Stock Assessment Form
Aristeus Antennatus

Reference Year: 2016
Reporting Year: 2017

Assessment of red shrimp (*Aristeus antennatus*) exploited by the Spanish trawl fishery (1997–2016): GFCM Geographical Sub-Area (GSA) 05 (Balearic Islands).

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The assessment of the red shrimp (*Aristeus antennatus*) in the GSA 05 is based on using official landing and data of size composition and estimated biological parameters obtained from monitoring sampling programme carried since 1992 year in Mallorca Island. The red shrimp is the target species for the trawlers fishing in the slope of GSA 05, mainly between 500 and 800 m depth. Landing of Mallorca corresponds approximately of 50% of the whole GSA 05 catches. Fleet vessel numbers have been reduced from the early years of monitoring, in the nineties of the XX century, of about 50%. Thus the fleet is composed for 19 vessels in the Mallorca Island and 34 in the whole GSA 05 in 2016 year. Landing from the beginning of 2000's are continuously diminishing, being in the last two years the lowest of the time series with 85 and 69 tonnes for 2015 and 2016 respectively for Mallorca Island. From 2007 to the present Ibiza (Ibiza and Formentera) and Mallorca follow a similar downward trend while Menorca (the northern Island) presented more stable catches. Annual landings fluctuated, lowest landing correspond to the autumn period. The state of exploitation of this stock was assessed by means of VPA Extended Survivor Analysis (XSA) (Shepherd, 1999). The software used was the Lowestoft suite (Darby and Flatman 1994) and FLR (Fisheries Libraries in R). The assessment was carried out for the years 1997-2016. Catchat-length data were converted into catch-at-age data by cohort slicing procedures by each sex afterwards summed for sex-combined XSA assessment. The XSA tuning was performed using abundance index series from MEDITS trawl surveys and CPUEs from commercial fleet (Palma and Soller). Yield-per-Recruit (Y/R) and Spawning-per-Recruit (SSB/R) analyses was conducted based on the exploitation pattern resulting from XSA model and population parameters. Several reference points were estimated based on this Y/R analysis. Sensitivity and retrospective analyses were applied in the XSA model in order to check the robustness of the assessment. Stochastic short term projections assuming equilibrium conditions were also produced. Exploratory analysis results showed CPUEs in kg per day similar to the previous years, declining Spawning Stock Biomass, Low recruitment with fluctuations and low Fbar. Was carried out using official landings and data on the size composition of trawl catches

Stock Assessment Form version 1.0 (January 2014)

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Stock assessment form

Contents

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Aristeus antennatus	[Red shrimp]	[45]
1st Geographical sub-area:	**2nd Geographical sub-area:**	**3rd Geographical sub-area:**
GSA 05		
4th Geographical sub-area:	**5th Geographical sub-area:**	**6th Geographical sub-area:**
1st Country	**2nd Country**	**3rd Country**
Spain		
4thCountry	**5thCountry**	**6thCountry**
Stock assessment method: (direct, indirect, combined, none)		
Indirect methods		
Authors:		
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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):

- Trawl survey

Indirect method (you can choose more than one):

- XSA
- Age based models

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

Red shrimp (*Aristeus antennatus*) exploited by trawl fisheries in GSA 05 has been considered as separate unit from GSA 06. Thus GSA 05 includes vessels targeting red shrimp in the slope of GSA 05. Trawl fishing exploitation in the Ibiza channel, south Ibiza in Formentera slope, in the slopes of Mallorca Island (the central Island) and in the slope and canyon of Menorca Islands (north of archipelago) corresponded to GSA 05. For assessment purposes it is being used the landing data and the biological data of the Mallorca fleet, which the sampling take place. In this Island the fishing intensity is considered high and the population around the slopes overexploited. Due to the continued fishing exploitation, the deep ecosystem in which is harvested the red shrimp suffers a continuous reduction on diversity also attributable to disappearance of vulnerable species (Cartes et al. 2011). Besides, it has been reduction of larger modal sizes for females and decreasing percentages of males in catches from 1992, year in which the monitoring of the species in the GSA 05 Mallorca Island started.

2.2 Growth and maturity

Incorporate different tables if there are different maturity ogives (e.g. catch and survey). Also incorporate figures with the ogives if appropriate. Modify the table caption to identify the origin of the data (catches, survey). Incorporate names of spawning and nursery areas and maps if available.

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

Somatic magnitude measured (LT, LC, etc)			**LC**	**Units**	mm
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	April-September
Maximum size observed	66	38	66	**Recruitment season**	Autumn-Winter
Size at first maturity	26	21	26	**Spawning area**	GSA 05
Recruitment size to the fishery	22	21	21	**Nursery area**	GSA 05

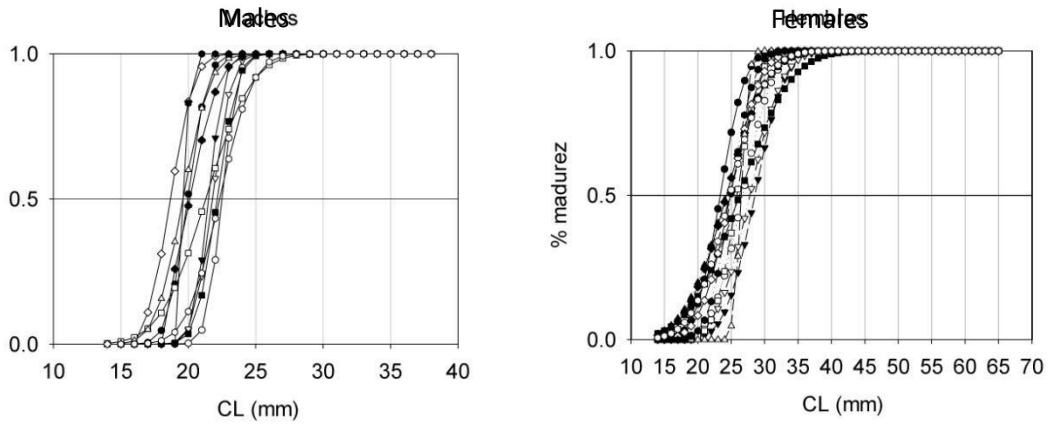


Figure 2.2-1. Red shrimp (A. antennatus) maturity ogives for different set of data, span 1992-2003 years. of the Deep-water-shrimp fishery Mallorca fleet (GSA 5).

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

Size/Age	Natural mortality	Proportion of matures
0	*1.20*	*0.27*
1	*0.67*	*0.60*
2	*0.50*	*1*
3	*0.42*	*1*
4	*0.38*	*1*
5+	*0.35*	*1*
scalar	*0.316*	*-*

Table .2.2-3: Growth and length weight model parameters

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**	mm	75.5	42	75.7	1992-2003
	K	mm/year	0.249	0.422	0.285	1992-2003
	t_0		-0.3944	0.6500	-0.45326	1992-2003
	Data source	*Spain_Data Collection Framework (DCF_EU)_2012/2015				
Length weight relationship	**a**		0.00244	0.00246	0.002426	
	b		2.4536	2.4311	2.4401	
	M (scalar)		0.363	0.517	0.363	
	sex ratio (% females/total)	80				

3 Fisheries information

3.1 Description of the fleet

In the Balearic Islands, the red shrimp (*A. antennatus*) is the most important resource of the middle slope, where is targeted by mid-large vessels. The most important landings port in 2016 was Andratx with 15 tonnes (t) landed, followed by Alcudia (at the north) and Palma (both 12 t) and Soller (10 t). The pattern of this fishery can be considered monospecific, where the discard is practically zero for this species. The whole discard fluctuated between 14 and 20% of the catches. The most important bycatch species corresponded among of fish to European hake (*Merluccius merluccius*), blue-whiting (*Micromesistius poutassou*), and great forkbeard (*Phycis blennoides*); for sharks velvet belly lanternshark (*Etmopterus spinax*) and blackmouth catshark (*Galeus melastomus*), invertebrates as crank species like *Geryon longipes*, and shrimps Plesionika species and cephalopods like *Todarodes sagittatus* among others are between the more frequent and abundant bycatch on this fishery. This fleet segment catches 80 t per year for the last recent three years and about 120 for the whole GSA 05.

Identification of Operational Units exploiting this stock.

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*	Spain	GSA 05	OTB_DWS	Bottom Otter Trawl (18-24 meters)	35 (deep shelf-slope species)	ARA

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 (*A.antenatus*)	Discards (other species caught)	Effort (units)
[GSA5] Mallorca [GSA5] Archipelago	19* 34****	69.52 Tn** 119.31 Tn	Yes	No***	28%	Trips (Days fishing trips)
Total						

* Number of vessels fishing red shrimp regularly in the 2016 in Mallorca.

