Anchovy Spawning Stock Biomass of the Gulf of Cadiz in 2017

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1. Introduction

The Daily Egg Production Method (DEPM) to estimate the Anchovy Spawning Stock Biomass (SSB) in the Gulf of Cádiz (ICES, Subdivision 9a South) is conducted every three years since 2005 by the IEO (Spain).

BOCADEVA 0717 has been carried out on board R/V *Ramón Margalef* (IEO) from 25st July to 2nd August 2017. The surveyed area extended from Strait of Gibraltar to Cape San Vicente (Spanish and Portuguese waters off the Gulf of Cadiz). Plankton samples, along a grid of 21 transects perpendicular to the coast, were obtained for the spawning area delimitation and density estimation of the daily egg production. The samples to estimate adult parameters (sex ratio, female mean weight, batch fecundity and spawning fraction) were obtained in the ECOCADIZ 2017-07 survey, carried out during the same period.

The survey objectives also included the characterization of the oceanographic and meteorological conditions in the study area during the survey.

This working document provides a brief description of the estimation procedures used to obtain the Gulf of Cadiz Anchovy SSB by DEPM for 2017 in the South-Atlantic Iberian Stock.

2. Methodology

Table 1 summarised a description of the methodology used to obtain egg (BOCADEVA 0717) and adult (ECOCADIZ 2017-07) samples (see more detailed information about sampling methodology and procedures in Jiménez *et al*., 2017 and Ramos *et al*., 2017, 2018).

Table 1. BOCADEVA 0717 & ECOCADIZ 2017-07. Information general on sampling methods.

Eggs	**Anchovy DEPM survey BOCADEVA 0717**
Survey area	(36º13'-36º50'N –6º07'–8º55'W)
R/V	*Ramón Margalef*
Dates	24 July to 2 August
Transects (Sampling grid)	21 (8x3)
Pairovet stations (150 μm)	151
Sampling maximum depth (m)	100
Hydrographic sensor	CTD SBE 911
Flowmeter	Yes
CUFES stations	142
CUFES (335μm)	3 n miles (sample unit)
Environmental data	Temperature and Salinity
Adults	**Acoustic survey ECOCADIZ 2017-07**
Survey area	(36º11'-36º47'N –6º12'–8º54'W)
R/V	*Miguel Oliver*
Dates	31 July to 13 August
Gears	Pelagic trawl
Hauls	25 (all of them positive for Anchovy)
Hauls time range	From 07:09 to 20:09 hrs GMT
Biological sampling	On fresh material, on board of the R/V
Sample size	At least 60 individuals randomly picked; up to 120 (adding batches of 10 randomly picked anchovies) if a minimum of 30 mature females were not found for spawning fraction estimation. A minimum of 150 hydrated females for batch fecundity estimation.
Fixation	4% Phosphate buffered Formaldehyde
Preservation	4% Phosphate buffered Formaldehyde

2.1. Sampling and processing

2.1.1. Eggs

An adaptive sampling was carried out in the East - West direction using a PairoVET net in fixed stations as main sampler and a continuous recording with CUFES (*Continuous Underwater Fish Egg Sampler*) as secondary sampler. The sampling grid was established on the continental shelf following

a systematic sampling scheme, with transects perpendicular to the coast and spaced 8 nm. Egg samples were always taken every 3 nm in the inner shelf (ICES, 2003). The inshore limit of transects was determined by bottom depth (as close to the shore as possible), while the offshore extension was adaptively decided depending on the results of the most recent CUFES sample.

Vertical hauls were carried out with a PairoVET sampler equipped with nets of 150µm mesh size. Hauls were carried out up to a maximum depth of 100m or of 5m above the bottom in shallower depths, with a speed of about 1 m/s. Sampling depth was recorded using an underwater positioning system HiPAP 500 Kongsber fitted to the net. Flowmeters were used to calculate the volume of filtered water during each haul. Anchovy eggs were classified in 11 developmental stages, according to the key proposed by Moser and Ahlstrom (1985).

