Preamble

The following working documents were compiled to be presented at WKPELA 2017 and include the work and discussions carried out during the WGACEGG meeting in November 2016 concerning the issues on the sardine stock from the ICES areas 9a + 8c. These manuscripts are reproduced here since the final version of the WGACEGG report is not yet available.

Working Document 1 - Summary of the revised DEPM data series estimations for the Atlanto-Iberian sardine (ICES 9a + 8c), 1988-2014, using the traditional methodology (in line with the 2012 revision).

Working Document 2 - Atlanto-Iberian sardine (ICES 9a + 8c) spawning stock biomass reanalysis for the DEPM data series, 1988-2014, considering egg production estimation using a mortality model obtained from aggregated data and with temperature as covariate.
Part I. SSB reanalysis for the DEPM data series, 1988-2014, considering egg production estimation using a mortality model obtained from aggregated data and with temperature as covariate.
Part II. - Comparison of trends in the sardine SSB estimates (ICES 9a + 8c) obtained from DEPM and acoustics surveys

Working Document 3 - Sardine Egg Production Estimation (ICES áreas 9a + 8c) using data from EPM surveys directed at mackerel and horse-mackerel.

Working Document 1

Summary of the revised DEPM data series estimations for the Atlanto-Iberian sardine (ICES 9a + 8c), 1988-2014, using the traditional methodology (in line with the 2012 revision).

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Summary

The Daily Egg Production Method (DEPM) has been applied for estimating the Atlanto-Iberian sardine Spawning Stock Biomass (SSB) since the late eighties/early nineties and since 2002 the surveys have been conducted within the framework of ICES, with co-financing from the EU, on a triennial basis. Collaborative work between Portugal (IPIMAR/IPMA) and Spain (IEO) over the years, led to increased coordination of the surveys and standardisation of surveying and analysis methodologies, and many developments have been achieved under the auspices of the ICES groups SGSBSA (Study Group on the Estimation of Spawning Stock Biomass of Sardine and Anchovy) and WGACEGG (Working Group on Acoustics and Egg Surveys for Sardine and Anchovy in ICES Areas 7, 8 and 9). DEPM estimates of sardine SSB were last revised in 2012 (WGACEGG report 2012), and this revision was presented to the 2012 ICES benchmark assessment of the Atlanto-Iberian stock. Since then, one more DEPM survey took place, in 2014, and the corresponding analyses were undertaken according to the 2012 agreed revision procedures. In view of the 2017 benchmark workshop we present in this document summary tables with survey information (table 1) and results for the whole series (table 2). All the methodological aspects adopted for the revision are fully reported in the WGACEGG reports from 2011 and 2012 (ICES, 2011, 2012) and the 2014 data details appear in the WGACEGG reports from 2014 and 2015 (ICES, 2014, 2015). Further information on the series historic data such environmental parameters and average egg distributions, etc, was collected in a ICES Cooperative Research Report (Massé *et al.* editors, 2016, CRR, 332). The results presented in this manuscript (*Working Document 1*) were compiled with the aim of updating the data series using the traditional methodology and for comparative purposes with the new approach presented in *Working Document 2*. The present view of the Group is that the more consistent SSB estimates for the DEPM historic series, in light of the current analysis developments, are the results achieved considering egg production estimation using a mortality model obtained from aggregated data and with temperature as covariate as suggested by Bernal *et al.* (2011).

<u>References</u>

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Massé, J., Uriarte, A., Angélico, M. M., and P. Carrera (editors) 2016 Pelagic survey series for sardine and anchovy in ICES subareas 8 and 9 (WGACEGG) – Towards an ecosystem approach. ICES Cooperative Research Report 332. (in press)

Table 1. DEPM surveys for the Atlanto-Iberian sardine stock (ICES areas 9a+8c), 1988-2014, surveying summary information.

Year	Strata	Dates	Research Vessel	Transects and Grid nm (transects x stations)	PairoVET Stations (% with eggs)	Eggs PairoVET	Max eggs/m2 PairoVET	Temp (°C) Min-Max	Survey area (km2)	Positive area (km2)	CUFES Stations	Eggs CUFES	Max eggs/m3 CUFES
1988	IXa South	28/03-30/03	Noruega	15 (7x7)	55(25.5)	344	1680	14.5-17.2	9037	2144			
	IXa West	01-08/03-21-28/03		42 (7x7)	249(35.7)	944	1360	12.8-16.1	39073	14889			
	IXa North+VIIIc	31/03-05/05	Cornide de Saavedra	68 (6x6-3)	516(51.7)	3922	2758.3	10.6-15.5	55492	26644			
	Iberian Peninsula			125	820(45.1)	5210	2758.3	10.6-17.2	103602	43676			
1990	IXa South												
	IXa West												
	IXa North+VIIIc	18/04-10/05	Investigador		475(36.6)	1494	2063.4	12.8-18.5	64185	30555			
	Iberian Peninsula												
1997	IXa South	18/03-25/03	Noruega	29 (7x7)	135(43.0)	868	5593.8	16-19.3	19951	8745			
	IXa West	01/03-16/03		39 (7x7)	238(16.0)	586	2012.3	14-16.9	37757	6696			
	IXa North+VIIIc	05/03-29/03	Cornide de Saavedra	44 (15 GAL,7.5 CANT x3)	515(16.7)	1465	5381	13.2-15.9	55870	10275			
	Iberian Peninsula			112	888(20.5)	2919	5593.8	13.2-19.3	113577	25716			
1999	IXa South	10/01-19/01	Noruega	77 (6x6)	147(36.7)	3184	13431	14-17.1	20633	7451			
	IXa West	19/01-03/02		(6x6)	272(23.2)	1926	6060	12.6-16.3	36919	9829			
	IXa North+VIIIc	17/03-03/04	Cornide de Saavedra	50 (15 GAL,7.5 CANT x3)	290(25.9)	900	1196.6	12.2-13.8	30316	7174			
	Iberian Peninsula				707(27.2)	6010	13431	12.2-17.1	87868	24454			
2002	IXa South	27/01-02/02	Noruega	53 (8x3-6)	152(32.2)	530	1733.4	14.5-16.9	16504	7702	168	2955	29.4
	IXa West	08/01-27/01		(8x3-6)	332(41.9)	2077	8328.2	12.1-16.8	34442	18711	375	8774	131
	IXa North+VIIIc	20/03-16/04	Cornide de Saavedra	36 (8x3-6)	220(58.6)	1939	1896.1	10.9-17.5	25476	15202	441	9669	40.6
	Iberian Peninsula				704(45)	4546	8328.2	10.9-17.5	76422	41615	984	21398	131
2005	IXa South	13/02-22/02	Capricórnio	(8x3-6)	159(41.5)	1733	4825.6	13.1-15.4	17321	7201	186	4991	30.4
	IXa West	29/01-12/02		(8x3-6)	249(32.9)	1942	8020	11.6-14.8	26808	10723	312	4278	55.6
	IXa North+VIIIc	13/04-01/05	Cornide de Saavedra	56 (8x3)	371(32.3)	3216	3231	12.4-16	38476	12307	323	9748	85
	Iberian Peninsula				779(34.4)	6891	8020	11.6-16	82605	30231	821	19017	85
2008	IXa South	20/01-27/01	Noruega	22 (8x3)	174(56.3)	5727	9842.5	14.8-17.1	18164	9692	181	10710	124.9
	IXa West	28/01-15/02		36 (8x3)	288(51.7)	7895	8142.4	13.3-16.7	30318	19296	315	19632	140
	IXa North+VIIIc	02/04-27/04	Cornide de Saavedra	56 (8x3)	426(54.2)	3788	8354.2	11.9-15.2	42381	24264	416	17225	162.7
	Iberian Peninsula			114	888(53.8)	17410	9842.5	11.9-17.1	90863	53252	912	47567	162.7
2011	IXa South	10/02-20/02	Noruega	21 (8x3)	170(31.8)	2208	4950	14.6-16.9	17578	6523	184	4607	81.7
	IXa West	20/02-08/03		36 (8x3)	309(12.9)	833	2970	13.5-16.1	32098	4817	308	479	6
	IXa North+VIIIc	25/03-10/04	Cornide de Saavedra	56 (8x3)	337(38.6)	1794	1537	12.5-14.6	33832	12405	291	19828	97.3
	Iberian Peninsula			113	816(27.5)	4835	4950	12.5-16.9	83508	23745	783	24914	97.3
2014	IXa South	15-26/04	Noruega	20 (8x3)	134(46.3)	2019	5500	14.5-19.1	14558.7	6824.8	146	2695	78.3
	IXa West	15-21/3; 4-15/4		38 (8x3)	265(38.1)	2164	1550	12.8-18.5	27357.3	11000.8	313	12709	61.7
	IXa North+VIIIc	29/3-9/4;16-21/4	Visconde de Eza	54 (8x3)	394(16.8)	313	704	12.3-14.9	38914.4	7494.5	339	2186	25.2
	Iberian Peninsula			112	793(28.9)	4496	7754	12.3-19.1	80830.5	25320.1	798	17590	78.3

