





Stock Assessment Form Demersal species

Reference year: 2014

Reporting year: 2015

The assessment of the stock of European hake, *Merluccius merluccius*, in the Ligurian and northern Tyrrhenian Sea (FAO-GFCM Geographical Sub-Area 9, GSA 9) was carried out by means of an Extended Survivor Analysis (XSA) run using FLR libraries. The assessment was carried out using as input data the period 2006-2014 for the catch data and 2006-2014 for the tuning file (Medits indices). The results of the assessment show a decreasing trend in the catches, a fluctuation in recruitment and SSB, and an estimated $F_{curr} = 0.96$. Current F is larger than $F_{0.1}$ (0.23), chosen as proxy of F_{MSY} and as the exploitation reference point consistent with high long term yields, which indicates that European hake stock in GSA 9 is exploited unsustainably.

Stock Assessment Form version 1.0 (January 2014)

Uploader: Alessandro Ligas

Stock assessment form

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1 Basic Identification Data

Scientific name:	Common name:	ISCAAP Group:				
Merluccius merluccius	European hake	32				
1 st Geographical sub-area:	2 nd Geographical sub-area:	3 rd Geographical sub-area:				
GSA 09						
4 th Geographical sub-area:	5 th Geographical sub-area:	6 th Geographical sub-area:				
1 st Country	2 nd Country	3 rd Country				
Italy						
4 th Country	5 th Country	6 th Country				
Stock assessr	nent method: (direct, indirect, com	ibined, none)				
	indirect					
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The ISSCAAP code is assigned according to the FAO 'International Standard Statistical Classification for Aquatic Animals and Plants' (ISSCAAP) which divides commercial species into 50 groups on the basis of their taxonomic, ecological and economic characteristics. This can be provided by the GFCM secretariat if needed. A list of groups can be found here:

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

Direct methods (you can choose more than one):

- 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)

Stock identification and biological information

Due to a lack of information about the structure of hake population in the western Mediterranean, this stock was assumed to be confined within the GSA 9 (Ligurian and northern Tyrrhenian Seas) boundaries (Figure 2-1).





Eurpean hake is distributed in the whole area between 10 and 800 m depth (Biagi *et al.,* 2002; Colloca *et al.,* 2003). Recruits peak in abundance between 150 and 250 m depth over the continental shelf-break and appear to move slightly deeper when they reach 10 cm total length. Crinoid (*Leptometra phalangium*) bottoms over the shelf-break are the main settlement habitat for hake in the area (Colloca *et al.,* 2004). Migration from nurseries takes place when juveniles attained a critical size between 13 and 15.5 cm TL (Bartolino *et al.,* 2008a). Maturing hakes (15-35 cm TL) persist on

the continental shelf with a preference for water of 70-100 m depth, while larger hakes can be found in a larger depth range from the shelf to the upper slope. Juveniles show a patchy distribution with some main density hot spots (i.e. nurseries areas) showing a high spatio-temporal persistence (Abella *et al.,* 2005; Colloca *et al.,* 2009) as also highlighted by the MEDISEH project in areas with frontal systems and other oceanographic structures that can enhance larval transport and retention (Abella *et al.,* 2008).

Although hakes are demersal fish feeding typically upon fast-moving pelagic preys while ambushed in the water column, there is evidence that they feed in mid-water or at the surface during nighttime, undertaking daily vertical migrations (Carpentieri *et al.*, 2005) which are more intense for juveniles. In GSA 9 many different studies are available on hake diet. Results from stomach data collected in the 1996-2001 period can be found in Sartor et al. (2003) and Carpentieri et al. (2005). Hake diet shifts from euphausids and mysiids consumed by smaller hake (<16 cm TL), to fishes consumed by larger hake.

Before the transition to the complete ichthyophagous phase (TL> 36 cm) hake shows more generalized feeding habits where decapods, benthic (Gobiidae, *Callionymus* spp.,) and necktonic fish (*S. pilchardus, E. encrasicolus*) dominated the diet, whereas cephalopods had a lower incidence.

Estimation of cannibalism rate has been provided for the southern part of the GSA (Latium, EU Because project). Cannibalism increased with size and can be considered significant for hakes between 30 and 40 cm TL (up to 20% by weight in diet) and seems to relate closely to hake recruitment density and level of spatial overlapping.

Consumption rate has been estimated for juveniles and piscivorous hakes. Daily consumption of juveniles, calculated in proportion of body weight (%BW), varied between 5 (July) and 5.9 % BW (Carpentieri et al., 2005). The estimated relative daily consumption for hake between 14 and 40 cm TL, using a bioenergetic approach (EU Because project), was between 2.9 and 2.3 BW%.

1.1 Stock unit

The stock unit is represented by the GSA 9.

1.2 Growth and maturity

Juvenile growth rate was estimated to be about 1.5 cm*month-1 using daily growth increments on otoliths (Belcari et al., 2006; Ligas et al., 2015). According to this growth rate, hake reaches an average length of about 18 cm TL at the end of the first year. According to these observations, the growth of hake in the GSA 9 seems to follow the pattern estimated in the NW Mediterranean (Garcia-Rodriguez and Esteban, 2002) adopting the hypothesis that two rings are laid down on otoliths each year. This new interpretation of otolith ring patterns returns a growth rate (L_{inf} = 103.9, k = 0.212, $t_0 = 0.031$) almost double than that assumed in the past.

