Aristaeomorpha foliacea* (Risso, 1827) is mainly found in the epibathyal and mesobathyal waters of the Mediterranean. *Aristeomorpha foliacea* is a large-sized decapod crustacean with a scarlet red coloured, firm though flexible and light exoskeleton and black eyes. In mature females the dorsal part of the abdomen is darker due to the black colour of the mature ovaries. Adult females are larger and have a longer rostrum, which extends far beyond the antennal scale. In males the rostrum is short and does not exceed the tip of the antennular peduncle. The giant red shrimp *Aristaeomorpha foliacea* has a wide geographic distribution. In the Mediterranean Sea the distribution of giant red shrimp is patchy in nature, with the highest abundances found in the central-eastern basins (Politou *et al.*, 2004).

2.1 Stock unit

The assessment on giant red shrimp carried out during the STECF EWG 22-16 (STECF, 2022a) considered the stock confined within the boundaries of GSAs 18, 19 and 20.

2.2 Growth and maturity

Growth and length-weight parameters derives from those explored and agreed on EWG 22-03 (STECF, 2022b): the growth parameters for the Giant red shrimp were provided through the DCF and they were common for GSAs 18 and 19 (Table 2.2-1 and Table 2.2-2). For GSA 20 no growth parameters were provided and the EWG decided to use the ones from GSA 18 and 19. The growth parameters were provided by sex and it was noted that these species exhibit a strong sexual dimorphism. Giant red shrimp spawns during the summer (June – July), thus it was decided to add a correction of 0.5 to the t0. Note that Table 2.2-2 reports t0 before the correction, thus values used in the assessment was 0.4. Regarding maturity, the young of the year recruiting in spring are immature, with only a few individuals reproducing during their first year. Gonadic development begins in winter and individuals become sexually mature in the second summer (Bianchini, 1999; Politou *et al.*, 2004). Once they have reached maturity male giant red shrimp have a protracted reproductive capacity and are ready to mate throughout the year, whilst females mature seasonally (Bianchini, 1999; Perdichizzi *et al.*, 2012). *A. foliacea* gather in shoals during the mating and spawning season (Bianchini, 1999), however only very limited information on the location of such spawning areas is available. From literature is known that the mature population rise out of the canyons to spawn on the upper slope. After the mating peak, the population goes back to the deeper grounds (D'Onghia *et al.*, 1998). Maturity vectors used by GFCM-WGSAD was derived from GSA 19 individuals (Table 2.2-3), by averaging over available years, suggesting most of the specimens were mature after second year of life.

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

Somatic magnitude measured (LT, LC, etc)			ML	**Units**	mm
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	Spring - Summer
Linf	74	53		**Recruitment season**	Fall
Size at first maturity			-	**Spawning area**	
Recruitment size to the fishery				**Nursery area**	

Table 2.2-2: Growth and length weight model parameters

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**		74	53		
	K		0.438	0.36		
	t_0		-0.1	-0.1		
	Data source					
Length weight relationship	**a**		0.00089	0.0013		
	b		2.78	2.63		
	M (scalar)					
	sex ratio (% females/total)	0.5				

Table 2.2-3: maturity vector derived from GSA 19 data.

Maturity	**0**	**1**	**2**	**3**	**4**	**5**
Males	0	0.35	0.97	1	1	1
Females	0	0.14	0.83	1	1	1

3 Fisheries information

3.1 Description of the fleet

The fleet targeting ARS (Table 3.1-1) is supposed to be the "Deep Water Shrimp", DWS, which is represented by a limited number of vessels. DWS trawlers are the only long-range fleet in the Mediterranean Sea and are characterized by high mobility (Armelloni *et al.*, 2021; Pulcinella *et al.*, 2023). In GSAs 18, 19 and 20 the main fleet targeting the Giant red shrimp is the bottom otter trawl (OTB). A few tons were coming from the Maltese fleet. A negligible amount of landings (< 0.5% in 2021) were coming from other gears, mostly nets.

Considering that the numbers of the other bottom trawlers fleets are not representative of the effort targeting deep water shrimps, in the Table 3.1-2 only DWS fishing days are reported. Data for the Greek fleet are absent, suggesting caution when using these data to attempt calculating catches per unit of effort.

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	18	E - Trawl	Otter trawl	33 - Demersal shelf species	
Operational Unit 2	ITA	19	E - Trawl	Otter trawl	33 - Demersal shelf species	
Operational Unit 3	GRC	20	E - Trawl	Otter trawl	33 - Demersal shelf species	
Operational Unit 4	MLT	19	E - Trawl	Otter trawl	33 - Demersal shelf species	
Operational Unit 5	MLT	20	E - Trawl	Otter trawl	33 - Demersal shelf species	

Table 3.1-2: Catch, bycatch, discards and effort by operational unit in the reference year

Operational Units*	Fleet (n° of boats)*	Catch (T or kg of the species assessed)	Other species caught (names and weight)	Discards (species assessed)	Discards (other species caught)	Effort (Fishing days)
Operational Unit 1		110				590
Operational Unit 2		155				4100
Operational Unit 3		24				0
Operational Unit 4		0				8
Operational Unit 5		3				0
Total		292				

3.2 Historical trends

Landings data by year, GSA, country are presented in Figure 4.1.1-1, Figure 4.1.1-2, Figure 4.1.1-3 and

Table 3.2-1. In all GSAs most of the landings come from otter trawls. The metiér level was not homogeneously filled: although it is expected that metier targeting Giant red shrimp is DWS, data were sporadically assigned to this metier. This issue made the calculation of fishing days potentially inaccurate. DCF data coming from other gear were considered inaccurate or sampled inconsistently; anyway, their catches were included in the stock assessment due to the low amounts. Length frequency distribution of the landings were available only from Italian fleet. For GSA 18, in EWG 22-03 the missing years were from 2003 to 2008, for GSA 19 from 2005 – 2007 and there was no information for length frequency distribution for GSA 20. For the needs of stock assessment, it was decided to use the LFD from GSA 19 for the years 2003, 2004 and 2008 for all the areas, while for the common missing years 2005 – 2007, no reconstruction was decided (Figures 5.12.4.4 – 5.12.4.6). In EWG 22-16 LFDs for GSA 18 were also not available for the years 2013, 2019 and 2020, which were retrieved from EWG 22-03 (data not shown in this report). As from EWG 22-03, EWG 22-16 decided that the discards for this species can be considered negligible and will not be used for the purposes of an assessment.

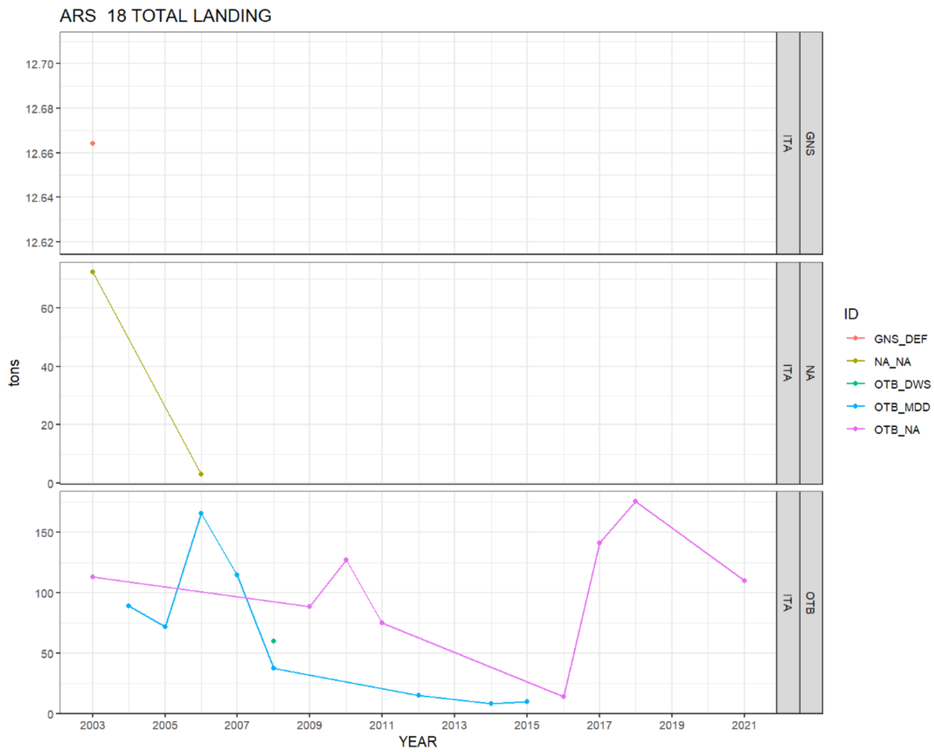

Figure 4.1.1-1: Landings data in tonnes by year, area country and fleet for in GSA 18.

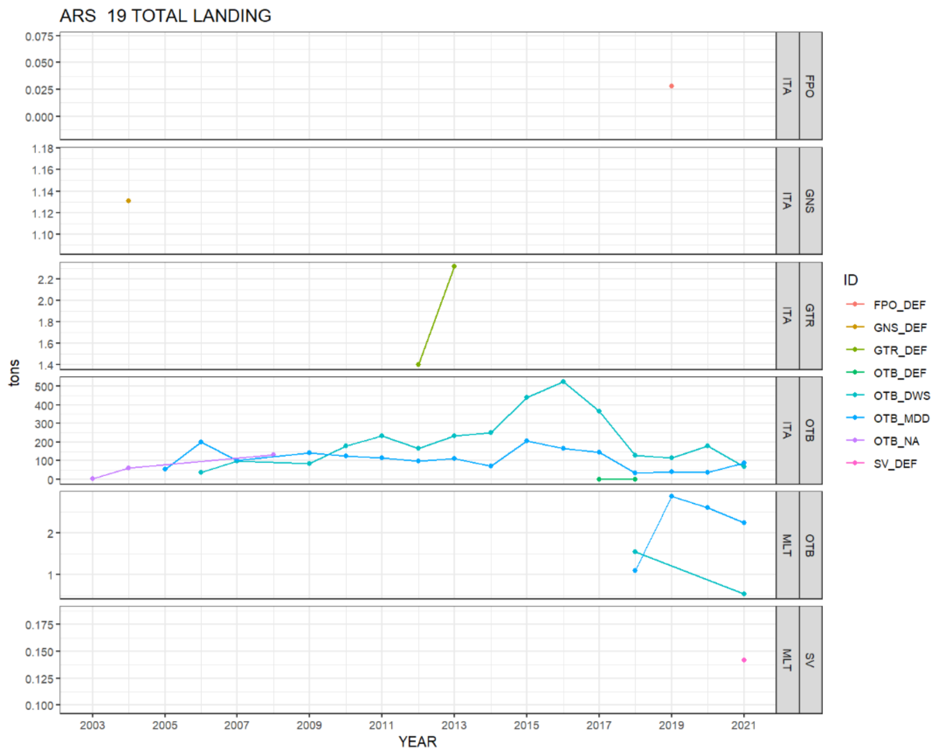

Figure 4.1.1-2: Landings data in tonnes by year, area country and fleet for in GSA 19.

