APPLICATION OF THE DAILY EGG PRODUCTION METHOD (DEPM) FOR SARDINE (*Sardina pilchardus*) IN THE INNER OF THE BAY OF BISCAY FROM 1997 UNTIL 2011.

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INTRODUCTION

The Daily Egg Production Method (DEPM) for sardine has been applied by Instituto Español de Oceanografía (IEO) to estimate the spawning stock biomass of the North Atlanto-Iberian sardine stock [1] since 1988 (1990, 1997, 1999, 2002, 2005, 2008 and 2011).(WGACEGG, WGANSA)

Spring surveys for the application of the DEPM, consisting of ichthyoplankton, adults and hydrographic sampling, and since 1997 the sampling area was extended in order to reach the 45 º N (Fig.1), covering the region from the northwestern (border Minho River), north Iberian Peninsula and inner part of the Bay of Biscay (to 45°N).

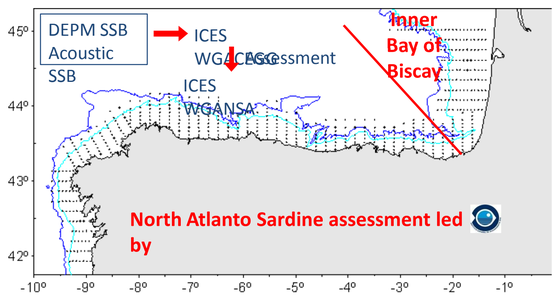


Fig. 1. Sardine DEPM survey area covered by IEO 1997-2011

OBJECTIVE

This work provides for the first time a description of the sampling, laboratory analysis and estimation procedures for the application of DEPM (Fig.2) conducted by IEO from 1997 to present in the inner of the Bay of Biscay.

Estimations for area delimitation (surveyed & spawning), egg ageing, mortality and model fitting for egg production (P0) are presented. Results from adults fishing sampling are showed and parameters from the mature fraction of the population (mean females weight, sex ratio, batch fecundity and spawning fraction) are calculated.

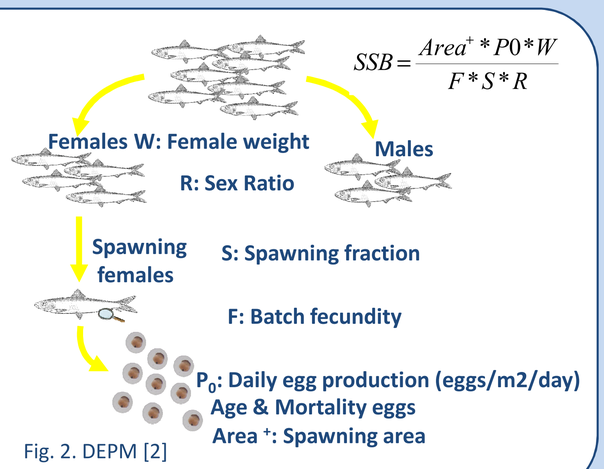


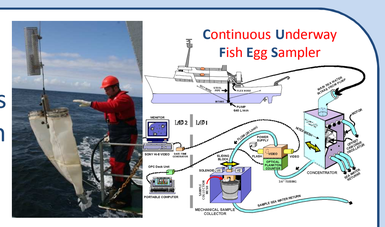
Fig. 2. DEPM [2]

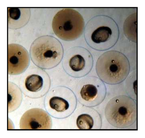
MATERIAL & METHODS

EGGS

Plankton Sampling:

- Vertical plankton hauls (PairoVET Ø 25cm-150 µm mesh size) along transects perpendicular to the coast (Fig. 1). A CTD profile (SST & SSS) was carried out in each station.
- CUFES: auxiliary egg sampler (to define offshore extension of the transects)





Laboratorial analysis:

- Sardine eggs sorted, counted and staged (PairoVET) according to 11 stages of development.

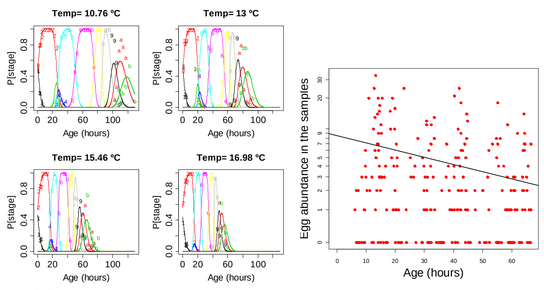
Data analysis: R packages available in open source project "*ichthyoanalysis* [2]"

- Spawning area: area with eggs defined by an automated procedure (geofun library).
- Egg aggeing: Multinomial Bayesian approach [3] using in situ SST (CTD)
- Normal distribution of the daily spawning cycle: peak at 21:00 h GMT and spawning period 15:00-03:00 h.
- Exponential model: E [P]= P0 e $^{-Z\,age}$ fitted by a GLM (negative binomial distribution).
- Tot. egg production(eggs/day)= Daily egg production(eggs/m2/day)*Spawning area.



Table 1. General survey eggs sampling DEPM 1997-2011 in the inner of the Bay of Biscay.