** Landing of red shrimp in Mallorca Island and in the whole archipelago in 2016.

*** Red shrimp discards can be considered negligible

****Number of vessels fishing red shrimp regularly in the 2016 in Balearic archipelago (GSA5)

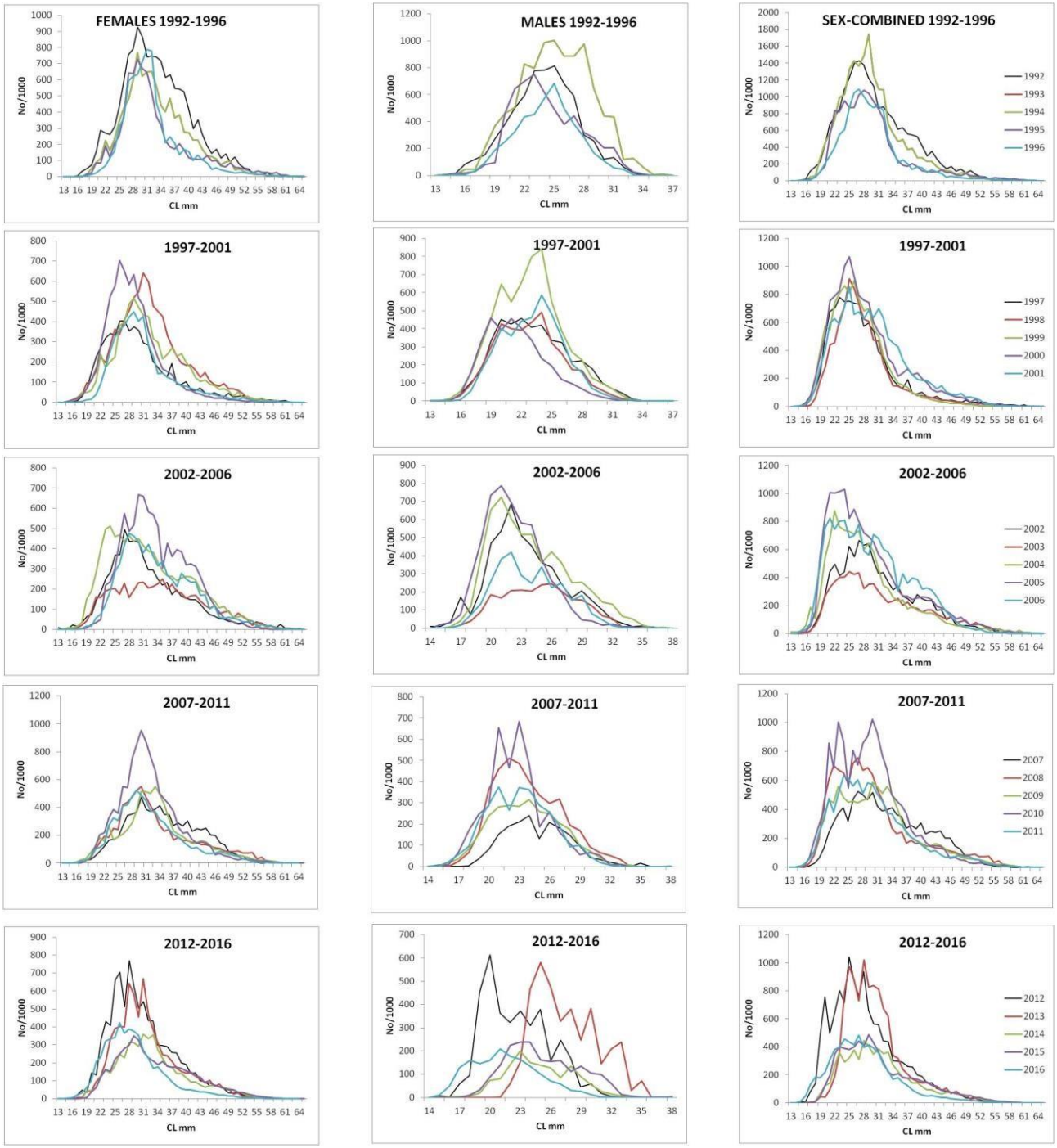


Figure 3.1-1: Catch numbers at length (per thousands) by year A. antennatus weighted for Mallorca Landings GSA 05. Most of the catches correspond to age 1 and 2. The lowest catches of the time series corresponded to the years 2014, 2015 and 2016.

3.2 Historical landings trends

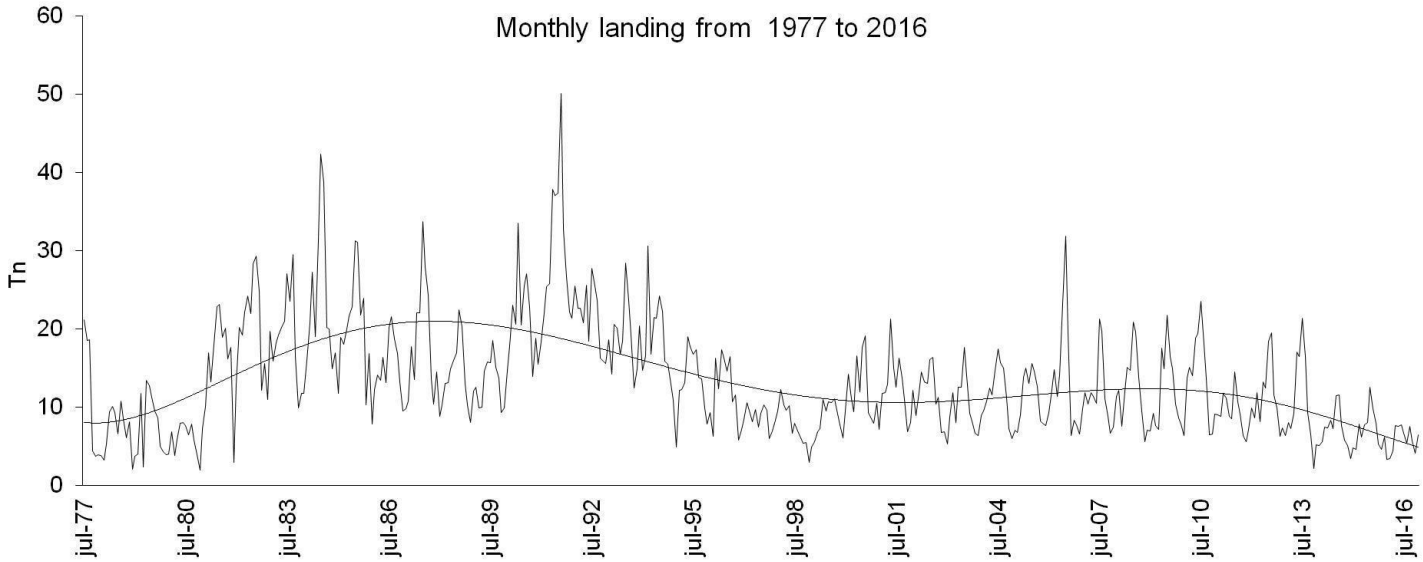


Figure 3.2-1. Monthly landings from 1977 to 2016 for red shrimp (A. antennatus) of the Deep-water-shrimp fishery Mallorca fleet (GSA 05).

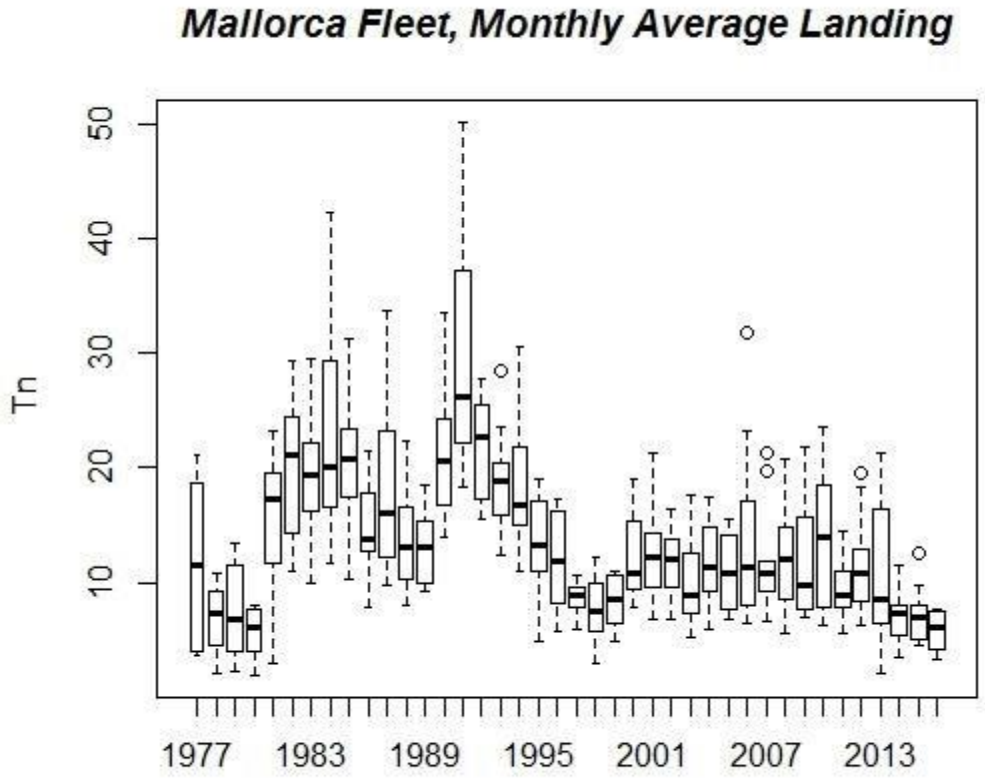


Figure 3.2-2. Average monthly landing for red shrimp (A. antennatus) Deep-water-shrimp fishery Mallorca fleet (GSA 05).

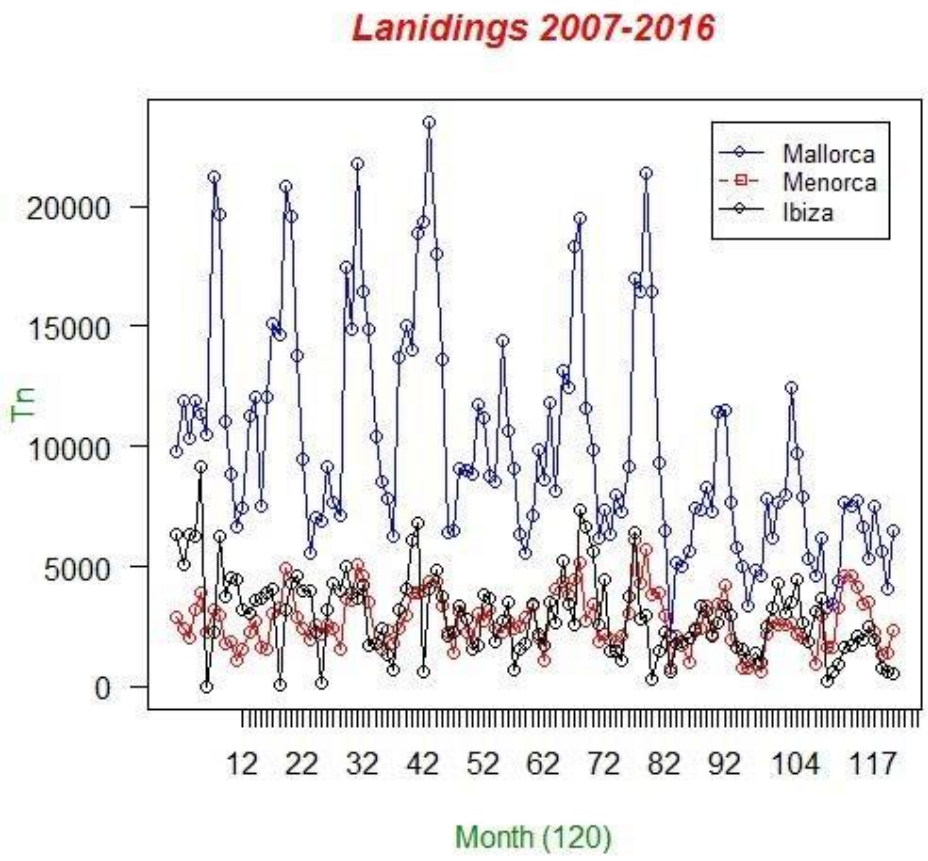


Figure 3.2-3. Monthly landings from 2007 to 2016 (120 months) for red shrimp (A. antennatus) of the Deep-water-shrimp fishery Balearic archipelago (GSA05).