Table 1. DEPM surveys for the Atlanto-Iberian sardine stock (ICES areas 9a+8c), 1988-2014, surveying summary information, continuation

Year	Strata	Fishing hauls (% positive)	Total sardine sampled	Males	Females	Females for histology	Hydrated females	Mature females (%)
1988	IXa South							
	IXa West							
	IXa North+VIIIc							
	Iberian Peninsula							
1990	IXa South							
	IXa West							
	IXa North+VIIIc							
	Iberian Peninsula							
1997	IXa South	12(83.3)	537	232	305	131	24	304(99.7)
	IXa West	28(57.1)	804	298	506	142	6	506(100)
	IXa North+VIIIc	9(77.8)	402	142	260	255	113	259(99.6)
	Iberian Peninsula	49(67.3)	1743	672	1071	528	143	1069(99.8)
1999	IXa South	12(100)	1208	536	672	151	19	624(92.9)
	IXa West	28(100)	2732	1125	1580	283	86	1479(93.6)
	IXa North+VIIIc	19(57.9)	997	532	463	100	19	422(91.1)
	Iberian Peninsula	59(86.4)	4937	2193	2715	534	124	2525(93)
2002	IXa South	31(96.8)	2416	934	1478	499	47	1462(98.9)
	IXa West	43(93.0)	2811	1104	1472	576	66	1217(82.7)
	IXa North+VIIIc	28(100)	2058	1019	1039	470	69	1038(99.9)
	Iberian Peninsula	102(96.1)	7285	3057	3989	1545	182	3717(93.2)
2005	IXa South	24(91.7)	1652	759	891	510	52	851(95.5)
	IXa West	42(97.6)	2915	1323	1533	983	1	1366(89.1)
	IXa North+VIIIc	76(46.1)	1625	721	897	562	115	755(84.2)
	Iberian Peninsula	142(69)	6192	2803	3321	2055	168	2972(89.5)
2008	IXa South	27(92.6)	1745	838	906	643	103	842(92.9)
	IXa West	58(87.9)	3195	1352	1839	1371	76	1554(84.5)
	IXa North+VIIIc	41(87.8)	2392	1157	1235	594	183	1235(100)
	Iberian Peninsula	126(88.9)	7332	3347	3980	2608	362	3631(91.2)
2011	IXa South	18(88.9)	975	480	495	397	11	495(100)
	IXa West	40(80)	2069	1028	1037	827	25	954(92)
	IXa North+VIIIc	53(18.9)	718	334	384	230	31	380(99)
	Iberian Peninsula	111(52.3)	3762	1842	1916	1454	67	1829(95.5)
2014	IXa South	17(94.1)	938	356	582	444	70	582(100)
	IXa West	47(70.2)	1635	969	666	705	21	646(97.0)
	IXa North+VIIIc	57(26.3)	755	443	624	262	119	624(100)
	Iberian Peninsula	121(52.9)	3328	1768	1872	1411	210	1540(98.7)

Table 2. DEPM surveys for the Atlanto-Iberian sardine stock (ICES areas 9a + 8c), 1988-2014. Summary of the results for eggs, adults, and SSB estimates carried out using the traditional methodology (ICES, 2011, 2012). Final egg production model for the Iberian Peninsula includes individual egg production estimates for each strata (9a South, 9a West (Pt) and 9a North–8c) and a common mortality (h^{-1}) for the whole area. * p<0.05, ** p<0.01, and *** p<0.001. Total egg production (Ptot), number of eggs x 10^{12} day^{-1}; Mean females weight (*W*), in grams; Batch fecundity (*F*), number eggs $female^{-1}$; sex ratio (*R*); spawning fraction (*S*) and spawning-stock biomass (SSB), in tonnes. *CV* corresponds to the coefficient of variation for each parameter estimated.

