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Revision of Sardine DEPM estimates (1988-2011) in the Iberian Peninsula ï ICES areas VIIIc and IXa

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1. Background

The Daily Egg Production Method has been applied for estimating the Atlanto-Iberian sardine Spawning Stock Biomass since late eighties/early nineties (Cunha *et al.*, 1992, Garcia *et al.*, 1992, Stratoudakis *et al.*, 2004, Stratoudakis *et al.*, 2006, ICES, 2009, ICES, 2010). Collaborative work between Portugal (IPIMAR) and Spain (IEO) over the years, lead to coordination of the surveys and standardisation of surveying and analysis methodologies. During the last decade in particular, owing to the efforts carried out under the auspices of the ICES groups SGSBSA and WGACEGG many developments have been achieved. Since 2002 coordinated surveys have been conducted within the framework of ICES, with co-financing from the EU, on a triennial basis. DEPM estimates of sardine SSB were last revised in 2006, and this revision was presented to the 2006 ICES benchmark assessment of the Atlanto-Iberian stock (Stratoudakis and Bernal 2006, ICES, 2006). Since then further progress was attained and the WGACEGG considered useful undertaking a new revision that would include not only the revised estimates but that would also report on all methodological changes and issues related to the analyses. A detailed description of the developments in the Atlanto-Iberian sardine (ICES areas IXa and VIIc) DEPM will be available through the WGACEGG. This WD summarises the revised estimates obtained using standardised analyses procedures and options for the whole data series. The results are discussed considering the changes introduced along the years and compared to previously reported estimates. A few notes on the comparison of the biomass estimates from DEPM and acoustic surveying are also presented. Some analytical issues and developments are still being addressed (*eg.* consider an external model to assess mortality, definition of the better model for fecundity) and therefore further discussions will be undertaken and presented at the next WGACEGG meeting. For 2011, spawning stock biomass is only estimated for the Northern area, whereas for the Southern and Western areas the present results are preliminary due to laboratory analysis being still in progress. While the final estimates are not compiled the authors of this document are responsible for the results here presented.

2. Data set

The data used for the present revision were obtained from IPIMAR and IEO revised data bases, which were merged in a common standardised dataset and include all surveys undertaken in the period from 1988 to 2011 (table 1). For 1988 and 1990 surveys only the egg data is used; the adult variables were not recovered in the standard manner used for other years of the series and that precluded its utilization for the present revision. The updated data set include minor general changes that were considered in order to allow the inclusion in the analyses of some observations that were not used before because they were not correct (*eg.* wrong geographical coordinates, duplicated points, ovary and total weights data, etc.). Additionally, the data from the fishing hauls performed by IEO in French and Portuguese waters (used before) were excluded from the analyses in the present revision. The 1999 adult data set for the northern stratum (IEO) was substantially altered in order to include recovered information that would better represent the sardine population parameters in that area and period (adults parameters were before estimated based on hydrated females obtained from the northern stratum and random data obtained in French waters). Extra data from the acoustic survey (Pelacus-99) carried out during the same period, were retrieved. Information from 7 new hauls were included in the data base and used for estimating female weight, sex ratio and fecundity. However, for spawning fraction estimation there was no possibility of adding observations since the ovaries were no longer available; consequently, it was decided to use in 1999 the S revised estimate obtained in the North for 1997. For the current revision, part of the histological material was also re-analysed and histological data reviewed for the initial surveys of the series, in particular the 1997 samples for the North and the 1997, 1999 and 2002 (survey) samples for the South and West strata. The revision of the histological slides was conducted in order to consider the methodological developments and the experience gained by the readers over the years.