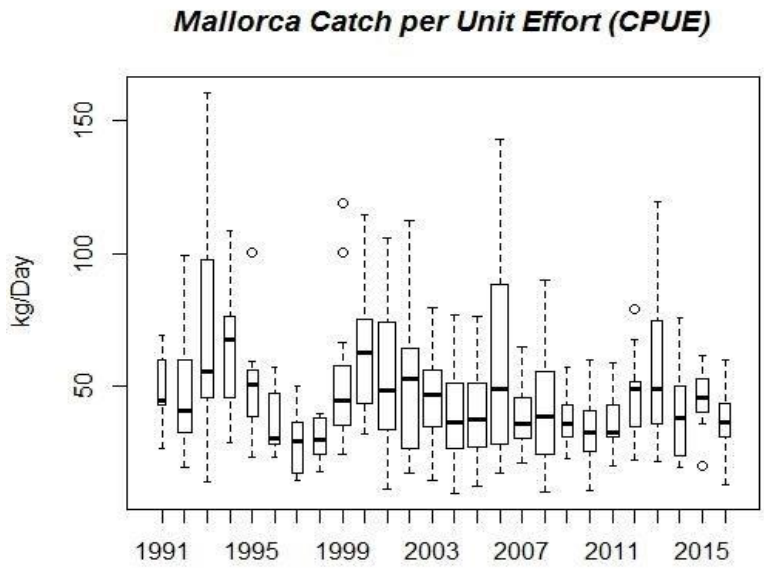


Figure 3.2-4, Average CPUEs for red shrimp (A. antennatus) of the Deep-water-shrimp fishery Mallorca fleet (GSA 05)

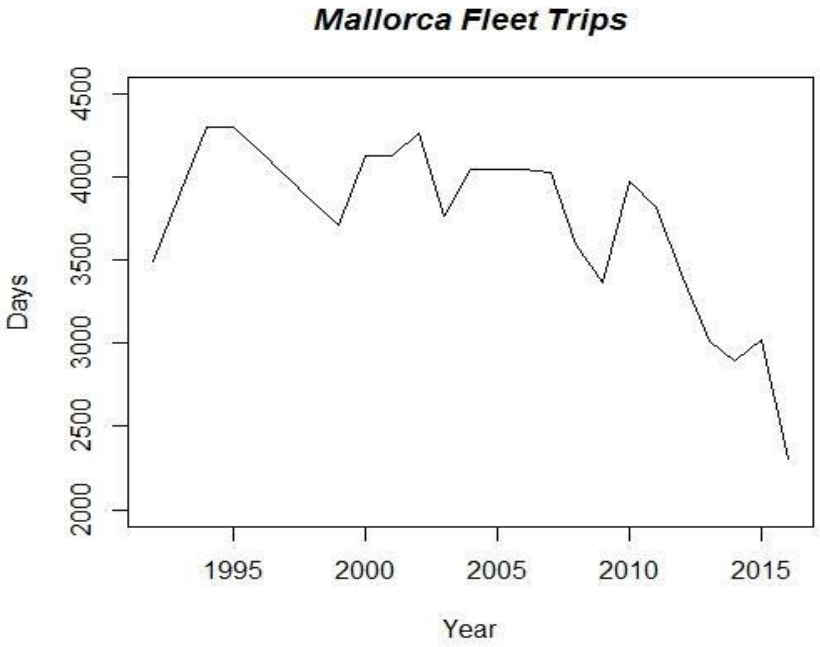


Figure 3.2-5. Annual trips Mallorca fleet from 1991 to 2016 for red shrimp (A. antennatus) Deep-watershrimp fishery (GSA 05).

COMMENT:

The more detailed landed catches information correspond to the Mallorca Island (Fig. 3.2.-1), where about half of the Deep-water-crustacean fishery catch red shrimps. Fleet monthly yields (Fig. 3.2.-2) presented four periods. The first corresponded to the years 1977-1980, with low yields likely attributable to a low fishing intensity; the second period corresponded to the decade between 1981 and 1992, in which the fleet increased until 39 vessels fishing in the Mallorca slope, over a total of 72 trawlers for the whole archipelago, monthly yields were the highest of the time series of around 20 tonnes per month; the third period extends from the nineties of to the first decade of the 2000 years (1990-2010) with a decrease of the yield of around half of the previous second period; the last five years presented even lower yields with a decreasing tendency, standing in the lowest levels of the whole time series of the 40 years.

Catch landings from the northern (Menorca) and southern (Ibiza and Formentera) islands corresponded to the period from 2007 to 2016 (ten years) (Fig. 3.2.-3). They presented different trends, thus while Mallorca and the Ibiza and Formentera Islands showed a similar fluctuating decreasing trend, Menorca landed catches had more stable captures.

The catch per unit of effort (CPUE) was for the Mallorca fleet (Fig. 3.2-4), the Island where onboard observers trawling programme is carried out sampling fishery and biological red shrimps. CPUEs showed a quite stable yield between 50 and 30 kg per trip since 1991, when the sampling programme begin. Effort trips for the last five years were diminished of about 15%, while landing reduction was 58% of the former 2010 year. This placed the exploitation in the lowest levels of their recorded history.

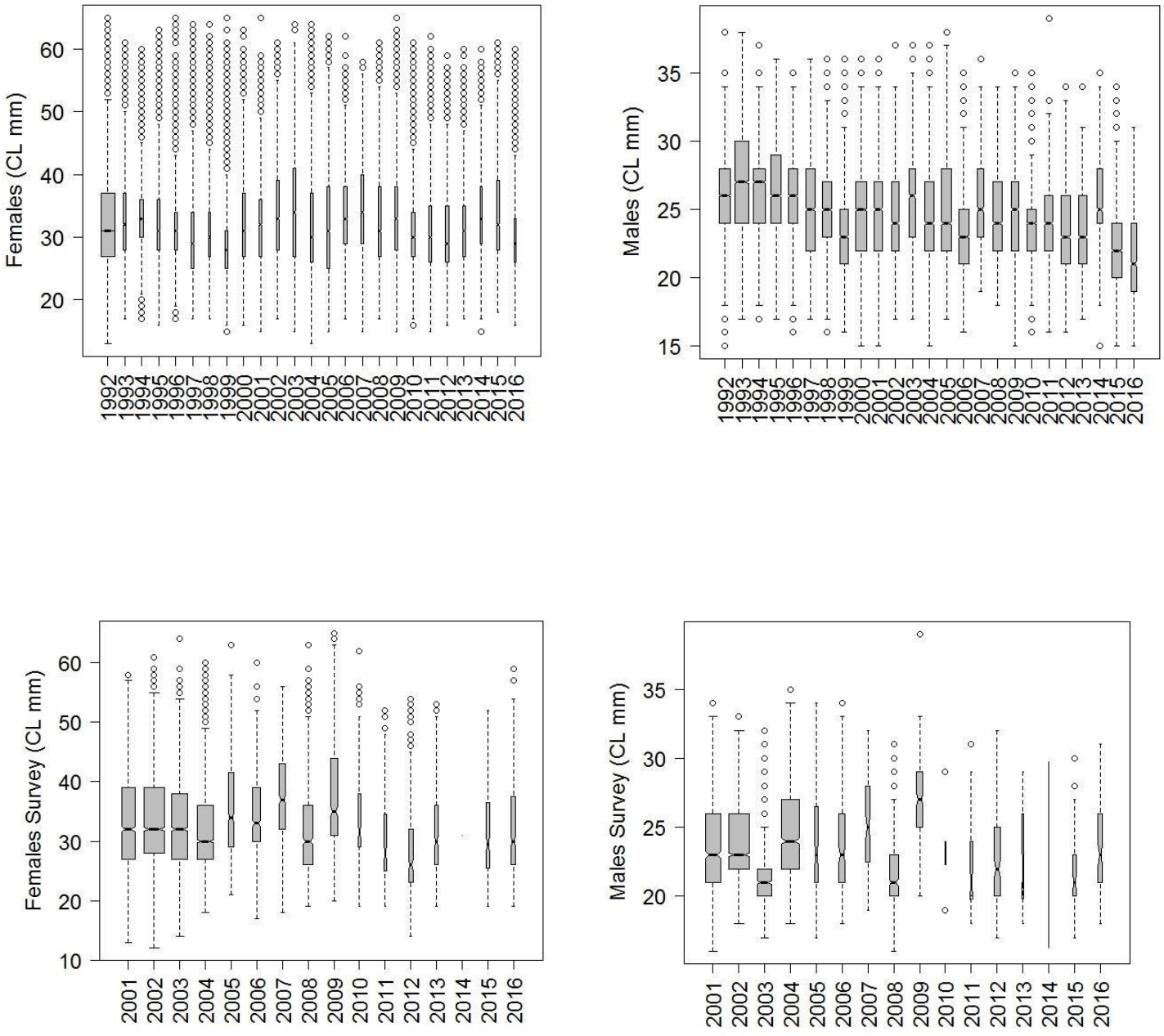


Figure 3.2-3. Box_plot size cefalotorax length (CL mm) interval range of commercial landings of Mallorca Island and for MEDITS surveys for females and males of A. antennatus respectively.

Historical size distribution characteristics of harvested population showed average mean size around 30 mm CL for females and 24 mm CL for males. There are decreasing trends of sizes for males, more pronounced from 2010 year and decreasing with fluctuations for females. Data from the experimental surveys carried out in spring- early summer shows scarcity and decreasing trend of sizes and abundances. Catches shows seasonal oscillations increasing from autumn to springsummer.

3.3 Management regulations

Based in the Current enforcement of EU CE Nº 1967/2006 Regulation, and with some regional/local regulations adopted to better accomplish and improve management and resources conservation. These regulations In the GSA 5 for the OTB_DWS with the Red Shrimp as target species can be grouped into:

Based on fishing selectivity

Technical vessels characteristics; technical operational gear characteristics, technical operational gear characteristics (mesh size of 40 mm square or 50 mm Diamond).

There are not MCRS (Minimum Conservation Reference Size) established for Red Shrimps (*Aristeus antennatus* and *Aristaeomorpha foliacea*)

Based in effort control

Control effort regulations are base in fishing 5 days a week as a maximum 12 hours at sea by fishing day. There is additional local regulation, diminishing fishing time to 11 hours, or reducing to 4 days of fishing, depending on zones and ports.

Based on temporal closures

There are not temporal closures in the GSA 5

Based on spatial closures

There are not spatial closures in the GSA5

Based on vulnerable sizes and vulnerable species

In support of management measures to mitigate bycatch and discard of vulnerable species, distributions and ranges of these species taken as bycatch, in particular rare, endangered, threatened or protected species should be mapped and their captures avoided.

Based on quotas

There is not quota management in the Mediterranean (with the exception of blue fin tuna).

3.4 Reference points

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

Indicator	Empirical reference value	Value	Target Reference point/empirical reference value	Value	Comments
B					
SSB					
F	Factual	F_{bar1-4}	0.62		
Y					
CPUE					
Index of Biomass at sea					

4 Fisheries independent information

4.1. BALAR-MEDITS bottom trawl survey

4.1.1. Brief description of the direct method used

From 2001, the Spanish Institute of Oceanography has performed annual bottom trawl surveys following the same methodology and sampling gear described in the MEDITS protocol (BALAR surveys, Massutí and Reñones, 2005). Since 2007, this survey has been included in the MEDITS program (Bertrand *et al.*, 2002). Mean stratified abundances and biomasses by km^2 has been computed using the methodology described by Grosslein and Laurec (1982), with the following formula:

$$1\ Y_{st} = N_h \cdot Y_h \qquad \overline{\qquad}$$

- Mean catch by stratum:

$$S_2(Y_{st}) = N_{1^{h-1}} \cdot (Y_h - Y_{st})_2$$ - Variance by stratum:

$$1$$

$$Y_t = \overline{A} \cdot (Y_{st} \cdot A_h)$$

- Mean total catch: $S^2(\overline{Y}_t) = \frac{1}{A^2} \cdot \frac{S^2(\overline{Y}_{st}) \cdot A_h^2}{N_h}$
- Total variance:
- SE (standard error): $SE = \sqrt{S^2(\overline{Y}_{st})}$

Nh: number of hauls in each sub-stratum; Yh: mean catch by haul in each sub-stratum;

A: total stratum area; Ah: sub-estratum area; $S_2(\overline{Y}_{st})$ variance in each sub-stratum.