Tahle	1 2-1.1	Maximum	size	size	at first	maturity	and	size	at r	ecruitm	ent
iubie	1.2-1.1	viuxiiiiuiii	SIZE,	SIZE	urjiist	muturity	unu	SIZE	uιı	ecruitin	ent.

Somatic mag	gnitude me LT	asured		Units	cm
Sex Fem Mal		Combined	Reproduction season	January-May; 2 peaks in February and May	
Maximum size observed	94	60		Recruitment season	May; July
Size at first maturity	33	22		Spawning area	Northern Tyrrhenian Sea, 200-500 m depth
Recruitment size to the fishery			10.5	Nursery area	100-200 m depths

The catchability of hake spawners to the Mediterranean trawl nets is rather limited. The distribution of adults which are more abundant on deeper or untrawlable grounds, or the ability of larger fish to avoid capture have been claimed as causes of the observed extremely reduced catch of adult hake by trawlers in the Mediterranean. Also during trawl surveys (MEDITS and GRUND) the catch rate of mature specimens was very low, reducing the possibility of use trawl survey data to explore patterns in gonad development as well as the relationships between growth rate and maturation processes.

Large size hake are targets of a specifically targeted gillnet fishery carried out by several vessels working in the southern part (northern and central Tyrrhenian Sea) of the GSA 9.

Reproductive biology and fecundity of hake have been studied in northern Tyrrhenian Sea (Recasens *et al.*, 2008) by monthly samplings of adults caught by trawling and gillnets.

Females in advanced maturity stages, spawning and partial post-spawning are present all year round, but reproductive activity is concentrated from January to May, with two peaks of spawning in February and May. The presence of hake spawners seems to be more concentrated in the southern part of GSA 9.

Female length at first maturity was estimated at 33 cm TL in northern Tyrrhenian Sea (Recasens *et al.,* 2008). This value is consistent with the observations obtained from trawl surveys over the Latium (Colloca, pers. comm.) reporting first maturity from 30 to 37 cm TL for females and from 21 to 25 cm TL for males.

Batch fecundity was about 200 eggs per gonad-free female gram, with asynchronous oocyte development (Recasens *et al.*, 2008).

Natural mortality was estimated using PRODBIOM (Abella *et al.*, 1997) and is shown in Table 2.2-2. The input parameters used were $L_{inf} = 103.9$, k = 0.212, $t_0 = 0.031$, a = 0.006657 and b = 3.028.

Age	Natural mortality	Proportion of matures
0	1.2	0.00
1	0.62	0.25
2	0.44	0.90
3	0.37	1.00
4	0.33	1.00
5	0.31	1.00
6+	0.29	1.00

Table 1.2-2: M vector and proportion of matures by size or age (Sex combined)

Table 2.2-3: Growth and length weight model parameters

			Sex				
		Units	female	male	Combined	Years	
	L∞	ст			103.9		
Growth model	К	years ⁻¹			0.21		
	to	years			0.03		
	Data source	Garcia Rodriguez and Esteban, 2002					
Length weight	а	g			0.006657		
relationship	b	g			3.028		
	sex ratio (% females/total)	75					

2 Fisheries information

2.1 Description of the fleet

Hake is one of the main target species of bottom trawlers in the GSA 9 in terms of landings, incomes and vessels involved. The analysis of available information suggests that about 50% of landings of hake are obtained by bottom trawl vessels, the remaining fraction being provided by artisanal vessels using set nets, in particular gillnets.

The trawl fleet of GSA 9 accounted for 197 vessels in 2014 based in several ports: Viareggio, Livorno, Porto Santo Stefano, Civitavecchia, Fiumicino, Anzio, Terracina, Gaeta, Formia. They accomplish daily fishing trips exploiting both continental shelf and slope areas. Hake fishing grounds comprise all the soft bottoms of continental shelves and the upper part of continental slope. Fishing pressure shows a spatial pattern inside the GSA 9 according to the consistency of the fleets and the distance of the fishing grounds from the main ports.

The artisanal fleets, according to the last official data (2014), accounted for 1006 vessels that operate in several harbours along the continental and insular coasts.

