Stock Assessment Form

Nephrops norvegicus

Reference year:

2012

Norway lobster is one of the main commercial species for trawlers exploiting fishing grounds on the upper slope to target mainly the deep water rose shrimp (*Parapenaeus longirostris*) and the giant red shrimp (*Aristaeomorpha foliacea*). The species can be considered a by-catch for trawlers exploiting giant red shrimp and deep sea pink shrimp on bathyal fishing grounds. Italian landings ranged between 428 and 797 t between 2004 and 2007 decreasing to 440 t in 2012. The contribution of the Maltese fleet was generally less than 1% in 2005- 2012. An a4a Statistical Catch at Age analysis of *N. norvegicus* in GSAs 15-16 was conducted t using Italian and Maltese annual catch data of the for the period 2002 to 2012 tuned with MEDITS survey data for the same period 2002-2012.

Stock Assessment Form version 1.0 (January 2014)

Uploader: *FRANCESCO COLLOCA*

Stock assessment form

1... Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Nephrops norvegicus	Norway lobster	43
1st Geographical sub-area:	2nd Geographical sub-area:	3rd Geographical sub-area:
[GSA_15]	[GSA_16]	
4th Geographical sub-area:	5th Geographical sub-area:	6th Geographical sub-area:
1st Country	2nd Country	3rd Country
[Malta]	[Italy]	
4th Country	5th Country	6th Country
Stock assessment method: (direct, indirect, combined, none)		
Indirect method (XSA, SCA)		
Authors:		
*Colloca F., *Fiorentino F.,* Gancitano V. and** Knittweis L.		
Affiliation:		
* IAMC-CNR (Mazara del Vallo-Italy) ** University of Malta		

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

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

Direct methods (you can choose more than one):

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

Indirect method (you can choose more than one):

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

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

2... Stock identification and biological information

2.1... *Stock unit*

Due to the lack of information about the structure of Norway lobster (*Nephrops norvegicus*) population in the central Mediterranean, this stock was assumed to be confined within the GSA 15-16 boundaries (Fig. 1.1.1.1.1).

Due to a lack of information about the structure of the blue and red shrimp population in the central Mediterranean, this stock was assumed to be confined within the boundaries of the GSA 15 and 16.

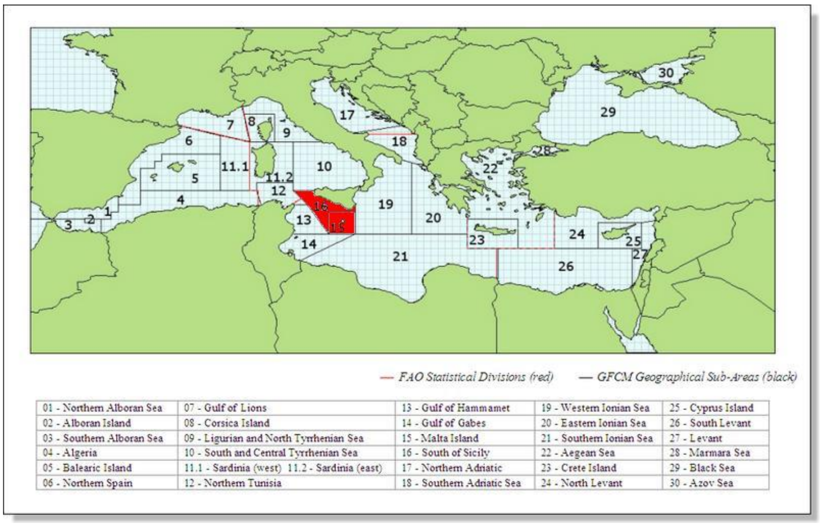


Fig. 1.1.1.1.1 Map showing the position of GSAs 15-16

N. norvegicus is a mud-burrowing species that prefers sediments with mud mixed with silt and clay in variable proportions. The emergence rhythmicity of individuals from burrows was found to be nocturnal with crepuscular peaks on the continental shelf, and diurnal on the continental slope. Emergence patterns were almost identical for males, females and berried females, and these were not size-dependent (Aguzzi et al., 2003).

2.2... Growth and maturity

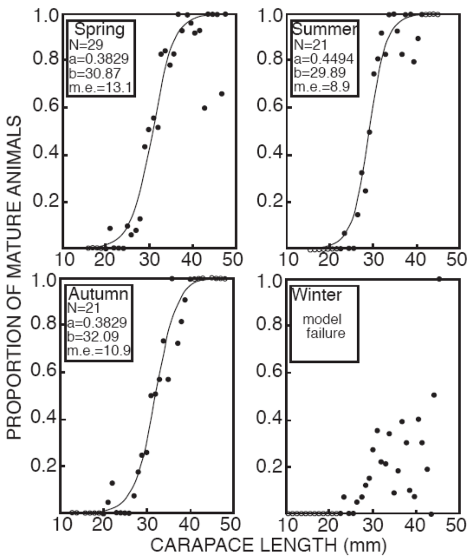
As there is not an estimation of growth parameters in the area, the used ones where those estimated for the GSA 09: $L\infty$=72.1, K=0.17, t0=0 (sex combined)

Length-weight relationships: a = 0.000373, b = 3.1576

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

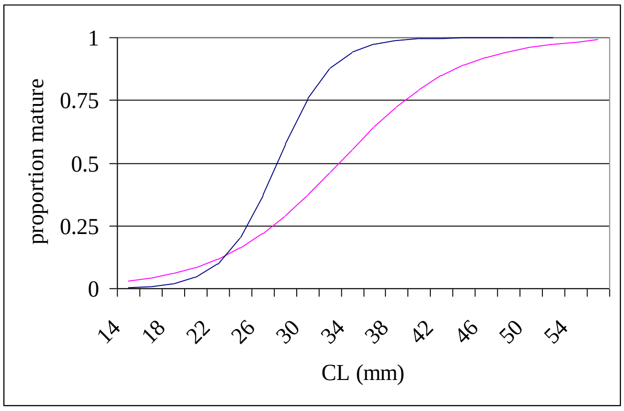
Somatic magnitude measured (LT, LC, etc)			CL	**Units**	mm
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	Spring
Maximum size observed			72.1	**Recruitment season**	Winter
Size at first maturity			22	**Spawning area**	
Recruitment size to the fishery			29	**Nursery area**	

Mature and ovigerous females occur throughout the Italian side of the Strait of Sicily and were caught in the whole depth range in which Norway lobster is distributed (150-600 m) (Bianchini et al., 1998). The main spawning period is Spring. Bianchini et al. (1998) observed females with green eggs on the pleopods are observed in Summer and Autumn in almost equal proportions, 40.0% and 40.4% respectively. No ovigerous females were captured in Spring; a very low number (12; i.e. 1.05%) appears in the Winter catch, scattered in the size classes (from 29 mm to 42 mm CL). The smallest ovigerous specimen was 22 mm CL. The gonadic maturity appeared therefore prolonged (Spring and Summer) and spawning activity (Summer-Autumn) with a brief resting phase (Winter). The estimated sizes at 50% of maturity can change according year and season(30.9, 29.9 and 32.1 mm for Spring, Summer and Autumn respectively). Temporal changes in the proportion of mature females have been observed in the area in more recent years.



Seasonal maturity ogive for Norway lobster females in the Strait of Sicily (from Bianchini et al., 1998).

The overall sex-ratio (fem/tot) was 0.48, and that all specimens above 51 mm CL are males, the largest size being 66 mm; females are slightly more abundant in the smallest classes (20-30 mm CL), then the ratio decreases linearly (Bianchini et al., 1998). The recruitment appears to be continuous during the year.



Maturity ogives of females Norway lobster in GSA 16 in 2002-2006 (pink) and 2009 (blue curve).

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

Size/Age	Natural mortality	Proportion of matures
…	…	…

Table 2-2.3: M vector and proportion of matures by size or age (Females)

Size/Age	Natural mortality	Proportion of matures
…	…	…

Table 2-3: Growth and length weight model parameters

			Sex			
		Units	female	male	Combined	Years
Growth model	L_∞	mm			72.1	
	K				0.17	
	t_0				0	
	Data source					
Length weight relationship	a				0.000373	
	b				3.1576	
	M (scalar)					
	sex ratio (% females/total)	0.48				

3... Fisheries information

Norway lobster is one of the main commercial species for trawlers exploiting fishing grounds on the upper slope to target mainly the deep water rose shrimp (*Parapenaeus longirostris*) and the giant red shrimp (*Aristaeomorpha foliacea*).

3.1... Description of the fleet

Identification of Operational Units exploiting this stock.