Year	Strata	Mortality		Ptot		W		R		F		S		SSB	
		Estim	C.V	Estim	C.V.	Estim	C.V.	Estim	C.V.	Estim	C.V.	Estim	C.V.	Estim	C.V.
1988	9a South			0.85	0.31										
	9a West	-0.019***	0.2	1.84	0.17										
	9a North+8c			4.3	0.15										
	Total Iberian Peninsula			6.99	0.11										
1990	9a North+8c	-0.034***	0.24	3.56	0.26										
1997	9a South			1.55	0.27	43.1	0.07	0.557	0.05	19062	0.12	0.104	0.13	60556	0.33
	9a West	-0.032***	0.23	2.09	0.29	48.5	0.07	0.637	0.04	22569	0.13	0.049	0.18	144012	0.37
	9a North+8c			2.91	0.27	72.2	0.05	0.493	0.14	28544	0.07	0.144	0.1	103611	0.33
	Total Iberian Peninsula			**6.55**	**0.16**									**308178**	**0.22**
1999	9a South			5.96	0.33	42.1	0.05	0.531	0.03	22436	0.11	0.074	0.22	284749	0.42
	9a West	-0.023**	0.34	3.59	0.3	44.9	0.06	0.639	0.05	24086	0.09	0.142	0.05	73672	0.33
	9a North+8c			0.95	0.33	65.9	0.09	0.514	0.04	34137	0.1	0.09	0.09	41963	0.37
	Total Iberian Peninsula			**10.5**	**0.22**									**400385**	**0.3**
2002	9a South			0.33	0.19	38.8	0.05	0.621	0.05	12881	0.06	0.035	0.19	45781	0.29
	9a West			1.38	0.12	43.3	0.05	0.619	0.03	15212	0.07	0.061	0.18	103982	0.24
	9a North+8c			0.85	0.11	75.6	0.05	0.505	0.08	29623	0.06	0.09	0.11	47747	0.2
	Total Iberian Peninsula			**2.56**	**0.08**									**197511**	**0.15**
2005	9a South			1.38	0.23	45.4	0.07	0.574	0.11	13169	0.08	0.135	0.13	61328	0.3
	9a West	-0.011*	0.4	1.87	0.21	46.2	0.06	0.556	0.06	15304	0.44	0.063	0.21	160988	0.54
	9a North+8c			2.7	0.21	80.7	0.04	0.51	0.07	34147	0.04	0.078	0.17	160346	0.28
	Total Iberian Peninsula			**5.95**	**0.13**									**382662**	**0.26**
2008	9a South			4.04	0.21	56.3	0.06	0.489	0.07	20956	0.06	0.088	0.08	252405	0.25
	9a West	-0.024***	0.18	3.93	0.18	59.3	0.03	0.593	0.03	26424	0.04	0.078	0.1	190549	0.22
	9a North+8c			3.79	0.17	83.9	0.04	0.482	0.06	35139	0.04	0.09	0.13	208604	0.23
	Total Iberian Peninsula			**11.76**	**0.11**									**651558**	**0.14**
2011	9a South			2.86	0.27	54.3	0.07	0.498	0.09	17157	0.11	0.081	0.09	223745	0.33
	9a West	-0.047***	0.13	0.84	0.29	50.1	0.06	0.496	0.04	11838	0.09	0.066	0.08	108154	0.32
	9a North+8c			4.04	0.24	85.9	0.03	0.487	0.12	40844	0.05	0.114	0.26	152954	0.38
	Total Iberian Peninsula			**7.74**	**0.16**									**484852**	**0.21**
2014	9a South			0.71	0.27	60.72	0.05	0.602	0.08	22673	0.07	0.080	0.15	39482	0.34
	9a West	-0.017***	0.36	0.97	0.23	52.63	0.14	0.505	0.06	21322	0.16	0.075	0.19	63216	0.38
	9a North+8c			0.31	0.26	48.70	0.11	0.397	0.15	17118	0.12	0.093	0.34	23887	0.48
	Total Iberian Peninsula			**1.99**	**0.16**									**126584**	**0.23**

Working Document 2

Atlanto-Iberian sardine (ICES 9a + 8c) spawning stock biomass reanalysis for the DEPM data series, 1988-2014, considering egg production estimation using a mortality model obtained from aggregated data and with temperature as covariate.

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Part I. SSB reanalysis for the DEPM data series, 1988-2014, considering egg production estimation using a mortality model obtained from aggregated data and with temperature as covariate

Background

In 2011 it was presented at the WGACEGG meeting a revision of the egg production estimates for the Atlanto-Iberian sardine DEPM data series (1988-2011) (ICES, 2011). The analyses were undertaken following the traditional approach (*eg*. Lasker, 1985) updated with the developments discussed, over the last decade, at the SGSBSA and WGACEGG and in the scientific literature. The review using the traditional method (described in detail in the 2011 report) was for the first time carried out in a standardized manner for the whole historic data. An important discussion raised during the revision was the reliability of the mortality estimates per strata obtained for each survey separately. In some cases (surveys or strata) spurious positive (or almost positive) egg mortality estimates were obtained from the observations taken during the egg production surveys. Bernal *et al* (2011a) and other before (*eg.* Parker, 1980, Stratoudakis et al., 2006) have discussed this issue. Bias mortality estimates can arise from problems with surveying or difficulties in fitting the mortality curve model, in particular related to the lack of observations at both tails of the egg age distribution, very young and very old eggs are often poorly represented in the plankton samples.

To overcome the problems mentioned above and attain statistically significant and biologically plausible mortality estimates the approach described by Bernal *et al.* (2011a and 2011b) was here adopted. Using all data available (1988-2014) the external mortality model developed by Bernal *et al.* (2011a) is updated and used to estimate mortality per strata for all surveys; the average mortality values are then used to obtain P0 estimates per strata.

In the model egg production and mortality are achieved considering spatial and temporal strata and water temperature. Temperature effects on reproductive capacity, egg development, or other physiological rates have been reported for marine organisms (e.g. as in Ottersen *et al*., 2001). The effect of temperature on egg mortality for different species including some cupleiformes has been referred in the literature (*eg.* Pepin, 1991).

Mortality, egg production and spawning stock biomass estimates obtained from the traditional method for the 2011 data series revision (ICES 2011) and the results from the Sardine DEPM survey carried out in 2014 are compared to the results achieved using the external mortality model. The implications for SSB estimation and sardine assessment modeling are discussed.

Methodology

Using the approaches by Bernal *et al*. (2007, 2011), three spatial and two temporal strata (1985 – 1994 and 1995 – 2014) were used. The geographical strata (Figure 1) considered were: South: from Gibraltar to Cabo de S.Vicente; West: S.Vicente to the northern Portuguese-Spanish border and North: the Spanish waters from Galicia to the French border. The spatial strata were selected to represent three spawning nuclei using the approaches by Bernal *et al.* (2007, 2011). The two temporal strata represent two periods with different extents of occupancy of the shelf.

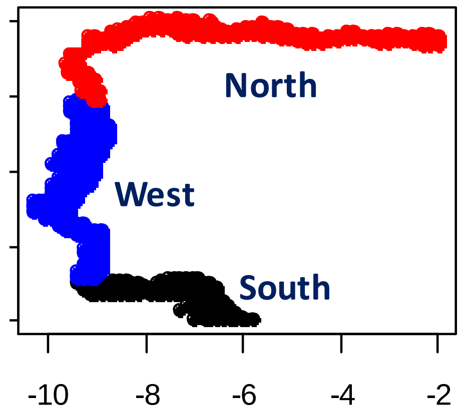

Figure 1. Strata used in the analysis. South, from the Strait of Gibraltar to Cape St.Vicente (black area), West, from Cape St. Vicente to the northern limit between Portugal and Spain (blue area), and North, between the Portuguese-Spanish border and the Spanish-French Atlantic limit (red area).

Mean surface temperature values by the strata used in the analysis are presented in figure 2. Temperature values ranged from 12.6 to 17.2 ºC. Temperature distribution followed the common patterns; the highest temperature values were observed in the southern area and the lowest values registered for the Cantabrian Sea. A marked interannual variability by strata is showed for the temperature registered along the DEPM surveys series, higher in southern and western areas than in the northern area.