4.1.2. Spatial distribution of the resources

A. antennatus is mainly distributed in the fishing grounds sited in the western of Mallorca and south of Menorca (Fig 4.1.2.-1).

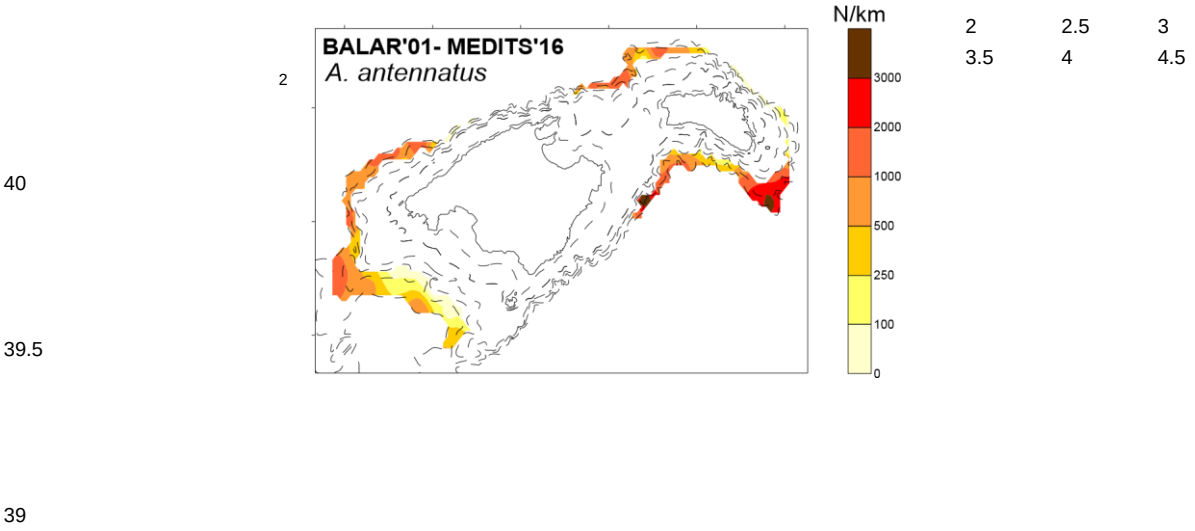


Fig 4.1.2-1. Spatial distribution of A. antennatus *around the Balearic Islands using information obtained from surveys.*

4.1.3. Historical trends

Biomass and abundance indices of *A. antennatus* in GSA 05 high values at the beginning of the data series (2001-2004) and low values since them (Fig 4.1.3-1).

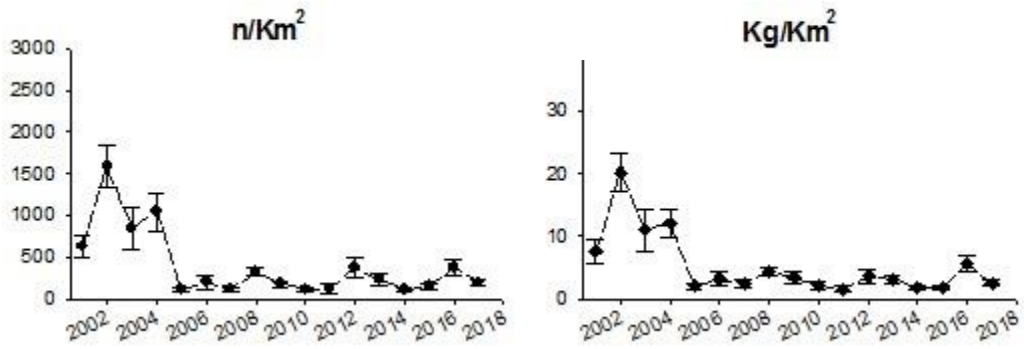


Fig. 4.1.3-1. Biomass and abundance indices of A. antennatus in GSA 05 from scientific surveys.

Table 4.1-1: Trawl survey abundance and biomass results

Depth Stratum	Years	kg per km^2	CV or other	N per km^2	CV or other
400-800	2001	7.53	25%	622.938	22%
400-800	2002	20.17	16%	1586.892	16%
400-800	2003	11.04	30%	841.727	30%
400-800	2004	12.04	18%	1043.279	22%
400-800	2005	2.05	24%	110.166	23%
400-800	2006	3.20	38%	203.437	39%
400-800	2007	2.44	22%	121.278	21%
400-800	2008	4.35	12%	322.31	15%
400-800	2009	3.47	28%	177.967	22%
400-800	2010	2.10	27%	113.404	17%
400-800	2011	1.53	33%	128.443	44%
400-800	2012	3.56	30%	372.022	31%
400-800	2013	3.05	23%	228.435	30%
400-800	2014	3.72	53%	119.221	25%
400-800	2015	1.74	21%	156.02	21%
400-800	2016	5.55	24%	373.593	25%

5. Ecological information

5.1. Protected species potentially affected by the fisheries

A list of protected species that can be potentially affected by the fishery should be incorporated here. This should also be completed with the potential effect and if available an associated value (e.g. bycatch of these species in T).

5.2. Environmental indexes

If any environmental index is used as i) a proxy for recruitment strength, ii) a proxy for carrying capacity, or any other index that is incorporated in the assessment, then it should be included here.

Other environmental indexes that are considered important for the fishery (e.g. Chla or other that may affect catchability, etc.) can be reported here.

6. Stock Assessment

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

6.1. {Separable Virtual Analysis and Extended Survivor Analysis}

Ad hoc methods for tuning single species VPA's to fleet catch per unit effort (CPUE) data are sensitive to observation errors in the final year because they make the assumption that the data for that year are exact. In addition, the methods fail to utilize all of the year class strength information contained within the catches taken from a cohort by the tuning fleets.

Extended Survivors Analysis (XSA), (Shepherd, 1992,1999), an extension of Survivors Analysis (Doubleday, 1981), is an alternative approach which overcomes these deficiencies. In general, the algorithms used within the *ad hoc* tuning procedures, exploit the relationship between fishing effort and fishing mortality.

XSA focuses on the relationship between catch per unit effort and population abundance, allowing the use of a more complicated model for the relationship between CPUE and year class strength at the youngest ages. (Darby and Flatman, 1994).

The XSA assessments were performed using the Lowestoft VPA Suite stock assessment software package (Darby and Flatman, 1994) and the open-source framework FLR (Fisheries Library for R) (Kett *et al*, 2007). Their results were analyzed and compared. FLR packages were also used to perform Exploratory Data Analysis, Sensitivity Analysis, Retrospective Analysis, Reference Points Estimation and Short Term Projections.

Shepherd J. G., 1999. Extended survivors analysis: An improved method for the analysis of catch-at-age data and abundance indices. ICES J. Mar. Sci 56: 584–591.

Darby, C. D., and S. Flatman. "1994. Virtual population analysis: version 3.1 (Windows/DOS) user guide." *Info. Tech. Ser. MAFF Direct. Fish. Res., Lowestoft* 1: 85.

Kell L.T., Mosqueira I., Grosjean P., Fromentin J-M., Garcia D., Hillary R., Jardim E., Pastoors M., Poos J.J., Scott F. & Scott R.D. 2007. FLR: an open-source framework for the evaluation and development of management strategies. *ICES J. of Mar. Sci. 20: 289-290*.

6.1.1. Model assumptions

The XSA tuning was performed using abundance index series from CPUEs from commercial fleet Soller port (GSA05, Northern Mallorca, Balearic basin).

Input Parameters

- Landings time series 1997-2016(official landings).
- Length distributions 1997-2016 (monthly onboard and port sampling).
- Catch-at-Length data converted to Catch-at-Age data using cohort slicing.
- Growth Parameters from DCF_EU 1992/2003 in the Spanish Mediterranean.
- Biological sampling 1992-2003 for Maturity and Length-Weight relationships.
- M vector by age using PROBION spreadsheet (*Abella et al, 1997*).
- Tuning data 1997-2016 from CPUEs from commercial fleet Soller port (GSA05, Northern Mallorca, Balearic basin).

Main Settings

- Ages 0 to 5+(Age 5 is a Plus Group)
- Fbar 1-4.
- Catchability dependent on stock size for ages <1
- Catchability independent of age sfor ages>=than2
- Survivor estimates shrunk towards the mean F of the final 3yrs or the 3 oldest ages.
- S.E. of the mean to which the estimates are shrunk = 1.0.
- Minimum standard error for population estimates derived from each fleet = 0.7.

Following the recommendations of previous demersal working group, several previous tentative assessment for male, female and unsexed data was carried out, in order to compare the results by sex and for male and female together. XSA assessment results (landings, recruitment, spawning stock biomass, total biomass and fishing mortalities) obtained for (male and female)and unsexed, showed no significant differences.

Data used:

6.1.2. Scripts

If a script is available which incorporates the stock assessment run (e.g. if using FLR in R) it should be provided here in order to create a library of scripts.

Script source FLR library: ("http://flr-project.org/R/instFLR.R")

6.1.3. Results

For analytical models: **catch matrix** in lengths or ages (see the example below for age). Specify if catch includes discards

Table 6.1.3-1. Catch-at age (per thousands) A. antennatus sex-combined Mallorca landings

AGE 0	1992	1993	1994	1995	1996	1997	1998
	2750.3	2490.3	2424.7	2279.2	2399.9	1200.6	611.6
1	11139.2	10347.1	9823.4	8875.9	8404.5	6738.2	6876
2	6903.4	7077.8	6991.4	3444.3	3015.3	1807.4	1384.4
3	1586.4	1616	1023	997.7	545.5	374	282
4	385.5	306.3	287.8	295.3	135.4	144.9	81.6
5	70.8	54.4	45.1	116.9	49.1	52.6	25.4
6	16.3	10.2	12.7	45.6	9.4	17.4	5.9
7	0	0	0	4.9	6.9	3	1
TOTALNUM	22843.9	21894.1	20608.1	16059.8	14566	10338.1	9267.9
TONSLAND	260	228	224	158	143	103	93

AGE 0	1999	2000	2001	2002	2003	2004	2005
	1460.7	1358.8	1108.4	622.8	686.3	1417.2	2010.9
1	8062.5	8672.4	7717.7	6076.1	3867.2	7288	8746.1
2	1265.8	2732.4	2968.1	2858.5	2307.8	2355.1	3389.3
3	183.6	612.3	729.4	739.9	758.5	558.5	1125.1
4	43.3	157.1	200.9	221.1	285.1	192.2	298.3
5	9.5	51.3	16.5	74	84.9	82.2	48.3
6	5.1	2.4	0	6.6	13.3	35.8	10.9
7	1.5	0.5	1	0	2.9	5	0
TOTALNUM	11032	13587.2	12742	10599	8006	11934	15628.9
TONSLAND	100	145	148	141	115	140	172

