Stock Assessment Form

Demersal species

Reference year:2015

Reporting year:2016

Stock Assessment Form version 1.0 (January 2014)

Uploader: *Silvia Angelini*

Stock assessment form

1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:
Merluccius merluccius	European hake	32
1st Geographical sub-area:	**2nd Geographical sub-area:**	**3rd Geographical sub-area:**
GSA 17	GSA 18	
4th Geographical sub-area:	**5th Geographical sub-area:**	**6th Geographical sub-area:**
1st Country	**2nd Country**	**3rd Country**
Italy	Croatia	Albania
4th Country	**5th Country**	**6th Country**
Montenegro		
Stock assessment method: (direct, indirect, combined, none)		
Combined: survey and SCAA		
Authors:		
Angelini S.[1], Bitetto I.[4], Arneri E.[5], Belardinelli A.[1], Carbonara P.[4], Casciaro L.[4], Ceriola L.[5], Colella S.[1], Croci C.[1], Domenichetti F.[1], Donato F.[1], Facchini M.T.[4]; Ikica Z.[6]; Isajlović I.[2], Kristo R.[7], Lembo G. [4]; Manfredi C.[3], Martinelli M.[1], Milone N. [5]; Morello E.B.[1], Panfili M.[1], Piccinetti C.[3], Santojanni A.[1], Spedicato M.T.[4], Tesauro C.[1], Vrgoč N.[2]		
Affiliation:		
[1] CNR – ISMAR (National Research Council - Institute of Marine Science), Italy [2] Laboratorio di Biologia Marina e Pesca, University of Bologna, Italy [3] Institute of Oceanography and Fisheries, Croatia [4] COISPA Tecnologia & Ricerca, Bari, Italy [5] FAO-AdriaMed, Rome, Italy [6] Institute of Marine Biology, University of Montenegro, Kotor, Montenegro [7] University of Agriculture, Tirana, Albania **Work conducted in the framework of *FAO AdriaMed Regional Project***		

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

The stock of European hake was assumed in the boundaries of the whole Adriatic Sea (GSA 17-18) (Fig. 2.1), as suggested by the genetic results of the MAREA StockMed project that shows a common sub-population of hake throughout the Adriatic Sea. However, project identifies two distinct stock units in the Adriatic Sea, uncorrelated with the GSA units (Fiorentino et al., 2014).

The northern Adriatic Sea is characterized by generally shallow waters, whereas the central part hosts a three consecutive depressions, called Pomo/Jabuka Pits, that reach ca. 270 m in their deepest part.

The Southern Adriatic Sea is characterized by the presence of a deep central depression known as the "South Adriatic Pit" (or Bari Pit) where the seabed reaches a depth of 1,233 m.

The northern and southern portions of the Southern Adriatic Sea feature substantial differences; the first contains a wide continental shelf (the distance between the coastline and a depth of 200 m is around 45 nautical miles) and a very gradual slope; in the second, the isobathic contours are very close, with a depth of 200 m already found at around 8 miles from the Cape of Otranto.

The continental shelf break is at a depth of around 160-200 m and is furrowed by the heads of canyons running perpendicular to the line of the shelf.

The Adriatic Sea, together with the Levant basin, is one of three areas in the Mediterranean where down-welling processes produced by surface cooling lead to the formation of so-called "dense waters", rich in oxygen, which supply the lower levels.

The species depth distribution (Fig. 2.2) ranges between several meters in the coastal area down to 800 m in the South Adriatic Pit (Kirinčić and Lepetić, 1955; Ungaro et al., 1993), though it is most abundant at depths between 100 and 200 m, where the catches are mainly composed of juveniles (Bello et al., 1986; Vrgoč, 2000). In the northern and central part of the Adriatic Sea adults are mainly caught at depths of 100 to 150 m (Vrgoč et al., 2004), whereas in the south Adriatic largest individuals are caught in waters deeper than 200 m and medium-sized fish appear in waters not deeper than 100 m (Ungaro et al., 1993).

The geographical distribution pattern of European hake has been studied in the area using trawl-survey data and geostatistical methods. This species presents the greatest abundance in the central Adriatic Sea in water deeper than 100 meters, whereas the greatest biomass is found in the eastern part of the Adriatic Sea, where the biggest sizes individuals are concentrated (Piccinetti et al., 2012). Nursery areas are located in the central Adriatic Sea, off Gargano promontory and in the southern part of Albanian coasts (Frattini and Paolini, 1995; Lembo et al., 2000; Carlucci et al., 2009) (Fig. 2.3), whereas the spawning grounds are located among the Croatian channels (Fig. 2.4).

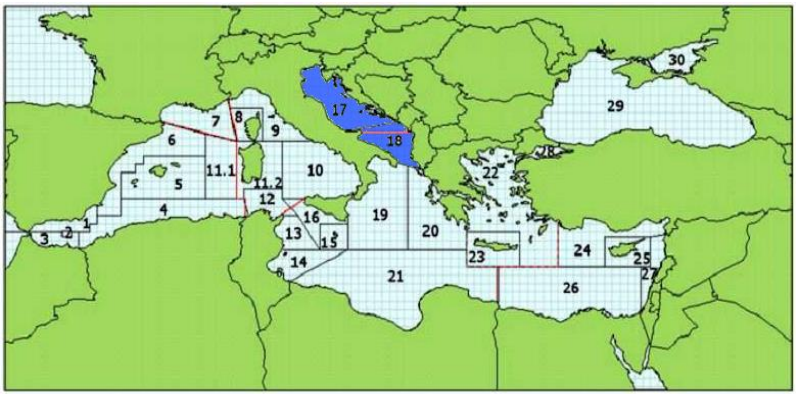

Fig. 2.1 .Geographical location of GSA 17 and 18.

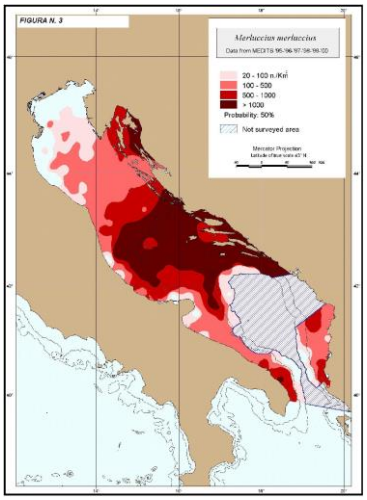

Fig. 2.2 - Distribution map of *Merluccius merluccius* in the Adriatic Sea (Sabatella and Piccinetti, 2005) from Medits Programme

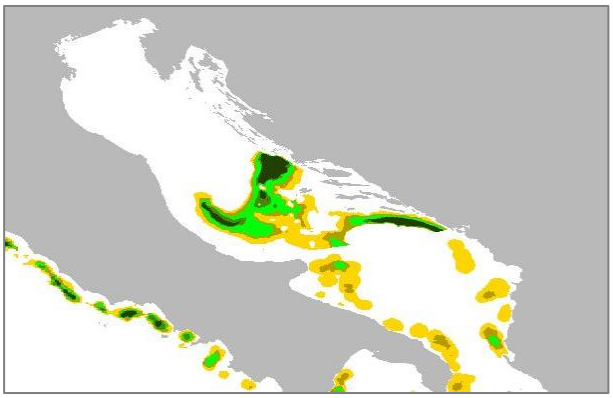

Fig. 2.3 Position of persistent nursery in the GSA 17 and 18 from MEDISEH project

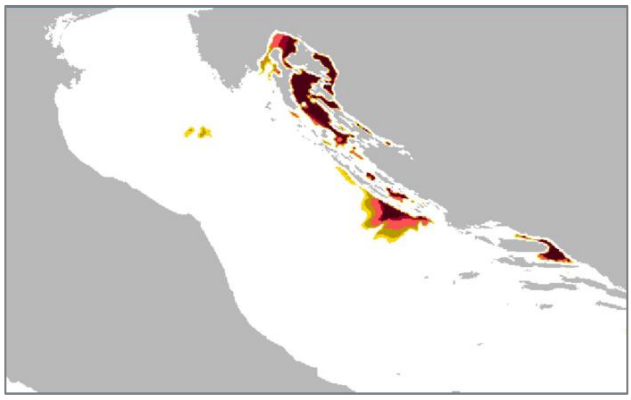

Fig. 2.4 Position of persistent areas of potential spawners in the GSA 17 from MEDISEH project

2.1 Stock unit

2.2 Growth and maturity

European hake can grow to 107 cm (Grubišić, 1959) of total length. The observed maximum lengths of European hake were 93.5 cm for females and 66.5 cm for males both registered during Medits samplings. In the commercial sampling also a female of 93.5 cm length was observed in 2009. However, its usual length in trawl catches is from 10 to 60 cm. This is a long-lived species, it can live more than 20 years. In the Adriatic, however, the exploited stock is mainly composed in number of 0, 1 and 2 year-old individuals.

In the DCF framework the growth has been studied ageing fish by otolith readings using the whole sagitta and thin sections for older individuals. However, the growth parameters used in this assessment come from the literature and specifically the VBGP reported in García-Rodríguez and Esteban (2002) were chosen (Table 2.2-3).

Females attain larger size than males, which grow more slowly after maturation at the age of three or four years. Consequently, the proportion of males in the population is higher in the lower length classes and proportion of females is higher for greater lengths. In the central and northern Adriatic, females already start dominating the population at lengths of about 30 to 33 cm. In trawl catches over 38 to 40 cm, almost all the specimens are females (Vrgoć, 2000).

In the Adriatic sea, European hake spawn throughout the year, but with different intensities. The spawning peaks are in the summer and winter periods (Karlovac, 1965; Županović, 1968; Županović and Jardas, 1986, Županović and Jardas, 1989; Jukić and Piccinetti, 1981; Ungaro *et al.*, 1993). Hake is a partial spawner. Females spawn usually four or five times without ovarian rests. In females in the pre-spawning stage, fish 70 cm long can contain more than 400,000 oocytes (Sarano, 1986). The earliest spawning in the Pomo/Jabuka Pit occurs in winter in deeper water (up to 200 m). As the season progresses into the spring-summer period, spawning occurs in more shallow waters. The recruitment of young individuals into the breeding stock has two different maxima. The first one is in the spring and the second one in the autumn.

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

Somatic magnitude measured (LT, LC, etc)				**Units**	
Sex	**Fem**	**Mal**	**Combined**	**Reproduction season**	**Summer - Winter**
Maximum size observed			107**	**Recruitment season**	Spring - Autumn
Size at first maturity	23.0 – 33.0*	20.00 – 28.00*		**Spawning area**	Eastern Adriatic
Recruitment size to the fishery				**Nursery area**	Pomo / Jabuka Pit

* Županović and Jardas, 1986 ** Grubišić, 1959

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

Age	Natural mortality*	Proportion of matures
0	0.69	0
1	0.29	1
2	0.21	1
3	0.18	1
4	0.16	1
5	0.14	1
6	0.14	1
7	0.13	1
8	0.12	1
9	0.12	1
10	0.12	1

*Prodbiom (Abella *et al.*, 1997)

Table 2.2-3: Growth and length weight model parameters

			Sex			
		Units	**female**	**male**	**Combined**	**Years**
Growth model	**L_∞**				106.8	
	K				0.1	
	t_0				-0.994	
	Data source	García-Rodríguez and Esteban, 2002				
Length weight relationship	**a**				0.0043	
	b				3.2	
	M (scalar)					
	sex ratio (% females/total)	50				

3 Fisheries information

3.1 Description of the fleet

European hake is one of the principal demersal species fished in the Adriatic Sea and it accounts for the highest landings quantity among demersal species. Fishing grounds mostly correspond to the distribution of the stock. The principal gears exploiting this stock are bottom trawls and longlines. Longlines are particularly important in Croatia and in the Italian side of the GSA 18.