3. Methodology

Surveying

A full description of the surveying methods and changes introduced along the years can be found in ICES reports and working documents (*eg.* Stratoudakis *et al*. 2004, ICES, 2010, ICES, 2011). Modifications in the plankton surveying design were introduced during the first years of the DEPM application; from 2002 onward a regular grid of transects, perpendicular to the coast and spaced 8 nmiles apart, has been occupied. Along the transects the plankton samples are taken using an adaptive approach, supported by the information given by underway egg sampling (CUFES), to allow better coverage of the inshore waters while guaranteeing coverage of the whole spawning area.. Fishing hauls are distributed over the surveyed region according to fish abundance distribution to provide an adequate representation of the sardine population. Additional fish samples from the commercial purse-seine fleet are regularly obtained during surveys in order to increase sample size. Water temperature data are obtained using profiling or underway flow-through probes. A summary of the information collected for each survey, per stratum is shown in table 1.

Analyses

The data analyses were undertaken using open source R libraries and scripts available at http://sourceforge.net/projects/ichthyoanalysis.

The geographical strata 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 definition of strata is the same as used before, however, slight modifications have occurred in the borders between S and W (at S.Vicente) and in the Bay of Biscay corner (between Spain and France) (the coordinates used in past analyses were not reported) and consequently, a few, minor changes may have occurred in observations stratum assignment.

The model of egg development with temperature was derived from the incubation experiment data available within the *sardata* R library. Egg ageing was achieved by a multinomial Bayesian approach described by Bernal *et al*. (2008) and using *in situ* SST. Distribution of the daily spawning cycle was assumed as a normal (Gaussian) distribution, with a peak at 21:00 h GMT and a standard deviation of 3 h (spawning period: 15- 3 h). The upper age cutting limit was determined using a maximum age for the strata considered and it is not dependent on the individual stations (upper.age=F). Older cohorts are dropped if their mean age plus 2* st-dev hours is over the critical age at which less than 5% of the eggs are expected to be still unhatched (how.complete=95%). The lower age cutting excluded the first cohort of stations in which the sampling time is included within the daily spawning period (lower.age=T).

The exponential model: $E[P] = P0\ e^{-Z\ age}$ was fitted as a Generalized Linear Model (GLM) with negative binomial distribution and log link. Weights proportional to the relative area represented by each station (estimated using the dirichlet tessellation and divided by the mean area represented by a station) were used to account for increased sampling in areas of expected high egg densities (in the early years of the time series). Finally, the total egg production is calculated multiplying the daily egg production ratio (eggs per m^2 and day) by the positive area (in m^2). During the process of revision several GLM models were considered to test different stratification combinations for egg production and mortality; see detailed discussion in the WGACEGG-2011 report. For the present document the GLM considering 3 strata for P0 and a common mortality for the whole area was selected for all years but 2002. For that survey a model without mortality was applied since an estimate for mortality led to non coherent (positive) mortality. Apart from the model with 3 different egg productions (intercepts), one per stratum, and 1 mortality (slope), the only other that was statistically coherent for all years was the option considering no strata (1 P0, 1 z). Egg production estimates obtained using different GLM models are presented and discussed in the 2011 WGACEGG report.

The adult parameters estimated for each fishing haul considered only the mature fraction of the population (determined by the fish macroscopic maturity data) and was based on the biological data collected from both surveys and commercial samples. Before the estimation of the mean female weight per haul (W), the individual total weight (Wt) of the hydrated females was corrected by a linear regression between the total weight of non-hydrated females and their corresponding gonad-free weight (Wnov). The sex ratio (R) in weight per haul was obtained as the quotient between the total weight of females on the total weight of males and females. The fraction of females spawning per day (S) was determined, for each haul, as the average number of females with Day-1 or Day-2 POF, divided by the total number of mature females (the number of females with Day-0 POF was corrected by the average number of females with Day-1 or Day-2 POF, and the hydrated females were not included).