	Country	GSA	Fleet Segment	Fishing Gear Class	Group of Target Species	Species
Operational Unit 1	ITA	GSA 9	VL1240	ОТВ	34, 47,45, 58	Hake, red mullet Deep- water pink shrimp, Norway lobster Giant red shrimp, blue and red shrimp
Operational Unit 2	ITA	GSA 9	VL0018	PGP	34, 58	Hake, red mullet, common sole, cuttlefish

Table 2-1: Description of operational units exploiting the stock

Table 2.1-2: Catch, bycatch, discards and effort by operational unit in the reference year

Operational Units*	Fleet (n° of boats)*	Catch (T or kg of the species assessed)	Other species caught (names and weight)	Discards (species assessed)	Discards (other species caught)	Effort (units)
Operational Unit1	197	1010	DPS 561 MUT 1204 EOI 655 MTS 593 PAC 434 SQR 291 SQM 290 HMM 268 CTC 218 OCC 201 GFB 187 WHB 126	286	MTS 314 DPS 45 HMM 200 PAC 198 GFB 135 MUT 106 DPS 45 SBA 29 CIL 29 EOI 17 SQM 17 POD 12	
Operational Unit2	910	253	CTC 353 MUR 230 OCC 169 MUT 84 SOL 57 MTS 47 PAC 41		HOM 6	
Total	1107	1263		286		

2.2 Historical trends

Hake is one of the main target species of bottom trawlers in the GSA 9 in terms of landings, incomes and vessels involved. The analysis of available information suggests that more than 50% of landings of hake are obtained by bottom trawl vessels, the remaining fraction being provided by artisanal vessels using set nets, in particular gillnets.

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	ОТВ	GNS	GTR
2002	508.16	154.32	236.15
2003	1147.56	658.51	258.39
2004	NA	NA	NA
2005	NA	NA	NA
2006	1179.96	592.57	403.96
2007	1024.96	576.22	131.85
2008	914.77	345.23	61.12
2009	853.24	401.26	53.98
2010	834.14	576.26	56.71
2011	795.36	502.08	54.30
2012	653.57	309.33	48.62
2013	1044.30	199.21	98.12
2014	1010.37	177.73	76.85

Table 3 2-1. European hake in	GSA 9 Annual landinas	(t) in GSA 9 hy agar	(source ELLDCE data)
Tuble 5.2-1. Lutopeuti tiuke itt	GSA 9. Annuul lunungs	(i) ili OSA 9 by yeur	(Source LO Der dutu).



Figure 3.2-1: European hake in GSA 9. Age frequency distribution of the landings from 2006 to 2014 as obtained from EU DCF data.

Information on OTB discards was available for 2006 and from 2009 to 2014. Several EU and national projects carried out in GSA 9 highlighted the problem of hake trawl discards. High quantities of hake are routinely discarded, especially in summer and on the fishing grounds located near the main nursery areas (Table 5.2.6.5.5.1).

The size at which 50% of the specimens caught is discarded is progressively increased in the last years from about 11 cm TL in 1995 to about 17 cm TL in 2006, due to the introduction of the EU Regulations on minimum sizes. This phenomenon might be also explained by a reduction of the fishing pressure on the nursery areas.

Table 3.2-2: European hake in GSA 9. Annual OTB discards in tons.

	OTB Discards					
2006	105.2					
2007	NA					
2008	NA					
2009	697.2					
2010	116.4					
2011	527.8					
2012	174.2					
2013	242.4					
2014	285.8					

The fishing capacity of the GSA 9 has shown in these last 20 years a progressive decrease. Fishing effort (kW*fishing days) performed by the GSA 9 trawlers decreased by 26% since 2004, from about 15,000,000 to 11,000,000 in 2014. The effort displayed by the artisanal fleet exploiting hake remained constant for vessels using trammel nets (GTR) whereas the effort of gillnetters decreased abruptly (-61%) from 2011 (Figure 3.2-2). Fishing effort by gill nets is decreasing in the last years; however, this could be due to the incorrect allocation of some of the fishing effort to trammel net fishery. Therefore, we can consider the fishing effort by set nets to be constant, while the landings by these gears, that are mainly catching the adult fraction of the population, are decreasing.



Figure 3.2-2: Effort trends (days and kW*days) by major fleets, 2004-2014.

2.3 Management regulations

In GSA 09, management regulations are based on technical measures, as closed number of fishing licenses and area limitation (distance from the coast and depth). In order to limit the over-capacity of fishing fleet, the Italian fishing licenses have been fixed since the late eighties and the fishing capacity has been gradually reduced.

Other measures on which the management regulations are based regards technical measures (mesh size), minimum landing sizes (EC 1967/06) and seasonal fishing ban (Fishing closure for trawling: 45 days in late summer). Regarding small scale fishery, management regulations are based on technical measures related to the height and length of the gears as well as the mesh size opening, minimum landing sizes and number of fishing licenses for the fleet.

A biological conservation zone (ZTB) was permanently established in 2005 off Giglio Island (50 km2, between about 160 and 220 m depth) (Decree of Ministry of Agriculture, Food and Forestry Policy of 16.06.1998). Professional small scale fishery using fixed nets and long-lines is permanently allowed, while trawling is allowed from July 1st to December 31st and the small scale fishery all year round; recreational fishery using no more than 5 hooks is allowed (Decree of Ministry of Agriculture, Food and Forestry Policy of 22.01.2009). Another ZTB area has been established off the coasts of southern Latium with the same rules as the above mentioned ZTB off the Giglio Island.

Since June 2010 the rules implemented in the EU regulation (EC 1967/06) regarding the cod-end mesh size and the operative distance of fishing from the coasts are enforced.