2.1.2. Adults

Adult Anchovy samples for DEPM were obtained during the ECOCADIZ 2017-07 survey from pelagic trawl hauls (Ramos *et al*., 2017, 2018).

Except for searching Anchovy females with hydrated gonads, fishing stations were mostly conducted during daylight hours, once echotraces supposedly belonging to Anchovy were detected by echo-sounder.

For the estimation of spawning fraction (S), a minimum of 30 mature, non-hydrated females per sample was sought, so a minimum of 60 random anchovies were sampled, adding batches of 10 random individuals to the sampling until the goal was achieved or a maximum of 120 anchovies were sampled. Sex-ratio (R), along with other parameters used in the DEPM, was also obtained from this random sampling.

When hydrated females (HF) appeared, an additional sampling was done in order to obtain a minimum of 150 HF for the whole area prospected. These females were sampled as described above. Gonads from both hydrated and non-hydrated females were preserved in 4% buffered formaldehyde.

2.1.3. Hydrography

A SBE 911 CTD profiler was used in each station to collect records of temperature, salinity, fluorescence and oxygen of the water column. Also, a continuous sampling of sea surface temperature and salinity was carried out.

2.2. Data analysis

2.2.1. Egg Production (z, P_0 and P_{tot}) estimation and area calculation

All calculations for area delimitation, egg ageing and model fitting for egg production (P_0) estimation were carried out using the R packages *geofun, spatstat, eggsplore and shachar* available at *ichthyoanalysis* (http://sourceforge.net/projects/ichthyoanalysis).

The surveyed area (*A*) was calculated as the sum of the area represented by each station. The spawning area (*A+*) was delimited with the outer zero Anchovy egg stations, and was calculated as the sum of the area represented by those stations.

The model of egg development with temperature was derived from the incubation experiment carried out in Cádiz in July 2007 (Bernal *et al*., 2012). A multinomial model was applied (Ibaibarriaga *et al.,* 2007, Bernal *et al.,* 2008) considering only the interaction Age*Temp (other interactions were not significant).

$$N_{i,t} \sim \text{Mult}\ (N\ ,\ p_{i,t}\ )$$

$$p_{i,t} = f\ (\text{Age, Temp})$$

Egg ageing was performed by a multinomial Bayesian approach described by Bernal *et al*. (2008) and using *in situ* SST; a normal probability distribution was used with peak spawning assumed to be at 22:00h with 2h standard deviation. This method uses the multinomial development model and the assumption of probabilistic synchronicity (assuming a normal distribution).

$$p(age \mid stage, temp, time)\ a\ p\ (stage \mid age, temp)\ p\ (age \mid time)$$

ageing development model synchronicity

Daily egg production (P_0) and mortality (z) rates were estimated by fitting an exponential mortality model to the egg abundance by cohorts and corresponding mean age. The model was fitted using a generalized linear model (GLM) with negative binomial distribution. The ageing process and the GLM fitting were iterative until the value of z converged.

[depm.control (spawn.mu=22; how.complete=0.95; spawn.sig=2), initial z = 0.01].

$$P_{age} = P_0\, e^{-z\,age}$$

$$\log\left(\frac{N_{age}}{area}\right) = \log(P_0) - z\,age \ \rightarrow\ \log(N_{age}) = \log(area) + \log(P_0) - z\,age$$

Finally, the total egg production was calculated as: $P_{tot} = P_0\ A+$

2.2.2. Adult parameters

The adult parameters estimated for each fishing haul considered only the mature fraction of the population (determined by the fish macroscopic maturity data).

Before the estimation of the mean female weight per haul (W), the individual total weight 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 and the total weight of males and females.

The expected individual batch fecundity 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.

The spawning fraction (*S*) is currently being determinate by histological analysis of the post-ovulatory follicles, POFs (Hunter and Macewicz, 1985). The fraction of females spawning per day (S) is 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 is corrected by the average number of females with Day-1 or Day-2 POF, and the hydrated females are not included).

The mean and variance of the adult parameters for all the samples collected was then obtained using the methodology from Picquelle and Stauffer (1985; *i.e.*, weighted means and variances). All estimations and statistical analysis were performed using the R software.