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	17	E – Trawlers (12- 24 metres)	03 - Trawls	33 – Demersal shelf species	Hake
Operational Unit 2	HRV	17	E – Trawlers (12- 24 metres)	03 - Trawls	33 – Demersal shelf species	Hake
Operational Unit 3	HRV	17	I - Long line (> 6 metres)	09 - Hooks and Lines	33 – Demersal shelf species	Hake
Operational Unit 4	ITA	18	E – Trawlers (12- 24 metres)	03 - Trawls	33 – Demersal shelf species	Hake
Operational Unit 5	ITA	18	F – Trawlers (>24 metres)	03 - Trawls	33 – Demersal shelf species	Hake
Operational Unit 6	ITA	18	I - Long line (> 6 metres)	09 - Hooks and Lines	33 – Demersal shelf species	Hake
Operational Unit 7	ALB	18	E – Trawlers (12- 24 metres)	03 - Trawls	33 – Demersal shelf species	Hake
Operational Unit 8	ALB	18	D – Trawls (6-12 m)	03 – Trawls	33 – Demersal shelf species	HKE
Operational Unit 9	ALB	18	F – Trawls (>24 m)	03 – Trawls	33 – Demersal shelf species	HKE
Operational Unit 10	MNE	18	E – Trawls (12-24 m)	03 – Trawls	33 – Demersal shelf species	HKE
Operational Unit 11	MNE	18	B – Minor gear with engine (<6 m)	07 – Gillnets and Entangling Nets	33 – Demersal shelf species	HKE
Operational Unit 12	MNE	18	C – Minor gear with engine (6-12 m)	07 – Gillnets and Entangling Nets	33 – Demersal shelf species	HKE

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

Operational Units*	Fleet (n° of boats)*	Catch (T of the species assessed)	Other species caught (names and weight)	Discards (species assessed)	Discards (other species caught)	Effort (units)
ITA 17 E 03 33 - HKE		2024				
HRV 17 E 03 33 - HKE		870				
HRV 17 I 09 33 - HKE		41				
ITA 18 E 03 33 – HKE + ITA 18 F 03 33 - HKE		1700				
ITA 18 I 09 33 - HKE		427				
ALB 18 d 03 33 – HKE + ALB 18 E 03 33 – HKE + ALB 18 F 03 33 – HKE		206				
MNE 18 E 03 33 – HKE		20				
MNE 18 B 03 33 – HKE + MNE 18 C 03 33 - HKE		90				

3.2 *Historical trends*

European hake landings estimated by FishStatJ – GFCM database and DCF data.

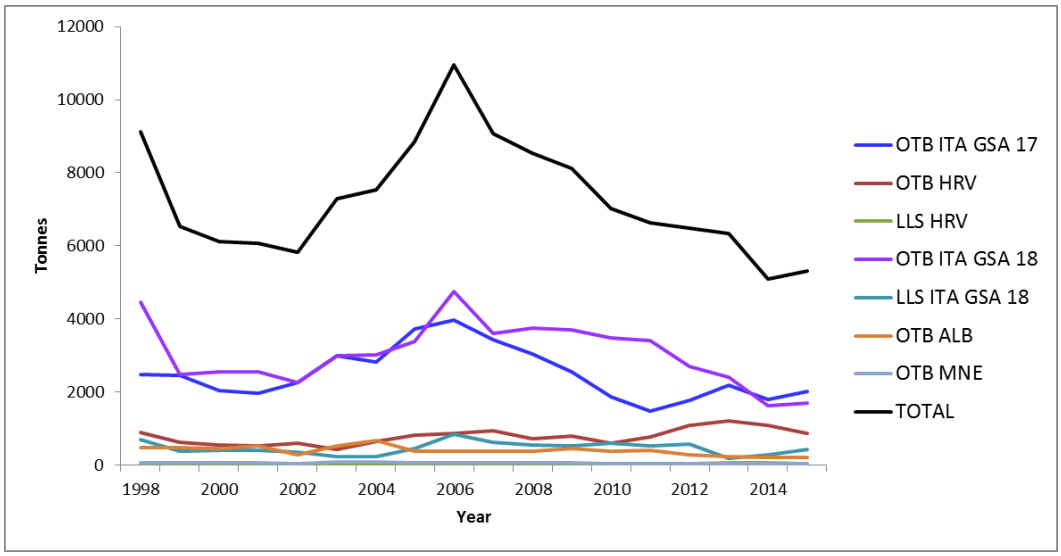

Figure 3.2.1 - Landings of European hake in GSA 17 and 18

3.3 *Management regulations*

Italy

Management regulations are determined by the EU regulations (mainly EC regulation 1967/2006):

- Minimum landing sizes: 20 cm TL for European hake
- Fishing closure for trawling: 30-45 days in summer.
- Codend mesh size of trawl nets: 40 mm (stretched, diamond meshes) till 30/05/2010. From 1/6/2010 the existing nets have been replaced with a cod end with 40 mm (stretched) square meshes or a cod end with 50 mm (stretched) diamond meshes
- Towed gears are not allowed within three nautical miles from the coast or at depths less than 50 m when this depth is reached at a distance less than 3 miles from the coast
- From the 26 of July 2015 to the 26 of July 2016 the Pomo Pit area was closed to the activity of the bottom trawlers

Croatia

Since the accession of Croatia to the EU the 1st of July 2013, the same regulations as in the Italy are implemented. Furthermore the following regulations are applied:

Bottom trawl fisheries is closed one and half NM from the coast and island in inner sea, 2 NM around island on the open sea, and 3 NM about several island in the central Adriatic. For vessel smaller than 15 meters, according derogation in sea deeper than 50 meters bottom trawl fisheries is forbidden till 1NM of the coast. Bottom trawl fishery is closed also in the majority of channel area and bays. About 1/3 of the territorial waters is closed for bottom trawl fisheries over whole year and additionally 10% is closed from 100-300 days per years. Minimum mesh size on the bottom trawl net was 20 mm ("knot to knot") in the open sea, and 24 mm ("knot to knot") in the inner sea. Recently, mesh site regulation is according EC 1967/2006 (ie. 40 mm square or 50 mm diamond).

Montenegro

In Montenegro, management regulations are based on technical regulations, such as mesh size (Official Gazette of Montenegro, 8/2011), including the minimum landing sizes (Official Gazette of Montenegro, 8/2011), and a regulated number of fishing licenses and area limitation (no–fishing zone up to 3 NM from the coastline or 8 NM for trawlers of 24+ m LOA). Currently there are no MPAs or fishing bans in Montenegrin waters.

Mesh size in Montenegro is according to the EC 1967/2006 (ie. 40 mm square or 50 mm diamond).

The landing data for Montenegro used in assesments are estimates, based on collecting data from a small number of vessels, and then raised to the total fleet in order to obtain the yearly estimate. Current national data collection in Montenegro is based on different methods (used by different agencies, namely, Statistical office of Montenegro – MONSTAT and the Ministry of agriculture and rural development, Department for agriculture statistics) which are not fully compliant with the requirements of the EU DCF, and are considered incomplete and not suitable for realistic analyses.

Albania

In Albania, a new law "On fishery" has now been approved, repealing the Law n. 7908. The new law is based on the main principles of the CFP, it reflects Reg. 1224/2009 CE ; Reg.1005/2008 CE; Reg. 2371/2002 CE; Reg. 1198/2006 CE; Reg. 1967/2006 CE; Reg. 104/2000; Reg. 1543/2000 as well as the GFCM recommendations. The legal regime governing access to marine resources is being regulated by a licensing system. Regarding conservation and management measures, minimum legal sizes and minimum mesh sizes is those reflected in the CE Regulations. Albania has already an operational vessel register system. It is forbidden to trawl at less than 3 nautical miles (nm) from the coast or inside the 50m isobath when this distance is reached at a smaller distance from the shore.

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	$F_{0.1}$	0.16			Reference: EWG 15-16
Y					
CPUE					
Index of Biomass at sea					

4 Fisheries independent information

4.1.1 MEDITS SURVEY - Brief description of the direct method used

European Union funded the MEDITS (MEDiterranean International Trawl Survey) survey in 1994. At the beginning only EU members (Italy, Spain, French and Greece) participated at this program, but from 1996 also Albania, Croatia and Slovenia joined this activity. This survey is included in the Data Collection Framework and it takes place every year during springtime. Its methodological sampling is common to all the countries involved in this project and was defined by Bertrand et al. (2002). Stations were selected on the basis of a stratified scheme with random selection of stations in every stratum (10-50m; 50-100m; 100-200m; 200-500m and over 500m). The number of stations in each stratum is proportional to the surface of the stratum. The sampling gear is a bottom trawl made of four panels, called GOC 73 bottom trawl made of four panels.

For this assessment the time series considered goes from year 1998 to year 2015; three survey series were taken in account: 1) Italy GSA 17 and Slovenia, 2) Croatia and 3) GSA 18.

Abundance and biomass indexes from MEDITS survey were computed using AtrIS software (Gramolini et al., 2005) which also allow drawing GIS maps of the spatial distribution of the stock, spawning females and juveniles. The abundance and biomass indices were calculated through stratified means (Cochran, 1953; Saville, 1977). This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum area in the GSA 17:

$Yst = \Sigma (Yi*Ai) / A$

$V(Yst) = \Sigma (Ai^2 * si^2 / ni) / A^2$

Where:

A=total survey area

Ai=area of the i-th stratum

si=standard deviation of the i-th stratum

ni=number of valid hauls of the i-th stratum

n=number of hauls in the GSA

Yi=mean of the i-th stratum

Yst=stratified mean abundance

V(Yst)=variance of the stratified mean

The variation of the stratified mean is then expressed as the 95 % confidence interval: Confidence interval = Yst ± t(student distribution) * V(Yst) / n

4.1.2 MEDITS ITA AND SLO GSA 17

Direct methods: trawl based abundance indices

Table 4.1.2-1: Trawl survey basic information

Survey	MEDITS	**Trawler/RV**	Andrea
Sampling season	Spring - Summer		
Sampling design	Random		
Sampler (gear used)	Trawl		
Cod –end mesh size as opening in mm	20		
Investigated depth range (m)	0 – 500		

Table 4.1.2-2: Trawl survey sampling area and number of hauls - MEDITS

Year	Total surface (km^2)	Trawlable surface (km^2)	Swept area (km^2)	Number of hauls
1998	59584			88
1999	59584			86
2000	60534			86
2001	60534			88
2002	60534			121
2003	60534			122
2004	60534			120
2005	59400			120
2006	59584			122
2007	59584			130
2008	59584			123
2009	59584			123
2010	59584			122
2011	59584			122
2012	59584			122
2013	59584			182
2014	59584			182
2015	59584			182

Table 4.1.2-3: Trawl survey abundance and biomass results - MEDITS

Depth Stratum	Years	kg per km²	CV or other	N per km²	CV or other
	1998	22.17	0.11	593.05	0.14
	1999	33.36	0.12	625.26	0.17
	2000	19.86	0.13	636.86	0.18
	2001	18.10	0.08	691.42	0.13
	2002	24.39	0.07	887.88	0.09
	2003	17.98	0.07	542.11	0.12
	2004	27.43	0.07	935.25	0.10
	2005	34.60	0.12	2038.00	0.17
	2006	33.49	0.07	1113.04	0.12
	2007	28.33	0.06	774.86	0.07
	2008	31.53	0.08	847.01	0.11
	2009	20.41	0.09	259.38	0.09
	2010	12.58	0.10	250.13	0.13
	2011	14.25	0.09	338.84	0.10
	2012	13.06	0.09	342.62	0.16
	2013	23.30	0.09	339.71	0.15
	2014	22.95	0.07	446.09	0.08
	2015	13.23	0.07	314.91	0.10

Direct methods: trawl based Recruitment analysis

Table 4.1.2-4: Trawl surveys; recruitment analysis summary

Survey	**MEDITS**	**Trawler/RV**	**Andrea**
Survey season		Spring - Summer	
Cod –end mesh size as opening in mm		20	
Investigated depth range (m)		0 – 500	
Recruitment season and peak (months)		May – June – October - November	
Age at fishing-grounds recruitment		0	
Length at fishing-grounds recruitment		3	

Table 4.1.2-5: Trawl surveys; recruitment analysis results - MEDITS

Years	Area in km²	N of recruit per km²	CV or other
1998		498.41	0.15
1999		444.60	0.20
2000		580.52	0.20
2001		622.33	0.15
2002		806.51	0.10
2003		478.65	0.14
2004		828.27	0.11
2005		1941.62	0.18
2006		980.95	0.14
2007		674.12	0.08
2008		724.73	0.12
2009		159.60	0.12
2010		153.15	0.11
2011		254.89	0.13
2012		293.76	0.19
2013		247.18	0.18
2014		344.95	0.10
2015		275.03	0.12

Recruits were estimated on the base of the LFD observed from the survey (0 – 20 cm) (Fig. 4.1.2-1). Recruits inhabit the entire Adriatic, with exception for the northernmost part of the basin and particularly abundant in the Central Adriatic Sea and in Croatian waters (Fig. 2.4).