Table 3-1: Description of operational units exploiting the stock

	Country	GSA	Fleet Segment	Fishing Gear Class	Group of Target Species	Species
Operational Unit 1*	ITA	99	E - Trawl (12-24 metres)	03 - Trawls	43 Lobsters, spiny-rock lobsters	NEP
Operational Unit 2	ITA	99	F - Trawl (>24 metres)	03 - Trawls	43 Lobsters, spiny-rock lobsters	NEP
Operational Unit 3	MLT	99	E - Trawl (12-24 metres)	03 - Trawls	43 Lobsters, spiny-rock lobsters	NEP
Operational Unit 4	MLT	99	F - Trawl (>24 metres)	03 - Trawls	43 Lobsters, spiny-rock lobsters	NEP

Table 3.1-2: Catch, bycatch, discards and effort by operational unit in 2012

Operational Units*	Fleet (n° of boats)*	Catch (T or kg of the species assessed)	Other species caught (names and weight)	Discards (species assessed)	Discards (other species caught)	Effort (units)
E - Trawl (12-24 metres)]		229				
F - Trawl (>24 metres)		214				
E - Trawl (12-24 metres)						
F - Trawl (>24 metres)		0.65				
[Operational Unit5]						
Total						

3.2... Historical trends

Landings

The stock is exploited by trawlers being basically a by-catch of vessels targeting deep-sea pink shrimps and giant-red shrimps. Landings data for GSA16 collected within the Data Collection Framework (DCF) ranged between 428 (2004) and 797 t (2007). The contribution of the Maltese fleet was less than 1% in 2005- 2011.

Annual landings (t) by fishing technique as reported to STECF EWG 12-10 through the DCF data call in GSA 15 and 16.

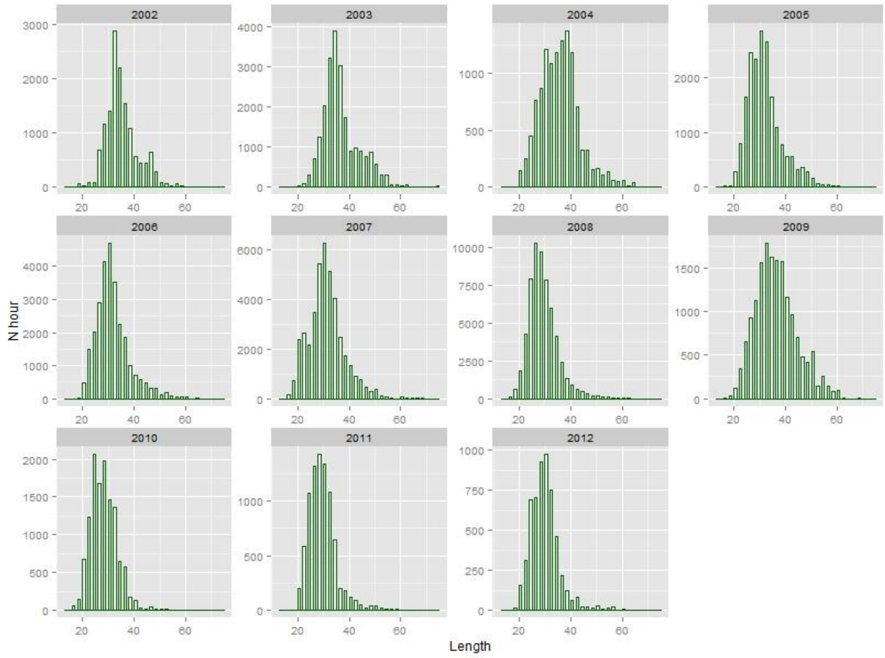
GSA 16

Fishery	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
DEMSP	460.1	678.2	428	489.9	673.4	797.23	672.55	371.25	320.29	366.19	229.40
VL1218									41.04	38.30	17.90
VL1224						797.23	672.55	371.25			
VL1824									75.85	108.45	78.60
VL2440									203.40	219.45	132.90
DWSP								68.69	32.40	49.39	27.90
VL2440								68.69	32.40	49.39	27.90
MDDWSP								196.55	268.13	215.46	186.20
VL2440								196.55	268.13	215.46	186.20
Total	460.1	678.2	428	489.9	673.4	797.23	672.55	636.50	620.82	631.04	443.50

GSA 15

Fishery	2005	2006	2007	2008	2009	2010	2011	2012
DEMSP						0.27	0.13	
DWSP						0.64	0.53	0.20
MDDWSP	3.40	0.01	0.63	1.21	3.72	3.46	2.17	0.45
Total	3.40	0.01	0.63	1.21	3.72	4.37	2.83	0.65

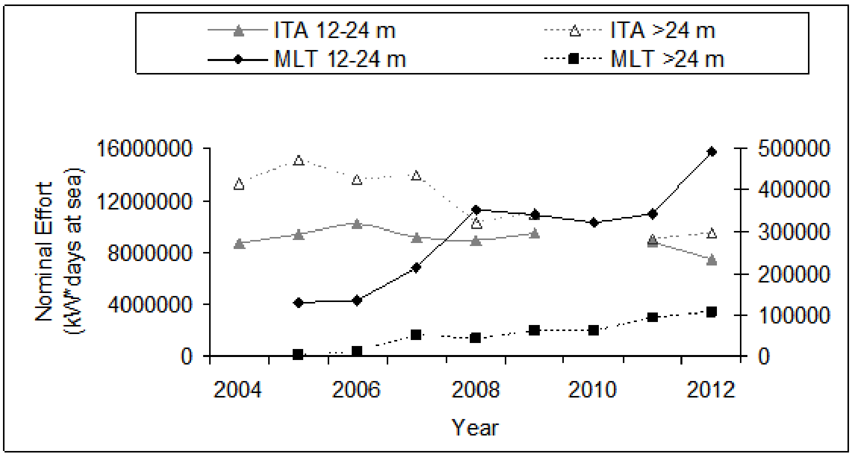
The length frequency distribution of landings appears almost constant through time.



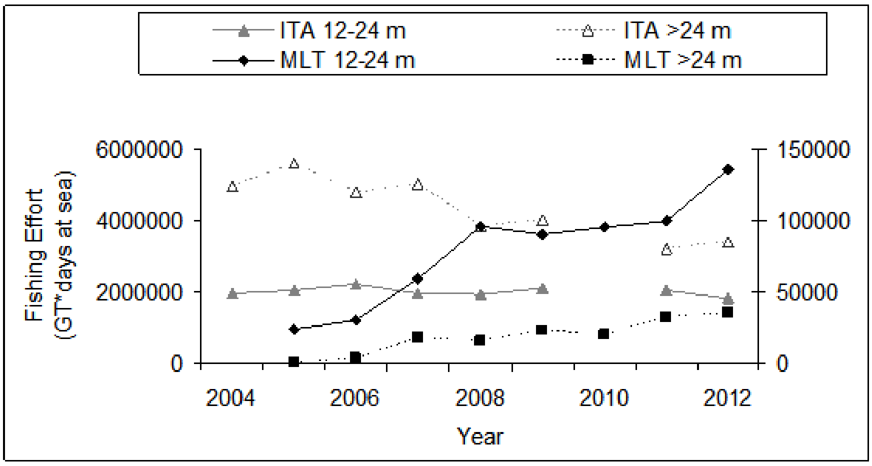
Length frequency distributions of Nephrops annual landings in GSAs 15-16 for the period 2002-2012

Fishing effort

The effort Italian otter trawl >24 m LOA decreased of 32% since 2004, while the effort of the smallest trawlers (12-24 m LOA) remained quite constant. The effort of Maltese trawlers of LOA>24 m showed an increasing trend.



*Nominal effort (kW*days at sea) trends of trawlers (OTB) by segments of Maltese (right) & Italian fleet (left), 2004-2011.*



*Fishing effort (GT*days at sea) trends of trawlers (OTB) by segments of Maltese (right) & Italian fleet (left), 2004-2011.*

3.3... Management regulations

There are no formal management objectives for Norway lobster in the Strait of Sicily. As in other areas of the Mediterranean, the stock management in Italy and Malta is based on control of fishing capacity (licenses), fishing effort (fishing activity), technical measures (mesh size and area/season closures). The minimum landing size (Reg. EC 1967/06) is 20 mm CL.

In order to limit the over-capacity of fishing fleet, no new fishing licenses have been assigned in Italy since 1989 and a progressive reduction of the trawl fleet capacity is currently underway. Maltese fishing capacity licenses had been fixed at a total of 16 trawlers since 2000, but eight new licenses were issued in 2008 and one in 2011, a move made possible by capacity reductions in other segment of the Maltese fishing fleet.

A compulsive fishing closure for trawlers is usually applied in Italy at end of summer (September) for 30 days. There is no closed season in place in Malta, but the Maltese Islands are surrounded by a 25 nautical miles fisheries management zone where fishing effort and capacity are being managed by limiting vessel sizes, as well as total vessel engine powers (EC 813/04; EC 1967/06). Trawling is allowed within this designated conservation area, however only by vessels not exceeding an overall length of 24 m and only within designated areas. Vessels fishing in the management zone hold a special fishing permit in accordance with Regulation EC 1627/94. Moreover, the overall capacity of the trawlers allowed to fish in the 25nm zone can not exceed 4 800 kW, and the total fishing effort of all vessels is not allowed to exceed an overall engine power and tonnage of 83 000 kW and 4 035 GT respectively. The fishing capacity of any single vessel with a license to operate at less than 200m depth cannot exceed 185 kW.

In order to protect coastal habitats the use of towed gears is prohibited within 3 nm of the coast or within the 50 m isobath if the latter is reached closer to the coast (EC 1967/2006; Res. GFCM 36/2012/3). In order to protect deep water habitats trawling at depths beyond 1000 m is also prohibited at EU and GFCM level (EC 1967/2006; Rec. GFCM 2005/1).