The expected individual batch fecundity (Fexp) for all mature females (hydrated and non-hydrated) was estimated by modelling the individual batch fecundity observed (Fobs) in the sampled hydrated females and their gonad-free weight (Wnov) by a GLM (with a negative binomial error distribution and an identity link). Revised estimations always considered geographical stratification (GLMs included a factor Stratum: Fobs ~ Wnov + Stratum): mean batch fecundity (F) was estimated for the three areas separately. In 1997 and 2005, very few hydrated females were collected off the West coast (n = 6 and 1, respectively): for these years, the model considered the West and South strata together, but F estimates were nevertheless calculated for the three strata separately. Several model options were tested for each year (same or different intercepts and/or slopes, intercepts through the origin or not), and the model considered as the most adequate was selected taking into account both biological and statistical significances: the model that best fitted the data (residual plots, lower AIC value, graphical representation of the regression curve) but models with significant positive or null intercepts not accepted (unless no negative intercepts were obtained). In 2008, the model that statistically best fitted the data was the most complex one (different slopes and intercepts) but problems in calculating the model variance which were not solved up to this stage prevented this model to be selected. Finally, the model used for all years was the one considering the same intercept but different slopes; though in 2008 and 2011 the option was to consider the models with null intercept.

For the present revision, a minimum sample criterion (n = 30) was introduced: a few hauls containing less than 30 fish sampled were excluded from the mean and variance calculations.

4. Notes on the results

Table 2 provides the new DEPM parameters and spawning stock biomass (SSB) estimates for the three strata, in comparison to the values previously reported (Stratoudakis and Bernal, 2006; ICES, 2010)

Regarding **egg production (P0)**, the results obtained were already discussed during the WGACEGG-2011 and included in the report; in summary they show that:

- The differences in total egg productions (sums of the three strata) between the revised and the old estimates are below 30% for all years, except for 1999, for all GLM models tested (not shown here, cf. section 5 of WGACEGG report).
- For 1988 and 1997, the revised estimates are higher than the previous ones while the opposite happens for the 2002 and 2005 surveys. 1999 is a particular case, the revised estimates of P0 increased substantially, in the South and West that was due to the fact that all observations were considered in the analyses, previously a couple of observations with a high percentage of eggs were considered outliers.
- However, depending on the stratification used in the GLM model (combinations of strata (S, N, W) for production (intercept) and mortality (slope)), the estimates between strata may vary considerably when compared to the previous reported estimates per stratum. This is particularly relevant for the initial years of the series and not so much for 2005 and 2008.
- The differences between the revised estimates and the previously reported are essentially due to decisions in the analyses, in particularly in relation to the daily spawning cycle (parameters of the normal PDF: hour of peak spawning and distribution along the day) and the cuts in the upper and lower ends of mortality curve. The options used in the revision are a bit more restrictive to reduce bias however in some cases that may affect the significance.
- The fact that all comparisons undertaken between the new estimates (using the different models) and the old ones generate differences lower than 30% (except for 99) suggest that the results/differences are within the error of the DEPM method (CV ~ 30%); precision in EPMs is low.

In relation to the revised estimates of **adult parameters**:

- Mean female weight (W): differences in comparison to the reported estimates are minor (max. 5%): the initial data used are nearly the same (though more female data could be included in the revised estimates), except for 1999 in the North (however, W changed only slightly with the revision). On the whole, W is always higher in the North strata, and shows an increasing trend since 1999 in the North and since 2002 in the West and South.
- Mean batch fecundity (F): differences between new and old estimates were below 30%, except for 1999 in the North (an increase of ~60%). These differences are likely related to different

models having been fitted to the data in the past and during this revision. The largest variation obtained in 1999 in the North is mainly due to the initial data set having changed: hauls from French waters, which contained females of lower mean weights and batch fecundities, were now excluded from the analysis. F usually follows a similar trend to the one of W, the exception being the 1999 estimate in the North (which is one of the highest while W is the lowest of the series) and the 2011 estimate in the South and West. In the former case, the data from hydrated females used to model batch fecundity were obtained only in Galician waters (one haul), though the model was then applied to all samples from Galician and Cantabrian waters (11 hauls); spatially related differences in relative fecundity (the slope of the regression curve) between the two areas may have resulted in diverging W and F estimates. In the latter case, relative fecundity was apparently lower for these strata in 2011.