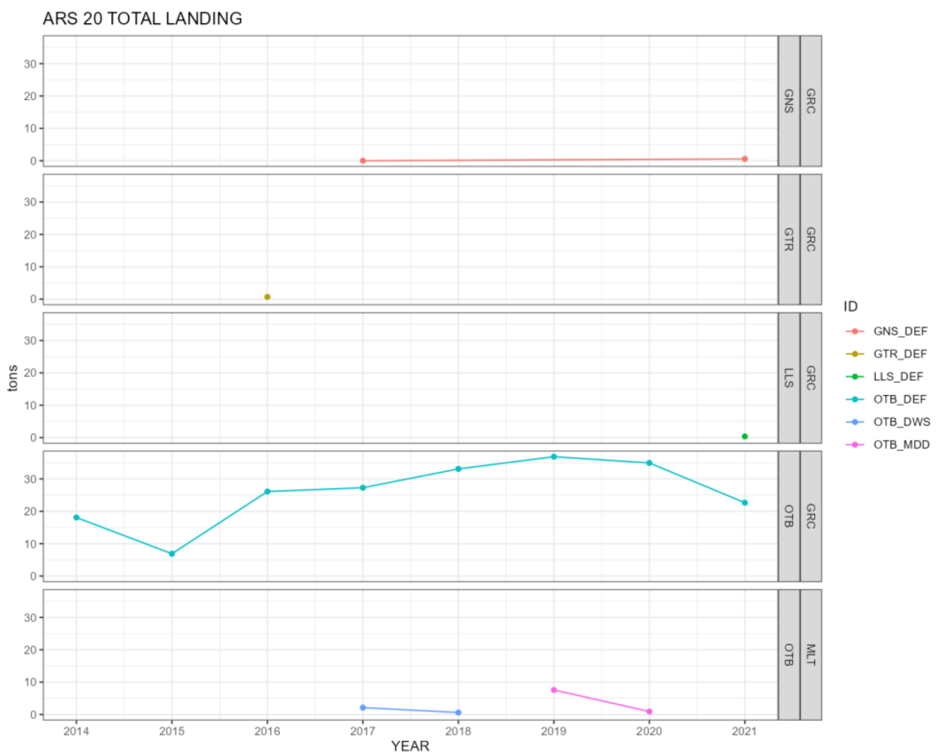

Figure 4.1.1-3: Landings data in tonnes by year, area country and fleet for in GSA 20.

Table 3.2-1: Landings by country and GSA.

Year	ITALY GSA18	ITALY GSA19	GREECE GSA20	MALTA GSA20	MALTA GSA19	Total landings
2003	198	4	0	0	0	202
2004	89	63	0	0	0	152
2005	72	55	0	0	0	127
2006	169	236	0	0	0	405
2007	115	199	0	0	0	313
2008	97	133	0	0	0	229
2009	88	226	0	0	0	314
2010	127	301	0	0	0	429
2011	75	347	0	0	0	422
2012	15	262	0	0	0	277
2013	15	349	0	0	0	363
2014	8	320	18	0	0	346
2015	9	646	7	0	0	662
2016	14	690	27	0	0	731
2017	141	509	27	2	0	680
2018	176	162	33	1	3	374
2019	106	157	37	8	3	310
2020	133	218	35	1	3	390
2021	110	155	24	0	3	292

3.3 Management regulations

In Italy management regulations are based on technical measures, closed number of fishing licenses for the fleet and area limitation (distance from the coast and depth). In order to limit the over-capacity of fishing fleet, the Italian fishing licenses have been fixed since the late eighties and the fishing capacity has been gradually reduced. Other measures on which the management regulations are based regards technical measures (mesh size), minimum landing sizes (EC 1967/06) and seasonal fishing ban. Regarding small scale fishery management regulations are based on technical measures related to the height and length of the gears as well as the mesh size opening, minimum landing sizes and number of fishing licenses for the fleet. In 2008 a management plan was adopted, that foresaw the reduction of fleet capacity associated with a reduction of the time at sea. The Protected Marine Area of Porto Cesareo, covering an area of 16,654 hectares (41 acres) (the third largest in Italy). A marine protected area (MPA) had been established in 1997. Since June 2010 the rules implemented in the EU regulation (EC 1967/06) regarding the cod-end mesh size is enforced.

3.4 Reference points

No agreed reference points were existing since it was the first time that this stock configuration was assessed. Refers to section XXX for details on the methodology used to derive reference points in the present assessment.

Table 3.4-1: List of reference points and empirical reference values previously agreed (if any)

Indicator	Limit Reference point/empirical reference value	Value	Target Reference point/empirical reference value	Value	Comments
B			Not Defined		
SSB			Not Defined		
F			$F_{0.1}$ as proxy for F_{MSY}		
Y			Not Defined		
CPUE			Not Defined		
Index of Biomass at sea			Not Defined		

4 Fisheries independent information

4.1 MEDITS

The MEDITS (Mediterranean International Trawl Survey) survey is an extensive trawl survey occurring in all European countries and included in the Data Collection Framework. According to the MEDITS protocol (Bertrand et al., 2002), it takes place every year during springtime, following a random stratified sampling by depth (5 strata: 0-50 m, 50-100 m, 100-200 m, 200-500m and over 500 m). The number of hauls in each stratum is proportional to the surface of the stratum and their positions were randomly selected and maintained fixed throughout the time. Same sampling gear (GOC73), characterized by a 20 mm stretched mesh size cod-end, is used throughout GSAs and years. The timing of the survey is shown in Figure 4.1.1-1. According to the MEDITS handbook procedures and what it is stated in MS EU-MAPs the period in which the survey should be carried out was not always respected: in 2014 the survey was carried out in September and in 2017 and 2020 in November-December. The survey coverage was not heterogeneous along the time series, since in GSA 20 the survey was missing in the years 2007, 2009 – 2013, 2015 and 2017. The lack of coverage for GSA 20 was considered a relevant issue since in this area are located hauls where high abundance is usually found (Figure *4.1.1-1*). EWG 22-03 addressed the issue of the heterogeneous coverage, comparing the index calculated on GSAs 18 and 19 with the one covering GSAs 18-20 (Figure *4.1.1-2*), and highlighting that including GSA 20 was determining a general increase of the survey index. EWG 22-16 continued to explore the possible bias introduced by the lack of coverage by fitting a tentative stock assessment model considering two separate indices: one for GSAs 18 and 19 and one for GSA 20. The attempt taken by EWG 22-16 did not cause a significant difference in the model fitting to use a single combined index for GSAs 18-20, probably due to the few data points provided by GSA 20 alone. As a result, EWG 22-16 agreed on using a combined index for GSAs 18-20, including all countries (Albania, Montenegro, Italy and Greece). Data were analysed using the JRC script.

Figure 4.1.1-1: Medits survey periods for GSA 18-19-20

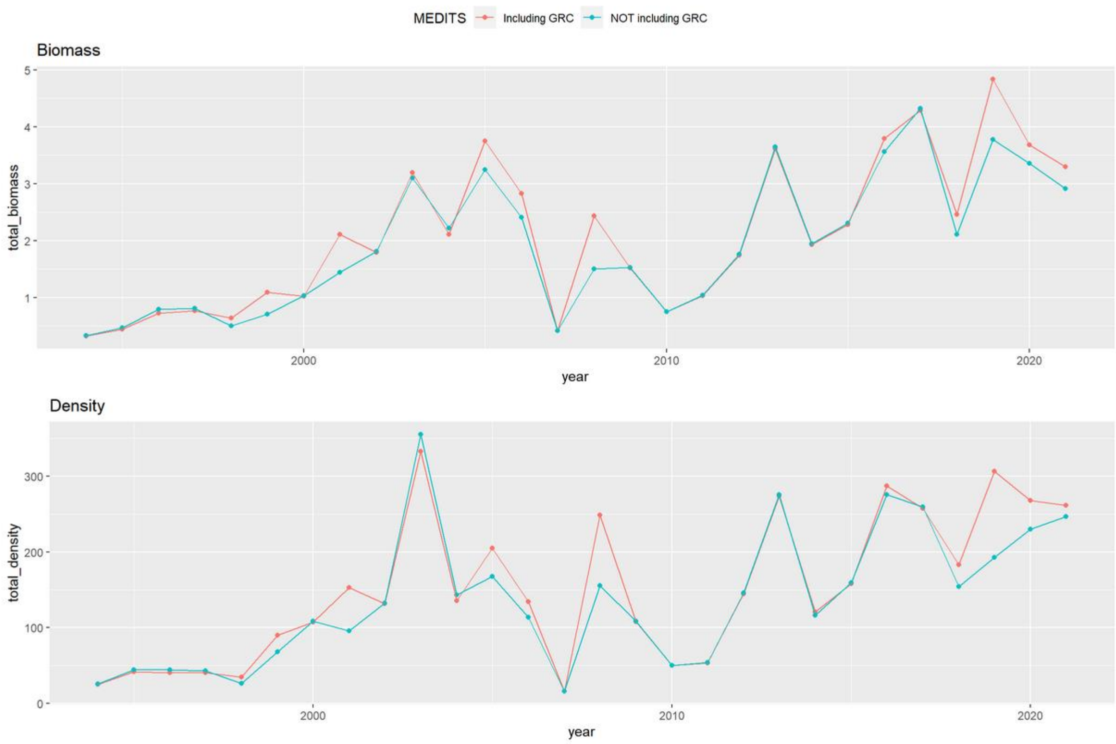

Figure 4.1.1-2: Density and biomass index when including (Including GRC) and excluding (NOT including GRC) GSA 20 from the Index computation.

Table 4.1-1: Trawl survey basic information

Survey	Medits	**Trawler/RV**	
Sampling season	Summer		
Sampling design	Stratified sampling design with the number of hauls proportionate to the strata surface		
Sampler (gear used)	GOC 73		
Codend mesh size as opening in mm	20		
Investigated depth range (m)	10 - 800		

Table 4.1-2: Trawl survey sampling area and number of hauls 2021.

Stratum	Total surface (km^2)	Trawlable surface (km^2)	Swept area (km^2)	Number of hauls
A	8470		0.994	23
B	12274		1.31	30
C	12501		2.03	42
D	14069		3.32	35
E	14864		4.48	50

Table 4.1-3: Trawl survey abundance and biomass results

Years	kg per km^2	St Dev	N per km^2	St Dev
1994	0.31	0.09	24.63	7.74
1995	0.43	0.14	41.40	14.43
1996	0.71	0.20	40.00	9.86
1997	0.75	0.24	39.96	11.42
1998	0.62	0.16	34.10	9.20
1999	1.07	0.48	88.84	36.18
2000	1.00	0.18	106.32	24.59
2001	2.07	0.92	149.79	76.03
2002	1.75	0.43	128.86	41.11
2003	3.12	0.50	325.08	57.28
2004	2.05	0.43	132.40	23.80
2005	3.65	0.77	200.13	43.56
2006	2.75	0.56	131.13	26.44
2007	0.40	0.12	15.59	4.45
2008	2.37	0.88	242.56	88.18
2009	1.48	0.30	106.09	22.87

Years	kg per km^2	St Dev	N per km^2	St Dev
2010	0.73	0.20	49.69	15.27
2011	1.01	0.23	52.37	10.68
2012	1.70	0.27	141.55	33.06
2013	3.53	0.74	267.31	64.31
2014	1.88	0.31	117.99	23.59
2015	2.24	0.42	155.00	31.41
2016	3.71	0.60	280.98	51.06
2017	4.25	0.62	254.80	43.66
2018	2.40	0.42	177.78	32.75
2019	4.68	1.03	296.63	73.50
2020	3.58	0.73	260.86	58.85
2021	3.22	0.55	255.16	44.74

4.1.1 Spatial distribution of the resources

According to data collected during Medits surveys, *A. foliacea* aggregates on the slope at the boundaries of the continental shelf, at depth higher than 200 m (Figure *4.1.1-1*).

