Revision of the life history parameters (proportion of mature and mean weights at age) for the Iberian (south) sardine stock (ICES 8c and 9a)

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Abstract

Background

Maturity and stock weights at age used in sardine assessment up to 2012 were obatined from (Portuguese and Spanish) spring acoustic surveys biological data. Following a recommendation of the WGANSA, the possible alternative use of the Daily Egg Production Method (DEPM) surveys to estimate maturity at age was evaluated, and a revision of these maturity ogives was undertaken for the last benchmark assessment (Silva et al. 2011, WKPELA 2012), the WG having decided that DEPM maturity ogives should be used in the assessment, and for years with no DEPM survey, 80% of fish mature would be assumed at age 1 (corresponding approximately to the historical mean of DEPM ogives), and for simplicity, 100% of fish are mature at age 2. But these estimates were obtained including information from both DEPM and acoustic surveys: maturity data from the DEPM for each stratum and year were combined to obtain stock estimates, using abundances at age from acoustic surveys as weighting factors; however, in most years, 1-2 months lagged between the two surveys in W and S strata. Revision of weights at age could not be carried out in 2012 due to time constraints, but the WGHANSA believes that it makes more sense that both life history parameters be derived from the same surveys. This WD describes the revision of both maturity and stock weights at age estimates, based uniquely on the DEPM surveys.

Data and methodology

Biological data from the Portuguese and Spanish Daily Egg Production Method (DEPM) triennial surveys covering the whole Iberian sardine stock area from 1997 to 2014 were used to estimate the proportion of mature and mean weights at age for the stock. Three geographical strata were considered: North (Cantabrian and Galician waters, ICES 9a North and 8c), West (Western Atlantic Portuguese waters, ICES 9a West), South (Southern Portuguese waters, ICES 9a South).
DEPM surveys are carried out close to sardine peak spawning period (Jan-Feb in strata W

and S, Mar-Apr in stratum N), though in 1997 and 2014 Portuguese surveys took place later, concurrently to the Acoustic ones. During the DEPM surveys, fishing hauls are performed opportunistically but ensuring a good coverage of the stock area according to fish abundance and distribution. Biological sampling is performed on a random sample of 60-100 fish per haul, and the following individual information is recorded (length, weight, sex, macroscopic maturity stage) (CRR 2016). The data available from the DEPM surveys will thus be assumed as representative of the population.

Microscopical information of the ovaries is obtained only for the 25-30 females of the haul. In the Spanish surveys, and until 2002 in the Portuguese ones, only females with macroscopic maturity stage 2 and above (2+, mature) are/were analysed microscopically, stage 1 (immature) females being not considered for histology. In light of this, and though some misclassifications in maturity stages are reported between macroscopic and microscopical analysis for sardine (Afonso-Dias et al. 2007), a good sampling coverage of both mature and immature fractions of the population is required, and therefore macro and not microscopic data will be used for the parameters estimation. The analysis carried out prior to the 2012 benchmark assessment showed that macro and micro length maturity ogives were not significantly different for the DEPM surveys (Silva et al. 2011). Though, we can rule out the possibility that some macro misclassifications may have existed in 1997 and 2014 when the Portuguese surveys took place later, toward the end of the spawning season.

Age data is not available for all fish sampled, the number of otoliths collected varies depending on the survey, and for the South and West strata, only females have age information for most of the survey years (Table 1). Therefore, for the purpose of the estimation of these parameters, only females data will be used. Nevertheless, considering the sampling strategy and taking into account that the growth pattern is very similar for both sexes up to age 6 in sardine (Silva et al. 2008) and that sexual dimorphism at first maturation is not known for the species (Silva et al. 2006), it will be assumed that age composition of males will be the same as for females, and that mean weight and proportion of mature at age estimated for females will be representative of both sexes. Data available from DEPM surveys are summarized in Table 1.

Table 1: Summary of the data available from the DEPM surveys, for each year and stratum (S: south, W: West, N: North). SSB: spawning stock biomass, estimated from the external eggs mortality model (in tons); Nind_WL: number of fish with length and weight information; Nind_age: number of fish with age data; Nind_Mat: number of fish with macroscopic maturity stage information.

Year	Stratum	SSB	Nind_WL		Nind_age		Nind_Mat	
			M	F	M	F	M	F
	S	61337	232	268	0	0	232	268
1997	W	108870	298	502	0	0	298	502
	N	81180	142	143	88	93	142	143
1999	S	311982	536	602	296	325	536	602

Year	Stratum							
	W	87832	1125	1553	300	699	1115	1550
	N	37104	532	463	307	339	532	463
	S	130406	894	1378	5	175	894	1378
2002	W	265984	1144	1492	0	146	1144	1492
	N	99989	1019	1004	733	757	1019	1004
	S	87103	751	830	2	88	751	830
2005	W	187676	1323	1533	0	183	1323	1533
	N	206668	721	712	418	362	721	712
	S	257403	758	741	1	648	758	741
2008	W	187640	1428	1720	0	1455	1418	1494
	N	179983	759	633	541	604	759	633
	S	116566	480	451	0	207	479	451
2011	W	51502	958	866	0	382	949	825
	N	58304	334	376	158	243	334	376
	S	59500	355	545	191	301	355	545
2014	W	82767	684	805	51	71	684	621
	N	22346	443	238	191	208	443	238