In terms of technical measures, EC 1967/2006 fixed a minimum mesh size of 40 mm for bottom trawling of EU fishing vessels. Mesh size had to be modified to square 40 mm square or at the duly justified request of the ship owner a 50 mm diamond mesh in July 2008; derogations were only possible up to 2010. Moreover diamond mesh panels can only be used if it is demonstrated that size selectivity is of equivalent or higher than using 40 mm square mesh panels (EC 1343/2011).

3.4... Reference points

Table 3.3-1: List of reference points and empirical reference values previously agreed (if any)

Indicator	Limit Reference point/empirical reference value	Value	Target Reference point/empirical reference value	Value	Comments
B					
SSB					
F					
Y					
CPUE					
Index of Biomass at sea					

4... Fisheries independent information

4.1... Medits trawl survey

4.1.1 Brief description of the direct method used

In order to collect fisheries independent data, which is a requirement of the EU DCF (Council Regulation 199/2008, Commission Regulation 665/2008, Commission Decision EC 949/2008 and Commission Decision 93/2010); the MEDITS international trawl survey is carried out in GSAs 15 & 16 on an annual basis.

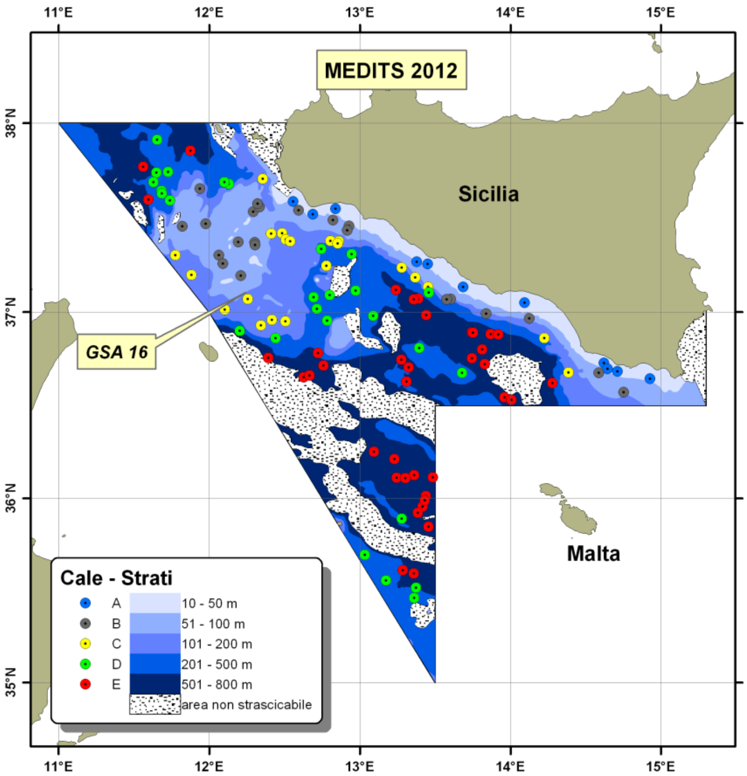
Direct methods: trawl based abundance indices

Table 4.1.1. Trawl survey basic information

Survey	MEDITS	**Trawler/RV**	TRAWLER
Sampling season	MAY-JULY		
Sampling design	Stratified with number of haul by stratum proportional to stratum surface (see MEDITS-Handbook. Revision n. 6, April 2012, MEDITS Working Group : 92 pp.)		
Sampler (gear used)	Bottom trawl made of four panels (IFREMER reference GOC 73)		
Cod –end mesh size as opening in mm	10 mm mesh size, which corresponds to ~ 20 mm of mesh opening		
Investigated depth range (m)	10-800m		

Table 4.1-1: Trawl survey sampling area and number of hauls; GSA 16 (2012).

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



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

The total number of trawl stations by depth strata and year in GSA 16 and 15 is showed in the tables below In GSA 16 the total number of hauls increased from 1994 to the current 120 hauls.

Number of hauls per year and depth stratum in GSA 16, 1994-2012.

Depth (m)	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	
10-50	4	4	4	4	4	4	4	4	7	
50-100	8	8	8	8	8	8	7	8	11	
100-200	4	4	4	4	5	5	6	5	10	
200-500	10	11	11	12	11	11	11	11	19	
500-800	10	14	14	13	14	14	14	14	19	
Depth (m)	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
10-50	7	7	10	10	11	11	11	11	11	11
50-100	12	12	20	22	23	23	23	23	23	23
100-200	8	9	18	19	21	21	21	21	21	21
200-500	18	19	28	31	27	27	27	27	27	27
500-800	20	19	32	33	38	38	38	38	38	38

Number of hauls per year and depth stratum in GSA 15, 2002-2010.

Depth (m)	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
10-50	1	1	2	1	1	0	0	0	0	0	0
50-100	5	5	4	5	5	12	6	6	6	6	6
100-200	13	13	13	13	13	12	13	14	14	14	14
200-500	10	10	10	9	10	4	9	10	10	10	10
500-800	16	16	15	17	16	17	17	15	15	15	15

Table 4.1-2: Trawl survey abundance and biomass results

Depth Stratum	Years	kg per km^2	CV or other	N per km^2	CV or other
10-800 m	1994	1.40	38.97	48.73	39
10-800 m	1995	2.20	49.69	96.20	41
10-800 m	1996	4.33	46.32	174.96	44
10-800 m	1997	1.53	57.80	65.08	34
10-800 m	1998	2.10	44.53	76.73	43
10-800 m	1999	1.99	35.58	79.70	48
10-800 m	2000	1.97	38.62	86.94	52
10-800 m	2001	2.28	39.78	118.87	48
10-800 m	2002	2.47	47.33	106.05	42
10-800 m	2003	2.10	43.73	74.52	41
10-800 m	2004	5.09	39.92	142.03	49
10-800 m	2005	3.59	63.08	97.69	41
10-800 m	2006	4.40	38.64	128.86	46
10-800 m	2007	5.96	46.42	170.69	46
10-800 m	2008	6.61	43.20	215.17	47
10-800 m	2009	7.03	45.01	232.38	47
10-800 m	2010	5.45	42.36	158.35	51
10-800 m	2011	4.16	43.67	121.36	44
10-800 m	2012	6.19	45.41	183.64	45
Total (10 – 800 m)	……				

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

Slicing method

The annual size distributions of the catch as well as of the surveys (MEDITS) were converted in numbers at ages classes 1-8+ using the slicing statistical approach developed during STECF-EWG 11-12 (Scott et al., 2011) and using the same growth parameters adopted to slice the MEDITS size distributions.

Table 4.1-3: Trawl survey results by length or age class

MEDITS index (2002-2012), N° per Km2

N (Total or sex combined) by Length or Age class	Year										
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
1	32.58	1726.35	4421.22	2959.2	844.89	281.9	53.73	24.48	32.58	1726.35	4421.22
2	0.01	602	2506.38	2234.6	1035.68	402.89	106.47	33.93	0.01	602	2506.38
3	118.22	2142.03	4823.98	4173.12	1483.83	729.71	170.29	144.5	118.22	2142.03	4823.98
4	29.55	1099.73	3492.02	2644.94	1170.17	565.51	125.64	45.76	29.55	1099.73	3492.02
5	62.6	1364.75	5388.18	3294.78	1276.42	400.38	118.73	90.02	62.6	1364.75	5388.18
6	48.43	2123.67	6544.02	4729.04	2040.71	704.52	124.94	41.28	48.43	2123.67	6544.02
7	201.1	4728.11	7519.6	5013	1670.63	649.76	205.19	143.12	201.1	4728.11	7519.6
8	114.97	4496.65	8852.7	5183.95	1737.13	837.88	179.26	94.79	114.97	4496.65	8852.7
Total	607.46	18283.29	43548.1	30232.63	11259.46	4572.55	1084.25	617.88	607.46	18283.29	43548.1

Sex ratio by Length or Age class	Year										
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
1											
2											
3											
4											
5											
6											
7											
8											
Total											

The sex ratio is around 0.5.