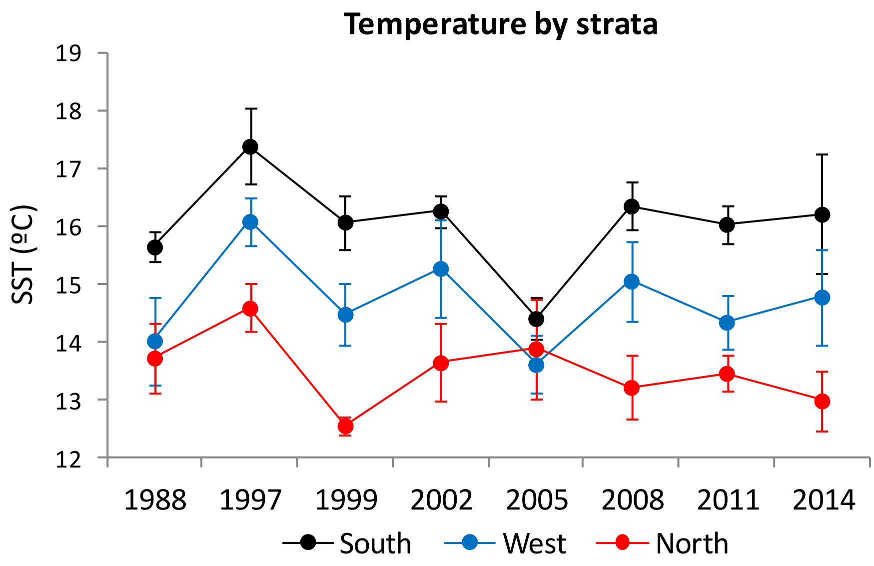

Figure 2. Mean temperature (SST) estimates for the three strata (South in black, West in blue, North in red) and year. Vertical lines indicate 2 standard-deviations

The approach described by Bernal *et al.* (2011) is summarized as follow:
1) Estimation of age and cohort abundance
2) Mortality estimation
3) Calculation P0 with the external mortality

Steps 1 and 2 are based on all available data on egg age and mortality, egg production calculation uses data from DEPM surveys.

Step 1: Egg stage and age are related to temperature with a multinomial model. Peak spawning time is used to define the cohorts, their abundance and mean age. Then the mortality curve is fitted to the abundance-by-cohort estimates.

- Multinomial model of sardine egg development was used to relate egg stage and age for the sampled temperatures. Egg ageing was achieved using the egg development multinomial model presented in Bernal *et al*. (2008) and the Bayesian approach described in Ibaibarriaga *et al.* (2007).
- Assumed peak spawning time (lognormal) was used to define the daily cohorts, cohorts abundance and mean cohort age for all stations
- New data with observed abundance-by-cohort used to fit the mortality curve

The first modification on the traditional application of the DEPM was to consider a lognormal distribution for the daily spawning cycle, usually a normal PDF is assumed (*eg*. Lo, 1985). Bernal *et al* (2011a) showed using stage I eggs and running females that the Atlanto-Iberian sardine is a late-evening spawner with a lengthier (non normal PDF) daily period than previously thought.

Step 2: Establishes a model for the expected number of eggs for a cohort with a given age, resulting from egg production rate and mortality.

$E[Na] = g^{-1}(\text{offset}(\log(Efarea)) + \log(D0) - ma)$ (1)

E [Na] = expected number of eggs in a cohort of mean age a
D0 = the rate of egg production
m = the mortality rate
g^1 = the inverse of the link function that relates the linear predictor and the response, Na

The equation (1) is then reformulated to allow both egg production and mortality to be a function of the spatial and temporal strata and also temperature, as well as their first-order interactions. Terms in which age is involved indicate mortality terms, and the rest of the terms affect egg production. From a general full model:

- Backward stepwise model selection was carried out. At each step, the term with least significance (<5%) was dropped, and this procedure repeated until dropping terms led to no improvement. The models were fitted by an iterative procedure.
- A comparison with Akaike information criterion (AIC) profiles of the model selection procedure was also performed.
- To avoid bias in the mortality model caused for the extremes of the data: lower limit and upper limits were set on the tails of the mortality curve. For the lower tail of the data set, the first cohort that fell within the spawning period in stations sampled during this period was excluded. At the other end (upper tail) the age limit was considered by stratum, and eggs excluded when 5% of the eggs would already have hatched considering the temperature of the 95% quantile (per stratum).

The process resulting in a model in which mortality is estimated by a general term and an interaction with temperature.

glm.nb(formula = cohort ~ offset(log(Efarea)) - 1 + Sstrata + Tstrata + Temp + Sstrata:Tstrata + Sstrata:Temp + Tstrata:Temp + age + Temp:age)

Step 3: An egg production model that can accommodate mortality estimates external to the estimation procedure is required. The optimized model is expanded to include weights for increased sampling in areas where high egg densities are expected and updated with the data from DEPM carried out in 2011 and 2014.

glm.nb(formula = cohort ~ offset(log(Efarea) - death * age) - 1 + Sstrata, data, weights = Rel.area)

Finally total egg production is calculated multiplying the daily egg production by the spawning area.

Egg Production (P0) and Spawning Stock Biomass (SSB) Estimation

Fitted parameters of the final mortality model updated with 2011 and 2014 in which mortality is estimated by a general term and an interaction with temperature are shown in table 1.

Table 1. Fitted parameters of the final mortality model updated with 2011 and 2014 data.

Variable	Estimate	s.e	z-value	Pr(>|z|)
Sstrata1	0.942	1.076	0.876	0.381
Sstrata2	5.980	0.880	6.793	0.000
Sstrata3	-0.817	0.832	-0.982	0.326
Tstrata1	4.570	0.911	5.018	0.000
Temp	0.440	0.060	7.314	0.000
age	0.045	0.015	2.896	0.004
Sstrata2:Tstrata1	-0.238	0.156	-1.528	0.127
Sstrata1:Temp	-0.122	0.076	-1.619	0.105
Sstrata2:Temp	-0.47	0.063	-7.405	0.000
Tstrata1:Temp	-0.351	0.065	-5.371	0.000
Temp:age	-0.005	0.001	-4.271	0.000

The z-value indicates the value of the z-statistics used to test the significance, and Pr(>|z|) the probability of the null hypothesis (H0: parameter does not differ from zero).

The resulting mortality values for the final model with temperature by spatial strata and by year (Table 2 and Figure 3) are significantly different from zero and biologically plausible. As it has been shown for other species (*eg*. Pepin, 1991) higher egg mortalities were observed at higher water temperatures, in the southern region and decreased in the northward direction. Egg mortality estimates (h^{-1}) obtained with the model described above varied between - 0.016, for the northern stratum, and -0.032 for the southern region; variability was higher in the western and southern regions.

Table 2. Egg mortality (hours^{-1}) estimates by year and spatial strata for the Atlanto-Iberian Peninsula DEPM surveys series. Standard errors are presented in brackets.

Year	South	West	North
1988	-0.026 (0.002)	-0.019 (0.0014)	-0.018 (0.0016)
1997	-0.032 (0.0035)	-0.028 (0.0024)	-0.022 (0.0015)
1999	-0.029 (0.0027)	-0.022 (0.0014)	-0.014 (0.0023)
2002	-0.029 (0.0027)	-0.025 (0.0018)	-0.018 (0.0015)
2005	-0.021 (0.0014)	-0.018 (0.0015)	-0.018 (0.0015)
2008	-0.03 (0.0029)	-0.024 (0.0016)	-0.018 (0.0016)
2011	-0.028 (0.0025)	-0.021 (0.0014)	-0.017 (0.0016)
2014	-0.027 (0.0023)	-0.023 (0.0016)	-0.016 (0.0019)