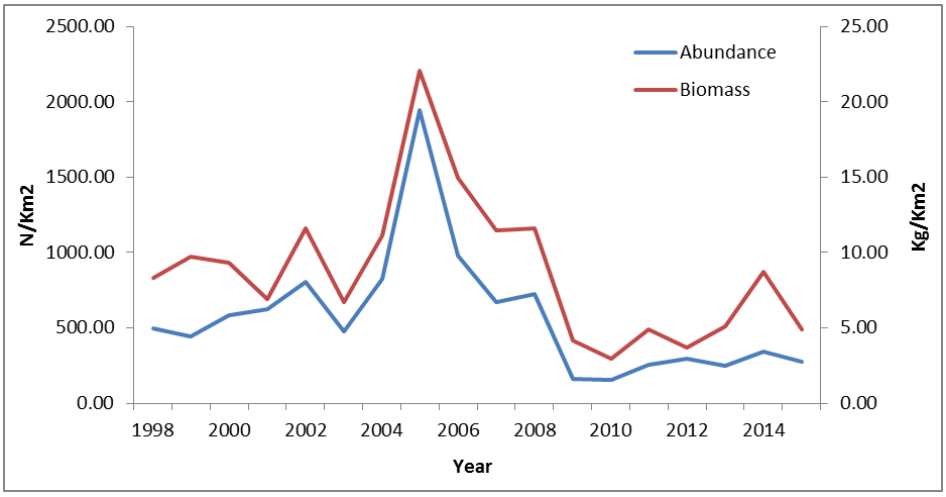

Fig. 4.1.2-1 Abundance and biomass indices of hake obtained from MEDITS surveys

Direct methods: trawl based Spawner analysis

Table 4.1.2-6: Trawl surveys; spawners analysis summary

Survey	**MEDITS**	**Trawler/RV**	**Andrea**
Survey season			Spring - Summer
Investigated depth range (m)			0 – 500
Spawning season and peak (months)			June – July – January – February

Table 4.1.2-7: Trawl surveys; spawners analysis results - MEDITS

Surveys	Area in km²	N (N of individuals) of spawners per km²	CV	SSB per km²	CV
1998		3.07	0.34	4.34	0.39
1999		6.07	0.21	12.32	0.22
2000		3.80	0.37	5.74	0.25
2001		2.60	0.23	5.60	0.23
2002		2.30	0.22	5.17	0.23
2003		2.12	0.21	4.95	0.21
2004		3.37	0.29	7.07	0.32
2005		2.04	0.36	4.75	0.37
2006		4.68	0.23	8.41	0.21
2007		4.35	0.18	8.35	0.16
2008		6.51	0.21	11.25	0.20
2009		3.97	0.19	7.90	0.19
2010		2.82	0.24	4.38	0.20
2011		2.92	0.20	5.41	0.19
2012		2.84	0.20	6.09	0.19
2013		4.87	0.16	9.33	0.14
2014		3.35	0.18	5.53	0.16
2015		3.77	0.18	6.02	0.14

Figure 4.1.2-2 shows the trends of abundance and biomass of spawners (individuals ≥ 35 cm). Maps shows that the spawners aggregates in the Central Adriatic, particularly in the Pomo/Jabuka Pit area and in Croatian waters (Fig. 2.3).

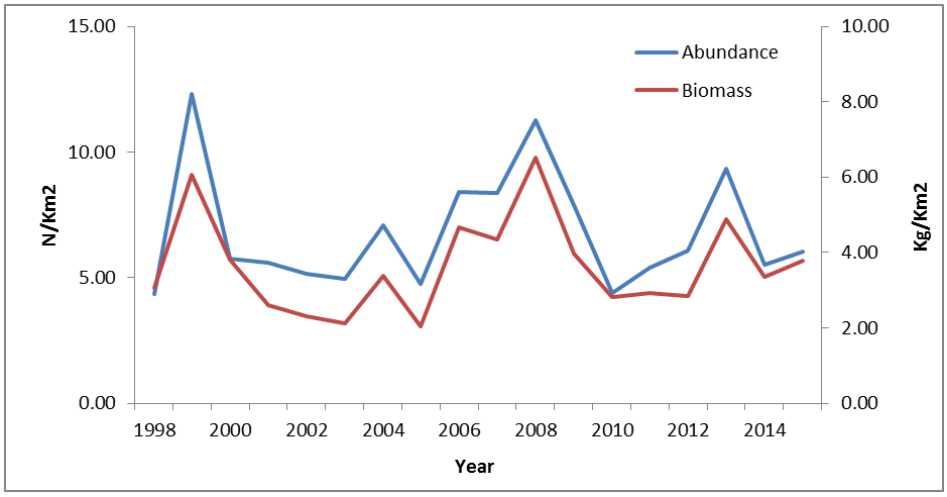

Fig. 4.1.2-2 Abundance and biomass indices of hake spawners obtained from MEDITS surveys

4.1.3 MEDITS CROATIA

Direct methods: trawl based abundance indices

Table 4.1.3-1: Trawl survey basic information

Survey	MEDITS	**Trawler/RV**	Andrea / Bios
Sampling season	Spring - Summer		
Sampling design	Random		
Sampler (gear used)	Trawl		
Cod –end mesh size as opening in mm	20		
Investigated depth range (m)	0 – 500		

Table 4.1.3-2: Trawl survey sampling area and number of hauls - MEDITS

Year	Total surface (km^2)	Trawlable surface (km^2)	Swept area (km^2)	Number of hauls
1998	31727			50
2000	31727			47
2001	31727			48
2002	31727			59
2003	31727			59
2004	31727			61
2005	31727			59
2006	31727			59
2007	31727			61
2008	31727			59
2009	31727			60
2010	31727			60
2011	31727			61
2012	31727			60
2013	31727			59
2014	31727			56
2015	31727			65

Table 4.1.3-3: Trawl survey abundance and biomass results - MEDITS

Depth Stratum	Years	kg per km²	CV or other	N per km²	CV or other
	1998	66.028	0.200	1154.149	0.137
	2000	33.018	0.106	749.449	0.112
	2001	44.089	0.133	887.231	0.181
	2002	55.269	0.128	1172.241	0.187
	2003	51.248	0.109	972.440	0.105
	2004	55.626	0.119	1126.081	0.099
	2005	66.063	0.096	1778.223	0.125
	2006	89.168	0.123	1713.346	0.110
	2007	63.883	0.130	1327.673	0.110
	2008	61.586	0.117	1445.093	0.160
	2009	47.199	0.140	608.547	0.135
	2010	28.983	0.124	603.742	0.119
	2011	30.502	0.120	603.991	0.108
	2012	43.217	0.093	1252.722	0.158
	2013	51.273	0.133	773.981	0.122
	2014	45.234	0.181	1006.351	0.287
	2015	44.016	0.098	916.138	0.129

Direct methods: trawl based Recruitment analysis

Table 4.1.3-4: Trawl surveys; recruitment analysis summary

Survey	**MEDITS**	**Trawler/RV**	**Andrea / Bios**
Survey season		Spring - Summer	
Cod –end mesh size as opening in mm		20	
Investigated depth range (m)		0 – 500	
Recruitment season and peak (months)		May – June – October - November	
Age at fishing-grounds recruitment		0	
Length at fishing-grounds recruitment		3	

Table 4.1.3-5: Trawl surveys; recruitment analysis results - MEDITS

Years	Area in km²	N of recruit per km²	CV or other
1998		812.330	0.142
2000		580.900	0.136
2001		650.500	0.233
2002		886.100	0.232
2003		733.730	0.132
2004		825.100	0.121
2005		1388.980	0.152
2006		1295.980	0.122
2007		1030.840	0.131
2008		1175.000	0.183
2009		342.900	0.137
2010		464.690	0.148
2011		454.020	0.123
2012		1071.430	0.181
2013		497.290	0.135
2014		397.750	0.144
2015		716.400	0.154

Recruits were estimated on the base of the LFD observed from the survey (0 – 20 cm) (Fig. 4.1.3-1). Recruits inhabit the entire Adriatic, with exception for the northernmost part of the basin and particularly abundant in the Central Adriatic Sea and in Croatian waters (Fig. 2.3).

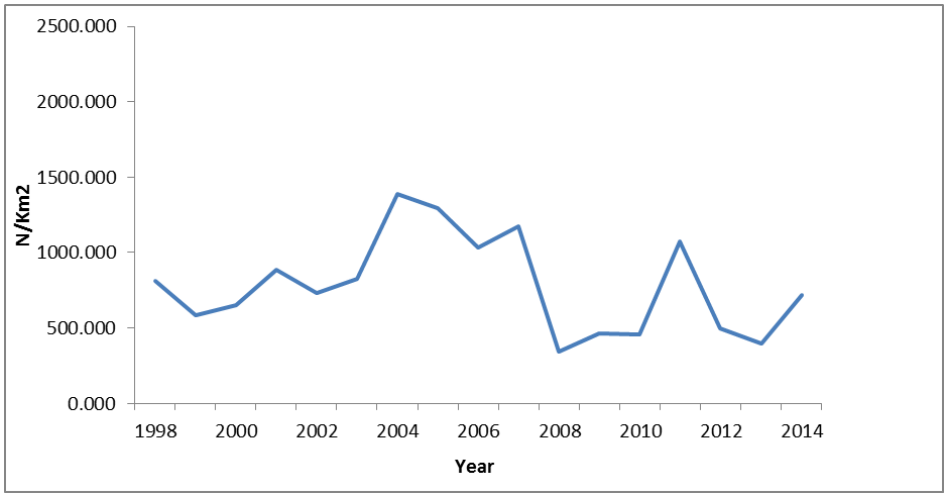

Fig. 4.1.3-1 Abundance and biomass indices of hake obtained from MEDITS surveys

Direct methods: trawl based Spawner analysis

Table 4.1.3-6: Trawl surveys; spawners analysis summary

Survey	**MEDITS**	**Trawler/RV**	**Andrea / Bios**
Survey season			Spring - Summer
Investigated depth range (m)			0 – 500
Spawning season and peak (months)			June – July – January – February

Table 4.1.3-7: Trawl surveys; spawners analysis results - MEDITS

Surveys	Area in km²	N (N of individuals) of spawners per km²	CV
1998		19.720	0.387
2000		9.970	0.314
2001		13.260	0.239
2002		20.680	0.194
2003		12.890	0.158
2004		17.740	0.200
2005		16.730	0.198
2006		31.890	0.185
2007		28.130	0.197
2008		30.070	0.202
2009		18.500	0.238
2010		13.830	0.228
2011		8.590	0.243
2012		17.880	0.152
2013		20.090	0.151
2014		17.580	0.200
2015		28.180	0.157

Figure 4.1.3-2 shows the trends of abundance and biomass of spawners (individuals ≥ 35 cm). Maps shows that the spawners aggregates in the Central Adriatic, particularly in the Pomo/Jabuka Pit area and in Croatian waters (Fig. 2.4).

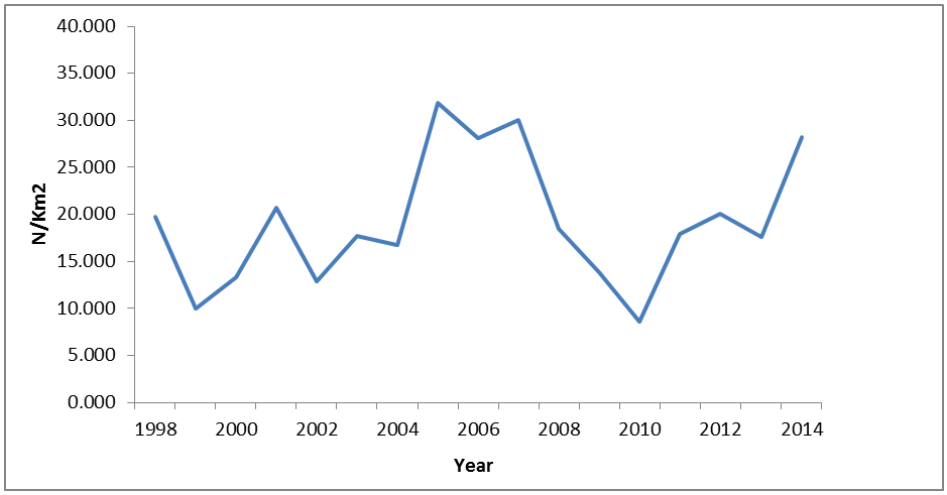

Fig. 4.1.3-2 Abundance and biomass indices of hake spawners obtained from MEDITS surveys

4.1.4 MEDITS GSA 18

Direct methods: trawl based abundance indices

Table 4.1.4-1: Trawl survey basic information

Survey	MEDITS	**Trawler/RV**	PEC
Sampling season	Summer		
Sampling design	Stratified sampling design with the number of hauls proportionate to the strata surface		
Sampler (gear used)	GOC 73		
Cod –end mesh size as opening in mm	20		
Investigated depth range (m)	0 – 800		

Table 4.1.4-2: Trawl survey sampling area and number of hauls - MEDITS

Stratum	**Total surface (km^2)**	**Trawlable surface (km^2)**	**Swept area (km^2)**	**Number of hauls**
10 – 50 m	3430			12
50 – 100 m	6435			20
100 – 200 m	9664			31
200 – 500 m	4761			13
500 – 800 m	4718			14
Total (10 – 800 m)	29008			90