	1997	1999	2002	2008	2011
PairoVET stations	140	48	75	97	134
Positive stations (%)	89 (64)	37 (77)	55 (73)	74 (76)	114 (85)
Total eggs	1123	586	1090	1104	2764
Max eggs/m2/station	1670	1185	1220	2332	2322
SST Min-Max ºC	12.8-15.3	12.5-13.3	12.1-15.4	12.6-16.9	13-14.7

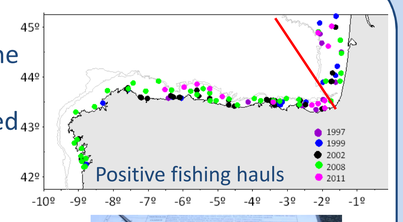


Multinomial egg aggeing and exponential model

ADULTS

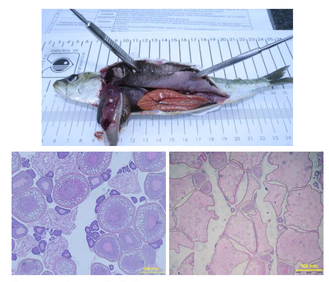
Adults sampling:

- Fishing hauls over the surveyed region: representation of the sardine population.
- Each haul: sardines randomly selected and biological information recorded for all fish. Ovaries preserved for histology .



Laboratorial analysis:

- Ovaries processed and slides examined for their maturity state and POF presence-age. Individual batch fecundity (hydrated oocytes) measured by the gravimetric method .



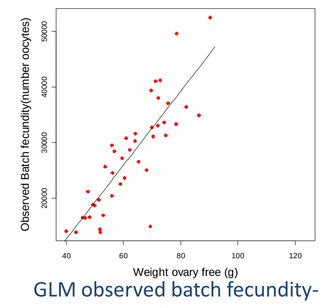
Sampling, POF & hydrated oocytes

Data analysis:

- Females weight (W): Weight of the hydrated females corrected by a linear regression (non-hydrated – gonad free weight).
- Sex ratio (R): Weight of females /Weight (males + females)
- Batch fecundity (F): GLM (with a negative binomial error distribution and identity link) to model individual batch observed & the gonad-free weight.
- Spawning fraction (S): Females Day-1 or Day-2/Mature females (Day-0 corrected & hydrated not included).

Table 2. General survey adults sampling DEPM 1997-2011 in the inner of the Bay of Biscay.

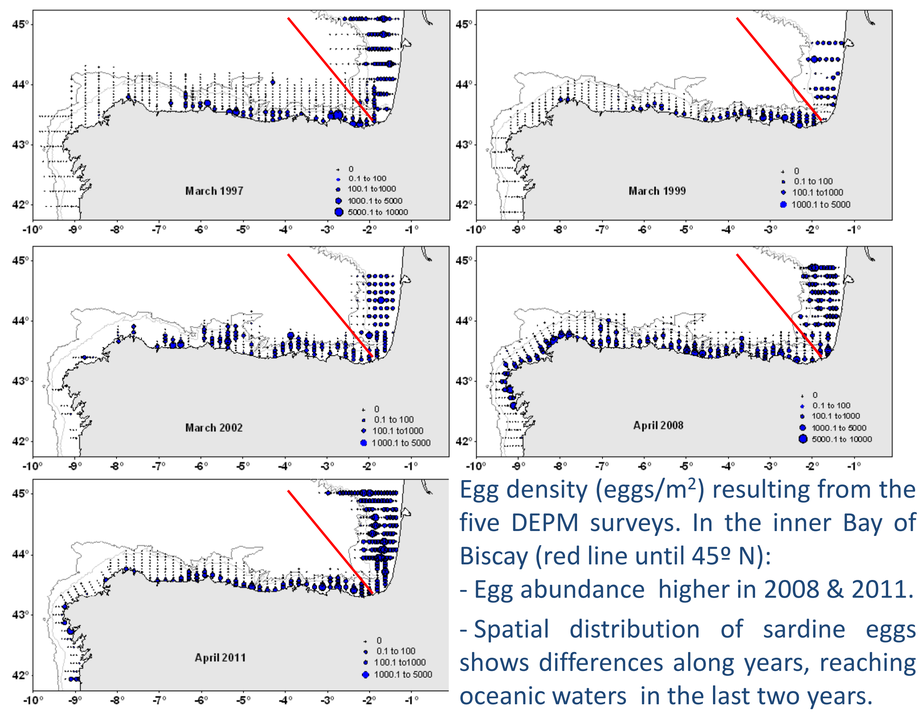
	1997	1999	2002	2008	2011
RV Fishing hauls	4	6	4	5	3
Total sampled	239	516	199	503	302
Tot. Females (% Mature)	135(100)	271(98)	93(100)	223(100)	152(100)
Females for histology	68	-	20	164	127
Hydrated females	42	-	-	3	14



GLM observed batch fecundity-gonad free weight

RESULTS

EGGS



Egg density (eggs/m^2) resulting from the five DEPM surveys. In the inner Bay of Biscay (red line until 45º N):

- Egg abundance higher in 2008 & 2011.
- Spatial distribution of sardine eggs shows differences along years, reaching oceanic waters in the last two years.