- Mean sex ratio (R): differences between reported and revised estimates are below 15%, and are likely due to the changes in the female weight data used (more females included, whereas male weight data did not change). In the North, R is more or less constant (around 0.5) whereas in the West and South, R is usually higher and variations show no apparent clear trend.
- Mean spawning fraction (S): differences in comparison to the reported estimates per strata are below 30%, except for 1997 in the South (increase of ~70%) and for 2002 in the West (increase of ~150%). These major changes were mainly the result of the re-analysis of the histological material. S estimates show marked geographical and temporal differences, but with no apparent clear trends: S is usually higher in the North than remaining areas, except for the South estimate in 2005; in the North S values are higher in the 90ôs and then decrease in the 2000ôs; S estimates are closer for the North and West strata and remain relatively constant in 2002, 2005 and 2008 while S fluctuates more in the South. Despite the fact that the revised histological data are now more reliable, the inter-annual variability of S estimates is being studied in more detail, and discussions are underway in order to define the validity of the estimation of this parameter for each survey separately. For instance, the preliminary results for 2011 (strata South and West) brought up this discussion since the estimates are very low and very likely not representing S very accurately.

The significance of inter-annual and between strata variability of the parameters are being studied and not yet presented. For instance, possible mismatch of the spawning peak period or a halt in the spawning activity during the season may be eventual causes for the non-accurate estimation of some of the parameters. Other factors being investigated in relation to the observed variability of the DEPM parameters include: population demography, seasonal dynamics of reproductive activity, environmental conditions, gear selectivity. More conclusive results on its comparisons will be presented at the next WGACEGG.

The revised **spawning stock biomass (SSB)** estimates show that:

- For the whole area, the changes in comparison to the reported values for the1997, 2005 and 2008 estimates were below 10%
- On the contrary, in 1999, there was a significant increase in the SSB estimate compared to the value reported previously, this increase being mainly due to the large increase of P0tot (though compensated by an increase of F)
- For 2002, the revision led to a large decrease of the SSB which is mainly due to a large increase of the S in the West
- However, it is noteworthy that some large changes in SSB per strata occurred despite the fact that the total SSB did not change considerably. For example, in 1997, although SSB changed only slightly for the whole area, there were major differences in the SSB per strata. This observation brings to attention the need to further discuss on how to achieve consistent estimations per strata that could be used in assessment modelling.
- The coefficients of variation for the revised estimates are lower than the ones reported before; this fact was mainly due to changes in the egg production CVs. However it should be noted that this change is partially due to the fact that in the present review the mortality curve was fitted using a model with a single mortality for the whole area (CVs for P0 with 1 z are smaller than when mortality is considered per strata; see WGACEGG - 11 report). Yet, for the present analyses (more restrictive since a common upper age cutting limit by survey was adopted) GLM models with mortality per each strata were not statistically coherent for all year but 2008 and 2011. Changes in precision estimation should be looked with caution to avoid eventual mathematical artefacts.

5. Comparison DEPM vs. acoustics

After the revision of DEPM estimates, the major discrepancies existing with acoustic surveys concern the years 2002, 2005 and 2008 (figure 1).

In 2005, differences are most likely explained by the demographic structure of the population. Indeed, following an important recruitment in 2004, a large proportion of the fish in the first quarter of 2005 were still immature. These young fish, though representing a considerable biomass, were not part of the spawning biomass (cf. SSB estimate of the 2005 acoustic survey).

In 2002 and 2008, several hypothesis have been discussed attempting to explain the differences in the SSB estimates from DEPM and acoustic surveys, but no clear conclusions are yet to be drawn. The following aspects were looked into:

- For the South and West strata, the DEPM and acoustics surveys are not carried out simultaneously (*ca.* 2 months apart), which may imply changes in population distribution and availability for the fishing gear and in environmental conditions affecting spawning activity
- Population demography: the length distribution obtained in fishing hauls from acoustic and DEPM surveys show a relatively similar structure, though the largest sardines (> 21 cm length) seemed to be more present in the DEPM survey. Preliminary results on age distribution in fishing hauls suggest that acoustic surveys tend to observe more younger ages (particularly age 1) whereas DEPM surveys to observe more older fish (ages 6 and above)
- The way the acoustic energy was allocated to sardine: comparatively to other surveys, the fishing trawls carried out in 2008 showed a particularly great mixture of species, mainly in all the area southern to Lisbon. Considering that the sardine Target Strength used (TS(b) = -72.6 dB) is much lower than the ones for the concurrent species (around -68dB), the partition of the acoustic energy (NASC) between species could have been one of the problems and the biomass of sardine derived from the acoustic energy underestimated. However, doing the exercise of recalculating the partition of the acoustic energy taking into account the proportion of sardine and other species in the fishing trawls and attributing a TS of -70 dB for those other species, the result was an increase of only 6% in the sardine biomass for the acoustic survey.