AGE 0	2006	2007	2008	2009	2010	2011	2012
	1739.1	354.7	971.2	1015.3	1239.1	907.1	1684.4
1	8701.8	4889.7	7281.6	5810.6	10027.2	6360.8	8427.9
2	3613.5	3080.4	2286.2	2741.2	3105	2296.7	2375.3
3	937.7	1277.9	818.3	790.8	650.6	584.2	498.2
4	121.2	207.4	402.1	246.5	142.1	231.6	111.7
5	9.7	7.9	74.5	74.2	45	30.1	10.5
6	2	0	6.2	8.5	9.2	5.6	0
7	0	0	0	2	0	1	0

TOTALNUM	15125	9818	11840.1	10689.1	15218.2	10416.2	13108
TONSLAND	164	140	143	135	164.37	129.2177	136.88
AGE 0	**2013**	**2014**	**2015**	**2016**			
	208.6	284.4	265.7	921.3			
1	7158.7	3956.4	4155.5	4695			
2	3036.4	1758.7	2040.7	1025			
3	899.7	484.5	567.2	220			
4	86.8	151.4	167.1	53.5			
5	9.9	9.5	32.3	8.4			
6	0.9	0	3.6	0.9			
7	0	0	0	0			
TOTALNUM	11398.3	6644.9	7232.1	6924.1			
TONSLAND	118.391	85.77523376	85.63	69.3925748			

Table 6.1.3 at age (per sex-combined A. antennatus -2 Catch- thousands) combined Palma fleet

Sex_Combined

AGE		1992	1993	1994	1995	1996	1997	1998
	0	335.5	216.8	135.1	65	158	317.3	285.8
	1	4099	3701.7	2342	2107.5	1497	1650.2	1781.9
	2	3402.3	3627.4	1732.4	1763.8	1153.6	964.2	1064.2
	3	2311.3	2254.8	1740.4	1235.3	1090.9	498.7	739.8
	4	1437	1135.1	1487.2	532.4	595	281.8	311
	5	957.6	696.3	680.9	204.1	305	201.1	186.5
	6	671.7	460.9	402.7	201	170.8	131.4	117.3
	7	459.5	288.3	251.7	107.7	135.2	77.8	72.6
	8	135	102.6	71.5	34.2	43.5	28.5	24.9
TOTALNUM		15800.9	14476.9	10837.9	8246	7145	6148	6582
TONSLAND		186	163	127	84	70	50	53
Effort (Trips days)		2893	2893	2893	2893	2055	2055	2055
AGE		**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
	0	406.4	350.6	89.2	189.6	219.1	97.1	227.8
	1	1639.4	1846.5	649.5	1063.6	983.1	1090	1221.9
	2	1448.6	859.8	430.1	697.6	693.7	554.6	827.2
	3	1050.3	858.4	633.3	708.7	330.3	452.1	686.7
	4	479.6	455.8	461.3	578.7	310.8	342.2	434.6
	5	234.8	268.7	253.2	402.2	259.9	203.1	263
	6	124.8	238.3	154.5	244.8	185	116.5	191.1
	7	71.6	159.4	108.8	213.4	126.2	74	159
	8	20.5	43.6	35.1	64.5	41.8	23.6	52.9
TOTALNUM		5476	5081.1	2815	4163.1	3149.9	2953.2	4064.2
TONSLAND		57	62	50	73	60.74	36.66	64.834
Effort (Trips days)		2055	1948.5	1842	1559	1318	1171	1171
AGE		2006	2007	2008	2009	2010	2011	2012

Table 6.1.3 *at age (per* *sex-combined A. antennatus*

	0	284.2	66.9	126.8	122.5	175.9	80	77.5
	1	1057.8	526	279.3	586.7	753.4	376.5	294
	2	567.7	303.6	137.3	260	658.8	221.6	246
	3	517.1	353.3	154.5	390.1	776.7	224.2	293.1
	4	363.4	318.7	107.9	370.5	421.5	169.4	197.4
	5	291.8	218.7	78.5	280.2	250.5	92.9	120.6
	6	240.6	168.6	57.8	151.5	118	47.8	77.2
	7	171	146.4	45.5	83.1	82.1	28.3	46.1
	8	56.5	50.7	16.5	28.5	24	9.3	15.1
TOTALNUM		3550.1	2152.9	1004.1	2273.1	3260.9	1250	1367
TONSLAND		48.04	42.42	20.07	42.56	41.27	15.30	32.00
Effort (Trips days)		1171	1027	1248	936	966	862	824

AGE	**2013**	**2014**	**2015**	**2016**
0	121.6	6.6	11.4	22
1	640	132.5	155.1	175.6
2	407.5	136.1	110.6	135.4
3	456.3	163.4	116.1	116.1
4	256.3	178.7	80.5	77.5
5	149.6	95.6	70.4	56
6	88.7	52.6	60	28
7	57.9	32	41.6	13.3
8	19.1	9.3	13.3	4
TOTALNUM	2197	806.8	659	627.9
TONSLAND	48.3	17.9	33	9
Effort (Trips days)	225	738	661	419

-2 Catch- *thousands)* *combined Soller fleet*

AGE	**2000**	**2001** 98.8	**2002** 43.9	**2003**	**2004**	**2005**	**2006**
0	294.9			449.7	263.7	452.5	18.5
1	1963.4	1811.2	1437.2	1207.8	2107	2085.7	1152.8

Table 6.1.3 *at age (per* *sex-combined A. antennatus*

	2	356.5	708.2	390.9	348.7	276.6	253.6	762.5
	3	102.9	160.6	198.1	83.8	76.1	72.7	266.8
	4	38.4	50.9	98.3	57.5	48.9	21.8	46.9
	5	5.8	6.2	46.9	30	16.8	5.8	0.4
	6	1.5	0	2.7	6	0.9	0.9	2
	7	0.5	1	0	1.5	0	0	0
TOTALNUM		2763.9	2836.9	2218	2185	2790	2893	2249.9
TONSLAND		29	36	32	24	28	25	34
Effort (Trips days)		860	957	1058	1013	1054	1039	948
AGE		**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
	0	70.6	60.1	214.2	311.3	210.6	192.7	92.4
	1	1561.9	1281	690.2	2014.5	1258.3	1986.7	1342.9
	2	510	329.7	299.5	477.7	289.2	364.1	371.6
	3	293.1	110.4	115.4	84.1	135.2	110.5	154.8
	4	56.2	49.6	47.6	36.6	41.3	35.2	26.8
	5	0.2	10.4	14.4	11	5.4	3.8	2.4
	6	0	1.9	1.9	2.9	0	0	0
	7	0	0	0	0	0	0	0
TOTALNUM		2492	1843.1	1383.2	2938.1	1940	2693	1990.9
TONSLAND		54	24	41	31	24	34	31
Effort (Trips days)		1001	902	811	902	948	925	896
AGE		2014	2015	2016				
	0	73	20.2	27.9				
	1	861.4	469.8	463.8				
	2	242.6	168.8	112.5				
	3	113.2	61.2	22.1				
	4	47.3	33.4	6.4				
	5	2.4	5.8	2.2				
	6	0	0.9	0				
	7	0	0	0				

Table 6.1.3	*at age (per*		*sex-combined A. antennatus*
TOTALNUM	1339.9	760.1	634.9
TONSLAND	18	10	8
Effort (Trips days)	716	460	320

-3 Catch- thousands) combined MEDITS Survey

	2001 53.1	**2002** 51.8	**2003**	**2004**	**2005**	**2006**
			155.1	51.1	4.5	10.7
1	1033.8	2696.3	1612.5	1773.5	194.4	385.9
2	766.3	1765.8	1310.3	810.5	136.2	291.7
3	347.7	939.2	406	452.8	71.8	115.1
4	165.1	360.4	129.1	228.1	21	32.4
5	61.4	146.8	39.2	139.1	7	10.2
6	20	56.7	8.2	58.4	1.5	5.5
7	24.2	64.2	11.3	69.7	1.8	5.7
TOTALNUM	2471.6	6081.2	3671.7	3583.2	438.2	857.2
TONSLAND	0.033	0.090	0.049	0.053	0.003	0.003
Effort (Km^2)	1	1	1	1	1	1
AGE	2007	2008	2009	2010	2011	2012
0	3.5	41.6	4.3	1.7	3.8	28.6
1	145.8	781.3	232.2	59.7	62.2	158.1
2	200.7	321.6	186.1	25.9	27.6	80.1
3	108.6	151.4	118.2	9.9	10	32.7
4	31.3	67.9	61.6	6.1	4.1	13.6
5	7.4	18.1	23.4	2.1	0.7	5.8
6	1.6	4.9	13.3	1.3	0.3	4.3
7	2	5.7	13.6	0.1	0.3	5.2
TOTALNUM	500.9	1392.5	652.7	106.8	109	328.4
TONSLAND	0.003	0.019	0.015	0.002	0.002	0.016
Effort (Km^2)	1	1	1	1	1	1
AGE	2013	2014	2015	2016		

Table 6.1.3 at age (per sex-combined A. antennatus

0	6.5	0.1	6.9	9.1								
1	126.7	3.7	73.1	170.6								
2	49.6	3.7	37.5	94.3	**3**	21.9	1.6	17.8	38.4			
4	5.3	1	7	16.7								
5	1.1	0.6	2.7	9.8	**6**	0.1	0.3	1.2	4.6			
			7	0.1		0.4		0.8	4.6			
	TOTALNUM			211.3		11.4		147	348.1			
	TONSLAND			0.013		0.008		0.008	0.012			
	Effort (Km^2)			1		1		1	1	1	1	

EXTENDED SURVIVOR ANALYSIS SEX-COMBINED

Table 6.1.4-1. XSA results of A.antennatus combined GSA5 Stock assessment 1997-2016

Year	Landing (t)	Fbar(1-4)	Recruit(0)	SSB(t)	Stock Number	Stock Biomass (t)
1997	103	1.05395	61290	231.98	80919	452.75
1998	93	0.8782	83238	260.26	105040	550.35
1999	100	0.48771	89058	301.03	118941	567.19
2000	145	0.74244	78082	355.85	112909	592.64
2001	148	0.6866	64481	370.80	96233	588.01
2002	141	0.67183	60035	374.88	87914	610.8
2003	115	0.73839	84624	362.36	110089	656.08
2004	140	0.72335	98837	382.43	132307	670.33
2005	172	1.03873	86506	439.87	125071	774.69
2006	164	0.66287	59273	405.75	95513	610.28
2007	140	0.66634	70976	402.79	98104	662.53
2008	143	0.78167	64880	361.59	94248	611.07
2009	135	0.79254	75426	344.14	102325	570.97
2010	164	0.85031	70392	341.61	100132	569.28
2011	129	0.93151	78276	315.71	105119	554.12
2012	137	0.76757	56227	322.00	86568	553.27
2013	118	0.74598	41671	273.32	65288	447.57
2014	86	0.61635	43674	246.27	61785	413.39
2015	86	0.79966	55974	245.19	74143	443.52
2016	69	0.45905	64668	237.17	86294	426.2