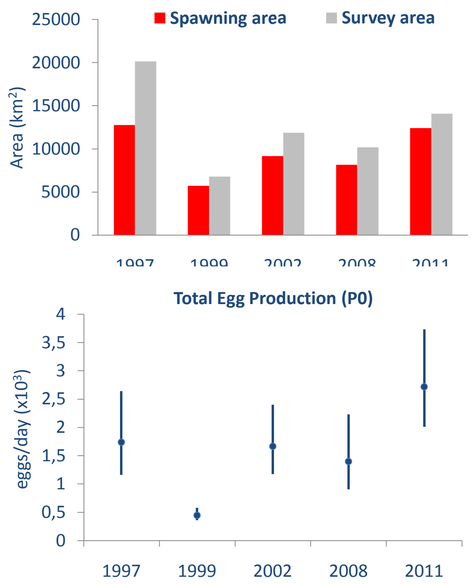


Fig. 3. Estimates of survey and spawning (above) areas and total egg production (below). Vertical lines indicate confidence intervals (95 %).

Table 3. Estimates for eggs parameters in the inner of the Bay of Biscay.

	1997	1999	2002	2008	2011
Z (hour^{-1}) (CV %)	-0.012(41)	-0.006(89)	-0.022(18)	-0.019(26)	-0.018(22)
Max.age (hour)	66.8	81.6	81.6	78.6	68.8
Daily mortality rate (%)	25.3	13.7	41.7	37.3	35.6
P0(eggs/m^2/day)(CV%)	136.6(20)	78.7(13)	182.3(19)	171.4(23)	219.1(16)
Spawning area (km^2)(%)	12755(63)	5724(84)	9154(77)	8167(80)	12400(88)
P0 tot(eggs/day)(CV%)	1.74(20)	0.45(13)	1.67(18)	1.4(23)	2.72(16)

- Mortality value for 1999 is not considered as reliable and egg production was estimated assuming no mortality.
- Spawning area covers a high % of surveyed area.
- P0 tot(eggs/day) in 2011 is the highest in the series meanwhile the lowest corresponds to 1999 (Fig.3).

ADULTS

Methodology to estimate F and S:

- F (1999, 2002, 2008) modelled polling data from the inner Bay of Biscay and North Atlantic Spanish coast (few or not hydrated females, table 2).
- S in 1999 assumed to be the same as in 1997 (no histology samples, table 2).

In 2002 only 1 haul of 4 carried out, was used to estimated F and S. In 1999 no histology samples available to estimate S.

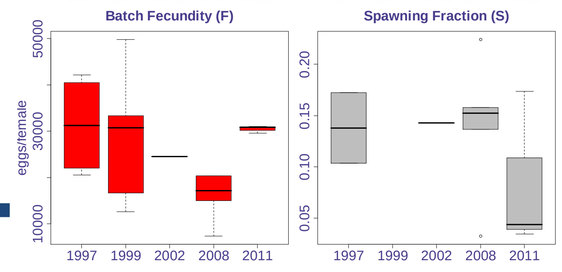


Fig. 4. Box plots show interquartile ranges, median values and 90 % confidence intervals for adult parameters estimates by haul and year.

Table 4. Mean estimates for adult parameters in the inner of the Bay of Biscay.

	1997	1999	2002	2008	2011
Female Weight (CV%)	74.5(11.8)	63.6(12.7)	62.9(5.6)	55.4(11.1)	61.3(9)
Sex Ratio (CV%)	0.508(8.1)	0.535(10.7)	0.492(22.9)	0.483(8.9)	0.51(19.6)
Batch Fecundity (CV%)	32269(17)	32704	24577	15849	30383(4)
Spawning fraction (CV%)	0.131(9.7)	0.131(9.7)	0.143	0.137(24.4)	0.066(49.2)
SSB (CV%)	**60332(31.4)**	**12494**	**60720**	**73942**	**162930(55.5)**

- Mean W: Similar for the whole series but considerably higher in 1997.
- Mean R: Quite homogeneous along the series.
- Mean F: In 2008 reduced by a half when compared most of the series.
- Mean S: Generally quite high except 2011.
- SSB: Interannual variability of parameters (eggs and adults) affect SSB estimates.

DISCUSSION

- Unreliable egg mortality estimated in 1999 could be avoid trying an aggregated model similar to that used by Bernal *et al.* [5].
- A bootstrap approach [6] to estimate adult parameters and their uncertainty could be used when individuals for the estimation were quite few or no data at all were available (F in 1999, 2002, 2008 and S in 1999).
- Given the strong influence of parameters affecting sardine DEPM SSB estimates, an analyses to investigate if parameters are statistically different between years should be done to assess validity of estimations for each survey vs. mean values or modeled estimates.
- The DEPM applied to the SSB estimation of sardine, both on the North Atlantic Spanish coast [7] and in the inner of the Bay of Biscay could be compared to investigate geographical variability of population (demography, seasonal dynamics or reproductive activity, environmental conditions).

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WGACEGG. ICES Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX.
WGANSA. ICES Working Group on Anchovy and Sardine.