Table 4.1.4-4: Trawl survey abundance and biomass results - MEDITS

Depth Stratum	Years	kg per km²	CV or other	N per km²	CV or other
	1998			431.663	0.11
	1999			292.687	0.129
	2000			503.129	0.0996
	2001			400.011	0.088
	2002			730.811	0.117
	2003			417.452	0.08
	2004			657.500	0.186
	2005			1586.058	0.182
	2006			641.128	0.224
	2007			532.420	0.097
	2008			1090.621	0.124
	2009			781.782	0.092
	2010			599.551	0.142
	2011			413.604	0.14
	2012			1441.646	0.137
	2013			556.180	0.129
	2014			508.292	0.157
	2015			168.560	0.188

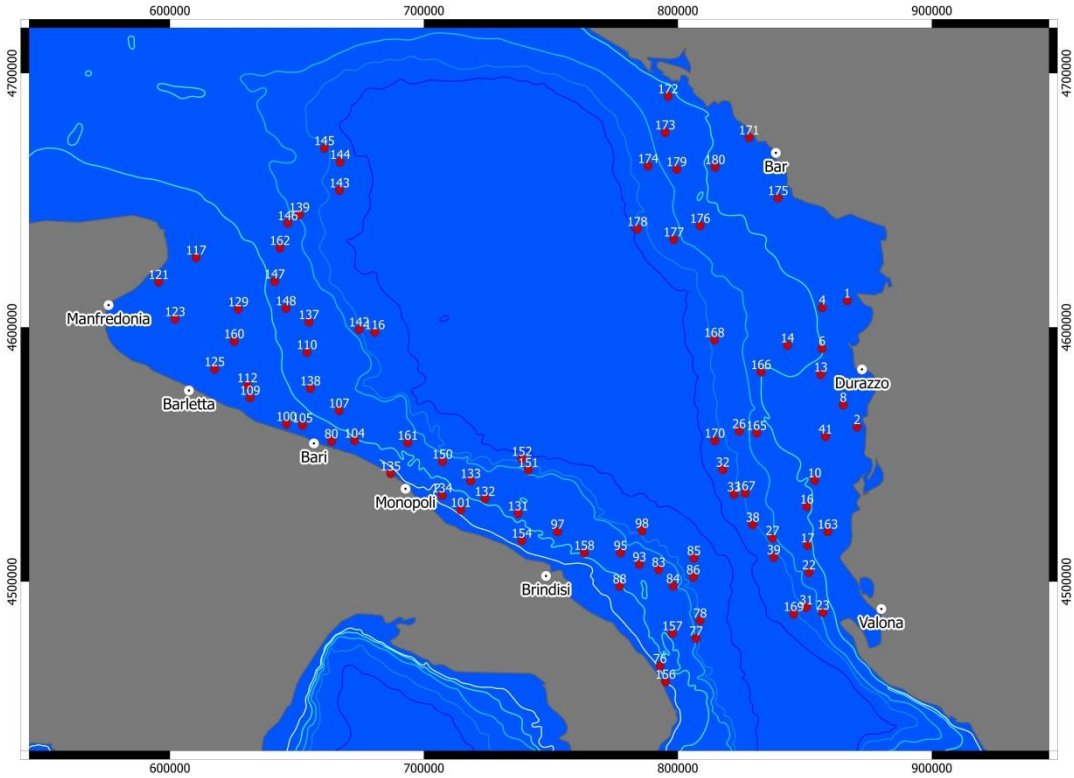

Fig. 4.1.4-1. Map of MEDITS haul positions in the GSA 18

Direct methods: trawl based Recruitment analysis

Table 4.1.4-4: Trawl surveys; recruitment analysis summary

Survey	**MEDITS**	**Trawler/RV**	
Survey season		Summer	
Cod –end mesh size as opening in mm		20	
Investigated depth range (m)		10-800	
Recruitment season and peak (months)		winter and late spring	
Age at fishing-grounds recruitment			
Length at fishing-grounds recruitment			

Table 3.4-5: Trawl surveys; recruitment analysis results - MEDITS

Years	Area in km²	N of recruit per km²	CV or other
1998	29008	329.893	0.125
1999	29008	200.058	0.102
2000	29008	411.995	0.137
2001	29008	310.353	0.090
2002	29008	654.332	0.201
2003	29008	336.893	0.215
2004	29008	551.016	0.258
2005	29008	1482.793	0.102
2006	29008	511.778	0.147
2007	29008	445.611	0.104
2008	29008	969.831	0.156
2009	29008	610.656	0.175
2010	29008	497.239	0.166
2011	29008	338.590	0.159
2012	29008	1357.172	0.166
2013	29008	462.152	0.223
2014	29008	442.224	0.171
2015	29008	116.846	0.284

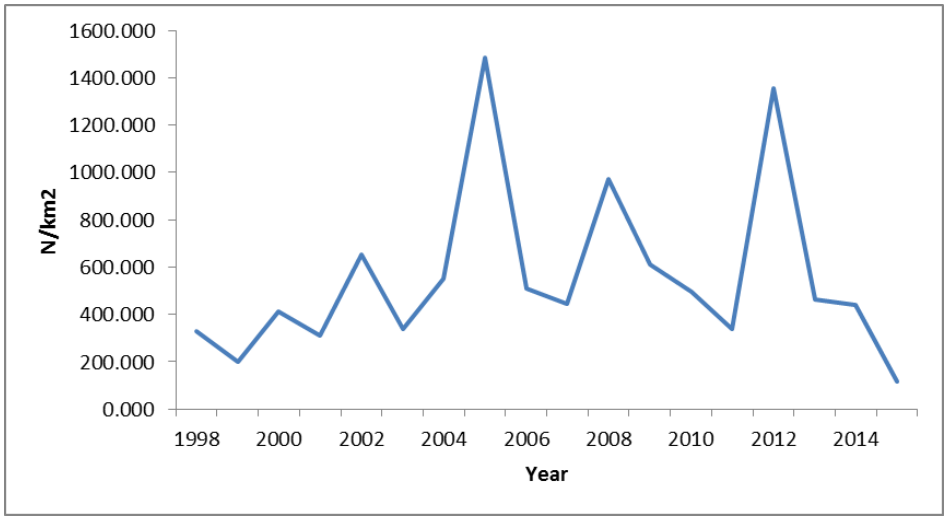

Fig. 4.1.4-2 Recruitment index of hake obtained from MEDITS surveys in GSA 18

Direct methods: trawl based Spawner analysis

Table 4.1.4-6: Trawl surveys; spawners analysis summary

Survey	**MEDITS**	**Trawler/RV**	
Survey season			Summer
Investigated depth range (m)			10-800
Spawning season and peak (months)			Summer and winter

Table 4.1.4-7: Trawl surveys; spawners analysis results - MEDITS

Surveys	Area in km²	N (N of individuals) of spawners per km²	CV
1998	29008	5.770	0.214
1999	29008	5.323	0.199
2000	29008	4.659	0.199
2001	29008	5.088	0.182
2002	29008	3.574	0.283
2003	29008	5.623	0.239
2004	29008	5.013	0.236
2005	29008	12.815	0.173
2006	29008	10.901	0.165
2007	29008	10.127	0.211
2008	29008	7.543	0.254
2009	29008	17.171	0.129
2010	29008	10.240	0.162
2011	29008	6.920	0.165
2012	29008	7.015	0.196
2013	29008	11.706	0.182
2014	29008	13.177	0.212
2015	29008	7.074	0.165

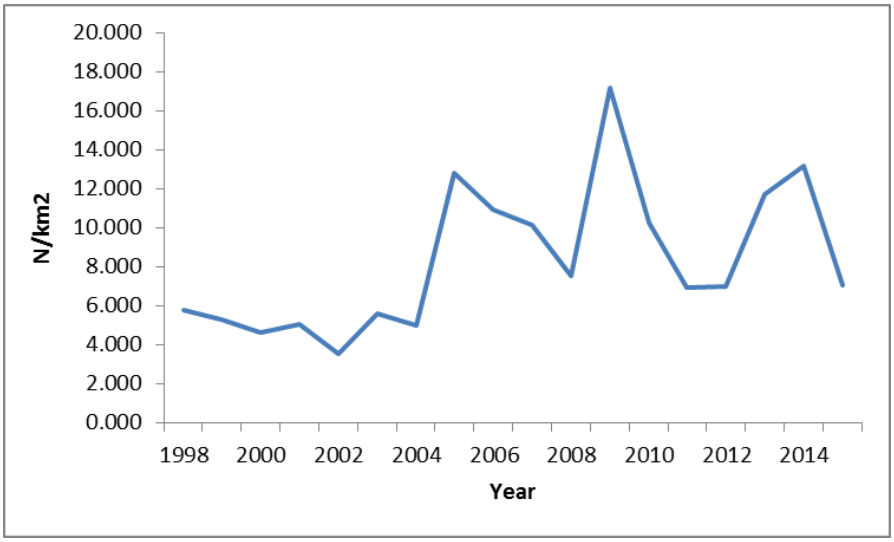

Fig. 4.1.4-3 Spawners index of hake obtained from MEDITS surveys in GSA 18

4.2.2 Spatial distribution of the resources

(see point 2)

4.2.3 Historical trends

The MEDITS trawl surveys provide data either on hake total abundance and biomass as well as on important biological events (recruitment, spawning).

Figure 4.2.3-1 shows the abundance indices of hake obtained from 1998 to 2015. The tree surveys (Medits ITA GSA 17, Medits HRV GSA 17 and MEDITS ITA GSA 18) show a generally fluctuating decreasing trend with a peak in 2005, whereas the 2012 peak is highlighted only by the Medits survey in GSA 18 and in the Croatia waters.

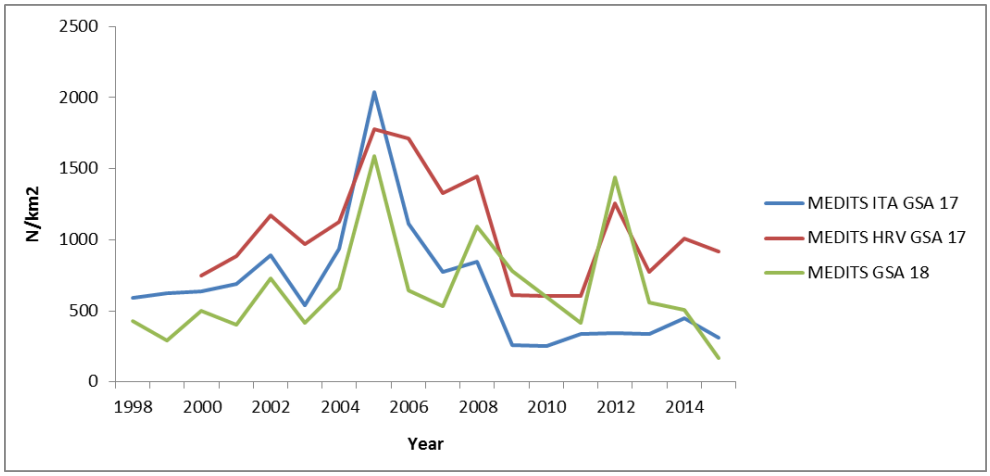

Fig. 4.2.3-1 Abundance and biomass indices of hake obtained from MEDITS survey

5 Ecological information

5.1 Protected species potentially affected by the fisheries

5.2 Environmental indexes

6 Stock Assessment

6.1 Statistical catch at age (SS3 model – Italy and Croatia)

6.1.1 Model assumptions

Stock Synthesis 3 (SS3) provides a statistical framework for the calibration of a population dynamics model using fishery and survey data. It is designed to accommodate both population age and size structure data and multiple stock sub-areas can be analyzed. It uses forward projection of population in the "statistical catch-at-age" (hereafter SCAA) approach. SCAA estimates initial abundance at age, recruitments, fishing mortality and selectivity. Differently from VPA based approaches (e.g. by XSA) SCAA calculates abundance forward in time and allows for errors in the catch at age matrices. Selectivity has been generated as age-specific by fleet, with the ability to capture the major effect of age-specific survivorship. The overall model contains subcomponents which simulate the population dynamics of the stock and fisheries, derive the expected values for the various observed data, and quantify the magnitude of difference between observed and expected data. Some SS3 features include ageing error, growth estimation, spawner-recruitment relationship, movement between areas; in the present assessment such features are not summarized in the results. The ADMB C++ software in which SS is written searches for the set of parameter values that maximize the goodness-of-fit, then calculates the variance of these parameters using inverse Hessian methods. The F at age has been estimated from the Z at age estimated by the model (subtracting M at age used in input); then, the Fbar has been estimated as average on ages 1 to 6.

The model allowed to specify the different source of data, providing different uncertainties estimates for each data set. In order to facilitate the convergence of the model a higher number of ages has been employed for natural mortality, fecundity and weight at age.

The SS3 analyses has been carried out considering the following seven fleets:

1. Italian bottom trawl GSA 17;
2. Croatian bottom trawl;
3. Croatian longlines;
4. Italian bottom trawl GSA 18;
5. Italian longlines GSA 18;
6. Montenegrin bottom trawl and nets;
7. Albania bottom trawls.