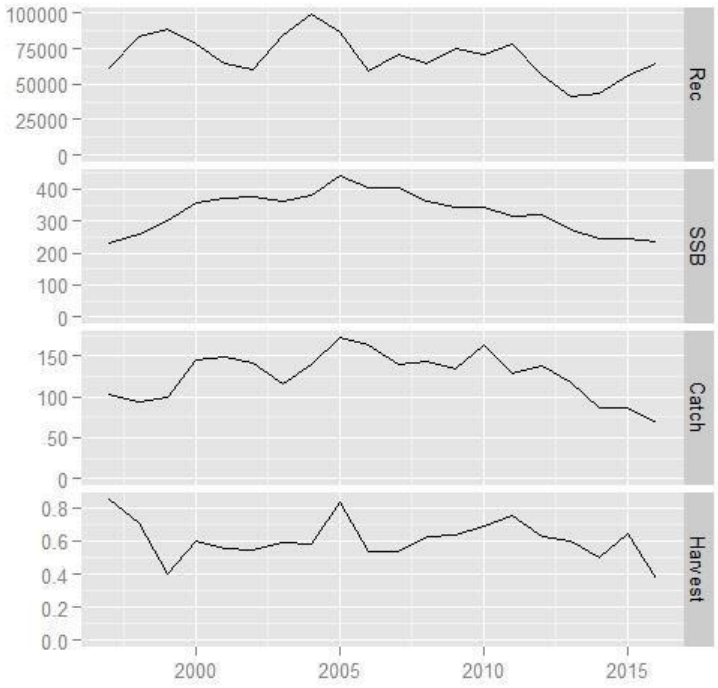


Figure 6.1.4-1. XSA sex combined Stock assessment 1997-2016 A.antennatus GSA5

Spawning Stock Biomass (SSB) and Recruitment (R), fluctuated until 2005 and declined from 2007 period. Fishing mortality (Fbar 1-4) has been relatively stable over the 2005-2016 period with small and fluctuations with slightly increasing trend.

6.1.4. Robustness analysis

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

6.1.5.1 . Retrospective analysis

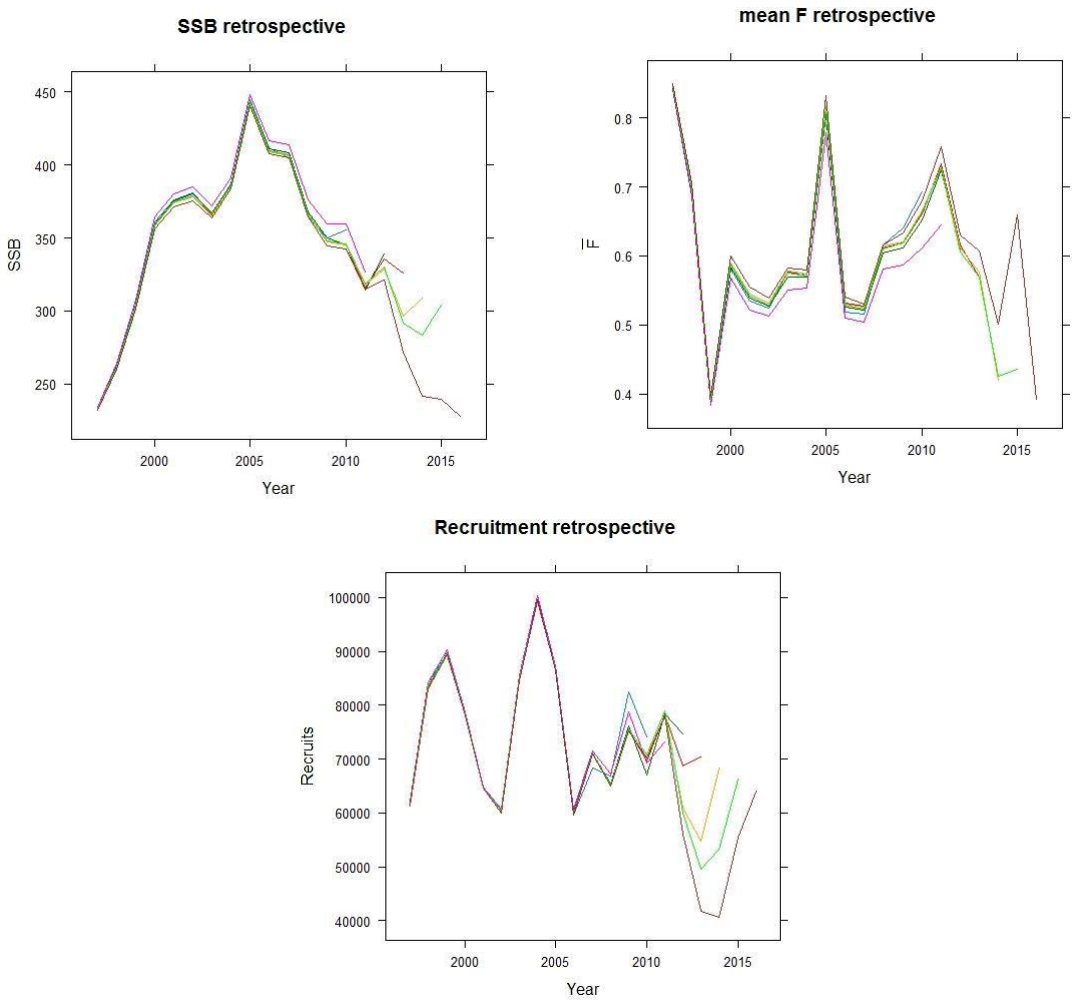


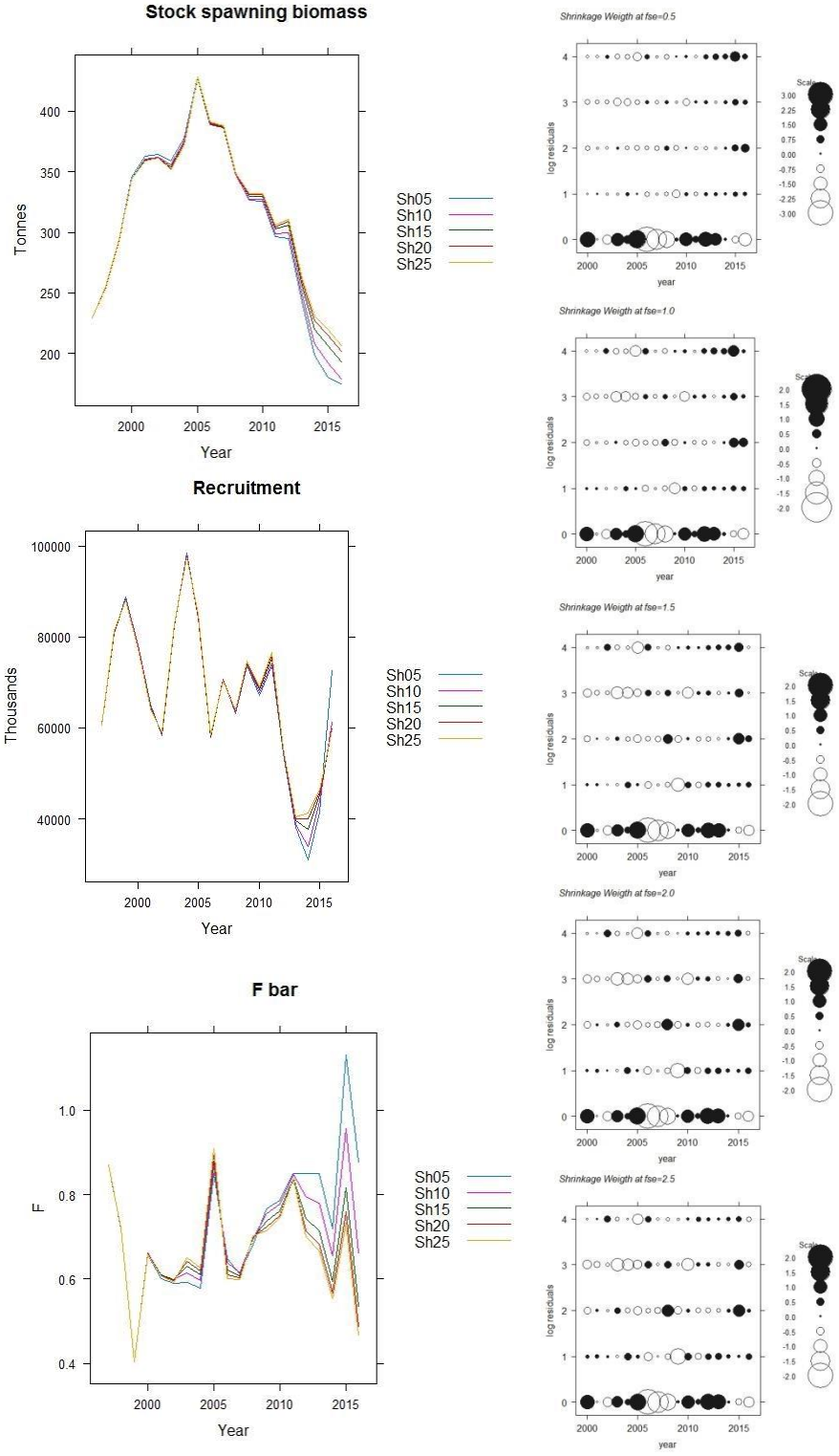
Figure 6.1.5. Restrospective analysis A.antennatus 2010-2016.

SSB, F and Recruitment retrospective analysis 2010-2016 showed underestimation bias on the true model fit, being the previous years overestimated in relationship to last year.

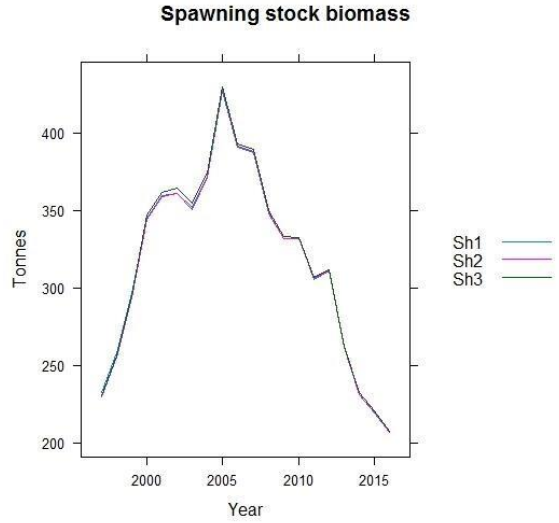
Age based XSA assessment for twenty years, span 1997-2016, tuned for 2000 to 2016 years. Biological information covers the population around the biggest Island of the Balearic archipelago (Mallorca Island), and landings and effort are also referred to this Island where is being carried the fishery monitoring. Thus, the results corresponded to the exploitation-state of this zone.