2.2.3. Spawning Stock Biomass

The spawning Stock Biomass was computed according to: $$SSB = \frac{P_{total} * W}{F * S * R}$$

3. Results

3.1. Sampling

3.1.1. Distribution and abundance of Anchovy eggs by PairoVET

The surveyed area (15556 km^2) extends from Cape Trafalgar (Spain) to Cape San Vicente (Portugal). A total of 151 PairoVET stations were carried out (53 with Anchovy eggs). Anchovy eggs presented a patched distribution along the area (Figure 1). A total of 950 Anchovy eggs were caught, and a maximum density (in number/m^2) of 2453 was obtained (Table 2).

Table 2. BOCADEVA 0717. Anchovy eggs (number and density) by PairoVET.

By PairoVET	Anchovy eggs
N stations	151
N positive stations	53
N total eggs	950
N máximum eggs	215
Total density (eggs/m^2)	10273
Maximum density (eggs/m^2)	2453

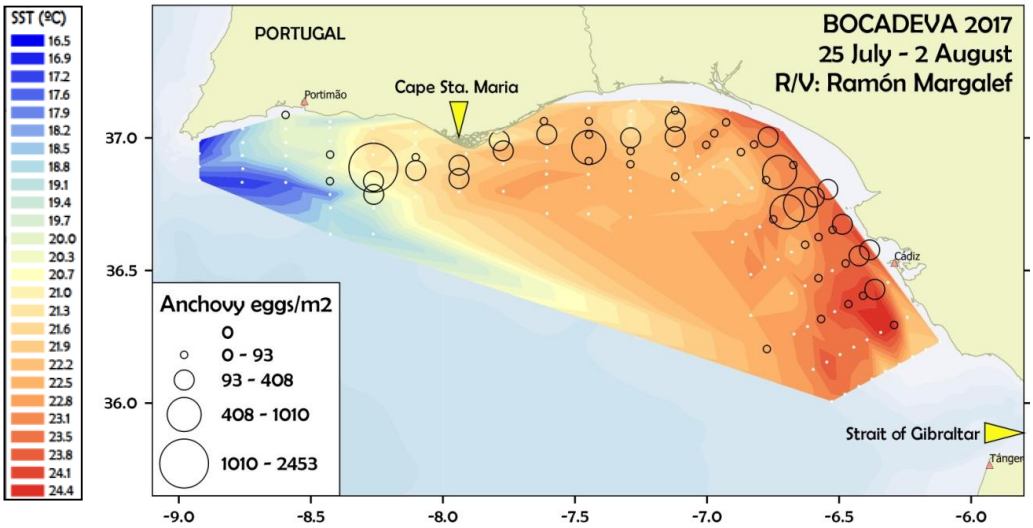

Figure 1. BOCADEVA 0717 survey. Abundance distribution of Anchovy eggs density (eggs/m^2) by PairoVET and SST.

3.1.2. Adults. Results of the pelagic hauls

See Ramos *et al*. (2017, 2018).

3.1.3. Hydrography

The SST ranged between 16.91ºC and 24.6 ºC (mean 22.0 ºC) in the whole area, and the SSS ranged between 36.1-36.6 (mean 36.4). However, the Gulf of Cadiz is divided in two areas located to the East and West of Cape Santa Maria. These areas are well differentiated by the oceanographic conditions like temperature, salinity or characteristic of the continental shelf (Jiménez *et al*., 2017).

3.2. Data analysis

3.2.1. Eggs parameters

The cumulative plot of the total density and temperature by range of temperature is shown in Figure 2. The temperature at 5 m depth has been used for the estimates. Daily egg production (P_0) and mortality (z) rates were estimated by fitting an exponential mortality model to the egg abundance by cohorts and corresponding mean age (Figure 3). The model was fitted using a generalized linear model (GLM) with negative binomial distribution. The ageing process and the GLM fitting were iterative until the value of z converged. [depm.control (spawn.mu=22; how.complete=0.95; spawn.sig=2), initial z = 0.01].