The length frequency distributions for each years and gear are shown in figures from 6.1.3.1 to 6.1.3.6, whereas survey information are summarized in figures from 6.1.3.7 to 6.1.3.11.

6.1.2 Scripts

All the input files and the software are available in the share point.

6.1.3 Input data and Parameters

Hake has a specific distribution in GSA 17, as showed in figures 2.2, 2.3 and 2.4, that has to be represented also by the length frequency distributions. This representation was obtained carrying on two work simultaneously:

1) Thanks to the availability of spatial information about the movement of fishing vessels (VMS data), it was possible to determine the most productive areas in the Adriatic Sea as well as the harbors accounting for the highest landings (Russo et al., submitted). The Pomo Pit area resulted the most productive zone in the Adriatic Sea both for hake and Norway lobster, whereas the harbors accounting for the highest hake landings resulted to be Termoli and San Benedetto del Tronto. Within this work the Adriatic Sea were divided in different fishing grounds and it was possible to determine the quantity of landings come from each fishing ground. Based on these estimates, official landing data were divided in landings come from the Pomo pit area (defined as 'Pomo') and landings come from the rest of the GSA 17 (defined as 'No Pomo').

2) Thanks to the availability of spatial information about each DCF sample, it was possible to allocate each LFD in each fishing ground; those were then grouped in LFDs come from the 'Pomo' area and LFDs come from the 'No Pomo' area. If in some years landings were presented for a specific area, but no LFD data were displayed for that area, the LFD comes from the same quarter of the closest year was reproduced in the missing years. Finally, LFDs were expanded to the total landings of GSA 17 (see point 1) taking in account quarters, years and areas.

Spatial information are available from year 2009, thus the Italian LFD for GSA 17 included in this work go from year 2009 to 2015 (Fig. 6.1.3.1).

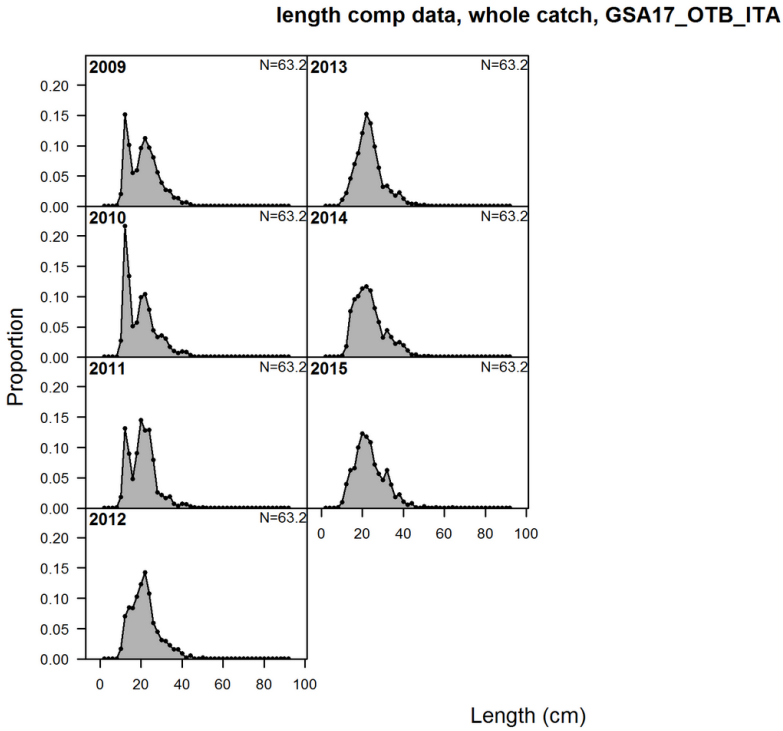

Figure 6.1.3.1 – Length frequency distribution for the Italian bottom trawlers in GSA 17

Croatian territorial waters are divided by fishing zone and the DCF sample is already organized taking in account these differences. The resulting LFDs are showed in figure 6.1.3.2 and 6.1.3.3.

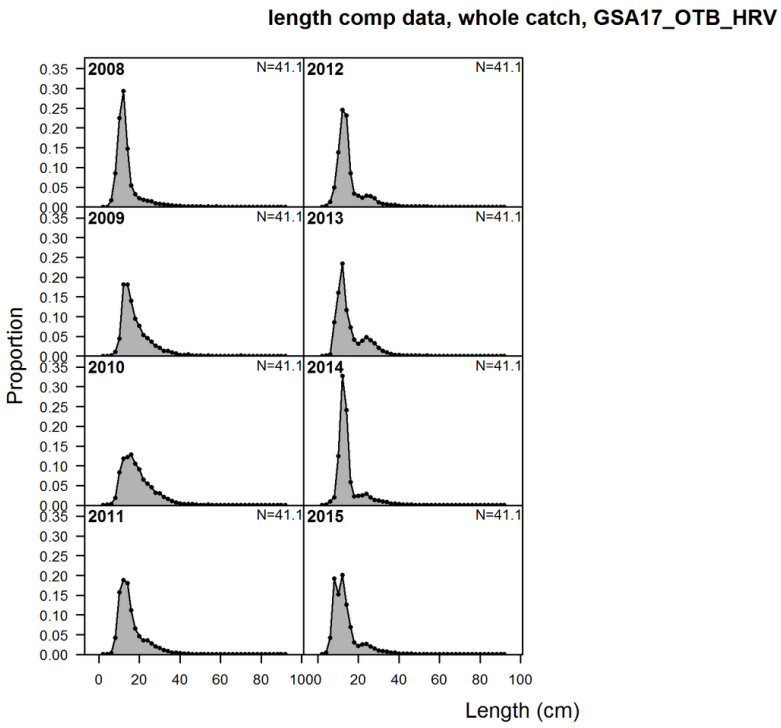

Figure 6.1.3.2 – Length frequency distribution for the Croatian bottom trawlers

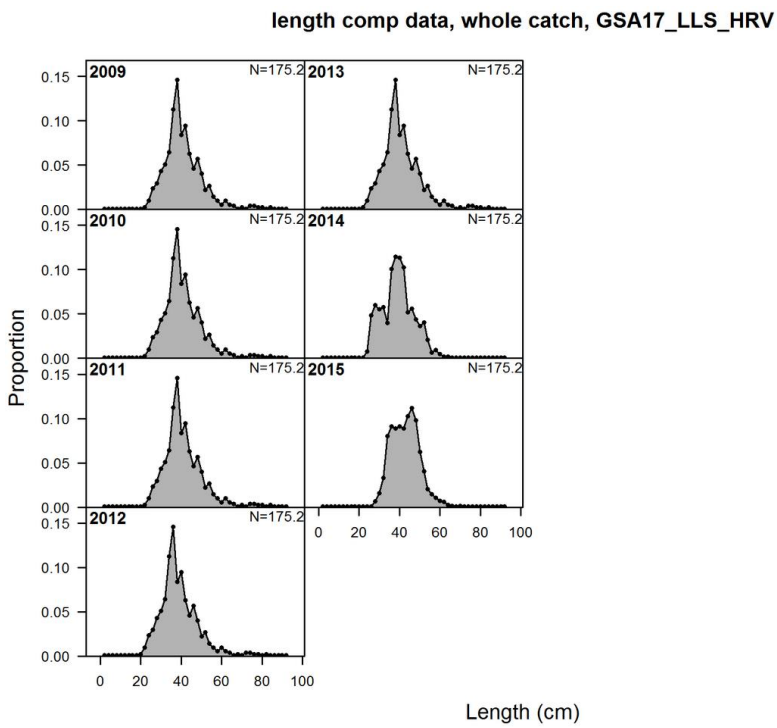

Figure 6.1.3.3 – Length frequency distribution for the Croatian longlines

The following figures show the length frequency distributions for the Italian bottom trawlers in GSA 18 (Fig. 6.1.3.4), the Italian longlines in GSA 18 (Fig. 6.1.3.5) and for the bottom trawls of Montenegro (Fig. 6.1.3.6).

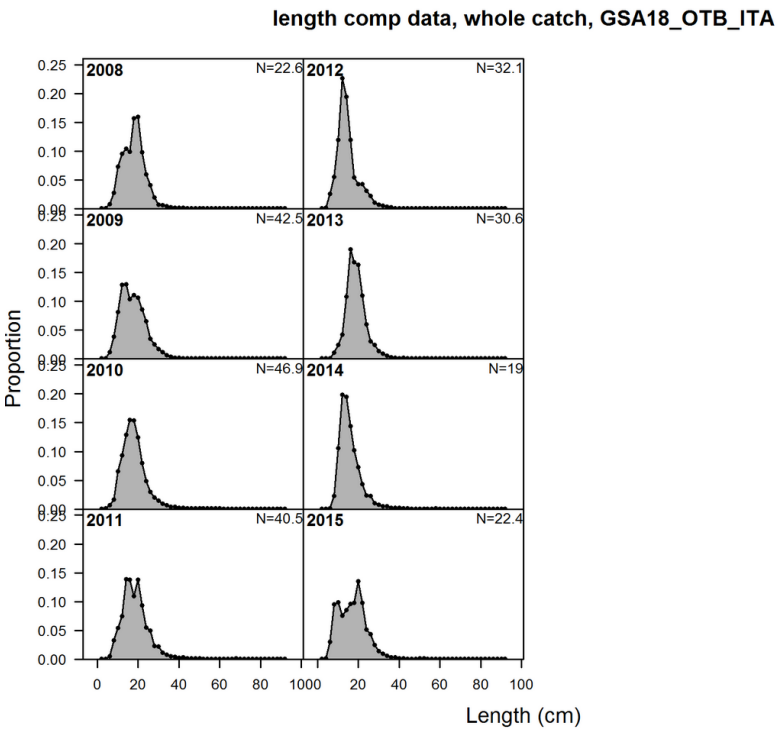

Figure 6.1.3.4 – Length frequency distribution for the Italian bottom trawlers in GSA 18

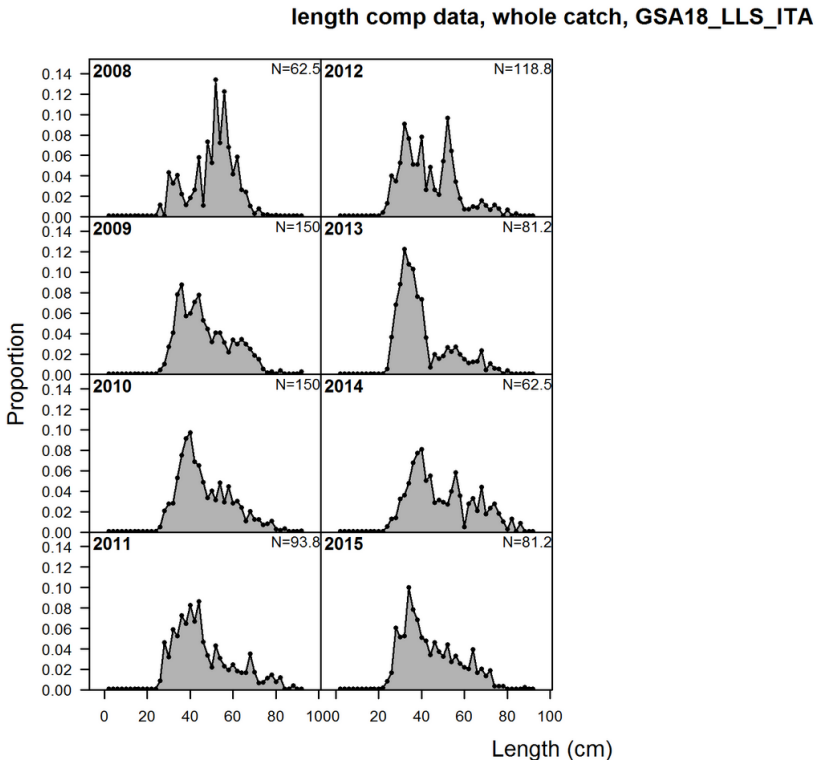

Figure 6.1.3.5 – Length frequency distribution for the Italian longlines in GSA 18

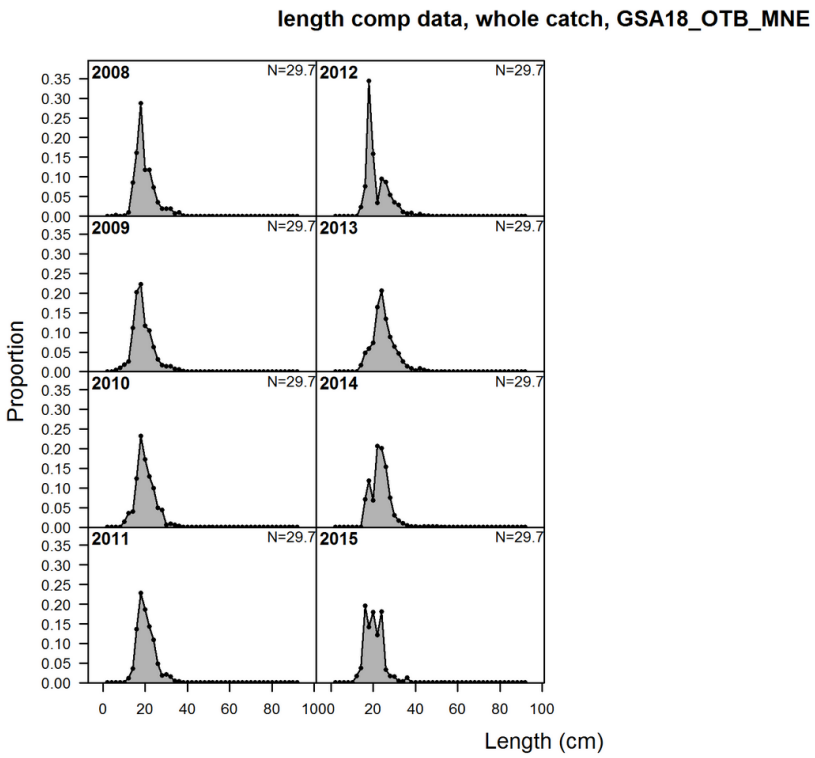

Figure 6.1.3.6 – Length frequency distribution for the bottom trawlers of Montenegro.