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Table 1. Summary of plankton and adult sampling in Portuguese (South and West) and Spanish (North) DEPM surveys for sardine. For Portuguese surveys both nets were used for egg density estimates while Spanish surveys used 1 net.

Year	Strata	Dates	PairoVET Stations (% with eggs)	Eggs	Max eggs/m2	Temperature (ºC) Min-Max	Positive area (km²)	Fishing hauls (% positive)	Total sardine sampled	Males	Females	Females for histology	Hydrated females	Mature females (%)	Active females %
1988	South	28/03-30/03	55(25.5)	344	1680	14.5-17.2	2143.7								
	West	01-08/03-21-28/03	249(35.7)	944	1360	12.8-16.1	14888.7								
	North	31/03-05/05	516(51.7)	3922	2758.3	10.6-15.5	26643.7								
	Total		820(45.1)	5210	2758.3	10.6-17.2	43676.0								
1990	South														
	West														
	North	18/04-10/05	475(36.6)	1494	2063.4	12.8-18.5	30554.9								
1997	South	18/03-25/03	135(43.0)	868	5593.8	16-19.3	8745.1	12(83.3)	537	232	305	131	24	304(99.7)	99.6
	West	01/03-16/03	238(16.0)	586	2012.3	14-16.9	6695.6	28(57.1)	804	298	506	142	6	506(100)	100.0
	North	05/03-29/03	515(16.7)	1465	5381	13.2-15.9	10275.5	9(77.8)	402	142	260	255	113	259(99.6)	98.6
	Total		888(20.5)	2919	5593.8	13.2-19.3	25716.2	49(67.3)	1743	672	1071	528	143	1069(99.8)	99.7
1999	South	10/01-19/01	147(36.7)	3184	13431	14-17.1	7451.3	12(100)	1208	536	672	151	19	624(92.9)	97.9
	West	19/01-03/02	272(23.2)	1926	6060	12.6-16.3	9828.9	28(100)	2732	1125	1580	283	86	1479(93.6)	94.9
	North	17/03-03/04	290(25.9)	900	1196.6	12.2-13.8	7174.0	19(57.9)	997	532	463	100	19	422(91.1)	91.1
	Total		707(27.2)	6010	13431	12.2-17.1	24454.3	59(86.4)	4937	2193	2715	534	124	2525(93)	95.0
2002	South	27/01-02/02	152(34.2)	508	1613.8	14.5-16.9	7535.4	31(96.8)	2416	934	1478	499	47	1462(98.9)	86.1
	West	08/01-27/01	332(44.6)	2077	4881.4	12.1-16.8	18309.0	43(93.0)	2811	1104	1472	576	66	1217(82.7)	76.0
	North	20/03-16/04	220(58.6)	1939	1896.1	10.9-17.5	15288.9	28(100)	2058	1019	1039	470	69	1038(99.9)	99.5
	Total		704(46.7)	4524	4881.4	10.9-17.5	41133.4	102(96.1)	7285	3057	3989	1545	182	3717(93.2)	85.8
2005	South	13/02-22/02	159(41.5)	1733	4825.6	13.1-15.4	7201.0	24(91.7)	1652	759	891	510	52	851(95.5)	97.0
	West	29/01-12/02	249(32.9)	1942	8020	11.6-14.8	10722.9	42(97.6)	2915	1323	1533	983	1	1366(89.1)	85.5
	North	13/04-01/05	371(32.3)	3216	3231	12.4-16	12307.1	76(46.1)	1625	721	897	562	115	755(84.2)	71.9
	Total		779(34.4)	6891	8020	11.6-16	30231.0	142(69)	6192	2803	3321	2055	168	2972(89.5)	85.4
2008	South	20/01-27/01	174(56.3)	5727	9842.5	14.8-17.1	9692.2	27(92.6)	1745	838	906	643	103	842(92.9)	98.5
	West	28/01-15/02	288(51.7)	7895	8142.4	13.3-16.7	19295.8	58(87.9)	3195	1352	1839	1371	76	1554(84.5)	94.7
	North	02/04-27/04	426(54.2)	3788	8354.2	11.9-15.2	24263.9	41(87.8)	2392	1157	1235	594	183	1235(100)	98.9
	Total		888(53.8)	17410	9842.5	11.9-17.1	53251.9	126(88.9)	7332	3347	3980	2608	362	3631(91.2)	96.6
2011	**South**	10/02-20/02	170(31.8)	2208	4950	14.6-16.9	6523.5	18(88.9)	975	480	495	397	11	495(100)	81.8
	West	20/02-08/03	309(12.9)	833	2970	13.5-16.1	4816.7	40(80)	2069	1028	1037	827	25	954(92)	80.5
	North	25/03-10/04	337(38.6)	1794	1537	12.5-14.6	12404.8	53(18.9)	718	334	384	230	31	380(99)	98.1
	Total		816(27.5)	4835	4950	12.5-16.9	23745.0	111(52.3)	3762	1842	1916	1454	67	1829(95.5)	84.9