Reference points

Table 2.3-1: List of	reference points	and empirical reference	values	previously ag	greed (if any)
----------------------	------------------	-------------------------	--------	---------------	----------------

Indicator	Limit Reference point/emp irical reference value	Value	Target Reference point/empi rical reference value	Value	Comments
В					
SSB					
F			F _{0.1}	0.22	STECF EWG 14-19 (Proxy of F_{msy})
Y					
CPUE					
Index of Biomass at sea					

3 Fisheries independent information

3.1 Mediterranean International Bottom Trawl Survey (MEDITS)

The Mediterranean International Bottom Trawl Survey (MEDITS) has been carried out in the Ligurian and northern Tyrrhenian Seas since 1994.

3.1.1 Brief description of the direct method used

Data were assigned to strata based upon the shooting position and average depth (between shooting and hauling depth). Catches by haul were standardized to 60 minutes hauling duration. Hauls noted as valid were used only, including stations with no catches of hake, red mullet or pink shrimp (zero catches are included).

The abundance and biomass indices by GSA were calculated through stratified means. This implies weighting of the average values of the individual standardized catches and the variation of each stratum by the respective stratum areas in each GSA:

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

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

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 \pm t(student distribution) * V(Yst) / n

It was noted that while this is a standard approach, the calculation may be biased due to the assumptions over zero catch stations, and hence assumptions over the distribution of data. A normal distribution is often assumed, whereas data may be better described by a delta-distribution, quasipoisson. Indeed, data may be better modelled using the idea of conditionality and the negative binomial (e.g. O'Brien et al. 2004).

Length distributions represented an aggregation (sum) of all standardized length frequencies (subsamples raised to standardized haul abundance per hour) over the stations of each stratum. Aggregated length frequencies were then raised to stratum abundance * 100 (because of low numbers in most strata) and finally aggregated (sum) over the strata to the GSA. Given the sheer number of plots generated, these distributions are not presented in this report.

Direct methods: trawl based abundance indices

Table 3.1-1: Trawl survey basic information

Survey	Mediterranean International Bottom Trawl Survey	Trawler	FV Libera
	(MEDITS)		

Sampling season	Spring-Summer
Sampling design	Random Stratified
Sampler (gear used)	Ifremer GOC73 bottom trawl net
Cod –end mesh size	20 mm
as opening in mm	
Investigated depth	10-800 m
range (m)	

Table 3.1-2: Trawl survey sampling area and number of hauls

Stratum	Total surface (km²)	Trawlable surface (km²)	Swept area (km²)	Number of hauls
10 – 50 m	5762	5762	0.75	15
50 – 100 m	5992	5992	0.95	19
100 – 200 m	10878	10878	1.45	29
200 – 500 m	10587	10587	3.6	36
500 – 800 m	9191	9191	2.1	21
Total (10 – 800 m)	42410	42410		120



Figure 3.1-1: Map of the position of MEDITS survey hauls in GSA 9.

Depth Stratum	Years	kg per km ²	CV (%)	N per km ²	CV (%)
10 – 200 m	2006	45.2	14.2	2447.8	19.6
200 – 800 m	2006	20.8	34.9	920.5	41.2
Total (10 – 800 m)	2006	33.8	14.3	1735.6	18.0
10 – 200 m	2007	42.2	18.2	3256.6	21.1
200 – 800 m	2007	8.8	26.4	715.5	42.8
Total (10 – 800 m)	2007	26.6	15.9	2071.6	19.0
10 – 200 m	2008	73.1	14.9	8603.2	19.9
200 – 800 m	2008	18.3	32.4	1762.9	51.5
Total (10 – 800 m)	2008	47.5	13.6	5413.2	18.6
10 – 200 m	2009	55.2	18.8	6002.6	22.0
200 – 800 m	2009	28.1	26.7	4026.2	33.8
Total (10 – 800 m)	2009	42.5	15.4	5080.9	18.7
10 – 200 m	2010	33.0	19.3	3705.8	33.8
200 – 800 m	2010	14.6	35.0	1088.0	54.6
Total (10 – 800 m)	2010	24.4	17.0	2485.0	29.1
10 – 200 m	2011	13.5	14.8	1170.7	20.5
200 – 800 m	2011	6.4	22.7	297.8	43.6
Total (10 – 800 m)	2011	10.2	12.4	763.6	18.5
10 – 200 m	2012	17.5	18.1	1140.0	29.1
200 – 800 m	2012	16.2	26.6	1886.7	36.8
Total (10 – 800 m)	2012	16.9	15.6	1488.2	24.8
10 – 200 m	2013	25.7	17.1	1788.5	32.7
200 – 800 m	2013	28.6	40.7	1714.6	50.3
Total (10 – 800 m)	2013	27.1	21.8	1754.0	29.0
10 – 200 m	2014	27.6	19.4	2433.6	26.1
200 – 800 m	2014	12.4	23.5	844.8	40.1
Total (10 – 800 m)	2014	20.5	15.4	1692.6	22.1

Table 3.1-3: Trawl survey abundance and biomass results

Comments

- Specify CV or other index of variability of mean
- Specify sampling design (for example random stratified with number of haul by stratum proportional to stratum surface; or systematic on transect;...)
- Specify if catchability coefficient is assumed =1 or other

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

Slicing method

The length frequency distributions have been transformed in age data applying the length-to-age slicing method.