Landing and length frequency distributions from Albania are currently under revision, for this reason LFDs were not considered in this assessment. However, the last version of the landing data made available from the last GSA 18 hake stock assessment (GFCM 2015) was included in this assessment.

Both abundance indexes (Figure 6.1.3.7, 6.1.3.8 and 6.1.3.9) and length frequency distributions from MEDITS survey are included in this model.

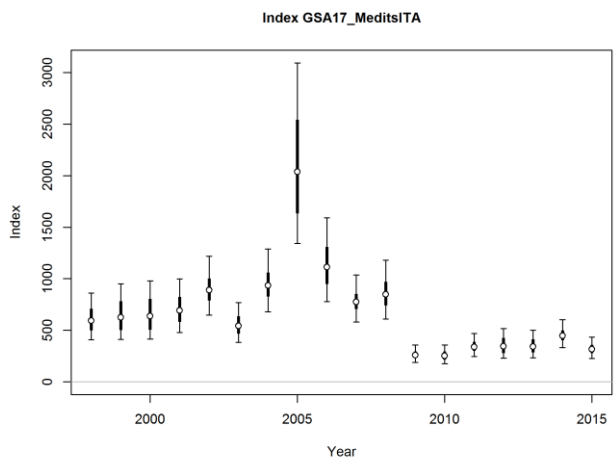

Figure 6.1.3.7 Abundance index – MEDITS survey ITA GSA 17

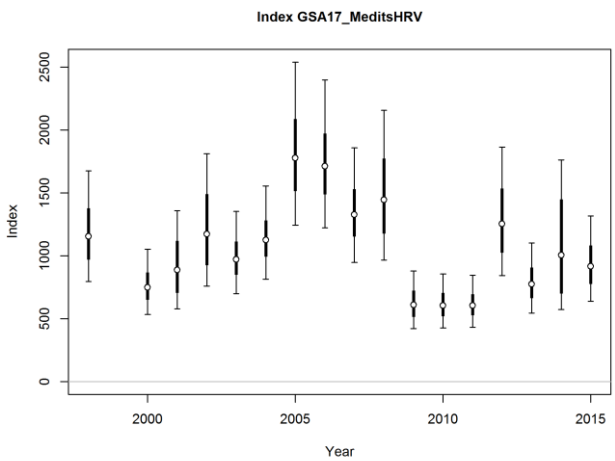

Figure 6.1.3.8 Abundance index – MEDITS survey HRV GSA 17

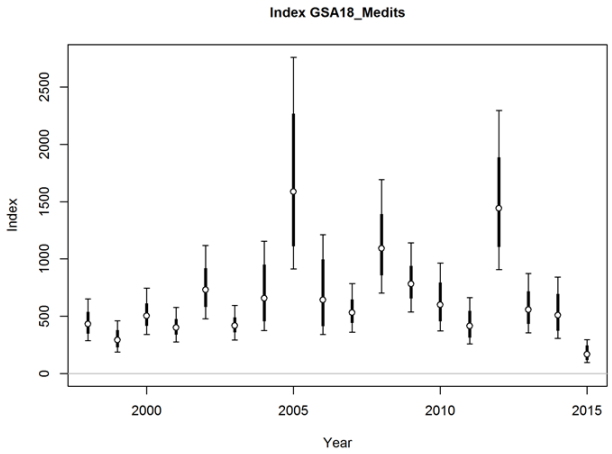

Figure 6.1.3.9 Abundance index – MEDITS survey GSA 18

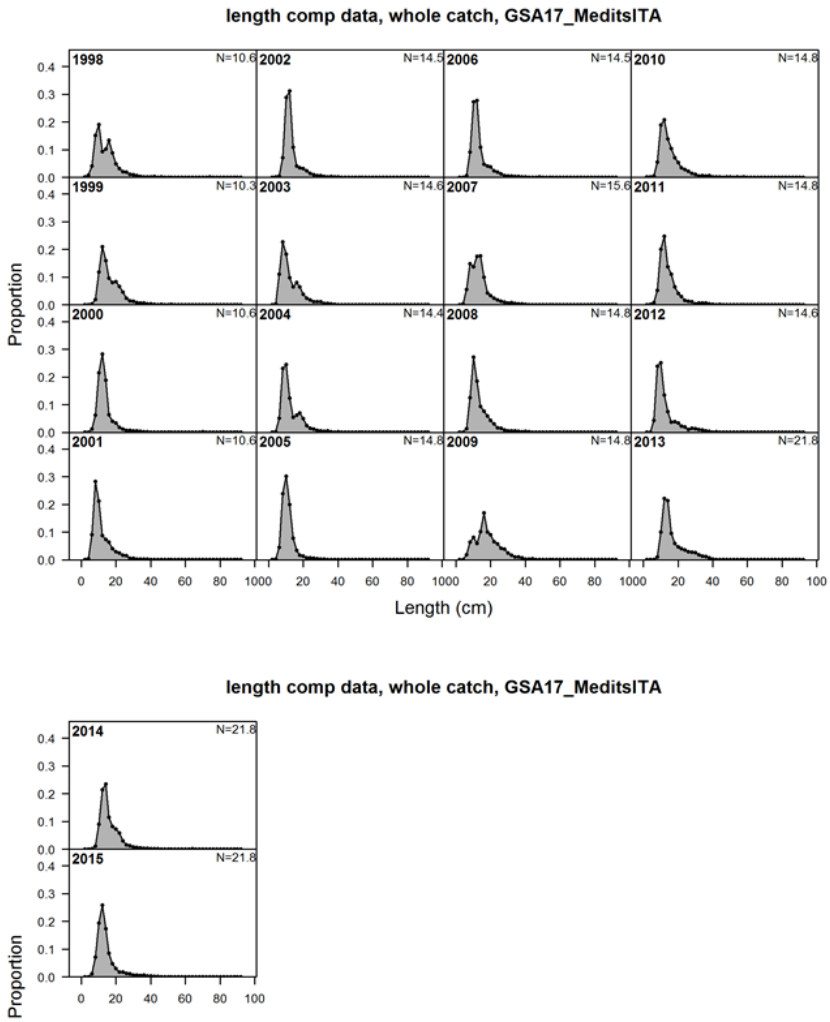

Figure 6.1.3.9 Length frequency distribution – MEDITS ITA GSA 17

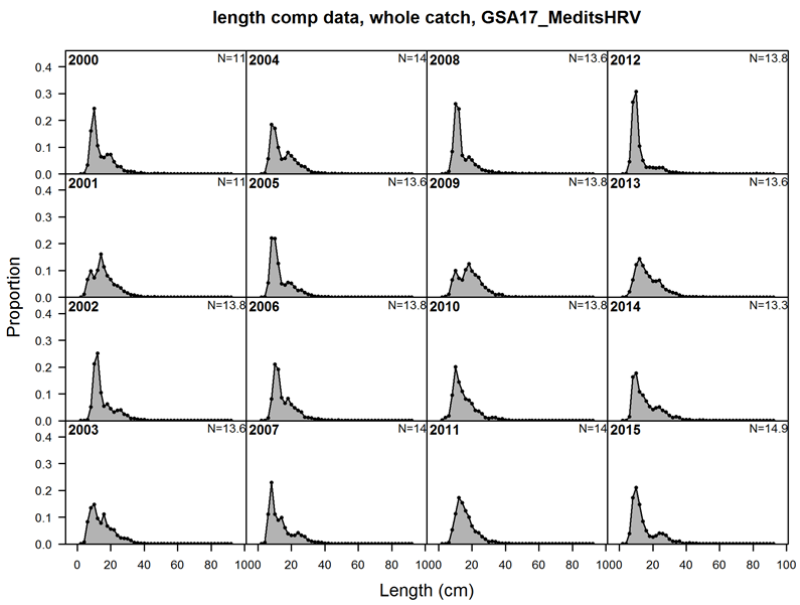

Figure 6.1.3.10 Length frequency distribution – MEDITS HRV GSA 17

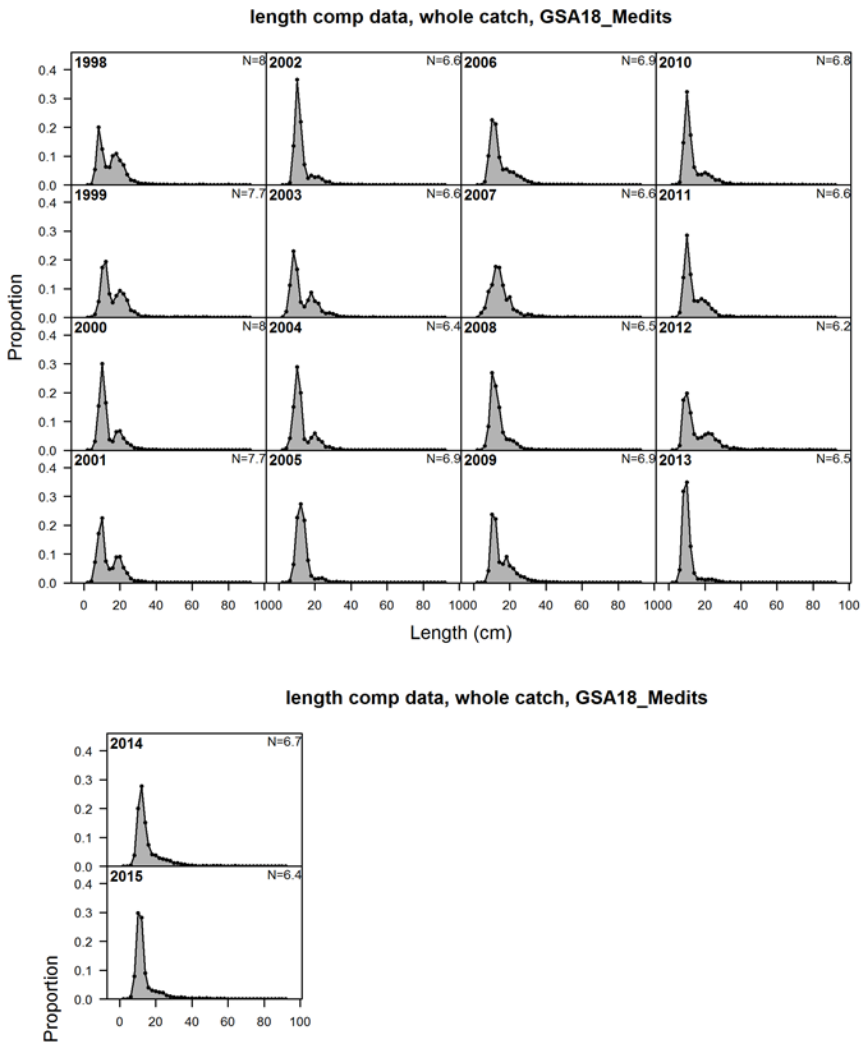

Figure 6.1.3.11 – MEDITS GSA 18

Input data are summarized in Figure 6.1.3.12.