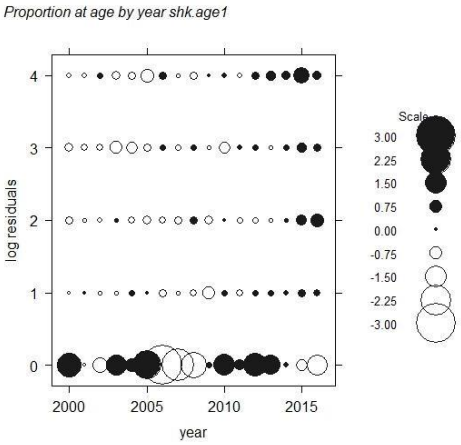
6.1.5.2. Sensitivity analysis

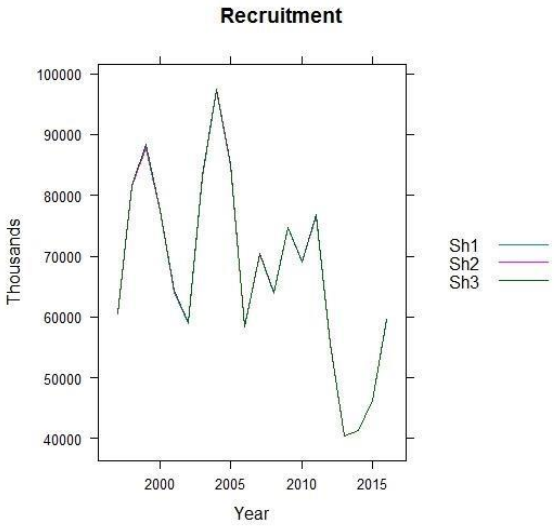
Sensitivity on shrinkage weight, fse=0.5, fse=1.0, fse=1.5, fse=2.0, fse=2.5

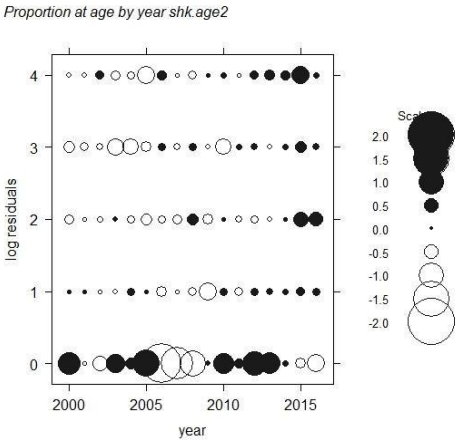


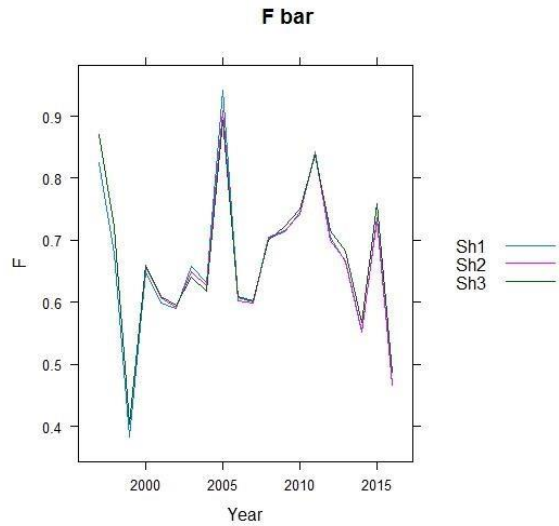
Sensitivity for different shrinkage ages with shrinkage weight 2.5, age 1, 2 and 3

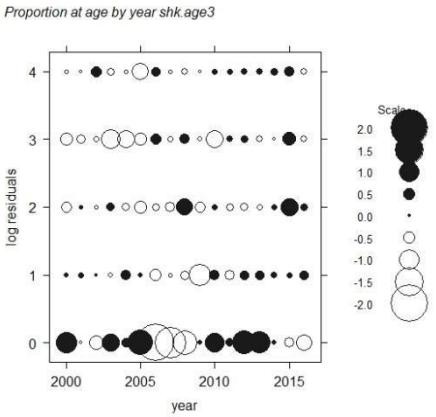




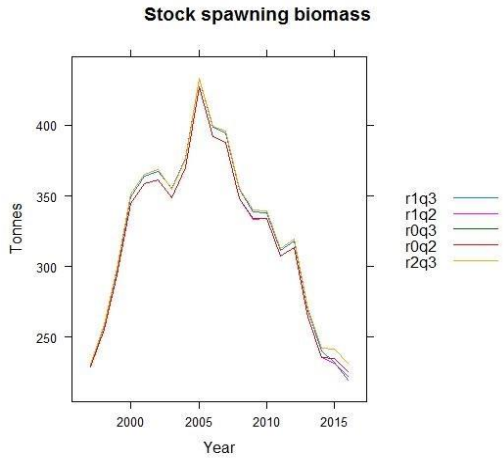


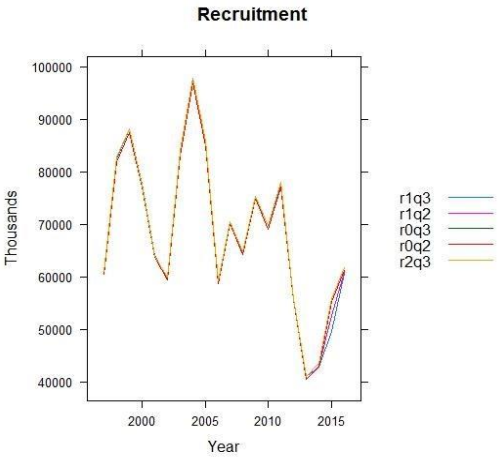


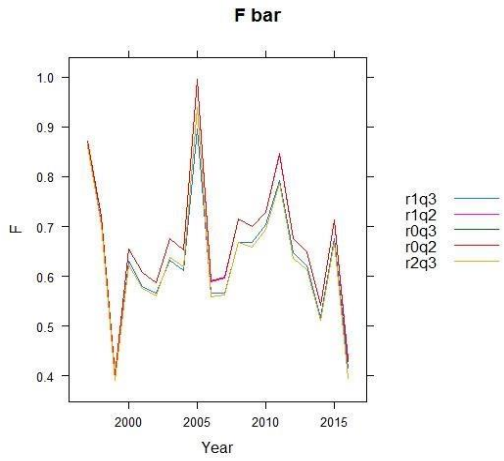


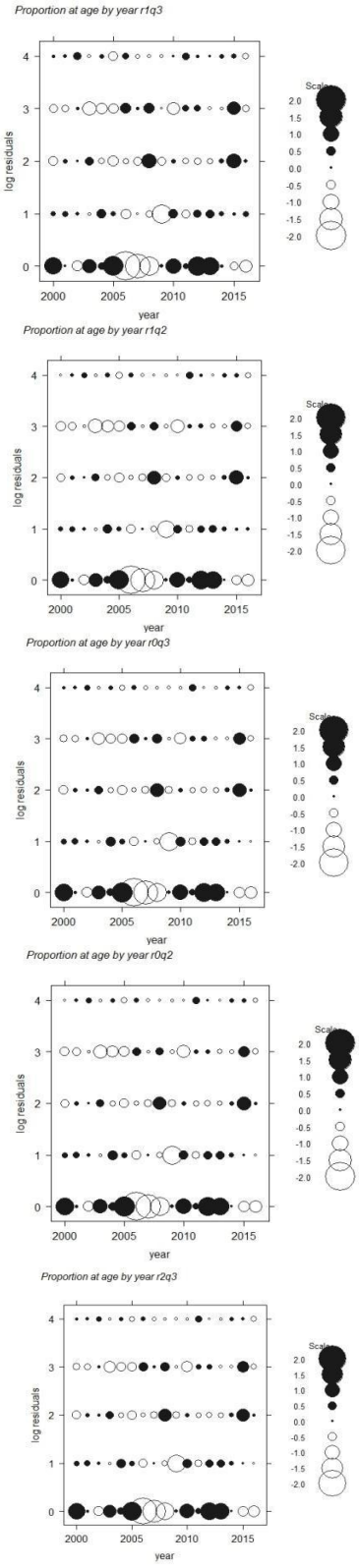


Sensitivity analysis on catchability independent of age"qage" and catchability dependendt on stock size for ages "rages".





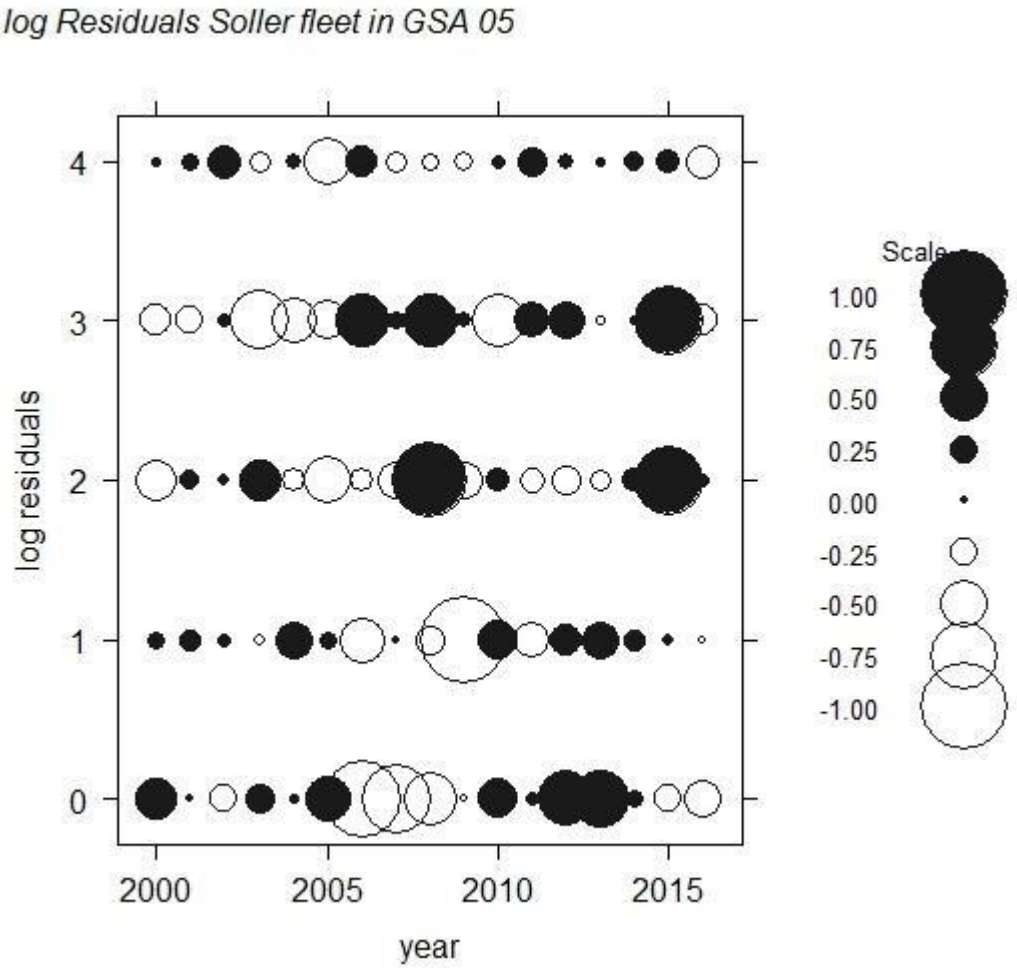




xsa_control <- FLXSA.control(x=NULL, tol=1e-09, maxit=150, min.nse=0.7, fse=2.5,rage=1, qage=3, shk.n=TRUE, shk.f=TRUE, shk.yrs=5, shk.ages=3, window=100, tsrange=20, tspower=0, vpa=FALSE)

6.1.6. Assessment quality

Stability of the assessment, evaluation of quality of the data and reliability of model assumptions



7. Stock predictions

When an analytical assessment exists, predictions should be attempted. All scenarios tested (recruitment and/or fishing mortality) should be reported. The source of information/model used to predict recruitment should be documented.