Year	F/F+M
2006	0.5
2007	0.53
2008	0.5
2009	0.52
2010	0.46
2011	0.49
2012	0.5

Direct methods: trawl based Recruitment analysis

Table 4.1-4: Trawl surveys; recruitment analysis summary

Survey	**MEDITS**	**Trawler/RV**	**SURVEY**
Survey season		MAY-JULY	
Cod –end mesh size as opening in mm		10 mm mesh size, which corresponds to ~ 20 mm of mesh opening	
Investigated depth range (m)		10-800	
Recruitment season and peak (months)		The recruitment appears to be continuous during the year	
Age at fishing-grounds recruitment			
Length at fishing-grounds recruitment		About 20 mm	

Table 4.1-5: Trawl surveys; recruitment analysis results

Years	**Area in km²**	**N of recruit per km²**	**SD**
1994		23.75	42.01
1995		61.62	55.32
1996		101.17	39.40
1997		41.54	51.09
1998		35.19	39.75
1999		47.37	34.25
2000		56.98	64.41
2001		85.75	52.04
2002		46.44	48.06
2003		17.73	70.30
2004		50.68	55.73
2005		32.32	62.10

2006		43.82	39.95
2007		61.78	41.51
2008		91.94	55.92
2009		106.57	55.20
2010		61.22	48.65
2011		52.65	65.97
2012		75.38	45.71

Comments

Direct methods: trawl based spawners analysis

Table 4.1-6: Trawl surveys; spawners analysis summary

Survey	**MEDITS**	**Trawler/RV**	**TRAWLER**
Survey season			MAY-JULY
Investigated depth range (m)			10-800
Spawning season and peak (months)			Spring-Autumn, peak in Spring

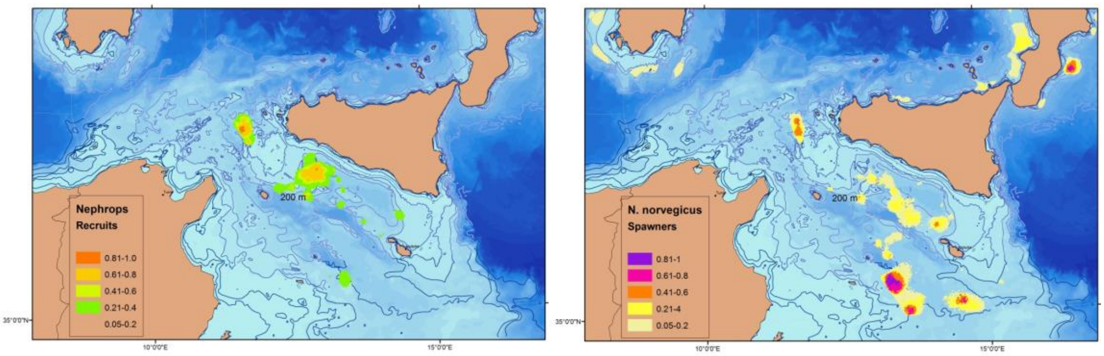
Table 4.1-7: Trawl surveys; spawners analysis results

Years	**Area in km^2**	**N of spawners per km^2**	**SD**
1994		**17.86**	**3.55**
1995		**25.22**	**5.90**
1996		**49.67**	**13.13**
1997		**16.95**	**4.60**
1998		**26.73**	**7.97**
1999		**25.05**	**5.32**
2000		**21.17**	**5.09**
2001		**21.13**	**6.59**
2002		**41.64**	**12.33**
2003		**38.14**	**9.13**
2004		**67.01**	**16.75**
2005		**45.52**	**10.68**
2006		**51.80**	**13.51**
2007		**76.40**	**19.60**
2008		**76.82**	**20.37**
2009		**80.33**	**21.05**
2010		**66.57**	**15.17**
2011		**52.65**	**65.97**

2012		**75.38**	**45.71**

4.1.2 Spatial distribution

The species is distributed in the whole area below 150 m depth. Two main nursery grounds have been identified on the Eastern and West side of the Adventure bank. Recruits (CL<23 mm) were distributed on the upper slope between 250 and 500 m depth, with a peak of abundance between 400 and 500 m (Garofalo et al., 2011). The main aggregation areas of spawners occur on the western side of the Adventure Bank and SW to Malta Island.

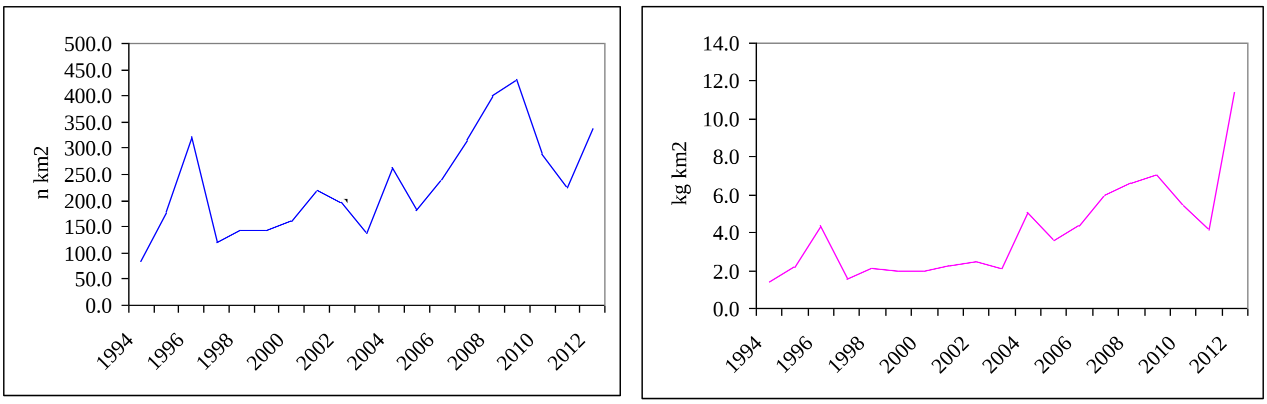


Distribution map of nurseries (left) and spawning grounds (right) of Norway lobster in the Strait of Sicily

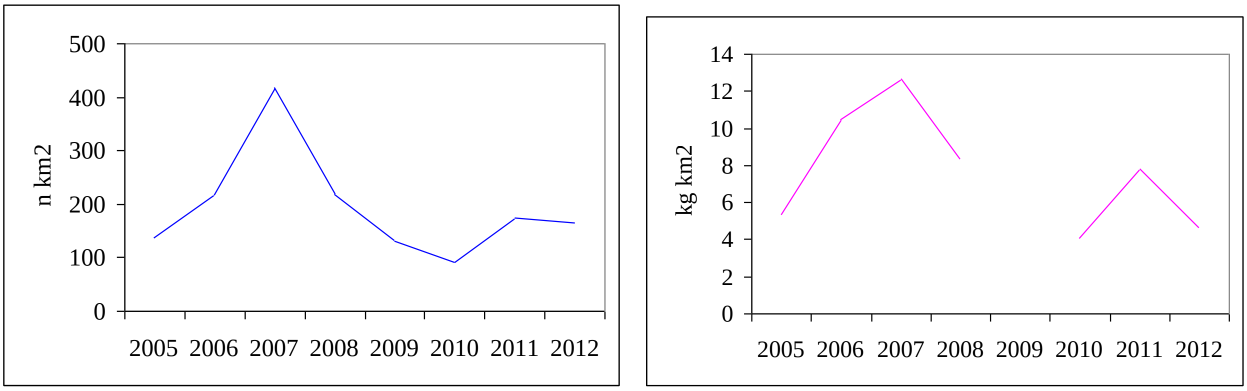
4.1.3 Historical trends

1.1.1.1.1 *Trends in abundance and biomass*

Medits indices for GSA 16 clearly showed an increased in the density and biomass of the stock since mid '90s whereas in Maltese waters the trend is opposite

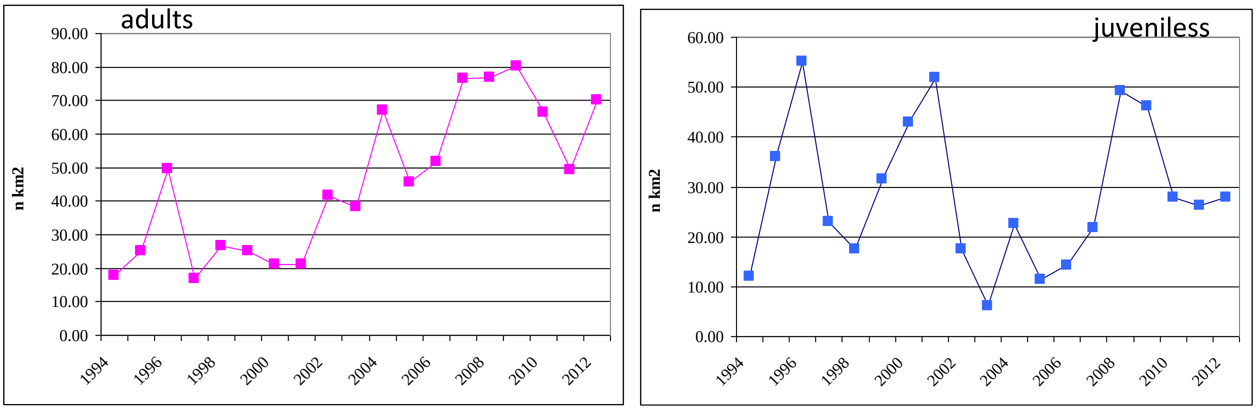


Abundance and biomass indices of Norway lobster in GSA 16



Abundance and biomass indices of Norway lobster in GSA 15

The Medits trend for adults Norway lobster in GSA 16 shows a clear increasing trend since 2000, whereas any trend can be observed for juveniles



Abundance indices of Norway lobster adults (ages 4-8+) and juveniles (ages 1-2) in GSA 16.

The length frequency distributions of Norway lobster in GSAs 15-16 by year (n km^2) are shown below.