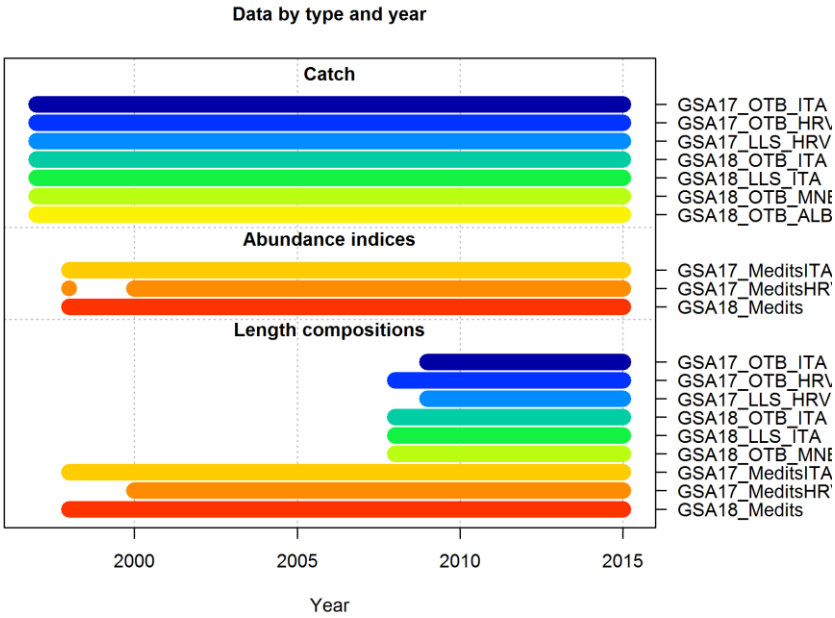

Figure 6.1.3.12 - Summary of input data used in the SS3 model

6.1.4 Results

SS3 allows to describe the selectivity for each fishery considered in the model. All the fisheries present a dome shaped selectivity, obtained using the length selectivity pattern 24 (double normal with defined initial and final selectivity level) or 27 (cubic spline). The resulting selectivity curves are showed in the next figures.

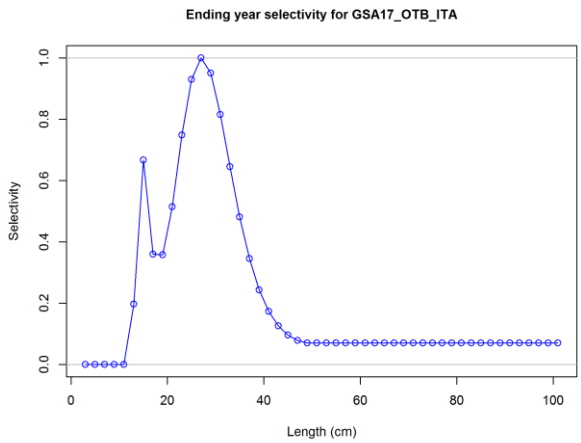

Figure 6.1.4.1 Selectivity pattern for Italian bottom trawlers in GSA 17

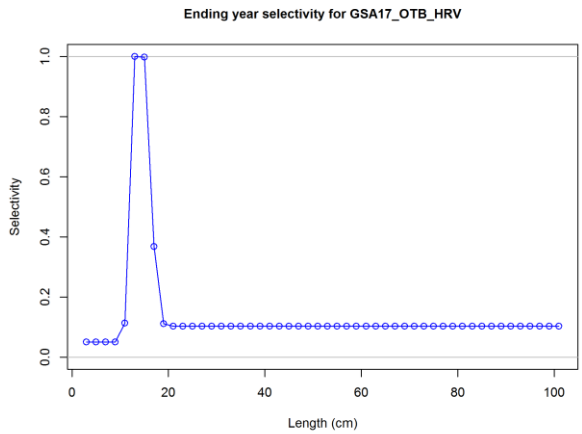

Figure 6.1.4.2 Selectivity pattern for Croatian bottom trawlers in GSA 17

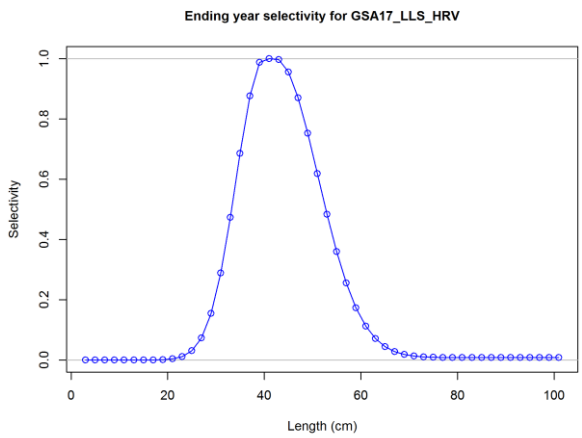

Figure 6.1.4.3 Selectivity pattern for Croatian longlines in GSA 17

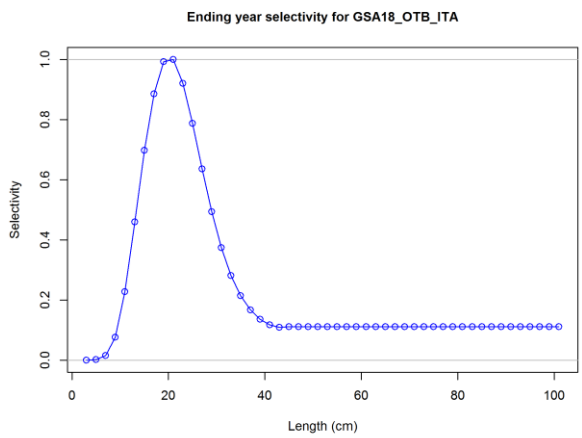

Figure 6.1.4.4 Selectivity pattern for Italian bottom trawlers in GSA 18

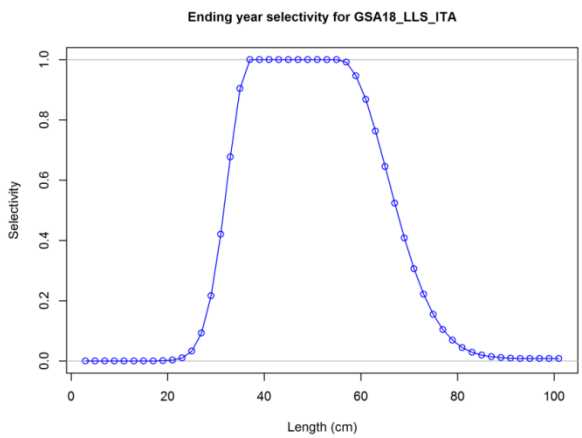

Figure 6.1.4.5 Selectivity pattern for Italian longlines in GSA 18

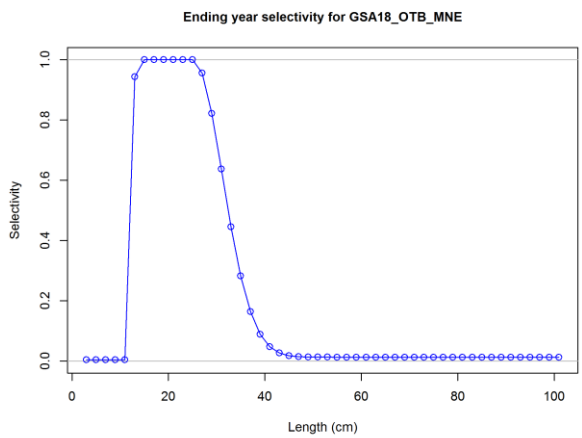

Figure 6.1.4.6 Selectivity pattern for bottom trawlers from Montenegro

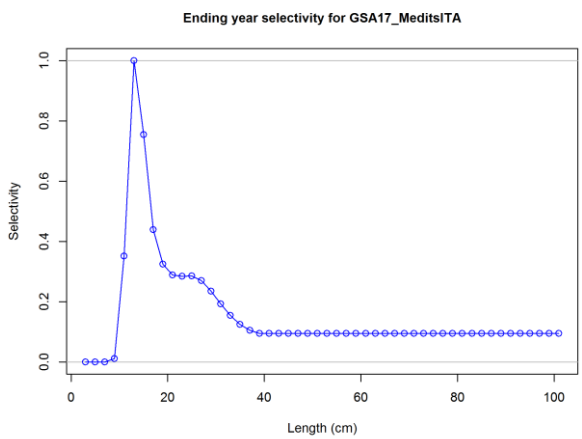

Figure 6.1.4.7 Selectivity pattern for the Italian Medits survey in GSA 17

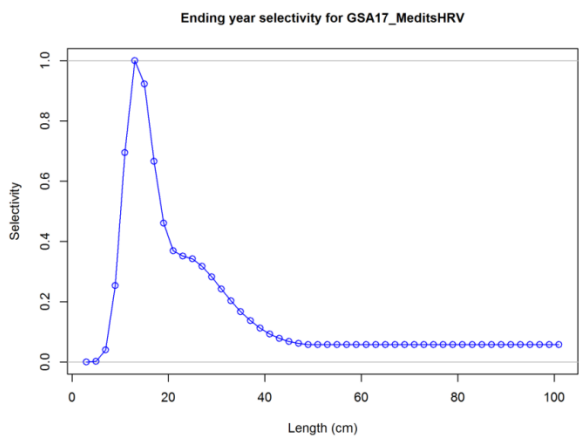

Figure 6.1.4.8 Selectivity pattern for the Croatian MEDITS survey in GSA 17

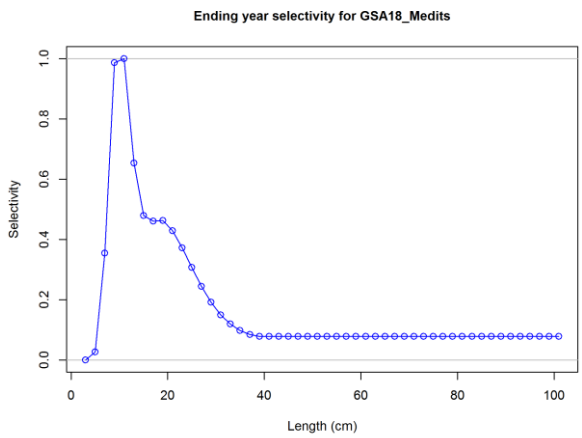

Figure 6.1.4.9 Selectivity pattern for the MEDITS survey in GSA 18

Figures from 6.1.4.10 to 6.1.4.13 show the model fitting to the data. Considering the fluctuating LFDs of each fishery we can state that the model has a quite good fitting to the catch data (Fig. 6.1.4.10). Also the MEDITS survey shows very fluctuacting trend among the years; this time the model shows some difficulties to fit the input data and particurarly in the case of high increases or decreases (figs 6.1.4.11, 6.1.4.12, 6.1.4.13).