Table 2. DEPM parameter estimates and sardine spawning biomass for the Portuguese (South and West) and Spanish (North) surveys over 1988-2011, using traditional estimation**.** DEPM parameters previously reported are shown and also the differences (as a percentage of the previous reported estimates) between previously reported estimates and the ones obtained in this revision. Egg production estimates refer to trillion eggs (x 10^{12}) and batch fecundity to thousand eggs (10^{3}), mean female weight in grammes. SSB tonnes x10^{3}. Values in brackets indicate coefficients of variation (%).

		Reported (ICES 2011)				**Reviewed (2012)**							
Year	**Variable**	**South Portugal**	**West Portugal**	**NW & N Spain**	**Total Iberia (Strata Sum)**	**South Portugal**		**West Portugal**		**NW & N Spain**		**Total Iberia (Strata Sum)**	
1988	Egg production		2.87(22)	2.97(33)	6.99(20)	0.85(31)		1.84(17)	*-36*	4.3(15)	*45*	6.99(11)	*20*
	Female weight		40.7(7)	76.8									
	Batch fecundity		17.4(6)	31.7									
	Spawning fraction		0.14(19)	0.14									
	Sex ratio		0.45(11)	0.55									
	Spawning biomass		**129.1(35)**	**180.2(50)**	**309.3(33)**								
1990	Egg production			1.78(58)						3.56(26)	*100*		
	Female weight			78.5									
	Batch fecundity			31.0									
	Spawning fraction			0.14									
	Sex ratio			0.51									
	Spawning biomass			**77.7(45)**	**77.7(45)**								
1997	Egg production	3.24 (39)	1.10 (34)	0.72 (82)	5.06(29)	1.55(27)	*-52*	2.09(29)	*90*	2.91(27)	*304*	6.55(16)	*29*
	Female weight	43.1 (7)	48.5 (7)	70.1(6)		43.14(7)	*0.1*	48.54(7)	*0.1*	72.15(5)	*2.9*		
	Batch fecundity	16.1 (6)	18.0 (6)	26.5(5)		19062(12)	*18.4*	22569(13)	*25.4*	28544(7)	*7.7*		
	Spawning fraction	0.061 (24)	0.060 (25)	0.18(15)		0.104(13)	*70.5*	0.049(18)	*-18.3*	0.144(10)	*-20.0*		
	Sex ratio	0.576 (6)	0.659 (4)	0.52(11)		0.557(5)	*-3.3*	0.637(4)	*-3.3*	0.493(14)	*-5.2*		
	Spawning biomass	**246.9 (47)**	**75.0 (44)**	**20.7(84)**	**342.6(36)**	**60.6(33)**	***-75***	**144.0(37)**	***92***	**103.6(33)**	***401***	**308.2(22)**	***-10***
1999	Egg production	3.15 (34)	2.07 (30)	0.34 (44)	5.56(22)	5.96(33)	*89*	3.59(30)	*73*	0.95(33)	*179*	10.5(22)	*89*
	Female weight	42.1 (6)	45.8 (6)	66.3(41)		42.12(5)	*0.0*	44.85(6)	*-2.1*	65.88(9)	*-0.6*		
	Batch fecundity	17.6 (6)	18.6 (6)	21.8(12)		22436(11)	*27.5*	24086(9)	*29.5*	34776(10)	*59.5*		
	Spawning fraction	0.070 (32)	0.133 (19)	0.14(26)		0.074(22)	*5.7*	0.142(5)	*6.8*	0.144(10)	*2.9*		
	Sex ratio	0.540 (7)	0.681 (5)	0.55(45)		0.531(3)	*-1.7*	0.639(5)	*-6.2*	0.514(4)	*-6.5*		
	Spawning biomass	**199.3 (48)**	**56.3 (37)**	**13.4 (77)**	**269(37)**	**284.7(42)**	***43***	**73.7(33)**	***31***	**24.3(37)**	***81***	**382.7(32)**	***42***
2002	Egg production	0.89 (36)	1.32 (24)	0.52(33)	2.73(18)	0.30(19)	*-66*	1.40(12)	*6*	0.85(11)	*63*	2.55(8)	*-7*