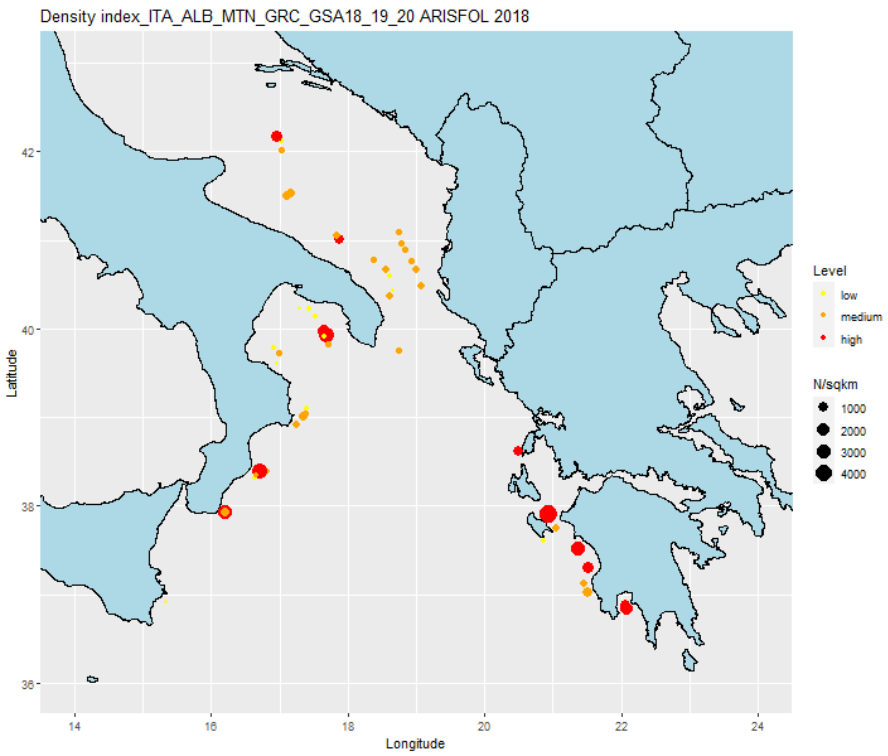

Figure 4.1.1-1: Maps distribution of Giant red shrimp in GSA 18-20 (bubbles: N km-2), based on Medits data.

4.1.2 Historical trends

The Medits trawl surveys provided data either on Giant red shrimp total biomass (Figure *4.1.2-1*) and density (Figure *4.1.2-2*). Both biomass and density index were suggesting a generally increasing trend, while oscillating between high and low peaks, with low values especially found in the years 2007 and 2010-2011. The year 2007 was considered not representative of the stock and was excluded by the present stock assessment. Length frequency distributions for sex combined are shown in Figure 4.1.2-3.

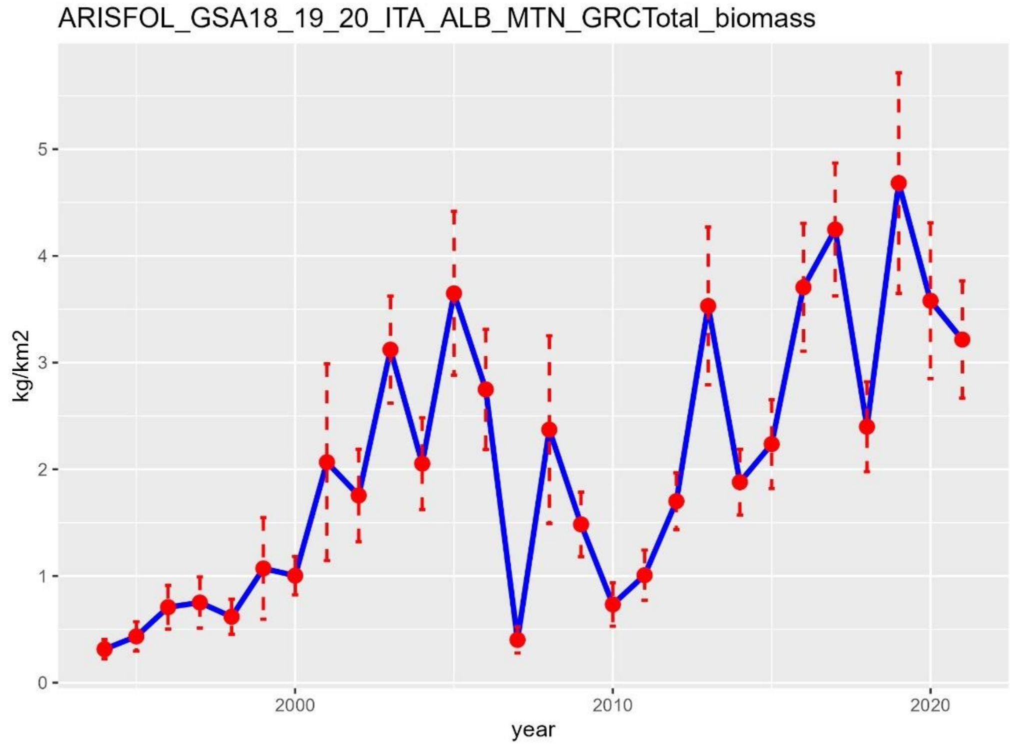

Figure 4.1.2-1: Estimated biomass indices from the MEDITS survey (kg/km2).

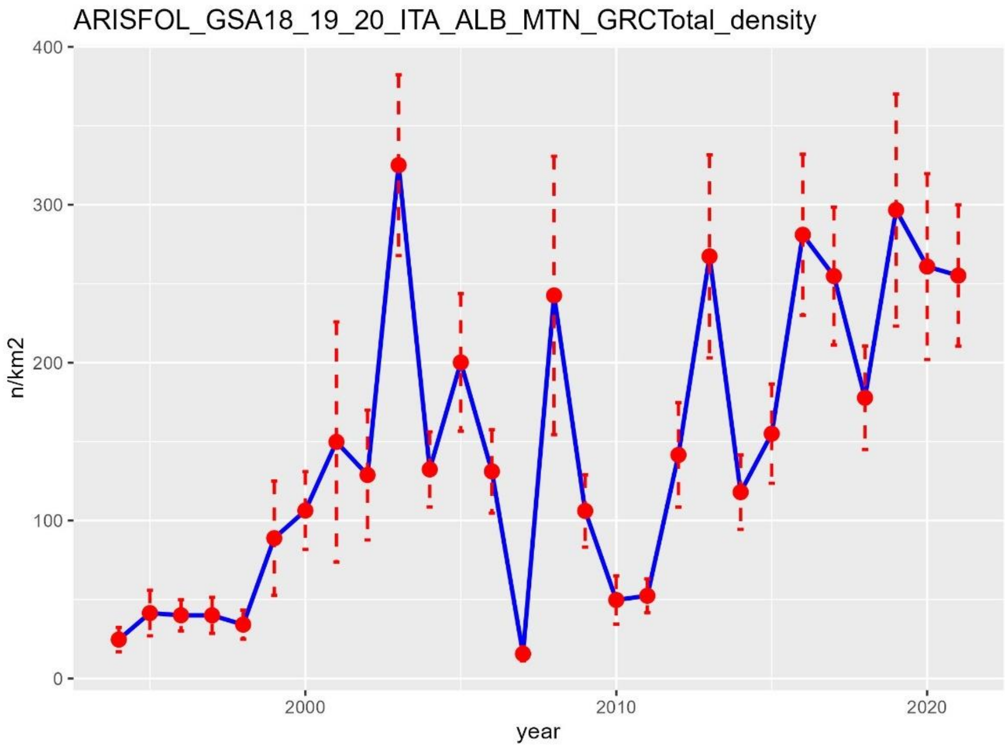

Figure 4.1.2-2: Estimated density indices from the MEDITS survey (kg/km2).

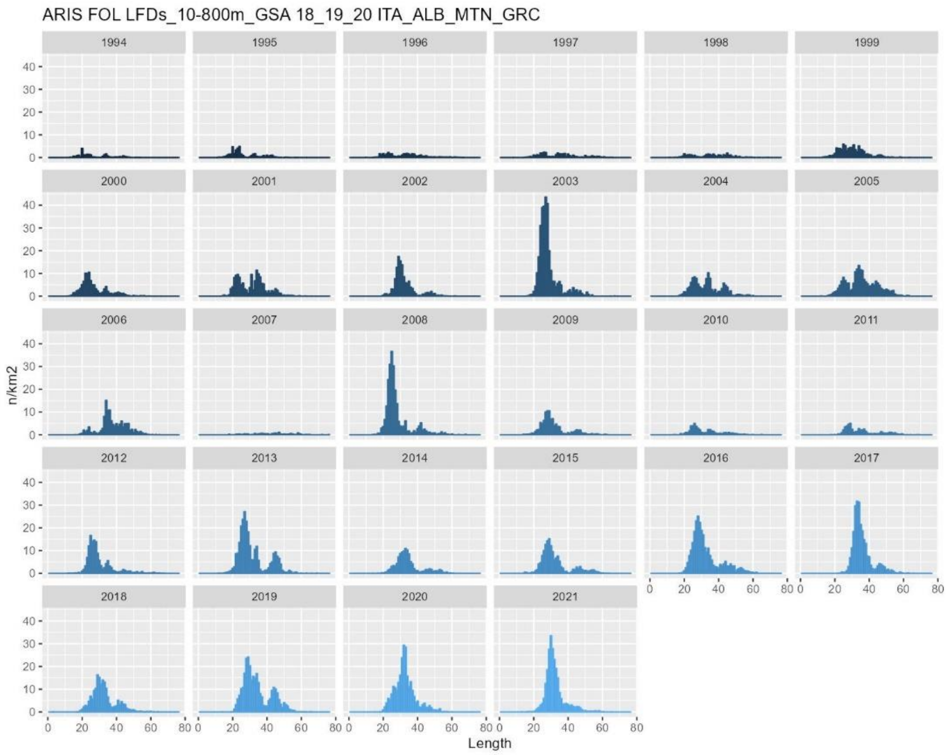

Figure 4.1.2-3 Stratified abundance indices by size, 2005-2019. Vertical line: size at first maturity

5 Ecological information

5.1 Protected species potentially affected by the fisheries

No analysis was carried out on this aspect. However, see (Pulcinella *et al.*, 2023) for a synthetic review of ecological consequences of deep-water fisheries.

6 Stock Assessment

6.1 A4a

6.1.1 Model assumptions

The stock in GSA 18, 19 & 20 was previously assessed by EWG 21-15 (STECF, 2021) based on survey indicators. A statistical catch-at-age assessment was carried out for this stock by EWG 22-16, using the Assessment for All Initiative (a4a) method (Jardim *et al.*, 2014). The a4a method utilizes catch-at-age data to derive estimates of historical population size and fishing mortality. However, unlike XSA, model parameters estimated using catch-at-age analysis are done so by working forward in time and analyses do not require the assumption that removals from the fishery are known without error.

The model was fitted using as input data the period 2003-2021 for the catch data (landings) and the tuning index.