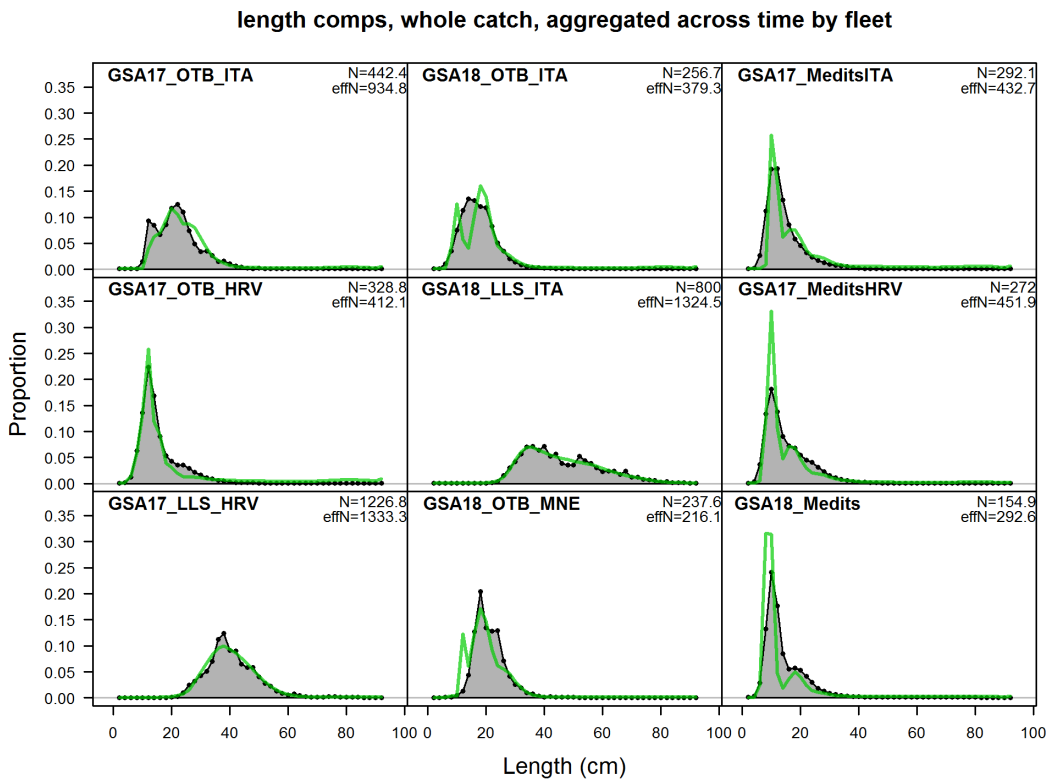

Figure 6.1.4.10 Model fitting to the catch length input data

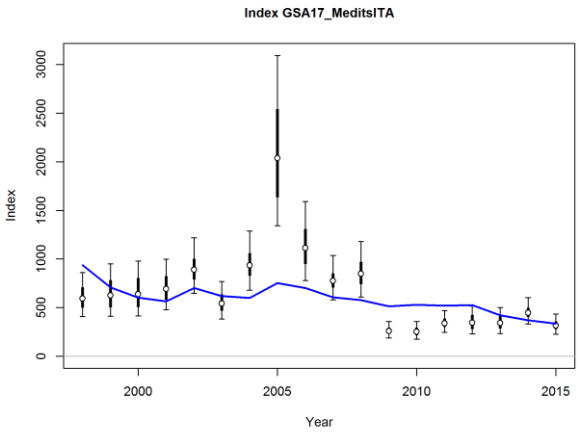

Figure 6.1.4.11 Model fitting to the Italian MEDITS survey data GSA 17

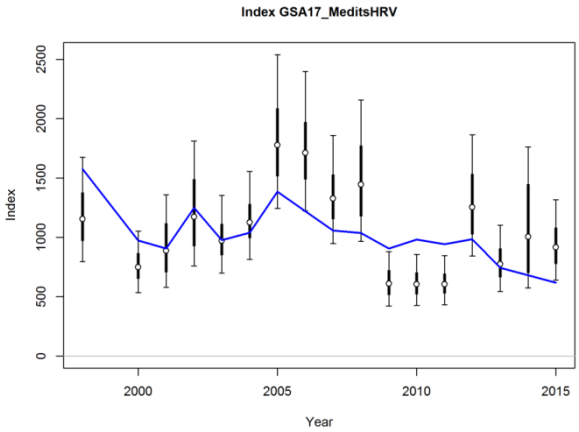

Figure 6.1.4.12 Model fitting to the Croatian MEDITS survey data GSA 17

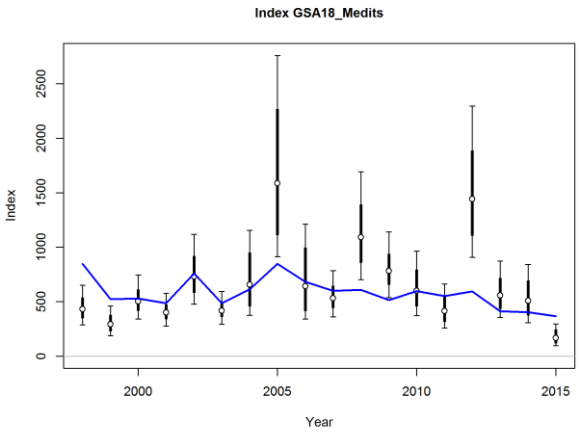

Figure 6.1.4.13 Model fitting to the MEDITS survey data GSA 18

The stock of European hake in GSA 17 and 18 show a concerning trend. In fact, both the total (Fig. 6.1.4.14) and the spawning biomass (Fig. 6.1.4.15) depict a decreasing trend over the years, accounting for the lowest value in 2015 (29,870 tonnes). Recruitment (Fig. 6.1.4.16) presents a fluctuating trend with peak in 2002, 2005 and 2012. The fishing mortality increases over the years. Specifically, F_{bar} was calculated considering the ages between 1 and 6 and it reaches the highest value in 2015 (F_{bar} = 0.546) (Fig. 6.1.4.17). The SS3 model allows to estimate the fishing mortality also by fleet (Fig. 6.1.4.18). Italian bottom trawlers of both GSA 17 and 18 account for the highest fishing mortality, whereas Croatian bottom trawlers start to increase their impact from 2011.

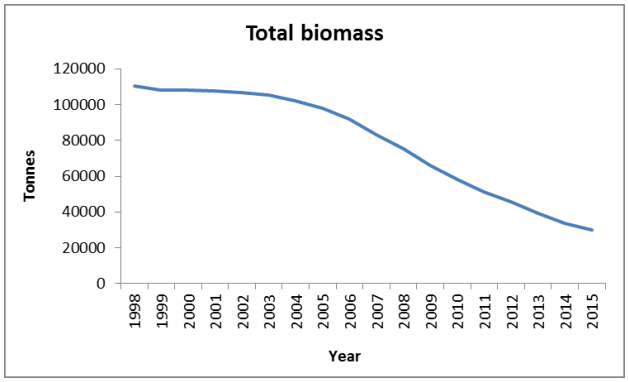

Figure 6.1.4.14 Result – Estimated total biomass from SS3 model

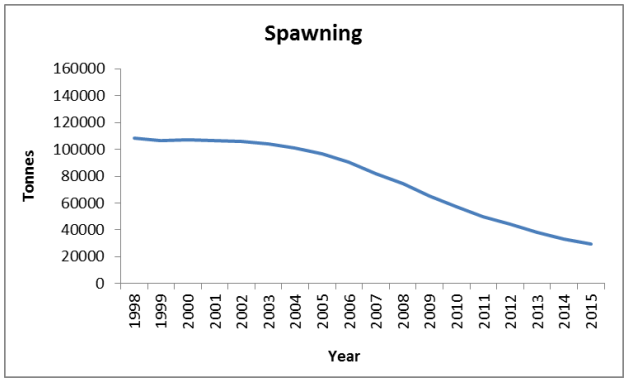

Figure 6.1.4.15 Result – Estimated spawning biomass from SS3 model

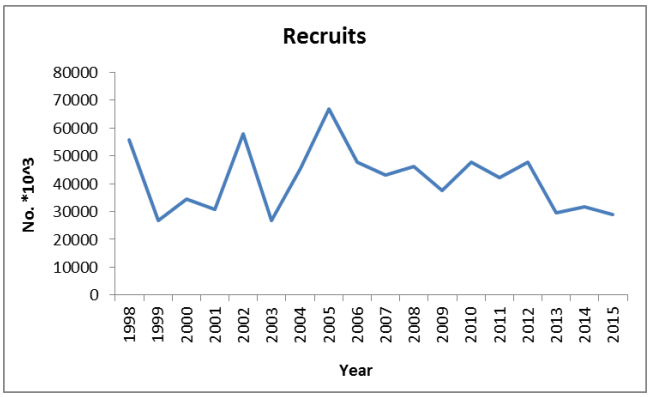

Figure 6.1.4.16 Result – Number of recruits estimated by the SS3 model

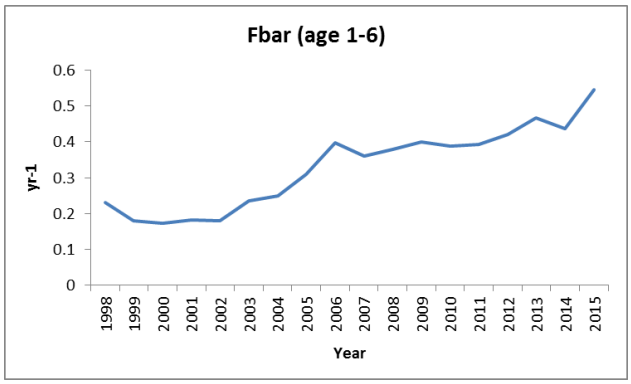

Figure 6.1.4.17 Result – $F_{bar(1-6)}$

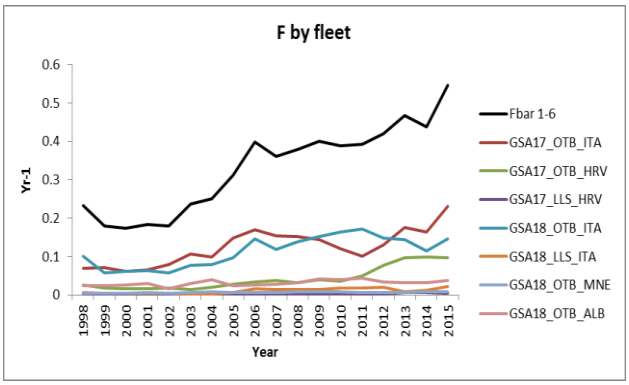

Figure 6.1.4.18 Result – F by fleet

<u>State of exploitation</u>: exploitation shows an increasing trend over the years reaching a peak of 0.546 in 2015, and the mean value of the last three years is 0.48. Italian bottom trawlers are the principal cause of fishing mortality for hake; specifically the Italian bottom trawlers of GSA 17 show a continuous increasing trend over the years reaching the maximum F value in 2015 (F_{1-6} = 0.23), whereas the minimum value (F_{1-6} = 0.06) is recorded in 2000. The Italian bottom trawlers of GSA 18 describe a continuous increasing trend of fishing mortality to 2011 (F_{1-6} = 0.17), then it decrease to 2014 (F_{1-6} = 0.11) to increase again in 2015 (F_{1-6} = 0.145). Among the other fleets, relevant is the fishing mortality caused by the Croatian bottom trawlers, and this is true particularly for the last 5

years.

State of the juveniles (recruits): recruitment show a fluctuating decreasing trend. The highest value has been estimated in 2005, followed by a generally decreasing trend to 2015.

State of the adult biomass: the spawning stock biomass (SSB) showed a continuous decreasing trend all over the year. For the last years estimates are more precise since different information are available. Thus suggests the decreasing trend is less negative that it appears, moreover hake of big sizes and old are absent both in the catches and surveys estimates.

6.1.5 Robustness analysis

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

6.1.7 Assessment quality

7 Stock predictions

The biological reference point has been estimated using the Yield per Recruits approach (Yield per Recruit Version 3.3 – NOAA Fisheries Toolbox), where $F_{0.1}$ is considered a proxy of F_{MSY}.

RPs suggest an overfishing situation for the hake stock.

Table 7.1 - Yield per Recruit outputs for SCAA.

	Current F ($F_{BAR\ 1\text{-}6}$)	**Reference Points**	**Harvest**	**Yield/R**	**SSB/R**	**Total biomass/R**
SCAA	0.48 (mean of the last three years)	$F_{0.1}$	0.208	0.094	0.978	1.113
		F_{max}	0.459	0.075	0.122	0.251

7.1 Short term predictions

7.2 Medium term predictions

7.3 Long term predictions

8 Draft scientific advice

Considering the results of SCAA analyses, it can be concluded that the resource is subjected to overfishing. A reduction of fishing mortality is recommended. SSB shows a clear decreasing trend. The SS3 model allows the assumption of a dome-shaped population selection curve, which determines more reliable values of SSB if compared with the historical yields. However we have to consider that the most reliable estimate were obtained for the last years of the time series considered, for which different data sets are available.

According to SCAA results, recruitment shows a fluctuating decreasing trend, accounting for the lowest value in 2003 and a peak in 2005.

Based on the SCAA estimates, in 2015 the fishing mortality appears higher than the respective estimates of $F_{0.1}$ and, hence, it can be concluded that the resource is in overexploitation. In this regard it must be kept in mind the different contribution of the fleets to the total F, since Italian bottom trawlers are the most influent factor.

The calculation of reference point has been updated according to the SCAA methodology and the value proposed is $F_{0.1}$ equal to 0.21. Such value is in accordance with previous analysis ($F_{0.1}$ = 0.2, EWG 13_05). Given the results of the present analysis ($F_{current(2013-2015)}$ is 0.48), the stock appears to be subject to overfishing. A considerable reduction is necessary to approach the reference point.

Considering the overexploited situation and the low values of SSB and biomass of the hake stock in GSA 17 and 18 a reduction of fishing mortality and an improvement in exploitation pattern is advisable, especially for bottom trawlers, which mainly exploit juveniles. Moreover, particular management measure can be considered for the Pomo area since it constitutes a nursery area for hake, supporting the entire Adriatic hake stock, and in the eastern part a persistency area for spawners has been revealed from the MEDISEH project.

Based on	Indicator	Analytical 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	$F_{0.1}$, = 0.21 F_{max}= 0.46	0.48		I	IO_H
	Fishing effort					
	Catch					
Stock abundance	Biomass				D	O_I
	SSB	62042 (33rd percentile) 101766 (66th percentile)	29208 (Spawning biomass 2015)		D	O_L
Recruitment						
Final Diagnosis		***The stock is overfished and in overfishing***				

The total F estimated by SS3 in the Adriatic Sea (GSA 17 and 18) for the 2015 is split in 42% exerted by Italian trawlers in GSA 17, 18% by Croatian trawlers, 27% by Italian trawlers in GSA 18, 7% by Albanian trawlers, 4% by Italian longlines in GSA 18, 1.6% by Montenegrin trawlers and 0.9% by Croatian longlines.

8.1 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)*