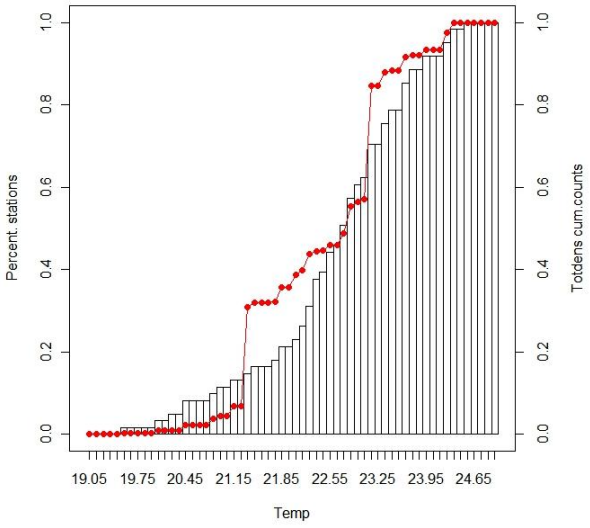

Figure 2. Gulf of Cadiz Anchovy DEPM in 2017. Cumulative plot of total density and temperature by range of temperature (inter=0.1)

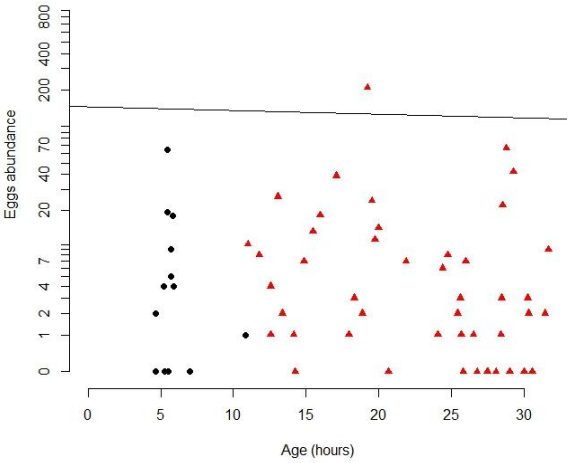

Figure 3. Gulf of Cadiz Anchovy DEPM in 2017. Exponential mortality model by cohort.

Eggs mortality rate was negative, but not significant, and a high CV was observed. The results show that 17% of the eggs dying per day. The CV associated to egg production is also high (0.55), probably due to the dispersion of the data. A post-stratified estimation was made, but the obtained results were not better.

3.2.2. Adult parameters by haul

The total weight of hydrated females was corrected for the increase of weight due to the hydration process by a linear regression model between individual data of gonad-free-weight (Wnov) and its corresponding total weight (Wt) from non-hydrated females (Figure 4). The expected female weight (Wexp) for all mature females was also estimated using this linear regression model.

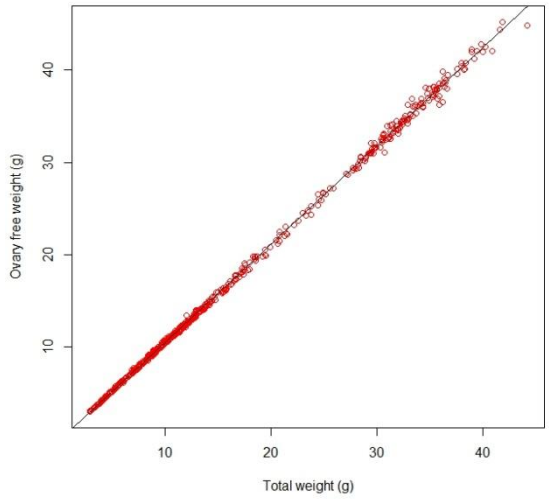

Figure 4. Gulf of Cadiz Anchovy DEPM in 2017. Plot of the linear regression model for the relationship between non-hydrated females total weight (Wt) and ovary-free weight (Wnov).

The expected batch fecundity for all mature females (Fexp) was estimated by modelling the observed individual batch fecundity (Fobs) in hydrated females in function of their gonad-free-weights (Wnov) by a GLM model (Figure 5).