Both catch numbers at length and index number at length were sliced by sex and GSA using the a4a age slicing routine in FLR, using for each GSA the same sex-specific growth parameters. Catch at age by sex was obtained by splitting commercial total length distribution according to a sex-ratio vector model obtained from DCF available sex ratio vectors in the respective areas. The analyses were carried out for the ages 1 to 5+. Concerning the Fbar, the age range used was 1-3.

6.1.2 Input data and revisions done by GFCM-WGSAD

The growth parameters used for VBGF were the ones reported in Table 2.2-1. Total catches and catch numbers at age (

Table 6.1-1) were used as input data. Catch numbers for 2007 for the MEDITS survey were removed from the input data due to the unrealistic low values of the LFDs for that year. SOP correction + raising was applied to catch numbers at age.

WGSAD highlighted inconsistency in the maturity at age vector used for the stock assessment done by EWG 22-16 (Figure 6.1.2-1) and required a revision. After inspection of the data, it was observed that uneven availability of maturity data over the assessment unit caused the final vector to oscillate. WGSAD adopted maturity at age from GSA 19 and applied to the entire time series. Slicing was applied and a new time series of catch-at-age was provided, and the maturity at age matrix used in the present assessment is shown in Table *6.1-3*.

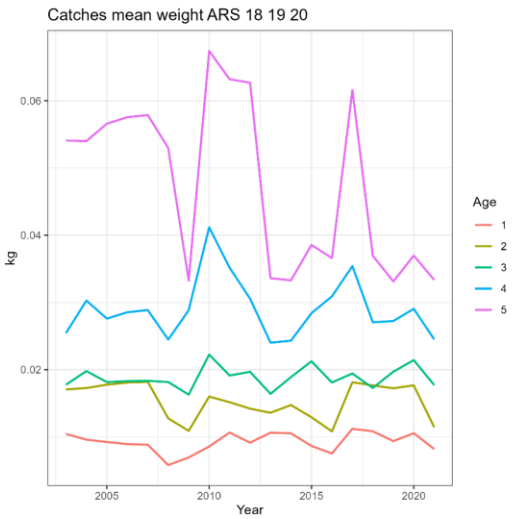

Figure 6.1.2-1: Giant red shrimp in GSA 18-20. Weight at age for stock used by STECF EWG 22-16 (STECF, 2022a).

Tables from

Table 6.1-1 to Table *6.1-6* lists the input data for the a4a model, namely catches, catch number at age, weight at age, maturity at age, natural mortality at age, Proportion of M and F before spawning, and the tuning series at age. Apart Maturity at age, all the other information was in line with EWG 22-16. Data suggested that most of the specimens were of age 1 or 2 with an increased presence of age 4 in some of the years. The mean weight of the ages varied slightly over the years.

Table 6.1-1: Giant red shrimp in GSA 18-20. Input data for the a4a model. Catch numbers-at-age matrix (thousands)

age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	4279.2	3450.7	3336.5	11402.4	9009.4	15121.9	20116.7	10395.5	12672.6	10135.3
2	5256.8	4105.2	2889.6	8739.9	6635.7	7538.8	10336.6	12064.9	10059.7	7799.0
3	3008.0	1840.5	1994.0	6487.8	5048.6	1852.9	3453.0	3723.6	5686.0	3093.1
4	416.3	306.2	232.2	706.9	537.9	405.7	153.5	924.2	483.9	334.5
5	58.7	44.8	35.1	109.9	84.4	30.4	24.7	382.1	138.5	43.5
age	2013	2014	2015	2016	2017	2018	2019	2020	2021	
1	12931.1	11029.3	25444.1	38544.6	14971.5	9273.5	8707.9	7833.4	12287.0	
2	11253.5	10391.7	22826.6	30084.5	15143.7	8289.0	8407.2	10833.5	10516.9	
3	4022.6	3803.1	6184.6	5233.4	8960.9	6347.1	3705.0	4689.0	3558.1	
4	261.9	173.0	473.8	607.1	1360.3	511.9	303.1	447.9	295.5	
5	20.5	23.7	56.3	43.8	238.9	105.7	77.6	53.8	20.5	

Table 6.1-2: Giant red shrimp in GSA 18-20. Input data for the a4a model. Weights-at-age (kg)

age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	0.010	0.010	0.009	0.009	0.009	0.006	0.007	0.009	0.011	0.009
2	0.017	0.017	0.018	0.018	0.018	0.013	0.011	0.016	0.015	0.014
3	0.018	0.020	0.018	0.018	0.018	0.018	0.016	0.022	0.019	0.020
4	0.025	0.030	0.028	0.029	0.029	0.024	0.029	0.041	0.035	0.031
5	0.054	0.054	0.057	0.058	0.058	0.053	0.033	0.067	0.063	0.063
age	2013	2014	2015	2016	2017	2018	2019	2020	2021	
1	0.011	0.011	0.009	0.008	0.011	0.011	0.009	0.011	0.008	
2	0.014	0.015	0.013	0.011	0.018	0.018	0.017	0.018	0.011	
3	0.016	0.019	0.021	0.018	0.019	0.017	0.020	0.021	0.018	
4	0.024	0.024	0.028	0.031	0.035	0.027	0.027	0.029	0.025	
5	0.034	0.033	0.039	0.037	0.062	0.037	0.033	0.037	0.033	

Table 6.1-3: Giant red shrimp in GSA 18-20. Input data for the a4a model. Maturity

age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
2	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
age	2013	2014	2015	2016	2017	2018	2019	2020	2021	
1	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	
2	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

Table 6.1-4: Giant red shrimp in GSA 18-20. Input data for the a4a model. Natural mortality.

age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	0.87	0.87	0.86	0.86	0.86	0.86	0.86	0.87	0.87	0.87
2	0.62	0.62	0.62	0.62	0.62	0.61	0.60	0.61	0.61	0.61
3	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.51	0.50	0.50
4	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.47	0.46	0.46
5	0.45	0.45	0.45	0.45	0.45	0.45	0.42	0.47	0.46	0.46
age	2013	2014	2015	2016	2017	2018	2019	2020	2021	
1	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	
2	0.61	0.61	0.61	0.60	0.62	0.62	0.62	0.62	0.60	
3	0.50	0.50	0.51	0.50	0.50	0.50	0.50	0.51	0.50	
4	0.45	0.45	0.45	0.46	0.46	0.45	0.45	0.45	0.45	
5	0.42	0.42	0.43	0.42	0.46	0.42	0.42	0.42	0.42	

Table 6.1-5: Giant red shrimp in GSA 18-20. Input data for the a4a model. Proportion of M and F before spawning vectors

age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
age	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	
1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
3	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	

Table 6.1-6: Giant red shrimp in GSA 18-20. Input data for the a4a model. Weights-at-age (kg). MEDITS number (n/km2) at age

age	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	159.65	45.73	46.63	15.49	NA	144.53	47.53	17.74	13.98	59.52
2	134.51	43.01	69.77	50.02	NA	74.96	41.82	17.55	16.87	54.04
3	28.64	38.50	72.43	58.37	NA	16.03	13.38	11.12	16.98	21.58
4	1.95	4.88	10.02	6.90	NA	3.37	2.77	2.63	4.09	4.61
5	0.22	0.23	0.64	0.32	NA	2.75	0.11	0.51	0.46	0.85
age	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	
1	100.22	37.45	56.33	100.13	55.09	58.43	70.21	96.57	90.99	
2	126.85	40.45	63.59	110.50	94.64	77.08	145.76	103.98	116.82	
3	36.59	37.42	31.02	40.50	98.72	38.16	76.81	58.03	35.46	
4	2.05	2.46	2.82	6.54	4.44	2.87	3.57	1.84	3.33	
5	0.40	0.10	0.11	0.04	0.28	0.13	0.19	0.02	0.30	

Figure *6.1.2-2* to Figure *6.1.2-5* show the age structure of the catches, of the index, the catch at age and MEDITS cohort consistency. Cohort consistency was good in the catches while it was poor in the Medits survey.