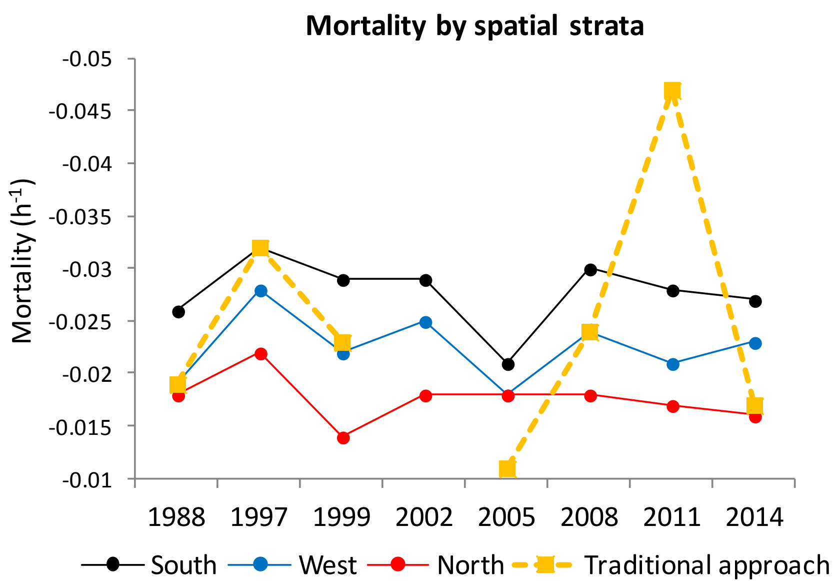

Figure 3. Egg mortality estimates (h^{-1}) per spatial strata and year, derived from the external model updated with the 2011 and 2014 dataset.

Egg production estimates obtained using the mortality results from the external model (Table 3 and figure 4) were in accord to the results presented by Bernal *et al*. (2011b). Moreover, as discussed by Bernal et al (2011b) the differences between the estimates obtained using their methodology and the results using the traditional approach (with a common mortality for all strata) were considerable for some years. Clearly the differences in the egg production estimates were more noticeable for years or strata for which before no realistic values of mortality were achieved. This is particularly noticeable for the 2002, survey, when no mortality estimation was attained previously, and for 2011, when for the southern and western strata the mortality estimates from the single dataset were quite high, the highest registered (ICES, 2011)

Table 3. Daily egg production (eggs/m^2/day) estimates by year and spatial strata for the Atlanto-Iberian Peninsula DEPM surveys series. Coefficients of variation are presented in brackets.

Year	South	West	North
1988	455.17 (0.26)	129.96 (0.1)	155.77 (0.07)
1997	179.03 (0.16)	236.15 (0.18)	221.77 (0.14)
1999	876.73 (0.19)	435.83 (0.15)	116.9 (0.16)
2002	121.93 (0.18)	188.91 (0.11)	116.89 (0.11)
2005	271.88 (0.16)	203.63 (0.12)	283.09 (0.12)
2008	425.27 (0.14)	200.71 (0.1)	134.95 (0.09)
2011	227.76 (0.16)	82.71 (0.18)	124.44 (0.11)
2014	156.41 (0.16)	115.72 (0.12)	38.55 (0.14)

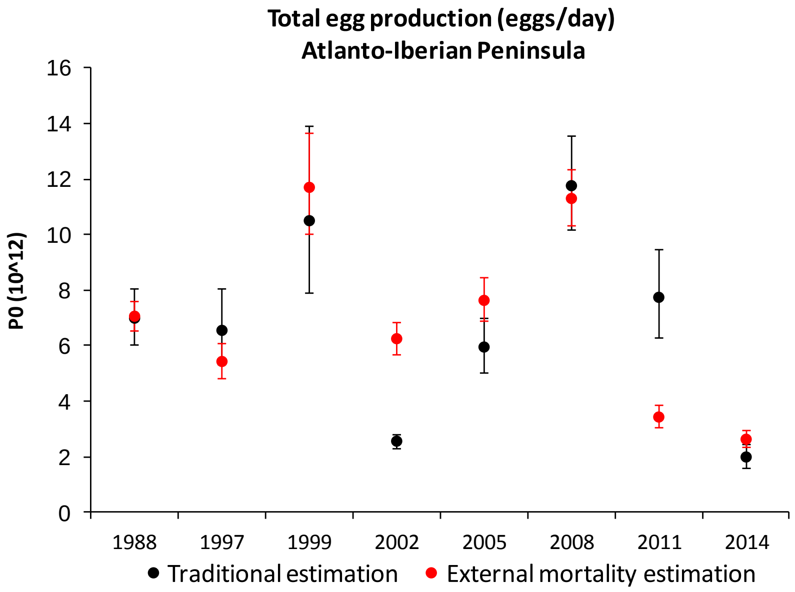

Figure 4. Total Egg production estimates (eggs/day) for the Atlanto-Iberian Peninsula (South+West+North strata) obtained by the traditional method (black dots) and using the mortalities obtained by the external model (red dots). The bars represent the confidence intervals for the estimates.

Spawning stock biomass estimates obtained from the traditional method (series revision, ICES 2011, 2012) and the results achieved using the external mortality model for egg production are plotted in figure 5. As a consequence of the largest differences encountered for the egg production in 2002 and 2011 the SSB estimates for these years suffered also the largest modification compared to the initial, traditional estimates.

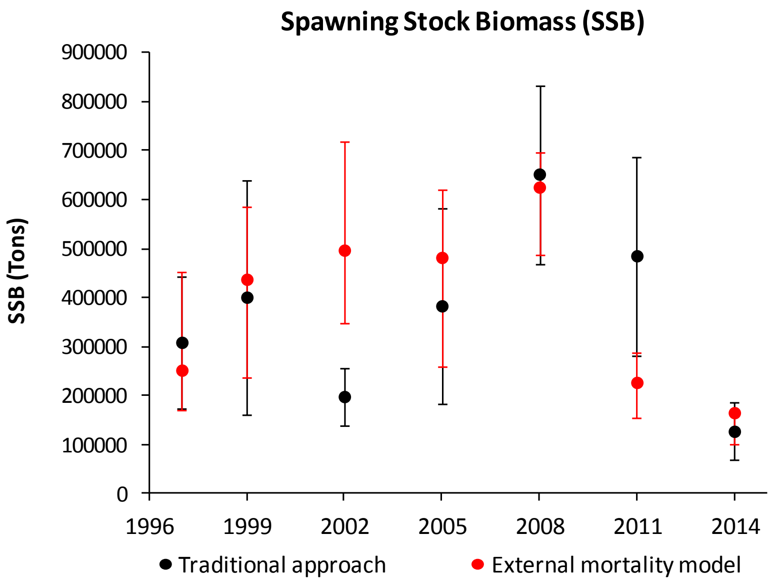

Figure 5. Spawning stock biomass (Tons) for the Atlanto-Iberian Peninsula (South+West+North strata) obtained by the traditional method (black dots) and using the mortalities obtained by the external model (red dots). The bars represent the confidence intervals for the estimates.

The revision of the P0 and SSB estimates for the DEPM data series here presented is considered statistically consistent and the results biologically plausible and less influenced by biased and imprecise, single survey, mortality estimates while at the same time allows P0 and mortality results per stratum. In addition, the current SSB estimates are more in line with the tendencies observed in the biomass calculations obtained along the series of annual acoustics surveys.

The external mortality model showed consistency in the results as few differences in previously estimated mortalities were observed when the model was updated with the datasets from the more recent surveys, in 2011 and 2014. However, in order to avoid changes in the past estimates each time the model is updated to include a new survey, it is considered that only the more recent estimate should be considered. A full revision of the series would be only considered for benchmark reviewing. The WGACEGG has considered that the SSB estimates here presented for the DEPM historic series are the more consistent in light of the current analysis developments.