N (Total or sex combined) by	Year								
class	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	1686.6	2514.3	5871.6	6573.9	2469.1	769.9	1464.4	1743.2	1564.2
1	58.6	38.9	57.2	52.8	37.3	29.4	21.9	35.3	27.1
2	2.5	2.2	1.2	1.1	2.6	1.3	1.0	1.0	1.9
3	0.3	1.5	0.3	0.5	0.1	0.3	0.5	0.1	0.2
4+	0.2	0.1	0.4	0.1	0.1	0.1	0.3	0.3	0.3
Total	1748.2	2557	5930.7	6628.4	2509.2	801	1488.1	1779.9	1593.7

Table 3.1-4: Trawl survey results by length or age class

Sex ratio by Length or Age	Year				
class	•••				
Total					

Comments

- Specify if numbers are per km² or raised to the area, assuming the same catchability .
- In case maturity ogive has not been estimated by year, report information for groups of years.
- Possibility to insert graphs and trends

Direct methods: trawl based Recruitment analysis

Table 3.1-5: Trawl surveys; recruitment analysis summary

Survey		Trawler/RV	
Survey se	ason		
Cod –end	mesh size as opening in mm		
Investigat	ed depth range (m)		
Recruitme	ent season and peak (months)		
Age at fisl	hing-grounds recruitment		
Length at	fishing-grounds recruitment		

Table 3.1-6: Trawl surveys; recruitment analysis results

Years	Area in km ²	N of recruit per km ²	CV or other

Comments

- Specify type of recruitment:
 - continuous and diffuse
 - discrete and diffuse
 - discrete and localised
 - continuous and localised.
- Specify the method used to estimate recruit indices
- Specify if the area is the total or the swept one
- Possibility to insert graphs and trends

Direct methods: trawl based Spawner analysis

Table 3.1-7: Trawl surveys; spawners analysis summary

Survey		Trawler/RV	
Survey se	eason		
Investigated depth range (m)			
Spawning	g season and peak (month	ıs)	

Table 3.1-8: Trawl surveys; spawners analysis results

Surveys	Area in km ²	N (N of individuals) of spawners per km ²	CV or other	SSB per km ²	CV or other

Comments

- Specify type of spawner:
 - total spawner
 - sequential spawner
 - presence of spawner aggregations
 - Specify if the area is the total or the swept one
- Possibility to insert graphs e trends

3.1.2 Spatial distribution of the resources

According to recent studies (Colloca et al., 2009), the density of hake recruits concentrations in nursery areas in GSA 9 is by far higher than that of the other GSAs of the western Mediterranean and, probably, also of the other Mediterranean GSAs (Figure 4.1.2-1).



Figure 4.1.2-1: European hake in GSA 9. MEDITS density indices of the hake recruits (<12 cm TL) obtained in different Mediterranean GSAs.



Figure 4.1.2-2: Temporal persistence of European hake nurseries calculated from MEDITS time-series density maps (1994-2012). The figure is taken from the MEDISEH project.

Generalized additive models were developed to investigate hake recruitment dynamics in the Tyrrhenian Sea in relation to spawner abundance and selected key oceanographic variables. Thermal anomalies in summer, characterized by high peaks in water temperature, revealed a

negative effect on the abundance of recruits in autumn, probably due to a reduction in hake egg and larval survival rate. Recruitment was reduced when elevated sea-surface temperatures were coupled with lower levels of water circulation. Enhanced spring primary production, related to late winter low temperatures could affect water mass productivity in the following months, thus influencing spring recruitment. In the central Tyrrhenian a dome-shaped relationship between wind mixing in early spring and recruitment could be interpreted as an "optimal environmental window" in which intermediate water mixing level played a positive role in phytoplankton displacement, larval feeding rate and appropriate larval drift (Bartolino *et al.*, 2008b) (Figure 4.1.2-3).



Figure 4.1.2-3: Effects of: (a) sstm.w, (b) sstmax8 and (c) wmix4 on hake recruitment in the central Tyrrhenian (from Bartolino et al., 2008b).

The temporal trend in spatial distribution of hake > 26 cm TL showed a clear reduction of distribution area, particularly in the Tyrrhenian part of the GSA (GRUND data, Figure 4.1.2-4).



Figure 4.1.2-4: Distribution of European hake larger than 26 cm TL in 1985-87, 1996-98, 2000-01, 2002-03.

3.1.3 Historical trends

Figure 4.1.3-1 displays the trend of hake biomass and density indices in GSA 9 (kg/km² and n/km², respectively) based on the MEDITS data. Both biomass and density showed large fluctuations without temporal trend.



Figure 4.1.3-1: European hake in GSA 9. MEDITS time series of survey biomass and density indices (mean +/- standard deviation).

Figure 4.1.3-2 displays the stratified abundance indices of European hake in GSA 9 from 1994 to 2014.



HKE-Merluccius merluccius GSA9

Figure 4.1.3-2: European hake in GSA 9. Stratified abundance indices by size, 1994-2014.