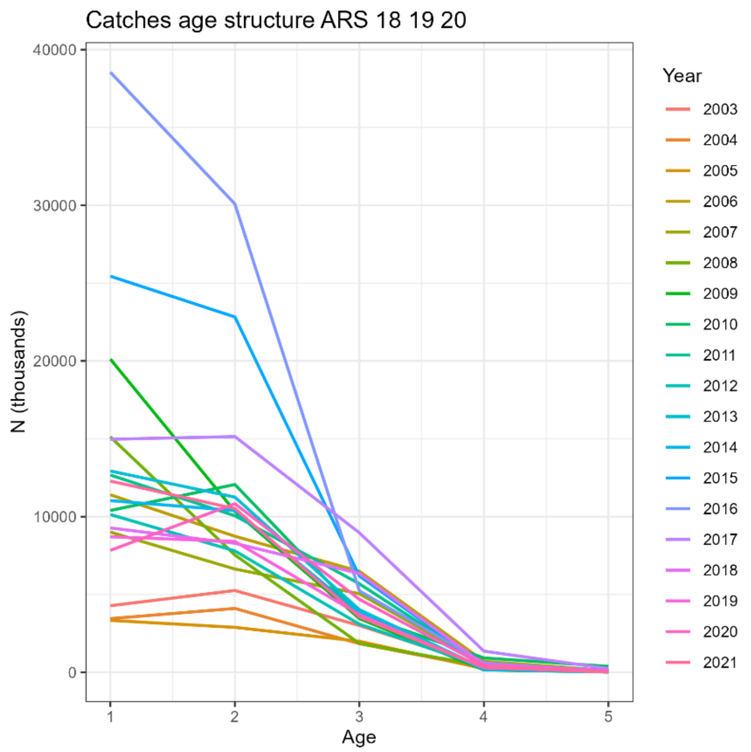

Figure 6.1.2-2: Giant red shrimp in GSA 18-20. Catch numbers for stock

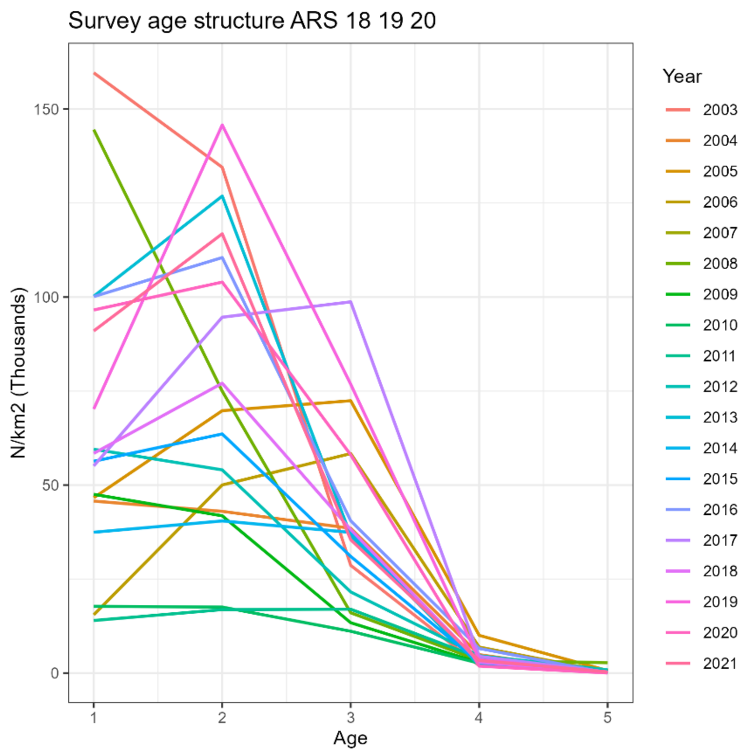

Figure 6.1.2-3: Giant red shrimp in GSA 18-20. Catch numbers for index

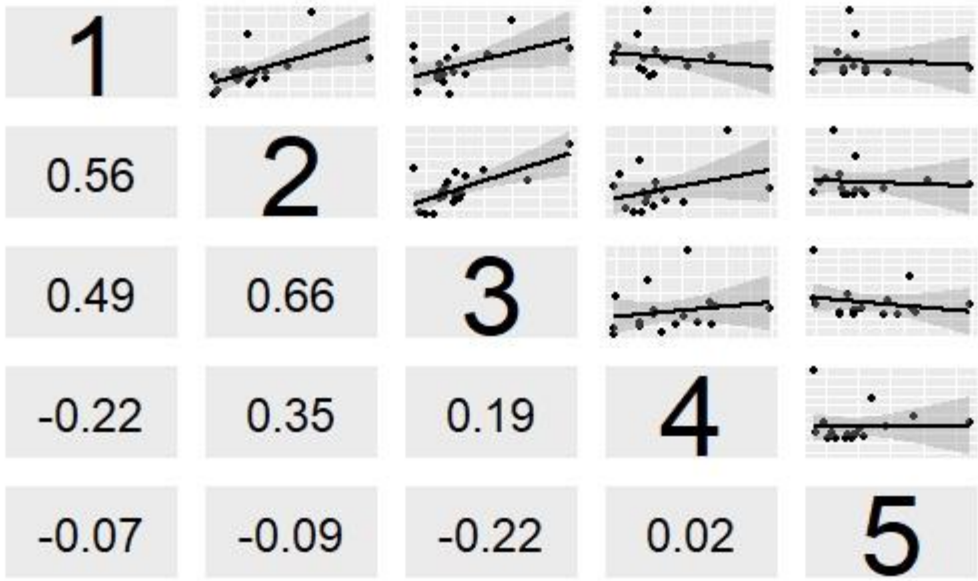

Figure 6.1.2-4: Giant red shrimp in GSA 18-20. Catch internal consistency plot

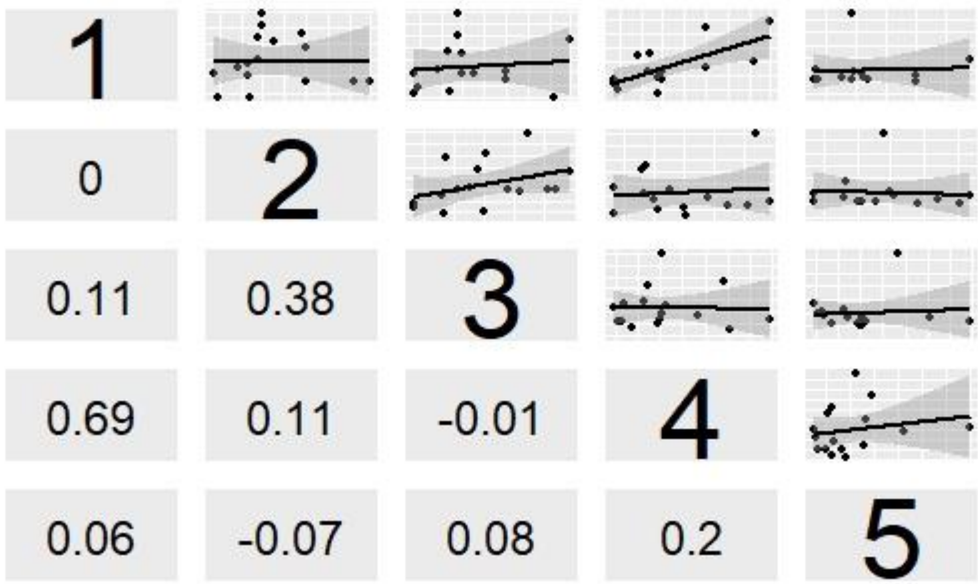

Figure 6.1.2-5: Giant red shrimp in GSA 18-20. MEDITS Index internal consistency table

6.1.3 Model results

Different a4a models were examined (a combination of different f and q models), including an exploration of dividing the MEDITS index in GSAs 18-19 and GSA 20. The best model (according to residuals and retrospective) was based on a single index for the target area and included:

Submodels:

fmodel: ~factor(replace(age, age > 2, 3))+s(year,k=6)

srmodel: ~s(year, k =9)

qmodel: MEDITS: ~factor(replace(age, age > 3, 4))

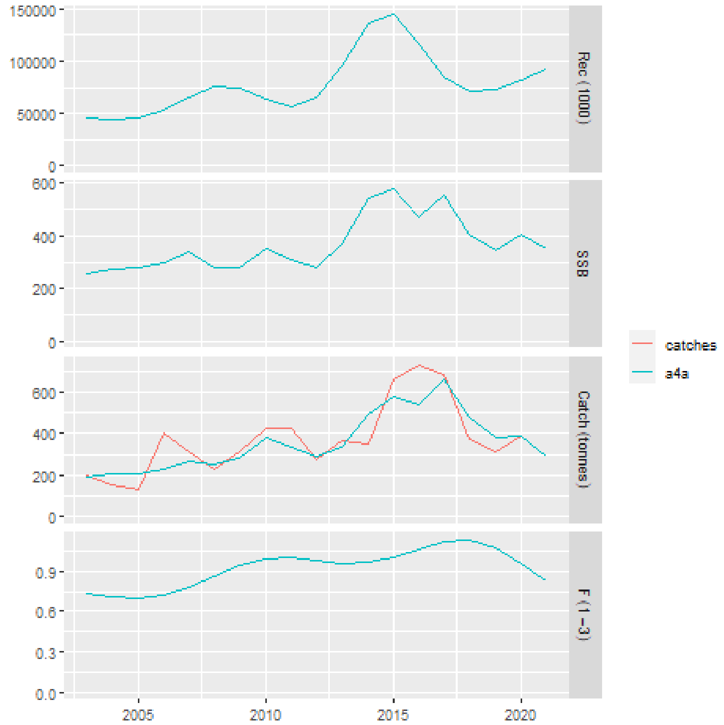

Figure 6.1.3-1: Giant red shrimp in GSA 18-20. Results of the a4a model

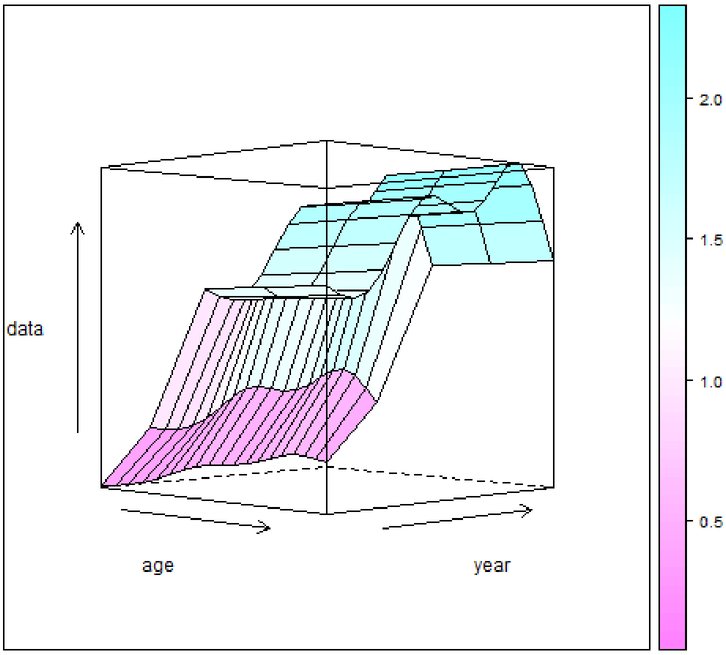

Figure 6.1.3-2: Giant red shrimp in GSA 18-20. 3D contour plot of estimated fishing mortality at age and year.

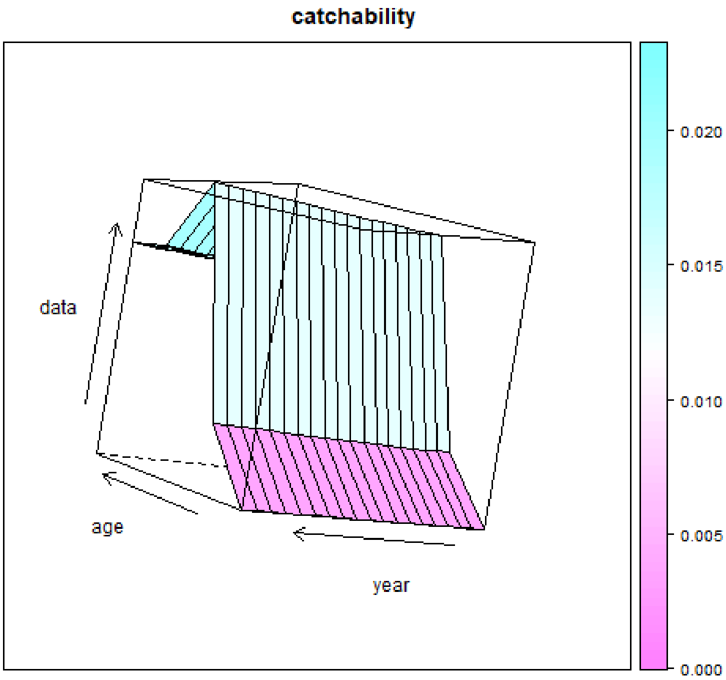

Figure 6.1.3-3: Giant red shrimp in GSA 18-20. 3D contour plot of estimated catchability at age and year.

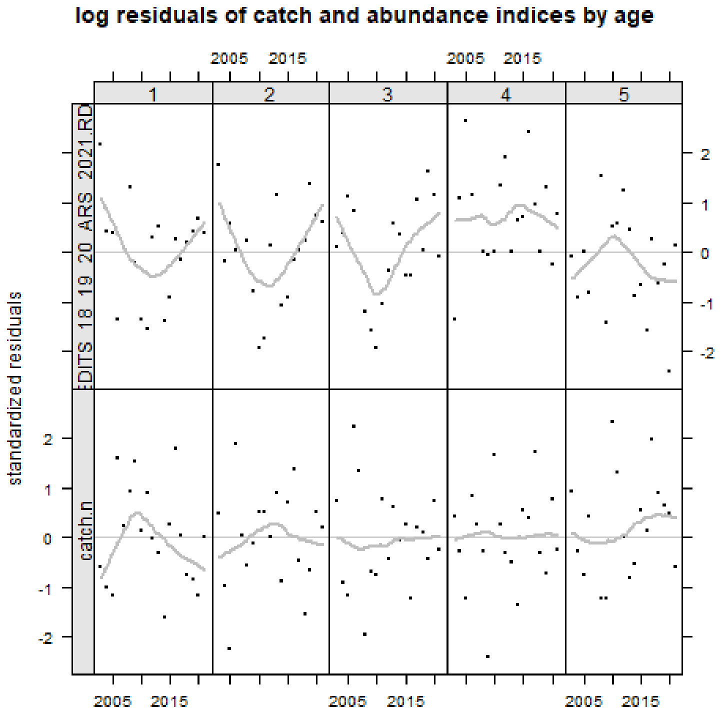

Figure 6.1.3-4: Giant red shrimp in GSA 18-20. Standardized residuals for abundance indices and for catch numbers (catch.n). Each panel is coded by age class, dots represent standardized residuals and lines simple smoothers.