Acknowledegements: Special recognition is due to Miguel Bernal and co-authors of the 2011 papers for having developed the approach here applied and in particular to Miguel for having made available the R routines for the analyses and for all the discussions and help during the process of implementation and updating.

Part II. Comparison of trends in the sardine SSB estimates (ICES 9a + 8c) obtained from DEPM and acoustics surveys

The issue on the dissimilary of the SSB estimates derived from acoustics and DEPM surveys in some years, has been discussed by the WGACEGG over the years and several causes related to these differences in the estimates have been addressed by the Group. Among them:

- Effect of time-lag between surveys on population structure and behaviour

The surveys are not entirely carried out simultaneously, especially in the Portuguese area. Differences in fish distribution, reproductive phase and interval from recruitment may play a significant role. The phase of the reproductive cycle affects the spatial distribution and aggregation pattern of the fish, and may vary along the surveyed area.
In addition, fish distribution and behaviour are notably modified by the weather conditions (that can vary between surveys); it is not uncommon to observe an appreciable decrease in the fish availability during events of stormy seas.
This may affect both the availability and accessibility of the surveying methods (both acoustics and DEPM) and may lead to results of difficult interpretation.

- Allocation of acoustic energy to pelagic species

While the DEPM results derive from direct observations on fish eggs and ovaries, acoustics needs a post-processing phase aiming to scrutinize the echograms and to allocate echo-integrated energy to target species. Several methods are described to perform this task (ICES 2015), but in most of them, an expertise judgement is needed. The use of multifrequency equipments and post-processing programs such as Echoview, LSSS or Movies among others, highly improved the quality of the scrutinization and allowed automated or semi automated methods to allocate echotraces to fish species be implemented. When this new tools are not available, ground-truth fish samples are used (McClatchie et al., 2000). In this case the total echointegrated energy is split among the different fish species accounting both for the abundance and the specific target strength. This may result in a bias if the fishing gear has different accessibility and catchability to the different fish species and sizes (lengths), giving, thus, a biased representation of the pelagic fish community both in terms of species composition and proportions but also in length structure. However, during a normal acoustic survey, several fishing stations are routinely performed on the same echo-types (i.e. similar echotraces corresponding to a group or single fish species with a given length distribution) in order to ensure the best representation of the pelagic fish community.

- Estimation of reproductive parameters

Some DEPM parameters such as spawning fraction, relative fecundity and egg mortality may be more complex to estimate for some particular surveys when sampling is not as comprehensive as desirable due to patchiness of the fish and eggs distribution. Problems related to sardine availability and catchability as described before, may result in a biased sample of sardine and therefore of the adult parameters. Sometimes the samples are not randomly taken, and samples could be only obtained from the high egg density areas, or from particular areas (i.e. offshore or inshore), where there are no restrictions for the fishing operations (i.e. bottom roughness or the presence of other static fishing gears). This is particularly relevant when the data available do not allow estimations stratified by geographical area or population length (age) composition.

- Differences on age catchability in acoustic surveys

As explained previously, either because the fishing stations are not randomly or due to a fishing selectivity issues, the length or age structure from the acoustic estimate would result biased in relation to the DEPM one. Moreover, if for both methods the adult sampling intensity is placed accounting, respectively, the egg and the echotrace abundances and if there is a mismatch between both areas, the resulted length or age structure could be different if there is a spatial age or length distribution pattern (i.e. both along the coast or length depth dependent gradient) .

Figure 1 shows the trends for both time series indices, despite some differences, and especially after the revision of the mortality estimation method for the DEPM series (part I of this WD) the trends are relatively similar. Major disagreement is due to the differences between indices in 2008. Excluding this particular year, the correlation between the series is 0.7 while using all the years is 0.3.

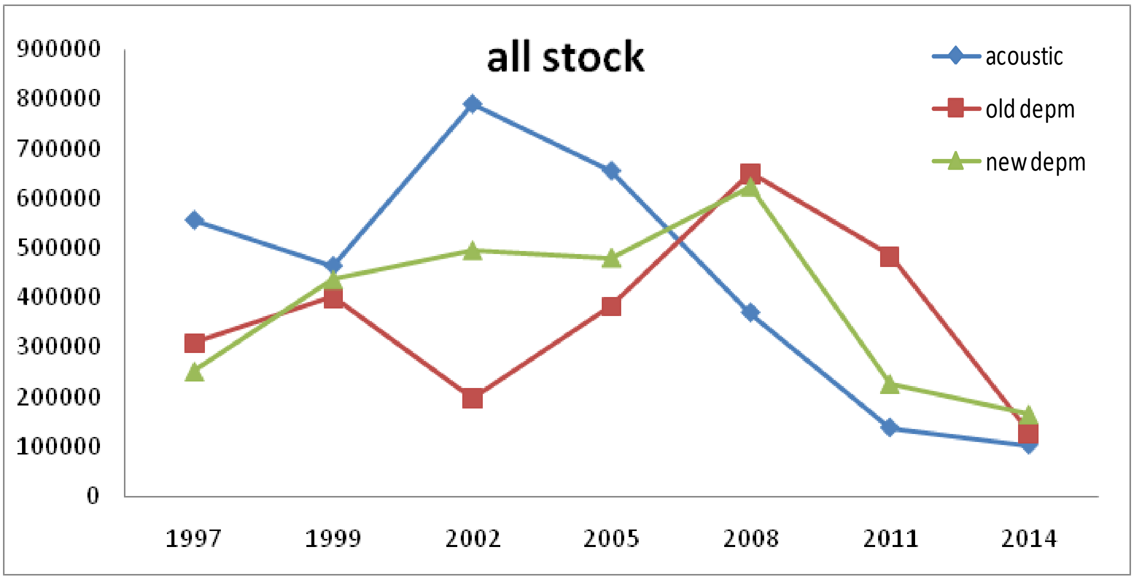

Figure 1. Sardine biomass estimates (tonnes) from acoustics and DEPM (traditional and using the revised mortality estimates). The DEPM estimates are for SSB while estimations from acoustics are Biomass$_{1+}$.

By strata the main differences between survey type estimations are observed in the south (figure 2).