4 Ecological information

4.1 Protected species potentially affected by the fisheries

The by-catch of protected, threatened or endangered species in the fisheries targeting European hake in GSA 9 is mainly represented by elasmobranchs, such as *Galeus melastomus*, *Scyliorhinus canicula*, *Raja clavata*, etc.

4.2 Environmental indexes

No environmental indices were used to perform the stock assessment of European hake in GSA 9.

5 Stock Assessment

FLR libraries were employed in order to carry out an Extended Survivor Analysis (XSA) assessment (Darby and Flatman, 1994).

5.1 Extended Survivor Analysis (XSA)

5.1.1 Model assumptions

5.1.2 Scripts

FLXSA.control.mm <- FLXSA.control(x=NULL, tol=1e-09, maxit=30, min.nse=0.3, fse=3.0, rage=1, qage=2, shk.n=TRUE, shk.f=TRUE, shk.yrs=3, shk.ages=2, window=100, tsrange=20, tspower=3, vpa=FALSE)

5.1.3 Input data and Parameters

The assessment by means of XSA was carried out using as input data the period 2006-2014 for the catch data and 2006-2014 for the tuning file (Medits indices).

The growth parameters used for VBGF were Linf= 103.9 cm TL; K = 0.21 yr-1; t0= 0.03 yr. The length-to-weight coefficients used were a= 0.006657, b= 3.028.

Catch numbers have been raised taking into account the LFD that were missing for some years and gears. For GNS and GTR in 2007 the LFD of GNS 2006 was used to raise the landings, for GTR of the other missing years the LFD of GNS of the same years were used. Discards for OTB in 2007 and 2008 were estimated as the mean discard % of the entire time-series (35.59%, 2007=364 tons and 2008=325 tons). The LFD of OTB discards of 2009 were used to raise the discards.

LFDA 5.0 slicing software has been used to transform the annual size distribution of the landings and MEDITS LFDs in age distributions in order to apply XSA model.

Zero values in the catch at age have been substituted with the lowest value in the time series.

The following tables summarize the input parameters to the XSA model, namely catch number-atage, tuning series at age (MEDITS), catches, weight-at-age, maturity vector, and natural mortality (M) vector. Natural mortality values (vector) were computed with the PROBIOM routine.

Discards were included in the catch-at-age matrix.

	Catch-at-age (thousands)									
Age class	2006	2007	2008	2009	2010	2011	2012	2013	2014	
0	23197.4	32439.2	35592.9	60804.2	11959.7	41216.3	12689.7	13083.2	30613.1	
1	5961.2	7990.1	5752.0	6327.5	5038.5	5913.9	4275.2	7206.2	5584.2	
2	1351.8	691.8	383.2	403.2	514.1	529.4	319.6	326.8	439.3	
3	170.6	73.1	92.5	105.1	132.5	96.1	82.4	40.3	77.0	
4	59.4	10.5	15.5	39.8	53.8	52.5	34.3	18.3	11.6	
5	1.7	0.0	11.6	9.2	25.8	13.0	7.6	3.1	2.8	
6+	0.0	1.1	3.6	1.9	5.5	2.5	0.9	0.5	0.7	

5.1.4 Tuning data

	Catch-at-a	age (thousa	nds)						
Age class	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	1686.6	2514.3	5871.6	6573.9	2469.1	769.9	1464.4	1743.2	1564.2
1	58.6	38.9	57.2	52.8	37.3	29.4	21.9	35.3	27.1
2	2.5	2.2	1.2	1.1	2.6	1.3	1.0	1.0	1.9
3	0.3	1.5	0.3	0.5	0.1	0.3	0.5	0.1	0.2
4+	0.2	0.1	0.4	0.1	0.1	0.1	0.3	0.3	0.3

Catch (tons) (including discards)

2006	2007	2008	2009	2010	2011	2012	2013	2014
2281.69	2097.81	1646.69	2005.74	1583.52	1879.53	1185.75	1584.06	1550.79

Weight-at-age matrix (kg)

Age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008
1	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166
2	0.578	0.578	0.578	0.578	0.578	0.578	0.578	0.578	0.578
3	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200
4	1.949	1.949	1.949	1.949	1.949	1.949	1.949	1.949	1.949
5	2.745	2.745	2.745	2.745	2.745	2.745	2.745	2.745	2.745
6+	3.529	3.529	3.529	3.529	3.529	3.529	3.529	3.529	3.529

Maturity and natural mortality vectors.

Age	0	1	2	3	4	5	6+
Maturity	0	0.25	0.9	1	1	1	1
м	1.2	0.62	0.44	0.37	0.33	0.31	0.29

The model settings that minimized the residuals and showed the best diagnostics outputs were used for the final assessment, and are the following:

Fbar	fse	rage	qage	shk.yrs	shk.age
0-2	3	1	2	3	2

5.1.5 Results

The results of the assessment run using XSA are shown in Figure 6.1.5-1, and Tables 6.1.5-1 – 6.1.5-3. The XSA results show a decreasing trend in the catches, a fluctuation in recruitment and SSB, and an estimated $F_{curr} = 1.03$.