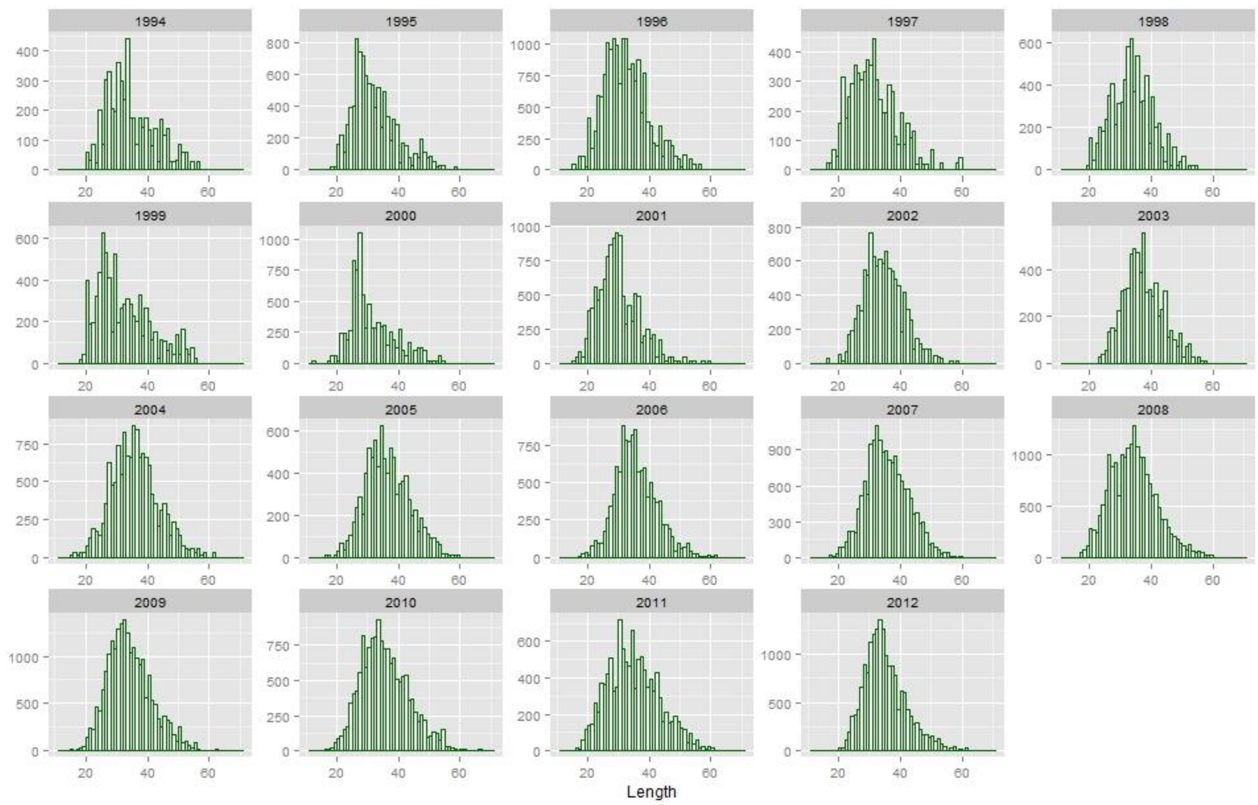


Fig. 1.1.3.1.4.1. Medits length frequency distributions of Norway lobster in GSA 16.

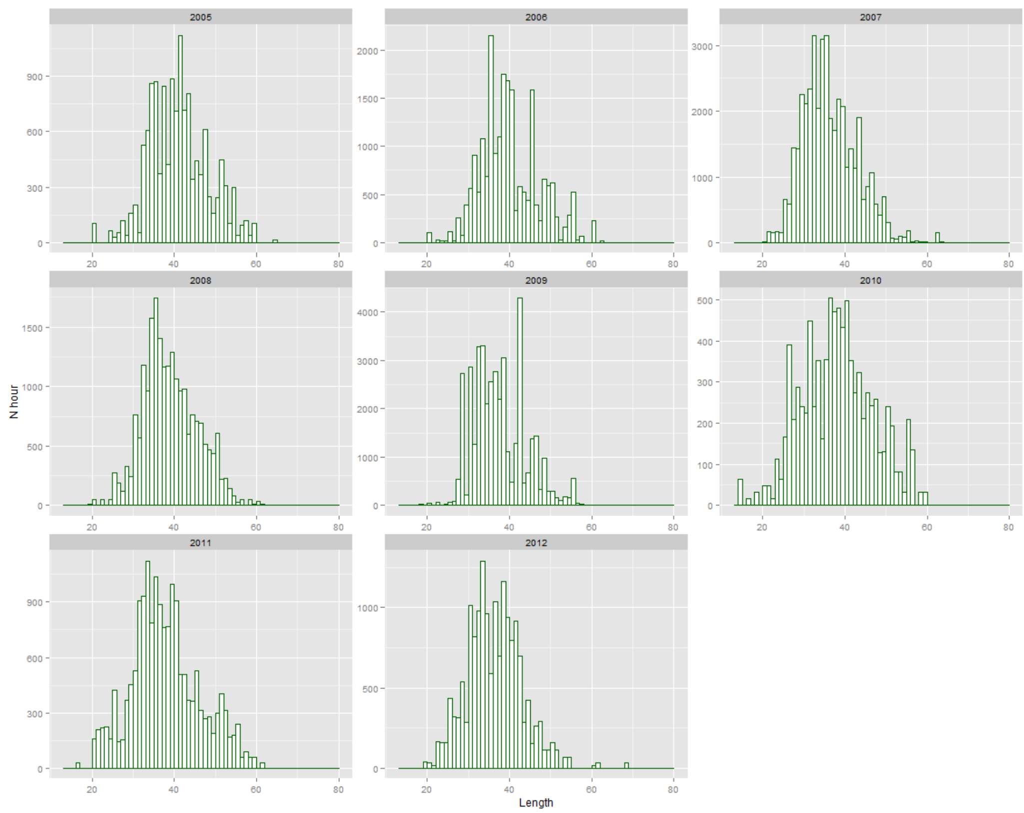


Fig. 1.1.3.1.4.2. Medits length frequency distributions of Norway lobster in GSA 15.

4.2... Stock Assessment

Norway lobster of GSAs 15-16 was for the first time assessed during EWG 13-09 using both XSA and Statistical Catch at Age using the a4a assessment model.

4.3... Method 1: XSA

An XSA assessment was run using the Italian and Maltese annual landings data of the GSAs 15-16 for the period 2002 to 2012 and calibrated with MEDITS survey data for the same period 2002-2012. The Maltese landings (GSA 15), corresponding to a proportion generally less than 0.25% of the Italian landings, were available for the period 2006-2012. An average proportion of 0.25% was added to the Italian landings for the period 2002-2006.

4.3.1 Model assumptions

4.3.2 Scripts

4.3.3 Input data and Parameters

The annual size distributions of the catch as well as of the surveys (MEDITS) were converted in numbers at ages classes 1-8+ using the slicing statistical approach developed during STECF-EWG 11-12 (Scott et al., 2011) and using the same growth parameters adopted to slice the MEDITS size distributions. Input data (mortality and maturity at age data) and XSA settings are given below.

XSA settings: Fse: 0.5, 1.0, 2.0 ; Rage: 2; Qage: 5; shk.yrs: 5; shk.ages: 5

Catch at Age (thousands)

age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	81.55	6.77	36.47	67.49	54.51	1203.71	203.99	70.93	687.23	45.66	92.43
2	2012.33	1733.24	2185.65	6695.24	9559.24	9205.07	10040.23	2837.89	12236.06	12081.88	7530.74
3	7468.74	8791.57	4021.56	8584.88	13113.02	14687.92	11120.46	6028.93	10336.79	9976.17	7440.99
4	2449.44	3162.95	3848.10	2193.15	2891.87	3432.23	2955.92	4395.14	2834.74	2846.43	1906.12
5	1163.33	1537.33	653.27	798.69	863.01	936.72	897.01	1293.39	741.77	754.62	488.19
6	502.62	1305.28	386.90	517.32	532.34	504.42	555.22	1089.77	535.26	597.68	378.26
7	28.85	177.64	97.72	59.85	94.93	60.29	103.47	227.22	99.51	109.77	92.25
8	106.17	263.69	287.95	76.41	195.11	157.31	212.93	393.22	112.97	161.32	155.33

Natural Mortality (M) at age (PRODBIOM)

age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
2	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41
3	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
4	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

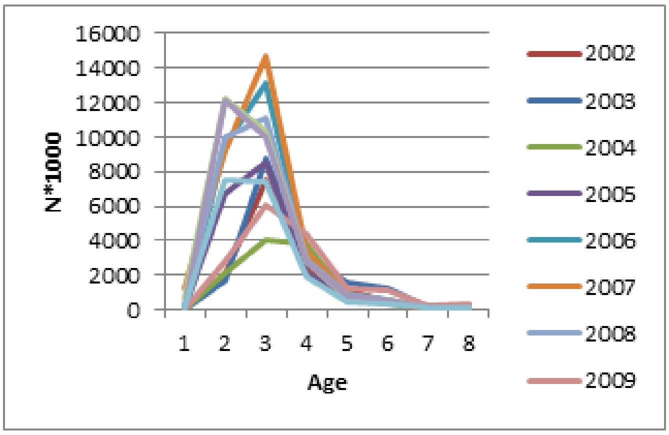
6	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
7	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
8	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27

Maturity at age

age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.01	0.01
3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.57	0.1	0.05
4	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.94	0.67	0.89
5	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.99	0.99	0.99
6	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1

MEDITS index (2002-2012)

age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1	32.58	1726.35	4421.22	2959.2	844.89	281.9	53.73	24.48	32.58	1726.35	4421.22
2	0.01	602	2506.38	2234.6	1035.68	402.89	106.47	33.93	0.01	602	2506.38
3	118.22	2142.03	4823.98	4173.12	1483.83	729.71	170.29	144.5	118.22	2142.03	4823.98
4	29.55	1099.73	3492.02	2644.94	1170.17	565.51	125.64	45.76	29.55	1099.73	3492.02
5	62.6	1364.75	5388.18	3294.78	1276.42	400.38	118.73	90.02	62.6	1364.75	5388.18
6	48.43	2123.67	6544.02	4729.04	2040.71	704.52	124.94	41.28	48.43	2123.67	6544.02
7	201.1	4728.11	7519.6	5013	1670.63	649.76	205.19	143.12	201.1	4728.11	7519.6
8	114.97	4496.65	8852.7	5183.95	1737.13	837.88	179.26	94.79	114.97	4496.65	8852.7



Catch at age data for Norway lobster in GSAs 16

4.3.4 Results

The final model is summarized in the figure below.