7.1. Short term predictions

The short term prediction maintains the results of catch and SSB obtained in the present assessment for the next two years.

Table 7.1.-1 Short term prediction of relative changes in Harvest, Catch, SBB and Recruitment over two years, based on output of XSA status quo F in different scenarios.

Ffactor	Fbar	Catch_2016	Catch_2017	Catch_2018	Catch_2019	SSB_2018	SSB_2019	Change_SSB	_Change_Cat
0.00	0.00	69.00	113.24	0.00	0.00	309.97	448.08	44.56	-100.00
0.10	0.06	69.00	113.24	14.38	20.56	309.97	429.40	38.53	-79.16
0.20	0.12	69.00	113.24	27.94	38.12	309.97	411.89	32.88	-59.51
0.30	0.18	69.00	113.24	40.73	53.09	309.97	395.47	27.58	-40.97
0.40	0.24	69.00	113.24	52.81	65.83	309.97	380.07	22.61	-23.47
0.50	0.30	69.00	113.24	64.21	76.62	309.97	365.62	17.95	-6.94
0.60	0.37	69.00	113.24	74.98	85.75	309.97	352.07	13.58	8.67
0.70	0.43	69.00	113.24	85.16	93.44	309.97	339.35	9.48	23.42
0.80	0.49	69.00	113.24	94.78	99.90	309.97	327.41	5.63	37.36
0.90	0.55	69.00	113.24	103.88	105.29	309.97	316.20	2.01	50.55
1.00	**0.61**	69.00	113.24	112.49	109.77	309.97	305.68	-1.39	63.03
1.10	0.67	69.00	113.24	120.64	113.47	309.97	295.79	-4.57	74.84
1.20	0.73	69.00	113.24	128.35	116.50	309.97	286.50	-7.57	86.02
1.30	0.79	69.00	113.24	135.66	118.96	309.97	277.78	-10.39	96.61
1.40	0.85	69.00	113.24	142.58	120.93	309.97	269.58	-13.03	106.64
1.50	0.91	69.00	113.24	149.15	122.48	309.97	261.87	-15.52	116.16
1.60	0.97	69.00	113.24	155.38	123.69	309.97	254.62	-17.86	125.19
1.70	1.04	69.00	113.24	161.29	124.60	309.97	247.81	-20.05	133.75
1.80	1.10	69.00	113.24	166.90	125.27	309.97	241.40	-22.12	141.88
1.90	1.16	69.00	113.24	172.23	125.72	309.97	235.36	-24.07	149.60
2.00	1.22	69.00	113.24	177.29	126.01	309.97	229.69	-25.90	156.94
0.51	0.31	69.00	113.24	65.18	77.48	309.97	364.40	17.56	-5.54

c

Figure 7.1.-1 Short term prediction of relative changes in Harvest, Catch, SBB and Recruitment of A. antennatus for F status quo and in increasing effort scenarios.

7.2. Medium term predictions

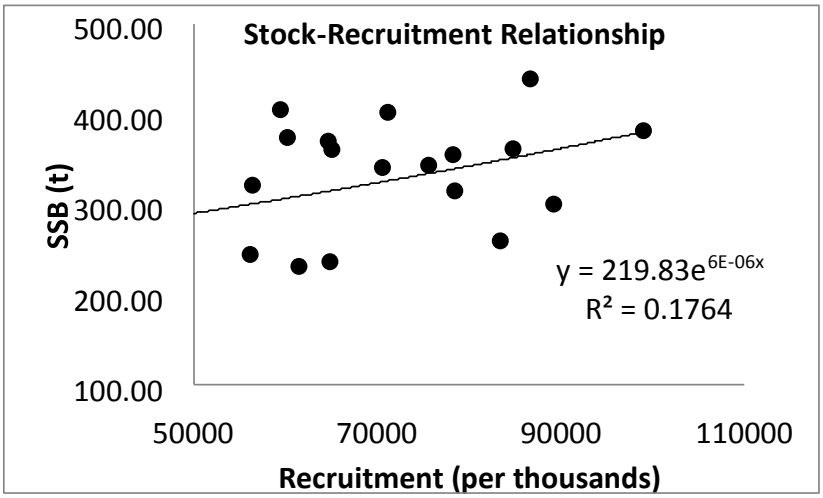


Figure 7.2.-1. Spawning stock biomass (SSB)-Recruitment (R) relationship

The relationship between SSB and R fluctuated with a slightly trend of high and low recruitments in agreement of high and low SSB, although the pronounced non-linearity of SSB_R relationship indicated that commercial catchability is not constant.

7.3. Long term predictions

Table 7.3.1. Yield per recruit analysis in grams (g) was conducted based on the exploitation pattern resultint from the XSA model and population parameters using the BLRP library from FLR.

refpt		harvest	Yield	SBB	Biomass
virgin		0.00	0	18.564	22.134
msy	>1		3.667	1.1	3.6667
crash		NA			
f0.1		0.29	1.810	7.7524	11.313
fmax	>1		3.667	1.1	3.6667
spr.30		0.48	1.980	5.5691	9.1223

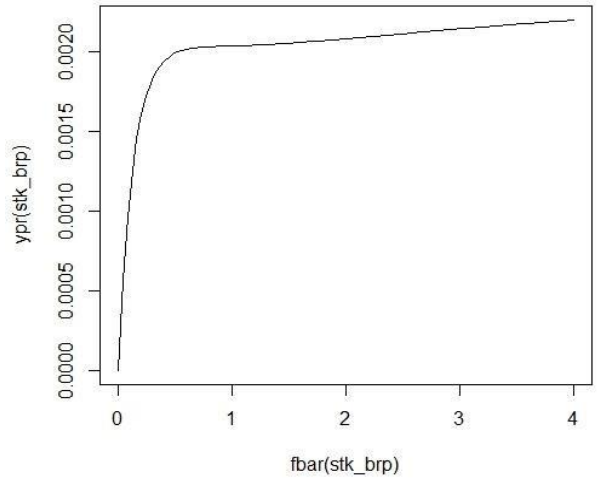


Figure 7.2-1 Equilibrium Yield (g) per Recruit and SSB (g) per Recruit (g) vs Fishingg mortality (F) including the corresponding yield and spawner reference points calculated using library (FLBRP) from FLR software.

Table 7.3.2. Yield per recruit analysis in kilograms, was conducted based on the exploitation pattern resulting from the XSA model and population parameters using using Virtual Population Analysis: version 3.1 (Windows/DOS) user guide

FMult	Fbar	Yield	Biomass	SSB
0	0.00	22.1	18.60	
	0.1	0.0888	1.10	16.8	13.30
0.2	0.1775	1.60	13.8	10.20
3	0.2663	1.80	11.9	8.30
4	0.355	1.90	10.6	7.00
0.5	0.4438	2.00	9.7	6.10
	0.5325	2.00	9	5.50
	0.6213	2.00	8.5	5.00
	0.71	2.00	8.1	4.60
	0.7988	2.00	7.8	4.30
	0.8875	2.00	7.6	4.00
	1.1	0.9763	2.00	7.4	3.80
1.2	1.065	2.00	7.2	3.70
	1.3	1.1538	2.00	7.1	3.50
1.4	1.2425	2.00	6.9	3.40
1.5	1.3313	2.00	6.8	3.30
	1.42	2.00	6.7	3.20
	1.5088	2.00	6.6	3.10
1.8	1.5975	2.00	6.6	3.10
	1.9	1.6863	2.00	6.5	3.00
	2	1.775	2.00	6.4	2.90

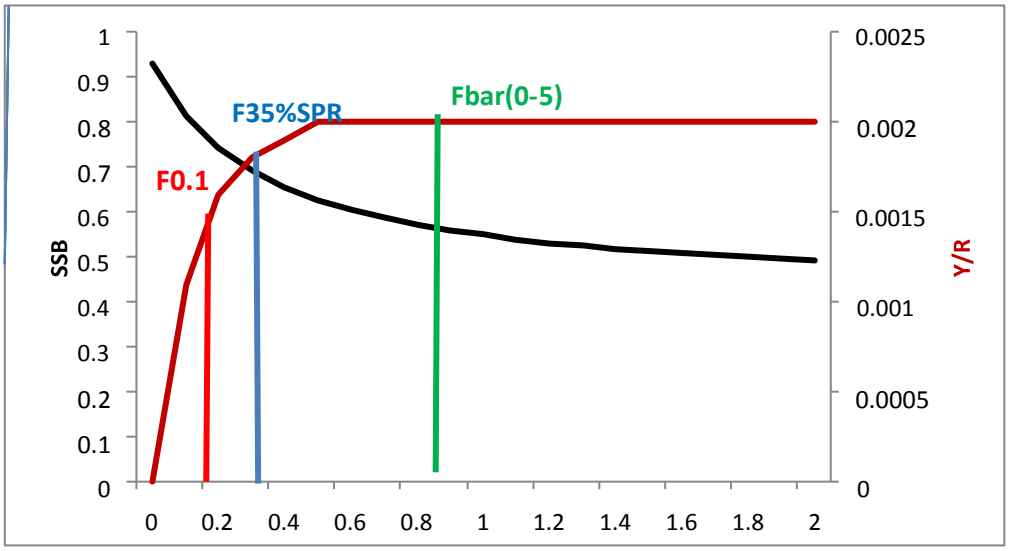


Figure 7.2-2 Equilibrium Yield (g) per Recruit and SSB (g) per Recruit (g) vs Fishingg mortality (F) including the corresponding yield and spawner reference points calculated using Virtual Population Analysis: version 3.1 (Windows/DOS) user guide.

Reference point	F multiplier	Absolute F
F bar(0-5)	1	0.8875
FMax	>=1000000	
F0.1	0.2974	0.2639
F35%SPR	0.4566	0.4052

8 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	($F_{0.1}$ = 0.31)	$F_c/F_{0.1}$=2.00		I	**IO_H**
	Fishing effort		2305 trips		D	
	Catch		69		D	
Stock abundance	SSB	242.9	33rd perc= 305.0 66th perc= 362.0		D	**IO_L**
Recruitment	Individuals	54.8	33rd perc= 62.1 66th perc= 76.9		D	
Final Diagnosis		High overfishing, relative low biomass. In the present status the tendency of the reduction of SSB could result in a short term recruitment overfishing.				

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).*