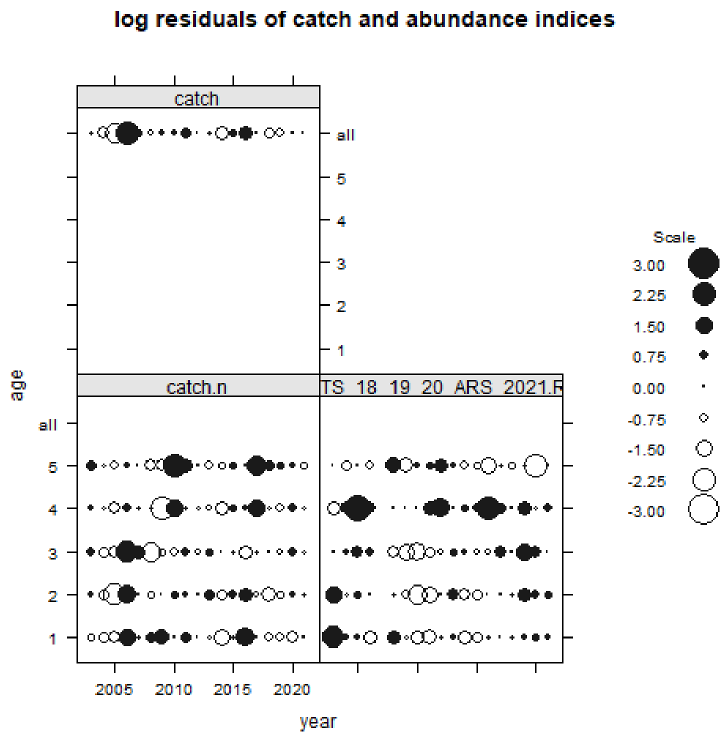

Figure 6.1.3-5: Giant red shrimp in GSA 18-20. Standardized residuals for abundance indices, catch and catch numbers.

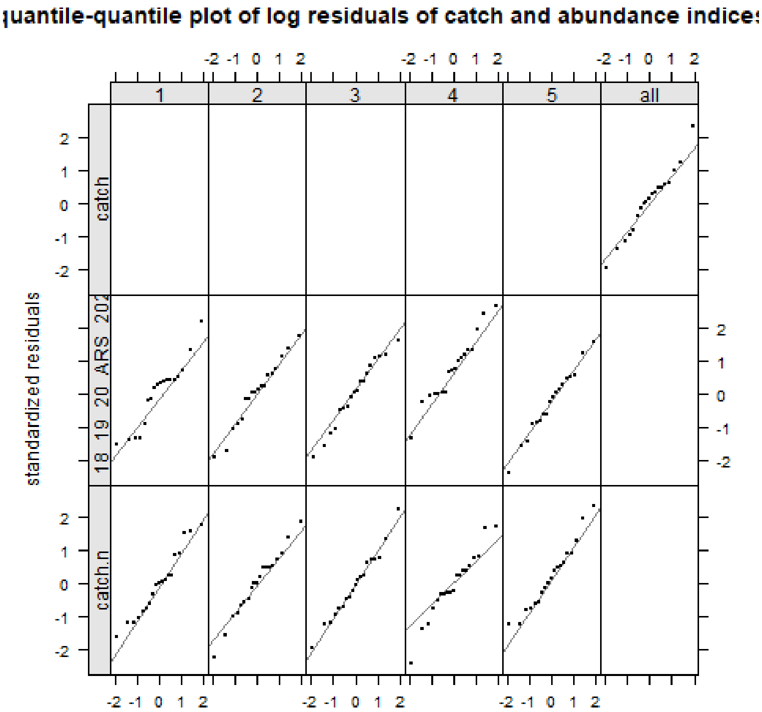

Figure 6.1.3-6: Giant red shrimp in GSA 18-20. Quantile-quantile plot of standardized residuals for abundance indices and for catch numbers (catch.n). Each panel is coded by age class, dots represent standardized residuals and lines the normal distribution quantiles.

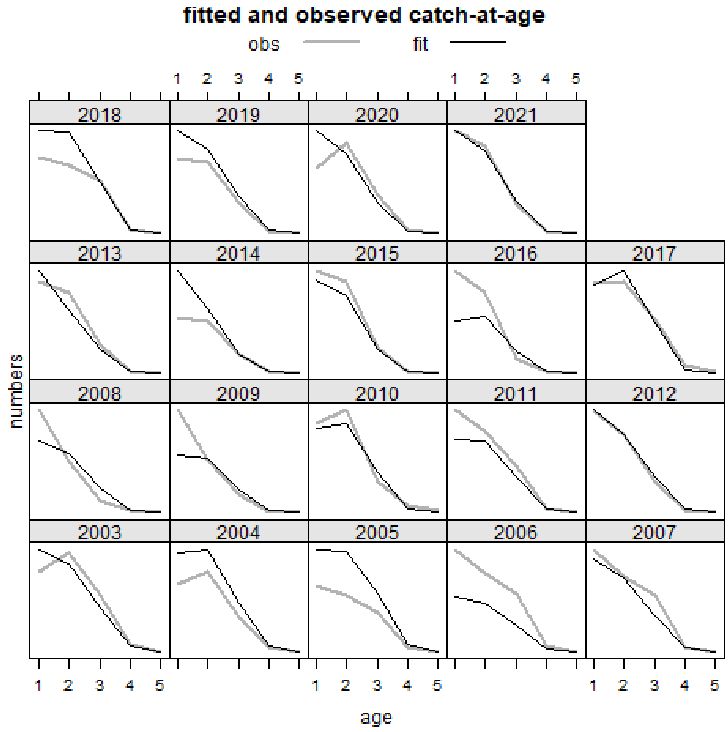

Figure 6.1.3-7: Giant red shrimp in GSA 18-20. Fitted and observed catch at age.

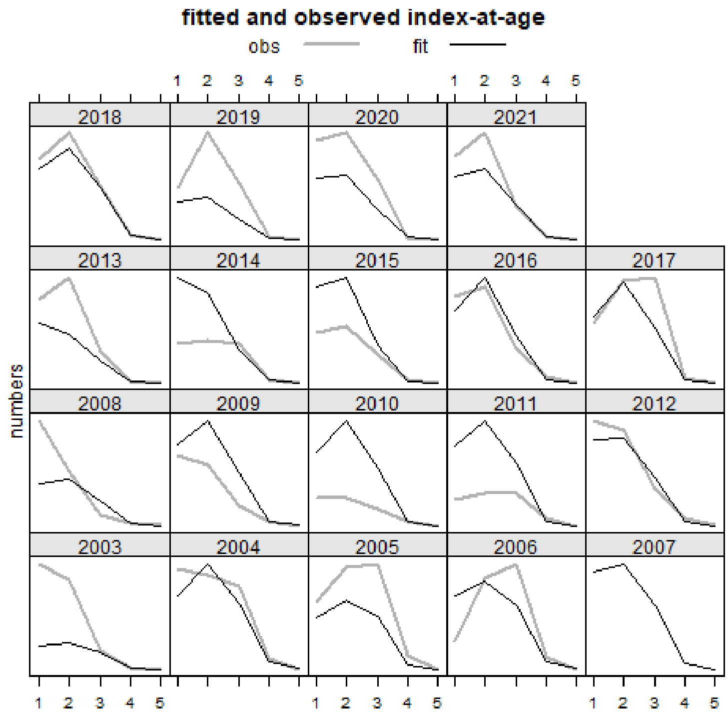

Figure 6.1.3-8: Giant red shrimp in GSA 18-20. Fitted and observed index at age.

Simulations

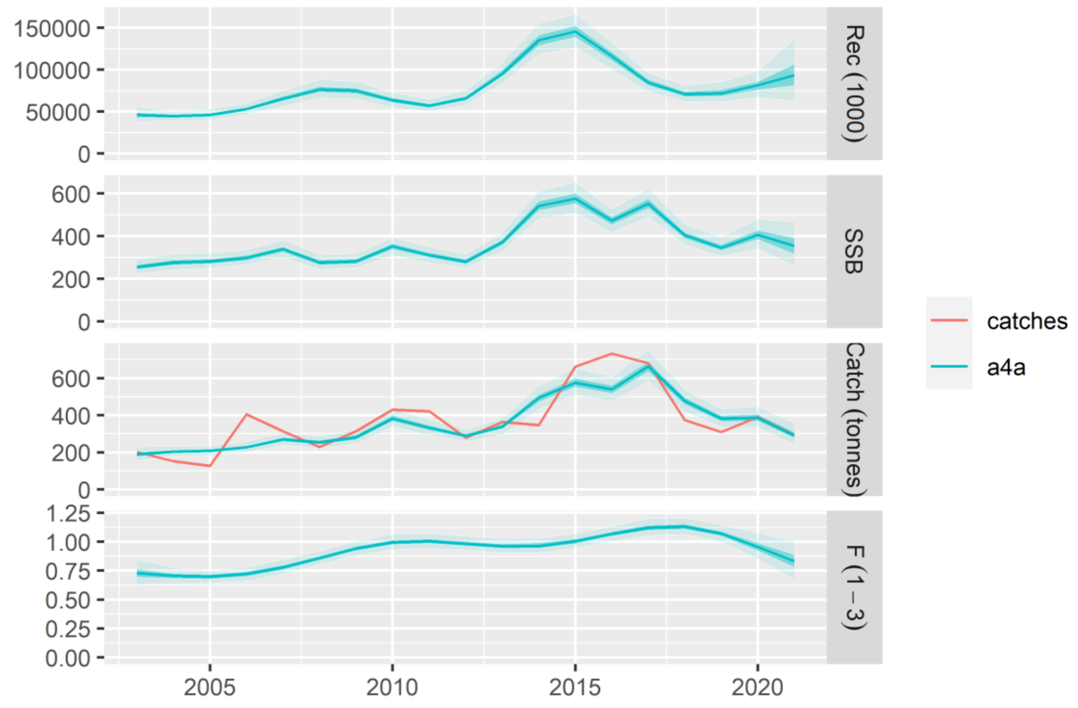

Figure 6.1.3-9: Giant red shrimp in GSA 18-20. Simulations over summary results.

In the following tables, the population estimates obtained by the a4a model are provided.

Table 6.1-7: Giant red shrimp in GSA 18-20. Stock numbers at age (thousands) as estimated by a4a.

Year	1	2	3	4	5+
2003	5404.2	4624.9	2335.9	346.0	26.8
2004	5081.4	5251.7	2528.2	344.7	57.1
2005	5204.0	5091.8	2992.8	396.3	65.0
2006	6169.1	5421.0	2990.9	487.6	77.6
2007	8187.4	6575.6	3165.0	475.9	92.8
2008	10500.3	8677.3	3625.5	455.5	84.4
2009	11154.0	10670.4	4366.4	441.1	68.9
2010	9906.7	10537.2	4820.0	443.6	53.6
2011	8967.5	8836.5	4375.0	431.2	45.6
2012	10181.7	7785.7	3596.2	381.2	42.7
2013	14479.1	8936.3	3243.0	326.9	40.1
2014	20601.2	13031.5	3856.5	312.1	37.0
2015	22938.4	19000.5	5669.6	372.2	35.4
2016	19301.6	21159.4	8011.3	509.9	38.5
2017	14716.2	17047.6	8312.2	635.6	45.0
2018	12417.8	12289.0	6132.6	584.3	49.6
2019	12039.0	9921.1	4283.4	416.2	45.1
2020	12242.8	9517.2	3609.2	318.0	36.0
2021	12277.6	9978.3	3862.8	327.7	33.8

Table 6.1-8: Giant red shrimp in GSA 18-20. a4a summary results.