In 2002-2012, the SSB ranged between about 690 and 960 t. In the same period recruitment at age 1 fluctuated widely between 37.7 and 93.3 million (Table 1.1.4.1.3 1). XSA estimates of $Fbar_{2-7}$ showed a declining temporal trend from 0.89 in 2003 to 0.42 in 2012 (Table 1.1.4.1.3 2). F was generally higher for age classes 3-6.

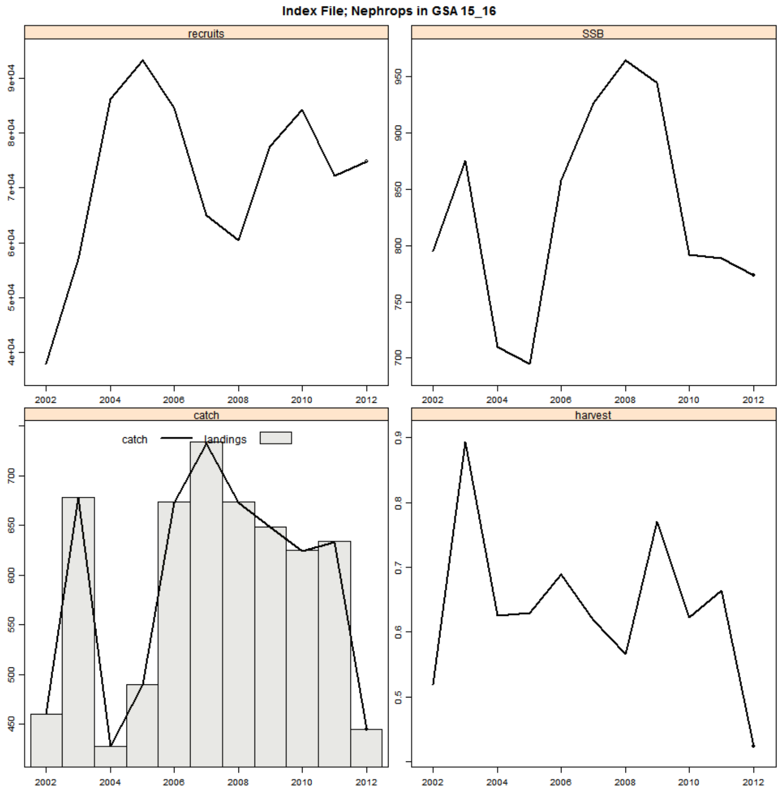


Fig. 1.1.4.1.3.4. XSA results for Norway lobster in GSAs 15 and 16: F, Recruitment, SSB and Yield.

Table 1.1.4.1.3 1. Spawning stock biomass (SSB), and recruitment estimates by XSA for Norway lobster in GSA 15 & 16 from 2006 to 2011.

	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
SSB (tons)	795.3	875.7 5	710.22	694.57	857.84	926.21	964.8	944.5	791.7	788.86	773.77
Recruitment (millions)	37.78 1	56.93 4	86.337	93.391	84.656	65.004	60.500	77.642	84.391	72.266	74.866

Table 1.1.4.1.3 2. Fishing mortality and numbers at age at age as estimated by XSA.

F-at-age	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
1	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00
2	0.08	0.10	0.08	0.18	0.24	0.27	0.41	0.10	0.41	0.37	0.25
3	0.68	0.69	0.45	0.70	0.81	0.98	0.75	0.57	0.89	0.90	0.51
4	0.58	0.86	0.93	0.57	0.65	0.63	0.62	0.93	0.72	0.79	0.50
5	0.44	1.11	0.49	0.59	0.53	0.54	0.37	0.71	0.46	0.49	0.34
6	0.81	1.71	1.17	1.11	1.21	0.83	0.81	1.25	0.88	0.96	0.55
7	0.52	0.89	0.63	0.63	0.69	0.46	0.43	1.07	0.38	0.49	0.41

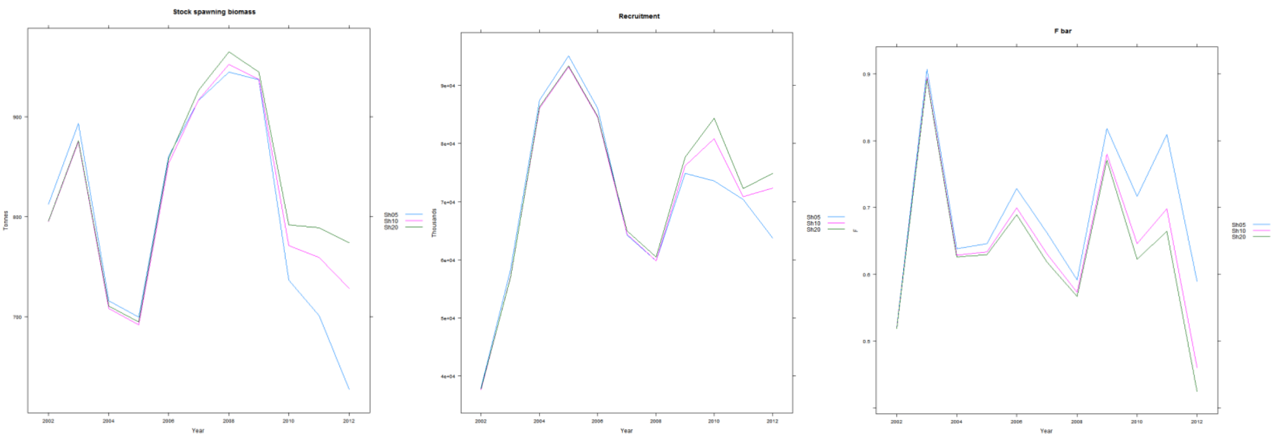
8	0.52	0.89	0.63	0.63	0.69	0.46	0.43	1.07	0.38	0.49	0.41
Fbar$_{(2-7)}$	**0.52**	**0.89**	**0.63**	**0.63**	**0.69**	**0.62**	**0.57**	**0.77**	**0.62**	**0.66**	**0.42**

4.3.5 Robustness analysis

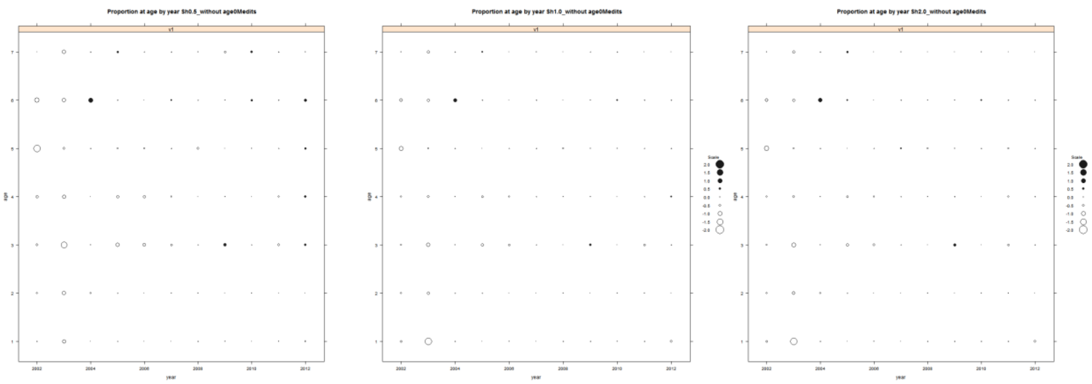
4.3.6 Retrospective analysis, comparison between model runs, sensitivity analysis, etc.

XSA was run setting shrinkage at 0.5, 1.0, 2.0 to assess the effect of different settings on the outcomes of the method. As showed below, the three different settings produced similar trend for recruitment and SSB. Fbar was estimated to be higher by the model with 0.5 shrinkage. Shrinkage set at 1.0 and 2.0 produced very similar Fbar estimates The final model adopted was the model with 2.0 shrinkage based on both residuals and retrospective analysis.