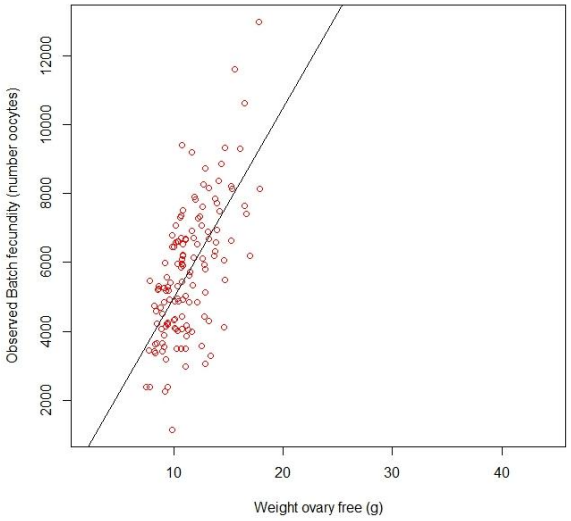

Figure 5. Gulf of Cadiz Anchovy DEPM in 2017. Generalized linear model for the relationship between observed individual batch fecundity (Fobs) and ovary-free weight (Wnov).

3.2.3. Spawning Stock Biomass

The total spawning area (*A+*) was 5080 Km^2. The results and their associated CV for the egg and adult parameters, and the SSB are summarized in the Table 3. A total Spawning Stock Biomass of 12392 tons has been estimated, 61% less than 2014. The results of the historical series are shown in Table 4.

Table 3. Gulf of Cadiz Anchovy DEPM in 2017. Summary of the results for egg and adult parameters and the SSB estimates (CVs in brackets).

Parameters	**Gulf of Cádiz 2017**
Eggs	
P_0 (eggs/m^2/day)	145.8 (0.55)
Z (day^{-1})	-0.16 (NA)
P_{tot} (eggs/day) (x10^{12})	0.740 (0.55)
Spawning area (Km^2)	5080
Adults	
Female Weight (g)	16.14 (0.17)
Batch Fecundity	7502 (0.17)
Sex Ratio	0.53 (0.009)
Spawning Fraction	0.234 (0.06)
SSB	
Spawning Stock Biomass (tons) (CV)	12392 (0.61)

Table 4. Gulf of Cadiz Anchovy SSB by DEPM. Historical series.

Year	2005	2008	2011	2014	2017
P_0 (eggs/m^2/day)	50.8 / 224.5	184 / 348	276	314	146
Z (day^{-1}) (CV)	-0.039	-1,43	-0.29	-0.33	-0,16
P_{total} (eggs/day) ($x10^{12}$)	1,13	2,11	1,87	1,95	0,74
Surveyed area (km2)	11982	13029	13107	14595	15556
Positive area (Km^2)	6139	6863	6770	6214	5080
Female Weight (g)	25.2 / 16.7	23,7	15,2	18,2	16,14
Batch Fecundity	13820/ 11160	13778	7486	7502	7502
Sex Ratio	0.53 / 0.54	0,528	0,531	0,54	0,53
Spawning Fraction	0.26 / 0.21	0,218	0,276	0,276	0,234
Spawning Biomass –tons	14673	31527	32757	31569	12392

The estimations of the Portuguese and Spanish acoustic surveys and from the DEPM are really similar throughout the historical series. Especially in 2017, the values obtained are practically the same (Table 5).

Table 5. Historical series of Gulf of Cadiz Anchovy biomass (ICES 9a South) estimated by acoustic (ECOCADIZ and PELAGO) and DEPM (BOCADEVA) surveys series.

Year	ECOCADIZ (Acoustic)	PELAGO (Acoustic)	BOCADEVA (DEPM)
2004	18177		
2005	-	15103	14673
2006	36521	24082	
2007	28882	39965	
2008	-	39667	31527
2009	21580	26834	
2010	12339 +	8583	
2011	-	27050	32757
2012	-		
2013	8487	16655	
2014	29219	30864	31569
2015	21305	33100	
2016	34184	65345	
2017	12229	13797	12392

(*) Spanish waters only

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