Year	F ages 1-3	Recruitment age 1 thousands	SSB tonnes	TB tonnes	Catch tonnes
2003	0.73	45830	253.53	792.74	187.09
2004	0.70	44494	275.84	803.60	202.98
2005	0.70	45957	281.12	812.83	207.55
2006	0.72	52848	298.56	880.73	226.26
2007	0.78	65362	337.26	1032.63	269.19
2008	0.86	76416	276.66	850.95	253.19
2009	0.94	74822	281.34	922.60	279.91
2010	0.99	63377	350.32	1117.54	382.67
2011	1.00	56872	310.23	1056.42	331.23
2012	0.98	65721	280.84	979.70	288.82
2013	0.96	95499	370.88	1392.94	337.83
2014	0.96	135525	542.47	2000.00	490.73
2015	1.00	145625	577.40	2013.46	576.54
2016	1.07	115994	471.35	1601.33	536.49
2017	1.12	84628	553.77	1864.84	660.87
2018	1.13	70941	403.98	1398.37	475.12
2019	1.07	72171	346.51	1188.70	381.00
2020	0.96	81201	406.07	1385.57	385.25
2021	0.83	92534	350.46	1176.17	292.09

Table 6.1-9: Giant red shrimp in GSA 18-20. a4a results F at age.

Year	1	2	3	4	5
2003	0.19	0.58	1.41	1.41	1.41
2004	0.18	0.56	1.36	1.36	1.36
2005	0.18	0.56	1.35	1.35	1.35
2006	0.19	0.58	1.39	1.39	1.39
2007	0.20	0.62	1.50	1.50	1.50
2008	0.23	0.69	1.66	1.66	1.66
2009	0.25	0.75	1.82	1.82	1.82
2010	0.26	0.80	1.92	1.92	1.92
2011	0.26	0.80	1.94	1.94	1.94
2012	0.26	0.79	1.90	1.90	1.90
2013	0.25	0.77	1.86	1.86	1.86
2014	0.25	0.77	1.87	1.87	1.87
2015	0.26	0.80	1.94	1.94	1.94
2016	0.28	0.85	2.06	2.06	2.06
2017	0.29	0.90	2.17	2.17	2.17
2018	0.30	0.90	2.19	2.19	2.19
2019	0.28	0.86	2.07	2.07	2.07
2020	0.25	0.77	1.85	1.85	1.85
2021	0.22	0.66	1.60	1.60	1.60

According to the age slicing, catches of Giant red shrimp include a large portion of not fully mature specimens, therefore the SSB represents just around one-third of the stock biomass. SSB of Giant red shrimp show an increasing trend from 2003 to 2017. Then catches started to decline steadily until 2021, while SSB was declining until 2019 and then it stabilized at around 400 tons. The assessment shows a general oscillating trend in the number of recruits, especially after 2012, with recent years indicating an increasing trend. Fbar (1-3) shows a slight continuous increase until 2017 while it starts declining until 2021 when it reached a value of F of 0.828.

The assessment appears to be stable, and the results are consistent between different models. The patterns in the residuals in the MEDITS survey were mostly attributable to the low values observed in the middle of the time series, causing a systematic overestimation from 2008 to 2012. Considering that the catches at age did not show clear patterns in the residuals and that the fit of this data source was generally good, it was considered that the model was estimating the age structure from the catches, giving precision to the model, while the index was mostly informing on the biomass scale. Considering the heterogeneity in the MEDITS coverage, lacking an area of high density for the population, a better fitting of the model to the Medits data is not expected. A decrease in maximum age for this stock could be explored given the low number of catches in age.

6.1.4 Reference points estimation

Biological Reference points (BRPs) exploration was done with FLRef package (https://github.com/henning-winker/FLRef) with the support of the GFCM-Secretariat. BRPs estimation procedure is directly fed by the outcomes of the stock assessment model (e.g.: weight at age, maturity at age, natural mortality at age selectivity-at-age). Therefore, it is assumed that the accepted assessment represents the best available information about the stock dynamics. To enable adequate interpretation, it is here stressed that any conflict between the biological assumption and the data (*i.e.* model specification) may impair the plausibility of biomass reference points and produce unrealistic scaling.

BRP estimation is based on per-recruit analysis (PRA), which is a useful tool to evaluate the truncation of the left part of the age-structure (growth overfishing). S-R configurations tested were geometric mean with Blim set to the breakpoint Blim = 0.25 BF01 (gm) and Beverton-Holt with a fixed h= 0.85 (s=0.85). Therefore, all the biomass reference point would be a function of the F01 estimation. PRA (Figure 6.1.4-1) describes a very resilient stock in terms of biomass depletion, requiring a large F to really diminish the yield. Recruitment seems to be just slightly affected by the level of exploitation. The type of SR used was not largely affecting the results, so it was agreed to follow up with geometric mean to produce biomass reference points (Table 2.2-1). The comparison between observed and unfished biomass (Figure 6.1.4-2) shed light on the matter: it emerges that low fishing mortality is imposed on small age classes, which are sustaining the stock. The PRA indicates that a4a estimate virtually no exploitation on Age class 1, which can be already contributing to SSB and thus keeping the stock status above the biomass reference point.

Similar observations were done for other shrimp stock in the Mediterranean, raising concern of the adequacy of F01 as a proper sustainable proxy for Fmsy for Mediterranean Sea shrimp stocks.

Table 6.1-10: reference points estimated for Giant red shrimp in GSA 18-20.

F01	SSBtarget	Blim	Flim	Yeq	B0	R0
0.371	634	178	2.61	289	1540	75800

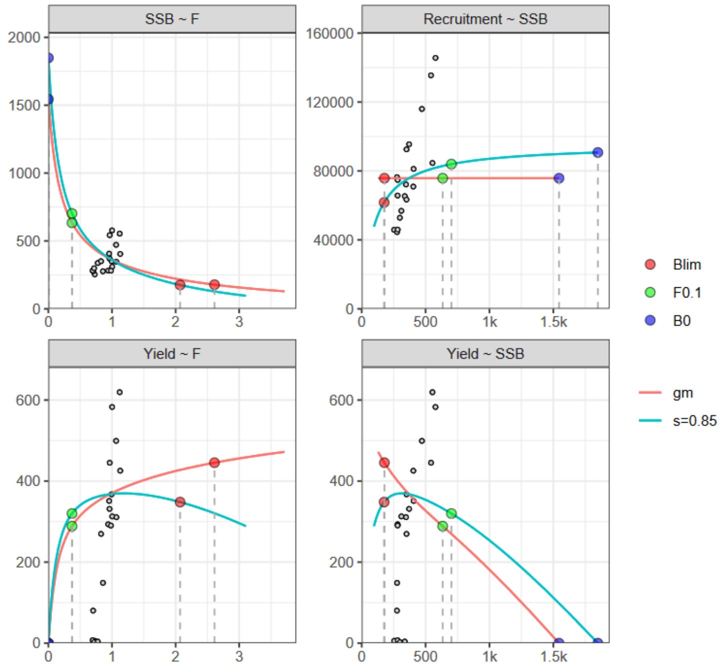

Figure 6.1.4-1: SRA for Giant red shrimp in GSA 18-20.

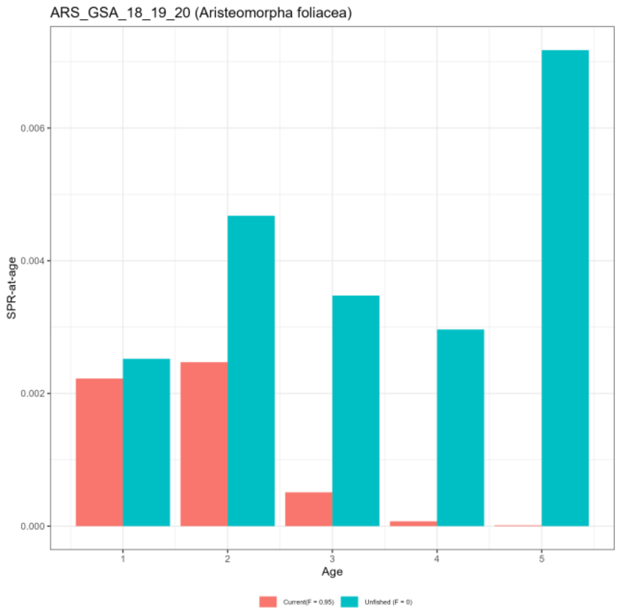

Figure 6.1.4-2: fishing pressure by age classes and estimated unfished biomass.

6.1.5 Summary of results

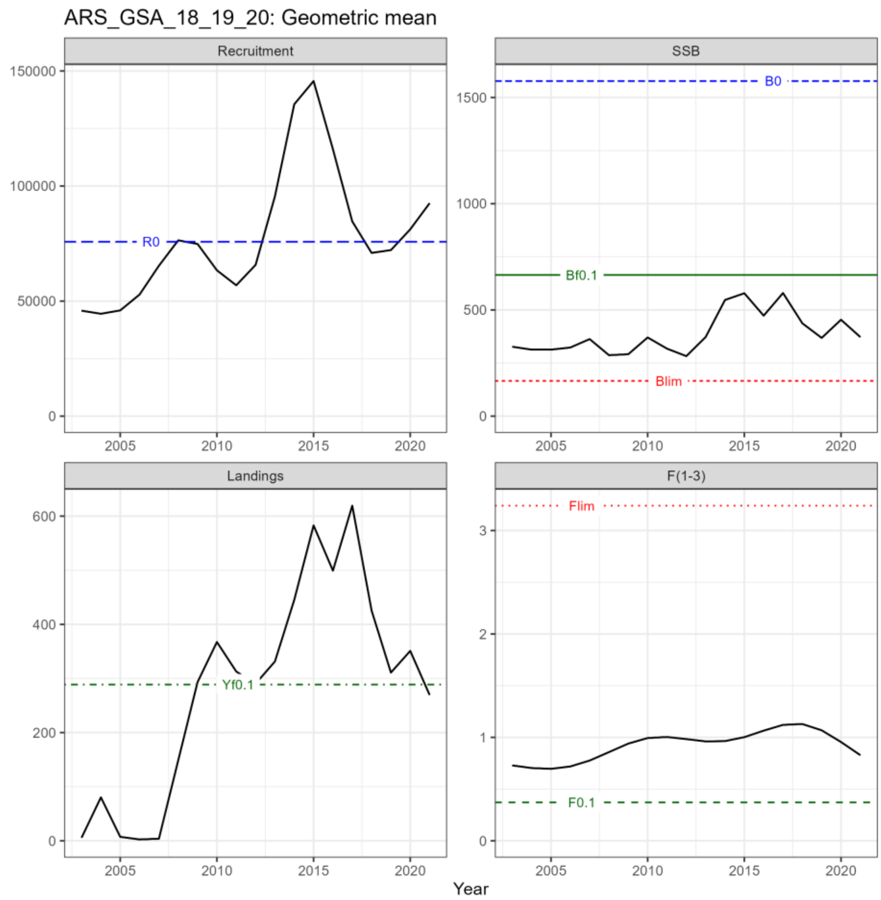

Table 6.1-11: Giant red shrimp in GSA 18-20. summary of final results from the a4a model.