Shrinkage=0.5 Shrinkage=1.0 Shrinkage=2.0

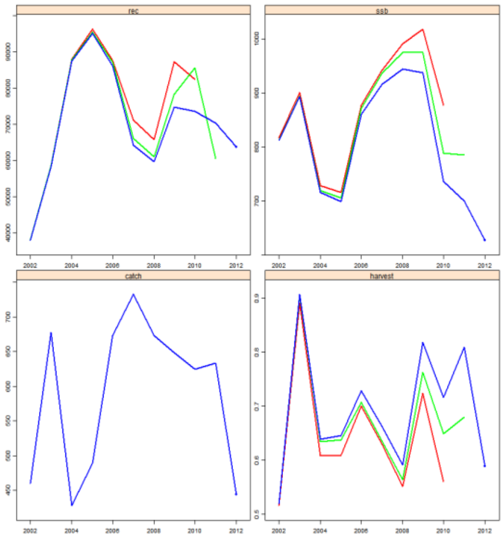


Estimates of SSB, recruitment and F using different values of shrinkage.

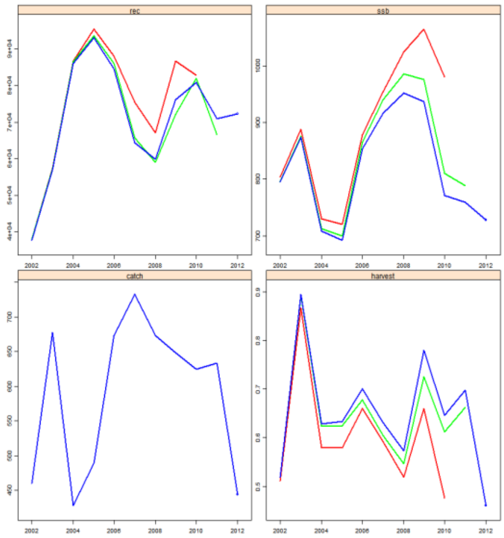


Residuals at age obtained with XSA models with different level of shrinkage

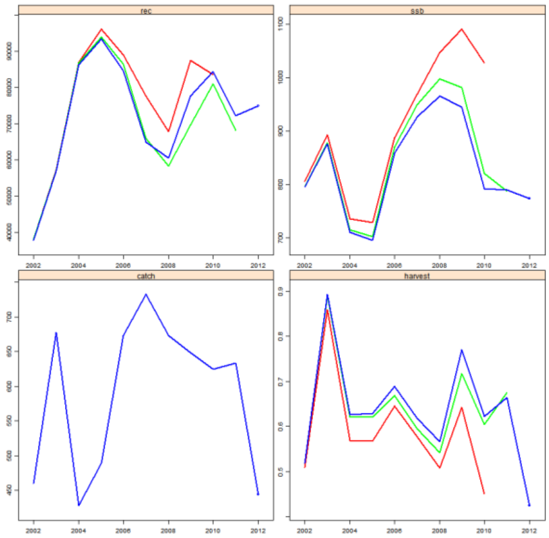
Shrinkage 0.5



Shrinkage 1.0



Shrinkage 2.0



Retrospective analysis for Norway lobster in GSAs15-16 using three different values of shrinkage.

4.3.7 Assessment quality

4.4... Method 2:

A4a statistical catch at age (Millar et al., 2012).

4.4.1 Model assumptions

The assessment model a4a (Millar et al., 2012) is based on a simple statistical catch at age (SCA) model in which the population dynamics are simply that the numbers of fish in a cohort declines from year to year due to a combination of natural mortality and fishing mortality. A4a uses splines and random effects to provide a robust and efficient way to constrain the model, and this is packaged in a robust and user friendly statistical framework under FLR. A4a assume a separable annual fishing mortality-at-age into age (selectivity) and year (fully selected fishing mortality) components to assist in fitting models to catch-at-age data. SCA approaches, in their simplest form, make the assumption of an invariant fishing selectivity-at-age pattern over time that determines the true age distribution of the total catch taken each year (Butterworth and Rademeyer, 2008). Differently to VPA-XSA that assume that the observed catch-at-age data are exact, with the fishing selectivity pattern consequently varying from year to year, SCA approaches assume the selectivity pattern to be fixed in time and consider the differences between observed and (constant selectivity) model-predicted catch-at-age data to reflect errors associated with age reading and other sources.

One of the advantages of a4a over the XSA is related to a more flexible parameterizations of selectivity-at-age that can be critical for species with a dome shaped selectivity-at age pattern. Differently to XSA which forces asymptotically flat selectivity the SCA-a4a allows this to be estimated from the data.

6.2.2 Scripts

A4a uses splines and random effects to provide a robust and efficient way to constrain the model, and this is packaged in a robust and user friendly statistical framework under FLR.

4.4.3 Input data and Parameters

Modelling was based on the same input parameters and catch data used for the XSA.

4.4.4 Results

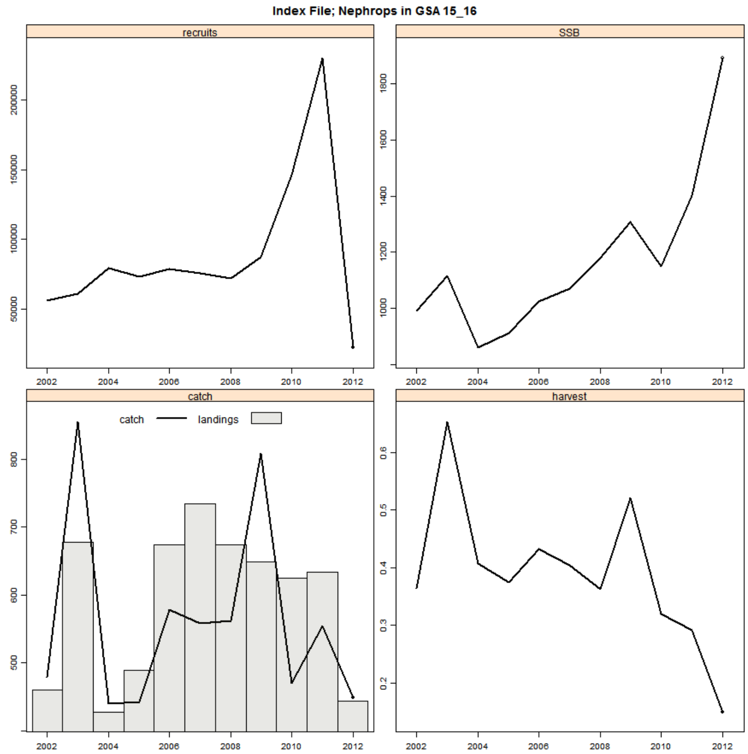
Different models assuming a separable effect on F (age, year) and a survey catchability effect were developed and evaluated against AIC. Models were also evaluated looking at the residuals about what the model predicts the catch should be.

```
fit1 <- a4a(~ age + year, list( ~ 1 ), stock = NEP.stk,  indices = NEP.idx)
fit1a <- a4a(~ age + s(year, k=3), list( ~ 1 ), stock = NEP.stk,  indices = NEP.idx)
fit1b <- a4a(~ age + s(year, k=3), list( ~ 1 ), stock = NEP.stk,  indices = NEP.idx)
fit2<-a4a(~age+ s(year,k=3), list(~factor(age)), stock = NEP.stk,  indices = NEP.idx)
fit3<-a4a(~ year*age, list( ~ 1 ), stock = NEP.stk,  indices = NEP.idx)
fit4<-a4a(~ s(year, k=3)+factor(age),list(~1), stock = NEP.stk, indices = NEP.idx)
fit5<-a4a(~ s(year, k=3)+s(age,k=3),list(~s(age, k=3)), stock = NEP.stk, indices = NEP.idx)
fit6<-a4a(~ s(age, k = 4)+factor(year),list(~s(age, k=3)), stock=NEP.stk, indices=NEP.idx)
fit7<-a4a(~ s(year, k=4)+s(age,k=3),list(~1), stock = NEP.stk, indices = NEP.idx)
fit8<-a4a(~ s(year, k=3)+factor(age),list(~factor(age)), stock = NEP.stk, indices = NEP.idx)
fit9<-a4a(~ factor(year)+factor(age),list(~factor(age)), stock = NEP.stk, indices = NEP.idx)
```

model	df	AIC
1	26	656.75
1a	27	620.90
1b	27	620.90
2	34	495.43
4	33	548.06
5	30	523.05
6	39	510.79

7	29	616.62
8	40	404.78
9	48	383.17

Based on the AIC score, the best model resulted model 9 assuming year, age and survey catchability as factors (see fig. below).



Model 9: a4a assessment results for Norway lobster in GSAs 15 and 16: F, Recruitment, SSB and catch.

The final model run estimated a fixed (invariant) selectivity at age (Fig. 1.1.4.2.3.3.). In 2002-2012, the SSB ranged between about 860 and 1892 t with a large increases in 2012. Recruitment at age 1 showed large fluctuations from about 230 and 22 million (Table 1.1.4.1.3 1) with an abrupt decline in 2012. (Fbar 2-7) was generally lower than 0.5 with a declining trend from 0.65 in 2003 to 0.15 in 2012(Table 1.1.4.1.3 2). F was generally higher for age classes 3-6.