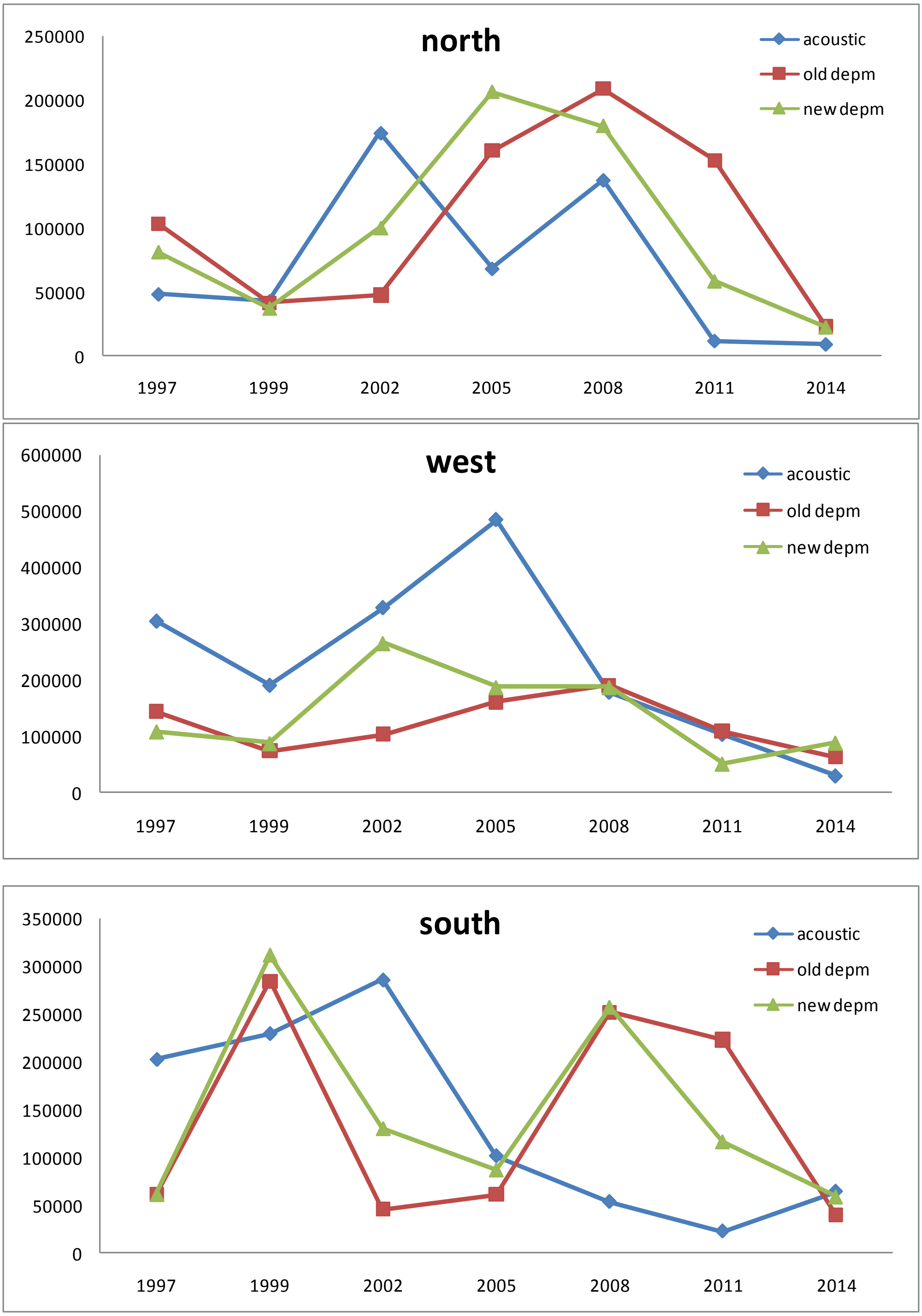

Figure 2. Sardine biomass estimates (tonnes) from acoustics and DEPM (traditional and using the revised mortality estimates) by strata. The DEPM estimates are for SSB while estimations from acoustics are Biomass$_{1+}$.

In addition, with respect to the methodological aspects the WGACEGG has discussed the procedures in use for both, the DEPM and the Acoustics surveys, and considers that the surveys are performing well and the work is being carried out complying with the standard agreed methodologies.

Still, the Group is pursuing further studies in order to better understand the differences found in the estimates from acoustics and DEPM, in some years or regions. Ongoing and future work include: (i) analyze fish spatial and depth distribution during surveys; (ii) use same regional stratification of the information for both survey types; (iii) calculate biomass estimation by age (length) for sardine; (iv) utilize CUFES data for egg production estimation and comparison to estimations undertaken for CalVET data; (v) discuss standardization of strata definition and (vi) assess bias in energy partition for particular areas.

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Working Document 3

Sardine Egg Production Estimation (ICES áreas 9a + 8c) using data from EPM surveys directed at mackerel and horse-mackerel.

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Rationale

The IEO and IPMA coordinated surveys for sardine spawning stock biomass estimation through DEPM have been taken place on a triennial basis since the late 90s. In order to attain higher temporal resolution for the egg production data series it was decided within WGACEGG that tests should be run using the egg samples/data available from other egg production surveys conducted in the same geographical areas during a similar period of the year in years without a dedicated sardine DEPM.

All the EPM surveys from which it was thought that information for sardine eggs was obtainable are listed in table 1.

Table 1. Surveys list by year and type (and plankton gear), indicating the egg data availability and/or processing phase, per strata: 1- South, 2- West Pt, 3- North (WGalicia+Cantabric)

Year	Survey type (plankton gear)	Egg data (11 stages)	P0 estimates
1988	regular PIL survey (CalVET)	1 inc, 2, 3	available (1, 2, 3) regular survey
1990	other (CalVET)	3	available
1995	MAC/HOM EPM (Bongo)	?,?, 3	na
1997	regular PIL survey (CalVET)	1, 2, 3	available (1, 2, 3) regular survey
1998	MAC/HOM EPM (Bongo)	?, ?, 3	na
1999	regular PIL survey (CalVET)	1, 2, 3	available (1, 2, 3) regular survey
2001	MAC/HOM EPM (Bongo)	1, ?, 3	na
2002	regular PIL survey (CalVET)	1, 2, 3	available (1, 2, 3) regular survey
2004	MAC/HOM EPM (Bongo)	1, 2, 3 (no stgs)	na
2005	regular PIL survey (CalVET)	1, 2, 3	available (1, 2, 3) regular survey
2007	MAC/HOM EPM (IEO: Bongo, IPMA DEPM, CalVET)	1, 2, 3	1, 2, 3
2008	regular PIL survey (CalVET)	1, 2, 3	available (1, 2, 3) regular survey
2010	MAC/HOM EPM (IEO: Bongo, IPMA DEPM, CalVET)	1, 2, 3	1, 2, 3
2011	regular PIL survey (CalVET)	1, 2, 3	available (1, 2, 3) regular survey
2013	MAC/HOM EPM (IEO: Bongo, IPMA DEPM, CalVET)	1 inc, 2, 3	1, 2, 3
2014	regular PIL survey (CalVET)	1, 2, 3	available (1, 2, 3) regular survey
2016	MAC/HOM EPM (IEO: Bongo, IPMA DEPM, CalVET)	1, 2, 3	1, 2, 3

Methodology

First the survey information was mapped and the spatial grids resolution were assessed. For this phase it was also decided to start the reanalyses from the more recent years backwards. The following step involved revisiting the samples for completing the egg staging process (11 stages). In addition to the laboratorial work, issues such as gear capturability versus area coverage were also addressed.

At present, data from four surveys (2007, 2010, 2013, 2016) are available and egg production estimations were calculated. The analyses were carried out using the standard methodology adopted for the 2012 revision (GLM, with a common slope and three intercepts: glm.nb(cohort ~ offset(log(Efarea)) -1 + Stratum+ age, weights=Rel.area , data=aged.data)) and described in ICES (2011, 2012) .