Label	Value
Fcurrent (2021)	0.83
F01 (2021)	0.371
Fcurrent/F01	2.25
Current Total Biomass (tonnes)	1185
Current SSB (tonnes)	351
SSBtarget (tonnes)	634
SSBlim (tonnes)	158
Current SSB / SSBtarget	0.55
Current SSB / SSBlim	2.22
Catches 2021 (tonnes)	271.4

State of exploitation: Fbar (1-3) shows a slight continuous increase until 2017 while it starts declining until 2021 where it reached a value of F of 0.828. F trajectory was higher than the reference point for the entire duration of the time series.

State of the biomass: SSB of Giant red shrimp show an increasing trend from 2003 to 2017. Then catches started to decline steadily until 2021, while SSB was declining until 2019 and then it stabilized around 400 tons. The assessment shows a general oscillating trend in the number of recruits, especially after 2012, with recent years indicating an increasing trend. SSB never went below the Blim for the entire duration of the time series.

6.1.6 Retrospective analysis

The retrospective analysis (Figure 6.1.6-1) was applied up to 3 years back. Model results are quite stable and show a slight tendency to underestimate SSB (Mohn's rho -0.1) and F (Mohn's rho -0.01).

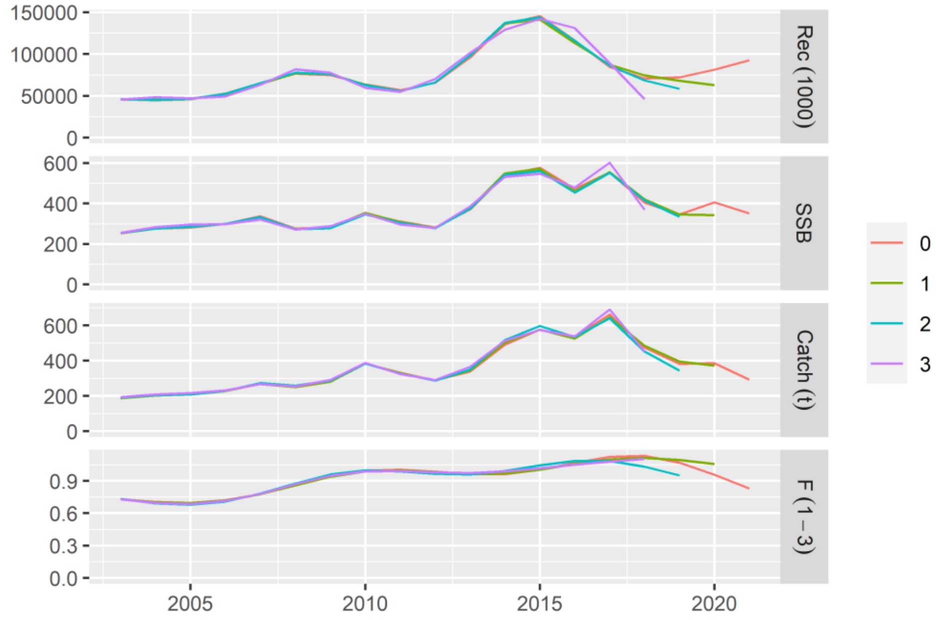

Figure 6.1.6-1: Giant red shrimp in GSA 18-20. Retrospective analysis.

6.1.7 Comparison with STECF EWG 22-16 results

A comparison between results provided by this assessment and the results found in STECF EWG 22-16 (STECF, 2022a) are shown in Figure 6.1.7-1. It emerges that the only slight difference is in the SSB, which is something expected considering the revision of the maturity at age. All the other stock trajectories are identical.

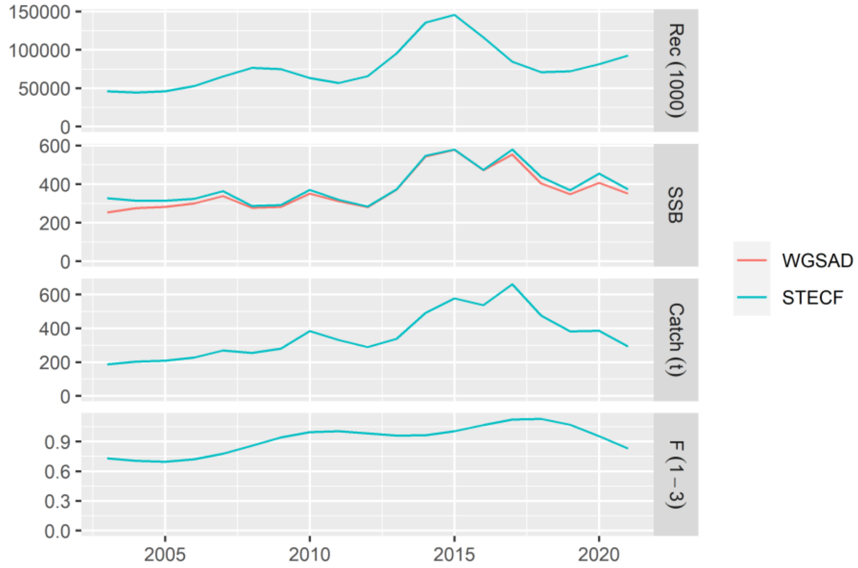

Figure 6.1.7-1: Giant red shrimp in GSA 18-20. Comparison between results provided by STECF EWG 22-16 and by the present assessment.

6.1.8 Assessment quality

The assessment appears to be stable, and the results are consistent between different models. The patterns in the residuals in the MEDITS survey were mostly attributable to the low values observed in the middle of the time series, causing a systematic overestimation from 2008 to 2012. Considering that the catches at age did not show clear patterns in the residuals and that the fit of this data source was generally good, it was considered that the model was estimating the age structure from the catches, giving precision to the model, while the index was mostly informing on the biomass scale. Considering the heterogeneity in the MEDITS coverage, lacking an area of high density for the population, a better fitting of the model to the Medits data is not expected. A decrease in maximum age for this stock could be explored given the low number of catches in age 5. Most of the concerns arise when comparing stock dynamic to reference points. In particular, the group noted that biomass increased despite a predicted increase of fishing pressure above levels above F0.1. Based on per-recruit analysis, the group observed that low fishing mortality is imposed by the SCAA model on young age classes (1 and 2), which are to a large extent sustaining the high biomass level. Stock recruitment relationship exploration also indicated that Biomass level of the stock never went below Blim. Given that similar patterns were observed for many other shrimp stocks, some concerns were raised if F01 is a sustainable proxy for Fmsy for shrimps in the Mediterranean Sea.

7 Stock predictions

No information available.

Draft scientific advice

The scientific advices in the following table are based on the a4a model results .

Table 7-1 Draft scientific advice

Based on	Indicator	Analytic al reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (2016-2021)	Stock Status
Fishing mortality	Fishing mortality	F01: 0.371	Fcurr: 0.83		D	IO
Stock abundance	Biomass	SSBlim: 158	SSBcurr: 351		I	Oi
Recruitment					C	
Final Diagnosis		**Reduce fishing mortality**				

8 Explanation of codes

Trend categories

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

Stock Status

Based on Fishing mortality related indicators

1) **N - Not known or uncertain** – Not much information is available to make a judgment;
2) **U - undeveloped or new fishery** - Believed to have a significant potential for expansion in total production;

3) **S - Sustainable exploitation**- fishing mortality or effort below an agreed fishing mortality or effort based Reference Point;
4) **IO –In Overfishing status**– fishing mortality or effort above the value of the agreed fishing mortality or effort based Reference Point. An agreed range of overfishing levels is provided;

Range of Overfishing levels based on fishery reference points

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

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

*Fc is current level of F

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

Based on Stock related indicators

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

Empirical Reference framework for the relative level of stock biomass index

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

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

Agreed definitions as per SAC Glossary

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

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

9 Literature cited

Armelloni, E. N., Tassetti, A. N., Ferrà, C., Galdelli, A., Scanu, M., Mancini, A., Fabi, G., *et al.* 2021. AIS data, a mine of information on trawling fleet mobility in the Mediterranean Sea. Marine Policy, 129: 104571. https://linkinghub.elsevier.com/retrieve/pii/S0308597X21001822.

Bertrand, J. A., Gil de Sola, L., Papaconstantinou, C., Relini, G., and Souplet, A. 2002. The general specifications of the MEDITS surveys. Scientia Marina, 66: 9. CSIC Consejo Superior de Investigaciones Cientificas 2. http://scientiamarina.revistas.csic.es/index.php/scientiamarina/article/view/605 (Accessed 14 June 2022).

Bianchini, M. 1999. The deep-water red shrimp, Aristaeomorpha foliacea, of the Sicilian Channel: biology and exploitation.

D'Onghia, G., Maiorano, P., Matarrese, A., and Tursi, A. 1998. Distribution, Biology, and Population Dynamics of Aristaeomorpha Foliacea (Risso, 1827) (Decapoda, Natantia, Aristeidae) in the North-Western Ionian Sea (Mediterranean Sea). Crustaceana, 71: 518–544. Brill.

Jardim, E., Millar, C. P., Mosqueira, I., Scott, F., Osio, G. C., Ferretti, M., Alzorriz, N., *et al.* 2014. What if stock assessment is as simple as a linear model? The a4a initiative. ICES Journal of Marine Science, 72: 232–236. Oxford University Press. https://academic.oup.com/icesjms/article/72/1/232/2804293 (Accessed 8 April 2022).

Perdichizzi, A., Pirrera, L., Micale, V., Muglia, U., and Rinelli, P. 2012. A histological study of ovarian development in the giant red shrimp Aristaeomorpha foliacea (Crustacea: Decapoda: Aristeidae) from the southern Tyrrhenian sea (Western Mediterranean).

Politou, C., Kapiris, K., Maiorano, P., Capezzuto, F., and Dokos, J. 2004. Deep-sea Mediterranean biology: the case of Aristaeomorpha foliacea (Risso, 1827) (Crustacea: Decapoda: Aristeidae). scientiamarina.revistas.csic.es, 68: 129–139.

Pulcinella, J., Armelloni, E. N., Ferrà, C., Scarcella, G., and Tassetti, A. N. 2023. Deepwater red shrimp fishery in the eastern-central Mediterranean Sea: AIS-observed monthly fishing effort and frequency over 4 years. Earth System Science Data, 15: 809–820. Copernicus Publications.

STECF. 2021. Scientific, Technical and Economic Committee for Fisheries (STECF) – Stock assessments in the Mediterranean Sea 2021 – (Adriatic and Ionian Seas) (STECF-21-15). Publications Office of the European Union, Luxembourg,2021.

STECF. 2022a. Scientific, Technical and Economic Committee for Fisheries (STECF)-Stock Assessments: demersal stocks in Adriatic, Ionian and Aegean Seas and straits of Sicily (STECF-22-16). Publications Office of the European Union, Luxembourg, 2023. https://joint-research-centre.ec.europa.eu.

STECF. 2022b. Scientific , Technical and Economic Committee for Fisheries (STECF) Quality checking of MED & BS data and reference points (STECF-22-03). EUR 28359 EN, Publications Office of the European Union, Luxembourg, 2022.