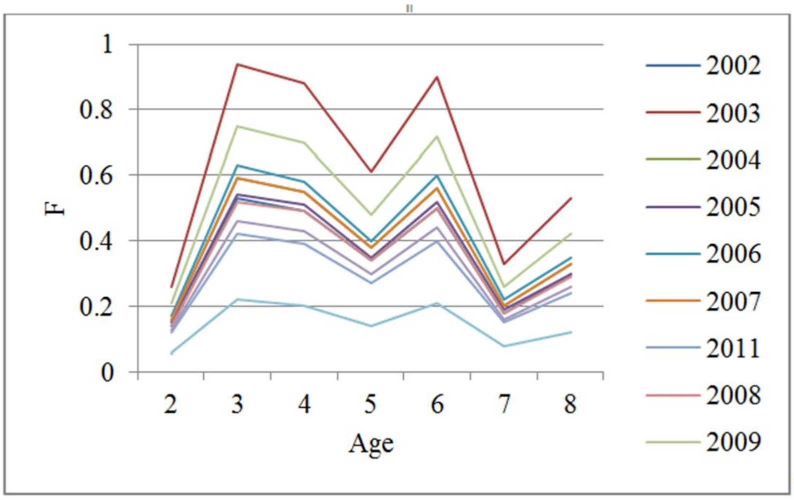
Table 1.1.4.2.3.1. Spawning stock biomass (SSB), and recruitment estimates by SCA for Norway lobster in GSA 15 & 16 from 2006 to 2011.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
SSB (tons)	990.9	1117.5	860.0	913.2	1026.2	1071.9	1180.1	1309.1	1151.0	1400.7	1892.4
Recruitment age 1 (millions)	56.178	61.146	79.374	73.290	78.717	76.003	72.141	87.502	146.460	230.332	22.383

Table 1.1.4.2.3.2. Fishing mortality and numbers at age at age as estimated by SCA.

F-at-age	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012

1	0	0	0	0	0	0	0	0	0	0	0
2	0.14	0.26	0.16	0.15	0.17	0.16	0.14	0.21	0.13	0.12	0.06
3	0.53	0.94	0.59	0.54	0.63	0.59	0.52	0.75	0.46	0.42	0.22
4	0.49	0.88	0.55	0.51	0.58	0.55	0.49	0.7	0.43	0.39	0.2
5	0.34	0.61	0.38	0.35	0.4	0.38	0.34	0.48	0.3	0.27	0.14
6	0.5	0.9	0.56	0.52	0.6	0.56	0.5	0.72	0.44	0.4	0.21
7	0.18	0.33	0.2	0.19	0.22	0.2	0.18	0.26	0.16	0.15	0.08
8	0.3	0.53	0.33	0.3	0.35	0.33	0.29	0.42	0.26	0.24	0.12
Fbar$_{(2-7)}$	**0.36**	**0.65**	**0.41**	**0.37**	**0.43**	**0.4**	**0.36**	**0.52**	**0.32**	**0.29**	**0.15**

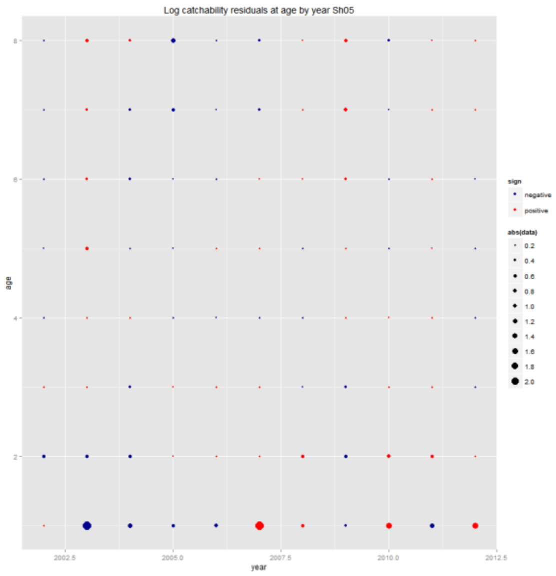


Selectivity at age estimated by a4a-SCA model 9.

4.4.5 Robustness analysis

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

Log residuals for modeled catch at age are showed in the fig. below.



Model 9: Log residuals for catch at age.

6.2.7 Assessment quality

5... 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.

5.1... Short term predictions

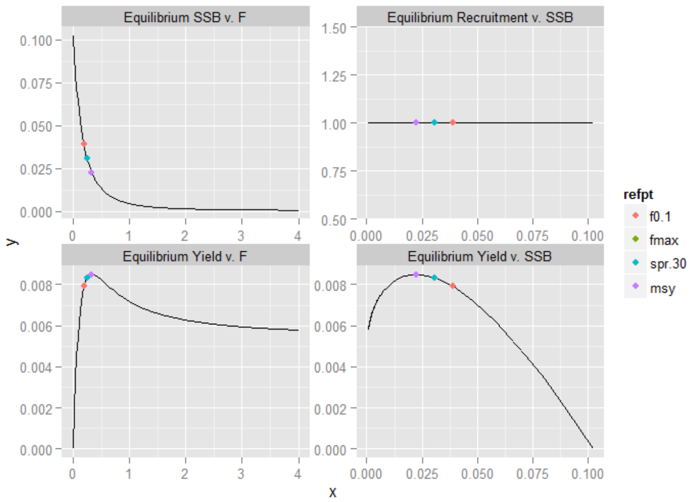
5.2... Medium term predictions

5.3... Long term predictions

5.3.1.1.1 Input parameters

Reference F for the Yield per recruit (YPR) analysis was estimated using 1 to 8+ years age classes using the FLR routine based on the exploitation pattern estimated by the statistical catch at age. F_{01} was estimated to be 0.20.

5.3.1.1.2 Results



Equilibrium reference points for Norway lobster in GSAs 15-16

5.3.2 Data quality

The time series of catch at age data and landings covered the period 2002-2012 for the Italian side of GSA 16. Data for GSA 15 were available since 2006. A fixed proportion of annual landings and a constant catch at age matrix was assumed for Maltese landings for the period 2002-2005. This assumption was considered to very poorly affect the quality of the input data for the assessment considering that the Maltese landing represents less than 1% of the Italian landing. Fishing effort data for the bottom otter trawl (OTB) fleet in GSA 16 was missing for the year 2010.

5.3.3 Scientific advice

The advice was based on the results of the statistical catch at age (SCA) carried out using the a4a package. The SCA was considered as more suitable in assessing F in the more recent years than the XSA also considering its flexible parameterization of selectivity-at-age. SCA, compared with XSA, returned a lower (30-60%) estimate of F_{bar} combined with higher and apparently, more reliable, estimates of SSB.

F0.1 ≤ 0.20 was adopted as a limit management reference point consistent with high long term yields (FMSY proxy) for the Norway lobster stock in GSAs 15 and 16. Based on the Fcur estimated by the statistical catch at age, the stock was exploited unsustainably in the period 2002-2011. The estimated Fcur was however below F_{MSY} in 2012 indicating that in the this year the stock was exploited sustainably. WGDS recommends the relevant fleets' effort or catches are not increased to maintain fishing mortality below the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings.

7.3.3.1.1 Short term considerations

5.3.3.1.1 State of the spawning stock size

In the period 2002-2012 the SSB, as reconstructed by SCA, showed an increases from 990 t to about 1.892 t in 2012. The survey data showed an increasing trend for spawners since 1994.

5.3.3.1.2 State of recruitment

Recruitment at age 1 varied between 60.5 and 85.4 million in the period 2002-2011 showing an abrupt decline to 19.3 million in 2012.

5.3.3.1.3 State of exploitation

The SCA model estimates similar stock trends compared to the XSA in the final run

5.3.3.2 Management recommendations

The relevant fleets' effort or catches should not be increased to maintain fishing mortality below the proposed F_{MSY} level, in order to avoid future loss in stock productivity and landings. This should be achieved by means of a multi-annual management plan.

6... Draft scientific advice

(Examples in blue)

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	($F_{0.1}$ = 0.2) Limit RP and proxy for F_{MSY}	$F_{2\text{-}7}$=0.15* ($F_{2\text{-}7}$based on 2012 estimate)		Decreasing (2002-2012)	**S**
	Fishing effort					
	Catch					
Stock abundance	Biomass				**O_H**	
	SSB				**O_H**	
Recruitment					No trend	
Final Diagnosis		The stock was subjected to overfishing in 1994-2011 and sustainably exploited in 2012				

6.1... Explanation of codes

Trend categories

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

Stock Status

Based on Fishing mortality related indicators

1) **N - Not known or uncertain** – Not much information is available to make a judgment;
2) **U - undeveloped or new fishery** - Believed to have a significant potential for expansion in total production;
3) **S - Sustainable exploitation**- fishing mortality or effort below an agreed fishing mortality or effort based Reference Point;
4) **IO –In Overfishing status**– fishing mortality or effort above the value of the agreed fishing mortality or effort based Reference Point. An agreed range of overfishing levels is provided;

Range of Overfishing levels based on fishery reference points

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

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

*Fc is current level of F

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

Based on Stock related indicators

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

Empirical Reference framework for the relative level of stock biomass index

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

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

Agreed definitions as per SAC Glossary

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

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