Figure 6.1.5-1: European hake in GSA 9. XSA results: fishing mortality (Harvest), recruitment, SSB, and yield.

Age	2006	2007	2008	2009	2010	2011	2012	2013	2014
0	84450.0	90885.0	100830.0	141620.0	53382.0	99813.0	63723.0	55923.0	88907.0
1	11107.0	12705.0	9571.0	10836.0	9284.6	9514.9	7443.1	12229.0	9663.6
2	2902.0	1602.8	974.1	929.9	1188.1	1299.2	780.9	868.3	1293.0
3	360.8	784.2	477.1	319.9	275.3	352.6	411.9	246.5	297.0
4	94.2	107.4	480.9	252.6	133.6	80.1	163.7	216.0	136.8
5	2.9	17.3	68.3	332.6	147.8	50.4	13.0	88.6	139.8
6+	1.8	11.1	21.0	69.5	31.3	9.4	1.5	15.2	33.4

Table 6.1.5-1: European hake in GSA 9. Stock numbers-at-age (thousands) as estimated by XSA.

Table 6.1.5-2: European hake in GSA 9. XSA summary results.

	F _{bar0-2}	Recruitment (thousands)	SSB (t)	TB (t)
2006	0.96	84450	2599.8	4833.0
2007	1.26	90885	2596.9	5005.9
2008	1.14	100830	2674.6	4738.4
2009	1.30	141618	2966.8	5516.1
2010	0.88	53382	2109.4	3765.1
2011	1.33	99813	1820.4	3887.8
2012	0.90	63723	1568.7	3055.9
2013	0.94	55923	1971.6	3995.3
2014	1.03	88907	2197.2	4194.2

Table 6.1.5-3: European hake in GSA 9. XSA summary results: F-at-age matrix.

	F-at-age										
	0	1	2	3	4	5	6+				
2006	0.69	1.32	0.87	0.84	1.36	1.13	1.13				
2007	1.05	1.95	0.77	0.12	0.12	0.12	0.12				
2008	1.03	1.71	0.67	0.27	0.04	0.22	0.22				
2009	1.52	1.59	0.78	0.50	0.21	0.03	0.03				
2010	0.52	1.35	0.77	0.86	0.64	0.23	0.23				
2011	1.40	1.88	0.71	0.40	1.49	0.36	0.36				

2012	0.45	1.53	0.71	0.28	0.28	1.15	1.15
2013	0.56	1.63	0.63	0.22	0.11	0.04	0.04
2014	0.99	1.55	0.55	0.37	0.11	0.02	0.02

5.1.6 Retrospective analysis, comparison between model runs, sensitivity analysis

Sensitivity analyses were conducted to assess the effect of the main parameters. Values ranging from 0.5 to 3 (0.5 increasing) for the shrinkage, values ranging from 1 to 3 for shrinkage years and a combination of values between 2 to 4 for the gage parameter and from -1 to 1 for the rage parameter have been tested. Comparison of trends between the settings has been done. Different combinations between the settings that looked more stable were tested.



Figure 6.1.6-1: European hake in GSA 9. Sensitivity on shrinkage weight.



Figure 6.1.6-2: European hake in GSA 9. Sensitivity on shrinkage age.



Figure 6.1.6-3: European hake in GSA 9. Sensitivity on qage and rage.

As a result, the settings that minimized the residuals and showed the best diagnostics output were used for the final assessment, and are the following:

Fbar	fse	rage	qage	shk.yrs	shk.age
0-2	3	1	2	3	2

The residuals pattern of the MEDITS trawl survey is shown in Figure 6.1.6-4.



Proportion at age by year Sh3.0

Figure 6.1.6-4: European hake in GSA 9. XSA residuals for the MEDITS survey from 2006 to 2014.

The results of the retrospective analysis are shown in Figure 6.1.6-5



Figure 6.1.6-5: European hake in GSA 9. XSA retrospective analysis.

Fishing mortality F split by gear is shown in the following table. The fishing mortality exerted by trawling is dominant in the first age classes, while the contribution by set nets (mostly gill net) is increasing in the older age classes.

age	Bottom otter trawl	Trammel net	Gill net
0	0.69	0.00	0.00
1	1.59	0.05	0.15
2	0.54	0.12	0.39
3	0.43	0.10	0.35
4	0.20	0.08	0.25
5	0.21	0.05	0.26
6+	0.01	0.08	0.42

Table 6.1.6.1: European hake in GSA9. Fishing mortality split by gear.

5.1.7 Assessment quality

Data from EU DCF 2014 as submitted through the Official data call in 2015 were used. Length-frequencies distributions (LFD) that were missing are presented in the following table. Missing LFD were borrowed from other fleet segments. EU DCF data prior to 2006 were considered incomplete, therefore they were not used for the stock assessment.

year	gear	fishery	species	Landings (t)
2007	GNS	DEMF	HKE	576.2
2006	GTR	DEMSP	HKE	403.9
2007	GTR	DEMSP	HKE	131.8
2009	GTR	DEMSP	HKE	53.9
2011	GTR	DEMSP	HKE	54.3
2012	GTR	DEMSP	HKE	48.6
2013	GTR	DEMSP	HKE	98.1
2014	GTR	DEMSP	HKE	76.8

Table 5.2.6.9.1. European hake in GSA 9. Missing LFD in the landings.