Arithmetic mean weights at age (with ages 6 and above pooled as a single age group 6+) were calculated for each haul directly from the fish with age data (hydrated females were excluded). Similarly, the macro maturity data of females with age information was used to calculate the proportion of mature fish for each haul. Then, for each stratum and year, these mean weights and proportions of mature at age were averaged, weighed by the number of females sampled in each haul. Finally, these per stratum estimates were combined to obtain stock mean weights at age, using as weighting factors the abundances at age by stratum and by year, obtained from the DEPM spawning stock biomass (SSB) estimates), according to the following (Uriarte 2015):

$$TSPa = (SSB/Wt)*Pa/TPma,$$

Where:
1) SSB is the spawning biomass estimates obtained after the last revision using the external eggs mortality model (cf. WD Diaz et al.)
2) Wt is the total mean weight of mature individuals, obtained from both females and males at maturity stage 2+ for each haul, and then weighed by the number of mature fish sampled in the haul
3) Pa is the proportion at age of mature fish, obtained as following: the length distribution (by half cm) of mature (stage 2+) males and females is obtained per stratum and per year, to which is applied an age-length key (ALK) estimated from the same stratum/year females with age data
4) TPma is the proportion of mature fish in each age group, obtained for each stratum and year based on the females with age information, and assuming that age composition and proportion of mature fish is the same for males and females (see above).

No estimates were available for 1997 due to the lack of age data for the S and W strata. For years with no DEPM survey between 1999 and 2014, a linear interpolation was carried out to obtain the intermediate estimates of mean weight and maturity at age.

For the years 2015 and 2016, after the observation that the age composition of sardine population was similar between 2014 and 2016 (cf. WD Silva & Riveiro), the same estimates were assumed for the period 2014-2016.
For the period 1978-1998:
- maturity at age: constant proportions of mature at age were assumed, based on the average of the estimates obtained from the 6 DEPM surveys of the 1999-2014 period, thus including both years of strong year classes and years of low recruitment.
- weight at age: considering the temporal trends observed (cf. Results, Figure 1), it was decided to consider the two closest DEPM surveys, and assume for that period the average between 1999 and 2002 estimates.

Results

Mean weight at age

Revised estimates are presented in Table 2, and compared to values used in the assessment up to now in Figure 1.

Table 2: Sardine mean weights at age (in grammes), those for the period 1978-1998 are fixed and equal the average of the first two DEPM surveys of the series (1999, 2002), whereas those for 2015 and 2016 are identical to the last DEPM survey (2014) estimates.

year	age1	age2	age3	age4	age5	age6+
1978-1998	25.58	39.69	50.93	61.51	60.62	63.53
1999	29.54	42.61	49.51	53.62	59.47	61.56
2000	26.90	40.66	50.46	58.88	60.24	62.88
2001	24.26	38.71	51.40	64.14	61.00	64.19
2002	21.62	36.77	52.34	69.39	61.77	65.50
2003	20.66	40.93	54.16	68.32	65.08	72.43
2004	19.70	45.09	55.98	67.25	68.40	79.36
2005	18.74	49.26	57.81	66.18	71.71	86.29
2006	23.64	51.73	59.78	67.48	71.68	83.81
2007	28.53	54.19	61.75	68.78	71.64	81.33
2008	33.43	56.66	63.72	70.08	71.61	78.85
2009	30.14	53.77	62.81	69.90	69.15	75.33
2010	26.86	50.87	61.89	69.72	66.70	71.81
2011	23.57	47.98	60.97	69.55	64.25	68.29
2012	26.54	48.40	62.22	68.40	68.45	72.57
2013	29.52	48.83	63.46	67.26	72.66	76.85
2014	32.50	49.25	64.71	66.12	76.87	81.13
2015	32.50	49.25	64.71	66.12	76.87	81.13
2016	32.50	49.25	64.71	66.12	76.87	81.13

Figure 1: Weight at age estimates, obtained from the revision based on the DEPM surveys (continous line and full circles), and those used up to now in the assessment based on the acoustic surveys (dashed lines and open circles)

The most significant differences between previous and revised estimates are observed at age 1, especially for the fixed estimate assumed for the period 1978-1998, for years 2008 and 2014 and for some of the resulting interpolated years (40-100% increase). For the older age group (age 6+), a considerable decrease of the mean weight for the period 1978-1998 is also observed in relation to the 0.1 kg mean weight assumed in the 2016 assessment, whereas differences were always lower than 25% for the other age groups. At older ages (4 to 6+), intersections between two consecutive years are observed in some years (e.g., 2002 and 2011 betwwen ages 4 and 5), possibly due to sampling bias at these ages. In both Acoustic and DEPM estimates, a slight increasing trend is apparent since the early 2000's in younger ages.