Egg Production

Egg production estimates for sardine were performed for the data from the four more recent mackerel and horse-mackerel egg production surveys which are presented in figure 1. IPMA is responsible for surveying the area of the southern stock of horse-mackerel (Gibraltar to Finisterre) while IEO´s campaigns cover Galician and Cantabrian shores. Since 2007 IPMA´s survey adopted the DEPM and the spatial resolution of the plankton sampling was increased while at the same time the CalVET system started to be used instead of the Bongo utilized during the previous AEPM campaigns. The changes introduced in IPMA´s surveys resulted from a compromise between the need to increase the spatial resolution and the sea time available. IEO surveys maintained the AEPM approach and have not introduced alterations in sampling design or gear used. During the period under analysis the spatial coverage of IPMA surveys varied, only in 2010 was the whole area of the horse-mackerel southern stock occupied; in 2007 and 2016 the northern limit of the planned grid was not attained and in 2013 the Bay of Cadiz was not surveyed. In order to fill in these gaps some assumptions were made taking in consideration the estimated spawning areas from other EPMs campaigns, with the highest temporal-proximity, in the regions for which there were some sampling gaps. In 2007 and 2016 the western Galician coast not sampled by IPMA was surveyed during IEO campaign.

To solve questions related to hauls effective area estimation and spawning area delimitation in AEPM surveys carried out by IEO, the values used in different functions to obtain the spawning areas were modified from the standard used for the sardine DEPM revision undertaken in 2012 (ICES, 2011, 2012). The minimum distance in ratio represented by each station was set to 25 km (15 km was set for sardine DEPM surveys) and no maximum and minimum values were fixed. In 2016, the AEPM survey carried out by IEO, used the auxiliary sampler CUFES to delimit the spawning area. Samples were taken every 3nm throughout the transects and once at the laboratory, sardine eggs were sorted and counted. The spawning area extension is computed as the sum of the area represented by the stations within the spawning area sampled by the CUFES. Despite the advantage of having the CUFES sampling for area definition there are still some issues relating to the area representativeness of each Bongo station for the total spawning area definition that will be further explored in coming analyses.

The egg production estimates obtained for 2007, 2010, 2013 and 2016 are included in the historic series plot presented in figure 2. The new results appear coherent within the data series, the decline in egg production observed since the 2008 survey is perhaps clear now with the new point for 2010, this tendency is possibly masked by the result in 2011 likely higher due to poor model fitting (see updated estimates using an external model for mortality estimation, previous section in this report). The WGACEGG discussed the analyses here presented and considered that this approach of using the information available from other years in between the dedicated sardine DEPM surveys are useful for completing the data series and can assist in describing the sardine biomass temporal trends during stock assessment analyses. The Group considers the extra data gathered in this way very valuable and supports the continuation of the analyses for other, past and future, surveys. In addition, considers that the new data from the four surveys presented should be analysed and included in the series of P0 (and SSB should adult parameter be available) estimates obtained using the external mortality model approach described in the previous section.

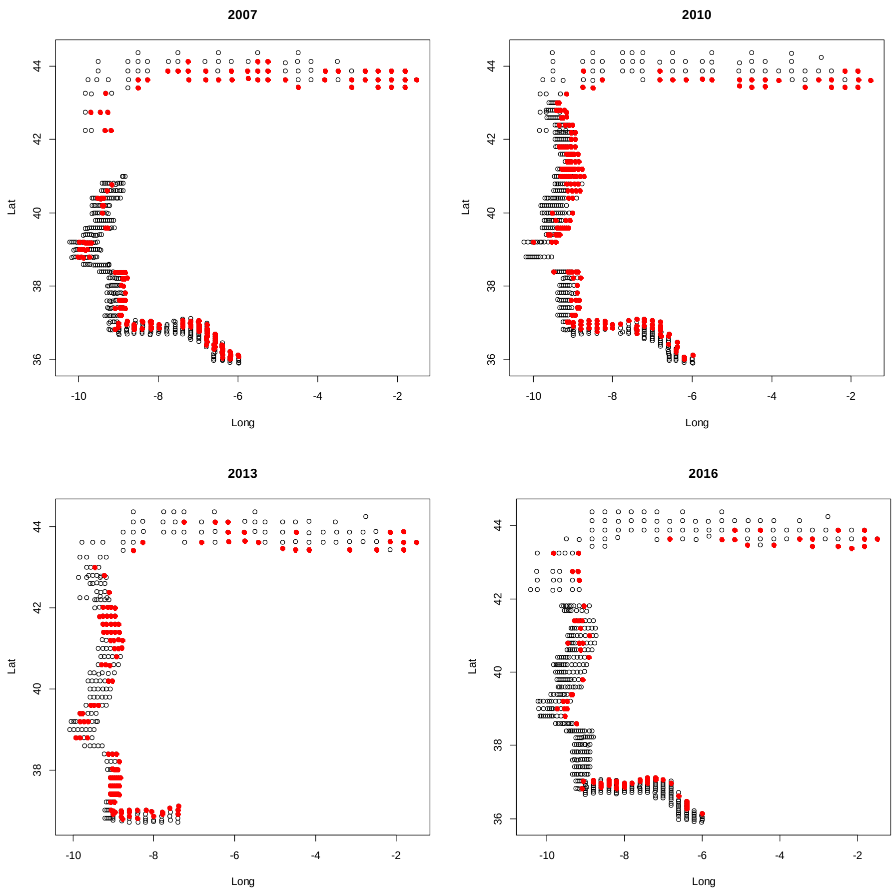

Figure 1. Plankton sampling coverage (and egg presence, in red) for the 2007, 2010, 2013 and 2016 surveys. Survey periods: 2007 - IPMA: 03/02-02/03; IEO: 15/03-17/04; 2010 - IPMA: 30/01 – 03/03; IEO: 07/03-29/03; 2013 - IPMA: 10/02 – 19/02; IEO: 01-22/04: 2016 - IPMA: 11/03 – 01/05; IEO: 11-25/04

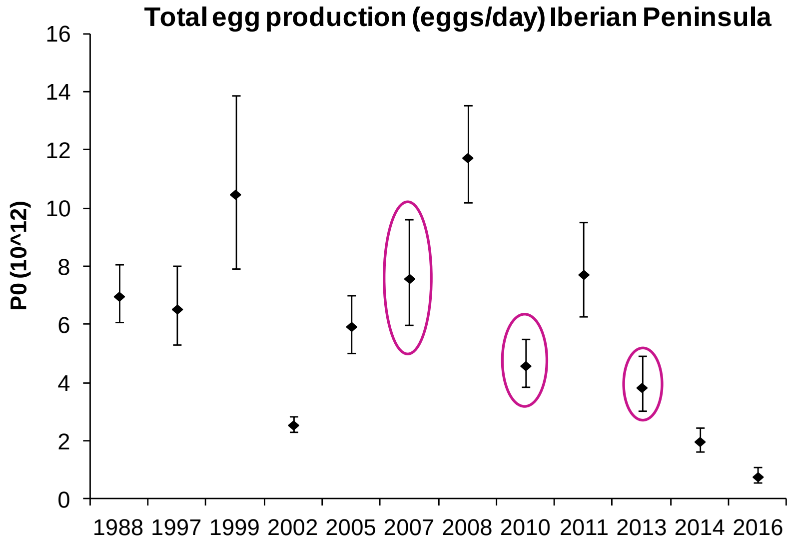

Figure 2. Total Egg production estimates (eggs/day) for the Atlanto-Iberian Peninsula (9a+8c) obtained by the traditional method (black dots); the new estimates carried out with information from mackerel and horse-mackerel EPM surveys are flagged by pink circles. The bars represent the confidence intervals for the estimates.

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