Discards data were missing for 2007 and 2008. Discards for OTB in 2007 and 2008 were estimated as the mean discard % of the entire time-series (35.59%, 2007=364 tons and 2008=325 tons). The LFD of OTB discards of 2009 were used to raise the discards.

6 Stock predictions

A deterministic short term prediction for the period 2015 to 2017 was performed using the FLR routines and based on the results of the XSA stock assessment.

6.1 Short term predictions

The input parameters for the deterministic short term predictions for the period 2015 to 2017 were the same used for the XSA stock assessment and its results. An average of the last three years has been used for weight at age, maturity at age and F at age.

Recruitment (age 0) has been estimated from the population results as the geometric mean of the last 3 years (68172.32 thousand individuals).

Rationale	Ffactor	Fbar	Catch 2014	Catch 2015	Catch 2016	Catch 2017	SSB 2016	SSB 2017	Change SSB 2016- 2017(%)	Change Catch 2014- 2016(%)
Zero catch	0	0.00	1553	1821	0	0	2567	6175	140.52	-100.00
High long term yield (F0.1)	0.24	0.23	1553	1821	635	1136	2567	4891	90.52	-59.10
Status quo	1	0.96	1553	1821	1867	1911	2567	2649	3.16	20.28
Different Scenarios	0.1	0.10	1553	1821	282	566	2567	5596	117.98	-81.82
	0.2	0.19	1553	1821	536	991	2567	5088	98.18	-65.51
	0.3	0.29	1553	1821	763	1305	2567	4640	80.74	-50.82
	0.4	0.38	1553	1821	969	1532	2567	4245	65.35	-37.56
	0.5	0.48	1553	1821	1156	1692	2567	3896	51.74	-25.56
	0.6	0.57	1553	1821	1325	1800	2567	3586	39.67	-14.66
	0.7	0.67	1553	1821	1479	1867	2567	3310	28.94	-4.73
	0.8	0.76	1553	1821	1620	1903	2567	3065	19.37	4.34
	0.9	0.86	1553	1821	1749	1916	2567	2845	10.82	12.64
	1.1	1.05	1553	1821	1977	1894	2567	2472	-3.72	27.31
	1.2	1.14	1553	1821	2077	1866	2567	2312	-9.93	33.81
	1.3	1.24	1553	1821	2171	1832	2567	2168	-15.54	39.84
	1.4	1.33	1553	1821	2258	1793	2567	2038	-20.62	45.43
	1.5	1.43	1553	1821	2339	1751	2567	1919	-25.24	50.64
	1.6	1.53	1553	1821	2414	1708	2567	1811	-29.45	55.51
	1.7	1.62	1553	1821	2485	1663	2567	1712	-33.30	60.06
	1.8	1.72	1553	1821	2551	1619	2567	1622	-36.83	64.33
	1.9	1.81	1553	1821	2614	1575	2567	1538	-40.08	68.35
	2	1.91	1553	1821	2672	1532	2567	1462	-43.07	72.13

Table 5.2.6.10.3.1. European hake in GSA 9. Short term forecast in different F scenarios.

6.2 Medium term predictions

No medium term predictions were carried out for this stock.

6.3 Long term predictions

No long term predictions were carried out for this stock.

7 Draft scientific advice

Based on	Indicator	Analytic al reference point (name and value)	Current value from the analysis (name and value)	Empirical reference value (name and value)	Trend (time period)	Stock Status		
Fishing	Fishing	$F_{0.1} = 0.23$	$F_{curr} = 0.96$		N	IOн		
mortality	mortality		(as F _{bar} 0-2, years 2012- 2014)					
	Fishing							
	effort							
	Catch							
Stock abundance	Biomass							
	SSB		SSB = 2197 t	SSB _{33p} = 2059 t	N	Oı		
				SSB _{66p} = 2597 t				
Recruitment								
Final Diagnosis		In high level of overfishing, and in relative intermediate level of spawning stock biomass						

The stock of European hake in GSA 9 was assessed applying an Extended Survivor Analysis (XSA) method calibrated with fishery independent survey abundance indices (MEDITS in GSA 9).

Input data on landings, discards and length frequencies were taken from EU DCF. Von Bertalanffy growth parameters and length-weight relationship were taken from parameters agreed and used in previous working groups.

SSB is fluctuating along the time series 2006-2014 with an average of 2900 t. Current SSB is falling within the range 33^{rd} and 66^{th} percentiles computed on the time series of data on SSB. Recruitment estimated for 2014 is 140913 thousand individuals, slightly lower compared to the series average (166055 thousand, period 2006-2014). Current F (0.96) is larger than F_{0.1} (0.23), chosen as proxy of F_{MSY} (F_{curr}/F_{MSY} ratio = 4.2) and as the exploitation reference point consistent with high long term yields, which indicates that European hake stock in GSA 9 is exploited unsustainably.

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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 (O₁): 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 33^{rd} 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 66^{th} 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)