Maturity at age

Revised estimates are presented in Table 3, and compared to values used in the assessment up to now in Figure 2.

Table 3: Sardine proportion of mature fish at age, those for the period 1978-1998 are fixed and equal the average of the 6 DEPM surveys of the series (1999-2014), whereas those for 2015 and 2016 are identical to the last DEPM survey (2014) estimates.

year	age1	age2	age3	age4	age5	age6+
1978-1998	0.842	0.986	0.986	0.994	0.994	0.996
1999	0.936	0.983	0.953	1.000	0.970	0.980
2000	0.840	0.981	0.968	0.990	0.980	0.987
2001	0.744	0.979	0.983	0.980	0.990	0.993
2002	0.648	0.978	0.998	0.971	1.000	1.000
2003	0.623	0.974	0.996	0.980	1.000	1.000
2004	0.597	0.970	0.994	0.990	1.000	1.000
2005	0.572	0.966	0.992	1.000	1.000	1.000
2006	0.683	0.974	0.990	0.999	1.000	1.000
2007	0.793	0.983	0.989	0.998	1.000	1.000
2008	0.904	0.991	0.988	0.996	1.000	1.000
2009	0.933	0.994	0.988	0.996	0.997	0.999
2010	0.962	0.997	0.988	0.996	0.995	0.999
2011	0.992	1.000	0.988	0.996	0.992	0.998
2012	0.994	1.000	0.992	0.998	0.995	0.999
2013	0.997	1.000	0.996	0.999	0.997	0.999
2014	1.000	1.000	1.000	1.000	1.000	1.000
2015	1.000	1.000	1.000	1.000	1.000	1.000
2016	1.000	1.000	1.000	1.000	1.000	1.000

Figure 12: Proportion of mature fish, obtained from the revision based solely on the DEPM surveys (continous line and full circles), and those used up to now in the assessment (dashed lines and open circles)

Sardine is known to mature between ages 1 and 2 (Silva et al. 2006), therefore maturity at age 0 is assumed to be zero and maturity at age 3 and above (3+) is considered to equal 1; the lower proportions obtained for ages 3+ in some years may likely be due to sampling bias. Within the whole series, the lower proportions at age are observed for the 2002 and 2005 DEPM surveys and these are likely related to these surveys having followed the strong recruitments of 2000/2001 and 2004. The estimation of length at first maturity (L_{50}) for the different DEPM survey years in the W stratum (a maturity ogive was not possible to fit to the data for most years in strata N and S) does not indicate fish have matured at higher lengths in 2002 and 2005 (Table 4); the lower proportions at age observed could be due to a higher proportion of smaller (immature) fish (resulting from these strong recruitments) being included in group age1.

Table 4: Estimates of length at first maturity (L_{50}) for stratum W, based on the DEPM surveys maturity data.

year	L_{50}
1997	NA
1999	11.10
2002	12.85
2005	11.56
2008	13.10
2011	NA
2014	11.25

References

Afonso-Dias I., Amorim P., Silva A. 2007. Problems with assigning the ovaries of sardine (*Sardina pilchardus*) to the appropriate macroscopic maturity stage. JMBA2 Biodiversity Records No. 5190: 4 pp. Published on-line.

Diaz et al. 2017 WD ???

ICES 2012. Report of the Benchmark Workshop on Pelagic Stocks (WKPELA 2012), Copenhagen, Denmark ,13–17 February 2012, ICES CM 2012/ACOM:47, 572 pp.

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

Silva A., Santos M.B., Caneco B., Pestana G., Porteiro C., Carrera P., Stratoudakis Y. 2006. Temporal and geographic variability of sardine maturity at length in the northeastern Atlantic and the western Mediterranean. ICES J. Mar. Sci. 63: 663–676.

Silva A., Carrera P., Massé J., Uriarte A.D., Santos M.B., Oliveira P.B., Soares E., Porteiro C., Stratoudakis Y. 2008. Geographic variability of sardine growth across the northeastern Atlantic and the Mediterranean Sea. Fish. Res. 90: 56–69.

Silva A., Nunes C., Perez J.R., Soares E., Diaz Conde P. 2011. Sardine maturity ogives. WD to the 2011 WGACEGG meeting, Barcelona, Spain, 21.25 Nov. 2011., 10 pp.

Silva A., I. Riveiro. 2017. Revision of the assessment of the sardine south stock (sardine in ICES

Divisions 8.c and 9.a) – Impact of revisions of input data on the 2016 assessment. WD to the Benchmark Workshop on Pelagic Stocks (WKPELA), Lisbon, Portugal, 6–10 Feb. 2017, 16 pp.

Uriarte A. 2015. Quantification of key biological processes determining the dynamics and the assessment of the anchovy population in the Bay of Biscay: growth, reproduction, demography and natural mortality. PhD thesis, University of the Basque Country, Faculty of Science and Technology, Bilbao, Spain, 333 pp.