	Female weight	40.0 (5)	45.1 (5)	75.0(5)		38.84(5)	-2.9	43.28(5)	-4.0	75.63(5)	0.8		
	Batch fecundity	12.6 (6)	14.5 (7)	26.1(6)		12881(6)	2.2	15212(7)	4.9	29623(6)	13.5		
	Spawning fraction	0.038 (31)	0.024 (27)	0.127(21)		0.035(19)	-7.9	0.061(18)	154.2	0.090(11)	-29.1		
	Sex ratio	0.612 (5)	0.608 (3)	0.542(9)		0.621(5)	1.5	0.619(3)	1.8	0.505(8)	-6.8		
	Spawning biomass	**121.5 (48)**	**281.4 (37)**	**50.7(33)**	**453.6(27)**	**41.6(29)**	-66	**105.5(24)**	-63	**47.7(20)**	-6	**194.9(15)**	-57
2005	Egg production	1.21 (39)	3.04 (34)	3.5(21)	7.75(17)	1.38(23)	14	1.87(21)	-38	2.70(21)	-23	5.95(13)	-23
	Female weight	46.4 (7)	45.4 (6)	78.5(22)		45.35(7)	-2.3	46.15(6)	1.7	80.67(4)	2.8		
	Batch fecundity	18.6 (8)	18.9 (7)	32.3(20)		13169(8)	-29.2	15304(44)	-19.0	34147(4)	5.7		
	Spawning fraction	0.122 (15)	0.060 (15)	0.06(40)		0.135(13)	10.7	0.063(21)	5.0	0.078(17)	30.0		
	Sex ratio	0.512 (13)	0.564 (6)	0.52(7)		0.574(11)	12.1	0.556(6)	-1.4	0.510(7)	-1.9		
	Spawning biomass	**48.3 (45)**	**215.8 (39)**	**154.5(29)**	**418.6(23)**	**61.3(30)**	27	**161.0(54)**	-25	**160.3(28)**	4	**382.7(26)**	-9
2008	Egg production	4.91 (25)	4.17 (23)	2.64(20)	11.72(14)	4.04(21)	-18	3.93(18)	-6	3.79(17)	44	11.76(11)	0.3
	Female weight	57.0 (5)	59.2 (4)	81.9(5)		56.34(6)	-1.2	59.26(3)	0.1	83.9(4)	2.4		
	Batch fecundity	21.0 (5)	25.8 (4)	34(7)		20956(6)	-0.2	26424(4)	2.4	35139(4)	3.4		
	Spawning fraction	0.086 (8)	0.078 (10)	0.09(18)		0.088(8)	2.3	0.078(10)	0.0	0.090(13)	0.0		
	Sex ratio	0.518 (1)	0.520 (1)	0.51(1)		0.489(7)	-5.6	0.593(3)	14.0	0.482(6)	-5.5		
	Spawning biomass	**300 (28)**	**245 (26)**	**142(30)**	**687(17)**	**252.4(25)**	-16	**190.5(22)**	-22	**208.6(23)**	47	**651.6(14)**	-5
2011	Egg production					2.86(27)		0.84(29)		4.04(24)		7.74(16)	
	Female weight					54.25(7)		50.07(6)		85.85(3)			
	Batch fecundity					17157(11)		12224(8)		40844(5)			
	Spawning fraction					0.003(35)		NA		0.114(26)			
	Sex ratio					0.498(9)		0.496(4)		0.487(12)			
	Spawning biomass									**153.8(38)**			

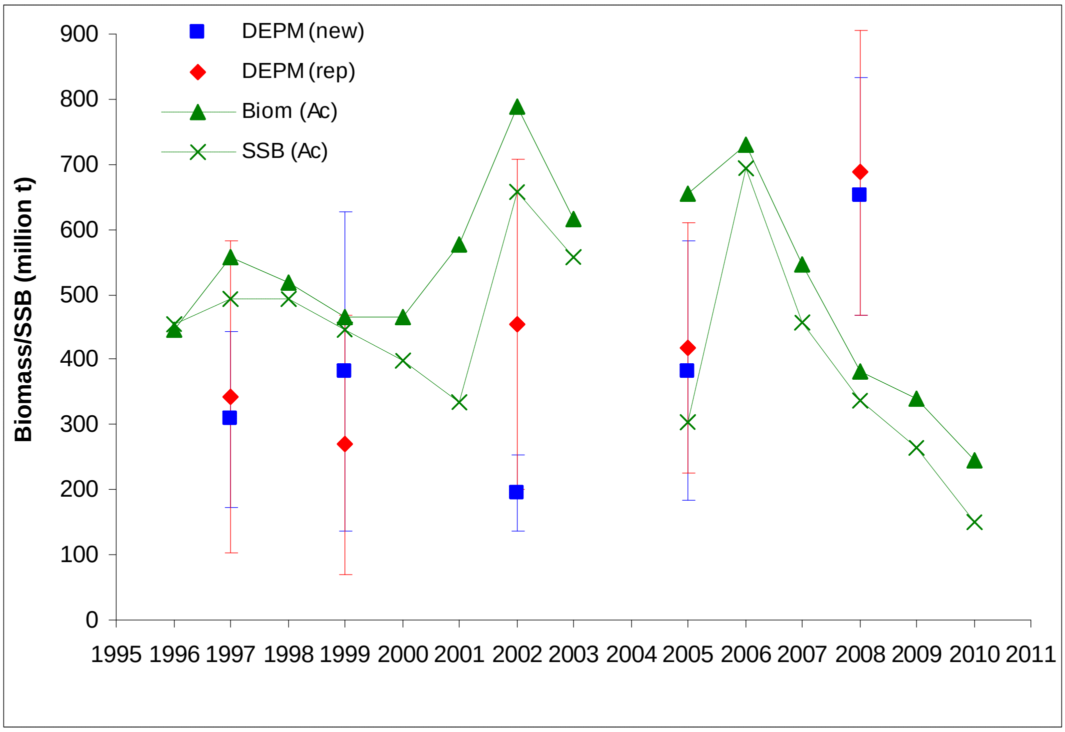

Figure 1: Estimates of spawning stock biomass (SSB) for the Atlanto-Iberian sardine in the period 1996-2010 from the DEPM surveys (red: revised estimates, blue: reported estimates) in comparison to the estimates of SSB (green, full line) and of total biomass (green, dotted line) from the acoustic surveys .Vertical lines for DEPM surveys indicate approximate 95% confidence intervals (i.e., ± 2 standard-deviations)